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WATER RESOURCES OF THE HUDSON BAY LOWLAND: A LITERATURE REVIEW AND ANNOTATED BIBLIOGRAPHY

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ABSTRACT

This report is divided into three sections: 1) a literature review which includes descriptions of studies carried out in water quality, water quantity, and oceanography, as well as summaries of data available in these areas and an assessment of data gaps and research needs; 2) an annotated bibliography with keywords and work location, arranged in alphabetical order by author; and 3) a keyword index listing publications by subject.

RÉSUMÉ

Le rapport est divisé en trois sections: 1) étude bibliographique, y compris description d'études de la qualité et du débit de l'eau et d'études océanographiques, ainsi que résumés des données disponibles dans ces domaines et évaluation des lacunes et des besoins de la recherche; 2) bibliographie annotée avec mots clefs et localisation des travaux, par ordre alphabétique et par auteur; et 3) index des mots clefs, énumérant les publications, par sujet.

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1. INTRODUCTION

As part of an environmental baseline study initiated by the Department of the Environment (DOE), Ontario Region in 1976, the Inland Waters Directorate was responsible for preparing a literature review on the water resources of the Hudson Bay Lowland[4]. It is one of a series of literature reviews to be produced by the agencies involved in the study. In 1978 a bibliography of all published and unpublished literature on the HBL was completed[5]. This was followed in 1979 by a literature review and annotated bibliography on the vegetation of the HBL[6].

It was originally intended to report only on HBL-related literature but, because of the paucity of citations, selected reviews of other wetland literature for North America and Europe are also included.

The literature review, annotated bibliography and keyword index are the major components of the report. Water quality, water quantity and oceanographic studies and data reports are summarized in the literature review. Gaps in knowledge and future research needs based on the literature review and assessment are discussed. The annotated bibliography is arranged alphabetically by author, and includes a brief summary of the publications. A location index is used to describe geographically where the work was done. For example, if the report was based on work completed in the HBL, the location will be cited as Ontario, Manitoba or Quebec. If the work was done outside the Lowland, the province or country in which it was done will be given. For each annotation there are keywords describing subject areas. In addition to the keywords, there is a keyword index arranged alphabetically by subject for quick cross-referencing. In the keyword index, citations within parentheses indicate that the work was not done in the HBL.

The Hudson Bay Lowland as defined by Hustich[7] is the area to the south and west of Hudson and James bays where Paleozoic strata overlie the Canadian Shield, or

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[4] Hudson Bay Lowland may be referred to as HBL or Lowland in this report.

[5] Haworth, S.E., Cowell, D.W. and Sims, R.A. 1978. Bibliography of published and unpublished literature on the Hudson Bay Lowland. Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont. Report O-X-273. 270 p.

[6] Sims, R.A., Riley, J.L. and Jeglum, J.K. 1979. Vegetation, flora and vegetational ecology of the Hudson Bay Lowland: a literature review and annotated bibliography. Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont. Report O-X-297. 177 p.

[7] Hustich, I. 1957. On the phytogeography of the subarctic Hudson Bay Lowland. Acta Geog. 16(1):1-48.

the furthest limit of submergence by marine water following melting of the Pleistocene glaciers. It covers approximately 324,000 km^2, of which over 80% is in Ontario. Over a large portion of the Lowland, a layer of peat 1-3 m deep has accumulated. Although there are several major rivers crossing the HBL, most of the area is poorly drained because of the gentle slope toward Hudson and James bays.

Water plays an important role in the HBL because it is used for transportation, municipalities, and recreation, and supports fish and wildlife populations on which many of the inhabitants depend. It is a very important nesting and summer feeding habitat for several species of migratory birds. For the proper management of such a vast water resource, a sound knowledge of the physical, chemical, biological and hydrological characteristics of the area is essential.

2. WATER QUALITY

Introduction

For the purpose of this review, measurements of water quality have been defined as those measurements made of water and the life it supports which describe the quality of the aquatic environment. Such measurements reflect physical, chemical, bacteriological and biological properties. The water types included in this report are surface, groundwater and precipitation.

Water Quality Studies

Surface and groundwater

Although little has been written on the water quality of wetlands in the HBL, considerable research has been done in this area in other parts of North America and Europe. An excellent summary of the terminology and concepts of wetland ecology is given by Jeglum et al.[8]

Sjörs (1959) was the first to do comprehensive ecological studies of wetlands in the HBL that included water quality sampling. His two study areas, Hawley Lake and the Attawapiskat River, are discussed in general physiographic and vegetational terms. Detailed results of the field work were published later (Sjörs 1961, 1963). One water sample was collected and numerous pH determinations were made at the Hawley Lake study area, while four water samples were collected at the Attawapiskat site. The water quality data and on-site pH readings were used in his wetland classification of the study areas.

Sjörs' classification was based on two main units: ombrotrophic and minerotrophic peatlands. The ombrotrophic peatland, generally termed bog,

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[8] Jeglum, J.K., Boissonneau, A.N. and Haavisto, V.F. 1974. Toward a wetland classification for Ontario. Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont. Inf. Rep. O-X-215. 54 p.

receives its water supply from precipitation. Its supply of mineral nutrients is very small in comparison with a minerotrophic peatland or fen which derives its water supply from waters that are or have been in contact with the mineral soil. Ombrotrophic peatlands show little variability while minerotrophic peatlands are quite variable. Sjörs further subdivided fens into poor intermediate, rich and extremely rich categories. These classifications are based on the chemical composition of water and plant indicators.

The four water samples collected in the Attawapiskat study showed the variability that can be expected in water chemistry. Samples were collected from a bog, poor fen, rich fen and the Attawapiskat River. Calcium concentrations were 0.5 mg/L for the bog, 1.7 mg/L for the poor fen, 8.9 mg/L for the rich fen and 15.8 mg/L for the river, while pH was 4.5 for the bog, 4.8 for the poor fen, 7.1 for the rich fen and 8.0 for the river.

Arthur (1976) carried out a vegetation study near the James Bay coast northwest of Moosonee. Twenty-three water samples were analyzed for major ions, nutrients and conductivity. The only interpretation of the water chemistry data consisted of correlating chloride concentrations with high and low tide.

Studies were undertaken in the Moosonee area to assess the feasibility of determining a broad biological baseline of the area (Jordan 1972). Water samples were collected at 11 sites from James Bay upstream of the confluence of the Moose and Abitibi rivers. Analyses were done for physical parameters, nutrients, bacteriological parameters, metals and pesticides. High mercury concentrations were reported at the confluence of the Moose and Abitibi rivers.

Several studies have been undertaken in Europe and North America on peatland development and classification systems based on vegetation and water chemistry. Some of the more recent work includes that of Gorham (1950) in which he found the water chemistry in two Swedish fens to be constant in some situations and quite variable in others. Sjörs (1950) related pH, conductivity and ionic composition in Swedish mire waters to vegetation patterns and found that pH was the better indicator of vegetation types. Gorham (1956) related the ionic composition of bog and fen waters in the English Lake District to plant distributions. Tolpa and Gorham (1961) did a similar study on Polish bogs and compared their findings with those of the English Lake District. The authors concluded that the main differences found were related to atmospheric transport of sea salt.

Peatland development in northern Britain has been detailed by Gorham (1957) in terms of changes in water chemistry and vegetation. Other environmental factors affecting development such as climate, topography and geology are discussed. Bellamy (1966) has des-

cribed the development of a mire in terms of vegetation, hydrological and water quality changes that take place in the process. Vegetation, habitat conditions, peatland development and water chemistry are discussed by Mörnsjö (1969) in his detailed study of peatlands in southern Sweden.

Boelter and Verry (1977) describe peatlands and their development and summarize ecological processes taking place in them. The paper is based on research that has taken place at a research station in Minnesota since the late 1950s. The streamflow chemistry and annual nutrient yield studies are cited in the water quality section of the paper.

Bellamy (1966) classified mires in Ireland on the basis of hydrology, floristics and water chemistry. He found that the mires under investigation fell into three main ecological categories, namely, rheophilous mires which are located in flowing mineral-rich waters, transition mires which show a decreasing influence of mineral-rich waters, and ombrophilous mires which are not influenced at all by mineral waters, their only source of nutrients being precipitation.

Schwintzer (1978) studied five fens in Michigan, identifying prevalent and dominant vegetation species as well as determining the water chemistry of the groundwater. The study sites were found to fit very well the descriptions and definitions of fen as proposed by Jeglum et al. (1974).

There has been considerable North American wetland research relating water chemistry to waterflow patterns; however, none of these studies was carried out in the HBL. Sparling (1966) measured flow rates at a number of sites in Algonquin Park and related these to various parameters while Heinselman (1970) discussed the effects of slope and drainage patterns on water chemistry. Vitt (1975) found that calcium is depleted as water flows through a fen. He also noted that pH and cation content of the groundwater greatly influenced the vegetation pattern of the study area.

Ingram (1967) investigated the hydrological aspects of mires in Europe and has detailed in his paper the transport of ions by moving water, the vertical movement of water, the ionic content and distribution of water, and ionic uptake by plants.

Malmer (1963), in his work on ionic concentrations in mire waters in Sweden, shows that in the more acidic waters there is no anion cation balance, and he attributes this to organic and inorganic constitutents of the water. Gorham (1966) postulates that the free acid in bogs comes from atmospheric sources, from the oxidation of sulphur compounds in the peat and from cation exchange.

