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Environment Canada

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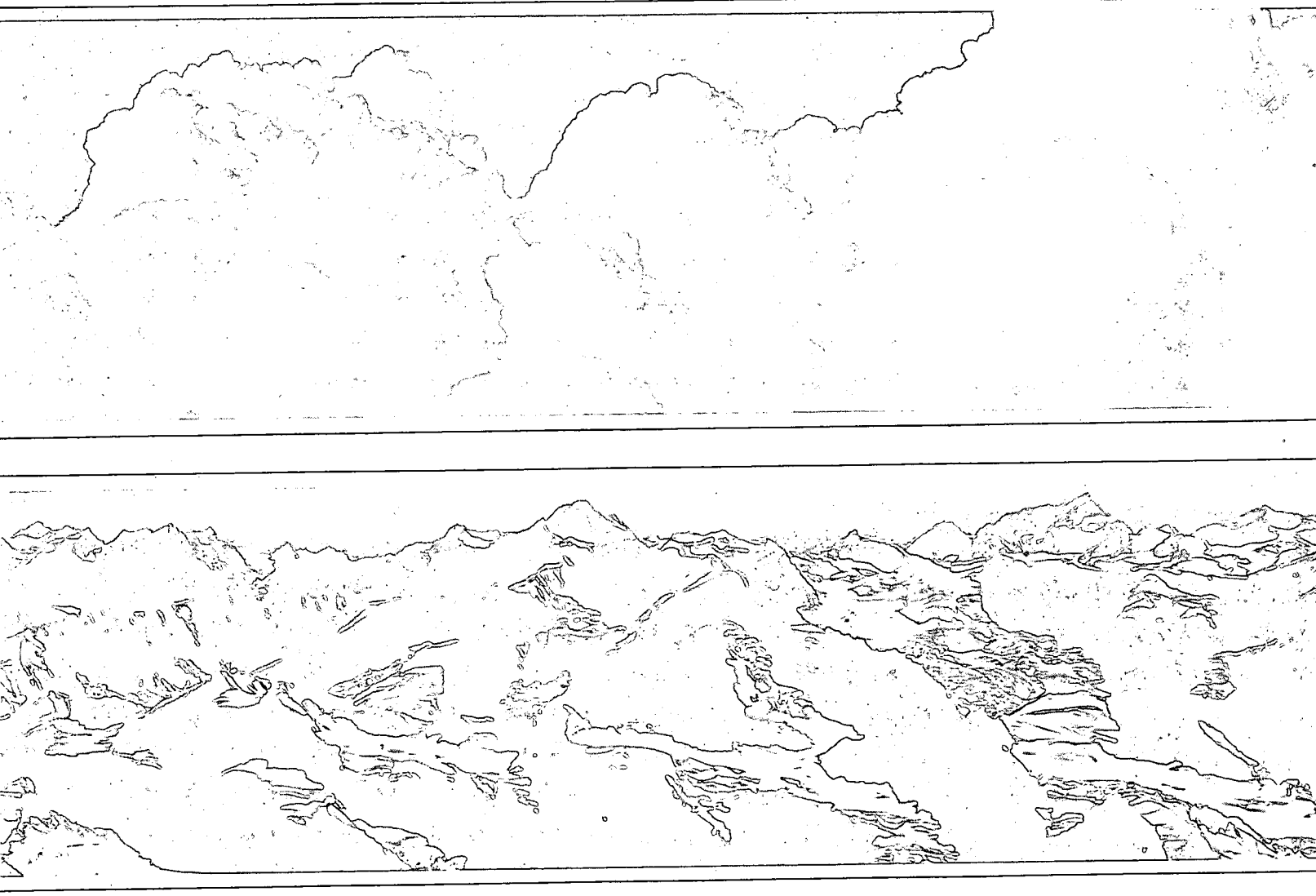
Research Program
Hydrology Research Division

Project Catalogue 1971-73



REPORT SERIES NO. 31

INLAND WATERS DIRECTORATE,
WATER RESOURCES BRANCH,
OTTAWA, CANADA, 1973.

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Preface

This publication is the fifth in a series detailing the research activities of what was until 1972 the Groundwater Subdivision of the Hydrologic Sciences Division, Inland Waters Branch (IWB), Department of Energy, Mines and Resources. A federal government reorganization has since led to the creation of the Department of the Environment (Environment Canada). The Groundwater Subdivision has, as a result, become the Hydrology Research Division. The new division is one of two research arms of the Water Resources Branch of the Inland Waters Directorate (IWD).

The preceding publications in this series are:

The Federal Research Program in Hydrogeology 1967-68. 60 p.

The Federal Groundwater Program. Annual Project Catalogue 1968-69. IWB Rept. Series 3, 82 p.

The Federal Groundwater Program. Annual Project Catalogue 1969-70. IWB Rept. Series 8, 108 p.

Limited numbers of these earlier publications are still available.

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Research Program, Hydrology Research Division

Project Catalogue 1971-73

1. Introduction

The activities of the Hydrology Research Division fall into two distinct categories: (1) those concerned primarily with hydrogeology and (2) those concerned with other aspects of the hydrologic cycle or with the hydrologic cycle in general. Almost three quarters of the projects listed in this catalogue fall into the first category.

The heavy emphasis on this single area of hydrologic research reflects, in part, an historical fact: the original nucleus of the Hydrology Research Division was a groundwater research group set up by the Geological Survey of Canada. This emphasis on groundwater studies is not misplaced, even now. The Hydrology Research Division is the federal agency charged with the conducting of field and laboratory studies in hydrogeology. As such, the Division has a unique and continuing responsibility to identify Canadian research needs in hydrogeology. It must, furthermore, attempt to establish priorities with respect to the satisfaction of these needs and, within the limits of its powers and resources, take steps to satisfy them. In identifying Canadian groundwater research needs and establishing priorities, effective liaison with provincial groundwater agencies is of paramount importance; only the provincial agencies have the day-to-day contact with practical groundwater evaluation problems that help point the finger at those problem areas where an investment of research effort is most likely to be fruitful. Thus, the provincial groundwater agencies may be regarded as important customers for scientific output falling into the hydrogeologic research category.

In the case of the Division's second main research category - research concerning the hydrologic cycle as a whole or into aspects of the cycle other than groundwater - the Division does not occupy the unique position that it does with respect to groundwater research. There are many other federal agencies both within and without Environment Canada that are conducting research into problems of this nature. Nevertheless, the scope for more generalized hydrologic research is broad and many-faceted and there are important problem areas relating particularly to the mission and objectives of Environment Canada that are not receiving the attention they deserve. The Hydrology Research Division has an obligation, in consultation with various operational groups in the Directorate, to identify these areas, to establish priorities and to select specified problems for attack and solution. In the case of this second research category, therefore, important customers for the Division's scientific output are to be found closer to home within the Inland Waters Directorate.

2. Research and Operational Projects

The studies conducted by the Hydrology Research Division and listed in the catalogue are classified either as research projects denoted by (GW or HR) or as operational projects (denoted by GWO or HRD). The present catalogue lists 41 research and 10 operational projects.

Operational projects are generally initiated at the request of other federal agencies and are performed as a service for these agencies. They may involve localized evaluations of groundwater resources or hydrologic budgets in areas that are either under federal jurisdiction (such as the national parks) or that are the sites of broadly based federal research programs requiring some groundwater or other specialized hydrologic input. Recently they have also included wide-ranging regional or national surveys of groundwater resources, aquifer distribution, and chemical characteristics of groundwater. An exception to the usual federal origin of these operational projects is provided by an oil-spill study (GWO 70-2) in which the Hydrology Research Division became involved at the request of a provincial groundwater agency.

Research projects generally originate within the Division but may, on occasion, be initiated as a direct result of problems brought to the attention of the Division by other units in the Inland Waters Directorate. The Division's decisions on the initiation of new research projects are influenced, as already suggested above, by its liaisons with provincial groundwater agencies and with operational units within the Directorate.

Research is the prime function of the Hydrology Research Division. Operational projects generally do not serve to advance research progress and it is important, therefore, that manpower resources are not committed unduly to these projects. A partial solution to the problem is utilization of the private sector for field management of operational projects and for conducting and reporting on groundwater-resource evaluation projects and regional survey projects. Utilization of the private sector is a policy with the Division and is believed to be contributing to the generation of a high degree of hydrogeologic competence in this sector. It represents, as well a first step in the transition to effective implementation of federal make-or-buy policy for scientific research.

3. Divisional Objectives and Operational Structure

The principal objectives of the Hydrology Research Division are:

1. To develop hydrologic techniques and methodologies for water resource management.

2. To identify operational areas in the water resource field where there are needs for research and to implement appropriate research projects and programs.

At present the Division is conducting or has recently initiated six research programs: Maritime Research, Subsurface Disposal Research, Interface Hydrology, Northern Hydrogeology, Paleoenvironmental Research and GOWN. The latter is an acronym for the Division's computerized groundwater data storage, processing and retrieval system.

The Maritime Research Program was set up in 1969 to investigate the intrusion of salt water into coastal aquifers in the Maritime Provinces and to devise ways and means of obtaining the best trade-off between high water production and minimization of intrusion. Since the permeability of these aquifers is very largely due to fractures, flow through fractured media has also been intensively studied. The program has been successful in substantially increasing our understanding of hydrogeological phenomena in coastal aquifers. Nevertheless, there are gaps remaining in this understanding and these gaps limit the practical application of the research findings. The thrust of the program is now being modified to place emphasis on an intensification of fracture flow studies and on the development of well-field simulation models for prediction of long-term effects of coastal groundwater development.

The Subsurface Disposal Research Program was formally initiated in 1970. The primary concern at that time was the question of disposal of fluid chemical wastes and brines through wells into deep-lying geological formations - a practice which has been adopted on an increasing scale in Canada, the United States and elsewhere. The objectives were to determine the effects of this practice, to improve understanding of the physical and chemical processes involved, and to develop techniques for monitoring and predicting waste movement. The program has led to the publication of a report reviewing the current status of subsurface waste disposal in Canada. Two related reports have been prepared but are not as yet published on regional evaluation of potential for underground disposal and on disposal-formation and injection-well hydraulics. Field studies have been carried out in deep-well disposal areas in and around Lambton County in southwestern Ontario. Examples of shallow subsurface contamination from surface sources are also under investigation. These include the effects of seepage from potash mine brine ponds in Saskatchewan and some preliminary investigations into the effects of oil spills on land in New Brunswick.

The Northern Hydrogeology Program dates back to 1971. It is concerned primarily with the northern groundwater-permafrost system and the way in which the groundwater-permafrost boundary is disturbed by groundwater movement and heat transfer. The ultimate objective is to apply the knowledge gained to prediction of the effects of pipelines, highways, etc. on this boundary, particularly with regard to such questions as slope stability and the creation of new groundwater recharge areas. Some northern data have been gathered relating permafrost configuration to natural and artificial surface fractures. A computer model is also under development which incorporates both groundwater flow and heat flow in order to predict changing positions of the groundwater-permafrost boundary in response to a variety of surface disturbances.

Both the Interface Hydrology Research Group and the Paleoenvironmental Research Program are recent innovations. The Interface Hydrology Group will be involved in the development and improvement of hydrologic simulation and forecast models and possibly in theoretical questions of network design as well. Its program is still in the process of being formulated. The Paleoenvironmental Research Program will be applying knowledge gained over the past five years on the ecology of marine invertebrates to the clarification of eutrophication problems. An important objective will be to use techniques already developed to discriminate between natural and man-caused eutrophication. The second type will presumably be, at least in some cases, reversible.

