Environment Canada   Environnement Canada

Water Resources Research in Canada in the Late 1970s

A.R. Lefeuvre

TECHNICAL WORKSHOP SERIES NO. 4

INLAND WATERS DIRECTORATE
OTTAWA, CANADA, 1984

(Version française á l'endos)

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Preface

This report provides an assessment of the current level and direction of water research in Canada, compares the results of this recent assessment with those of an earlier assessment conducted in 1966, and identifies emerging issues in water resources management as a basis for research in the future.

The assessment was designed not only to identify the emerging issues in water resources management, but also to determine where the problems are most severe, how they relate to the various research categories, where the gaps in knowledge are, and whether the research being conducted now provides the information that will be needed to address these issues.

While recognizing the need to clearly identify the total national picture, it was thought equally necessary and advantageous to identify those unique concerns and perspectives of each of Canada's regions. To this end, workshops were held in five cities from Halifax to Vancouver. In this way, in addition to becoming fully aware of the simple needs and issues in their own regions, water resource managers were made aware of similar and different needs in other regions, as well as national concerns and priorities. Thus, the national program can be responsive to these viewpoints and can address the commonalities which exist in each of the regions.

Abstract

A combination of mailed questionnaires and personal interviews was used to estimate the total effort (as expressed by dollars expended) for water resources research in Canada during the 1979-80 fiscal year. The results are presented for the four economic sectors - federal government, provincial governments, universities and private industry - in terms of dollars expended, who did the research and who funded it. Comparison of current (1979) resource allocations with those reported in a similar study by Bruce and Maasland (1968) entitled "Water Resources Research in Canada" provides an indication of the change in research funding during this period. Regional water resources management issues and associated research needs (current and future decade) identified in five regional workshops held across the country are presented. Research needs are summarized in 9 categories and 49 sub-categories.

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Introduction

The wise management of water resources, a responsibility that is shared by all levels of government, requires knowledge based on data gathering and research. It is self evident that this research effort should be reviewed periodically to ensure that it is adequate and moving in the right direction.

The Inland Waters Directorate (IWD) of Environment Canada undertook such a review in 1979 to determine the current level and direction of research in water resources in Canada, and thus make it possible to identify the appropriate direction for future research efforts.

The review was national in scope and was undertaken in two phases. The first phase, designed to document the 1979 research effort, was undertaken by E.F. Durrant by means of a questionnaire and personal interviews. The second phase was met through a series of regional workshops, with the intent of gathering first-hand input from the water resources managers and research managers in the various regions of the country. This is where most of the responsibility for management resides. Also, the various regions are quite dissimilar, with many unique research needs.

Water resources research in Canada is funded or performed by four distinct economic sectors - the federal government, provincial governments, universities and private industry. The report reflects this shared input and differentiates between the research funded by each sector and the research funded by the sector but carried out by others.

In preparation for the workshops, and to provide a basis for discussion, three background papers were prepared for advance distribution. The first by E.F. Durrant was entitled "Water Resources Research in Canada: 1979/80". The second, by André Marsan and Associates was entitled "How to Get More Out of the Environmental Research Dollar". The third, by Dr. W.R. Derrick Sewell, was entitled "The Changing Context of Canadian Water Research".

An Earlier Assessment - 1966

This is not the first report on water resources research undertaken by the federal government. In 1968, the Science Secretariat published a report by Bruce and Maasland entitled "Water Resources Research in Canada". The current report can be considered a sequel to the 1968 report. Indeed, one section documents and discusses the trend of research effort since 1968.

The Bruce-Maasland report came at a time of awakening interest in environmental concerns generally, and helped to focus attention on water resources management concerns specifically. It was the first comprehensive summary of ongoing Canadian water resources research and, as such, provided an excellent point of reference. The extensive research and monitoring activities on the Great Lakes in the late sixties and early seventies were good examples of the heightened interest in water resources - especially water quality. The formation of the federal Department of the Environment, the proclamation of the Canada Water Act, as well as major new federal research institutes at Burlington, Ontario and Winnipeg, Manitoba were responses to this interest. After more than a decade of growth and change, it was deemed appropriate to update the 1968 report, to review the decade past, and to once again look ahead to the decade before us.

The Bruce-Maasland report considered the same institutional sectors, i.e., federal and provincial governments, universities and private industry. It also established the categorization of research activity which was followed in this report. This categorization was originally adapted from one used by the U.S. Committee on Water Resources Research of the Federal Council for Science and Technology. The major categories adopted by Bruce and Maasland were:

1. Nature of Water
2. Water Cycle
3. Water Supply Augmentation and Conservation
4. Water Quantity Management and Control
5. Water Quality Management and Protection
6. Economic, Social and Institutional Aspects
7. Resources Data
8. Engineering Works

As with any attempt at categorization, many specific research projects did not fit neatly. Indeed, the trend toward multi-disciplinary studies made "fitting" especially difficult. Numerous alternative categorizations could have been considered, but to provide some continuity with the 1968 report, it was decided to follow the Bruce-Maasland scheme.

There is one major change from the above listing. In the intervening years since the 1968 report, the topic of environmental management and environmental impact assessment has become very important. For this reason it was deemed necessary to add a ninth major category entitled "Environmental Management and Protection". This category includes studies on the impact of lake level regulation and river regime changes on ecological systems. It also includes some economic and institutional studies.

Establishing the Level of Research Effort

The data compiled by Bruce-Maasland and by Durrant are an indication of the level of research effort as reflected in monetary budgets. However, the output of research effort is new knowledge. Since such an output is almost impossible to quantify, one must assume, on average, that the useful output (new knowledge) is roughly proportional to the quantifiable level of effort. This assumes that all research effort is equally efficient. This certainly is not the case.

For the purpose of this report it was assumed that, on average, the research budget allocated to a research category is a reasonable indication of level of effort even though it is not a very good indicator of output. The research budget is made up of several components which often are reported differently by different institutions.

The level of research effort reported by Bruce and Maasland was representative for the time period of the 1966-67 fiscal year, that is, April 1, 1966 to March 31, 1967. Because some agencies were on different fiscal years, the period is roughly calendar 1966 or the 1966 field season. The Durrant report was based on estimates of level of research effort during the 1979-80 fiscal year or roughly the 1979 field season. Thus, there is a 13-year interval between the two sets of figures.

Direct costs of a research project usually are readily apparent. These include salaries, operation and maintenance, and capital. Sometimes the salary costs must be estimated by multiplying person years by an average annual salary; operating and maintenance usually are accounted for on a project basis and capital cost is directly identifiable with the equipment used.

Indirect or overhead costs are not so easily identified. These include administration and common services such as library, major common-user facilities and housing. In some cases, quantification of the level of effort is further complicated by the provision of "free" services from other agencies. Some institutions spread these overhead items across the research projects on a pro-rata basis. In many cases, however, this major item is omitted from the reported costs.

The Current Research Effort

The Durrant paper contains a good estimate of the level of water resources research effort undertaken in 1979. The data base is admittedly incomplete. Anyone active in the field could, no doubt, identify specific omissions or incorrect categorizations. Taken in total, however, it is a good representation of current effort in monetary terms. The paper also helped to tie the workshop discussion to the earlier study. The inclusion of a complete description of the categorization was especially valuable. Data from the Durrant paper are provided in Tables 1 and 2. The figures in these tables differ slightly from the Durrant report because some additional data from British Columbia were added after his report was completed.

The Workshops

Each regional workshop started with the presentation of a key-note paper prepared by the IWD Regional Office. The purpose was to set the stage from a regional perspective, and identify some of the issues that should be addressed in the work groups. There was considerable variation among the key-note papers for the various workshops. The discussion that followed presentation of the key-note papers provided a solid basis for further discussion in the work groups.

The prime objective of the regional workshops was to bring together local representatives of the four institutional sectors, i.e., federal government, provincial government, universities and the private sector. Ideally there should have been an equal balance of the sectors at the workshops and in each work group. In actual fact, this objective was never achieved. Each sector was represented but not in balanced numbers.

TABLE 1 SOURCE OF WATER RESOURCES RESEARCH FUNDS-1979
(in thousands of dollars)

SOURCE	CATEGORY*									
	100	200	300	400	500	600	700	800	900	TOTAL
FEDERAL	310	6,840	490	710	14,520	910	1,160	1,610	2,610	29,160
PROVINCIAL	160	3,480	40	1,540	4,510	180	720	290	4,480	15,400
PRIVATE	-	1,200	20	20	1,740	80	110	1,760	1,120	6,050
UNIVERSITY	-	630	30	-	270	60	280	80	40	1,390
TOTAL	470	12,150	580	2,270	21,040	1,230	2,270	3,740	8,250	52,000

TABLE 2 WATER RESOURCES RESEARCH EXPENDITURES-1979
(in thousands of dollars)

NAME	CATEGORY*									
	100	200	300	400	500	600	700	800	900	TOTAL
FEDERAL	210	5,260	290	660	11,050	680	800	390	2,200	21,540
PROVINCIAL	-	2,860	40	1,630	2,710	620	600	280	4,380	13,120
PRIVATE	-	1,760	20	20	3,360	80	190	3,000	1,400	9,830
UNIVERSITY	70	2,610	260	150	2,810	140	540	880	460	7,920
TOTAL	280	12,490	610	2,460	19,930	1,520	2,130	4,550	8,440	52,410

*see Table 5 for clarification of category 100, 200, 300, etc.

In practice, the workshop attendees were divided into four work groups for detailed discussion. Work groups convened after lunch on the first day and reported back to the plenary after lunch on the second day. Thus, over half of the workshop was devoted to detailed work group activity. The work group structure was as follows:

WG-1	Water Resources Data and Hydrology
WG-2	Water Quantity Management and Engineering Works
WG-3	Water Quality Management and Impacts
WG-4	Socio-economic Concerns

It had been hoped that each work group would include representatives of all four institutional sectors. This, of course, did not happen, In most cases, however, at least two or three sectors were included. The important thing was that each participant was given ample opportunity to express his views. There was enough diversity to encourage discussion. The plenary session also provided an opportunity for input on topics not covered in a particular work group.

In the closing plenary each work group was asked to report back in about 10 minutes, which allowed about 20 minutes for discussion. The amount of discussion varied tremendously, but in each workshop there was no lack of time for this "wrap-up".

In hindsight, it is obvious that there should have been more representation from major water users, such as agriculture and fisheries, at both the federal and provincial levels.

The total attendance for each workshop ranged from 26 to 31. This was close to the target of 30, which was thought to be optimum for a workshop-type format.

A Comparison of Research Efforts - 1966 vs 1979

Because the categorization was not identical in the two reports, it may seem that a direct comparison cannot be made. However, even though the Bruce-Maasland study does not show any effort in environmental management and protection, it does not follow that work was not undertaken in this category. What it probably means is that this activity was incorporated elsewhere in the table.

Inflation has been a major economic factor during this time period so it is important to account for this in comparing the 1966 and 1979 data. Durrant acknowledged this factor as follows: "To convert a 1966 expenditure to a 1979 equivalent, it was assumed that $1 in 1966 is equivalent to $2.43 in 1979". This factor is taken from the implicit price index for gross national expenditures as reported in National Income and Expense Accounts. Table 3 has been prepared to depict the research expenditures for 1966 in 1979 dollars.

Table 4 displays and compares the research effort in 1966 and 1979 and shows that the total funding increased to $52 million in 1979 from $20 million (1979 dollars) in 1966.

TABLE 3 1966 FUNDING FOR WATER RESOURCES RESEARCH EXPRESSED IN 1979 DOLLARS (in thousands of dollars)

NAME	CATEGORY*									
	100	200	300	400	500	600	700	800	900	TOTAL
FEDERAL (Plus Foreign & Other)	60	6,680	930	550	3,610	550	860	920	0	14,160
PROVINCIAL	0	2,300	100	170	710	90	150	20	0	3,540
PRIVATE	40	60	10	0	1,710	0	30	220	0	2,070
UNIVERSITY	0	490	10	0	110	40	0	20	0	670
TOTAL	100	9,530	1,050	720	6,140	680	1,040	1,180	0	20,440

*see Table 5 for clarification of category 100, 200, 300 etc.

TABLE 4 COMPARISON BETWEEN 1966 AND 1979 RESEARCH FUNDS (in thousands of dollars and percent)

NAME		CATEGORY*									
		100	200	300	400	500	600	700	800	900	TOTAL
Federal	1966	60	6,680	930	550	3,610	550	860	920	0	14,160
	1979	310	6,840	490	710	14,520	910	1,160	1,610	2,610	29,160
	Change	250	160	- 440	160	10,910	360	300	690	2,610	15,000
	% Change	417	2	- 47	29	302	65	35	75	Large	106
Provincial	1966	0	2,300	100	170	710	90	150	20	0	3,540
	1979	160	3,480	40	1,540	4,510	180	720	290	4,480	15,400
	Change	160	1,180	- 60	1,370	3,800	90	570	270	4,480	11,860
	% Change	Large	51	- 60	806	535	100	380	1,350	Large	335
Private	1966	40	60	10	0	1,710	0	30	220	0	2,070
	1979	0	1,200	20	20	1,740	80	110	1,760	1,120	6,050
	Change	- 40	1,140	10	20	30	80	80	1,540	1,120	3,980
	% Change	-Large	1,900	100	Large	2	Large	267	700	Large	192
University	1966	0	490	10	0	110	40	0	20	0	670
	1979	0	630	30	0	270	60	280	80	40	1,390
	Change	0	140	20	0	160	20	280	60	40	720
	% Change	0	29	200	0	145	50	Large	300	Large	107
Total	1966	100	9,530	1,050	720	6,140	680	1,040	1,180	0	20,440
	1979	470	12,150	580	2,270	21,040	1,230	2,270	3,740	8,250	52,000
	Change	370	2,620	- 470	1,550	14,900	550	1,230	2,560	8,250	31,560
	% Change	370	27	- 45	215	243	81	118	217	Large	154

*see Table 5 for clarification of category 100, 200, 300, etc.

