

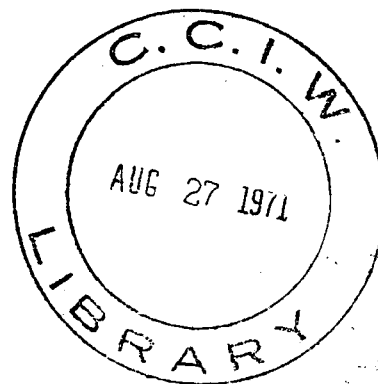
CANADA • Inland Waters Directorate
Report Series.

#13



INLAND WATERS BRANCH

DEPARTMENT OF ENERGY, MINES AND RESOURCES



THE FEDERAL GROUNDWATER PROGRAM

Annual Project Catalogue 1970-71

REPORT SERIES NO.13

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no. 13**



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THE FEDERAL GROUNDWATER PROGRAM

Annual Project Catalogue 1970-71

**INLAND WATERS BRANCH
DEPARTMENT OF ENERGY, MINES AND RESOURCES
OTTAWA, CANADA, 1971**

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FEDERAL GROUNDWATER RESEARCH

1. Introduction

The division of responsibilities between federal and provincial governments with respect to water resources has evolved from the British North America Act and interpretations placed upon it, notably by the Canadian Council of Resource Ministers. In the case of groundwater, this division is particularly clear-cut. Inventory, evaluation and development of groundwater are generally regarded as provincial matters; provision of financial and technical assistance, basic data and research lie within the sphere of the federal government. Both types of activities - resource evaluation and research - are, of course, federal groundwater responsibilities in the territories; the federal government may also, in some cases, contribute to provincial groundwater resource evaluation if there is mutual federal-provincial agreement concerning the desirability of such an arrangement.

The federal agency charged with conducting field and laboratory studies in hydrogeology is the Groundwater Subdivision of the Hydrologic Sciences Division, Inland Waters Branch. The activities of the Subdivision are not confined, however, strictly to the hydrogeologic field: roughly a quarter of the projects listed in this catalogue are concerned in some way with other aspects of hydrology such as evaporation and rainfall-runoff relationships. These other aspects may assume increasing importance as operational units in the Inland Waters Branch define more precisely their needs for research support and these needs are compared with current research activities.

The studies conducted by the Subdivision comprise a number of projects that fit into two distinct categories - operational (GWO) and research (GW). This Project Catalogue lists 6 operational and 37 research projects and provides information on objectives and progress for each.

Operational projects are generally initiated at the request of other federal departments and are performed as a service for these departments in areas that are either under direct federal jurisdiction (such as the national parks) or that are the sites of broadly based federal research programs requiring some groundwater input. An exception is provided by the Shippegan oil spill study (GWO 70-2) in which the Groundwater Subdivision became involved at the request of a provincial agency. The emergency nature of this project and the ad hoc approach that had to be adopted preclude its classification as a true research project.

Research projects originate within the Subdivision, Division or Branch. Related research projects with common objectives may be grouped together to form a program. A proposed new project may be seen either as the logical extension of an existing program or as the appropriate response to a new area of concern in groundwater hydrology.

Research is the salient activity of the Groundwater Subdivision. Operational projects generally do not serve to advance research progress and it is important therefore, that manpower resources should not be unduly committed to these projects. A partial solution to the problem is utilization of the private sector for field management of operational projects. Consultants may also be used to advantage in research projects, not only for field management, but also for such purposes as the development of new instrumentation. Utilization of the private sector is a policy with the Subdivision and it is anticipated that it will contribute to another benefit - the generation of a high degree of hydrogeologic competence in this sector.

2. The Research Framework

Prominent among the criteria defining the research framework within which the Groundwater Subdivision should operate is the dual requirement that individual scientific projects should generally rate highly in terms of both national need and scientific significance. Further criteria are provided by three important Branch objectives. These are, in order of priority:

1. Achievement, setting and maintenance of water quality standards appropriate to the nature, management and use of surface and groundwaters in Canada.
2. Determination of water quantities in rivers, lakes, aquifers and glaciers to the accuracy desired for planning and optimum water management.
3. Development, review, evaluation and recommendation of technical plans and procedures for implementing water resource management, conservation and development with respect to both quality and quantity.

Evaluation of existing or proposed programs or projects in terms of these criteria is playing an important part in the development of Subdivision research activities. As was suggested above, specific hydrologic research needs can undoubtedly be outlined by the operational units within the Branch and these can be fitted into Groundwater Subdivision programs as financial and manpower resources permit. Provincial groundwater agencies can also provide input concerning national research needs.

3. Current Activities

The Groundwater Subdivision has developed four main research programs. These are:

1. The Maritime Research Program consisting of research projects GW 67-8, 68-10, 68-11, 68-12, 69-1, 70-1, 70-7, and 70-9.
2. The Basin Management Program consisting of research projects GW 67-1b, 67-2b, 67-13, 67-14, 67-19, 68-4, 68-5, 68-6, 70-3, 70-4, 70-5, 70-6 and 70-10.
3. The Subsurface Disposal Research Program consisting of research projects GW 67-4, 67-9, 67-12 and 70-8.
4. Hydrologic Systems Analysis consisting of research projects GW 67-11, 68-2, 68-7, 68-8 and 69-2.

Seven other projects are listed in this catalogue, two of which (GW 68-3 and 68-9) are now completed. Of the other five, two (GW 67-5 and 70-2) are concerned with climatology and bear some relation to the activities of the Hydrologic System Analysis group. One (GW 70-11) is a study of the effects of joints and fractures on groundwater flow in the prairies and is similar to fracture studies (GW 68-11 and 70-1) being conducted as part of the Maritime Research Program. The two remaining projects not presently incorporated into the four research programs listed above deal with ostracode ecology (GW 67-6) and groundwater flow in two sub-basins of the Lower Fraser valley in British Columbia (GW 67-16). Project GW 67-6 has implications for the study of eutrophication. Project "GW 67-16" is related to the program of the Hydrologic Systems Analysis group but is expected to be completed this year so that there is little point in considering its formal inclusion into that program.

Of the four programs listed above, two - the Maritime Research Program and Hydrologic Systems Analysis - have been carried over from the listing in last year's catalogue. The new Basin Management Program is a logical development of the original GOWN program for computerized storage and retrieval of groundwater data. Its inclusion in this year's catalogue of Subdivision activities was forecast last year. The basic theme of the Basin Management Program is the development of automated methods to provide, process and present relevant geohydrologic data to basin managers to enable them to make logical informed decisions concerning not only the storage, use and allocation of water resources but also those engineering or agricultural practices which might tend to influence the hydrologic regime. A long-range aim is to integrate computer-oriented geohydrologic data-processing techniques with similar techniques concerned with surface water and water quality. These

techniques are under development elsewhere in the Branch.

The second new program listed above is the Subsurface Disposal Research Program. The development of this program was also foreseen in last year's catalogue. The initial emphasis will be on deep-well disposal of industrial wastes but one project (GW 67-12) is concerned with the shallow hydrogeologic effects of disposal of brines from potash mining into surface ponds. The group involved in this program is also taking some preliminary interest in subsurface disposal of radioactive wastes and will be on the alert for research opportunities related to other subsurface contamination problems. These could include groundwater pollution due to garbage dumps, sanitary land fills, solid waste disposal and surface disposal of waste industrial chemicals.

Administratively, the Groundwater Subdivision is divided into four sections (see organization chart). Generally, there is a good correlation between programs and sections: the Maritime Research Section handles the Maritime Research Program and this is its sole responsibility; a similar relation holds for the Computer Research Section and the Basin Management Program and for the Eastern Research Section and the Hydrologic Systems Analysis program. The activities of the Western Research Section, however, include not only the Subsurface Disposal Research Program but also most of the continuing projects that do not at present form part of any of the four main research programs. It is anticipated that there will be some further rationalization of programs and regrouping of projects during the coming year so that the number of isolated projects will be fewer, but it appears inevitable that there will always be a few projects not assignable to major programs.

4. Future Activities

A major objective for the coming year is a re-examination of the program of the Hydrologic Systems Analysis group in the Eastern Research Section. Progress to date will be critically reviewed and a concerted effort will be made to develop a strongly integrated new program with a pronounced emphasis on physically based hydrologic modeling. Preliminary discussions have suggested that lack of progress by hydrologic investigators generally in deriving adequate hydrologic forecasting models can be ascribed in large measure to the heterogeneity of the systems that are being dealt with and to the effects of fluid turbulence in micro- and mesoscale meteorology. These problems generally induce investigators to divert their efforts to superficial short-term studies with immediate engineering applications.

The new research emphasis must be, therefore, not only on the physical bases of hydrologic phenomena but must also eventually take into account statistical and stochastic variations due to fluid turbulence and heterogeneity. These variations will surely limit the accuracy with which

models can predict. Determination of heterogeneity indices for individual components of a hydrologic system could be a study objective in itself and could lead to estimates of maximum attainable accuracies for hydrologic forecasting. This might perhaps tend to reduce extensive expenditures of effort on "optimization" of forecasting procedures.

As was suggested in the preceding section, further rationalization of Groundwater Subdivision programs is expected to take place during the coming year. It is anticipated that the concept of one research group - one research program will be almost completely realized in a year's time and that the administratively oriented sections will be replaced by program oriented task forces or research groups. These groups will not be static but will be created, expand, contract and dissolve as programs are conceived, get under way, mature and eventually meet their objectives. This approach is believed to provide the Subdivision with the maximum flexibility required to meet the new challenges and demands of the future.

Ottawa, February 19, 1971.

A handwritten signature in dark ink, appearing to read "D. H. Lennox". The signature is fluid and cursive, with a large initial "D" and a stylized "L".

D. H. Lennox, Head,
Groundwater Subdivision.

ORGANIZATION CHART

Mr. D. H. Lennox, *Head*

Mrs. H. Burns, *Secretary*

Eastern Research Section

Dr. H. Ryckborst, *Head*
Mr. J. E. Charron
Dr. R. L. Harlan
Dr. F. I. Morton

Western Research Section

Dr. R.O. van Everdingen,
Officer-in-Charge
Mrs. M. Cool, *Secretary*
Dr. L. D. Delorme
Dr. R. M. Holmes
*Dr. J. A. Vonhof
Mr. J. A. Banner

Computer Research Section

Mr. J. A. Gilliland, *Head*
Mr. G. Grove
Mr. R. L. Herr
Mr. S. Y. Shiau
Mr. J. French
Miss D. Gagnon

Maritime Research Section

Dr. M. L. Parsons, *Head*
Dr. P. A. Carr **
Dr. H. Lazreg
Mr. A. Vanden Berg

Vancouver Office

Mr. E. C. Halstead

Educational Leave

Mr. D. W. Lawson

Stores

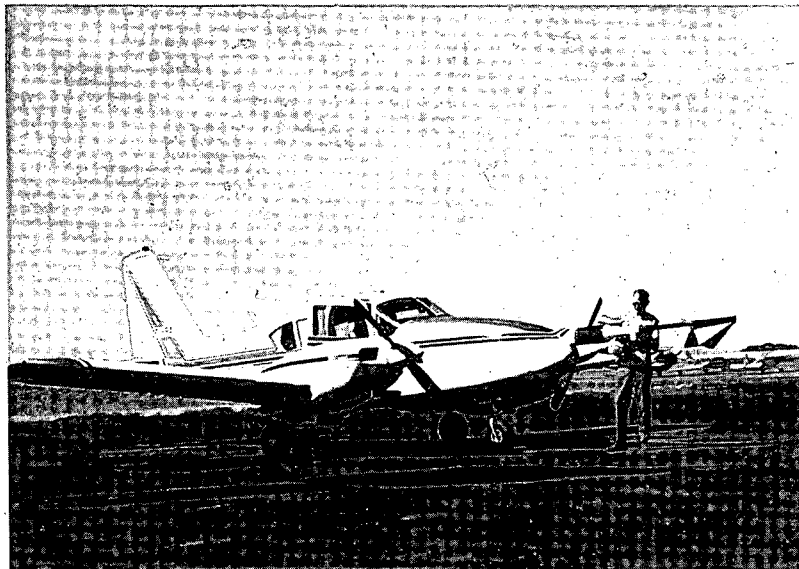
Mr. V. Leveck

*815 Colony Street, Saskatoon.

** On leave of absence in Fiji with UN.



*Figure 1. Diefenbaker Lake, Riverhurst Area,
Saskatchewan, July 1965.*



*Figure 2. Instrumented Aztec aircraft used for
airborne remote and immersion sensing.*

CATALOGUE OF CURRENT PROJECTS

Western Research Section

1. Western Research Section

During 1969 the Western Research Section, based in Calgary, Alberta, lost two of its scientists. A. Lissey moved to Brock University in St. Catharines, Ontario, and R. A. Freeze started work at the Thomas J. Watson Research Centre of IBM, in Yorktown Heights, New York. Their projects (GW 67-1a, GW 67-2a and GW 67-3) were terminated on their departure. J. A. Vonhof was transferred to the Western Research Section from the Eastern Research Section, in connection with the location of his studies of the effect of waste disposal basins on groundwater (GW 67-12), as well as his involvement with the newly undertaken research program, subsurface disposal of waste, which is being coordinated by R. O. van Everdingen in Calgary.