GOWN (as stated above) is the Hydrology Research Division's computerized groundwater data storage, processing and retrieval system. The long-range objective in the GOWN program is to develop the system as a tool for integrated water resource management. Some data are stored in the system but they are there simply as working material for the development of the system's capabilities for data processing and presentation. Other Division programs provide input into the GOWN program in the form of programmable techniques and methodologies for the analysis and application of hydrologic data. GOWN now has developed a good capability in terms of groundwater data storage and selective retrieval and presentation of these data. The immediate objectives of the program are to enlarge the scope and flexibility of the retrieval functions and to develop some capability as a tool to deal with interconnected aquifer and surface-water systems.

An organization chart for the Division is given on a following page.

4. Future Activities

It has been stated above that the long-range objective for GOWN is its development as a tool for integrated water resource management and that the other Hydrology Research Division programs will ultimately provide the techniques and methodologies that will make up GOWN. The long-range GOWN objective is of course a reflection of the two divisional objectives cited earlier. The objective of integrated water-resource management cannot, however, be treated as a discrete

entity isolated from the effects of man's other activities. Water-resource management decisions will have repercussions on land management, on the development of other resources, and on the environment generally. Conversely, decisions in these other areas will most certainly impinge on and have consequences for water-resource management.

Thus what we are and should be concerned about is management of the total environment. This thesis has been proposed and strongly supported in a recent Inland Waters Directorate internal report.* In the case of the Hydrology Research Division the concern might be made more specific. It is a concern with research into the hydrologic effects of environmental management.

It is anticipated that the Division will become more involved with specific projects and programs directly related to the hydrologic effects of environmental management. Through the interface Hydrology Group integrated studies will be initiated in selected areas where changing patterns of land use and resource development are altering or are expected to alter the hydrologic regime. The researches of the other program groups in the Division will also contribute to a better understanding of these effects.

In conducting these studies it will be borne in mind that one of the basic problems is an inability to describe the natural systems under consideration with exactitude. Elements of complexity and heterogeneity in the natural systems lead to uncertainties in describing the systems and in predicting long-term effects. Methods of statistical and stochastic hydrology will be brought to bear in an effort to determine the relative magnitudes of these uncertainties. The provision of such measures of inexactitude will have significant consequences for the design of hydrologic networks and the analysis of the effectiveness of forecasting and hydrological data transfer procedures.

Ottawa, October 1, 1973.

D. H. Lennox,
Chief, Hydrology Research Division.

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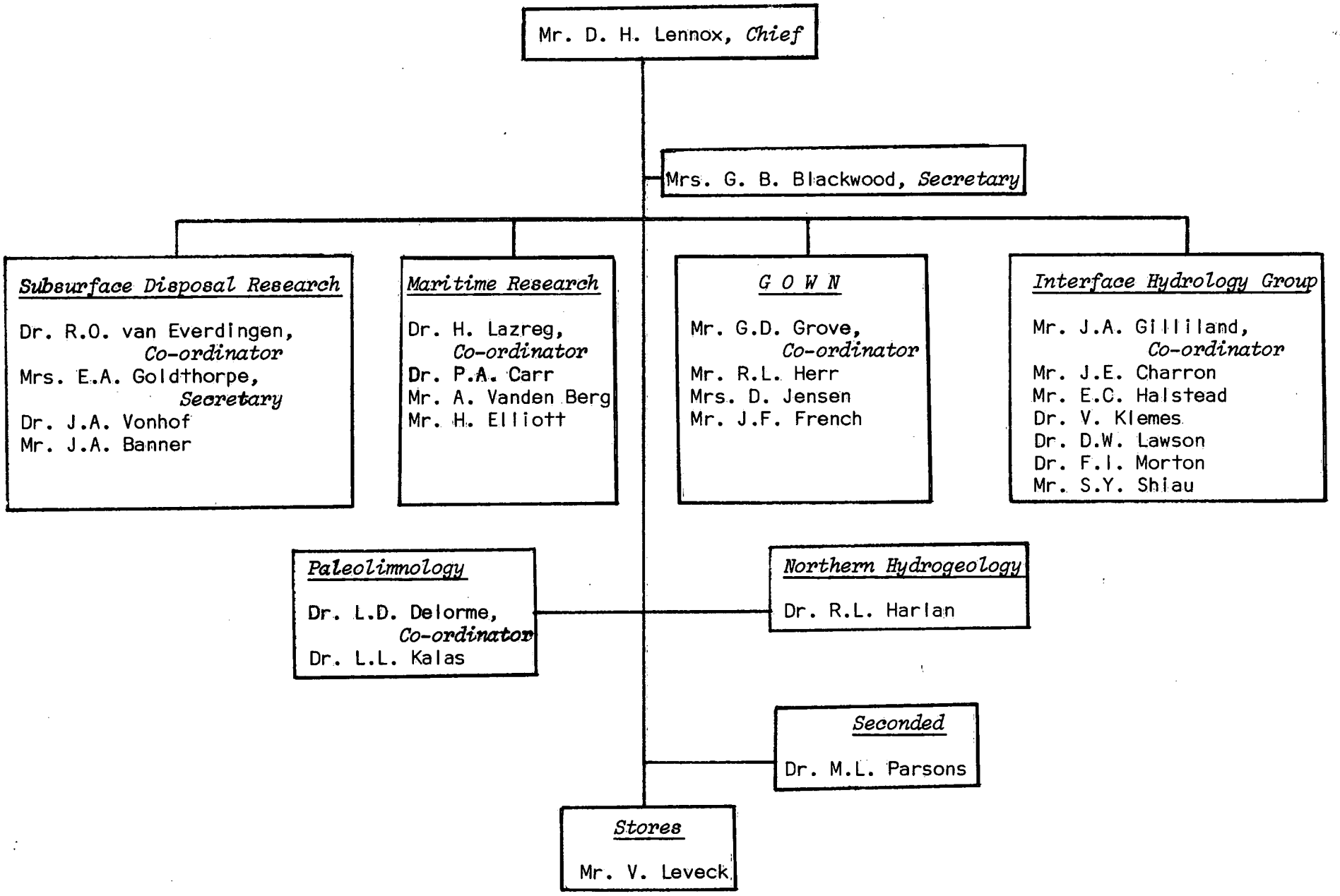
* Gilliland, J.A. and A.D. Stanley (1973): Research in the Inland Waters Directorate. A report prepared for the Office of the Research Advisor, Water Management Service.

ORGANIZATION CHART



Catalogue of Current Projects

1. Interface Hydrology Group

Project No. GW 67-5 R. M. Holmes

Hydroclimatology of Foothills 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 Microclimatology, Kananaskis, Alberta.

2. Field

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

During summer months each site is visited twice daily by a field crew, and observations are made. In the 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. This observation program has been continued through the summer of 1972. The last summer's observations were carried out by contract due to the departure of the principal investigator.

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.

The principal investigator left the government service at the end of March 1972. The project will not be continued by the Hydrology Research Division but efforts have been made to see whether some other research group might be interested in continuing the observation program and in eventually determining the energy budget. The University of Alberta's Department of Geography has shown some interest but has made no firm commitment.

The Hydrology Research Division's involvement with field activities for this project has now been terminated. The Division intends, however, to publish the data collected in an Inland Waters Directorate Report.

E. COMPLETION DATE:

March 31, 1974.

Project No. GW 67-11 H. Ryckborst

Parametric Hydrology of a Glaciated Basalt Plateau

A. OBJECTIVES:

To show the feasibility of linear system synthesis in the Fraser River forecast models. For this purpose a forecast of the daily flows of 38 large drainage areas in the Fraser River Catchment is to be provided for the water year, April 1, 1970 - March 31, 1971.

B. PREVIOUS WORK:

1. Field

During the summers of 1969 to 1970, a total of almost 150 instrument installations were made at selected sites in the Bonaparte River basin of the Cariboo region of British Columbia. These included:

11 stream level recorders
13 groundwater level recorders
16 sand point observation wells
29 piezometers
9 ground level recording rain gauges
10 Atmospheric Environment Service rain gauges
29 other rain gauges
4 ground level recording snow gauges
4 thermo hydrographs
1 hygristor
1 barometer
4 anemometers
12 wind-tower-mounted thermistors
1 Eppley short wave radiation sensor

During the spring of 1971, all instrumentation was removed and the instrumented sites were returned to their original condition. Twenty-five trees more than 300 years old were cut for dendro-chronological analysis and for the abstraction of information on long-term cyclic variations in hydrologic conditions.

C. WORK IN PROGRESS:

Four manuscripts have been prepared dealing with various aspects of the hydrologic studies in the Bonaparte Basin. These are:

Ryckborst, H. and A.A. Fischer. Precipitation and streamflow gauge spacing analysis.

Ryckborst, H. The crawfish model.

Ryckborst, H. and R.O. Christie. Feasibility of electro-magnetic streamflow measurements.

Ryckborst, H. and Madill, D. Optimum snow sampling in mountains.

D. FUTURE WORK:

All field work completed.

E. COMPLETION DATE:

March 31, 1974.

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

A. OBJECTIVES:

To analyze the hydrologic regime in a thick sequence of unconsolidated surficial deposits constituting a valley fill.

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. 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.

E. COMPLETION DATE:

March 31, 1974.

Project No. GW 68-2

E. Wojtek and H. Ryckborst

Parametric Hydrology of the Northern Lake Ontario Basin

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

A. OBJECTIVES:

To simulate daily runoff from daily rainfall for 28 watersheds on both the Canadian and American sides of the Lake Ontario basin for a three-year period.

B. PREVIOUS WORK:

1. Publications

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

2. Field

Six ground-level rain gauges were installed in 1969 in the basins of the Ganaraska, Lynde and Little Rouge Rivers on the Ontario side of the lake. Dye experiments with Rhodamine-B were conducted during the spring and summer of 1970 and 1971 in these three rivers to investigate nonlinearity in open-channel flow.

C. WORK IN PROGRESS:

One manuscript describing results from this investigation has been prepared and is undergoing editing and review:

Ryckborst, H. and E. Wojtek. Linear synthetic hydrographs from Southern Ontario.

D. FUTURE WORK:

Field studies are complete.

E. COMPLETION DATE:

March 31, 1974.

Project No. GW 68-7 J.E. Charron

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. (in press). A study of groundwater flow in Russell County, Ontario. Inland Waters Directorate Tech. Bull.

2. Field

Regional water sampling and well inventory programs were carried out in 1968, 1969, 1970 and 1971 in Russell, Prescott, Glengarry and Stormont Counties respectively.

C. WORK IN PROGRESS:

1. Publications

Charron, J.E. (in preparation). A Study on the direction of groundwater flow, Prescott County, Ontario

2. Office

Compiling and analyzing data accumulated for Glengarry and Stormont Counties and preparation of reports.

D. FUTURE WORK:

To extend this study into the Ottawa-St. Lawrence interstream area lying in the province of Québec, partly by a field program similar to those carried out in the years 1968 to 1971 and partly by correlation of field results with the findings of

Tremblay, J.J. L. and G.D. Hobson (1962). Vaudreuil map-area, Québec. Geol. Surv. Can. Paper 61-20.

E. COMPLETION DATE:

December 31, 1974.

Project No. GW 68-8 F.I. Morton

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, Dept. 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 observations. Symposium on World Balance, Reading, Int. Assoc. Sci. Hydrol. Pub. 93.

