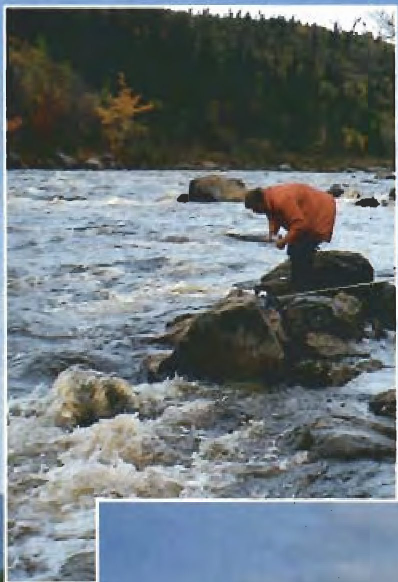
Regional Water Resources Study of the Bonavista Bay Area



GOVERNMENT OF NEWFOUNDLAND AND LABRADOR

DEPARTMENT OF ENVIRONMENT AND LANDS
WATER RESOURCES DIVISION

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REGIONAL WATER RESOURCES STUDY
OF THE
BONAVISTA BAY AREA

Prepared by:

SHAWMONT NEWFOUNDLAND LIMITED
P.O. Box 9600
St. John's, Newfoundland
A1A 3C1

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REGIONAL WATER RESOURCES STUDY
OF THE BONAVISTA BAY AREA

EXECUTIVE SUMMARY

The purpose of the study is to provide information to government on the planning and management of water resources in the study area. Specific objectives requested in the Terms of Reference included:

(i) assessment of water availability,
(ii) assessment of water quality,
(iii) examination of present conditions and future needs,
(iv) ranking areas according to their demand/supply situation, and
(v) suggesting recommendations to government on priorities and future directions for water management.

The study area of about 18,800 km^2 is bounded on the east by the coastline from Sunnyside to Gander Bay, on the north and west by the watershed limits of the Gander, Terra Nova and Pipers Hole rivers, and to the south by a line from Swift Current to Sunnyside, as shown in Figure 1.1. Some 47,000 people live in this area at present.

The availability of water and its distribution in time and space were evaluated by a regional hydrologic study. From this study, generalized descriptions of the main hydrologic parameters were developed for use in other phases of the study. Information developed from the hydrology study included - an isorunoff map and storage-yield relationships. Also investigated were low flow and flood probabilities. These hydrologic analyses concluded that the present flow gauging network was adequate for drainage areas in excess of 40 km^2 but that more information about runoff from small basins [<10 km^2], typical of many water supply sources, would be desirable. Evaluation of groundwater resources relied on earlier studies by others, that attempted to relate well yield with types of surficial deposits and bedrock type. Well yields were generally found to be low [<15 l/min] from most bedrock units due to the absence of primary permeability. Moderate to high yields [>25 l/minute] are obtainable in some areas from glaciofluvial surficial deposits. Overall, the potential for groundwater supply in the study area was judged to be poor.

The water quality assessment compared water quality data collected at fourteen long term monitoring stations against recommended water quality standards for domestic, livestock/wildlife; aquatic life, fish plants and recreational uses. The issues of acid rain and herbicide/pesticide contamination were also investigated.

Present water quality for both surface and groundwater sources was found to be good with little evidence of local anthropogenic influences and is generally satisfactory for most uses. The main future concern is the problem of acid rain. The waters of the area are moderately to extremely sensitive to acidification, due to the low availability of carbonate minerals in soil and bedrock. Acid rain is mainly an imported problem, with pollution carried by weather systems into the area from central and eastern North America. Levels of acid pollution, in the order of 0.2 kg/ha/year, are relatively low and, to date, there is no evidence of damage to the aqueous environment.

Recent water quality tests for "exotic" chemicals (pesticide and herbicides, etc.) have revealed traces of several undesirable products in water samples, albeit at extremely low concentrations. The implication on aquatic and (ultimately) human health, from regular ingestion of trace amounts of such chemicals is at present unknown. Once again most of these products are uninvited guests transported into Newfoundland with the weather. No pollution problems were identified, although harbour pollution in some locations is suspected. A future concern is localized pollution of surface and groundwater from careless disposal of agricultural, municipal or fish plant wastes.

The waterways in the study area support three valuable instream uses, hydro power production, sport fishery and recreational uses. At present these uses co-exist without conflict. Significant potential exists for further development of all three uses.

The main withdrawal uses of water are for municipal or fish plant supply. Reliable data on both municipal demands and fish plant requirements are scarce. Measurements of yield from basins developed for water supply are also lacking. Data collected on municipal systems indicate that 78% of the population are served by surface water supply systems, 8% by municipal well supplies and 14% by private supplies. Surface water supplies were generally satisfactory with most sources capable of meeting probable increases in demand until the year 2011. Municipal groundwater (well) supply systems on the other hand, were often unsatisfactory (13 out of 23 systems); the usual problem being that the wells dried up during dry periods. Fish plant demands for water were found to vary greatly from minimal at salt fish plants to many thousands of m^3 per year in primary fish plants. A feature of fish plant operations is the possibility of substituting seawater for freshwater in most functions.

The comprehensive assessment of the water supply situation focused on the peninsula areas, where population densities are relatively high and the local water resource bases are limited by narrow (peninsular) land forms. The possibility of "shortages in the midst of plenty" was investigated. This is a situation that could arise if a suitable watersource could not be found within an "economic" distance (3 to 4 kms) from a small community. It was concluded that ample water sources are available even in the most restricted area - the Eastport Peninsula. It was also concluded that adequate surface water sources are available in the vicinity of all communities, presently served by marginal or unsatisfactory well systems. In most areas there are possibilities for interconnection of two or more systems. There are also opportunities for further hydro power, fishery enhancement and recreational water use developments in most areas, as well as risks of local pollution problems. Care will be required to harmonize such development opportunities. However, good design can mitigate many of the adverse impacts.

At present, jurisdiction for planning, management and operation of water supply systems is in the hands of numerous small municipal and local service district authorities. It is believed that significant economies could be achieved if water supply systems were developed on a regional basis to supply several communities, wherever this is feasible.

An important impression that emerged during the course of the study was that recreational and sport fishery uses were of major economic importance in this mainly rural area. Protection of water quality on which these activities depend should be a main aim of government water resource management policy.

RECOMMENDATIONS

Recommendations for future water resource management fall into three general categories:

- recommendations regarding data needs and further studies to provide an improved understanding of the water resources in the region,
- recommendations on existing problems,
- recommendations regarding planning and management for future water resource uses in the region.

Data Requirements

Streamflow data provides the most satisfactory basis for evaluation of a water source. Existing streamflow gauges provide adequate coverage for drainage areas greater than 40 km^2. However, no data are available for very small drainage areas, from 5 to 10 km^2 in extent, which are often developed for municipal water supply.

Water use statistics from both municipal and fish plant operations are also scarce.

The following recommendations are proposed to deal with these requirements:

(i) All water supply systems should be provided with meters at source.

(ii) Water supply system operators should be encouraged to maintain complete records on system water use, including spill and return flows where practical.

An alternative approach, in the event the above suggestions are impractical to implement, would be for the Department of Environment and Lands to establish streamflow gauges on a minimum of three small streams, with drainage areas between 5 to 10 km^2.

(iii) Meters should be installed and complete records maintained of water use by all major commercial and industrial users.

(iv) Methods for direct estimation of evapotranspiration in Newfoundland are still unavailable. While this question is of mainly scientific interest, considerable insights into local climatic factors would be obtained if this problem was thoroughly studied. Government should encourage research into this problem.

(v) Glaciofluvial aquifers show promise as reliable sources of good quality water for municipal supply. It is suggested that the groundwater potential of selected glaciofluvial deposits near water short communities be investigated, preferably in collaboration with the Surface Geology Division of the Department of Mines and Energy, as an addition to their on-going program of surficial geology mapping.

Given the generally low potential of bedrock aquifers in the study area, it is recommended that further investigation of the yield of bedrock aquifers in this area be assigned a low priority.

(vi) Data from the Bonavista Region alone were minimal as a basis for stochastic analysis. However, if stochastic analyses were carried out on an Island wide basis using all available data more useful results may be obtainable, witness the recent Regional Flood Frequency Analysis Study, RFFA. Accordingly, it is recommended that Island wide stochastic hydrology analyses be undertaken, to update both the Atlantic Development Board Water Resources Study of 1968 and the RFFA. These analyses could draw on recently collected hydrologic data, as well as, on the mass of physiographic data collected at great expense during the ADB water resources study in the 1960s and which are now in the archives of Environment Canada, Inland Water Directorate -Ottawa. This study should be taken up following the conclusion of this present series of regional water resources studies.

(vii) Government should continue monitoring pH in streams and lakes so as to be aware of trends in water acidification.

Present Situation and Future Prospects

The study area and its water resource base are large compared to the population. Furthermore, the settlement pattern is rural and water requirements dispersed. As a result, water demands for a variety of uses are, at present, satisfied without conflicts.

Future development prospects include:

- continuing development of surface water sources to provide reliable municipal water supplies and meet future population and industrial growth,
- potential hydro developments,
- recreational developments,
- withdrawal demands for agriculture,
- freshwater fisheries enhancement schemes.

These future developments will create greater competition for water uses and greater possibilities for conflict between different water users.

Future problems could include:

- localized pollution from release of agricultural, municipal or industrial wastes into lakes, rivers or harbours, loss or degradation of fish habitat due to stream diversions and/or reservoir operation for hydro or water supply developments,

- conflicts between hydro and/or municipal water supply developers and recreational and/or sport fishery users.

Many of these problems can be avoided or mitigated by careful design.

The greatest potential threat to the well-being of the water resources of the study area is windborne pollution in the forms of acid rain and toxic chemical deposition.

Dealing with these problems will require vigilance on the part of government in the management of water resources in the study area. Accordingly the following recommendations are suggested:

(i) Government should carefully screen development proposals to ensure that appropriate measures are provided to protect water quality of lakes and rivers in the vicinity of the developments.

(ii) Government should prepare master plans for water use in the Eastport and Bonavista peninsulas where risks of conflict are greatest.

(iii) Government should require the maintenance of appropriate minimum flow levels in streams for maintenance of aquatic life in streams supporting significant fish populations.

(iv) Government should monitor water quality, as necessary, to ensure that developers comply with government regulation.

(v) Government should consider the development of design guidelines for ocean outfalls to replace inadequate guidelines currently in use.

(vi) Government should exercise whatever means are available to encourage the responsible Canadian and U.S.A. authorities to deal with acid rain at its source.

(vii) Government should continue its program of pesticide monitoring in order to establish baseline data and identify trends in contamination by such products. This program should be reviewed frequently and modified to take advantage of the latest findings of environmental toxicologists.

(viii) It is recommended that the list of parameters tested under the water quality program of the Department of Environment and Lands be extended to include all the parameters recommended in the Canadian Water Quality Guidelines for drinking water and freshwater aquatic life. This would involve testing for the following inorganic parameters:

- aluminum
- boron
- cyanide
- mercury
- selenium
- silver, and
- thallium

Testing for organic chemicals should be targeted on products likely to be employed in the area, typically - herbicides/pesticides used in forestry or agriculture.

Planning and Management

At present water supply systems in the study area are developed and operated in a patchwork style by a multitude of very small local government organizations. It is believed that this uncoordinated approach is wasteful. Accordingly, it is recommended that Government review the present mode of operation, and examine other options with the aim of improving the cost effectiveness of providing water supply and sewage collection services.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

This report, on the regional water resources of the Bonavista Bay area, is the third of a series which will eventually cover the whole province. The previous two reports cover the Avalon Peninsula (1, 2).*

1.2 OBJECTIVES

The objective of the study is to provide information to government on the planning and management of water resources in the study area. Specific objectives, requested in the Terms of Reference, include:

(i) assessment of the availability of water using existing data,

(ii) examination of present and future needs,

(iii) assessment of water quality,

(iv) ranking of areas according to their supply-demand situation, and

(v) to suggest recommendations to government on future priorities and directions for water management policy in the study area.

It is also anticipated that the study report will serve as a prime reference source on water resources in the Bonavista Bay region for many years to come and that copies will be widely distributed among Provincial and Municipal agencies; consultants and other interested parties.

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* Refers to list in Reference Section at end of the chapter.

1.3 STUDY AREA

The southern boundary of the study area is defined by a line between Swift Current and Sunnyside, the eastern boundary by the coastline from Sunnyside northwards to Gander Bay; while the nominal interior boundary is from Gander Bay to Gander and thence to Swift Current. Since watersheds are the natural units for water resources analysis, the interior boundary of the study area has been taken as the height of land, for the purpose of the study (see Figure 1.1). With the exception of Random Island, offshore islands are excluded from the study area. Several large rivers, notably: Gander, Pipers Hole and Terra Nova flow through the study area. The total land area to the height of land is about 18,800 km^2.

The study area is exposed to a modified continental type of climate in which extremes of temperature are moderated by proximity to the ocean, especially in coastal areas. In the interior, away from the ocean's influence, the climate exhibits a more continental character with greater variations between winter and summer temperatures. Excepting the southern portion of the study area, in the vicinity of Swift Current and Sunnyside, the study area is somewhat sheltered from the dominant cyclonic weather systems coming from the west and southwest. On the other hand, the area is directly exposed to weather from the east and the chill of the Labrador current.

The study area straddles two geological zones, the Gander and Avalon zones (3). The broad characteristics of these zones are believed to relate to interaction of large tectonic plates. A feature of the Gander zone is the presence of granites and the intensity of deformation and metamorphism, both of which increase eastwards toward the contact with the Avalon zone. The Avalon zone lies to the east of the Gander zone and is separated from it by a major fault running from Dover to Hermitage Bay. The Avalon zone is characterized by mildly deformed late Precambrian, volcanic and sedimentary rocks. As the Avalon zone has no correlative to the west, it appears to be a far travelled terrain that collided with the Gander zone about 400 million years ago. It is similar in character to areas of Southern Europe and North Africa.

The physiography of the study area is characterized by a deeply indented coastline defining several peninsular arms, the most important of which are the Bonavista and Eastport peninsulas. In most locations the land rises rapidly from the coast to a plateau that varies in elevation from about 80 m on the peninsulas to 200 m in the interior of the study area.

Glaciers have greatly altered land surface features, reducing relief, modifying drainage patterns and leaving behind a landscape of rounded hills, and plateau areas dotted with a multitude of lakes and swamps (lake surfaces comprise about 7% of the surface area, Reference 4). Boreal forests, mainly of spruce and fir, are supported on a thin mantle of recent soil. Bedrock exposures are common.

The main economic activity in the area is the fishery. Forestry, tourism and agriculture are also important economic activities. The area is home to a population of about 47,000 people (1986 census).

1.4 SOURCES OF DATA

The study was based for the most part on existing information, supplemented by discussions with individuals in government, industry and Memorial University.

Published sources cited in this study are noted in reference sections at the end of each chapter.

1.5 ACKNOWLEDGEMENTS

During the course of this study information was supplied by many individuals in federal, provincial and municipal, government departments and agencies, and Memorial University. Their assistance is much appreciated. We would especially like to thank the individuals listed below whose help was particulary valuable. These include:

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- Jim Harty, P. Eng., Department of Municipal Affairs
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- Calvin Baker, Environment Canada, W.S.C.

- Bruce Bradbury, Terra Nova National Park
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- Ron Kidd, Facilities Survey
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- David M. Besaw, Groundwater and water quality
- Phil C. Helwig, Technical direction, water use analysis and overall study management
- Connie Beck, Drafting
- Gertie Reddy, Report typing
- Bill Stiebel, Ground water specialist, Monenco, Rexdale, reviewer for sections on groundwater and water quality.
- C. Paul Ruggles, Aquatic biologist, Monenco - Maritimes, Halifax, reviewer for sections on water quality and instream uses.

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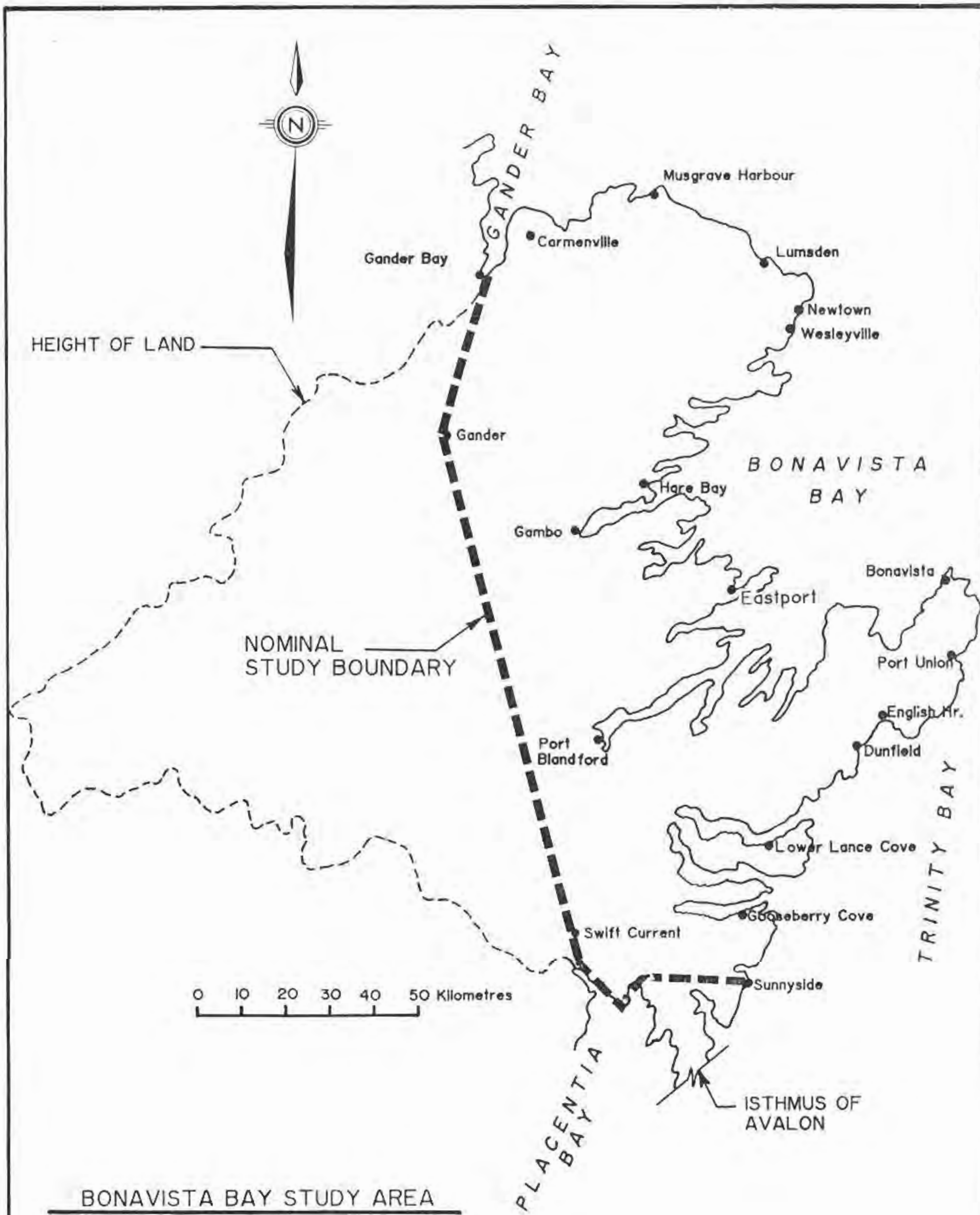


BONAVISTA BAY STUDY AREA

FIGURE I . I

CHAPTER TWO

SURFACE WATER QUANTITY

2.1 INTRODUCTION

Evaluation of the water resources of a region requires knowledge of the amount of water available and its distribution in time and space. This requirement is addressed in this chapter which summarizes hydrologic analyses for the study area. Regional hydrologic factors derived from these analyses are applied in subsequent chapters for evaluation of municipal water supplies and assessment of hydroelectric potential.

2.2 SOURCES OF DATA

Hydrological analyses were based, for the most part on streamflow data collected by the Water Survey of Canada (W.S.C.) and climatological data collected by the Atmospheric Environment Service (A.E.S.). Some supplementary data were also obtained from Newfoundland Light and Power Company which operates two hydro plants in the study area. Unfortunately, no useable data could be obtained from records of municipal water supply systems.

Tables 2.1 and 2.2 summarize the available data base; while Figure 2.1 shows station locations.

2.3 CLIMATE

2.3.1 Overview

The climate of the study area can be described as a modified continental type. Continental because the weather originates from the west over continental North America and modified because of proximity to the ocean. The Labrador current along the east coast makes for cool summers while

TABLE 2.1

W. S. C. STREAMFLOW GUAGING STATIONS

Station Number	Station Name	Location	Drainage Area (km^2)
02YQ001	Gander River at Big Chute	49 00 55 N 54 51 13 W	4400
02YQ002	Gander River at Outlet of Gander Lake	48 56 00 N 54 52 00 W	4160
02YQ004	Northwest Gander River near Gander Lake	48 46 07 N 55 04 52 W	2150
02YR001	Middle Brook near Gambo	48 48 28 N 54 13 28 W	267
02YR002	Ragged Harbour River near Musgrave Harbour	49 23 35 N 54 06 25 W	399
02YR003	Indian Bay Brook near Northwest Arm	49 02 24 N 53 53 00 W	554
02YS001	Terra Nova River at Eight Mile Bridges	48 26 30 N 54 22 21 W	1290
02YS002	Rocky Pond Brook at Rocky Pond	48 31 37 N 53 57 32 W	2.31
02YS003	Southwest Brook at Terra Nova National Park	48 36 25 N 53 58 50 W	36.7
02YS005	Terra Nova River near Glovertown	48 39 43 N 54 01 05 W	2000
02ZH001	Pipers Hole River at Mothers Brook	47 56 49 N 54 17 08 W	764
02ZH002	Come-by-Chance River near Goobies	47 55 07 N 53 56 59 W	43.3
02ZJ001	Southern Bay River near Southern Bay	48 22 44 N 53 40 36 W	67.4
02ZJ002	Salmon Cove River near Champneys	48 23 45 N 53 18 06 W	73.6
02ZJ003	Shoal Harbour River near Clarenville	48 12 24 N 54 02 23 W	106

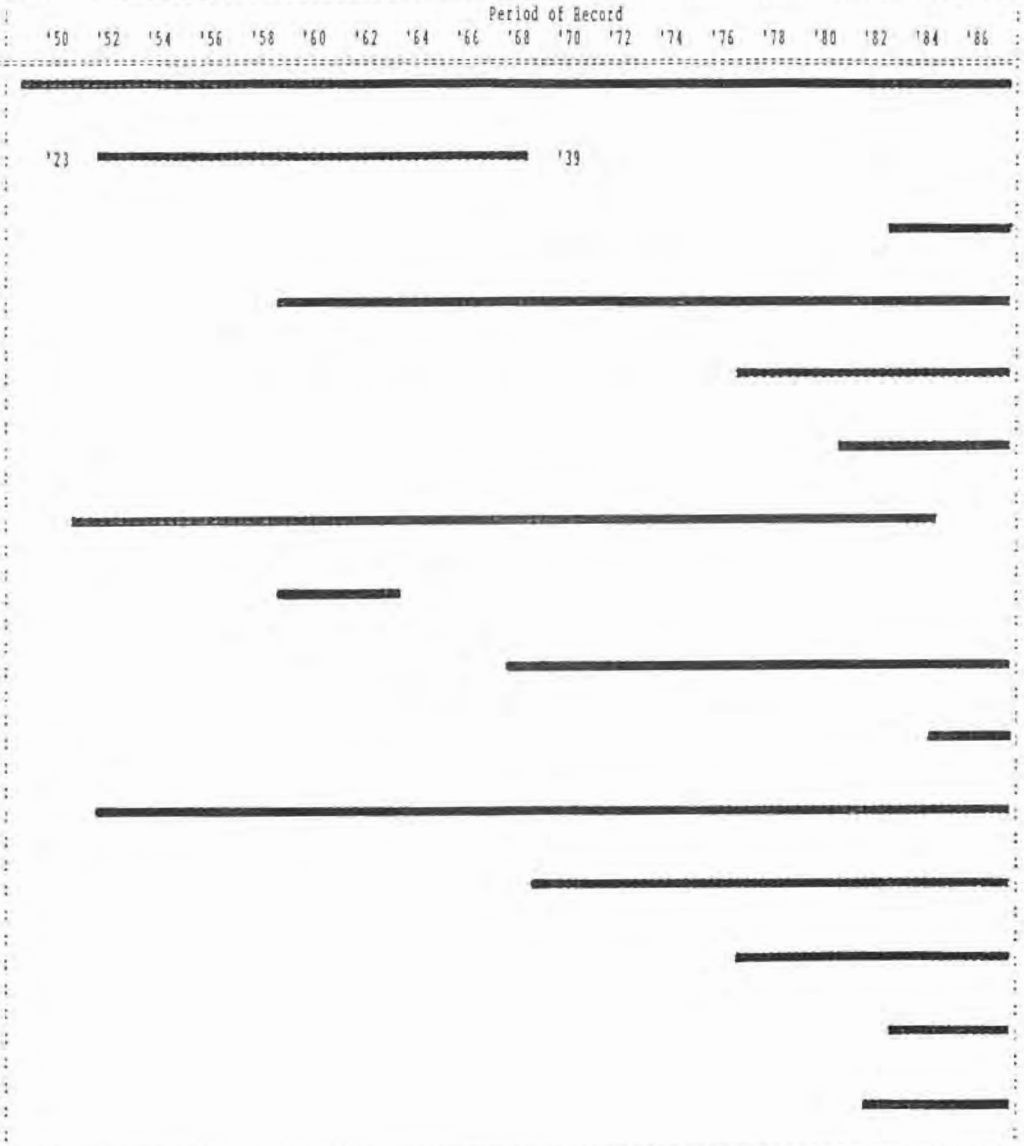
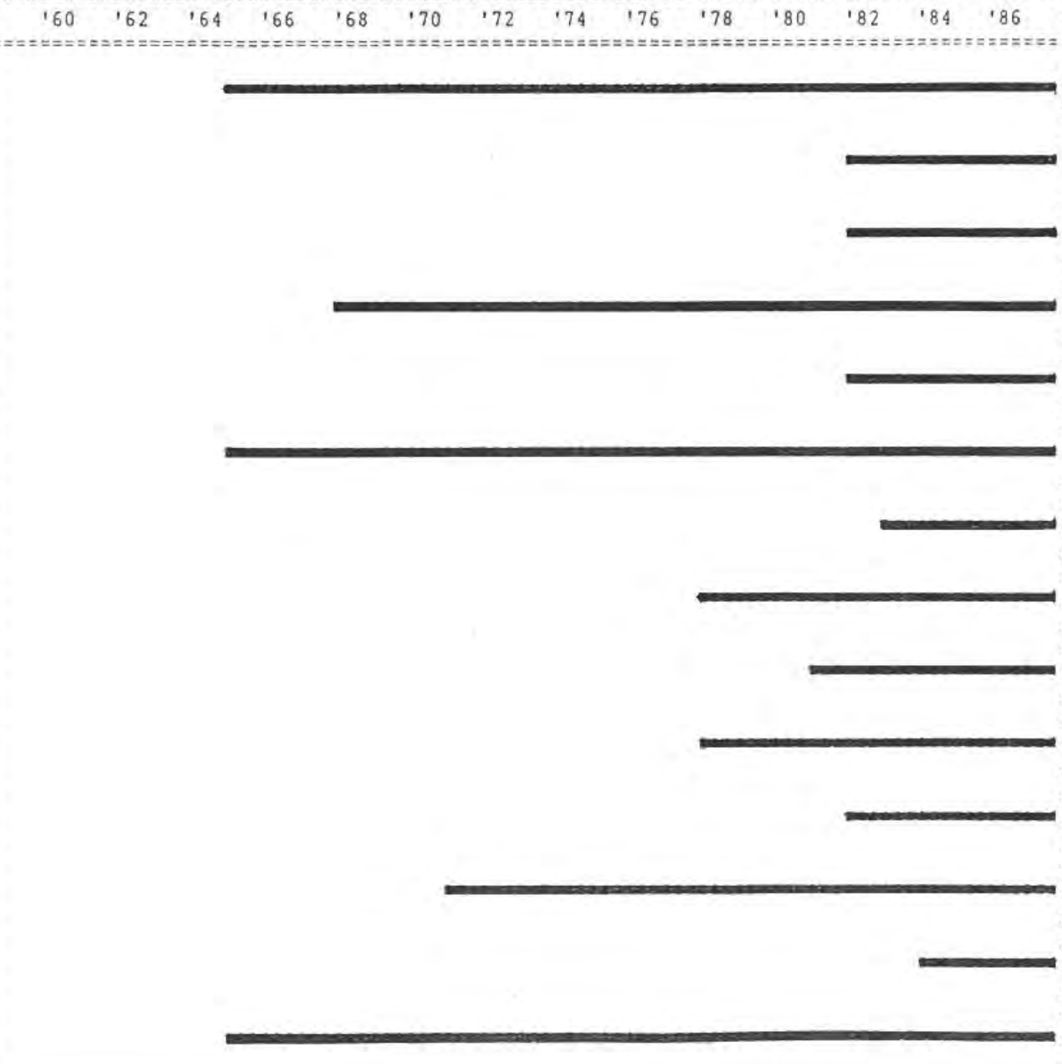


TABLE 2.2
A.E.S. CLIMATOLOGICAL STATIONS

Station Name	Location	Elevation (m)
Bonavista	48 28 N 55 05 W	25
Carmanville		
Clarenville		
Come by Chance	47 48 N 54 01 W	27
Gambo		
Gander International Airport	48 57 N 54 34 W	151
Gander Bay South		
Goobies		
Lethbridge		
Musgrave Harbour		
Port Blandford		
Sunnyside	47 51 N 53 57 W	46
Swift Current		
Terra Nova National Park	48 33 N 53 58 W	46



the heat stored in the ocean delays the onset of autumn and keeps winter temperatures from falling as low as on the Mainland (1).

The weather is controlled by mainly westerly winds which bring air masses from the interior of the Continent, from the Gulf of Mexico and from the Arctic into the region. Many of the migratory low pressure weather systems moving across North America eventually track through Atlantic Canada. As a result of this the area suffers more frequently from storms than Mainland Canada. These systems provide an ample supply of precipitation to the Island (2). The study area lies in the lee of the main storm directions and in the rain-shadow of the south coast, except for the areas in the vicinity of Placentia Bay which are directly exposed to the weather systems arriving via Placentia Bay. Easterly onshore winds are less frequent and are usually associated with episodes of drizzle and fog. Figures 2.2 and 2.3 summarize precipitation and temperature patterns at an inland location - Gander and a coastal location - Bonavista. As can be seen from these graphs the range between summer and winter temperatures is somewhat greater at Gander than at Bonavista; also Gander receives a greater proportion of its total precipitation in the form of snow than Bonavista. These differences are evidence that inland areas enjoy a somewhat more continental climate than coastal areas, although these differences are not great.

Further details on the climate of the study area can be obtained from McPherson (3). Other climate studies concerning the study area include Peach's study on climate and recreation (4) and Dzikowski's Study on climate and agriculture (2).

The starting point for a water resource study is to develop an understanding of the main elements of the hydrologic cycle, the processes of precipitation, evapotranspiration (including lake evaporation) and runoff. Precipitation, evapotranspiration and lake evaporation were investigated using climatological records collected by A.E.S. while runoff was evaluated on the basis of flow records collected by W.S.C.

2.3.2 Precipitation

Altogether there are thirteen climatological stations within the study area. Most of these stations are located along the coast, with the single exception of the station at Gander International Airport. Two of these stations (Bonavista and Gander International Airport) are major climatological stations at which the full complement of atmospheric observations are made by employees of A.E.S. The other stations are contributing stations at which daily precipitation and temperature data are collected by part time observers.

At contributing stations, rainfall is measured in standard collectors while snowfall is estimated by measurement of the depth of newly fallen snow which is then converted to equivalent (rainfall) precipitation depths assuming a specific gravity of 0.10. At Gander International Airport and Bonavista snowfall is measured directly in Nipher snow gauges.

Sites for climatological stations are carefully selected to avoid or minimize factors that would cause errors of measurement. The main concern is to avoid overly exposed or "windy" sites, since the main measurement problems are caused by localized wind effects in proximity to the instruments. Wind effects normally reduce "catch" and hence cause underestimation of actual precipitation.

Following accepted practice, analyses were based on stations having periods of record of ten or more years. Data from Come-by-Chance, which lies just outside the boundary of the study area, were also included since a long term climatological station is located in that community.

All analyses were based on the same standard twenty year span of records, 1968 to 1987. Stations having less than twenty years of records were normalized by estimating missing data by correlation with a nearby climatological station having a twenty year period of record (see Appendix I).

Six stations were included in this analysis: Bonavista, Come-by-Chance, Gander International Airport, Musgrave Harbour, Sunnyside and Terra Nova National Park. Table 2.3 summarizes the mean annual precipitation at these stations, while areal distribution is shown in Figure 2.4.

Table 2.3

Mean Annual Precipitation

STATION	MEAN ANNUAL PRECIPITATION (mm)
Gander International Airport	1162
Musgrave Harbour	901
Terra Nova	1171
Bonavista	1012
Sunnyside	1364
Come-by-Chance	1257

Figure 2.4 reveals that precipitation is less as one moves northwards. Precipitation patterns differ between inland and coastal stations as shown in Figure 2.2 and 2.3. This indicates a somewhat more continental climate at inland locations (as previously noted).

2.3.3 Evapotranspiration

Evapotranspiration is the term in the water balance equation that accounts for the amount of moisture returned directly to the atmosphere by the processes of evaporation and plant transpiration. Direct measurement of evapotranspiration is difficult; however, several empirical methods are available for estimating evapotranspiration using readily available meteorological data. One of the best known of these methods is the Thornthwaite Method that has been adapted to Canadian conditions by meteorologists at the Canadian Climate Centre (5). This method estimates monthly evapotranspiration as a function of monthly temperature, monthly precipitation and a soil storage index. Arrangements were made with the Canadian Climate Centre to calculate evapotranspiration losses for stations in the study area using the modified Thornthwaite procedures. Their calculations gave annual evapotranspiration losses, for the period 1968-1987, ranging from 486 mm at Sunnyside to 455 mm at Musgrave Harbour.

An approximate check on the validity of these results can be obtained by comparing lake evaporation with evapotranspiration. This comparison was carried out using pan evaporation data, for the summer months - June through September, collected at Gander International Airport, over the decade 1972-1982 (see Appendix I). Lake evaporation was estimated from pan evaporation measurements by applying a pan coefficient of 0.70 as suggested by Linsley, Kohler and Paulhus (6).

This comparison found that lake evaporation at Gander International Airport (360 mm/year) to be about 77% of the Thornthwaite estimates of evapotranspiration (469 mm/year), when in fact one would expect lake evaporation to be somewhat greater than evapotranspiration (see Table 2.4).

This finding suggests that the modified Thornthwaite procedure over-estimates actual evapotranspiration by some 15% to 30%. This question is further explored in the following sub-section.

Table 2.4

Comparison of Evapotranspiration Values

Estimated from Pan Evaporation and by Thornthwaites Method

at Gander International Airport

Year	JUNE		JULY		AUGUST		SEPTEMBER	
	0.70 pan mm	AE mm	0.70 pan mm	AE mm	0.70 pan mm	AE mm	0.70 pan mm	AE mm
1972	-	99.5	99.4	117.1	64.8	72.7	36.5	52.9
1973	-	86.9	68.3	133.0	50.3	92.0	48.0	66.8
1974	79.8	84.3	68.3	105.6	53.1	72.6	41.3	68.6
1975	-	78.2	92.7	98.8	66.6	73.7	37.9	73.9
1976	75.6	79.7	73.9	117.3	79.2	51.7	37.5	74.7
1977	-	97.0	89.4	108.2	76.2	93.8	43.4	57.2
1978	73.2	96.6	93.0	122.2	79.2	60.5	43.3	56.0
1979	98.7	106.5	83.1	93.0	64.3	103.8	49.9	66.1
1980	-	87.6	61.4	109.3	56.0	87.4	49.6	62.3
1981	73.2	88.0	90.2	114.8	66.9	101.4	28.9	71.4
1982	73.2	71.8	71.1	113.9	72.5	104.5	48.6	69.8
Mean	79.0	83.8	79.8	112.1	66.3	83.1	42.3	65.4

1. Lake evaporation = 0.70 x Pan evaporation.
2. Evapotranspiration calculated by Thornthwaites (modified) procedure = AE.
3. Determination of annual lake evaporation as follows:

$$\sum_{\text{June - Sept.}} AE = 349.5 \text{ mm}$$

$$\sum_{\text{June - Sept.}} 0.70 \text{ Pan} = 267.4 \text{ mm}$$

$$\sum_{\text{Jan. - Dec.}} AE = 468.9 \text{ mm}$$

$$\sum_{\text{Jan. - Dec.}} 0.70 \text{ Pan} = 267.4 \times \frac{468.9}{349.5} = 359 \text{ mm (annual)}$$

2.3.4 Water Balance

To prepare a detailed water balance of a river basin would require that water balances be summed for each process in the hydrologic cycle. However, for the purposes of this study, only the main inputs and outputs are of interest and the hydrologic cycle may be treated as a black box. Figure 2.5 shows that net input, precipitation minus evapotranspiration should equal stream runoff, provided storage changes within the system are small in relation to inputs and output. This is normally the case when the water balances are calculated over a relatively long period - say yearly. Thus water balance calculations provide a means of evaluating the reliability of runoff estimated from climatologic data (precipitation minus evapotranspiration) versus runoff estimated from flow data.

Strictly speaking runoff estimated as precipitation minus evapotranspiration, represents point values while estimates from streamflow measurements represent areally averaged values. However, it is usually assumed that the mean areal value and point value of the basin centroid should be approximately equal. When point runoff values are compared with runoff values estimated from streamflow measurements (see Section 2.4.1 for details) the two sets of values differ considerably, as noted in Table 2.5.

Table 2.5

Comparison of Runoff Estimates

STATION	PRECIP. P (1) (mm)	EVAPO. TRANS. AE (mm)	(a) P -AE (mm)	(b) STREAMFLOW RUNOFF (2) (mm)	DIFFERENCE (b) - (a) (mm)
Gander	1162	469	693	700	7
Musgrave Harbour	902	455	446	720	274
Terra Nova	1171	469	702	900	198
Bonavista	1012	457	555	980	425
Sunnyside	1364	486	878	1300	422

1. From tables in Appendix I.
2. Estimated from isorunoff contours in Figure 2.6.

The discrepancy between both methods for determining runoff has been noted by other investigators (7, 8).

Several factors could contribute to these discrepancies:

(a) Thornthwaite's procedure is essentially an empirical procedure that was developed for conditions on Mainland Canada that may not apply in Newfoundland. [The defect in this procedure, when applied in Newfoundland, may be due to the way in which condensate from fog is accounted for. Condensate would simultaneously increase precipitation and reduce evapotranspiration. This may explain why runoff estimated as precipitation minus evapotranspiration (by Thornthwaite) underestimates runoff].

(b) Most precipitation stations are at low elevations and may not reflect orographic effects that give increased precipitation on the plateaus where runoff is collected in river basins. [The significance of orographic precipitation in the study area would be limited to precipitation associated with onshore winds from the east and northeast, estimated to be about 1/5 to 1/3 of total annual precipitation].

(c) It is also possible that precipitation measurements might be underestimated by standard A.E.S. instruments, due to high mean wind speeds affecting catch of rainfall and (especially) snowfall.

The fact that the largest discrepancies are found at coastal stations supports the foregoing observations in (a) and (b).

More work is required on the above problems before one can reliably estimate runoff from climatological factors. Research on evapotranspiration, from a forestry point of view, is being carried out by A.W. Robertson (Canadian Forest Service, Pleasantville). A study by Dr. J. Price - Dept. of Geography, Memorial University, on marsh hydrology including assessment of evapotranspiration losses is planned. It is hoped that the results of these studies will provide a better understanding of these details of the hydrologic cycle in Newfoundland.

2.4 REGIONAL HYDROLOGY

In order to facilitate evaluation of water resources in the study area, a regional hydrology study was carried out. The main factors examined in the study were:

- mean annual runoff
- flood flows
- low flows

  and
- reservoir storage/yield relationships

These factors are the main inputs to engineering design of water resources systems and water control structures.

Following accepted practice hydrological analyses were based mainly on streamflow records having a period of record of ten or more years. Streamflow records of less than ten years were used to provide approximate checks on the findings of the regional analyses. All analyses were based on the same standard twenty year period of records 1968-1987. Stations having less than twenty years of record were "normalized" by estimating missing data by correlation with data at an adjacent gauging station. Data from eight gauging stations were used in these analyses:

- Gander River at Big Chute
- Ragged Harbour River
- Middle Brook (Gambo)
- Terra Nova River at Eight Mile Bridges
- Southwest Brook (Terra Nova National Park)
- Southern Bay River
- Come-by-Chance River
- Pipers Hole River

Summaries of monthly flows from all streamflow gauging stations in the study area are provided in Appendix I.

2.4.1 Mean Annual Runoff

The most useful method of representing regional runoff is by means of an isorunoff map, showing contours of equal runoff depths. For preparation of this map long term runoff values were computed for all stream flow gauging stations, with ten or more years of record, eight in total. Runoff at a ninth point was also determined from the plant records at Lockston Generating Station. An attempt was made to extend the data base by inclusion of runoff estimates derived from climatological stations. Unfortunately reliable estimates could not be obtained from climatological data because of uncertainties associated with evapotranspiration and total precipitation measurements. However, the nine available data points do provide a reasonably uniform coverage of the study area (see Figure 2.6).

The relationship between mean annual runoff (MAR) and several physiographic parameters was investigated by multiple regression analyses. The best correlation was found to be between mean annual runoff (MAR), latitude (LAT) and distance from the sea in a westerly direction (WEST), giving the following correlation equation:

$$MAR = 8971.5 - 179.202\ LAT + 2.074\ WEST \quad \text{.... Equation 2.1}$$

Coefficient of correlation R = 0.918; significant at 1%; standard error of estimate 89.7.

Where:

MAR = mean annual runoff (mm)

LAT = latitude (degrees)

WEST = distance from centroid of drainage area to sea in a westerly direction (km).

[Further details on this analysis are given in Appendix I].

This formula can be used to estimate MAR for basins within the study area, knowing the latitude and distance to the west coast of a basin's centroid. Alternatively, MAR, can be estimated from the isorunoff map.

As an approximate check on the accuracy of the above determinations, calculated MAR values were compared against values estimated from short term gauges that were not used in the analysis. This comparison is shown below in Table 2.6.

Table 2.6

Comparison of Estimated Mean Annual Runoffs

River Basin (Station Code)	Mean Annual Runoff (mm)		
	From flows	From Figure 2.6	From Equation 2-1
Indian Bay River (02YR003)	794	740 (93%)	830 (105%)
Northwest Gander River (02Y004)	909	800 (88%)	770 (85%)
Salmon Cove River (02ZJ002)	1153	1070 (93%)	1120 (97%)

Note: Percentages are calculated with reference to measured values.

The differences between measured and estimated values, within 15%, provide a reasonable verification of the isorunoff map and correlation equation.

2.4.2 Flood Estimation

Estimation of design floods for design of hydraulic structures or other engineering works is a major objective of engineering hydrology. Ideally, such analyses should be based on a suitably long (20 year plus) period of site specific records.

When records are of short duration or entirely absent, the best approach is to use appropriate regional flood frequency formulae. Such formulae were recently developed for the Island of Newfoundland in the Regional Flood Frequency Analysis (RFFA) by Panu and Smith (10). Three sets of RFFA formulae were developed for north and south regions and the entire Island. In applications at ShawMont, the "Entire Island" formulae have been found to be the most useful, hence these are given below:

$$Q_2 = 10^{-2.5824} \times DA^{0.8310} \times MAR^{1.7260} \times ACLS^{-1.3269} \times SH^{-0.7894} \quad \text{... Equation (2.2)}$$

$$Q_{20} = 10^{-2.8741} \times DA^{0.7911} \times MAR^{2.0070} \times ACLS^{-1.4736} \times SH^{-0.7031} \quad \text{... Equation (2.3)}$$

$$Q100 = 10^{-3.1500} \times DA^{0.7662} \times MAR^{2.1684} \times ACLS^{-1.5134} \times SH^{-0.6581} \quad \text{... Equation (2.4)}$$

Range of Validity:

DA (km^2)	3.9 to 4400
MAR (mm)	788 to 2124
ACLS (%)	55 to 100
SH	1.24 to 2.45

where DA = drainage area (km^2)
MAR = mean annual runoff (mm)
ACLS = area controlled by lakes and swamps (%)
SH = shape factor

[Definitions of these variables, together with formulae for Q_5, Q_{10}, Q_{25} and Q_{50} are given in Reference 10].

These formulae were based on multiple regression analyses in which flood flows for selected return periods were correlated against basin physiographic parameters. Only unregulated rivers with periods of record greater than ten years were considered. The applicability of this method was investigated by comparing estimates of Q_2, Q_{20} and Q_{100} computed using the RFFA formulae against estimates obtained by site-specific frequency analyses for gauged rivers in the study area having ten or more years of record. This comparison is shown in Table 2.7 (next page).

About half of the comparison agreed within $\pm$ the applicable standard error of estimate and about 60% within $\pm$ 33 1/3% of the RFFA value. The major exceptions were Pipers Hole River, which was found to exhibit anomalous behavior in the RFFA study, Ragged Harbour and Gander Rivers, where the "northern" zone formulae gave somewhat better fits. Overall this comparison confirms that the RFFA formulae provide a reasonable design basis for most engineering requirements, but they should be used with mature engineering judgement.

2.4.3 Low Flow Frequency Analysis

The probabilities of the occurrence of low flows in a river are of interest in the design of water supply systems or investigations of other uses of the river, where artificial storage is not available. To this end, a series of low flow frequency analyses was conducted to determine flow levels corresponding to mean annual lows, 1 in 10 year lows (probability of exceedance 0.90) and 1 in 20 year lows (probability of exceedance 0.95). These analyses considered daily, weekly and monthly average flows.

Table 2.7

Flood Frequency Analysis Comparison

Station Number		RFFA			Site-Specific Frequency Analysis		
		Q_2 cu.m/s	Q_{20} cu.m/s	Q_{100} cu.m/s	Q_2 cu.m/s	Q_{20} cu.m/s	Q_{100} cu.m/s
02YQ001	Gander River at Big Chute*	469	635	699	584 (+25%)	898 (+41%)	1060 (+52%)
02YR001	Middle Brook near Gambo*	37.3	54.0	62.0	29.2 (-22%)	44.1 (-18%)	51.5 (-5%)
02YR002	Ragged Harbour River	63.6	88.1	98.0	66.8 (+5%)	121 (+37%)	166 (+69%)
02YS001	Terra Nova* River at Eight Mile Bridges	142	202	230	174 (+23%)	257 (+27%)	296 (+29%)
02YS003	Southwest* Brook at Terra Nova National Park	11.0	17.4	21.3	12.7 (+16%)	18.3 (+5%)	21.2 (-0.5%
02ZH001	Pipers Hole River at Mother's Brk	173	259	303	218 (+26%)	405 (+56%)	514 (+70%)
02ZH002	Come-by-Chance River near Goobies	25.1	45.2	59.3	28.3 (+13%)	47.9 (+6%)	57.7 (-2%)
02ZJ001	Southern Bay River near Southern Bay	28.2	46.4	57.7	21.1 (-49%)	38.0 (-42%)	48.4 (-16%)
Standard Error of Estimate		+25.6% -20.4%	+24.1% -19.4%	+25% -20%			

* Gauged rivers used in Regional Flood Frequency Analysis (10).

Data were fitted to a Log Pearson Type III distribution using the CFA computer program (11). This distribution was found to give the best fit to points at the low end of the curve. Table 2.8 summarizes the results of this analysis (further details are given in Appendix I).

Table 2.8

Low Flow Analyses for Selected Gauged Rivers

River	Drainage Area (km^2)	1 in 10 Year Low Flows					
		Daily		Weekly		Monthly	
		m^3/s	non dim	m^3/s	non dim	m^3/s	non dim
Come-by-Chance (02ZH002)	43.3	0.02	0.011	0.04	0.022	0.08	0.043
Terra Nova River at Eight Mile Bridges (02SY001)	1290	2.60	0.075	3.00	0.087	4.00	0.116
Pipers Hole River (02ZH001)	764	1.00	0.039	1.10	0.043	1.70	0.067
Ragged Harbour River (02YR002)	399	0.06	0.007	0.08	0.009	0.11	0.012
Southwest Brook (02YS003)	36.7	0.03	0.029	0.06	0.057	0.09	0.086
Gander River (02Y002)	4400	8.00	0.066	9.68	0.083	12.0	0.099
Middle Brook (02YR001)	267	0.25	0.037	0.30	0.045	0.40	0.059
Southern Bay River (02ZJ001)	67.4	0.022	0.011	0.044	0.021	0.07	0.034

Flows were non-dimensionalized by dividing by mean annual flow.

Relationships between 1 in 10 year low flows for daily, weekly and monthly periods were examined by means of multiple regression analysis considering several basin physiographic parameters. A very strong correlation was found with drainage area. Inclusion of other parameters did not improve the correlations. Regression analysis was done on transformed data (common logs). The resulting regression equations are:

$$Q_{10:daily} = 10^{-3.831} \times DA^{1.283} \qquad \text{... Equation 2.5}$$

$R = 0.95$ Significant at 1%

Standard error of estimate +112%
-53%

$$Q_{10:weekly} = 10^{-3.329} \times DA^{1.145} \qquad \text{... Equation 2.6}$$

$R = 0.93$ Significant at 1%

Standard error of estimate +113%
-53%

$$Q_{10:monthly} = 10^{-3.000} \times DA^{1.081} \qquad \text{... Equation 2.7}$$

$R = 0.92$ Significant at 1%

Standard error of estimate +116%
-54%

Where:

$Q_{10:daily}$ = 1 in 10 year low daily flow (m^3/s)
$Q_{10:weekly}$ = 1 in 10 year weekly flow (m^3/s)
$Q_{10:monthly}$ = 1 in 10 year monthly flow (m^3/s)

2.4.4 *Flow Duration Curves*

When availability of supply over time is of more interest than the severity of individual low flow incidents, it is more useful to base low flow analyses on flow duration curves. A flow duration curve is a cumulative distribution of daily flows, usually selected on a seasonal or annual basis. Flow duration curves were developed for several rivers in the study area. Figure 2.7 shows a comparison between unitized flow duration curves for Come-by-Chance River and Middle Brook (flow duration curves for the remaining rivers can be found in Appendix I).

Design is often based on availability of flow as a percentage of time. Flow ratios for typical reliabilities are summarized in Table 2.9.

Table 2.9

Unitized Flow Durations for Selected Rivers

Rivers	Mean Flow m^3/s	Flow Ratios for Various Durations				
		>100%	>95%	>90%	>70%	>20%
Southern Bay River (02YJ001)	2.20	0.063	0.230	0.285	0.469	1.468
Gander River (02YQ001)	122.0	0.025	0.169	0.243	0.472	1.552
Middle Brook (02YR001)	6.72	0.012	0.129	0.211	0.467	1.521
Come-by-Chance (02ZH002)	1.25	0.004	0.083	0.149	0.391	1.540

The flow duration curves given in Appendix I are based on the available period of record. This fact should be remembered should these curves be used for design.

2.4.5 Storage/Yield Analysis

In nature river flows vary considerably from month to month and from season to season; while most water demands are relatively constant. Where reservoir storage is available it is possible to significantly increase the useable flow or "yield" from a river by means of flow regulation. Essentially, surplus river flows are stored in a reservoir and released when required. In an area like Newfoundland with topography favourable to the development of storage, it is worthwhile to know the relationship between yield and storage. This relationship was investigated for the following six rivers, all of which have long term records:

- Pipers Hole
- Terra Nova (at Eight Mile Bridges)
- Come-by-Chance River
- Southwest Brook
- Middle Brook
- Gander River

For these analyses, a simple water balance model was used. This model simulates the operation of a single reservoir system, subject to a constant monthly demand (Q_f). Simulations were carried out using monthly flow data for the complete period of record for each of the above long term gauging stations. Demand ratios were varied and the corresponding storage ratios determined. Two failure criteria were used in defining basin yield. The first criterion allowed no failures for the period of record, and corresponds to the current design standard recommended by government guidelines (12). The resulting relationships are shown graphically in Figure 2.8. The second criterion is based on a probabilistic reliability approach, accepting one monthly failure per ten years. The results of this set of analyses are shown in Figure 2.9.

Curves were plotted on a unitized basis to facilitate comparison. The variables are defined, as below:

$$\text{Storage Ratio} = \frac{\text{Storage, } m^3}{\text{Mean annual flow volume, } m^3}$$

$$\text{Yield Ratio} = \frac{\text{Firm (regulated) outflow, } m^3/s}{\text{Mean annual flow, } m^3/s}$$

$$= \frac{\text{Usable Flow, } m^3}{\text{Mean annual flow volume, } m^3}$$

Differences between curves indicate that flow patterns differ somewhat from one river basin to the other. Factors which contribute to these differences could include:

- varying runoff rates due to topography (lake-bog areas, basin size, drainage efficiency, depth of overburden, etc.),
- variations in snow melt regime,
- variation in precipitation patterns.

Figures 2.8 and 2.9 provide a reasonable basis for preliminary design, when applied with mature engineering judgement.

2.5 CONCLUDING COMMENTS

The following comments deal with the adequacy of the data base:

(a) The eight flow gauging stations within the study area provide good coverage, sufficient for estimating mean annual runoff and flow patterns for rivers with drainage areas greater than 40 km^2 in area.

(b) The thirteen climatological stations, with the exception of Gander, are all located at low elevations along the coast. Additional inland stations would be desirable. [Possible sites for inland stations include the village of Terra Nova, and a location along the Bay d'Espoir Highway (Route 360), which are both readily accessible locations].

(c) It is regrettable that no flow data are currently collected from municipal water supply systems. These systems are often on very small watersheds, areas <10 km^2, for which data is lacking. It is suggested that the Department of Environment and Lands make suitable arrangements with Municipal Affairs and/or selected community councils to collect such data in the future. If this approach is unsuccessful, Environment and Lands should independently establish, three flow gauges on streams with drainage areas of 10 km^2 or less.

(d) Newfoundland Light & Power Company should be encouraged to supply data on reservoir operations and water use for their plants in Port Union and Lockston.

(e) At present no reliable method is available to determine evapotranspiration losses in coastal Newfoundland. This is primarily a scientific problem and not an urgent practical necessity, nonetheless government should encourage research on this topic and monitor the findings.

(f) Data from the Bonavista region alone is minimal for stochastic analysis. More useful results could be obtained by using an island wide data set as was done for the RFFA study. [It is suggested that this task be taken up in the 1990's, following the completion of the current series of regional water resources studies. This analysis could draw on the large collection of physiographic data assembled at great expense for the ADB Water Resource Study (13) during the 1960s. This data is stored in the archives of Environment Canada (IWD) in Ottawa].

Overall the available data base, particularly flow data, is considered to provide an adequate basis for practical engineering design requirements; more so when periods of record reach 10+ years, at the more recently established gauging stations. These investigations have also confirmed past ShawMont experience that flow data provides a much more satisfactory basis for engineering design than climatologic data (precipitation and temperature).

