WATER RESOURCES STUDY

of the

PROVINCE OF NEWFOUNDLAND AND LABRADOR

for

ATLANTIC DEVELOPMENT BOARD

Volume TWO B

NATURAL WATER RESOURCES INVENTORY

THE SHAWINIGAN ENGINEERING COMPANY LIMITED
JAMES F.MacLAREN LIMITED

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23 AVAILABLE INFORMATION

23.1 Review of Data Collected by Different Agencies

Existing information on the chemical, physical, bacteriological, and ecological characteristics of the surface waters of the Island, and to a lesser extent of Labrador, were made available from the following agencies:

a) The Canada Department of Energy, Mines and Resources, Inland Waters Branch.

b) The Canada Department of National Health and Welfare in conjunction with the Provincial Department of Health.

c) The Canada Department of Fisheries, Resource Development Branch.

d) The Canada Department of Fisheries, Inspection Branch.

e) The Fisheries Research Board of Canada.

f) The Canada Department of Indian Affairs and Northern Development, Canadian Wildlife Service.

g) Miscellaneous Reports prepared for the Atlantic Development Board, and for municipal authorities by Consulting Engineers.

The scope of the analyses carried out by each agency is given in Table 23-1.

a) The data available from the Canada Department of Energy, Mines and Resources were those published in the Industrial Water Resources of Canada - Water Survey Report No. 11/1954-56, and those to be published in Water Survey Report No. 15, both by J. F. J. Thomas.

As stated in Report No. 1 of these series, the chief purpose of the survey is "to determine the chemical character of major Canadian water supplies available for industrial and domestic use". The reports of the survey tabulate the analytical data on samples taken from both surface and municipal water supplies.

These reports provide the only source of estimating the variation, with time, of water quality data on some of the rivers of the Island, in that samples were taken at more or less monthly intervals over a one-year period in 1955-56 on six river basins. (Table 23-2) The eight locations where samples were taken in 1966 have been set as semi-permanent stations since they are a part of the International Hydrological Decade program for the Island. The purpose of this sampling program is to provide base-line water quality data on relatively unpolluted rivers. In discussion with Messrs. J. F. J. Thomas and R. M. Gale of the Department in July 1967, it was indicated that the number of IHD stations was to be increased to ten late in 1967. The continuation of this sampling program will provide a fund of information.

In addition to the above "continuous" sampling stations, a number of individual grab samples from other rivers and lakes were analyzed for the survey of the Island in the 1953-56 period and of the Island and Labrador in the 1965-67 period as well as the samples of municipal water supplies in both periods. The location, period covered, and number of samples are shown in Table 23-3.

Most of the samples of municipal water supplies were obtained from surface water sources; that is, 22 of 23 in the earlier period and 17 of 19 in the later period. Of the surface waters sampled continuously in the two periods, four series were taken generally at the same sampling stations - Grand Lake outlet, Gander River, Rocky River, and Piper's Hole River; three were backed up by samples in the other period (the earlier series from the Corner Brook River were backed up by one sample in the later series; the earlier upper Humber by one in the later series; and the later series from the Exploits at Grand Falls by 5 samples taken from the 1953-56 series). Fifteen of the municipalities sampled in the mid 1950's were sampled in the later period. (Botwood, Buchans, Carbonear, Corner Brook, Curling, Deer Lake, Freshwater, Gander, Grand Falls, Lewisporte, Placentia, St. John's, Springdale, Stephenville, and Windsor.)

Six of the rivers sampled on a continuous basis are sampled at flow gauging stations. Of the remaining two IHD stations, flow gauging is to commence on the Harry's River in 1968 and, on the Terra Nova River, flow is measured at Eight Mile Bridge which is nine miles upstream of the quality sampling station. Terra Nova Lake is located between the two stations, that is upstream of the quality sampling station and downstream of the flow measuring stations. The Corner Brook River, sampled continuously in the 1955-56 period, was not gauged.

b) The data available from the Department of National Health and Welfare were, generally, analyses carried out by this Department on behalf of the Provincial Department of Health. Representatives of the latter body collected these samples, mostly from existing municipal water supplies, and sent them to the Federal agency in Moncton for analysis. A few of the analyses provided by DNHW were forwarded to them by other agencies - CNR, Department of Transport, Acres-Canadian Bechtel (Churchill Falls), RCMP, RCAF, and the Department of Indian Affairs and Northern Development.

As discussed later, the analyses carried out in this program are more limited in scope (Table 23-1) than those carried out by the Department of Energy, Mines and Resources mainly because the Department of National Health and Welfare analyses were more oriented towards the suitability of water for human consumption, that is, from the public health point of view.

The information supplied covers 1959 to 1967 with 1966-67 representing 75 percent of the total number of analyses. The latter period was chosen by the Federal and Provincial Department for pooling their resources and carrying out a program to investigate the quality of Provincial municipal water supplies. At the time of writing, the grab sample investigation of these water supplies was virtually complete.

These analyses are significant because they represent a cross section of (mainly) surface water supplies across the Island and a few in Labrador. The bulk of the source for municipal water supplies are from small ponds and rivers rather than from major drainage basins.

There were a total of 114 analyses obtained from these agencies representing sources from 62 communities on the Island and 7 in Labrador; 95 analyses were of surface water and 19 from wells. In addition 15 analyses were obtained from water in Terra Nova Park.

In addition to the above chemical analyses, the Provincial Department of Health makes a regular check of the bacteriological qualities of municipal water supplies. The majority of these are taken after chlorination and are strictly for determining the bacteriological safety (that is, the proper functioning of the chlorination system), and generally do not indicate the natural bacteriological qualities of the water.

c) The data available from the Resource Development Branch of the Canada Department of Fisheries were limited analyses, specifically aimed at determining the quality of a number of streams on the Island from the point of view of the pollution by upstream industrial and/or mining activities. The analyses were limited to those factors which could render the waters unsuitable for fish life (Table 23-1). A series of programs were carried out in co-operation with the former Canada Department of Mines and Technical Surveys.

The data provided by the Canada Department of Fisheries were included in the following formats:

1. Report No. MPT 61-114 - Canada Department of Mines and Technical Surveys, Mineral Processing Division. "Chemical Quality of Mine Waste Waters and Surface Wastes at Buchans, Newfoundland", November 9, 1961.

2. Report No. MPT 61-115 - Canada Department of Mines and Technical Surveys, Mineral Processing Division. "Chemical Quality of Industrial Waste Waters and Surface Waters at Grand Falls, Newfoundland", November 9, 1961.

3. Report MPT 65-38 - Canada Department of Mines and Technical Surveys, Mineral Processing Division. "Preliminary Survey of Water Quality in Wabush Lake System, Labrador, Newfoundland", November 15, 1965.

4. The results of analyses carried out by the Canada Department of Mines and Technical Surveys on samples collected by the Canada Department of Fisheries of the Exploits River system between Buchans and Bond Bridge below Bishop's Falls, including sampling of Red Indian Lake. These analyses cover the periods August 9 to 27, 1962, and August 12 to September 6, 1963.

5. The results of analyses carried out by the Canada Department of Fisheries on samples collected by them from the Exploits River system between Buchans and Bond Bridge, including Red Indian Lake and a few samples from the Buchans Mine outfall; the effluent of the Price pulp and paper mill at Grand Falls; the Exploits estuary at Sandy Point (approximately six miles down from the Trans-Canada highway bridge over the Exploits); and at Wigwam Point opposite the north shore of the mouth of the Norris Arm.

6. The results of analyses carried out by the Canada Department of Fisheries, on samples collected by them, of the waters of Rambler Pond and the upstream end of South Brook, a tributary to the east side of Baie Verte.

   This sampling program was aimed at determining the effects of Consolidated Rambler Mines (copper and gold) on these waters.

7. The results of analyses carried out by the Canada Department of Fisheries on samples collected by them of the water of Gull Pond, Gull Brook, and South Brook which discharges into the south end of Hall's Bay. These samples were collected to determine the effects of the Gullbridge Mines Limited (copper) on these waters.

The location, number of samples, and period of sampling for the analyses included in the reports listed under 5, 6 and 7 are shown in Table 23-4.

In addition to the above data, which formed part of their regular program of investigations and analyses, the Resource Development Branch assisted in the investigations for this report by obtaining and analyzing samples from rivers not normally investigated by them during their 1967 sampling period. This program consisted in the main of grab samples taken along the Trans-Canada Highway in addition to some collected on the Great Northern Peninsula. The supplementary data gathered by the Department in this period are also listed in Table 23-5.

d) The data from the Inspection Branch of the Canada Department of Fisheries consisted of the results of the bacteriological examination (coliform group and faecal coliform) of the waters used in the fish processing plants on the Island. The purpose of these samples is to determine the suitability of the waters being used; in general, where bacteriological contamination is found, it is of a local nature caused mainly by the fish plant operations or by discharge of local domestic sewage. Any pollution so determined is normally not related to either general pollution problems on the Island or the specific pollution load expected from a fish processing plant since the samples are taken only from the water supply.

e) The Fisheries Research Board of Canada were contacted, and it is noted that they have carried out an ecological study of the Little Codroy River at the south end of the west coast of the Island. However, it is not expected that these data will be available until late 1968.

f) The data available from the Canadian Wildlife Service of the Canada Department of Indian Affairs and Northern Development consisted of complete analyses, carried out by the Canada Department of Energy, Mines and Resources, on samples collected by the subject agency from lakes in the Terra Nova National Park and in the proposed Bonne Bay National Park. The numbers and dates of collection of these samples are shown in Table 23-6. The report by the Canadian Wildlife Service entitled "The Chemical Composition of Lake Waters, Gros Morne Proposed National Park, December 1967", is based upon the samples collected from Bonne Bay.

g) There were a few miscellaneous water quality reports. The analyses collected are as follows:

Location	Samples Collected By	Analyses Made By	Authority
Clarenville Lower Shoal Harbour River Gaultois	Newfoundland Design Associates Ltd	Warnock Hersey Company Ltd	Clarenville
Big Piccaire (1 No.) Cluetts Pond (2 No.)	Canadian British Engineering Consultants	Dearborn Chemical Company Ltd	Atlantic Development Board

23.2 Supplementary Water Quality Survey

As can be seen from a review of the data in Section 23.1, there are few water quality analyses for the surface waters of the Island. For five of the larger basins selected for detailed study - Conne River, Salmon River, Grey River, White Bear River, and Cat Arm River - no such data existed at the time of writing. The situation was the same for most of the major tributaries to the three largest basins on the Island (Exploits, Humber, and Gander rivers), and for most of the relatively large river basins in the group selected for study on the Avalon Peninsula and the Burin Peninsula.

In view of this paucity of data, it was decided that the only manner in which an overall picture of the quality of the surface waters on the Island could be presented (with specific reference to the river basins selected for detailed study) would be an attempt to relate the characteristics of the waters on which analyses were available, to the characteristics of their drainage basins. Having established such a relationship it was thought possible that a reasonable extrapolation could then be made of the characteristics of waters for those drainage basins for which no water quality data were available. The basin characteristics selected were the physiographic, geologic, demographic, and hydrologic, all of which were readily available from data being collected. These extrapolations of existing water quality are discussed in more detail in Section 26.

In order to assist in the evaluation of the accuracy of these estimated water qualities, it was decided to institute a sampling program which would consist of the collection and analyses of grab samples from a number of accessible rivers (main rivers in all accessible basins and main tributaries in the larger basins). Such a program was carried out in the period from September 20 to October 22, 1967, using a portable Hach Test Kit for the bulk of the determinations, in combination with a portable dissolved oxygen meter, specific conductivity meter, and a portable incubator and millipore filter apparatus for coliform determinations. The data so collected were used to complement the data where surface water quality analyses were available, and to supply these data where none were available. At the same time, since a significant amount of the time spent in sampling was consumed in travelling from one sampling point to another, the opportunity was taken to supplement existing data on groundwater quality which, prior to the grab sampling program, consisted of only 19 analyses from widely separated points on the Island.

The location and dates of the analyses carried out in the framework of this program are shown in Table 23-7.

23.3 Critical Discussion of Available Information

Table 23-1 indicates the constituents and properties for which analyses were made by or for each of the above noted agencies on the water samples collected by them. It may be noted that the most complete analyses made were by the Department of Energy, Mines and Resources. These analyses are followed in order of completeness: by the analyses executed for the Canadian Wildlife Service and the miscellaneous analyses for Consulting Engineers; then by those made by the Department of National Health and Welfare and Shawinigan-MacLaren; the Department of Fisheries (Resource Development Branch); and finally by those carried out by the Department of Fisheries (Inspection Branch) and the Newfoundland Department of Health.

This order of the detail of the analyses reflects, in the main, the purpose for which they were intended. The program of the Department of Energy, Mines and Resources is the most general in that it is designed to provide as much information as is practicable on the chemical and, to a lesser extent, the physical properties of the water investigated from the point of view of their suitability for use as a supply for industrial and domestic waters, the emphasis being on the former. The analyses given make it possible in most cases to determine either the suitability of the water for a given process or, if unsuitable, to make a reasonable estimate of the type and cost of any treatment which would be necessary to render the waters suitable for such processes. In addition, the data will provide a base line for the determination of the extent of future pollution in the rivers studies.

In addition to the fact that the analyses made by this agency are the most exhaustive, this is the only agency which is recording any analyses on a number of basins on a year-round basis, thereby enabling a determination of any seasonal variation of characteristics which might obtain. As noted in this agency's Report No. 1, because of the large territory covered by the Federal body it is not feasible to collect daily samples on a given river over a two or three-year period with complete analyses being made on composite samples of several days. Such a program would have greatly enhanced the value of the already significant efforts of this organization. As suggested in Section 22, in view of its importance to water quality, the planned gauging station on the Exploits River below Grand Falls should be an automatic monitoring station.

At the time of writing Report No. 1, all samples from all basins under study in Canada were sent to Ottawa. Recently a laboratory capable of executing as complete water analyses as that at Ottawa has been established in Moncton, New Brunswick, by the Department of Energy, Mines and Resources. This will undoubtedly reduce the load on the central laboratory, and may open the way to more truly "continuous" sampling programs of selected basins in the Atlantic area and elsewhere.