Morton, F.I. (1971). Catchment evaporation and potential evaporation - further development of a climatologic relationship. Journal of Hydrology, Vol. 12, pp. 81-89.

2. Office

(a) Formulation of model which permits the areal 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. Preparation of evaporation map of Canada.

2. Test of model against precipitation less runoff data for a wide range of climatic and geologic conditions in North America and Ireland.

D. FUTURE WORK:

1. Test of basic concept against energy budget evaporation values for the Mer Bleue experimental site.

2. Preparation of final report.

3. Use of basic concept to develop an antecedent moisture index for flood forecasts.

E. COMPLETION DATE:

December 1974.

Project No. GW 70-2 R.M. Holmes

Airborne Studies of the Atmospheric Boundary Layer

A. OBJECTIVES:

1. To develop an "immersion sensing" instrumentation system to study the behaviour of the atmospheric boundary layer with particular reference to the flux of heat, momentum and water vapor.

2. To use airborne instrumentation developed under (1) to study the nature of the atmospheric boundary layer and its dependence on that of the underlying surface.

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., v. 62, pp. 546-549.

Holmes, R.M., and K.D. Hage, 1971. Airborne observations of three chinook-type situations in Southern Alberta. J. Appl. Meteorology, v. 10, pp. 1138-1153.

2. Unpublished Internal Report

Holmes, R.M., 1971. An airborne instrument system for atmospheric boundary layer and climatological research. 286 pages.

3. 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 than that provided by the 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.

The initial phase of field operations was to have terminated at the end of September, 1970 and to be followed by a period of a year or more during which the data collected would be evaluated and their practical application demonstrated. Shortly before the termination of field operations, a disastrous laboratory fire destroyed all of the airborne immersion sensing instrumentation as well as a large percentage of the data taken during the previous summer on which the evaluation was to be based.

The decision was subsequently taken in mid 1971 to rebuild the airborne immersion sensing system and to engage in an intensive data-gathering exercise during the balance of that fiscal year. Progress in rebuilding was slow, however, so that the system was not fully operational until late in the fiscal year and few useful data were collected. The principal investigator resigned from the federal service at this point, leaving the future of the system in some doubt.

C. WORK IN PROGRESS:

Through arrangements with a contractor, the airborne immersion sensing system has recently been used in studies over Lake Ontario for the International Field Year on the Great Lakes. More significantly, however, the system was flown simultaneously with a similar airhorne system belonging to the National Research Council. The comparison between results obtained with the two systems will have important consequences for the future of the Hydrology Research Division's system.

D. COMPLETION DATE:

March 31, 1974.

Project No. GW 70-6 J.A. Gilliland

Interaction of Groundwater and its Environment

A. OBJECTIVES:

1. 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 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°C, P 5,000 bars).

2. To relate theoretical results to field examples.

B. PREVIOUS WORK:

Other commitments have prevented the effective initiation of this project. Other projects have, in the meantime, invaded some of the subject areas listed above. Project Nos. 67-4 and 70-8 are concerned with chemical reactions under a wide range of temperatures and pressures; Project No. 71-3 with the permafrost-groundwater relationship.

C. WORK IN PROGRESS:

The project has been terminated.

D. COMPLETION DATE:

March 31, 1973.

Project No. GW 70-10

Frank W. Schwartz

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:

1. Publications

Schwartz, F.W., 1972. Digital simulation of hydrochemical patterns in regional groundwater flow. Unpublished Ph.D. thesis, Univ. of Illinois.

2. Field

Hydrologic and hydrochemical field investigations were carried out in the Upper Kettle Creek Watershed of the Lake Erie basin, beginning in 1970. These investigations included the installation of hydrometeorologic instruments and the collection of both till and water samples. The latter included precipitation, surface-water and groundwater samples.

3. Laboratory

Mineralogic and granulometric analyses were performed on the till samples; chemical analyses on the water samples.

4. Office

A data processing system was developed for the rapid evaluation of hydrochemical analyses. A two-dimensional mass transfer simulation model was developed for the

characterization of the hydrochemical regime in the Upper Kettle Creek watershed. The model was applied to the watershed data and the results discussed in the thesis listed above.

C. WORK IN PROGRESS:

Consideration is being given to the publication of thesis in the IWD Scientific Series.

D. COMPLETION DATE:

March 31, 1974.

Project No. GW 71-1 E.C. Halstead

Hydrogeology, Fraser Valley

A. OBJECTIVES:

To evaluate the source, movement and distribution of groundwater in the lower Fraser Valley.

B. PREVIOUS WORK:

Well inventory and geological mapping were carried out by the Geological Survey of Canada during the late 1950's. Groundwater reports were published as a result of the reconnaissance for each of the following municipalities: Surrey, Langley, Matsqui, Sumas and Chilliwack.

C. WORK IN PROGRESS:

Correlation of all drill records for installations and test holes completed during the last 10 years; water quality monitoring of certain springs, flowing artesian wells and surface streams; chemical analyses of most recently drilled wells; interpretation of field results to define local, intermediate and regional flow systems; monitoring of water tables in certain free aquifers to determine direction of groundwater flow in relation to possible contamination from septic tanks, fertilizers and sanitary land fills.

D. FUTURE WORK:

Continue correlation of well data and interpretation of field results. Further define the stratigraphy and flow net relations.

E. COMPLETION DATE:

March 31, 1974.

Project No. GW 71-4 S.Y. Shiau

Water Balance, IHD Representative Basins

A. OBJECTIVES:

To arrive at an annual water balance of a high-mountain and two parkland representative basins based on the results of groundwater investigations and incorporated with the field measurements and analysis of other hydrologic aspects. This project is a contribution to Canada's program for the International Hydrological Decade (IHD) and is a composite of three previous projects (GW 67-1[b], GW 67-2[b], GW 67-19) reported on in earlier catalogues in this series.

B. PREVIOUS WORK:

1. Instrumentation

(a) Oak River basin (Manitoba) - 4 stream gauges;
1 class A weather station;
5 temperature-precipitation stations;
9 carborundum block evaporation stations;
75 piezometers in 35 nests.

(b) Good Spirit Lake basin (Saskatchewan) - 1 stream gauge;
3 temperature precipitation stations;
4 isolated piezometer nests;
5 carborundum block evaporation stations;
3 recharge-discharge sites, each with piezometer nest, a water table well and a bank of soil moisture cells.

(c) Trapping Creek basin (British Columbia) - 2 stream gauges;
1 Fischer-Porter precipitation recorder;
2 Sacramento storage precipitation gauges;

- 3 integrating anemometers;
  3 hygrothermographs;
  3 snow courses;
  2 sunshine recorders;
  8 evaporimeter nests;
  3 soil moisture stations;
  24 piezometers in 7 nests;
  11 water table wells.

2. General

(a) Laboratory calibration of soil moisture cells for different type of soils.

(b) Development of computer programs for the automatic processing. interpretation and plotting of soil moisture, piezometer, temperature and precipitation data.

(c) Studies of the groundwater flow systems, the recharge-discharge profiles and the field and/or theoretical mapping of the recharge-discharge areas.

(d) Studies of the evaporation patterns in a mountainous basin - Trapping Creek basin.

C. WORK IN PROGRESS:

1. Routine survey, general maintenance of instrumentation and continuous data collection.

2. Processing, interpretation and analysis of basic hydrologic data for the assessments of the water balance.

3. Preparation of data for the groundwater flow pattern analysis to estimate the groundwater component of the water balance.

4. Development of water balance models based on the results of groundwater investigation and incorporated with the analysis of other hydrologic aspects.

D. FUTURE WORK:

1. Maintain instrumentation and continue field measurements.
2. Preparation of reports on water balance.

E. COMPLETION DATE:

December 31, 1974.

Project No. HR 72-2 D.W. Lawson

Hydrologic Modelling

A. OBJECTIVES:

1. To determine the accuracy and efficiency of existing models for the simulation of the hydrologic cycle.

2. To investigate the effects on accuracy and efficiency of incorporating soil moisture and groundwater phenomena into these models.

3. To determine for each model the optimum levels of accuracy for subsurface input data; by considering the trade-off between such factors as over-all model accuracy and efficiency, relative effects of errors in the determination of other phases of the hydrologic cycle, and costs.

4. To improve the accuracy and efficiency of the existing models and to develop new models.

5. To design the soil moisture and groundwater instrumentation networks required for the practical use of each model.

6. To develop a procedure for selecting the appropriate model under any given, contemplated or selected set of circumstances.

B. PREVIOUS WORK:

1. Publications

Lawson, D.W., 1968. Groundwater flow systems in the crystalline rocks of the Okanagan Highland, British Columbia. Can. J. Earth Sciences, 5, pp. 813-824.

Lawson, D.W., 1970. A rational approach to groundwater investigations in representative basins. Inter. Assoc. Sci. Hydrol., Publ. No. 96, Symposium on the Results of Research on Representative and Experimental Basins, Wellington (N.Z.), pp. 652-667.

Lawson, D.W., 1971. A distributed hydrological model based on the concept of groundwater recharge, transmission, and discharge. J. Hydrol. (N.Z.), 10 (2), pp. 133-140.

C. WORK IN PROGRESS:

1. Publications

Gray, D.M. and D.W. Lawson, (in preparation). Groundwater investigations in research basins. UNESCO, Technical Paper in Hydrology (see Project No. GWO 72-1).

2. Office

Formulation of the methodology to achieve the objectives stated above.

Cooperating with the Canadian Forestry Service and the School of Agricultural Engineering, University of Guelph in developing the subsurface components of the Marmot Creek Model.

Consideration of the operational needs of the Applied Hydrology Division, Water Resources Branch in developing models for use in conjunction with regional and national hydrometric networks.

Project No. HR 73-1 V. Klemes

Effects of Model Heterogeneity on the Modelling Process

A. OBJECTIVES:

1. To investigate the effects of variations in model prototypes on the parameters of the modelling process. Statistical distributions of parameters will be sought and confidence limits for various model prototypes established.

2. To analyze the accuracy of forecasting for selected deterministic (parametric and physically based) hydrological models.

3. To evaluate the impact of model heterogeneity on the planning objective and water management strategy.

B. PREVIOUS WORK:

1. Publications

Klemes, V., 1971. Some Problems in Pure and Applied Stochastic Hydrology. Symposium on Statistical Hydrology, University of Arizona, Tucson.

Klemes, V., 1973. Watershed as a Semi-Infinite Storage Reservoir. ASCE National meeting on Water Resources Engineering, Washington D.C.

Klemes, V., (submitted). The Hurst Phenomenon - a Puzzle?

Klemes, V., (submitted). Distribution of Outflow from a Lake with serially correlated Inflow.

2. Office

A preliminary analysis was carried out of the impact on a storage reservoir performance of the probability distribution model of mean annual flows.

C. WORK IN PROGRESS:

1. An analysis has been initiated of the differences in the properties of a time series generated by means of some currently used stochastic models (Markov chains, fractional noises, broken-line processes, autoregressive integrated moving average (ARIMA) processes).

2. The validity and importance of the assumption of stationarity in time series models is being investigated.

3. An analytical formulation of the distribution of reservoir outflow in terms of corresponding inflow properties and reservoir parameters is being sought. Monte-Carlo and matrix solutions are being tested.

D. FUTURE WORK:

1. Completion of the work in progress.

2. As per objectives Nos. 2 and 3.

Project No. HR 73-2

V. Klemes

Application of Runoff Forecasting to Storage Reservoir Operation

A. OBJECTIVES:

1. To investigate the possibilities and limits of improvement in operation efficiency of flow-regulating storage reservoirs by means of application of runoff forecasting.