Oxidation-reduction in wetlands has been investigated by Pearsall (1939), Pierce (1953), 1957) and Bonner (1968). Pearsall ascertained that the change

from oxidizing to reducing conditions in natural water systems could take place at very low oxygen levels. Pierce found in his studies that the mineral content of groundwater and its degree of stagnation were correlated with specific conductance and oxidation-reduction potential. Bonner found that microorganisms were important in the activation of redox systems. Other findings showed that negative potentials are indicative of oxygen deficiencies and increased solubility of aluminum, iron and manganese.

Given (1975) summarizes the state of the art in the environmental organic chemistry of wetlands. Most of the literature he cites is of North American and European origin. He discusses the ecological aspects of peatlands, ion exchange characteristics of organic and mineral soils, and the ion exchange behavior of peats and organic acids. Given also examines the effects of human development on wetlands and cites the Florida Everglades as an example.

Little has been written on the variability of mire waters or on proper sampling techniques for minimizing this variability. Summerfield (1974) found large seasonal variations in major ions at four wetland sites in England. He also found spatial variation at each site and recommended a specific sampling methodology for minimizing such variation.

Precipitation chemistry

Very little in the way of precipitation chemistry data has been collected in the HBL. Kramer (1973, 1975, 1976) reports on data collected at stations located in the southern part of the Moose River drainage basin. Samples were analyzed for major ions, metals and nutrients. In Kramer's reports, time trends, atmospheric loadings and parameter distributions are discussed and the data are presented in the form of statistical summaries, parameter distribution maps and loadings graphs.

In 1977, the Canadian Network for Sampling Precipitation (CANSAP) was established by the Atmospheric Environment Service of Environment Canada. Two stations are located in the Lowland, one at Moosonee and the other at Churchill. Two other stations are located on the Canadian Shield, at Pickle Lake and Trout Lake. These stations are situated in drainage basins whose water eventually flows through the Lowland. Samples are collected on a monthly basis and analyzed for pH, conductance, acidity, major ions and nutrients. Results of analyses are published quarterly.

Water Quality Data Reports

Data summaries

Work done by Thomas (1958, 1959 and 1973) provides background information on the water quality of rivers, lakes and municipal water supplies in the Hudson Bay drainage basin. A detailed account of sampling methodology and analytical procedures has been published (Thomas 1953). Six

surface water stations and four municipal water supplies in the HBL were sampled. Most of the data reported are from stations situated in the Shield portions of the drainage basins. Although the reports are mainly data summaries, some general observations and interpretation are included as well. Accompanying maps indicate sampling locations, sampling frequency and the hardness of municipal water supplies.

Lammers (1973) describes the province's involvement in the Northern Ontario Water Resources Study. He outlines briefly the breakdown of provincial and federal work and summarizes what is available in the series of data reports produced. Five data reports were produced by the Ontario Water Resources Commission (Anon. 1969, 1970, 1972a) and the Ministry of the Environment (Anon. 1974a and 1975). The reports summarize results from approximately 30 surface and groundwater stations located in the Lowland as well as another 60 stations located in the Canadian Shield. Two interpretive reports based on these five data reports have been written. Wang and Chin (1978) detail the hydrogeology and groundwater quality. The chemical quality of water from crystalline rocks, sedimentary rocks and overburden is discussed by river basin and compared with recommended criteria for public water supplies. Roy (1979) has interpreted the data collected on water chemistry, sediment chemistry and phytoplankton from lakes in the five major river basins draining into Hudson and James bays. Twelve of the 28 lakes studied are located in the Lowland.

The Ontario Ministry of Natural Resources has collected water quality data on 20 lakes and five rivers in the Hudson Bay Lowland. Data on dissolved oxygen, pH, alkalinity, total dissolved solids, Secchi disc and color are available at the Ministry's Moosonee office.

Water quality networks

Both the federal and provincial governments operate water quality monitoring networks that include stations located in the Lowland or on drainage basins that flow through the Lowland. The most recent publication by the Ontario Ministry of the Environment (Anon. 1980) includes 1979 data on 15 water quality stations in the Moose River basin, all of which are located on the Canadian Shield. The most recent federal station list for Ontario shows that, of 18 stations currently being monitored in the Hudson Bay drainage basin, eight are situated in the Lowland (Fig. 1).

Both the Ontario Ministry of the Environment (Networks Unit, Water Resources Branch, Toronto) and Environment Canada (Data and Instrumentation Section, Water Quality Branch, Ottawa) operate water quality data banks. Retrievals may be requested from either agency.

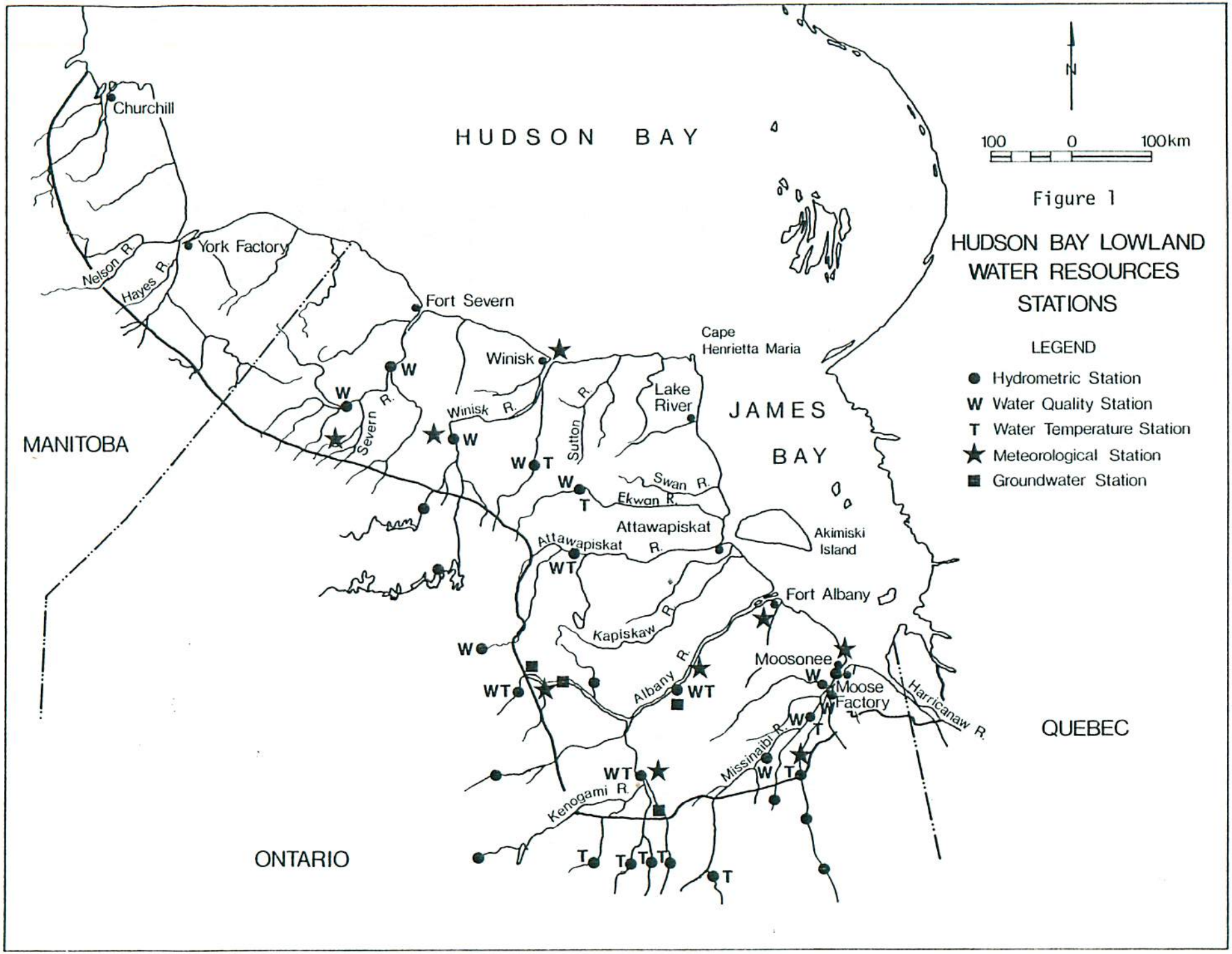

Figure 1

HUDSON BAY LOWLAND WATER RESOURCES STATIONS

LEGEND

- Hydrometric Station
- W Water Quality Station
- T Water Temperature Station
- Meteorological Station
- Groundwater Station

Assessment of Gaps and Research Needs

Available water quality data for the Lowland are very limited, and continuous records with infrequent sampling at specific sites are restricted to a few rivers. Since development will likely occur within the next decade, baseline studies must be undertaken to quantify present water quality levels with which future conditions may be compared. In addition to determining existing quality, it is essential to understand the ecosystems and processes operating within them so that a predictive capability can be developed to determine the environmental impact of man's activities.

Studies must be intiated to determine spatial and temporal variations in the water quality of the major rivers such as the Moose, Albany, Attawapiskat, Winisk and Severn in order to develop an adequate water quality data base for the Lowland.

The water chemistry characteristics of various wetland types must be determined, preferably as part of an ecological classification of the Lowland by a multidisciplinary team. Results of such surveys would then be mapped into ecologically significant units and used for environmental assessment purposes.

Specific water quality studies complementing hydrologic studies should be set up as the need arises. Nutrient budget and loading calculations would be done in conjunction with groundwater movement and drainage basin studies. An understanding of the interaction between hydrologic processes and water quality in wetlands is important if we are to predict the consequences of human impacts.

