SCIENCE COUNCIL OF CANADA

A Major Program of Water Resources Research in Canada

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Report No. 3

A Major Program of Water Resources Research in Canada

SEPTEMBER 1968

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September 1968.

The Right Honourable PIERRE ELLIOTT TRUDEAU, P.C., M.P.,
Prime Minister of Canada,
House of Commons,
Ottawa 4, Ontario.

Dear Mr. Prime Minister,

In accordance with the provisions of sections eleven and thirteen of the Science Council of Canada Act, I submit herewith the views and recommendations of the Council on Canadian activities in water resources research, in the form of a report under the title "A Major Program of Water Resources Research in Canada".

Yours very truly,

O. M. SOLANDT,
Chairman.

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SYNOPSIS

The Science Council of Canada believes that research into Canada's water resources is important to the nation. A Study Group has assessed current activities and the Council now makes recommendations for a national policy of water resources research.

The study confirms that this subject is important but shows that it has attracted neither adequate attention nor money. Government laboratories do good work but universities lack funds and industrial research is undeveloped. The Science Council recommends:

1. the co-ordination of research into Canadian water resources;
2. a target of twenty per cent per annum for rate of growth of research towards a proposed annual expenditure of $25 million by 1972-73;
3. the greater involvement of industry.

The Council further recommends that the National Advisory Committee on Water Resources Research be reconstituted to represent government, universities and industry more equitably and that it be responsible for the recommending of policy and for advising on the distribution of funds to assist university and industrial research.

Section 1

INTRODUCTION

Without water, air and a place to stand men cannot live, but nature has provided these elements so abundantly in Canada that we take them for granted. To our great benefit we have harnessed our waters as sources of energy, used them as channels for transportation, developed them for industrial and municipal use and spent our leisure hours in recreation upon them, but in the process we have often reduced our streams, lakes and rivers to sewers for refuse. When we examine our vital surroundings we often see that careless advance has left us with the smell of polluted air, the taste of dirty water and the sight of devastated landscapes. We have not learned to conserve and care for natural riches.

In these basic respects our ancestors of prehistoric times were better off than we are today; their air was pure, their rivers clean and their habitat luxuriant. What benefit our mechanical advances if nature becomes a slum? What triumph our ingenuity in flying to the moon if our surroundings are dirty? Today everyone realizes this neglect, many demand palliatives, some have a duty to rectify errors. How are we to enjoy the benefits of nature without destroying them in the process?

Late in 1966, the Science Secretariat, acting on behalf of the Science Council, established a Study Group assisted by a Committee of twenty-two experts under the chairmanship of Mr. J. P. Bruce to investigate the state of water resources research in Canada. The findings of this group are being published as background to this Report in Science Secretariat Special Study No. 5, *Water Resources in Canada,* by J. P. Bruce and D. E. L. Maasland.

A year later the Science Council established a Special Committee[1] on Water Resources Research to review the results of Special Study No. 5 and to draft the present report. The Science Council at its Twelfth and Thirteenth Meetings held at Sheridan Park, Toronto, on May 16 and 17 and at Chalk River, Ontario, on June 26 and 27, 1968, discussed, accepted and now issues this report recommending policy for water resources research for Canada.

[1]Appendix I contains a list of the members.

Section 2

WATER IN CANADA

Canada has a multitude of fresh water lakes which cover eight per cent of the country, an area greater than that of the Province of Alberta. The Canadian portion of the Great Lakes, covering 36,000 square miles, contains about one tenth of the world's supply of fresh surface water and all Canadian lakes together may contain one third.

Canada possesses some of the world's largest rivers and their total discharge to the sea averages 2.5 million cubic feet a second, some six per cent of the world's total. In comparison Canada's area is about seven per cent of the land surface of the globe.

As Canadians form only two thirds of one per cent of the world's population, Canada's water supply per capita is lavish. We have enough water to provide for the needs of agriculture and industry and, to a much greater extent than most other people, we have water for power, transportation and recreation. Seventy per cent of Canadian power is generated by hydro-electric plants, although we have developed only one quarter of the known potential. Ships on the Great Lakes and the St. Lawrence Seaway transport fifty million tons of goods a year. In Canada, most recreational activity depends on water. These observations and other data provided by the Science Secretariat's Special Study No. 5 demonstrate the abundance of water in Canada and emphasize its value.

Some other aspects are less gratifying. The distribution of rainfall is uneven, total run-off is no greater than the world average; in some places surface supplies are deficient and elsewhere groundwater is saline or limited in supply by permanently frozen ground or impervious Precambrian rock.

Nevertheless, without minimizing the local handicaps imposed by such deficiencies, it is clear that Canada is endowed with more fresh water than most countries. Our water problems are peculiarly our own—those of a vast land with superabundance in many parts and paucity in a few. We should tailor our policy to our conditions. We need not repeat the investigations of less fortunate countries whose difficult circumstances have already forced them to do much research on purifying waste water and on generating fresh water from saline. We should rather concentrate research upon our own problems which concern the wisest methods of using the wealth of fresh water that is our heritage.

Canada's supplies appear so abundant that some people have suggested we sell and export fresh water. Here it is important to distinguish between

the volume of our lakes and reservoirs and the rate at which they are replenished, to consider the reliability of rainfall and run-off, to assess the scarcity of water in some parts of our own country and to predict the future growth of our own requirements. Some parts of Canada already suffer from shortages. In others an existing, apparent surplus may be only temporary. Extensive water diversions could flood much valuable land. Should any pressure to export fresh water arise, Canada would first require detailed estimates on future supply and demand upon which to base any decisions. One objective of Canadian water resources research should be to provide that information.