2. To develop methods for an objective assessment of economic benefits of flow forecasting networks, and possible guidelines (such as recommended forecast period, maximum admissible forecast error, etc.) for the development of flow-forecasting networks for specific water-resource projects (hydro-power schemes, flood control projects, etc.).

B. PREVIOUS WORK:

1. Publications

Klemes, V., 1973. Optimum Runoff Forecast for a Flood-Control Reservoir. International Symposium on River Mechanics, Bangkok.

2. Office

Benefits of a hypothetized zero-error flow forecasting were investigated for a single-purpose flood-control reservoir.

C. WORK IN PROGRESS:

1. Flow-forecast benefits are being analyzed for multiple-purpose reservoirs.

2. Effects of forecast errors on the forecast benefits are investigated.

D. FUTURE WORK:

To apply the developed methods to some existing schemes and to generalize the results.

Project No. HR 73-4 K.U. Weyer, J. Cherry

Application of Runoff and Temperature Measurements in the Analysis of Baseflow Data

A. OBJECTIVES:

1. To demonstrate the application of runoff and temperature measurements made in a small Canadian watershed (Wilson Creek, Manitoba) to the identification and precise location of effluent and influent conditions in small creeks of the watershed.

2. To measure with precision both baseflow and, in the case of an effluent stream, the localized increments in baseflow due to points or concentrated areas of groundwater inflow.

3. To integrate the results of the study with those from parallel studies being conducted by the University of Waterloo on major-ion chemistry, conductivity and pH for streams of the Wilson Creek watershed.

B. PREVIOUS WORK:

1. One of the principal investigators (K.U.W.) has applied the combination of runoff and temperature measurements in a similar investigation of a number of small watersheds in West Germany.

2. Ten years of hydrologic records have been collected for the watershed; related hydrologic research has been actively under way for five years.

3. Preliminary work has been initiated at the University of Waterloo on the application of stable-isotype and major-ion analyses in base-flow studies for the watershed.

4. A reconnaissance field trip has been made to the watershed for the selection of appropriate sites for measurement of flows and temperatures and for sampling.

5. Between August 5 - 10, 1973, flow, temperature data and water samples have been collected in Wilson Creek basin.

C. WORK IN PROGRESS:

1. Office compilation of flow and temperature data at Ottawa.
2. Major-ion and O^{18} analysis at the University of Waterloo.
3. Deuterium Analysis of some water samples at AECL in Chalk River.
4. Analysis of results and integration of studies 1, 2 and 3.

D. FUTURE WORK:

1. Preparation of a paper in collaboration with John Cherry and Peter Fritz, University of Waterloo.
2. Extension of the field work by a new field trip in July 1974 to Wilson Creek Basin for one month.

E. COMPLETION DATE OF PRESENT STUDIES:

March 31, 1974.

Project No. GWO 69-2 J.A. Cherry

Kenora Lakes Study, Fisheries Research Board

A. OBJECTIVES:

1. To provide a detailed understanding of the mechanisms of groundwater inflow into Rawson Lake 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 was originally allocated to Dr. J.A. Cherry, then (1969) Associate Professor of Hydrogeology, University of Manitoba. The project continued under his supervision after his subsequent move to the University of Waterloo. Dr. Cherry 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 are now being utilized by graduate students as thesis material. Annual progress reports have been submitted by Professor Cherry to the Hydrology Research Division. A comprehensive final report will be prepared on the completion of the project.

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

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. During 1970 a network of over 160 groundwater piezometers and wells was installed in the Rawson Lake watershed.

3. The piezometer and well network was operated on a routine basis during the nonwinter months of 1971. A large amount of hydrochemical data was collected during the 1971 field season and the soils and surficial deposits were mapped. Drill data and samples from 1970 were re-evaluated.

4. The east and northeast sub-basins of the Rawson Lake watershed were singled out for more intensive hydrogeologic study during the 1972 field season. The piezometer network was expanded in both of these sub-basins, additional test holes were drilled in the east sub-basin, and more sampling of waters from piezometers, springs, seeps and streams was carried out. Two wells were drilled along the shore of the lake for aquifer testing and permeability estimation.

5. A preliminary groundwater progress report for 1969-70 was prepared early in 1970 and was incorporated into the preliminary progress report for the comprehensive study. A similar report was prepared for 1970-71, followed by a preliminary report of field and laboratory activities in 1971. The status of the investigations was reviewed again in March 1973 and a draft copy provided of a M.Sc. thesis on the geohydrology and geochemistry of the Rawson lake watershed. A second M.Sc. thesis study will deal with subsurface geochemical processes in the Rawson Lake basin.

E. FUTURE WORK:

Field work is virtually complete. There is a need, however, to carry out some supplementary test drilling and aquifer testing in order to obtain more reliable hydraulic conductivity estimates. There is an order-of-magnitude uncertainty in the conductivity estimates obtained to this point. This uncertainty has a significant bearing on the estimation of the relative importance of groundwater flow through the Rawson Lake basin as part of the total through flow. At one end of the scale, groundwater flow will be relatively small and it should therefore be possible to arrive at a satisfactory hydrologic budget for the watershed; at the other, groundwater flow will be relatively large and its precise estimation difficult. In the second case there is some question whether it will be possible to arrive at a satisfactory precise over-all hydrologic budget for the watershed.

A short drilling and pump-testing program is scheduled for the 1973 field season in the hope that the hydraulic conductivity uncertainty will be resolved.

F. COMPLETION DATE:

March 31, 1974.

Project No. GWO 70-I E.C. Halstead

Benchmark Basin Program

A. OBJECTIVES:

1. To assist in the selection of benchmark 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 Hydrology Research Division 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 and three observation wells were installed there during the autumn of 1971.

D. FUTURE WORK:

Basin selection and evaluation for groundwater purposes will continue.

E. COMPLETION DATE:

March 31, 1974.

Project No. HRO 72-I D.W. Lawson

Groundwater Investigations in Research Basins

A. OBJECTIVES:

To prepare a technical paper on the above subject for UNESCO.

B. NATURE OF REQUEST:

Verbal and subsequent written request from Dr. D. Gray, University of Saskatchewan, on behalf of the Working Group on Representative and Experimental Basins of IAHS.

C. ORGANIZATION OF PROJECT:

The paper is to be co-authored by Dr. Gray and Dr. D.W. Lawson.

D. PRESENT STATUS OF PROJECT:

The table of contents has been prepared and the writing divided equally between the two authors. Sections are being exchanged for review by the other author as they are written. Approximately one third of the paper had been prepared by mid-1973.

E. COMPLETION DATE:

December 31, 1973.

2. GOWN

Project No. GW 67-13 J.A. Gilliland

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

Various types of analog and digital recorders were installed at Swift Current and Good Spirit Lake, Saskatchewan; Ottawa, Ontario; and Prince Edward Island. Four wells of various designs were installed at Delta, Manitoba, together with an experimental transducer-recorder system and some meteorological instruments. Total number of installations was 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. The six wells in Prince Edward Island have since been transferred to provincial jurisdiction. These wells continue to be maintained and serviced by the Water Survey of Canada.

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. The results 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.

C. WORK IN PROGRESS:

1. Publications

Gilliland, J.A. Application of correlation functions to the analysis of groundwater hydrographs. Water Resources Research (in press)

Jackson, R.E. Evapotranspiration of groundwater: a time series analysis of the hydrologic regimen of a groundwater discharge area. IWD Scientific Series No. 17 (in press)

Jackson, R.E. Time-series analysis of groundwater hydrographs from surficial aquifers of the Canadian Shield (in press)

Jackson, R.E., J.A. Gilliland and K. Adamowski. Time series analysis of the hydrologic regimen of a groundwater discharge area. Water Resources Research (in press)

D. FUTURE WORK:

The project will be complete with the publication of the manuscripts listed above.

E. COMPLETION DATE:

March 31, 1974.

Project No. GW 67-14 J.A. Gilliland

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) as listed in publication for Project No. GW 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 were installed at Swift Current and Good Spirit Lake, Saskatchewan; Ottawa, Ontario; and Prince Edward Island. Four wells of various designs were installed at Delta, Manitoba, together with an experimental transducer-recorder system and some meteorological instruments. The total number of installations was 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.

The six wells in Prince Edward Island have since been transferred to provincial jurisdiction. These wells continue to be maintained and serviced by the Water Survey of Canada.

3. Laboratory and Office

Prototype models of the VTI recorder have been manufactured. Water-level data are recorded on paper tape and difficulties have been encountered in the development of programs for the inputting of the data via a tape recorder into digital computer core storage. There may also be some hardware problems with the recorder itself, the exact nature of which should become more obvious when the software problems are resolved. Much of the recorder testing and development work has been carried out by the Instrumentation Section, Glaciology Division, Water Resources Branch.

C. WORK IN PROGRESS:

1. Publications

Gilliland, J.A. and R.E. Jackson. Some principles of observation well network design (in preparation).

D. FUTURE WORK:

The network design aspects of this project will be terminated with the appearance of the publication listed above.

Development of the VTI recorder has been temporarily suspended, in part because of the development problems outlined above but also because there now appear to be other attractive possibilities for the design of a non conventional recorder particularly suited for operation under Canadian climatic conditions.

E. COMPLETION DATE:

March 31, 1974.

Project No. GW 68-4 R.L. Herr

Hydrogeological Maps of the Lake Ontario Basin

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 continues for some 60,000 wells in the Ontario portion of the Lake Ontario drainage basin. Edited and compiled well data are being inserted into the GOWN system (see Project No. GW 68-5).

D. FUTURE WORK:

The immediate priority in this project is the preparation by computer techniques of hydrogeological maps for the following sub-basins of the Lake Ontario Basin:

1. Forty Mile Creek
2. Oakville Creek
3. Wilmot Creek
4. Moira Creek

The computer-produced maps are to be compared with maps prepared manually by the Ontario Ministry of the Environment.

This project was conceived as a contribution to the International Field Year on the Great Lakes.

E. COMPLETION DATE:

March 31, 1974.

Project No. GW 68-5 G. Grove and J. French

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 Directorate and other agencies.

2. To produce automatically maps and sections 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.

Grove, G., and R.L. Herr, 1971. Storage and retrieval of groundwater data. Proc. IHD Workshop Seminar on Computer Storing and Processing of Hydrological Data, Quebec. Can. Natl. Comm. IHD, pp. 21 - 25.

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. Publications

Gilliland, J.A., and G. Grove. Some principles of data storage and information retrieval and their implications for information exchange. Jour. Int. Assoc. Math. Geol. (in press).

Grove, G. and J.A. Gilliland. GOWN - groundwater data storage and retrieval system (accepted for publication in GSC paper on computer techniques applied to geoscience).

2. Office

(a) Editing and storage of the data for the Lake Ontario drainage basin is nearing completion. Quality control checks and updating of information will constitute the routine maintenance of the data (see also Project No. GW 68-4).

(b) Development of programs for contouring (work done by Computer Science Division) is completed, testing of the retrieval system is now in progress with various hydrogeological maps being produced for the Lake Ontario drainage basin (see also Project No. GW 68-4).

(c) Data for approximately 9,000 wells from Manitoba has been coded and the locations have been digitized in preparation for storage of the data (see also Project No. GW 71-6).

(d) GOWN staff are participating in an investigation of integration of various Directorate data storage and retrieval systems. 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.

E. COMPLETION DATE:

Continuing.