Diversity is still the mark of the activities of the section. During 1970 studies of thermal and mineral springs in the Rocky Mountains were completed with the preparation of a number of reports; studies of the chemistry and movement of formation waters in the Western Canada Sedimentary Basin were continued; piezometric observations on aquifers underlying Diefenbaker Lake are drawing to a close (GW 67-4). The instrumentation for airborne observation of climatological parameters was transferred to a larger two-engined aircraft to reduce the noise-level in the recorded data resulting from wing vibrations (GW 67-5). The land-based phase of this project related to the energy budget at the ground-air interface was continued in the Cypress Hills area. Collection of background data on the taxonomy of recent and fossil freshwater ostracodes in Western Canada, and on their recent ecology, was completed (GW 67-6). A statistical study of environmental parameters has been started, and detailed studies are being made of ostracode assemblages in cores of lake and pond sediments to arrive at paleolimnological interpretations. A new project (GW 70-8) was started to deal with various aspects of the subsurface disposal of waste.

The laboratory of the section was used for limestone-treatment tests on acidic, heavy-metal carrying spring water to investigate precipitation of the heavy metals; for preparation of ostracode samples; and for maintenance of instruments. Work was started on the development of apparatus for testing of formation fluids and cores under pressures up to 2000 psi. Data acquisition at the experimental plot, for use by the Eastern Research Section, was continued.

Bedrock Aquifers of the Western Sedimentary Basin

A. OBJECTIVES:

1. To investigate properties and processes, leading to an explanation of the chemistry and movement of formation waters in the basin.
2. Assessment of the potential of the formation waters as an economic resource (in terms of both water and dissolved constituents).

B. PREVIOUS WORK:

1. Office

- a. Computer programs for the selective printout of formation-water analyses and drill-stem test results, and for correlation and map plots were successfully tested on data from Manitoba.
- b. Reports were prepared on the results of the investigation of springs in the Rocky Mountains.

2. Field

- a. The investigation of mineral and thermal springs in the Rocky Mountains was rounded off with the investigation of a sulfur spring near Frank, Alberta, in the Crowsnest Pass.
- b. Piezometric measurements in the Riverhurst (Sask.) area, around Diefenbaker Lake, were continued on a monthly basis.

3. Laboratory

- a. Heavy-metal precipitation tests on the acidic heavy-metal carrying water from the Paint Pots springs in Kootenay National Park and on synthetic acidic metal-bearing solutions were completed and a report prepared.

4. Publications

van Everdingen, R. 1969. Degree of saturation with respect to CaCO_3 , $\text{CaMg}(\text{CO}_3)_2$ and CaSO_4 for some

R. O. van Everdingen

thermal and mineral springs in the Southern Rocky Mountains, Alberta and British Columbia. Can. J. Earth Sciences, vol. 6, p. 1421-1430.

- van Everdingen, R. O. 1970. The Paint Pots, Kootenay National Park, British Columbia - acid spring water with extreme heavy-metal content. Can. J. Earth Sciences, vol. 7, p. 831-852.
- van Everdingen, R. O. 1970. Prediction of saturation precipitation of low-solubility inorganic salts from subsurface waters under changing conditions of total concentration, temperature and pressure. Inland Waters Branch, Technical Bulletin 30.
- van Everdingen, R. O. 1970. Seasonal variations, Sulphur Mountain Hot Springs, Banff, Alberta. Inland Waters Branch, Technical Bulletin 33.
- van Everdingen, R. O. 1970. Surface-water composition in Southern Manitoba reflecting discharge of saline subsurface water and subsurface solution of evaporites. Geol. Assoc. Canada, Symposium Geoscience Studies in Manitoba, Special Volume #9 (in press).
- van Everdingen, R. O. and Banner, J. A. Precipitation of heavy metals from natural and acidic aqueous solutions during neutralization with limestone. Inland Waters Branch, Technical Bulletin 35.

C. WORK IN PROGRESS:

1. Office

- a. Coding of chemical analysis and pressure data from petroleum drilling in Saskatchewan and British Columbia has been started.
- b. An extensively illustrated report on the mineral and thermal springs studied in the past two years has been submitted for publication. Although it contains all data available on these springs, it is aimed at a mixed technical and non-technical audience. It is hoped a format can be found that would be suitable for distribution to visitors to the Rocky Mountain National Parks, in addition to its use as a guidebook for field trips in the Rocky Mountains.

2. Field

- a. Piezometer measurements in the Riverhurst area, Sask., will be continued on a monthly basis until the end of 1970. P.F.R.A. will continue measurements on a 3 to 4 times per year basis after that.

3. Laboratory

- a. Equipment is being put together for the testing of formation water samples (for pH, Eh and conductivity) under pressures approximating the original subsurface reservoir pressure.
- b. Equipment is being assembled for the testing of permeability of cores under reservoir pressure, with formation-water samples collected under reservoir pressure.

D. FUTURE WORK:

1. Office

- a. Coding and processing of chemical and pressure data.
- b. Preparation of a final report on the Riverhurst piezometer observations between Jan. 1965 and Jan. 1971.

2. Field

- a. Obtain formation-water samples under reservoir pressure, with measurement of formation temperature and shut-in fluid pressure, for testing in the laboratory.

3. Laboratory

- a. Testing of formation water chemistry and core permeability under reservoir pressure.

Hydro-Climatology of Hills and Prairie

A. OBJECTIVES:

To investigate the energy budget of the ground-air interface over an area of transition between prairie and foothills terrain, with particular reference to the hydrologic balance, using data obtained from standard weather stations.

B. PREVIOUS WORK:

1. Publications

Holmes, R. M., 1969. A study of the climate of the Cypress Hills. Weather, v. 24, pp 324-330.

Holmes, R. M., 1969. Oasis effects caused by the Cypress Hills. Proc. 3rd Conf. Forest Micro-climatology, Kananaskis, Alberta.

2. Field

- a. A transect of prairie to foothills (Cypress Hills) terrain has been instrumented with standard weather observing instruments to measure the climatic transition at the surface from one area to the other. These data are augmented by observations taken by the Departments of Transport and Agriculture at nearby Prairie sites. Observations taken at the various sites vary somewhat depending on the location but include maximum and minimum temperature, grass minimum (summer only), hygrothermograph trace, miles of wind, "A" pan evaporation (summer only), latent evaporation (summer only), wind speed and direction, soil temperature at 4" and 8", hours of sunshine (summer only), barometric pressure, rainfall, rainfall intensity, and dew point. Initial plans called for at least an 8-year observation program with data processing to begin following the 6th season. 1970 represents the 5th observational season.

C. WORK IN PROGRESS:

1. Field

- a. During summer months each site is visited twice daily by a field crew, and observations are made. In the

R. M. Holmes

winter months, the sites are visited once a week and charts are changed on the hygrothermographs and observations are made of snowfall, wind mileage, and soil temperature.

2. Office

Climatic data are abstracted from instrument observations, charts, and traces, and pertinent summary calculations are made. This tabulation and reduction of surface data takes place on a continuing basis and is maintained in an easily available form for processing.

D. FUTURE WORK:

The first three seasons were occupied largely in organization, obtaining equipment, and setting up of the present program. During the following seasons the surface observational work proceeded with a program of data tabulation, and reduction. It is envisaged that at least 6 years of data will be necessary to sample a suitable number of climatic variables at the surface sites to begin initial data processing. The past two seasons produced data which show that this experiment has significant application in climatology and hydrology. It is of value to note that the instrumentation thus far used, is that which is routinely available for all standard stations. The relationships arrived at from this study will then have ready application to all areas where standard observation techniques are used.

Paleohydrogeology of the Interior Plains of Canada

A. OBJECTIVES:

1. To determine tolerance limits of freshwater ostracodes to the chemical and physical parameters from the natural laboratories of ponds, lakes, and streams.
2. To assess the relationship of the chemistry of pond, lake, and stream water to geology, hydrology, botany, and climate.
3. To reconstruct the past history of ponds and lakes by means of water quality and quantity models.
4. To assess ostracodes as a paleolimnological tool.

B. PREVIOUS WORK:

1. Publications

Delorme, D. L., 1964. A checklist of Pleistocene and Recent freshwater ostracodes in Canada: *Sterkiana*, no. 14, p. 39-44.

Klassen, R. W., Delorme, L. D., and Mott, R. J., 1967. Geology and paleontology of Pleistocene deposits in southwestern Manitoba: *Can. Jour. Earth Sci.*, vol. 4, no. 3, p. 433-447.

Delorme, L. D., 1967. Freshwater ostracode synonyms: *Jour. Paleontology*, vol. 41, no. 3, p. 792-794.

Delorme, L. D., 1967. New freshwater Ostracoda from Saskatchewan, Canada: *Can. Jour. Zoology*, vol. 45, p. 357-363.

Delorme, L. D., 1967. Field key and methods of collecting freshwater ostracodes in Canada: *Can. Jour. Zoology*, vol. 45, p. 1275-1281.

Delorme, L. D., 1968. Pleistocene freshwater Ostracoda from Yukon, Canada: *Can. Jour. Zoology*, vol. 46, no. 5, p. 859-876.

Delorme, L. D., 1969. The ostracode genera Cypriconcha and Megalocypris: *Can. Jour. Zoology*, vol. 47, no. 3, p. 271-281.

- Delorme, L. D., and Donald, D., 1969. Torpidity of freshwater ostracodes. *Can. Jour. Zoology*, v. 47, no. 5, pp 997-999.
- Delorme, L. D., 1969. Appendix In McAllister, D. E., and Harington, C. R. Pleistocene Grayling, Thymallus, from Yukon, Canada. *Can. Jour. Earth Sci.*, v. 6, no. 5, pp 1185-1190.
- Delorme, L. D., 1969. Ostracodes as Quaternary paleoecological indicators. *Can. Jour. Earth Sci.*, v. 6, no. 6.
- Delorme, L. D., 1970. Freshwater ostracodes of Canada, Part I. Subfamily Cypridinae. *Can. Jour. Zoology*, v. 48, no. 1, p. 153-169.
- Delorme, L. D., 1970. Freshwater Ostracodes of Canada, Part II. Subfamilies Cypridopsinae, Herpetocypridinae, and family Cycloocyprididae. *Can. Jour. Zoology*, v. 48, no. 2, p. 253-266.
- Delorme, L. D., 1970. Canadian freshwater Ostracoda, part III. Family Candonidae: *Can. Jour. Zoology*, v. 48, no. 5, p. 1099-1127.
- Delorme, L. D., 1970. Canadian freshwater Ostracoda, part IV. Families Ilyocyprididae, Notodromadidae, Darwinulidae and Entocytheridae, subfamily Cytherideinae: *Can. Jour. Zoology*, v. 48, no. 6.
- Delorme, L. D., 1971. Canadian freshwater Ostracoda, part V. Family Limnocytheridae: *Can. Jour. Zoology*, v. 49, no. 1, (in press).
- Delorme, L. D., (in press). Paleoecological determinations using Pleistocene freshwater ostracodes: *Centre Rech. Pau-SNPA Bull.*
- Delorme, L. D., (In press), Paleoecology of Holocene sediments from Manitoba using freshwater ostracodes: *Geol. Assoc. Canada, Symposium*, v. 9.

2. Field

- a. 1966 - 768 samples were collected from 49,000 square miles in south central Alberta; 18,000 ostracode specimens were collected. Complete chemical analyses for major ions were made on the 768 surface water samples.

L. D. Delorme

- b. 1967 - 1,650 samples were collected from 105,600 square miles in central and northern Alberta, Northwest Territories, and the western half of Saskatchewan; 42,000 ostracode specimens were collected. Chemical analyses for major ions were made on the 1,650 surface water samples.
- c. 1968 - 1,500 samples were collected from 96,000 square miles in eastern Saskatchewan, Manitoba, and southwestern Ontario; 37,500 ostracode specimens were collected. Chemical analyses for major ions were made on 1,500 water samples.
- d. 1969 - 75 samples were collected of which 24 were from the Kenora lakes on which the Fisheries Research of Canada, Freshwater Institute, Winnipeg are carrying out fertilization studies; 51 samples were collected on a 10-day cruise of Lake Winnipeg also in conjunction with the Freshwater Institute, Winnipeg. Chemical analyses for major ions were also made on these water samples.
- e. 1969 - 24 cores were collected during the summer of 1969 using a Minuteman Mobile Drill modified to obtain a core. 360 feet of core were obtained producing 1589 samples.
- f. 1970 - 28 cores were obtained using a Minuteman Mobile Drill, yielding 450 feet of core or 4,500 samples. Approximately 1,600 of these samples are to be used for ostracode extraction. The cores were obtained from selected sites in the three prairie provinces.