A comprehensive precipitation chemistry network which would be more representative of the HBL needs to be established. As increasing attention is being focused on the long range transport of pollutants, data are required for accurate determinations of atmospheric deposition for both precipitation and dry fallout and of their resultant effects on Lowland ecosystems. The existing network could be increased and located with an expanded meteorological network as is recommended in the next section.

3. WATER QUANTITY

Introduction

The hydrologic balance is the numerical expression of the water regime in an enclosed system. It includes the processes of precipitation, evaporation, transpiration, surface water flow, groundwater flow and water storage. In addition to providing information on these processes for a given area, a complete hydrologic balance can be useful in the prediction of processes in similar areas for which only limited data are available. The study of only a limited number of hydrologic components, such as hydraulic conductivity and groundwater levels, can also

contribute information valuable to the the understanding of peatland ecosystems, as water movements and the associated levels of dissolved nutrients are the dominant factors in determining the patterns and development of such ecosystems (Ingram 1967, Sjors 1976).

Hydrologic Studies

Hydrologic balance studies

No published reports of hydrologic balance studies within the HBL were found. Such studies in wetlands appear to have received only limited attention in North America. Kadlec (1976) studied the hydrologic balance of a peatland in Michigan for one summer, and found that there was minimal vertical flow through the clay layer beneath the peat, with the result that the groundwater level was dependent largely on precipitation and evapotranspiration.

The hydrologic balance of wetlands has received considerably more attention in Europe. Romanov (1968) outlined a complex method of computing a hydrologic balance for wetlands which involves some questionable assumptions. A great deal of data that are unavailable at the present time would be required for testing the applicability of this method. However, Romanov's work is the most comprehensive available on wetlands hydrology. He covers a wide range of topics in detail, and provides much useful information.

Various components of hydrologic balances of bogs and fens are discussed by Dooge (1972). His paper also contains numerous references to the work conducted by others in this field in Europe. (Most of the European work has been on bogs, as their ombrotrophic nature makes them easier to study than fens.) The reports of Eggelsmann (1972) and Bavina (1972) are two examples of European efforts in the area of wetland hydrologic balance studies.

Surface water and groundwater studies

It is assumed that "surface water" refers to rivers, lakes, ponds and pools in a peatland matrix while "groundwater" refers to the water at or below the wetland surface as well as that contained in the mineral soil.

A joint federal-provincial study of the water resources of northern Ontario was begun in 1966. The objectives of the study, as discussed by Lammers (1973), were to assess the quantity and quality of water resources, to determine present and future requirements for such waters, and to assess alternative possibilities for the utilization of the waters locally or elsewhere through diversions. Most of the provincial publications contain data with no interpretation, as is discussed in the next section of this report. The federal reports were the result of feasibility studies of potential diversions and hydroelectric generation on the major rivers flowing through the Lowland (Anon. 1973). A summary of the federal

studies was prepared by Ellis (1974).

The influence of bogs on streamflow was studied by Verry and Boelter (1972). The authors concluded that neither perched bogs nor groundwater bogs have a regulating effect on streamflow.

The hydraulic conductivity of wetlands has been the subject of many studies, but little of this work has been in the HBL. Rycroft et al. (1975a) gave a good summary of the theoretical considerations and of the work done by others. Boelter (1965), Irwin (1968), Dai and Sparling (1973) and Rycroft et al. (1975b) gave descriptions of their efforts to measure hydraulic conductivity and to interpret the results. The effects of hydraulic conductivity on the vegetation in wetlands has been studied in Europe. Ingram (1967) gave a very good discussion of this topic.

Fluctuation of groundwater levels in peatland is another component of the hydrologic balance that has not been studied in the HBL. Bay (1965, 1968, 1970), Boelter (1964, 1966, 1972) and Dai et al. (1974) have studied this subject in the United States and near Cochrane, Ontario.

Studies of the thermal regime of some rivers in the Manitoba portion of the Lowland have been carried out. MacKay and MacKay (1965) statistically analyzed the relation of freezeup and breakup dates to air temperature, while Newbury (1968) studied ice processes and ice effects on the Nelson River.

Hydrologic Data Reports

Surface and groundwater data

The major source of surface water hydrometric data for the HBL is Water Survey of Canada, Department of the Environment.

Data are available for 16 continuous recording hydrometric gauges operated by Water Survey of Canada within the HBL (Fig. 1). Some of these stations have been in continuous operation since the mid 1960s. Four are on rivers whose headwaters are located within the HBL, while the other 12 are on rivers for which a large portion of the flow comes from the Precambrian Shield. An additional 15 hydrometric stations are located on major rivers in the Precambrian Shield within 80 km of the HBL-Precambrian Shield boundary (Fig. 1). The daily mean water levels and discharges for these stations are published by the Department of the Environment (1965b), and monthly mean and extreme streamflows for the available period of record are also published (Anon. 1970-).

The above-mentioned hydrometric data have been used to prepare maps of mean annual runoff in the form of isolines. Such maps can be used to give an indication of the runoff for a given basin, but are insufficient for hydrologic balance studies.

Additional streamflow data were collected and published by the Ontario Water Resources Commission and the Ontario Ministry of the Environment as part of

the Northern Ontario Water Resources Studies (Anon. 1969, 1970, 1972a, 1974, 1975). The maps contained in the reports show the location and groundwater observation stations (discussed below). Most of the streamflow data were intermittent rather than continuous, and the periods of record and number of stations were limited, and therefore are not sufficient for calculating hydrologic balances.

The majority of available information on groundwater in the mineral soil has been collected by provincial agencies as part of the same studies. The data consist of static water level records at four wells in the Albany River Basin, none of which are currently operating, and are contained in the above-mentioned publications. In addition, the Water Resources Branch of the Ministry of the Environment has records on water wells drilled in the area.

Data on the thermal regime of water in the HBL are limited. The Department of the Environment has published data on river water temperatures at seven hydrometric stations within the HBL as well as at six hydrometric stations in the Precambrian Shield within 80 km of the HBL border (Anon. 1976). Occasional measurements have been taken since the establishment of these stations. Richards and Webb (1971) recorded summer surface water temperatures on four lakes near Ogoki in the HBL for four years, while Burbidge and Lauder (1962) published maps of average freezeup and breakup dates. According to MacKay and MacKay (1965), additional data on freezeup and breakup dates are contained in the Hudson Bay Company archives.

Meteorological data

Precipitation data have been collected at nine stations, of which six are southeast of the Albany River and three are west of the Winisk River (Fig. 1) (Anon. 1916, 1965a). The station at Moosonee has been collecting data since 1878, and has continuous records since 1940. The other eight stations have records covering periods that range from eight to twelve years.

Bruce (1968) prepared an atlas of rainfall intensity-duration-frequency maps for all of Canada, including the HBL. Average values of precipitation for all areas of Canada are given in Chapman and Thomas (1968) and in a publication by the Department of the Environment (Anon. 1972c).

In addition to precipitation, air temperature is recorded at Winisk, Fort Albany and Moosonee. Other parameters recorded at Moosonee are air pressure, vapor pressure, cloud cover, visibility, windspeed and direction, daily bright sunshine and pan evaporation. Meteorological records are also available for locations in the Precambrian Shield near the HBL. These records are published by the Department of the Environment (Anon. 1916-). In addition, average temperature values for Canada are contained in Anon. (1972c).

Assessment of Gaps and Research Needs

It is evident from the literature review that little work has been done in the HBL in the area of comprehensive hydrologic balance studies. Even studies limited to portions of the hydrologic balance, such as surface water or groundwater, have been neglected in the HBL. Furthermore, information on precipitation, evapotranspiration, groundwater movements and surface flow, which are the main components of a hydrologic study, is limited.

The major need is for comprehensive hydrologic studies of representative areas within the Lowland. These studies need to be on two scales, that of the individual drainage basin and that of specific bogs, fen, or swamp bodies. The results of such studies will lead to an understanding of the hydrologic processes and will assist in the prediction of these processes in other areas in the Lowland. These studies will require intensive collection of meteorological and hydrologic data in the study areas.

The network of meteorological stations in the Lowland is inadequate. There are no stations located between the Albany and the Winisk rivers, and two-thirds of the stations at other locations in the Lowland collect only precipitation data. The network needs to be expanded considerably to provide sufficient baseline meteorological data for the Lowland.

Available data on the thermal regimes of surface waters in the HBL are limited. Baseline data on water temperature, ice thickness, freezeup and breakup dates are needed to assist in the evaluation of the environmental impacts of any future developments.

4. OCEANOGRAPHY

The existing data base for the Hudson/James Bay region is sufficient to provide a general description of physical characteristics such as surface circulation patterns, extent and periods of ice cover, salinity, temperature distribution, etc. Cardinal and Caron (1978) in their bibliography on the oceanography of Hudson, James and Ungava bays provide a comprehensive list of work done in this field. Of the 160 pages of references in the publication, 140 pages are related specifically to Hudson and James bays. However, very little of this information is directly applicable to the HBL area with the exception of hydrographic surveys of the Moose, Albany and Attawapiskat rivers (Langford 1963, Wade 1976). Other site-specific information on the coastal waters the HBL is provided in the description of natural seabed conditions, ice formation, tides, meteorological data, etc., as an aid to navigation (Anon. 1974b). Furthermore, there is considerable detailed information on the tides and tidal currents of Hudson and James bays (Manning 1950, 1951; Dohler 1966, 1967; Godin 1972, 1974; Freeman 1976).