Project No. GW 70-3 G. Grove

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

Program was written for automatically calculating permeabilities from Hvorslev slug tests.

C. WORK IN PROGRESS:

Nil. Other commitments have increasingly interfered with the studies originally planned for this project. The project has been discontinued but it is anticipated that aquifer analysis problems of interest will be encountered and dealt with in other projects.

D. COMPLETION DATE:

March 31, 1973.

Project No. GW 70-4 S.Y. Shiau

Flow Pattern Analysis

A. OBJECTIVES:

To develop GOWN-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:

1. Finite element analysis and programming of 2-dimensional steady state groundwater flow.

2. Development of programs for automated formation of the finite elements according to the permeability configuration.

D. FUTURE WORK:

1. To develop programs for the construction of the equipotential map, the flow net and the recharge-discharge profile.

2. 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.

E. COMPLETION DATE:

March 31, 1974.

Project No. GW 70-5 G. Grove

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.

Grove, G. and R.L. Herr, 1971. Storage and retrieval of groundwater data. Proc. IHD Workshop Seminar in Computer Storing and Processing of Hydrological Data, Quebec. Can. Natl. Comm. IHD, pp. 21 - 25.

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. Publications

Gillilland, J.A. and G. Grove. Some principles of data storage and information retrieval and their implications for information exchange. Jour. Int. Assoc. Math. Geol. (in press).

Grove, G. and J.A. Gillilland. GOWN - groundwater data storage and retrieval system (accepted for publication in GSC Paper on computer techniques applied to geosciences).

2. Office

(a) Programming of hydrograph file is nearing completion with testing of the operation of the programs for editing and storing hydrograph data.

(b) 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 a set of programs for converting Stevens recorder charts and Fischer-Porter, Ott and Boyle recorder tapes in a computer processable format in preparation for input into the hydrograph file.

2. To integrate the hydrograph file into the retrieval system through the development and adoption of plotter and statistical routines for time series data.

3. To develop new data files for borehole log information, etc. as these become needed.

4. To investigate display techniques such as the automated production of fence diagrams.

5. To develop programs for statistical and mathematical analysis of hydrogeologic data and for manipulation of geochemical and meteorological data.

E. COMPLETION DATE:

Continuing.

Project No. GW 71-6 R.L. Herr

Hydrogeological Maps of Manitoba

A. OBJECTIVES:

To construct hydrogeological maps of selected areas in Manitoba utilizing the GOWN computerized groundwater data storage and retrieval system.

B. PREVIOUS WORK:

With the cooperation of the provincial government, water-well data for approximately 9,000 Manitoba wells were collected and coded in the GOWN format as part of a 1971 federal government winter works program. These data have now been keypunched, the well locations digitized, and all data put on magnetic tape for editing.

C. WORK IN PROGRESS:

Activity in this project has been suspended for the time being to allow emphasis to be placed on higher-priority projects.

D. FUTURE WORK:

1. Editing of the data now on magnetic tape.
2. Preparation of automatically constructed maps for selected areas.

E. COMPLETION DATE:

Uncertain at this time due to other priorities.

Project No. GWO 69-3 R.L. Herr

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 Hydrology Research Division.

C. ORGANIZATION OF PROJECT:

Groundwater aspects carried out by the Hydrology Research Division staff in co-operation with personnel of the Geological Survey of Canada and Central Research Forest who were engaged in related investigations.

D. PRESENT STATUS:

1. Publications

Bik, M.J.J., R. Herr and J. Salm, 1971. Saline groundwater, Central Research Forest, Ramsayville, Ontario. Report of Activities, Part A: April to October, 1970. GSC Paper 71-1A, pp. 149 - 154.

2. Field

Field studies began in 1969 and included some test drilling and the installation of piezometer nests and shallow observation wells. Pumping tests were also carried out and groundwater sampled for conductivity measurement. A number of continuous water level recorders were also installed. A resistivity survey was conducted.

3. Office

Observation well hydrographs are being collected for insertion into the GOWN hydrograph file.

E. FUTURE WORK:

A report describing the results of the resistivity survey will be completed. This will complete the investigation as far as the Hydrology Research Division is concerned. Water-level data will continue to be collected, however, and will be available to the Manager and staff of the Central Research Forest.

F. COMPLETION DATE:

March 31, 1974.

Project No. GWO 71-1

R.L. Herr

Hydrogeological Maps of Canada

A. OBJECTIVES:

To construct hydrogeological maps of Canada on a scale of 1:10,000,000 as follows:

1. Surficial hydrogeology showing location and distribution of surficial aquifer materials, yields of wells, and water quality.

2. Bedrock hydrogeology showing location and distribution of bedrock aquifers, yields of wells and water quality.

3. Observation wells showing location and agency involved, purpose, and whether well is for water table or piezometer measurements.

B. NATURE OF REQUEST:

Written request from the Canadian Secretariat of the International Hydrological Decade (IHD) to contribute to the IHD's Canadian Hydrological Atlas.

C. PREVIOUS WORK:

1. Office

Data have been collected from Federal and Provincial agencies and other sources. These have been edited, compiled and placed on suitable base maps.

2. Field

Visits were made to provincial agencies to obtain unpublished data.

D. FUTURE WORK:

Completion of mapping and submission of maps to IHD.

E. COMPLETION DATE:

December 31, 1973.

3. Maritime Research Program

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

Parsons, M.L., 1972. Determination of Hydrogeological Properties of Fissured Rocks. Proc. Int. Geol. Con., 24th Session, Sect. II, Montreal.

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:

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.

D. ESTIMATED COMPLETION DATE:

March 31, 1974

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. Publications

Lazreg, H., 1972. Application of surface resistivity methods to the detection of salt water intrusion in Shippegan, N.B. CIM Trans. 25, pp. 32-41.

Lazreg, H., 1973. Master curves for the Wenner array. IWD Sci. Series 15, 109 pages.

2. Field

(a) Delineation of the lateral intrusion zone, in Shippegan and Cap Pélé, N.B.; and in the Eliot River area, P.E.I. by surface electrical resistivity profiling.

(b) Investigation of the vertical variation in conductivity of the geological formations by resistivity soundings in the above-mentioned areas.

(c) 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 Pélé and Shippegan, N.B.

(d) 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.

(e) Delineation by resistivity profiling of lateral saline water contamination resulting from brine disposal in Esterhazy, Saskatchewan.

(f) Determination of horizontal variations in near-surface salinity due to a presumed upward flow of groundwater at Mer Bleue, Ontario.

(g) Application of VLF ground survey (EM-16) to Shippegan saltwater intrusion.

(h) Application of surface resistivity to the delineation of conductive zones in granitic rocks near Halifax, N.S.

(i) Observation of displacement and distortion of the salt water-fresh water interface in Shippegan, N.B., by surface resistivity.

C. WORK IN PROGRESS:

1. Publications

Lazreg, H. Reconnaissance resistivity survey around a brine pond, Esterhazy, Saskatchewan (under review).

2. Field

Application of borehole geophysical logging to the study of maritime aquifers.

3. Office

Preparation of reports on resistivity results obtained in Summerside, P.E.I.; Mer Bleue, Ontario and Sable Island, N.S.

D. FUTURE WORK:

1. Field

Field testing of Magneto-telluric sounding.

2. Office

(a) Preparation of reports.

(b) Literature survey of the application of airborne geophysical techniques and satellite measurements to groundwater studies.

E. COMPLETION DATE:

March 31, 1974

Project No. GW 70 - 1 J.E. Gale

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 hydraulic characteristics of a major shear zone and its influence on the local and regional groundwater flow system.

3. To evaluate the applicability of pump test theory to flow in fractured rocks by (1) attempting to measure the change in fracture apertures with change in pore pressures and (2) measuring the potential distribution in the plane of individual fractures under pumping conditions.

B. PREVIOUS WORK:

1. Field

(a) Geological mapping and measurement of fracture systems in the slates, quartzites, and granite of Halifax County.

(b) Drilling in 1970 of two vertical holes and one inclined hole to explore the characteristics of a major shear zone at depth. Piezometers were installed in the two vertical holes, slug tests were performed, and the water levels in the two piezometers were monitored for a one month period in 1971 and for a three month period in 1972.

(c) Two NX diamond drill holes and four percussion drilled wells (4-inch diameter) were drilled during the 1972 field season. The two NX holes were logged with a borehole periscope to a depth of 40 feet and all the fractures observed were pressure tested. These wells were drilled at the Sambro test site located about 20 miles southwest of Halifax.

(d) Water well recorders were placed on three of the 4-inch wells.

2. Office

(a) Published water-well data for the three fractured rock aquifers (slates, quartzites, and granite) in Halifax County were analyzed to determine the distribution of specific capacity and transmissibility values for the three aquifers.

(b) Pressure test data from wells drilled in the saltes and quartzites in the city of Halifax were used to calculate values of permeability.

(c) Data collected from the measurement of spacing and orientation of fracture systems were analyzed to calculate the components of the permeability tensor for 15 different localities in Halifax County. Several additional calculations will be made using different aperture distribution models.

(d) A two-dimensional, coupled stress-flow, finite-element model developed by the Geological Engineering department, University of California at Berkeley was used to obtain soem idea of aperture changes to be expected with different pore pressures.

3. Laboratory

(a) A device for measuring the changes in fracture aperture was designed in conjunction with Dr. J. Kruus during 1971-72 and was fabricated by F.P. Industries of Ottawa during the period of May to September 1972.

(b) A constant-head discharge-control tank for controlling the rate of flow during pump testing of small capacity wells was constructed and successfully field tested during May 1972. Construction of the tank was based on suggestions made by Mr. T. Hurr of the U.S.G.S., Denver Office.

(c) Inflatable packer assemblies were constructed for pressure testing individual fractures and were successfully field tested during June, 1972.

C. WORK IN PROGRESS:

1. Publications

A paper is being prepared dealing with the geometric and hydrologic parameters of the fractured rocks in Halifax County, Nova Scotia.

2. Field

Rainfall and water levels are being measured at the Sambro test site. Stevens' F recorders have been mounted on three wells and weekly water level measurements are being made in the remaining wells. This will provide information on the hydraulic connection between the wells and the response of the individual wells to rainfall.

3. Office

(a) Attempting to correlate piezometric data from a major shear zone with barometric, surface temperature, and tidal information.

(b) Analysis of the data obtained from pressure tests and pump tests carried out at the Sambro test site in 1972.

(c) Using the results from the above analysis, a digital model of the Sambro test site will be constructed using an axi-symetric, coupled stress-flow finite-element program.

4. Laboratory

(a) Calibration and laboratory testing of the fracture displacement gauge.

(b) Laboratory testing of diamond drill cores to determine the constants to be used in the digital model.

D. FUTURE WORK:

1. Field

(a) Field testing of the fracture deformation gauge and collection of data on fracture aperture changes with changes in pore pressure.

(b) Periscope logging and pressure testing of the four percussion holes drilled in late August, 1972.

2. Office

(a) Comparison of aperture changes measured in the field and aperture changes predicted by the digital model.

E. COMPLETION DATE:

All field work will be completed during the summer of 1973. The estimated completion date, including the preparation and finalization of reports, is March 31, 1974.

Project No. GW 70-7 G. van der Kamp

Natural 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 confining layers.

2. To develop practical methods of analyzing tidal fluctuations and of removing these from water level records such as drawdown data.

3. To compare aquifer parameters determined by pump testing to those determined by tidal analysis.

4. To study the natural variations of water salinity in coastal aquifers with position and time and attempt to find a relation between these and the observed tidal fluctuations, mean water levels, and aquifer characteristics.