Table 5 shows the percentage distribution of funding among the categories in 1966 and 1979. The first thing one notices is a significant increase in the funding for research in water quality management and protection. It advanced from 30% of total funding in 1966 to 40% in 1979-80. This increase, together with the increase in overall funding (factor of 2-1/2) raised the expenditure from $6 million (1966) to $21 million (1979-80). This has been due to the large increase in federal programs. A large part of the federal increase in expenditure has been focused on the problems of the Great Lakes.

Another variation in Table 5 worth considering is the large drop in the relative importance of research on the water cycle, from 47% to 24%. Because of the increase in overall funding, however, there was actually a small increase in absolute terms, from $9.5 million in 1966 to $12 million in 1979-80. It is probable that the strong national concern for water quality in the past decade has been the cause of reduced emphasis on water cycle research.

Taken together, the increase in expenditure for water quality management and protection ($15 million) plus the expenditure for environmental management and protection ($8 million) account for 75% of the overall increase in water research funding from 1966 to 1979/80. The increase in research effort in all other categories has been limited to a relatively small amount. The concentration of funds and personnel on problems in these two categories, no doubt, reflect the priorities of governments during the past decade.

TABLE 5 PERCENTAGE DISTRIBUTION OF FUNDING AMONG CATEGORIES IN 1966 AND 1979

Expenditure Category		Percent of Total	
		1966	1979
100	Nature of Water	0.5	0.5
200	Water Cycle	47	24
300	Water Supply Augmentation and Conservation	5	1
400	Water Quantity Management and Control	4	4.5
500	Water Quality Management and Protection	30	40.5
600	Economic, Social, and Institutional Aspects	3	2
700	Resources Data	5	4.5
800	Engineering Works	5.5	7
900	Environmental Management and Protection	-	16
		100	100

The Changing Climate for Research

Durrant notes that the 250 percent increase in water resources research effort between 1966 and 1979 fell far short of the recommendations of the Bruce-Maasland report. One major reason for this shortfall was a general weakening of the Canadian economy. The environment, and especially water quality, was a high profile issue during this period. However, except for a major emphasis on the water quality of the Great Lakes, little increase in effort was possible. The research programs related to the Great Lakes were given added support by the signing of the Canada-United States Agreement on Great Lakes Water Quality on April 15, 1972.

The Agreement called for two major studies to be undertaken through the auspices of the International Joint Commission (IJC). The first one, a study of the water quality of Lakes Superior and Huron, was conducted by the Upper Lakes Reference Group. This was essentially an extension of a similar study conducted earlier on Lakes Erie and Ontario plus the International section of the St. Lawrence River during the period 1966-1969. The Upper Lakes Reference Group was formed in 1972 and submitted its report to the IJC in 1976. The second study was directed to pollution loads coming into the Great Lakes from land use activities. These diffuse, or nonpoint source, loads were identified as a significant, but poorly quantified, pollution load to the lakes. The Pollution from Land Use Activities Reference Group (PLUARG) was formed in 1972 and submitted its report to the IJC in 1978.

The Lower Lakes study was just getting underway in 1966 and represented a major research effort for the federal government and the Province of Ontario. In response to these needs, a major research centre, the Canada Centre for Inland Waters, was built and staffed at Burlington, Ontario.

These Great Lakes programs create a complication in the trend analysis discussed above. With only two data points (1966 and 1979), one is inclined to assume a straight line relationship between them. In fact, there has been a significant decrease in research since the mid-seventies. The two IJC references were completed during that period and the special research programs under the Canada-Ontario Agreement on Great Lakes Water Quality of 1971 also were completed.

Since the early seventies most research budgets have been held at constant dollar values or decreased. Even at fixed levels the ravages of inflation have caused a severe constriction in research efforts.

Emerging Issues

The emerging issues in water resource management can be grouped in several ways to indicate their relationship to other factors. The accompanying Appendix groups the issues according to two classifications: (i) the physiographic region in which the issue occurs, and (ii) the category of research to which the issue belongs.

In choosing a classification for grouping issues according to the region of occurrence, it was noted that the major physiographic regions used by Energy, Mines and Resources Canada, are influenced by significantly different kinds of water resource management challenges. The regions are, in order of size, the Canadian Shield, the Interior Plains, the Cordilleran, the Arctic Lowlands and Plateaus, the Hudson Bay Lowlands, the Appalachian, the Innuitian, and the Great Lakes and St. Lawrence Lowlands. We have adopted this same regional breakdown except for the Arctic Lowlands and Plateaus, Hudson Bay Lowlands and Innuitian regions, which have been grouped along with the northern extremities of the Shield, Interior Plains and Cordilleran regions under the general heading The North. The first section of the Appendix reveals the regional issues in detail.

Because much of the discussion at the workshops tended to follow the research categorization it was natural to follow that structure in the second entry in the Appendix. Relating the emerging issues to specific fields of research has the advantage of thus interfacing the issues with specific research activity, and conversely, providing a focus for the application of the new knowledge to actual needs of water resource managers.

Conclusions

The data and opinion gathering process of this exercise leads to several conclusions regarding water resources research in Canada. The more obvious of these conclusions are:

Unique Regional Issues: The input received from the regional workshops indicated very clearly that many water resource management issues are unique to a given region. For example, the Great Lakes Water Quality Agreement is unique to Ontario and the issues raised about the Fraser estuary are unique to British Columbia. It does not necessarily follow that the research needed to address the issues is similarly unique. For example, the study of toxic substances could be equally applicable to the Great Lakes and to the Fraser estuary.

It is important to keep the unique regional issues in mind when developing research programs which, in themselves, may be applicable generally. There must be an efficient and effective feedback to the regional water resource manager.

Multi-Regional Issues: A number of the important issues noted above are common to several or all regions. This broader area of concern can raise the priority of such an issue and more importantly, suggest a national rather than a regional response.

The Canada-wide, even worldwide, nature of the toxic substances issue suggests a national as well as regional approach to its solution.

The long range transport of airborne pollutants, by its very nature, is a multi-regional issue. Polluted air travels vast distances from source to area of impact and shows no respect for geographical or political boundaries.

Because the water resource management issues associated with the forest industries arise in each region, the research addressing these issues has wide applicability.

Almost all regions support agricultural activity. The kind of agriculture varies significantly from the prairie grain fields of the interior plains to the fruit farms of the Annapolis valley in the Appalachian region, but one common factor is the need for water. Indeed, agriculture is one of the major users of the water resource but most of it is supplied directly as rain or snow within the water cycle.

Shift to Water Quality Issues: The analysis of past funding trends illustrates clearly a major shift of research activity into the water quality and environmental impact areas. This is matched by a major reduction in water cycle research. Category 300, Water Supply Augmentation and Conservation, fell from 5% in 1966 to 1% in 1979.

If the resources allocated to Environmental Management and Protection were reallocated among the categories used by Bruce-Maasland by assuming 60% to Water Quality Management and Protection, and 40% to Economic, Social and Institutional Aspects, the former would rise to almost 50% of all resources while the latter would rise to about 9%. This reallocation demonstrates even more clearly the shift between categories over time.

Funding Trends: Total resources for all categories rose by 250% from 1966 to 1979 in constant dollars. This is a significant increase in 13 years. It is, however, more indicative of the very low resource level in 1966 than of a sufficient resource commitment in 1979. If the recommendations of the Bruce-Maasland report had been followed, the increase would have been ninefold.

Federal support for water resources research more than doubled in 13 years from $14.2 million to $29.2 million, whereas provincial support quadrupled during the same interval from $3.5 million to $15.4 million.

APPENDIX

I. EMERGING REGIONAL ISSUES IN WATER RESOURCE MANAGEMENT

1 The Cordilleran Region

The Cordilleran region is about 800 km wide and 2500 km long and includes the greatest complex of mountain systems and plateaus in Canada. The rocks range in age from Precambrian to Cenozoic. Two mountain systems dominate: the Rocky Mountain Area on the east and the Coast Mountain Area on the west.

The region is Canada's largest producer of lumber and possesses a sizable pulp and paper industry. Although there is little cultivable land, dairy and fruit farming are important, for example in the Okanagan and Lower Fraser valleys. Irrigation is carried out extensively in parts of the interior which, in contrast to the humid coastal regions, even reach desert conditions in marked rain shadow areas. Hydro-electric power potential is great, and one of the major issues identified within this region was associated with development of this potential.

1.1 Hydro-Electric Power

British Columbia, through its provincial government energy policy, is committed to a program of development of the hydro power resources of such rivers as the Peace, Columbia, Stikine-Iskut, Liard, Homathko, etc. Since most of these rivers are located in remote regions of the province where hydrologic data on streamflow, climatology, suspended sediment, ice, and water quality are generally non-existent (or at best of short duration), the collection of such data is of paramount importance. Research studies are urgently required in all of these categories to provide information required for the design of projects and for environmental impact assessments. The issue is data needs and impact models.

1.2 Multiple-Use

With expanding development, multiple watershed use becomes a necessity. Logging, mining, agriculture, fisheries, urbanization, water supply, highway construction, and recreation are only some of the conflicting uses which have an impact on the watersheds. The Fraser Estuary, which is an important water resource management issue in British Columbia, serves as but one example of the problem.

As indicated above, the mountainous relief of the Cordilleran provides a minimum of land suitable for agriculture and urban development. One of the largest areas of such a character is the delta and estuary of the Fraser River. The City of Vancouver and the majority of the population are located in this area. The estuary is the basic resource for a multitude of often conflicting uses. It is the gateway to the upper Fraser for the migration of salmon. It is the terminus of downstream bound logging operations. It is a major waterfowl habitat and also the receptor for liquid wastes from local municipalities and industries. The marsh lands of the delta are an attractive site for land development. The steep slopes of the drainage basin and the low relief of the delta make it especially susceptible to floods. Reservoirs upstream help to lessen the threat of flooding and also produce hydro power. Unfortunately, they also make it difficult for salmon to reach upstream spawning grounds.

Water quality degradation reduces the suitability of water as habitat for fish and waterfowl and for recreation. Industrial and residental development bring changes in the quality and quantity of the drainage. Decreased average permeability due to paving and roofing increases the runoff, and the quality of the runoff is degraded even in separate storm sewers. Point source discharges from waste treatment plants and industries add to the problem.

The inter-tidal habitat plays an important role for waterfowl. The importance of these areas for salmon is not well understood. Strong pressures exist to dredge and fill such areas for industrial and residential development.

Logging activities have been an important industrial enterprise in the estuary for many years. This use, however, can have deleterious impacts on other uses such as fisheries and waterfowl. The processes involved are not easily understood.

The descriptions of multiple and conflicting water uses as noted above for the Fraser Estuary could equally be ascribed, in part, to many other water resource management sites. The issue is methods of managing multiple-use water resource systems.

1.3 Eurasian Water Milfoil

The recreational and esthetic values of some lakes are being degraded due to the proliferation of exotic vegetation. Eurasian water milfoil was introduced to North America accidentally and has spread rapidly to infest many freshwater systems. This problem is especially serious in the Okanagan system. Chemical, biological and mechanical control methods are being investigated. The issues are the economics of milfoil control and the impact of control on water quality.

1.4 Inter-basin Diversion

Although there are no plans at present to divert water southward to the U.S., there are plans for inter-basin transfers of water within the region. Two such diversions currently under investigation include the Kootenay Diversion and the McGregor Diversion projects, which contemplate diverting southward flowing rivers north.

A major concern with inter-basin transfer is the possibility of introducing foreign biological species which could upset the ecological balance of the receiving basin. Such concerns were a significant point of contention in the massive Garrison Diversion proposal into the Red River watershed. The issue is the socio-economic and environmental impacts of inter-basin transfer of water resources.

1.5 Flooding

Flooding is a very serious problem in the Cordilleran region. Steep, impervious slopes and cultural development in the flood plains of narrow valleys combine to produce recurring flood damages. Structural and non-structural solutions must be sought to reduce these losses.

The key to short-term flood flow prediction is reliable meteorological forecasts, particularly quantitative precipitation forecasts on a watershed basis. Coastal mountain watersheds are especially difficult to forecast and require considerable research effort. The short-term issue is real time data for flood forecasting, but the long-term issue is flood damage reduction by non-structural measures.

1.6 Forestry

The vast forest covering the lower slopes of the Cordilleran region is a major economic resource. The harvesting of the resource, however, can have serious consequences for water resource management. Clear-cutting on steep slopes may make it impossible to re-establish the forest for future generations. In this sense forestry cannot be considered a "renewable" resource.

Clear-cutting of large areas of a watershed can produce significant changes in the rainfall-runoff relationships and increase flood flows. Research is needed to enable predictions of these effects so that pre-, and post-cutting streamflow records can be reconciled for hydrologic time series analysis.

Chemical spraying of forests for insect control can have serious impacts on aquatic biota. Water quality is also affected by increased sediment loads associated with logging operations, especially clear-cutting on steep slopes. The issue is integrated renewable resource management.

1.7 Irrigation

Intensive agriculture in some of the interior valleys is turning increasingly to irrigation because of the "rain shadow" effect of the coastal range. This activity is important to water resource managers both in terms of water supply and consumption, as well as water quality degradation from return flows. Much of this agriculture is of high value, such as fruit growing in the Okanagan Valley, so that a significant research effort would be economically justified. The issue is competing demands for water resources and increased efficiency of irrigation.

1.8 Ground Water

The aquifers underlying the valley lands are a major source of water supply for a multitude of uses. The close relationship between the aquifer and the river system requires new management procedures to reconcile conflicts regarding withdrawal rights. These conflicts will intensify in the future as major withdrawals for irrigation and other uses increase. The issue is management of competing uses of ground water.

2 Interior Plains

The water resource on the plains has some significant characteristics which are important in the discussion of issues, specifically:

(1) Water flows from the mountains to the east and to the north.

(2) The eastern flows go through three political jurisdictions each of which controls the water resources in its area. The federal government also shares certain responsibilities, particularly where the north/south situation of rivers causes them to cross the international boundary between Canada and the United States. They then become boundary waters by definition under the Boundary Waters Treaty of 1909.

(3) The southern watersheds are generally populated (in contrast to the north) and attractive to economic development.

(4) The southern watersheds are subject to periods of recurring, and sometimes prolonged, drought.

(5) Water shortages and water diversion opportunities do exist. Most of the diversion opportunities are in the Province of Alberta.