3. Office

- a. Computer Sciences of Canada (Calgary) are completing refinements on computer programs previously prepared for paleolimnological determinations.
- b. Identification of ostracode species and ostracode based paleolimnological interpretations were made for the following people:

Mr. D. Singh

Department of Geology
Panjab University
Chandigarh, INDIA
November 20, 1969, 1 sample

L. D. Delorme

Dr. R. S. Anderson	Canadian Wildlife Service University of Calgary Calgary, ALBERTA November 13, 1969, 2 samples
Dr. R. W. Klassen	Geological Survey of Canada Calgary, ALBERTA November 26, 1969, 1 sample
Dr. C. R. Harington	National Museum of Canada Curator of Quaternary Zoology October 27, 1970, 11 samples Old Crow River Basin, Yukon
Mr. C. McLay	Department of Zoology Institute of Animal Resource Ecology University of British Columbia December 11, 1969, 2 samples + many slides
Dr. J. Brophy	North Dakota State University of Agriculture and Applied Science January 13, 1970, 1 sample North Dakota
Mr. D. Donald	Department of Biology University of Calgary March 13, 1970, 1 sample Calgary
Dr. V. N. Rampton	Geological Survey of Canada Ottawa, Ontario April 21, 1970, 3 samples McKenzie River, N.W.T.
Dr. A. Ashworth	North Dakota State University of Agriculture and Applied Science February 18, 1970, 11 samples
Mr. D. Rosenberg	Department of Entomology University of Alberta May 22, 1970, 50 samples Ellerslie, Alberta
Dr. A. MacStalker	Geological Survey of Canada Ottawa, Ontario July 8, 1970, 1 sample

L. D. Delorme

Mr. D. Singh	Department of Geology Panjab University Chandigarh, INDIA September 25, 1970, 1 sample
Dr. J. E. Hazel	U. S. Geological Survey Washington, D. C. September 25, 1970, 2 samples Arctic Village, Alaska
Dr. P. P. David	Department de Geologie Université de Montreal September 25, 1970, 1 sample Empress, Alberta
Mr. J-S. Vincent	University of Ottawa October 7, 1970, 1 sample Temiscamingue County, Quebec
Mr. J. Matthews	Department of Geology University of Alberta October 21, 1970, 1 sample Cape Deceit, Seward Peninsula, Alaska
Dr. O. L. Hughes	Geological Survey of Canada Calgary, Alberta October 29, 1970, 110 samples Old Crow Basin, Yukon
Dr. R. W. Klassen	Geological Survey of Canada Calgary, Alberta November 2, 1970, 7 samples Assiniboine Valley, Manitoba
Dr. L. S. Kornicker	Smithsonian Institution U. S. National Museum Division of Crustacea August 24, 1970, 6 samples Siberia, 1933 Mozley collection

C. WORK COMPLETED:

1. Systematic collection of Recent freshwater ostracodes in the central prairies region.
2. Systematic collection of fossil freshwater ostracodes from selected areas in the south-central prairies region.

L. D. Delorme

3. Systematic study of freshwater ostracodes from the central prairies of Canada, their taxonomy and systematic description (see the 5-part series on Canadian ostracodes under "publications").

D. WORK IN PROGRESS:

1. Publications

Delorme, L. D. (In preparation), Freshwater ostracodes, their ecology and distribution in Lake Winnipeg, Manitoba, Canada: Canada Fisheries Res. Board Jour.

Delorme, L. D. (In preparation), Paleolimnology of Lake Agassiz terrace deposits in the Assiniboine River, Valley, Manitoba: Can. Jour Earth Sci. (Title tentative).

Delorme, L. D. (In preparation), Male sexual adaptations in the large megalocypridinid ostracodes: Can. Jour. Earth Sci. (Title tentative).

Delorme, L. D. (In preparation), Ecology of freshwater ostracodes: Ecology. (Title and publisher tentative).

2. Office

- a. To assess environmental data and its relationship to ostracodes.

E. FUTURE WORK:

1. To assess ostracodes as a paleolimnological tool.

Principles of Groundwater Pollution

A. OBJECTIVES:

1. To gain an understanding of the theory of physio-chemical transport phenomena in porous media.
2. To develop mathematical models of physio-chemical transport phenomena.
3. To demonstrate the employment of these models in studies of waste disposal, salt-water intrusion, tracer movement, etc.

B. PREVIOUS WORK:

1. Publications

Elrick, D. E. and D. W. Lawson, 1969. Tracer Techniques in Hydrology. National Research Council, Proc. Hydrology Symposium No. 7: Instrumentation and Observation Techniques, Victoria, pp. 155 - 187.

Bachmat, Y. and D. W. Lawson, 1970. A new conductivity method for determining concentrations in parallel plate models. J. Hydrology, Vol. 11, No. 2, pp. 145 - 152.

2. Office

- a. An introduction to the theory of physio-chemical transport phenomena is contained in the above-mentioned paper by Elrick and Lawson.
- b. A preliminary literature review of hydrodynamic dispersion (theory, mathematical modeling, experimentation) has been completed. Hydrodynamic dispersion - the continuous change in the volume occupied by a given mass of solute due to convection and molecular diffusion.
- c. Laboratory equipment for determining hydrodynamic dispersion coefficients has been designed.
- d. Laboratory equipment for studying dispersion in non-uniform flow fields has been designed.

3. Laboratory

- a. A new technique has been developed for determining solute concentrations in parallel-plate sand models and is described in the paper by Bachmat and Lawson.

D. W. Lawson

- b. The equipment for determining dispersion coefficients has been constructed and a series of experiments has been conducted.

C. WORK IN PROGRESS: (Ph.D. Program at University of Guelph)

1. Publications

Lawson, D. W., (submitted). Two improvements in the finite-difference solution of the hydrodynamic dispersion equation.

2. Office

- a. The literature review of hydrodynamic dispersion continues to be improved.
- b. The data from the dispersion coefficient experiments continue to be analyzed.

D. FUTURE WORK:

1. Office

- a. A literature review of physio-chemical transport phenomena in porous media.
- b. Development of mathematical models for subsurface water quality problems.

2. Laboratory

As dictated by the results of the WORK IN PROGRESS and OBJECTIVES 1, 2, 3.

*The Effect of Waste Disposal Basins
on the Groundwater Regime*

The research project is being carried out around International Minerals and Chemical Corporation (Canada) Limited, K-2 (potash) mine in the vicinity of the town of Esterhazy in southeastern Saskatchewan with full cooperation of the company. Large volumes of waste, both solid and liquid, are generated as a result of mining and processing of potash ore. These wastes are stored in natural depressions and/or constructed pond areas near the plant.

A. OBJECTIVES:

1. To study the effect of the waste disposal basin on the local groundwater regime.
2. To determine if and when remedial measures must be taken to limit the spread of subsurface pollution.
3. To evaluate the long-term effects of the waste disposal basin on the surface water resources in the area.
4. To recommend possible alternative solutions to the waste disposal problem around potash mines based on the outcome of the above study.

B. PREVIOUS WORK:

1. 1967 - Field work during the summer of 1967 consisted primarily of a farm well inventory, collecting of water samples for chemical analysis, map compilation and augering.
2. 1968 - A test drilling program was conducted during the summer to determine the regional geological setting of the area. Additional water samples were collected to better define the groundwater chemistry of the area.
3. 1969 - A test drilling and sidehole sampling program to obtain detailed stratigraphic information in the vicinity of the disposal basin near I.M.C.C. K-2 mine was completed during the summer of 1969. An additional test drilling program will be carried out during the winter of 1969 - 1970 to supplement the first drilling program and to finish the detailed geological investigation phase of the study.

4. 1970 - A surface resistivity survey was carried out by Dr. H. Lazreg, Groundwater Subdivision, Inland Waters Branch. Six observation wells and three still wells were constructed during the winter of 1970-1971.

The data obtained from the regional and detailed test drilling programs show:

- a. On the bedrock surface (Riding Mountain Formation of Upper Cretaceous age) the presence of a large basin partially flanked on each side by bedrock uplands with three outlets at different elevations.
- b. A large aquifer system in the basin covering an area of approximately 1,000 square miles.
- c. The presence of a large recharge area, connected with the aquifer system, approximately 10 miles north of Esterhazy. Only the southern limit of this recharge area has been reasonably well defined. A typical geological section shows 5 - 10 feet of oxidized sandy and silty till, (Battleford Formation) overlying 100 - 150 feet of sand. The water table is approximately 50 feet below surface.
- d. The presence of badland topography on the bedrock surface in the vicinity of I.M.C.C. K-2 mine.
- e. The presence of buried valleys filled with sand and gravel, under the waste disposal basin.
- f. The presence of silty and sandy beds in the Riding Mountain Formation which underlies the Pleistocene sediments.

Detailed stratigraphic work has been done on the Pleistocene sediments. A number of excellent exposures of fractured tills were found, and fracture patterns and fracture densities were measured. The significance of the fractures is that they constitute highly permeable paths in an otherwise poorly permeable sediment.

The data obtained from a surface resistivity survey show three well-defined areas of low resistivity in the vicinity of the waste disposal basins.

C. WORK IN PROGRESS:

Data analysis.

D. FUTURE WORK:

1. 1971 - 1972 - Construction of an analog model of the waste disposal basin. Monitoring of model. Theoretical study of flow in fractured till.

During this period a number of publications are expected to be finished.

Additional surveys under consideration for this period are:

- a. Remote sensing using techniques such as infra-red imagery.
- b. Determination of the effect of brines on the permeability of a montmorillonitic till.
- c. Study of the effect of airborne salt on the hydrochemistry of the shallow groundwater in selected areas.

Airborne Studies of the Atmospheric Boundary Layer

A. OBJECTIVES:

1. To investigate the application of airborne techniques to studies of the behaviour of the atmospheric boundary layer with particular reference to the flux of heat and water vapor.
2. To use airborne instrumentation developed under (1) to study the nature of the atmospheric boundary layer as related to the underlying surface, with particular regard to the flux of heat, momentum and water vapor.

B. PREVIOUS WORK:

1. Publications

Holmes, R.M., 1969, Note on low level airborne observations of temperature near prairie oases. Monthly Weather Review, v. 97, pp 333 - 339.

Holmes, R.M., 1969. Airborne measurements of thermal discontinuities in the lowest layers of atmosphere. Proc. 9th Conf. Ag. Met., Univ. Washington, Seattle.

Holmes, R.M., 1970. Airborne techniques in climatology; oasis effects above prairie surface features. Inland Waters Branch Technical Bulletin No. 19.

Holmes, R.M., 1970. Meso-Scale Effects of Agriculture and a Large Prairie Lake on the Atmospheric Boundary Layer. Agronomy J., vol. 62, pp 546 - 549.

2. Field

This project was begun as part of project GW 67-5 in order to provide a continuum of atmospheric data from the study area (Cypress Hills, Alberta) surface into the atmosphere as high as the effects of the study surface could be measured. Some preliminary data related to this phase have been published as listed above. However, the work of developing airborne instrumentation required a somewhat broader base of reference with regard to study area. Therefore during the process of instrument evaluation, as each additional part of the instrumentation became available, other surfaces were sought for study.

Consequently, cooperative projects were established where other scientists provided ground truth for airborne observations over the Utah Salt Flats, and over an extensive irrigated oasis in the Snake River Valley of Idaho. Two other short term cooperative studies were made near Calgary in the Foothills area. In developing the airborne instrument system, each segment was flight tested and evaluated before proceeding to the next. Hence a complete picture of the developing system was available during the first phase of the project. Each portion of the system met the design specification. An additional capability in IR Remote Sensing was developed and various surface phenomena such as surface heating characteristics were studied as could be determined with an IR line-scanner.

C. WORK IN PROGRESS:

1. Publications

Holmes, R.M. and K. Hage. Airborne observations of three Chinook type situations in South Alberta.

Holmes, R.M. An airborne instrument system for studies of the atmosphere processes in the boundary layer - an evaluation.

Holmes, R.M. Spatial and temporal variations of heat and water vapor flux over an irrigation oasis in Idaho.

Holmes, R.M. Sensible heat flux divergence over the Utah Salt Flats.

Holmes, R.M. IR Remote Sensing techniques in Quaternary Research.

2. Field

The initial phase of field work was to have been terminated at the end of September. Shortly before that time a disastrous laboratory fire destroyed all of the aircraft instrumentation and a large percentage of the data taken during the summer.

3. Office

Data collected to date are being processed in order to demonstrate the application of the airborne techniques (Objective 1). A manuscript describing the airborne system is also under preparation (see above).

D. FUTURE WORK:

The project is now in an evaluation phase and its future course depends on the results of the evaluation. If the decision is made to continue, it is probable that it will lead to other cooperative projects for which adequate ground truth will be essential to make the airborne measurements meaningful. This ground truth will have to be supplied by cooperating scientists. Enquiries received to date suggest that there is a great deal of interest in the potential of the airborne measurements which may indeed prove to be the most suitable approach to the study of spatial and temporal variations in heat and water vapor transport in the atmospheric boundary layer.

Subsurface Disposal of Wastes

A. OBJECTIVES:

1. Collection of background data for evaluation of subsurface waste-disposal potential in Canada.
2. Extension of understanding of physical and chemical processes involved in the movement and behaviour of waste materials after injection into the subsurface.
3. Development of rational guidelines and quantitative criteria for use in the regulation and control of subsurface disposal of waste.
4. Development of methods for the monitoring of the movement and behaviour of injected waste.
5. Development of techniques for the prediction of movement and behaviour of injected waste.

B. PREVIOUS WORK:

1. Office

Literature survey, and preparation of a preliminary appraisal of the subsurface disposal method.