This type of information is limited with respect to the objectives of the HBL program which is aimed more at establishing a reference state for environmental impact assessments. In this regard, a better understanding of coastal processes is essential as it is the land/water interface which is the least understood, yet most susceptible to impacts. Very little information from studies done in other coastal areas can be applied to the HBL coast, as it is unique in physical characteristics, with tidal flats up to several kilometres wide and extreme rates of isostatic rebound in the evolutionary processes. As a result of these unique characteristics, the HBL coast provides essential habitat for many estuarine species and plays an important role in shore stabilization, flood control and water purification.

Further research is required on physical processes including estuarine circulation and freshwater discharge, salt water intrusion, sediment transport systems and coastal geomorphology. This would permit estimates of the movement of pollutants through river systems and along the coast, the evolution and stability of feeding and breeding habitats, and the dynamics of the freshwater budget, and would generally provide a sound basis upon which other evolutionary processes may be determined such as the dynamics of peat formation. Such information would be a valuable addition to coastal mapping of the HBL and is essential for determining alterations to natural systems and consequent impacts.

5. ANNOTATED BIBLIOGRAPHY

ANON. 1916-. Monthly record, meteorological observations in Canada. Dep. Environ., Atmosph. Environ. Serv., Toronto, Ont. (monthly).

A monthly report of meteorological recordings at stations in Canada. Stations in the HBL are at Moosonee, Fort Albany and Winisk.

Keywords: meteorology, air temperature, precipitation

Location: Ont. HBL, coastal area

ANON. 1962-. Water levels. Dep. Fish. Oceans, Marine Serv., Ottawa, Ont. (annual).

An annual publication of the times and heights of high and low tides derived from records obtained at various permanent gauging stations in Canada.

Keywords: tidal times, gauging stations

Location: Man. HBL, Que. HBL, Ont. HBL

ANON. 1965a. Supplementary precipitation data. Dep. Environ., Atmosph. Environ. Serv. (semi-annual).

A listing of precipitation data at gauges throughout Canada. Six gauges are located in the HBL at Agusk Lake, Ranger Lake, Ogoki Post, Ghost River, Onakawana, and Mammamattawa.

Keywords: precipitation

Location: Ont. HBL

ANON. 1965b. Surface water data Ontario. Dep. Environ., Inland Waters Dir., Ottawa, Ont. (annual).

These reports list the years's streamflow records at the Water Survey of Canada gauges, of which there are 14 in the HBL.

Keywords: streamflow

Location: Ont. HBL.

ANON. 1966. Canadian tide and current tables, vol. 4, Arctic and Hudson Bay. Dep. Fish. Oceans, Can. Hydrogr. Serv., Ottawa, Ont. (annual)

Contains predicted times and heights of high and low tides for reference ports in the Canadian Arctic, Hudson Bay and James Bay, and information and tidal differences which permit calculation of tides at secondary ports.

Keywords: tide heights, tide times, tidal differences

Location: Man. HBL, Ont. HBL, Que. HBL

ANON. 1969. Data for northern Ontario water resources studies 1966-1968. Water Res. Bull. 1-1. Ont. Water Res. Comm., Toronto, Ont. 131 p.

Bulletin 1-1 is a presentation of data collected from 1966

to 1968 by the Hydrologic Data Branch and the Surveys and Projects Branch. Field work consisted of measuring streamflow, rainfall, snowfall and ground water levels and collecting water quality samples. Some geologic mapping and bathymetric studies were carried out at selected sites. Work was done in the five major river basins of the Arctic watershed. Water quality sampling was done on lakes, rivers and wells at approximately 100 locations. Of these, approximately one-third were in the Lowland, and about two-thirds were in the Albany basin. Only three wells were analyzed for water quality and all were located in the Albany basin in the Lowland.

Keywords: streamflow, water quality, groundwater, snowfall, precipitation, bathymetry, geology

Location: Ont. HBL

ANON. 1970. Data for northern Ontario water resources studies 1968-1969. Water Res. Bull. 1-2. Ont. Water Res. Comm., Toronto, Ont. 57 p.

This report contains a summary of data collected in 1968 and 1969. As in Bulletin 1-1, stream flow, rainfall, snowfall and groundwater levels were monitored. Water quality and geological studies were also carried out. The water quality sampling was done in the Albany, Severn and Winisk basins. Approximately 65 sites were sampled, one-third of which were in the Lowland. At 13 of these sites, nine of which were in the Lowland, well water was sampled.

Keywords: streamflow, water quality, groundwater, snowfall, precipitation, geology

Location: Ont. HBL

ANON. 1970-. Historical stream flow summary-Ontario. Dep. Environ., Inland Waters Dir., Ottawa, Ont. (triennial).

Contains a summary of monthly and annual discharges, annual maximum instantaneous discharges, annual maximum and minimum daily discharges, identification of the extremes recorded for the period of record and annual total discharge for streamflow gauges in Ontario, including the HBL.

Keywords: streamflow

ANON. 1972a. Data for northern Ontario water resources studies 1970. Water Res. Bull. 1-3. Ont. Water Res. Comm., Toronto, Ont. 135 p.

Bulletin 1-3 presents data collected during the 1970 field season. Measurements of streamflow, snowfall, and groundwater levels as well as bathymetric, water quality and geologic surveys were carried out. Phytoplankton analyses were conducted on surface waters and routine chemical analyses were carried out. Of the 175 sites, 110 were well water, the majority of them in the Albany and Moose basins in the Shield area. Only 23 sites were sampled in the Lowland.

Keywords: water quality, phytoplankton, groundwater, geology, snowfall, streamflow

Location: Ont. HBL

ANON. 1972b. Harmonic constants and associated data for Canadian tidal waters, Vol. 4, Arctic and Hudson Bay. Dep. Fish. Oceans, Ottawa, Ont.

A publication containing the tidal constituents and associated data derived from tidal records collected at various sites in the Arctic, Hudson Bay and James Bay.

Keywords: harmonic constants, tidal records

Location: Man. HBL, Ont. HBL, Que. HBL

ANON. 1972c. Temperature and precipitation 1941-1970, Ontario. Dep. Environ., Atmosph. Environ. Serv., Downsview, Ont. 90 p.

A climatological series of six volumes which provide normal values of temperature and precipitation elements for all regions (Atlantic, Quebec, Ontario, Prairies, British Columbia, Territories) in Canada based on the period 1940 to 1970 as recommended by the World Meteorological Organization.

Keywords: air temperature, precipitation

Location: Man. HBL, Ont. HBL, Que. HBL

ANON. 1973. Northern Ontario water resources studies. Summary report on engineering feasibility and cost investigations. Dep. Environ., Inland Waters Dir., Ottawa, Ont. 39 p.

The summary of a series of reports considering the technical and economic aspects of diversion and power developments on the Severn, Winisk, Attawapiskat and Albany rivers.

Keywords: water diversions, power development

Location: Ont. HBL

ANON. 1974a. Data for northern Ontario water resources studies 1971. Water Res. Bull. 1-4. Ont. Min. Environ., Toronto, Ont.

Monitoring of streamflow, groundwater levels, snowfall, water chemistry, water biology and hydrogeologic studies was carried out for the 1971 field season. Of the 67 surface waters sampled in the five basins, only 17 were in the Lowland. Thirty-five wells in the Albany and Attawapiskat basins, none of which were located in the Lowland, were sampled for water quality. Water samples were collected for phytoplankton, zooplankton and chlorophyll analyses in the Albany, Attawapiskat and Moose basins.

Keywords: streamflow, water quality, water biology, groundwater, snowfall, hydrogeology

Location: Ont. HBL

ANON. 1974b. Sailing directions. Labrador and Hudson Bay and James Bay including Chesterfield Inlet. 3rd ed. Dep. Environ., Ottawa, Ont. 335 p.

The text is divided into three sections. Part A contains general navigation information including ship routing, charting, navigational publications, buoyage, radio aids, pilotage, regulations and submarine cables. Part B includes general geographic information and broad descriptions of port facilities. Part C describes natural conditions such as seabed, ice information, tides, tidal streams and currents, meteorological information and tables.

Keywords: hydrographic surveys, navigation information, port facilities

Location: Man. HBL, Ont. HBL, Que. HBL

ANON. 1975. Data for northern Ontario water resources studies 1972-1973. Water Res. Bull. 1-5. Ont. Min. Environ., Toronto, Ont. 234 p.

Data on streamflow, groundwater levels, snowfall, water chemistry, water biology and hydrogeology are included in Bulletin 1-5. Well drilling and surficial geological studies were undertaken as well. Water analyses were done on surface waters in the Winisk, Ekwan, Severn, Attawapiskat, Albany and Moose basins. In addition, well water from 16 wells in the Moose basin was analyzed. Approximately half of the water quality samples selected were from sites located in the Lowland. Chemical analyses were done on sediments at 34 locations and phytoplankton and zooplankton samples were collected from selected surface waters.

Keywords: streamflow, water quality, groundwater, water biology, sediment chemistry

Location: HBL, Ont

ANON. 1976. Water temperatures of selected streams in Ontario. Dep. Environ., Water Surv. Can., Guelph, Ont. 279 p.

Water temperatures at six Water Survey of Canada streamflow gauges in the HBL have been measured on an intermittent basis. The period of record is usually 1967-1975.

Keywords: water temperature

Location: Ont. HBL

ANON. 1980. Water quality data Ontario lakes and streams, 1979. Ont. Min. Environ., Toronto, Ont. Vol XV. 657 p.