The analyses of the 1966 sampling program instituted by the Canadian Wildlife Service are less detailed than those normally carried out by the Department of Energy, Mines and Resources, mainly because no analyses were made for heavy metals or of suspended and dissolved matter by evaporation and ignition. These samples were taken as a part of an overall study of the waters of the two national parks involved (Terra Nova Park and the proposed Bonne Bay Park). The study is being made with a twofold aim, firstly as a part of a basic resource study of the national parks, and secondly as a study of the fisheries of the national park system and the capacity of the waters in the parks for further development in this regard. On December 21, 1967, a representative of the Service said that a further set of samples had been taken on these waters in 1967, and that their analyses would include copper and zinc. Since the samples collected by this agency are from ponds with relatively small drainage basins, significant variation in qualities could be caused by extremely local variations in the physical or geological characteristics of the basins which may be hard to detect. Therefore no generalized relationships can be based on these analyses.

In addition to these chemical-physical analyses, The Wildlife Service, in conjunction with the National Museum, are carrying out studies of the invertebrate population of the same ponds. A paper discussing the findings of the ecological survey will be published in 1968.

The miscellaneous analyses carried out for consulting engineers appointed by the Atlantic Development Board (Water Supply for Gaultois Fish Processing Plant, and the Town of Clarenville) were executed for the purpose of determining the suitability of these waters for industrial and domestic uses. Again these data serve to supplement the information on the water qualities on minor drainage basins on the Island.

As previously noted, the analyses made by the Department of National Health and Welfare on samples collected by the Newfoundland Department of Health were mainly made on waters from community water supplies. These analyses exclude the minor cations (except iron and manganese), and were collected to determine the qualities of the municipal water supplies from a public health aspect. These samples are of limited usefulness in that, similar to the Canadian Wildlife Service, they generally represent samples of sources of limited drainage areas (ponds and small river basins). However, they do have the advantage over the Canadian Wildlife Service in that they represent sources from many points throughout the Island, some of which are in the river basins and study areas designated for detailed investigation. In addition, this source provided 14 of the 17 analyses on the quality characterisitics of well waters of the Island (the remaining three being from the Department of Energy, Mines and Resources).

As discussed in Section 23. 2, a grab sampling program was instituted by Shawinigan-MacLaren to supplement the available data and to provide further checks on the present water quality extrapolations made for this report. A shown in Table 23-1, the analyses were less comprehensive than those made by the Department of Energy, Mines and Resources due to the time available for the program, the limitations of the equipment used, and because of the purpose for which the data was required. The data collected in this program were sufficient to carry out as many checks as were reasonably feasible on the extrapolations, plus the provision of information on the major ionic contents of the water sampled. Although it was not possible to measure colour and oxygen consumed, which would have been desirable, information was collected on coliform organisms and the dissolved oxygen concentration as well as field determinations of pH and carb_n dioxide.

The Resource Development Branch of the Canada Department of Fisheries, as mentioned previously, confine their investigations to those fish-bearing waters in which pollution threatens the fish environment. Nevertheless these investigations provide further background for the assessment of surface water quality on the Island.

Because of the special field of interest of this Department, the data collected are somewhat limited in contrast with the previously discussed sources of information. It is in the category of ionic concentrations that the information is most restricted in that only copper and zinc (and in a few instances lead and iron) have been measured. These are the cations which are potentially lethal to the fish at relatively low concentrations. The physical-chemical and non-ionic data collected by this agency almost coincide with the data provided by the Department of Energy, Mines and Resources with the major exception of colour. The data provided by this department is the only source of information on the biochemical oxygen demand and dissolved oxygen concentrations of the surface waters of the Island. In carrying out the supplementary sampling program for the current report, this department also determined the colour of the waters sampled.

Details of the scope of the bacteriological sampling carried out by the Inspection Branch, Department of Fisheries, and the Newfoundland Department of Health are also indicated in Table 23-1.

A representative set of water quality analyses is presented on Table 23-8. The set consists of one analysis from each of the study areas, and one from each of the study basins for which a meaningful analysis was available.

WATER QUALITY SAMPLING PROGRAMS

CLASSIFICATION	ANALYTICAL DATA	CANADA DEPARTMENT OF ENERGY MINES AND RESOURCES	CANADA DEPARTMENT OF NATIONAL HEALTH AND WELFARE	NEWFOUNDLAND DEPARTMENT OF HEALTH	CANADA DEPARTMENT OF FISHERIES RESOURCES DEVELOPMENT BRANCH	CANADA DEPARTMENT OF FISHERIES INSPECTION BRANCH	CANADA DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT CANADIAN WILDLIFE SERVICE	MISC. REPORTS G - GAULTOIS C - CLARENVILLE	GRAB SAMPLE PROGRAMME
FIELD DATA	DATE OF COLLECTION	●	●	●	●	●	●	●	●
	TIME OF COLLECTION				●				●
	WATER DISCHARGE (CFS)	● WHERE AVAILABLE FROM DEPT. OF ENERGY, MINES AND RESOURCES GAUGING STATIONS OR POWER PLANT DATA							●
	STORAGE PERIOD	●							●
	WATER TEMP °C ON COLLECTION	●			●		●		●
	WATER TEMP °C AT TEST	●			●		●		●
BIOCHEMICAL BACTERIOLOGICAL DISSOLVED GASES	OXYGEN CONSUMED BY PERMANGANATE PPM	●					●	● COD G	
	COLIFORM / 100 ML			●		●			●
	FAECAL COLIFORM / 100 ML					●			●
	CARBON DIOXIDE PPM MEASURED IN FIELD								●
	CARBON DIOXIDE PPM CALCULATED						●	● G (FIELD OR LAB)	
	DISSOLVED OXYGEN PPM (MEASURED IN FIELD)				● NOT GENERALLY				●
	BIOCHEMICAL OXYGEN DEMAND				● NOT GENERALLY				
PHYSICAL PHYSICAL-CHEMICAL AND MISCELLANEOUS CHEMICAL	pH IN FIELD	● (IN SOME CASES)					● (IN SOME CASES)		●
	pH IN LABORATORY	●	●		●		●	● C AND G	●
	COLOUR (PLATINUM UNITS)	●	●		● DETERMINED FOR SERIES FOR SHRIMP		●	● C AND G	
	TURBIDITY (JACKSON UNITS)	●	●		●		●	● C & G (SiO_2 & J.U.)	●
	SUSPENDED MATTER PPM (DRIED AT 105°C)	● IN A FEW CASES						● C	
	SUSPENDED MATTER PPM (IGNITED AT 550°C)	● IN A FEW CASES							
	RESIDUE ON EVAPORATION (DRIED AT 105°C)	● IN A FEW CASES						● C	
	IGNITION LOSS AT 550°C PPM	● IN A FEW CASES	● IN SOME CASES					● C	
	SPECIFIC CONDUCTANCE (MICROMHOS AT 25°C)	●	●		●		●	● C	●
	SULPHITE WASTE LIQUOR				● EXPLOITS ONLY				
CATIONS	CALCIUM (Ca)	●	●				●	● C AND G	● BY CALCULATION
	MAGNESIUM (Mg)	●	●				●	● C AND G	● BY CALCULATION
	IRON (Fe) TOTAL	●	●				● IN SOME CASES		
	IRON (Fe) DISSOLVED	●			● ONLY IN 1964 EXPLOITS AT [illegible] BRIDGE			● C AND G	● NOT IN ALL CASES
	MANGANESE (Mn) TOTAL	●	●				● IN SOME CASES		
	MANGANESE (Mn) DISSOLVED	●						●	
	ALUMINUM (Al)	● NOT ALWAYS					● IN TWO CASES		
	COPPER (Cu)	●			●				● [illegible] ONLY
	ZINC (Zn)	●			●				
	SODIUM (Na) CALCULATED		●						●
	SODIUM (Na) MEASURED	●					●	● C AND G	
	POTASSIUM (K)	●					●	● G	
	AMMONIA (AS NH_4)	● 1965-1967 MUNICIPALITIES							
	AMMONIA (AS NH_4)	● ALL OTHERS						● G	
ANIONS	CARBONATE (CO_3)	●	●				●	● G	● BY CALCULATION
	BICARBONATE (HCO_3)	●	● (AS CO_3)				●	● C AND G	●
	SULPHATE (SO_4)	●	●				●	● C AND G	●
	CHLORIDE (Cl)	●	●				●	● C AND G	●
	FLUORIDE (F)	●	●				●		● ST. LAWRENCE ONLY
	PHOSPHATE (PO_4) TOTAL	●							
	PHOSPHATE (PO_4) DISSOLVED	●					● IN SOME CASES		
	NITRATE (NO_3)	●	●				●	● C AND G	●
SILICA	(SiO_2)	●	●				●	● G	
NON IONIC	ALKALINITY AS $CaCO_3$								
	PHENOLPHTHALEIN (DETERMINED IN 1965 - 67 DATA)	●	●				●	● C AND G	●
	TOTAL	●	●		●		●	● C AND G	●
	HARDNESS AS $CaCO_3$	●							
	CARBONATE	●						● C	● CALCIUM
	NON CARBONATE	●					●	● C	● MAGNESIUM
	TOTAL	●	●		●		●	● C AND G	●
NITROGEN	NITRATE N		●					● C	●
	NITRITE N		●					● C	●
	FREE AMMONIA N		● ON OCCASION					● C	
	ALBUMINOID N		● ON OCCASION					● C	
CALCULATED VALUES	SUM OF CONSTITUENTS	●					●	● C	
	TOTAL DISSOLVED SOLIDS ★ DETERMINED		●		● ON OCCASION				
	TOTAL DISSOLVED SOLIDS CALCULATED		●						
	PER CENT SODIUM	●					●		
	SATURATION INDEX AT TEST TEMP.	●					●		
	STABILITY INDEX AT TEST TEMP.	●					●		
	SODIUM ADSORPTION RATIO	●					●		

● INDICATES ANALYSIS IS DONE.

★ THE DETERMINED TOTAL DISSOLVED SOLIDS WAS RECORDED HERE SINCE THIS DATA INDICATES A CHECK ON THE CALCULATED TOTAL DISSOLVED SOLIDS.

TABLE 23-1

WATER QUALITY SAMPLING PROGRAMS CARRIED OUT BY THE CANADA DEPARTMENT OF ENERGY, MINES AND RESOURCES

RIVER OR LAKE	LOCATION	PERIOD	NUMBER OF ANALYSES	REMARKS
Corner Brook	Corner Brook	1955-56	14	Monthly
		1966-67	10	15 month period
Grand Lake Outlet*	Deer Lake	1955-56	12	Monthly
		1966-67	9	12 month period
Upper Humber	Deer Lake	1955-56	12	Monthly
Gander	Glenwood	1955-56	13	Monthly
		1966-67	7	13 month period
Rocky*	Colinet	1955-56	7	Bi-monthly
		1966-67	10	13 month period
Pipers Hole	Swift Current	1955-56	5	Bi-monthly
		1966-67	13	Monthly
Exploits*	Grand Falls	1966-67	6	8 month period
Harry's	Black Duck	1966-67	7	8 month period
Isle aux Morts*		1966-67	8	13 month period
Pipers Hole*	Mother's Brook	1966-67	12	Monthly
Terra Nova*	Terra Nova	1966-67	13	14 month period

* Semi-permanent stations (part of the International Hydrological Decade Program for Newfoundland)

Note: For extent of analyses conducted refer to Table 23-1

TABLE 23-2

WATER QUALITY GRAB SAMPLING PROGRAMS
CARRIED OUT BY
THE CANADA DEPARTMENT OF ENERGY, MINES AND RESOURCES

INDIVIDUAL SAMPLING LOCATIONS

SURFACE WATER SAMPLES

LOCATION	PERIOD	NUMBER OF SAMPLES	NUMBER OF STATIONS
Island	1953-56	14	8
Island	1965-67	30	27
Labrador	1965-67	9	9

DOMESTIC WATER SUPPLY SAMPLES

LOCATION	PERIOD	NUMBER OF SAMPLES	NUMBER OF STATIONS
Island	1953-56	41	23
Island	1966-67	29	19

Note: For extent of analyses conducted refer to Table 23-1.

WATER QUALITY SAMPLING PROGRAMS
CARRIED OUT BY
THE CANADA DEPARTMENT OF FISHERIES

RIVER OR LAKE	LOCATION	PERIOD	NUMBER OF ANALYSES	REMARKS
Shanadith:: River		Sept 22/67	1	*
Victoria River		Sept 22/67	1	*
Lloyds River		Sept 22/67	1	*
	Mine Outlet	Nov 16/ to Dec 14/66	5	
	at Buchans	Jan 4/ to Nov 30/67	21	
	Tailings Dam at Buchans	Sept 7-13/67	3	
	Powerhouse at Buchans	Sept 7-15/67	4	
Buchans Brook	At Highway 50	Nov 16/ to Dec 7/66	4	
		Jan 4/ to Nov 30/67	25	
		Sept 22/67	1	*
Buchans Brook	Mouth	Sept 13-15/67	3	
Red Indian Lake	6 Sampling Stations	May 12/ to Oct 16/67	2 at each	Top and Bottom
	3 of 6 Stations	Sept 22/67	2 at each	*
Exploits River	16 miles above	Aug 17-19/64	4	
	Badger	June 29/ to Aug 28/65	8	
		May 16/ to June 27/66	5	
		May 12/ to Nov 30/67	18	
Exploits River	Just above	June 16/ to Nov 13/65	28	
	Grand Falls	June 13/ to Sept 26/66	20	
		May 4/ to Nov 30/67	23	
		Sept 23/67 to	1	*
Exploits River	Price (Nfld) Forebay	June 20/ to Sept 27/66	16	BOD only
	Price (Nfld)	June 16/66	1	BOD only
	Sulphite Waste Liquor	Oct 14-16/67	3	BOD only
	Price (Nfld)	June 18/19 to Sept 26/66	16	BOD only
	North Sewer	July 12 to Oct 15/67	4	pH Total Solids and BOD only

* analyzed by Department of Energy, Mines and Resources.

Note: For extent of analyses conducted, refer to Table 23-1.