C. PRESENT WORK:

1. Office

- a. Continued survey of relevant literature.
- b. Acquisition of background data on geology, stratigraphy, structure, seismic activity and mineral resources, for use in regional evaluation of the potential for subsurface disposal of waste.

2. Laboratory

Development of apparatus to be used in tests of the compatibility of injected waste with formation fluids and formation rocks, under reservoir pressures.

D. FUTURE WORK:

1. Office

- a. Preparation of a country-wide evaluation of the gross potential of the subsurface for the injection of liquid wastes.
- b. Preparation of guidelines and criteria to be used in the regulation and control of subsurface disposal of waste.

2. Field

Collection of samples of formation fluids, under reservoir pressure, for use in compatibility tests.

3. Laboratory

- a. Compatibility tests.
- b. Further development of the "compatibility tester" to enable study of the effects of temperature.

*Jointed Tills and Upper Cretaceous Sediments
in Western Canada*

A. OBJECTIVES:

1. To determine physical characteristics of joints (extent, density, distribution, size, etc.).
2. To determine the significance of the joints for the rate and direction of movement of groundwater and pollutants.

B. PREVIOUS WORK:

Several joint patterns in tills were measured in outcrops in Alberta, Saskatchewan, and Manitoba during the summer of 1970. The results obtained from the field work were presented at the annual meeting of the Geological Association of Canada in Winnipeg.

C. WORK IN PROGRESS:

1. Publication

Joint patterns in tills in western Canada.

D. FUTURE WORK:

Measurement of several more joint patterns in both Pleistocene and Upper Cretaceous sediments in western Canada. Theoretical study of flow in jointed till. Development of method for field testing jointed tills.

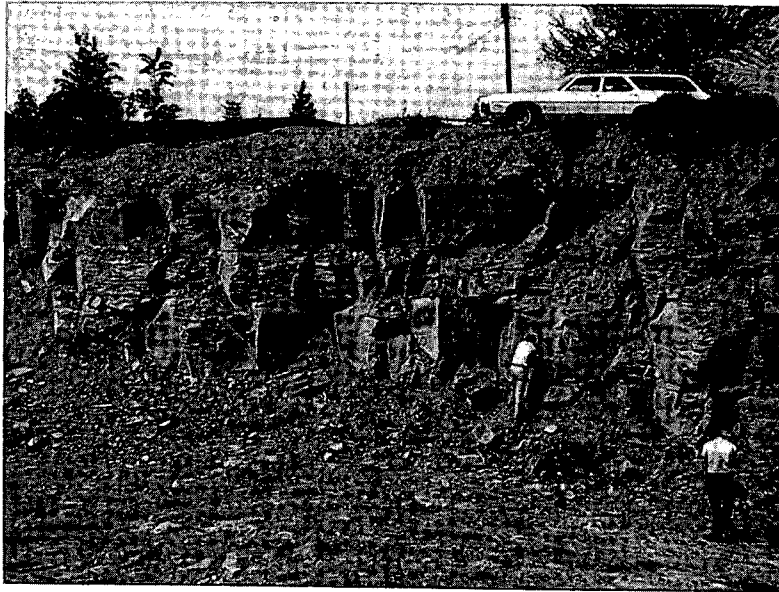


Figure 3. Measuring fracture orientations in the lower Derby sandstone quarry near Newcastle, New Brunswick.



Figure 4. Plumose and conchoidal structure on the surface of a fracture in the Shediac sandstone quarry, New Brunswick.

2. Maritime Research Section

The Maritime Research Section has seen two recent personnel changes. P. A. Carr is now on leave of absence with the United Nations in Fiji. He will be carrying out groundwater resource studies and looking into salt-water intrusion problems while there. A. Vanden Berg has joined the Section from the Research Council of Alberta and will be investigating aquifer response in coastal aquifers.

The Maritime Research Section is responsible for the operation of the Maritime Research Program. During two years of operation attention has been focused on the evaluation of hydrologic parameters of the groundwater flow medium and on the surface geophysical detection of the fresh-saline groundwater interface. More specifically project GW 67-8 and GW 70-7 have been concerned with analysis of coastal aquifer response to tidal fluctuations with the latter project concentrating on aquifers characterized by leakage or unconfined conditions. Project GW 68-11 is nearing completion of its first phase which is an evaluation of the influence of bedrock fractures in the permeability of the flow medium in the Carboniferous Basin. Surface electrical resistivity studies (GW 68-12) are in the final interpretation stage and have demonstrated the possibility of detecting subsurface changes from fresh to brackish groundwater. Recently the scope of Project GW 68-12 has been logically extended to include borehole geophysical techniques and Project GW 70-1 has been initiated to study the hydrology of fractured metamorphic and igneous rocks in the Halifax area. The data provided by these projects and the methodology developed will contribute to a basis for rational groundwater development in the Maritimes coastal regions.

However if these data and methods are to be applied in practice, the Maritimes Research Program must continue to be involved with problems associated directly with real development projects. Such an involvement should also result in a greater awareness by the researchers of the needs for relevant research. Hence the Program has a continuing interest in the Shippegan and Summerside groundwater development problems to the solutions of which Projects GW 68-10 and GW 68-12 have made significant contributions. The former project which initially defined the salt-water intrusion problem at Shippegan is nearing completion as a Ph.D. thesis study. The availability of borehole geophysical logging equipment will make possible the regular acquisition of precise subsurface hydrogeologic data to supplement drilling information. Therefore, this equipment will make possible the application of techniques which have proven useful in many other regions of the world. The logging system will be available for use in research drilling programs and groundwater development projects, particularly those which are of interest to the Maritimes Research Program.

In the future more effort will be devoted to the evaluation and application of available analytical and numerical techniques to the solution of groundwater development problems, and research will be directed to the development of new techniques of well field design in coastal aquifers subject to sea-water intrusion. An essential aspect of well field design research must be the evaluation of the effectiveness of a well field based on long term monitoring of groundwater production and aquifer response.

*Sea-water Intrusion Study in the Pennsylvanian
and Permian Rocks of New Brunswick and Prince Edward Island*

A. OBJECTIVES:

1. To comprehend the relationship between seawater and fresh groundwater in the interbedded fractured sandstones and mudstones which characterize the bedrock hydrogeologic environment in the Maritime Provinces with the aim of establishing criteria necessary for the safe development of well fields near the sea.
2. To establish methods of determining regional aquifer parameters from the observation of groundwater levels fluctuating with the tides.

2. PREVIOUS WORK:

1. Publications

Carr, P. A., 1967. Salt-water Intrusion Studies in the Maritimes. Maritime Sediments, Vol. 3, No. 4, pp. 109 - 111.

_____, 1969. Salt-water Intrusion in Prince Edward Island. Can. J. Earth Sci., Vol. 6, No. 1, pp. 63 - 74.

Chipping, D. H. 1967. Groundwater Conditions Beneath Georgetown, Prince Edward Island. Student Research Report, Department of Geology, Stanford University, California.

Carr, P. A. and van der Kamp G., 1969. Determining Aquifer Characteristics by the Tidal Method. Water Resources Research, Vol. 5, No. 5, pp. 1021 - 1031.

Carr, P. A., in press. The use of Harmonic Analysis to study Tidal Fluctuations in Aquifers near the Sea.

2. Field

Field work is completed.

C. WORK IN PROGRESS:

P. A. Carr

1. Office

A comparison was attempted of aquifer diffusivity values determined by the tidal method with those determined by the analysis of groundwater recession (Rorabough, 1960)*. However, the latter method did not yield reliable results since the period of recession in Prince Edward Island was too short to make a valid analysis.

D. FUTURE WORK:

Project completed.

* Rorabough, M.I., 1960. Use of Water Levels in Estimating Aquifer Constants in a Finite Aquifer, Int. Assoc. Sci. Hydrology; No. 52, pp. 314 - 323.

*Seawater Intrusion at Shippegan,
Taylor Island, New Brunswick*

A. OBJECTIVES:

1. To determine the influence on groundwater flow systems of salt-water intrusion induced by municipal and industrial pumping in the Shippegan area.
2. To predict rate and future extent of intrusion and to determine under what conditions the transition zone between fresh and salt water may stabilize.

B. PREVIOUS WORK:

1. Two wells drilled in 1967 by the New Brunswick Department of Natural Resources to determine depth of zone of diffusion near the centre of Taylor Island.
2. During August, 1967 and May to September, 1968 and 1969
 - a. 57 test holes drilled and logged
 - b. 54 piezometers installed in fourteen nests
 - c. 15 wells pump tested
 - d. 16 groundwater level, 1 tidal and 2 precipitation gauges installed
 - e. about 2,000 samples bailed from the salt-water intrusion wedge and titrated for chlorides
 - f. elevations obtained for all open wells and piezometers with respect to mean tide datum
 - g. 115 groundwater samples analyzed for all major ions
 - h. tidal efficiency and time lag determined on 54 piezometers and 30 open wells
 - i. piezometric heads measured weekly and flow net sections and plans prepared
 - j. slug tests conducted to determine permeability of claystone units.

C. WORK IN PROGRESS:

Preparation of final report to be submitted as a thesis study to the University of Western Ontario.

D. FUTURE WORK:

Field work completed.

*Regional Groundwater Flow and
Subsurface Temperatures in a Maritime Province Coastal Environment*

A. OBJECTIVES:

1. To investigate the natural regional groundwater flow and heat transfer in fractured media in a Maritime Province coastal environment.
2. To assess the effect of groundwater withdrawal on the regional groundwater hydrodynamics, in particular on the fresh-saline groundwater transition zone.
3. To explore the application of geothermal measurements to the evaluation of groundwater flow.

B. PREVIOUS WORK:

1. Publications Nil
2. Field
 - a. Measurement of fracture orientations in outcrops along 65 sample lines in eastern New Brunswick and 18 sample lines in Prince Edward Island.
 - b. Water injection testing in six existing observation wells in Prince Edward Island and eight existing observation wells at Shippegan, New Brunswick, totalling 1,500 feet of borehole.
 - c. Temperature logging of 23 existing observation wells in the Eliot River area, Prince Edward Island and 17 observation wells at Shippegan, N.B. in 1969 and 1970.
 - d. Installation of 5 piezometers and 1 deep open hole in two nests at Cap Pelé, New Brunswick to define the geology of the project area and to obtain groundwater head data. Water injection testing of the open borehole and geophysical borehole logging of the deepest borehole in each nest were completed.
 - e. Geophysical borehole logging of existing observation wells in New Brunswick and Prince Edward Island to determine stratigraphic variations and borehole conditions, a knowledge of which is necessary for the proper interpretation of injection test data.

- f. Borehole photography of two observation wells in Prince Edward Island.

3. Office

- a. Preparation of a computer program to analyze water injection test data and to estimate the mean and standard deviation of the fracture aperture population.
- b. Preparation of a computer program to determine geometric parameters of rock fracture sets.
- c. Preparation of a computer program to calculate the intrinsic permeability tensor and principal permeability axes.

C. WORK IN PROGRESS:

1. Field

Nil

2. Office

- a. Refinement of analysis of fracture permeability using data supplied by the geophysical borehole logging program.
- b. Analysis of borehole temperature logs.
- c. Preparation of a report on the hydrogeologic parameters of fractured media in the Carboniferous Basin.

D. FUTURE WORK:

1. Field

Continued measurement of the subsurface temperature field in coastal regions.

2. Office

- a. Numerical modelling studies of the coastal groundwater thermal system.
- b. Preparation of a report in collaboration with coordinators of GW 70-7 and GW 70-9 on the hydrogeology of the Cap Pelé study site.

*Geophysical Methods Applied to the
Study of Seawater Intrusion*

A. OBJECTIVES:

Evaluation of the application of geophysical methods in the characteristic hydrogeologic environment of the Maritime Provinces to:

1. the location of the interface or transition zone between fresh and saline waters in aquifers affected by seawater intrusion
2. the determination of horizontal and vertical variations in groundwater quality in the vicinity of the interface or transition zone
3. the observation of displacement, distortion or broadening of the interface or transition zone due to natural or man-made causes.

B. PREVIOUS WORK:

1. Delineation of the lateral intrusion zone, in Shippegan and Cap Pelé, N.B.; and in the Eliot River area, P.E.I. by surface electrical resistivity profiling.
2. Investigation of the vertical variation in conductivity of the geological formations by resistivity soundings in the abovementioned areas.
3. Application of induced polarization as an aid in differentiating between sandstone saline water bearing formations and clayey layers in P.E.I. and in Cap Pelé and Shippegan, N.B.
4. Installation of conductivity cells in deep formations at Summerside, P.E.I. to serve as a warning device to monitor and predict vertical movements of the fresh-brackish water interface.
5. Delineation by resistivity profiling of lateral saline water contamination resulting from brine disposal in Esterhazy, Saskatchewan.

6. Determination of horizontal variations in near-surface salinity due to a presumed upward flow of groundwater at Mer Bleue, Ontario.
7. Preliminary investigations on apparent geo-electrical anisotropy in Shippegan, N.B.

C. WORK IN PROGRESS:

1. Interpretation of field results.
2. Calibration of conductivity cells.
3. Preparation of reports on resistivity results obtained to date in the Maritime Provinces.
4. Acquisition and assembly of borehole geophysical logging equipment.