Section 3

SOME GENERAL CONSIDERATIONS ON SCIENTIFIC RESEARCH IN CANADA

A policy for water resources research must be consistent with any comprehensive policy for the use and development of science and technology which may be adopted in Canada. In preparing this statement, the Science Council has therefore sought to place water resources research in its proper perspective, within the Council's present concept of a national science policy. Some of the ideas which have contributed to this concept are sketched in the following paragraphs.

Canadians should decide what they want to preserve from their heritage or to develop from their resources and then apply their scientific effort to achieve those aims. The Economic Council has postulated some goals: full employment, a growing economy, price stability. To these, most Canadians would add many others. The basic policy being proposed by the Science Council is that the nation should harness its scientific efforts to contribute to the realization of the above-listed aims.

Criteria for selecting research and development programs are:

1. their relevance to Canada;
2. lack of appropriate technology already developed elsewhere; and
3. potential social and economic returns.

If Canada is to support extensive programs of research and development, then the first criterion means that these programs should seek solutions to pressing Canadian problems. The only exception to immediate relevancy is some allocation of funds to pure research directed by curiosity alone and carried out chiefly in the universities.

Because Canadian research effort is small (slightly over one per cent of the world's total), it is profligate to duplicate programs underway elsewhere. Hence, the second criterion is that Canada should not hesitate to import technology in these areas which have been studied in detail elsewhere and should maintain only a few active specialists in each selected topic to facilitate the transfer. The importation of technology, linked with better application of existing knowledge, will contribute much and will permit Canada to devote its own research efforts to those problems which are particularly influenced by Canadian conditions.

The third criterion is that research and development can only expand to the extent that they lead to a growing economy, a profitable industrial

base and achievement of the country's aims. In the past year, Canada spent slightly more than one per cent of its Gross National Product on research and development. This proportion is growing and the Science Council believes that it might well be doubled by 1975.

The Council holds that the major sectors of the economy—government, industry and the universities—each have their particular functions, none of which can be exercised effectively without research. While it is comparatively easy to define the responsibilities of each sector, it is harder to decide the amount and type of research appropriate to the role of each. The Science Council holds that industry and universities should do most of the research, while governments need to do enough research to permit them to carry out their responsibilities effectively.

This report recognizes but does not attempt to distinguish between the roles of the three levels of government—federal, provincial and municipal.

It is the responsibility of industry, both public[2] and private, to use research and to innovate, because innovation, not research, creates new benefits. If a principal reason for water resources research is the expectation of profit, for example from savings in construction costs, then the Science Council holds that research and development should be done by industry which can capitalize upon the new knowledge. The Science Council considers that a shortcoming of past Canadian scientific efforts has been the failure of innovation to keep pace with research. No program of research and development, however well executed, will lead to economic or social advance if the results are not brought into use. The gap between the research laboratory and the production unit must be bridged. It should be emphasized also, that while continuing research is needed in many fields, such as water resources, there is much need for the effective application of existing knowledge.

Finally, it is the responsibility of universities to educate. Research should continue its traditional role in graduate teaching in universities which should bear in mind the needs of the country when selecting fields for research and training. In Canada, as elsewhere, academics have traditionally generated their own programs which has led to concentration upon fundamental research. To accept the right of university scientists to choose their research programs or topics does not imply that the country must support each to the same extent. Indeed, what better way of relating the training role of the universities to the needs of the country than by encouraging research in subjects related to important national objectives?

The Science Council believes that most of Canada's whole scientific effort should be organized into 'major programs' each having some important long-range mission and each being a co-ordinated effort involving all sectors of the economy—government, industry and university. Water resources research should be one such program.

[2] The Science Council prefers to consider publicly-owned hydro-electric utilities as part of the industrial sector, although in Special Report No. 5 the Study Group classified them as governmental.

The selection of topics for major programs and the allocation of priorities to them requires detailed information on men available and money invested, on strengths and weaknesses, and on the ease or difficulty of mounting programs in Canada. With such information available, the three above-noted criteria of relevance, necessity and promise can be applied to reach decisions. To obtain the required information the Science Council has commissioned a series of studies, some of which are complete, on Upper Atmosphere and Space Programs[3], on Physics[4], on Psychology[5] and on Water Resources Research[6] while others are still in progress on Chemistry, on Biology, on Agricultural Research and on Engineering Research.

This proposal to foster major programs does not call for the establishment of monolithic government agencies, but rather for co-ordinating bodies, in which governments, industries and universities will participate to guide and co-ordinate all programs and to influence the provision of money. The National Aeronautics and Space Administration which co-ordinates the United States space program and which distributes funds to all sectors of the U.S. economy in support of its mission has some of the characteristics which we seek.

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[3] Science Secretariat Special Study No. 1, *Upper Atmosphere and Space Programs in Canada,* by J. H. Chapman, P. A. Forsyth, P. A. Lapp, G. N. Patterson—February 1967 (Ottawa: Queen's Printer, 1967, Price $2.50).

[4] Science Secretariat Special Study No. 2, *Physics in Canada, Survey and Outlook,* prepared by a Study Group of the Canadian Association of Physicists headed by D. C. Rose—May 1967 (Ottawa: Queen's Printer, 1967, Price $2.50).

[5] Science Secretariat Special Study No. 3, *Psychology in Canada,* by M. H. Appley and Jean Rickwood—September 1967 (Ottawa: Queen's Printer, 1967, Price $2.50).

[6] Science Secretariat Special Study No. 5, *Water Resources Research in Canada,* by J. P. Bruce and D. E. L. Maasland—September 1968 (Ottawa: Queen's Printer, 1968, Price $2.50).