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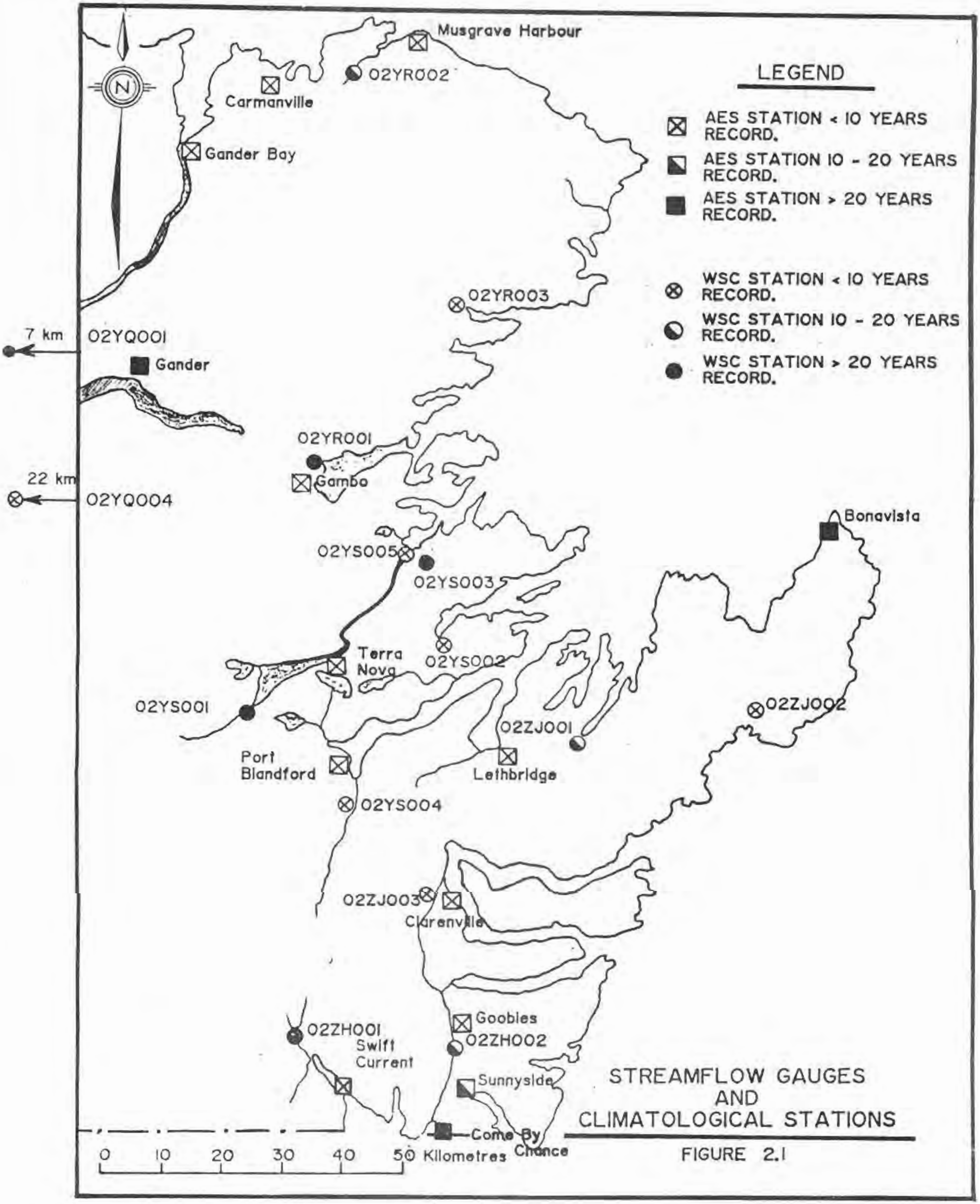
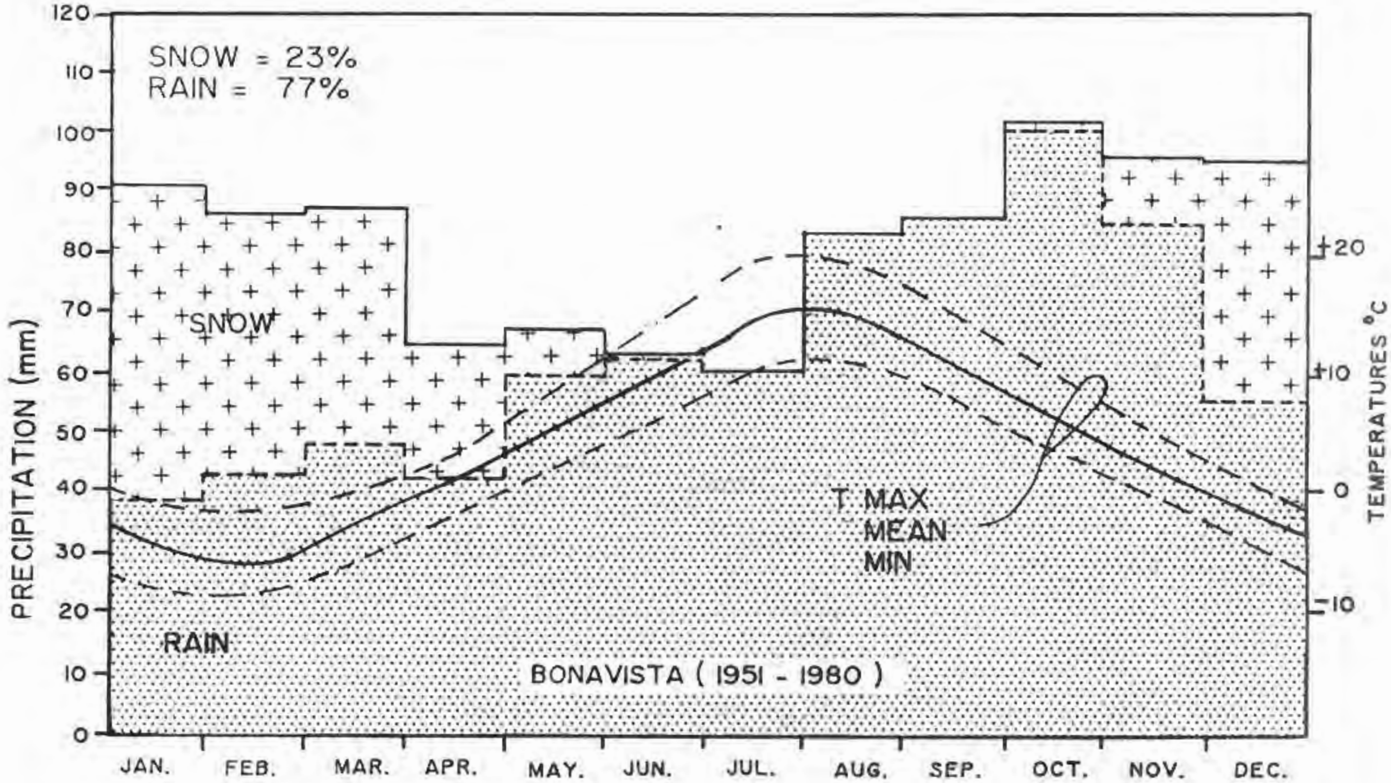


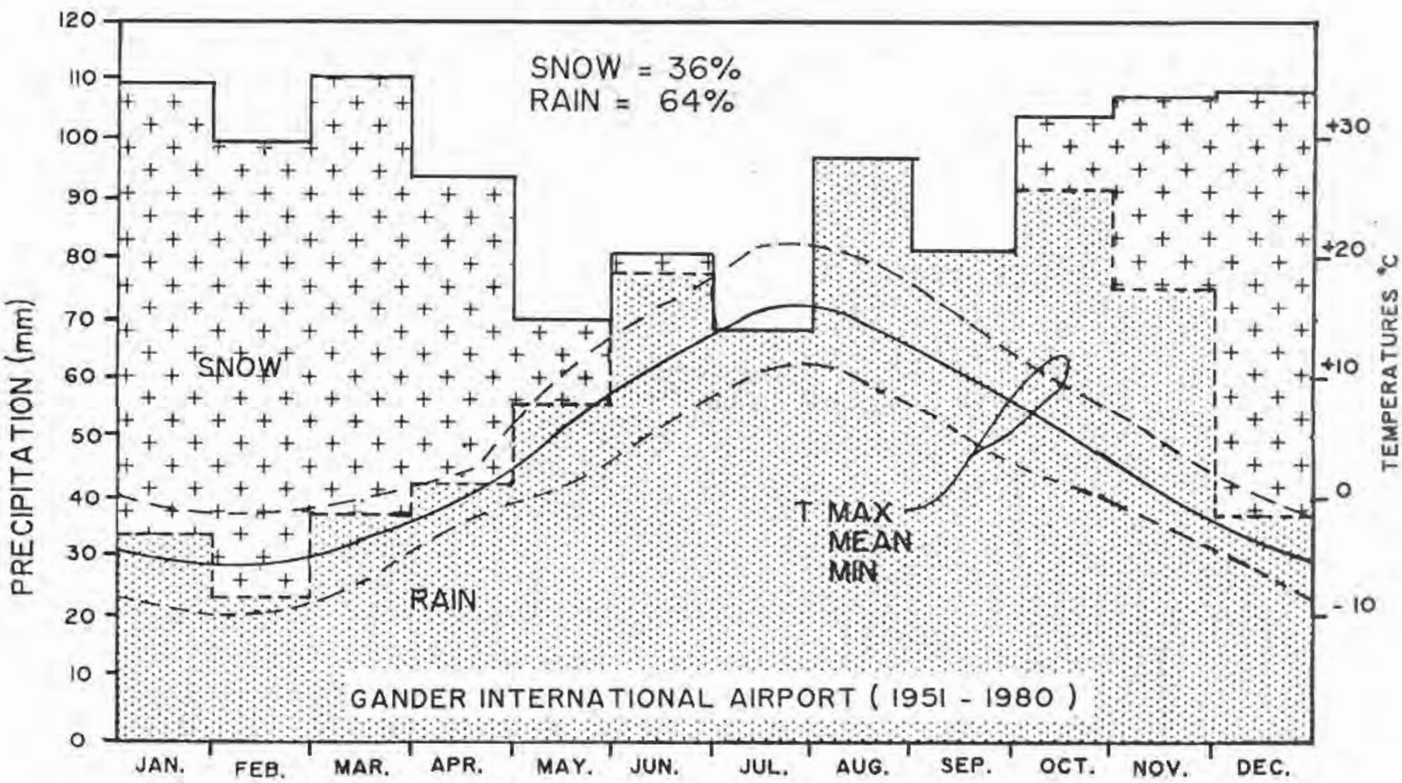
STREAMFLOW GAUGES
AND
CLIMATOLOGICAL STATIONS

FIGURE 2.1



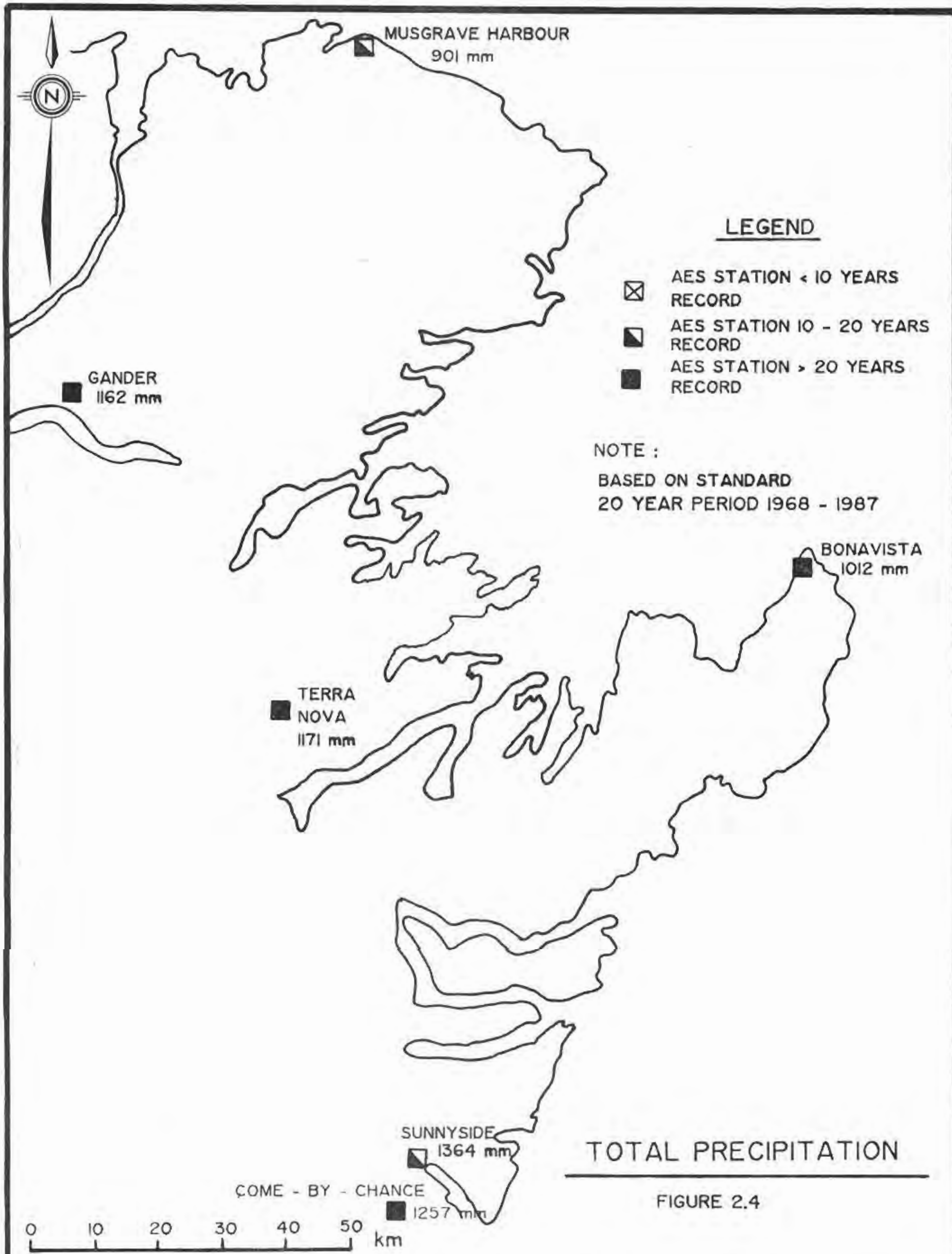
TEMPERATURE & PRECIPITATION -COASTAL STATION

FIGURE 2.2



TEMPERATURE & PRECIPITATION - INLAND STATION

FIGURE 2.3



TOTAL PRECIPITATION

FIGURE 2.4

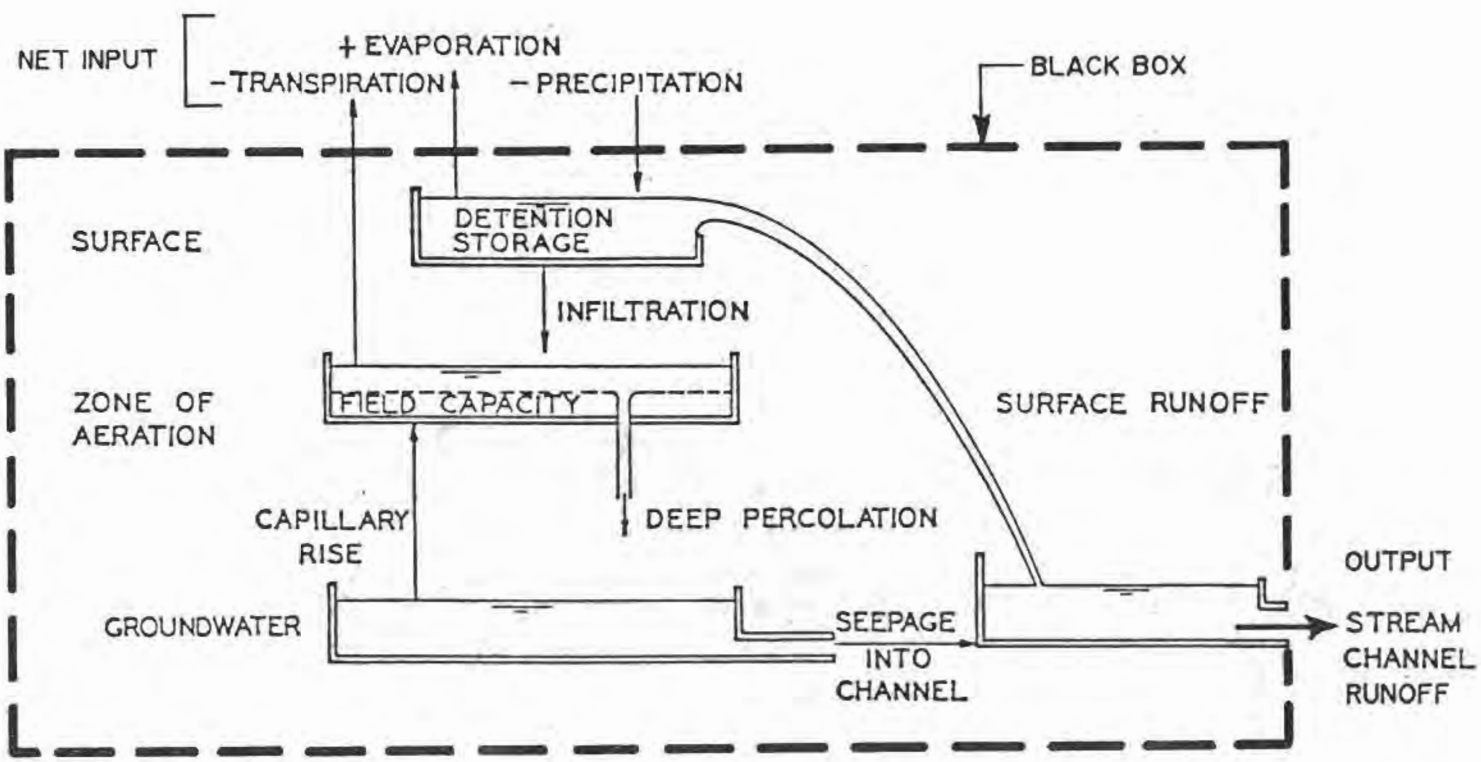
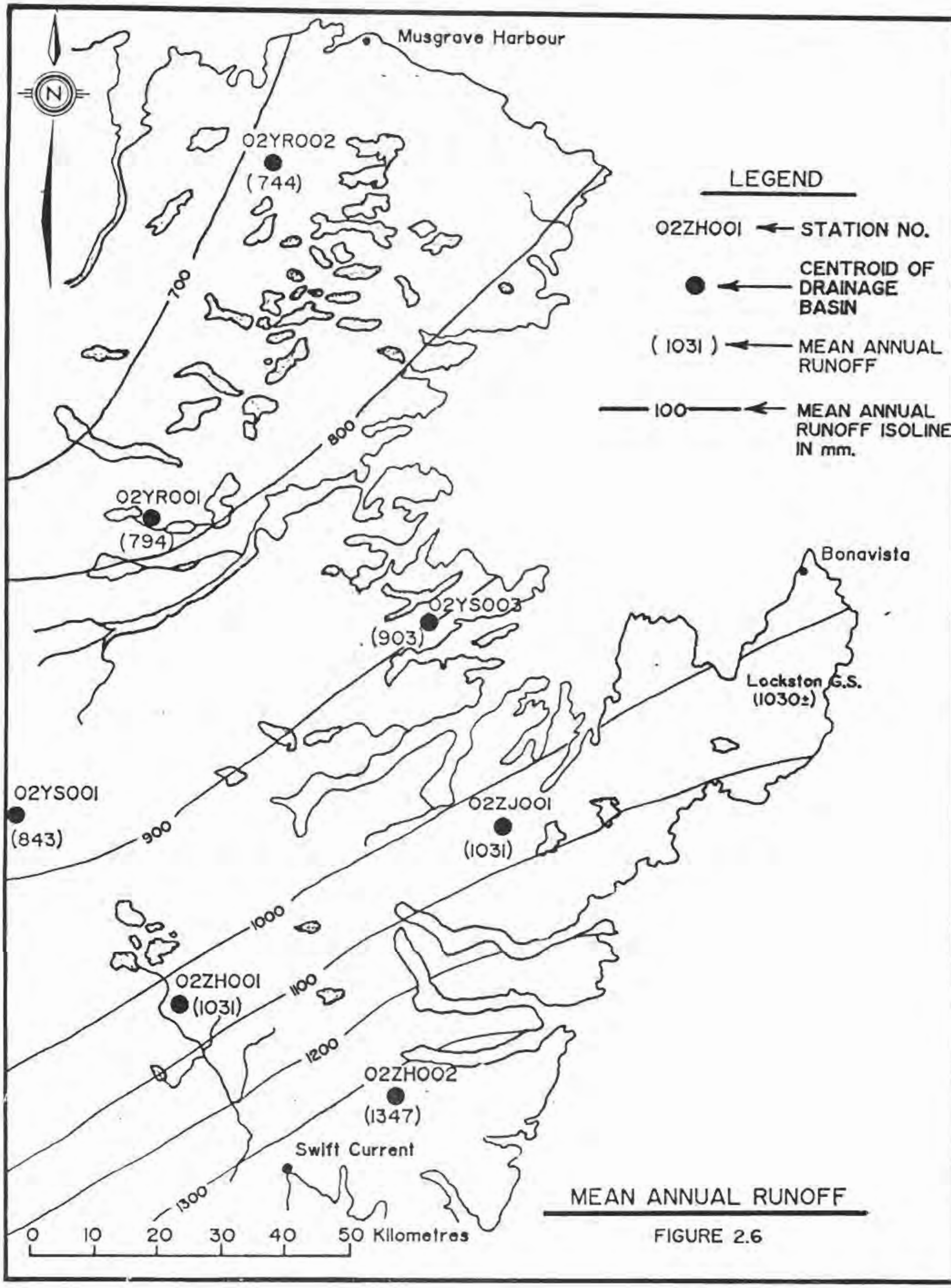


FIGURE 2.5

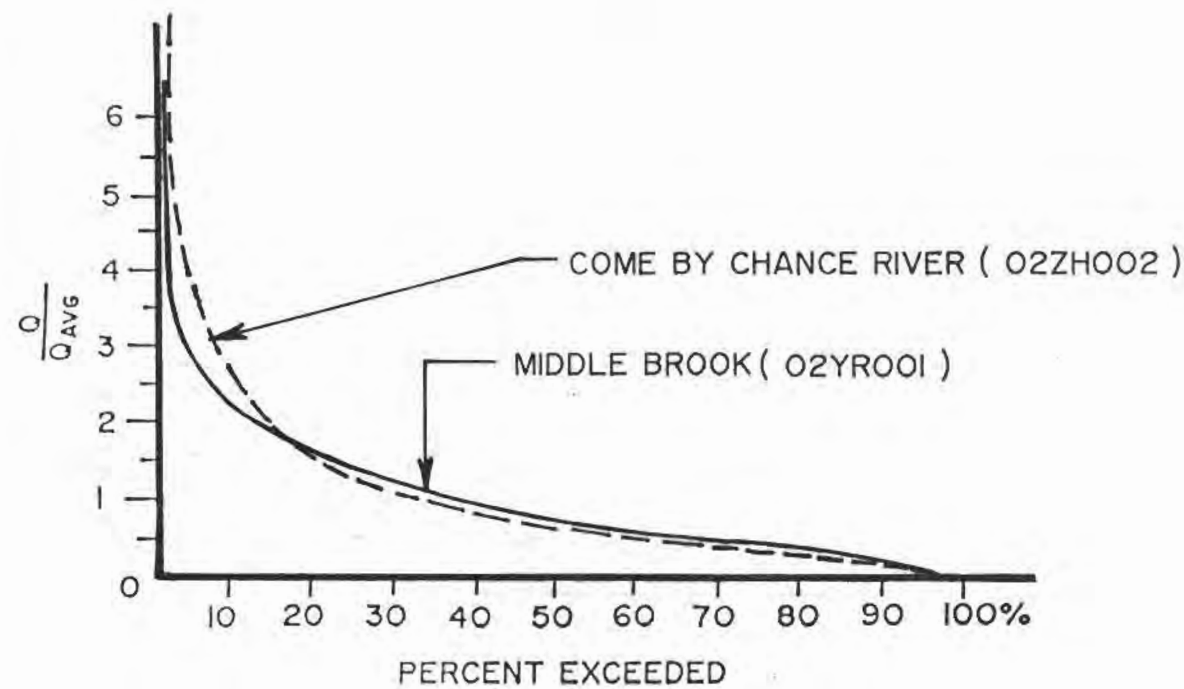
IDEALIZED WATERSHED MODEL

FROM: "HYDROLOGY FOR ENGINEERS AND PLANNERS"
BY A.T. HJELMFELT AND J.J. CASSIDY
REFERENCE (9)



MEAN ANNUAL RUNOFF

FIGURE 2.6



TYPICAL DAILY FLOW DURATION CURVES

FIGURE 2.7

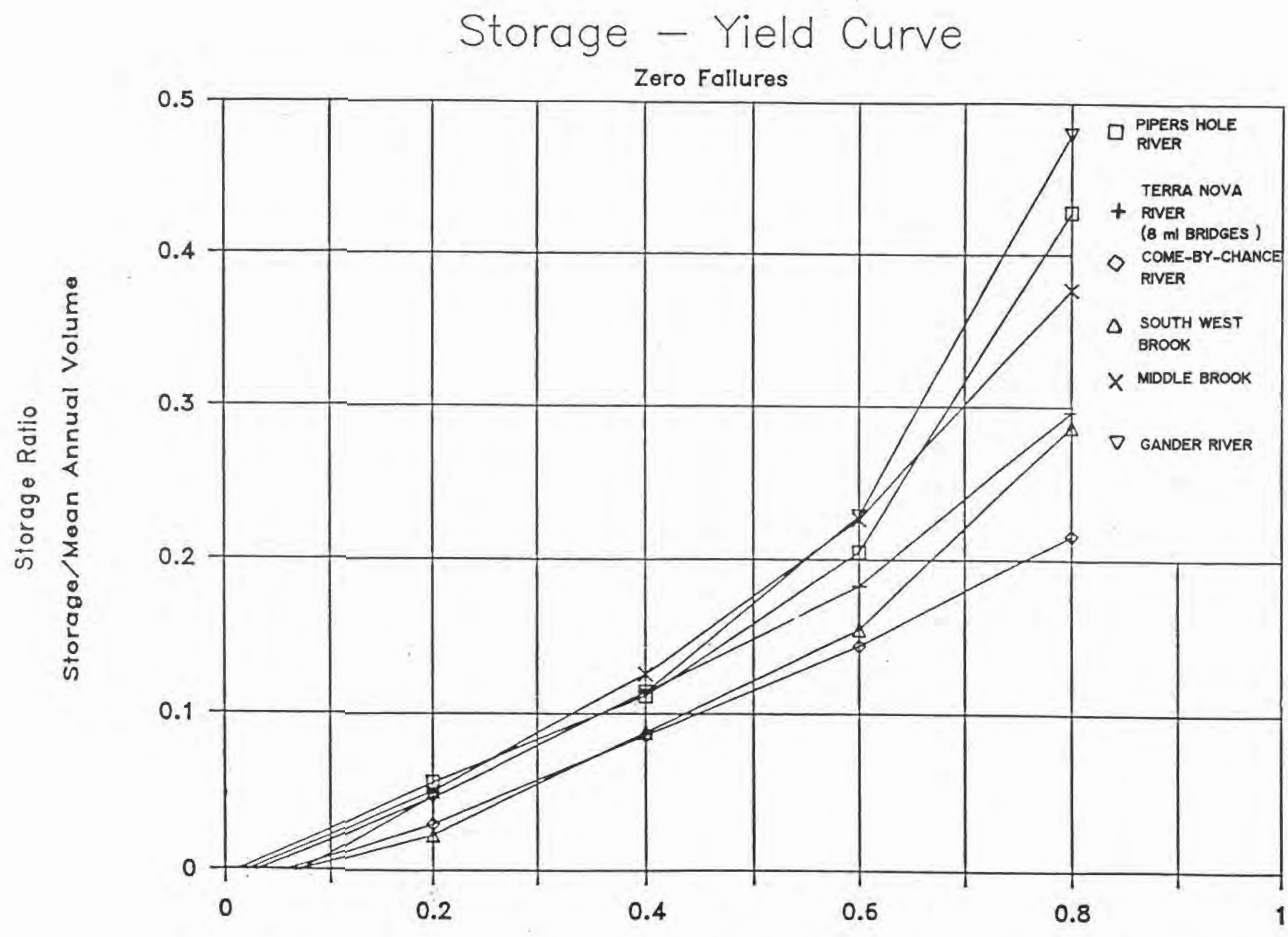

Storage — Yield Curve
Zero Failures
Storage Ratio
Storage/Mean Annual Volume
0.5
0.4
0.3
0.2
0.1
0
0
0.2
0.4
0.6
0.8
1
PIPERS HOLE RIVER
TERRA NOVA RIVER (8 ml BRIDGES)
COME-BY-CHANCE RIVER
SOUTH WEST BROOK
MIDDLE BROOK
GANDER RIVER
Yield Ratio = Qfirm/Qaverage

FIGURE 2.8

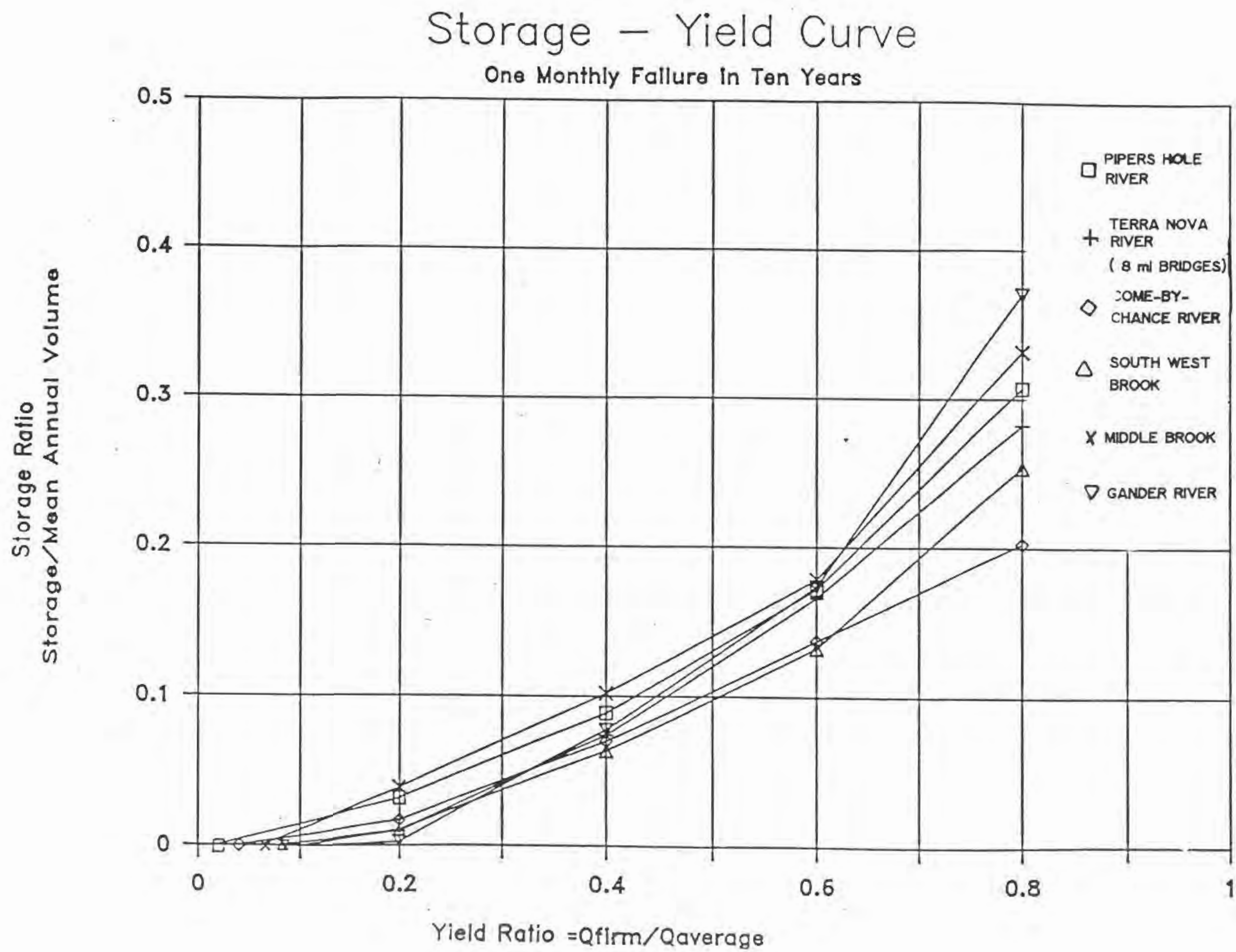

Storage — Yield Curve
One Monthly Failure In Ten Years
Storage Ratio
Storage/Mean Annual Volume
0.5
0.4
0.3
0.2
0.1
0
0
0.2
0.4
0.6
0.8
1
Yield Ratio =Qfirm/Qaverage
PIPERS HOLE RIVER
TERRA NOVA RIVER (8 mi BRIDGES)
COME-BY-CHANCE RIVER
SOUTH WEST BROOK
MIDDLE BROOK
GANDER RIVER

FIGURE 2.9

CHAPTER THREE

GROUNDWATER AVAILABILITY

3.1 INTRODUCTION

The hydrogeology of the Bonavista Bay area has been the subject of two studies by Nolan Davis and Associates (1, 2) for the provincial Department of Environment and Lands, in 1981 and 1982, respectively. Much of the material in this section comes from their reports, supplemented by some recent well data from wells drilled since 1981. In both reports, sets of hydrostratigraphic units were proposed relating surficial and bedrock geology to well yields. This chapter reviews and summarizes the main observations from these studies.

3.2 PHYSIOGRAPHY

It is convenient to divide the study area into two zones:

- a coastal zone, lying between the Trans Canada Highway and the ocean with elevations rarely exceeding 80 m,
  and
- an inland zone, at higher elevations, hereafter called "the interior uplands". The interior uplands is essentially a plateau at an elevation of about 200 m. Isolated peaks rise above this elevation, the highest of which is Mount Sylvester, elevation 381 m.

Surface features are much affected by glaciation giving rise to a landscape of low ridges interspersed with lakes, peat bogs, areas of exposed bedrock and low lying areas covered with glacially transported material. The glacial material in the coastal area is generally a thin mantle of till, generally less than 3 m in thickness. However, many valleys leading from the interior of the study area to the sea contain glacial and river outwash deposits of sand and gravel.

Little is known about the physical nature of the moraine deposits in the interior upland. Their morphological expression on aerial photographs suggests thicker deposits than in the coastal areas.

3.3 GROUNDWATER FLOW SYSTEMS

Groundwater sources can be classified into three categories;

(i) surficial sources: groundwater stored in unconsolidated surficial deposits, above bedrock and typically exploited in shallow wells,

(ii) bedrock with primary permeability: typically sedimentary rock formations where the rock mass is generally permeable via interstitial voids,

(iii) bedrock with secondary permeability: rocks in which significant water movement occurs mainly through fracture systems associated with folding or faulting, or in solution channels along fractures and bedding planes.

3.4 SURFICIAL HYDROGEOLOGY

Nolan and Davis (1,2) define two major surficial hydrostratigraphic units:

- moraine/glacial tills
- glaciofluvial

Moraine/glacial tills contain appreciable amounts of very fine-grained materials that reduce permeability; hence, wells in this unit are poor producers. Previous work suggests that the average yield of dug wells in till is less than nine litres per minute (1,2).

By contrast glaciofluvial deposits, which consist mainly of outwash sands and gravels, are much more permeable and consequently wells in this unit are much better producers. The limited data available suggest production rates generally superior to 50 litres per minute (see Table 3.1).

Table 3.1

Characteristics of Community Wells in Glaciofluvial Deposits

Location	No. of Wells	Yield (l/min)		Depth (m)
		Mean	Range	
Terra Nova	9	114	56 - 181	7 - 18
Carmanville	1	273		8.0
Shoal Harbour	3	78	18 - 81	not available

The Department of Mines and Energy, Environmental Section, has mapped the glaciofluvial deposits from aerial photographs (3) and by ground sampling along road and rail corridors under the Aggregate Resource Mapping Program (4). This latter program has delineated a substantial glaciofluvial deposit along the Sandringham - Eastport - Sandy Cove corridor, on the Eastport Peninsula. Ample municipal water supplies for Sandringham and Eastport are drawn from wells located in this deposit.

Other communities located near glaciofluvial deposits include:

Gander Bay
Gambo - Middle Brook
Glovertown
(see Figure 3.1 for locations)

3.5 BEDROCK HYDROGEOLOGY

Most of the wells drilled in the study area have been drilled into bedrock. Based on statistics associated with these wells the study area was divided into five bedrock hydrostratigraphic units which have boundaries similar to related geologic formations or groups of formations (1,2), see Figure 3.1.

The approach in producing these hydrostratigraphic units was to relate well yields to bedrock formations. This approach, though necessary in a preliminary examination of groundwater, is very approximate and should be used cautiously especially in areas where groundwater resources depend on secondary permeability.

Most bedrock formations within the study area, because of their age, genesis and composition, contain little if any primary permeability, thus rock formations with secondary permeability predominate. In this kind of terrain it is the structural features such as faults and shear zones that are of prime interest when searching for groundwater. Where bedrock exposures are common it is often possible to identify targets for well drilling with reasonable reliability. On the other hand, if bedrock is covered with overburden and its structure obscured, well drilling becomes a hit or miss proposition. Nevertheless, some very successful wells have been drilled in this terrain when located in appropriate structures. Mean yields from various bedrock types vary from 7 l/min for Bedrock Unit 1 to 28 l/min for Bedrock Unit 5, as shown in Figure 3.1.

3.6 EXPERIENCE WITH GROUNDWATER SUPPLY

Groundwater supply is a significant source of water supply in the study area. About 14% of the population obtain their water from private shallow or drilled wells. Additionally, there are several municipal and local service districts which depend on wells and supply about 8% of the population (5). Information collected in the Facilities Survey portion of this study (5) indicates that many of these systems are inadequate, suffering from inadequate yields during dry periods. This problem is probably due to inherent low storage capacity of shallow surface aquifers and bedrock aquifers supplied by secondary permeability systems.

3.7 CONCLUDING COMMENTS

The potential for groundwater development in the study area is limited due to the prevalence of bedrock types having minimal primary permeability.

Available experience suggests that glaciofluvial deposits provide the most dependable aquifers and the performance of wells located in such deposits have generally been satisfactory. While some wells drilled in bedrock units have been good producers many have performed poorly. This is probably due to the fact that many bedrock aquifers are of limited extent and consequently provide inadequate groundwater storage.

It is suggested that Government consider testing the groundwater potential of major glaciofluvial deposits that would be potential candidates for municipal water supply. Such a testing program could be undertaken in cooperation with the ongoing surficial mapping programs of the Department of Mines and Energy. Further investigation of bedrock aquifers should be assigned a low priority, since water resources in such aquifers is judged to be poor.

REFERENCES FOR CHAPTER 3

1. Nolan Davis and Associates (1981)
"Hydrogeology of Bonavista Bay Area, Report 2-3"
for the Government of Newfoundland and Labrador, Department of Environment.

2. Nolan Davis and Associates (1982)
"Hydrogeology of Trinity Bay Area, Report 2-4"
for the Government of Newfoundland and Labrador, Department of Environment.

3. Provincial Department of Mines and Energy, Aerial Photos Interpretation NTS Series, 1:50,000.

4. Provincial Department of Mines and Energy, Aggregate Resource Map Series, Map Numbers 83-7, 8-13, Scale 1:250,000.

5. ShawMont Newfoundland Limited, (1989)
"Bonavista Water Resources Study. Survey of Facilities"
for the Government of Newfoundland and Labrador. Department of Environment and Lands.

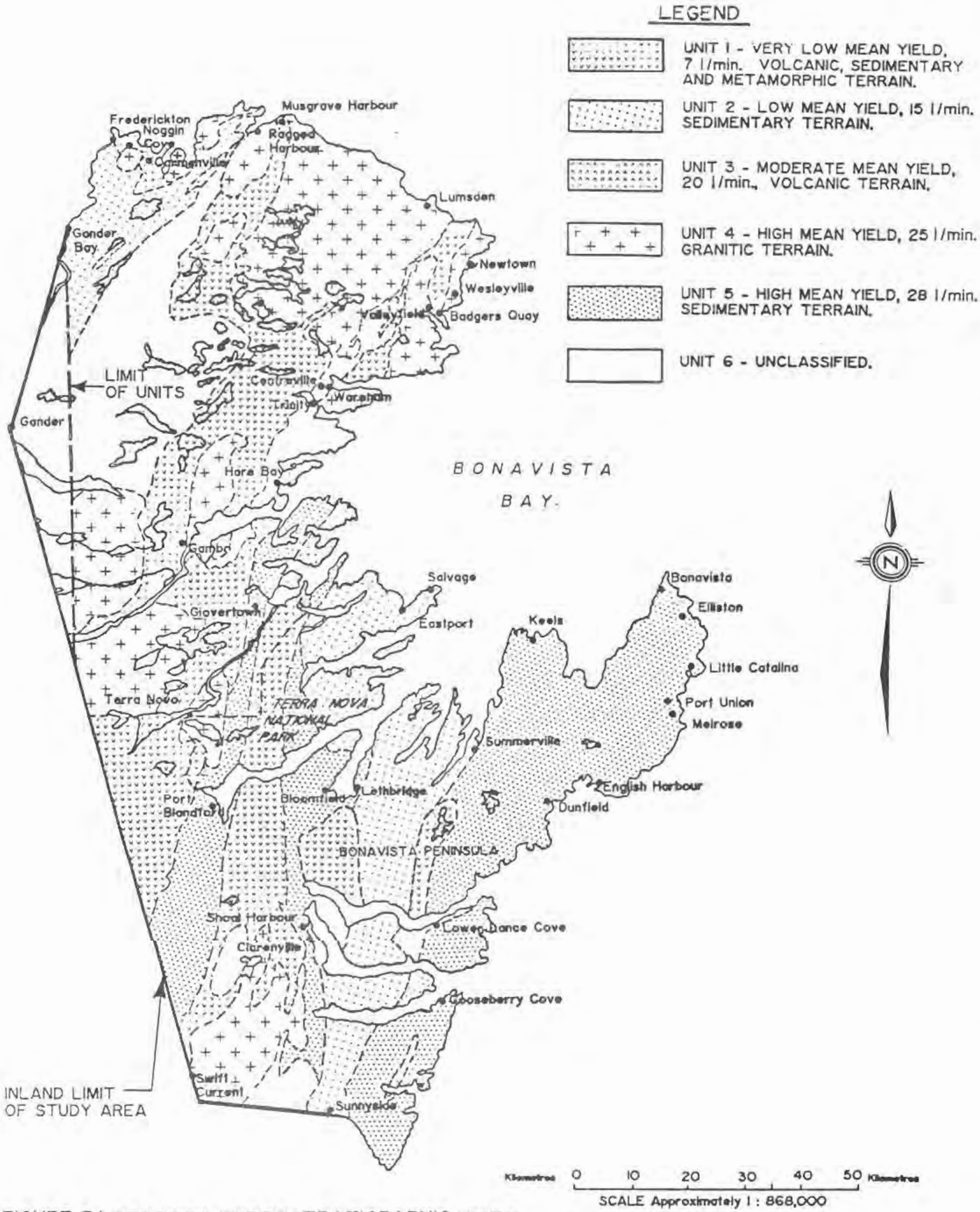


FIGURE 3.1: BEDROCK HYDROSTRATIGRAPHIC UNITS.
BONAVISTA BAY STUDY AREA (FROM REFERENCES 1 AND 2)

CHAPTER FOUR

WATER QUALITY

4.1 INTRODUCTION

In this chapter the quality of surface and groundwater resources is assessed with the objectives of identifying existing or potential water quality problems.

This assessment is based on available water quality data (see Section 4.2). No water testing was undertaken as part of the study.

The study area has a relatively low population density (2.5 persons per km^2) distributed in numerous small (mostly coastal) communities. As a result there is rarely more than a single withdrawal user on any brook or river. Sewage disposal is either by private septic tanks or via ocean outfalls in communities having sewage collection systems.

Industrial development in the study area is limited to traditional resource based industries, mainly: fishery, forestry and some agriculture. There are no mines, pulp and paper mills or heavy industries. Tourism is an important economic activity, based on outdoor activities, notably the sport fishery.

At the present time the main uses for water are: municipal and private (domestic) water supplies, fish plant supplies, livestock and wildlife watering, hydropower production and recreational uses.

4.2 AVAILABLE DATA

The water chemistry analyses, on which this section of the report is based, were provided by various agencies, or taken from reports written since 1965, as follows:

(i) Environment Canada, Water Quality Data Newfoundland 1965-1980 (1).
Environment Canada, Water Quality Data Newfoundland 1981-1985 (2).

Between 1965-1985 Environment Canada collected and tested water samples from Gander River, Ragged Harbour River, Terra Nova River, Come By chance River, Southern Bay River, Bread Cove Brook, Hare Bay Brook, Southwest Brook, Big Brook and several ponds in Terra Nova National Park. The parameters tested include physical parameters, major nutrients, pH, specific conductance, temperature, dissolved oxygen, and coliform bacteria.

(ii) Environment (Nfld), Water Quality Data Summary Statistics 1977-1986 (3).

The Government of Newfoundland and Labrador, Department of Environment published a statistical summary for the years 1977-1986 of water quality data collected by the Water Resources Division. Four rivers were monitored in the Bonavista study area. They are Ragged Harbour River, Middle Brook, Southwest Brook and Southern Bay River.

(iii) Canada-Newfoundland Water Quality Monitoring Program, 1987 (4).

In 1986 the Canada-Newfoundland Water quality Monitoring Agreement was ratified. One of its objectives is to detect long term trends in surface water quality. Monitoring of Southwest Brook and

Southern Bay River, initiated by the Department of Environment and Lands, is continued under this program which has been expanded to include Gander River, Pound Cove Brook, two stations on Terra Nova River, Bread Cove Brook and Pipers Hole River. Monitoring stations of Ragged Harbour River and Middle Brook were retired at the end of 1986. Apart from the standard water quality parameters, the Southern Bay River station was also tested for organochlorine, pesticides and polychlorinated biphenyls (OC-PCBs group) in water, see Table 4.13, at the end of this chapter.

(iv) Data Provided by Environment and Lands (unpublished at present).

In 1986 the Newfoundland Department of Environment and Lands collected water samples from eight water supplies of the following communities in the Bonavista study area: Port Blandford, Plate Cove East, Bonavista, Newtown, Trinity, Gambo, Gander Bay South and Hickman's Harbour. The water analysis included selected toxic chemicals. The sampling and testing, excepting toxic chemicals, were continued into 1987 for protected watershed areas in the Bonavista study area.

(v) Hydrogeology Reports by Nolan Davis and Associates (5,6).

Two hydrogeologic studies were undertaken by Nolan Davis and Associates for the Government of Newfoundland and Labrador, Department of Environment in 1981 - 1982 which discuss well water and surface water quality.

(vi) Environment Canada, Water Quality of Surface Waters in Newfoundland and Labrador (7).

In 1982, Environment Canada published a report on water quality of surface water of Newfoundland and Labrador. Pertinent to the Bonavista study area are water quality analyses of four inland ponds in the study area (7).

Tables 4.12 and 4.13 list the parameters tested under each of the above programs.

All of the data published in the above reports, except item (v), are archived in the NAQUADAT data base of Environment Canada (4).

4.3 WATER QUALITY ASSESSMENT

4.3.1 Introduction

The water quality of sources within the study area was assessed by comparing measured values of water quality parameters from long term water quality monitoring stations against recommended water quality guidelines for the main water uses. (See Figure 4.1 for station locations and Tables 4.9 to 4.11, for data summaries - at end of the chapter). For the most part, water quality guidelines were taken from the publication "Canadian Water Quality Guidelines", published by the Canadian Council of Resource and Environment Ministers (8). This publication provides water quality guidelines for the following uses:

- domestic consumption
- livestock/wildlife

- fresh water aquatic life
- fish plants, and
- recreational uses.

Other issues examined in this chapter include, acid rain, pesticide/herbicide contamination and harbour pollution.

4.3.2 Domestic Consumption

Guidelines for domestic water quality recommend criteria for inorganic, organic, physical, radiological and bacteriological parameters of drinking water in terms of maximum acceptable limits. Drinking water that contains substances in concentrations outside these limits may either produce adverse effects on health or be aesthetically objectionable. Table 4.1 summarizes drinking water guidelines for treated drinking water (values in parenthesis indicate raw water limits). Limits on organic chemicals and radiological parameters, excepting strontium, are omitted from this list since they are rarely tested for in Newfoundland. The issue of water contamination from organic chemicals in herbicides and pesticides is discussed later in Section 4.5.

The most representative data on water quality in the study area are from the fourteen rivers and lakes which have been regularly monitored. These data are summarized in Tables 4.9 to 4.10 at the end of this chapter. Station locations are shown in Figure 4.1. These tables summarizes mean measured values for most water quality parameters. For problem parameters, mean, minimum and maximum values are shown as well. Data on water quality from groundwater sources are summarized in Table 4.11.

Table 4.1

Water Quality Guidelines

Water for Domestic Consumption

PARAMETER	UNIT	LEVEL	PARAMETER	UNIT	LEVEL
Bacteria: (4)			Manganese	mg/l	0.05
Fecal Coliform	no/dl	ND (1000)	Mercury	µg/l	1
Total Coliform	no/dl	ND (5000)	Nitrate as N (1)	mg/l	10.0
Inorganic			Nitrite as N (1)	mg/l	1
Parameters:			pH	mg/l	6.5-8.5
Alkalinity,	mg/l	30-500	Selenium	mg/l	0.01
Total as $CaCO_3$			Silver	mg/l	0.05
Ammonia, as N	mg/l	LE 0.5	Sulphate	mg/l	500
Arsenic, as As	mg/l	LE 0.5	Sulphide as H_2S	mg/l	0.05
Antimony	mg/l	-	Total dissolved	mg/l	500
Arsenic	mg/l	0.05	solids		
Asbestos	mg/l	-	Uranium	mg/l	0.02
Barium	mg/l	1.0	Zinc	mg/l	5.0
Boron	mg/l	5.0	Selected Physical		
Cadmium	µg/l	5	Parameters:		
Chloride	mg/l	250	Colour	TCU (2)	15
Chromium	mg/l	0.05	Turbidity	NTU (3)	5
Copper	mg/l	1.0	Selected		
Cyanide	mg/l	0.2	Radiological		
Fluoride	mg/l	1.5	Parameters:		
Hardness	mg/l	-	Strontium	Bq/l	40,000
Iron	mg/l	0.3			
Lead	mg/l	0.05			

Source: Canadian Water Quality Guidelines, Reference 8, unless otherwise noted.

1. Where both nitrate and nitrite are present the total nitrate plus nitrite nitrogen should not exceed 10 $mg.L^{-1}$.
2. True colour units.
3. Nephelometric turbidity units.
4. From Water Quality Source Book (9).

When measured values of water quality parameters are compared with the guideline values the following points are observed:

(i) Raw waters are relatively free from bacteriological contamination with fecal and total coliform counts usually within normal background levels (fecal coliforms <20/dl and total coliforms <100/dl*) and always within the maximum raw water limits.

(ii) Waters are relatively pure having low values of turbidity and total dissolved solids (TDS).

(iii) Waters are soft and usually acidic.

(iv) Waters generally meet the criteria stipulated in the Canadian Water Quality Guidelines.

(v) Out of range measurements were observed for the following water quality parameters:

- alkalinity
- colour
- iron
- manganese
- pH
- turbidity

The significance of these departures from the guidelines is discussed below:**

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* From References 5 and 6, as further discussed in Section 4.3.3.

** These discussions are based largely on the commentaries contained in the Canadian Water Quality Guidelines (8) and the Water Quality Sourcebook (9).

(a) Alkalinity

Alkalinity is a measure of a water's capacity to neutralize an acid. Since most of this capacity is due to the carbonate-bicarbonate buffering system, alkalinity is usually expressed as a calcium carbonate ($CaCO_3$) equivalent. Alkalinity of surface water sources is much below the recommended minimum of 30 mg/l for all surface stations, with average values ranging from 1.1 mg/l to 10.3 mg/l. Values reported for groundwater are higher, usually above 40 mg/l, to a maximum of 160 mg/l. Generally, low values of alkalinity are due to the lack of readily available carbonate minerals in the soil and bedrock. Somewhat higher values in groundwater are due to longer residence times in various bedrock aquifers. No relationship could be discerned between bedrock type, as defined in Figure 3.1, and alkalinity.

(b) Colour

Colour of raw water is mainly due to the presence of certain mineral and/or organic materials in solution or colloidal suspension. For water in the study area the most probable culprits are iron and manganese compounds, humic products and lignins from bog and forest. These give the water brownish "tea" like colour.

Colour is either measured in true colour units (TCU), using filtered water samples, or as relative units (RU) when measured using unfiltered samples. Where turbidity is low, which is often the case in the study area, there is close agreement between the two measures.

Colour is not considered to be a serious pollution problem since it does not produce an adverse effect on health. However, excess colour is undesirable for aesthetic reasons and because coloured water may stain clothes and plumbing fixtures. For these reasons the guidelines recommend a maximum limit of 15 TCU* for domestic water.

Measured values for colour from waters in the study area were consistently found to exceed the guideline limit, for most surface and groundwater sources. For surface waters the mean value was 46 RU with an overall range of 0-180 RU. For groundwater the mean exceeds the guidelines with a range of 5-200 RU. An exception was groundwater from Bedrock Unit 2, which was usually within the guideline limit.

Organic colour can be reduced by coagulation and filtration, while iron and manganese can be removed by precipitation (24). Both processes are relatively complicated and are very expensive to apply on small water supply systems. In fact the only water treatment process that is widely used in the study area is chlorination, which is required for disinfection. It is now known that small amounts of potentially harmful chloromethanes can be produced by reaction between chlorine and organic materials in solution or in colloidal suspension. This is now

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* In water with low turbidity true colour units (TCU) approximately equal relative units (RU).

seen as a particular problem with highly organically coloured waters. The significance of this problem is currently being studied by the Canadian Drinking Water Guidelines Committee (25).

(c) Iron

The presence of iron in water is objectionable mainly for aesthetic reasons, since it does not have an adverse impact on human health. Problems associated with excess iron include staining of clothes and plumbing fixtures and bad taste. For these reasons the water quality guidelines recommend a maximum limit of 0.3 mg/l. About half of the surface water stations report mean iron concentrations in excess of the prescribed limit, and all stations report occasional measurements above this limit. These excursions above the prescribed limit generally occur during low flow periods when a higher than average proportion of river flow is from groundwater. Iron concentrations in groundwater sources appear to be generally higher than for surface waters. This is particularly demonstrated in the Bedrock Unit 5. Other units would probably show this trend if sufficient data were available.

Higher concentrations of iron in groundwater are due to two factors:

- longer residence times and more intimate contact with rock minerals,
- probable occurrence of anaerobic conditions permitting removal of iron from the parent rock in the relatively soluble ferrous form.

(d) Manganese

Manganese, a metallic cation, is similar to iron in its chemical behaviour and is frequently found in association with iron. The main sources of manganese are soil and bedrock. Low pH values and anaerobic conditions enhance its solubility. Like iron, the main objections to the presence of manganese in domestic water, are aesthetic. Manganese can stain clothing and plumbing fixtures, and imparts a bad taste to water when present in concentrations greater than 0.2 mg/l. For these reasons the guidelines set a limit of 0.05 mg/l for water for domestic consumption.

Data from surface water quality monitoring stations show that 2 stations out of 14 have mean concentrations in excess of the prescribed limits.

Concentrations of manganese measured in groundwater tend to be higher than values from surface water sources, with most samples from Bedrock Units 4 and 5 exceeding the guidelines.

(e) pH

pH is a measure of the concentration of hydrogen ions in water and is an indication of the balance between acids and bases in the water. The relative concentrations of hydrogen and hydroxide ions control many physical-chemical and biological processes in an aqueous environment. pH is measured on a logarithmic scale as the negative logarithmic value of the concentration of hydrogen ion. Neutral water has a pH of 7.0. Values of pH < 7.0 indicate acidic conditions while values of pH > 7.0 indicate basic conditions. Natural waters in Newfoundland tend to be acidic due to the small amounts of carbonate minerals in soil and bedrock and the presence of organic acids in runoff from bogs.

One effect of acidic water is the enhanced solubility of metals from bedrock and sediment. Low pH (acidic water), low concentrations of alkalinity (as $CaCO_3$) and high concentrations of iron and manganese observed in the study area are all interrelated.

A wide variation of pH is observed in natural waters ranging from 4.0 to 9.0. Low values of pH cause corrosion in metal piping, while high values interfere with water treatment processes. For these reasons the guidelines recommend a range of pH from 6.5 to 8.5.

The mean pH values for surface waters in the study area are consistently below the guideline limits with means between 6.0 and 6.4 and an overall range of 4.5 to 8.4.

On the other hand, measured values of pH for groundwater meet the guidelines [6.5 < pH < 8.5].

The combination of low dissolved solids and low pH tends to make these waters "aggressive", i.e. likely to corrode metal piping (10). Even though low pH values can be readily adjusted in water treatment plants, by addition of lime, only two communities, Newtown and Gander apply pH adjustment.

Like much of insular Newfoundland, the study area is vulnerable to acid rain, and consequently increase in water acidity is a potential problem. (This issue is further discussed in Section 4.4).

(f) Turbidity

Turbidity is a measure of the suspended particles, such as silt, clay, organic matter, micro-organisms, in water which are held in suspension by turbulence and Brownian movement. Turbidity does not usually affect the safety of drinking water unless asbestiform minerals are present, but it does affect consumer acceptability. The guidelines recommend a maximum value of 5 JTUs for treated water. No recommendations are given for raw water. The data from surface water quality monitoring stations, indicates that both surface and groundwater sources generally meet the guideline criterion. Rare excursions above guidelines have been observed - notably on Ragged Harbour River - where a maximum value of 7.5 JTU was measured in 1980. Turbidity is reported to be a problem for some communities in the study area, which draw their water from shallow lakes. These are sporadic problems that occur with lake water overturns in the spring or as a consequence of the entrainment of bottom sediments by currents produced by windstorms (11).

Overall turbidity may be considered a minor problem, and with a few exceptions, treatment of raw watering by filtration or clarification is not required; in fact, only four communities treat their water for turbidity: Clarenville by clarification and Gander, Glovertown and Lumsden by filtration.

(g) Localized Problems

A few localized water quality problems were identified in the facilities survey (12). These included contamination of wells by road salt as well as by seawater intrusion. Pollution due to farm runoff contaminated by animal wastes and fertilizers is a potential problem. Contamination of surface water supplies by sewage is an unlikely problem in the study area since most communities are located on the coast and discharge their waste waters to the ocean. Only in the Gander River basin is there potential for pollution of downstream supplies from treated sewage discharge at Glenwood, Appleton and Gander.

Some degradation of water quality has been reported on Gander River just downstream from Glenwood and Appleton. This problem is attributed to unsatisfactory operation of sewage treatment plants in those communities. As one moves down river from Glenwood/Appleton the water quality improves again as wastewater discharges are further diluted and aerated. Sewage treatment plants in Gander appear to function well and wastewater discharges do not degrade the receiving waters: Beaver Brook and Jonathan's Pond Brook.

Finally, there are risks of contamination of shallow private wells situated too close to privies or septic tanks.

(h) Observations

The following conclusions can be drawn from the foregoing comparison of actual water quality versus the guidelines for domestic consumption:

(i) At present water quality is good and lakes and rivers in the study area are in pristine condition showing little evidence of anthropogenic (manmade) change,

(ii) Waters tend to be naturally acidic due to the low buffering potential of most water sources and prevalence of organic acid runoff from bogs,

(iii) The few out of range water quality parameters (alkalinity, colour, iron, manganese, pH and turbidity) are from natural causes. These shortcomings affect the aesthetic quality of water only and do not cause health problems.

(iv) Potential problems include risks of localized pollution and the threat to forest and aquatic life from increasing acidification due to acid rain.

4.3.3 Livestock and Wildlife Watering

Water quality guidelines for livestock and wildlife watering are summarized in Table 4.2.

Table 4.2

Guidelines for Livestock & Wildlife Drinking Water Quality

Parameters	Guidelines (mg/L)
Major Ions and Nutrients	
Calcium	1000
Nitrate plus nitrite	100
Nitrite alone	10.0
Sulphate	1000
Total dissolved solids	3000 (tolerance varies with species)
Heavy Metals and Trace Ions[1]	
Aluminum	5.0
Arsenic	0.5 5.0 (when not added to feed)
Beryllium[2]	0.1
Boron	5.0
Cadmium	0.02
Chromium	1.0
Cobalt	1.0
Copper	1.0 (cattle) 5.0 (swine and poultry) 0.5 (sheep)
Fluoride	2.0 1.0 (if feed contains fluoride)
Iron[3]	-
Lead	0.1
Manganese[3]	-
Mercury	0.003
Molybdenum	0.5
Nickel	1.0
Selenium	0.05
Uranium	0.2
Vanadium	0.1
Zinc	50.0
Pesticides	See discussion on guidelines for drinking water, Chapter 1, Reference 8 for details
Biological Parameters	
Blue-green algae	Avoid heavy growths of blue-green algae
Pathogens and parasites	Water of high quality should be used
Fecal coliform[4]	< 0 - 20
Total coliform[4]	< 0 - 100

1. Guidelines expressed as total concentrations.
2. Tentative guideline.
3. No guideline recommended at this time.
4. Suggested in Reference 5, for undisturbed woodland areas.

These guidelines were taken from the publication "Canadian Water Quality guidelines" (8). They are general guidelines designed to protect farmyard animals, poultry and, by extension, wildlife. Parameter values are based on the resistance of the most sensitive species, unless otherwise noted.

The Canadian Water Quality Guidelines do not provide specific limits for the bacteriological quality of raw water, and so for the purposes of this study, it is assumed that raw water quality having fecal coliform and total coliform counts within background values, should be suitable for wildlife and free ranging animals. Where animals are reared intensively there is a greater risk of contamination from animal wastes. In these situations good farmyard hygiene is mandatory, possibly including water treatment.

A comparison of these guidelines with data from water quality monitoring stations confirms, as one would expect, that all water sources in this study are safe for livestock and wildlife watering.

4.3.4 Freshwater Aquatic Life

Table 4.3 summarizes the main inorganic and physical parameters recommended for freshwater aquatic life in the Canadian Water Quality Guidelines (8).

These are general guidelines which are probably conservative. They seek to protect all life forms that exist in a good quality freshwater environment (i.e., a

Table 4.3

Water Quality Guidelines for Freshwater Aquatic Life

Parameter	Guideline	Comments
Inorganic parameters		
Alkalinity[1]	20-500* $mg.L^{-1}$	
Aluminum	0.005 $mg.L^{-1}$	pH<6.5;[Ca^{2+}]<4.0 $mg.L^{-1}$;DOC<2.0 $mg.L^{-1}$
	0.1 $mg.L^{-1}$	pH≥6.5;[Ca^{2+}]≥4.0 $mg.L^{-1}$;DOC≥2.0 $mg.L^{-1}$
Antimony	ID[2]	
Arsenic	0.05 $mg.L^{-1}$	
Beryllium	ID[2]	
Cadmium	0.2 $\mu g.L^{-1}$	Hardness 0-60 $mg.L^{-1}(CaCO_3)$
	0.8 $\mu g.L^{-1}$	Hardness 60-120 $mg.L^{-1}(CaCO_3)$
	1.3 $\mu g.L^{-1}$	Hardness 120-180 $mg.L^{-1}(CaCO_3)$
	1.8 $\mu g.L^{-1}$	Hardness >180 $mg.L^{-1}(CaCO_3)$
Chlorine (total residual chlorine)	2.0 $\mu g.L^{-1}$	Measured by amperometric or equivalent method
Chromium	0.02 $mg.L^{-1}$	To protect fish
	2.0 $\mu g.L^{-1}$	To protect aquatic life, including zooplankton and phytoplankton
Copper	2 $\mu g.L^{-1}$	Hardness 0-60 $mg.L^{-1}(CaCO_3)$
	2 $\mu g.L^{-1}$	Hardness 60-120 $mg.L^{-1}(CaCO_3)$
	3 $\mu g.L^{-1}$	Hardness 120-180 $mg.L^{-1}(CaCO_3)$
	4 $\mu g.L^{-1}$	Hardness >180 $mg.L^{-1}(CaCO_3)$
Cyanide	5.0 $\mu g.L^{-1}$	Free cyanide as CN
Dissolved oxygen	6.0 $mg.L^{-1}$	Warm-water biota - early life stages
	5.0 $mg.L^{-1}$	- other life stages
	9.5 $mg.L^{-1}$	Cold-water biota - early life stages
	6.5 $mg.L^{-1}$	- other life stages
Iron	0.3 $mg.L^{-1}$	
Lead	1 $\mu g.L^{-1}$	Hardness 0-60 $mg.L^{-1}(CaCO_3)$
	2 $\mu g.L^{-1}$	Hardness 60-120 $mg.L^{-1}(CaCO_3)$
	4 $\mu g.L^{-1}$	Hardness 120-180 $mg.L^{-1}(CaCO_3)$
	7 $\mu g.L^{-1}$	Hardness >180 $mg.L^{-1}(CaCO_3)$
Mercury	0.1 $\mu g.L^{-1}$	
Nickel	25 $\mu g.L^{-1}$	Hardness 0-60 $mg.L^{-1}(CaCO_3)$
	65 $\mu g.L^{-1}$	Hardness 60-120 $mg.L^{-1}(CaCO_3)$
	110 $\mu g.L^{-1}$	Hardness 120-180 $mg.L^{-1}(CaCO_3)$
	150 $\mu g.L^{-1}$	Hardness >180 $mg.L^{-1}(CaCO_3)$
Nitrogen		
Ammonia (total)	2.2 $mg.L^{-1}$	pH 6.5; temperature 10°C
	1.37 $mg.L^{-1}$	pH 8.0; temperature 10°C
Nitrite	0.06 $mg.L^{-1}$	
Nitrate		Concentrations that stimulate prolific weed growth should be avoided
Nitrosamines	ID[2]	
pH	6.5-9.0	
Selenium	1 $\mu g.L^{-1}$	
Silver	0.1 $\mu g.L^{-1}$	
Thallium	ID	
Zinc[3]	0.03 $mg.L^{-1}$	
Organic parameters	(see Canadian Water Quality Guidelines), Reference 8.	

1. Montreal Engineering Co. Ltd. (15).
2. Insufficient data, no guideline recommended.
3. Tentative guideline.

water source little affected by human activities). Recommended parameter limits are based on the latest available information. While some limits have been established on the basis of conclusive research, many parameter values are still based on professional judgement, guided by preliminary or incomplete research findings. This is due to the fact that ecosystems and their interaction with the physical and chemical factors in freshwater are very complex and much work remains to be done before a satisfactory understanding of these interactions is achieved. The authors of the guidelines recognize that the guidelines may not fit all situations and that adjustment for site-specific conditions may be required. They also expect that the guidelines will require regular updating as the findings of new research become available.

Present water quality from monitoring stations within the study area was found to generally meet guideline criteria; however, problem parameters were pH and copper.

The guidelines recommend a pH range of 6.5 to 8.5, while mean pH values are generally lower than 6.5, ranging from pH = 6.0 for Terra Nova River at Glovertown to pH = 6.4 for Southern Bay River. Sporadic values of pH as low as pH = 4.4, have been recorded, at Middle Brook and Southern Bay River. A major concern is the impact of low values of pH on salmon and trout. This problem has been investigated by several researchers, as discussed by Scruton (13). Their conclusions were that salmon and trout were relatively tolerant of acidic waters. Based on such studies the Department of Fisheries and Oceans suggest the following pH tolerance limits:

Table 4.4

pH Tolerance Limits for Salmonids

SPECIES	pH LIMIT
Atlantic Salmon (and ouananiche)	5.0 - 5.5
Brown trout	5.0
Brook trout	about 4.5 - 5.0

Notes:

(1) Tolerance limits indicate conditions under which fish species decline, cease to reproduce or disappear.
(2) From Reference (14), Table 2.

When these limits are compared with the mean pH values from monitoring stations in the study area it is observed that present pH levels are safely above these limits for the salmon and trout species resident in the study area. Since pH varies with the hydrologic cycle there will be short periods of time when pH falls below pH = 5.0, the suggested tolerance limit for salmon, ouananiche and brown trout. It is known that these species will resist short periods when pH < 5.0, but the nature of this resistance is poorly understood (13).

Copper concentrations appeared to be above the recommended criteria on several of the monitored rivers, with average concentrations ranging from 0.010 mg/l - 0.054 mg/l versus the recommended criterion of 0.002 mg/l (see Tables 4.9 and 4.10). The effects on trout and salmon are the main concern. A study by Montreal Engineering Co. Ltd. (MECo) (15) for a fish hatchery in New Brunswick notes that salmonids are particularly sensitive to heavy metals (copper, lead and zinc) but only to that portion which is "bio-available". MECo also found that ordinary water analyses which report total heavy metals overstates the "bio-available" metal by significant amounts. Fishery scientists questioned on this issue reported that they were unaware of copper or heavy metal poisoning affecting trout or salmon in the study area. This suggests that the bio-available concentrations of copper are much less than the total copper concentrations measured at monitoring stations.

Other important factors affecting fish life are:

- oxygen > 7 mg/l, recommended in Reference 15,
- temperature 0.5°C - 19°C, recommended in Reference 15

Data from the monitored rivers consistently show satisfactory oxygen contents. Systematic temperature measurements are not recorded in the main data sources used in this study, however some data are available in Reference (16) which gives some water temperature measurements at time of sampling. These data show that temperatures in excess of 19°C (up to 24°C) occur occasionally in rivers in the study area.

It is probably worth noting that the level of dissolved solids in most waters in the study area is low. This indicates a relatively pure water but also indicates a low biological productivity (also see Section 5.4.1).

The following conclusions can be drawn from the foregoing review:

(i) Fresh water quality is good, generally meeting the guidelines for freshwater aquatic life.

(ii) Low values of pH and above guideline values for copper are due to natural causes.

(iii) There is no evidence that salmon and trout are adversely affected by existing pH and copper values although these are outside of guideline limits.

4.3.5 Fish Plants

Fish plants are the only significant industrial water users in the study area. Water use varies considerably from plant to plant, depending on the process involved. Water is used mainly for fluming, washing fish, cleaning equipment, ice making, supplies for fishing boats and domestic requirements. Seawater may be used instead of freshwater for many of these functions. Table 4.5 (next page) summarizes water quality requirement for fish plants and is based on the general food process category given in the Canadian Water Quality Guidelines (8).

These standards would apply to primary processing where water is not incorporated into the final product. In secondary fish processing and other food processing industries more stringent standards would apply which vary from one industry to another. Freshwater which meets drinking water norms would usually be satisfactory for secondary fish processing and meet most other food industry requirements (8). The main concern in fish processing is that the process water be contamination free.

Table 4.5

Water Quality Guidelines - Primary Fish Processing

PARAMETER	UNIT	LEVEL
Colour	RU	5-10
Turbidity	NTU	1-10
Suspended solids	mg/l	-
Dissolved solids	mg/l	<850
Calcium	mg/l	-
Magnesium	mg/l	-
Iron	mg/l	<0.2
Manganese	mg/l	<0.2
Copper	mg/l	-
Fluoride	mg/l	<1
Silica	mg/l	-
Hardness (as $CaCO_3$)	mg/l	10-250
Alkalinity	mg/l	30-250
Hydrogen sulphide	mg/l	-
Oxygen consumed	mg/l	-
Carbon tetrachloride extract	mg/l	-
Chloroform extract	mg/l	-
Nitrite	mg/l	-
Organic matter	mg/l	-

These requirements are stipulated in the fisheries inspection regulations, as below (cited from Reference 17):

"Water of acceptable quality is water that meets the requirements set out in the Fish Inspection Act c.F-12, R.S.C. 1970. Section 3 and the Fish Inspection Regulations c.802, C.R.C. 1978:

(1) An adequate supply of salt, sanitary water that:
   (a) has a coliform bacteria count, determined by a method acceptable to the Minister, of not more than two per hundred millilitres, or
   (b) is derived from a source approved by the Minister

shall be provided under a minimum operating pressure of twenty pounds per square inch.

(2) Notwithstanding subsection (1), an establishment may use water other than water referred to in subsection (1) for fire protection, boilers or auxiliary services if there is no connection between the water systems providing water to the establishment.

If the raw water source has a coliform count of 2 or more than 2 per hundred millilitres, then the following applies: The bacteriological quality of the raw water shall determine the minimum water disinfection treatment necessary for each water supply as follows:

(a) if the source contains up to 100 coliforms per 100 ml, treatment by chlorination, iodization, ozonation, or ultra-violet light shall be considered adequate;
(b) if the source exceeds 100 coliforms per 100 ml but is less than 4,000 coliforms per 100 ml, ozonation or filtration (by sand or other filtering medium) followed by chlorination, shall be considered adequate,
(c) raw water supplies with bacteriological counts exceeding 4,000 coliforms per 100 ml shall not be approved for use in registered fish processing plants."