This is a printed summary of water quality data collected by the Ministry in Ontario. It includes data for stations in the Moose River basin, all of which are located on the Canadian Shield.

Keywords: water quality data

Location: Ont. HBL

ARTHUR, M.D., and MARSHALL, I.F. 1976. Vegetation survey, nine kilometers northwest of North Point, southwestern James Bay, summer of 1975. Ont. Min. Nat. Resour., Toronto, Ont. Office of the Scientific Advisor. 27 p.

The report deals mainly with the vegetation found on three transects extending approximately 1000 m inland from the intertidal zone. Six water quality stations were established on a small stream that crossed one of the transects. Twenty-three samples were collected and analyzed for chloride, calcium, magnesium, sodium, total Kjeldahl nitrogen, total phosphorus and conductivity. The only interpretation of the water quality data related chloride to the salt content of the stream at high and low tides.

Keyword: vegetation zonation, salt tolerance, water quality, salinity

Location: Ont. HBL, North Point

BARBER, F.G., GODIN, G. and MURTY, T.S. 1972. On the oceanography of James Bay, the tides of James Bay and the circulation in James Bay. Dep. Environ., Marine Sci. Br., Ottawa, Ont. Ms. Rep. Ser. No. 24. 193 p.

The three reports contained within the manuscript consider the possible influence of the development of proposed hydroelectric power projects on the marine environment and rivers draining into James Bay.

Keywords: environmental impact, tides, circulation, tidal progression, cotidal charts

Location: Ont. HBL, Que. HBL

BAVINA, L.G. 1972. Water balance of swamps in the forest zone of the European part of the USSR. Hydrology of marsh-ridden areas. p. 297-303 *in* Proc. Minsk Symp., Minsk, USSR.

"This paper considers the main problems involved in the investigation and calculation of the water balance components of swamps,....and presents results of the calculation of water balance components in typical upland and lowland swamps. Then examines the relationship between the hydrological regime of swamps and that of rivers by the comparison of the runoff from swamps as calculated by the water balance equation and the runoff from river basins." (in original abstract)

Keywords: water balance, runoff

Location: USSR

BAY, R.R. 1965. Influencing soil-moisture relationships in undrained forested bogs. p. 335-343 *in* Proc. Internatl. Symp. For. Hydrol., Penn. State Univ., University Park, Penn.

The author discusses the factors that control the groundwater elevation in a bog, and the hydrologic implications.

Keywords: groundwater

Location: United States

BAY, R.R. 1968. The hydrology of several peat deposits in Northern Minnesota, U.S.A. p. 212-218 *in* Proc. 3rd Internatl. Peat Congr., Quebec City, Que.

The paper discusses the relationships between groundwater levels, precipitation and runoff in a bog and a fen. The author concludes that local hydrologic characteristics influenced the hydrology of bogs, but did not influence fens. Height of the water table and the type of peat were good indicators of available storage capacity. Runoff was found to be dependent upon the groundwater level.

Keywords: groundwater, precipitation, runoff

Location: United States

BAY, R.R. 1970. Water table relationships on experimental basins containing peat bogs. p. 360-368 *in* IASH-UNESCO Symposium on the Results of Research on Representative and Experimental Basins, Wellington, New Zealand. Publ. No. 96.

Precipitation, runoff and water level data were collected on five perched bogs and one low bog, all of which were forested. Preliminary results of clearing parts of one bog indicated that it had little effect on the water level.

Keywords: precipitation, runoff, groundwater

Location: United States

BELLAMY, D. 1966. Peat and its importance. Discovery, XXVII (6):12-16.

The author discusses the development of a mire system in a hypothetical situation, describing in detail the vegetational, hydrologic and chemical changes that take place in the various stages of its development.

Keywords: peat development, hydrology, water chemistry, vegetation

Location: Ireland

BELLAMY, D. and BELLAMY, R. 1966. An ecological approach to the classification of the lowland mires of Ireland. Proc. R. Irish Acad. 65B (6):237-251.

The author undertook floristic analysis and collected water samples at selected mires in Ireland. These were classified into three main ecological categories on the basis of hydrology: 1) rheophilous mires located in flowing waters rich in dissolved minerals, 2) transition mires which show a decreasing influence of mineral-rich waters, and 3) ombrophilous mires which are not influenced at all by mineral waters.

Keywords: mire classification, hydrology, water chemistry

Location: Ireland

BOELTER, D.H. 1964. Water storage characteristics of several peats in situ. Soil Sci. Soc. Am. Proc. 28:433-435.

The author discusses the water storage capabilities of several types of peat as well as the hydrologic implications.

Keywords: groundwater

Location: United States

BOELTER, D.H. 1965. Hydraulic conductivity of peats. Soil Sci. 100(4):227-231.

The vertical and horizontal hydraulic conductivities of different peat types were measured in Minnesota peats in the field and in the laboratory.

Keywords: hydraulic conductivity

Location: United States

BOELTER, D.H. 1966. Hydrologic characteristics of organic soils in Lake States watersheds. J. Soil and Water Conserv. 21(2):50-53.

The author found that the volume of water stored in peat bogs and the rate of release of this water are dependent on the type of peat.

Keywords: groundwater

Location: United States

BOELTER, D.H. 1972. Preliminary results of water level control on small plots in a peat bog. Proc. 4th Internatl. Peat Congr., Helsinki, Finland.

The author maintained water table levels in test plots in a peat bog at depths of 0.0 m, 0.3 m and 0.6 m. He monitored the change in surface elevation and the evapotranspiration for the plots. The highest water table resulted in a rise in the surface elevation and the highest evapotranspiration while the two lower water levels resulted in ground subsidence and lower evapotranspiration.

Keywords: groundwater, evapotranspiration

Location: United States

BOELTER, D.H. and VERRY, E.S. 1977. Peatland and water in the northern lake states. USDA For. Serv., Gen. Tech. Rep. NC-31. 22 p.

The authors cover the basic principles of peatland ecology as elucidated through watershed research in the 1950s and 1960s. The report discusses the development of peatlands and the cause of their diversity, their vegetation properties and organic soil characteristics, and finally the hydrology and water chemistry of various peatland types.

Keywords: peatland ecology, streamflow, vegetation, water chemistry

Location: United States

BONNER, F.T. and RALSTON, C.W. 1968. Oxidation-reduction potential of saturated forest soils. Soil Sci. Soc. Am. Proc. 32:111-112.

The authors discuss redox potentials measured over a 25-day incubation period and conclude that microorganisms play a vital role in the activation of redox systems in waterlogged soils in situations favorable to microorganism activity. They found that negative potentials are indicative of oxygen deficiencies and increased solubility of iron, aluminum and manganese.

Keywords: redox potential, saturated soils, microorganism

Location: United States

BRUCE, J.P. 1968. Atlas of rainfall intensity-duration-frequency data for Canada. Dep. Transp., Meteorol. Br., Climatol. Stud. No. 8. 31 p.

Rainfall intensity maps for Canada are shown for durations of 5, 10, 15, 30 and 60 minutes and 24 hours for return periods of 2, 5, 10 and 25 years. Techniques to compute rainfall amounts for return periods and for durations other than those for which the maps are available are outlined.

Keywords: precipitation

Location: Ont. HBL, Man. HBL, Que. HBL

BURBIDGE, F.E. and LAUDER, J.R. 1957. A preliminary investigation into breakup and freezeup conditions in Canada. Dep. Transp., Meteorol. Br., CIR-2939, TEC-252, 26 p.

This report contains maps of average freezeup and breakup dates for Canada.

Keywords: breakup, freezeup

Location: Ont. HBL, Man. HBL Que. HBL

CARDINAL, A. et CARON, S. 1978. Bibliographie des travaux océanographiques effectués dans les baies de James, d'Hudson et d'Ungava. Groupe Interuniv. Rech. Oceangr. Que., Rapport à la Societé d'Enérgie de la baie James. 160 p.

The authors list references on geological, physical and biological oceanography for Hudson, James and Ungava bays. Other oceanography citations that do not fall within these classifications are included under a general information section for each area.

Keywords: oceanography: geographical, physical, biological; bibliography

Location: Ont. HBL, Que. HBL

CHIN, V.I. and Eddie, J.D. 1978. Northern Ontario water resources studies, general characteristics and frequency analyses of streamflows. Ont. Min. Environ., Toronto, Ont. Water Res. Rep. 11a.

This foldout leaflet provides flow-duration and flow-frequency analyses of locations in northern Ontario that were instrumented with automatic streamflow recorders and for which several years of continuous daily records are available. Streamflow characteristics are generalized and stations are grouped together on the basis of similarities in their flow-duration curves.

Keywords: streamflow, precipitation

Location: Ont. HBL

DAI, T.S. and SPARLING, J.H. 1973. Measurement of hydraulic conductivity of peats. Can. J. Soil Sci. 53: 21-26.

The measurement of hydraulic conductivity of peats in a northeastern Ontario peatland is described. Various lengths of piezometer chamber were used to measure both vertical and horizontal components of hydraulic conductivity at a number of peatland sites. A significant correlation between the differential heads and hydraulic conductivity is demonstrated.

Keywords: hydraulic conductivity

Location: Ontario

DAI, T.S., HAAVISTO, V.F. and SPARLING, J.H. 1974. Water level fluctation in a northeastern Ontario peatland. Can. J. For. Res. 4:76-81.

Depths to water level and changes due to local climate were dissimilar in five peatland conditions in northeastern Ontario. These include ombrotrophic bog, stagnant bog, lagg, and lake sites. Water level fluctuation was affected by inflow run-off, seepage and evapotranspiration.