TABLE 23-4
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RIVER OR LAKE	LOCATION	PERIOD	NUMBER OF ANALYSES	REMARKS
Exploits River	Bond Bridge	Apr 20/ to Oct 14/67	70	5-DO and BOD 1-DO 21-SWL
		Sept 23/67	1	
Exploits River	Sandy Point	May 11/ to Oct 15/67	70	6-SWL 27-SP. COND. and DO and BOD 29-SP. COND. and DO 1-BOD
Exploits River	Wigwam Point	May 11/ to Oct 15/67	51	5-SWL 18-DO and SP. COND. and BOD 12-DO 12-DO and SP. COND 1-BOD
Exploits River	Aspen Brook	May 12/ to Oct 15/67	5	
Exploits River	Norris Arm	Aug 14/67	6	DO only
Exploits River	Botwood Island	Aug 14/67	6	DO only
England's Brook	Upstream of Mine Tailings Disposal Rambler Mines	June 24/ to Nov 7/65 June 14/ to Dec 22/66 Jan 3/ to June 20/67	6 14 19	
Rambler Lake	Outlet from Tailing Disposal Area Rambler Mines	Sept 1/ to Nov 7/64 June 24/ to Nov 7/65 May 17/ to Dec 21/66 Jan 3/ to June 29/67	2 7 15 11	Copper and Zinc only
	Upstream and Rambler Lake	Nov 7/64 June 24/ to Nov 9/65 June 14/ to Dec 21/66 Jan 3/ to June 22/67	1 4 12 15	Copper and Zinc only
Little Lake	Discharge into Rambler Lake	July 5-8/66	4	

RIVER OR LAKE	LOCATION	PERIOD	NUMBER OF ANALYSES	REMARKS
Exploits River	Price (Nfld)	June 18/19 to Sept 26/66	20	BOD only
	Sourth Sewer	July 12 to Oct 16/67	4	BOD only
Exploits River	Price Bridge	May 11/ to Sept 13/67	15	
		June 30/ to Oct 14/67	44	SWL only
Exploits River	Gorge	Nov 13/65	7	SWL only
		Jan 13/ to May 18/66	26	pH, TDS and SWL
		June 16/ to Sept 6/66	14	BOD only
		May 20/ to Sept 13/67	6	
		May 17/ to Oct 14/67	[illegible]	SWL only
Exploits River	Dump	Aug 19-27/65	16	pH and DO only
	(1½ mi downstream of Price Mill)	May 18/66	6	SWL only
		May 11/ to Sept 12/67	9	5 BOD only
Exploits River	Above Great Rattling Brook	Aug 19-27/65	18	DO only
Exploits River	Deckers Cabin (just above Bishop's Falls Dam)	Aug 19-27/65	13	6 pH and DO only 7 DO only
		June 16-28/66	3	BOD only
		May 11/ to Oct 15/67	17	5 SWL only 2 DO only 5 DO and BOD only
Exploits River	Bond Bridge	Aug 16/ to Sept 22/64	8	
		June 28/ to Nov 13/65	106	8-SWL only 17-DO only
		Jan 13/ to Sept 26/66	113	14-pH and SWL only 9-BOD only 1-pH, SP, Cond and SWL 8-pH, TDS and SWL

RIVER OR LAKE	LOCATION	PERIOD	NUMBER OF ANALYSES	REMARKS
Little Lake	In the Middle of Rambler Lake	July 5-8/66	4	
	South Brook at Bridge on Road to Mine (just North of Rambler Lake)	Nov 7/64	1	Copper and Zinc only
		June 19/ to Nov 7/65	9	
		May 17/ to Dec 22/66	14	
		Jan 3/ to June 29/67	16	
Gull Pond	From South end to North end	Nov 20/ and Nov 29/66	3	At 4 Stations
			3	At 2 Stations
Gull Outlet		May 5/ to Nov 11/64	10	2 Copper only 1 pH and Copper only
		June 7/ to Nov 21/65	9	
		May 17 to Dec 22/66	14	
		Jan 4/ to June 22/67	17	
South Brook	Junction of Gull Brook and South Brook	June 14/ to Sept 29/66	5	
		June 8/67	1	
	Between South Pond and Hall's Bay	May 5/ to Aug 31/64	8	
		June 7/ to Sept 21/65	9	
		May 17 to Dec 22/66	11	
		Jan 4/ to June 22/67	16	

SUPPLEMENTARY WATER QUALITY SAMPLING PROGRAMS CARRIED OUT BY THE CANADA DEPARTMENT OF FISHERIES

RIVER OR LAKE	LOCATION	PERIOD - 1967	NUMBER OF ANALYSES
Come By Chance		Sept 21 - Nov 30	3
Exploits River*	Above Grand Falls	May 11 - Oct 12	6
	At Sir Robert Bond Bridge	May 11 - Oct 12	6
Harry's River	At bridge on Highway 47	Aug 28 - Nov 29	4
Humber River	At bridge on Trans-Canada Hwy	Aug 28 - Nov 29	4
Gander River	At bridge on Trans-Canada Hwy	Sept 13 - Nov 30	3
Terra Nova River	At bridge on Trans-Canada Hwy	Sept 13 - Nov 30	3
Gambo River	At bridge on Trans-Canada Hwy	Sept 13 - Nov 30	3
Southwest Brook	South of Terra Nova at bridge on Trans-Canada Highway	Oct 10 - Nov 30	2
Northwest River	South of Terra Nova at bridge on Trans-Canada Highway	Sept 13 - Nov 29	3
Indian River	Near bridge on Trans-Canada Hwy	Apr 20 - Nov 29	3
Portland Creek (Great Northern Pen)	At bridge on Highway 73	Sept 7 - 21	3
River of Ponds (Great Northern Pen)	At bridge on Highway 73	Sept 2 - 20	3
Torrent River (Great Northern Pen)	At bridge on Highway 73	Sept 2 - 20	4
Salmon River (Great Northern Pen)	At bridge on Highway 74	Sept 2 - 20	4

* Part of the Department's regular sampling program.

Note: For extent of analyses conducted refer to Table 23-1

TABLE 23-5

WATER QUALITY SAMPLING PROGRAMS CARRIED OUT BY

THE CANADA DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

CANADIAN WILDLIFE SERVICE

ANALYSES FROM	LOCATION	PERIOD	NUMBER OF ANALYSES	REMARKS
Ponds	Terra Nova National Park	March 24 to August 31/66	29	16 ponds
River and Ponds	Bonne Bay National Park (Proposed)	September 13 - 21/66	15	1 river 9 ponds

Note: For extent of analyses conducted refer to Table 23-1.

TABLE 23-6

WATER QUALITY SAMPLING PROGRAM CARRIED OUT BY SHAWINIGAN - MACLAREN

SURFACE WATER

RIVERS IN OR NEAR	LOCATION	DATE (1967)	
Come By Chance and Environs Study Area			
Northeast River	At bridge on Highway 6	Sept	20
Southeast River	1.6 miles west of junction of Highways 6 and 8	Sept	20
Black River	At bridge on Highway 11	Oct	11
Come By Chance River (limited analysis)	At 47° 57' 41" Latitude	Nov	26
	At 47° 55' 07" Latitude	Nov	26
	At 47° 50' 47" Latitude		
	At 47° 50' Latitude	Nov	26
North Harbour River	Downstream of Highway 11	Oct	11
Pipers Hole River	50 yards downstream of Highway 11	Oct	11
Bonavista Peninsula Study Area			
Discharging at:			
Bonavista	In Bonavista	Oct	8
Little Catalina	100 feet north of Highway 24 bridge	Oct	8
Champneys	At bridge on Highway 24	Oct	7
Lockston	At bridge on Highway 24	Oct	7
Port Union	From powerhouse tailrace	Oct	7
Trouty	At bridge on Highway 24	Oct	7
St. John's and Environs Study Area			
Broad Cove River	50 yards upstream of Highway 3	Oct	1
Goulds Brook	At bridge on Highway 66	Oct	6
Manuels River	20 yards downstream of Highway 3	Oct	2
North Arm River	20 yards downstream of new Highway 3	Oct	4
Mobile River	Powerhouse tailrace	Oct	21
Pierres Brook	Witless Bay powerhouse tailrace	Oct	21
Quidi Vidi River	At bridge on Quidi Vidi Road	Oct	21
Raymond Brook	At Petty Harbour powerhouse tailrace	Oct	21
Seal Cove River	30 yards downstream of powerhouse	Oct	2
Waterford River	100 yards downstream of bridge near Blackhead Road	Oct	21

TABLE 23-7
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SURFACE WATER

RIVERS IN OR NEAR	LOCATION	DATE (1967)	
<u>Burin Peninsula Study Area</u>			
Grand Bank Brook	At water supply reservoir	Oct	11
Tributary to Great Lawn Harbour	West tributary, 100 yards upstream of Highway 14	Oct	11
Salmonier River	Half a mile upstream of bridge on Highway 14	Oct	11
Tides Brook	At bridge on Highway 12	Oct	10
<u>Exploits River Basin</u>			
Badger Brook	At bridge on Trans-Canada Highway	Oct	14
Buchans Brook	At bridge on Highway 50	Oct	16
Exploits River	Grand Falls (chipping mill tailrace)	Oct	17
	At bridge on Trans-Canada Highway	Oct	14
Mary March's Brook	At bridge on Highway 50	Oct	17
Shanadithit Brook	100 yards upstream of bridge on access road	Oct	16
Northern Arm Brook	Half a mile upstream of bridge on Highway 42	Oct	13
Peters Arm Brook	At bridge on Highway 42	Oct	13
<u>Stephenville and Environs Study Area</u>			
Harry's River	At bridge on Highway 47	Oct	19
Southwest Brook	100 yards downstream of bridge on Trans-Canada Highway	Oct	19
<u>Humber River Basin</u>			
Humber River	At bridge on Trans-Canada Highway	Oct	18
Humber River	Grand Lake outlet	Oct	17
Upper Humber River	At bridge on Highway 42	Oct	18
<u>Gander River Basin</u>			
Gander River	At bridge on Trans-Canada Highway	Oct	13
<u>Terra Nova River Basin</u>			
Terra Nova River	At Eight Mile Bridge	Oct	12
	At bridge on Trans-Canada Highway	Oct	13

GROUNDWATER

COMMUNITY IN OR NEAR	WELL OWNERSHIP	LOCATION	DATE (1967)	
St. John's and Environs Study Area				
Bauline	Community	Upper of two wells	Oct	2
		Lower of two wells	Oct	2
Bay Roberts	Private	Avalon Coal Company	Oct	5
		Residence, R. Noseworthy	Oct	5
Holyrood	Private	Furey's Hotel	Oct	4
		Fishery Products Limited	Oct	4
		Golden Eagle Refinery (4)	Oct	4
Long Pond	Private	Bishops Service Station	Oct	3
		Bishops Apartments	Oct	3
St. John's	Private	St. John's Concrete Products	Oct	3
Topsail	Private	Residence, F. W. Dunn	Oct	2
		Residence, Dr. Shapter	Oct	3
Bay de Verde	Community	Easterly well	Oct	5
Goulds	Private	Williams Dairy Farm	Sept	23
Trepassey	Private	Fishery Products	Sept	21
		Daniels Point	Sept	21
Whitbourne	Private	Residence, Manager of Nfld L & P	Oct	6
		C.S.S.R Rectory	Oct	6
Winterton	Community	Abandoned well	Oct	5
	Private	General Store, R. Mindy	Oct	5
Come By Chance and Environs Study Area				
Placentia	Private	Calm-Lot Restaurant	Sept	20
		St. Edwards School	Sept	20
Clarenville	Private	RCMP detachment	Oct	7
Burin Peninsula Study Area				
Burin	Private	Residence, Mr. Hollett	Oct	10
Marystown	Community	Pumping Station No. 1	Oct	10
St. Lawrence	Community		Oct	10

GROUNDWATER

COMMUNITY IN OR NEAR	WELL OWNERSHIP	LOCATION	DATE (1967)	
Stephenville and Environs Study Area				
Stephenville Crossing	Private	Dug well, residence, I. White	Oct	19
O'Regans	Private	Shallow well, residence, J. Smith	Oct	19
Robinsons	Community		Oct	19
South Branch	Private	Residence, E. J. Gillam	Oct	19
Corner Brook-Deer Lake Study Area				
Deer Lake	Private	E. P. A. terminal	Oct	17
Badger and Botwood Study Area				
Badger	Private	Presentation Convent	Oct	14
Norris Arm	Community	South of Trans-Canada Highway	Oct	14
		North of Trans-Canada Highway	Oct	14
Baie Verte	Private	Terra Nova Motel	Oct	17
		Esso Service Station	Oct	17
Gander Study Area				
Glenwood	Community	North of Trans-Canada Highway	Oct	13
Bonavista Peninsula Study Area				
Bonavista	Private	Residence, H. T. Hurdle	Oct	9
Catalina	Private	E. C. Kean	Oct	9
Elliston	Private	U. C. C. High School	Oct	9

Note: For extent of analyses conducted refer to Table 23-1.

24 RELATIONSHIP BETWEEN WATER QUALITY AND PHYSIOGRAPHIC FACTORS

24.1 Physical Characteristics

The natural factors which most affect the physical characteristics of the surface waters of the Island are the geological characteristics of the surficial deposits and, more important, those characteristics which have been grouped under the heading "physical-geography" of the basins.

The surface cover features which are considered under physical geography are: bogs or swamps; forests; exposed water surfaces (lakes, ponds and rivers); and the remainder of the land surface. The latter may vary in make-up from areas of exposed rock outcroppings through stony areas of sparse grass cover to areas which may contain clumps of forest and peaty and marshy areas. These areas are referred to as "barrens". Where the areas of the lands were measured for specific drainage basins and broken down into the above classifications, the latest available issue of the maps of the National Topographic System were used (1:250,000 scale maps for the larger and 1:50,000 scale maps for the smaller basins). In addition to the above, other characteristics which would fall under this classification would be the slope of the river, the size and shape of the river basin, and the location of the various surface characteristics within the river basin.

The physical characteristics of the water (turbidity, colour, and dissolved oxygen) are much more dependent on these surface features, than on the geological characteristics.

A brief commentary on the effects of the above characteristics follows, but it should not be interpreted as being exhaustive nor should it be construed as being without exception.

24.1.1 Turbidity

A number of factors affect both the turbidity of surface waters and its variation. It is normally due to the suspension of clay, silt, finely divided organic matter and similar substances. The flashiness of the stream (as measured by the ratio of peak to average flow) would affect the range of variation of this characteristic (a river with a small drainage basin would be more likely to be a flashy stream and to have a wider range of turbidity). The presence of a lake or lakes in the course of the stream would tend to reduce the range of the turbidity, but experience indicated that it would also tend to extend the length of time over which peak turbidities in the system occur. A small depth of over-burden (a geomorphological characteristic) would likely result in a low turbidity due to the absence of particles which could enter into suspension.

24.1.2 Colour

The colour of natural waters is due to dissolved or colloidal substances of vegetable origin extracted from leaves or peaty matter and is most intense in water draining from swamps. It follows that coloured surface waters would result from relatively high proportions of bogs and swamps, barrens (on the basis that these areas include not only sparse grass lands but a significant proportion of peaty and marshy areas), as well as forested areas. Colour is measured by comparison with platinum-cobalt standards, and is reported in terms of colour units.