D. FUTURE WORK:

1. Field

- a. Further earth resistivity survey in Shippegan to study apparent electrical anisotropy in sandstone formations.
- b. Field testing and operation of borehole geophysical logging equipment.

2. Office

- a. Literature survey of the application of airborne geophysical techniques and satellite measurements to groundwater studies.
- b. Computer simulation of field apparent resistivity curves to validate interpretations by curve-matching techniques.

Pumping Experiments with Coastal Wells

A. OBJECTIVES:

1. For typical coastal aquifers, to examine the effects of pumping from wells completed in the vicinity of the transition zone between fresh and salt waters.
2. To evaluate the possibility of using special techniques (such as 'doublet wells' producing from both the fresh-water zone and the underlying saltwater zone) to maximize long-term freshwater production while avoiding 'upconing' or other harmful effects due to excessive modification of the pre-existing distribution of fresh, brackish and salt waters.
3. To develop field methods for the accurate observation of the movement of hydrochemical boundaries due to pumping from the vicinity of the transition zone.

B. PREVIOUS WORK:

A test drilling program was conducted in the autumn of 1969 near Rice Point on the south coast of Prince Edward Island to obtain an accurate picture of the subsurface distribution of fresh, brackish and salt waters. This water quality information is required for the intelligent design of pump test experiments. Two successful test holes were put down - to depths of 420 and 220 feet. Water-quality results indicated that total-solids content varies with the stratification, hence, at least in this particular location, the hydrogeologic conditions necessary for the construction of a 'doublet well' do not exist. Since there is good reason to believe that similar conditions would hold elsewhere in the Maritimes, the project has been terminated and the data obtained turned over to Project No. GW 68-12.

C. FUTURE WORK:

Project complete.

*Hydrogeology of Fractured Media
in the Halifax Area*

A. OBJECTIVES:

1. To evaluate the geometric and hydrologic parameters, of fractured rock in the Halifax area.
2. To evaluate the influence of major shear zones on the regional groundwater flow system.
3. To evaluate the applicability of pump test theory to fractured flow media.

B. PREVIOUS WORK:

1. Publications

Nil.

2. Field

- a. Reconnaissance survey of an area within a radius of 60 miles of Halifax to determine the presence of bedrock exposures suitable for measurements of rock fractures. The west side of the Bedford Basin was selected as the principal area of investigation and 15 sites within this area were selected for fracture orientation and frequency measurements.
- b. Geological mapping of the principal area of investigation on a scale of 1:12,500 and mapping of individual test plots on a scale of 1:500.
- c. Drilling of two vertical and one inclined holes to explore the characteristics of a major shear zone at depth. Piezometers were installed in the two vertical holes.
- d. Analysis of grain size distribution of surficial materials as a preliminary indication of the significance of these materials in controlling fracture flow in the area.
- e. Liaison with MacLaren Atlantic Limited during the drilling and water injection testing program carried out as exploration for the Halifax sewer interceptor tunnel project.

3. Office

- a. Analysis of water well data in the study area collected by the Groundwater Section of the Nova Scotia Department of Mines.
- b. Literature review of the geology of the Meguma Series and the Devonian granite.

C. WORK IN PROGRESS:

1. Analysis of field data.
2. Planning of an extensive drilling program to collect groundwater head data and to obtain measurements of fracture properties in the subsurface.

D. FUTURE WORK:

1. Installation of observation wells and acquisition of subsurface hydrogeological data.
2. Continued surface mapping of fracture systems.

Groundwater Motion in Coastal Aquifers

A. OBJECTIVES:

1. To study tidally induced groundwater motions and their relation to the hydraulic characteristics of the main water-bearing aquifers and of the continuing layers.
2. To develop practical methods of correcting observed drawdowns for tidal fluctuations, and to compare aquifer parameters determined by pump testing to those determined by tidal analysis.
3. To study the variations of water salinity in coastal aquifers with position and time, and attempt to find a relation between the observed tidal fluctuations and the position and width of the fresh-salt water transition zone.

B. PREVIOUS WORK:

1. Carr, P. A. and van der Kamp, G., 1969. Determining Aquifer Characteristics by the Tidal Method. Water Resources Research, Vol. 5, No. 5, pp. 1023 - 1031. (Work done under Project No. GW 67-8).
2. Field
 - a. Exploratory drilling and observations during July and August, 1969, at York Point, Prince Edward Island, and Cap Pelé, New Brunswick.
 - b. Completion of a three-dimensional array of wells and piezometers, 24 holes in all, at the Cap Pelé study site; and completion of a two-dimensional array of wells and piezometers, 13 holes in all, at the York Point study site.
 - c. Installation of tidal gauges and collection of the necessary water level records from all wells at the two study sites.
 - d. Pump testing of the main aquifers at both sites, a total of six tests. The pump test on the top aquifer at Cap Pelé was designed to measure directional permeability, and involved a total of 13 observation wells.

- e. Slug testing of all wells to determine well response, and to obtain an estimate of local permeability.
- f. Surveying of all wells for relative positions and for elevations with respect to effective mean sea level.
- g. Determination of water salinities in time and space before, during and after drilling and pump testing. Observations at York Point indicated the presence of an aquifer with separate salt water tongues intruding into each of the main sandstone beds.

3. Office

- a. Development of a simple method for separating observed tidal fluctuations into the two main sinusoidal components.
- b. Analysis of preliminary results, and development of a working hypothesis for tidal motions in a semiconfined aquifer.

C. WORK IN PROGRESS:

1. Publications

Nil

2. Field

- a. Water samples and water levels are being collected monthly from the wells at York Point, and from other piezometers nearby in the Eliot River area. The salinities are measured in the laboratory of the Prince Edward Island Water Authority, and will be studied with respect to seasonal movements of the salt-fresh water interface.
- b. Water levels are being measured weekly at Cap Pelé, and will be analyzed for regional flow patterns.

3. Office

Field data is being analyzed and used in the empirical verification of theory for groundwater motions in coastal aquifers.

D. FUTURE WORK:

Theory for the induction and propagation of tidal motions, and for salt water intrusion in coastal aquifers will be further developed with emphasis on practical applicability. More field data will be collected if warranted by theoretical and practical considerations.

*Hydrogeological Reconnaissance Study
Newcastle - Chatham Area*

A. OBJECTIVES:

1. To determine the hydrostratigraphy of the Newcastle - Chatham region in relation to future development of municipal and industrial groundwater supplies.
2. To identify saline groundwater intrusion problems on which future groundwater development research may be focused.

B. PREVIOUS WORK:

None

C. WORK IN PROGRESS:

None

D. FUTURE WORK:

1. Office

Examination of available water well inventory data.

2. Field

- a. Surface geology studies
- b. Surface geophysical surveys to delineate stratigraphy and to detect groundwater quality variations.
- c. Drilling program in conjunction with geophysical surveys to determine hydrostratigraphy and groundwater quality.

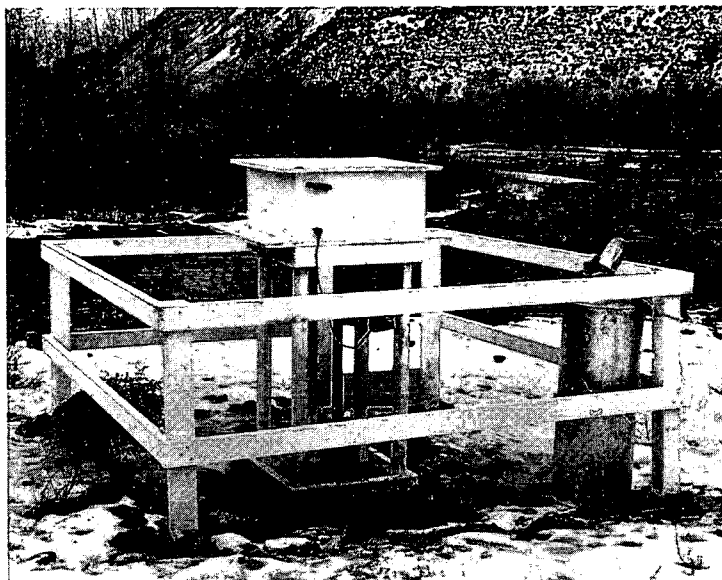


Figure 5. On the bank of the Bonaparte River in British Columbia the ground water level is measured to record flow from the river into the bank or vice versa. The propane bottle provides fuel to heat the recorder shelter. This installation is part of a group of ten water level recorders at location.



Figure 6. The water level recorder on the middle Bonaparte River, British Columbia is located in a narrow canyon in the basalt and ash succession of the Thompson plateau. At this location, the groundwater table fluctuates at an average elevation of 8 feet below the impermeable bottom of the perched river. The bridge serves for stage-discharge measurements.

3. Eastern Research Section

Personnel changes in the Eastern Research Section during the past year saw C.J. Haefeli return to Switzerland to join a consulting firm and R. L. Herr and J. A. Vonhof transferred to other sections. Dr. E. Wojtek, a postdoctoral fellow returned to Czechoslovakia. As a result of these changes the Eastern Research Section is now a more closely knit group whose projects are all related to hydrologic systems analysis.

The two parametric hydrology projects (GW 67-11 and GW 68-2) are now in their final stages. Field work will be completed on the first during the spring and was completed last summer on the second. The investigation of groundwater flow into Lake Ontario (GW 68-3) was also completed and a related project (GW 68-4) was transferred to the Computer Research Section because of its heavy reliance on computer methods.

The study of the relation between potential and regional evaporation (GW 68-8) is virtually complete. The instrumentation for measurement of snowmelt infiltration and associated groundwater recharge (GW 69-2) was installed and the first measurements of interest should be obtained during the 1971 snowmelt season. The study of the relations between groundwater chemistry and groundwater movement in the interstream area between the Ottawa and St. Lawrence Rivers (GW 68-7) has continued and has one more field season to go.

Parametric hydrology of a glaciated basalt plateau

A. OBJECTIVES:

To show the feasibility of linear system synthesis in the Fraser River hindcasting and forecasting models. For this purpose a set of coupled differential equations describing water flow through (a) a soil with water, water vapour and air, (b) an aquifer which is locally recharged, (c) an aquifer which discharges into or recharges from a river, must be combined with the open channel flow equations.

B. PREVIOUS WORK:

During the summer of 1970, 29 rain gauges and 29 piezometers were installed in addition to the 88 operating recorders. The program of field measurements will terminate in June 1971. The field data are coded and analyzed up to April 1, 1970.

C. WORK IN PROGRESS:

1. Publications

- a. Comparison of rainfall measurements at ground level, 30 cm and 150 cm above ground level.
- b. Optimum sampling time for rainfall measurements at ground level.
- c. Periodicities in tree ring width of very old trees from the Cariboo.

D. FUTURE WORK:

1. Publications

- a. Peak flow and low runoff design discharges for the Fraser River basin.
- b. A linear rainfall model over a plateau.
- c. Snowfall measurements in a ground level rain gauge and on the B.C. hydraulic snow gauge.

- d. The monoclinic wave runoff routing model in the Fraser River system.
- e. A parametric model of snowmelt and rainfall infiltration to the groundwater table.
- f. The crawfish model.
- g. A network analysis of the present DOT and WSC gauging system in the Fraser basin.
- h. Frequency of high and low groundwater tables in the British Columbia plateau areas.
- i. Bank storage effects on river discharge.

2. Field

The 146 instruments will be taken out of the field in June and July 1971.

Parametric Hydrology of the Northern Lake Ontario Basin

A hydrogeological project for the International
Field Year on the Great Lakes - IFYGL

A. OBJECTIVES:

To develop and apply a mathematical model for channel networks, represented by directed graphs on a rectangular grid, to generate synthetic hydrographs of 28 river basins along Lake Ontario.

B. PREVIOUS WORK:

1. Publications

Osterveld, M., 1969. A soil moisture index on the Lake Ontario basin. Unpubl. M.Sc. thesis, University of Guelph.

2. Field

- a. Installation of 6 groundlevel rain gauges in the basins of the Ganaraska, Lynde and Little Rouge rivers.
- b. Dye experiments to determine time of travel at different discharges in the Ganaraska, Lynde and Little Rouge Rivers.
- c. Dye experiments in the Ganaraska and Lynde Creeks to determine the transformation of the dye time-concentration in the downstream direction in the river.

C. WORK IN PROGRESS:

1. Office

To prepare the simulation results and field experimental results for publication.

D. FUTURE WORK:

Project will be completed with completion of manuscript on simulation and field results.

Groundwater Flow into Lake Ontario

A hydrogeological project for the
International Field Year on the
Great Lakes (IFYGL)

A. OBJECTIVES:

1. To determine the groundwater flow into the Canadian side of Lake Ontario. The study is a part of the IFYGL terrestrial water budget of Lake Ontario and its basin.
2. Regional importance: amount, storage and flow systems of groundwater in the Lake Ontario basin.