B. PREVIOUS WORK:

1. Publications

van der Kamp, G., 1972. Tidal fluctuations in a confined aquifer extending under the sea, 24th International Geological Congress, Section 11, pp. 101-106.

2. Field

(a) Installation of arrays of observation wells at Cap Pelé, N.B., and York Point, P.E.I., during 1969, 1970, 1971.

(b) Collection of all relevant data including water-level records, pump-test and slug-test data, well elevations, and water salinities during summers of 1970, 1971, 1972.

(c) Monthly measurements of water levels and salinities at York Point, P.E.I. and in other piezometers in the nearby Eliot River area, during the two year period, 1970-72.

3. Office

(a) Development of simple methods for separating observed tidal fluctuations into two main components, with or without use of a computer.

(b) Analysis of tidal and pump-test data.

(c) Development of a general theory for tidal motions in confined, semiconfined, and unconfined aquifers.

C. WORK IN PROGRESS:

1. Publications

van der Kamp, G. The propagation of tidal fluctuations through thin aquifers, Ph.D. Thesis, Free University of Amsterdam.

2. Office

Further analysis of tidal and pump-test data.

D. FUTURE WORK:

1. Office

(a) Further analysis of data and development of theory for subsea tidal fluctuation. Publication on subsea tidal fluctuations and the "loading" effect, if warranted by results.

(b) Analysis of salinity and mean water-level data in order to obtain better understanding of the process of salt-water intrusion under natural conditions. Preparation of informal or of a publication if warranted by results.

(c) Preparation of a manual on use of the tidal method with emphasis on practice if warranted by requests and enquiries.

(d) The work might also extend into an analysis of data and development of theory for well response and preparation of a report on well-aquifer systems including discussion of slug tests, well oscillations and correction of tidal and pump-test water-level data for well response.

E. COMPLETION DATE:

March 31, 1974.

Project No. GW 70 - 9 H. Lazreg

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:

1. Field

(a) Forty deep resistivity soundings to delineate the hydrostratigraphy of the area and to detect groundwater quality variations.

(b) Drilling of test-holes which confirmed the presence of salt-water intrusion along the south side of the Miramichi River at Chatham, N.B.

2. Office

Examination of available water - well inventory data and interpretation of field results.

C. WORK IN PROGRESS:

Preparation of final report: Hydrogeology of the Chatham-Newcastle area, N.B. - a geoelectrical study (under review).

D. COMPLETION DATE:

December 31, 1973.

Project No. GW 71-5 A. Vanden Berg

Well-Field Design,
Coastal Environment

A. OBJECTIVES;

1. To develop a mathematical model and computer program to simulate salt water intrusion induced by production of fresh water from a coastal aquifer.

2. To develop design criteria for the development of well fields in coastal aquifers.

B. PREVIOUS WORK:

A mathematical model and computer program have been prepared to simulate the movement of a salt-water intrusion front during pumping from a well field in a coastal aquifer. The model uses a standard finite-difference technique for the calculation of the time-dependent piezometric surface; from the piezometric surface, the gradients and velocities of a set of moving particles located on the fresh water - salt water boundary are determined. These gradient and velocity values are then used to establish the new positions of the moving particles after the passage of a selected finite time element. The model is limited at present to horizontal, confined and isotropic aquifers; these however may be inhomogeneous. It is furthermore based on the assumption that no vertical stratification of salt and fresh water occurs or, in other words, that the density contrast can be neglected. The model has been shown to perform well by comparison with analytical solutions for the case where a single pumping well is located near an infinite linear recharge boundary.

Furthermore, a set of basic criteria for the position and pumping rate of a single well in a coastal aquifer have been developed. These relate the extent of the intrusion, and the time taken for the intrusion to advance to the well, to the magnitude of the piezometric gradient in the aquifer under nonpumping conditions.

C. PRESENT WORK:

1. Field

Test drilling and pump testing in Chatham, N.B., to acquire the necessary hydrogeologic information for application of the model as an aid in the design of a well field.

2. Office

Development of design criteria for coastal well fields of more than one well, of which some are pumping salt water. An analytic procedure has been worked out for the case of two wells (one salt water well, one fresh water well); a computer procedure for the drawing of flow nets in a multiple well field is in progress.

D. FUTURE WORK:

1. Extension of the model to allow for anistropy and leaky aquifers, and possibly for pressure dependence of transmissivity.

2. Development of a model suitable to a system of horizontally layered aquifers, by means of a cylindrical coordinate system and superposition of solutions for the representation of boundaries.

3. An assessment of the effects of uncertainties in the values of transmissivity assigned to the model.

4. Subsurface Disposal Research Program

Project No. GW 67-4 R.O. van Everdingen

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 water, dissolved constituents, contained heat) and as an engineering hazard.

B. PREVIOUS WORK:

1. Office

(a) Selected chemical and pressure data from petroleum drilling in Alberta and Saskatchewan have been coded.

(b) A report on "Groundwater in Permafrost Regions of North America" was prepared with J.R. Williams of U.S.G.S. Boston, Mass.

(c) Reports have been prepared on results of investigation of thermal and non-thermal springs in North British Columbia and Yukon Territory.

2. Field

(a) P.F.R.A. is continuing piezometric measurements in the Riverhurst area, around Diefenbaker Lake, Sask., on a four times per year basis since January, 1972.

(b) A number of springs and major groundwater discharge areas were investigated in Northern Yukon and the District of Mackenzie during the summer of 1973./

3. Laboratory

(a) Testing of the combination glass and reference electrode for pH measurements under pressures of up to 3000 psi was delayed by the need for special parts.

(b) Work was started on development of instrumentation of pressure, temperature and H_2O- phase (liquid or solid) in freeze-thaw environments. A resistance frost gauge and thermisters were installed in the experimental plot at the ISPG building in Calgary in November, 1972. An AC ohm meter was developed as the readout instrument for this.

4. Publication

Williams, J.R. and van Everdingen, R.O., 1973. Groundwater investigations in Permafrost Regions of North America. North American Contribution, Permafrost Second Int. Conference, NRC/NAS. Washington, D.C., p. 435-446.

C. WORK IN PROGRESS:

1. Office

(a) Coding of additional analysis and pressure data from petroleum drilling in the Yukon and Northwest Territories.

(b) Correction of data files for Saskatchewan and Alberta.

(c) Inventory of major groundwater discharge areas, winter open water and aufeis occurrences in Yukon Territory and western district of Mackenzie.

(d) Preparation of a paper on "Groundwater in permafrost regions of Canada" for the IHD Permafrost Hydrology Symposium, Calgary, February, 1974.

2. Laboratory

(a) Adaptation and testing of pressure transducers for measurement of pressures in freeze-thaw conditions.

(b) Development of instrumentation for measurement of temperature using diodes.

D. FUTURE WORK:

1. Office

(a) Coding and processing of remaining chemical and pressure data.

(b) Preparation of reports on results of field investigations and laboratory studies.

2. Field

(a) Further investigation of groundwater discharge phenomena in Yukon Territory and District of Mackenzie.

(b) Field testing of "frost" instrumentation.

3. Laboratory

Further development of instrumentation.

E. COMPLETION DATE:

March 1974 for portion of project dealing with data processing (only if additional help can be obtained). Portion of project dealing with influence of permafrost is just starting and no estimate of completion date can be given at this stage.

Project No. GW 67-9 D.W. Lawson

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.

Lawson, D.W., 1971. Improvements in the finite difference solution of two-dimensional dispersion problems. Water Resources Research, 7 (3), pp. 721-725.

Lawson, D.W., 1971. A new method for determining and interpreting dispersion coefficients in porous media. Ph.D. thesis, Univ. Guelph, Guelph, Ontario, Canada.

Lawson, D.W. and D.E. Elrick, 1972. A new method for determining and interpreting dispersion coefficients in porous media. International Symposium on the Fundamentals of Transport Phenomena in Porous Media, ISSS and IAHR, University of Guelph, Guelph, Ontario, Canada, Aug. 7-11, Volume 2, pp. 753-777.

2. Office

(a) An introduction to the theory of physio-chemical tranport phenomena is contained in the above-mentioned paper by Elrick and Lawson.

(b) Laboratory equipment for determining hydrodynamic dispersion coefficients has been designed and it is described in the author's Ph.D. thesis.

(c) Improvements have been made in the finite difference solution of the hydrodynamic dispersion equation (Lawson, 1971a).

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.

(b) The equipment for determining dispersion coefficients has been constructed and a series of experiments have been conducted. These experiments have been interpreted in the paper by Lawson and Elrick.

C. WORK IN PROGRESS:

1. Office

Preparation of a paper on dispersion equations for hydraulically classified flow in porous media.

D. FUTURE WORK:

1. Office

(a) A continuing review of the literature on physio-chemical tranpsort phenomena in porous media.

(b) Development of mathematical models for subsurface water quality problems.

(c) A comprehensive review of groundwater contamination problems and research needs.

E. ESTIMATED COMPLETION DATE:

Continuing.

Project No. GW 67-12 J.A. Vonhof

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. Publications

Vonhof, J.A., 1971. Waste disposal problems near potash mines in Saskatchewan, Canada: XV Cong. Int. Union Geodesy and Geophysics, Moscow, U.S.S.R., Proc. Symp. Pollution of Groundwater (in press).

2. Field

(a) 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.

(b) 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.

(c) 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.

(d) 1970 - A surface resistivity survey was carried out by Dr. H. Lazreg, Water Resources Branch. Seven observation wells and one still well were constructed during the winter of 1970/71.

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

(i) 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.

(ii) A large aquifer system in the basin covering an area of approximately 1,000 square miles.

(iii) 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.

(iv) The presence of badlands topography on the bedrock surface in the vicinity of I.M.C.C. K-2 mine.

(v) The presence of buried valleys filled with sand and gravel, under the waste disposal basin.

(vi) 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:

1. Publications

Vonhof, J.A. Hydrostatic Response- or slug tests as a means to monitor the rate of well development (under review)

Vonhof, J.A. Cypress Hills Formation in Southwestern Saskatchewan and adjacent parts of Southeastern Alberta: A redefinition (under review)

2. Office

Data compilation and analysis and preparation of reports.

3. Field

Continuous recording of observation wells.

D. FUTURE WORK:

1973/74 - Construction of an analog model of the waste disposal basin. During this period a number of publications are expected to be finished. Sequential water sampling and redevelopment of observation wells.

Additional surveys under consideration for this period are:

(a) A study of diagenetic processes of solid waste with respect to changes in permeability and porosity.

(b) Obtain core samples of sediments underlying the brine pond and determine infiltration depth of brine.

E. ESTIMATED COMPLETION DATE:

March 31, 1974.

Project No. GW 70-8 R.O. van Everdingen

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. Publications

Vonhof, J.A. and van Everdingen, R.O., 1973. Subsurface Disposal of Industrial Liquid Wastes. CIMM Bull., vol. 66., p. 108-114.

van Everdingen, R.O. Subsurface disposal of waste in Canada - II. Disposal formation and injection-well hydraulics (in press).

van Everdingen, R.O. Subsurface disposal of waste in Canada - III. Regional evaluation of potential for underground disposal of industrial liquid wastes (in press).

C. PRESENT WORK:

1. Office

(a) Continued survey of relevant literature.

(b) Continuing inventory of data on existing waste-disposal wells.

2. Field

A joint federal-provincial study of subsurface waste disposal in southwestern Ontario was started in 1972 (see project No. GW 72-1).