Section 4

A STUDY OF WATER RESOURCES RESEARCH

On March 9, 1968, J. P. Bruce and D. E. L. Maasland presented Special Study No. 5 to the Council's Committee on Water Resources Research who accepted it as a comprehensive and satisfactory document, except that the Committee believed that industry should do more of the proposed research. The Science Council agrees.

The Special Study discusses the definition of water resources research, pointing out that research may be categorized by discipline or by purpose and that water resources research is defined by its purpose. Workers from many disciplines such as engineering, the natural sciences, economics and sociology, are drawn together with the common object of furthering a knowledge of water resources.

In the United States the aim of the federal research program[7] has been stated to be:

"1. To develop methods for conserving and augmenting the quantity of water available.
2. To perfect techniques for controlling water so as to minimize erosion, flood damage, and other adverse effects.
3. To develop methods for managing and controlling pollution so as to protect and improve the quality of the water resource.
4. To develop and improve procedures for evaluating water resource development and management so as to maximize net socio-economic benefits.
5. To understand the nature of water, the processes which determine its distribution in nature, its interactions with its environment and the effects of man's activities on the natural processes. This is basic to the successful prosecution of Items 1 through 4.
6. To develop techniques for efficient, minimum cost design, construction, and operation of engineering works required to implement the water resources development program. Overriding considerations of effectiveness and safety, and of economy in connection with the already huge and mounting costs of executing and operating water resource developments that are rapidly growing in number, size and complexity, require the best efforts we can bring to bear on these problems.
7. To develop new methods for efficient collection of the field data necessary for the planning and design of water resource projects...."

The present Report considers water resources research to consist of studies that lead to these goals. From a practical point of view, difficulties arise in distinguishing the limits of water resources research. Many research

[7] Committee on Water Resources Research, Federal Council for Science and Technology, *A Ten-Year Program of Federal Water Resources Research*, U.S. Government Printing Office, Washington, D.C. 1966, 88 pages.

projects contain an element of "water activity", but are predominantly oriented towards other purposes such as fisheries or agriculture. This report will confine itself to those projects relevant to the seven purposes stated above.

Since water resources research is primarily an applied field of science it is difficult to distinguish some of it from routine work. Our guide has been the definition adopted by the Organization of Economic Co-operation and Development (OECD): "Research is work undertaken primarily for the advancement of scientific knowledge, with or without specific application in mind. Work in which the element of innovation was lacking, such as in the regular collection of scientific data, was *not* considered to be research."

The Study Group made an inventory of current activities in eight categories of water resources research in Canada:

1. The 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

Appendix II further subdivides these categories into more detailed topics.

The Study Group tried to ascertain how much support each sector of the economy had provided and what work it had done in water resources research during whatever twelve-month reporting period most closely corresponded to the federal fiscal year 1966-67.

Tables 1 and 2 summarize[8] the sources and expenditures of money for water resource research. All three levels of government have been combined under a common heading.

Table 1.—Sources of Funds for Water Resources Research, 1966-67

Item	Government	Industry	University	Other	Totals
Support ($'000)	6,940	852	276	323	8,391
Approximate Distribution (Percentage)	83	10	3	4	100

[8] Derived from Table 6, Special Study No. 5.

Table 2.—Expenditures on Water Resources Research, by Sector of Performance, 1966-67

Item	Government	Industry	University	Other	Totals
Expenditure ($'000)	5,495	1,178	1,629	89	8,391
Approximate Distribution (Percentage)	66	14	19	1	100

Section 6 of this Report discusses the Science Council's views upon how expenditures should be distributed in future between the principal sectors.

The Study Group reported the distribution of Canadian expenditures in 1966-67 by topic, and recommended the allocation of expenditures for 1972-73. Table 3 summarizes that information by major categories. A projection of United States Federal Intramural Expenditures for 1970-71 is included to show that the different problems facing the United States demand that they allocate their resources according to a different pattern.

Table 3.—Proposed Distribution of Expenditures, by Categories

Categories	Total Canadian Expenditures		U. S. Federal Intramural Expenditures
	Reported 1966–67 (Percentages of Total)	Suggested 1972–73 (Percentages of Total)	Projected 1970–71 (Percentages of Total)
1. Nature of Water	0.5	1	2.7
2. Water Cycle	46.6	40	17.1
3. Water Supply Augmentation and Conservation	5.1	6	18.2
4. Water Quantity Management and Control	3.6	5	5.8
5. Water Quality Management and Protection	30.0	28	37.0
6. Economic, Social and Institutional Aspects	3.3	6	9.3
7. Resources Data	5.1	6	2.8
8. Engineering Works	5.8	8	7.1
Totals	100.0	100.0	100.0

Chapter V of Special Study No. 5 concludes that $25 million should be spent on water resources research in 1972-73, which implies an average annual growth of 20 per cent. Section 6 of this Report discusses this recommendation.

Section 5

THE ALLOCATION OF EFFORT AMONG SUBJECTS

The Study Group considered carefully the relative support desirable for different aspects of water resources research in Canada. Their opinion represents the view of twenty-four of the leading specialists in water resources in Canada. They had the benefit of reports commissioned from three groups of Canadian consultants, the advice of United States authorities and some knowledge of work in other countries. In general the Science Council agrees with their recommendations[9], which aim to redistribute research efforts to correspond more closely to the needs of Canadian conditions and problems.

The main point is that Canada must continue to emphasize research in two major categories: the water cycle, and water quality management and protection (i.e., the occurrence of water and the reduction of pollution.)

Research on *the water cycle* is principally concerned with the occurrence, distribution and movement of water on and under the earth's surface. Good management of Canada's water resources demands understanding of their extent and variability. Canada has had some substantial programs in the past, but should now change emphasis to increase studies of:

1. the hydrologic cycle, including the relationships between rainfall and run-off and between surface and groundwater;
2. precipitation, the source of all fresh water, but the recipient of little attention in Canada;
3. streamflow, on which Canada spends about $10 million annually to collect data, but only $124,000 on research; and
4. the problems of our lakes, particularly the larger ones.