B. PREVIOUS WORK:

1. Field

- a. Instrumentation for baseflow analysis - installation and maintenance of 3 stream gauging stations (in cooperation with the Water Survey of Canada), 4 groundwater level recorders, 2 conductivity recorders.
- b. Use of tracers to evaluate travel time in relation to discharge and slope for stream baseflow study.
- c. Selection of some 20 suitable watersheds for baseflow analysis.
- d. Temperature survey along the shore of Lake Ontario to spot and verify major groundwater outlets (buried channels). The investigations were carried out by boat and by airplane (infrared) in cooperation with the National Research Council and the Canada Centre for Inland Waters, Burlington.
- e. Drilling and testing of 7 deep exploration holes to delineate and determine hydrogeological conditions in buried bedrock channels in the Toronto area.
- f. Seismic survey along the shore of Lake Ontario from Trenton to Scarborough (approximately 80 miles) to determine drift depth and bedrock surface (in cooperation with the Geological Survey of Canada).
- g. Survey of existing wells in the area between Toronto and Lake Simcoe to locate the groundwater divide between the Lake Simcoe and Lake Ontario basins.

2. Office

- a. Compilation of a geological map of the Lake Ontario basin using published and unpublished documents.
- b. Airphoto interpretations with particular regard to geological structures and hydrogeological features.
- c. Application and development of computer program for stream hydrograph analysis.
- d. Analysis of hydrogeological conditions in some 20 watersheds situated around Lake Ontario. Evaluation of: baseflow recession, transmissibility, storage, infiltration, drainage pattern and density, effects of soil, overburden and bedrock on groundwater flow.

C. WORK IN PROGRESS:

1. Publications : Two manuscripts have been prepared and are now in press:
 - a. Groundwater Flow between Lake Simcoe and Toronto.
 - b. Groundwater Inflow along the Shore of Lake Ontario.

D. FUTURE WORK:

- a. The project will be completed with publication of the two manuscripts listed above.

*A hydrochemical study in the interstream
area of the Ottawa and St. Lawrence Rivers*

A. OBJECTIVES:

To investigate groundwater chemistry with the specific objective to determine the direction of groundwater movement.

B. PREVIOUS WORK:

1. Publications

Charron, J. E., 1971. A hydrochemical study of Russell County, Ontario. Inland Waters Branch (Report completed and being edited).

2. Field

A regional sampling program and well inventory was carried out in 1968, 1969 and 1970 in Russell, Prescott and Glengarry Counties respectively.

C. WORK IN PROGRESS:

1. Publications

A hydrochemical study of Prescott County. Inland Waters Branch publication in preparation.

2. Office

Compiling and analyzing data accumulated for Glengarry County during the field season of 1970 in order to prepare a report.

D. FUTURE WORK:

To extend this study into Stormont County in 1971. The four counties of Russell, Prescott, Glengarry and Stormont will provide the data required for the hydrochemical evaluation of groundwater movement.

*Potential Evaporation
Significance and Measurement*

A. OBJECTIVES:

1. To test the significance of potential evaporation as a manifestation of the evaporation from the surrounding region.
2. To relate the potential evaporation to climatologic and evaporimeter observations.
3. To relate evaporation from a large region to climatologic or evaporimeter observations.
4. To relate catchment runoff to climatologic and/or evaporimeter observations.

B. PREVIOUS WORK:

1. Publications

Morton, F.I. (1965). Potential evaporation and river basin evaporation. J. Hydraul. Div., Proc. Am. Soc. Civil Engrs., Vol. 91, No. HY6.

Morton, F.I. (1967). Closure to potential evaporation and river basin evaporation. J. Hydraul. Div., Proc. Am. Soc. Civil Engrs., Vol. 93, No. HY4.

Morton, F.I. (1967). Evaporation from large deep lakes. Water Res. Research, Vol. 3, No. 1.

Morton, F.I. (1969). Evaporation and climate, a study in cause and effect. Scientific Series 4, Inland Waters Branch, Department of Energy, Mines and Resources.

Morton, F.I. (1969). Potential evaporation as a manifestation of regional evaporation. Water Res. Research, Vol. 5, No. 6.

Morton, F.I. (1970). Catchment evaporation as manifested in climatologic investigations. Symposium on World Water Balance, Reading, Int. Assoc. Sci. Hydrol. Pub. 93.

2. Office

- a. Formulation of model which permits the regional evaporation to be estimated by its effects on climatologic or evaporimeter observations.
- b. Test of the model over a wide range of climatic and geologic conditions.

C. WORK IN PROGRESS:

1. Investigation of climatic significance of pan evaporation.
2. Preparation of maps of Canada showing areal and seasonal variation of regional evaporation.

D. FUTURE WORK:

1. Design and testing of evaporation pan to provide accurate and undistorted estimates of potential evaporation.
2. Investigation of seasonal variations in catchment storage by means of a water balance based on model estimates of evaporation with the object of establishing a general relationship between precipitation and runoff.

Snowmelt Infiltration
and Associated Groundwater Recharge

A. OBJECTIVES:

1. To determine the mechanisms of snowmelt infiltration and associated groundwater recharge.
2. To investigate the applicability of a physically-based snowmelt infiltration - groundwater recharge model in hydrologic systems analysis.

B. PREVIOUS WORK:

1. Field

- a. An experimental plot on the Central Experimental Forest near Ottawa has been established and instrumented for the investigation of snowmelt processes, infiltration of snowmelt waters, and associated groundwater recharge. Instrumentation of the experimental plot is a cooperative undertaking by the Glaciology and Groundwater Subdivisions.
- b. A weekly measurement program has been carried out on an experimental plot at Calgary, Alberta, since the fall of 1968.

2. Office

Computer programs for simulating one-and-two-dimensional saturated and/or partially-saturated fluid flow through heterogeneous porous materials under isothermal conditions have been developed.

3. Laboratory

In cooperation with Dr. R. A. Freeze and J. A. Banner, laboratory studies have been conducted to assess the utility and develop means for the interpretation of electrical-resistance soil-moisture data for a freeze-thaw environment.

C. WORK IN PROGRESS:

1. Publications

Harlan, R. L., Water transport in frozen and partially-frozen porous media (In preparation).

Harlan, R. L., J. A. Banner and R. Allan Freeze, Interpretation of electrical-resistance soil-moisture data for a freeze-thaw environment (submitted to Canadian Journal of Soil Science).

2. Field

Monitoring of soil-moisture, groundwater, soil temperature, and meteorological conditions at the Calgary and Central Experimental Forest experimental plots is continuing.

3. Office

- a. Work is in progress on the extension of the one-and-two-dimensional computer simulation programs to include a two-phase mathematical formulation to account for entrapment of air within the unsaturated zone and gas flow.
- b. A computer program for simulation of the simultaneous transfer of water in its liquid and gaseous phases and heat is being developed.

4. Laboratory

Measurement of the transmission and moisture retention properties of soils is in progress.

D. FUTURE WORK:

1. Field

- a. Monitoring of the soil-moisture and groundwater regimes, and meteorological conditions during snow accumulation and snowmelt periods at the Central Experimental Forest study site will be continued.
- b. The weekly measurement program at the Experimental plot in Calgary will be continued.

2. Office

- a. An evaluation of alternative theoretically-based simulation models will be carried out to determine under what conditions a two-phase formulation is necessary to describe the infiltration process.
- b. An evaluation of the consequence of error in estimation of the controlling hydrologic parameters and functional relationships on accuracy of computer simulations will be conducted.

3. Laboratory

R. L. Harlan

Soil column experiments involving the simultaneous transfer of water and heat in variably saturated porous media will be conducted.

Computer Research Section

4. Computer Research Section

There was one personnel change in the Computer Research Section during the past year. R. L. Herr joined the Section from the Eastern Research Section bringing with him the computer-oriented project to construct geologic maps and cross sections for the Lake Ontario basin (GW 68-4).

As a result of changing priorities in the Water Sector, and in the light of new Branch objectives, the program of the Computer Research Section has been revised and modified to bring the activities of the Section into line with the new priorities.

The recently enacted Canada Water Act emphasizes the need for good management of all aspects of water resources, including quantity and quality. A viable program should therefore consider both these aspects. The Act also provides for the establishment of management areas, based on natural basins.

The activities of the Section are now all part of one program - The Basin Management Program. Within this program, the special competence of the Section is directed towards the following objective: "To develop methodology to manage all aspects of the groundwater component of the water resources within a basin, with particular emphasis on automated techniques".

Thus the activities of the Section are one part of a comprehensive program to manage all aspects of the water resources in a basin.

To meet the new objective, changes in the Section's activities have been made. Some projects reached completion in 1970. Those projects which did not fit into the new program were terminated or were cut back to data collection only. Other projects which fitted the new objective were extended and several new projects were initiated.

The basic information handling facility for all projects is GOWN, the Section's data processing system.

*Water Balance, Good Spirit Lake Basin
Saskatchewan*

A. OBJECTIVES:

To arrive at an annual water balance of a parkland representative basin as part of Canada's program for the International Hydrological Decade.

B. PREVIOUS WORK:

1. Publications

Freeze, R. A., 1969. Hydrology of the Good Spirit Lake Drainage Basin, Saskatchewan. Inland Waters Branch Technical Bulletin No. 14.

2. Field

Present instrumentation in the Good Spirit Lake Basin includes:

- 3 temperature-precipitation meteorological stations
(operated by the Meteorological Branch, Department of Transport)
- 1 stream gauge (operated by the Water Survey of Canada)
- 1 isolated observation well measuring lake levels
- 3 recharge-discharge sites, each with a piezometer nest, an observation well, a bank of soil moisture cells and switchbox and rain gauges
- 4 isolated piezometer nests
- 7 Carborundum block evaporimeters measuring (daily) evaporating power during the growing season

This instrumentation (except for evaporimeters) has been measured weekly. Previous measurements have also been made of formation permeability, surface sand depth (by hammer seismograph) and water table profiles. Samples have been collected for chemical analysis from the lake, sloughs, streams, groundwater and geological formations. A random slough survey was carried out in the summer of 1966.

C. WORK IN PROGRESS:

1. Programs for automated evaluation of soil moisture cell data to obtain the soil temperature and soil moisture content are being developed and tested.
2. Preparation of report is in progress.

D. FUTURE WORK:

Maintain instrumentation and continue field measurements data processing until at least the end of the IHD.

Water Balance, Oak River Basin, Manitoba

A. OBJECTIVES:

To arrive at an annual water balance of a parkland representative basin as part of Canada's program for the International Hydrological Decade.

B. PREVIOUS WORK:

1. General

The hydrogeological aspects of this study were started in 1963 by A. Lissey. The results were summarized in his Ph.D. Thesis "Surficial Mapping of Groundwater Flow Systems with Application to the Oak River Basin, Manitoba", 1968.

2. Field

Present instrumentation in the Oak River Basin includes:

- 4 recording stream gauges (operated by the Water Survey of Canada)
- 1 Class A weather station (operated by the Meteorological Branch of the Department of Transport)
- 5 temperature and precipitation stations (operated by Met. Branch, DOT)
- 2 precipitation stations (operated by the Met. Branch, DOT)
- 77 piezometers arranged in 35 nests (read weekly from May, 1965 to September, 1967)
- 11 Carborundum block evaporimeters (daily measurement, growing season)

C. WORK IN PROGRESS:

Preparation of report is in progress.

D. FUTURE WORK:

Maintain instrumentation and continue field measurements and data processing until at least the end of the IHD.

Computer Research on Groundwater Hydrographs

A. OBJECTIVES:

1. To determine the applicability of techniques from communication theory to hydrograph analysis.
2. To utilize large quantities of computer-compatible hydrograph data to detect small periodic fluctuations in groundwater hydrographs.
3. To study the phenomenon of water table fluctuations in response to changes in barometric pressure.

B. PREVIOUS WORK:

1. Publications

Gilliland, J. A., 1969. A Rigid Plate Model of the Barometric Effect. J. of Hydrology, Vol. 7, pp. 233-245.

2. Field

Total number of installations is 13 water-table wells, 36 piezometers, 2 barographs, 5 nests of soil moisture cells, 1 hygrothermograph, 2 recording rain gauges, 1 recording temperature gauge, and approximately 50 plastic rain gauges. In addition the 6 wells in Prince Edward Island (project 67-14) are being used for correlation studies.

3. Laboratory and Office

Computer programs have been developed to derive various correlation functions from hydrograph data. Hydrograph and barograph data have been digitized, and calculations carried out. These results will be published in 1970. They indicate that small fluctuations can be detected using communication theory techniques. A conceptual model of the effect of changes in barometric pressure on water levels in wells in unconfined aquifers has been developed.

J. A. Gilliland

C. WORK IN PROGRESS:

Preparation of report is in progress.

D. FUTURE WORK:

Extension of the work on correlation functions to evaluate techniques of cross-spectral analysis is planned.

Network Design

A. OBJECTIVES:

1. To establish design criteria for networks of groundwater observation wells, measuring natural water levels and monitoring changes in groundwater storage, with particular reference to optimum well spacing.
2. To establish design criteria for observation wells and monitoring instruments.
3. To develop a recorder working on the variable time interval (v.t.i.) principle (see Gilliland 1968a, in Publications for project 68-5).

B. PREVIOUS WORK:

1. Publications

Gilliland, J. A., 1967. Observation Well Program.
Inland Waters Branch Paper 67-1.

Gilliland, J. A., 1969. Groundwater Instrumentation
and Observation Techniques. Proc. Hydrology
Symposium 7.