The Department of Fisheries and Oceans presently recommends that all water used in fish processing be chlorinated even if coliform levels are below two per 100 ml (17). When measured water quality parameters from monitoring stations are compared with the guideline norms, the existing water quality is found to meet most of the requirements. Problem parameters are colour and total iron plus manganese. Colour is in excess of the guideline (>10 RU) at all monitoring stations, while total iron and manganese marginally exceed the norm ($Fe + Mn < 0.2$ mg/l) at Southwest Brook, Southern Bay and Ragged Harbour rivers.

Where such deficiencies are a problem the processor would provide his own treatment to solve the problem.

4.3.6 Recreational Water Quality

The use of lakes and rivers for water sports, (primarily swimming and boating) and the contribution of lake and river vistas to the general enjoyment of the outdoors are the recreational uses considered in the guidelines. Recreational water quality guidelines deal with health, safety and aesthetic concerns, as explained in the Canadian Water Quality Guidelines (8).

Recreation freshwater quality guidelines, taken from the above document are summarized in Table 4.6 (next page).

In general the water quality at all monitoring stations meet the guideline norms. The only problem parameter, is high colour which may, in some locations, reduce clarity below the suggested limit.

4.4 ACID RAIN

Acid rain is caused by the release to the atmosphere of oxides of sulphur and nitrogen during the burning of fossil fuels at coal-fired thermal generating stations, smelters and by automobiles. These oxides in turn combine with water

Table 4.6

Guidelines for Recreational Water Quality

Parameter	Guideline	Parameter	Guideline
Bacteriological		Aesthetics	All water should be free from: - materials that will settle and form objectionable deposits; - floating debris, oil, scum and other matter; - substances producing objectionable colour, odour, taste or turbidity; and - substances and conditions or combinations thereof in concentrations which produce undersirable aquatic life
Fecal coliforms	The geometric mean of not less than 5 samples taken over a 30-day period should be less than 200 fecal coliforms per 100 mL. Resampling should be performed when any sample exceeds 400 fecal coliforms per 100 mL.		
Other pathogens	see Canadian Water Quality Guidelines (8)		
Clarity	The water should be sufficiently clear that a Secchi disc is visible at a minimum depth of 1.2 m.	Oil and grease	Oil or petrochemicals should not be present in concentrations that: - can be detected as a visible film, sheen or discolouration on the surface; - can be detected by odour; or - can form deposits on shorelines and bottom deposits that are detectable by sight and odour.
pH	5.0-9.0		
Turbidity	The turbidity of water should not be increased more than 5.0 NTU over natural turbidity when this is low (<50 NTU)	Aquatic plants	Rooted or floating plants which could entangle bathers or obstruct boating and fishing should be absent

vapour in the atmosphere to form sulphuric and nitric acids. The acids thus formed may be transported over long distances before being deposited as rain, snow or dry particles (14).

The prime evidence of acidification is the pH of rain. Under natural conditions rainfall is slightly acidic, due to absorption of atmospheric carbon dioxide, and has a pH of about 5.6. Values of $pH < 5.6$ are indicative of acid rain. Actual values, measured during the last ten years, range from 4.0 to 4.2 in the northeastern U.S., where conditions are severe, to an average of $pH = 4.5$ in southwestern Newfoundland and $pH = 4.8$ in the Bonavista Bay area (14).

The Atlantic Provinces lie downwind of major pollution sources in the eastern seaboard of the U.S. and St. Lawrence - Great Lakes regions and receive most of their acidic precipitation from these sources (19). Newfoundland receives the least amount of acidic precipitation of all the Atlantic Provinces with the southwest corner of the Island receiving the highest doses (including contamination from Cape Breton thermal power and steel plants) with deposition rates declining in the northeast direction (14). The mean annual areal deposition rate for hydrogen ion, H^+, on the Island is in the order of 0.2kg/ha (18).

The impact of acid rain on the acidity of receiving waters is moderated by the buffering capacity of such waters. This buffering action largely depends on the concentrations of bicarbonate-carbonate ions in solution which are derived from soil and bedrock. Thus carbonate rock and carbonate rich soil types have a high buffering capacity, while igneous rocks, such as granites, will have a low buffering potential. Likewise fine grained soils (with long residence times) will have a higher buffering potential than coarse grained soils, for soils having the same mineralological composition.

Figure 4.2 (at end of the chapter) delineates bedrock zones of various acidification sensitivities on a map of the Island. This map is based on an examination of regional geology for the Island using the classification given in Table 4.7 (next page). An alternative classification system is based on the calcite saturation index (CSI) which is defined:

$$CSI = \log (Ca^{++}) + \log (HCO_3^-) + pH - \log K_2 - \log K_{sp}$$

where:

Ca^{++}	=	molar concentration of calcium ion
HCO_{-3}	=	molar concentration of bicarbonate ion
pH	=	negative common logarithm of the concentration of hydrogen ion.
$\log K_2$	=	common logarithm of the disassociation constant for carbonic acid.
	=	-10.3
$\log K_{sp}$	=	common logarithm of the disassociation constant for calcite
	=	-8.3

As can be seen from an examination of Figure 4.2 the majority of the study area is classified into categories 4 and 5 indicating moderate to high levels of sensitivity to acidification. CSI values, ranging from -4.76 on Gander River to -5.58 on Ragged Harbour River, reported by Scruton (13) together with values of -4.2 for Pipers Hole River and -4.9 for Terra Nova River, reported by Clair and Whitfield (19), further confirm the sensitivity of the rivers in the study are to acid rain.

pH data from two rivers in the study area, Terra Nova and Pipers Hole, were tested by statistical methods for evidence of trend by Clair and Whitfield (19). The data bases used were:

Terra Nova River - August 1969 - November 1978
Pipers Hole River - July 1969 - November 1977

Table 4.7

Classification Systems for Sensitivity to Acid Rain

Class	Relative Sensitivity	Geology	CSI
1	Low	Extensive areas of lime-stone and dolomite	>-2
2	Low to Moderate	Sedimentary rocks, con training widespread calcium magnesium carbonates	
3	Moderate	Volcanic terrains; major mafic igneous complexes	-2
4	Moderate to High	Quartz-feldspar gneisses; sedimentary rocks poor in calcium and magnesium carbonates	to -3
5	High	Granites and related rocks	<-3

Source: "Acid Rain: a Newfoundland and Labrador Perspective", Table 1 (14).

No trend was detected on Pipers Hole River, while a trend of decreasing pH was noted on the Terra Nova River. Another study, which included eight Island rivers (Pipers Hole but not Terra Nova), concluded that no long term trend for pH could be detected (20). In a paper to be published in 1989, Ryan et al (21) reviewed the behaviour of the North West Gander River from 1977-1987 and found a reduction in acidity. This improvement, they conclude, is probably due to reductions in sulphur dioxide emissions since implementation of industrial emission controls in eastern North America.

Two acid rain monitoring stations are located in the study area one in Terra Nova National Park, and the other on Pipers Hole River. These stations monitor for pH, sulphate, and nitrate among other water quality parameters. There is no report available on the Terra Nova station. However, the Bay d'Espoir and Cormack stations indicate a decrease in the rate of sulphate deposition over the past decade. Trends on nitrate deposition rates are not clear. Figure 4.3 gives plots of variations over time for pH on Pipers Hole and Terra Nova Rivers. These plots confirm that there are significant seasonal and sub-seasonal variations in pH values. In general, pH values are highest during periods of low flow and lowest during winter and spring floods when the contribution to runoff from snowmelt is greatest. These seasonal variations in pH complicate the analysis for long term trend.

Three important conclusions can be drawn from this review of data on acid rain and from the discussion in Section 4.3.4 about the impact of water acidification on fish life:

(i) Present levels of pH in the study area do not appear to cause adverse effects on resident fish species.

(ii) Evidence of temporal trends in pH values (either worsening or improving) are inconclusive.

(iii) Most of the study area is moderately to highly sensitive to acid rain, which therefore remains a threat. The study area is regionally considered an area at risk to acidification since bedrock is non-carbonate and soils are shallow and generally low in sulphate absorption.

The impact of acid precipitation on forest plants was not examined, as this issue was outside the Terms of Reference.

4.5 PESTICIDES AND HERBICIDES

Pesticide and herbicide use within the study area is not extensive and is limited to the following uses:

- pesticide spraying for control of spruce budworm and hemlock looper
- pesticide use in agriculture
- application of herbicides to control growth of broad-leafed plants

In Newfoundland, aerial spraying of forest lands to control insect pests, is carried out under the direction of the Provincial Department of Forestry. Annually, between 1968 and 1986, small areas near the Gander Bay Road, on Random Island and near Port Blandford have been sprayed to control infestations of spruce budworm and hemlock looper. Areas sprayed in any one year were relatively small, generally less than 50 km^2, see Table 4.14 (page 4-45).

Pesticides used for control of spruce budworm and hemlock looper, include:

Matacil (aminocarb)*
Folithion/Sumithion (fenitrothion)
Futura XLV Dipel/Thuricide (BT, bacillus Thuringiensis)

Both Newfoundland Hydro and Newfoundland Light and Power Company Limited use herbicides for controlling the growth of broad-leafed plants along transmission line right-of-ways. Tordon 101 (2,4-D and Picloram) is the most commonly used herbicide for this purpose. Newfoundland Light and Power Company Limited also make use of Dycleer (Dicamba), and sodium TCA (sodium trichloroacetate) but to a limited extent.

For vegetation control in sub-station yards where total eradication of all vegetation is the objective, Newfoundland Light and Power Company Limited employs a soil-sterilizant type herbicide, such as - Spike 5g (Tebuthioron).

Not much information is available about agricultural pesticide use in the study area.

Details on the above products, including their persistence in the environment are given in Table 4.8 (next page).

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* Trade name/s are given first followed by name/s of active ingredient/s in brackets.

INSECTICIDES AND HERBICIDES*

TRADE NAME	ACTIVE INGREDIENT	USE AND MODE OF ACTION	PERSISTENCE IN ENVIRONMENT
Folithion/Sumithion	Fenitrothion	Broad spectrum insecticide used in agriculture and forest pests Absorbed through skin and stomach.	Between 21 days and 1 year after normal application residue is reduced to less than 0.005 mg/l.
Futura XLV/Dipel/ Thuricide	Bacillus Thuringiensis (BT)	An insecticide toxic specifically to larvae and pest of the order lepidoptera (butterflies and moths). A stomach poison if ingested, is not a contact poison. BT produces spores and protein crystals in the alkaline insect gut which convert to toxic protein molecules.	
Matacil	Aminocarb	An insecticide effective in controlling larvae of spruce bud-worm must use higher rates for controlling other insect pests. It is a contact and stomach poison and is absorbed through skin.	Degrades rapidly under aquatic and terrestrial conditions
Tordon	Picloram and 2,4-D	A herbicide used on right-of-ways to control unwanted brush and broad leaves weeds apply by hand as pellets or spray. 2, 4-D mode of action is auxin-like growth regulator, same as picloram.	Picloram absorbed by clay and organic matter. Leaching limited to surface soil, micro organisms. Breakdown occurs in water especially in clear shallow water. Photodegradable (UV). Persistence of 2, 4-D in most soils is short, generally less than one month. Microbial activity is the major means for degradation. Absorbed by soil organic matter which tends to reduce mobility.
Vision/Roundup	Glyphosate	Spray absorbed through leaves. Selective to broad-leafed plants, not to conifers. Inhibits formation of amino acids in plants, causing metabolic failure and death. Absorbed rapidly by leaves. Used in silviculture (Vision) and agriculture (Roundup).	Degrades within 4 days to virtually non-toxic and subdetectable levels.
Spike 5g	Tebuthioron	Broad spectrum herbicide used to control vegetation at substations. Readily absorbed by roots, less so through foliage. Inhibits photosynthesis.	It is rapidly metabolized and excreted in vertebrates. Half-life in soil is 12-15 months in areas receiving 1000 to 1500 mm annual rainfall.
Dycleer	Dicamba	Broad spectrum herbicide used to control phenoxy resistant (2, 4-D) vegetation (broad-leafed). Absorbed by leaves. Mode of action similar to phenoxy herbicides (eg. 2, 4-D).	Low order of toxicity to wildlife and fish. Under conditions amenable to rapid metabolism dicamba has half life or less than 14 days. However, can migrate in soil in humid areas. Also, may exist longer in areas of low soil moisture and rainfall.
Sodium TCA	Sodium Trichloro-acetate	Herbicide primarily used for control of grasses and grass-like plants.	Is broken down in soils by micro-organisms with in three to ten weeks.

* Richard Martin, Environmental Biologist, Environment & Lands, Personal Communication.

No chronic pollution by toxic substances has been reported in surface waters, in the study area, probably because of the small volume of spraying, the relatively rapid degradation rates of chemicals used and minimal agricultural requirements for pesticides. In 1986, Environment Canada initiated a toxic organic chemical testing program on the Island of Newfoundland. Eight of the water supplies sampled were in the Bonavista study area. Water samples were tested for up to eighteen chemicals (see Table 4.13). Preliminary reports indicate that only trace amounts of these chemicals were found, far below the concentrations dangerous to human health, wildlife or aquatic life; however, more intensive testing may be required to fully evaluate water contamination from these chemicals.

The impacts of low levels of concentration of toxic products in water and their long term effects on aquatic, animal and human life are still poorly understood. As knowledge is gained one can expect new guidelines to be produced adjusting acceptable levels of contamination. As a start, Environment Canada has recently issued a toxic substance priority list which is reproduced in Table 4.15 (further details are given in Reference 26).

In addition, the Canadian Council of Resource and Environment Ministers, sponsor toxicological studies on selected organic chemicals in support of the Canadian Water Quality Guidelines program.

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* Bacillus thuringiensis

Excepting DDT*, Diazinon**, "2,4-D", fenitrothion and other chemicals commonly used in forestry or agriculture, a large portion of the chemicals detected appear to result from airborne contamination originating from the U.S. or Central Canada that is deposited with rain or as dry particulate matter in Newfoundland waters. A report on this study was pending from Environment Canada - EPS, at time of writing.

The main conclusions that can be drawn from this review of the presence of toxic organic compounds in study area waters are:

(i) Most of the toxic compounds detected appear to be transported by the weather from areas on Mainland Canada and the U.S.

(ii) These products were detected in very minute concentrations far below the levels that are believed to be harmful to human, animal or fish health, given present knowledge and existing standards.

(iii) The field of environmental toxicology is developing rapidly, hence guidelines on water contamination are evolving and subject to change.

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* Traces of DDT detected in recent water quality samples originate from spraying done more than ten years ago, due to slow rate of decay of this chemical.

** Diazinon is a chemical in common use in gardening and farming operations.

4.6 HARBOUR POLLUTION

Most of the sewage collection systems serving communities in the study area discharge directly into the ocean. Proper site selection for discharge lines is essential if this approach to sewage treatment is to be successful, see Allen and Sharp (22). Most outfall designs for communities in the study area are based on engineering judgement without the benefit of current measurements or analytical studies, and consequently not all work as well as would be desired (11). Harbours at risk to pollution are those where oceanic circulation is poor at the discharge point.

For the above reasons, it is suspected that pollution of harbour waters may be a problem at some communities in the study area.

Seawater pollution is an important concern to fish plant operators because the ocean is a convenient source of process water required in their operations. In order to further assess this problem, officials in the Fisheries Inspection Branch - Dept. of Fisheries and Oceans were contacted and asked if they knew of any locations in the study area where seawater pollution was a problem. Only a general reply was received which did not indicate if there were problems or where such problems were located (17).

4.7 *CONCLUDING COMMENTS*

Present day water quality of both surface and groundwater sources is good and there is little evidence of anthropogenic changes in water quality. Raw water is suitable, with minimal treatment for domestic and industrial use (normally only chlorination is needed).

Without treatment raw waters in the study area also meet the requirements for livestock/wildlife watering and recreation.

Increased acidification due to acid rain is the main concern for the future. Waters in the study area are moderately to highly at risk from acid rain due to their low buffering capacities. There is no evidence to date that acid rain has caused adverse effects on water quality.

Acidification is due to airborne contamination carried into the study area from the eastern seaboard of the U.S. and Great Lakes region of Canada and the U.S. and must ultimately be solved in those regions. While there are some indications that reductions in acidic emissions are being achieved, improvements are marginal and continuing vigilance is required. Accordingly, Government should continue its monitoring of acid rain and river and lake pH values. Monitoring of rivers and lakes should be on a temporal basis preferably once a month (quarterly as a minimum).

With the exception of local water quality problems in the Gander River just downstream of Glenwood/Appleton no water pollution problems in freshwater were reported in the facilities survey (12); however, there is always a risk that such problems could occur on a local scale from poorly sited or untreated discharges of municipal sewage, animal or industrial wastes. Government should be alert to the potential for such problems when assessing or approving municipal, agricultural or industrial development projects.

There is also some evidence to suggest that seawater pollution may be a problem in some areas. As a means of preventing future problems of this kind Government should consider developing of design guidelines on the siting and design of ocean outfalls to replace the inadequate information provided in the current water and sewer design guidelines (27).

The widespread and continuing use of pesticides, herbicides and other exotic organic chemicals on a continent wide basis poses a potential threat to water supplies in the study area. Government should be alert to this problem. The program of testing for toxic products recently initiated under the Canada-Newfoundland Water Quality Monitoring Program of 1988 may be considered a starting point for assessing this problem and should be continued. This program should be regularly updated to reflect the latest findings from research in environmental toxicology.

It is recommended that the list of parameters tested under the water quality program of the Department of Environment and Lands be extended to include all the parameters recommended in the Canadian Water Quality Guidelines for drinking water and freshwater aquatic life. This would involve testing for the following inorganic parameters:

- aluminum
- boron
- cyanide
- mercury
- selenium
- silver, and
- thallium

Testing for organic chemicals should be targeted on products likely to be employed in the area, typically - herbicides/pesticides used in forestry or agriculture.

The testing program should be sufficient, as a minimum to establish baseline conditions and verify that these parameters are indeed within safe limits.

TABLE 4.3
SURFACE WATER QUALITY LEVELS
USES VS QUALITY AT INDEX STATIONS
BONAVISTA STUDY AREA

Parameter	Unit	WATER QUALITY GUIDELINES: Domestic Consumption	Livestock & Wildlife Watering	Food Processing Industry	Freshwater Aquatic Life	Recreational Waters	INDEX MONITORING STATIONS: 18 Gander River	20 Pound Cove Brook	21 Terra Nova River (U/S)	22 Southwest Brook	23 Bread Cove Brook	24 Terra Nova River (D/S)	34 Pipers Hole River	35 Southern Bay River
Period of Record							1966-87	1986-87	1966-87	1980-86	1981-87	1986-87	1980-87	1977-87
Alkalinity, total as $CaCO_3$	mg/l	30-500	-	L 150	GT 20	-	3.4/L .5-14.1	L 2.8	1.1/L 0.5 - 5.3	3.2/0.00 - 12.2	2.78/1.6-5.1	L 3.9	3.3/L .1 - 10.0	5.2/0.0 - 28.0
Aluminum as Al	mg/l	-	L 5	-	L 0.100	-	L 0.14	LT 0.33	0.06 - 0.29	0.135 - 0.221	0.069 - 0.14	L 0.33	L 0.01 - 0.16	5.0/0.0 - 28.1
Ammonia, as N (Total)	mg/l	L 0.5	-	-	-	-	L 0.001-0.04	-	0.017 - 0.15	0.000 - 0.079	LT 0.005 - 0.07	-	-	L 0.228
Arsenic, as As	mg/l	L 0.05	L 0.05	L 0.05	L 0.05	L 0.05	-	-	-	0.000 - 0.033	-	-	-	0.0 - 0.036
Fecal Coliform	No./dl	ND	-	LT 10	-	LT 100	L 10 - GT 1000	-	-	77/0 - 600	-	-	55/0 - 290	33/0 - 600
Total Coliform	No./dl	L 10	-	L 100	-	LT 500	L 20 - GT 2000	-	-	213/0 - 1600	-	-	124/L 20 - 460	180/0 - 1600
Barium, as Ba	mg/l	L 1.0	-	-	-	-	-	L 0.0002	L 0.002	L 0.0039	L 0.0001	L 0.0003	L 0.004	L 0.0022
Boron, as B	mg/l	L 5.0	-	-	-	-	-	-	-	-	-	-	-	-
Cadmium, as Cd	mg/l	L 0.005	L 0.010	L 0.01	LT 0.2	L 0.01	L 0.1	L 0.0001	L 0.001	0.000	LT 0.0001 - 0.001	L 0.0003	L 0.0001 - 0.005	0.0 - 0.014
Calcium, as Ca	mg/l	L 200	L 1000	-	-	-	0.3-9.5	L 0.9	0.7 -7.1	1.0 - 4.27	0.85 - 1.7	L 1.0	0.85 - 3.5	1.2 - 150.0
Chloride, as Cl	mg/l	L 250	-	L 250	-	-	1.4-85.0	L 11.6	0.7 - 9.5	3.8 - 26.0	2.8 - 12.5	L 4.6	1.8 - 10.1	90/3.0 - 5615.0
Chromium, as Cr	mg/l	L 0.05	L 0.05	L 0.1	0.04	L 0.1	L 0.0016	L 0.0008	0.0002	0.0 - 0.010	L 0.0014	L 0.0018	L 0.003	L 0.0001
Cobalt as Co	mg/l	-	L 1.0	-	-	-	-	L 0.0002	-	L 0.0003	L 0.0002	L 0.0005	L 0.0002	-
Colour	RU/TCU	L 15	-	L 5	-	L 100	37/5-60	60 - 150	20 - 100	65/40 - 180	41/10 - 60	10 - 50	34/5 - 100	45/5 - 80
Conductance (SP)	µs/cm	-	-	-	-	-	8-347	25.0 - 42.9	11 - 45	10.0 - 78.4	19 - 52	14.3 - 21.9	13 - 52	0.10 - 16500.0
Copper, as Cu	mg/l	L 1.0	L 0.5	-	LT 0.002	-	L 0.001 - 0.05	L 0.003	L 0.001 - 0.09	0.0 - 0.96	LT 0.002 - 0.008	L 0.004	0.00 - 0.99	0.0 - 0.930
Cyanide, as CN	mg/l	L 0.2	-	-	LT 0.005	-	-	-	-	-	-	-	-	-
Fluoride, as F	mg/l	L 1.5	L 2.0	L 1	-	-	L 0.05 - 0.11	-	L 0.05 - 0.1	-	-	-	-	-
Hardness, Total as $CaCO_3$	mg/l	L 120	-	L 150	-	-	1.6 - 34.0	-	2.8 - 19.8	3.9 - 14.3	-	-	-	5.6 - 37.9
Iron, as Fe	mg/l	L 0.3	-	L 0.2	LT 0.300	-	0.07/0.01 - 0.18	0.1 - 0.7	0.06/0.01 - 0.13	0.59/0.03 - 1.76	0.17/0.09 - 0.28	L 0.3	0.21/0.05 - 0.61	0.22/0.0 - 2.4
Lead, as Pb	mg/l	L 0.05	0.05	-	LT 0.030	-	L 001 - 0.007	L 0.001	L 0.001 - 0.007	0.0 - 0.021	LT 0.002	L 0.001	L 0.01	0.0 - 0.020
Magnesium, as Mg	mg/l	L 150	-	-	-	-	0.2 - 3.0	L 0.9	0.2 - 0.6	0.29 - 0.91	0.27 - 0.55	L 0.4	0.22 - 0.78	8.6/0.39 - 297.0
Manganese, as Mn	mg/l	L 0.05	-	L 0.2	-	-	0.00 - 0.02	L 0.02	0.01/L 0.01 - 0.04	0.077/0.0 - 2.76	0.018/L 0.01 - 0.03	L 0.3	0.016/0.00 - 0.14	0.23/0.0 - 16.6
Mercury, as Hg	µg/l	L 1.0	L 3	L 1	LT 0.1	-	L 0.05 - 0.15	L 0.02	0.02	-	L 0.03	L 0.02	L 0.02 - 0.10	-
Molybdenum as Mo	mg/l	-	L 0.01	-	-	-	L 0.0002	L 0.0002	0.0001	L 0.0002	L 0.0003	L 0.0006	L 0.0006	L 0.0001
Nickel	mg/l	-	-	-	-	-	L 0.01	-	-	0.0 - 0.02	-	-	-	L 0.0005
Nitrate + Nitrite as N	mg/l	L 10.0	L 20	L 10	-	-	-	L 0.08	L 0.001 - 0.04	L 0.01 - 0.02	L 0.01	L 0.08	L 0.01 - 0.11	-
Oxygen (Dissolved)	mg/l		-	-	-	-	7.3 - 9.2	-	8.8	3.2 - 14.5	3.2 - 14.5	-	5.3 - 14.6	4.4 - 15.1
pH		6.5-8.5	-	6.5-8.5	-	GT 6.0	4.7 - 8.4	5.3 - 5.8	4.5 - 7.3	4.9 - 7.05	5.7 - 7.4	5.8 - 7.4	5.0 - 7.4	4.4 - 7.4
Phosphorus, as P (Total)	mg/l	L 0.2	-	-	-	-	L 0.001 - GT 1.58	L 0.03	0.001 - 0.048	0.0 - 0.152	0.002 - 0.094	L 0.008	L 0.001 - 0.08	L 0.007
Silica as Si	mg/l	-	-	L 50	-	-	0.5 - 3.7	-	L 0.1 - 3.0	1.3 - 5.7	0.3 - 2.4	-	0.60 - 4.10	-
Sodium, as Na	mg/l	L 270	-	-	-	-	0.6 - 50	L 6.3	0.9 - 5.1	1.96 - 10.13	1.8 - 6.4	L 3.4	1.3 - 3.9	13.2/0.13 - 496.0
Strontium	mg/l	L 10	-	-	-	-	L 0.008	L 0.007	0.005	L 0.013	L 0.008	L 0.01	L 0.01	L 0.011
Sulphate, as SO_4	mg/l	L 500	L 1000	L 250	-	-	L 0.5 - 15.5	L 5.8	L 1.0 - 5.9	0.0 - 7.0	0.9 - 3.7	L 3.6	0.8 - 6.0	15.1/0.0 - 1000.0
Total Dissolved Solids (TDS)	mg/l	L 500	L 2500	500	-	-	5 - 158	16.2 - 27.8	-	-	14.6 - 18.3	10.4 - 18.8	-	286.1/0.06 - 10,725
Turbidity	NTU	L 5	-	ND	-	L 50	0.57/L 0.1 - 5.4	L 1.3	1.1/L 0.1 - 20.5	0.17 - 3.5	0.45/0.3 - 0.7	L 0.52	0.45/0.3 - 1.5	0.72/0.07 - 11.0
Vanadium as V	mg/l	-	L 0.1	-	-	-	L 0.0004	L 0.0008	-	L 0.0008	L 0.0004	L 0.0009	L 0.0069	(0.0002
Zinc, as Zn	mg/l	L 5.0	L 25	-	LT 0.030	-	L 0.01	L 0.003	L 0.001 - 0.33	0.00 - 0.076	L 0.001 - 0.002	L 0.001	0.0009 - 0.04	0.0 - 0.086

Notes:

1	-	Canadian Quality Guidelines (8)	50/0.0 - 28.0	-	Mean/Range
2	-	Maximum Acceptable	mg/l	-	milligrams/litre
3	-	Locations show in Figure 4.1	No./dl	-	number/decilitre
GT	-	Greater Than	µg/l	-	micrograms/litre
L	-	Less Than or Equal to	NTU	-	Nephlometric Turbidity Units
LT	-	Less Than	TCU	-	True Colour Units
ND	-	Not Detectable	FU	-	Relative Colour Units

Data is non-existent where parameter values are absent

Statistics include flagged values

TABLE 4.10
SURFACE WATER QUALITY LEVELS
USES VS QUALITY
BONAVISTA STUDY AREA

Parameter	Unit	WATER QUALITY GUIDELINES: Domestic Consumption	Live-stock & Wildlife Watering	Food Processing Industry	Fresh-water Aquatic Life	Recreational Waters	MONITORING STATIONS: Come-By-Chance River	Big Brook	Middle Brook	Michin Pond	Pine Hill Pond	Fagget Harbour
Period of Record							1971-79	1980-81	1977-85	1980-81	1980-83	1977-85
Alkalinity, total as $CaCO_3$	mg/l	30-500	-	L 150	GT 20	-	4.1/0.5 - 8.8	3.5/1.4 - 6.0	2.0/0.0 - 15.4	4.4/3.1 - 7.3	10.3/L 0.05 - 21.7	2.3/0.00 - 14
Aluminum as Al	mg/l	-	L 5	-	L 0.100	-	-	0.03 - 0.25	-	0.08 - 0.13	0.01 - 0.50	-
Ammonia, as N (Total)	mg/l	L 0.5	-	-	-	-	-	-	0.000 - 0.058	L 0.005 - 0.060	L 0.005 - 0.16	0.00 - 0.036
Arsenic, as As	mg/l	L 0.05	L 0.05	L 0.05	L 0.05	L 0.05	-	-	0.00 - L 0.050	-	-	0.01/L 0.005 - 0.05
Fecal Coliform	No./dl	ND	-	LT 10	-	LT 100	L 10 - 220	-	121/0 - 1220	-	-	0 - 100
Total Coliform	No./dl	L 10	-	L 100	-	LT 500	L 20 - 120	-	96/0 - 1600	-	-	0 - 280
Barium, as Ba	mg/l	L 1.0	-	-	-	-	-	-	-	-	-	-
Boron, as B	mg/l	L 5.0	-	-	-	-	-	-	-	-	-	-
Cadmium, as Cd	mg/l	L 0.005	L 0.010	L 0.01	LT 0.2	L 0.01	L 0.001	L 0.001	0.00 - 0.001	L 0.001	L 0.001 - 0.002	0.00 - 0.005
Calcium, as Ca	mg/l	L 200	L 1000	-	-	-	0.5 - 4.29	0.79 - 1.68	0.81 - 52.4	1.9 - 2.0	6.2 - 7.2	0.87 - 6.27
Chloride, as Cl	mg/l	L 250	-	L 250	-	-	3.4 - 23.0	1.3 - 6.3	9.9/3.2 - 438	4.1 - 5.7	52/1.9 - 440	3.8 - 17.0
Chromium, as Cr	mg/l	L 0.05	L 0.05	L 0.1	0.04	L 0.1	L 0.01	-	0.000	-	-	0.00 - 0.01
Cobalt as Co	mg/l	-	L 1.0	-	-	-	-	-	-	-	-	-
Colour	RU/TCU	L 15	-	L 5	-	L 100	39/5 - 80	70/30 - GT 100	33/10 - GT 70	37/30 -50	21/5 - 60	56/10 - 90
Conductance (SP)	µs/cm	-	-	-	-	-	22 - 78	19 - 184	-	29 - 36	10 - 1450	11 - 67.3
Copper, as Cu	mg/l	L 1.0	L 0.5	-	LT 0.005	-	L 0.01 - 0.02	L 0.002 - 0.006	0.00 - 0.06	L .002 - 0.007	L 0.002 - 0.009	0.0 - 0.04
Cyanide, as CN	mg/l	L 0.2	-	-	LT 0.005	-	-	-	-	-	-	-
Fluoride, as F	mg/l	L 1.5	L 2.0	L 1	-	-	L 0.05 - 0.11	-	-	-	-	-
Hardness, Total as $CaCO_3$	mg/l	L 120	-	L 150	-	-	3.2 - 14.6	-	4.6 - 6.8	-	-	5 - 18
Iron, as Fe	mg/l	L 0.3	-	L 0.2	LT 0.300	-	0.35/0.29 - 0.42	0.56/0.26 - 1.20	.15/0.0 - 2.3	0.1/0.05 - 0.20	0.1/0.01 - 0.61	0.3/0.1 - 0.65
Lead, as Pb	mg/l	L 0.05	0.05	-	LT 0.030	-	L 0.01	L 0.004	0.0 - 0.01	L 0.002 - 0.019	L 0.002 - 0.005	0.001 - 0.025
Magnesium, as Mg	mg/l	L 150	-	-	-	-	0.3 - 1.3	0.30 - 0.69	0.38 - 25.4	0.47 - 0.58	L 0.1 - 2.6	0.6 - 2.41
Manganese, as Mn	mg/l	L 0.05	-	L 0.2	-	-	0.03/L 0.01 - 0.045	0.02/L 0.01 - 0.05	0.01/0.0 - 0.7	0.01/L 0.01 - 0.03	0.03/L 0.01 - 0.21	0.05/0.00 - 3.14
Mercury, as Hg	g/l	L 1.0	L 3	L 1	LT 0.1	-	L 0.05 - 0.07	-	-	-	L 0.02	-
Molybdenum as Mo	mg/l	-	L 0.01	-	-	-	-	-	-	-	-	-
Nickel	mg/l	-	-	-	-	-	L 0.01	-	0.0 - L 0.01	-	-	L 0.01
Nitrate + Nitrite as N	mg/l	L 10.0	L 20	L 10	-	-	L 0.001 - 0.17	-	-	L 0.01 - 0.7	L 0.01 - 2.10	-
Oxygen (Dissolved)	mg/L		-	-	-	-	6.9 - 8.4	-	6.2 - 14.95	-	1.1 - 220.0	3.4 - 15.1
pH		6.5-8.5	-	6.5-8.5	-	GT 6.0	5.1 - 7.2	5.3 - 7.0	4.5 - 7.5	6.3 - 6.8	5.3 - 7.4	5.1 - 7.5
Phosphorus, as P (Total)	mg/l	L 0.2	-	-	-	-	L 0.002 - 0.02	L 0.001 - 0.002	0.000 - 0.193	0.003 - 0.009	0.002 - 0.014	L 0.005 - 0.17
Silica as Si	mg/l	-	-	L 50	-	-	L 0.1 - 6.5	2.5 - 5.9	-	2.3 - 3.4	0.20 - 5.50	-
Sodium, as Na	mg/l	L 270	-	-	-	-	1.8 - 8.8	2.2 - 3.2	2.2 - 217.0	2.9 - 3.7	1.1 - 220.0	2.5 - 6.6
Strontium	mg/l	L 10	-	-	-	-	-	-	-	^-	-	-
Sulphate, as SO_4	mg/l	L 500	L 1000	L 250	-	-	1.0 - 8.0	0.9 - 3.8	5.0 - 48.0	1.6 - 3.5	0.2 - 24.0	0.0 - 5.0
Total Dissolved Solids (TDS)	mg/l	L 500	L 2500	500	-	-	11 - 39	-	15 - 25	-	-	15 - 38
Turbidity	NTU	L 5	-	NO	-	L 50	1.2/L .1 - 6.3	0.5/0.3 - 0.7	0.696/0.10 - 3.20	0.4/0.2 - 0.5	0.4/0.2 - 1.7	0.9/0.1 - 7.5
Vanadium as V	mg/l	-	L 0.1	-	-	-	-	-	-	-	-	-
Zinc, as Zn	mg/l	L 5.0	L 25	-	LT 0.030	-	L 0.01 - 0.07	L 0.002 - 0.1	0.000 - 0.090	L 0.002 - 0.030	L 0.002 - 0.050	0.0 - 0.25

Notes:

1 - Canadian Quality Guidelines (G)
2 - Maximum Acceptable
3 - Locations show in Figure 4.1
GT - Greater Than
L - Less Than or Equal to
LT - Less Than
ND - Not Detectable

50/0.0 - 28.0 - Mean/Range
g/l - milligrams/litre
No./dl - number/decilitre
g/l - micrograms/litre
NTU - Nephlometric Turbidity Units
TCU - True Colour Units
RU - Relative Colour Units

Data is non-existent where parameter values are absent

Statistics include flagged values

Table 4.11

Anomalous Parameters in Geologic Bedrock Units

Groundwater

Bonavista Study Area

Parameter	Guidelines for Domestic Consumption	Bedrock Units			
		1	2	4	5
Alkalinity (mg/L)	30-500	13.9 1 well	74.7/11-220 6 wells	61.4/51-106 4 wells	77.3/9.6-160 25 wells
Colour (RU)	≤15	<15 1 well	5-10 7 wells	100/30-140 3 wells	38.6/5-200 23 wells
pH	6.5-8.5	8.47 1 well	8.0/6.6-9.4 7 wells	7.3/6.42-8.68 3 wells	7.3/5.2-9.4 26 wells
Iron (mg/L)	<0.3	0.02 1 well	0.13/0.1-0.42 6 wells	4.3/3.3-7.3 4 wells	1.93/<0.01-16.95 26 wells Approx. 40% of wells >0.025
Manganese (mg/L)	<0.05	<0.05	0.04/0.01-0.06 6 wells	0.61/0.12-1.08 4 wells	0.46/0.005-1.54 28 wells 58% >0.05
TDS mg/L			93-222 3 wells	84-105 2 wells	4.84.9/50-1944 19 wells

Notes: 1. - *Maximum Acceptable from Reference 8.*
2. - RU = Relative Units.
3. - No water quality data was available for Bedrock Unit 3.

Table 4.12

Water Quality Parameters Tested

PARAMETER	CHECK LIST OF PARAMETERS		
	#1	#2	#3
Water temperature	X		X
pH	X	X	X
Specific conductance	X	X	X
Oxygen (dissolved)	X	X	X
Turbidity	X	X	X
Colour - RU	X	X	X
Calcium	X	X	X
Magnesium	X	X	X
Potassium	X	X	X
Sodium	X	X	X
Alkalinity, total as $CaCO_3$	X	X	X
Alkalinity, gran.	X		X
Chloride	X	X	X
Sulphate	X	X	X
Carbon, organic	X		X
Carbon, inorganic	X		X
Nitrogen, total Kjeldahl	X		X
Nitrate	X	X	
Nitrate + Nitrite	X		X
Ammonia	X	X	
Nitrogen, total	X	X	
Phosphorus	X	X	X
Aluminium	X		X
Barium			X
Cadmium	X	X	X
Cobalt			X
Chromium		X	X
Copper	X	X	X
Beryllium			X
Iron	X	X	X
Lithium			X
Manganese	X	X	X
Molybdenum			X
Nickel		X	X
Strontium		X	X
Vanadium		X	X
Zinc	X	X	X
Mercury	X		X
Residue - nonfiltrable	X	X	
Residue - filtrable	X	X	
Humic acid	X		
Silica	X		
Lead	X	X	X
Chemical oxygen demand		X	
Arsenic		X	
Coliform, total		X	
Coliform, fecal		X	

#1 Canada-Newfoundland Water Quality Program 1965-1980 (1)
1981-1985 (2)
#2 Environment & Lands, Water Quality Program 1977-1986 (3)
#3 Canada-Newfoundland, Water Quality Monitoring Program 1988

Table 4.13

Toxic Chemical Sampling

[Organo-chlorides and PCBs]

Parameter	Detection Limit
Hexachloro-Benzene	0.4 ng/l
Alpha-BHC	0.4 ng/l
Gamma-BHC/Lindane	0.4 ng/l
Heptachlor	0.4 ng/l
Aldrin	0.4 ng/l
Heptachlor Epoxide	0.4 ng/l
Gamma-Chlordane	0.4 ng/l
Alpha-Chlordane	0.4 ng/l
p,p-DDE	0.4 ng/l
Heod/Dieldrin	0.4 ng/l
Endrin	0.4 ng/l
o,p-DDT	0.4 ng/l
p,p-TDE	0.4 ng/l
p,p-DDT	0.4 ng/l
Beta-Endosulfan	0.4 ng/l
Mirex	0.4 ng/l
Methoxy-Chlor	0.4 ng/l
Total PCB's	9.0 ng/l

Source: Technical Sub-Committee note, Canada-Newfoundland Water Quality Monitoring Agreement

Table 4.14

Forest Areas Sprayed

YEAR	HERB/PEST	LOCATION	SQ. KM
1968	Fen	Gander Bay Road	294.0
1969	Fen	Gander Bay Road Area	311.5
1969	Fen	Gambo Area	100.3
1977	Mat/Aminocarb	Port Blandford	2.4
		Gander Bay	3.5
		Jonathons Pond	1.2
1978	Mat	Port Blandford	2.4
		Adeytown	1.0
		Random Island	9.7
		Ocean Pond	88.3
		Gambo	78.9
		Gander Bay Road	107.1
		Gander Bay	3.2
1980	BT	Adeytown	1.2
		Port Blandford	2.8
		Spenser Ridge	1.0
		Drovers Ridge	1.8
		Gander Bay	5.2
1981	Mat	Weirs Pond	96.8
		Ocean Pond	214.8
1982	Mat	Weirs Brook	13.5
		Island Pond Brook	11.1
1983	Mat	Weirs Brook	13.5
		Island Pond	11.1
1984	Mat	Weirs Brook	13.3
		Gander Bay Road	16.2
1985	Mat	Weirs Brook	13.3
		Gander Bay Road	16.2
	Fen	Port Blandford Area	5.2
1986	BT	Gander Bay	31.9
	Fen	Weirs Pond	22.3
	Fen	Clode Sound	6.6
	Fen	Ocean Pond	51.8
	Fen	Rocky Pond	6.7
	Fen	Random Pond (Big Pond)	1.8
	Fen	Beaver Pond (St. Jone's Within)	10.7

Notes

1. Fen = fenitrothion
2. Mat = matacil
3. BT = bacillus Thuringiensis

Table 4.15

Toxic Substances Priority List

Environment Canada

Substance in Order of Priority	Definition of Nature of Substance	Substance in Order of Priority	Definition of Nature of Substance
1. Polynuclear aromatic hydrocarbons	Mixture of complex multicyclic hydrocarbons formed during heating and burning of carbon compounds	26. Used Crankcase Oils	
2. Chlorofluoro-carbons	Substances having the molecular formula $C_nCl_xF(2_n+2-x)$	27. Respirable mineral fibres	Materials that are retained in the lungs during inhalation; asbestos; fibreglass; mineral wool
3. Benzene		28. Hydrocarbon solvent mixtures	
4. Chlorinated Methanes	Substances formed during chlorination of water and sewage	29. Chlorinated aliphatic ethers	Chloromethylmethyl ether; dichloroethyl
5. Chlorinated ethylenes	Particular emphasis on tri- and tetra-chloroethylenes	30. Xylenes	All isomers with CAS No.s 1330-20-7, 95-47-6 108-38-3, 106-42-3
6. Chromium	and its compounds	31. Phihalate	Including but not limited to di-n-octylphlhalate di-(2-ethylhexyl) phthalate
7. Lead	and its compounds	32. Styrene	
8. Mercury	and its compounds	33. Bleach plant effluent from kraft and sulphite mills	Full range of compounds found in those effluents, particularly organochlorine compounds
9. Cadmium	and its compounds	34. Organotin compounds	Including, but not limited to, tributyl tin
10. Nickel	and its compounds	35. Fluorides	Inorganic compounds
11. Arsenic	and its compounds	36. Aromatic amines	Contaminants from axo-dyes, e.g. benzidline; dichlorobenzidine, 3,5 dimethylanlline
12. Vinyl chloride	Sometimes referred to as vinyl chloride monomer	37. Aniline	
13. Chlorinated paraffin waxes	Complex mixture of compounds having more than 10 carbon atoms and 35-70 percent chlorine by weight	38. Acrylic esters	Several simple esters including but not limited to methyl-methacrylate
14. Benzenes, chlorinated	All congeners	39. Formaldehyde	
15. Polychlorinated dibenzodioxins		40. 1,1,1-Trich-loroethane	
16. Polychlorinated dibenzofurans		41. Toluidine	All isomers
17. Chlorinated ethanes	Example: 1,1,2,2-tetachloroethane	42. Acroleine	
18. Nitrogen oxides	All oxides including N_2O	43. N-Nitroso	N-nitroso derivatives of mono, di an tri-ethanolamine
19. Methyl tertiary butyl ether		44. 1,2-Dibromo-ethane	
20. Commercial pentachloro-phenol mixtures	Contains tetra-and tri-chlorophenols	45. Organic Isocyanates	Including diphenyl-methane, diisocyanate (MDI) and toluene disocyanate (TDI)
21. Sour gas	All components	46. Nitrophenols	Including 2,4 -dinilro-phenol and nitrophenols (o,m,p)
22. Gasoline	Source of volatile aromatic hydro-carbons, e.g. benzene	47. Creosote	Mixture of phenolic substances
23. Naturally occurring radionuclides	Radon and radon Daughters	48. Phenol	
24. Toluene		49. Ketones	Including methylethyl ketone (MEK) methyl isobutylketone (MIBK) and isophorone
25. Dichloromethane		50. Acrylonitrile	

[From Reference 26]

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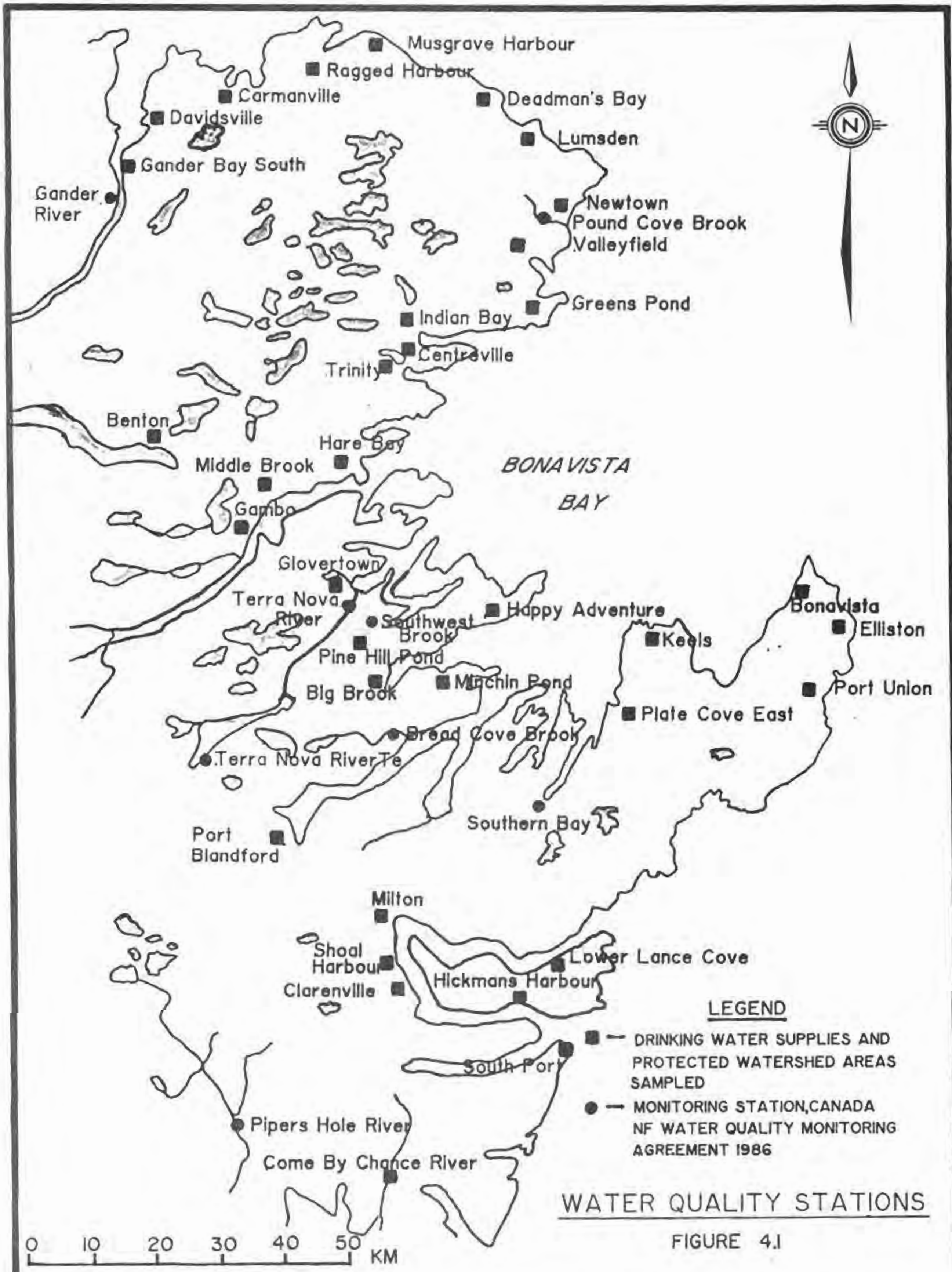
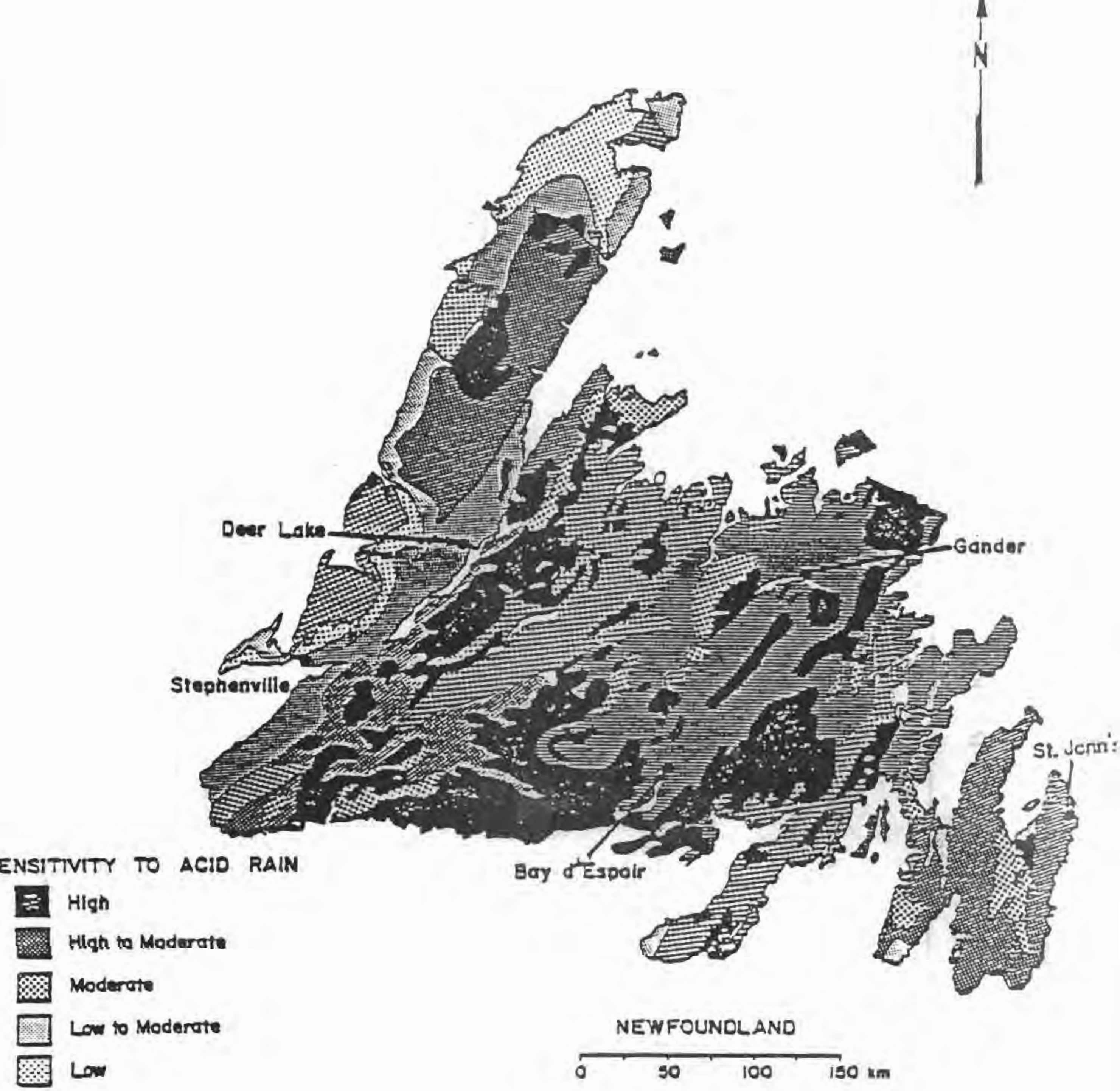


WATER QUALITY STATIONS

FIGURE 4.1

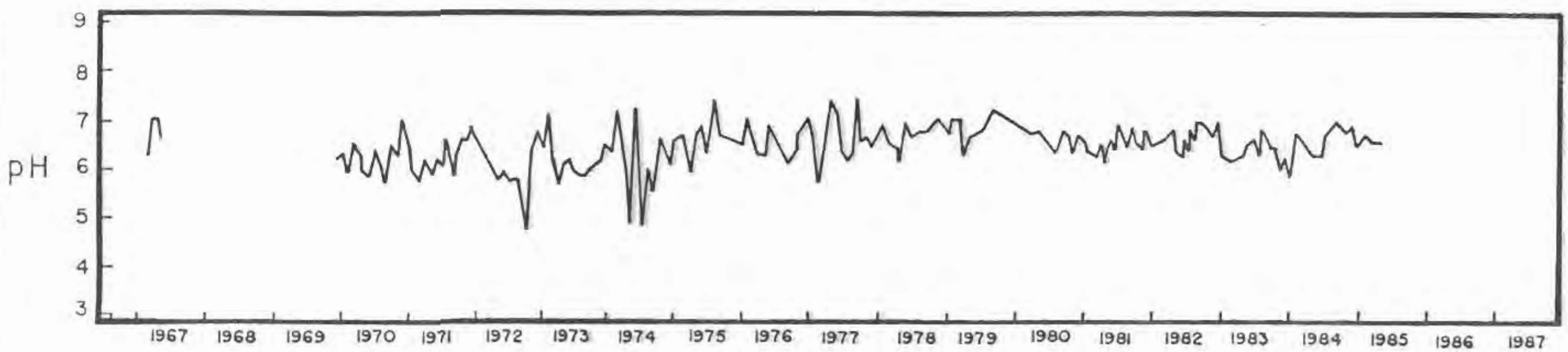


SENSITIVITY OF INSULAR NEWFOUNDLAND TO ACID PRECIPITATION, ON THE BASIS OF BEDROCK GEOLOGY.

FIGURE 4.2

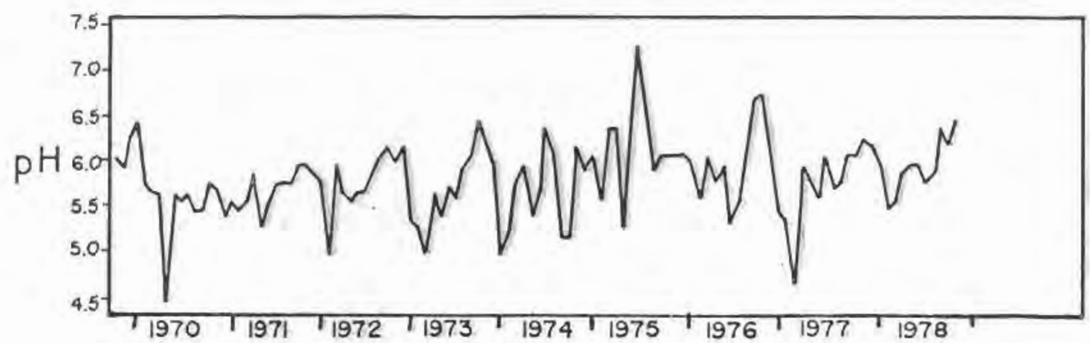
FIGURE 4.3

PIPERS HOLE RIVER



(FROM REFERENCE 20)

TERRA NOVA RIVER



(FROM REFERENCE 19)

VARIATION OF pH WITH TIME

CHAPTER FIVE

INSTREAM USES

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5.1 INTRODUCTION

Demands for freshwater can be classified as either instream demands or withdrawal demands. Instream uses are nonconsumptive, but may alter river or lake water quality. Withdrawal demands, on the other hand, are consumptive to some degree, and often result in degradation of water quality. Instream uses are the subject of this chapter while withdrawal demands will be discussed in Chapter 6.

The most common instream uses in the study area are:

- hydropower production,
- recreation and tourism
- freshwater (sport) fishery,

These uses are discussed in more detail in the following subsections.

5.2 HYDROPOWER PRODUCTION

5.2.1 Existing Development

There are two existing hydro plants in the study area - Lockston, which develops the Trinity Pond watershed and Port Union on Main Brook, Port Union. Both plants are owned and operated by the Newfoundland Light and Power Company. Particulars on these plants are given in Table 5.1. Their locations are shown in Figure 5.1.

Table 5.1

Characteristics of Existing Hydropower Plants

Plant	Developed Drainage Area (sq.km)	Capacity (kW)	Gross Head (m)	Average Annual Energy (GWh)	Year Com-pleted
Lockston	38.2	3000	82.5	7.5	1955
Port Union	98.5	500	21.6	2.5	1917

A common method for evaluating the value of power produced by small hydro plants is to treat such plants as fuel savers for interconnected thermal plants, in this case to save fuel at Newfoundland and Labrador Hydro's Holyrood Thermal Plant. Assuming the cost of bunker "C" fuel at Holyrood is $20 per barrel and the net energy conversion rate is 600 kWh/barrel, gives a unit value of 5 cents per kWh. On this basis values of energy production are:

- at Lockston $250,000 per annum
- at Port Union $ 83,300 per annum

The comparable values for water were determined from the above energy evaluations and plant water consumptions:

- at Lockston 0.59 cents per m^3 (42.1×10^6 m^3/year)
- at Port Union 0.15 cents per m^3 (54.3×10^6 m^3/year)

At small plants such as Lockston and Port Union, Newfoundland Light and Power does not collect data on spillage or on reservoir levels that would permit an evaluation of water balances. Accordingly, it is not possible to reliably estimate water use factors at these plants. However, available evidence suggests that water use at Lockston is high - approaching 100% usage; while usage at Port Union is much less, probably under 75% of available flow. It is perhaps worth noting, for the record, that there was a third small hydro plant on Shoal Harbour River near Clarenville having a capacity of about 100 kW. This plant was built in 1935 and was retired from service in 1956, when power from Lockston became available. The old hydro dam is still in use today as part of the Clarenville - Shoal Harbour water supply system.

5.2.2 Future Development Prospects

While the study area is not as well favoured by topography and precipitation as other areas of the Province, there remain nonetheless several opportunities for small and large scale hydro development. Two large scale schemes have been identified, on the Terra Nova and Pipers Hole rivers. Development of the Terra Nova River was studied extensively in the 1960s, but was not pursued due to adverse environmental impacts. The development concept, as proposed in 1966, would involve diversions from the upper reaches of Pipers Hole River, Northwest River - Port Blandford and Salmon Brook, as shown in Figure 5.1. The scheme would incorporate two generating stations, Mollyguajeck (44 MW) on the Upper Terra Nova and Clode Sound (100 MW) on the Lower Terra Nova River between Pitts Pond and sea level at Clode Sound, and would produce an annual energy output of 782 GWh (1). Adverse environmental impacts would result from extensive reservoir flooding, stream diversions and construction of access roads, gravel pits, etc. Some of these adverse effects can be eliminated or reduced by redesign, notably by locating power structures underground and by providing flow releases below diversion dams. Although part of the development lies within Terra Nova

National Park, the Province of Newfoundland still retains the water rights (6).

Pipers Hole Development has been evaluated only to the extent of a preliminary or "desk" level study.

The potential for small scale hydro development (1 MW to 20 MW) suitable for interconnection to the Island power grid has recently been the subject of an inventory survey by ShawMont Newfoundland Limited (2) and a follow-up (ranking) study by SNC-BAE Joint Venture (3). Four small hydro sites in the study area were judged to be economic, but with the exception of Black River, they rank well behind more attractive sites on the Northern Peninsula and in southwestern Newfoundland; hence it is unlikely that these sites will be candidates for development in the near future. Particulars on both small and large hydro (> 20 MW) plants in the study area are summarized in Table 5.2 (next page); while development locations are shown in Figure 5.2.

There is also potential for very small or micro hydro schemes that would serve a small lodge or a few homes. However, such schemes are unlikely to be economically viable in an area served by the main Island power grid.

Deterioration in water quality due to increases in heavy metal concentrations, eutrophication or inadequate aeration of bottom waters are sometimes associated with large reservoirs. For small reservoirs (such as those on the Lockston and Port Union schemes) which were created by raising existing pond levels by only a few metres, such problems are uncommon. These reservoirs function much like

Table 5.2

Characteristics of Prospective Hydro Developments

Plant	Drainage Area (sq.km)	Capacity (kW)	Gross Head (m)	Average Annual Energy (GWh)	Remarks
Terra Nova: a) Clode Sound b) Mollyguajeck	 2537 1825	 100,000 44,000	 89.9 57.9	> 782	Includes diversions from N.W. Brook, Piper's Hole River and Salmon Brook (1)
Pipers Hole	765	24,000	76.2	175	Possibility of diversions to increase output
Black River	160	2,600	49	31.0	Reference (3)
Southwest River Port Blandford	415	8,100	53.3	37.1	Reference (2)
Northwest River	570	6,000	30.0	29.3	"
Maccles Lake	202	3,800	55.0	21.5	"

natural lakes without significant effect on water quality. A thorough review of the potential environmental impacts associated with small hydro developments is provided in reference 18.

5.3 RECREATION AND TOURISM

5.3.1 Background

The study area is one of the four major recreational areas in the Province, the others being St. John's, Corner Brook - Gros Morne and L'Anse aux Meadows. While Terra Nova

National Park is without doubt the key attraction in the area, the area is also well served by the provincial park system and private facilities.

Recreation and tourism contribute significantly to the regional economy. Data from exit surveys (auto and air) conducted by the Department of Development and Tourism indicate that about $5,300,000 was spent by out-of-province visitors in the study area in 1987 (4). Detailed statistics on expenditures by Newfoundland residents are not available; however, it is suggested that expenditures by Newfoundland residents would be two to three times greater than by out-of-province visitors (5). On this basis the value of the recreation-tourism industry in the area was estimated to be between $15,000,000 and $21,000,000 in 1987. The main attractions in the study area are described in the following subsections.

5.3.2 Terra Nova National Park

Terra Nova National Park occupies about 400 km^2 of varied plateau, fjord and coastal terrain. Over the years an extensive system of hiking trails, nature trails and canoe routes have been developed as well as several picnic, interpretation centres and swimming areas. The park also preserves several areas of special environmental interest (6). The facilities cater primarily to day visitors, tent and trailer campers, with only a few cabins provided for people who want the "comforts of home". Originally the park was only open during the summer months; however, the park now remains open year-round to cater to cross-country skiers and hardy winter campers.

The park provides semiserviced campsites at two major campgrounds, Newman Sound Campground (400 campsites) on the Trans Canada Highway and Malady Head (165 campsites on Eastport Road). Twenty-four housekeeping cabins are also available on Newman Sound. The park includes some 160 km of sheltered coastline that is ideal for sailing and boating. Finally, a challenging nine hole golf course is located at Twin Rivers just outside the southern entry to the Park.

5.3.3 Provincial Parks

The goal of the provincial park system, as stated in Reference 7, is "to provide a wide variety of high quality outdoor recreation opportunities for residents and visitors, and to preserve and protect in perpetuity provincially significant representative and special natural landscapes and features, and outstanding recreational environments". In order to meet these broad objectives, alternative types of parks are developed that cater to several categories of usage, ranging from relatively intensive usage in "outdoor recreation" parks, moderately intensive usage in "natural environment" and "natural and scenic" parks, to low intensity usage in "wilderness area" parks (where preservation is the main goal).

The following types of development are provided in each of these categories:

(a) Outdoor Recreation Parks

- campsites, picnic sites, activity centres, interpretive exhibits and trails,
- private concessions such as boat rentals, at some parks.

(b) Natural Environment Parks

- picnic and/or campsites in more accessible and least environmentally sensitive areas,
- trails and lookouts,
- interpretation/education programs.

(c) Natural and Scenic Parks

- access and parking, picnic tables and toilets (where required),
- interpretion facilities.

(d) Wilderness Parks

- no recreational facilities provided.

Three of these four categories are represented in the fifteen provincial parks located in the study area, as summarized in Table 5.3.

Table 5.3

Provincial Parks

Parks	Area ha	Camp Sites	Category
Jonathan's Pond	446	96	Natural Environment
David Smallwood	51	27	"
Windmill Bight	365	29	"
Lockston Path	773	20	"
Piper's Hole River	497	30	"
Square Pond	39	93	Outdoor Recreation
Eastport North	8	-	"
Thorburn Lake	35	-	"
Smith Sound	18	-	"
Deadman's Bay	72	-	Natural and Scenic
Northeast Arm	3	-	"
Rattle Falls	21	-	"
Jiggin Head	4	-	"
Marberly	1	-	"
Dungeon	2	-	"

Park locations are shown in Figure 5.3.