In general, it is expected that there will be an increase in population with influx of the labour force, particularly in the energy and resource sectors, and a trend towards urbanization.

Economically, the major job producers will be secondary industries; food processing industries; mining operations; renewable resource industries. All the above will have impacts on the environment and in particular, the water sector.

2.1 Water Scarcity

Intensive use of the fertile soils in the south for agriculture has transformed the face of the land by the damming of rivers and creation of many small local lakes and reservoirs for water conservation, irrigation and recreational purposes. Issues related to these concerns are important in this region. In particular, soil salinity and its effects on agricultural production and water usage was identified as an issue. The Interior Plains Region has remained a constant challenge. Drought years in the 1930s were disastrous to farmers and technological and institutional modifications had to be made. The prime federal response to this crisis was the creation of the Prairie Farm Rehabilitation Administration (PRFA) to control and coordinate federal efforts to meet the needs of Canada's prairie agricultural community. The Prairie Provinces Water Board, which oversees the sharing of water within the three prairie provinces, was a further major step.

While many advances have been made since the thirties in ways to reduce the impact of drought through river basin planning and management and better agricultural and relief practices, the threat of drought remains an issue. The ability to forecast periods of drought, in particular, and water shortages in general, are areas requiring unique attention in this Region. Options will have to be considered for management of drought-prone areas as well as developing long-term water supplies which are not subject to periodic disruption by drought.

2.2 Energy vs Agriculture Water Demands

In terms of consumptive use, the two competing sectors will be energy and agriculture. Not surprisingly, these two economic sectors will also have the greatest impact on water quality.

The tar sands and heavy oil resources will require vast quantities of water to produce usable crude oil. Unfortunately these demands occur in regions of water shortage. Water used for these purposes will reduce the quantity and quality of water available for agricultural purposes. The issues are resource conservation and equitable sharing of available resources.

2.3 Water in Agriculture

Competing demands for the available water supply will require increased efficiency in agricultural water use. This will apply to both precipitation and irrigation.

The water reaching the land as rain or snow is a precious resource which must be used efficiently. Current practices, such as snowdrift management and summer fallow, must be reviewed, and new methods developed to optimize the use of this resource.

Irrigation is an essential activity in some agricultural areas in this region. The delivery efficiency of these systems must be increased to provide the maximum amount of usable water to the crops in the field. Phreatophyte and seepage control will be required. A significant amount of irrigation water seeping from canals causes waterlogging and salinization of the soil.

A third issue of major concern is soil salinity control. In some locations a significant amount of irrigation water is used to flush the salts from the top soil. In other cases, salt-tolerant species have been developed. The initial quality of irrigation water is an important factor in the build-up of salts in the soil. A watershed approach is required with emphasis on ground water management to keep salt concentrations low in the sub-soil and to control and reclaim saline seeps. The issue is improvement in food supply through increased efficiency of water use.

2.4 Diversions

The geographical mismatch of water supply and water demand suggests a variety of inter-watershed diversions. As these large or small schemes are considered, the long-term impact must be evaluated. The introduction of biological species and their parasites or diseases into the neighbouring watershed is an especially important problem. The issue is the development of socio-economic benefit/cost analyses which include damages in the receiving basin and upstream losses in the donor basin.

2.5 Ground Water

Ground water is a major source of supply throughout most of the Interior Plains. Emerging concerns with this resource relate to deep well disposal of waste, artificial recharge of shallow aquifers, shallow ground water flow patterns and management of ground water for irrigation. The issue is management of the ground water resource for competing uses.

3 The Canadian Shield

The Canadian Shield is the largest physiographic region in Canada. It occupies almost half of the total land area. It includes most of Ontario and Quebec and major portions of Manitoba, Saskatchewan and the Northwest Territories. This highly contoured and lightly mantled region is dotted with lakes of all sizes which comprise an immense surface water resource. The geology and topography of the region has encouraged mineral extraction and hydro-electric development. Forestry also is a major industry. The Shield has remained unattractive to farmers, even though relatively small districts in the clay belt have been settled. Lack of suitable soil, a harsh climate and lack of accessibility to northern areas are factors which lessen settlement of this area.

3.1 Mining

The very old geologic age of the Shield provides an excellent source of a wide variety of minerals for commercial extraction. These mining operations and the associated milling and smelting produce many polluting by-products. Slag heaps and the aftermath of years of air pollution have laid waste many thousands of acres in the region.

Leachate from slag disposal has an impact on water quality. Pollutants in the air are washed out or settle as dust. Waste water from a variety of ore processing operations contaminates surface and ground water. The issue is mining waste management.

3.2 Acid Rain

The granitic surface geology of the region provides very little buffering capacity for surface waters. This makes these lakes very susceptible to the impact of acid rain. Thousands of Shield lakes have been killed, from a biological point of view, by acidification. The socio-economic impact is enormous because these lakes support a very large recreation industry based largely on fishing. The Great Lakes are not threatened yet because of their large buffering capacity, but localized acidification occurs during spring runoff of acidified snow and some young-of-the-year fish are affected. The issue is air pollution control on a continental scale.

3.3 Forestry

The forest industry and associated pulp and paper operations are significant sources of water pollution. Waste effluents from mills are important point sources of pollutants. Timbering operations can increase erosion and the release of sediments into rivers and lakes. Insect control by the use of chemical pesticides contributes to the pollution of surface waters and can seriously affect fish and wildlife. The issues are the same as for the Cordilleran region.

3.4 Hydro Power

The surface water resources of the Shield provide a large potential for hydro-electric power generation. The huge James Bay development in Quebec is an example of the magnitude of potential projects. Many other sites are being considered, such as the rivers draining into Ungava Bay, and the North Slope watersheds in northern Ontario and northern Manitoba.

Hydrologic data are sparse and possible environmental consequences almost totally unknown. Power transmission over such long distances to load centres is a major technological challenge.

The experience of the James Bay mega project in Quebec should be applied to other proposed developments, especially in the area of potential environmental impact. This will require a continuing monitoring of ecosystems in the La Grande watershed and James Bay to calibrate the models which have been developed to predict impact.

3.5 Disposal of Radioactive Waste

The very stable and deep geologic mass of the Shield makes it a prime candidate area for the long-term disposal of high level radioactive waste from nuclear power generation. Many perplexing questions remain to be answered before such a use can be approved. The low population density in the northern part of the Shield is an added attraction. The issue is ground water contamination.

4 The Great Lakes - St. Lawrence Lowlands

This relatively tiny region is tremendously important because it is the location of most of Canada's industrial development and over half of the population. It includes the megalopolis stretching from Windsor, Ontario, to Quebec City which is home to most of the population of the provinces of Ontario and Quebec. It is the industrial heartland of Canada and is blessed with the world's greatest fresh water resource - the Laurentian Great Lakes watershed.

The portion of this region in Ontario is dominated by the Great Lakes and their connecting channels. Most water resource management issues here have an international component. The portion of the region in Quebec is dominated by the St. Lawrence River, which is an international waterway but, in the Quebec reach, is wholly Canadian.

The Great Lakes are an important natural resource, providing benefits vital to the economies of both Canada and the United States in the form of municipal and industrial water supply, power generation, navigation, irrigation, fishing, etc. Exploitation of some of these uses, however, has not been without impacts on others and it is these conflicts which have given rise to water resources management issues.

4.1 Toxic Substances

Probably the most pressing issue in the Great Lakes is that of toxic contaminants because of their persistence, their tendency to bioaccumulate and their potential impact on human health. Many of these substances have already been identified in lake sediments and biota (including man) at concentrations high enough to warrant the implemented control programs and to require the careful monitoring of lakes, fish and foods which is now underway.

With respect to persistent toxic substances the only acceptable management option is control at source (i.e., zero discharge). At present, for many of these substances this is both technologically and economically unfeasible. There is an urgent need for better pre-screening technologies, better inventories of these substances and better means of detecting them at an early stage in the environment before their impacts reach crisis proportions as has happened in the past, for example, with DDT, mercury, and PCBs. Several bans or restrictions have been implemented in the fishery as a result of these substances.

This existing pollution which has accumulated over the years has left serious problems in several areas that will demand continued attention even after the major sources of contamination have been eliminated. Energetic programs for assessing the effects of contaminants on water resources and the early detection and control of "new" pollutants must be continued if an environment relatively free of contaminants is to be obtained and water resources are to provide their full potential to the basin's population. The issue is better management of toxic substances.

4.2 Lake Level Regulation

Variation in water levels and flows is a concern in the Great Lakes System. The natural, self-regulating characteristic of this system of huge reservoirs gives shore property owners a false sense of security. Normal short-term variation in levels and flows is much less than for most other river and lake systems. Prolonged periods of above or below normal rainfall, however, can produce high water years and low water years which occur on a frequency measured in decades.

These extreme conditions, coupled with storm events, have caused extensive erosion and inundation losses. Low water extremes impact on navigation and hydro power generation. In spite of these serious impacts, extensive studies of the system have concluded that further artificial regulation of levels and flows is not economically justified. Local structural and non-structural solutions to these losses must be developed.

Furthermore, in terms of land use, owing to changing public and policy attitudes, there is simultaneously a higher value being placed on the preservation of shorelands, including the remaining wetlands in Ontario, and greater pressure to destroy them. Ontario Region is concerned about physical reductions and deterioration in shoreline fish spawning and nursery areas and waterfowl habitat through marsh drainage, excessive sedimentation and pollution. Most of the marshes adjoining the lower lakes have been lost; those not in public ownership as parks and wildlife areas soon will be lost. The issue is how to manage hazard lands and areas of ecological sensitivity.

4.3 Management of International Waters

Water resources management in the region is very much characterized by an international flavour because of the Great Lakes which are a vital resource and major responsibility of two countries. The international nature of the Great Lakes requires that each jurisdiction be free to develop its own program to achieve common goals as expressed in the 1978 Canada/United States Great Lakes Water Quality Agreement. The phosphorus control programs in Canada and the United States reflect different approaches to the same goal. Likewise the two governments have used somewhat different approaches to control and to limit the introduction of toxic substances. The issue here is to develop bi-national coordination and concerted action in restoring and maintaining the integrity of the waters of the Great Lakes Basin ecosystem without sacrificing jurisdictional autonomy.

4.4 Eutrophication

Major nutrient control programs for phosphorus in the Great Lakes Basin have been implemented by both countries for point source discharges, and new target loadings for phosphorus have been established in each of the Great Lakes (1978 Can/U.S. Agreement). More recent studies have indicated that non-point sources, including the atmosphere and land drainage, are a significant source of phosphorus loading to the lakes. Future management strategies must take these into consideration. In addition, while the phosphorus/eutrophication issue has been addressed on a basin-wide basis, future options must include management, possibly using a blend of strategies, on a smaller, localized basis.

4.5 St. Lawrence River Navigation

The St. Lawrence River remains the most important transportation corridor in the region. The establishment along its shores of large industrial complexes serviceable by ocean transport, yet easily accessible to both North American and European markets, is expected to increase. Year-round navigation currently extends upstream to Montreal. There is considerable pressure, especially from U.S. interests, to provide year-round or at least extended season navigation for the entire system. This raises many environmental and flow control issues.

Winter navigation in the river above Montreal would provide significant economic benefits to Great Lake ports, especially those in the United States. Such a scheme, however, could have very serious consequences to hydro-electric interests and also to the ability to manage outflow and water levels. Canada must be well prepared technically to critique U.S. proposals.

4.6 Flooding

Although tributary rivers have been important to the development of the region, they have also brought flooding problems, particularly in spring. The northward flowing rivers of the south shore, and the Ottawa River system around the Montreal area, annually give rise to several million dollars of damage. The Great Lakes tributaries in Southern Ontario have similar flooding problems.

Accelerated programs of agricultural land drainage have raised questions regarding the impacts of this practice, including increased flood risks, and water quality problems. Coupled with this is the acute problem of pig manure disposal to watercourses. As a preliminary control step, the Government of Quebec has proclaimed a moratorium on the establishment of new pig-raising operations in Quebec.

Flooding problems have been addressed by both structural and non-structural programs. The River Basin Conservation Authorities in Ontario are engaged in a major program of flood control and hazard land designation. This is supported by the Federal Flood Damage Reduction program. Quebec has joined the federal government and Ontario in a joint effort to reduce flooding by the Ottawa River through coordinated control of the storage capacity of the series of hydro-electric reservoirs in the watershed.

4.7 Diversions

Transfer of water out of the Great Lakes-St. Lawrence watershed has been proposed on a number of occasions. Neighbouring regions have coveted this massive fresh water resource during periods of localized water shortage.

Three interbasin transfers have operated for many years. Water flows out at Chicago 91 m^3/sec and in at Ogoki 127 m^3/sec and Long Lac (40 m^3/sec). The actual, current riparian consumption of water from the system is of the same order of magnitude.

Future, large-scale diversions may be proposed and Canada must be prepared technically to continually review and, if necessary, counter such proposals. Today the policy of government is "no water export". In the future it may be necessary to re-evaluate this policy in exchange for other economic benefits. An in-depth assessment of potential gains and losses is needed.

In any event, the consumption of water from the basin will continue to increase and hydro-electric interests and navigation interests will have to be prepared for resulting changes in levels and flows.

4.8 St. Lawrence River Pollution

The large dependable flow in the St. Lawrence has tempted riparian municipalities and industries to use it as a receptor of liquid waste. This has caused serious pollution problems downstream. The problem of pollution caused by municipal and industrial activities in Quebec has provoked a response from the provincial government. A coordinated program in which industrial and municipal pollution problems are resolved on a watershed basis has recently been implemented. This is presently envisioned as a $6 billion clean-up program scheduled over the next 10 years. This program will have a considerable effect on water-related issues in Quebec and will require efforts in wastewater treatment technology and operator training programs to ensure future treatment effectiveness.

4.9 Agricultural Drainage

This region contains some of the most valuable farm land in Canada. There is potential for large increases in agricultural production based upon land drainage. This is a costly process and may have serious environmental impacts. Recent studies of the South Nation watershed in southeastern Ontario are indicative of this kind of issue.