24.1.3 Dissolved Oxygen

The dissolved oxygen content of any surface water is a function of the pollution load and/or the re-aeration capacity of the stream (its ability to absorb any pollution load imposed on it). The pollution load is generally independent of the character of the stream and, with the exception of any pollution deriving from natural vegetation or fauna in the contributing basin, is independent of the natural regional characteristics of its drainage basin. The re-aeration characteristics of the stream are a function of the hydraulic conditions of the stream flow. For example, a river with moderate to high velocities would have a good re-aeration capacity, whereas a slow-moving, sluggish river would have poor re-aeration characteristics. A relationship between re-aeration capacity and stream velocities based on experience has been suggested for the purpose of the water quality extrapolations as described in the next section.

24.2 Chemical Characteristics

The natural factors which most affect the chemical characteristics of the surface waters of the Island are the geological and geomorphological characteristics of both the bedrock and surficial deposits. It is possible to relate the chemical characteristics of surface waters to bedrock since the bulk of the drift in the Island is derived from moraine materials which have not been transported far from the original location of the rock fragments.

As far as the effect on the concentration of dissolved salts in the water is concerned (total dissolved solids) the bedrock may be divided into two groups:

a) Those which make up by far the greatest proportion of the Island:

- the major igneous intrusions (Hydropetrologic unit R1)

- the Pre-Cambrian sediments and volcanics (units R2 and R3)

- the Cambrian to Devonian metamorphic, volcanics and sediments (units R4, R5, and R6)

- the St. Lawrence granite (unit R9)

b) Those which form a significant part of the area in and adjacent to the Long Range Mountains:

- the carboniferous sediments (unit R7)

- the series with dominant limestone and dolomite (unit R8)

The geological units of group a) are responsible for the generally low total dissolved solids, low hardness, and relatively low pH's of the waters of the Island. These characteristics may be attributed to the low solubility of the rocks and/or their chemical constituents. The geological units of the second group could well be responsible for high total dissolved solids in waters originating from both units and, in unit R8, for a higher hardness and pH.

An indication of the effect of the geological characteristics of the drainage basins on the chemical characteristics of river waters may be illustrated by a comparison of the analyses of two samples obtained during the Shawinigan-MacLaren grab sampling program. One sample each was taken from the waters of the Southwest Brook and Harry's River on October 19, 1967, with the following pertinent characteristics being determined:

	Southwest Brook	Harry's River
Total dissolved solids		
Concentration of major ions (epm)	1.04	2.98
Specific conductance (micromhos)	30.50	132.00
Hardness - total as $CaCO_3$ (ppm)	10	55
pH - Laboratory tested within 6 hours of sampling.	6.6	7.45

These two rivers are on the west coast of the Island; both discharge into St. George's River, and have almost the same drainage areas. The bedrock in the Southwest Brook is made up of 94 percent unit R1 and 6 percent - units R2 and R3; that for Harry's River is made up of 2 percent - unit R1, 10 percent - units R2 and R3, 34 percent - units R4 and R5, and R6, 22 percent - unit R7, and 32 percent - unit R8. Southwest Brook, therefore, contains none of the rocks of group b), but Harry's River is made up of 54 percent of these rocks. Further the waters of Harry's River most likely reflect the influence of the unit R8 bedrock rather than a combination of the effects of units R7 and R8 due to the great depth of overburden in the lower reaches of the river's course, the area in which the unit R7 occurs. This situation results from glacial outwash deposits derived from the area to the east.

The effect of the unit R7 on the surface waters has not been substantiated due to the lack of surface water samples taken in the area of this unit.

The depth of the surficial deposits will also affect the concentration of dissolved solids. Since streams generally derive their base flow from the groundwater source, the greater the depth of overburden through which the water must pass, the greater the contact time between the water and the rock, the latter being the major source of dissolved inorganic solids.

Local variations in the geology of individual river basins will affect the concentration of specific ions in the surface waters derived from the respective basins. Such variations will be discussed in more detail below.

The physical-geography of the basins, as described in Section 24.1, also has some effect on the chemical characteristics of the surface waters. These effects are not nearly so extensive as those resulting from the petrology of the bedrock and surficial deposits.

Regarding the effects of the physical-geography on pH, Hem (1959) notes that surface waters originating in humid regions commonly have a pH of slightly below 7. In general, this appears to be the case in the Island, the exception being those areas on the west coast affected by the limestone deposits where pH's are generally high. Also contributing to the lower pH's in the surface waters are the relatively high proportions of swamps and bogs (so designated on the maps) which are increased by the marshy and peaty areas normally contained in the barrens.

Reasonably high concentrations of iron might be expected from the decomposition of the great quantities of organic matter in the swamps and bogs. It is likely, however, that this iron is bound to the organic molecules of ions which impart the generally high colour of the surface waters of the Island.

24.2.1 Ionic Composition

24.2.1.1 General

As indicated in Sections 23.1 and 23.3, the only major sampling programs which provide a significant amount of data on chemical quality are those instituted by the Department of Energy, Mines and Resources, the Department of National Health and Welfare (in conjunction with the Newfoundland Department of Health), and the Canadian Wildlife Service. In order to indicate the chemical qualities of the surface waters of Newfoundland in more detail than that provided by the water quality extrapolations discussed in Section 26, and as determined by actual water analyses, Figure 24-1 has been prepared. This figure indicates by means of "clock" diagrams, the total concentrations of the major cations and anions in epm (equivalents per million = $\frac{\text{parts per million (ppm)}}{\text{equivalent weight}}$) as well as the percentage of each of the ions making up this total. As can be seen from the figure, the ions considered were as follows:

cations: calcium, magnesium, and sodium plus potassium

anions: carbonate plus bicarbonate, sulphate, and chloride plus nitrate.

No other ions were considered since the effect of the very small quantities of such materials normally dissolved in surface waters would not noticeably affect these diagrams.

In the plotting of the data for locations for which more than one sample was available; for example, the International Hydrologic Decade stations, a simple average of the analyses was calculated and has been plotted. Less direct approaches could have been used to weight the individual analyses for such an averaging, but it was considered that there were insufficient sampling data to warrant such an approach. Where the composition of individual samples has been plotted, the date of the sample is indicated.

24.2.1.2 Relationship Between Chemical Concentration and Specific Conductance

Also plottted on the above figures are the results of the chemical analyses carried out on the samples obtained in the Shawinigan-MacLaren grab sampling program of September-October 1967. In visually comparing the total epm's, that is, the radii of the "clock" diagrams, plotted for these analyses against those plotted for the analyses of samples obtained from other sources at the same locations, it was noted that in some cases there was a considerable discrepancy between the two. This disparity was particularly noticeable where the total epm's were low in the analyses carried out by others.

The analyses carried out for the grab sampling program were executed using less refined methods and equipment than those available in a laboratory, namely, by means of a Hach test kit. Further, it was not possible to determine the concentrations of sodium and potassium using the available apparatus and their concentrations were calculated by subtracting the total determined major cations, $Ca^{++} + Mg^{++}$ from the total determined anions, $CO_3^{=} + HCO_3^{-} + SO_4^{=} + Cl^{-} + NO_3^{-}$. In view of these limitations it was considered likely that the apparatus used in the program was inaccurate at the low ionic concentrations which occur in most of the surface waters of Newfoundland. In order to check the reliability of the results of the ionic concentrations as determined by the grab sampling program, a least squares analysis of the relationship between $\frac{\text{epm cations} + \text{epm anions}}{2}$ and Specific Conductance was carried out on all available samples, excluding the grab sampling program.

The relationship so determined was:

$$\text{epm cations} = \text{epm anions} = 0.0095 \times \text{Specific Conductance} - 0.01$$

The analysis was carried out on a sample population of 321, including both surface and ground water samples taken from all areas of the Island. The resultant Coefficient of Correlation, r, was 0.9943. With such a large population and such a high correlation coefficient, it was considered that a comparison of ionic concentrations, as determined by analysis, and those determined, using the measured specific conductance and the above equation, would be a reasonable indication of the reliability of the former.

Table 24-1 shows the results of a comparison of determined versus calculated ionic concentrations.

The limits used in Table 24-1 to indicate the degree of correlation between the determined and calculated ionic concentrations correspond to those used on the Figures 24-1 and 24-2. Those ratings were applied to the samples analyzed in the grab sampling program.

A "G" rating (good) indicates that the determined value was within $\pm$ 15 percent of the calculated; a "B" rating (borderline) indicates that the determined value was $>$ 15 percent but with $\pm$ 30 percent of the calculated,and a "U" rating (unreliable) indicates that the determined value differed by more than 30 percent from the calculated. These evaluations indicate the degree of reliability of the ionic concentrations only. Other determinations should be of significantly greater accuracy.

The $\pm$ 15 percent limit was selected on the basis that conductivity measurements made in the field cannot be expected to be more accurate than $\pm$ 10 percent, and that a 5 percent error in determinations with the Hach kit would be about the best that could be expected.

The $\pm$ 30 percent limit was selected as being the limit beyond which it could not be projected that the results were within the proper order of magnitude.

It is readily apparent from a review of the Table 24-1 that the chemical analyses carried out in the grab sampling program were less accurate than those executed under laboratory conditions. The most interesting aspect of the above comparison is the extremely poor correlation between the determined and calculated ionic concentrations when the specific conductivity falls below 50 u mho's. It follows that, since the majority of the surface waters of the Island are low in total dissolved solids, there appears to be a very low level of accuracy for the ionic concentrations of the surface water samples analyzed in the grab sampling program. A comparison of the grab sample analyses with the average of a number of analyses taken by others at the same location does indicate that the error lies not in the determination of any one cation or anion, but is probably distributed among all seven of the determined ions. Because of the method of determination of the $Na^+ + K^+$ described previously the total error is reflected in this determination.

Although the analyses marked "U" (Figure 24-1) should not be used as an indication of detailed chemical make-up, it is generally the case that analyses so marked are very low in total ionic concentration and are even lower than the "clock" diagrams indicate. Such low concentrations of the major ions are not likely to be harmful to most industrial processes and domestic uses provided that requirements for possible corrosion protection are considered.

It is stressed that the B, G, and U designations apply to the ionic concentrations only. The remaining characteristics determined in the grab sampling program would deviate little from true values.

24. 2. 1. 3 Discussion of the Ionic Composition of the Waters of the Island of Newfoundland

The following is a discussion of the major trends in ionic composition of waters of the Island. It will be appreciated, and evident, that there are exceptions to these noted trends.

The major factors which might affect the ionic composition of surface waters are the bedrock geology of the basin, the proximity of the sea, and the effect of domestic and industrial pollution. The geology would affect the nature and concentration of dissolved salts, as discussed previously. The proximity of the sea would result in an increase in Na^+ and Cl^- caused by wind blown sea water in coastal areas. Man-induced pollution would increase the concentration of Na^+, K^- and No_3^- in addition to specific chemical wastes discharging from industry. Plant and animal life would also affect the concentrations of the major ions but not to the extent of the above factors.

The geological characteristics affecting the total ionic concentrations and the proportion of each major ion making up this total are the same as those affecting total dissolved solids and hardness, as discussed in Section 24. 2. Hydropetrologic unit R8 series with dominant limestone and dolomite would result in higher than normal ionic concentrations with calcium and carbonate dominating. Water affected by Carboniferous sediments (hydropetrologic unit R7) are expected to have high concentrations of dissolved salts of varying composition. Insufficient analyses of the latter effect are currently available.

The effect of the major limestone and dolomite groups can be seen in many samples taken along the west coast: for example, Flowers Cove and the Stephenville area.

Some of the lakes in the Bonne Bay and Terra Nova Park areas display the possible effect of wind-blown salt spray, as evidenced by the relatively high proportions of Na^+ and Cl^- in their composition. Since these waters are generally low in total ionic (or dissolved solids) concentration, it does not require great quantities of spray to affect their composition. The sample at Ramea island seems to indicate strongly the effect of wind-blown salt spray or possibly salt water intrusion. The island is located in the Atlantic Ocean in an area where rocks have a low solubility, thus accentuating the presence of wind-blown salt in the chemical constituents of the surface waters.

The waters in Exploits River, Gander River, and Terra Nova River basins are typical of those that could be expected in the inland waters of the Island in that the total concentrations are low with no one combination of cations and anions predominating.

The waters of the Quidi Vidi Lake and Waterford River display characteristics similar to those of the rest of the Avalon Peninsula with the exception of the much higher total ionic concentration. This characteristic is attributable to the pollution of these streams, whose drainage basins both lie in built-up areas of St. John's.

As discussed elsewhere, the waters of the Exploits River also display the effects of pollution, but this is with regard to specific pollutants and is not evidenced as a change in the general chemical characteristics of its waters.

24.3 Biological Characteristics

The major biological effect on water of the physiographic factors of a drainage basin is evidenced by the content of organic matter. The content of organic matter in surface waters may arise from two main sources - natural and man-induced. The natural organic pollution is discussed below.

Natural sources of organic pollution originates from plant and animal matter. The content of such organic matter in the water, therefore, relates to the proportion of swampland, barrens, and forests in the areas under investigation, with swampland being expected to provide the most organic matter and forest areas the least. It is to be expected that the variation in organic content would be seasonal; that is higher in summer than in winter, because of the relationship between the rate of degradation of organics and temperature.

A number of methods are available for the determination of organic matter. Those most frequently used in the data available on water quality are: oxygen consumed by permanganate, loss on ignition of total and dissolved solids, nitrogen (nitrate N, Nitrite N, free ammonia N, albumoid N), and biochemical oxygen demand.

Reference to Table 23-1 indicates that the Department of Energy, Mines and Resources data, the most extensive data available on the larger river basins, include only analyses for oxygen consumed, ignition loss, and nitrates, with the test for nitrates being performed in every case, oxygen consumed in most cases, and ignition loss less frequently. Each of these methods of determining organic matter has its own particular limitations and significance.