5.3.4 Other Facilities

The existence of Terra Nova National Park has undoubtably stimulated the growth of private tourist and recreational developments in the vicinity, which offer a variety of accommodation and recreational opportunities not available in Terra Nova Park. The communities benefiting most from this economic activity are: Glovertown and Traytown on Alexander Bay; Sandringham, Eastport, Happy Adventure, Sandy Cove and Salvage on the Eastport Peninsula and Charlottetown and Port Blandford on Clode Sound. A total of 140 rooms of private tourist accommodation is now available in these communities (8).

Gander remains the second most important hospitality centre in Newfoundland with some 500 rooms of hotel, motel and guest house accommodation. The hotel industry in Gander originally grew in response to the airline business. It now depends on business travellers, convention and tourist business.

Clarenville is the other subregional centre catering both to tourist and business travellers. Motel, hotel and guest house accommodation is also provided in many of the smaller coastal settlements (8).

5.3.5 Present Situation and Future Prospects

The study area is a popular holiday destination for both out-of-province and provincial residents, as shown in Table 5.4.

Table 5.4

Park Use Statistics - 1987

Parks	Camper Nights	Total Visitors
Terra Nova National Park	95,800	455,327
Lockston Path	4,532	8,474
Square Pond	26,916	99,656
David Smallwood	2,520	19,283
Windmill Bight	8,040	45,374
Jonathans Pond	8,928	66,179

1. Sources: Provincial Park Statistics - 1987, Reference 9. B. Bradbury, Sup't - Terra Nova National Park, personal communication;
2. Assumes: 3.5 persons per campsite, out-of-province, 4.5 persons per campsite, Newfoundland residents

The majority of visitors are Provincial residents, in the order of 90%, while the remainder are from out-of-province. Facility use rates (1987 data) were high about 80% in the provincial parks for the "high season" (July and August) and 60% overall May 24 - September 6). Statistics (1987) for Terra Nova National Park indicate a usage rate of about 50% annually.

Data collected in auto and air exit surveys conducted by the Department of Development and Tourism indicate the main purposes for visiting the area are sight seeing, (36.1%) visiting friends and relatives (35.9%) and other business (13.9%). Relatively few (1.5%) cited fishing as the main purpose of their visit. Less information is available on the vacation habits of provincial residents; however, a vacation preference survey of St. John's residents generally confirms that sight-seeing and visiting friends and relatives were among the most important vacation objectives (10).

Tourist interests have also been assessed in recent surveys conducted by the Department of Development and Tourism. The findings of these surveys are summarized, by category and activity, in Table 5.5.

Table 5.5

Visitor Interests

	ACTIVITY	RESIDENTS		NON-RESIDENTS	
		% liking	% participating	% liking	% participating
WATER	Canoeing	75.2	42.0	44.5	9.8
	Fishing	82.8	79.2	61.0	40.2
	Swimming	93.0	82.0	74.7	44.1
	Sailing/Boating	85.6	62.5	55.2	33.0
OUTDOORS	Go to Beach	94.4	85.6	74.4	63.9
	Camping	87.0	81.0	67.2	53.6
	Hunting	52.2	37.3	19.8	6.3
	Picnics	95.4	92.6	80.9	71.8
	Hiking	73.8	57.0	34.2	20.4
	Sight-seeing	91.6	88.4	90.8	95.4
	Visit Parks	93.7	90.4	80.9	84.7
	Photography	88.6	84.0	85.8	92.6
	Horseback Riding	70.8	29.4	31.6	5.1
CULTURAL	Visit Historic Sites	92.4	82.4	80.2	84.9
	Meet Locals	97.4	90.5	90.2	95.6
	Attend Festivals	88.1	65.4	59.7	42.9
	Night Life	87.1	78.3	40.8	26.9
	Visit Friends & Relatives	94.3	87.6	71.9	62.2
	Tennis	66.9	28.7	24.8	5.4

1. Based on Non-Resident Auto-Survey and Resident Survey data supplied by Department of Development and Tourism.

2. Table includes activities about which either residents or non residents expressed a % liking > 50%.

It can be seen that water-related and outdoor activities are generally popular but with varying levels of participation. The difference between percent liking and percent participating is considered by the Department of Development and Tourism as an indicator of latent demand. Significant latent interests related to water include canoeing, swimming (at beaches) and boating/sailing.

Tourism is one of the fastest growing industries in the area and has been growing at a steady rate of about 6% per annum (real rate about 2% with inflation discounted). Future growth depends to some extent on enhancements to the tourism infrastructure (accommodation and food services) and more effective marketing (5). Some growth will also result from providing new attractions for visitors.

A major limitation to development of tourism is the seasonal nature of the business, with most activities occurring during the high summer period - July to September (corresponding to school vacation period).

One interesting development is the White Hills Ski resort in Clarenville, which opened in late 1988 and where there is promise of year round activity.

Among water related activities, there is latent demand for canoe routes, beaches for swimming and facilities for boating. There are two types of canoeing activities:

- "white water" canoeing, mainly the descent of fast rivers, and
- "flat water" canoeing, involving cross-country travel, typically from lake to lake.

Prospects for white water canoeing have been surveyed by the Canoe Club of Newfoundland, who have identified three rivers in the study area as suitable for white water canoeing. These rivers are:

- N.W. Gander and Gander Rivers
- Terra Nova River
- Northwest River (Port Blandford)

While on this subject it is interesting to note that a reach on the Terra Nova River has been proposed as the site for a provincial waterway park (11).

Prospects for flat water canoeing in Terra Nova National Park are minimal, and the route from Sandy Pond to Dunphy's Pond, already developed, is probably the only practical route within Park boundaries (6). Only one mention of "flat water" routes outside of Terra Nova National Park was found in the documents consulted during the course of this study (19). There is nonetheless great potential for flat water canoeing in the study area. Inspection of topographic maps suggests that the areas having the greatest potential are:

- the inland from the Musgrave Harbour to Lumsden shore,
- the headwaters area of Pipers Hole River,
- Northwest River and Soulis Pond - Traverse Brook (19).

The desire for improved facilities for swimming is a particular concern of out-of-province visitors, but less so to permanent residents. This concern should be taken into consideration by park planners and developers.

Data on interest in boating and sailing include both freshwater and seawater components. The study area provides some spectacular opportunities for seawater boating and sailing enthusiasts, especially in the sheltered bays and fjords in the vicinity of Terra Nova National park. While some freshwater sailing and boating is carried out on larger lakes (notably: on Gander and Gambo Lakes) for the most part these activities are predominantly seawater activities.

There are some cottage developments on lakes in the study area, but data on this activity are scarce. The extent of such developments is believed to be small at present.

Freshwater angling, while seldom identified in the auto and air exit surveys as the main vacation objective, is nonetheless a major activity* often associated with other vacation activities. Because of its importance it is discussed separately in Section 5.4.

5.3.6 Value of Water for Recreation

There is no straightforward way of placing a meaningful value on water used for recreational purposes in terms of cents/m^3 or dollars/hectare. The important observation is to note that the majority of recreational activities involve either direct water use such as: - swimming, boating/sailing and angling, or indirect water use, such as: - sight-seeing, hiking, photography, picnicking, and the like. While to some extent these activities may involve ocean waters, at present the uses of freshwater resources

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* Sixty-two percent of non-resident respondents in the 1985 sport fishing survey stated that they would not have come to the province if there were no fishing opportunities (12).

are much more significant. It is therefore apparent that loss of use or enjoyment of freshwater resources in the study area would jeopardize the recreation and tourism industries - currently worth about $15,000,000 to $21,000,000 per annum.

5.4 FRESHWATER (SPORT) FISHERY

5.4.1 Description

Freshwater fishing in lakes and rivers is a major recreational - even cultural - activity for area residents and other Newfoundlanders. In addition, the opportunities for trout and salmon fishing are a significant attraction for out-of-province visitors. The study area is well endowed with lakes (7% of surface area = 1300 km^2) and also contains 24 of the Provinces 155 scheduled salmon rivers. For the most part the rivers and lakes in the study area remain in pristine condition little altered by human activities. Relatively few fish species are found in freshwaters of the study area. These species are:

- atlantic salmon and ouananiche (land-locked salmon)
- brook (or mud) trout,
- brown trout
- arctic char,
- American smelt,
- three spine stickle back,
- nine spine stickle back,

  and
- American eel

Salmon, trout and ouananiche, which are the commonest game fish on the list, are much sought after by anglers.

The waters in the study area are relatively pure, and for this reason, have relatively low biological productivities, in comparison with world standards (6). This situation is somewhat redressed by the fact that desirable fish species constitute a larger portion of the standing crop, compared with Mainland North America where "trash" fish are more prevalent.

The importance of sport fishing in Newfoundland is evaluated periodically in a continuing series of five year surveys that are carried out cooperatively between provincial and federal fisheries agencies. Three of these surveys have been carried out so far; the latest of which was completed in 1985 (12). These surveys show that sport fishing is a major recreational activity for Newfoundlanders, with a participation rate of about 27% of the provincial population, who fish on an average of twenty-four days per year according to the 1985 survey (12). Sport fishing is also a major attraction to visitors, who account for 11% of the provincial sport fishing effort. Both residents and visitors prefer fishing for trout and atlantic salmon, in that order, and prefer fishing in freshwater over fishing in seawater. Table 5.6 summarizes some of the characteristics of the sport fishery for the Central/Bonavista, area which is representative of the study area.

The 1985 sport fishing survey also provides some estimates of the overall economic value of this activity. Based on these statistics it is estimated that sport fishing activities in the study area amounted to approximately $10,000,000 in 1985. About half of this would have been spent on supplies and services and about half on durable products (boats, ATVs, camping equipment and the like) attributed to fishing activities.

Table 5.6

Salient Statistics on Sport Fishing in Central/Bonavista[1]

ITEMS	RESIDENT	NON RESIDENT	REMARKS
Participation	14,100	300	Age 18 years +
Angling Effort (rod-days)	338,000	1,900	
Preference of Species (%)			
Trout (all species)	64.5%	51.4%	
Atlantic salmon	16.9%	39.1%	
Other freshwater	1.4%	6.7%	
Cod	12.6%	2.2%	
Other seawater	4.6%	0.6%	
Harvest by Species (%)			Total catch retained:
Trout (all species)	63.0%	68.9%	~ 1.8 million kg
Salmon/Ouananiche	1.3%	9.8%	~ 0.7 million kg
Other freshwater	2.6%	8.2%	
Cod	16.5%	4.9%	
Other seawater	16.6%	8.2%	

1. Central/Bonavista includes the study area plus the Bay d'Espoir and Harbour Breton areas.
2. Source, "Sport Fishing in Newfoundland, 1985" - Reference 12.

Other interesting information include the following factors:

Average cost per angler day

- residents $ 16 per day
- non-residents $140 per day

Cost per kg, trout[1]

- residents $ 23 per kg
- non-residents $230 per kg

Cost per kg, salmon[2]

- residents $ 45 per kg
- non-residents $400 per kg

Value of commercial salmon ~ $3.50 per kg

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1. Based on a mean weight of 0.14 kg for trout
2. Based on a mean weight of 1.80 kg for salmon

Sports fishing is a significant cultural activity for Newfoundlanders, in which other factors are at least as important as fishing itself - as summarized in Table 5.7.

Table 5.7

Relative Importance of Factors Affecting

Fishing Enjoyment in Newfoundland in 1985

FACTORS	RANKING SCORE %		
	Residents	Non-residents	All Anglers
1. Beauty of Surroundings	12.9	12.6	12.9
2. Quality of Water	12.3	12.4	12.3
3. Weather Conditions	11.5	7.0	11.3
4. Access to Wilderness	9.9	10.9	10.0
5. Angling for Wild Fish	9.8	11.5	9.8
6. Escape Routine	9.7	10.4	9.7
7. Privacy	9.3	10.7	9.4
8. Catch Species Desired	8.2	9.4	8.2
9. Size of Fish Caught	6.2	7.0	6.3
10. Number of Fish Caught	5.9	6.6	5.9
11. Catch as Source of Food	4.3	1.5	4.2

Source: "Sport Fishing in Newfoundland, 1985" Reference (12).

5.4.2 Present Situation and Future Prospects

At present the catch of nonmigratory fish, mainly trout, is still small relative to the available resource; nonetheless many of the more accessible lakes show the effects of over-fishing (6). The present situation concerning salmon is more complex since a substantial proportion of salmon are caught at sea by commercial fishermen. Catch and effort data collected by the Department of Fisheries and Oceans, Figure 5.4, shows a slow but steady increase in total catch in response to increased fishing effort and slow rate of decline in success rate (catch per unit effort). Considerable variations in catch (and abundance) occur from year-to-year. These variations are due, in part to spawning success in prior years, and in part due to conditions at sea. Low spawning success rates are usually associated with low water levels and high river temperatures during the summer months, June through September. Under these conditions salmon encounter difficulties in their upstream migration to spawning areas.

The recent occurrence of two dry summers in close proximity, 1987 and 1989, and poor catch successes in the early summer of 1989 have given rise to serious concerns on the state of the salmon fishery (13). At the time of writing, it was still too early to objectively assess the situation, since final statistics on the 1988 salmon fishery were unavailable.

The study area contains twenty-four scheduled salmon rivers some of which have potential for significant enhancement by construction of fishways and/or channel improvements to eliminate obstructions to upstream migration (15). [Scheduled salmon rivers are listed in Table 5.8]. According to officials in Fisheries and Oceans (Canada) the most probable candidates for enhancement would be larger rivers, such as: Terra Nova River, Traverse Brook, or Indian Bay Brook.

Table 5.8

Scheduled Salmon Rivers in Study Area

1. Gander River including Northwest and Southwest Gander and all tributary streams,
2. Ragged Harbour River and tributary streams,
3. Anchor Brook,
4. Deadman's Bay River and tributary streams,
5. Windmill Brook,
6. Northwest Brook Indian Bay,
7. Indian Bay River and tributary streams,
8. North West Brook, Trinity, Bonavista Bay,
9. Traverse Brook and tributary streams,
10. Middle Brook including Square Pond Brook and Burnt Pond Brook,
11. Gambo River and tributary streams, including Mint Brook, Narrows, Triton Brook, Riverhead Brook and Parsons Brook,
12. Northwest Brook, Alexander Bay,
13. Terra Nova River downstream from Mollyguajeck Falls and tributary streams, including Maccles Brook, George's Brook and Butt's Brook,
14. Northwest Brook (Port Blandford) and tributary streams,
15. Southwest Brook (Port Blandford) and tributary streams,
16. Salmon Brook (Port Blandford) and tributary streams,
17. Salmon Cove River, Trinity Bay,
18. Trouty River, Trinity Bay,
19. Pope's Harbour River, Trinity Bay,
20. Shoal Harbour River,
21. Deer Harbour River (Random Island),
22. Come-by-Chance River,
23. North Harbour River, and
24. Pipers Hole River.

Some enhancement facilities have already been constructed on the Terra Nova River (fishways at mile 5, mile 14 and Mollyguajeck Falls). No work has been carried out on other rivers. Another approach to enhancement is to stock lakes with hatchery reared fingerlings. This approach would apply on lakes where recruitment is constrained by shortage of spawning habitat (16) at a level below that which could be sustained by nutrient supply.

A decline in salmon production is reported on Mint Brook (a major tributary of Gambo Lake) following removal of log driving dams on North Pond and Masons Pond (20). In order to enhance salmon production in this watershed it is suggested that these dams be restored and outflows regulated to maintain river habitat and flow levels.

The main concerns for the future are the adverse effects of acidification on fish life, (as discussed in Section 4.4) and possible conflicts between water users. Conflicts over water use would mainly oppose hydro or water supply developers against sport fishermen or recreational water users. In many such situations remedial measures can be provided to maintain fish habitat and recreational uses without robbing excessive amounts of water from other developments, as discussed in Reference 17. Another potential conflict opposes the sport fisherman against the commercial salmon fisherman. Government should consider the relative importance of both fisheries when setting policy.

5.4.3 Value of Water for Sport Fishing

Availability of high quality water is an essential requirement for the maintenance of a sport fishery in the study area. As noted above the economic value of this activity is high in the order of $10,000,000 per year. Of equal or greater importance is the cultural value attached to this activity by Newfoundlanders. The point to be emphasized is that care should be taken in the management of this resource that is at least proportional to its $10,000,000 per year contribution to the regional economy.

5.5 OTHER USES

Three other instream uses for rivers were also investigated. These are use of rivers for log driving, transportation and for sewage dilution.

Enquiries addressed to the Department of Forestry confirmed that no log driving operations remain in the study area.

Where rivers and lakes are navigable in small boats they provide access and transportation routes for travellers, mainly hunters and sport fishermen. The rivers and lakes most used for this purpose are Gander River (navigable by "Gander River" boats for 50 km from Glenwood to Gander Bay) and Gambo Lake.

Disposal of sewage in rivers of the study area is rare since most communities are located on the coast. The only exception is the Gander River which receives treated sewage from Gander, Glenwood and Appleton. Some degradation of water quality has been reported on the Gander River just downstream of Glenwood and Appleton. This problem is attributed to unsatisfactory operation of the sewage treatment plants in those communities. As one moves downstream from Glenwood/Appleton water quality improves as waste water discharges are further diluted and aerated.

Sewage treatment plants in Gander appear to function satisfactorily and waste water discharges do not degrade the receiving waters, Beaver/Soulis Brook, Jonathan's Pond Brook.

5.6 CONCLUDING COMMENTS

Three valuable instream water uses exist in the area - hydropower, recreational and freshwater (sport) fishing. At present these uses are not in conflict. There are significant opportunities for further development of all these uses. Thus in the future there will be a greater likelihood of conflicts between users. Accordingly, developers should be encouraged to include mitigative measures into the design of their projects so as to eliminate or minimize adverse impacts on other instream water users.

The most important future concern is acid rain. Acidification of rivers and lakes in the study area would have serious effects on the recreation/tourism and sport fishing industries, which are of particular importance in the study area.

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2. ShawMont Newfoundland Limited, (1986), "An Inventory of Small Hydro Sites for Energy Supply to the Island Grid" (Volumes 1 and 2), for Newfoundland and Labrador Hydro.

3. SNC-BAE Joint Venture, (1988), "1987 Small Hydro Studies - Screening Small Hydro Sites for Energy Supply to the Island Grid", for Newfoundland and Labrador Hydro.

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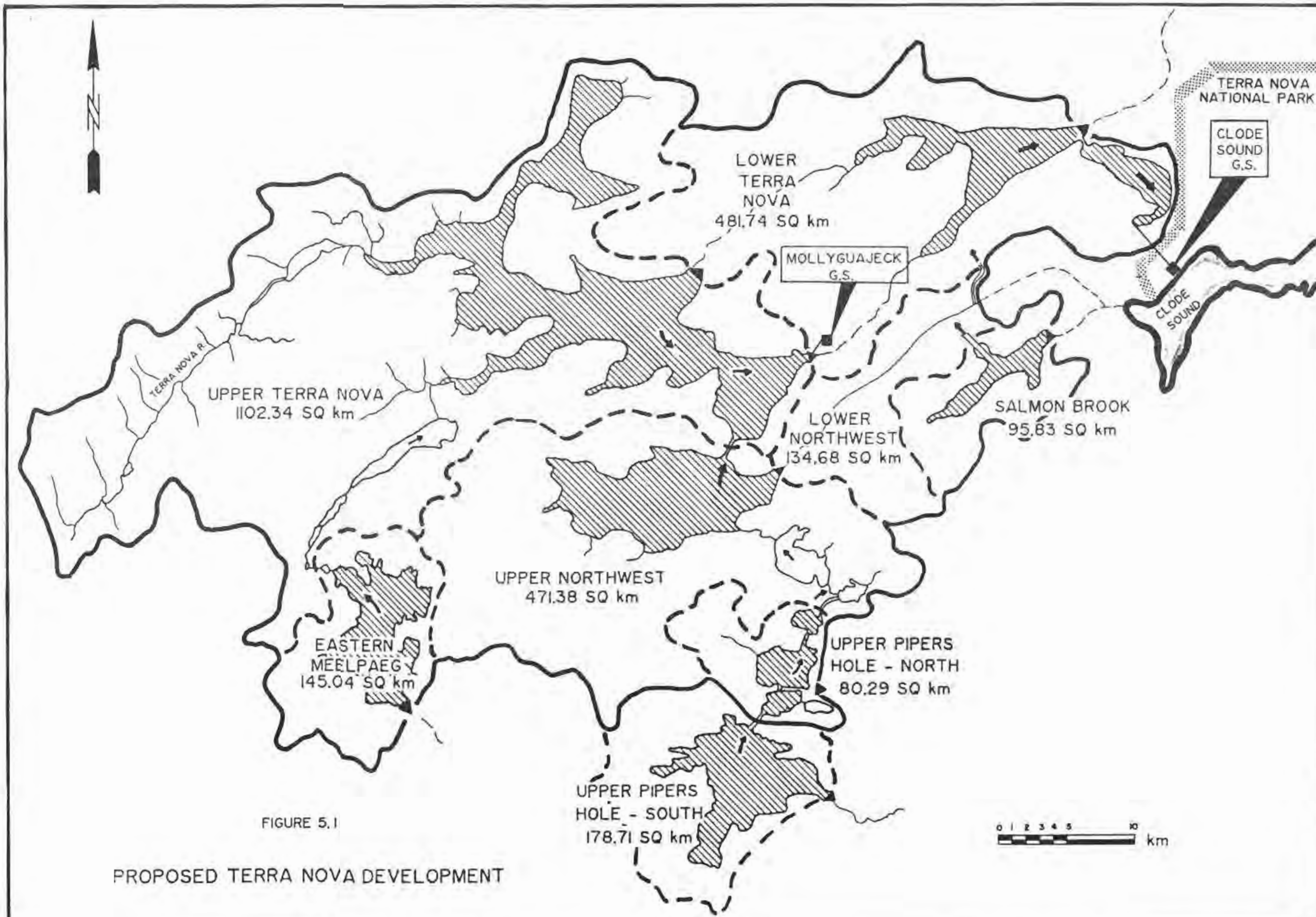
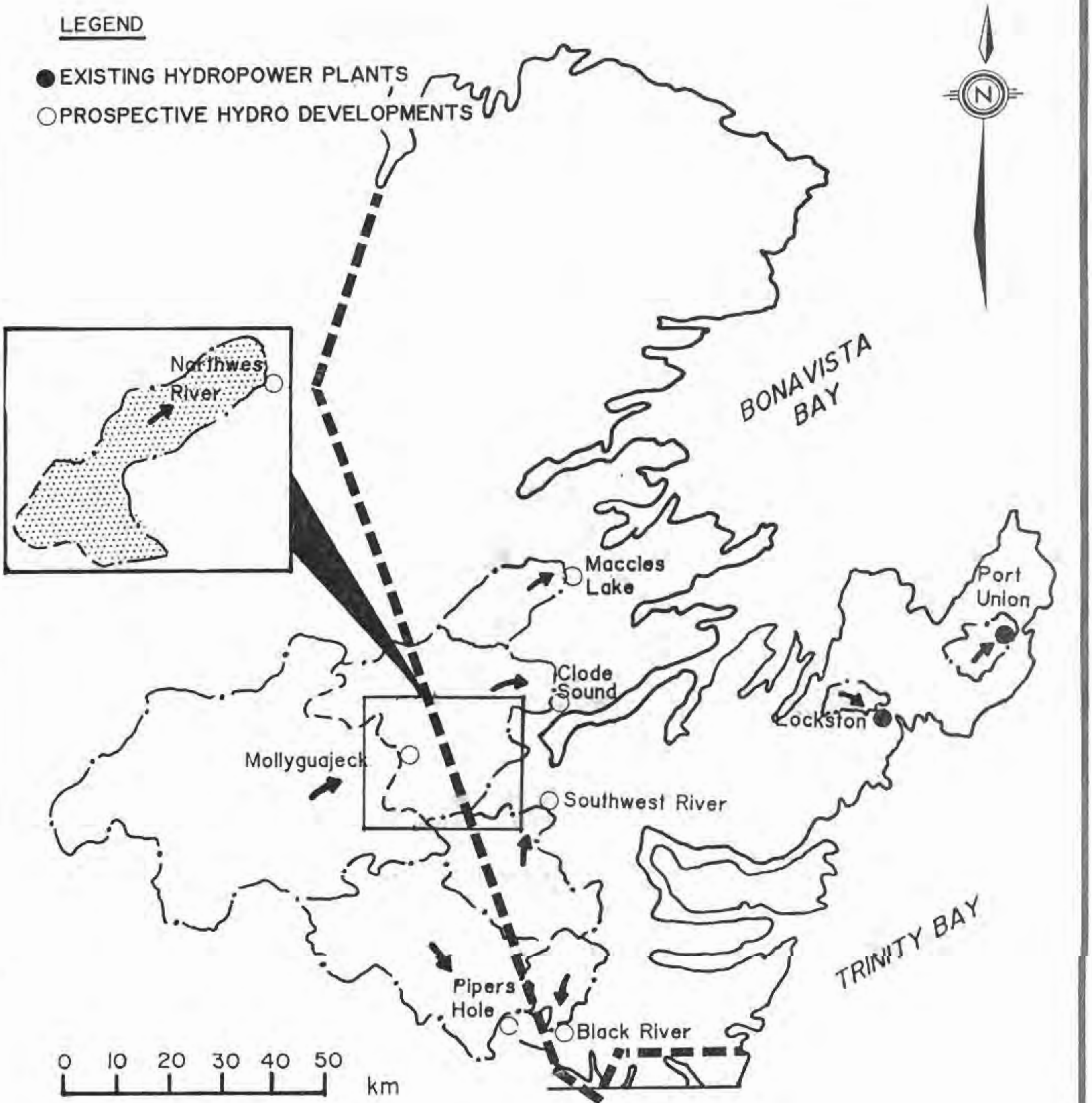


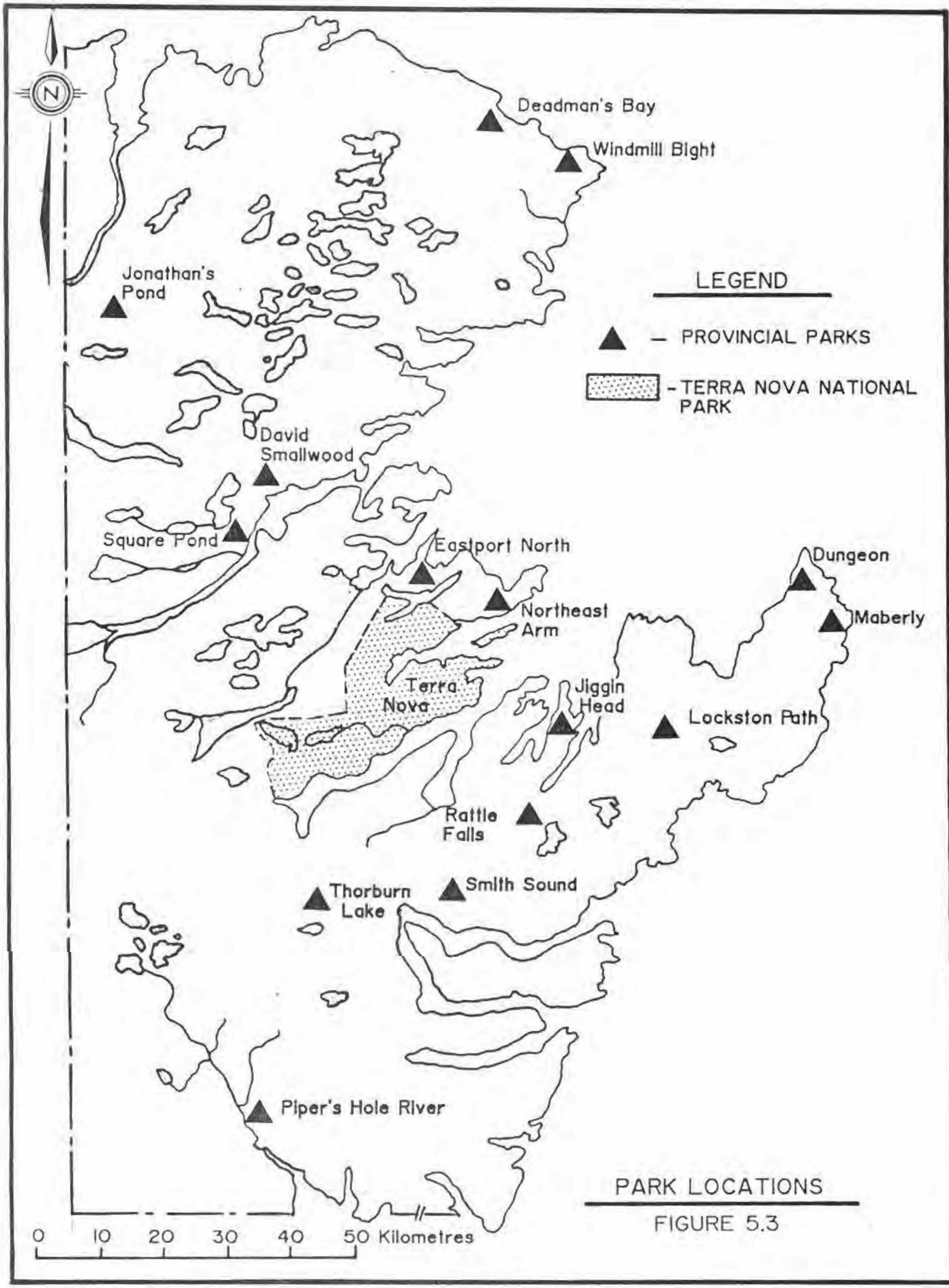
FIGURE 5.1

PROPOSED TERRA NOVA DEVELOPMENT



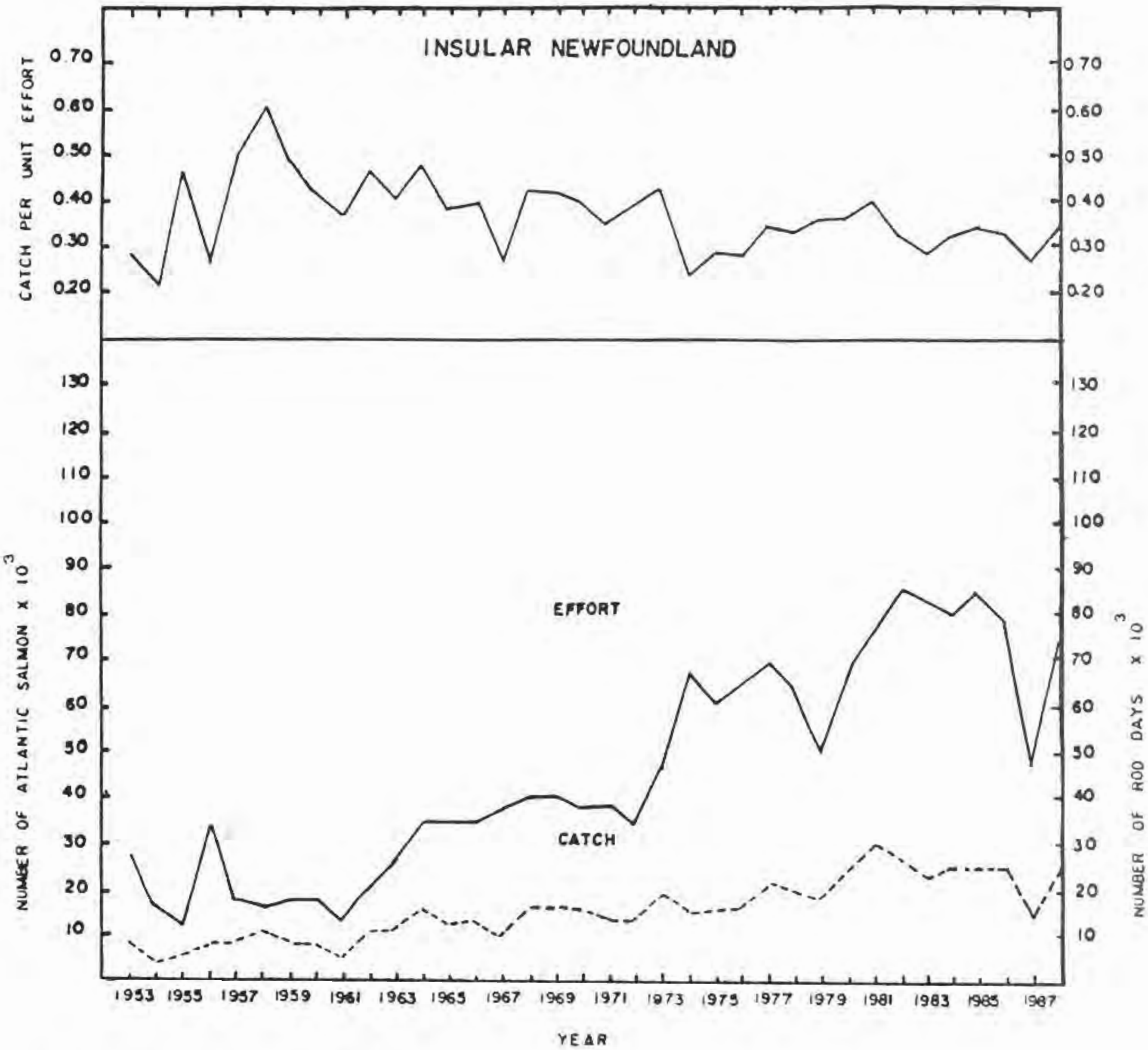
EXISTING AND POTENTIAL
HYDROPOWER DEVELOPMENTS

FIGURE 5.2



PARK LOCATIONS

FIGURE 5.3



[From Reference 14]

CATCH AND EFFORT DATA FOR

ATLANTIC SALMON SPORT FISHERY

FIGURE 5.4

CHAPTER SIX

WITHDRAWAL USES

6.1 INTRODUCTION

Uses requiring withdrawal of water from lakes, rivers or groundwater are termed "withdrawal" uses. These uses often involve some degree of consumption, since the amount of water returned to the river or lake of origin is usually reduced. When return flows are polluted, which often happens, the water is considered by some authorities to be "consumed" in the sense that it may no longer be usable due to its degraded quality.

In the study area withdrawal demands are limited to agriculture, fish plant and municipal water supply uses. Except for fish plant demands there are no significant industrial requirements at the present time or new industrial demands in the foreseeable future.

6.2 AGRICULTURAL DEMANDS

The possibilities for agriculture in the study area are limited by the low proportion of the area suitable for cultivation. From an examination of the soil capability map for Bonavista it is estimated that 1.5% of the area is occupied by mineral soils which are marginally cultivable, 17.5% by mineral soils suitable for forage only, 6% by organic soils; while the remanding, 75%, is of no agricultural value (1). Organic soils (bog-lands) are potentially very productive but are expensive to develop. Development of bog-lands would normally involve drainage and treatment with lime. These soils remain very soft and require special farming equipment. The agronomy of bog-lands is now well understood as a result of a research carried out over the past twenty odd years by Agriculture

Canada in Newfoundland. Farmers are now putting this knowledge to practical use and there are several new and successful operations on the Island. Future prospects are encouraging.

Climatic conditions for agriculture in the study area are the best on the Island, with a growing degree-day total (1300°C days >5°C), hours of bright sunshine (900 hours, May to September), growing season (175 days) and frost free period (120 days), (2).

There are scattered agricultural activities in the area involving, provision growing, root crops and some animal husbandry. Much of this activity is subsistence farming, centred around individual vegetable gardens, to provide for family needs. Somewhat less than half of the population still engage in this activity. It is estimated that there are about 75 full time farmers in the study area. They are involved in the following types of farming:

- vegetable production
- eggs - poultry
- beef
- dairy
- hogs
- fox farming
- strawberries

The estimated value of agriculture in the study area, was about $4,000,000 in total farm receipts in 1987. Future growth in the agricultural sector is expected to be slow except, perhaps, for bog-land cultivation where the technology has recently come of age.

Water is used for irrigation at one farm and at the Twin Rivers golf course but details on water consumption were unavailable. Greenhouse operations would also require irrigation. [Greenhouse operations would require up to 30 m^3/hectare/day for vegetable or flowers]. Elsewhere cultivation relies on rainfall and therefore does not involve water withdrawal. A small withdrawal demand is created by livestock, as summarized in Table 6.1.

Table 6.1

Water and Biological Oxygen Demands for Livestock

Animal	Daily Requirement litres/animal	Daily Wastes BOD grams/animal
Horses	45	no data
Beef Cattle	45	255
Dairy Cows		875
- dry	55	
- milking	130	
Hogs	15	115
Sheep	8	no data
Goats	8	no data
Chickens	0.2 - 0.4	7 - 11
Turkeys	0.4 - 0.7	14 - 19

1. From Reference (3)
2. From Reference (4)

Where animals are crowded together, as in intensive poultry, hog, or dairy operations, the pollution loads of runoff and wastewater may be high enough to seriously degrade the water quality of receiving water bodies. On the other hand it is less likely that water quality problems will be produced by free ranging livestock.

Another potential problem related to agriculture is contamination of water sources with toxic chemicals from pesticides spraying. As noted in Section 4.5, this does not appear to be a problem in the study area, at present.

In summary, withdrawal demands for agriculture are minimal at present and are unlikely to become significant on a regional scale during the study period. Nonetheless there is a potential for localized pollution problems to be caused by farmyard wastes, if proper care is not taken on their treatment and disposal.

6.3 FISH PLANTS

6.3.1 Background

The commercial fishery is the main industrial activity in the study area. Altogether there are twenty-seven fish processing plants, which provide employment for about 4000 fish plant workers and 2300 licensed fishermen. The value of fish plant production in 1987 was about $90,000,000. [Figure 6.1 shows location of fish plants].

In the short term the fishing industry faces difficult times due to declining fish stocks. The total allowable catch allocated to the offshore dragger fleet was substantially reduced in 1989 and it is possible that there will be further cuts in 1990. Difficulty in controlling the catch taken by foreign fleets complicates fisheries management. If present initiatives are successful, increases in the volume of catch should again be possible a few years from now. However, it is unlikely that future volumes of catch will be significantly higher than historical levels of the recent past, since current fishing levels are close to (or above) the yield that is biologically sustainable.

The most likely opportunities for future growth in the industry would come from:

- increases in secondary processing

  and/or

- increased utilization of underutilized species.

Past experience has shown that market opportunities and product price, not catching or processing technologies, will determine whether new species will be exploited. For example, two decades ago there was no market for crab, lump fish roe, caplin or eels, all of which are valued fisheries today.

Given the above uncertainties, it is difficult to forecast future changes in the industry. The most likely prospect would be for slow growth or no growth over the study period (1987-2011).

6.3.2 Fish Plant Water Demands

Water, both freshwater and seawater, is used for many purposes in fish plants. These purposes include: fluming fish, washing fish, cleaning plant and equipment, domestic uses, supplies for fishing boats, ice making, condenser cooling in refrigeration systems, and the like. A high bacteriological water quality is required for many of these uses (see Section 4.3.4); for this reason recycling of water is not practical. Water demands for fish plants vary widely from plant to plant depending on the types of products produced and on in-plant technology. At several communities in the study area fish plant demands exceed domestic demand.

In view of the importance of fish plant water demands, a survey was undertaken in which questionnaires on plant operations and water use were sent out to all fish plants in the study area. The results of this survey are summarized in Table 6.2 (next page).

Survey results confirm that water consumption varies widely from very low demands in salt fish operations to very high demands for primary processors. The data also suggest that water use efficiency improves as plant size increases. It is perhaps worthwhile to compare these results with the results of previous studies carried out by Montreal Engineering (5) and Shawinigan-MacLaren (6) as shown in Table 6.3.

Table 6.2

Survey of Water Usage at Fish Plants (in 1988)

No. of questionnaires sent out = 27
Replies = 7

SUMMARY OF RESULTS

ITEMS	Type of Plant						
	Primary Ground Fish			Primary Crab, etc.			Salt-fish
Volume Freshwater (thous.m^3)	29.7	619	760	220	0.68	-	
Volume Seawater (thous.m^3)	49.1	2832	1000	180	-	<250	
Production (thous.kg)	1640	14000	16200	3200	318	845	domestic water only
Unit Demands (l/kg)							
- fresh	180	44	47	69	2	-	
- sea	300	202	62	57	-	<300	
- overall	480	246	109	126	2	<300	
Duration of Operations (weeks)	22	45	18	16	17	40	
Remarks:							
Seawater for condenser cooling	*						
Seawater use not given		*					
Seawater for fluming, fish washing plant cooling (50%)			*			*	shell fish, salmon, cod
Crab				*	*		lumpfish saltfish

Table 6.3

Comparison of Unit Water Demands

Type of Operation	Water Demand l/kg (finished product)				
	Study Area		Maritimes		
	Min	Max	Min	Max	Mean
Primary Groundfish					
- freshwater	44	180	15	168	65 (75)
- seawater	62	300	47	233	145
- total water	109	480	80	300	210
Saltfish	-	-	-	-	2 - 4

Notes:

1. Values from MECO Study (5) covered to l/kg (finished product) assuming 33% yield on whole fish and landed catch gutted head on.
2. From SECO (6).

None of the fish plant operators was able to estimate the proportions of water used in various plant activities, but when contacted by phone several advised that fluming and washing consumed the greatest amounts of water. This is consistent with the findings of a survey of fish plant water use in the Maritimes done by Montreal Engineering Co. (5) and summarized in Table 6.4.

Survey results also confirmed that seawater can be substituted for practically every purpose except for supply of potable water. However, development of seawater supplies is very dependent on plant location and, as a result, use of seawater is not a practical alternative at every plant.

Table 6.4

Percentage of Water Used for Each Purpose

PURPOSE	PERCENTAGE OF TOTAL WATER INTAKE
Fluming of whole fish fillets and offal	50 - 65%
Fish washing, scaling, filletting and skinning	15 - 25%
Clean-up in plant, vessel wharf, etc.	12 - 18%
Fish meal plant	2 - 4%
Ice making	1 - 3%
Freshwater for fishing vessels	1 - 2%
Toilets and washrooms	1 - 2%
Boiler feedwater, cooling water, etc.	1 - 2%

Of the twenty-seven fish plants in the study area, fifteen obtain their freshwater from municipal water supply systems, five own and operate their own freshwater supplies, while five use seawater exclusively for plant operations. The water sources for two operations are unknown. Water demands at individual fish plants, where known, were taken into consideration in determining of municipal supply forecasts as further explained in Section 6.5.2. The seasonal nature of fish plant operations in the study area also has important implications for the design and operation of water supply systems for fish plants. Most plants only operate for two-four months each year, during the fishing season.

Many of the waste products from fish processing are composed of edible material (offal). At some plants this material is collected and used as raw material for production of fish meal. At other plants the offal is dumped into the ocean where it provides food for scavengers (sea gulls, cunners, etc.). Fish plant wastes are not usually disposed of in freshwater sources. Some pollution of harbour waters probably occurs; however investigation of this problem was beyond the scope of the study.

6.3.3 Value of Freshwater

The cost of water is a relatively minor cost input to the processing of fish products. A typical primary fish plant, supplied from a government owned municipal or industrial supply, would be charged about 7.5 cents per m^3 for freshwater, and about 6.5 cents per m^3 for saltwater. Assuming a freshwater consumption of 50 litres/kg and a seawater consumption of 200 litres/kg gives a water cost of 1.7 cents per kg. When compared with a typical production cost of $3.50 per kg for cod block, water costs are only about 0.5% of production costs. It should be noted, however that water costs at most fish plants in the study area are based on recovery of operating expenses only. If water prices included for capital recovery, charges to fish plants would be much higher, in the range of 50 - 70 cents per m^3.*

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* Several of the fish plants in the study area are supplied from industrial supplies financed by grants from the Atlantic Development Board in the 1960's.

The results from the survey suggests that there are significant opportunities for water conservation. However, the incentives to conserve vary from plant to plant depending on cost, availability of freshwater and the economics of alternative seawater supplies.

6.4 OTHER INDUSTRIES

Other industrial activities in the study area include: forestry operations (pulpwood harvesting and lumbering), boat building, tourism, aircraft service, etc. None of these activities is a significant consumer of water. In addition there are the usual service operations such as dry cleaning, auto repair and service stations, pharmacies, retail stores, and the like, which constitute the commercial sector. Much of the recent growth in commercial sector activities has been to the benefit of the larger towns, notably - Clarenville and Gander which have become regional service centres, serving populations far beyond their boundaries. In general, the size of the commercial sector, and hence its water demand, is proportional to the population served. Typically, some 20%-25% of water demand is generated by commercial sector activity. Commercial residential demands are often "lumped" together in a per capita demand rates used in water system planning.

6.5 MUNICIPAL WATER SUPPLY

Altogether there are 56 municipal water systems which supply 86% of the population - 78% from surface water sources and 8% from wells (see Figure 6.2). About 14% of the population do not obtain their water from municipal water supplies but rely instead on private supplies, usually from shallow wells (7).

Municipal demand from these communities constitutes the greatest withdrawal demand in the study area.

6.5.1 Existing Demand and Supply

A facilities survey (7) was undertaken to collect data on existing demands, characteristics and conditions of existing water supply systems in the study area. The main approaches and findings from this survey are summarized below. Readers requiring more detailed information on individual water supply systems are referred to the facilities survey report (7). The purpose of the facilities survey was to develop statistics on each water supply system in the study area, recording basic data on existing demand, characteristics of the resource and water delivery system, and information about future requirements, in so far as they were known to the local authorities. The survey involved reviewing existing plans and engineering reports, followed by site visits to meet local authorities and inspect facilities. Documentary data on the existing systems were found to be somewhat incomplete, and staff interviewed at local municipal council offices, typically town clerks, were often unable to provide complete technical information. In particular, data on the basin yield, demand and delivery system capacity were often unavailable. It was therefore necessary, for the purposes of this study, to estimate values for these parameters. The techniques applied are discussed in the following paragraphs.

(a) Basin Yield: Approaches to estimating basin yield vary considerably and there does not seem to be a general consensus on this matter. Government of Newfoundland Guidelines (8) recommend that the water source "be adequate to meet the projected water demand of the service area as shown by calculations based on the extreme drought of record". This approach could give optimistic values for yield where records are of short duration, and pessimistic values when the period of records is long.

A more rational approach would be to base design on a statistically determined measure of supply reliability. For the purposes of this study, the criterion adopted allows a failure rate of one month per ten years. Basin yield, based on this criterion, was estimated using a mean unitized storage - yield curve, Figure 6.4. Where supplies were taken from a pond or reservoir a drawdown of 1.0 m was assumed for estimation of live storage, except where the live storage volume was known.

(b) Well Yield: Insufficient information was available to permit estimation of well yields.

(c) Demand: Data on water demand was difficult to obtain, since only a handful of municipalities regularly read their water meters. The data reported are on gross use excluding fish plant demands and thus include commercial demands and leakage. An effort was made to obtain comparative per capita demand statistics from elsewhere. Table 6.5 tabulates the statistics obtained.

Table 6.5

Comparative Per Capita Demands

Source	Range (l/day)	Mean (l/day)
Data collected in Facilities Survey	243 - 700	442
D.Tate and D.Lacelle [reference 6]		
- Newfoundland	(not reported)	679
- Prince Edward Island		528
- Nova Scotia		705
- New Brunswick		1433

When available data were corrected for major industrial demands (usually fish plants) as in Table 6.6, use of the conventional per capita design rate of 450 l/day [= 100 gals/day] seemed reasonable.*

Accordingly, a value of 450 l/person/day was used to estimate daily demands where such data was missing (industrial demands were added separately). The peak daily demand was taken as double the mean daily demand.

Data on demand patterns, were available for only one water supply - Clarenville for which an annual pattern was available (10). A graph of this data is given in Figure 6.3.

* J. Harty, P. Eng. - Department of Municipal Affairs, Gander (personal communication) advises that design rates are typically 450 l/person/day for municipal status systems and 225-350 l/person/day for local service district (L.S.D.) systems.

(d) <u>Delivery System Capacity:</u> Where delivery system capacity was not reported, capacity was estimated using the following formula:

$$Q = 0.04\ d^2$$

where d = diameter of supply main (mm)

Q = maximum daily demand (l/min)

This formula is based on the optimum diameter for a pumped supply, as determined by the methods of calculus applied to the following cost equation:

$$Y = 8.25d + 17400.\frac{Q^{2.87}}{d^{4.78}} + K \qquad \text{(in 1988 dollars)}$$

Where:

$8.25d$ = installed cost per 100 m of PVC (150 psi) pipe. Based on a material price of 1.25 cents per 100 ml, with d measured in mm.

$17400\ \frac{Q^{2.87}}{d^{4.78}}$ = present value of headlosses per 100 m, based on:
Hazen-Williams Equation (C = 150),
pump efficiency = 80%,
electric energy = 65 c/kWh,
interest rate = 10%, and
service life = 30 years

K = cost of excavation and backfill [minimum practical size - invariable for the range of pipe diameters of interest].

Y = total lifetime cost per 100 m of pipeline

For the minimum cost $\frac{dY}{dd} = 0$,

Whence:

$$d = 4.93\ Q^{0.493} \quad \text{or} \quad Q = 0.0386d^{2.04}$$

or approximately: $Q = 0.04d^2$

6.5.2 Future Demand

Growth in future water demand is the aggregate of domestic, commercial and industrial demands. Domestic and commercial are usually lumped together and determined as a function of population numbers; while industrial demands are added separately on a plant by plant basis.

Population growth is due to natural increase (births - deaths) plus the effects of migration into or out of an area. Whether people move into or out of an area depends very much on opportunities for employment. As previously discussed, prospects for growth in the following primary industries are weak:

- fishery (low or no growth)
- tourism (about 2% per annum, in real terms)
- agriculture (unknown, but minimal overall).

The prospects for growth of employment in the forest industry are also poor since current annual rates of harvesting generally exceed rates of forest regeneration (according to data obtained from the Department of Forestry). There is no mining industry or known "hot" prospects. Finally no major industrial development is forecast for the study area within the immediate future.

In these circumstances, the most practical way of estimating future demands was by projections of the 1986 population statistics to the 2011 planning horizon using past trends (see Table 6.6, next page). In communities showing declining populations, population levels were assumed to remain stable. Forecast demands also include populations not presently served by existing public water supply systems. Projected demands are based on a per capita demand of 450 litres/person/day plus industrial demands.

Impacts of the Hibernia Development in the study area are expected to be small (as further discussed in Section 6.6.4).

6.6 ASSESSMENT OF THE SUPPLY-DEMAND SITUATION

This assessment was based on data from fifty six systems that were collected during the facilities survey (7). Twelve mainly small communities are not covered since no data on their water supply situation is available. Of those fifty-six systems, twenty-nine systems utilize surface sources and twenty-seven systems utilize groundwater sources, distributed across the study area. For convenience of comparison, the study area has been subdivided into four subareas, roughly separating the main peninsula regions - as shown in Figure 6.1. The supply-demand situation in each of these subareas will be examined in turn.

TABLE 6.6

BONAVISTA BAY REGIONAL WATER RESOURCES STUDY
Population Statistics: 1966 - 1986
Population Forecast : 2011

Community	Census Division	Population 1966	1971	1976	1981	1986	Forecast Population 2011
Sunnyside	1		716	726	703	635	635
Lumsden	8		630	597	645	635	635
Musgrave Harbour	8	1183	1232	1530	1554	1530	1530
Carmanville	8	938	839	911	966	985	1062
Badgers Quay, Valleyfield, Pools Island & Sunnyside	7	2704	2599	2635	2791	2795	2913
Bonavista	7	4192	4215	4229	4460	4605	5217
Clarenville	7	1813	2193	2807	2878	2965	8400 (4536) *
Duntara	7	195	149	138	124	120	120
Eastport	7	437	438	567	597	610	950
Elliston	7			540	527	565	633
Gambo	7	1460		2994	2932	2720	2720
Glovertown	7	1246	1195	2158	2165	2180	2235
Greenspond	7	655	449	382	423	460	460
Happy Adventure	7	413	364	387	352	355	355
Hare Bay & Dover	7			2488	2445	2345	2345
Indian Bay	7			198	192	215	264
Keels	7		146	142	129	115	115
Kings Cove	7		271	239	253	255	255
Musgrave Town	7			641	635	715	940
Newtown	7	562	513	490	511	530	530
Plate Cove East	7	237	209	164	172	175	175
Plate Cove West	7	255	308	284	302	305	305
Port Blandford	7			815	702	730	730
Port Rexton	7		384	463	489	465	465
Port Union, Catalina, Little Catalina, Melrose	7		2809	2932	2999	3051	3386
Salvage	7			242	244	270	355
Sandringham	7		223	260	271	280	409
Sandy Cove	7	128	158	168	187	190	258
Shoal Harbour	7			1009	1000	1050	1160
Terra Nova	7	151	107	88	62	45	45
Tray Town	7			379	383	390	419
Trinity Bonavista Bay	7		577	559	522	420	420
Trinity Trinity Bay	7		288	367	375	355	355
Centreville & Wareham	7		921	1188	1062	1030	1255
Musgravetown	7			641	635	715	940
Gander	7			9301	10404	10205	12900

Source: Census Data from Statistics Canada

Notes: * 8400 - Optimistic growth rate of 3% per annum.
4536 - Pessimistic growth rate of 0.5% per annum.

6.6.1 Subarea 1

Table 6.7 summarizes the existing supply-demand situation in Subarea 1.

Altogether there are eighteen water supply systems in Subarea 1 of which fifteen are from surface sources and four from wells. Five systems supply more than one community, they are:

(a) Main Point and Davidsville
(b) Badgers Quay, Valley Field, Pool's Island, Pound Cove and Wesleyville
(c) Centreville and Wareham
(d) Hare Bay and Dover, and
(e) Newtown and Templeton

Basin yields for all of the surface systems are adequate to supply the forecast 2011 demand. Problems are reported on the Greenspond system which transports water from Shambler's Cove Pond, on the mainland, to Greenspond Island via a surface 150 mm pipe*. This is essentially an emergency supply designed to provide water during the summer to supply the fish plant. Greenspond town council has applied to Municipal Affairs for funding to provide a more reliable supply.

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* Pipeline was not buried because the Department of Transportation and Communications recommended that burial be delayed until causeway settlement had stabilized.

TABLE 6.7

SUPPLY-DEMAND SITUATION IN SUBAREA 1

SUBAREA 1

Community	Source	Population		Demand (l/min)		Supply (l/min)		S/D Ratio
		1986	2011	1986	2011	Basin Yield	Existing Capacity	
Badgers Quay (Valley Field + Pool's Island + Wesleyville)	Pound Cove Middle Brook	2795	2913	1360	1400	9400	3200	6.7
Benton	Little Pond Brook	200	~200	63	63	225	335	3.6
Centreville (+ Wareham)	North West River	1030	1255	380	392	30000	2200	77
Deadman's Cove	Deadman's Brook	250	250	78	78	28000	225	124
Gambo	Goose Pond + Dark Cove Pond	2720	2720	850	850	3000	900	3.5
Gander	Gander Lake	10205	12900	4735	6000	1.3 Ml/s	15800	217
Gander Bay S.	Berry's Brook	250	~250	75	78	11000	100	141
Greenspond	Shamblers Cove Brook	460	~460	144	144	600	900	4.2
Hare Bay (+Dover)	Hare Bay Pond Brook	2345	~2345	630	733	2300	790	3.1
Indian Bay	Indian Bay River	215	264	90	90	36000	190	400
Lumsden	Gull Pond Brook	635	~635	107	199	10000	365	50
Musgrave Harbour	Rock Pond Brook	1530	~1530	617	617	6200	2500	10
Newtown (+ Templeton)	Carters Pond Brook	530	530	139	166	2600	400	16
Trinity B.B.	Southwest Feeder Brook	420	~420	190	190	7200	-	38
Cape Freels North	Cape Freels Brook	130	~130	40	40	Unknown	Unknown	
Carmanville	Wells	985	1062	308	330	Unknown	Unknown	
Gander Bay North	Wells	1130	~1130	350	350	Unknown	Unknown	
Main Point/ Davidsville	Wells	250	~250	78	78	Unknown	Unknown	
Noggin Cove	Wells	200	200	63	63	Unknown	Unknown	

Notes:

[1] S/D Ratio = supply/demand ratio in 2011

Trinity, B.B. is presently supplied by its own system from Southwest Feeder Brook. Although this source should be adequate for many years into the future, it may be more convenient to hook into the Indian Bay - Wareham system (11).

Problems were reported on all groundwater systems, mainly inadequate yields during dry periods. Alternative surface water sources are available near most of these communities, as below:

Gander Bay Brook near Main Point - Davidsville
Noggins Cove Brook near Noggins Cove
Grandfather Pond near Carmanville

Engineering studies recommend development of Grandfathers Pond to supply Carmanville (12). As a first step, this watershed has been registered as a protected watershed, reserved for water supply. The Department of Municipal Affairs intends to extend the Carmanville water system to Noggins Cove when the Grandfather Pond water supply system has been put in place (13).

6.6.2 Subarea 2

Table 6.8 summarizes the existing supply-demand situation for Subarea 2.

There are a total of ten water supply systems in this subareas, of which four are supplied from surface sources and seven depend upon wells.

TABLE 6.8

SUPPLY-DEMAND SITUATION IN SUBAREA 2

SUBAREA 2

Community	Source	Population 1986	Population 2011	Demand (l/min) 1986	Demand (l/min) 2011	Supply (l/min) Basin Yield	Supply (l/min) Existing Capacity	S/D Ratio
Glovertown +	Northeast Pond Brook	2180	2654	807	830	10,000	3,600	12.0
Traytown	Wells	390						
Happy Adventure	Happy Adventure Brook	355	~355	110	110	1,600	160	13.6
Port Blandford	Middle Brook Noseworthy Pond	730	~730	228	228	44,200	1,580	194
Sandy Cove	Water Pond	190	258	60	81	190	155	2.3
Burnside - St. Chads	Wells	165	~165	52	52	Unknown	Unknown	
Charlottetown	Wells	350	~350	109	109	Unknown	Unknown	
Eastport	Wells	610	950	191	297	Unknown	Unknown	
Salvage	Wells	270	355	84	110	Unknown	Unknown	
Sandringham	Wells	280	409	88	128	Unknown	Unknown	
Terra Nova	Wells	45	~45	14	14	Unknown	Unknown	

Notes:

[1] S/D Ratio = supply/demand in 2011.
[2] Eastport, Happy Adventure and Sandy Cove systems are interconnected (but operated separately)

Water supply systems for Eastport, Happy Adventure and Sandy Cove are interconnected, but Eastport and Sandy Cove both continue to operate their own systems independently; thus the Happy Adventure system functions essentially as an emergency supply to these communities (13).

Traytown reports its primary supply is from wells, but has recently been interconnected to Glovertown for supplementary supplies. It is planned that future growth in demand at Traytown would be supplied from the Glovertown system which has ample basin yield to accommodate both communities.

Groundwater supplies are reported to be satisfactory at Charlottetown, Sandringham and Terra Nova, but problematic at Eastport, Salvage and Burnside-St. Chads. In recent years the main well in Salvage has suffered from salt intrusion. Eight additional wells have recently been drilled at Salvage into a well defined fault zone but to no avail, since all eight wells were dry! At present the recommended solution is to develop a surface supply (13). At Eastport one well is satisfactory while the other is contaminated by road salt. At Burnside-St. Chads many private wells run dry during periods of drought. At these times, residents use the Government well that provides a more dependable supply. There are ponds near both communities which could be developed, or alternatively, an interconnection with Sandringham could be considered.

6.6.3 Subarea 3

Table 6.9 summarizes the existing supply-demand situation in Subarea 3.

TABLE 6.9

SUPPLY-DEMAND SITUATION IN SUBAREA 3

SUBAREA 3

Community	Source	Population		Demand (l/min)		Supply (l/min)		S/D Ratio
		1986	2011	1986	2011	Basin Yield	Existing Capacity	
Bonavista	Long Pond Brook	4,605	5,217	2,000	2,200	7,500	3,000	3.4
Elliston	Sand Cove Brook	565	633	175	199	388	760	2
Georges Brook	Georges Brook	450	~450	140	140	3,000	-	21
Newmans Cove	Heale Pond Brook	200	~200	160	160	300	400	1.9
Plate Cove East	Eastern Pond Brook	175	~175	54	54	4,300	900	80
Port Union	Middle Brook	3,051	3,386	2,100	2,200	30,000	20,000	14
Duntara	Wells	120	120	40	40	Unknown	Unknown	Unknown
Harcourt	Wells	600	600	188	188	Unknown	Unknown	Unknown
Keels	Wells	115	~115	36	36	Unknown	225	Unknown
Kings Cove	Wells	255	~255	80	80	Unknown	Unknown	Unknown
Musgravetown	Wells	715	940	223	294	Unknown	Unknown	Unknown
Plate Cove West	Wells	305	~305	96	96	Unknown	Unknown	Unknown
Port Rexton	Wells	465	~465	146	146	Unknown	Unknown	Unknown
Spillars Cove	Wells	200	~200	63	63	Unknown	Unknown	Unknown
Summerville - Princeton - Southern Bay	Wells	1,000	~1,000	313	313	Unknown	Unknown	Unknown
Trinity, T.B.	Wells	355	~355	110	110	Unknown	Unknown	Unknown

Notes:

[1] S/D Ratio = supply/demand ratio in 2011.

There are, in total sixteen water supply systems in Subarea 3, of which seven are from surface water sources and nine are from wells. Two systems supply more than one community, they are:

(a) Summerville - Princeton - Southern Harbour, from wells

(b) Little Catalina - Catalina - Port Union - Melrose, from Main Brook, Port Union.

With the possible exception of Elliston, which has a supply/demand ratio ˜ 2.0, all surface water supply systems have ample yield to satisfy the forecast 2011 demand.

Well water supply is reported to be satisfactory from the following four communities, Duntara, Plate Cove West, Port Rexton and Trinity, but unsatisfactory at five other communities, Harcourt, Kings Cove, Musgravetown, Spillars Cove and Summerville - Princeton - Southern Bay. The typical problem is wells that dry up in the summertime. Salt water intrusion is reported from wells in Kings Cove and in Summerville - Princetown - Southern Bay systems, while contamination from road salt has affected one well in Trinity, T.B.

Alternative surface water sources are available near most of these communities, as below:

- from Northwest Pond for Musgravetown
- from Southern Bay River for Southern Bay
- from Seal Cove Pond for Princeton
- from Indian Arm Brook for Summerville
- from Kings Cove Brook for Kings Cove

No obvious surface water source is evident near Spillars Cove or Harcourt.

6.6.4 Subarea 4

Table 6.10 summarizes the existing supply - demand situation in Subarea 4.

In total, there are nine water supply systems in Subarea 4, of which three are supplied from surface sources and six from wells. With one exception, all systems serve single communities. The exception is Shoal Harbour - Clarenville where the separate water supply systems were recently interconnected (1988). At the present time both systems are operated separately, with the interconnection available to supply water to Clarenville in case of water shortage. Such a shortage was in fact experienced during the summer of 1987 which was exceptionally dry. Citizens and fish plant operators were asked to conserve water. This action was sufficient to maintain the supply on this occasion.

A study on the demographic impact of the Hibernia Project was carried out in 1985 by Community Resources Limited (14), one in a series of studies undertaken for the Hibernia environmental impact assessment. The purpose of the study was to estimate the demographic impact of the Hibernia Project on three target areas, Come-by-Chance, Argentia and St. John's and to advise on measures to mitigate adverse impacts. The main practical recommendations from this study were:

TABLE 6.10

SUPPLY-DEMAND SITUATION IN SUBAREA 4

SUBAREA 4

Community	Existing System	Population		Demand		Supply		S/D Ratio
		1986	2011	1986	2011	Basin Yield	Existing Capacity	
Clarenville	Lower Shoal Harbour & Shoal Harbour River	4,015	8,400 4,536	1,275	2,625 1,420	14,250	5,300	5.4 10.0
Goobies	Pond Brook	200	~200	63	63	1,300	400	20
Lower Lance Cove	Big Long Pond Brook	280	~280	88	88	700	700	8
Deep Bight	Wells	300	~300	94	94	Unknown	Unknown	
Elliotts Cove	Wells	~400	~400	125	125	Unknown	Unknown	
Hodges Cove	Wells	450	~450	140	140	Unknown	Unknown	
N.W. Brook	Wells	300	~300	94	94	Unknown	Unknown	
Petley	Wells	300	~300	94	94	Unknown	Unknown	
Sunnyside	Wells	635	~635	198	198	Unknown	Unknown	

Notes:

1 S/D Ratio - supply/demand ratio in 2011
2 Optimistic population growth forecast (3% p.a.)
3 Pessimistic population growth forecast (0.5% p.a.)