2. Field

Various types of analog and digital recorders have been installed at Swift Current and Good Spirit Lake, Saskatchewan; Ottawa, Ontario; and Prince Edward Island. Four wells of various designs have been installed at Delta, Manitoba, together with an experimental transducer-recorder system and some meteorological instruments. The data from P. E. I. will be analysed in project 67-13. Data from other installations await evaluation.

J. A. Gilliland

C. WORK IN PROGRESS:

1. The study of the areal variability of meteorologic phenomena and its effect on network design has been completed and a report is in press.
2. Testing of v.t.i. recorders continues by the Instrumentation Section, Water Science Subdivision.

D. FUTURE WORK:

Project has terminated.

Water Balance, Trapping Creek Basin, B. C.

A. OBJECTIVES:

1. The original objective of Trapping Creek basin was to study the groundwater flow systems in an area of high relief underlain by crystalline bedrock. This aspect of the project was completed by D. W. Lawson in 1968.
2. To arrive at an annual water balance of a high-mountain representative basin as part of Canada's program for the International Hydrological Decade.

B. PREVIOUS WORK:

1. Publications

Lawson, D. W., 1967. A Groundwater Investigation of the Trapping Creek Basin. Unpubl. M.Sc. Thesis, Univ. of Guelph, Guelph, Ontario.

Lawson, D. W., 1968. Groundwater Flow System in the Crystalline Rocks of the Okanagan Highlands, British Columbia. Can. J. Earth Sciences, v. 5, pp 813-824.

2. Field and Laboratory

a. The following instrumentation has been installed:

- 5 soil moisture stations
- 1 permanent stream gauge (at mouth of basin)
- 3 temporary stream gauges (on 3 major sub-basins)
- 1 Fischer-Porter precipitation recorder
- 2 Sacramento Storage precipitation gauges
- 3 integrating anemometers (11.4 ft.)
- 3 Lambrecht-type hypothermographs (with maximum, minimum and present temperature checks)
- 10 evaporation stations (Carborundum block evaporation meter)
- 3 snow courses (10 points)
- 2 sunshine recorders
- 25 piezometers in 7 nests
- 12 water table wells

b. Laboratory calibration of soil moisture cells.

c. Field density estimation of soils by volume measure test.

C. WORK IN PROGRESS:

1. Programs for automated evaluation of soil moisture data to obtain soil moisture content are being developed and tested.
2. Preparation of report is in progress.

D. FUTURE WORK:

1. Maintain instrumentation and continue field measurements and data processing until at least the end of IHD.
2. Testing and modification of the evaporation pattern.

Hydrogeological Maps of the Lake Ontario Basin

A hydrogeological project for the International
Field Year on the Great Lakes - IFYGL

A. OBJECTIVES:

1. To develop computer methods for the construction of hydrogeological maps.
2. To develop a computerized method for correlating computer-constructed geological cross-sections.

B. PREVIOUS WORK:

1. Computerized method developed for construction of geological cross-sections.
2. Plotting routine developed for checking digitized values with actual plotted values.

C. WORK IN PROGRESS:

Editing and compilation of well data.

D. FUTURE WORK:

1. Construction of maps and cross-sections by means of special GOWN retrieval programs.
2. Computerized comparison and verification of the maps produced.

GOWN - Operation and Maintenance

A. OBJECTIVES:

1. To operate and maintain a general purpose hydrogeologic data storage and retrieval system for all types of hydrogeologic data for the use of the Inland Waters Branch and other agencies.
2. To produce automatically, maps and sections displaying hydrogeological information.

B. PREVIOUS WORK:

1. Publications

Gilliland, J. A., 1968^a. Digitizing, Storing and Recovering Groundwater Hydrographs. Jour. of Hydrology, Vol. 6, pp. 143 - 167.

Gilliland, J. A., and A. Treichel, 1968. GOWN - A Computer Storage System for Groundwater Data. Can. Jour. Earth Sci., Vol. 5, pp. 1518 - 1524.

Grove, G. and J. A. Gilliland, 1969. Manual on Groundwater Data Storage System. Internal Publication, IWB, 4th ed.

2. Office

- a. Programming of well log, well data and catalogue files completed and operation tested. Programs have been production tested.
- b. A PDP-8/I digital computer interfaced with a D-Mac Pencil Follower is being used to process data for this project.

C. WORK IN PROGRESS:

1. Digitizing locations of wells in Lake Ontario drainage basin and coding of well logs in cooperation with Ontario Water Resources Commission for the International Field Year on the Great Lakes is completed. Editing and storage of the data are in progress.

2. Development of programs for contouring and drawing sections (work done by Computer Science Division) is completed, testing of the retrieval system is now in progress with various hydrogeological maps being produced using data from the Lake Ontario drainage basin.
3. A feasibility study for the integration of data systems (project BM-1-4) is being made. Adoption of an integrated system would make other types of data (geochemical, meteorological, etc.) available to GOWN users.

D. FUTURE WORK:

1. Maps and sections displaying various hydrogeological parameters will be produced on a routine basis.
2. Digitizing, coding and storage of data as required.
3. Project is continuing.

Inventory of Canadian Lakes

A. OBJECTIVES:

1. To produce an inventory of Canadian fresh-water lakes larger than 100 square kilometers for hydrologic purposes, for the IHD (this differs from the CLI lake survey, which is intended to assess the suitability of lakes for sport fishing, recreation, etc.).

B. PREVIOUS WORK:

Two programs have been written to compute the total area, water surface area, center, maximum dimension and direction of maximum dimension for small lakes and large lakes (small lakes are those whose outline is represented by less than 750 points). The input to these programs is cards produced by the D-Mac pencil follower. The output is obtained as tables, cards and plots. Lakes in Quebec were digitized by personnel of the Quebec Department of Natural Resources in cooperation with the Inland Waters Branch. The results of the inventory have now been published in atlas form.

C. WORK IN PROGRESS:

Completion of the program for determination of lake volumes from test soundings.

D. FUTURE WORK:

Project will terminate upon completion of the program for lake volume determination.

Aquifer Analysis

A. OBJECTIVES:

To develop GOWN-oriented computer programs for the automated analysis of the effect of artificially induced aquifer stresses.

B. PREVIOUS WORK:

Office

- a. Program for automatically calculating permeabilities from Hvorslev slug tests has been written.
- b. Previous work on aquifer analysis will be used as much as possible in developing the programs.

C. WORK IN PROGRESS:

Nil

D. FUTURE WORK:

1. Automation of present techniques of aquifer based on analysis of pump-test, slug-test, injection test and similar data evaluation.
2. Development of new automated methods for analysis of aquifer test data.

Flow Pattern Analysis

A. OBJECTIVES:

To develop GOKN-oriented computer program for the automated analysis of groundwater flow patterns to obtain:

- a. basin recharge-discharge profiles
- b. natural basin yields
- c. basin-wide water balance evaluations based on a and b.

B. PREVIOUS WORK:

Theoretical analysis of regional groundwater flow by R. A. Freeze.

C. WORK IN PROGRESS:

Nil

D. FUTURE WORK:

1. To develop retrieval programs for the input parameters used for flow pattern analysis.
2. To develop programs for the construction of the equipotential map, the flow net and the recharge-discharge profile.
3. To develop programs for the calculations of the natural basin yield, the evapotranspiration from the discharge and recharge areas and their contribution to the basin-wide water balance evaluations.

Development of GOWN

A. OBJECTIVES:

1. To develop new files as necessary for the automated storage of new types of data for GOWN.
2. To develop new automated procedures and formats for displaying hydrogeological information.

B. PREVIOUS WORK:

1. Publications

Gilliland, J. A., 1968. Digitizing, Storing and Recovering Groundwater Hydrographs. Jour. of Hydrology, Vol. 6, pp. 143 - 167.

Gilliland, J. A., and A. Treichel, 1968. GOWN - A Computer Storage System for Groundwater Data. Can. Jour. Earth Sci., Vol. 5, pp. 1518 - 1524.

Grove, G., and J. A. Gilliland, 1969. Manual on Groundwater Data Storage System. Internal Publication, IWB, 4th ed.

2. Office

- a. Programming of well log, well data and catalogue files completed and operation tested. Programs have been production tested.
- b. A PDP-8/1 digital computer interfaced with a D-Mac Pencil Follower is being used to process data for this project.

C. WORK IN PROGRESS:

1. Programming of hydrograph file under way.

2. A "general purpose retrieval" program for retrieving unprocessed data from the well log, well data and catalogue files has been linked with a set of programs for processing the retrieved data. These programs output basic hydrogeologic maps (water table contour, isopach, etc.) by a completely automated process. The programs are being production tested using data from the Lake Ontario drainage basin.

D. FUTURE WORK:

1. To develop new data files for borehole log information, etc. as these become needed.
2. To investigate display techniques such as the automated production of fence diagrams.
3. To develop programs for statistical and mathematical analysis of hydrogeologic data and for manipulation of geochemical and meteorological data.
4. Project is continuing.

Interaction of Groundwater and its Environment

A. OBJECTIVES:

To study the interaction of groundwater with its environment and its function as a transport agent with particular reference to:

- a. its action in dissolving, transporting and precipitating inorganic and organic solutes at relatively low temperatures and pressures (0 - 150°C, 1 - 5 bars)
- b. its interaction with ice (and frozen ground) both in permafrost regions and during seasonal freezeup
- c. the action of aqueous and non-aqueous fluids in the solution, deposition and transport of mineral species at high temperatures and pressures ($T > 150^{\circ}\text{C}$, $P > 5,000$ bars).

To relate theoretical results to field examples.

B. PREVIOUS WORK:

The starting point for this project will be the work done by Freeze, Parsons, etc. in studying groundwater flow and coupled heat/groundwater flow.

C. WORK IN PROGRESS:

A theoretical investigation of the laws of groundwater flow is in progress to determine which equations are useful.

D. FUTURE WORK:

The project will be split into three phases, each one being self-contained, but dependent on the results of the earlier phases, later phases being more difficult than earlier ones.

1. Phase I will be concerned with a single component system (H_2O) which should be easier to study than a multiple component system. This phase will consider heat and fluid flow and phase transformations in a water/ice system.

J. A. Gilliland
S. Y. Shiau
G. Grove

The results of this phase should yield useful results for: a) thermal pollution problems, b) development of groundwater supplies in permafrost areas, c) studying water flow through glaciers, d) evaluating the effect of buildings, etc. in permafrost areas on the groundwater/permafrost regime, e) frost effect on groundwater flow systems in more southern parts of Canada.

*Hydrochemical Evolution of
Natural Groundwater*

A. OBJECTIVES

1. Development of a digital model to simulate the hydrochemical evolution of natural groundwaters.
2. Application of the model to the Upper Kettle Creek Basin, Ontario.

B. PREVIOUS WORK

Nil

C. WORK IN PROGRESS

A data processing system is being developed for rapid evaluation of hydrochemical analyses.

D. FUTURE WORK

1. Office

- a. Develop and test the digital model.
- b. Process hydrochemical field data.

2. Laboratory

Detailed mineralogic and granulometric analyses of glacial drift samples from the field area.

3. Field

- a. Collection of stream, groundwater and precipitation samples.
- b. Installation of hydrometeorologic instrumentation.
- c. Collection of drift samples.

Other Research Projects

*Nicomekl-Serpentine Basin Study,
Fraser Lowland, B. C.*

A. OBJECTIVES:

1. To analyze the hydrologic regime in a thick sequence of unconsolidated surficial deposits constituting a valley fill.
2. To arrive at a decennial water budget for IHD purposes.

B. PREVIOUS WORK:

Groundwater and well inventory carried out in 1953 by Armstrong and Brown was followed by B. C. Water Resources rotary drilling program of eleven 1,000-foot test holes and a quantitative study of aquifers. In 1966 another test hole was put down to a depth of 987 feet for correlation purposes with the eleven B. C. test holes. Sieve analyses of samples collected at 10-foot intervals have been done. Two hundred and fifty water samples were collected and analyzed using a Hach chemical kit. A 795 foot test hole was drilled in the upland area in 1969. Three rotary test holes were drilled and electrologged in 1970 to depths of 714, 420 and 600 feet, for stratigraphic correlation and identification of lithological units.

C. WORK IN PROGRESS:

Analysis of data collected. Continuous collection of records from piezometers and observation wells.

D. FUTURE WORK:

Continuing observation program of piezometric levels, and periodic sampling programs. Hydrochemical mapping of groundwater types, pH, temperature and conductivity readings of each well drilled since 1955. Installation of shallow (less than 10 feet) observation wells to determine water table fluctuations in drainage areas. Work on this project is now complete except for these observation and sampling programs and for preparation of reports incorporating the results of the study.

*Investigation of Infrared Anomalies in
the Lake of Two Mountains, Quebec*

A. OBJECTIVES:

1. To determine whether observed anomalies on infrared (IR) imagery taken over the Lake of Two Mountains are related to the discharge of groundwater into the lake through buried valleys lying below lake level.
2. To assess the IR scanner as a tool for prospecting for groundwater.

B. PREVIOUS WORK:

1. Field

- a. Three flights of IR imagery have been made: one in October, 1965, one in August, 1968 and the other in October, 1969. The 1965 flight was conducted by another agency. Later examination of the 1965 results led to the initiation of this project.
- b. Preliminary temperature measurements have been made on the lake.
- c. A sparker seismic survey has been made on the lake and three boreholes were drilled in the buried valleys by a consulting company.