DETERMINED VS CALCULATED IONIC CONCENTRATION

SOURCE OF SAMPLES	OUTSIDE AGENCY		GRAB SAMPLE PROGRAM	
	Number	% Total	Number	% Total
1 Total samples (including surface and groundwater)	321	100	82	100
Samples with Specific Conductance (SC) > 50 micromhos	221	69	32	39
2 Samples whose determined $\frac{epm}{2}$ was within ± 15% of calculated				
a) Total	227	86	28	34
b) With SC > 50 micromhos	194	70% of 277	0	0% of 28
3 Samples whose determined $\frac{epm}{2}$ was within ± 30% of calculated				
a) Total	308	96	40	49
b) With SC > 50 micromhos	212	69% of 308	0	0% of 40
4 Samples whose determined $\frac{epm}{2}$ was ± 30% of calculated				
a) Total	13	4	42	51
b) With SC > 50 micromhos	9	69% of 13	32	76% of 42
5 Grab Sample Program				
i) Well samples a) Total			41*	51
b) With SC > 50 micromhos			0	0
whose determined $\frac{epm}{2}$ was within ± 15% of calculated			26	63%
whose determined $\frac{epm}{2}$ was within ± 30% of calculated			34	83
ii) Surface samples a) Total			41	
b) With SC > 50 micromhos			32	78
whose determined $\frac{epm}{2}$ was within ± 15% of calculated			2	5
whose determined $\frac{epm}{2}$ was within ± 30% of calculated			6	15

* Excluding two wells at Trepassey (specific conductance readings erroneous)

TABLE 24-1

25 CHANGES IN WATER QUALITY DUE TO HUMAN ACTIVITY

25.1 Physical and Chemical Changes

Because of the complexity of human activity, and therefore the extremely varied and complicated changes which such activities can have on surface water quality, only a few examples will be given.

Log driving and agriculture can have a considerable effect on water quality, both capable of causing a significant increase in turbidity. Trace amounts of fertilizer and insecticides can have a detrimental effect on the surface water in that the former may result in the fertilization of the water with the resultant development of unsightly algae, and the latter may be toxic to the animal life of the stream or lake. Decomposition of the waste products of timbering may increase the organic load on the receiving body, whilst log driving may result in the depletion of oxygen because of the oxygen demands of decomposing bark deposited in the river.

The increase in the quantity of settleable matter, which may result from many of man's activities including log driving, agriculture, construction, and mining, may destroy the growth of bottom dwelling flora and fauna and fish spawning beds.

Mining may also result, as has been the case in a number of Island rivers, in the solution of heavy metal ions. Such ions may, in sufficient concentration be toxic to both fish life and animal life, including man. In addition, mine wastes may cause pollution by changing pH, and introducing high turbidities.

Many industrial processes may produce liquid waste by products which may be detrimental to fish and animal life.

Man's existence by itself may effect changes in surface water qualities through waste discharges either through bacteriological contamination, discussed below, or through changes in physical and chemical composition; for example, increased turbidity and increased total ionic concentrations.

25.2 Bacteriological Changes

The bacteriological characteristics of a surface water are related to demographic conditions, sewage disposal systems, livestock, and natural fauna in the contributing basin.

The only source of bacteriological analyses of some of the major surface water basins on the Island is, with the exceptions of the Newfoundland Department of Health and the Department of Fisheries, Inspection Branch, the Shawinigan-MacLaren grab sampling program. This program used the millipore filter technique and determined the members of the coliform group of bacteria only. This group of bacteria has been accepted as an "indicator" organism in the sanitary engineering field since it has, as one of its primary habitats, the human intestinal tract. The presence in water of bacteria of this group indicates the potential presence of other organisms that originate in the human and other warm blooded animal intestinal tracts. However, the test involved is not specific in that another group of so-called non-fecal coli (aerobacter aerogenes), which originate in soil, grain, and decaying vegetation, are also isolated in this determination. Therefore, although a positive coliform-group determination may indicate human contamination, a high coliform count could well result in an area where contact with human beings is almost non-existent. (This occurred in the Shanadithit River with a count of 20 per ml).

26 WATER QUALITY EXTRAPOLATIONS

26.1 Approach

As noted in Section 23, an attempt has been made to relate the characteristics of the waters, on the major drainage basins for which analyses were available, to the physical-geographic (topographic), geologic, demographic, and hydrologic features of these basins. By extrapolation, these relationships were applied to those basins for which no such data were available so that a projection of the existing water qualities could be made for this report. Such extrapolations were made for main tributaries of the major rivers selected for detailed study, and for the large river basins in the Avalon, Burin, and Bonavista peninsulas.

The selections of the water quality characteristics to be extrapolated were based on two main factors:

a) The uses to which the qualities of the water would be related.

b) The physical, chemical, and "biological" characteristics of the water which could be related to the basin characteristics with a reasonable degree of confidence, and which could still be used as an indication of the suitability of the water for the selected uses.

The uses selected for the water were fisheries (suitability as an environment for fish), and industrial and domestic (suitability as a source of industrial and domestic water supplies) as these would present a broad range of water use and would bear a reasonable relationship to the present and future development of the Island economy. Since industrial water quality requirements in general can represent an extremely broad range of qualitative requirements, depending on the specific uses to which the water will be put, the requirements of the kraft pulp industry were selected as being representative of industrial water requirements.

The water quality characteristics which were selected as being pertinent to one and/or all of the three selected uses, and which could be related to the basin characteristics, are indicated in the following table which also indicates their applicability to the selected use.

Quality Designation	Specific Characteristics	Applicable to Use by: Fish	Industry	Domestic
Physical	Turbidity (T)	-	yes	yes
	Colour (C)	-	yes	yes
	Dissolved oxygen (O)	yes	-	yes/no
Chemical	pH (pH)	yes	yes	yes
	Hardness (H)	-	yes	yes
	Total dissolved solids (S)	yes	yes	yes
"Biological"	Pollution by domestic wastes (P)	-	-	yes
	Oxygen consumed by permanganate (O_2)	-	-	yes
	Re-aeration capacity (R)	yes	-	-

It is realized that some of the parameters not considered in the evaluation of the usefulness of the waters, particularly for the sustenance of fish life, may affect such usefulness under abnormal conditions. For instance, turbidity is a factor which can affect fish life in a number of ways; a turbidity of something in excess of 25 units may be harmful to spawning beds (by deposition of settleable solids) or one of 10,000 units could be directly harmful to the fish. However, turbidities of such magnitude do not presently obtain in the surface waters of the Island and therefore were not assessed in the current evaluation.

The bases used for the water quality extrapolations, and the relating of these extrapolations to each of the above uses, is discussed below. The results of the extrapolations for the basin studies are shown on Figure 26-1.

Bases for Extrapolation

The approach to the relationship of the qualities to be extrapolated and the river basin characteristics was basically an extension of the relationship already discussed in Section 24. The data on the river basin characteristics used in the water quality extrapolations are given in Table 26-1. The geological data was obtained from the maps included in Figures 5-1, 5-2, and 5-3. The hydrological data was obtained from the Department of Energy, Mines and Resources Papers "Surface Water Data for Atlantic Drainage". The physical-geographical data was obtained from the latest available publication of the Surveys and Mapping Branch of the above Department.

It should be noted that the data given in Table 26-1 are those for the individual drainage areas shown on Figure 26-1. The data used for the extrapolations are combined as necessary; for example, the data for Granite Lake Brook, Burnt Pond River, and White Bear River were combined for the White Bear River extrapolation.

26.2 Physical Characteristics

26.2.1 Turbidity

The turbidities of the waters of the Island are generally low. This is mainly due to the relative absence of fine grained materials in the glacial deposits as compared to other areas in Canada. Starting with this basic condition, the criteria which were considered in building up the relationship between the turbidity and the basin characteristics were:

a) Any evidence of deposition along the route of the river under investigation (on the 1:50,000 scale map) has been taken as evidence of a possible average turbidity of > 5.

b) Moderate average velocities (2.5 to 5.9 fps) in the streams in combination with a) were taken as indications of periods of higher turbidities than normal in peak flow periods.

c) A lake of significant size, downstream of a relatively large river or stream, could be expected to dampen the peak turbidities but would probably result in longer periods of turbidity higher than the average in the entering river.

d) A lower depth of overburden (a high percentage of unit R1 - predominantly exposed bedrock - Table 26-1) would likely result in a turbidity lower than normal.

e) Mining operations (man's activities) where tailings are discharged directly into the stream would result in erratic and generally high turbidities.

f) The flashiness of the stream. This would relate to the range of the variation of turbidity. Flashiness is dependent on several factors, including topography, geology, and vegetation. For this study an arbitrary limiting area of 100 square miles was set down as being the characteristic of a basin which would result in a "flashy" stream and which could present a wide variation

2B

in the range of turbidities. Larger basins would be less flashy, and therefore would have fewer fluctuations in the range of turbidity values (the variation of some of the characteristics with flow is discussed below).

The ranges of turbidity used for the visual indication of the extrapolated water qualities on Figure 26-1 are:

- rating	=	0 to 5 Units
0 rating	=	5 to 10 Units
- rating	=	greater than 10 Units

26.2.2 Colour

The generally high proportion of peat cover on the Island creates higher than normal concentrations of colour in the surface water. The colour would probably be greatest from an area with a high proportion of swamp, through an equal area of barrens, to the least from an area with a high proportion of forests.

Since the organic matter of the swamp lands are the most important source of colour, their locations in relation to the other areas of cover is important. This seems to be the case in the Harry's River area where the grouping of the swampy areas in the low lying lands at the downstream end of the drainage basins (near the sea) results in a colour concentration lower than "normal" for the Island. It is possible that the water from the swamps escapes to George's River through the overburden.

The range of colour used for the visual presentation of the water quality extrapolations on Figure 26-1 are:

- rating	=	0 to 10 Units
0 rating	=	10 to 20 Units
- rating	=	greater than 20 Units

26.2.3 Dissolved Oxygen

Because of the general characteristics of the profiles of the rivers of the Island (Section 5) the surface waters in their natural state would have a high dissolved oxygen concentration. More specifically, rivers with both steady slopes and moderate to high velocities and sections of river with flat gradients in combination with rapids would have good re-aeration characteristics and, barring pollution, would have high dissolved oxygen concentration.

Dissolved oxygen concentrations in lakes do not generally vary with depth, as the lakes are exposed to high winds which improve circulation.

Man's activities can have a significant effect on the dissolved oxygen concentration since both industrial and domestic wastes may have high biochemical oxygen demands which must be satisfied by the level of dissolved oxygen upstream of the pollution in combination with the re-aeration capacity downstream. The extent of the depletion of the dissolved oxygen is a function of pollution load and the stream flow characteristics. The length of the reach over which the depletion lasts is a function of the re-aeration capacity.

The ranges of dissolved oxygen concentration used for the rating of the extrapolations on Figure 26-1 are:

+ rating	=	greater than 6.0 mg/litre
0 rating	=	between 5 and 5.9 mg/litre
- rating	=	less than 4.9 mg/litre

26.3 Chemical Characteristics

26.3.1 pH

The bulk of the pH determinations in the quality analyses available from the Department of Energy, Mines and Resources were made in Ottawa, but some were measured both in the field and in the laboratory. In most cases where the two measurements were made, the field determination tended to be higher than that made in the laboratory; that is, the pH tended to be lower on storage. This trend seemed to be borne out by the supplementary grab sampling program of Shawinigan-MacLaren in which the pH's determined in the field were generally higher than those extrapolated from the Department of Energy, Mines and Resources laboratory determination. The reason for this lowering of the pH in storage was due to the change in the carbon dioxide-bicarbonate-carbonate equilibrium in the sample, resulting from a loss of CO_2 on temperature rise.

Since there are two pH's of interest for the uses selected as quality standards - that in situ for fish and that after storage for domestic and possibly industrial use - it was decided to try to project, on the basis of the data at hand, the pH results in the field and in the laboratory. The criteria used for the projection of pH are as follows:

a) A high proportion of vegetative cover (swamps and forests plus barrens) would tend to result in a pH below 7 but probably not below 6.5. This is generally the case over the Island.

b) A high proportion of swamps and barrens, or swamps alone, would result in a pH even lower than that projected for a).

c) A high percentage of unit R8 bedrock (limestone and dolomite) will raise the pH, probably to above 7.

d) Many of the mine processes used on the Island involve the use of slaked lime. This results in the raising of the pH of the water discharged with the mine tailings to between 7.5 and 11.5, and this in turn tends to raise the pH of the stream into which the tailing water discharges.

e) Because of the "soft" classification of the water and generally low total dissolved solids, a considerable change of pH value may be expected between the in situ tests and laboratory tests. Results to date indicate the latter to be lower.

The ranges of pH used for the visual indication of the extrapolated water qualities on Figure 26-1 are:

+ rating	=	6.5 to 8.5
- rating	=	less than 6.49
0 rating	=	in the area of 6.5

In no case has a pH greater than 8.5 been recorded in the surface water of the Island.

26.3.2 Hardness

The surface waters of the Island are generally very soft, reflecting the characteristics of the greater proportion of the rocks of the Island (units R1 to R7, inclusive).

The only rock which increases the hardness of the waters above the soft range, to the moderately hard, is unit R8 (series with dominant limestone and dolomite) on the west coast of the Island. The limestone rocks are the most soluble rocks on the Island and are high in calcium carbonate, hence, the relatively high hardness of the waters.

The depth of overburden affects the hardness of the waters emanating from the unit R8 rocks. The greater depths of overburden will lengthen the time of contact with rock, and will result in higher concentrations of $CaCO_3$.

The ranges of hardness used for rating the extrapolated water qualities on Figure 26-1 are:

+ rating	=	(soft) 0 to 50 mg/l*
0 rating	=	(moderately hard) 50 to 150 mg/l*
- rating	=	(hard) greater than 150 mg/l*

* total hardness as $CaCO_3$

26.3.3 Total Dissolved Solids

In general, the surface waters of the Island are low in total dissolved solids. The major factors affecting the total dissolved solids content of the surface waters are similar to those affecting hardness, as follows:

a) The nature of the rock. The order of solubility of the rocks is as follows:

Unit R1	Major igneous intrusions - relatively insoluble.
Units R2 and R3	Mainly Pre-Cambrian sediments and volcanics - relatively insoluble, most of the more readily dissolved components of the volcanic sequences having long since been carried off in solution.
Units R4, R5, and R6	Cambrian to Devonian metamorphics, volcanics, and sediments - slightly more soluble than Units R1, R2, and R3, but still relatively insoluble.
Unit R7	Carboniferous sediments - generally relatively insoluble containing a reasonable proportion of soluble components such as anhydrite, gypsum, and sodium chloride.
Unit R8	Series with dominant limestone and dolomite. The most soluble rock on the Island with a high proportion of calcium carbonate and less of calcium magnesium carbonate.