Keywords: groundwater, runoff, evapotranspiration

Location: Ontario

DOHLER, G.E. 1966. Tides in Canadian waters. Dep. Mines Tech. Surv., Can. Hydrogr. Serv., Marine Sci. Br., Ottawa, Ont. 14 p.

The main forces that cause tides are discussed and the resulting tidal features in Canadian waters including Hudson and James bays are described.

Keywords: tidal features

Location: Man. HBL, Ont. HBL
Que. HBL

DOHLER, G.E. 1967. Tides and tidal currents in Hudson Bay. p. 824-837 *in* C.S. Beal, *Ed.* Science and history of Hudson Bay. Dep. Energy, Mines, Resour., Ottawa, Ont.

Details of the tides and tidal currents in Hudson Bay and the geographical features which influence them are described.

Keywords: tides, tidal currents

Locations: Man. HBL, Ont. HBL

DOOGE, J. 1972. Water balance of bogs and fens. Hydrology of marsh-ridden areas. p. 233-271 *in* Proc. Minsk Symp., Minsk, USSR.

This paper describes briefly the components of the hydrologic cycle and the various forms of the water balance equation. It then deals with the classification of bogs and fens to which the water balance equation is to be applied. It discusses the nature of peat, along with the various moisture characteristics (hydraulic conductivity, water holding capacity, coefficient of drainage) of peat. It deals with the individual components of the hydrologic cycle which enter into water balances, and the overall water balance and the relationship between the individual components. The paper contains numerous references to the work of others in Europe.

Keywords: water balance, hydraulic conductivity, evaoration, runoff, groundwater

Location: Europe

EGGELSMANN, R. 1972. The water balance of lowland areas in northwestern region of the FRG. Hydrology of marsh-ridden areas. p. 335-367 *in* Minsk Symp., Minsk, USSR.

A brief discussion of peat hydrology is followed by the establishment of relationships "between soil moisture, groundwater, runoff morphology, evaporation and microclimate in catchments having different plant associations. The water balance and water storage in peat soils and their influence on the hydrography of the landscape before and after drainage and cultivation are examined" (in original abstract). Each subject is discussed very briefly and data are limited.

Keywords: water balance, ground water, soil moisture, evaporation, runoff

Location: Federal Republic of Germany

ELLIS, A.L. 1974. Northern Ontario water resources studies-general description. Dep. Environ., Environ. Manage. Serv., Ottawa, Ont. 37 p.

The author describes and summarizes studies by the federal government of potential diversions and power developments on the Severn, Winisk, Attawapiskat and Albany rivers.

Keywords: water diversions, power development

Location: Ont. HBL

FREEMAN, N.G. and MURTY, T.S. 1976. Numerical modelling of tides in Hudson Bay. J. Fish. Res. Bd. 33(10):2345-2361.

A two-dimensional numerical model is developed to study the co-oscillating and independent tides in Hudson Bay. Over all, the model provides good qualitative agreement with shore-based data and can be used to interpret tidal propagation in the Hudson-James bays system.

Keywords: numerical model, tidal propagation

Location: Man. HBL, Ont. HBL, Que. HBL

GIVEN, P.H. 1975. Environmental organic chemistry of bogs, marshes and swamps. p. 55-80 *in* G. Eglington, *Ed.* Environmental Chemistry, Vol. 1. Chem. Soc., London, Eng.

Given discusses the characteristics of wetlands as well as their ecological significance. He treats the environmental chemistry of wetlands very thoroughly, discussing organic and inorganic interactions and organic constituents in great detail.

Keywords: environmental chemistry, ion exchange behavior, humic and fulvic acids

Location: United States

GODIN, G. 1974. The tides in eastern and western James Bay. Arctic 27(2):104-110.

The tides in eastern and western James Bay are reconstituted for the summers of 1947 and 1950 from recent cotidal charts, and the predictions are compared with some observations made during those years. The predictions and the observations are found to agree in general, thereby confirming the validity of the cotidal charts.

Keywords: cotidal charts

Location: Ont. HBL, Que. HBL

GORHAM, E. 1950. Variation in some chemical conditions along the borders of a *Carex lasiocarpa* fen community. Oikos 2(2):217-240.

"A study has been made of some chemical conditions (pH in water and peat, Ca, Na, K and conductivity in water) along the borders of *Carex lasiocarpa* abundance in two middle Swedish mires of different type. The results indicate that, while in some locations chemical conditions may be relatively constant along this boundary, in others they may vary widely. In this connection the need for detailed local studies of the factors governing plant distribution is pointed out." (in original abstract)

Keywords: water chemistry, chemical variability, plant distribution

Location: Sweden

GORHAM, E. 1956. The ionic composition of some bog and fen waters in the English Lake District. J. Ecol. 44:142-152.

Twenty-five water samples were collected for analyses of specific conductivity, pH and major ions. Each sampling area is described in detail in terms of its water chemistry and plant distribution, and ionic interrelations are disussed.

Keywords: bog, fen, ionic, composition, plant distribution

Location: England

GORHAM, E. 1957. The development of peatlands. Quart. Rev. Biol. 32:145-166.

Bog development is described in northern Britain. Chemical changes in the water and plants during peatland development and environmental factors affecting development such as climate, topography, geology and anthropogenic effects are discussed. The interactions of the environmental factors affecting development and their interrelationships are stressed.

Keywords: peatland development, water chemistry, climate, topography

Location: Britain

GORHAM, E. 1966. Some chemical aspects of wetland ecology. p. 20-30 *in* Proc. 12th Muskeg Res. Conf., May 19-20, 1966. Natl. Res. Counc. Can. Tech. Memo No. 90.

The terms "minerotrophic" and "ombrotrophic" are defined by Gorham in his discussion of water chemistry of bogs and fens in the English Lake District. He postulates that the free acid in bogs comes from atmospheric sources, from the oxidation of sulphur compounds in the peat and from cation exchange. Atmospheric ion supply is discussed and the chemical composition of rain and bog waters is compared.

Keywords: water chemistry, atmospheric deposition, fens, bogs

Location: Britain

HEINSELMAN, M.L. 1970. Landscape evolution, peatland types and the environment in the Lake Agassiz peatlands natural area, Minnesota. Ecol. Monogr. 40:235-261.

This is a very detailed study which relates the vegetation and peatland types to topography, water flow patterns and water chemistry. Landscape evolution of the area is also discussed. The author describes how peatland relief affects water quality and relates chemical gradients to slope and drainage patterns.

Keywords: landscape evolution, peatland types, waterflow patterns, topography, water chemistry

INGRAM, H.A.P. 1967. Problems of hydrology and plant distribution in mires. J. Ecol. 55: 711-724.

The author discusses the probable causes and the concept of "water tracks". Hydrological aspects of mires such as transport of ions by moving water and vertical movement of water are detailed. Water chemistry is discussed in terms of ionic content and distribution and ionic uptake by plants.

Keywords: hydrology, water chemistry, water tracks

Location: Europe

IRWIN, R.W. 1968. Soil water characteristics of some Ontario peats. p. 219-223 *in* Proc. 3rd Internatl. Peat Congress, Quebec City, Que.

"Investigations of physical properties of reclaimed peat soils from seven commercial agricultural areas in Ontario show the variation between these soils to be small. Problems in sampling are discussed. Field measurements were made to determine the saturated in situ hydraulic conductivity. The average value of 5.7 x 10^{-4} cm/sec is less than many fine-grained mineral soils. There was significant differences in vertical and horizontal hydraulic conductivity. Laboratory measurements were made to determine specific gravity, ash content, bulk density, void ratio, permeability and porosity. The water retention characteristic curve shows that peat soils yield water slowly as tension is increased." (in original abstract)

Keywords: hydraulic conductivity

Location: Ontario

JORDAN, D.C. 1972. Microbial ecological study of the Canadian sub-Arctic and low Arctic regions. Progress report of a feasibility study supported by the Research Advisory Board of the University of Guelph. 24 p.

The study was undertaken to determine the feasibility of establishing a broad biological baseline so that any deterioration may be detected in the future. The majority of work was carried out in the Moosonee area and included microbial biomass activity studies, soil studies, water chemistry, sediment and fish studies.

Keywords: biological baseline, ecological studies, microbiological

Location: Ont. HBL

KADLEC, R.H. 1976. Surface hydrology of peatlands. Freshwater Wetlands and Sewage Effluent Disposal Symp. Univ. Mich., Ann Arbor, Mich.

The author discusses the hydrologic components of a water balance with reference to a peatland in Michigan. The discussion of each component is brief.

Keywords: water balance, runoff, precipitation

Location: United States

KRAMER, J.R. 1973, 1975, 1976. Fate of atmospheric sulphur dioxide and related substances as indicated by chemistry of precipitation. Dep. Geol., McMaster Univ., Hamilton, Ont.

The rain chemistry stations in Kramer's work were located in the Sudbury area of northern Ontario; six of these were in the Arctic drainage basin. The purpose of the study was to determine amounts and types of chemical constituents washed and scavenged from the atmosphere. Kramer also determined the source of

the constituents, their background levels and the resultant effects of the precipitation additions.

Keywords: precipitation chemistry, atmospheric loadings, time trends, scavenging

Location: Ontario

LAMMERS, W. 1973. Objectives and scope of water resources study in northern Ontario by the Ministry of the Environment. p. 104-111 *in* Proc. Symp. on the Physical Environ. of the Hudson Bay Lowlands. Guelph, Ont.