Other Research programs, including those concerned with snow, ice and groundwater, should continue, but need not expand so rapidly because they are already large.

Another reason for pursuing research into the water cycle in Canada is the complex problem of water export. To reach proper solutions Canada should know the extent of its resources and of its needs.

We are all conscious of the problems of *water pollution.* A significant part of Canada's total effort should continue to be directed to their solution and the problems tackled should be particularly related to Canadian conditions. Canadian industry should be encouraged to develop techniques for identifying pollutants, finding their sources and tracing their fate in Canadian waters. Some sources of pollution are obvious industrial and municipal

[9] See Special Study No. 5, Chapter V, for detailed recommendations.

outfalls, but others are less well defined. How important as sources of pollution are salts used on icy winter roads, pesticides and fertilizers used on farm lands, and animal wastes from agricultural areas and septic tanks? What is the effect of ice cover on lakes and rivers upon pollutant concentration and dispersal? These problems are urgent. Little is being done to solve them, but they will remain unanswered for Canadian conditions until tackled in Canada. By contrast, information about water treatment can be readily imported and Canada should use foreign results in preference to increasing its own efforts. (By 1970-71 the United States federal government is expecting to spend $21 million on research into this topic.)

Table 3 indicates how much of Canada's program has been, and should continue to be, devoted to these two major categories, but there are also some smaller topics which should be given more support.

In the past, little attention has been paid to ways of using water of impaired quality, or to the problems of water conservation in domestic, industrial or agricultural use.

Research is badly needed into the neglected social, economic and legal aspects of water resources. Potential economic benefits often conflict with social considerations of an aesthetic, health or recreational nature. Some dams for example, may improve their surroundings; others will destroy beauty or spoil recreation. There is particular need to understand and evaluate available options.

Water law in Canada is not as clear as it might be, especially where more than one governmental jurisdiction is involved. Conflicting claims to the use of water have not been numerous and have usually been resolved without resort to the courts. In consequence, there has been little opportunity for judicial interpretation or clarification of the applicable laws. The Science Council recommends that the effort devoted to these subjects should be increased.

One other topic not emphasized by the Study Group deserves attention because it has been neglected and it would involve increased industrial participation. This is research and development concerned with major pieces of engineering equipment used in water programs. Special Study No. 5 states that in 1966 Canada spent $1.46 billion on the construction of structures for the control and treatment of water. Each year the demand increases for large pumps, valves and other equipment. It would seem desirable for Canada to develop these components, bearing in mind that the domestic market is only a small fraction of the world demand.

Development of instruments is also important, including those capable of operating unattended for long periods in severe environments. The advent of satellites for surveying resources will increase the need for sophisticated instrumentation. Canada should develop and manufacture much of the necessary equipment.

In many other topics of water resources, Canada can import the results of work done elsewhere, and should not make unnecessary expenditures at home.

Section 6

THE FUTURE FUNDING OF WATER RESOURCES RESEARCH

The Study Group estimated what future expenditures would be adequate for water resources research and at the same time justifiable in comparison with other demands. This they did by assessing *each* of the topics listed in Appendix II for:

1. the economic and social importance of the problems involved;
2. the adequacy or lack of present activity;
3. the rate of increase required to make the level of effort correspond to the gravity of the problem.

For the *whole field* of water resources research, they also sought to assess:

4. whether the recommended growth can be achieved with the currently available manpower; and
5. what facilities the universities need to train more men.

The Study Group concluded that $25 million would be required for the field of water resources research in 1972-73, which is about three times the $8.4 million spent in 1966-67. This implies an annual growth rate of 20 per cent for the next few years. By extrapolation, the Study Group then predicted expenditures in 1978-79 of $75 million. In projecting future re-

Table 4[a].—Proposed Expenditures on Water Quality Management and Protection, by Topics

Topic	Reported Expenditures 1966–67 ($'000)	Proposed Expenditures 1972–73 ($'000)	Approximate rate of Growth Implied (Percentages per annum)
Identification of Pollutants	110	580	29
Sources and Fate of Pollution	270	1,590	33
Effects of Pollution	470	1,590	23
Waste Treatment Processes	930	1,740	11.8
Ultimate Disposal of Wastes	40	150	25
Water Treatment	30	150	30
Water Quality Control	660	1,300	10.6
Totals	2,510	7,100	Average 19.5

[a] Based on Special Study No. 5, Table 14.

quirements, the Study Group followed the example of the Economic Council of Canada in using a two-per cent implicit price increase.

Although the average growth suggested is 20 per cent, the rate naturally varies between categories and from topic to topic. Table 4 illustrates this by presenting details for each topic in the category of Water Quality Management and Protection.

To avoid a possible source of confusion it should be noted that Special Study No. 5 and this Report use percentages in two different ways when referring to individual topics. In Table 3 of this Report, for example, the percentages are of the total expenditure on water resources research, but in Table 4, the percentages are recommended rates of growth per annum.

Such large expenditures require justification. This may be done from two points of view: by judging the economic and the social importance to the nation.

From the *economic* point of view the Study Group sought to evaluate costs and benefits. They found that in 1966 the $1.46 billion spent in Canada on structures to control, convey and treat water and sewage amounted to 2.5 per cent of the Gross National Product (GNP) of $58 billion. Projections suggest that this percentage will remain constant, so that in 1978, when the GNP should reach $128 billion, the annual investment in these structures may reach $3 billion. The value of a resource on which we expect to spend so vast a sum each year must be great indeed and there are already evident a number of areas in which research, even at a cost of $75 million a year, could more than pay for itself.