C. WORK IN PROGRESS:

1. Office

A technical bulletin entitled "Investigation of Infrared Anomalies in part of the Ottawa River, Quebec" has been prepared and is undergoing review.

D. FUTURE WORK:

Project is complete except for publication of the technical bulletin.

6. Operational Projects

Three of the four operational projects listed in last year's catalogue are still active. These are the study of groundwater inflow into a lake in the Kenora area (GWO 69-2) being carried out under contract by Dr. J.A. Cherry of the University of Manitoba, the study of the groundwater regime in the Central Research Forest (GWO 69-3), and consultation concerning groundwater supply for the new Montreal International Airport (GWO 69-4). Field work is now complete in the case of Project GWO 69-3.

Three new operational projects have been initiated. One of these, the evaluation of groundwater in the Gatineau Park area (GWO 70-3) is now complete. It was handled by a consultant. A project to provide groundwater expertise and advice for the Benchmark Basin Program of the Water Survey of Canada (GWO 70-1) is likely to continue for some years. The third new operational project (GWO 70-2) involved emergency action and subsequent study of subsurface contamination due to an oil spill at Shippegan, N.B. The Groundwater Subdivision has collaborated in this study with a consultant acting on behalf of the New Brunswick Water Authority.

Kenora Lakes Study, Fisheries Research Board

A. OBJECTIVES:

1. To provide a detailed understanding of the mechanisms of groundwater inflow into "Lake 239" which is one of the lakes in the Kenora area selected for eutrophication studies by the Fisheries Research Board.
2. To provide a network of groundwater observation wells and piezometers to determine the quantity and chemical composition of the groundwater inflow.

B. NATURE OF REQUEST:

Written request by the Director of the Federal Freshwater Institute in Winnipeg to the Inland Waters Branch.

C. ORGANIZATION OF PROJECT:

Because of its location and interdisciplinary interest, the direct supervision of this project has been allocated to Dr. J.A. Cherry, Associate Professor of Hydrogeology, University of Manitoba. He will be integrating the groundwater aspects of the study into the overall evaluation of the hydrologic budget of the watershed being conducted by Dr. R.W. Newbury, Associate Professor of Civil Engineering, University of Manitoba. Some of the groundwater data may be suitable for use by graduate students as thesis material. Progress reports and a comprehensive final report will be submitted by Professor Cherry to the Groundwater Subdivision.

The Groundwater Subdivision has provided funds and administrative arrangements for drilling contracts, field instruments and other services that have been required.

The project is part of a large assistance program by the Inland Waters Branch coordinated by Dr. R.K. Lane.

D. PRESENT STATUS OF PROJECT:

1. During the summer of 1969 a drilling program and a hammer seismic program were carried out to determine bedrock depths in the research drainage basin. The Exploration Geophysics Division of the Geological Survey of Canada carried out the seismic survey. During the same summer a detailed topographic map with 5-foot contour intervals was prepared using existing air photographs.
2. A preliminary groundwater progress report was prepared early in 1970 and was incorporated into the preliminary progress report for the comprehensive study.
3. During 1970 a network of over 160 groundwater piezometers and wells was installed.

E. FUTURE WORK:

1. Compilation of groundwater subroutines for a water budget computer program and incorporation into the main program.
2. Collection and interpretation of data (1970).
3. Preparation of final report on the groundwater balance and groundwater chemistry of the research lakes.

Expected date of final report - June 1971.

Project No. GWO 69-3

*Groundwater Regime
Central Research Forest*

A. OBJECTIVES:

To determine the direction of groundwater movement, and the magnitude of the annual water-table fluctuation throughout the Central Research Forest of the Federal Forest Management Institute.

B. NATURE OF REQUEST:

Verbal request by the Manager of the Central Research Forest to the Groundwater Subdivision.

C. ORGANIZATION OF PROJECT:

This project is carried out under the direction of Mr. R. L. Herr of the Groundwater Subdivision in view of his interest in computerized data retrieval systems.

D. PRESENT STATUS OF PROJECT:

Data acquisition and compilation phase.

E. FUTURE WORK:

1. Design of computer program to calculate changes in groundwater storage during selected periods.
2. Occasional synoptic water-table measurements on water-table wells installed by Mr. Herr and those installed previously by Dr. Bik (ongoing).
3. Organization of bi-annual groundwater reports to the Manager of the Central Research Forest (ongoing).

Groundwater Assessment, New Montreal Airport

A. OBJECTIVES:

1. To determine whether the water supply for the new Montreal International Airport (an estimated 2 million gallons daily) can be obtained from aquifers underlying airport land.
2. To design a well field for efficient economical extraction of this supply.

B. NATURE OF REQUEST:

Verbal and subsequent written requests from the Construction Branch, Department of Transport.

C. ORGANIZATION OF PROJECT:

Exploration and development phases to be carried out by consultants; the Groundwater Subdivision will provide periodic appraisals of consultants' proposals and reports.

D. PRESENT STATUS OF PROJECT:

Consultants conducted a field study during the autumn of 1970. Results of the study were appraised by the subdivision.

Benchmark Basin Program

A. OBJECTIVES:

1. To assist in the selection of bench mark basins free of cultural changes for the long-term study of natural time trends in hydrologic phenomena.
2. To advise on the number and location of groundwater observation wells and piezometers in benchmark basins.
3. To coordinate record analysis, to assess network efficiency and to complete scientific interpretation.

B. ORGANIZATION OF PROJECT:

The overall program is being coordinated by the Water Survey of Canada. Mr. E.C. Halstead of the Groundwater Subdivision is responsible for carrying out the three special objectives listed above.

C. PRESENT STATUS OF PROJECT:

Mr. Halstead has visited the proposed benchmark basins at Baker Lake, Northwest Territories; Northeast Pond Benchmark Station, Newfoundland; and Kelly Creek Benchmark Station in the Chignecto Game Sanctuary, Nova Scotia. Groundwater instrumentation was recommended only in the case of the Nova Scotia basin.

D. FUTURE WORK:

Basin selection and evaluation for groundwater purposes will continue.

Shippegan Oil Spill

A. OBJECTIVES:

1. To recommend and adopt emergency measures designed to eliminate or minimize subsurface effects of a major spillage of oil and gasoline at a petroleum products storage site.
2. To observe and measure the effects due to the spillage and to the emergency measures adopted.
3. To arrive at one or more contingency plans for coping with other similar spills and to evaluate their possible advantages or disadvantages.

B. NATURE OF REQUEST:

Verbal request from the consultant appointed as well field manager, Shippegan water well field, on behalf of the New Brunswick Water Authority, to obtain Subdivision advice and assistance in handling of emergency situation. The request was made at the end of April on the day following the spill.

C. ORGANIZATION OF PROJECT:

Emergency measures were adopted after a preliminary evaluation of the situation by the wellfield manager and Mr. D.H. Lennox representing the Subdivision. Measures included:

1. Digging of interceptor trenches to depths below the water table to intercept natural flow of oil and gasoline towards the Shippegan water-well field in the direction of the natural water-table gradient.
2. Digging of extraction pits from which water was pumped to reverse the natural direction of flow and thus direct flow toward the site of the spill.
3. Periodic skimming of oil and gasoline collected on water surfaces in the extraction pits and storage in spare tanks brought to the site for the purpose. Some subnatant water was unavoidably collected and stored as well.
4. Digging of a number of test pits both on the storage site and between the site and the town's producing wells in order to check for the spread of contaminants.

5. Circulation with simultaneous chemical treatment of water pumped from pits and trenches through a lagoon and back into the ground through a disposal pit. Chemical treatment was with chlorine dioxide and was for the removal of dissolved phenols.
6. Twice-weekly and subsequently weekly sampling of waters in pits and trenches to monitor movement of oil, gasoline and phenols.

D. PRESENT STATUS OF PROJECT:

In July seasonally declining water levels drew the water table down below the maximum depth to which pits and interceptor trenches could be dug by back hoe. Water levels recovered briefly during the fall but have receded again. The emergency measures had consequently to be suspended. A specific program of test drilling, water and soil sampling and water and soil analysis has been recommended to enable estimation of total hydrocarbons remaining in the ground and, hence, an appraisal of the effects of the emergency program.

F. FUTURE WORK:

Pumping, circulation and chemical treatment of trench and pit waters will resume in the spring, as will a regular program of water sample analysis. The program to assess total hydrocarbons remaining in the ground will be undertaken if funds can be made available.

Gatineau Park Groundwater Study

A. OBJECTIVES:

1. To evaluate distribution, movement, quantity and quality of groundwater in Gatineau Park, Quebec as part of a comprehensive hydrologic survey of the park area conducted by various units of the Departments of Energy, Mines and Resources and National Health and Welfare.
2. To evaluate present and future effects of park development on the groundwater regime.

B. NATURE OF REQUEST:

Written request by the Chairman of the National Capital Commission to the Department of Energy, Mines and Resources.

C. ORGANIZATION OF REQUEST:

Specifications for the survey were drawn up and tenders requested from several qualified consulting firms. The successful bidder carried out the survey in the late autumn of 1970 and presented a final version of his report in January 1971. The report indicated the more promising aquifers, all of which are in the overburden, and the possibility of providing good groundwater supplies for campsites and recreational areas from these aquifers. Additional testing is required, however, to confirm these findings. The report also suggested that consideration should be given to the effects of sewage disposal facilities on groundwater supplies and recommended monitoring of selected wells for observation of these effects. A copy of the report was forwarded to the over-all survey coordinator on January 11, 1971.

D. PRESENT STATUS OF PROJECT:

Completed.

7. Active Project Index

A. By Project Number

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* C - Completed or in final publication stage.

D - Discontinued

P - Progressing

S - Starting.

7. Active Project Index

B. By Investigator

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8. Completed Project Index

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GW 67-1 ^a	Natural groundwater recharge	1969-70
GW 67-2 ^a	Hydrogeology, Oak River basin	1969-70
GW 67-3	Permafrost hydrogeology	1969-70
GW 67-7	Assiniboine basin	1968-69
GW 67-10	Groundwater flow in the clay belt	1969-70
GW 67-15	Water, Mt. Kobau watershed	1969-70
GW 67-17	North Nashwaaksis basin	1968-69
GW 67-18	Lac du Bonnet	1968-69
GW 68-1	Hydrologic response model	1968-69
GWO 69-1	Groundwater, Bell's Corners	1969-70

Report Series Publications

- No. 1 PLAIN FORTRAN - A guide to compatibility in computer programming. J.J. Therrien.
PLAIN FORTRAN is a restricted but compatible FORTRAN intended for the scientist who does not wish to become involved in the comparison of different versions of FORTRAN to determine their compatibility.
- No. 2 North-Central Baffin Island Field Report 1967.
A synopsis of the 1967 Baffin Island operation performed by the Geographical Branch.
- No. 3 The Federal Groundwater Program - Annual Project Catalogue 1968-1969.
A catalogue of current groundwater studies summarizing the objectives and progress of each project.
- No. 4 Glacier Survey in Alberta. P.I. Campbell, I.A. Reid and J. Shastal.
A report on the method used and the results obtained in computing the volumetric change of two glaciers in Alberta.
- No. 5 Glacier Survey in British Columbia. P.I. Campbell, I.A. Reid and J. Shastal.
A report on the method used and the results obtained in computing the volumetric change of five glaciers in British Columbia in 1966.
- No. 6 Analysis of wave motion in a rectangular channel using electrical network analogy. L.F. Ku.
A clear and systematic approach to solving problems of wave motion using the method applied to electrical network analysis.
- No. 7 Ice Studies in the Department of Energy, Mines and Resources - 1969.
A catalogue of current projects and a general introduction to the ice studies carried out during 1969 by the Department of Energy, Mines and Resources.
- No. 8 The Federal Groundwater Program - Annual Project Catalogue 1969-70.
A catalogue of current groundwater studies summarizing the objectives and progress of each project.
- No. 9 A Storage and Retrieval System for Water Quality Data.
A report describing the data processing system being implemented for storing and retrieving Water Quality Data.
- No. 10 Glacier Surveys in British Columbia - 1968, Vol. 1. English System; Vol. 2. Metric System. I.A. Reid and J. Shastal.
A report for 1968 on the method used and the results obtained in computing the volumetric change of five glaciers in British Columbia. Vol. 1 contains the text and five glacier maps based on the English System; Vol. 2 contains only the five maps based on the Metric System.
- No. 11 Computer Programs in Use in Water Quality Division - Vol. 1. A. Demayo.
A report containing computer programs offering 1) least square fit to various types of polynomial expressions 2) least square fit to a linear expression with two and three variables, and 3) solutions to a polynomial equation.
- No. 12 Interlaboratory Quality Control Study No. 1 - Calcium, Total Hardness, Sodium and Potassium. W.J. Traversy and R.W. Wales.
A report on analytical quality control of the Water Quality Division to ensure a high quality of performance in Divisional laboratories in Ottawa and Burlington, Ontario; Moncton, New Brunswick; and Calgary, Alberta.

Copies of this publication may be obtained by writing to:

Director,
Inland Waters Branch,
Department of Energy, Mines and Resources,
588 Booth Street,
Ottawa, Ontario.

Environment Canada Library, Burlington



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