The total dissolved solids would be expected to increase slightly in the surface waters emanating from the first three of the above grouping (all other characteristics being similar). A marked increase in total dissolved solids would be expected in waters passing through unit R7 rocks with by far the greatest total dissolved solids occurring in waters passing through areas of unit R8 rocks.

b) The depth of overburden will affect the total dissolved solids since it affects the length of contact time between the solvent (that portion of the surface water emanating from the ground water source - the base flow) and the solute - the rock.

The ranges of total dissolved solids concentrations used for the rating of the extrapolations on Figure 26-1 are:

+ rating	=	0 to 100 mg/l
0 rating	=	100 to 200 mg/l
- rating	=	greater than 200 mg/l

26.4 Biological Characteristics

The term "biological" is used with qualification since the characteristics involve a measure of the bacteriological quality (pollution by population), a measure of organic content (oxygen consumed by permanganate), and a measure of the physical characteristics of the river profile (re-aeration capacity).

26.4.1 Pollution by Domestic Wastes

The projection of the extent of pollution by domestic wastes was made strictly on a mathematical calculation of the expected E. Coli counts (the bacteria of the coliform group confined to the intestinal tract). The determination of the E. Coli count was based on the data given by Fair and Geyer (p. 512); that is, a daily per capita excretion of close to 400 x 10^9 members of the coliform group of organisms, approximately 90 percent of which are E. Coli. On this basis and on a conservative assumption of no die-off, the E. Coli count of a given river with flow Qcfs, into which a population P is discharging its domestic raw sewage upstream of the point being investigated, would be

$$16.3 \times \frac{P}{Q} \quad \text{E. Coli/100 ml}$$

The limits of E. Coli/100 ml used for visual presentation of pollution by domestic wastes on Figure 26-1 are:

+ rating	=	a projection of less than 1 E. Coli/100 ml
0 rating	=	a projection of 1 E. Coli/100 ml
- rating	=	a projection of greater than 1 E. Coli/100 ml

The theoretically calculated E. Coli counts were used for the determination of the condition of all basins since the only source of coliform counts on some of the major basins and their tributaries was the Shawinigan-MacLaren sampling program which only determined the coliform group of organisms and was not specific for E. Coli. The specific test for the special group (the IMVIC test) was far more complex and time consuming than the facilities and the time available for the program permitted.

26.4.2 Oxygen Consumed by Permanganate

The analyses made on waters from the larger drainage basins of the Island indicate values of this parameter ranging from 1 to 23 mg/l with an average over 38 basins of approximately 8.5 mg/l. Factors which appeared to affect this characteristic and which were used as criteria in the extrapolations were:

a) The relative proportions of swamp and barrens affects the oxygen consumed, as does forest land to a lesser extent.

b) As with colour, the location of the swampy areas affects the oxygen consumed. For example, in the Harry's River basin the swampy areas are located in the low lying area at the bottom of the drainage basin near George's River. The result is relatively low oxygen consumed probably due to the water from the swamps escaping to George's River through the overburden.

c) A high proportion of low depths of overburden in combination with significant proportions of swamp and barrens seems to result in a high oxygen consumed (upper Humber River).

d) The discharge of waste waters high in organics results in a higher oxygen consumed. This is especially pronounced where bottom deposits of organic debris, such as decomposing bark, have accumulated over long periods of time.

The limits of oxygen consumed by permanganate used for visual presentation on Figure 26-1 are:

- rating	=	less than 10 mg/l
0 rating	=	about 10 mg/l
- rating	=	greater than 10 mg/l

26.4.3 Re-aeration Capacity

The re-aeration capacity of each river and tributary under consideration was determined on the basis of two simplified relationships. Firstly, a relationship between the character and slope of the stream or body of water and the velocity, and secondly, the relationship between the velocity and a re-aeration capacity.

The data used to relate slope to velocity were based on the formula developed by D. L. Sokolovskii.

$V = 31 \, I^{0.40} \, h^{0.5}$ where I = water surface slope and H = average water depth in feet.

These data were further simplified in the publication so that a subjective estimate could be made of the velocity on the basis of the slope and the characteristics, as follows:

Topographic Characteristics	Slope I (ft/ft)	Velocities - V(fps) Small Basins ($h < 3$ feet)	Large Basins ($h > 3$ feet)
Lowland	0.0001 - 0.0005	1.0 to 1.7	1.3 to 2.7
Plain	0.0005 - 0.005	2.7 to 4.0	3.3 to 5.0
Highland	0.005 - 0.01	5.0 to 8.3	6.7 to 8.3
Mountain	0.01 - 0.05	8.3 to 11.7	8.3 to 15.0

The re-aeration capacities were then qualitatively related to the estimated stream velocities on the following bases (the ratings used coinciding with those shown on Figure 26-1):

Rating	Description of Body of Water	Velocity (fps)
-	Small ponds, backwaters, sluggish streams, and large lakes	0 to 2.4
0	Large stream of low to moderate velocity	2.5 to 6.0
+	Swift streams and rapids	greater than 6

The river or tributary under consideration was divided into reaches with more or less uniform slope (as determined from the difference in elevation and distances as taken from the topographic mapping), and the velocity over each such reach then determined. The average velocity over the entire reach was then determined on a weighted average basis (the sum of the velocities x the reaches over which they applied divided by the total length of river), and the re-aeration capacity of the tributary was based on this weighted average velocity.

26.5 Variation of Quality with Flow

In order to make the water quality extrapolations more meaningful, an attempt was made to establish a relationship between as many of the individual characteristics as possible and the flow variations. The determinations of such a relationship were of necessity restricted to those basins on which more or less continuous flow and quality measurements had been made on a year round basis.

As indicated in Section 23, the data from the Department of Energy, Mines and Resources (Table 23-2) provide the only source of such information, and that is of a limited nature. The data provided by the Department of Fisheries on the Exploits provide additional data on this river since the samples were taken at more or less regular intervals over periods of several months. However none of the latter series of samples represents a full year since the Department is only interested in the period which most affects the salmon's life cycle. In addition to this limitation, the flow of the Exploits River below Red Indian Lake is controlled by the Millertown dam and it appears that, possibly as a result of this control, the characteristics of the waters of the Exploits do not bear a direct relationship to the flow.

Of the ten basins on which the Department of Energy, Mines and Resources data were available (Corner Brook, Grand Lake outlet, Upper Humber River, Gander River, Rocky River, Pipers Hole River, Exploits River at Grand Falls, Harry's River, Isle aux Morts River, and the Terra Nova River), two were discarded immediately on the basis that no flow data was available - Corner Brook and Harry's River. The Isle aux Morts River was discarded because, at the time of writing, only six analyses were available and corresponding flow data were available for only three of these.

The attempts made to discern a relationship between some of the water quality characteristics on the Grand Lake outlet, the Gander River, the Exploits River below Grand Falls (applying where possible the Department of Fisheries data), and the Terra Nova River were unsuccessful. A plot of the quality data versus flow, in all cases, resulted in a series of points either very widely scattered or clumped together, from which no discernable trend could be reasonably inferred. It is of interest to note that the one characteristic which each of the basins had in common was the existence, upstream of the sampling station, of a lake of significant size, Grand Lake, Gander Lake, Red Indian Lake, and Terra Nova Lake respectively. It may well be that in each case the lake dampened the variation of the characteristic under consideration, and that in such a situation a relationship betwen flow and quality could not reasonably be expected.

The relationship between some of the water quality characteristics used in the extrapolations and flow were determined for the remaining basins - Pipers Hole River, Rocky River, and the Upper Humber River at Deer Lake. Of the characteristics three were not considered in the variations - dissolved oxygen, pollution by population, and re-aeration capacity - primarily since these were based purely on extrapolation and also since the variation of these particular qualities is not of too great interest. No discernable trend could be established for the variation of colour with flow and the data on oxygen consumed by permanganate was insufficient to establish a trend with a reasonable degree of confidence.

Therefore, the characteristics for which trends were determined for their variation with flow were turbidity, pH, hardness and total dissolved solids. The results of the investigations of these variations are shown on Figures 26-2 to 26-5 inclusive, and have been plotted in two ways; that is, in absolute values (the measurement of the characteristic versus the measured flow for each basin) and in relative values (the percentage of the characteristic at average flow conditions versus the percentage of the average flow). The curves were calculated on the basis of the least-squares approach and were originally plotted on log-normal paper. For the purposes of establishing the validity of the curves, the actual values are plotted on the graphs of absolute values. It will be noted that no curve of relative values has been included for the variation of total dissolved solids with flow for the Pipers Hole River, since the imposition of a straight line on the data plotted on log-normal paper was questionable. Similarly, the plot of variation of hardness with flow for this river is also questionable, although it is included.

26.6 Reliability Rating of Water Quality Extrapolations

In order to be able to express a relative degree of reliability of the water quality extrapolations shown on Figure 26-1, an attempt has been made to evolve a series of "Reliability Indices" which could be used for this purpose. The indices were developed on a twofold basis. Firstly, an assessment was made of the ability to project each of the nine parameters making up the extrapolation, within the range of limits used to define the characteristic of the particular parameter (a plus characteristic for turbidity has a range of 0 to 5 units, etc) and secondly, an allowance was made for the degree of confirmation obtained from the data available.

Of the total of 100 percentage points for an absolutely perfect extrapolation in combination with a high degree of confirmation, 81 points were applied against the extrapolation of each of the nine parameters and the remaining 19 points were assessed on the basis of the degree of confirmation. The reliability indices were developed as follows:

26.6.1 Unconfirmed Extrapolation

The 81 points were divided equally among the nine parameters. The base reliability index for an extrapolation without confirmation was established upon the following assessment of the point value of each parameter.

Turbidity and colour are parameters with three possible distinct categories (0, plus, and minus). If the projected rating was a plus, then it could be stated with assurance that the average would not fall into the 0 range, and vice-versa. If it was extrapolated that the parameter fell within the 0 range, there would be a low degree of assurance that it would not fall into either the plus or minus range. It was therefore concluded that without confirmation turbidity and colour extrapolations could be assigned only five of a possible nine reliability points.

Dissolved oxygen, hardness, total dissolved solids and pollution by population are all parameters with a very high probability of being extrapolated correctly. However, since a 100 percent accuracy of prediction would be an unreasonable assumption, each of these parameters was assessed at 8.5 points out of 9.

pH is a parameter with only two effective categories plus (> 6.5) and minus (< 6.5). The nature of the bulk of the waters on the Island is such that there was a good possibility that the pH would fall into the range of 6.5 ±. On the basis of this latter condition, this parameter, without confirmation, was allocated 4.5 points.

Oxygen consumed by permanganate is also a parameter with two possible categories, plus (< 10) and minus (< 10). Available data indicate a strong possibility that this would be less than 10 (that is, plus), however, there was less than a 60 percent chance that this was the case. The evaluation of this extrapolation, without confirmation, was 5 out of 9.

Re-aeration capacity is strictly a calculated evaluation. However, some reservations must be placed on the bases used and this parameter was assessed at 6.5 points. In summary, therefore, the Reliability Index for an unconfirmed extrapolation is made up as follows:

Parameter	Percentage Points
Turbidity	5
Colour	5
Dissolved Oxygen	8.5
pH	4.5
Hardness	8.5
Total Dissolved Solids	8.5
Pollution by Population	8.5
Oxygen Consumed by Permanganate	5
Re-aeration Capacity	6.5
Reliability Index	60.0%

26.6.2 Confirmation by Grab Sampling Program

Four parameters are confirmed by Shawinigan-MacLaren, namely, dissolved oxygen, pH, hardness and total dissolved solids. As discussed previously, D.O., hardness and TDS are probably at their optimum rating, therefore only the pH parameter rating was increased and that to 6.5. On the basis that four parameters were confirmed 4/9 of the 19 percentage points allowed for confirmation were added to the revised base index. Therefore, the Reliability Index for an extrapolation with an S-M confirmation becomes

$$60.0 + 2.0 + 8.0 = 70\%$$

26.6.3 Substantial Confirmation by Any Authority

A substantial confirmation, (that is, five or more analyses) by any authority, particularly Department of Energy, Mines and Resources, would, in addition to that outlined in 26.6.2, provide confirmation for turbidity, colour, and oxygen consumed by permanganate. On this basis, the assessment of the nine point allowance for each parameter was increased as follows:

Turbidity	from 5 to 7.5
Colour	from 5 to 8
Oxygen Consumed by Permanganate	from 5 to 7.5

Therefore, the Reliability Index for an extrapolation with a significant amount of confirmatory data would be

$$\underset{(pH)}{60 + 2} + \underset{(turb.)}{2.5} + \underset{(colour)}{3} + \underset{(O_2\ cons.)}{2.5} + 7/9 \times 19 = 85\%$$

26.6.4 Reliability Index

A reliability index of 75 percent was selected for a degree of confirmation falling between (26.6.2) and (26.6.3).

The bases used for the reliability indices as described above could certainly not be termed exact as they were based on judgement of the degree of confidence which could be placed in the extrapolations. Since the extrapolations themselves are largely made up of subjective decisions, it is not unreasonable to assume that a similar approach to the indices is justified and further that a statistical approach to them could be misleading.

In summary, therefore, the reliability indices evolved for the extrapolations are as follows:

Degree of Confirmation	Reliability Index
None	60%
Shawinigan-MacLaren Program	70
Shawinigan-MacLaren Program plus two or three analyses from other sources	75
A significant number of analyses by any source	85

On the basis of the above, the following is a list of the reliability indices of the various extrapolations made for this study.

River Basin	Description of Tributary or Reach	Reliability Index
St. John's Area	Quidi Vidi Lake Outlet	70%
	Waterford River	70
	Raymond Brook	70
	Pierres Brook	70
	Mobile River	70
	North Arm River	70
	Goulds Brook	70
	Manuels River	70
	Seal Cove River	70
Burin Peninsula Area	Grand Bank Brook	70
	Salmonier River	70
	West Tributary to Great Lawn Harbour	70
	East Tributary to Great Lawn Harbour	60

River Basin	Description of Tributary or Reach	Reliability Index
Burin Peninsula Area	Tides Brook	70%
	Garnish River	60
Come By Chance Area	Piper's Hole River	85
	Black River	75
	North Harbour River	75
	Come By Chance River	85
Conne River	Conne River	60
Salmon River	Meelpaeg Lake	60
	West Salmon River	60
	North Salmon River	60
	Salmon River	60
Grey River	Grey River	60
White Bear	Granite Lake Brook	60
	Burnt Pond River	60
	White Bear River	60
Exploits River	Lloyds River	60
	Victoria River	60
	Star Lake River	60
	Shanadithit Brook	70
	Buchan's Brook	85
	Mary March's Brook	75
	Red Indian Lake	85

River Basin	Description of Tributary or Reach	Reliability Index
Exploits River	Badger Brook	60%
	Noel Pauls Brook	60
	Exploits River at Grand Falls	85
	Great Rattling Brook	60
	Exploits River at Bishop's Falls	85
Stephenville Area	Harry's River	85
	Southwest River	70
Humber River	Adies River	60
	Upper Humber River (N)	60
	Upper Humber River (Deer Lake)	85
	Lewaseechjeech River	60
	Hinds Brook	60
	The Main Brook	60
	Grand Lake	85
	Humber River	75
Cat Arm River	Cat Arm River	60
Gander River	Northwest Gander River	60
	Southwest Gander River	60
	Gander Lake	85
	Gander River	80*
Terra Nova River	Upstream of Terra Nova Lake	75
	Terra Nova River	85

* No confirmation, but little change expected from Gander Lake outlet.