Another economic measure of appropriate expenditures can be based upon the Gross Expenditure on Research and Development (GERD). The Science Council has already stated[10] that by 1975 a GERD of between 2.1 and 2.4 per cent of GNP would be reasonable. In 1978 a GERD of 2.2 per cent of GNP would equal $2.8 billion. The Study Group have proposed that the proportion of the GERD allocated to water resources research should rise from 1.2 per cent in 1966 to 2.5 per cent in 1978. If this is accepted and achieved it would provide $70 million for water resources research in 1978, which is close to the figure recommended.

Besides the direct economic benefits in dollars the program would have *social* and aesthetic returns which cannot be expressed in dollars but which would probably have a greater value to the Canadians concerned than the direct economic benefits. A reduction in the pollution of our lakes and waterways would bring more than economic benefits. A recent report[11] on the aftermath of the sinking of the oil tanker *Torry Canyon* in the English Channel concludes with the words: "We are progressively making a slum

[10] Science Secretariat Special Study No. 4, *The Proposal for an Intense Neutron Generator, Scientific and Economic Evaluations,* a Preparatory Study by a Committee of the Science Council of Canada—December 1967 (Ottawa: Queen's Printer, 1967, Price $2.00) p. 102.

[11] *"Torry Canyon" Pollution and Marine Life,* J. E. Smith, Ed., Cambridge University Press, 1967.

of nature and may eventually find that we are enjoying the benefit of science and industry under conditions which no civilized society should tolerate".

The authors of Special Study No. 5 point out that ultimately their final conclusions are based on their "informed judgment" upon future needs. The Science Council cannot affirm that priorities placed today on water resources research will be valid in 1978-79, but accepts the allocation of 2.5 per cent of Canada's research effort to water resources as a reasonable long-term target which can be adjusted later. Meanwhile, the Science Council recommends that expenditures in Canada on research and development of water resources should be increased by 20 per cent per annum to reach $25 million in 1972-73.

In the previous section the Science Council expressed the view that industry should be more involved in water resources than is proposed by Special Study No. 5. When one considers the Council's emphasis on the development of equipment, the need to increase industrial participation becomes more pressing.

Accepting an increase of 20 per cent per annum in total expenditures, this change in emphasis leads the Council to recommend the division of expenditures by sectors of performance, given in Table 5.

Table 5.—Proposed Distribution of Expenditures, by Sector of Performance

Sectors	Reported 1966–67		Proposed 1970–71		Proposed 1972–73	
	$'000	Per Cent	$'000	Per Cent	$'000	Per Cent
Government	5,500	66	8,200	48	11,000	44
University	1,600	19.5	5,000	30	7,000	28
Industry	1,200	14.5	3,600	22	7,000	28
Totals	8,300	100	16,800	100	25,000	100

The amounts quoted for university and industry are exclusive of funds provided for operational studies, which may include an element of research, and which would be contracted by departments of government from the "Government" allotment in Table 5.

Until 1970-71 the rates of growth proposed for industrial and university programs are nearly equal; thereafter the emphasis should shift in favour of industry. Hence, if these trends continue, industry's share will grow more rapidly than the shares of the others. The Council proposes an immediate large increase in expenditures to establish centres of research and to train the men required for the whole program (See also Section 8.2).

Section 7

THE CO-ORDINATION OF CANADIAN PROGRAMS IN WATER RESOURCES RESEARCH

In a forthcoming report the Science Council will recommend that an important feature of future Canadian science should be a series of major programs of which water resources research should be one.

In co-ordinating research in these major programs, the Science Council distinguishes between subjects which fall essentially within the jurisdiction of a single Federal department and those which are a major concern of several departments. An example of the latter case has been dealt with in the Report, *A Space Program for Canada,*[12] where the Science Council recommends establishing a Central Space Agency to co-ordinate efforts. In the case of water resources research, on the other hand, the main responsibility within the Federal Government rests with a single department, that of Energy, Mines and Resources, and in this case the Science Council suggests that the co-ordinating powers be vested in a committee which would be the principal advisor to the Minister concerned. It should be appropriately constituted and widely representative.

The Science Council believes that if the National Advisory Committee on Water Resources Research were somewhat reconstituted it would be suitable and should be given those powers.

The present terms of reference of the National Advisory Committee on Water Resources Research require that it:

"1. provide continuing advice to the Minister of Energy, Mines and Resources on needs and priorities for research on water resources in Canada, including water pollution research;

2. assist in the co-ordination of water resources research;

3. review and make recommendations on applications for grants-in-aid of research from the Department of Energy, Mines and Resources".

The Science Council recommends that the mandate of the Committee be expanded by requiring that it:

4. provide continuing advice to the Minister of Energy, Mines and Resources on the use and application of science to water resources management and development.

[12] Science Council of Canada Report No. 1, *A Space Program for Canada,* July 1967.

With this amendment, the terms of reference of the National Advisory Committee would fit the role which the Council would have it play.

The present mechanism of having appointments to such committees made by the Governor-in-Council on the advice of the Minister has in the past proven to be quite satisfactory since the Minister concerned has in turn had available a wide range of advice from the scientific community.

The experience of other advisory committees leads the Science Council to believe that if such committees appear to be dominated by members from a single department of government, then other members feel that their influence is slight and they do not take the work of the committee seriously. Outside ideas are not given adequate attention and the point of establishing the committee is largely lost.

On the other hand, a committee which is and which appears to be independent, is more likely to produce ideas and to be effective. Government departments have nothing to fear and much to gain from the advice of such committees.