- implement local labour preference policies,
- provide training programs to assist local residents to acquire the needed skills,
- control hiring by means of hiring offices, so as to minimize influx of "speculative" labour,

  and

- provide construction camp accommodations for all non-resident workers.

In the demographic study, the impact areas were defined as the combined census divisions forming a 40 km radius around the target community. Although the study is now somewhat dated, due to changes in the proposed Hibernia Development program, it nonetheless provides useful insights into the factors contributing to demographic changes in the area. The main conclusion that can be drawn from this study is that the impact on the Come-by-Chance area (and by extension, the area from Come-by-Chance to Clarenville) will be transitory, since most economic activities would depend on construction and will disappear once construction is complete. Neither the demographic report, or the latest studies reviewed (15), holds out much hope for continuing use of the special construction facilities created in Come-by-Chance for the Hibernia Project. The inescapable conclusion is that the impact on permanent population growth in the study area will be minimal.

Nevertheless, one would anticipate that an accelerated growth of service, tourism and entertainment sectors, would result from the Hibernia Project mostly in the Clarenville - Shoal Harbour area. In the absence of better information, a 3% growth rate, somewhat better than the 1966-1986 rate, has been assumed for Clarenville. This rate predicts doubling of the Clarenville area population by the year 2011. If Hibernia does not go ahead a pessimistic growth rate of 0.5% is assumed, based on the mean growth rate between 1976-1986. Population growth estimates for other communities in Subarea 4 are for slow growth or no growth, based on extrapolation of past population trends.

Existing surface water supplies in Subarea 4 have ample basin yields for probable growth in population, with or without Hibernia.

Of six well systems, in Subarea 4, only the Petley system is reported to be satisfactory; four are reported to be unsatisfactory - Deep Bight, Hodges Cove, North West Brook and Sunnyside. The adequacy of the well supply at Elliotts Cove is unknown. Alternative surface water sources are available near each of these communities, as below:

from Deep Bight River	for Deep Bight
from Hodges Cove Brook or Bald Head Pond	for Hodges Cove
from North West Brook or Black Brook	for North West Brook
from Come By Chance River	for Sunnyside

6.7 LEAKAGE

No data were available on water losses; however, leakage losses may be significant. Tate and Lacelle (9) report system losses and unaccounted/non-billed demands to range from 3.5% to 44%. Assuming 50% of these amounts are for municipal uses, actual leakage losses could range from 2% to 20%, from well to poorly maintained systems. An estimate of water losses can be made by observing water consumption during early morning hours, say at 3:00 a.m., when most users would be asleep. At this time of night the domestic demand should be negligible and the remaining demand composed of leakage plus measurable industrial requirements. Regular reading of the 3:00 a.m. flow would allow trends to be observed and problems to be detected. This practice should be encouraged by Government.

6.8 OBSERVATIONS

Tables 6.11 and 6.12, (pages 6-34 and 6-35) summarize statistics on water supply systems in the study area (4). Several general observations can be drawn from these summaries to complement the observations noted above.

(a) Population Served at Present (1986)

By Surface Water System	=	37257	78%
By Council Wells	=	3688	8%
By Private Wells	=	6675	14%
Total Population in Study Area	=	47620	100%

(b) Adequacy of Supplies

Type of Supply	Quantity	Quality
Surface	28 (S) + 1 (U)	28 (S)
Wells (see note)	10 (S) + 13 (U)	21 (S) + 3 (U)
Totals	37 (S) + 14 (U)	49 (S) + 3 (U)

S = satisfactory, U = unsatisfactory

Note: Adequacy of supplies are unknown at four communities (quantity) and three communities (quality).

Surface supplies are generally reported to be satisfactory both with respect to quantity and quality, with most systems benefitting from storage provided in small lakes and ponds which permit a high degree of utilization of basin runoff. Well systems on the other hand, are often unsatisfactory with respect to quantity and about 60% are reported to run low or dry up during periods of drought. However, the quality of well water is generally satisfactory. Problems with well supply no doubt are due to:

(a) the generally poor yields and low storage capacity of bedrock aquifers where groundwater flow depends on secondary permeability features, or

(b) poor yield from shallow wells in relatively impervious surficial deposits of shallow depth and limited storage.

(c) <u>Metering</u>

Only 13 (44%) of 28 surface water systems had meters to measure water supply at source. Several municipalities meter flows to major customers, usually fish plants. Universal metering was not practised on any system.

Even on metered systems, record keeping is indifferent - hence water use statistics are of variable quality.

(d) Treatment

Most surface water systems employ some form of treatment, as follows:

Chlorination	= 26	pH adjustment	= 2
Filtration	= 2	Iodization	= 1
Clarification	= 1	No treatment	= 1

Several communities employ multiple treatment, filtration, clarification or pH adjustment in addition to chlorination. Most well supplies are untreated (23 out of 27 systems surveyed).

(f) Investment in Water and Sewage System

Based on information supplied by the Department of Municipal Affairs, capital investment in water and water and sewage systems in the study area amounts to about $55,000,000 (since 1965). The replacement value of this investment in 1988 dollars would be about $90,000,000.

(g) Operating and Maintenance Costs

Order of magnitude operating costs for water supply and sewage disposal are:

System	Annual Operation & Maintenance per capita
Water Distribution	$20.00
Water Treatment	$13.00
Waste Water Collection	$9.00

[Source, Reference 12, updated to 1988]

Based on the above values the cost of municipal water is estimated to be in the range of 60-80 cents per m^3. These costs are comparable to values assigned to municipal water by Muller (17) and Tate (18).

(h) Jurisdiction

Responsibility for management of water supply systems is shared by a large number of very small municipal and local service district authorities. Responsibility is thus very fragmented and many opportunities for rational development are missed since each authority tends to go "its own way".

6.9 CONCLUDING COMMENTS

The following broad conclusions can be drawn, about the supply-demand situation in the study area:

(a) The area is well supplied with water for the size of population and types of withdrawal demands (municipal, fish plant and agriculture).

(b) Surface water sources appear more dependable than groundwater sources. Most areas with inadequate water supply from wells have surface water sources within easy reach.

(c) Population growth will continue to be slow, at an estimated average rate of about 0.6% per annum,

(d) Rate of increase in water demand will be a function of population growth as there are no indications of major industrial growth. Much of this demand will probably be generated by conversion from marginal well based systems to surface sources of supply.

(e) There is potential for localized pollution problems from agricultural, fish plant and municipal wastes, discharged into rivers or harbours. Government should monitor future developments to avoid such problems.

(f) Freshwater use in fish plants is high and there are opportunities for conservation and/or substitution of seawater.

(g) The present system of flat rate charges to domestic consumers may encourage wasteful practices. Government should review the pros and cons of charging for water use on the basis of consumption.

TABLE 6-11

SURFACE WATER SUPPLIES - STATISTICAL SUMMARY

Community	Status	Population Served	Basin Yield l/min	Average Demand l/min	System Capacity l/min	Treatment	Metered at Source	Capital Investment to Date
Badgers Quay, etc.	M	2797	9400	1360	3200	Cl	Y	$2,920,000 (W+S)
Benton	LSD	200	335	63	225	Cl	N	$ 291,000 (W)
Bonavista	M	2600	7500	440	3000	Cl	N	-
Centreville & Wareham	M	1089	30000	380	2200	Cl	Y	$1,178,000 (W+S)
Clarenville	M	2967	5250	950	2500	Cl, Clar	Y	$6,680,000 (W+S)
Deadman's Cove	LSD	250	28000	78	225	Cl	Y	-
Elliston	M	564	388	175	760	Cl	Y	-
Gambo	M	2723	3000	850	900	Cl	N	$6,180,000 (W+S)
Gander	M	10000	22.1	4735	15800	Cl	Y	$5,935,000 (W+S)
Gander Bay S.	LSD	250	11000	75	100	Cl	Y	$ 60,000 (W)
Georges Brook	LSD	450	3000	140	-	Cl	N	$ 37,000 (W)
Glovertown	M	2184	10000	685	3600	Cl, Filt	N	$3,610,000 (W+S)
Goobies	LSD	200	1300	60	400	Cl	N	$ 36,000 (W)
Greenspond	M	460	600	144	900	None	N	587,000 (W)
Happy Adventure	M	354	1600	118	160	Cl	N	$2,142,000 (W+S)
Hare Bay & Dover	M	1436	2300	630	790	Cl	N	$2,030,000 (W+S)
Indian Bay	M	200	36000	90	190	Cl	N	$ 261,000 (W+S)
Keels	M	115	900	36	225	Cl	N	-
Lower Lance Cove	LSD	280	700	88	-	Cl	N	$ 38,000 (W)
Lumsden	M	636	10000	107	365	Cl, Filt	Y	$1,045,000 (W+S)
Musgrave Harbour	M	1527	6200	617	2500	Cl	Y	$2,818,000 (W+S)
Newmans Cove	LSD	200	300	160	400	Cl	N	$ 124,000 (W)
Newtown	M	529	2600	139	400	Cl, pH	Y	$ 113,000 (W)
Plate Cove East	M	173	4300	54	900	Cl	N	-
Port Union	M	2995	30000	950	20000	Cl	Y	$5,376,000 (W+S)
Port Blandford	M	729	44200	225	1580	Cl	Y	$1,302,000 (W+S)
Sandy Cove	M	193	190	60	155	Cl	Y	$ 115,000 (W)
Shoal Harbour	M	1049	9000	325	2800	Cl	Y	$2,832,000 (W)
Trinity, B.B.	M	357	7200	190	-	Cl	N	$2,920,000 (W+S)
Totals	M = 22 LSD = 7	37507				Cl = 26 Filt = 2 Clar = 1 pH = 1 No treat. =1	Y = 12 N = 15	$44,397,000 (W+S) $ 4,233,000 (W)

Key:
- M - municipality
- LSD - local service district
- Cl - chlorination
- Filt - filtration
- Clar - clarification
- pH - pH adjustment

TABLE 6-12

SUPPLIES FROM WELLS - STATISTICAL SUMMARY

Community	Status	Population Served	Yield	Bacteriological Quality	Capital Investment to Date
Burnside-St. Chads	LSD	-	U	S	$300 (W)
Cape Freels North	LSD	-	U	S	$17,500 (W)
Carmanville**	M	987	U	S	$1,534,000 (W+S)
Charlottetown	LSD	-	S	S	$25,000 (W)
Deep Bight	LSD	-	U	U	$21,200 (W)
Duntara	M	-	S	S	-
Eastport**	M	609	S	1-S * 1-U (salt)	$1,626,400 (W+S)
Elliott's Cove	LSD	-	-	-	$22,900 (W)
Gander Bay North	LSD	-	U	S	-
Harcourt	LSD	-	U	-	$14,500 (W)
Hodges Cove	LSD	-	U	S	Nil
Kings Cove**	M	300	U	S	-
Main Point/ Davidville	LSD	-	U	S	$12,200 (W)
Musgravetown	M	-	-	S	-
Noggin Cove	LSD	-	U	S	Nil
North West Brook	LSD	300	U	S	$16,100 (W)
Petley	LSD	300	S	S	$64,700 (W)
Plate Cove West	M	307	S	S	-
Port Rexton	M	468	S	-	-
Salvage**	M	80	S	1-S 1-U (salt)	$ 500,000 (W)
Sandringham	M	282	S	S	$ 247,000 (W)
Spillars Cove	LSD	-	U	S	Nil
Summerville/ Princeton/ Southern Bay	LSD	-	-	U	$37,200 (W)
Sunnyside	M	-	U	S	-
Terra Nova	M	-	S	S	-
Traytown	M	-	-	S	$356,500 (W)
Trinity - T.B.	M	55	S	U (road salt)	-
Total = 27	M = 13 LSD=14	3688	S = 10 U = 13 Unknown = 4	S = 21 U = 3 Unknown = 3	$3,160,400 (W+S) $1,335,100 (W)

Key:
- M = municipality
- LSD = local service district
- S = satisfactory
- U = unsatisfactory
- \- = data not available
- * = two wells
- ** = water treatment by chlorination

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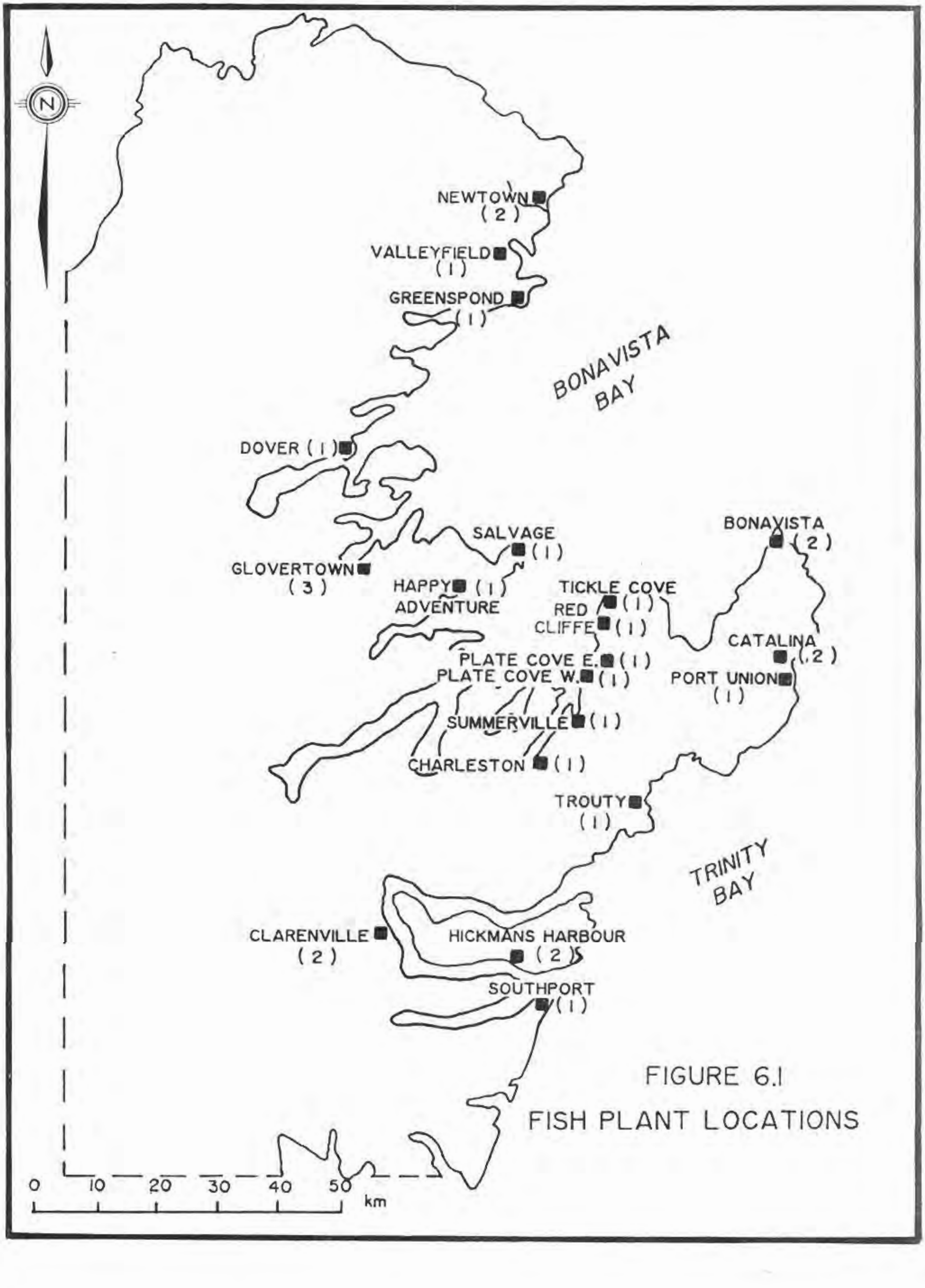
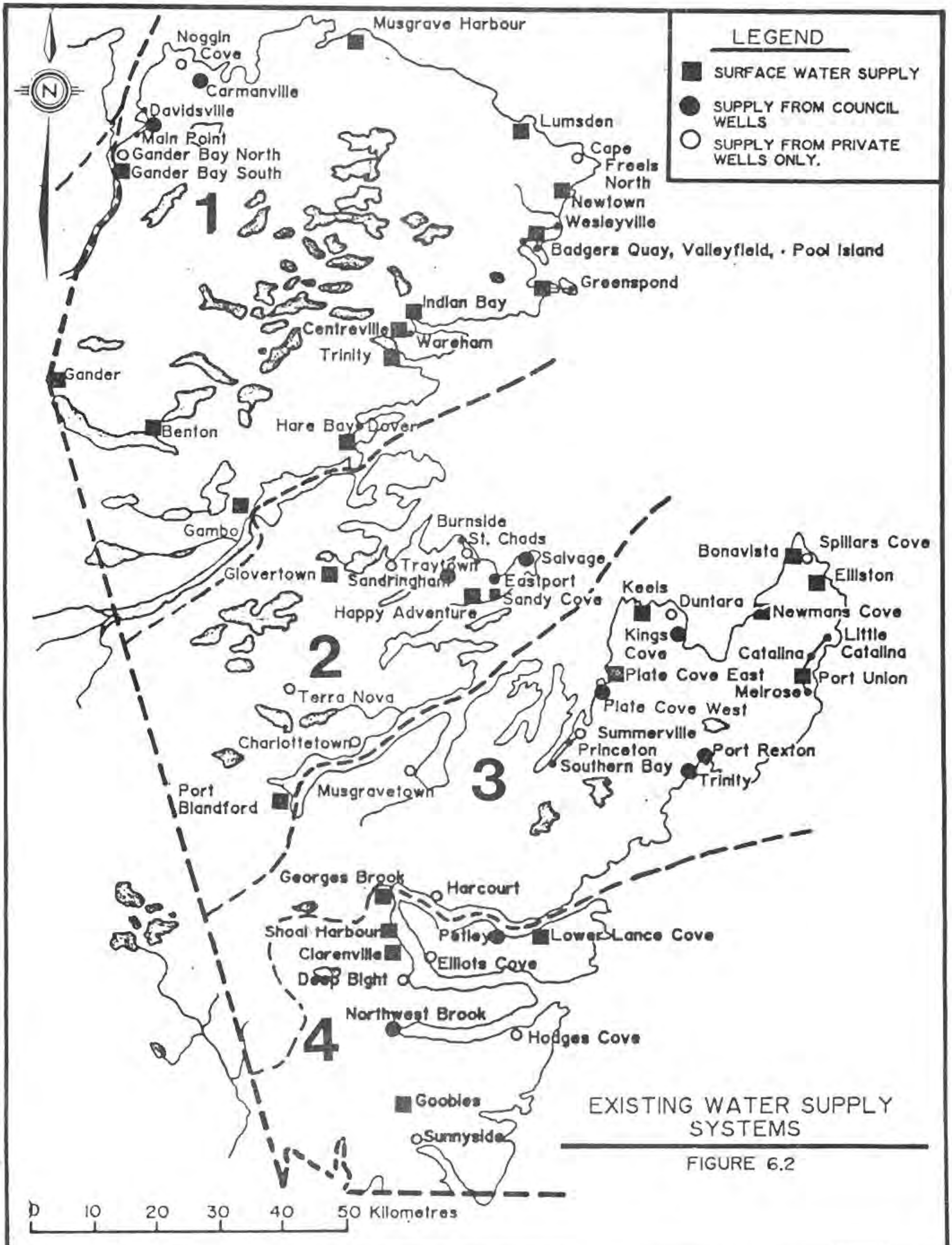


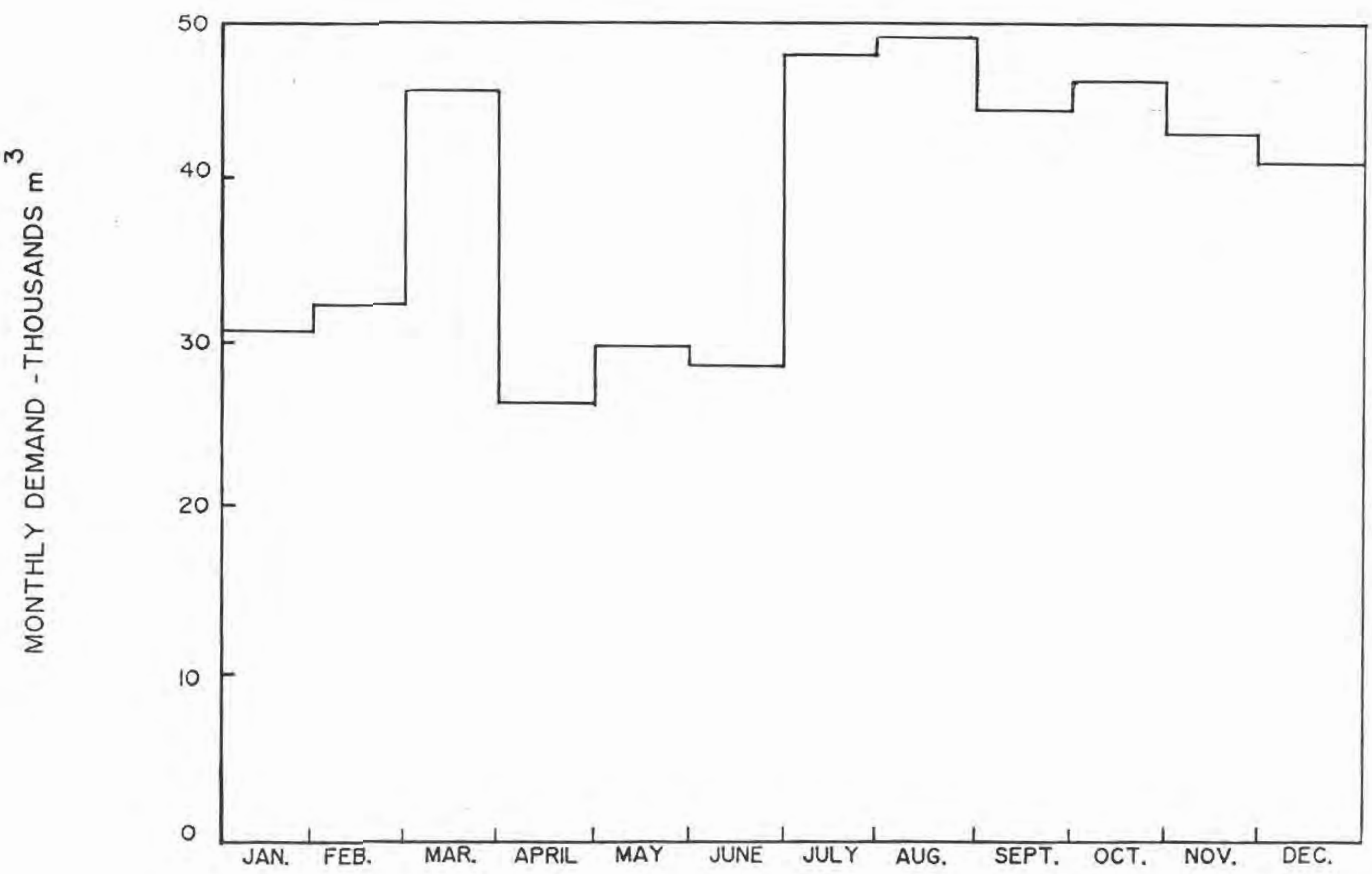
FIGURE 6.1

FISH PLANT LOCATIONS



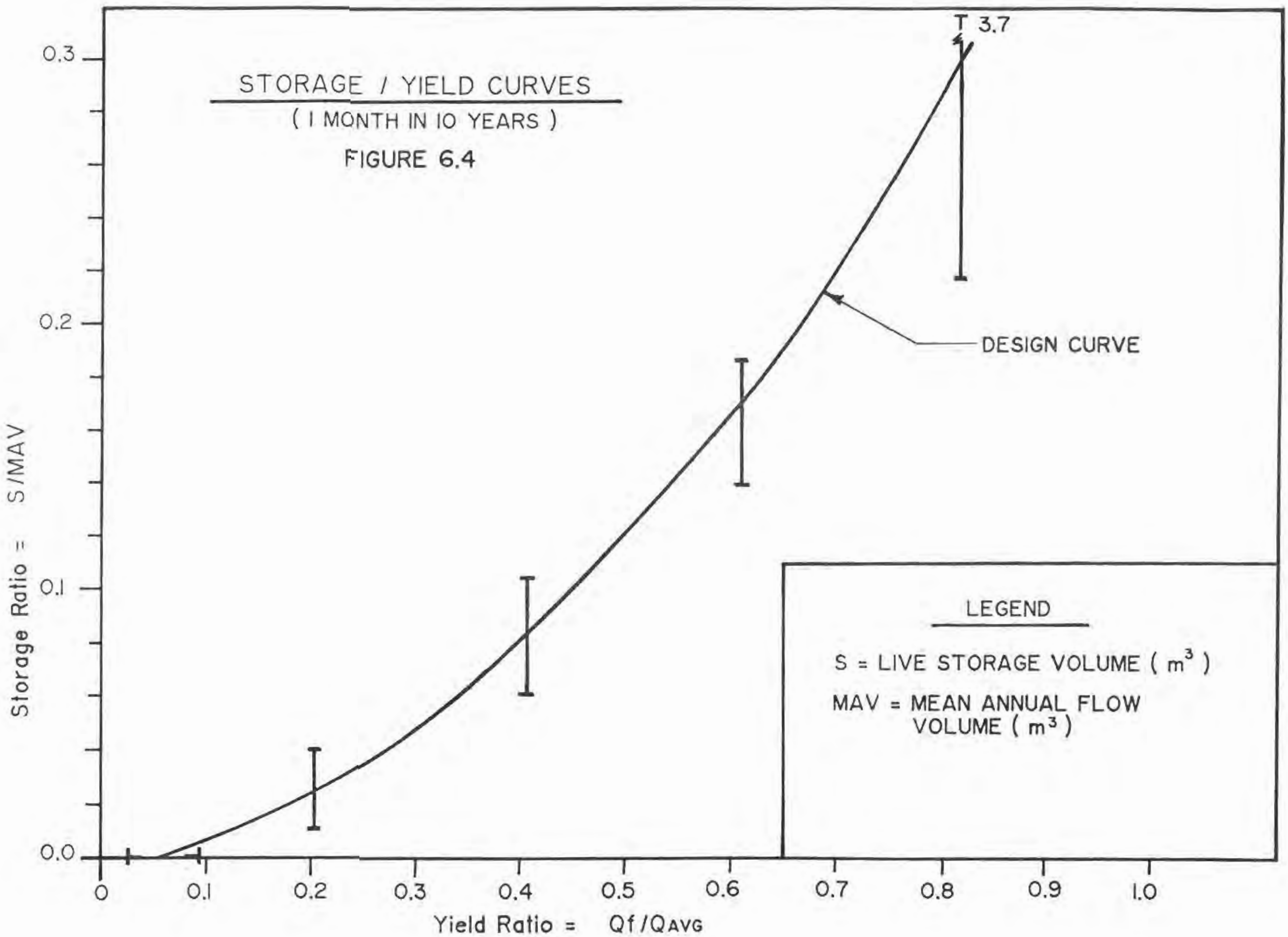
EXISTING WATER SUPPLY SYSTEMS

FIGURE 6.2



CLARENVILLE DEMAND PATTERN BY MONTH IN 1983

FIGURE 6.3


STORAGE / YIELD CURVES
(1 MONTH IN 10 YEARS)
FIGURE 6.4
3.7
DESIGN CURVE
LEGEND
S = LIVE STORAGE VOLUME (m³)
MAV = MEAN ANNUAL FLOW VOLUME (m³)
0.0
0.1
0.2
0.3
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Storage Ratio = S/MAV
Yield Ratio = Qf/QAVG

CHAPTER SEVEN

COMPREHENSIVE ASSESSMENT OF WATER RESOURCES

7.1 INTRODUCTION

In the preceding chapters the climate, hydrology, instream use and withdrawal demands have been studied. It is the purpose of this chapter to bring these diverse studies together and to produce a comprehensive assessment of the regional water resources picture in a manner that will contribute to effective water resource management.

7.2 APPROACH

This comprehensive assessment is based upon an examination, by subarea, of the present water use situation and forecast requirements over a twenty-five year planning period from 1987 to the year 2011. Existing water use conflicts and problems are noted and potential problems identified. For the most part, the comprehensive assessment in each area relies upon a tabular comparison of the main findings from the previous chapters. Some pertinent information on special issues not covered in those chapters is also included.

The four subareas used are the same that were applied in the review of municipal water withdrawal demand - Section 6.6. This choice of subareas (Figure 7.1) recognizes the importance of the settlement pattern in the study area in which headland areas were favoured over the bays. [Sub-dividing the study area on this basis was deemed to provide a more appropriate context for assessing regional water resources than sub-division by river basin that is more usual in water resource studies].

The following factors are examined, for each subarea, in Tables 7.1 to 7.4.

- withdrawal uses
- instream uses
- conflicts and/or problems
- priority concerns

Some general concerns which apply to all sub-areas are discussed separately.

7.2.1 Withdrawal Uses

In assessing future withdrawal demands, special attention is paid to peninsular areas since these areas have simultaneously the highest densities of population together with limited local water resource bases due to narrow peninsular land forms. Another concern is the possibility of "shortages in the midst of plenty" where suitable surface water sources may not be available within an economic radius of a small community. Based on a review of water supply designs this economic radius is estimated to be about 3 to 4 km. With the exception of the above points, the summaries of municipal and fish plant water use in Tables 7.1 to 7.4 are based upon the findings in Chapter 6.

Withdrawal demands for agriculture are very small and are likely to remain so in the foreseeable future and are therefore omitted from the comparison.

7.2.2 Instream Uses

Instream uses include:

- hydropower
- recreation
- sport fishing

The summaries on instream uses given in Tables 7.1 to 7.4 are based on the findings of Chapter 5.

7.2.3 Conflicts/Problems

Existing and potential problems and water use conflicts are identified from analysis of the comprehensive listing of water uses in Tables 7.1 to 7.4.

7.2.4 Priority Concerns

Priority issues related to conflicting water uses are also identified from analysis of water use listings in Tables 7.1 to 7.4.

7.3 ASSESSMENT BY SUBAREA

Comprehensive assessments of all water uses are done in tabular format for each of the subareas, as below:

Subarea 1 - in Table 7-1
Subarea 2 - in Table 7-2
Subarea 3 - in Table 7-3
Subarea 4 - in Table 7-4

These tables are included on the following pages.

Table 7-1

SUBAREA 1 - COMPREHENSIVE ASSESSMENT

<table>
<tr><th>FACTOR</th><th>REMARKS</th></tr>
<tr><td>WITHDRAWAL USES</td><td><u>Surface Supplies:</u>

No. = 15
Population = 23715 (1986), 26802 (2011)
Demand (l/min) = 9498 (1986), 11040 (2011)

<u>Present Situation:</u>

Greenspond is the only problem system, others are satisfactory. Basin yields are ample to meet 2011 demands.

<u>Well Supplies:</u>

No. = 4
Population = 2365 (1986), 2642 (2011)
Demand (l/min) = unknown (1986), 823 (2011)

<u>Present Situation:</u>
Supply quantity inadequate on all systems.

<u>Future Prospects:</u>

Consider replacing inadequate well supplies with nearby surface sources. Surface sources are available within an economic radius from all communities.</td></tr>
<tr><td>INSTREAM USES

- Hydro

- Recreation

- Sport Fishery</td><td>

<u>Existing plants:</u> none

<u>Future Prospects:</u> none

"Flat water" canoeing - Ragged Harbour River, Deadman's Brook, Indian Bay Brook and Traverse Brook Basins.
"White water" canoeing - N.W. Gander and Gander Rivers

<u>Scheduled Salmon Rivers:</u>

Gander including N.W. and S.W. Gander
Ragged Harbour River
Anchor Brook
Deadman's Brook
Northwest Brook (Indian Bay)
Indian Bay River
N.W. Brook (Trinity, B.B.)
Traverse Brook
Middle Brook
Gambo River and tributaries

<u>Fishery Enhancement Prospects:</u>

Indian Bay Brook, Traverse Brook & Mint Brook (Gambo River basin)</td></tr>
<tr><td>CONFLICTS/PROBLEMS</td><td><u>Present Situation:</u>

1. Localized pollution downstream of Glenwood/Appleton on Gander River.
2. Occasional flooding in Glenwood/Appleton (1).
3. Unreliable surface supply to Greenspond.

<u>Future Prospects:</u>

1. Development of surface sources to replace or supplement unsatisfactory well supplies could conflict with sport fishery and recreational uses.
2. Fishery enhancement developments could conflict with recreational uses.</td></tr>
<tr><td>PRIORITY CONCERNS</td><td>1. Implementation of zoning plans in Glenwood/Appleton to minimize future flood damages.
2. Resolve operating problems at Glenwood and Appleton sewage treatment plants.
3. Upgrading of unsatisfactory municipal water supply system.</td></tr>
</table>

Table 7-2

SUBAREA 2 - COMPREHENSIVE ASSESSMENT

FACTOR	REMARKS
WITHDRAWAL USES - Eastport Peninsula [See Figure 7.2]	Supply Systems: = 5 (surface = 2, wells = 3) Population = 1870 (1986), 2492 (2011) Demand (l/min) = 585 (1986), 778 (2011) Developable Yield: Surface = 5900 l/min. Wells = 500 l/min Present Situation: Surface water supplies are satisfactory. Ground water supplies are unreliable, except in Sandringham. Future Prospects: Development of surface sources to replace or supplement inadequate well supplies and available within an economic radius of all communities.
- Elsewhere	Supply Systems: = 4 (surface = 2, wells = 2) Population = 3695 (1986), 3779 (2011) Demand (l/min) = 1158 (1986), 1181 (2011) Present Situation: All supplies satisfactory. Future Prospects: Charlottetown supply to be upgraded to improve fire fighting capacity.
INSTREAM USES - Hydro	Existing Plants: none Potential Developments: - Terra Nova River = 144 MW - Maccles Brook = 8.1 MW - Northwest River (Port Blandford) = 3.8 MW
- Recreation	Terra Nova National Park located in Sub-Area, is a major attraction. Flat water canoeing in Terra Nova Park White water canoeing on Terra Nova and Northwest River (Port Blandford)
- Sport Fishery	Scheduled Salmon Rivers: Northwest Brook (Alexander Bay) Terra Nova River and tributary streams downstream from Mollyquajeck Falls, Northwest River (Port Blandford) Fishery Enhancement Prospects: Terra Nova River and tributary streams
CONFLICTS/PROBLEMS	Present Situation: 1. Present surface supplies are ample. 2. No conflicts exist between various uses. 3. Occasional flooding occurs in Glovertown (2). Future Prospects: 1. Hydro development could conflict with sport fishery and recreational uses. 2. There is potential for conflict between recreational use and municipal uses, especially on the Eastport Peninsula.
PRIORITY CONCERNS	1. Implementation of zoning plan to minimize flood damage in Glovertown. 2. Development of master plan for water use on Eastport Peninsula.

Table 7-3

SUBAREA 3 - COMPREHENSIVE ASSESSMENT

FACTOR	REMARKS
WITHDRAWAL USES	
Bonavista Peninsula [See Figure 7.3]	Supply Systems: = 7 (surface = 4, wells = 3) Population = 6060 (1986), 6740 (2011) Demand (l/min) = 2554 (1986), 2778 (2011) Developable Basin Yield = 19000 l/min Present Situation: Surface water sources are satisfactory. Well supply is satisfactory at Duntara but unsatisfactory at Kings Cove and Spillars Cove. Future Prospects: Development of surface sources to supplement or replace inadequate well supplies Surface sources are available within an economic radius of all communities.
Elsewhere	Supply Systems: = 9 (surface = 3, wells = 6) Population = 7080 (1986), 7676 (2011) Demand (l/min) = 3370 (1986), 3541 (2011) Present Situation: Surface water supply systems are satisfactory. Supplies from wells are satisfactory in three communities and unsatisfactory in three others. Future Prospects: Development of surface supplies to supplement or replace inadequate well supplies.
INSTREAM USES	
- Hydro	Existing Plants: - Lockston = 3.0 MW - Port Union = 0.5 MW Potential Developments: - Southwest River (Port Blandford) = 6.0 MW
- Recreation	No special opportunities
- Sport Fishery	Scheduled Salmon Rivers: Southwest Brook (Port Blandford) Salmon Brook (Port Blandford) Salmon Cove River (T.B.) Trouty River Popes Harbour River Fishery Enhancement Prospects: No special opportunities were identified.
CONFLICTS/PROBLEMS	Present Situation: There are no conflicts between various users. Future Prospects: 1. Hydro development on Southwest River could conflict with sport fishery. 2. Municipal development and recreational uses could conflict in some areas.
PRIORITY CONCERNS	Development of master plan for water use on Bonavista Peninsula.

Table 7-4

SUBAREA 4 - COMPREHENSIVE ASSESSMENT

FACTOR	REMARKS
WITHDRAWAL USES	
- Random Island [See Figure 7.4] Gooseberry Cove Southport Peninsula	Random Island: Population (est'd) = 1600 (1986), 1600 (2011) Demand (l/min) = 507 (1986), 507 (2011) [includes Hickmans Harbour, Aspey Brook & Snooks Harbour] Developable Basin Yield (l/min) = 6760 Gooseberry Cove - Southport: Population (est'd) = 300 (1986), 300 (2011) Demand (l/min) = 95 (1986), 95 (2011) Basin Yield (l/min) = 560 Present Situation: Ample supply available in both areas.
- Elsewhere	Supply Systems: Population = 5900 (1986), 6421 to 10285 (2011) Demand (l/min) = 1864 (1986), 2009 to 3,214 (2011) Basin Yield (l/min) = 15,500 Present Situation: Surface supplies are satisfactory. Well supplies are unsatisfactory but alternative surface sources are available within economic radii.
INSTREAM USES	
- Hydro	Existing plants: none Potential Developments: - Pipers Hole River = 24 MW - Black River = 2.6 MW
- Recreation	"Flat water" canoeing in head water ponds of Pipers Hole River.
- Sport Fishery	Scheduled Salmon Rivers: Shoal Harbour River Deer Harbour River (Random Island) Come-by-Chance River North Harbour River Pipers Hole River
CONFLICTS/PROBLEMS	Present Situation: No conflicts. Future Prospects: 1. Potential conflict between hydro and sport fishery on Pipers Hole River.
PRIORITY CONCERNS	1. Upgrading of unsatisfactory well supply systems.

7.4 GENERAL CONCERNS

General concerns which affect each sub-area equally include:

- the threat of acidification of water bodies due to acid rain,
- the risk of localized pollution from careless discharge of municipal, fish plant or agricultural wastes into lakes and rivers,
- harbour pollution from discharge of municipal sewage via poorly sited and inadequately designed ocean outfalls.

[The above points were discussed in Chapter 4].

Responsibility for development and operation of municipal water supply systems is shared by a large number of small municipal agencies, each looking out for its own particular interests. This situation tends to encourage sub-optimal development and duplication of services, and ultimately higher costs of service (3). A more rational approach would be to develop and operate water supply systems on a regional basis to serve several interconnected communities, wherever it is economical to do so.

7.5 CONCLUDING OBSERVATIONS

Several general observations can be made about the water resources of the study area.

(a) The study area is generously blessed with abundant sources of unpolluted water in lakes and rivers throughout the region.

(b) The most important withdrawal uses are for domestic consumption or fish plant use.

(c) Municipal supplies from rivers or lakes were generally found to be adequate to meet present and future demands. Municipal supplies from wells, on the other hand are often unsatisfactory because many wells dry up during periods of dry weather. However, alternative surface sources (rivers or lakes) are available in the vicinity of all communities now relying on wells.

(d) Important instream uses include hydro development, sport fishery and recreational uses.

(f) At present there are few conflicts between different water users and no problems requiring urgent attention.

(g) Future concerns for water management include:
   - increased potential for conflicts between recreational, sport fishing uses and municipal and hydro projects,
   - localized pollution problems from discharge of farming, municipal sewage or fish plant waste waters into freshwater bodies or seawater harbours,
   - degradation of water quality due to acid rain contamination.

(e) Responsibility for development of municipal water supplies is shared by a large number of small municipalities and local distribution districts, each looking out for its own particular interests. A more rational approach would be to examine water requirements on a regional basis and develop systems to serve several interconnected communities where-ever it is economical to do so.

(f) The greatest risks of conflicts between various water uses are on the Eastport and Bonavista peninsulas, where significant percentages of local water resources are already exploited. Accordingly, it is suggested that master plans for water use be prepared in these areas.

REFERENCES FOR CHAPTER 7

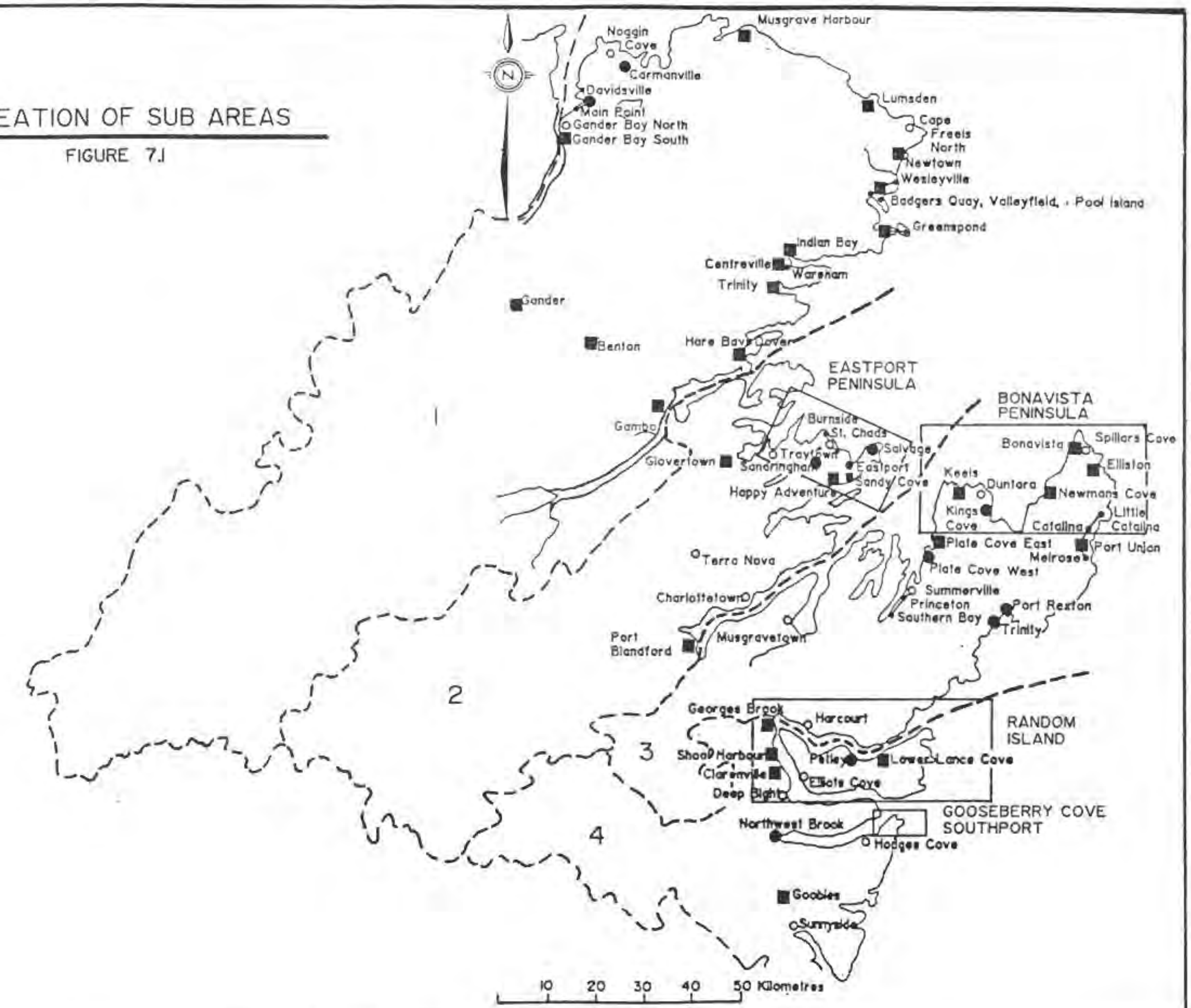
(1) ShawMont Newfoundland Limited (1989) "Glenwood/Appleton Flood Study Report" under the Canada-Newfoundland Flood Damage Reduction Program, Department of Environment and Lands and Environment Canada, St. John's.

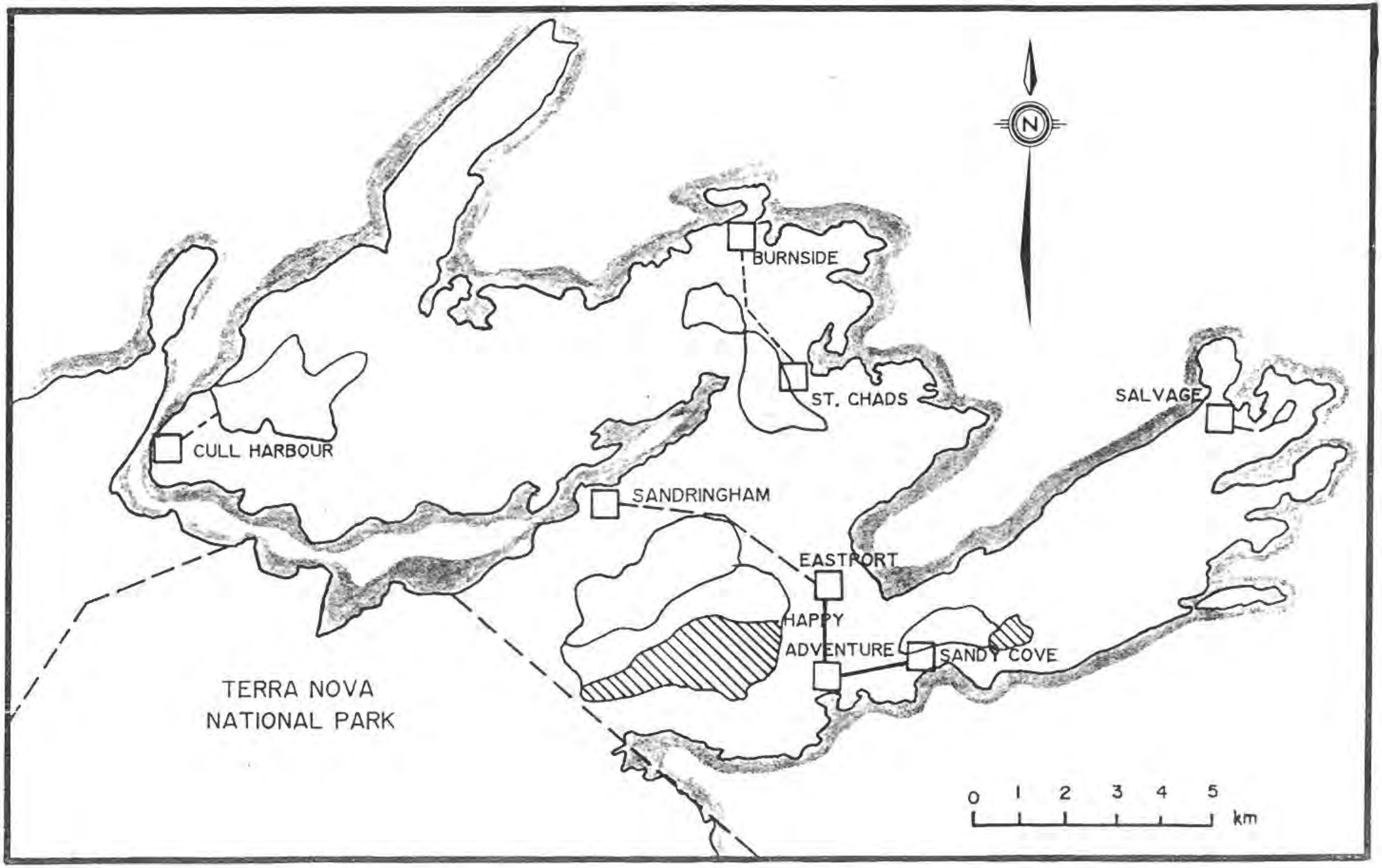
(2) ShawMont Newfoundland Limited (1989) "Glovertown Flood Study Report" under the Canada-Newfoundland Flood Damage Reduction Program, Department of Environment and Lands and Environment Canada, St. John's.

(3) Whalen, H.J. [Chairman], (1974) "Royal Commission on Municipal Government in Newfoundland and Labrador" for the Government of Newfoundland and Labrador.

DELINEATION OF SUB AREAS

FIGURE 7.1





EXISTING SUPPLY

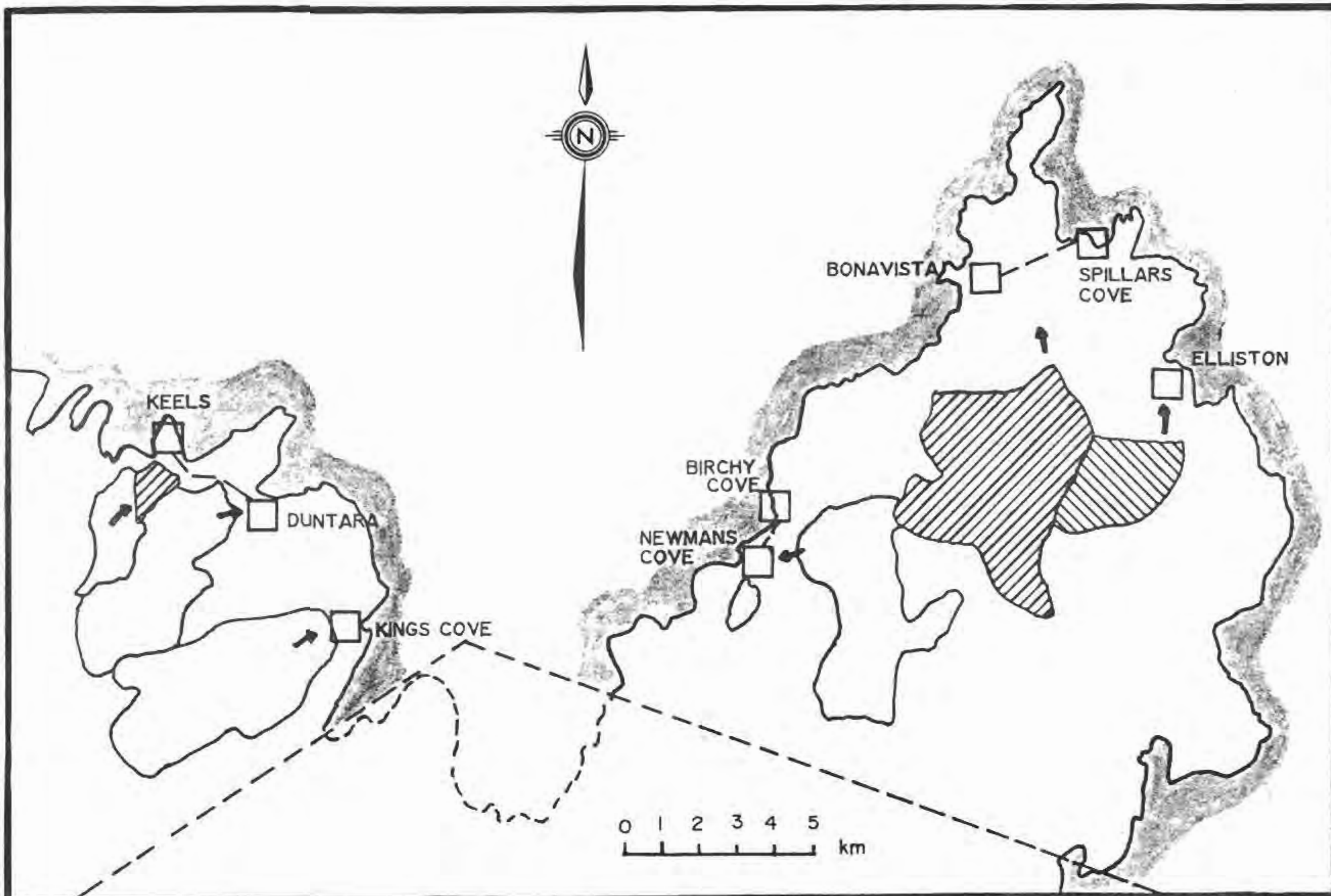
DEVELOPABLE SOURCE

EXISTING INTERCONNECTIONS

PROPOSED FURTURE INTERCONNECTIONS

EASTPORT PENINSULA WATER RESOURCES BASE

FIGURE 7.2



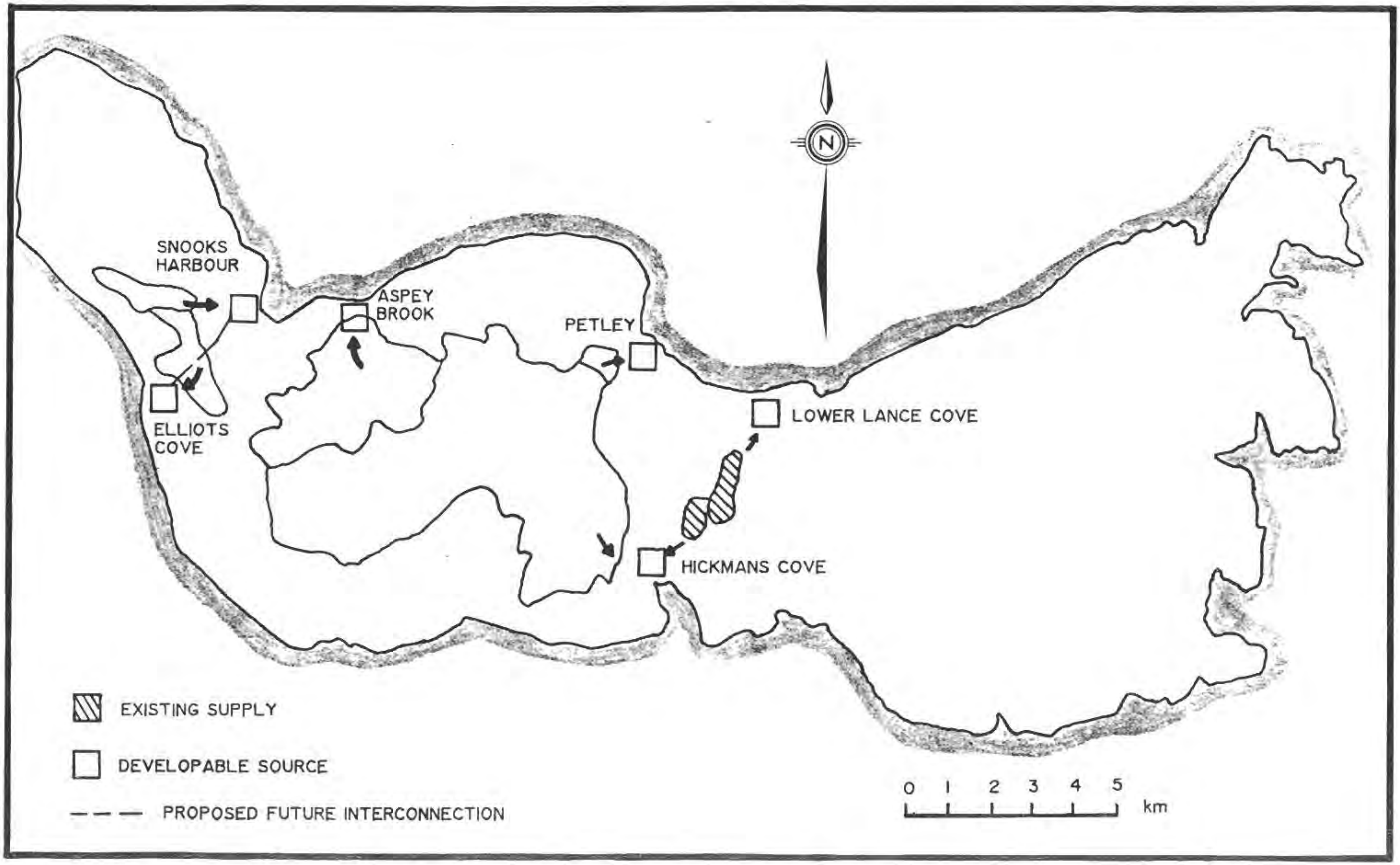
BONAVISTA PENINSULA WATER RESOURCES BASE

FIGURE 7.3

EXISTING SUPPLY

DEVELOPABLE SOURCE

PROPOSED FURTURE INTERCONNECTIONS



RANDOM ISLAND WATER RESOURCE BASE

FIGURE 7.4

CHAPTER EIGHT

CONCLUSIONS AND RECOMMENDATIONS

8.1 GENERAL CONCLUSIONS

This study of the water resources of the Bonavista Bay area has confirmed that the region has abundant water resources, which are ample for the forecasted needs of the population well into the next century. The quality of lake, river and ground water is good and adverse impacts from human activities in the study area are minimal, although the effects of acid rain are of concern. The main water uses in the area are: withdrawal uses - water for domestic and fish plant use, and instream uses - hydro power, sport fishery and recreation. At the present time, these various uses are widely dispersed across the region and there are no conflicts between competing uses.

Water use for recreation and the sport fishery appears to be of relatively greater importance in this mainly rural region than in an urban region. This conclusion is based on its high value of the tourism/recreation industry and the potential for economic growth and employment creation.

Municipal and fish plant supplies from surface sources (lakes and rivers) were found to be generally satisfactory in terms of quality and quantity. Municipal supplies from wells, on the other hand, are often insufficient and many communities report wells that "dry-up" during dry periods. In general, the region is not well endowed with groundwater resources, and wells provide at best a marginal supply of water.

Jurisdiction for planning, management and operation of water supply systems is in the hands of numerous small municipal and local service district authorities, with the result that responsibilities are extremely fragmented. It is believed that significant economies could be achieved if water supply schemes were developed and managed on a more coordinated regional basis.

The main future concerns are:

- increasing acidification due to acid rain,
- localized pollution problems in lakes, rivers or harbours due to disposal of agricultural, municipal or fish plant wastes,
- greater potential for conflicts as demands on water resources increase.

In preparing a strategy for water resources management, the above factors should be kept in mind.

8.2 RECOMMENDATIONS

Recommendations for future water resource management fall into three general categories:

- advice regarding data needs and further studies to give an improved understanding of the water resources in the region,
- recommendations about existing problems,

- recommendations regarding planning and management for future water resource uses in the region.

8.2.1 Data Requirements

Streamflow data provide the most satisfactory basis for evaluation of a water source (see Section 2). Existing streamflow gauges provide adequate coverage for drainage areas greater than 40 km^2. However, no data are available for very small drainage areas, from 5 to 10 km^2 in extent, which are often developed for municipal water supply.

Water use statistics from both municipal and fish plant operations are also scarce. The following recommendations are proposed to deal with these requirements:

(i) All water supply systems should be provided with meters at source.

(iii) Water supply plant operators should be encouraged to maintain complete records on system water use, including spill and return flows where practical.

An alternative approach, in the event the above suggestions are impractical to implement, would be for the Department of Environment and Lands to establish streamflow gauges on a minimum of three small streams, with drainage areas between 5 to 10 km^2.

(iii) Meters should be installed and complete records maintained of water use by all major commercial and industrial users.

(iv) Methods for direct estimation of evapotranspiration in Newfoundland are still unavailable. While this question is of mainly scientific interest, considerable insights into local climatic factors would be obtained if this problem was thoroughly studied. Government should encourage research into this problem.

(v) Glaciofluvial aquifers show promise as reliable sources of good quality water for municipal supply. It is suggested that the groundwater potential of selected glaciofluvial deposits near water short communities be investigated, preferably in collaboration with the Surface Geology Division of the Department of Mines and Energy as an addition to its ongoing program of surficial geology mapping.

Given the generally low potential of bedrock aquifers in the study area, it is recommended that further investigation of the yield of bedrock aquifers in this area be assigned a low priority.

(vi) Data from the Bonavista Region alone were minimal for stochastic analysis. However, if stochastic analyses were carried out on an Island wide basis using all available data more useful results may be obtainable, witness the recent Regional Flood Frequency Analysis *Study, RFFA (1). Accordingly, it is recommended that* Island wide stochastic-hydrology analyses be undertaken, to update both the ADB study (2) and the RFFA. These analyses could draw on recently collected hydrologic data and on the mass of physiographic data collected at great expense during the ADB water resources study in the 1960s and now in the archives of Environment Canada Inland Water Directorate - Ottawa. This study should be taken up following the conclusion of this present series of regional water resources studies.

(vii) Government should continue monitoring pH in streams and lakes so as to be aware of trends in water acidification.

8.2.2 Present Situation & Future Prospects

The study area and its water resource base is large compared to the population. Furthermore, the settlement pattern is rural and water requirements dispersed. As a result, water demands for a variety of uses are, at present, satisfied without conflicts.

Future prospects include:

- continuing development of surface water sources to provide reliable municipal water supplies and meet future population and industrial growth,
- potential hydro developments,
- recreational developments,
- withdrawal demands for agriculture,
- freshwater fisheries enhancement schemes.

These future developments will create greater competition for water uses and greater possibilities for conflict between different water users.

Future problems could include:

- localized pollution from release of agricultural, municipal or industrial wastes into lakes, rivers or harbours,
- loss or degradation of fish habitat due to stream diversions and/or reservoir operation for hydro or water supply developments,
- conflicts between hydro and/or municipal water supply developers and recreational and/or sport fishery users.

Many of these problems can be avoided or mitigated by careful design.

The greatest potential threat to the well-being of the water resources of the study area is windborne pollution in the forms of acid rain and toxic chemical deposition.

Dealing with these problems will require vigilance on the part of government, in the management of water resources in the study area. Accordingly the following recommendations are suggested:

(i) Government should carefully screen development proposals to ensure that appropriate measures are provided to protect water quality of lakes and rivers in the vicinity of the development.

(ii) Government should prepare master plans for water use in the Eastport and Bonavista peninsulas where risks of conflicts are greatest.

(iii) Government should require the maintenance of appropriate minimum flow levels in streams for maintenance of aquatic life in streams supporting significant fish populations.

(iv) Government should monitor water quality, as necessary, to ensure that developers comply with government regulation.

(v) Government should consider the development of design guidelines for ocean outfalls to replace inadequate guidelines currently in use.

(vi) Government should exercise whatever means are available to encourage Canadian and U.S.A. authorities to deal with acid rain at its source.

(vii) Government should continue its program of toxic chemical monitoring in order to establish baseline data and identify trends in contamination by such products. This program should be reviewed frequently and modified to take advantage of the latest findings of environmental toxicologists.

(viii) It is recommended that the list of parameters tested under the water quality program of the Department of Environment and Lands be extended to include all the parameters recommended in the Canadian Water Quality Guidelines for drinking water and freshwater aquatic life. This would involve testing for the following inorganic parameters:

- aluminum
- boron
- cyanide
- mercury
- selenium
- silver, and
- thallium

Testing for organic chemicals should be targeted on products likely to be employed in the area, typically - herbicides/pesticides used in forestry or agriculture.

8.2.3 Planning and Management

At present water supply systems in the study area are developed and operated in a patchwork style by a multitude of very small local government organizations. It is believed that this uncoordinated approach is wasteful. Accordingly, it is recommended that Government review the present mode of operation, and examine other options with the aim of improving the cost effectiveness of providing water supply and sewage collection services.

REFERENCE FOR CHAPTER 8

(1) Panu, U.S. and Smith, D.A. (1986)
"Users Guide: Regional Flood Frequency Analysis for the Island of Newfoundland"
for the Department of Environment (Nfld) and Environment Canada.

(2) Shawinigan Engineering and James F. MacLaren (1968)
"Water Resources Study of the Province of Newfoundland and Labrador"
for the Atlantic Development Board.

APPENDIX I

HYDROLOGY - BACKGROUND MATERIAL

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

I.1 REMARKS

Appendix I contains background material used in the hydrology study that formed the basis of Chapter 2.