D. FUTURE WORK:

1. Office

(a) Preparation of reports on southwestern Ontario study (GW 72-1)

(b) Continued survey of literature and inventory of disposal wells in Canada.

2. Laboratory

Compatibility tests on formation and waste samples.

E. COMPLETION DATE:

March 1974, with the possible exception of work under C2 and D2, which depends on technical support staff and outside factors.

Project No. GW 70-11 J.A. Vonhof

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. Publications

Vonhof, J.A., 1970. Joint patterns in tills in western Canada, Geol. Ass. Canada, Annual meeting, Winnipeg, (Abstract).

Vonhof, J.A., 1972. Jointed Tills in Trunk sewer shaft near Sutherland, Saskatoon (in press).

D. FUTURE WORK:

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

E. COMPLETION DATE:

June 1975.

Project No. HR 72-1 J.E. Charron, D.W. Lawson

Deep-Well Disposal, Southwestern Ontario

A. OBJECTIVES:

To produce hydrochemical maps of the area of southwestern Ontario in and around Lambton County that will:

1. indicate the direction of groundwater flow and

2. provide information on the hydrochemical effects of deep-well injection of brines and industrial wastes.

B. PREVIOUS WORK:

1. Office

(a) Available existing data have been collected from the Ontario Department of Mines and Northern Affairs (DMNA). These include: location maps for oil, gas and disposal wells; 2,979 schedule and completion reports for oil and gas wells; 22 schedule and completion reports for brine and other liquid waste disposal wells; a complete feasibility study for one disposal well; 65 formation water analyses plus a number of incomplete groundwater analyses.

(b) Available existing data have also been collected from the Ontario Ministry of the Environment (MOE). These include a printout of data for over 3,800 water wells and 77 groundwater analyses.

(c) Data compilation has been completed. Since there is a considerable denisty of data for a relatively small area, one of

the investigators (JEC) quickly realized that computerized mapping of various subsurface parameters could provide a rapid insight into regional hydrogeology. Among the parameters so mapped were bedrock contours, and depths to and piezometric levels for formations producing fresh, hydrogen sulphide, and salt waters.

2. Field

(a) Hydrogeological mapping was carried out in Lambton County during the summer of 1972, making extensive use of the agricultural soils map, geological maps and air photos.

(b) Sixteen formation water samples were taken from oil wells; well over 100 samples were collected from water wells.

C. WORK IN PROGRESS:

1. Office

(a) Further refinement of the computerized maps, examination and (if warranted) removal of anomalies, review of effects of variations in mapping techniques, etc.

(b) Preparation of hydrochemical maps to show directions of groundwater flow.

(c) A research contract has been awarded to the University of Waterloo for the development of a finite-element model to simulate and give some insight into the behaviour of lost-circulation zones.

D. FUTURE WORK:

Completion of items listed under C above and review of results with MOE officials.

E. COMPLETION DATE:

March 31, 1974.

Project No. GWO 70-2 D. H. Lennox

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 advice and assistance in handling of emergency situation. The request was made at the end of April 1970 on the day following the spill.

C. ORGANIZATION OF PROJECT:

Emergency measures were adopted after a preliminary evaluation of the situation by the well field manager and Mr. D.H. Lennox. 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 simulataneous 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.

In July 1970 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 subsequently 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 was recommended with the following objectives:

1. To obtain a reliable estimate of the total amount of hydrocarbons remaining in the ground at and in the vicinity of the spill site.

2. To determine how far the spilled oil and gas and the groundwater contaminated by them have spread from the spill site, particularly in the direction of the Town of Shippegan's two major producing wells.

3. To review the various methods employed in:

   (a) containing the spill,

(b) minimizing its effects,

(c) purifying the contaminated groundwater,

and to assess the effectiveness of these measures.

4. To make recommendations concerning suitable measures for controlling surface spills of this type.

A contract was awarded in September 1971 to James F. MacLaren Limited to carry out the test drilling and sampling program. The final version of the consultant's report was submitted to the Hydrology Research Division in September 1972.

D. PRESENT STATUS OF PROJECT:

Field studies are complete.

E. FUTURE WORK:

The consultant's report will be suitably modified and revised and published as a Directorate publication.

F. COMPLETION DATE:

March 31, 1974.

Project No. GWO 71-3

D.W. Lawson

Impact of Nitrilotriacetic Acid on Groundwater

A. OBJECTIVES:

To determine the likely maximum concentrations of nitrilotricacetic acid (NTA) in groundwater and its effect on trace metal concentrations and other environmental factors. NTA is a substitute for phosphate in laundry detergents.

B. NATURE OF REQUEST:

Memorandum from the Director of the Inland Waters Branch (now Directorate) dated October 29, 1971.

C. ORGANIZATION OF PROJECT:

This project is part of a program on the environmental impact of NTA which is being coordinated by CCIW.

D. PRESENT STATUS OF PROJECT:

The first phase of the project came to a close on March 9, 1972 when Dr. Lawson presented the results of preliminary sampling in Ontario and Manitoba to a technical research meeting at CCIW. Subsequently, in conjunction with the reduction of phosphate levels in detergents from 20% P_2O_5 to 5% P_2O_5 as of January 1, 1973, the Department became committed to a continuing NTA environmental monitoring program. Thus, the second phase of the project got under way in September 1972 and involves the collection of monthly samples in Manitoba and Ontario. Present plans call for expanding the network to Alberta and Nova Scotia.

E. FUTURE WORK:

Continuing interpretation of the data, modification of the network, and submission of reports to CCIW.

5. Paleoenvironmental Research Program

Project No. GW 67-6 L.D. Delorme

Paleohydrogeology of the Interior Plains of Canada

A. OBJECTIVES:

1. To determine tolerance limits of freshwater ostracodes and other shelled invertebrates 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 and molluscs as a paleoenvironmental 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. On the identity of the ostracode genera *Cypriconcha* and *Megalocypris:* Can. Jour. Zoology, v. 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 Harrington, 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 paleo-ecological 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 Cyclocpprididae. Can. Jour. Zoology, v. 48, no. 2, p. 253-266.

Delorme, L.D., 1970. Freshwater ostracodes of Canada, Part III. Family Candonidae: Can. Jour. Zoology, v. 48, no. 5, p. 1099-1127.

Delorme, L.D., 1970. Freshwater Ostracodes of Canada, Part IV. Families Ilyocyprididae, Notodromadidae, Darwinulidae, and Emtocytheridae, subfamily Cytherideinae: Can. Jour. Zoology, v. 48, no. 6, p. 1251-1259.

Delorme, L.D., 1971. Freshwater Ostracodes of Canada, Part V. Family Limnocytheridae: Can. Jour. Zoology, v. 49, no. 1, p. 43-64.

Delorme, L.D., 1971, in Cvancara, A.M., Clayton, L. Bickley, Jr., W.B., Jacob, A.F., Ashworth, A.C., Brophy, J.A., Shay, C.T., Delorme, L.D., and Lammers, G.E., 1971, Paleolimnology of late Quaternary deposits Seibold site, North Dakota: Science, v. 171, no. 3967, p. 172-174.

Delorme, L.D., 1971. Paleoecology of Holocene sediments from Manitoba using freshwater ostracodes: Geol. Assoc. Canada, Symposium, Spec. Paper No. 9, p. 301-304.

Delorme, L.D., 1971. Paleoecological determinations using Pleistocene freshwater ostracodes: Centre Rech. Pau-SNPA Bull, v. 5, suppl., p. 341-347.

Delorme, L.D., 1972. Groundwater Flow Systems, past and present: 24th Internat. Geol. Congress, Montreal, Canada.

Delorme, L.D., 1972. Freshwater ostracodes (Crustacea) from near Ottawa: Trail and Landscape, v. 6, no. 2, p. 44-47.

Delorme, L.D., 1972. Paleoenvironmental research within the Federal Government: Task Force Rept., Res. Advisor, Inland Waters Directorate, Water Management, Environment Canada.

Delorme, L.D., in Karrow, P.F., Anderson, T.W. Delorme, L.D., and Clarke Jr., A.H. (in preparation). Stratigraphy, paleontology, and age of Lake Algonquin sediments in southwestern Ontario, Canada.

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

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.

(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 our fertilization studies; 51 samples were collected on a 10-day cruise of Lake Winnipeg also in conjunction with the Freshwater Institute, also made on these water samples.

(e) 1979 - 24 cores were collected during the summer of 1969 using a Minutemam Mobile Drill modified to obtain a core. 360 feet of core were obtained producing 1589 samples.

(f) 1970 - 28 cores were obtained using a Minutemam 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.

(g) 1971 - 508 modern samples were obtained of which 195 were from the Okanagan chain lakes in British Columbia and 313 were from the Northwest Territories in conjunction with the inter-disciplinary research project under the Environmental-Social program, Northern pipelines. Chemical analyses were made for all the major ions from these samples.

(h) 1972 - 194 modern samples were obtained from the Yukon Territories in conjunction with the inter-disciplinary research project under the Environmental -Social program, Northern Pipelines. Chemical analyses were made for all the major ions from these surface water samples.

(i) 1972 - March 22 to May 26, on special assignment with the Inland Waters Directorate, office of Research Advisor, as chairman of a Task Force

commissioned to look at "Paleoenvironmental Research within the Federal Government". Report was submitted on May 26, 1972.

3. Office

(a) Computer Sciences of Canada (Calgary) are completing refinements on computer programs previously prepared for paleoenvironmental determinations.

(b) Dr. L. Kalas was hired as a term casual to study the molluscs from the 5000 plus samples collected.

(c) Interest in the expertise acquired through this project for the identification of ostracode species and for ostracode-based paleoenvironmental interpretations remains high. During the period from November, 1970 to August, 1972 twenty-eight such requests were received, principally from Canada and the U.S. but including one from New Zealand as well. Almost 500 samples were involved, among them a number from Zambia, Guam and Kenya.

(d) Dr. Kalas' malacological expertise is now being utilized in a similar way for the identification of snails and molluscs and for paleoenvironmental interpretation.

C. WORK COMPLETED:

1. Systematic collection of Recent freshwater ostracodes and molluscs in the central prairies region and the Territories.

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

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), 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 megalocypridnid ostracodes: Can. Jour. Zoology (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 by use of Principle Component Analysis and Stepwise Multiple Regression Analysis.

(b) To assess mollusca in the same manner.

E. FUTURE WORK:

1. To assess ostracodes as a paleoenvironmental tool

2. To assess mollusca as a paleoenvironmental tool

F. COMPLETION DATE:

April 1973.

Project No. HR 73-3 L.D. Delorme

Paleoenvironmental Research

A. OBJECTIVES:

1. To determine tolerance limits of freshwater ostracodes and molluscs to the chemical and physical parameters from the natural laboratories of ponds, lakes and streams.

2. To determine the rates of both natural and man-induced eutrophication during the past several hundred years in Echo Lake of the Qu'Appelle System in Saskatchewan.

3. To determine the rates of both natural and man-induced eutrophication during the past several hundred years in the Bay of Quinte (North Shore of Lake Ontario), Ontario.

B. PREVIOUS WORK:

1. Publications

Delorme, L.D., and Emmens, D., 1972. Paleoenvironmental research within the Federal Government: Task Force Report to the Inland Waters Directorate, Water Management Service, Environment Canada.

C. WORK IN PROGRESS:

1. Field

(a) 300 modern samples were collected from the Bay of Quinte system for shelled invertebrates. Complete chemical analyses for major ions were made of 300 water samples from the same localities.