The Science Council recommends revising the membership of the National Advisory Committee on Water Resources Research as follows:

1. Members should represent all sectors of the economy, Federal and provincial public services, universities and industry. No sector should dominate the Committee.
2. The membership of the Committee should reflect, as far as possible, the wide range of disciplines which contribute to water resources research.
3. The senior representative of the Department of Energy, Mines and Resources on the Committee should be appointed Convenor of the Committee.
4. The Chairman of the Committee need not be a Federal public servant, but should be elected to the position by the members of the Committee.
5. The Chairman should be elected for a term of three years, which could be once renewable. Members should also be appointed to the Committee for three year terms which could be once renewable.
6. The present Committee seems large; it probably needs only fourteen members (including the Chairman, Convenor and Secretary).
7. The Department of Energy, Mines and Resources should provide a non-voting Secretary and the Secretariat.

An important role of the National Advisory Committee is the provision of advice on the distribution of funds to universities and to industry. The Council recommends that the funds of concern to the Committee be provided as a distinct item in the budget of the Department of Energy, Mines and Resources, and that the responsibility for advising the Minister on the distribution of these funds should rest solely with the Committee and its

appropriate sub-committees. Section 8 of this Report includes specific recommendations on amounts.

Two sub-committees of the National Advisory Committee already deal with the social sciences and the natural sciences respectively. The Council recommends that these sub-committees continue to provide detailed advice on the distribution of funds to universities. A third sub-committee, established to advise on the program of the Canada Centre for Inland Waters at Burlington, already influences an important segment of the Federal effort.

The Council recommends that a new sub-committee of the National Advisory Committee be formed to consider and recommend what programs of research should be carried out by industry, but this sub-committee should not directly select recipients for funding. In order to avoid conflicts of interest, the Council suggests that the selection of organizations to receive contract funding be made the responsibility of an impartial body drawn from the secretariat provided by the Department of Energy, Mines and Resources. The allocation of contracts would then be done in consultation with the Department of Industry, Trade and Commerce.

The Council believes that the National Advisory Committee should represent all interests and should frame a detailed national policy for water resources research, including the total Federal and provincial programs, and that all groups involved should follow its advice.

This Report is principally concerned with research, but the Council recognizes that this is being conducted to provide knowledge for the management, utilization and development of Canada's waters. The Federal Government is considering a "Canada Water Act", one provision of which would establish a "Canada Water Advisory Board". This board would report to the Minister designated to co-ordinate all Federal water programs (currently the Minister of Energy, Mines and Resources), it would advise on questions relating to Canada's water policy and in particular it would assist in the co-ordination of all aspects of water management in Canada. If such a board is established, the Science Council recommends that the National Advisory Committee on Water Resources Research should become its scientific arm.

Section 8

THE PROPOSED GROWTH OF WATER RESOURCES RESEARCH IN CANADA

1. The Growth of Government Research

The Science Council recognizes the Government's need to do research into water resources and to continue some of its own programs. While the growth rate suggested for these programs in Table 5 is healthy, it is less than those recommended for universities and industry.

In Table 5, the Science Council recommends increases of governmental expenditures from $5.0 millions in 1966-67 to $11 millions in 1972-73, at an average rate of 13 per cent per annum. Special Study No. 5 recommended that provincial efforts should grow faster than the Federal and such a redistribution could take place within our recommendations and still permit both levels to grow.

2. The Growth of Research in Universities

To provide specialists, a particularly rapid expansion is needed in universities during the next few years.

In the past, the National Research Council has provided most of the support for water resources research at universities by grants. These awards are based on the ability of the applicant and not on the recognizable potential value of the research. Some research projects which are directed by curiosity alone, should continue to be supported even if they appear to have no practical value beyond the training of students, but this support should grow slowly.

As expenditures mount, an increasing proportion should be directed into fields where research is likely to have potential value and where trained men are required. Such research should be supported through the National Advisory Committee on Water Resources Research which should identify important projects and recommend support for them.

The Science Council recommends that from 75 to 80 per cent of the total Federal funds for university activities in water resources research should be allocated in support of mission-oriented programs following the advice of the National Advisory Committee, while the National Research Council should disburse the remainder as grants-in-aid of research on topics dictated by the interests of the researchers.

The Science Council, in advocating that two different bodies be involved in the funding process, recommends that adequate communication be established and maintained between them through joint membership.

Table 6 of Special Study No. 5 identifies the Federal Government as the source of 60 per cent of the funds for water resources research in the universities. The Council recommends that this should continue. Bearing in mind the objectives proposed above for the National Advisory Committee and for the National Research Council in supporting university research, Table 6 of this Report sets forth the levels of funding which these bodies should provide in 1970-71 and 1972-73.

Table 6.—Proposed Federal Support of Universities for Water Resources Research, by Source

Dispersal Source	Expenditures Proposed 1970–71 ($'000)	Expenditures Proposed 1972–73 ($'000)
National Advisory Committee	2,250–2,400	3,150–3,360
National Research Council	750 – 600	1,050 – 840
Totals	3,000	4,200

The Science Council and the Canada Council expect to make recommendations during 1968 on the support of research in universities. The mechanism for the support of water resources research should then be modified if necessary to conform to these recommendations. Should the Council recommend an increase in payments for overhead charges, the funds proposed in Table 6 would have to be increased.

The grants from the National Research Council ensure that any active scientist, even if isolated, can get some support, but the Science Council believe that some aspects of research flourish best in reasonably large scientific communities, and that it should be the role of the National Advisory Committee to foster them.

The Science Council recommends that a few universities (not more than half a dozen) should establish institutes or departments specializing in water resources research. Each institution which obtains major support, besides maintaining a general, multidisciplinary competence, should specialize. Possible fields of specialization are:

(a) social, economic and legal aspects of water resources research, including policies and planning;
(b) water pollution;
(c) hydraulic engineering and instrumentation;
(d) water resources in cold climates; and
(e) the water cycle.