5 Appalachian Region

The Appalachian physiographic region includes all of the Atlantic provinces (New Brunswick, Nova Scotia, Prince Edward Island and Newfoundland) plus the Quebec south shore east of Quebec City. The topography varies from low mountains to lowland plains.

The island of Newfoundland is a continuation of the Appalachian Highlands. There are many peninsulas, bays, lakes and river basins on the island. About 8% of the surface area is freshwater. Total occupied farmland is only about 0.05% of the island's land area.

The coast of Nova Scotia is bold and rugged with excellent harbours. The Atlantic upland is a distinctive feature of the province, consisting of five detached fragments of uniform upland surface separated by lowlands and fertile valleys. There are many rivers and lakes.

About 14% of the total land area of Nova Scotia is occupied farmland with the most notable agricultural region being the Annapolis Valley.

New Brunswick has low, rounded hills and rolling uplands of moderate altitude. Much of the soil is rocky and arable land is scarce. There are many rivers.

Prince Edward Island's irregular coastline has large bays, long inlets, high cliffs and sandy beaches. Both climate and soil are well suited to mixed farming and about 66% of the province is occupied farmland.

In general, the Region is characterized primarily by its relationship to the ocean. All four provinces have major links to the sea and the impact of maritime climate affects most water resources in one way or another.

Inland water is an important resource, but it is vastly overshadowed by salt water or oceanic interests. In many cases the estuaries are of vital concern and the impact of changes in quantity or quality of the freshwater inflow is critical. The relatively small watersheds provide limited surface water supplies so that a significant portion of the drinking water is taken from ground water sources.

5.1 Estuaries Management

Estuaries are of special interest in the Region. Most of the population lives near the coast and usually on an estuary. The estuaries are seriously impacted by the inland waters flowing into them. The degraded quality of these inland waters affects the important shellfish industry, and sediment carried from the land causes navigational and flooding problems. The ocean tides, in turn, have a significant effect on flood stage in the lower reaches of the rivers. Thus, the Flood Damage Reduction Program must take storm tides into account.

Each of the many estuaries in the region presents a unique management problem. In most cases, several uses compete for the resource and have conflicting demands. The role of the freshwater inflow varies from place to place but usually is important in maintaining the balance between salt and fresh water required to support the biological population. Contamination of the freshwater supply is of special significance to many uses. Control of pollutant loading must be exercised inland at the point of discharge. Population pressures will require protection of coastal marshes from dredge and fill land development. The fishery resource is so important to the Appalachian Region that any management scheme must give it a high priority.

One major difficulty in dealing with estuaries is jurisdiction. Being neither strictly fresh nor salt water, this region falls between the mandates of the Inland Waters Directorate of Environment Canada and the Department of Fisheries and Oceans. A similar jurisdictional problem occurs at the provincial level and between the federal and provincial governments. It was noted that in some cases one Department has the responsibility to manage while another Department has the tools.

Tidal power is a feasible alternative energy source in some locations. The massive structures of such a project may interfere seriously with other uses of the water resource such as fish habitat and recreation.

5.2 Forestry

Forestry is a very important industry in this region. Newfoundland is estimated to have almost 88 000 km^2 of productive forestland which support a thriving pulp and paper industry. Forests cover almost 80% of Nova Scotia and 86% of New Brunswick.

As in other regions, the forest industry involves insect control with its resultant pollution of surface water, and the waste effluents from pulp and paper mills. Solutions to these problems will have applications in most regions of the country.

The pesticide problem can only be controlled by the development of new insect control methods which are less harmful to the aquatic ecosystem. A reliable estimate of the dollar cost of pesticide-related pollution would help to place the potential forestry loss in perspective for the political decision-makers.

5.3 Mining

Coal is the most important mineral resource in the region. Other mineral deposits include gypsum, barite, and salt. Acid mine drainage and seepage from slag and tailings cause water quality degradation.

Peat is an important quasi-mineral resource which is being developed. The hydrology of peat bogs is poorly understood and the "brown water" associated with them creates problems for water treatment processes.

5.4 Resource Data Collection

The remoteness and inaccessibility of some hinterland locations make resource inventorying difficult and expensive. The lack of water resource data (especially in Newfoundland and Labrador) is similar to the northern parts of the other regions. One difference is the rapidly varying topography. Once again, the "need to know" and some quantification of the "cost of ignorance" would be helpful. This problem is compounded, in the case of hydrologic data by the fact that what one really needs is a long time series. Past data cannot be recovered at any price, but new stochastic techniques are helpful in this regard.

5.5 Ground Water Management

Ground water is a vital resource in the Appalachian region. Management of both quantity and quality is required. Withdrawal rates and interwell interference may be problems requiring new analytical and predictive modelling techniques. The movement of contaminants with ground water flow needs additional study and management of solid and liquid waste disposal sites must be undertaken. The fractured rock character of region aquifers poses special management problems. The proximity of most urban areas to the ocean provides the potential for salt water intrusion into fresh water aquifers.

Ground water may be a usable energy source. This hot ground water (geothermal energy) might be used for space heating or agriculture. Potential impact on other ground water strata and the disposal of waste water must be evaluated.

5.6 Institutions for Water Management

The multi-provincial nature of the political structure presents special problems of jurisdiction. Even within a given province, responsibilities are split between several departments. Some joint, regional resource planning between jurisdictions has already been initiated. An important role for the federal government is to encourage and facilitate such regional initiatives.

One institutional arrangement suggested at the workshop was the establishment of drainage basin water authorities. This procedure has been successful in Britain and also in Ontario. The drainage basin is a very logical choice as a management and jurisdictional area because it ties together the upstream - downstream interests along with all of the water-related land uses. The major difficulty is in deciding how much authority and autonomy such a body should have. As in several other regions, research on institutional aspects is urgently needed.

6 The North

The North and far North are composed of a variety of land forms including the Canadian Shield, the Hudson Bay Lowlands, the Interior Plains, the Cordilleran, and the Arctic Lowlands and Plateaus. Vastness, remoteness, a harsh climate, scarcity of population, and a wealth of mineral and hydrocarbon resources are some of the main characteristics of this region. In essence, many of the fundamental environmental management problems facing Canada today are associated with development in the North. In this region the contradictory or overlapping goals of resource development, largely in the energy sector, social development, short-term profitability, and long-term viability, are particularly evident.

Already, extensive hydrocarbon drilling has taken place from ice platforms in the Arctic Archipelago, from artificial islands in the Beaufort Sea and from conventional platforms in Hudson Bay. Various pipeline routes have been proposed to transport the gas to various centres in the South.

Although a considerable amount of new knowledge, including baseline data, will be required for wise management of the water resources of this region, the very remoteness of this area makes acquisition of this knowledge extremely difficult because of problems associated with accessibility and logistics. Understanding of functional relationships in northern systems is very limited.

6.1 Inter-basin Transfers

Proposed interbasin transfers from this region to the south are an important issue. With the north-south orientation of the rivers there is both the opportunity and the pressure to divert water from northern regions to the more populated and developed regions of the south. Before this occurs, the future water uses in the North must be understood. By running water southward, constraints will be released in the south and activities will locate in the south that may otherwise not exist or could possibly locate in the North. Management decisions must be based on a good understanding of how northern systems operate.

The Northwest Territories on the other hand, being a downstream jurisdiction, is concerned that development in the headwaters located in British Columbia, Alberta and Saskatchewan may have adverse effects on the quality and quantity of waters in the Territories.

6.2 Population Increase

The further development of this region will greatly increase population and the problems associated with human activity. A year-round supply of water for drinking and other municipal purposes is scarce in some parts of the region. Similarly, the climate requires novel approaches to the treatment and disposal of waste waters.

6.3 Hydro Power

The development of hydro power on the Mackenzie-Liard watershed poses special problems because of the northern climate. The possible impact of large alterations in the flow regime downstream on very sensitive and fragile Arctic ecosystems is poorly understood.

7. Multi-Regional Issues

The discussion above focuses attention on the individual regions of Canada and the water resource management issues associated with these regions. It becomes obvious, however, that a number of important issues are common to several or all regions. This broader area of concern can raise the priority of such an issue and, more importantly, suggest a national rather than a solely regional response.

7.1 Toxic Substances

The issue of toxic substances was listed specifically in the Great Lakes-St. Lawrence Lowlands region, but clearly, the problem exists in all regions. It is not surprising that this issue should manifest itself first and most acutely in this region because of its high population density and industrialization. The Canada-wide nature of this issue suggests a national approach to its solution. Indeed, the federal government has established a major program to address the issue in cooperation with the provinces. Major research programs within several departments of the federal government are underway to augment the similar programs of the provinces and other economic sectors. The results of the research will be generally applicable in all regions. It is hoped that the less developed areas of Canada will benefit from the past mistakes made in the Great Lakes-St. Lawrence Lowlands region.

7.2 Airborne Pollutants

The long range transport of air pollution, by its very nature, is a multi-regional issue. Polluted air travels vast distances from source to area of impact. This movement does not recognize geographical or political boundaries.

The federal government has taken the lead in developing a coordinated, Canada-wide program. The international character of this issue made it especially necessary for federal involvement. It is particularly serious in the Canadian Shield and Appalachian regions because the surficial geology does not provide sufficient buffering capacities to the surface runoff to neutralize the acid load.

The increasing use of high sulphur coal for the generation of electricity can only intensify the issue. The U.S. policy of oil-to-coal conversion will add significantly to the acid rain problem in central and eastern Canada. Many scientific questions regarding impact and control technology remain unanswered.

7.3 Forestry

Canada is blessed with a massive forest resource which is distributed throughout most regions. The water resource management issues associated with the forest industries arise in each of these regions so that the research addressing these issues has wide applicability. The Forestry Service of Environment Canada supports a large research program in institutions spread across the country. This research supports the resource managers in the various provinces. Forestry research is seeking ways to reduce the impact on the water resource of such practices as insect control and logging operations.

7.4 Agriculture

Almost all regions support agricultural activity. The kind of agriculture varies significantly from the prairie grain fields of the Interior Plains to the fruit farms of the Annapolis valley in the Appalachian region, but one common factor is the need for water. Indeed, agriculture is one of the major users of the water resource but most of it is supplied directly as rain or snow. Irrigation from surface or ground water is increasing and several regions identified it as an issue. In some locations, growth is almost totally dependent on this source of moisture. Thus, agriculture represents an increasing demand for water resources, often in locations of limited supply.

As with almost all other uses of water, the portion returned to the watershed is degraded in quality and greatly reduced in quantity. Underflow from irrigation contains increased levels of dissolved solids as well as agricultural chemicals. The surface runoff from irrigated and unirrigated fields carries eroded soil particles along with chemicals which have been applied for fertilization and pest control. Bacteriological contamination from animal wastes presents another problem. This type of non-point source pollution was considered by the International Joint Commission study of pollution of the Great Lakes from land use activities.

Most of the water supplied to agriculture for irrigation is transpired by the plants or incorporated into the product. Thus, irrigation water is largely "consumed" in the process. This is quite different from, for instance, cooling water which is almost totally returned to the source. Water thus consumed is not available for reuse downstream. The nature and quantity of this kind of demand must be considered in planning water using projects downstream. Hydro-electric installations will suffer significant economic losses which must be measured against the benefits of irrigation.

Much of the research on soil moisture and infiltration is of value to both agriculturalists and hydrologists. There is a need for closer coordination between water resource managers in the general sense and major water resource users such as agriculture.

7.5 Municipal Water Management

The satisfaction of the wants and needs of Canadians is the primary reason for water resource use and abuse. This relationship is seen most clearly in municipalities whose sole function is to provide services to people.

Municipal water supply usually is of the highest priority and physical constraints on this service can effectively constrain the growth of the municipality. The high value of drinking water has justified massive and long distance transport since the time of the Roman aquaducts.

Most of Canada is well supplied with water but in certain areas the quality of the water is a problem. Some well water has undesirable levels of dissolved solids and some taste and odour problems. Some surface water is degraded owing to prior use upstream. Some kinds of contamination can be removed by filtration and chlorination, but other toxic substances would require much more sophisticated treatment.

The other water-related function of municipalities is sewage treatment and disposal. In fact, most of the water drawn in as water supply is returned to the river basin in this way. Most cities have adequate treatment facilities to treat dry weather flow for removal of organic contaminants and suspended solids. Effluents from such plants still contain nutrients such as phosphorus. Stormwater overflows and bypasses pose a serious intermittent pollution load to receiving waters.

The continuing trend to urbanization will increase the demands for water supply and waste disposal.

Similar problems are encountered to a lesser extent in non-urban populations, e.g., rural communities and cottages that have significant localized effects on lake and stream water quality.

7.6 Recreation

Recreation is another activity which meets the need of Canadians directly. Many forms of recreation are water-related such as fishing, boating, swimming, or just viewing. In some cases, such as water contact sports, the quality of the water is of direct and measurable concern. In other cases the aesthetic value of "clean water" is less quantifiable and can even relate to waters never actually seen by the individual, such as the Arctic ecosystems.

In the water-rich central and coastal regions of Canada, good recreational waters are taken for granted. In the Prairie Provinces, even limited recreational waters are of great local value.

7.7 Resource Data Collection

The primary requirement for management is knowledge of the magnitude of the resource and the characteristics of its spatial and temporal variability. The Water Survey of Canada (WSC) is dedicated to providing this essential knowledge. The provincial governments, in concert with WSC, participate in the acquisition of this information. In the Province of Quebec, the provincial government gathers the water resource data instead of WSC. The funds for operating gauges are provided according to uniform cost-sharing agreements. Users of these data include hydro-electric commissions and consulting engineers for a wide range of water uses.

The vastness of the country and its relatively sparse population make it very difficult and expensive to collect much of the data. Improved and automatic instrumentation is needed to increase efficiency and enable the monitoring of many remote river basins.

It will always be impracticable to field measure every river basin which might be of economic importance at some time. Thus, it is essential to develop techniques to permit the estimation of hydrologic data on ungauged watersheds. This technique is especially important because it is usually a long time-series of data that is needed. Historical data are unavailable at any price and simulated hydrology, calibrated to current conditions, is the only option available.