It is envisaged that this compilation of background data will be useful for two purposes:

(i) to provide a record of the basis of the hydrologic analyses, and

(ii) to provide background data to facilitate interpretation and application of the findings of the study.

The tables and graphs which follow summarize the climatological and hydrological data from basins used in the hydrologic analyses, together with the results of several site-specific analyses. A complete listing of data compiled in this section is given in the Table of Contents of Appendix I.

I.2 TABLES

Table I.1

A.E.S. CLIMATOLOGICAL STATIONS

Station Name	Location	Elevation (m)
Bonavista	48 28 N 55 05 W	25
Carmanville		
Clarenville		
Come by Chance	47 48 N 54 01 W	27
Gambo		
Gander International Airport	48 57 N 54 34 W	151
Gander Bay South		
Goobies		
Lethbridge		
Musgrave Harbour		
Port Blandford		
Sunnyside	47 51 N 53 57 W	46
Swift Current		
Terra Nova National Park	48 33 N 53 58 W	46

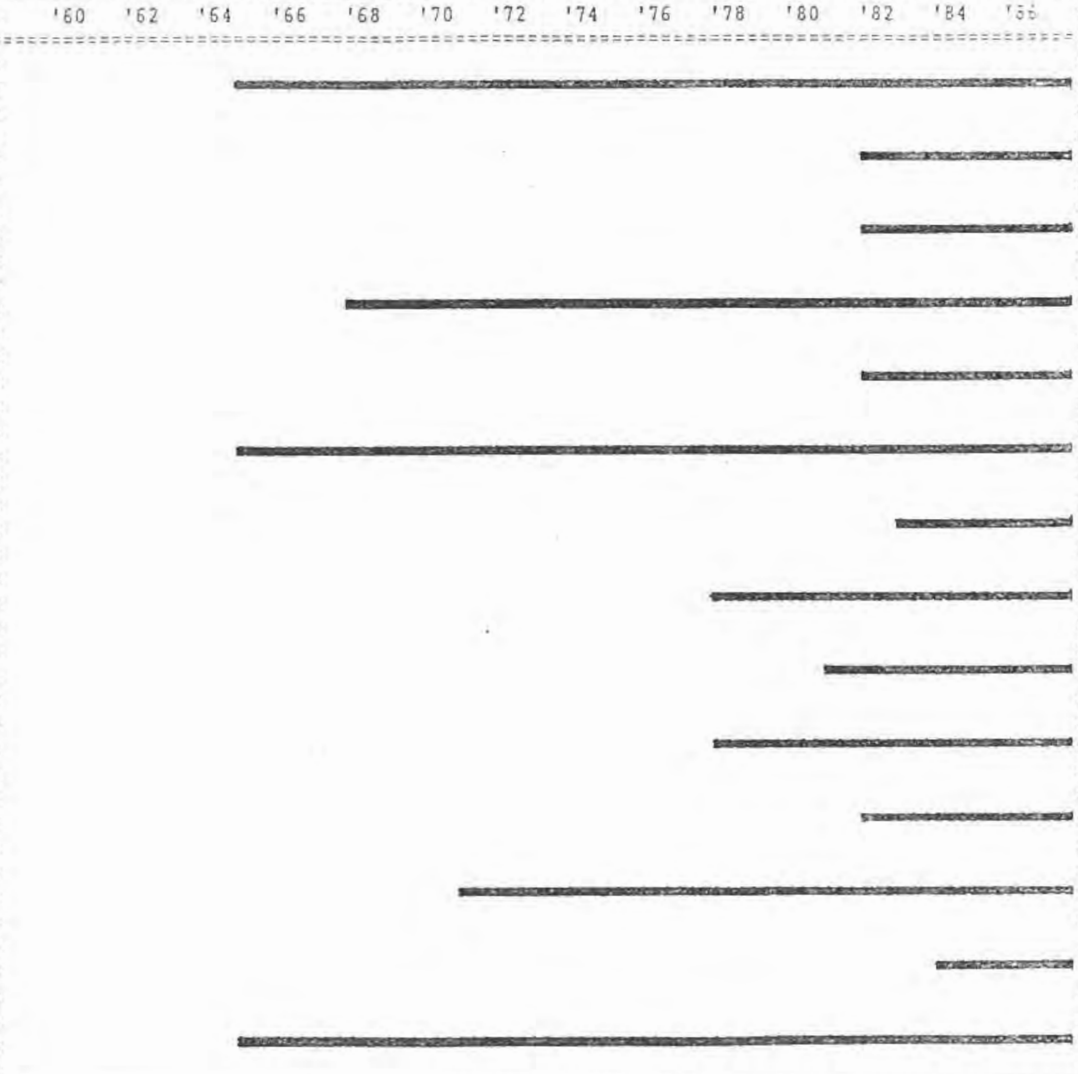


Table I.2

MONTHLY PRECIPITATION

Station: Bonavista
Latitude: 48 42 (dm) N
Longitude: 53 05 (dm) W
Elevation: 25 m

Year	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean	Total
1968	76.7	128.5	122.2	35.3	82.8	154.2	84.1	125.5	27.4	146.8	114.3	113.0	100.9	1210.8
1969	91.9	72.9	96.0	74.2	78.7	30.5	56.6	89.4	127.3	100.3	99.3	87.1	83.7	1004.2
1970	53.3	191.5	65.5	118.6	121.9	60.7	60.7	131.8	82.6	63.0	138.2	123.2	100.9	1211.0
1971	100.3	39.4	93.7	117.6	25.7	70.4	82.8	101.1	76.7	61.5	178.8	90.9	86.6	1038.9
1972	35.6	72.4	65.3	75.2	98.6	65.5	25.9	85.1	36.1	115.6	124.2	109.7	75.8	909.2
1973	70.4	114.6	58.4	27.2	116.1	102.6	43.7	105.2	72.6	94.5	90.4	59.2	79.6	954.9
1974	66.3	51.3	142.7	92.7	40.6	60.5	32.8	103.9	108.5	174.0	70.4	91.9	86.3	1035.6
1975	62.7	37.1	69.9	85.3	60.2	20.1	30.2	45.5	78.0	142.0	84.8	63.8	65.0	779.6
1976	101.9	73.9	46.7	62.5	33.5	96.3	37.3	15.2	86.4	148.1	89.9	129.3	76.8	921.0
1977	130.1	61.5	52.1	52.0	68.2	50.1	64.5	75.2	66.8	82.3	48.0	110.2	71.8	861.0
1978	90.4	25.9	56.8	66.3	48.5	38.3	66.3	24.2	159.9	50.3	65.9	96.0	65.7	788.8
1979	101.8	29.8	89.0	45.3	77.9	25.4	73.8	86.4	81.5	144.4	66.9	87.9	75.8	910.1
1980	55.2	67.2	81.7	20.8	103.4	97.4	160.6	173.4	130.6	102.0	114.6	107.4	101.2	1214.3
1981	108.6	70.5	77.1	50.2	64.7	137.2	62.3	127.9	146.8	106.8	84.5	91.6	94.0	1128.2
1982	146.6	93.0	44.7	68.6	99.8	77.1	67.4	49.0	99.8	151.4	103.9	120.4	93.5	1121.7
1983	120.1	112.8	125.2	59.6	77.4	52.4	67.0	121.0	125.0	111.6	133.8	76.5	98.5	1182.4
1984	124.8	101.0	81.8	105.4	90.6	110.0	31.2	118.8	135.8	53.1	75.4	67.6	91.3	1095.5
1985	69.4	67.8	46.8	91.0	68.2	81.6	106.4	86.4	36.4	54.0	66.4	87.8	71.9	862.2
1986	80.6	108.2	99.4	79.6	52.2	53.6	94.8	41.8	102.4	119.6	129.8	37.0	83.3	999.0
1987	157.8	136.4	75.8	86.2	50.6	37.4	37.0	38.2	88.8	77.8	81.4	135.0	83.5	1002.4
Mean	92.2	82.8	79.5	70.7	73.0	71.1	64.3	87.3	93.5	105.0	98.0	94.3	84.3	1011.5

Table I.3

MONTHLY PRECIPITATION

Station: Come By Chance (Extended Using Bonavista Data)
Latitude: 47 48 (dm) N
Longitude: 54 01 (dm) W
Elevation: 27 m

Year	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean	Total
1968	94.9	138.5	160.8	46.9	107.8	169.2	110.8	157.4	28.8	165.3	130.3	143.8	121.2	1454.5
1969	113.7	119.4	126.3	98.5	109.2	62.2	74.5	172.2	133.8	112.9	94.7	110.9	110.7	1328.4
1970	65.9	206.4	86.2	157.5	158.7	99.1	79.9	165.3	86.8	70.9	157.5	156.8	124.3	1491.2
1971	124.1	42.5	123.3	156.2	33.5	114.9	109.0	126.8	80.6	69.2	203.8	115.7	108.3	1299.6
1972	44.0	78.0	85.9	99.9	128.4	106.9	34.1	106.7	37.9	130.2	141.6	139.6	94.4	1133.3
1973	87.1	123.5	76.9	36.1	151.2	167.4	57.6	131.9	76.3	33.5	86.9	75.4	92.0	1103.7
1974	82.0	55.3	170.2	130.3	55.4	80.5	85.6	100.8	113.5	259.3	80.3	207.0	118.4	1420.2
1975	141.5	56.4	92.0	133.6	42.2	61.5	74.7	85.3	43.7	165.6	148.3	88.1	94.4	1132.9
1976	136.9	103.9	91.9	129.5	66.8	45.2	77.7	54.6	71.4	114.3	33.0	124.7	87.5	1049.9
1977	94.1	49.3	43.4	38.5	79.6	67.6	29.0	55.5	58.5	43.1	55.6	105.8	60.0	720.0
1978	164.5	52.7	85.9	59.0	66.6	100.2	46.6	29.9	94.4	60.6	45.6	108.2	76.2	914.2
1979	111.0	34.1	105.3	33.4	84.2	106.4	66.5	92.8	74.5	214.5	126.3	128.8	98.2	1177.8
1980	83.2	96.7	146.8	88.6	118.7	187.6	131.1	184.8	173.0	96.3	130.6	111.6	129.1	1549.0
1981	156.5	69.0	85.3	74.4	84.3	171.1	142.0	116.9	152.0	172.4	148.3	107.0	123.3	1479.2
1982	166.8	96.5	51.4	99.5	100.1	117.2	105.6	71.3	130.0	90.1	109.1	106.9	103.7	1244.5
1983	130.7	81.4	129.5	98.2	113.9	162.2	102.7	122.4	149.6	119.5	104.8	124.9	120.0	1439.8
1984	161.2	137.8	93.6	102.2	141.9	114.7	56.7	200.7	180.2	58.2	82.7	124.4	121.2	1454.3
1985	63.0	59.0	92.5	79.1	118.2	131.0	187.5	112.5	44.5	77.0	100.2	134.3	99.9	1198.8
1986	143.0	115.0	156.7	105.2	54.9	163.5	86.4	73.2	100.8	113.5	162.3	73.2	112.3	1347.7
1987	116.4	112.0	88.8	110.7	84.6	90.4	34.4	28.2	133.7	196.4	93.4	112.0	100.1	1201.0
Mean	114.0	91.4	104.6	93.9	95.0	115.9	84.6	109.5	98.2	118.1	111.8	120.0	104.8	1257.0

* Estimated data in boxes

Table I-4

MONTHLY PRECIPITATION

Station: Gander International Airport
Latitude: 48 57 (dm) N
Longitude: 54 34 (dm) W
Elevation: 151 m

Year	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean	Total
1968	75.4	89.2	121.2	34.0	133.4	146.6	67.8	161.3	43.2	99.6	125.5	74.2	97.6	1171.4
1969	106.2	74.4	152.4	64.8	126.5	61.5	51.3	80.8	101.9	93.2	117.9	128.3	96.6	1159.2
1970	61.0	118.4	86.4	176.3	65.3	65.8	98.3	132.3	67.6	75.7	119.1	140.5	100.6	1206.7
1971	91.9	43.4	94.0	68.6	24.9	57.7	79.5	79.5	54.4	56.9	175.3	89.9	76.3	916.0
1972	38.4	48.3	113.5	127.0	133.4	98.0	45.2	62.5	50.5	127.0	96.6	120.4	88.4	1060.8
1973	67.8	117.9	105.7	34.8	98.3	146.3	59.2	162.1	80.8	134.9	86.4	49.5	95.3	1143.7
1974	58.4	74.2	170.7	114.8	71.1	106.4	50.5	52.6	70.4	153.9	67.1	150.4	95.0	1140.5
1975	89.9	61.2	99.1	112.0	55.1	24.4	62.0	70.9	89.9	188.0	150.1	120.7	93.6	1123.3
1976	167.9	94.0	66.0	72.6	39.1	85.1	70.6	19.1	100.3	186.4	77.2	116.6	91.2	1094.9
1977	122.8	97.4	60.3	78.0	112.5	47.1	100.0	82.5	117.2	127.3	35.7	167.7	95.7	1148.5
1978	126.3	50.5	93.6	94.7	39.4	58.4	70.0	55.9	106.9	76.3	97.2	115.2	82.0	984.4
1979	186.6	105.1	132.4	93.4	108.9	30.1	83.8	103.5	106.4	128.5	100.4	100.0	106.6	1279.1
1980	99.5	105.3	115.6	67.4	149.1	127.5	131.8	186.7	101.4	67.6	195.4	89.2	119.7	1436.5
1981	120.5	42.9	176.2	52.5	125.9	80.9	58.6	100.0	122.8	208.7	129.7	129.6	112.4	1348.3
1982	133.3	153.1	57.0	71.7	104.7	77.0	81.5	38.2	105.6	131.0	103.8	137.4	99.5	1194.3
1983	142.6	148.4	119.0	45.8	76.5	45.8	138.2	155.4	67.0	42.2	126.4	84.4	99.3	1191.7
1984	157.7	142.7	174.4	97.8	92.2	115.9	63.2	181.8	113.4	59.4	73.6	68.2	111.7	1340.3
1985	96.0	91.4	51.0	86.6	37.2	124.2	107.8	110.0	75.6	72.3	71.8	95.0	84.9	1018.9
1986	73.4	125.0	85.5	130.0	45.0	96.8	113.2	61.8	138.5	113.4	138.3	68.0	99.1	1188.9
1987	163.2	129.1	99.7	100.7	90.6	59.6	10.5	51.4	68.0	80.2	87.7	141.3	90.2	1082.0
Mean	108.9	95.6	108.7	86.2	86.5	82.8	77.2	97.4	89.1	111.1	108.8	109.3	96.8	1161.5

Table I.5

MONTHLY PRECIPITATION

Station: Musgrave Harbour
Latitude: N/A (dm) N
Longitude: N/A (dm) W
Elevation: N/A m

Year	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean	Total
1968	72.9	116.4	110.6	30.9	73.4	128.8	71.7	151.5	24.6	111.6	100.0	97.6	90.8	1090.0
1969	87.3	66.0	86.9	64.9	69.8	25.5	48.3	107.9	114.4	76.2	86.9	75.3	75.8	909.4
1970	50.6	173.5	59.3	103.8	108.1	50.7	51.8	159.1	74.3	47.9	120.9	106.4	92.2	1106.4
1971	95.3	35.7	84.8	102.9	22.8	58.8	70.6	122.0	69.0	46.7	156.5	78.5	78.6	943.6
1972	33.8	65.6	59.1	65.8	87.5	54.7	22.1	102.7	32.5	87.9	108.7	94.8	67.9	815.0
1973	66.9	103.8	52.9	23.8	103.0	85.7	37.3	127.0	65.3	71.8	79.1	51.1	72.3	867.6
1974	63.0	46.5	129.1	81.1	36.0	50.5	28.0	125.4	97.5	132.2	61.6	79.4	77.5	930.4
1975	59.6	33.6	63.3	74.6	53.4	16.8	25.8	54.9	70.1	107.9	74.2	55.1	57.4	689.3
1976	96.8	67.0	42.3	54.7	29.7	80.4	31.8	18.3	77.7	112.6	78.7	111.7	66.8	801.6
1977	123.6	55.7	47.2	45.5	60.5	41.8	55.0	90.8	60.1	62.5	42.0	95.2	65.0	779.9
1978	85.9	23.5	51.4	58.0	43.0	32.0	56.6	29.2	143.8	38.2	57.7	65.0	57.0	684.2
1979	89.4	42.4	82.0	22.7	55.8	26.6	60.9	61.6	76.3	98.1	94.8	94.1	67.1	804.7
1980	98.9	71.6	42.6	44.8	79.0	85.6	99.8	137.9	97.7	61.6	107.3	50.1	81.4	976.9
1981	94.6	30.4	81.1	63.8	85.8	64.0	66.2	69.2	95.4	121.7	131.0	100.4	83.6	1003.6
1982	73.5	86.5	45.0	59.0	155.5	69.5	72.5	73.0	116.0	100.2	79.0	98.7	85.7	1028.4
1983	161.4	121.1	127.1	48.9	62.2	57.7	88.8	161.2	69.8	52.6	112.0	86.8	95.8	1149.6
1984	158.2	86.2	119.0	65.1	45.6	80.8	46.0	104.9	106.6	32.4	46.4	61.9	79.4	953.1
1985	59.7	84.6	37.4	51.8	40.6	56.0	110.2	65.4	65.4	54.2	37.7	63.8	60.6	726.8
1986	54.2	106.6	73.0	92.0	17.6	61.6	42.2	84.4	157.6	80.6	94.0	55.0	76.6	918.8
1987	126.2	83.0	46.5	83.2	65.6	59.6	10.6	45.3	66.4	97.8	47.6	108.2	70.0	840.0
Mean	87.6	75.0	72.0	61.9	64.7	59.3	54.8	94.6	84.0	79.7	85.8	81.5	75.1	901.0

* Estimated data in boxes

Table I.6

MONTHLY PRECIPITATION

Station: Sunnyside (Extended Using Bonavista Data)
Latitude: 47 51 (dm) N
Longitude: 53 57 (dm) W
Elevation: 46 m

Year	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean	Total
1968	92.3	167.8	168.1	46.7	114.0	268.5	128.7	168.7	34.7	198.6	146.3	139.3	139.5	1673.8
1969	110.6	95.2	132.1	98.2	108.4	53.1	86.6	120.2	161.2	135.7	127.1	107.4	111.3	1335.8
1970	64.2	250.1	90.1	157.0	167.9	105.7	92.9	177.1	104.6	85.2	176.9	151.9	135.3	1623.6
1971	120.8	51.5	128.9	155.7	35.4	122.6	113.8	137.9	75.7	94.2	228.9	93.7	113.2	1359.0
1972	117.9	54.9	83.6	89.2	101.3	82.8	38.4	108.0	92.5	214.1	167.6	102.4	104.4	1252.7
1973	75.9	128.5	56.4	20.6	138.2	104.1	130.8	161.3	99.3	58.4	134.1	118.1	102.1	1225.7
1974	91.4	106.9	92.2	159.0	47.8	52.6	57.4	111.3	120.7	251.7	73.7	190.0	112.9	1354.7
1975	86.6	63.5	130.6	113.0	75.7	61.5	74.7	89.4	58.7	200.2	169.2	58.4	98.5	1181.5
1976	123.7	138.9	74.2	105.9	73.7	94.5	90.2	52.3	95.0	143.0	49.0	170.7	100.9	1211.1
1977	94.1	89.2	62.2	42.0	79.6	47.1	67.6	64.8	99.2	87.4	115.0	104.1	79.4	952.3
1978	92.5	47.3	104.7	107.2	97.5	160.6	84.4	47.5	185.3	77.7	64.1	43.6	92.7	1112.4
1979	107.3	22.2	88.6	31.7	101.1	101.7	100.9	109.8	96.6	235.3	128.4	105.8	102.5	1229.4
1980	88.8	108.0	182.4	69.8	146.0	209.6	112.6	171.8	168.8	141.2	167.1	129.8	141.3	1695.9
1981	124.8	84.5	123.5	66.4	106.2	166.2	159.8	127.5	167.1	215.2	179.4	111.1	136.0	1631.7
1982	184.8	92.6	62.4	93.6	110.5	173.8	102.9	93.2	150.0	81.2	116.7	123.3	115.4	1385.0
1983	94.4	76.8	129.5	123.2	92.3	161.8	124.0	161.6	172.2	114.7	78.4	136.3	122.1	1465.2
1984	150.5	189.6	125.2	116.8	142.7	105.4	61.2	194.0	197.0	62.0	66.0	120.0	127.5	1530.4
1985	128.0	160.0	99.0	53.0	117.0	132.0	210.4	104.6	56.6	72.9	94.0	134.3	113.5	1361.8
1986	143.0	115.0	131.4	102.5	70.7	173.6	91.7	104.6	100.0	143.0	141.9	73.2	115.9	1390.6
1987	128.5	120.0	123.4	119.3	83.4	98.2	37.7	41.2	131.3	226.6	86.3	112.0	109.0	1307.9
Mean	111.0	108.1	109.4	93.5	100.5	123.8	98.3	117.3	118.3	141.9	125.5	116.3	113.7	1364.0

* Estimated data in boxes

Table I.7

MONTHLY PRECIPITATION

Station: Terra Nova National Park
Latitude: 48 33 (dm) N
Longitude: 53 58 (dm) W
Elevation: 46 m

Year	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean	Total
1968	80.3	110.0	124.7	42.7	137.2	163.6	90.2	156.5	35.3	87.4	125.0	98.0	104.2	1250.9
1969	139.7	114.3	154.2	90.7	126.2	51.3	72.1	98.0	150.6	79.2	67.6	144.5	107.4	1288.4
1970	64.5	134.9	105.2	200.2	98.8	87.6	80.0	204.0	79.5	86.6	178.3	139.3	121.6	1458.9
1971	166.4	49.5	97.5	127.5	49.3	72.6	109.5	100.8	38.6	52.8	234.7	82.6	98.5	1181.8
1972	39.1	46.0	70.1	87.6	76.2	61.2	38.4	72.9	58.4	183.9	179.1	78.0	82.6	990.9
1973	72.4	131.8	87.9	17.0	135.6	131.3	67.1	104.4	79.8	126.7	106.2	45.0	92.1	1105.2
1974	66.5	88.1	140.2	65.3	59.4	60.2	53.8	93.5	62.5	220.5	88.4	138.9	94.8	1137.3
1975	82.0	52.3	86.3	88.1	59.9	20.6	60.2	73.2	90.7	99.8	101.3	85.9	75.0	900.3
1976	165.0	81.0	71.6	74.4	47.5	112.0	58.4	31.2	102.1	150.6	67.1	85.6	87.2	1046.5
1977	91.1	103.7	52.5	59.7	122.4	42.2	110.0	84.2	133.0	126.4	36.3	151.1	92.7	1112.6
1978	113.2	53.7	81.5	89.6	42.7	49.6	41.5	57.1	201.8	38.4	66.9	150.6	82.2	986.6
1979	167.7	124.7	92.6	55.3	141.5	30.9	71.7	79.8	57.3	108.9	91.7	110.2	94.4	1132.3
1980	70.0	106.3	85.4	30.9	178.4	69.4	130.9	164.9	112.6	95.8	144.9	77.9	105.6	1267.4
1981	119.9	82.7	113.1	89.4	137.0	105.0	103.1	129.3	135.7	211.5	121.3	99.2	120.6	1447.2
1982	79.9	116.0	45.4	70.9	83.4	109.2	88.5	60.1	111.9	112.5	126.5	134.0	94.9	1138.3
1983	152.9	130.0	107.0	71.2	110.6	61.9	105.4	120.8	113.6	74.2	101.4	80.9	102.5	1229.9
1984	130.1	118.5	140.9	73.3	105.6	127.1	122.0	117.9	149.2	64.8	60.4	79.9	107.5	1289.7
1985	108.7	113.2	65.7	92.6	60.5	114.3	123.2	141.3	47.4	68.5	71.0	122.0	94.0	1128.4
1986	101.4	156.8	70.7	94.4	44.7	94.1	134.6	51.7	163.6	133.0	153.9	34.9	102.8	1233.8
1987	129.6	122.8	101.2	110.5	64.5	62.8	36.0	48.7	97.4	85.3	89.7	135.2	90.3	1083.7
Mean	107.0	101.8	94.7	81.6	94.1	81.3	84.8	99.5	101.1	110.3	110.6	103.7	97.5	1170.5

* Estimated data in boxes

Table I.8

Gander International Airport

Total Lake Evaporation Calculated from Pan Evaporation Data

Year	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1972							124.0	92.6	52.1			
1973							97.6	71.9	68.5			
1974						114.0	97.5	75.9	59.0			
1975							132.7	95.2	54.2			
1976						108.0	105.5	113.2	53.5			
1977							127.7	108.9	62.0			
1978						104.6	132.8	113.2	61.8			
1979						141.0	116.7	91.8	71.3			
1980							87.7	80.0	70.8			
1981						104.6	128.9	95.5	41.3			
1982						95.5	101.6	103.5	69.4			
MEAN						111.3	113.9	94.7	60.4			

Table I.9

W. S. C. STREAMFLOW GUAGING STATIONS

Station Number	Station Name	Location	Drainage Area (km²)	Period of Record ('50 – '86)
02YQ001	Gander River at Big Chute	49 00 55 N 54 51 13 W	4400	
02YQ002	Gander River at Outlet of Gander Lake	48 56 00 N 54 52 00 W	4160	'23 '39
02YQ004	Northwest Gander River near Gander Lake	48 46 07 N 55 04 52 W	2150	
02YR001	Middle Brook near Gambo	48 48 28 N 54 13 28 W	267	
02YR002	Ragged Harbour River near Musgrave Harbour	49 23 35 N 54 06 25 W	399	
02YR003	Indian Bay Brook near Northwest Arm	49 02 24 N 53 53 00 W	554	
02YS001	Terra Nova River at Eight Mile Bridges	48 26 30 N 54 22 21 W	1290	
02YS002	Rocky Pond Brook at Rocky Pond	48 31 37 N 53 57 32 W	2.31	
02YS003	Southwest Brook at Terra Nova National Park	48 36 25 N 53 58 50 W	36.7	
02YS005	Terra Nova River near Glovertown	48 39 43 N 54 01 05 W	2000	
02ZH001	Pipers Hole River at Mothers Brook	47 56 49 N 54 17 08 W	764	
02ZH002	Come-by-Chance River near Goobies	47 55 07 N 53 56 59 W	43.3	
02ZJ001	Southern Bay River near Southern Bay	48 22 44 N 53 40 36 W	67.4	
02ZJ002	Salmon Cove River near Champneys	48 23 45 N 53 18 06 W	73.6	
02ZJ003	Shoal Harbour River near Clarenville	48 12 24 N 54 02 23 W	106	

Table I.10

MONTHLY STREAMFLOW

Station: Come By Chance River Near Goobies
Station No: 02ZH002
Latitude: 47 55 07(dms) N
Longitude: 53 56 59(dms) W
Drainage Area: 43.3 km^2

Year	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
1968	0.818	0.425	1.960	2.680	3.370	0.440	0.097	0.032	0.043	0.853	0.792	0.886	1.033
1969	0.744	5.239	2.759	2.812	1.550	0.621	0.200	0.248	1.550	1.875	2.280	3.530	1.951
1970	0.664	4.920	5.090	2.270	1.400	1.730	1.490	4.800	1.050	1.640	3.200	2.880	2.595
1971	0.856	4.220	2.600	5.610	0.998	1.080	1.370	1.120	0.672	1.180	4.020	1.680	2.117
1972	1.330	0.942	2.660	2.040	2.990	0.977	0.371	0.205	0.862	3.660	3.630	1.910	1.798
1973	1.080	4.590	1.130	2.280	2.940	1.990	1.510	2.410	1.090	1.460	2.780	2.180	2.120
1974	0.699	1.020	2.110	3.920	2.160	0.941	0.877	0.559	1.150	4.240	1.600	3.070	1.862
1975	0.436	0.114	1.130	5.650	2.150	0.246	0.110	0.394	0.602	2.560	2.740	2.210	1.529
1976	3.250	2.210	1.870	2.770	1.350	1.020	0.676	0.568	0.450	2.520	1.380	3.050	1.760
1977	2.280	0.800	1.410	2.220	1.700	0.647	0.364	0.647	1.360	1.950	1.950	3.380	1.559
1978	3.860	0.739	1.430	3.100	2.630	1.620	0.835	0.147	1.640	1.640	1.310	1.370	1.693
1979	2.980	1.460	2.540	0.935	1.440	0.522	0.485	1.140	0.878	2.980	2.650	1.800	1.651
1980	1.310	0.599	3.200	4.450	2.590	2.470	2.090	1.880	2.420	2.270	3.020	1.830	2.344
1981	2.500	2.430	2.430	2.410	2.030	1.550	1.960	1.300	1.910	3.560	2.830	1.710	2.218
1982	1.200	0.876	1.350	4.750	3.030	1.120	1.070	0.399	1.490	1.360	1.470	3.080	1.766
1983	3.530	0.851	3.170	2.330	1.200	1.880	0.416	1.930	2.180	1.340	2.700	1.920	1.954
1984	2.870	3.700	1.630	3.780	3.230	1.260	0.412	1.640	2.340	0.756	0.904	2.100	2.052
1985	0.599	0.780	1.100	2.460	4.030	1.440	2.440	0.979	1.290	0.478	2.180	1.500	1.606
1986	3.650	1.020	1.990	5.020	0.821	1.340	0.772	0.644	1.130	1.860	2.460	1.130	1.820
1987	0.988	1.230	2.940	4.750	1.550	0.733	0.147	0.037	0.724	3.000	2.420	1.580	1.675
Mean	1.782	1.908	2.225	3.312	2.158	1.181	0.885	1.054	1.242	2.059	2.316	2.140	1.855

* Estimated data in box

Table I.11

MONTHLY STREAMFLOW

Station: Gander River At Big Chute
Station No: 02YQ001
Latitude: 49 00 55 (dms) N
Longitude: 54 51 13 (dms) W
Drainage Area: 4400 km^2

Year	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
1968	108.000	142.000	174.000	160.000	195.000	164.000	85.100	48.100	109.000	71.700	145.000	190.000	132.658
1969	69.700	288.000	181.000	176.000	221.000	88.300	25.800	28.500	35.300	87.100	157.000	261.000	134.892
1970	116.000	73.800	138.000	209.000	370.000	125.000	85.000	102.000	98.800	51.400	148.000	178.000	141.250
1971	77.100	119.000	72.600	446.000	163.000	48.600	66.100	38.900	42.100	37.300	178.000	147.000	119.642
1972	58.700	25.100	88.600	161.000	379.000	152.000	82.400	28.400	25.800	132.000	218.000	102.000	121.083
1973	50.100	133.000	76.300	153.000	414.000	130.000	95.400	106.000	65.100	107.000	233.000	101.000	138.658
1974	49.300	26.800	63.900	224.000	328.000	163.000	44.500	28.700	40.100	136.000	112.000	175.000	115.942
1975	48.100	23.800	39.400	148.000	268.000	39.000	13.900	12.900	20.900	156.000	171.000	207.000	95.667
1976	172.000	168.000	97.800	317.000	156.000	99.600	40.700	21.000	54.600	185.000	146.000	97.400	129.592
1977	130.000	76.500	74.000	271.000	277.000	127.000	56.700	58.000	68.300	188.000	86.000	123.000	127.958
1978	226.000	91.000	56.700	199.000	250.000	74.000	36.300	14.700	8.920	36.600	58.900	66.800	93.243
1979	180.000	205.000	260.000	139.000	163.000	37.700	15.600	35.100	80.200	84.000	182.000	79.100	121.725
1980	65.300	34.700	42.800	329.000	260.000	140.000	125.000	179.000	112.000	106.000	179.000	126.000	141.567
1981	130.000	139.000	160.000	222.000	253.000	68.600	47.300	56.200	61.300	269.000	161.000	184.000	145.950
1982	65.100	42.000	65.100	242.000	336.000	56.300	50.800	39.200	48.800	119.000	70.600	113.000	103.992
1983	352.000	87.900	188.000	237.000	117.000	84.100	47.600	157.000	83.200	39.300	75.500	94.300	130.242
1984	117.000	283.000	133.000	225.000	371.000	159.000	48.200	113.000	196.000	85.600	50.000	83.500	155.358
1985	36.300	26.900	42.500	110.000	272.000	130.000	89.100	65.300	93.800	30.500	49.400	36.900	81.892
1986	86.000	133.000	51.300	402.000	107.000	74.500	56.400	34.800	55.500	116.000	86.400	69.500	106.033
1987	40.700	60.000	92.200	513.000	140.000	39.800	18.300	6.920	6.250	27.000	130.000	111.000	98.764
Mean	108.870	108.925	104.860	244.150	252.000	100.025	56.510	58.686	65.299	103.225	131.840	127.275	121.805

Table I.12

MONTHLY STREAMFLOW

Station: Middle Brook Near Gambo
Station No: 02YR001
Latitude: 48 36 25 (dms) N
Longitude: 53 58 50 (dms) W
Drainage Area: 36.7 km^2

Year	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
1968	5.540	7.530	8.500	8.540	11.100	10.600	5.410	2.430	5.870	4.100	8.380	10.000	7.333
1969	5.930	14.600	14.000	10.900	12.500	8.290	1.930	1.560	1.360	4.290	6.610	12.000	7.831
1970	6.810	5.950	10.300	16.000	17.100	7.070	3.120	3.840	4.720	3.910	8.290	10.900	8.168
1971	6.550	7.750	5.460	19.600	8.880	3.070	4.990	1.640	0.953	0.696	9.500	10.800	6.657
1972	4.600	1.900	4.630	10.500	20.400	8.280	4.030	1.520	0.745	2.700	11.600	8.460	6.614
1973	4.680	9.430	6.600	8.620	22.000	10.600	6.400	3.390	2.800	4.660	10.800	4.870	7.904
1974	3.100	2.040	4.180	12.700	16.900	12.100	3.280	1.180	1.360	7.380	6.660	10.600	6.790
1975	4.490	2.550	2.360	14.300	14.800	3.690	1.220	0.662	1.080	9.170	12.000	12.300	6.552
1976	10.400	8.760	5.720	12.100	6.730	6.120	2.340	0.989	0.794	6.620	7.960	5.790	6.194
1977	6.860	4.150	4.480	13.100	14.800	7.180	2.340	2.910	2.760	7.580	4.690	5.920	6.398
1978	9.670	1.190	3.950	10.500	10.900	3.810	1.470	0.531	0.371	0.821	2.130	4.070	4.118
1979	10.000	14.700	15.900	10.100	12.800	2.640	0.890	0.665	1.280	3.230	8.610	6.630	7.287
1980	4.940	2.640	4.590	17.100	18.200	9.510	6.700	10.000	6.310	5.520	10.900	9.090	8.792
1981	8.400	7.830	12.800	12.200	12.100	4.300	2.840	2.210	2.070	12.300	9.560	10.800	8.118
1982	5.010	4.350	5.230	12.200	17.700	4.380	3.140	1.700	1.300	5.980	5.330	6.920	6.103
1983	12.300	6.280	11.300	14.100	7.120	4.070	1.740	3.070	4.530	1.930	3.250	5.740	6.286
1984	7.720	12.800	9.610	13.800	16.200	9.380	2.860	4.590	8.930	4.500	2.890	4.720	8.167
1985	2.150	1.790	2.570	6.400	11.900	5.520	5.450	3.410	4.040	1.770	3.240	2.520	4.230
1986	3.250	4.180	3.170	18.000	7.400	3.710	3.550	1.730	2.630	7.410	5.290	3.920	5.353
1987	4.050	5.530	7.020	23.400	9.320	3.850	1.250	0.314	0.255	0.536	3.800	6.560	5.490
Mean	6.323	6.298	7.119	13.208	13.443	6.409	3.248	2.417	2.708	4.755	7.075	7.631	6.719

Table I.13

MONTHLY STREAMFLOW

Station: Pipers Hole At Mothers Brook
Station No: 02ZH001
Latitude: 47 56 49 (dms) N
Longitude: 54 17 08 (dms) W
Drainage Area: 764 km^2

Year	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
1968	23.600	41.800	45.100	18.200	34.500	28.900	14.100	26.300	19.500	10.400	34.300	34.400	27.592
1969	9.840	69.300	36.500	37.200	20.500	8.220	2.640	3.280	20.500	24.800	41.600	60.500	27.907
1970	15.900	47.100	65.900	35.700	19.000	14.500	4.600	25.800	13.600	19.300	41.200	38.800	28.450
1971	16.600	58.500	34.200	79.100	19.000	9.040	12.700	9.920	7.470	10.400	44.200	26.700	27.319
1972	20.800	17.300	41.700	33.300	40.300	9.510	5.810	2.350	5.210	35.000	39.700	18.400	22.448
1973	13.600	44.400	16.500	38.700	46.000	22.100	20.200	32.200	14.200	27.700	43.500	25.100	28.683
1974	10.100	11.500	17.400	47.300	31.000	9.900	4.940	4.010	7.390	48.800	26.800	41.500	21.720
1975	7.330	3.670	9.350	68.100	36.700	3.370	1.900	3.530	7.190	31.600	37.000	38.900	20.720
1976	54.700	32.500	28.800	48.600	16.700	12.100	2.760	1.650	2.970	22.600	23.100	42.100	24.048
1977	36.300	17.500	23.800	41.100	29.600	14.400	4.450	6.380	11.900	20.900	16.200	45.400	22.494
1978	66.900	14.200	21.100	46.700	30.300	10.400	7.700	1.580	7.200	19.100	13.900	18.200	21.440
1979	42.800	26.500	43.500	14.900	18.400	2.730	1.570	9.900	8.650	29.600	35.800	28.000	21.863
1980	12.200	5.420	28.000	80.600	43.400	25.900	25.200	29.700	31.700	29.600	54.800	27.400	32.827
1981	38.300	33.100	32.400	36.500	32.000	9.020	26.400	14.900	24.700	64.200	37.500	33.000	31.835
1982	20.200	13.600	30.900	74.100	51.200	10.100	11.000	4.170	13.400	15.500	13.400	42.300	24.989
1983	59.300	18.100	73.000	32.200	19.900	16.600	7.060	18.200	30.000	12.900	31.400	21.100	28.313
1984	56.900	63.800	29.800	49.900	38.400	19.400	6.310	13.800	37.300	16.000	9.910	19.900	30.118
1985	9.550	7.810	13.000	36.000	56.700	18.400	22.900	8.420	16.200	4.620	15.100	12.400	18.425
1986	40.800	18.400	29.200	86.900	15.300	17.800	7.440	4.950	7.350	23.600	29.400	15.300	24.703
1987	10.800	15.500	35.800	76.700	22.100	7.550	2.600	0.559	1.520	13.000	40.400	24.400	20.911
Mean	28.326	28.000	32.898	49.090	31.050	13.497	9.614	11.080	14.397	23.981	31.461	30.690	25.340

Table I.14

MONTHLY STREAMFLOW

Station: Ragged Harbour River Near Musgrave Harbour
Station No: 02YR002
Latitude: 49 23 35 (dms) N
Longitude: 54 06 25 (dms) W
Drainage Area: 399 km^2

Year	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
1968	7.773	10.565	11.927	11.983	15.575	14.873	7.591	3.410	8.236	5.753	11.758	14.031	10.290
1969	8.320	20.486	19.644	15.294	17.539	11.632	2.708	2.189	1.908	6.019	9.275	16.837	10.988
1970	9.555	8.349	14.452	22.450	23.993	9.920	4.378	5.388	6.623	5.486	11.632	15.294	11.460
1971	9.190	10.874	7.661	27.501	12.460	4.308	7.002	2.301	1.337	0.977	13.330	15.154	9.341
1972	6.454	2.666	6.496	14.733	28.624	11.618	5.655	2.133	1.045	3.788	16.276	11.870	9.280
1973	6.567	13.231	9.261	12.095	30.869	14.873	8.980	4.757	3.929	6.539	15.154	6.833	11.090
1974	4.350	2.862	5.865	17.820	23.713	16.978	4.602	1.656	1.908	10.355	9.345	14.873	9.527
1975	6.300	3.578	3.311	20.065	20.766	5.178	1.712	0.929	1.515	12.867	16.837	17.258	9.193
1976	14.592	12.291	8.026	16.978	9.443	8.587	3.283	1.388	1.114	9.289	11.169	8.124	8.690
1977	9.625	5.823	6.286	18.381	20.766	4.740	1.430	1.240	1.520	14.200	4.930	8.361	8.109
1978	14.000	4.220	4.230	21.300	13.500	3.650	0.917	0.203	0.266	1.620	6.000	6.320	6.352
1979	19.200	27.300	22.000	13.800	19.200	1.650	0.291	0.153	0.695	3.310	11.300	8.920	10.652
1980	4.850	2.660	5.170	32.500	20.600	9.980	5.240	13.800	7.570	6.380	21.400	13.900	12.004
1981	8.310	10.400	18.900	17.000	14.200	4.260	1.310	1.340	4.680	20.500	15.500	17.800	11.183
1982	5.060	5.400	7.140	20.700	26.400	3.660	1.670	1.000	3.100	11.200	8.100	10.700	8.678
1983	26.800	7.180	18.200	18.100	4.170	3.680	1.030	5.580	5.440	1.680	7.720	11.200	9.232
1984	11.500	19.300	13.900	22.500	24.100	8.800	2.000	1.750	5.740	3.550	3.350	6.040	10.211
1985	4.370	3.110	3.580	12.200	19.100	4.570	4.150	1.560	4.030	1.770	5.910	4.050	5.700
1986	5.250	6.610	5.000	31.000	8.880	3.980	1.300	0.872	11.000	12.500	7.130	5.260	8.232
1987	4.870	7.580	7.960	39.900	8.570	2.070	0.480	0.085	0.115	0.348	8.220	9.530	7.477
Mean	10.421	9.376	10.608	22.900	15.872	4.630	1.839	2.634	4.264	6.286	9.463	9.372	8.972

* Estimated data in box

Table I.15

MONTHLY STREAMFLOW

Station:	Southern Bay River Near Southern Bay
Station No:	02ZJ001
Latitude:	48 22 44 (dms) N
Longitude:	53 40 36 (dms) W
Drainage Area:	67.4 km^2

Year	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
1968	1.572	2.699	3.894	2.328	3.358	3.379	1.067	2.328	0.902	1.685	3.667	2.184	2.422
1969	0.979	5.521	5.089	4.100	3.523	1.498	0.394	0.698	1.772	1.939	2.452	4.203	2.681
1970	0.773	2.946	4.079	6.449	3.214	1.881	0.898	2.823	1.415	1.766	4.430	3.379	2.838
1971	1.949	3.976	2.122	6.922	1.158	0.779	1.759	0.546	0.385	0.595	4.224	1.801	2.185
1972	1.181	3.544	3.173	2.720	6.160	1.378	0.367	0.212	0.453	2.720	4.285	1.294	2.290
1973	0.812	3.997	1.498	3.255	5.872	2.555	0.915	1.349	1.477	2.452	2.555	1.160	2.325
1974	0.328	0.253	1.203	4.636	3.750	1.790	0.461	0.435	0.894	4.656	1.836	3.214	1.955
1975	0.698	0.494	1.930	6.593	2.967	0.538	0.214	0.387	0.688	2.699	3.296	2.390	1.908
1976	3.214	1.106	1.770	2.884	1.710	2.810	0.242	0.115	0.567	2.200	1.100	1.310	1.586
1977	2.470	1.100	0.959	2.060	5.080	1.830	0.165	0.176	0.347	1.230	1.420	1.820	1.555
1978	1.520	0.641	1.140	3.510	4.350	0.806	0.268	0.069	0.472	1.360	0.983	2.620	1.478
1979	4.840	4.530	5.430	2.360	4.490	0.187	0.266	0.263	0.169	2.190	3.340	1.850	2.493
1980	1.440	0.437	1.120	5.330	4.590	1.800	3.240	3.640	3.300	1.880	5.190	4.440	3.034
1981	3.910	3.080	4.720	5.410	3.320	1.220	1.620	1.070	2.300	6.210	2.790	1.990	3.137
1982	1.670	1.410	3.180	6.170	4.410	1.070	0.590	0.256	0.408	1.640	1.400	2.940	2.095
1983	6.130	1.560	6.070	2.350	0.998	1.080	0.269	0.299	1.370	0.885	2.450	1.250	2.059
1984	3.080	3.180	2.000	4.950	4.980	1.810	0.412	0.821	3.370	0.870	0.768	2.170	2.368
1985	0.681	0.491	1.290	2.890	4.090	0.945	1.710	0.404	0.585	0.280	0.856	1.150	1.281
1986	1.740	1.460	1.320	7.840	1.880	0.807	0.862	0.384	0.567	2.290	2.620	1.190	1.913
1987	1.230	2.180	1.670	5.880	1.450	0.322	0.082	0.018	0.202	0.605	2.240	2.010	1.491
Mean	2.610	1.824	2.627	4.432	3.603	1.080	0.862	0.673	1.190	1.767	2.187	2.130	2.082

* Estimated data in box

Table I.16

MONTHLY STREAMFLOW

Station: Southwest Brook At Terra Nova Park
Station No: 02YS003
Latitude: 48 36 25 (dms) N
Longitude: 53 58 50 (dms) W
Drainage Area: 36.7 km^2

Year	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
1968	0.763	1.310	1.890	1.130	1.630	1.640	0.518	1.130	0.438	0.818	1.780	1.060	1.176
1969	0.475	2.680	2.470	1.990	1.710	0.727	0.191	0.339	0.860	0.941	1.190	2.040	1.301
1970	0.375	1.430	1.980	3.130	1.560	0.913	0.436	1.370	0.687	0.857	2.150	1.640	1.377
1971	0.946	1.930	1.030	3.360	0.562	0.378	0.854	0.265	0.187	0.289	2.050	0.874	1.060
1972	0.573	1.720	1.540	1.320	2.990	0.669	0.178	0.103	0.220	1.320	2.080	0.628	1.112
1973	0.394	1.940	0.727	1.580	2.850	1.240	0.444	0.655	0.717	1.190	1.240	0.563	1.128
1974	0.159	0.123	0.584	2.250	1.820	0.869	0.224	0.211	0.434	2.260	0.891	1.560	0.949
1975	0.339	0.240	0.937	3.200	1.440	0.261	0.104	0.188	0.334	1.310	1.600	1.160	0.926
1976	1.560	0.537	0.859	1.400	0.826	1.300	0.276	0.121	0.402	1.430	0.794	0.882	0.866
1977	0.727	0.347	0.666	1.910	1.700	0.555	0.329	0.502	0.621	1.260	0.542	1.310	0.872
1978	1.160	0.429	0.960	2.130	1.400	0.345	0.243	0.126	0.730	0.706	0.693	0.710	0.803
1979	2.280	1.500	2.220	1.030	2.040	0.169	0.136	0.214	0.191	0.983	1.120	0.935	1.068
1980	0.384	0.225	0.594	2.930	2.080	0.856	1.410	1.590	1.140	0.965	2.280	1.030	1.290
1981	1.110	1.210	2.060	1.760	1.070	0.517	0.557	0.754	1.160	2.570	1.550	1.170	1.291
1982	0.613	0.715	0.928	3.020	1.680	0.607	0.449	0.205	0.723	1.260	1.070	1.590	1.072
1983	2.120	0.748	2.400	1.570	0.722	0.539	0.293	0.637	0.781	0.488	0.977	0.774	1.004
1984	1.380	1.440	1.140	2.160	2.160	1.050	0.294	1.010	1.520	0.572	0.547	0.822	1.175
1985	0.271	0.291	0.347	1.340	1.680	0.810	1.030	0.635	0.624	0.316	0.580	0.410	0.695
1986	0.759	0.398	0.527	3.160	0.723	0.543	0.780	0.407	1.200	1.480	0.884	0.579	0.953
1987	0.606	1.050	1.330	3.760	0.651	0.420	0.236	0.067	0.342	0.388	1.030	0.855	0.895
Mean	0.850	1.013	1.259	2.207	1.565	0.720	0.449	0.526	0.666	1.070	1.252	1.030	1.051

Table I.17

MONTHLY STREAMFLOW

Station: Terra Nova River At Eight Mile Bridges
Station No: 02YS001
Latitude: 48 26 30 (dms) N
Longitude: 54 22 21 (dms) W
Drainage Area: 1290 km^2

Year	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
1968	34.200	42.600	53.100	41.000	55.400	43.300	25.000	15.600	35.300	21.100	41.000	64.000	39.300
1969	23.300	80.800	48.100	52.100	49.400	24.800	8.700	8.910	18.400	36.600	47.600	78.100	39.734
1970	36.200	19.500	55.200	67.900	71.400	36.400	22.200	27.600	32.100	25.300	52.900	56.900	41.967
1971	24.100	42.200	29.600	133.000	42.900	17.500	23.200	13.100	12.200	12.300	49.900	43.100	36.925
1972	27.000	15.200	26.300	35.700	100.000	28.800	17.700	6.710	8.310	43.100	55.600	32.600	33.085
1973	16.300	36.000	19.600	32.700	104.000	39.200	29.800	30.800	22.700	27.700	59.400	28.100	37.192
1974	15.000	8.560	21.200	47.000	72.000	30.200	12.500	8.040	9.950	49.000	34.000	57.200	30.388
1975	14.700	6.830	13.500	71.700	74.200	9.540	3.180	5.110	11.300	46.800	48.200	68.300	31.113
1976	48.600	47.500	26.800	77.900	38.900	28.500	8.820	4.110	7.910	38.100	37.700	39.700	33.712
1977	42.400	22.400	20.500	65.500	59.700	32.600	13.400	20.200	22.500	41.200	23.000	29.800	32.767
1978	72.600	20.700	17.500	55.300	56.400	20.100	13.200	2.520	4.320	17.600	18.800	18.100	26.428
1979	44.900	74.400	66.600	31.700	31.700	9.140	4.610	11.300	20.100	33.400	53.800	38.100	34.979
1980	21.900	15.500	18.200	21.200	29.400	38.300	46.100	53.800	40.500	38.700	40.900	42.600	33.925
1981	44.000	49.200	50.000	65.200	73.100	15.600	18.600	22.400	23.400	97.700	44.200	49.200	46.050
1982	16.900	10.900	18.000	63.700	100.000	18.000	15.000	9.600	16.000	33.500	17.600	38.600	29.817
1983	98.500	30.900	57.000	65.500	33.200	24.300	10.500	39.900	35.700	15.600	32.300	40.500	40.325
1984	37.200	78.200	36.000	62.800	76.400	49.300	17.000	30.100	58.300	26.400	14.600	17.900	42.017
1985	11.103	9.204	10.727	31.290	55.990	21.810	30.204	27.423	33.980	13.217	18.552	14.132	23.136
1986	16.783	21.494	13.232	88.002	34.871	14.658	19.674	13.913	22.121	55.330	30.291	21.983	29.363
1987	20.914	27.510	29.301	114.403	43.815	15.211	6.928	2.525	2.145	4.002	21.759	36.788	27.108
Mean	33.330	32.980	31.523	61.180	60.139	25.863	17.316	17.683	21.862	33.832	37.105	40.785	34.466

Table I.18

BASIN PHYSIOGRAPHIC CHARACTERISTICS

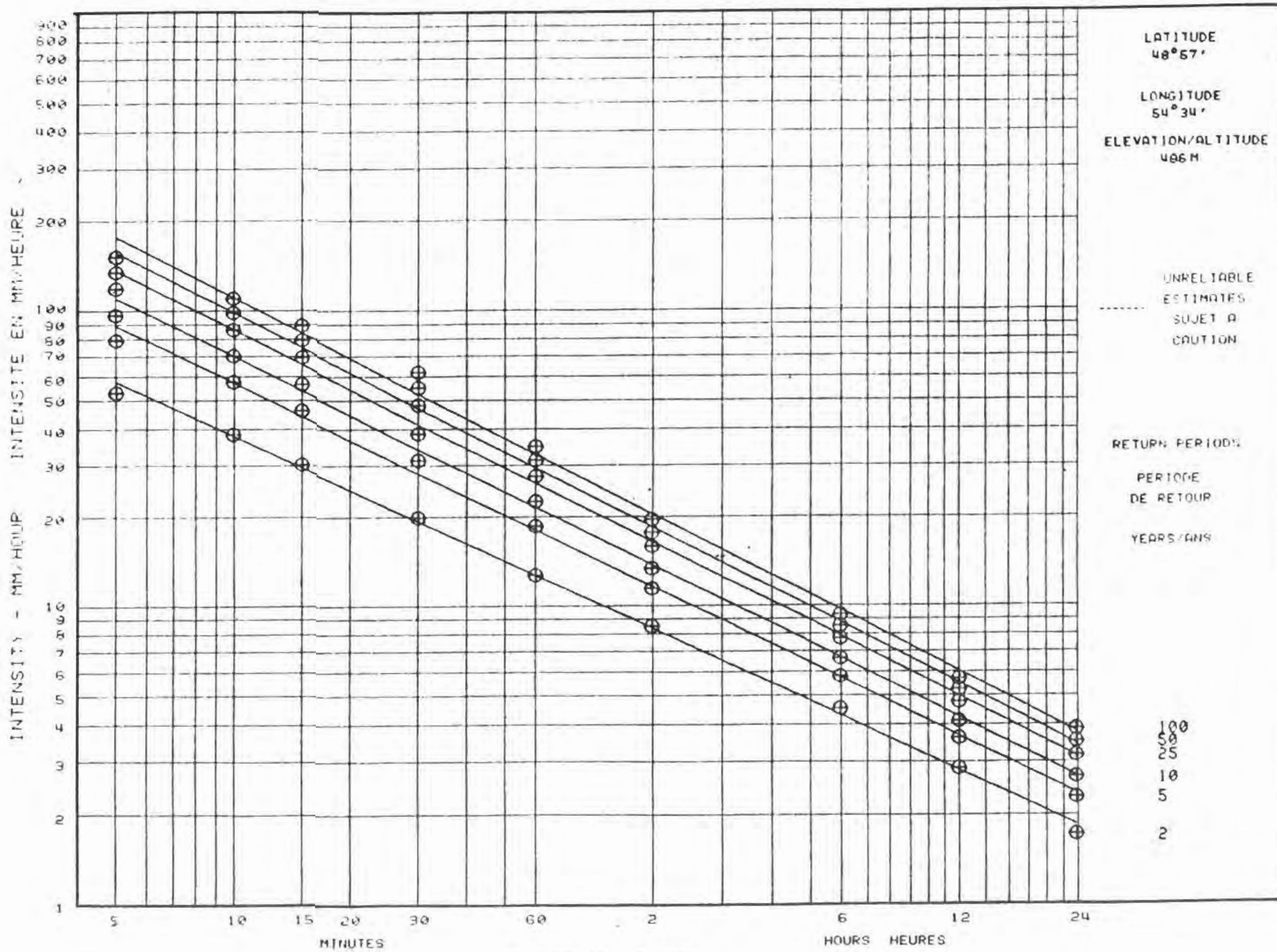
Basin Name	Station Number	Centroid Lat. (dd)	Centroid Long. (dd)	ACLS (%)	Drain Area (km^2)	Lake Area (km^2)	Swamp Area (km^2)	Forest Area (km^2)	Barren Area (km^2)	Channel Length (km)	Channel Slope (%)	Shape Factor	Centroid Elev. (m)	Divide Elev. (m)	Dist to Sea SW (km)	Dist to Sea W (km)	Drainage Density (km/km^2)
Gander River at Big Chute	02YQ001	48.630	55.200	91	4400.0	375.30	366.80	3355.2	302.78	133.8	0.222	2.08	152	297.2	160	257	0.452
Middle Brook near Gambo	02YR001	49.288	54.170	98	267.0	46.75	18.33	199.7	2.26	49.3	0.359	1.93	183	176.7	180	310	0.255
Ragged Harbour River near Musgrave Harbour	02YR002	49.393	54.107	92	399.0	61.58	48.64	288.8	0.00	20.6	0.363	1.48	69	106.7	270	295	0.428
Terra Nova River at Eight Mile Bridge	02YS001	48.377	54.873	92	1290.0	117.50	266.77	715.2	190.50	105.0	0.197	2.35	183	207.3	120	283	0.726
Southwast Brook at Terra Nova National Park	02YS003	48.582	54.035	100	36.7	0.78	5.06	30.7	0.18	11.2	1.282	1.43	30	143.2	150	338	0.641
Pipers Hole River at Mothers Brook	02ZH001	48.053	54.462	91	764.0	137.50	365.77	82.0	178.72	50.9	0.407	1.67	168	207.2	70	356	0.709
Come by Chance River near Goobies	02ZH002	47.965	53.963	92	43.3	3.41	0.86	17.5	21.51	17.0	0.645	1.66	91	109.7	20	403	1.110
Southern Bay River near Southern Bay	02ZJ001	48.332	53.722	84	67.4	5.98	2.58	58.3	0.56	27.0	0.339	1.48	84	137.2	110	378	0.509