In order to encourage the establishment of such institutes or specialized departments, large grants, including some capital costs, should be given for

about three years. Thereafter, each institution should seek annual grants based upon its needs and performance.

Efforts should be made to encourage more pure scientists to engage in problems concerned with water. For example, mathematicians might study circulation and flow; chemists could improve the detection and analysis of minute amounts of insecticides and other dangerous pollutants; physicists could attempt to measure precipitation over large lakes which is believed to be different from that over their shores. At the same time, the Study Group pointed out that most of the scientists currently involved in water resources research have been trained as engineers and that progress in water resources research may depend upon continuing to attract large numbers of engineers to it.

3. The Growth of Water Resources Research in Industry

The Science Council wishes to encourage the growth of Canadian industry and recommends that industrial research into water resources be increased. It may be argued that an industry appropriate to this field scarcely exists in Canada. In reply, the Council maintains that much of the proposed expansion should be executed through industrial contracts to supplement industry's own investments.

The Canadian geophysical industry offers a successful example of this. Although magnetic surveys were begun in 1841, small progress was made until a century later when a modern, airborne instrument was developed by the Gulf Oil Company. This was first demonstrated in Canada in 1945 at the invitation of the Department of Mines and Technical Surveys, which recognized the instrument's value. It established a geophysical survey section, but contracted most of the field work to private companies. This created opportunities for established companies and led to the formation of new ones. The companies were highly competitive and sought alternative sources of support. They undertook contracts for foreign governments and for mining companies; they formed branches all over the world; they undertook the design and manufacture of geophysical instruments and they expanded to produce other types.

One cannot say whether individual surveys conducted by contract were more or less expensive than if they had been made by Government but, because the Government employed only a few civil servants, its commitment has remained small. The policy has led to co-operation between Federal and provincial governments in joint support of some surveys. Today, magnetic surveys have covered large areas and Canada is a world leader in the thriving geophysical industry as demonstrated by the First International Conference on Mining and Groundwater Geophysics which in September 1967 attracted 600 delegates to Niagara Falls from 50 countries. The inclusion of groundwater geophysics is significant for this Report.

Some persons may claim that these surveys have collected data and do not provide a pattern for research. Even if this were partly true, those engaged have done much research and development to improve their techniques.

The analogy between magnetic surveys and water resources research may not be a perfect one, but it does suggest a satisfactory method for involving industry in the execution of complex surveys of the most modern kinds over vast areas of Canada. It suggests that much research and collection of data which governments now do should in future be done by contract.

The Science Council recommends that the Federal Government institute a program of contract allocation, to involve industry and consulting firms in specific water resources research projects, selected with the advice of the National Advisory Committee. Such contracts would foster industrial participation and act as incentives, but should not prevent industry from increasing its own investment in water resources research.

Table 6 of Special Study No. 5 shows that the Federal Government provided almost one third of the funds spent by industry in water resources research. The Council recommends that this policy should continue and that the National Advisory Committee on Water Resources Research should advise the Federal Government on the provision of about $1.2 millions for industrial contracts in 1970-71 and about $2.3 millions in 1972-73, including negotiated overhead charges. This would be in addition to any operational contracts from governments. The Council believes that this money is necessary to stimulate and support industrial interest in some aspects of water resources research. As recommended in Section 7, once the broad outlines have been established, the allocation and administration of individual contracts should be delegated to a group drawn from the Department of Energy, Mines and Resources, whose members would not suffer any conflict of interest in dealing with private companies.

One object should be to encourage Canadian industry to supply the nation's needs for equipment and instruments and thereby save importing. All levels of government should pursue purchasing policies which encourage Canadian industry, because it is only by creating a demand in the market that the final step from development through innovation to production can be promoted. Equipment developed by Canadian industry to operate reliably under Canadian conditions should find ready acceptance elsewhere.

The Science Council believes that if contracts for the collection of certain types of data were also given to industry such a policy would develop the climate and facilities in which industrial research could flourish and would encourage industry to sponsor research.

Throughout this Report, the Council has emphasized the need to foster the growth of a "water resources industry" in Canada and has made some specific recommendations upon how expenditures in the private sector should grow. This must be coupled to the need to foster a greater awareness of water resources research, and its results, on the part of those other industries whose operations involve the use of water.

Growth in the private sector should be an important trend. To ensure this, the Council endorses the recommendation of Special Study No. 5 that water resources research be reviewed in 1971. The review should seek to determine whether or not industrial participation in water resources research has developed in the manner herein recommended.

Section 9

SUMMARY OF RECOMMENDATIONS

1. Canada with its abundance of surface water has different problems in water resources research from other countries and should develop its own policy.

2. As in other fields, the policy should be to support research:
(a) which is relevant to Canada;
(b) which has not already been done elsewhere; and
(c) which has potential economic or social returns.

3. Canada's efforts in water resources research should be redistributed to emphasize those problems which we must solve for ourselves. This involves giving more support to those subjects which have been neglected and are crucial to Canada. These include particular aspects of water pollution, the social and legal aspects of water, the ecologic impact of water development, engineering equipment and materials, and some aspects of the water cycle where knowledge is needed to permit sound management of our resources. On the other hand, modest rates of growth will suffice where investment has already been large (e.g. on snow and ice and on groundwater) or where Canada should use the results of research done elsewhere (e.g. on saline water conversion, on water quality control and on waste treatment processes).

4. Water resources are so important to Canada and research has been so neglected that the Council recommends an increase in expenditures on research and development in this field at an annual rate of 20 per cent from $8.4 million in 1966 towards a target of $25 million in 1972-73.