Flow under an ice cover and flooding due to ice jamming are common occurrences in the Canadian climate. Both of these phenomena are of interest not only because of the direct effect on the conveyance capacity of the river but also because instantaneous flow is inferred from a measured river stage or water surface elevation. The presence of an ice cover or ice jamming will modify this stage-discharge relationship and invalidate the flow estimate. Ice jamming can cause disastrous flooding in built-up areas and hamper hydro-electric power production downstream.

The phenomenon of spring break-up of the ice cover is related to ice jamming and needs further study. This is especially serious in northward flowing rivers where the upper reaches break up while the downstream reaches are still solidly frozen.

7.8 Socio-economics of Water Management

Every water resource management option costs money, and affects people positively and negatively. Technical solutions must be assessed in their socio-economic context.

In most cases, water resource management is in the public domain, so the political process cannot be ignored. In fact, many decisions are primarily political, but they should be made with the support of the best available technical knowledge.

New techniques and procedures are necessary to improve our ability to interface the technical and socio-economic knowledge so as to provide the politician with the best possible advice in a form he can readily understand.

One of the most important tools in this regard would be a means of quantifying the social cost of pollution for comparison with the primary and secondary costs of pollution control.

8. Federal-Provincial Programs

The discussion of regional issues was categorized by geographical or physiographic description, but it must be remembered that this translates politically to provincial jurisdictions. Indeed, the Canadian Constitution maintains that the provinces have ownership of resources, including water.

Each province devotes significant resources to the management of its water resource. These managers will have to deal with the issues arising in the physiographic regions represented in their province. This will require a good two-way communication between federal and provincial managers and researchers.

In most cases, the federal role is supportive and provides research and resource data. In multijurisdicitional situations the federal government has a more direct responsibility. International boundary waters are a joint responsibility of the two senior levels of government. Issues arising in this context require a high degree of federal-provincial collaboration. Interprovincial waters also require federal involvement. The federal government and individual provinces have developed joint programs of water resource management under the Canada Water Act.

Studies such as those for the Okanogan and Fraser Estuary have been conducted under such arrangements. The Canada-Ontario Agreement on Great Lakes Water Quality is an example of an ongoing joint activity under the Canada Water Act.

II. EMERGING ISSUES RELATED TO THE RESEARCH CATEGORIES

Category — The Bruce-Maasland report established the categorization of research activity that has been followed in this report. A listing of these categories (and sub-categories) together with some explanation of each is reproduced at the end of this appendix.

100 **Nature of Water**

The 1968 report by Bruce and Maasland noted that category 100 was the only one in this categorization which could be called "pure" research. Indeed, if you move toward an application of this knowledge base you immediately move within another category.

101 **Properties of Water**

The workshop at Regina noted a need to better understand the thermodynamics of snow and permafrost. This could be included in 203, but there still is a need for basic research in a carefully controlled laboratory setting. The Halifax workshop identified the need for more knowledge of the dielectric, optical and mechanical properties of snow and ice. This knowledge would assist remote sensing techniques.

102 **Aqueous Solutions and Suspensions**

This sub-category is related to ground water contamination issues as noted by the Regina and Halifax workshops. Migration of potash and uranium through ground water is a concern on the prairies. Arsenic and uranium contamination of ground water in the Appalachian region is an issue. A better understanding of aqueous solutions and suspensions would aid in the above applied ground water studies. This basic research would find applications in most regions and should be developed at one or two centres for application to local issues.

200 Water Cycle

This category is concerned with the occurrence and movement of water in all phases of the hydrologic cycle. Because it is a cyclic process, water is a renewable resource to be used over and over again. An understanding of each phase of the cycle is essential to the wise management of the resource. As noted in the 1968 report, research of this kind received a big boost from the International Hydrologic Decade (IHD). The trend in recent years (post-IHD) has been a decline in Water Cycle research in favour of a major emphasis on water quality research.

201 General

Research involving two or more phases of the hydrologic cycle is included in this sub-category. This includes many interface problems, such as rainfall-runoff or surface water - ground water. This leads to hydrologic modelling. The Vancouver workshop saw a need for short-term and seasonal runoff forecasts and mathematical techniques for computing probable maximum floods.

The Regina workshop identified the need for specialized models for the North. Models to forecast parameters other than stream flow, e.g., soil moisture, are needed. Forecasts should be user specific, i.e., agricultural, flood control, waterfowl. The Toronto workshop noted also the need for models to extrapolate historical flow data and to transfer hydrologic data from gauged to ungauged watersheds. The Toronto and Halifax workshops noted the need for models applicable to peat lands.

202 Precipitation

This is the most easily observed, if not quantified, phase of the hydrologic cycle. It is also highly variable in space and time as well as in the form, such as rain, hail, freezing rain, and snow. It has been extensively studied. The extreme variability of topography in the mountainous Cordilleran region poses special problems in variability. Orographic effects dominate and there is a need to predict the elevation where rain turns to snow. Radar and remote sensing techniques are needed which will quantify precipitation. The Regina workshop pointed to the need for better instrumentation, especially for snow. The Toronto workshop noted the need for drought modelling with 3- to 6-month forecasts. The long range transport of air pollutants was of concern to all regions. The possibility of climatic change and its effect on precipitation needs further study.

203 <u>Snow and Ice</u>

Canada's geographic location makes this an especially important subject. Indeed, a significant and sometimes major portion of streamflow is derived from snow melt and glacier melt. The Vancouver workshop was especially interested in all aspects of glacier behaviour. Ice on lakes, reservoirs and rivers require additional study. Ice formation and break-up on rivers have a significant influence on levels and flows. Bank erosion and bed scouring related to ice also are of interest. Techniques and instruments for flow measurement under ice are required. In the prairies where most of the soil moisture comes from snow melt there is a need for snow cover management techniques. Snow making and recreational uses of snow are important areas of research. There is a need to study snow cover redistribution by wind, snow entrainment, deposition and sublimation in transit. The Toronto workshop identified similar needs and also infiltration during winter. A water quality problem related to snow and ice is the spring thaw acid shock caused by the rapid release of acid stored in the snow. This effect can be serious even in well-buffered lakes.

204 <u>Evaporation and Transpiration</u>

An understanding and quantification of evaporation and transpiration is essential to the management of water resources. It provides a "short circuit" in the hydrologic cycle by returning surface and ground water to the atmosphere. It is a major factor in the water balance for lakes and reservoirs. All regions expressed the need for a better understanding of these processes. The Regina workshop noted a particular interest in the transpiration by riparian vegetation along the banks of irrigation supply canals. The Toronto workshop was interested in the impact on evaporation rates of waste heat discharges into lakes and rivers.

205 <u>Streamflow</u>

The flow of water in streams and rivers is the predominant means of transport from watershed to lake or ocean. Next to precipitation, it is the most apparent phase in the water cycle. Many millions of dollars are spent to utilize streamflow or to protect against massive property damage due to flooding. Occasional periods of very low flow can have serious impact on important uses such as water supply, waste dilution, and transport.

All regions identified the need for better forecasting of extreme flow events. The Vancouver workshop noted a need for correlation techniques that would extend historic streamflow records for long-term estimates of hydro power potential. It also noted the need for better methods to detect sites for small-scale hydro projects. Several regions suggested studies to predict the impact of major changes in streamflow regime on bed erosion, flood wave propagation and pulse-stable processes.

The annual spring flood backflow from the Peace River into Lake Athabasca was an example of a pulse-stable system. The water budget of Lake Athabasca includes an annual inflow from the Peace River spring flood. The set of channels connecting Lake Athabasca to the Peace River actually reverse direction when the Peace is in flood. This important backflow was drastically reduced when the magnitude of the spring flood on the Peace River was reduced by the Bennett Dam. Periodic flooding is not necessarily a bad thing.

The Regina workshop was interested in the effects of agricultural drainage on streamflow. The Toronto workshop noted a need for better methods for computing flood damage. What are the effects of agriculture, forestry, urban and industrial development on river regime? The Halifax workshop noted the need for a better understanding of the effect of tides on water levels and flows in estuaries. All regions sought the ability to transpose hydrologic data from gauged to ungauged watersheds. Great strides have been taken in the last few years to mathematically model streamflow but much remains to be done, especially in real time control methods such as telemetered water levels.

206 <u>Ground Water</u>

Ground water is a significant source of fresh water for domestic, industrial and agricultural uses. Its occurrence varies greatly in both quantity and quality. Many ground water reservoirs are recharged naturally by infiltration of surface water and therefore are renewable. Other ground water reservoirs receive very little or no recharge and, like oil or gas, are a non-renewable resource. Ground water flow is very slow so that any contamination will remain for a very long time. Because of this fact, water resource managers are especially concerned about anything that threatens to contaminate it. Deep well injection of wastewater, improper drilling practices and leaching from surface waste dumps, all have the potential to contaminate ground water.

The Vancouver workshop noted that we need more knowledge about the ground water contribution to basin runoff, and salt water intrusion into fresh water aquifers in coastal areas. The Regina workshop was especially alert to ground water research because of the relative scarcity of good surface water. Questions needing study included: ground water/surface water relationships for better allocation; feasibility of using aquifers to store surplus surface water by injection or water spreading; and impact of surface soil conditions on recharge. What impact does the agricultural practice of field drainage have on the ground water regime? Another important question is the movement of contaminants through sub-surface formations. Can movement be managed to control potash, herbicides, fertilizer, and industrial waste dispersions?

The Toronto workshop noted many of the above research needs and also pointed to the need for better instrumentation for both quality and quantity. Improved models of ground water transport are needed. What is the role of ground water in modifying the effects of acid rain?

The Halifax workshop was especially interested in sub-surface flow in fractured rock as contrasted with granular aquifers. Another unknown was the effect of urbanization on the underlying ground water system. Most regions expressed concern for the general lack of data on the ground water resource.

207 Water in Soils

This major interface feature in the hydrologic cycle is important to hydrologists as it relates to infiltration. It is the prime concern for agriculturalists because it is the basis for all crop production. The hydrologist is interested in soil moisture as it affects rates of infiltration and thus the rainfall-runoff relationship. The agriculturalist sees soil moisture as the most important feature controlling transpiration, which is directly linked to plant growth.

The Vancouver workshop noted the need for research on soil moisture indices for hydrological modelling and the state of the soil as it affects infiltration and thus runoff. The Regina workshop suggested that this sub-category be expanded to include the active layer in permafrost regions. More research is needed to understand the infiltration process, especially in frozen ground and permafrost. Several regions supported the need for remote sensing techniques to map soil moisture. The Toronto workshop drew attention to the effect of soil moisture on slope stability. The Halifax workshop was especially interested in soil moisture studies in peat soils.

The range of interest in this sub-category was greatly enhanced by participation in the Agriculture Canada Research Branch Work Planning Meeting on the subject of water in agriculture. As noted earlier, the agriculturalist views soil moisture from quite a different view point than the hydrologist. Research topics relating to this sub-category included: physicists' perception of soil water research needs, effects of agriculture on water quality, water management for coarse-textured irrigation soils, soil management for conservation of soil moisture, water management, soil erosion and compaction, and improved management of wet soils.

208 Lakes

Lakes are a dominant feature of Canada's water resources. Probably the most significant water resources research efforts in Canada to date are the studies of the Laurentian Great Lakes under the Canada-United States Great Lakes Water Quality Agreement. This multimillion dollar effort began in the mid-sixties and is still ongoing.

Although the Great Lakes are the largest, they are by no means the only lakes of significance. Manitoba, Alberta and the Northwest Territories have lakes which are among the largest in the world and many thousands of smaller lakes are scattered across the landscape from British Columbia to the Maritimes.

Large reservoirs behave like lakes and have similar problems. Hydro power developments in British Columbia have created many large reservoirs. The Vancouver workshop noted the need for research into reservoir regulation using stochastic flow derivations. Wave and seiche studies in reservoirs also are needed. Lakes in the prairies need special attention because they are very different from lakes in the mountains or on the Precambrian Shield. Small water bodies such as sloughs are very important to the ground water regime and as habitat for wildlife - especially waterfowl. Many larger water bodies have high salinity and only occasional outflow. They usually are relatively shallow with heavy aquatic plant life. There is a need for continuing research on the physical, chemical and biological processes in these prairie lakes and their status in the overall water budget. Prairie sloughs are a good example of competition between uses. Wildlife and naturalist groups want to preserve them as vital habitat. Agriculturalists see them only as uncultivable acreage and want to drain them to increase crop production.

In Ontario the dominant water resource is the Great Lakes. This major water resource system has been the focus of many research projects and is the subject of numerous Canada-United States Agreement. While much has been learned in the past 20 years, a number of important questions remain. For example, the fraction of the total phosphorus loading which is available for biological uptake is still unknown and the causes for the areas of anoxia in the hypolimnion of Lake Erie are still debated within the scientific community.

The Halifax workshop, like the Vancouver workshop, was very interested in impoundments and the impact they have on the ecosystem. Post-reservoir construction studies, as suggested in the Marsan paper, were recommended.

209 Water and Plants

In this sub-category, as in 207 Water in Soils, there is a marked difference in perspectives between the hydrologists and the agriculturalists. The Vancouver workshop noted a need for research on the interception of rainfall by plants and thus their impact on the rainfall-runoff process. Workshop participants were also interested in the role of plants in holding snow cover and managing wind drift. Further research on the impact of various cropping practices on ground water quality was suggested in the Regina workshop.

The agriculturalist, on the other hand, saw this subject as his raison d'être. The use of fall vegetation to control wind erosion and to manage snow cover is related directly to next year's crop. From either point of view, further research is called for.

210 Erosion and Sedimentation

Movement of sediment by flowing water results in many adverse effects. Soil washed from fields is a serious loss of top soil from farm land. This sediment causes serious problems as it is carried through streams and rivers. Localized erosion of river banks and shorelines can be particularly damaging to riparian land owners. Sediment is deposited in quiescent regions of streams and rivers. It finally ends up in lakes and reservoirs.

The sediment transport processes are not fully understood and new or improved models are needed to predict these processes more accurately. The impact of a dam on the regime of the river is important and often far-reaching. Deposition of the sediment in the reservoir may cause subsequent erosion downstream, as well as decrease the effective storage capacity of the reservoir. New and improved methods for measuring sediment transport are needed. Better methods for quantifying soil loss from fields are needed. More needs to be known about overland transport and the effects of changing land use such as clear-cutting, urban development and no-till corn production.