Study Area	Description of Tributary or Reach	Reliability Index
Come By Chance and Environs	Southeast River	70%
	Northeast River	70
Badger-Botwood	Peters Arm Brook	70
	Northern Arm Brook	70
Bonavista Peninsula	Trouty River	70
	River at Lockston	70
	River at Champneys	70
	River at Port Union	70
	River at Little Catalina	70
	River at Bonavista	70

26.7 Summary

Some efforts are being made by the Federal and Provincial Governments to establish the water quality of many of the surface waters of the Island of Newfoundland. The most significant of the surveys involved are those being executed by:

a) The Canada Department of Energy, Mines and Resources, with regard to the establishment of base line data on many of the major river basins.

b) The Canada Department of Fisheries, Resource Development Branch, by tracing the effects on fish life of specific pollutants generated by man's activities on some of the rivers of the Island and Labrador.

c) The recently completed survey of water supply characteristics of most of the communities of the Province having water supply systems, as executed by the Provincial Department of Health in conjunction with the Department of National Health and Welfare.

These data provide a foundation for the great quantity of sampling, analyses, and similar investigations which are still needed to establish a definitive picture of the quality and condition of the surface waters of the Province.

To supplement these meagre data, a method was specially developed for estimating the quality of waters for which analyses were not available. This scheme was established by relating quality to the physical characteristics of a river basin. With these relationships established and physical characteristics generally known for all of the basins of the Island, the general quality conditions could be synthesized. The results obtained were then checked through a grab sampling program carried out during the study for this purpose. Water quality conditions so developed were then rated for reliability utilizing a special index developed for this situation.

On the whole excellent confirmation was achieved and a reliable albeit general picture of water quality throughout the Island was developed.

The waters were found to be generally very low in turbidity, but with natural colour being generally higher than 15 units. Because the low level of human usage and in view of the relatively good mixing qualities in most lakes and rivers of the Province, dissolved oxygen concentrations normally approached saturation.

The pH of most waters although approaching neutral was slightly acid except on the west coast of the Island where limestone and dolomite in the bedrock elevated it to neutral or slightly basic. With the exception of the moderately hard waters of the west coast (due to limestone bedrock) the surface waters proved extremely soft and so it follows that with the exception of the west coast total dissolved solids were also low.

The level of pollution as measured by oxygen demand and toxicity is generally low although several critical areas on the Churchill and Exploits Rivers do exist where industrial wastewaters have degraded quality and domestic wastewaters have caused problems in the St. John's area. More specific aspects are outlined in Volumes Six and Seven.

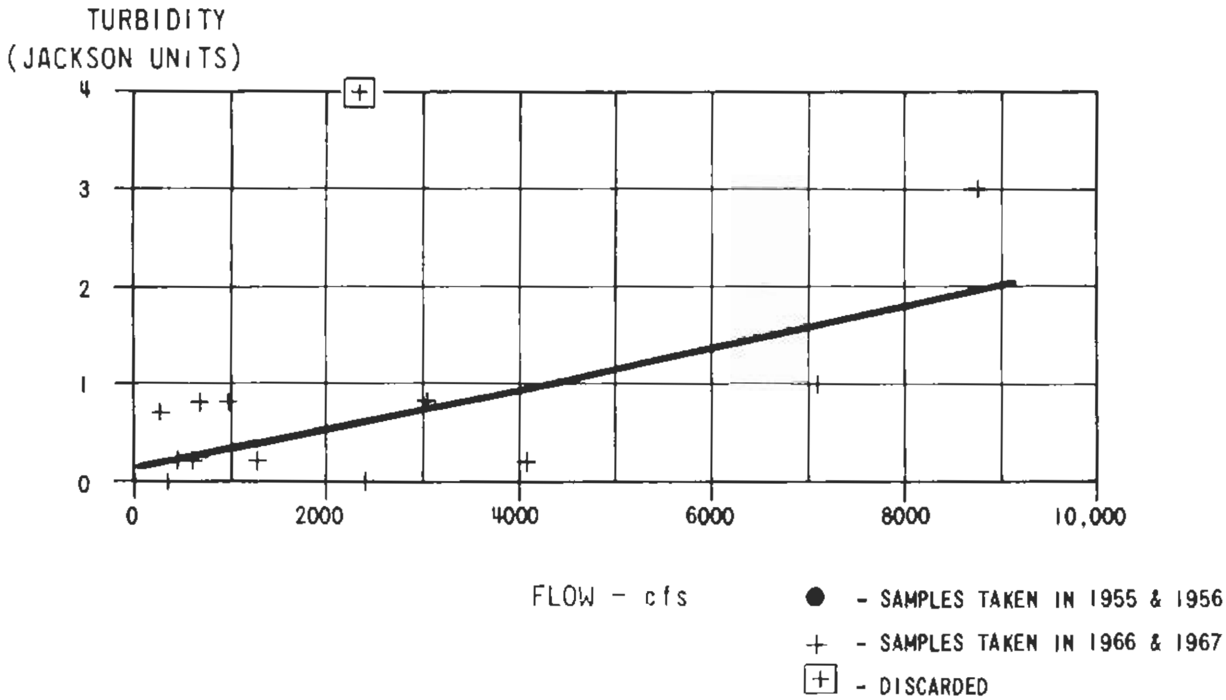
The level of pollution as measured by the concentration of coliform bacteria in the surface waters is extensive in all areas where any significant concentration of population exists. This is because domestic wastes are normally discharged in a raw state to the surface waters or to improperly constructed septic tanks. In many instances groundwater is also polluted for the same reasons.

The natural organic content of most surface waters of the Province, as measured by the oxygen consumed test, is high due apparently to the large areas of swamps and bogs in the Province. Re-aeration capacities and therefore recovery capability of the rivers can be generally described as good.

Despite the lack of adequate analyses, a specially designed water quality extrapolation scheme has disclosed that the existing water quality of the Province of Newfoundland and Labrador ranks among the best in North America. The maintenance of such a general condition and the correction of specific degraded areas will permit the Province to offer its people an invaluable asset in their future development.

NEWFOUNDLAND
VARIATION OF TURBIDITY WITH FLOW

UPPER HUMBER RIVER



ROCKY RIVER

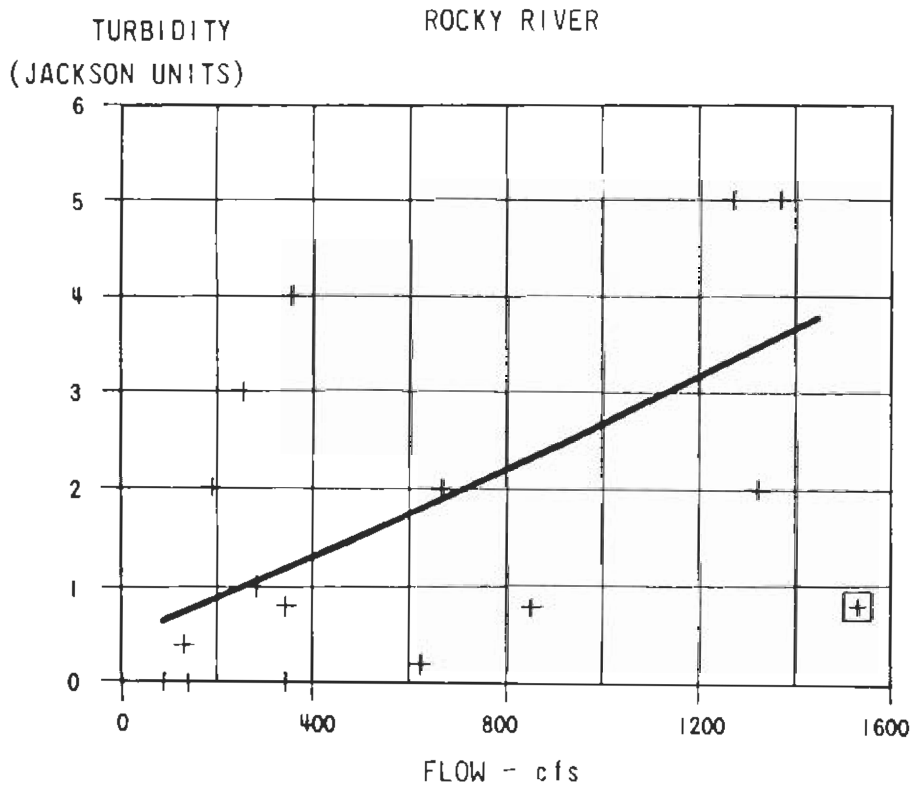
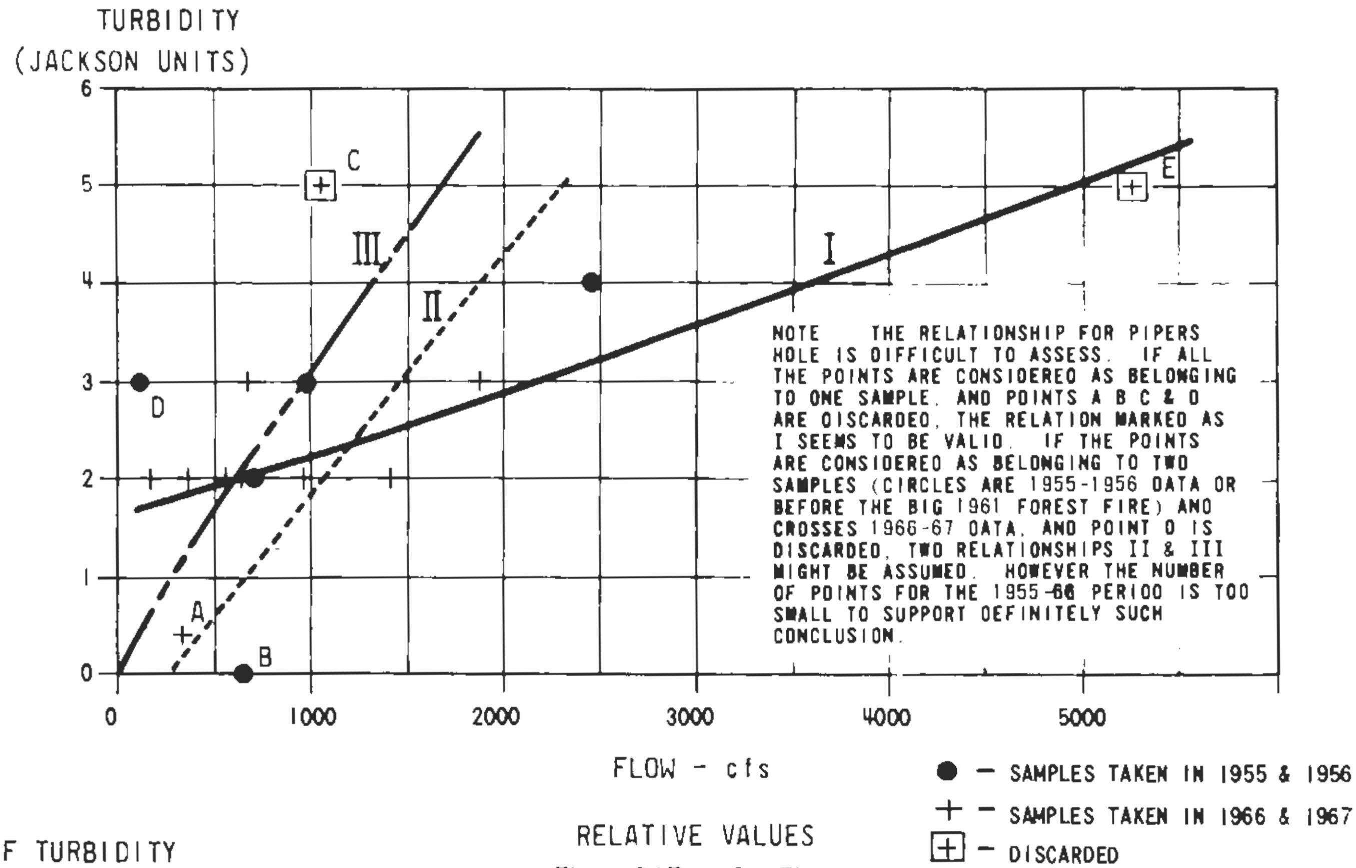