The author gives a detailed overiew of the rationale and background of the study. He describes the hydrometric and water quality networks initiated, as well as other work done on meteorology and hydrology in the Arctic drainage basin. Water resource evaluation studies and water use studies were also carried out under the terms of reference for the study.

Keywords: streamflow, water quality, meteorology, water resources, water use

Location: Ont. HBL

LANGFORD, C.J. 1963. Moose River and approaches. Survey of tides, currents, density and silt. Dep. Mines Tech. Surv., Can. Hydrogr. Serv., Ottawa, Ont. 94 p.

This report is on a survey of the tides, tidal streams and currents in the lower reaches of Moose River and its seaward approaches. In the course of this survey measurements of the silt in suspension and of the density at a series of depths from near surface to near bottom water layers were obtained at a number of sites. Representative samples of the material on the riverbed, shoals and foreshores were also obtained. The cores and soil samples obtained were subjected to a petrographic analysis by the Geological Survey.

Keywords: tides, currents, silts, soil samples

Location: Ont. HBL

MACKAY, D.K., and MACKAY J.R. 1965. Historical records of freeze-up and break-up on the Churchill and Hayes rivers. Geogr. Bull. 7 (1):7-17.

The paper discusses freezeup and breakup dates extracted from Hudson Bay Company records. A statistical analysis is made of the data and an attempt is made to relate the dates to air temperature.

Keywords: breakup, freezeup

Location: Man. HBL

MALMER, N. 1963. Studies on mire vegetation in the Archaean area of southwestern Gotland. Botaniska Notiser 116:249-256.

The author looked at the relationship between specific conductivity and the concentration of ions in mire waters. He found

that in some of the more acidic waters there was not equivalence between cations and anions and attributed this to the organic and inorganic constituents as well as to the acid-base status of the waters.

Keywords: specific conductivity, cation, anion, fen, bog, humus, colloids

Location: Sweden

MANNING, T.H. 1950. Notes on tides along the south Hudson Bay and west James Bay coast. Arctic 3:95-100.

The author presents a qualitative description of the tides from Moosonee to York Factory based on visual observations taken while he was engaged in establishing astronomical control positions.

Keywords: tides

Location: Ont. HBL

MANNING, T.H. 1951. Remarks on the tides and driftwood strand lines along the east coast of James Bay. Arctic 4(2):122-130.

A comparison and description of tides along the east coast of James Bay as observed with a tide scale at various locations from Long Island to Moose River. The effects of wind and formation of driftwood strandlines are discussed in general terms.

Keywords: tides, driftwood strandlines

Location: Que. HBL, Ont. HBL

MÖRNSJÖ, T. 1969. Studies on vegetation and development of a peatland in Scania, South Sweden. Opera botanica No. 24.

This is a very detailed peatland study which encompasses descriptions of the area, its vegetation, habitat conditions, deposits and development of peatlands. Water quality aspects of the paper include interpretation of samples collected for pH, specific conductivity, Na, Ca, K, Mg, Mn, Fe, Cl, SO_4, N, H_2S and redox.

Keywords: physiography, vegetation habitat, water chemistry, stratigraphy, peatland development

Location: Sweden

NEWBURY, R. 1968. The Nelson River: a study of subarctic river processes. Ph.D. Thesis, Johns Hopkins Univ., Baltimore, Md.

The author discusses formation and characteristics of the Nelson River, definition and analysis of ice processes, and the effect of ice in river channels.

Keywords: river morphology, ice processes, ice effects

Location: Man. HBL, Nelson River

PARSONS, M.L. 1969. Groundwater movement and subsurface temperatures in a glacial complex, Cochrane District, Ontario. Ph.D. Thesis, Univ. Mich., Ann Arbor, Mich.

The author discusses groundwater flow and its effect on the subsurface temperature distribution for a location in the Clay Belt near Cochrane. The work is not directly applicable to the HBL.

Keywords: groundwater

Location: Ontario

PEARSALL, W.H. and MORTIMER, C.H. 1939. Oxidation-reduction potentials in water-logged soils, natural waters and muds. J. Ecol. 27(2):483-501.

Products of oxidation such as nitrate, sulphate and ferric iron were found in soils, waters and muds with redox potentials greater than 350 mv at pH 5, whereas below 350 mv, ammonia, sulphide and ferrous iron were present. The authors found that redox potential is influenced by the presence of oxygen and that the change from oxidizing to reducing conditions in natural water systems may take place when oxygen levels are at 8% saturation or less.

Keywords: oxidation-reduction, oxygen saturation, water chemistry

Location: Britain

PIERCE, R.S. 1953. Oxidation-reduction potential and specific conductance of groundwater: their influence on natural forest distribution. Soil Sci. Soc. Am. Proc. 17: 61-65.

Lowland and peat soil groundwater analyses carried out in Wisconsin and Ontario show relationships between the properties of groundwater and the natural distribution of forest stands. Specific conductance, oxidation-reduction, dissolved oxygen and total hardness were measured. Mineral content of groundwater and its degree of stagnation were found to be correlated with specific conductance and oxidation-reduction potential.

Keywords: oxidation-reduction, specific conductance, groundwater

Location: United States and Canada

PIERCE, R.S. 1957. Groundwater, its nature, properties and effects on forest growth. Ph.D. Thesis, Univ. Wisconsin.

"This study was concerned with the effect of physical and chemical properties of groundwater on forest growth. The investigations covered broad geographic regions including northern Ontario, Wisconsin, the Missisippi Delta and the Gulf Coast in northern Florida. Aside from the physical aspects of groundwater, particular attention was paid to its chemical and electro-chemical properties as

expressed by the activity of free hydrogen ions, reduction potential and specific conductance." (from original abstract)

Keywords: groundwater, chemical, electro-chemical, specific conductance, reduction potential

Location: United States and Canada

PIKULA, R.J., WANG, K.T. and ROY, A. 1971. Northern Ontario water resources survey. Ont. Water Resour. Comm., Div.Water Res., Toronto, Ont.

A reconnaissance survey of surface water and groundwater resources was done in five major basins in Ontario draining into Hudson Bay. It involved water balance studies and the collection of hydrometric, water quality and other water use data.

Keywords: water balance, runoff, groundwater

Location: Ont. HBL

RICHARDS, T.L. and WEBB, M.S. 1971. Water temperature and evaporation regime and freeze-up characteristics of selected lakes in northern Ontario. Dep. Environ., Atmosph. Environ. Serv., Toronto, Ont. Climatol. Stud. No. 18. 53 p.

The surface water temperatures for the summer months from 1966 to 1969 were measured for Missisa Lake, Wabmeig Lake and two unnamed lakes in the HBL. The monthly mean evaporations were estimated using these data and meteorological records.

Keywords: water temperature, evaporation, freeze-up

Location: Ont. HBL near Ogoki

ROMANOV, V.V. 1968. Hydrophysics of bogs. Israel Program for Scientific Translations, 1968 (original version published in 1961). 229 p.

Topics covered in the book include: structure of peat deposits, water properties of bogs and moisture movement in them, thermal properties of bogs, freezing of bogs, evaporation from bogs, and water balance of bogs. The term "bog" also includes fens, but the emphasis is on bogs in the strict sense.

Keywords: water balance, groundwater, hydraulic conductivity, runoff, evaporation

Location: USSR

ROY, A.C. 1979. Northern Ontario water resources studies: The water quality of selected lakes in the Arctic watershed of Ontario. Ont. Min. Environ., Toronto, Ont. Water Resour. Rep. 11c. 95 p.

"This report utilizes data from 28 lakes and bogs that were studied intensively to characterize the water quality of the various lakes within the study area. On the basis of morphology, water

chemistry and phytoplankton populations, the 28 lakes are divided into five general groups. Three groups consisting of a total of sixteen lakes illustrate the general characteristics of lakes on the Precambrian Shield. One group consisting of three bogs and another group consisting of nine lakes illustrate the general characteristics of bogs and lakes on the Hudson Bay and James Bay Lowland." (in original abstract)

Keywords: water chemistry, sediment chemistry, phytoplankton

Location: Ont. HBL

RYCROFT, D.W., WILLIAMS, D.J.A. and INGRAM, H.A.P. 1975a. The transmission of water through peat, I. Review. J. Ecol. 63:535-556.

Theoretical considerations of hydraulic conductivity are discussed, along with methods of measuring it in the field. The attempts of others to measure hydraulic conductivity and their results are discussed.

Keywords: hydraulic conductivity

Location: Great Britain

RYCROFT, D.W., WILLIAMS, D.J.A. and INGRAM, H.A.P. 1975b. The transmission of water through peat, II. Field experiments. J. Ecol. 63:557-568.

The authors used the Kirkham seepage tube method in an attempt to determine hydraulic conductivities. The effects of time, head, and degree of humification on the hydraulic conductivity were studied.

Keywords: hydraulic conductivity

Location: Great Britain

SCHWINTZER, C.R. 1978. Vegetation and nutrient status of northern Michigan fens. Can. J. Bot. 56:3044-3051.

Five fens in Michigan were examined for vegetation and water chemistry and were compared with descriptions of fens reported by Jeglum et al. (1974). Shallow groundwater samples were collected at three sample sites in each fen and were analyzed for pH, calcium, magnesium and total alkalinity. All sites were found to be minerotrophic with pH ranging from 5.7 to 7.0 and calcium concentrations from 11.0 to 75.0 mg/L.

Keywords: water chemistry, fens, minerotrophic, vegetation

Location: United States

SJÖRS, H. 1950. On the relation between vegetation and electrolytes in North Sweden mire waters. Oikos 2(2):241-258.