211 Chemical Processes

The chemistry of a body of water has a major impact on its usability. Changes in this chemistry can affect many elements of the ecosystem. All regions were concerned about the impact of acid rain on the water resources. Many other substances in precipitation also impact the chemistry. In

Lake Superior, for example, the phosphorus load from the atmosphere represents a very significant part (37%) of the total load.

The chemistry of ground water and the impact of pollutants need further study. Deep well injection and leaching from chemical waste disposal sites pose serious threats to this important water resource.

212 Estuarine and Coastal Zone Problems

Canada has a very long coastline which is further increased when the shores of the Great Lakes are included because they behave similarly. One of the important features of a coastal zone is the estuary. Most maritime communities are sited on estuaries and many aquatic life forms depend on the partly fresh, partly salt water conditions found there. The interaction of inland watershed with the ocean creates numerous water resource management challenges. What is the impact of reservoir construction on downstream estuaries? In some cases the reduction in sediment load has led to beach erosion. Shell fish are ruined as food because of pollutants coming from upstream and from the local municipalities. Conversely, tidal effects and storm surges contribute to flooding locally and upstream.

The Halifax workshop identified a non-technical problem with research and management of estuaries. That is the multijurisdictional problem. Who is responsible? The local municipality? The provincial government? or the federal government? Responsibilities often are divided between different departments in the same jurisdiction. Consequently, problems often fall between the cracks. One department has the responsibility to manage but lacks the tools, while another agency has the capability but not the mandate. Basin water authorities were suggested as a possible solution.

300 Water Supply Augmentation and Conservation

As the population of Canada continues to grow, the demand for resources like water also increases. In some local situations further growth is limited by the limits of the available water resource. Such a problem may be addressed in two different ways. One is to augment the supply. The second is to reduce the per capita demand. Research in this category addresses either of these strategies.

301 Saline Water Conversion

Many water uses require "fresh" water. In some localities "brackish" water is the only kind available. Research is needed on ways to treat this water so as to make it usable for domestic or farm use. Some well waters contain a specific chemical such as iron, sulphur or nitrate. Research into treatment for specific chemicals is needed.

302 Water Yield Improvement

The magnitude and timing of spring runoff can be affected by managing the character of the upstream watershed. Forestry and agricultural practices can delay or advance the timing of snow melt, and small tributary reservoirs can hold back a portion of the runoff and release it later, either through direct release or via ground water to the stream bed. The Alberta Watershed Research Program is a good example of such studies. Similar work is necessary in other parts of the country. The potential payoff with these studies is very important for some water-short regions.

303 Use of Water of Impaired Quality

Sub-category 301 noted that many water uses require fresh, clean, potable water. Other uses, however, do not depend on the quality of the water or can be adapted to use impaired quality water. Further research is needed to develop crops which can tolerate higher salt levels in irrigation water. Water for many industrial uses, such as cooling or waste flushing water, can be highly polluted from a quality point of view.

304 Conservation in Domestic Use

The largest portion of the water used in the home is used to flush away sanitary and in some cases kitchen wastes. New designs are needed to reduce these demands. Probably the most effective way to reduce domestic use overall is to increase the cost to the consumer. Socio-economic research needs to address the subject.

Another significant waste of domestic water is in simple leakage of the municipal distribution system. As water becomes more expensive, the cost of repairing the distribution system will become economically justified. In some systems leakage represents 50% of the total demand.

305 Conservation in Industry

Modern designs in water-short regions have demonstrated that there is a lot of scope for reducing industrial water demand. In many cases a significant capital investment is required and much research into new processes and potential recirculation is necessary. In one steel plant the demand for water per unit of production fell from 180-270 thousand litres per ton of steel produced to 6.4 thousand litres per ton. This, admittedly, is an extreme example, but very significant reductions in demand are possible. The Regina workshop was especially sensitive to the need for water conservation in industry. The recent initiatives in the energy industry will greatly increase water demand in areas where water already is in short supply.

306 Conservation in Agriculture

Irrigation of agricultural crops is a major use of water in some areas, notably southern Alberta. Specialty crops, such as small fruits and vegetables, are irrigated at critical growth stages in many other areas of Canada. Water for irrigation is the largest part of the demand for water in agriculture. New equipment and management techniques are needed to optimize this use of water. The Regina workshop expressed a major interest in this sub-category. Research is needed which will assist the decision maker (farmer) to use his water supply efficiently. This would include topics such as remote sensing of soil moisture; improved mathematical modelling of soil moisture needed; improved collection and publishing of soil moisture data; and real time radar facility for measuring soil moisture by the dielectric method. The Waters in Agriculture Work Planning Meeting discussed numerous studies relating to soil moisture management. Topics included: physicist's perception of soil water research needs; water use by crops in western Canada; water management for coarse-textured irrigated soils; soil management for irrigated crops; water application systems; aquatic weed control; irrigation scheduling; and effluent irrigation. All of the above studies have the potential to reduce wastage of irrigation water.

307 Weather Modification

Man has demonstrated a very limited ability to modify weather. Much more research is needed. The hail suppression program in Alberta is a good example. Saskatchewan is interested in a study of precipitation enhancement and its impact locally and downwind. Would the evaporation suppression schemes of the prairies have an impact on local weather? As might be expected, Regina was the only workshop which addressed this topic.

400 Water Quantity Management and Control

Man has exerted some control over water for many thousands of years. Early irrigation schemes and the aquaducts of Rome are some examples. Other activities of man also have had an impact on the water resource, often in a negative and unrecognized way. Some of man's most grandiose construction projects are dedicated to this control, e.g., huge dam projects and extensive navigation schemes. Despite these many years of experience, there still is much to learn, especially about the unintentional impacts.

401 Control of Water on the Land

Because the use of engineering works will be discussed in category 800, research in this sub-category will emphasize the impact of other related activities. The Regina workshop simply agreed with the Durrant discussion. This was augmented by the Lethbridge Agriculture Canada work planning meeting to provide the following needs.

Land drainage has been used for many years to convert swampy waste land into high quality farm land. Tile drainage can also speed the drainage of spring snow cover to permit earlier spring planting. Research is needed to determine what impacts occur downstream from such drainage. As noted earlier, the draining of prairie sloughs would provide more cultivable land but this might aggravate spring flooding in downstream areas. What would be the impact on the ground water?

In some cases tile drainage can have a direct impact on ground water levels and lower the water table. Research is needed to determine the best depth and spacing for tile drains as a function of slope and soil texture.

Agricultural and other land management practices have an impact on the quality of the runoff and ground water. Migration of nutrients and pesticides need additional study.

Major changes in land use can affect the climate. What climatic change should be expected as land use changes from forest to row crop to urban?

402 Ground Water Management

Ground water is an important source of water in most parts of the country. Management of ground water requires control of withdrawals and recharges.

In many cases withdrawal exceeds recharge and in such cases water is being "mined". What are the socio-economic and political implications of water mining? These questions take on added importance when large withdrawals are used for irrigation. Does a landowner have unlimited access to water under his property? What is the possible impact on his neighbour? Regional, interprovincial and sometimes international management may be necessary.

Sometimes deep aquifers of poor quality water are used as a sink for industrial waste products by deep well injection. What safeguards are needed to protect other aquifers in the same soil columns? Does water migrate from one aquifer to another?

Shallow ground water is often recharged locally. Research is needed on shallow ground water flow patterns and interaction with deep ground water. Shallow ground water can be contaminated by poor quality recharge such as seepage from sanitary landfill sites, and waste chemical dumps. Shallow ground water usually flows toward a local stream bed where it supplies the base flow to the stream. In this way the ground water can form a link between waste dump leachate and nearby surface streams. A better understanding and quantification of these processes is needed. The United States super fund program[1] for clean-up is an example of the magnitude of this kind of problem.

Many of the schemes proposed for the safe storage of highly radioactive waste fuel from nuclear power production would rely on very deep underground storage. The possibility of dispersion of this waste in ground water systems is a key unknown which requires additional research.

In some areas the ground water can be recharged artificially by water spreading. The processes involved need additional research, especially with regard to pore clogging and chemical reactions.

403 <u>Effects of Man's Activities on Water</u>

Man has developed the ability to drastically change the geography of the landscape and especially the nature of the surface water drainage system. Huge dams convert rushing rivers into almost stagnant reservoirs. Water is redirected across watershed boundaries. Canals link ocean with ocean and the Great Lakes to tide water. In the process many intended and unintended changes occur. These mega projects must be evaluated beforehand as to their impact on the environment in which they are situated. Both physical and social impacts must be considered. In many cases it is possible to survey the pre-project environment to identify the biota and people which will be affected, but there is a great void of understanding of the processes involved in the impact. The anticipated impact must be based on incomplete understanding. Much basic research would be helpful here, but also, as noted in the Marsan paper, the project itself can be used as a mega experiment by continuing to monitor the various elements of the environment well into the post-project period. In this way it will be possible to compare the measured impact with the predicted impact and thus calibrate the model for more accurate predictions on other proposed projects.

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[1]A multi-billion dollar program to clean up and properly contain the many hundreds of waste chemical dumps in the United States.

The urbanization of vast land areas also has had an impact on the water resource. Surface drainage is interrupted and redirected by roads and buildings. Ground water is impacted by sewer and water distribution systems. The infiltration of rainfall is prevented by paved and built-up acreage. Local streams and rivers are contaminated by storm water from sewer outfalls. Research is required into the above impacts so that appropriate management decisions can be made. Widespread landscape changes such as forest clearing can have major impacts on surface flow quantities and quality. The increased erosion can fill up downstream reservoirs and destroy fish spawning areas.

500 Water Quality Management and Protection

As noted in the main body of the report, there was a major increase (from 30% to 40%) in the allocation of resources to this category between 1966 and 1979. This trend illustrates the major increase in concern for the quality of the environment during that period. The concern for our environment, or more correctly the ecosystem of which we are a part, has continued at a high level, but a very weak economy has seriously curtailed the increase in research which is needed. The Great Lakes Water Quality Agreement is the most notable response to this concern. In recent years, the focus of our concern has shifted from eutrophication-related issues to toxic substances in the ecosystem because we have developed the analytical capability to identify and quantify these pollutants at extremely small concentrations.

501 Identification of Pollutants

Recent advances in analytical chemistry have led to the identification of pollutants which heretofore have gone undetected. Research and development in this area must continue because there still are many pollutants for which adequate methods of analysis do not exist. Each of the workshops identified toxic substances as a high priority problem. Research in this sub-category is not site specific and the new methodologies developed have wide applicability.

502 Sources and Fate of Pollution

This sub-category covers a very large body of research. The link between source and sink is a very complex pathway through the ecosystem. In our case, the pathway usually lies within the water. Sources include industrial and residential point source discharges, runoff from non-point source land use activities, atmospheric deposition, and sediment resuspension. Mechanisms can be physical, chemical and biological. With respect to toxic organics one very important property of the biological mechanism is the ability of these compounds to bioaccumulate as they pass upward through the food chain. Persistent substances such as PCBs occur at almost undetectable concentrations in the water, but in higher predators such as fish and herring gulls concentrations can be so high that public health is endangered. A chemical mechanism of increasing concern is the chlorination of sewage containing organics. This process can produce chlorinated organics which are highly persistent and in some cases carcinogenic. The most likely sink for most pollutants is the bottom sediments. This makes sediment cores a valuable historic record of the contamination of the water body.

The Vancouver workshop was interested in sources such as oil spills in the Arctic, placer mining, NO_3-based explosives, and fertilizer and pesticides from forestry and agriculture. The transport of toxicants through food chains, especially in estuaries and intertidal habitats, was discussed.

The Regina workshop noted the importance of the internal mode of nutrient loading. This is a re-release of P from the sediments. Another source of pollutants (in this case also nutrients) is the spraying of sewage treatment plant effluent on farm crops as a special case of irrigation. The nutrients are useful, but more research is needed to determine the effects of other substances, such as heavy metals in the effluent, on crop growth. There also was a call for improved knowledge of the toxicity of the degradation products of some pollutants which appear to be innocuous in their parent state.

The Toronto workshop suggested research on food chain dynamics and community structure as they relate to pathways and biomagnification. It also noted the need to understand synergistic and antagonistic effects of mixtures of pollutants. The workshop attendees also suggested a study on the use of biological species as filters to biodecontaminate waters. The bioavailability of various forms of phosphorus was suggested as a subject for continuing research. Acid rain, as a special case of atmospheric deposition, was identified as an area requiring much more research.

The use of road salt for de-icing was identified in the Halifax workshop as a possible contaminant source. Another source of salt contamination requiring further study is salt water intrusion into coastal aquifers. The workshop also noted the need for further research in the use of certain biota in the pathway as bioindicators of water quality.

503 Effects of Pollution

By definition, the effect of pollution is to prevent or interfere with some desirable use of the resource. It could be a cultural use or a wildlife use if it is the intention of society to protect that wildlife.

The Vancouver workshop was concerned about the impact of spilled oil on the fragile ecology of the Arctic. More research is needed to determine the recuperative powers of these ecosystems. Transfers of water from one watershed to another pose the threat of introducing foreign organisms into the receiving watershed, which could upset the ecological balance. The use of pesticides in forestry and agriculture may affect fish and other non-target organisms. Further research is needed to predict these impacts and to develop alternatives to chemical pesticides which would be less damaging.

The Fraser estuary is a good example of impacts on various species. Pollutants from logging and waste treatment plant effluent may endanger the use of the estuary for waterfowl or juvenile salmon. More research is needed to determine if these effects actually occur.

The Regina workshop noted the impact of highly saline water for irrigation on agricultural crops. Eutrophication has a serious impact on the recreational use of lakes and reservoirs. As in all regions, there was great concern for the impact of acid rain on the many small lakes on the Shield and such pH-related effects as heavy metal mobilization.

The Toronto workshop was especially concerned with toxic substances and their impact on various biological components of the ecosystem including man. There is a great need for research on lethal and chronic effects of many toxic substances. The quantification of the impact of pollutants is the most serious deficiency in the management of the problem. It now is routine to quantify and identify most of the trace pollutants, but in many cases the numbers are meaningless because of the unavailability of threshold levels of significance to human or other biotic species. Cultural eutrophication and the management of phosphorus still is an important issue. The weak link in the management strategy is the lack of knowledge of the processes which connect phosphorus control to effects in the lakes and impacts on uses of the water resource.