I.3 GRAPHS

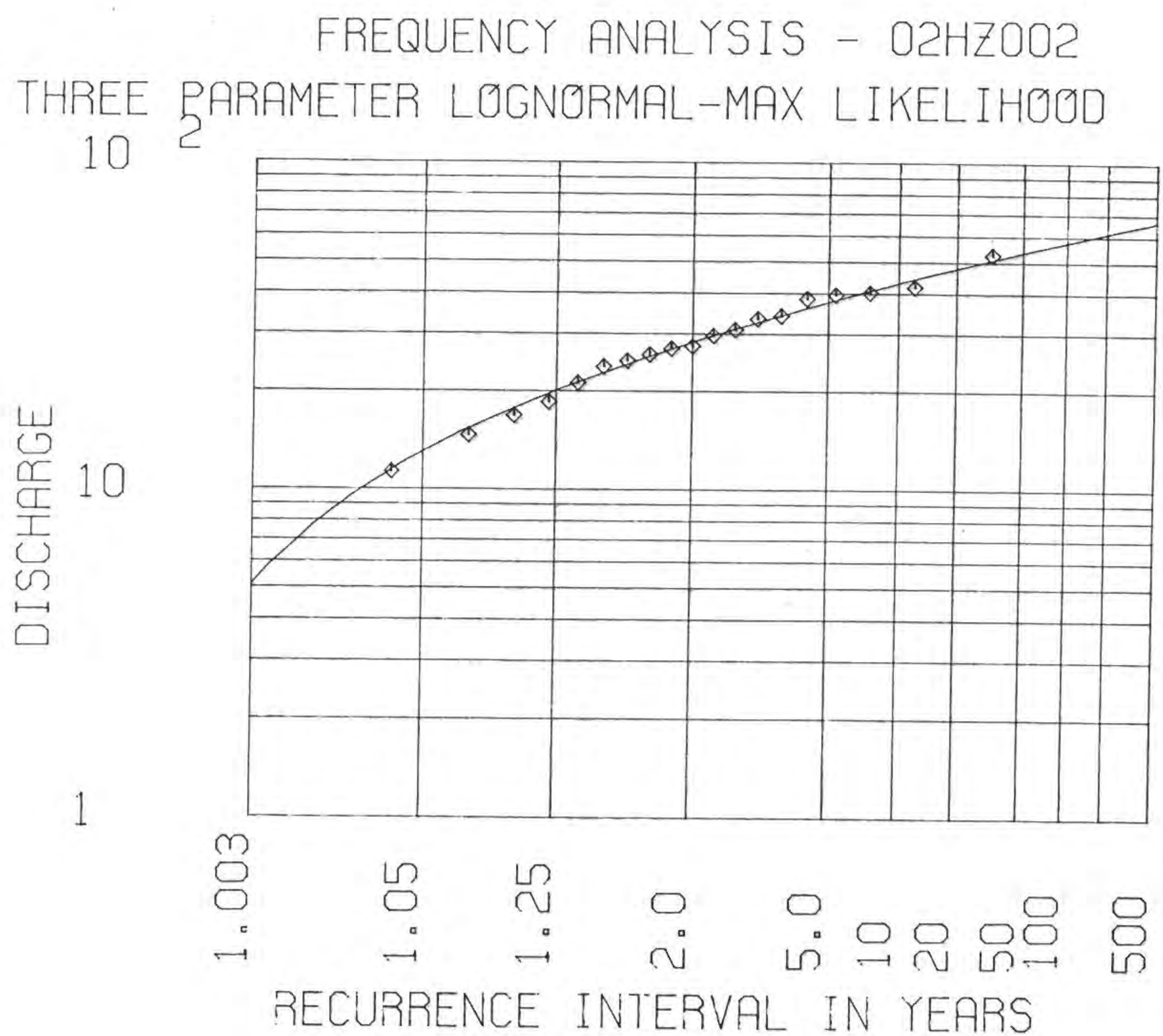
GANDER INTERNATIONAL AIRPORT

RAINFALL INTENSITY-DURATION- FREQUENCY CURVES

1939 - 1983

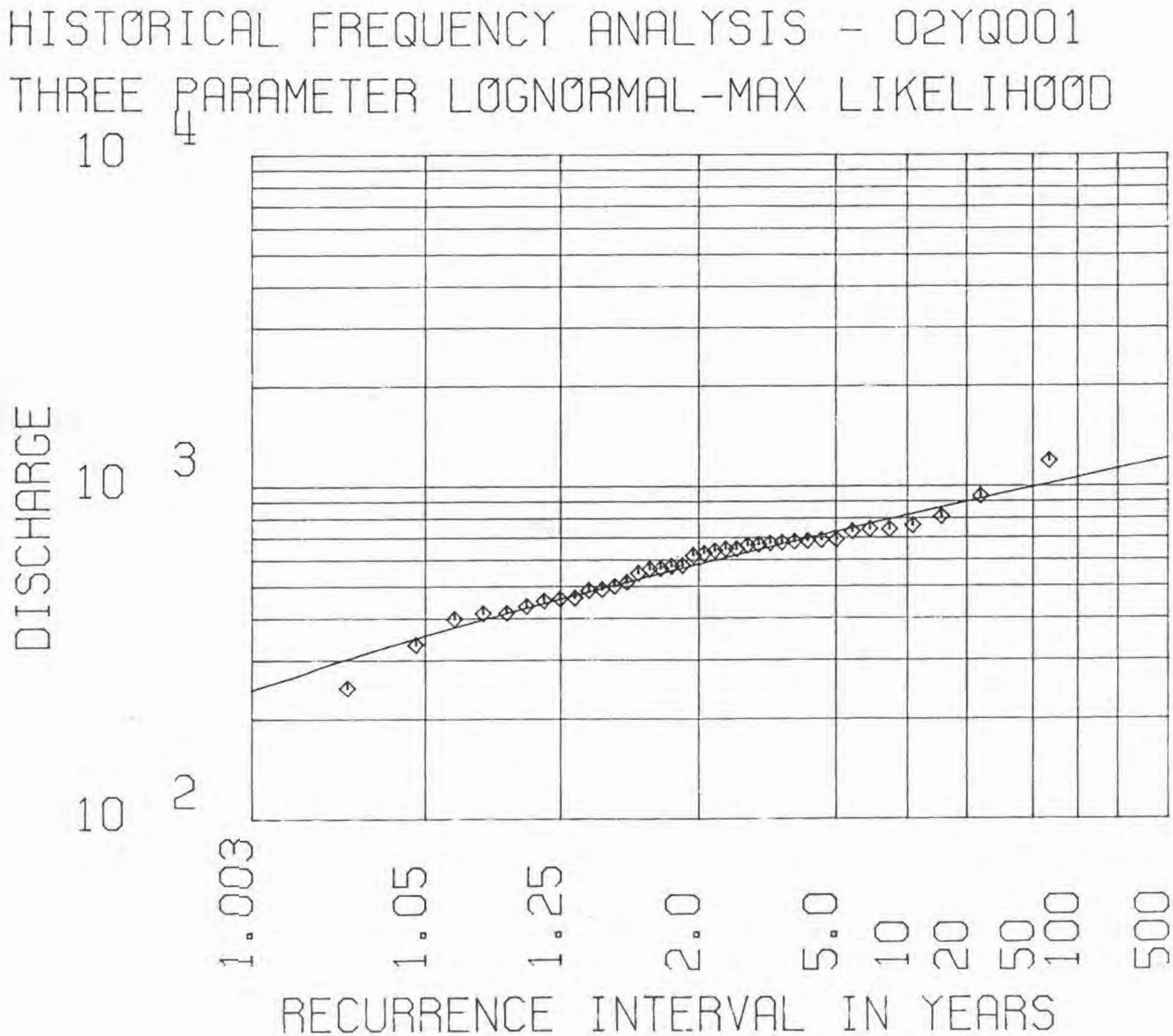


Graph I.1



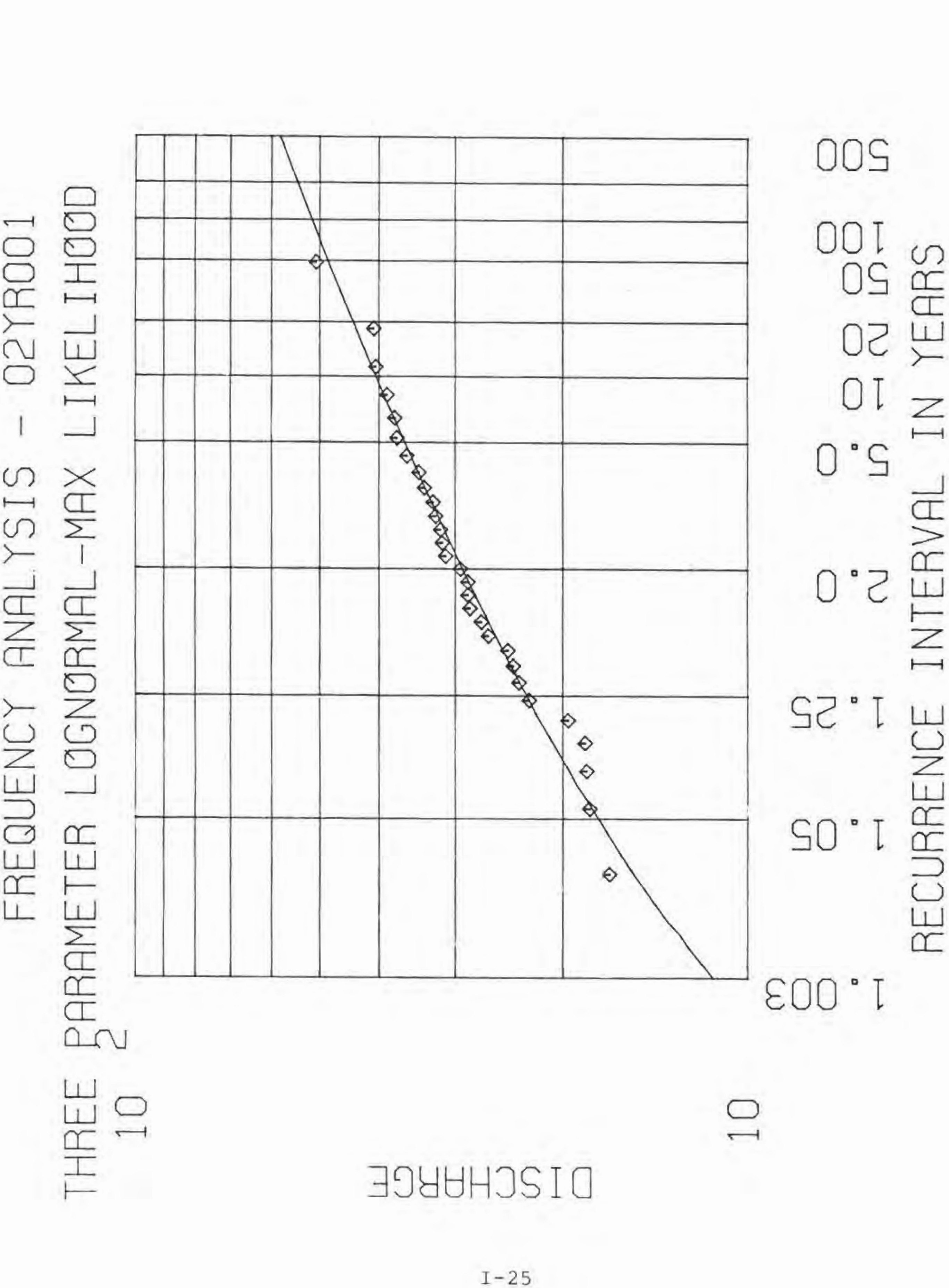
COME BY CHANCE RIVER

Graph I.2

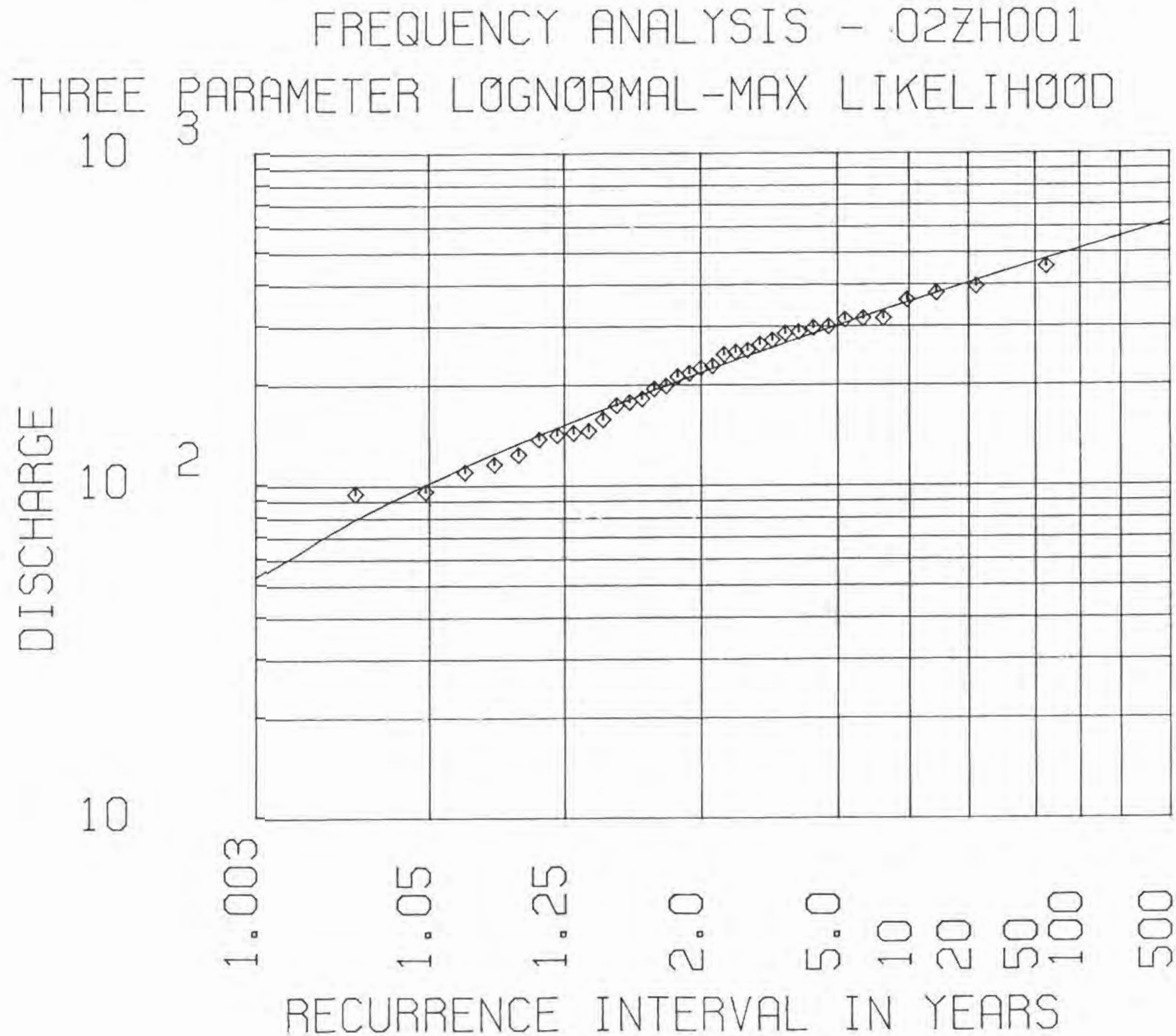


GANDER RIVER AT BIG CHUTE

Graph I.3

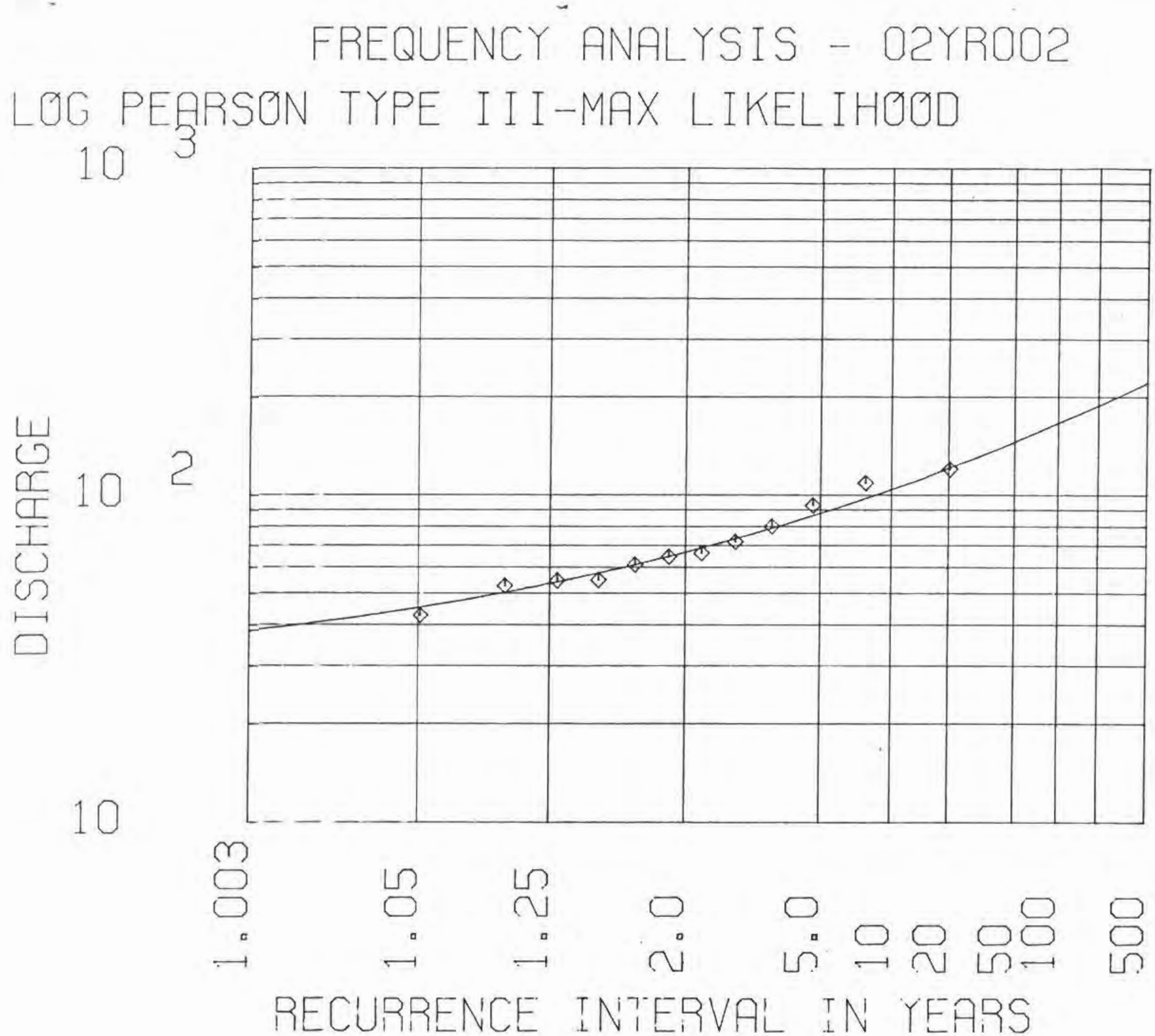


MIDDLE BROOK
Graph 1.4



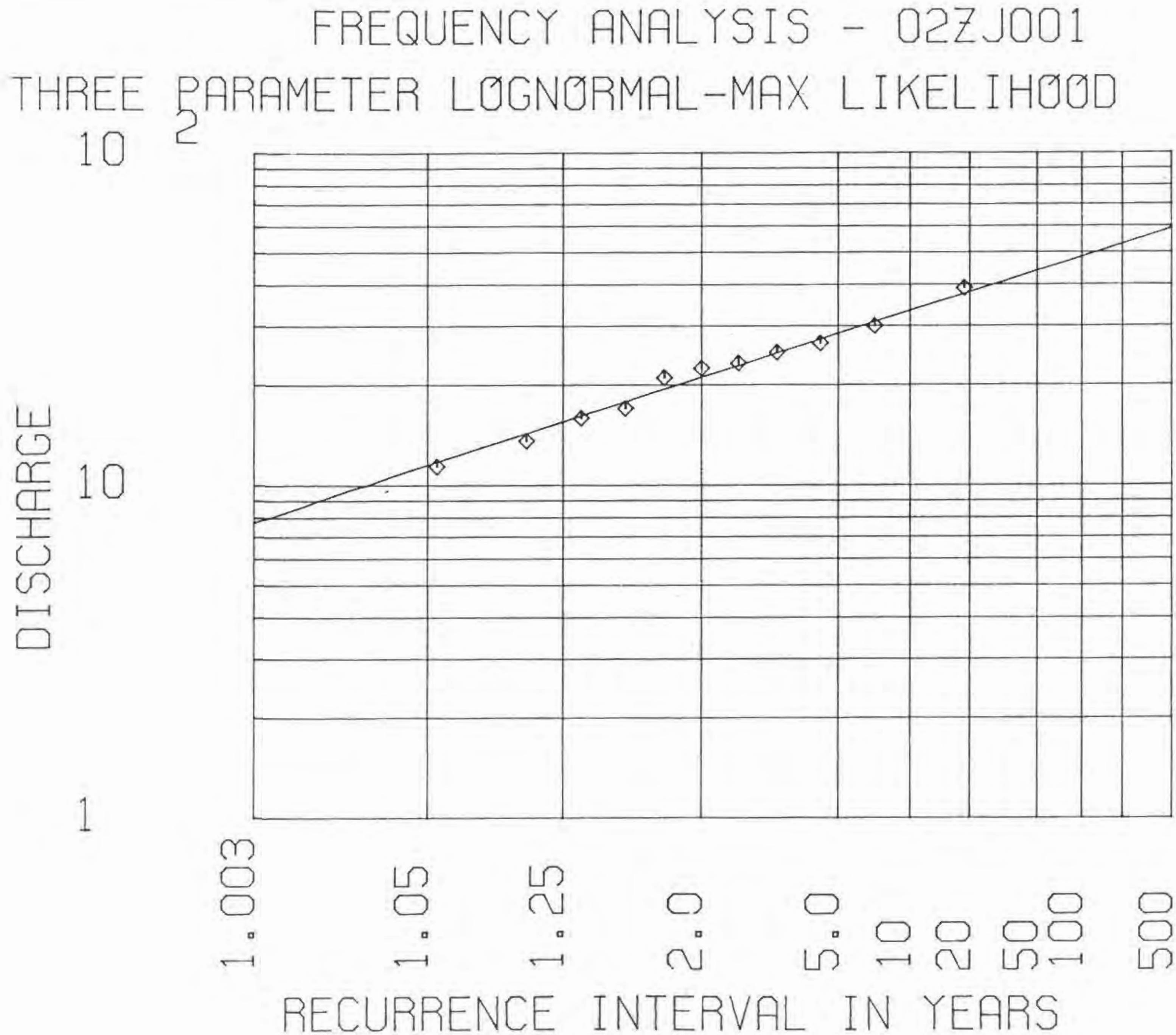
PIPERS HOLE RIVER

Graph I.5



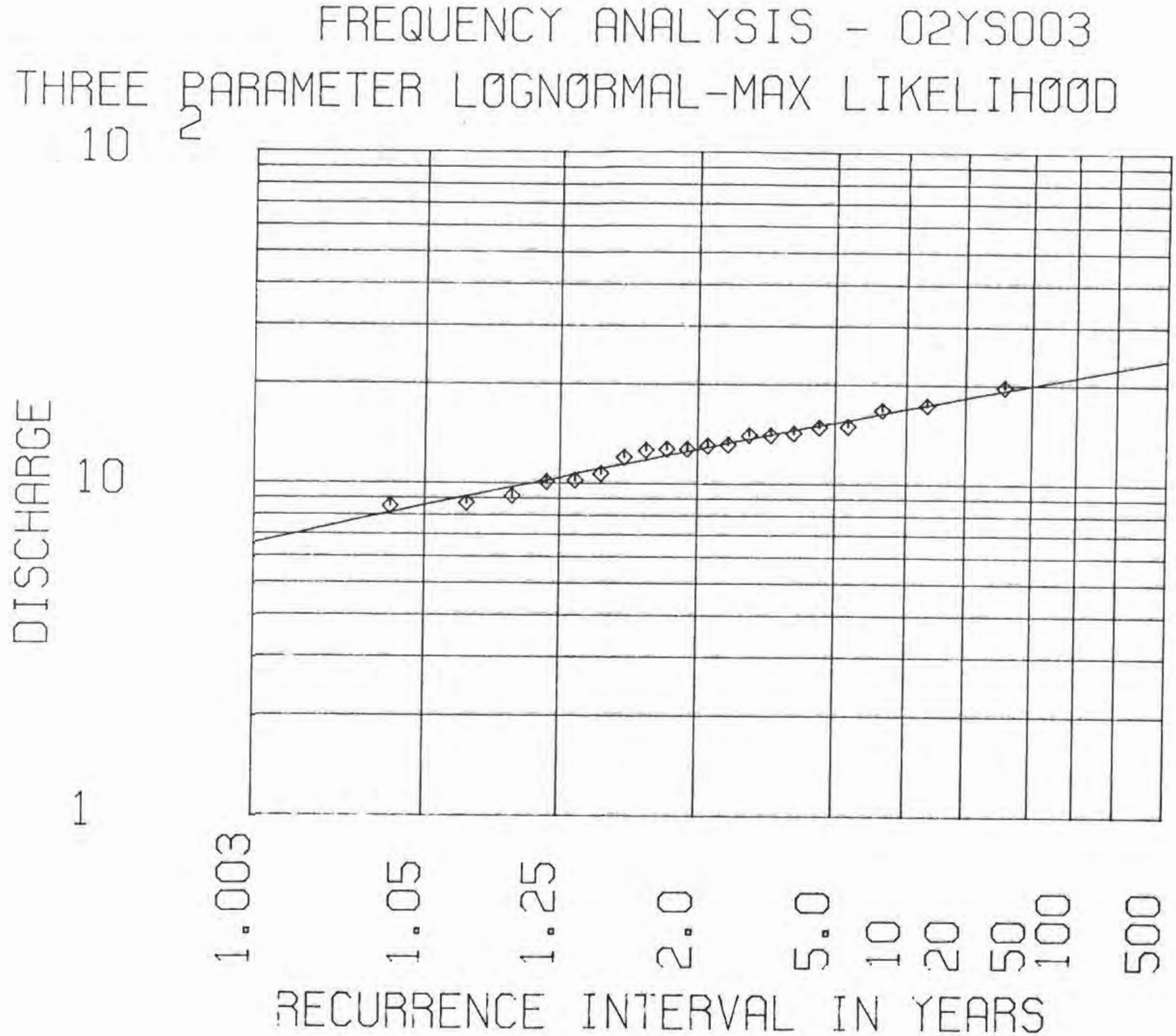
RAGGED HARBOUR RIVER

Graph 1.6



SOUTHERN BAY RIVER

Graph I.7

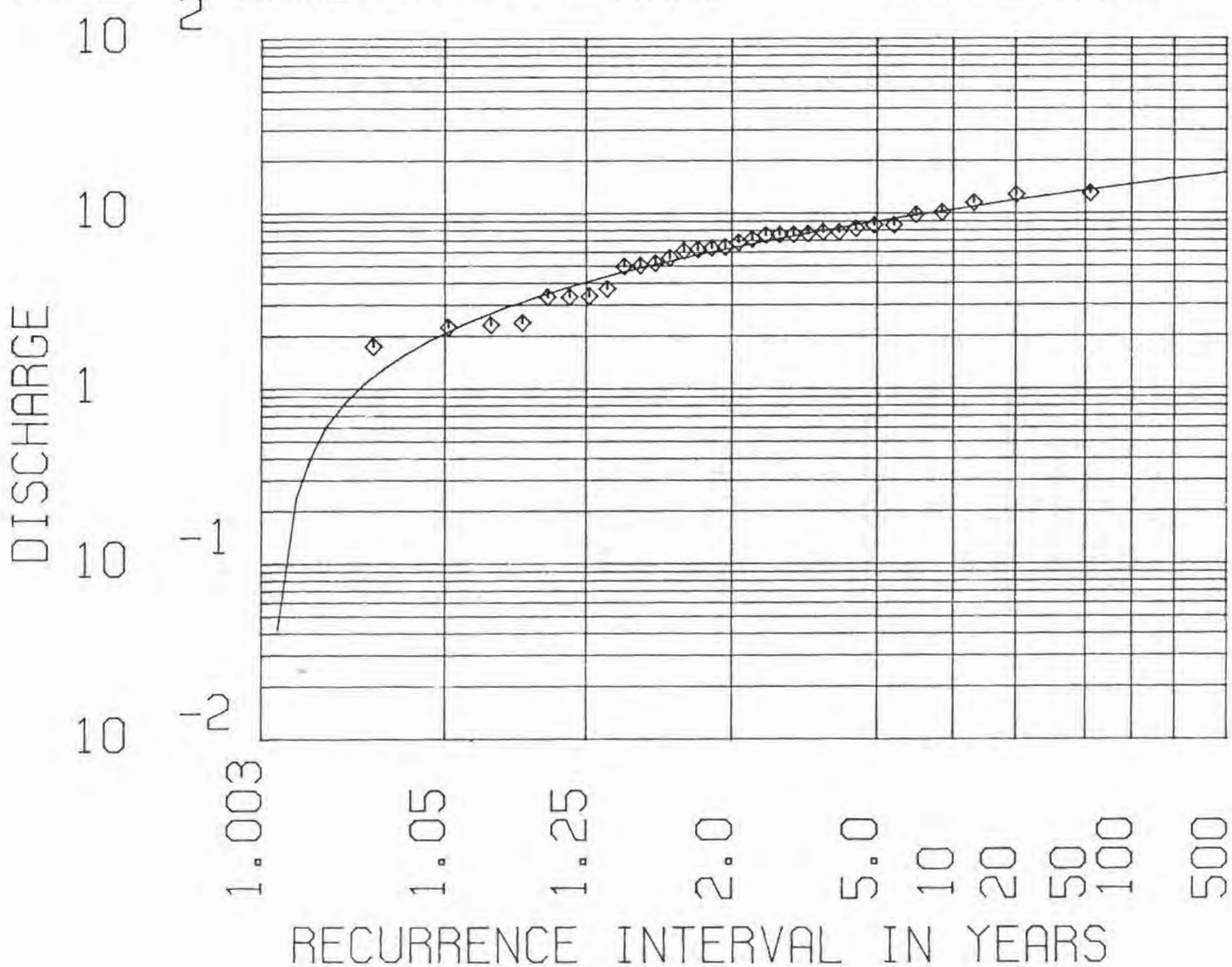


SOUTHWEST BROOK

Graph I.8

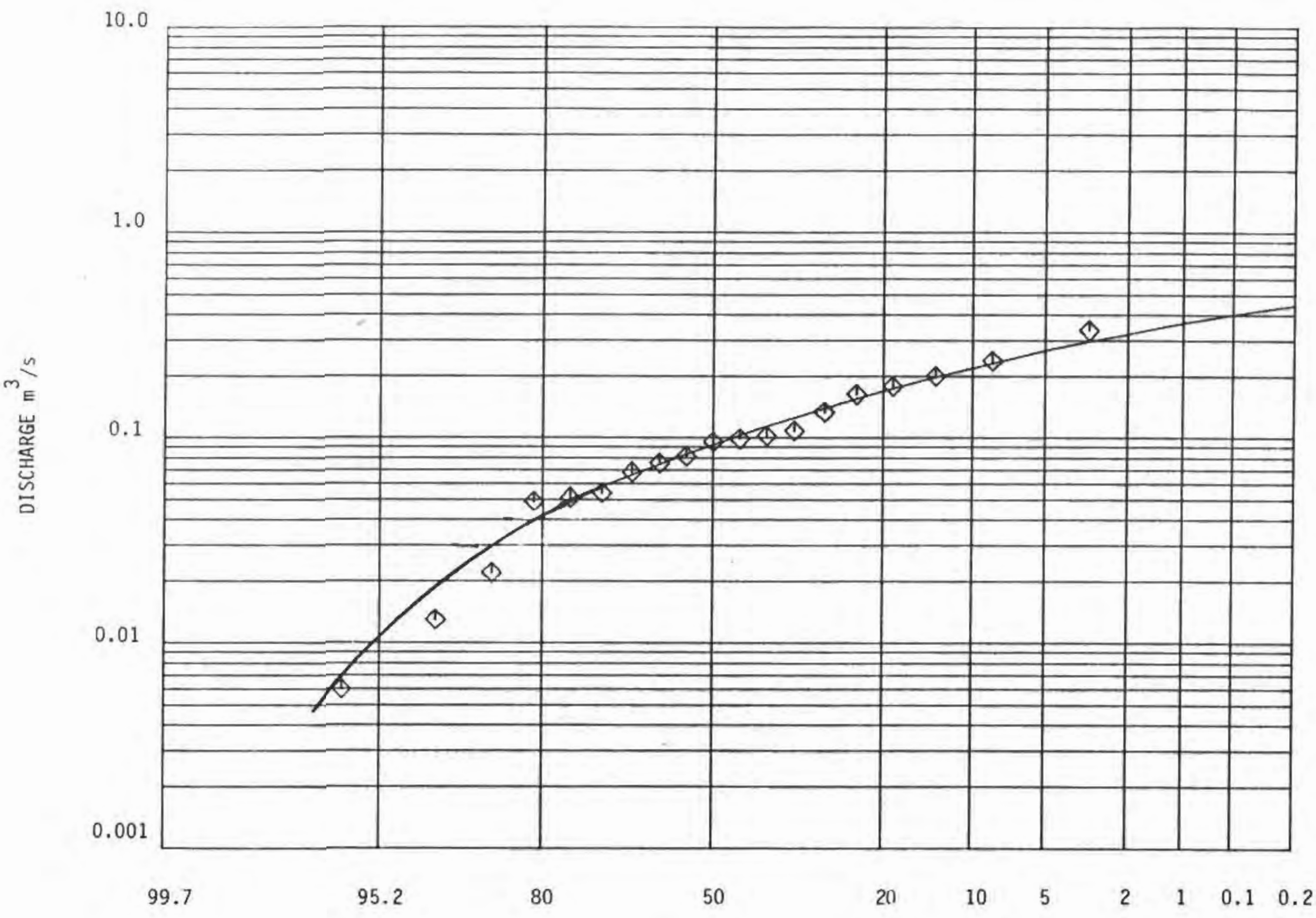
FREQUENCY ANALYSIS - 02YS001

THREE PARAMETER LOGNORMAL-MAX LIKELIHOOD



TERRA NOVA RIVER AT EIGHT MILE BRIDGE

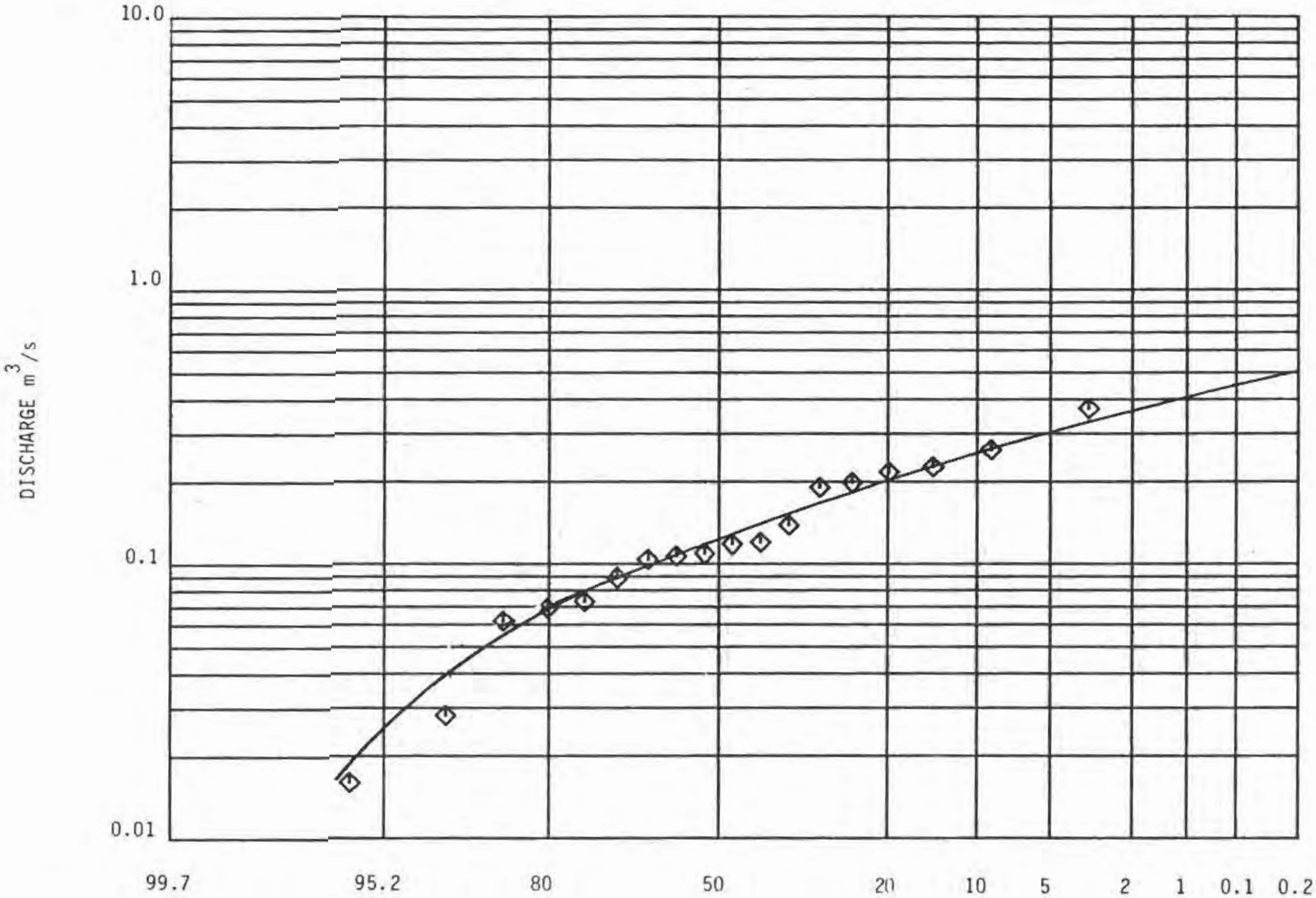
Graph I.9



DAILY LOW FLOW FREQUENCY

COME BY CHANCE RIVER - STATION 02ZH002

Graph I.10

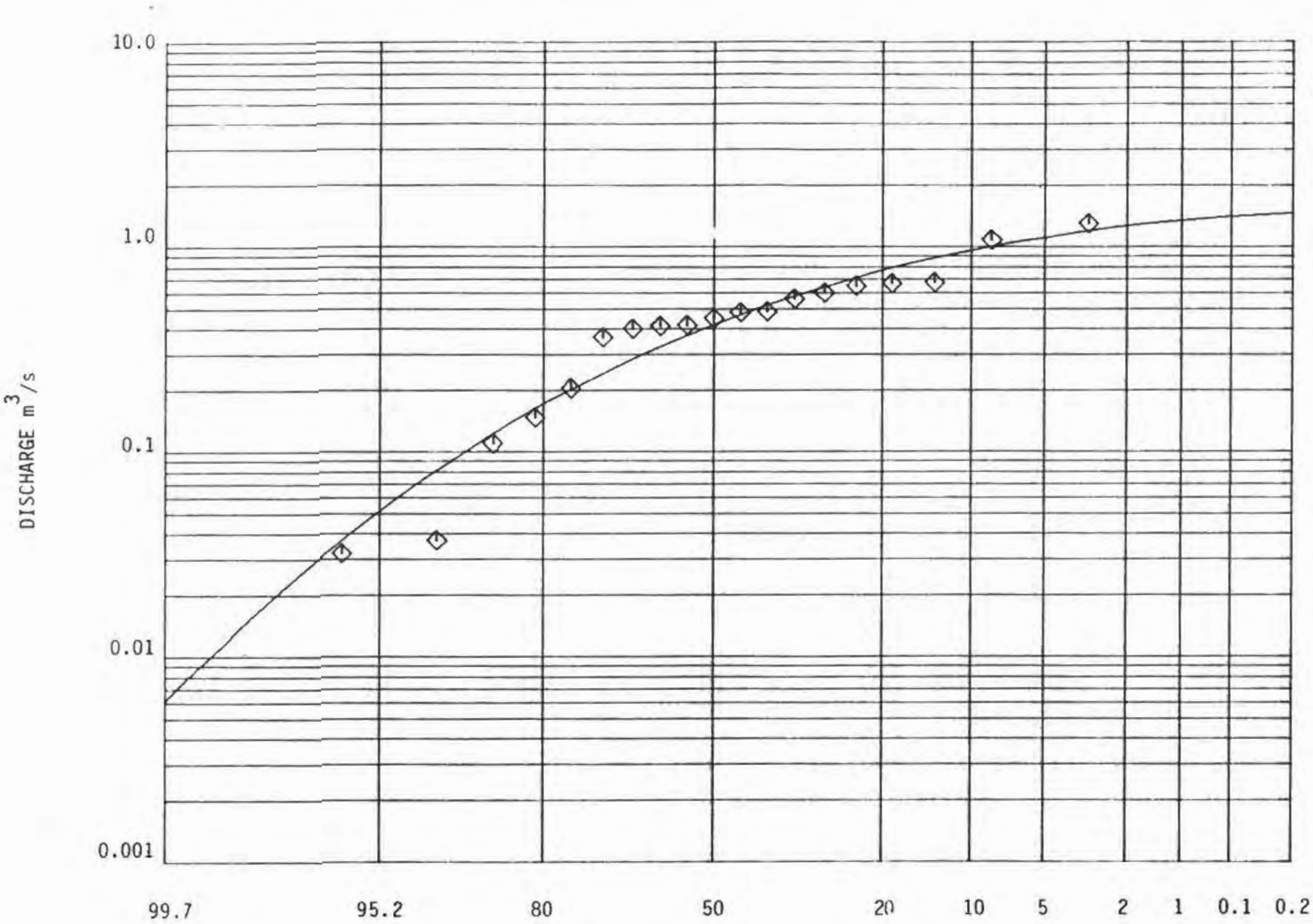


PERCENT EXCEEDED

WEEKLY LOW FLOW FREQUENCY

COME BY CHANCE RIVER NEAR GOOBIES - STATION 02ZH002

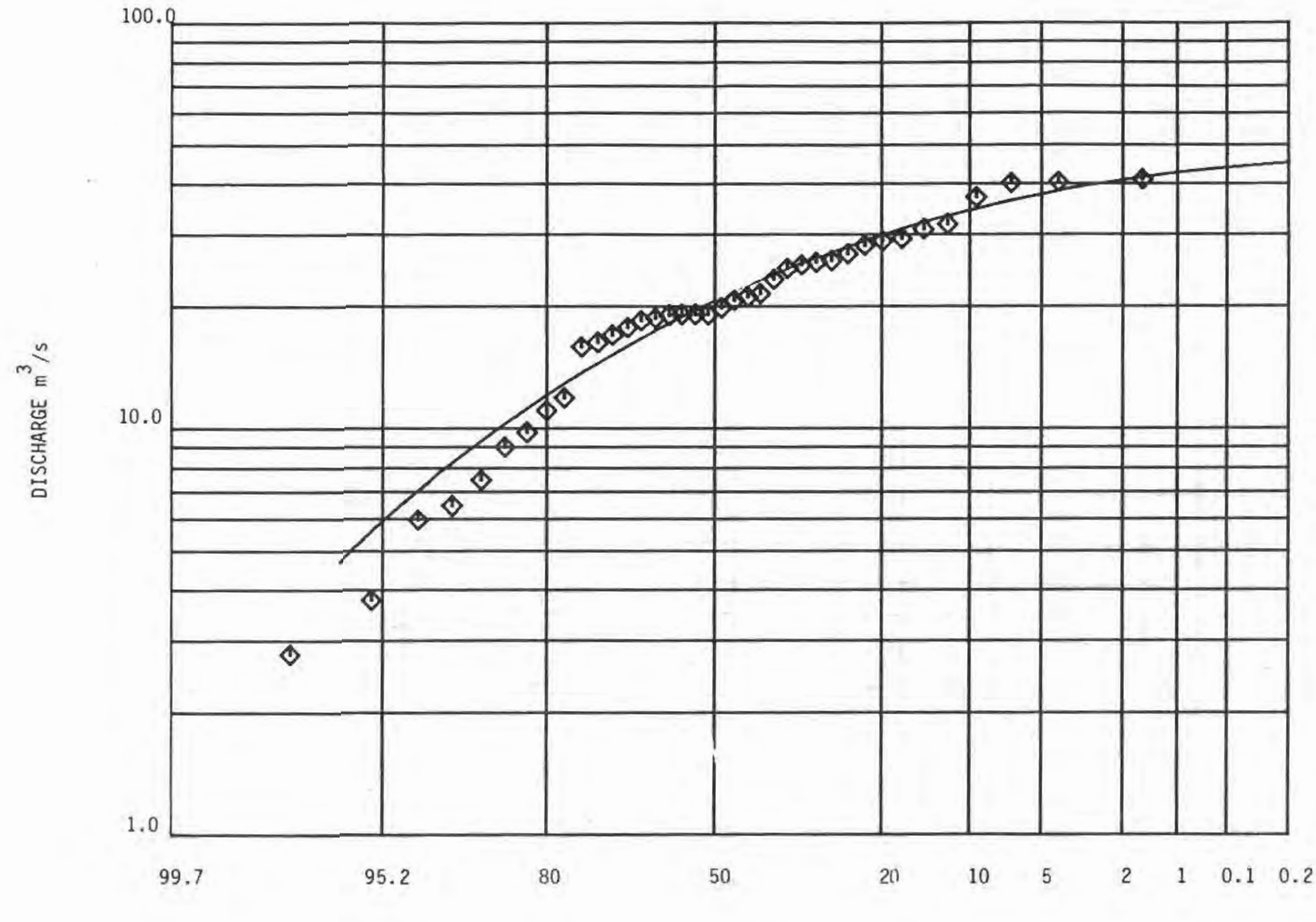
Graph I.11



MONTHLY LOW FLOW FREQUENCY

COME BY CHANGE RIVER - STATION 02ZH002

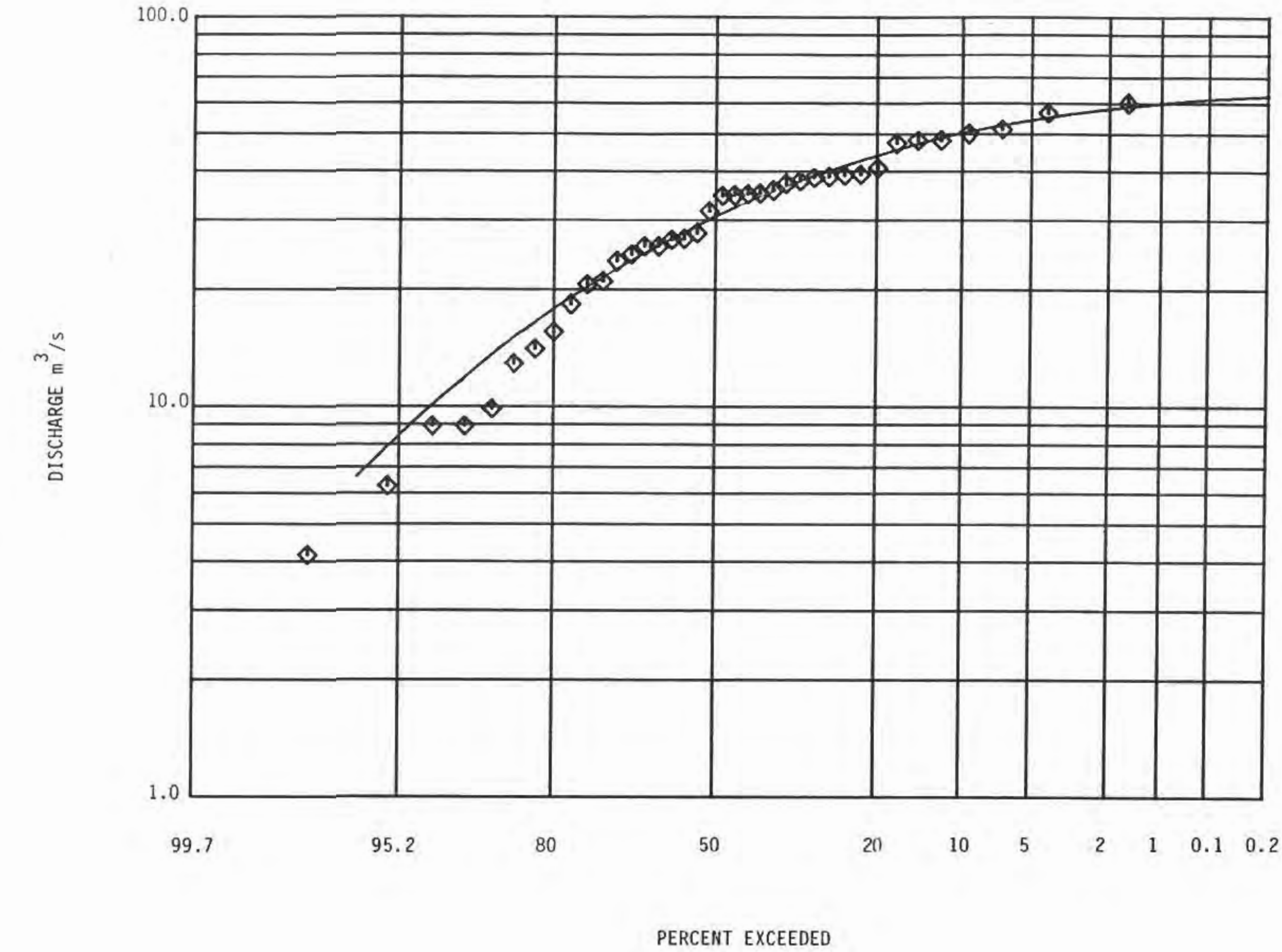
Graph I.12



DAILY LOW FLOW FREQUENCY

GANDER RIVER AT BIG CHUTE - STATION 02YQ001

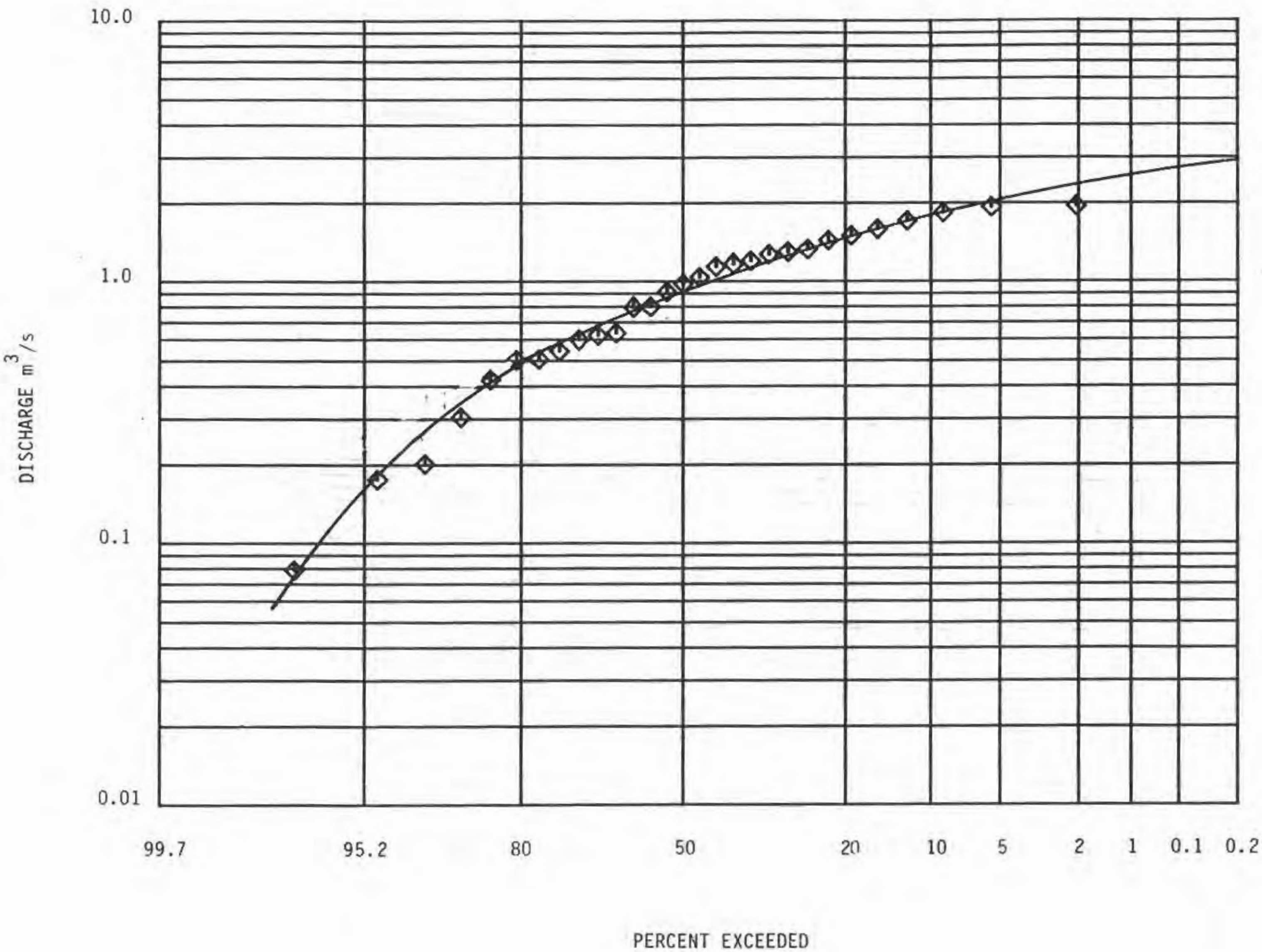
Graph I.13



MONTHLY LOW FLOW FREQUENCY

GANDER RIVER AT BIG CHUTE - STATION 02YQ001

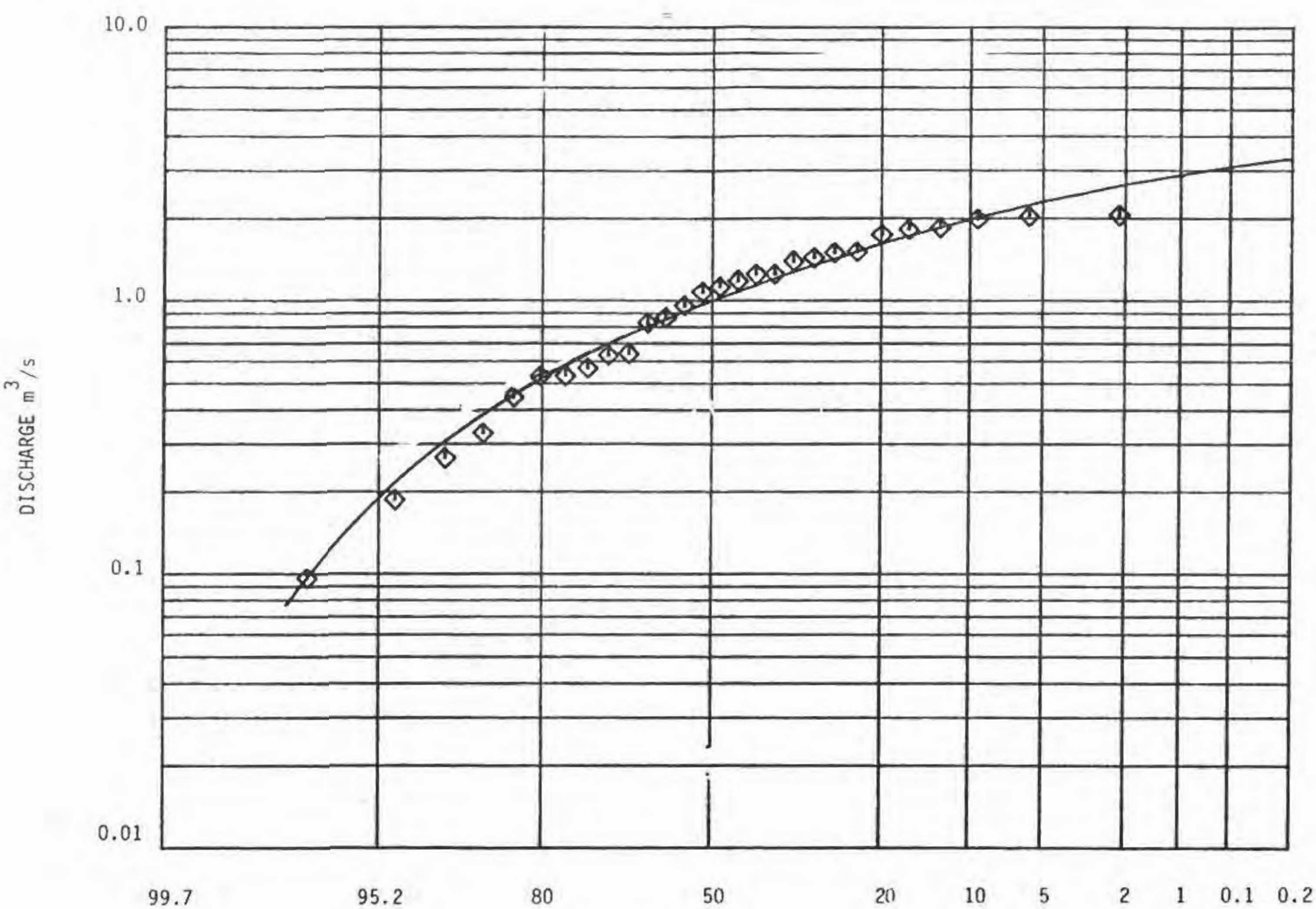
Graph I.14



DAILY LOW FLOW FREQUENCY

MIDDLE BROOK NEAR GAMBO - STATION 02YR001

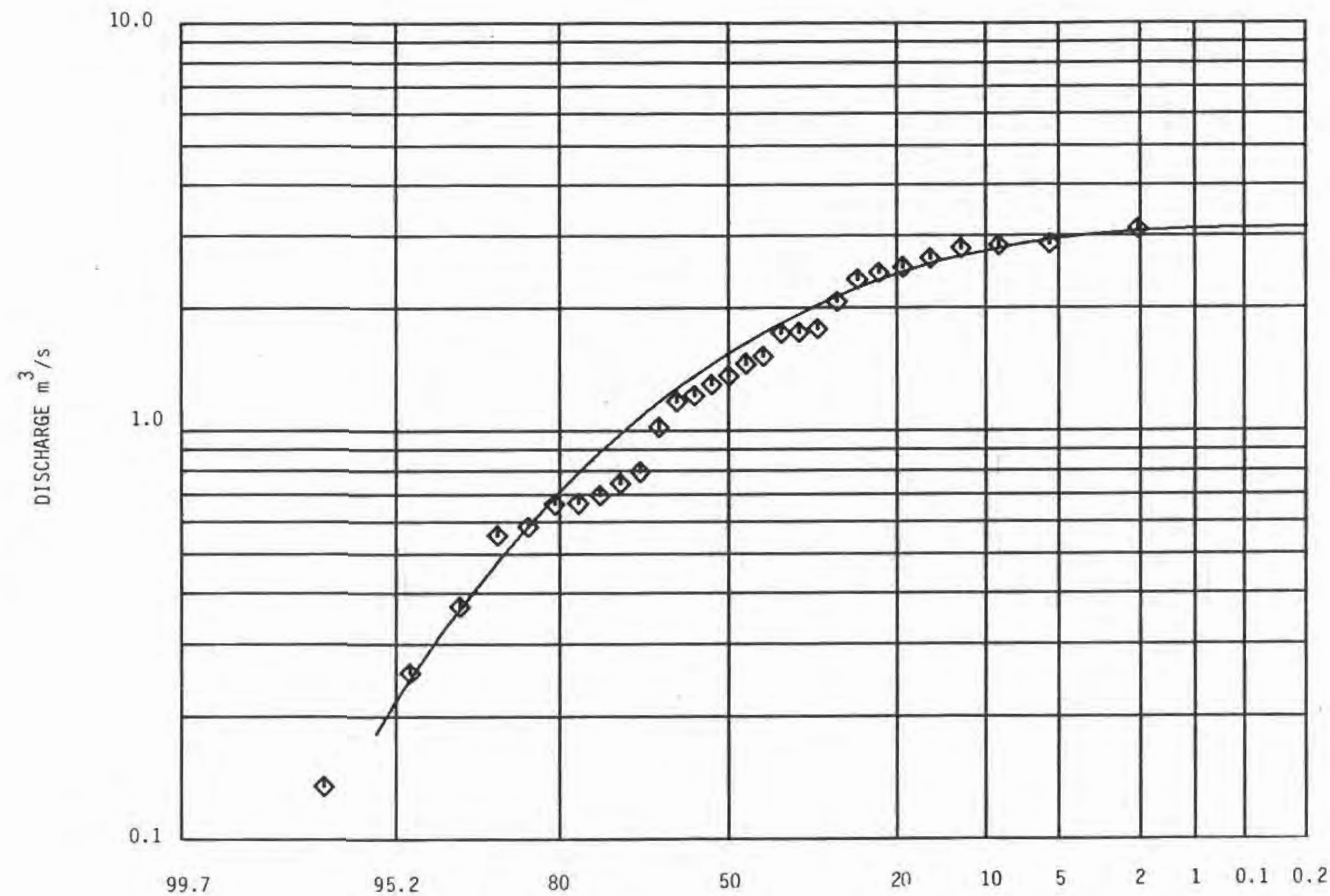
Graph I.15



WEEKLY LOW FLOW FREQUENCY

MIDDLE BROOK NEAR GAMBO - STATION 02YR001

Graph I.16

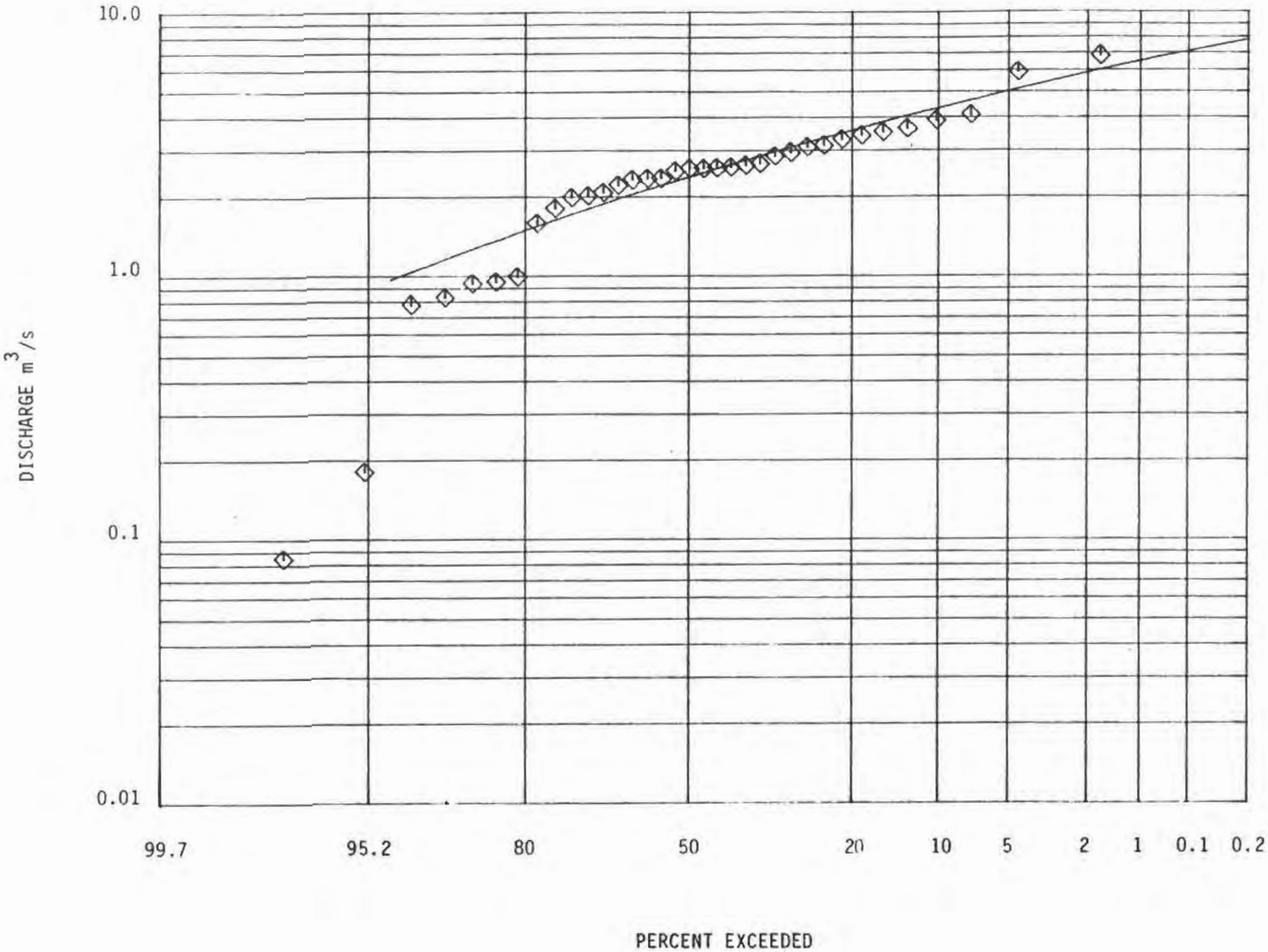


PERCENT EXCEEDED

MONTHLY LOW FLOW FREQUENCY

MIDDLE BROOK NEAR GAMBO - STATION 02YR001

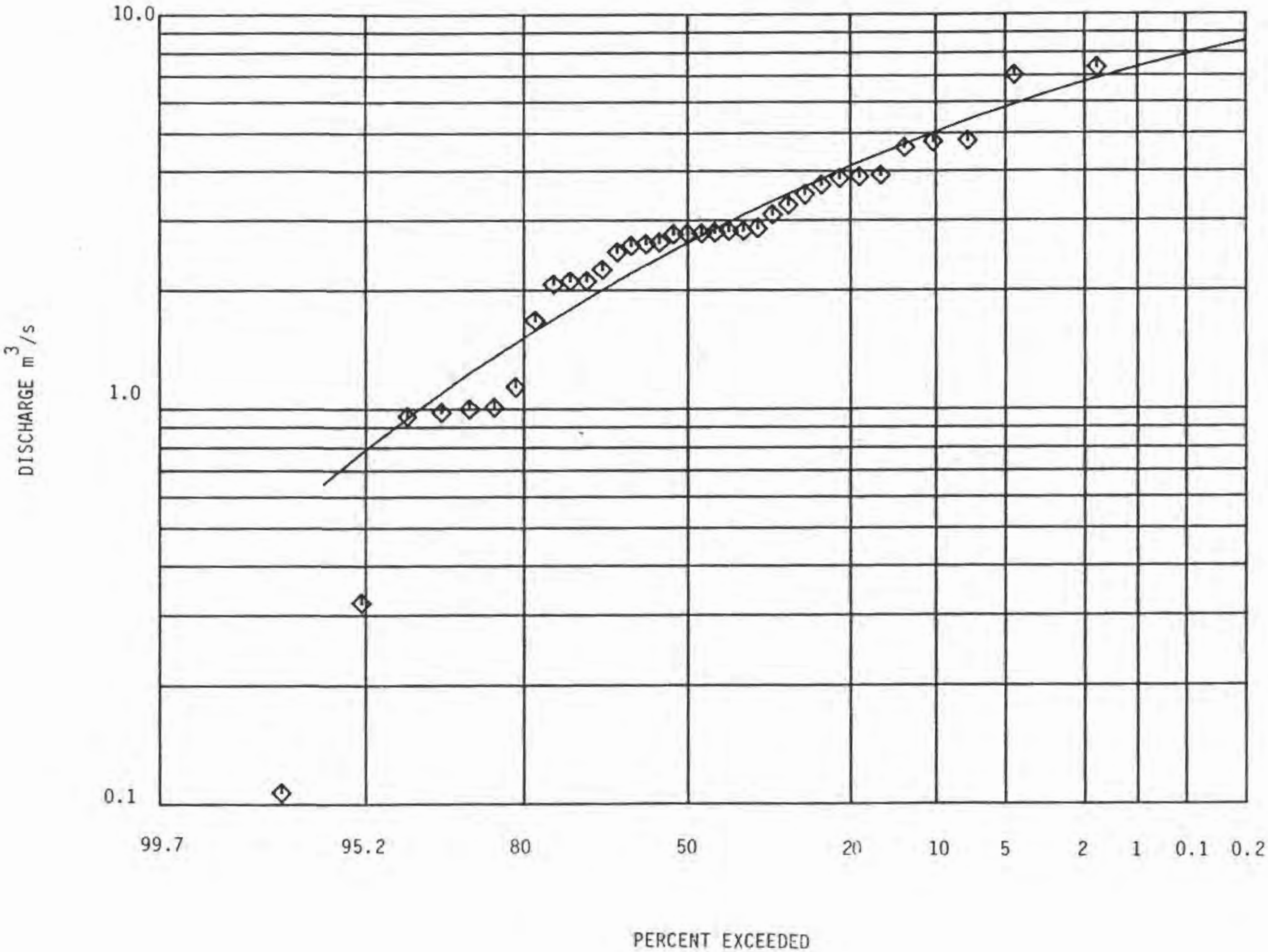
Graph 1.17



DAILY LOW FLOW FREQUENCY

PIPERS HOLE RIVER - STATION 02ZH001

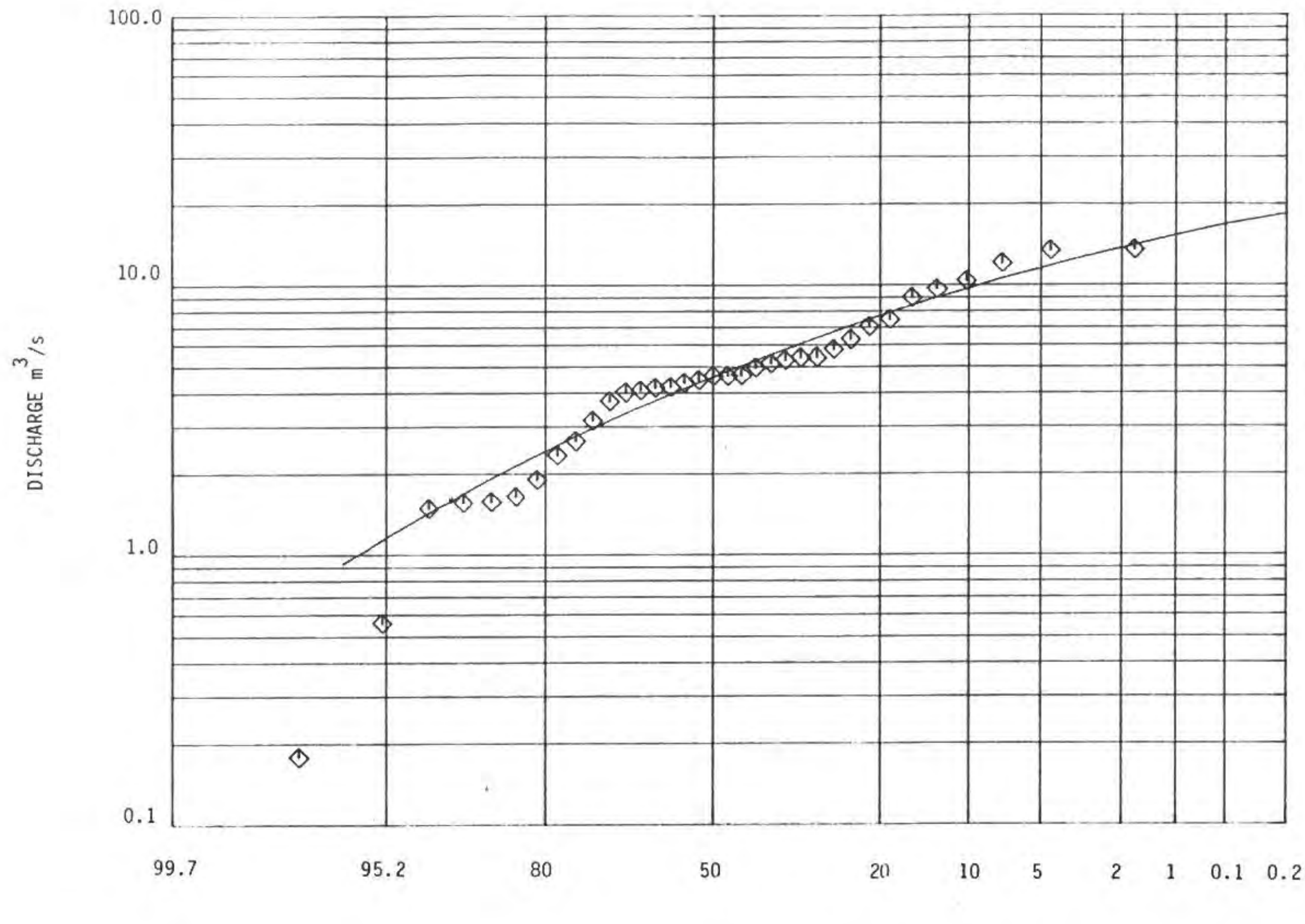
Table I.18



WEEKLY LOW FLOW FREQUENCY

PIPERS HOLE RIVER - STATION 02ZH001

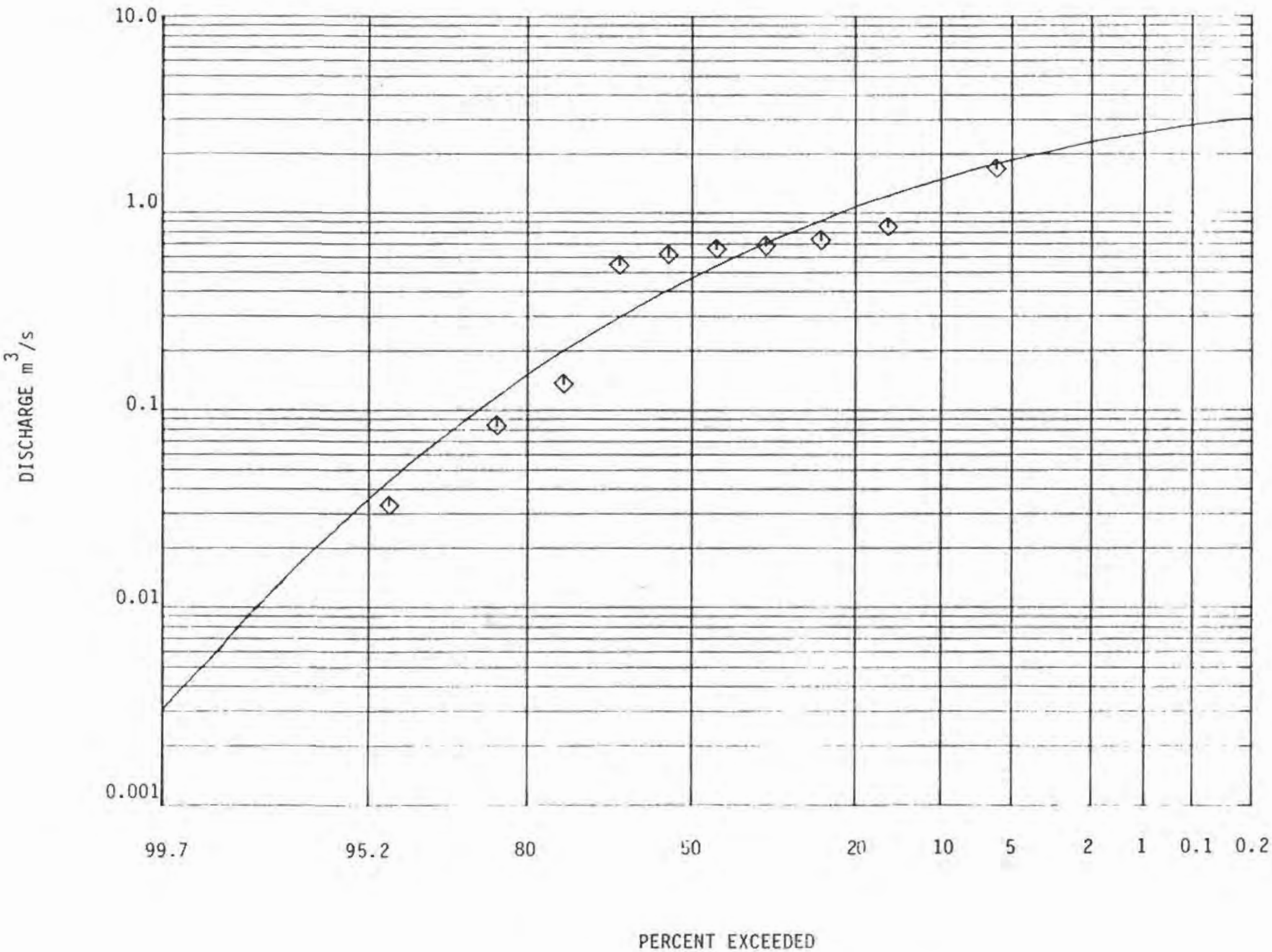
Graph I.19



MONTHLY LOW FLOW FREQUENCY

PIPERS HOLE RIVER - STATION 02ZH001

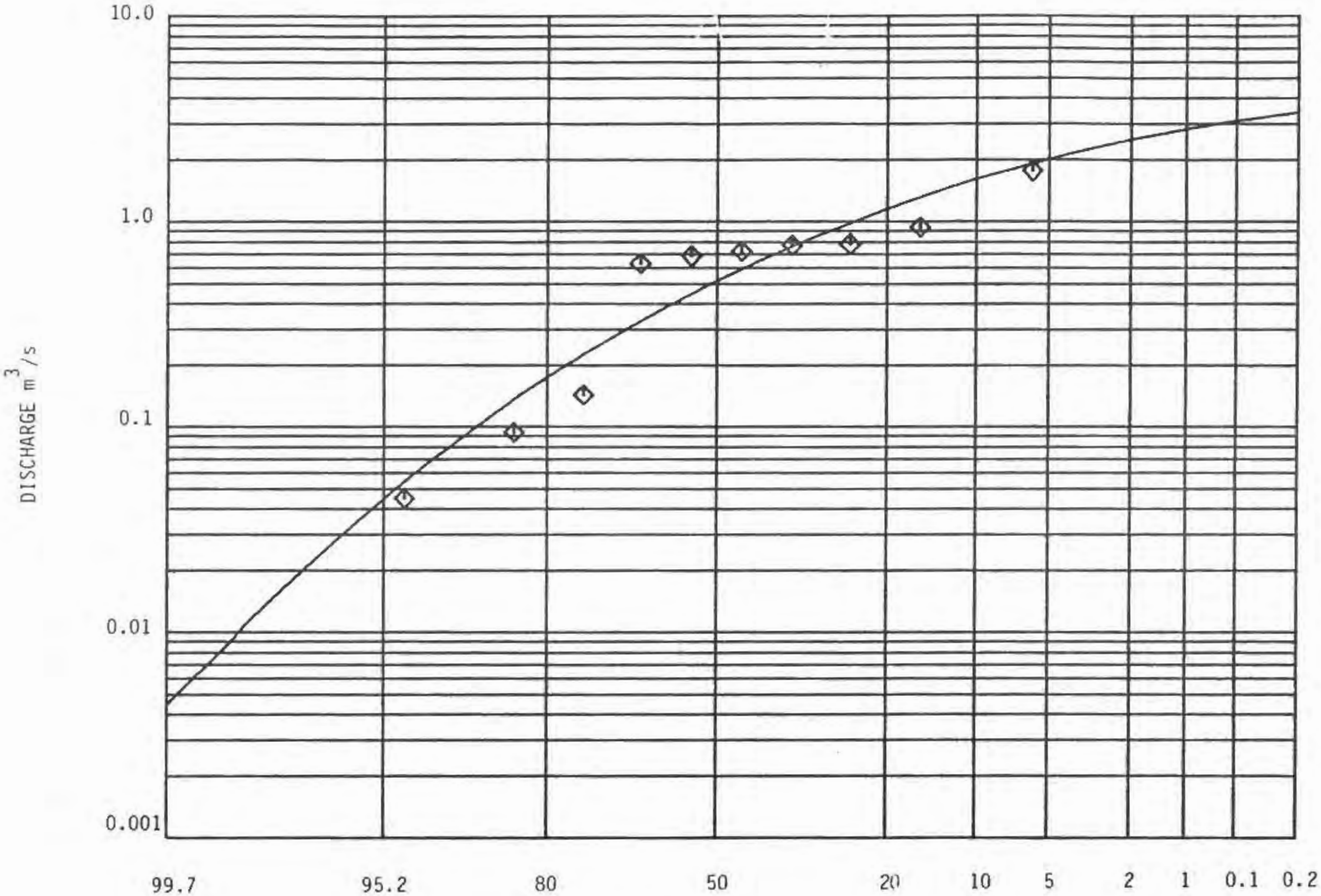
Graph I.20



DAILY LOW FLOW FREQUENCY

RAGGED HARBOUR RIVER - STATION 02YR002

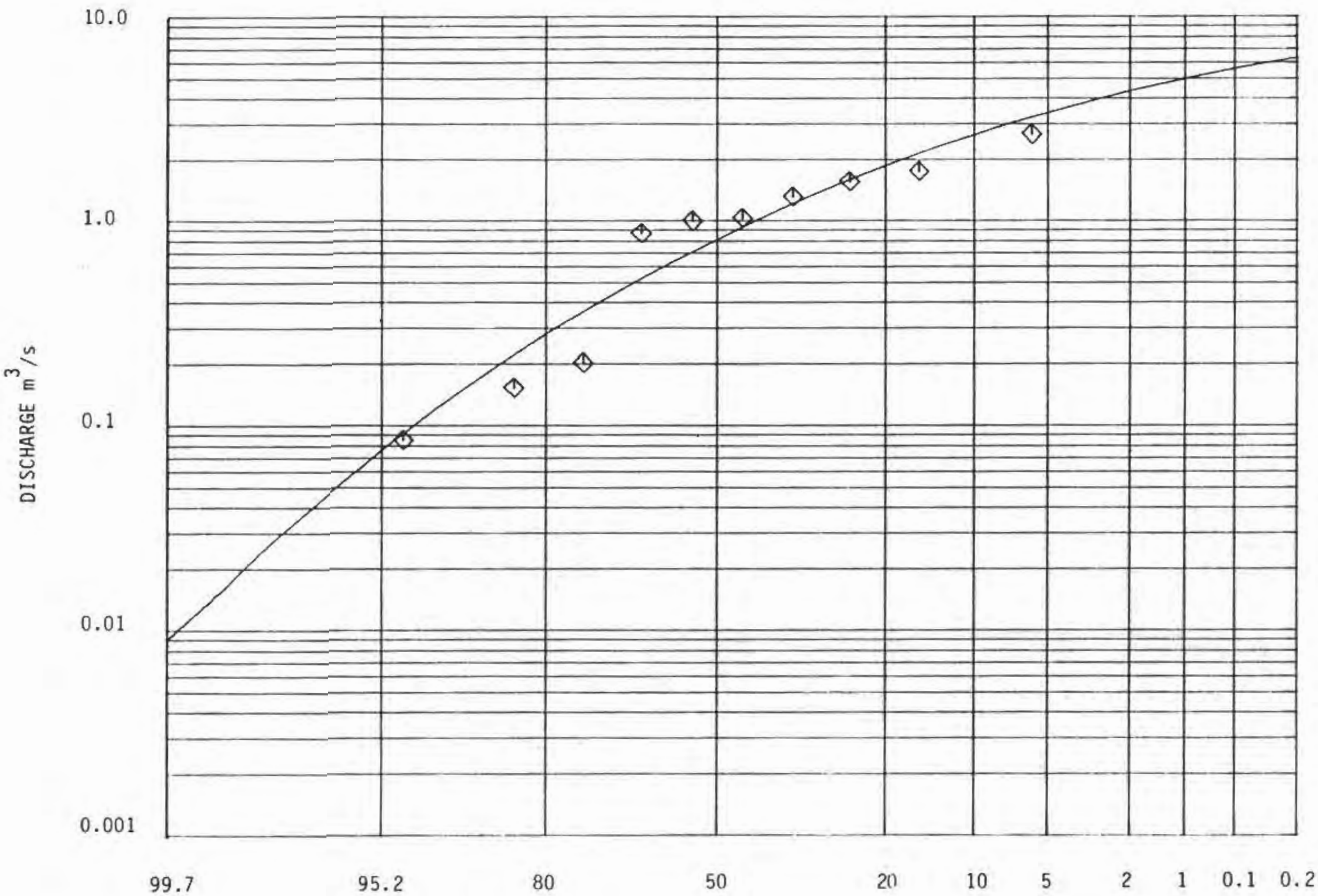
Graph I.21



WEEKLY LOW FLOW FREQUENCY

RAGGED HARBOUR RIVER - STATION 02YR002

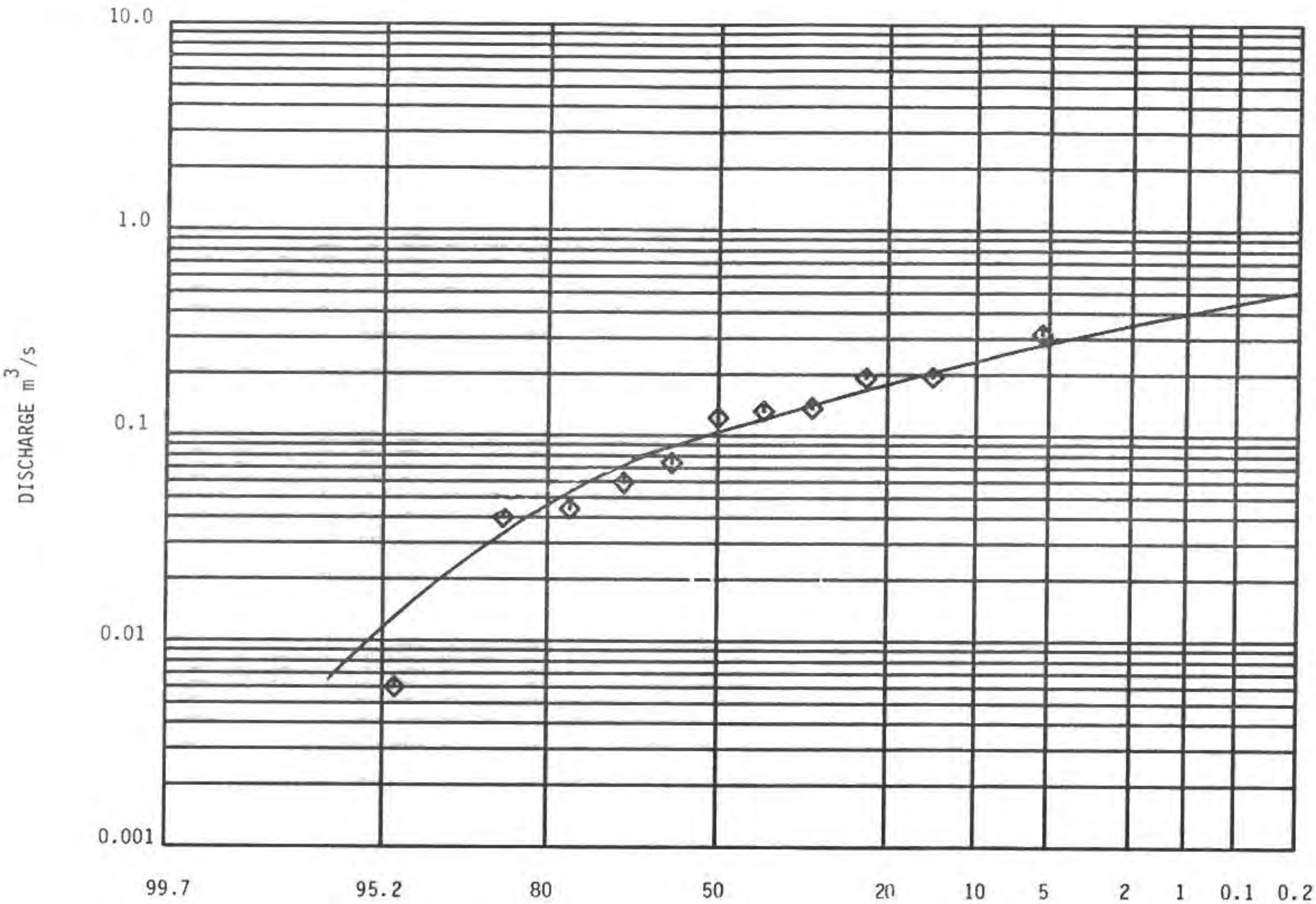
Graph I.22



MONTHLY LOW FLOW FREQUENCY

RAGGED HARBOUR RIVER - STATION 02YR002

Graph I.23

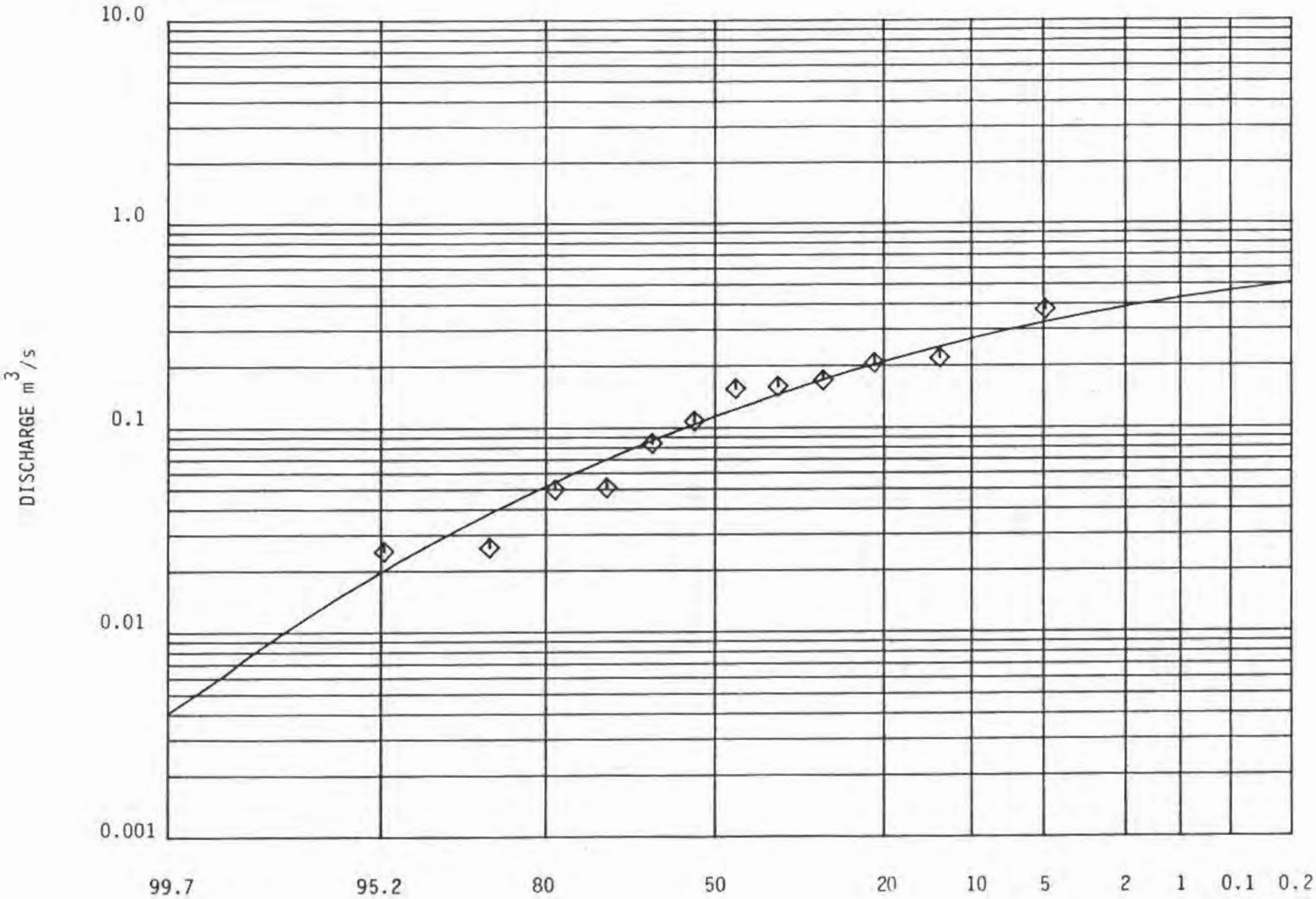


PERCENT EXCEEDED

DAILY LOW FLOW FREQUENCY

SOUTHERN BAY RIVER NEAR SOUTHERN BAY - STATION 02ZJ001

Graph I.24

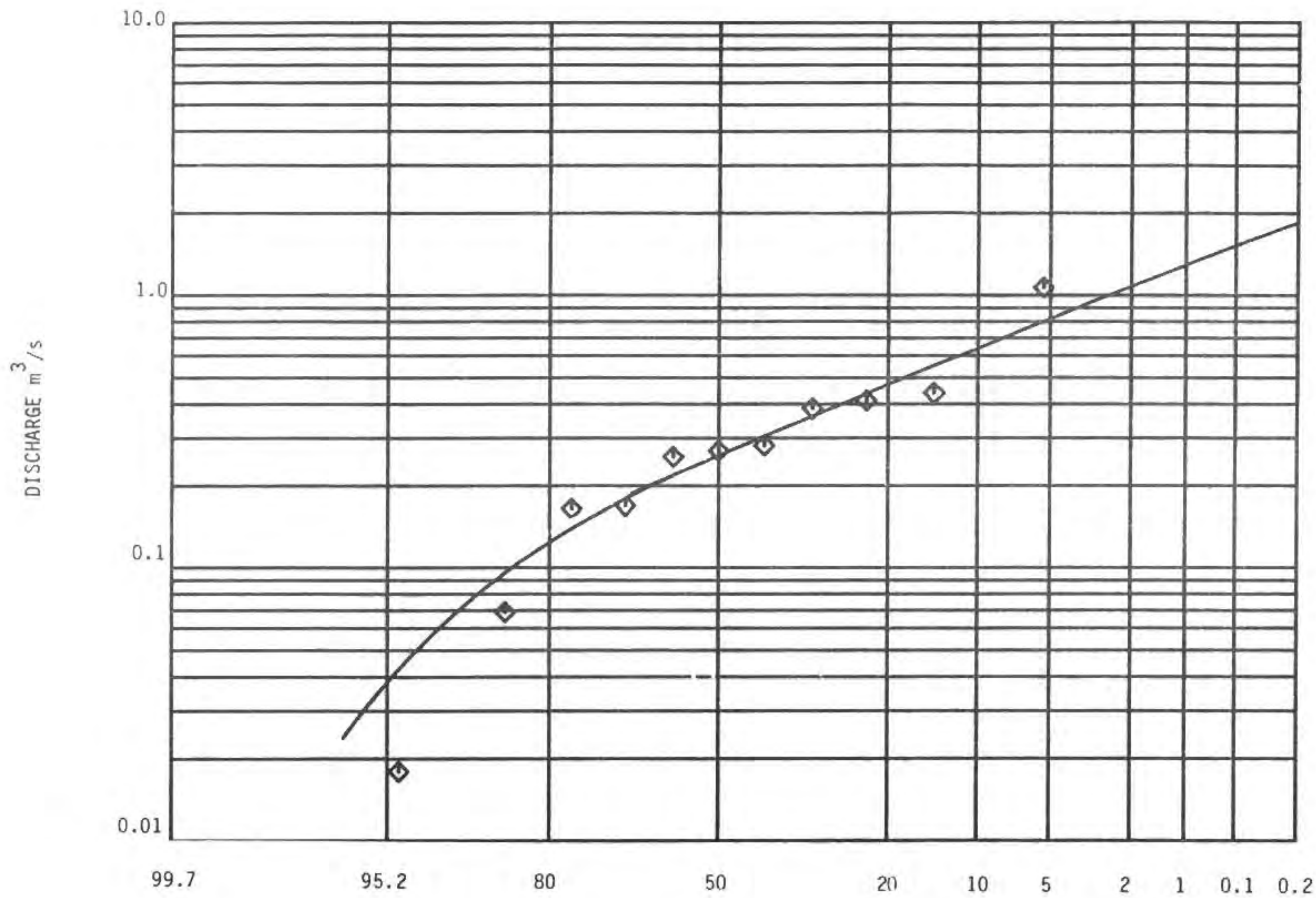


PERCENT EXCEEDED

WEEKLY LOW FLOW FREQUENCY

SOUTHERN BAY RIVER NEAR SOUTHERN BAY - STATION 02ZJ001

Graph I.25

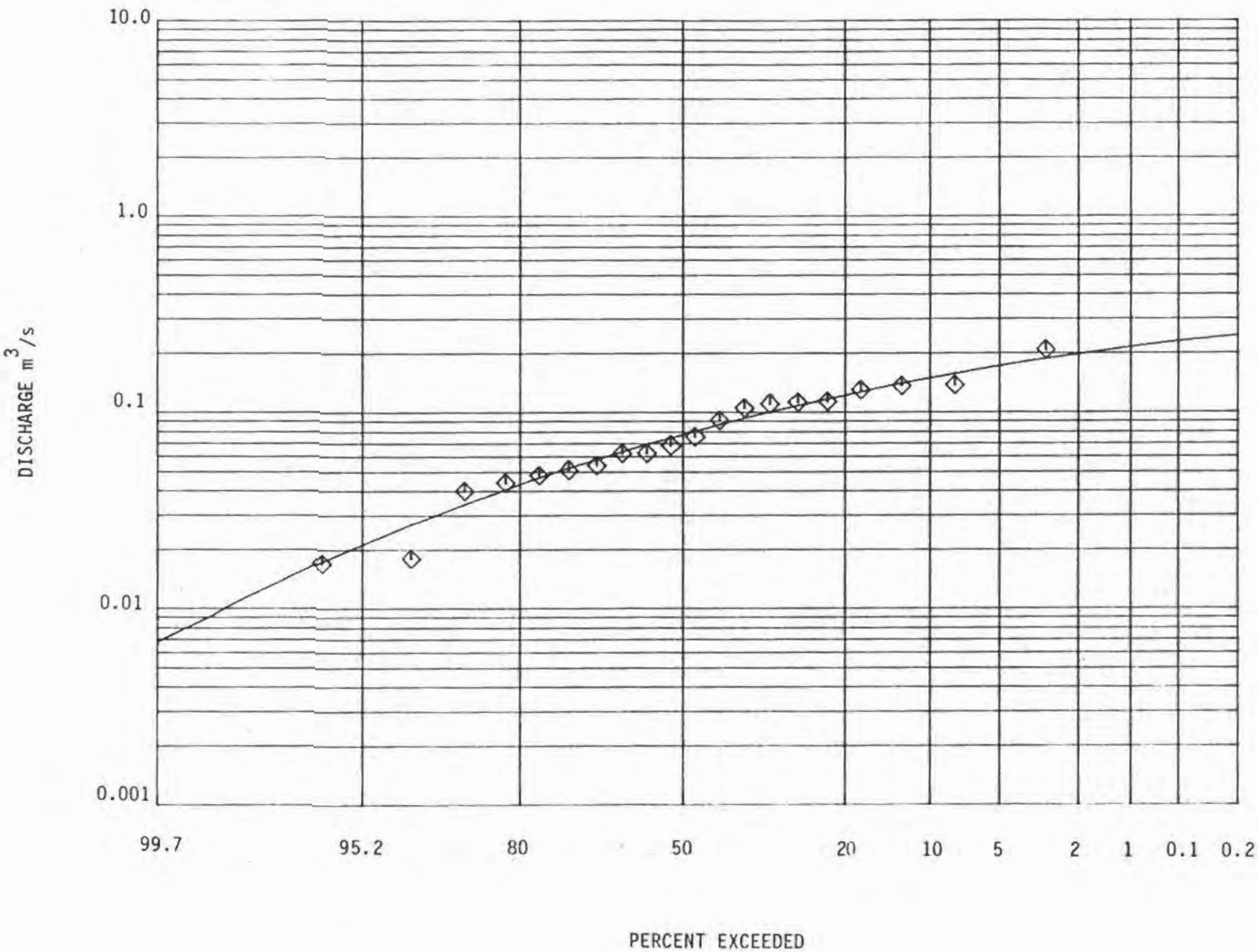


PERCENT EXCEEDED

MONTHLY LOW FLOW FREQUENCY

SOUTHERN BAY RIVER NEAR SOUTHERN BAY - STATION 02ZJ001

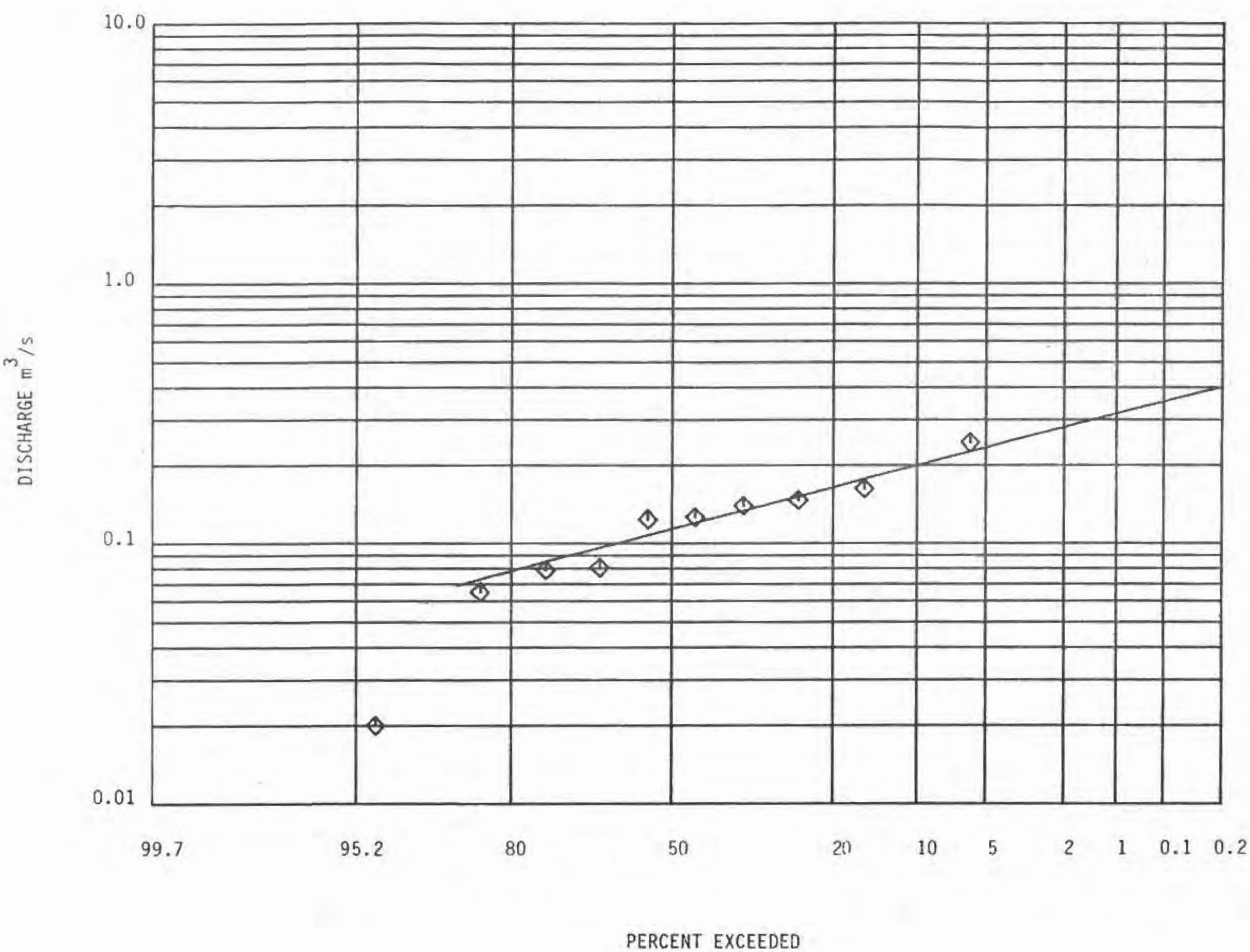
Graph 1.26



DAILY LOW FLOW FREQUENCY

SOUTHWEST BROOK AT TERRA NOVA NATIONAL PARK - STATION 02YS003

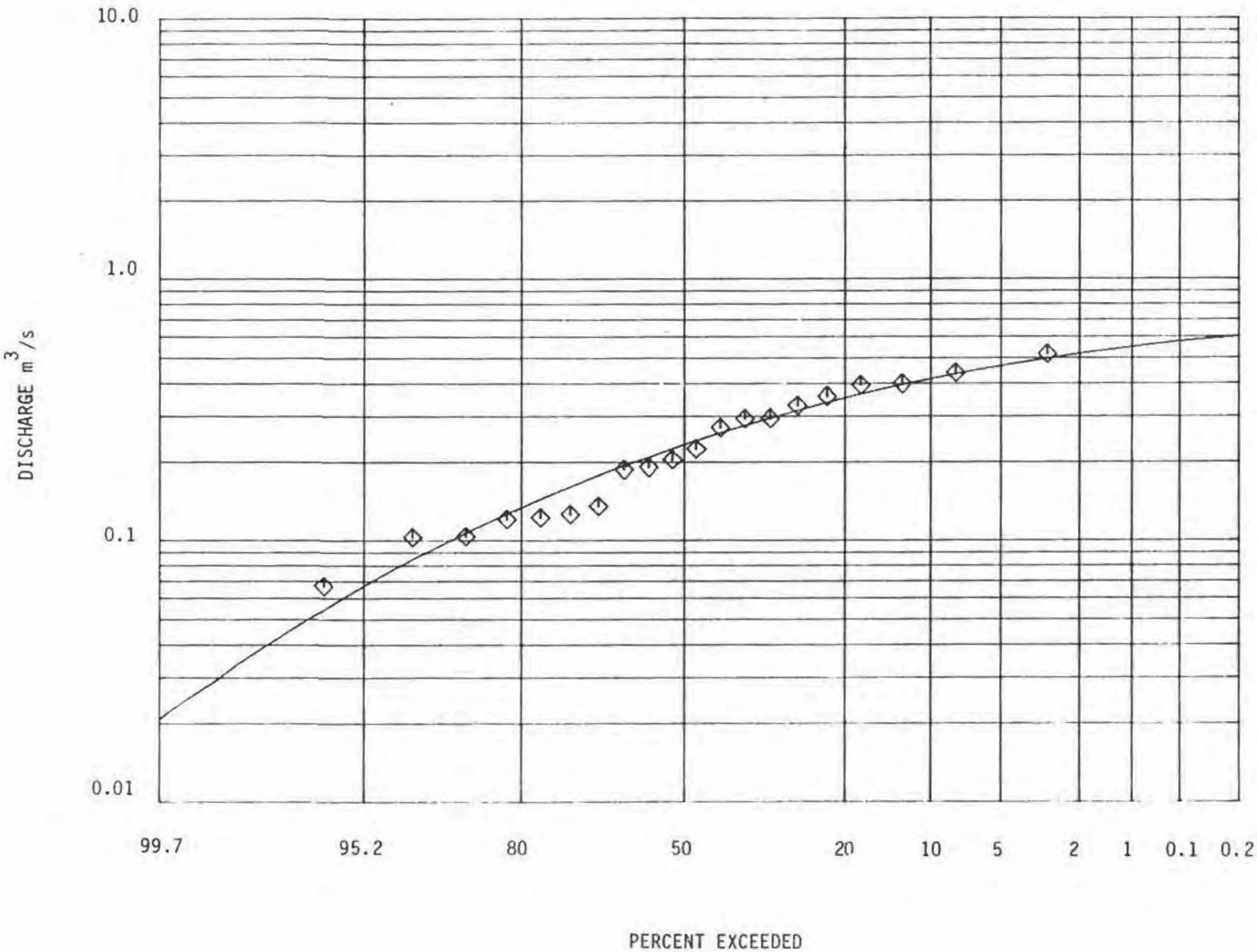
Graph I.27



WEEKLY LOW FLOW FREQUENCY