5. For 1970-71 and for 1972-73 the recommended targets are:

	1970-71 ($000,000)	1972-73 ($000,000)
Governments	8.2	11
Universities	5.0	7
Industry	3.6	7

6. Canada needs to strengthen the research capacity of its water resources industry and can do this by contracting a large proportion of research and data collection to private companies, as the Government has successfully done in the case of geophysical surveys.

7. Government laboratories should do enough research to ensure that those responsible for administering water resources in Canada are fully acquainted with the latest developments in all fields. This requires only a modest rate of growth in their already relatively large annual expenditures.

8. The Federal Government should encourage university participation in water resources research by assisting the establishment in Canadian universities of a few major research institutes specializing in different fields.

9. The Science Council recommends that the co-ordination of a major program of water resources research be made the responsibility of the National Advisory Committee on Water Resources Research, provided that the following conditions are met.

(a) The terms of reference of that Committee should be expanded by adding the requirement "to provide continuing advice to the Minister of Energy, Mines and Resources on the use and application of science to water resources management and development."

(b) The Committee should be immediately reorganized to reduce its size, to bring about better representation of all sectors of the economy, particularly by appointing representatives from industry, to redress any imbalance of disciplines, and to elect a Chairman.

(c) The funds of concern to the National Advisory Committee should form a separate and identifiable item within the budget of the Department of Energy, Mines and Resources, and the responsibility for advising the Minister on the distribution of these funds should rest solely with the Committee and its appropriate subcommittees.

(d) The present arrangement, whereby the two existing subcommittees of the National Advisory Committee (those on the natural and the social sciences) provide detailed recommendations on the distribution of funds to the universities, should continue.

(e) A new subcommittee should be appointed to make detailed recommendations on research programs which should be contracted out to industrial or consulting organizations.

(f) By the fiscal year 1970-71, the Federal Government should be providing from $2.25 to $2.4 million to universities and about $1.2 million to industrial enterprises and engineering consultants in support of programs which further the policies proposed by the National Advisory Committee.

(g) The National Advisory Committee should regularly consult with the appropriate Grants Selection Committees of the National Research Council on the question of support for university activities in water resources research.

10. The Council recommends a review in 1971 of Canadian water resources research with a view to a particular examination of the degree of industrial participation achieved.

APPENDIX I

MEMBERS OF THE SCIENCE COUNCIL COMMITTEE ON WATER RESOURCES RESEARCH

CHAIRMAN: Dr. J. Tuzo Wilson,
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MEMBERS

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The Committee is grateful to its secretary, Mr. J. Mullin, and to its advisers, Mr. J. P. Bruce and Dr. E. L. Maasland.

*Members of the Science Council of Canada.

APPENDIX II

CATEGORIES AND TOPICS OF WATER RESOURCES RESEARCH

(This Report refers to the eight major divisions as Categories and their subdivisions as Topics. The list and definitions are precisely those which the Study Group used in its questionnaire and follows United States practice.)

1. Category: Nature of Water

This Category deals with fundamental research on the water substance.

Topics: *Properties of Water*—Study of the physical and chemical properties of water, including its thermodynamic behavior in its various states.

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

2. Category: Water Cycle

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

Topics: *General*—Studies involving two or more phases of the water cycle such as hydrologic models; rainfall-runoff relations; surface and groundwater relationships; watershed studies; geomorphology.

Precipitation—Investigation of spatial and temporal variations of precipitation; physiographic effects; time trends; extremes; probable maximum precipitation; structure of storms, quantitative precipitation forecasting.

Snow and ice—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.

Evaporation and transpiration—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.

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

Groundwater—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.

Water in soils—Infiltration; movement and storage of water in the zone of aeration, including soil.

Lakes—Hydrologic, hydrochemical, and thermal regimes of lakes; water level fluctuations; currents and waves.

Water and plants—Role of plants in hydrologic cycle; water requirements of plants; interception of precipitation.

Erosion and sedimentation—Studies of the erosion process; prediction of sediment yield; sedimentation in lakes and reservoirs; stream erosion; sediment transport; river-bed evaluation.

Chemical processes—Chemical interactions between water and its natural environment; chemistry of precipitation.

Estuarine problems—Special problems of estuarine environment; effect of tides of flow and stage; deposition of sediments; sea water intrusion in estuaries.

3. Category: Water Supply Augmentation and Conservation

As water use increases Canada must pay increasing attention to methods for augmenting and conserving available supplies. Research in this Category is largely applied research devoted to this problem area.

Topics: *Saline water conversion*—Research and development related to methods of desalting sea water and brackish water.

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

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.

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

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

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

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

4. Category: Water Quantity Management and Control

This Category includes research directed to the management of water, exclusive of conservation, and the effects of related activities on water.

Topics: *Control of water on the land*—Effects of land management on run-off; land drainage; potholes; etc.

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

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

5. Category: Water Quality Management and Protection

An increasing population increases the wastes and other pollutants entering our water supplies. The Category deals with methods of identifying, describing and controlling this pollution.

Topics: *Identification of pollutants*—Techniques of identification of physical, chemical and biological pollutants; rational measures of character and strength of wastes.

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.

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.

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 re-use.

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

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

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.

6. Category: Economic, Social and Institutional Aspects

The problems of achieving an optimal plan of water development are becoming increasingly complex. The Category 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.

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

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.

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

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

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

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

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

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

7. Category: Resources Data

Planning and management of our water resources require information. The Category 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.

Topics: *Network design*—Studies of data requirements and of the most effective methods of collecting the data.

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.

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

8. **Category: Engineering Works**

To implement water development plans requires engineering works. The Category 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.

Topics: *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.

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

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

REPORT No. 3

A Major Program of Water Resources Research in Canada