The Quebec City workshop noted the need for a better understanding of the impact of development in the far north on the native people who live there. There is a need for more research on the unique problems in the north. This workshop noted also the need to keep aware of research in other countries which could be applicable in Canada.

The Halifax workshop was especially concerned about impacts of pollutants on ground water quality. The surficial geology of the region makes the shallow ground water particularly susceptible to contamination from waste dumps. This workshop suggested more research on bioindicator organisms, which is really a study of the measurable or observable impact of a pollution source on a specific biological species.

504 Waste Treatment Processes

Processes for treating liquid wastes from municipalities and industries have been in use for many years. Municipal waste treatment plants normally remove most of the biochemical oxidation demanding (BOD) material and the suspended solids. Chlorination is used to destroy pathogenic bacteria.

This "primary" or "secondary" treatment process does little to remove nutrients, such as phosphorus, or toxic substances, such as heavy metals and chlorinated organics. Tertiary or advanced waste treatment is required to remove or reduce these substances. In most cases tertiary processes must be tailored to a specific waste stream. The desired quality in the receiving water environment also must be considered.

The Province of Quebec was several years behind most provinces because the St. Lawrence River's vast, fast-flowing water seemed inexhaustible. The Canada-Quebec study of the St. Lawrence identified the limited assimilative capacity of the river and the urgent need for waste treatment facilities.

The Toronto workshop noted the need for more research on recycling of waste. In many cases, it can be considered a resource. A good example of this is the use of liquid effluent from waste treatment plants as nutrient-rich irrigation water. In certain areas this is a proven technology, but much more research is needed to expand its applicability. Sewage sludge can also be used as fertilizer if it is not contaminated with heavy metals or other toxic substances. Research is needed either to remove these toxic substances in the treatment process or to keep them out of the waste stream by prohibiting industry from putting them in the municipal sewers. The second possibility would require research on pretreatment for specific industrial pollutants. In most cases it would be easier to deal with these substances in relatively high concentrations at the factory rather than after they have been diluted in the main flow of domestic sewage.

The Regina workshop identified the need for more cost-effective methods for treating wastes from rural communities. Livestock wastes could be handled more effectively. There is a real concern for the impact of irrigating with sewage effluent on the quality of the ground water.

The research needs in this sub-category should be focussed on toxic substances not treated by conventional technology and on reuse or recycling of waste.

505 Ultimate Disposal of Waste

Some aspects of the ultimate disposal of waste have been touched upon in earlier sub-categories, but they will be reiterated in this section for completeness.

Domestic waste treatment plants produce solid and liquid wastes which must be disposed of. The liquid effluent often is discharged to a river or lake where the natural biodegradation disposes of the pollution. The recuperative capacity of natural systems is only partly understood and major economies in treatment would be possible if we could accurately predict the natural carrying capacity of the receiving water body.

The liquid waste can be used as irrigation water for growing crops while at the same time fertilizing the crop. Many questions remain such as the effect of pathogenic bacteria or viruses carried by wind into neighbouring areas, impact of toxic substances on the crop or the users of the crop, and the quality of the underflow and its impacts on ground water and surface streams.

The solid or semi-solid sludge, which is a concentration of the suspended solids in the original sewage, must be disposed of. In some cases the sludge is dewatered and burned. This causes air pollution. The sludge can be carted to sanitary landfill dumps and buried. Alternatively, if it does not contain heavy metals like mercury, it can be used as a fertilizer in farm crop production.

Industrial wastes require specific waste treatment processes and in some cases there is no practical treatment available. In such cases the waste can be diluted to acceptably low concentrations, such as in ocean dumping, or it can be "permanently" removed from the biosphere by deep well injection. Both of the above "solutions" require additional research. Concerns for the safe, long-term disposal of wastes has become a very important topic.

506 Water Treatment

A dependable and safe supply of drinking water is taken for granted almost everywhere in North America. Indeed, in terms of the conventional pollutants, this is true. In recent years, however, we have become aware of toxic substances which, even at very low concentrations, can have serious sub-lethal and long-term impacts on public health. In other cases the water may be "safe" but unpalatable.

In some areas the chlorination process for control of bacterial pollution can actually produce carcinogenic substances by reacting with organics in the raw water supply. The same problem can be caused by post-chlorination of sewage effluent.

Because of the relatively small volumes involved, it may be more cost-effective to control some kinds of pollution in the water by treatment processes close to the point of use, rather than to eliminate it from the environment. This can be taken one step further and provide final "polishing" at the kitchen tap by the use of carbon filters. Much research and development is needed to determine the most appropriate method of treatment for a given situation.

One advantage of activated carbon filtering at the tap is that it is also effective in removing many of the objectionable tastes and odours. By placing the filter just ahead of the drinking water tap, it is not necessary to treat all of the water supply, most of which is used for washing and for flushing of toilets. The socio-economic consequences of shifting water treatment to the drinking water tap should be studied carefully.

One important disadvantage of this approach is that it does not protect the non-human elements of the ecosystem, or prevent human health impact through consumption of other species (such as fish) which can concentrate some of these pollutants.

Little is known of the virology of water. The effectiveness of agents to destroy viruses, and their side effects, are much needed areas of research.

507 Water Quality Control

The ambient quality of surface waters determines what the water can be used for. Conversely, a desired use will set limits on some quality parameters. Control of water quality can be either preventive or remedial. For example, the dissolved oxgyen in a water body can be maintained by limiting the oxygen-consuming inputs. Conversely, the deficient oxygen content can be augmented by mechanical aeration. In most natural water bodies the former is the only practical solution and oxygen-consuming effects must be controlled at the source.

The impact of acid rain was identified as an important issue at every workshop. One solution to degrading water quality, in this case pH, is to eliminate SO_2 at the stack. A second solution is to control the pH of the local lake by adding lime. A great deal of research is needed in this area. Many other pollutants also come from atmospheric deposition.

Pollution from land use activities is a significant load to many water bodies. Because of the non-point source of this kind of pollution, any control action will involve a great many individual landowners. Pollution loadings can be reduced substantially by new land management techniques such as no-till corn growing and grassed margins to water courses. In this case, government action must be in the form of education and incentive grants. Socio-economic and agricultural research is needed in this area.

There are many non-agricultural land uses which contribute to water pollution. Drainage from mining operations is a serious problem in the Appalachian Region and is important in most other provinces as well. Research is needed on methods to treat or contain these pollutants or change the refining process to reduce the waste loading.

In some cases the biological communities themselves can control or eliminate some pollutants. For example, Lake Erie, with very high biological activity, has a relatively minor toxic substances problem. It is believed that the algae trap many toxic substances and carry them to the bottom. Higher trophic levels such as fish also extract toxics from the water. Much more needs to be known about these processes. We may be creating more problems than we solve by some of our control programs.

600 <u>Economic, Social and Institutional Aspects</u>

The ecosystem view of our world places man within the system, so that any planning to manage any component of the system must include a consideration of man and his institutions. This aspect adds considerable complexity to the planning process because social, economic and political implications are internalized. This category looks at the planning process with special emphasis on man in the ecosystem. Much socio-economic research is needed to deal with the planning process in this context.

601 <u>Planning</u>

The planning function, by its very nature, is forward looking or predictive. This requires some kind of modelling which permits extrapolation. Many techniques have been developed to permit this extrapolation, such as systems analysis, linear programming, probability theory, and mathematical simulation. The Vancouver workshop noted the need for "strategic" planning. This kind of planning deals with broad issues of competing uses and major impacts, of changing or alternative future scenarios and the challenges to the management function. Strategic planning is anticipative rather than reactive. It is very much concerned with the kinds of questions posed in this report. What will the managers of water resources need to know in the future and what research should be undertaken now to provide that needed knowledge? It is planning at a higher level of abstraction than the detailed planning for a specific water resource project.

Clearly, both kinds of planning are needed. Attempts at "strategic" planning are in essence socio-economic research. There also is a great need for more socio-economic analysis and interpretation in the more traditional planning for water resources management. In many cases it is important to give attention to "non-structural" solutions.

602 Evaluation Process

The decision to implement a planned water resource project must be based on a number of different criteria. Political and economic considerations usually dominate the decision process. The economic considerations can be quantified by benefit-cost analysis, but many factors which need to be considered are not easily quantified or described in terms of dollars.

There is room for considerable improvement in the benefit-cost procedures, especially the techniques for quantifying non-monetary interests such as recreation and environmental effects. The Quebec workshop noted that there is a great need for long-range planning, which must project current economic and environmental features many years into the future. This usually is done by developing a variety of possible future scenarios. A simple extrapolation of current conditions is almost certain to be incorrect.

603 Cost Allocation

Who should pay for large water resource projects? This question is the subject of much debate. Many projects are on a scale such that several levels of government are involved. Should the farmer using irrigation water pay some portion of the cost of providing it, or just the cost of handling it on his own property? What is the limit of responsibility of governments to "bail out" the home owner who builds in the flood plain of a river or on the erodable shoreline of a lake? There is a great need for socio-economic and political science research in this area. The Quebec workshop suggested that a "user should pay" principle was appropriate in the case of services such as Water Survey of Canada hydrologic data.

Another aspect of resource economics is the damages or disbenefits suffered by some interests in order to provide benefits for other interests. Research is needed to develop better techniques for handling such cases. At the present time, the dollar is the only measure, and this might under-play the important societal or political considerations.

604 Water Demands

The Vancouver workshop noted the need to know what the demand for water will be in the future. In actuality, this is asking what the demand will be for the things for which we use water. Navigation, recreation, cooling, electricity, fishing, etc., require water of a given quality, of a given quantity or at a given depth. These needs must be estimated into future scenarios. Research is needed on ways we can "manage" demand. For example, the demand for domestic water supply can be reduced considerably by installing water meters in each home. What other strategies are there? Water rationing has been necessary in some cases.

The quality of water required for given uses must be determined and there is a need to avoid using high quality water where it is not necessary. What would be the socio-economic impact of point-of-use treatment or double plumbing with potable and non-potable water systems? This system was in vogue a hundred years ago with well water for drinking and rain water for washing.

605 Water Law

Many of the water resource management issues discussed earlier would require changes to existing legislation or development of new legislation. At the moment, there are two divergent approaches to water law. The riparian law allocates rights of use to the landowner who has access. The water rights legislation commonly used in "water short" areas makes the right to use water a salable quantity. Large withdrawals from ground water reservoirs must be regulated in some equitable way.

The consumption as differentiated from withdrawal of water poses some very difficult problems from a legal point of view. Court cases arising from "rain making" are a good example of the legal complexities of "managing" a resource.

606 Institutional Aspects

Water resources are managed within certain institutional frameworks. Various levels of government write laws to regulate the resource and spend vast sums of money to develop projects which utilize it. Some institutions, by their structure and mandate, are better able to manage water effectively while other institutions are severely limited.

The International Joint Commission (I.J.C.) is an example of an institution created specifically to assist the governments of Canada and the United States to effectively manage the boundary waters which they share.

The Halifax workshop suggested that a better way to develop water resources in the Atlantic region would be to create a new set of institutions called "River Basin Authorities". Research in political science is needed to evaluate the effectiveness of present institutions and to suggest new ones which could be more effective.

Non-governmental organizations (NGO's) have sprung up in recent years to channel and organize public opinion. Pollution Probe is an example of these new institutions which are challenging the "old order", especially in environmental issues.

Old, established institutions are changing their methods and incorporating public participation into the planning and environmental impact assessment processes. There is room for considerable improvement in these processes and a greater emphasis on socio-economic and political science research is needed.

The Vancouver workshop saw the need for more anticipatory planning rather than reactionary planning to solve existing problems. This was supported by the Quebec workshop call for long-range rather than short-range planning.

607 <u>Sociological and Psychological Aspects</u>

"Beauty is in the eye of the beholder" and the way people perceive water resources determines how they will support water resource management. The political process, by its very nature, is responsive to public opinion and the rapid development of water pollution control agencies in the mid to late sixties was largely a reaction to a heightened public consciousness of pollution problems.

Studies are needed to determine public attitudes toward water and the way it should be used and protected. How does the public perceive the efforts of the government agencies to regulate and manage the resources? The socio-economic disciplines should be included in the planning team for major water resource management projects. How do you anticipate public reaction to change and regulation? What is an acceptable balance between a highly regulated society vs individual freedom and private enterprise? In what way is each individual responsible for the preservation of "spaceship earth" in the global sense.

608 <u>Ecologic Impact of Water Development</u>

Man is an integral part of the ecosystem and any major water resource development will affect him directly or indirectly. Research is needed to predict or anticipate these effects. What about the farmer whose land is flooded by a new reservoir?

Many water resources projects are of such a large scale that they have an impact on the entire ecosystem. The James Bay project in northern Quebec displaced many native people and changed the habitat for fish and wildlife. Even the local weather will be affected by the huge reservoirs. In the place of small mammals, large lake type fish will develop. Is that a desirable shift of the ecology? It is, if you enjoy fishing and boating on a large body of water rather than hunting. It is a very subjective decision. What will be the impact on the circulation in James Bay of a vastly different flow regime in the La Grande River?

The James Bay Project is used here only as an example of the kinds of impact that should be anticipated with any major water resource project. Indeed, the André Marsan thesis would have us use each project as a megastudy to refine our predictive capability for future studies.

700 <u>Resources Data</u>

The ability to manage water resources is directly dependent on the information which is available about the resource. Quantification of the magnitude and quality, along with its spacial and temporal variability, is essential to any significant planning exercise. The vastness and, in many cases, the inaccessibility of much of Canada demands careful design of the data-gathering network and highly sophisticated instrumentation.

701 <u>Network Design</u>

The gathering of hydrologic data is very labour intensive and, in remote areas, very costly in terms of logistics. It is essential that the design of the network is as efficient as possible. The Vancouver workshop noted the need to optimize the set of parameters measured. Real time data are needed for the management of floods by reservoir manipulation and for flood warnings.