Sjörs discusses his rationale for, and method of, correcting pH and conductivity determinations for mire waters. The author found that pH is more strongly related to wetland vegetation types than is salt content of the water. The vegetation groups as defined by Du Rietz (1949) have definite but

wide ranges for pH and even wider ranges for salt content.

Keywords: pH, conductivity, pH vegetation correlation, electrolyte vegetation correlation

Location: Sweden

SJÖRS, H. 1959. Bogs and fens in the Hudson Bay Lowlands. Arctic 12(1):12-19.

This paper deals with a general physiographic and vegetational description of the two study areas visited by the author in 1957. His work at Hawley Lake and in the Attawapiskat area were published in more detail in subsequent papers in "Contributions to Botany".

Keywords: physiography, vegetation, pH, major ions, bogs, fens

Location: HBL, Hawley Lake and Attawapiskat

SJÖRS, H. 1961. Forest and peatland at Hawley Lake, northern Ontario. Natl. Mus. Can. Bull. No. 171. Contrib. to Bot. 1961. p. 1-31.

Sjörs describes in detail the physiographic and vegetational attributes of the study area. In this discussion of peatland classification he notes that there are great similarities in the vegetation composition of peatlands in northern Europe and eastern Canada. Only one water sample was collected and that was from Hawley Lake. It was analyzed for pH, conductivity, Ca, Mg, Na, K, total Fe, CO_3, HCO_3, S_4 and Cl. Numerous pH determinations were taken from surface waters.

Keywords: topography, vegetation, peatland classification, water chemistry

Location: Ont. HBL, Hawley Lake

SJÖRS, H. 1963. Bogs and fens on the Attawapiskat River, northern Ontario. Natl. Mus. Can. Bull. No. 186. Contrib. to Bot. 1960-61. p. 45-133.

The author describes the study area in detail in terms of its physiography and vegetation. Four water samples were collected and the analytical results were related to the vegetation and to the trophic types of peatland. Analyses were done for pH, conductivity, Fe, Ca, Mg, K, Na SO_4, Cl, HCO_3, loss on ignition and residue on ignition. Several field pH readings were taken. Ombrotrophic and minerotrophic peatlands, their structure and occurrence are described in detail. Sjörs also included a section on stratigraphy, succession and the potential resources of the area.

Keywords: physiography, vegetation, trophic types, water chemistry, stratigraphy, succession

Location: Ont. HBL, Attawapiskat-Muketei River confluence

SPARLING, J.H. 1966. Studies on the relationship between water movement and water chemistry in mires. Can. J. Bot. 44(6):747-758.

The author briefly discusses two methods of measuring the flow of water through mires. The rates of water movement were measured at a number of sites in Algonquin Park and the water chemistry was related to flow rates for specific conductivity, oxygen saturation, pH, iron, manganese and aluminum.

Keywords: water movement, water chemistry, mires, minerotrophic bog, acid fen

Location: Ontario

SUMMERFIELD, R.J. 1974. The reliability of mire water chemical analysis data as an index of plant nutrient availability. Plant and Soil 40:97-106.

Concentrations of Ca, Mg, Na, K, and Fe as well as conductivity were shown to have large seasonal variations at four mire sites in England. The fact that these variations were also evident with horizontal distance led the author to the conclusion that samples should be collected (1) at the exact rooting depth of the species under investigation, (2) within 10 cm of a specific plant, and (3) at a specific time of year.

Keywords: mire water, mineral nutrient content, sampling methodology

Location: England

TALLIS, J.H. 1973. Studies of southern Pennine peats. J. Ecol. 61 (1): 1-22.

Some of the components of hydrology and erosion are discussed for a peatland, with the emphasis of the study on a single gully. Many assumptions are made.

Keywords: runoff, groundwater, erosion

Location: Great Britain

THOMAS, J.F.J. 1953. Scope, procedure and interpretation of survey studies. Dep. Mines Tech. Surv. Ottawa, Ont. Water Surv. Rep. No. 1. 69 p.

This report outlines the sampling procedures and methods of analysis used for subsequent water survey reports covering the major drainage basins in Canada. It also contains a section on the reporting of analytical results and their interpretation.

Keywords: sampling procedures, analytical methods, data interpretation

Location: Canada

THOMAS, J.F.J. 1958. Churchill River and Mississippi River drainage basins in Canada, 1952-1954. Dep. Mines Tech. Surv., Ottawa, Ont. Water Surv. Rep. No. 9. 53 p.

Report No. 9 includes water quality data on surface waters and municipal water supplies in the Churchill drainage basin in Alberta, Saskatchewan and Manitoba. Although no surface water data are available for the Lowland, data are available showing the quality of rivers flowing into the Lowland. Chemical analyses were done on the Fort Churchill municipal water supply.

Keywords: water quality, municipal water supplies, water use

Location: Man. HBL, Churchill River Basin

THOMAS, J.F.J. 1959. Nelson River drainage basin in Canada, 1953-1956. Dep. Mines Tech. Surv., Ottawa, Ont. Water Survey Rep. No. 10. 147 p.

The report presents, in tabular form, data on municipal water systems, chemical analyses of municipal water supplies and chemical analyses of surface waters in Saskatchewan, Manitoba and Ontario. There is only one surface water station located in the Lowland.

Keywords: water quality, municipal water supply, water use

Location: Man. HBL, Nelson River Basin

THOMAS, J.F.J. and GALE, R.M. 1973. The Hudson Bay, Labrador and Arctic drainage basins 1959-1965. Dep. Environ., Ottawa, Ont. Water Surv. Rep. No. 15. 147 p.

Data are presented on municipal water systems, chemical analyses of municipal water supplies and chemical analyses of surface waters in the Hudson Bay drainage basin. A very general interpretation of surface water quality is given. Of the 78 surface water stations sampled in Ontario, only five were located in the Lowland. Only three municipal and community water supplies were sampled in the Lowland, while 33 were sampled in the Shield area.

Keywords: water quality, municipal water supplies, water use

Location: Man. HBL, Ont. HBL, Que. HBL

TINNEY, B.L. 1977. Automated tidal reductions. Lighthouse, Can. Hydrogr. Assoc. 15:9-12.

A digital cotidal chart of Hudson Bay, developed for automated sounding reductions during offshore hydrographic surveying, is described.

Keywords: digital cotidal charts, automated sounding reductions

Location: Man. HBL, Ont. HBL

TOLPA, S. and GORHAM, E. 1961. The ionic composition of waters from three Polish bogs. J. Ecol. 49:127-133.

The chemical composition of bog waters from upland raised bogs, Baltic raised bogs and continental flat bogs was studied and compared with the ionic concentrations found in British bogs. Physical, climatic and vegetational data were also collected. The authors found great similarities in the water chemistry between Polish and British bogs with most differences being associated with the atmospheric transport of sea salt in the British bogs.

Keywords: ionic composition, water chemistry bogs, vegetation types

Location: Poland

VERRY, E.S., and BOELTER, D.H. 1972. The influence of bogs on the distribution of streamflow from small bog-upland water sheds. Hydrology of marsh-ridden areas. p. 469-478 *in* Proc. Minsk. Symp., Minsk. USSR.

Studies of the effects of bogs on streamflow led the authors to the conclusion that neither perched bogs nor groundwater bogs in upland areas have a regulating effect on stream flow.

Keywords: runoff, groundwater

Location: United States

VERRY, E.S. 1975. Streamflow chemistry and nutrient yields from upland-peatland watersheds in Minnesota. Ecology 56(5):1149-1157.

Stream water quality was studied over a five-year period in five upland-peatland watersheds which included both oligotrophic and minerotrophic conditions. Annual nutrient yields were calculated for two of the watersheds. The total area of peatland in each watershed ranged from a low of 11% to a high of 30%.

Keywords: bogs, fens, nutrient yields, water chemistry, water quality, upland-peatland

Location: Minnesota

VITT, D.H., ACHUFF, P. and ANDRUS, R.E. 1975. The vegetation and chemical properties of patterned fens in the Swan Hills, north central Alberta. Can. J. Bot. 53(23):2776-2795.

Three patterned fens were studied and the vegetation patterns were analyzed. Vegetation was divided into two flark and two string associations by means of indirect gradient analysis and minimum variance cluster analysis. Intensive water quality sampling was carried out in one fen and related to its vegetation.

Keywords: Fen, flarks, strings, vegetation patterns, water chemistry

Location: Alberta

WADE, G.E. 1976. James Bay survey June-September 1976. Final field report. Dep. Environ., Can. Hydrogr. Serv., Central Region, Burlington, Ont. Project file number 6600-72-1. 16 p.

In response to requests for charting of the Attawapiskat and Albany rivers and approaches, a shore-based hydrographic survey party obtained sounding coverage of these two rivers during the summer of 1976.

Keywords: charting, soundings, hydrographic survey

Location: Ont. HBL, Albany and Attawapiskat Rivers

WANG, K.T., and CHIN, V.I. 1978. Northern Ontario water resources studies: ground water resources. Ont. Min. Environ., Toronto, Ont. Water Res. Rep. 11b. 121 p.

"The report presents brief descriptions of geography and geology but deals in detail with the distributions, subsurface characteristics and hydraulic properties of aquifers. Water quality, water uses and the potential for future development are dealt with in lesser detail." (in original abstract)

Keywords: hydrogeology, groundwater, water quality

Location: Ont. HBL

6. KEYWORD INDEX

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Boelter 1972, Dai et al. 1974

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