(b) Six cores were obtained from Echo Lake (3 sites each with 2 cores).

(c) Four cores were obtained from Big Bay of the Bay of Quinte (2 sites each with 2 cores).

(d) 380 modern benthic samples were collected by CCIW from Lake Superior for study of shelled invertebrates.

2. Office

(a) Development of a trophic state index for use on interpreted paleoenvironmental parameters based on work done by E. Shannon, CCIW.

6. Northern Hydrogeology Program

Project No. GW 69-2

R.L. Harlan

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 Hydrology Research Divisions.

(b) A measurement program has been carried out on an experimental plot at Calgary, Alberta, since the fall of 1968.

2. Office

A mathematical model describing coupled heat-fluid transport in porous media in the presence of freezing and thawing has been developed and solved numerically by finite differences.

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.

4. Publications

Harlan, R.L., 1971, Water transport in frozen and partially-frozen porous media. Proc. 8th Can. Hydrol. Symp. - Runoff from Snow and Ice 1: 109-129.

Harlan, R.L., J.A. Banner and R. Allan Freeze, 1971. Interpretation of electrical-resistance soil-moisture data for a freeze-thaw environment. Can. J. Soil Sci. 51: 249-259.

Harlan, R.L., 1972. Ground conditioning and the groundwater response to winter conditions. Proc. Intern. Symposia on the Role of Snow and Ice in Hydrology, UNESCO Symp. on Properties and Processes (in press).

C. WORK IN PROGRESS:

1. Field

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

2. Office

(a) Work is progressing on the verification of the numerical simulation model using experimentally obtained data from the Calgary and Central Experiment Forest experimental plots.

(b) The application of the theoretically based mathematical model is being extended to the analysis of ground conditioning processes and groundwater and streamflow response under winter conditions.

3. Publications

Harlan, R.L., An analysis of simultaneous heat-fluid transport in partially-frozen porous media., Water Resour. Res., (in press).

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 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

Column experiments involving simultaneous transfer of water and head in a variably saturated, partially-frozen soil are contemplated.

E. COMPLETION DATE:

December 1973.

Project No. GW 71-3 R.L. Harlan

Hydrogeology, Mackenzie Valley

A. OBJECTIVES:

To evaluate groundwater and permafrost conditions in the Mackenzie River Valley and to identify those hydrogeological situations which pose special problems for northern development, in general, and for the design, construction, and operation of an oil and/or gas pipeline system, in particular.

B. PREVIOUS WORK:

A reconnaissance aerial photograph interpretation study of groundwater features and conditions in the Mackenzie River Valley Region has been completed and surficial geology, surficial hydrogeology, and bedrock hydrogeology maps prepared for a 50-mile wide band, approximately 25 miles on each side of the Mackenzie River between Fort Simpson and Fort McPherson, NWT.

Drilling programs have been conducted - at Norman Wells and Inuvik, NWT in 1971 and in the Norman Wells area in 1973. A groundwater observation well network has been installed at Norman Wells to document seasonal pressure fluctuations within the groundwater system and rates of groundwater recharge, discharge, and flow.

C. WORK IN PROGRESS:

Available geologic, hydrologic, geophysical, and borehole data are being compiled and analyzed to define the patterns of regional groundwater flow in the Mackenzie River Valley and to determine the role of groundwater in the regional hydrology. Supplementary to these regional investigations, numerical simulation studies are in progress to evaluate the interrelationships between groundwater and permafrost and to predict quantitatively the consequences of surface disturbances and the construction and operation of an oil or gas pipeline on the configuration of permafrost at depth and on the groundwater regime.

D. FUTURE WORK:

Present plans provide for: (1) field inspection and evaluation of those sites, which after details of a pipeline application are known, present special problems to the construction, operation, or termination of a pipeline system, (2) continuation of modelling studies to evaluate long- and short-term implications of the construction and operation of a pipeline at specific locations along the proposed route, and (3) intensification of work on the hydrodynamic behaviour of water in permafrost.

E. COMPLETION DATE:

1975.

7. Miscellaneous Projects

Remote Sensing - Selected Areas in Alberta

A. OBJECTIVES:

To determine the relative value of various remote sensing techniques in the assessing of the nature of the surface of the earth, with particular reference to the heat budget and hydrology of the surface.

B. PREVIOUS WORK:

1. Publications

Holmes, R.M. and M.D. Thompson, 1972. Infrared remote sensing in quaternary research. Proc. Conf. Geol. Soc. Am., Calgary May 1971 (In press).

2. Field

Preliminary infrared (IR) imagery was obtained of areas in southern Alberta in 1969 and 1970. In 1969 the XIRC North Star aircraft and crew cooperated with the Inland Waters Branch (IWB) in obtaining these data. The imagery was of poor quality and the correlated photography was poorer still. During 1970 IWB obtained an IR Scanner system and our own crews and aircraft were used to obtain data that were considered to be of high quality. No photography was obtained.

During 1971 a scanner system, aircraft and crew were again available. Simultaneous aerial photography was also taken of the 5 selected and representative surfaces in Alberta (Turner Valley, Dalemead, Suffield, Taber, and Foremost). These areas were small in size and relatively convenient to Calgary in order to simplify ground truthing and logistics.

Experimental procedure called for the two (IR scanning and photographing) aircraft to obtain simultaneous coverage of the same surface. Simultaneous ground truthing was done where observers (usually two) took visual observations of the surface, eye level color photographs, as well as thermometric measurement of surface temperature, air and

dew point temperatures. Vegetal characteristics were noted (crown cover, surface cover, species of plant, vigour of vegetation, etc.). The surface hydrology (surface water, soil moisture, etc.) was also noted.

The aircraft obtained thermal IR imagery as well as color and false color IR photographs (9" x 9" positive transparencies).

3. Office and laboratory

All data were reassessed and collated to ensure that ambiguities were absent from the ground truthing. All data were carefully sorted to permit future analysis. Photographs were examined for proper overlap and continuity. Stereo photo pairs were examined for synchronization with ground truth points and some areas were revisited to confirm detail in the imagery.

D. FUTURE WORK:

Analysis of the collected and collated data should help determine the relative merits of thermal IR, false color IR and color imagery in determining characteristics of surface features. All imagery and ground truth data should be analyzed with particular emphasis on relating the surface moisture and water regimes, and the resultant vegetation, to the images obtained.

It was also intended that thermal IR would be used to relate surface heat geometry to similar geometries that might exist in the atmosphere. This was to be accomplished by utilizing data from simultaneous immersion sensing with another aircraft designed for making atmospheric measurements. This procedure could provide meaningful data about the various scales involved in heat and moisture fluxes from the surface.

The principal investigator left the government service at the end of March 1972. Consideration is being given to alternative means of completing the data analysis and evaluation.

E. COMPLETION DATE::

March 31, 1974.

Project No. GW 71-7 H. Ryckborst

Electromagnetic Streamflow Measurements

A. OBJECTIVES:

To develop an economical method based on the principles of electromagnetic induction (EMI) for the instantaneous measurement of streamflows in large rivers, tidal or nontidal, to an accuracy of 5 percent.

B. PREVIOUS WORK:

A feasibility study was carried out during (1) April and May 1971 on the Rideau River and (2) July and September 1971 on the Fraser River to gain a better understanding of the interactions between electrical components of an experimental EMI streamflow measurement system. An uninterrupted series of discrete EMI measurements was subsequently recorded for the Fraser River for the 5-day period September 19 to 23, 1971. Observations during this period of record were made at 10-second intervals. The record was in general appearance consistent with expectations for a record of varying streamflow as should be revealed by the variation in electrical currents generated by the interaction of Fraser River flow with the earth's magnetic field.

C. WORK IN PROGRESS:

A manuscript describing the results of the experiment has been prepared and is under review.

D. FUTURE WORK:

Completion of the manuscript and submission to a journal.

E. COMPLETION DATE:

March 31, 1974.

Project No. GWO 69-4 D. H. Lennox

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 carried out by consultants; the Hydrology Research Division was to 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 division. The decision was made subsequently to adopt a piped-in surface-water supply.

E. COMPLETION DATE:

Completed.

Project No. GWO 70-3 D.H. Lennox

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 Environment 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 (Hydrology Consultants Ltd.) 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 was suggested, 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.

The consultant's recommendation to conduct additional testing was subsequently acted upon and a second contract awarded to

Hydrology Consultants Ltd. Aquifer tests were conducted both in unconsolidated sedimentary deposits located along the central bedrock valley occupied by Lac Phillipe, Lac Mousseau and Meach Lake and in fractured Precambrian bedrock at selected sites in more elevated areas of the park. The consultant's report in its final version was received in August 1972.

D. PRESENT STATUS OF PROJECT:

Completed.

Project No. GWO 71-2

D. H. Lennox

High-Yield Aquifers Saskatchewan-Nelson Basin

A. OBJECTIVES:

1. To provide background information on groundwater resources of the Saskatchewan-Nelson Basin.

2. To identify high-yield aquifers in the basin and to discuss their groundwater quality.

3. To estimate safe groundwater yields and groundwater in storage on an aquifer or aquifer system basis in order to arrive at corresponding estimates for the whole of the basin area.

4. To discuss or speculate on the interactions between major groundwater systems and existing or proposed surface-water storage or diversion works.

5. To recommend specific future groundwater programs to fill in knowledge gaps, either those currently existing or those arising from the implementation of future development programs.

B. ORGANIZATION OF PROJECT:

This survey was initiated in the early months of 1971 at the request of the Saskatchewan-Nelson Basin Board. It was a federal-provincial project coordinated by the Inland Waters Directorate and contributed to by three provincial agencies: Water Resources Division, Alberta Department of the Environment; Saskatchewan Research Council; Water Resources Branch, Manitoba Department of Mines and Natural Resources.

C. PRESENT STATUS OF PROJECT:

All three provincial agencies have submitted chapters describing groundwater occurrence and high-yield aquifers for those

areas of each province lying within the Saskatchewan-Nelson Basin. These chapters also provided information to meet the other project objectives. Introductory and summary chapters were prepared by the Inland Waters Directorate. The whole report has been thoroughly reviewed by all the agencies involved and a final version prepared and submitted to the Saskatchewan-Nelson Basin Board in June, 1972. The report was published as Part F (Groundwater) Appendix 7 (Environmental Considerations) of the Saskatchewan-Nelson Basin Board's report on "Water Supply for the Saskatchewan-Nelson Basin".

D. COMPLETION DATE:

1972.

8. Active Project Index

8. Active Project Index

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* C - Completed or in final publication stage

D - Discontinued

P - Progressing

S - Starting

8. Active Project Index

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van Everdingen, R.O.	GW 67-4, GW 70-8

Investigator	Project Nos.
Vonhof, J.A.	GW 67-12, GW 70-11
Weyer, K.U.	HR 73-4
Wojtek, E.	GW 68-2

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Project	Short Title	Last Catalogue Giving Detailed Information
GW 67-1[a]	Natural groundwater recharge	1969-70
GW 67-2[a]	Hydrogeology, Oak River basin	1969-70
GW 67-2[b]	Water balance, Good Spirit Lake	1970-71
GW 67-3	Permafrost hydrogeology	1969-70
GW 67-7	Assiniboine basin	1968-69
GW 67-8	Sea-water intrusion, P.E.I.	1970-71
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
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GW 68-3	Groundwater flow in to Lake Ontario	1970-71
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GW 68-9	Infrared anomalies	1970-71
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GW 69-1	Pumping experiments, coastal wells	1970-71
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