Rain and snow measurements and methods to extrapolate to ungauged areas are needed. Better extrapolation techniques could reduce the number of gauging points necessary. Network design should be based on statistical and systems analysis of historical data.

702 Data Acquisition

The technology of data generation needs continuing research and development. Current methods are labour intensive, and logistically expensive, so that improvements could produce significant cost savings.

The integration of quantity and quality networks could eliminate costly duplication. This would require better training of field technicians. It may require some compromises in site selection.

Automation of the instrumentation along with longer time intervals between servicing would be very beneficial. Real time readout and telemetering is possible now, but simpler, cheaper, and more reliable technology is needed.

Several workshops identified remote sensing as a promising technology for hydrologic data gathering and for extrapolating "ground truth" monitoring data to ungauged areas. Radar quantification of rainfall distribution is another technique needing further research and development.

The Halifax workshop noted the need for better technology transfer from research to operations. Pilot projects in the regions could assist in this activity.

The Regina workshop noted the need to ensure the compatibility of data sets. Research is needed to test for compatibility and to develop techniques for manipulating data sets to make them more compatible.

The Toronto workshop noted the need for sampling and analysis of interstitial water and inferring what the "in situ" characteristics are. Ground water presents many difficulties in accurate quantification of aerial extent, flow and quality.

Remote sampling stations require better energy supply systems, possibly including solar energy or wind. Data transmission via satellite is available now but could be further developed to reduce cost and increase reliability.

703 Evaluation, Processing and Publishing

The quality of the field data must be evaluated before it can be used to interpret the actual field conditions. Better procedures for cross-checking, and for providing some desirable redundancy, are needed. The interpretation of outliers is especially important. Automatic stations need provision for automatic or remote interrogation calibration. Fail-safe, back-up redundancy is needed to avoid "loss of record". Data needs to be gathered in computer-compatible format to minimize the workload of processing and publishing.

The format in which the data are "published" or made available to the user could be improved considerably. Hard copy will always be convenient for those who want some small quantities of specific information. In most cases, however, the user will want the data in computer-readable form. Additional information about the environment in which the data were generated could be very important to some users. Field notes and other descriptive information should be available.

800 Engineering Works

Engineering works have provided the ability to control many aspects of water resources. It is this ability to control which permits, and requires, management of the resource. New and improved engineering works will improve the ability to control and to manage. Research and development is essential to providing new and improved control.

801 Specifications and Design

The design of engineering works to control water resources is based on an application of the scientific knowledge created by fundamental research. The engineering "solution" is always problem oriented and there is an ongoing need for this kind of applied research which solves problems in resource management by using the best available knowledge.

Modern computers make it possible to mathematically simulate many water resource processes. Computers provide a very powerful tool for designing engineering works. The HEC models of river flow and the prediction of floodlines is a good example of this technology. There is a continuing need for novel designs and improvements on existing designs.

The unique design challenges of arctic and sub-arctic environments create the need for research which will permit the adaptation of design experience in other regions to Canada's northern frontier. Surface ice and frozen ground water (permafrost) call for novel engineering design.

802 Materials

The materials available have a major impact on engineering design, and novel materials or applications can dramatically change design concepts. The introduction of a wide range of engineering fabrics is a case in point. These fabrics can be used to produce an impermeable membrane to eliminate seepage from storage ponds or to stabilize foundations and embankments. The cold climate of Canada presents many challenges to a whole host of materials, and research in this area may, in some cases, be critical to the management of the resource.

803 Operations

The effectiveness of an engineering work is only as good as the operation of the facility. In some major systems, the operation is quite complex and research is needed to devise improved operating guides. For instance, some modern waste treatment plants are using automated control based on real-time measurement feedback. Large watersheds with multiple reservoirs and a network of hydrologic sensors can use computers to optimize the management to satisfy the needs of several different users. Sewer systems can be designed and operated to minimize the peak flow to waste treatment facilities. There is a large potential for increased use of computers to optimize a variety of water resource management functions.

900 Environmental Management and Protection

This category did not exist in the 1968 report. It was added to accommodate recent topics in environmental management and environmental impact assessment. This category also includes some economic and institutional studies. It tends to be a collection of topics which did not fit well in other more specific categories.

901 Lake Levels

Engineering works have given man the ability to control the level of lakes by damming the outlet channel. Thus, it is possible to significantly alter the natural regime of levels. We are just beginning to understand the impacts that such a regime change can have on many different aspects of the ecology of the lake.

We have already noted the impact on Lake Athabasca of the change in the regime of the Peace River because of the Bennett Dam. A recent IJC study of the proposed partial regulation of Lake Erie water levels revealed a number of environmental impacts owing to regulation. There is much more to know about these impacts and much more research will be required. Even the brief investigation of the Lake Erie study identified likely impacts on marsh habitat for fish, waterfowl, and small mammals; fish spawning beds; and water quality. Much more field work and interpretation would be required to effectively quantify these effects.

The Vancouver workshop noted a great need for a better understanding of northern lakes and the effects to be expected under a number of stresses including water level manipulation. Reservoirs are a special case in which the "lake" is man-made. The initial shock of flooding is often exacerbated by the periodic drawdown called for in the operating guidelines.

902 <u>River Regime</u>

Modification of a river by engineering works such as dams, levees or dredging can have a profound impact on the natural regime of the river both upstream and downstream. The flooding behind a dam is dramatic and obvious. Not so obvious, but also important, are the other effects such as erosion downstream because of interrupted sediment transport, and oxygen deficiencies if bottom water is withdrawn from the reservoir. The natural habitat for wildlife is destroyed and a whole new thermal structure is created in the impoundment. Upward migration of anadromous fish is interrupted. Few if any of these effects are understood sufficiently to enable a quantified prediction of the impact. Much research is needed to improve the knowledge base to permit more accurate impact assessment.

903 <u>The Sociological Role of Water-Enhanced Environment</u>

The presence of a body of water in the landscape has a positive psychological effect on most people. Just knowing that a body of water is polluted or that a sparkling, lively rapid has been drowned out by a dam has a negative psychological effect. More sociological research is needed to better understand these phenomena and, if possible, to quantify them in economic terms. If a recreation use is affected, there are some techniques to estimate economic effects but these techniques need refining.

904 <u>Impact of Environmental Constraints on Development Potential</u>

Most environmental protection measures carry with them a sizable cost. This cost must be passed along to the consumer of the goods or services involved. Moreover, if similar protection measures are not required of all similar industries, the affected industry will be placed at an economic disadvantage. Thus, the imposition of controls to protect the environment can have a negative impact on local communities. These potential impacts on development potential are poorly understood, so that there is a need for considerable socio-economic research.

Categories from the Bruce-Maasland report

WATER RESOURCES RESEARCH CATEGORIES

100. NATURE OF WATER
Category 100 deals with fundamental research on the water substance.

101. Properties of water — Study of the physical and chemical properties of water, including its thermodynamic behavior in its various states.

102. Aqueous solutions and suspensions — Study of the effects of various solutes on the properties of water; surface interactions; colloidal suspensions.

200. WATER CYCLE
Category 200 covers research on the natural processes involving water. It is an essential supporting effort to applied problems in later categories.

201. General. Including: studies involving two or more phases of the water cycle such as hydrologic models; rainfall-runoff relations; surface and ground-water relationships; watershed studies; geomorphology.

202. Precipitation. Including: investigation of spatial and temporal variations of precipitation; physiographic effects; time trends; extremes; probable maximum precipitation; structure of storms; quantitative precipitation forecasting.

203. Snow and ice. Including: studies of the occurrence and thermodynamics of water in the solid state in nature; spatial variations of snow and frost; formation of ice; break-up of river and lake ice; glaciers; ice forces; permafrost and its effects on groundwater and the water cycle.

204. Evaporation and transpiration. Including: investigation of the process of evaporation from lakes, soil, and snow and of the transpiration process in plants; methods of estimating actual evapotranspiration; energy balance.

205. Streamflow. Including: mechanics of flow in streams; flood routing; bank storage; space and time variations (includes high and low-flow frequency); droughts; floods.

206. Groundwater. Including: study of the mechanics of groundwater movements; multiphase systems; sources of natural recharge; mechanics of flow to wells and drains; subsidence; properties of aquifers; saline water intrusion in coastal aquifers.

207. Water in soils. Including: infiltration; movement and storage of water in the zone of aeration, including soil.

208. Lakes. Including: hydrologic, hydrochemical, and thermal regimes of lakes; water level fluctuations; currents and waves.

209. Water and plants. Including: role of plants in hydrologic cycle; water requirements of plants; interception of precipitation.

210. Erosion and sedimentation. Including: studies of the erosion process; prediction of sediment yield; sedimentation in lakes and reservoirs; stream erosion; sediment transport; river-bed evaluation.

211. Chemical processes. Including: chemical interactions between water and its natural environment; chemistry of precipitation.

212. Estuarine problems. Including: special problems of the estuarine environment; effect of tides on flow and stage; deposition of sediments; sea water intrusion in estuaries.

300. WATER SUPPLY AUGMENTATION AND CONSERVATION
As water use increases we must pay increasing attention to methods for augmenting and conserving available supplies. Research in Category 300 is largely applied research devoted to this problem area.

301. Saline water conversion — Research and development related to methods of desalting sea water and brackish water.

302. Water yield improvement — Increasing streamflow or improving its distribution through land management; water harvesting from impervious areas; phreatophyte control; reservoir evaporation suppression.

303. Use of water of impaired quality — Research on methods of agricultural use of water of high salinity; use of poor quality water in industry; crop tolerance to salinity.

304. Conservation in domestic use — Methods for reducing domestic water needs without impairment of service.

305. Conservation in industry — Reduction in both consumption and diversion requirements for industry.

306. Conservation in agriculture — More efficient irrigation practices. Chemical control of evaporation and transpiration; lower water use plants; optimum use of soil moisture; etc.

307. Weather Modification — artificial stimulation of precipitation; climate modification by changes in land and water surfaces; etc.

400. WATER QUANTITY MANAGEMENT AND CONTROL
Category 400 includes research directed to the management of water, exclusive of conservation, and the effects of related activities on water.

401. Control of water on the land — Effects of land management on runoff; land drainage; potholes; etc.

402. Groundwater management — Artificial recharge; conjunctive operation; relation to irrigation.

403. Effects of man's related activities on water — Impact of urbanization, highways, logging, etc., on water yields and flow rates.

500. WATER QUALITY MANAGEMENT AND PROTECTION
An increasing population increases the wastes and other pollutants entering our water supplies. Category 500 deals with methods of identifying, describing and controlling this pollution.

501. Identification of pollutants — Techniques of identification of physical, chemical and biologic pollutants; rational measures of character and strength of wastes.

502. Sources and fate of pollution — Determination of the sources of pollutants in water; the nature of the pollution from various sources; path of pollutant from source to stream or groundwater; prediction of pollution concentrations including prediction by means of mathematical models; effects of ice cover on dissolved oxygen and other pollutants in streams and lakes; etc.

503. Effects of pollution — Definition of the effect of pollutants, singly and in combination, on man, aquatic life, agriculture and industry under conditions of sustained use; eutrophication; influence of prolonged ice-cover on effects of pollutants; etc.

504. Waste treatment processes — Research to improve conventional treatment methods to gain efficiency or reduce cost; processes to treat new types of waste; advanced treatment methods for more complete removal of pollutants including purification for direct reuse.

505. Ultimate disposal of wastes — Disposal of residual material removed from water and sewage during the treatment process; disposal of waste brines; underground waste disposal.

506. Water treatment — Development of more efficient and economical methods of making water suitable for domestic or industrial use.

507. Water quality control — Research on methods to control stream and reservoir water quality such as flow augmentation; stream and reservoir aeration; control of natural pollution; control of pollution from pesticides and agricultural chemicals; control of acid mine drainage; control of erosion and sedimentation; etc.

600. ECONOMIC, SOCIAL AND INSTITUTIONAL ASPECTS
The problems of achieving an optimal plan of water development are becoming increasingly complex. Category 600 covers research devoted to determining the best way to plan, the appropriate criteria for planning and the nature of the economic legal and institutional aspects of the planning process.

601. Planning — Application of systems analysis to project planning; treatment of uncertainty; probability studies; non-structural alternatives.

602. Evaluation process — Development of methods, concepts and criteria for evaluating project benefits; discount rate; project life; methods for economic, social and technological projections; reliability of projections; research on the value of water in various uses; etc.

603. Cost allocation, cost sharing, pricing/repayment — Research on methods of calculating repayment and establishing prices for vendible products; techniques of cost allocation, cost sharing; pricing and repayment policy.

604. Water requirements — Research on the water quantity and quality requirements of various uses.

605. Water law — Studies of provincial and federal water law looking to changes and additions which will encourage greater efficiency in water use.

606. Institutional aspects — Investigation of institutional structures and constraints which influence decision on water at all levels of government; case studies; jurisdictional problems.

607. Sociological and psychological aspects — Attitudes to use of water; perception of responsibilities.

608. Ecologic impact of water development — Effects of water management operations on overall ecology, including human ecology, of the area. Excludes effect of pollution under 503.

700. RESOURCES DATA
Planning and management of our water resources require information. Category 700 includes research oriented to data needs and the most efficient methods of meeting these needs. Basic data collection in itself is not here considered research, but studies of ways to improve data collection are included.

701. Network design — Studies of data requirements and of the most effective methods of collecting the data.

702. Data acquisition — Research on new and improved instruments and techniques for collection of water resources data, including data on water use and water and erosion damage; telemetering equipment.

703. Evaluation, processing and publication — Studies of effective methods of processing data; form and nature of published data; maps of data.

800. ENGINEERING WORKS
To implement water development plans requires engineering works. Category 800 describes research on design, materials and construction which is specifically useful to water management. Works relevant to a single specific goal, such as water treatment or desalination, are included elsewhere if an appropriate category exists.

801. Specifications and Design — Studies of functional requirements of water structures: research leading to improved design of dams, canals, pipelines, locks, fishways and other works required for water resource development.

802. Materials — Research to improve existing structural materials and to develop new materials for use in water control and conveyance structures.

803. Operations — Research on efficient operating procedures, and maintenance procedures for water control systems.

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