SOUTHWEST BROOK AT TERRA NOVA NATIONAL PARK - STATION 02YS003

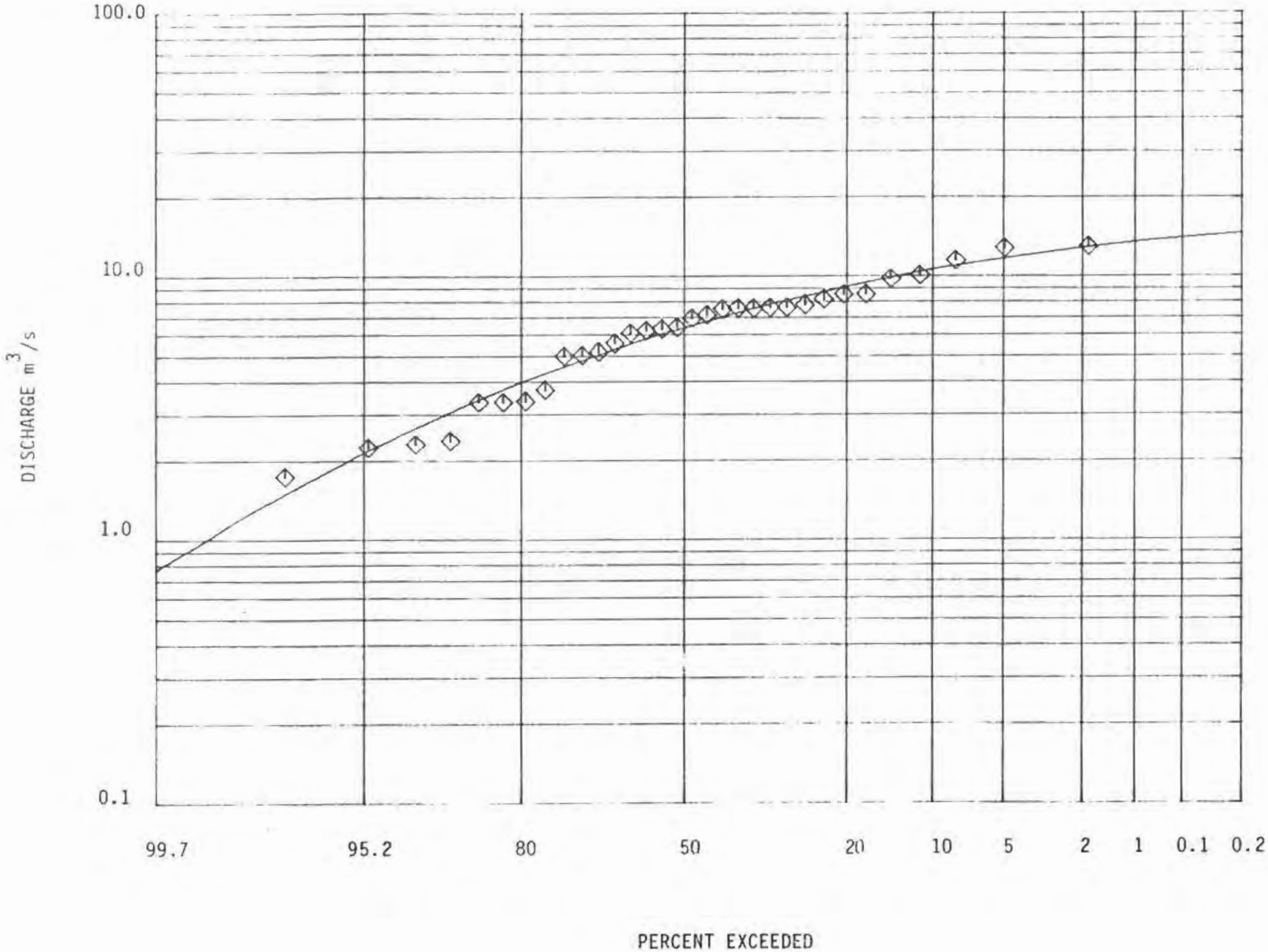
Graph I.28



MONTHLY LOW FLOW FREQUENCY

SOUTHWEST BROOK AT TERRA NOVA NATIONAL PARK - STATION 02YS003

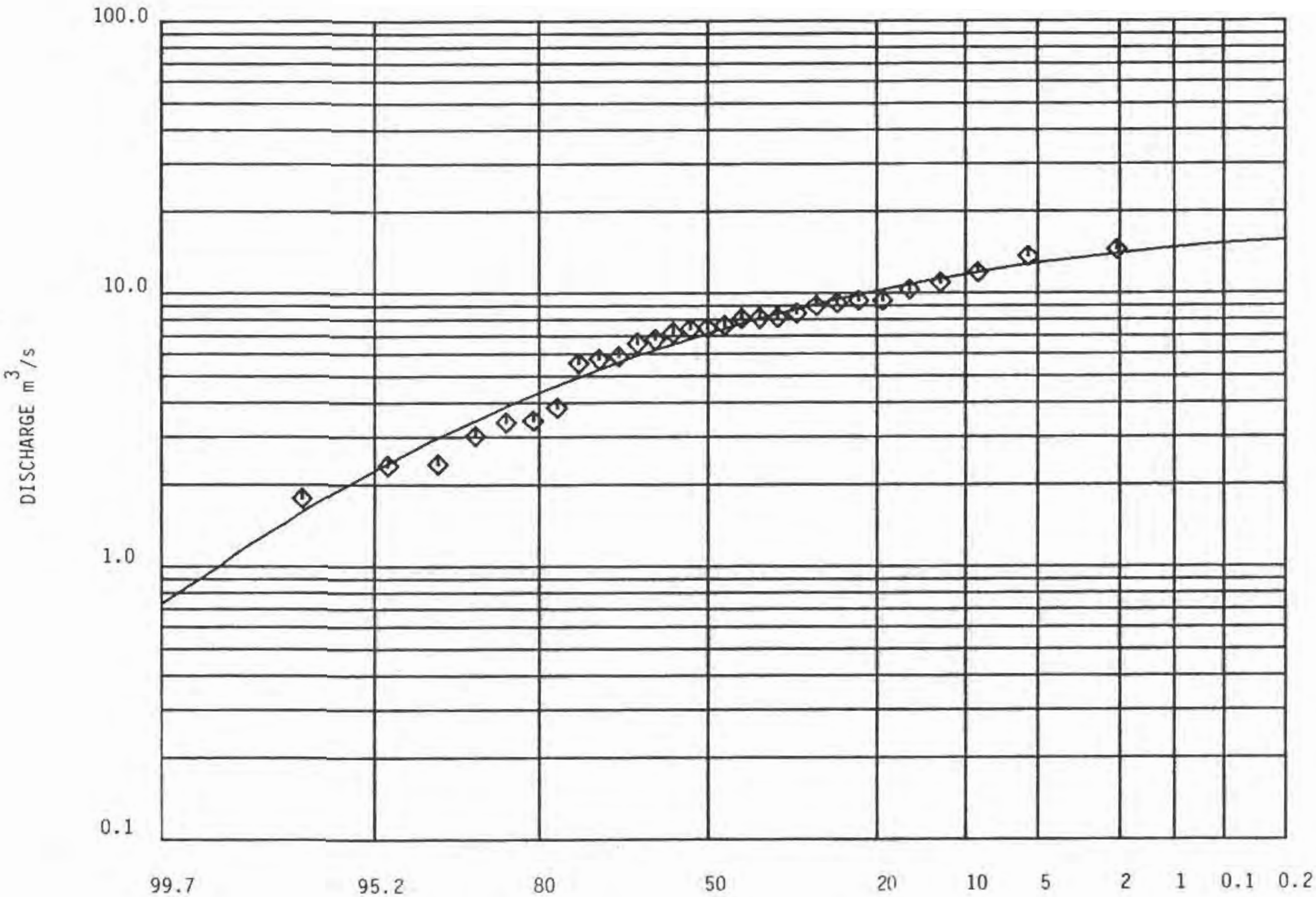
Graph I.29



DAILY LOW FLOW FREQUENCY

TERRA NOVA RIVER AT EIGHT MILE BRIDGES - STATION 02YS001

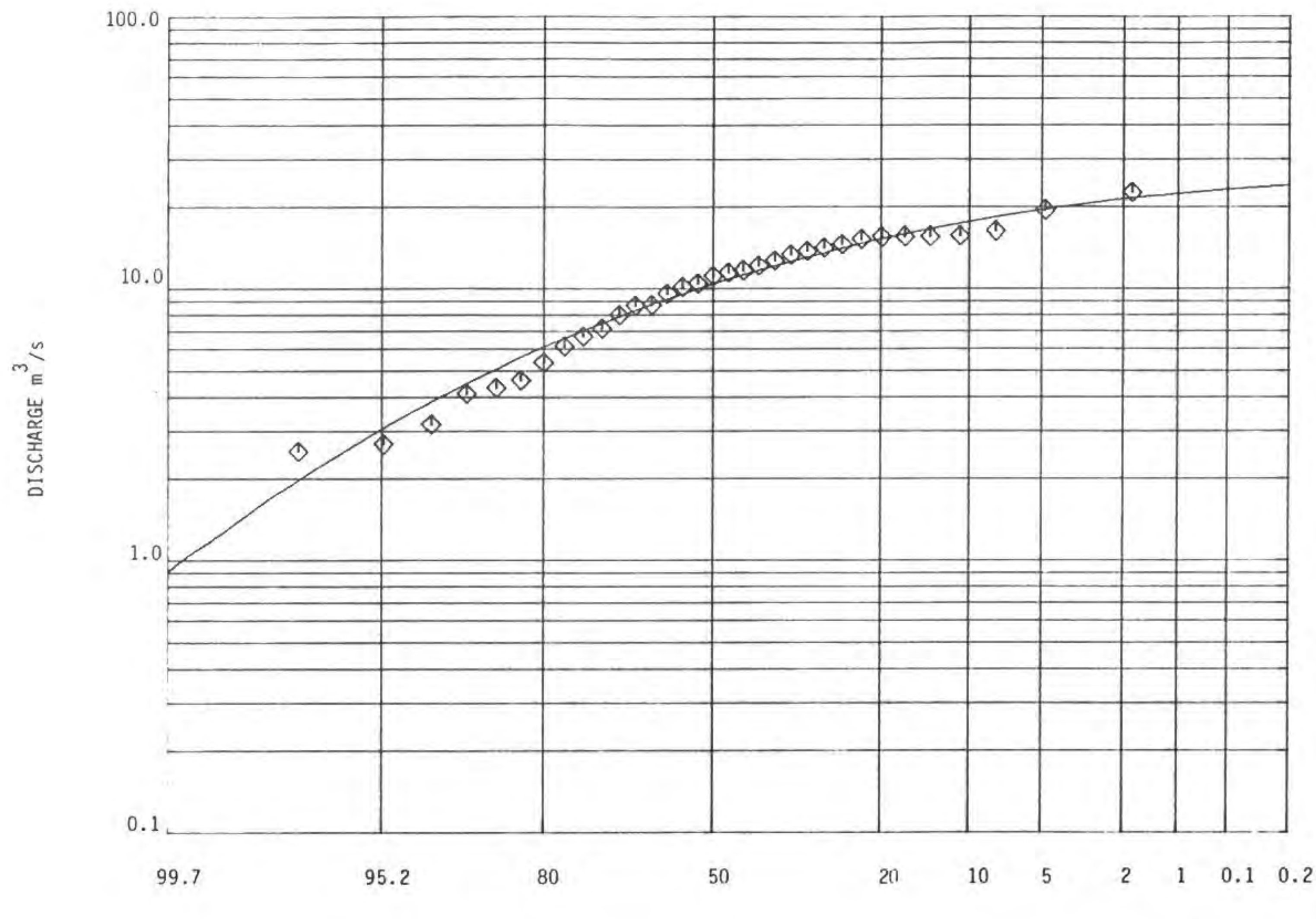
Graph I.30



WEEKLY LOW FLOW FREQUENCY

TERRA NOVA RIVER AT EIGHT MILE BRIDGES - STATION 02YS001

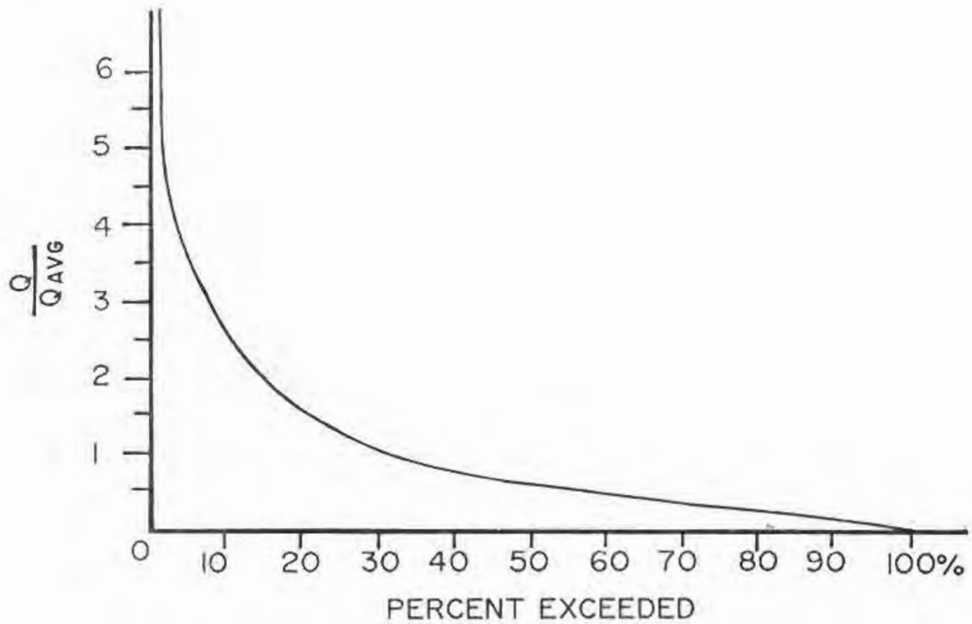
Graph I.31



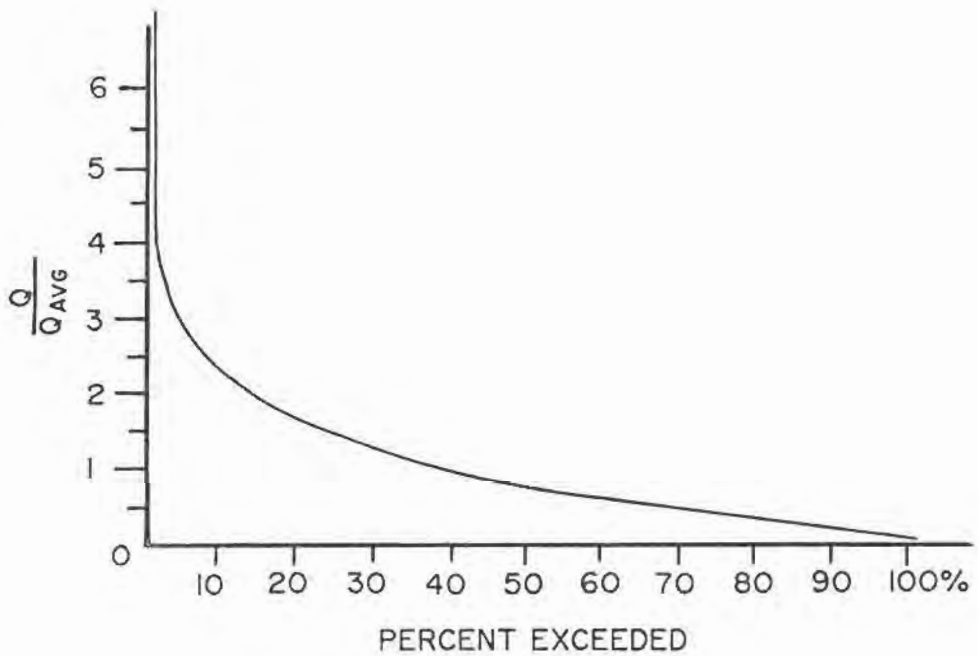
MONTHLY LOW FLOW FREQUENCY

TERRA NOVA RIVER AT EIGHT MILE BRIDGE - STATION 02YS001

Graph I.32



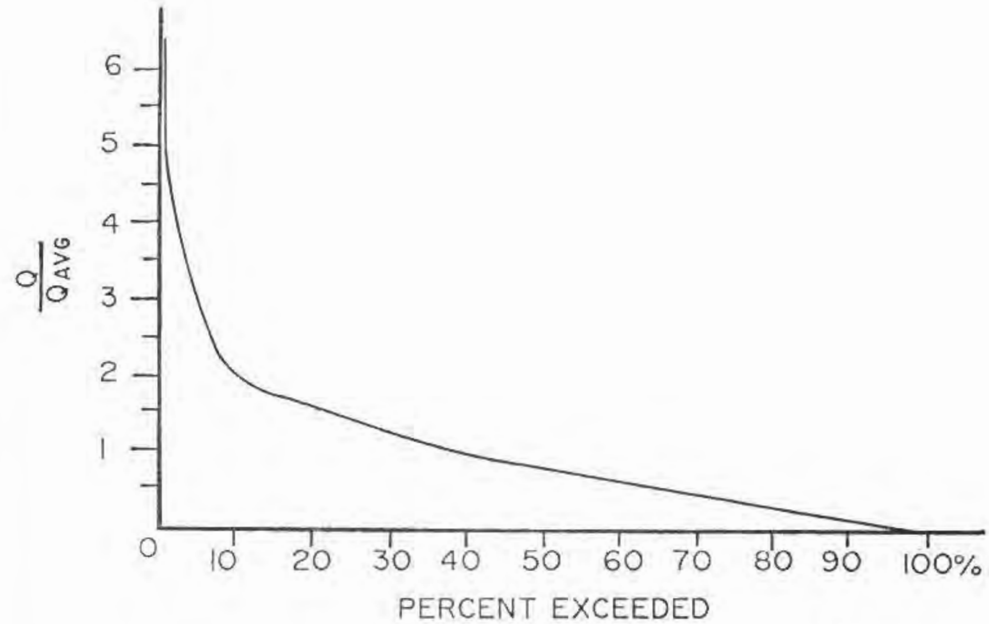
COME-BY-CHANCE RIVER (02ZH002)



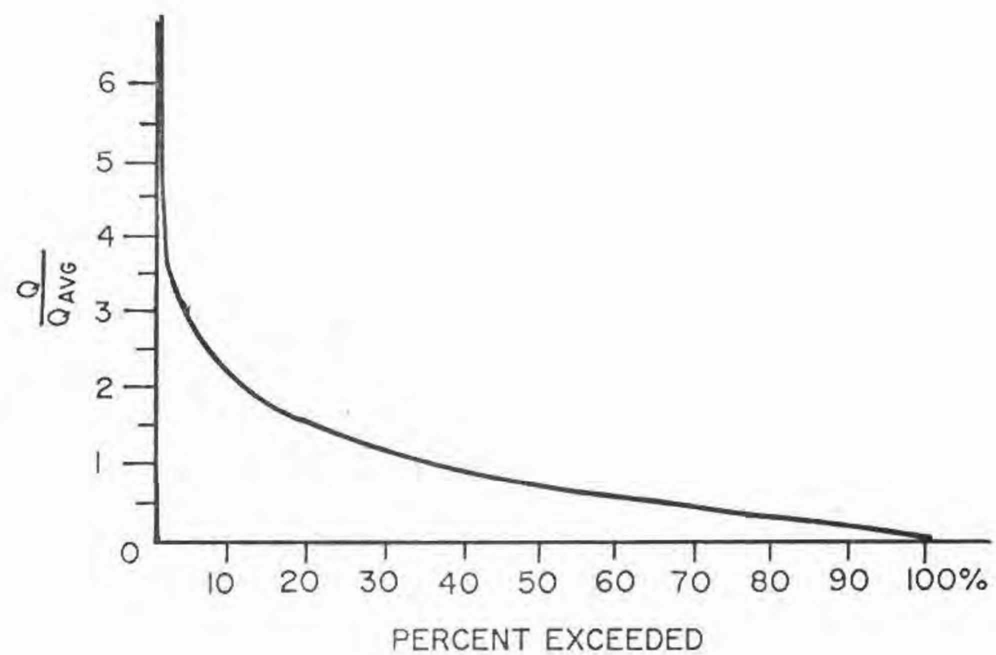
MIDDLE BROOK (02YR001)

DAILY FLOW DURATION CURVES

Graph I.33



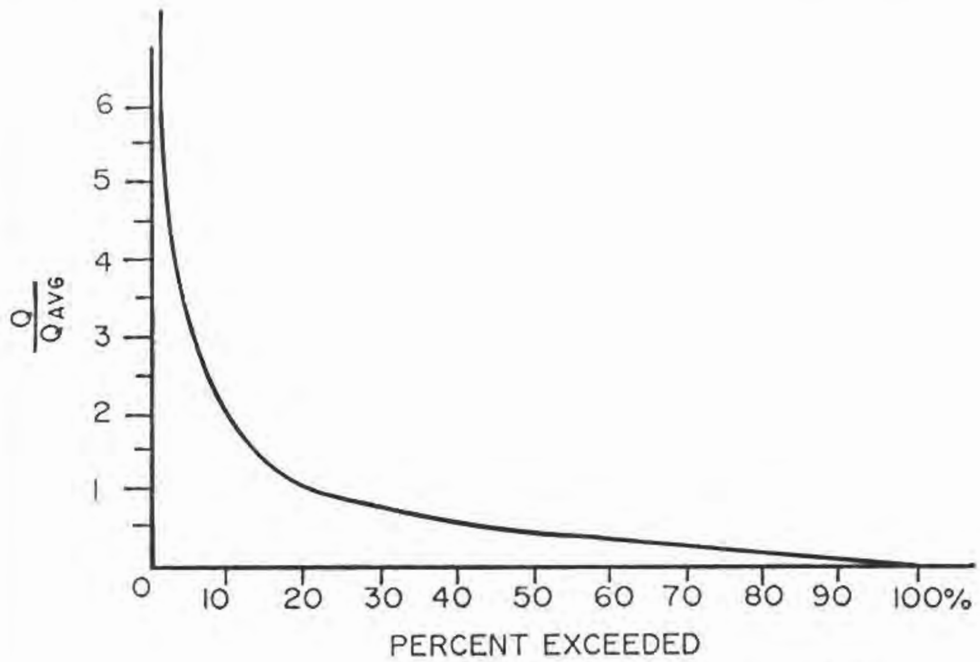
PIPERS HOLE RIVER (02ZH001)



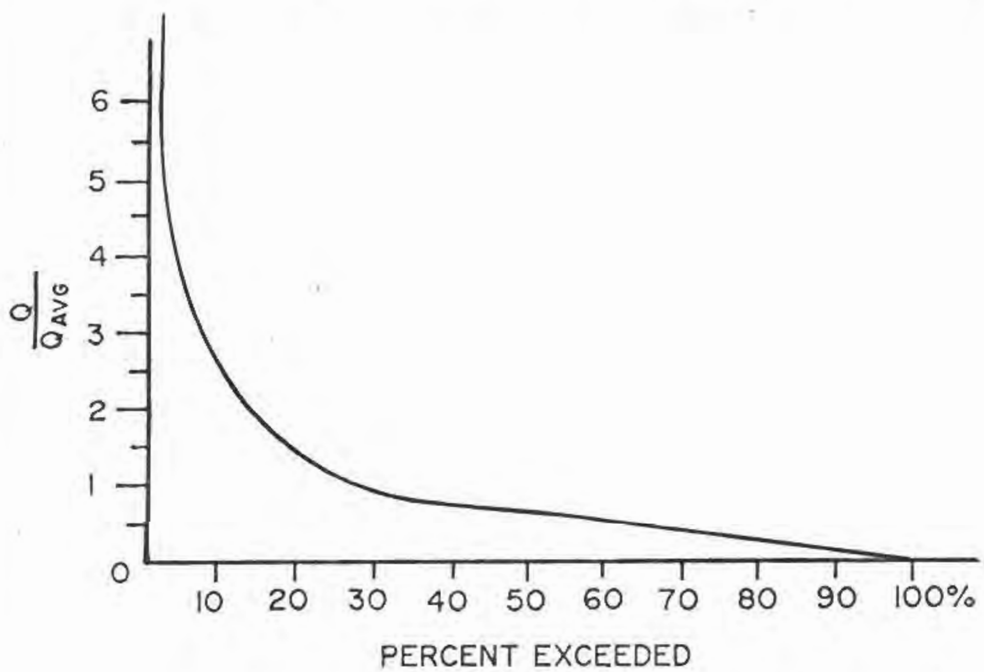
GANDER RIVER AT BIG CHUTE (02YQ001)

DAILY FLOW DURATION CURVES

Graph 1.34



TERRA NOVA RIVER (02YS005)



ROCKY POND BROOK (02YS002)

DAILY FLOW DURATION CURVES

Graph I.35

I.4 RESULTS OF MULTIPLE REGRESSION ANALYSIS

PROBLEM: MAR VS. LAT AND WEST

1. Descriptive Statistics

VARIABLE	MEAN	S.D.
LAT WEST MAR	48.577 327.500 945.750	0.524 49.979 191.589

2. Correlation Matrix

Correlations

	WES	MA
LAT WEST	-.584 .827	-.806

3. Analysis of Variance

SOURCE	SS	DF	MS
Regression Residual	216753.606 40191.893	2 5	108376.803 8038.378
Total	256945.500	7	

R^2 = 0.8435 ST. ERROR = 89.657
F(2,5) = 13.482 P = 0.010

Regression Coefficients

INTERCEPT = 8971.5489

VARIABLE	WEIGHT	F	PROB.
LAT WEST	-179.2016 2.0744	5.055 6.158	0.073 0.055

VARIABLE	PARTIAL CORRELATION	SQUARED SEMI-PARTIAL
LAT WEST	0.5027 0.5519	0.6507 0.1926

Formula: MAR = 8971.5489 - 179.2016 LAT + 2.0744 WEST

PROBLEM: Q_{10}:daily versus log DA

1. Descriptive Statistics

VARIABLE	MEAN	S.D.
LAREA LQ1	2.461 -0.673	0.746 1.012

2. Correlation Matrix

Correlations

	LQ1
LAR	.946

3. Analysis of Variance

SOURCE	SS	DF	MS
Regression Residual	6.420 0.750	1 6	6.420 0.125
Total	7.171	7	

R^2 = 0.8953 ST. ERROR = 0.327
F(1,6) = 51.328 P = 0.000

Regression Coefficients

INTERCEPT = -3.8310

VARIABLE	WEIGHT	F	PROB.
LAREA	1.283	51.328	0.000

Q_{10}:daily = $10^{-3.831} \times DA^{1.283}$

PROBLEM: Q_{10}:weekly versus log DA

1. Descriptive Statistics

VARIABLE	MEAN	S.D.
LAREA LQ7	2.461 -0.511	0.746 0.915

2. Correlation Matrix

Correlations

	LQ7
LAR	.933

3. Analysis of Variance

SOURCE	SS	DF	MS
Regression Residual	5.112 0.760	1 6	5.112 0.126
Total	5.872	7	

R^2 = 0.8705 ST. ERROR = 0.329
F(1,6) = 40.362 P = 0.001

Regression Coefficients

INTERCEPT = -3.3293

VARIABLE	WEIGHT	F	PROB.
LAREA	1.1446	40.362	0.001

Q_{10}:weekly = $10^{-3.3293} \times DA^{1.145}$

PROBLEM: Q_{10}:monthly versus log DA

1. Descriptive Statistics

VARIABLE	MEAN	S.D.
LAREA LQ30	2.461 -0.342	0.746 0.874

2. Correlation Matrix

Correlations

	LQ3
LAR	.923

3. Analysis of Variance

SOURCE	SS	DF	MS
Regression Residual	4.560 0.788	1 6	4.560 0.131
Total	5.348	7	

R^2 = 0.8526 ST. ERROR = 0.335
F(1,6) = 34.715 P = 0.001

Regression Coefficients

INTERCEPT = -3.0004

VARIABLE	WEIGHT	F	PROB.
LAREA	1.0809	34.715	0.001

Q_{10}:weekly = $10^{-3.000} \times DA^{1.081}$