FIGURE 26-2A

NEWFOUNDLAND
VARIATION OF TURBIDITY WITH FLOW

PIPERS HOLE RIVER



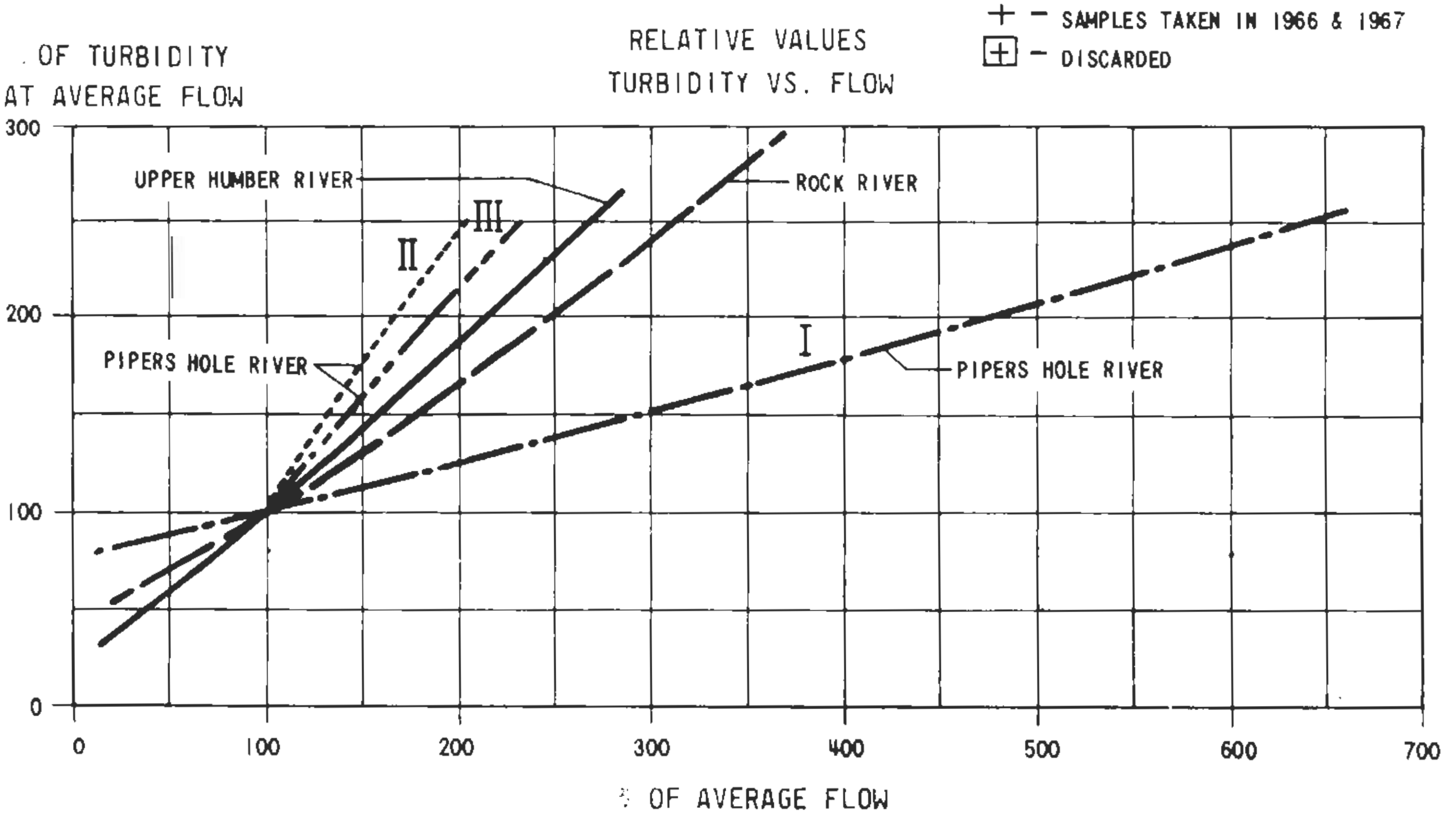
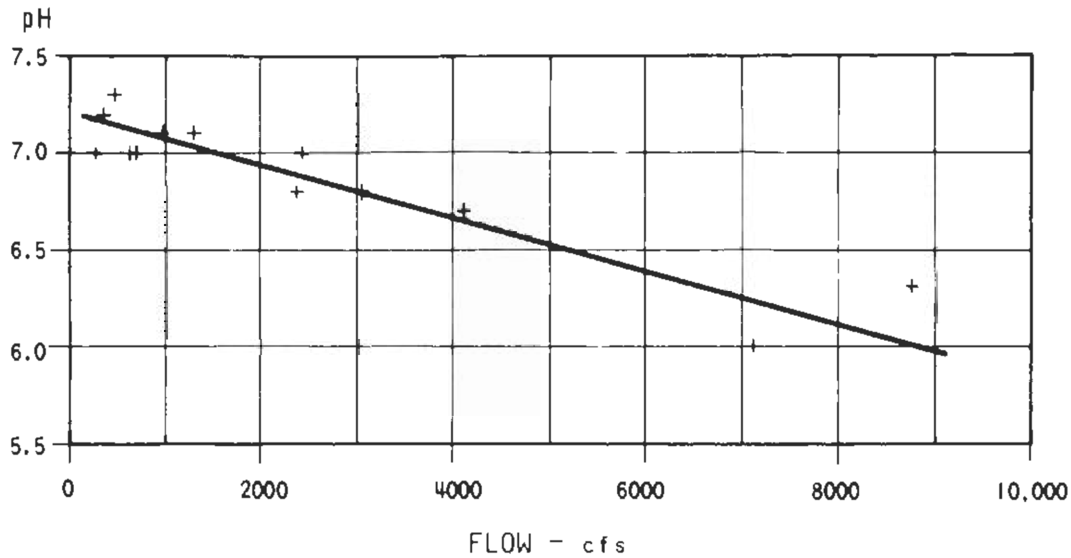


FIGURE 26-2B

NEWFOUNDLAND
VARIATION OF pH WITH FLOW

UPPER HUMBER RIVER



ROCKY RIVER

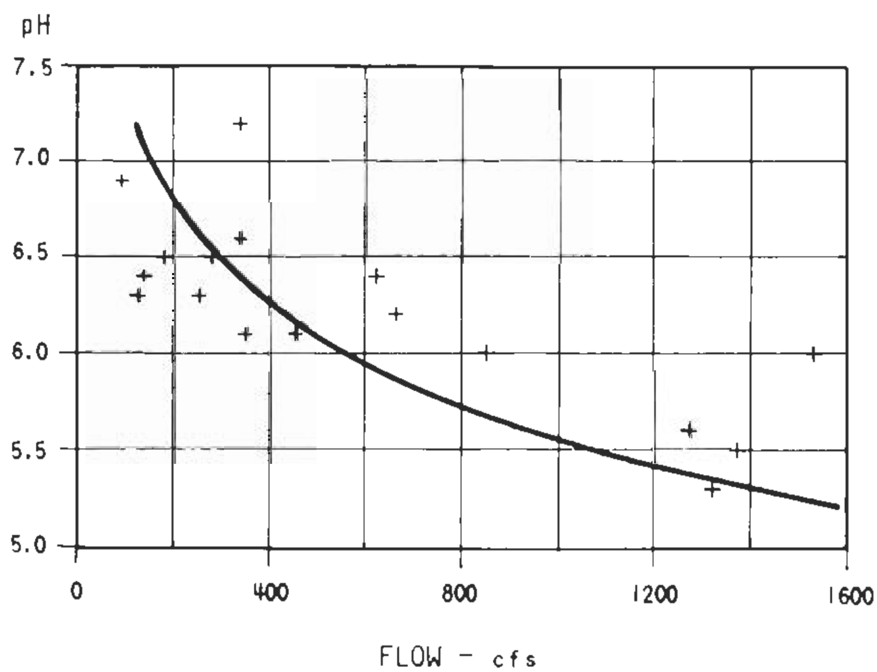
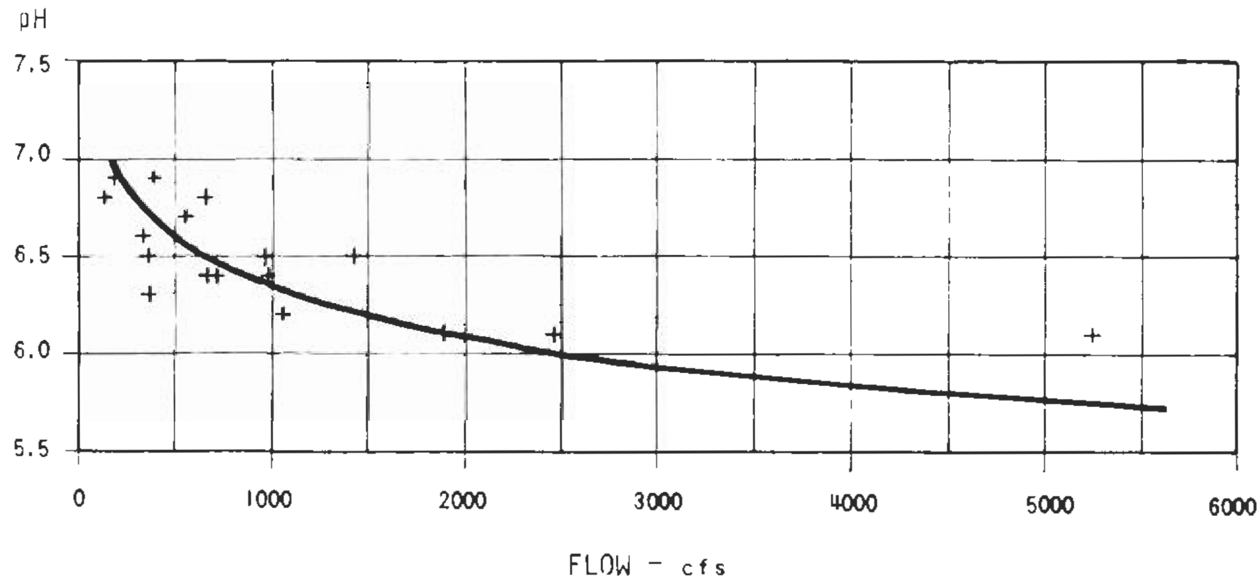


FIGURE 26-3A

NEWFOUNDLAND
VARIATION OF pH WITH FLOW

PIPERS HOLE RIVER



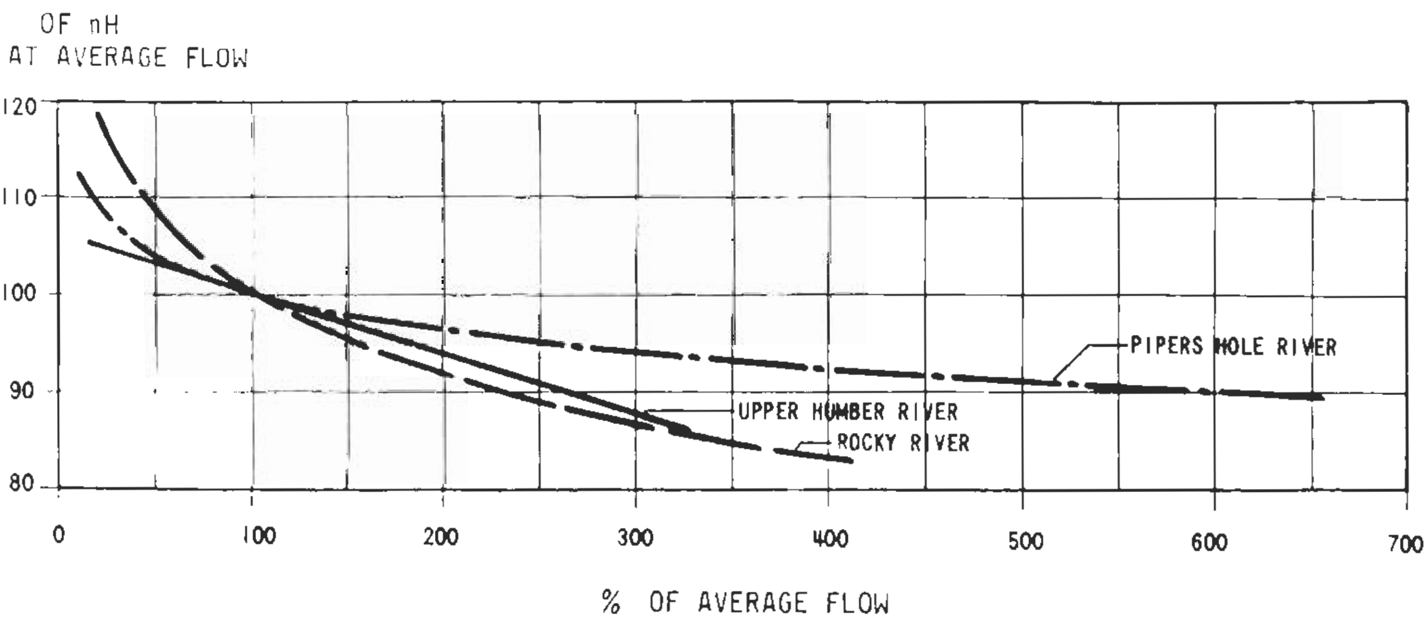
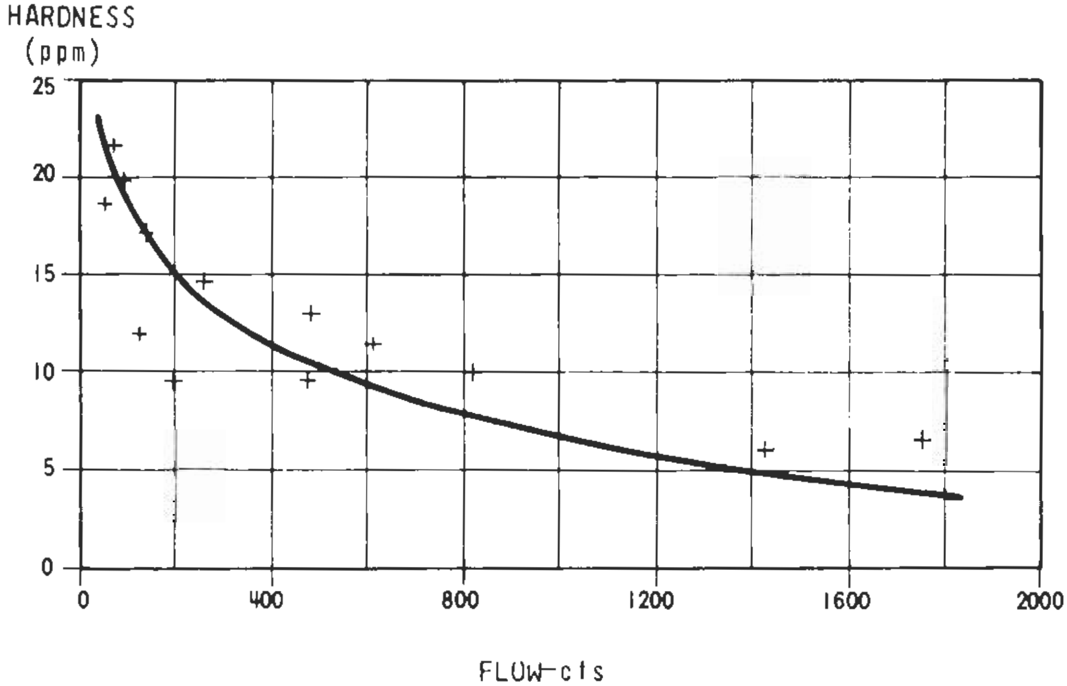


FIGURE 26-3B

NEWFOUNDLAND
VARIATION OF HARDNESS WITH FLOW

UPPER HUMBER RIVER



ROCKY RIVER

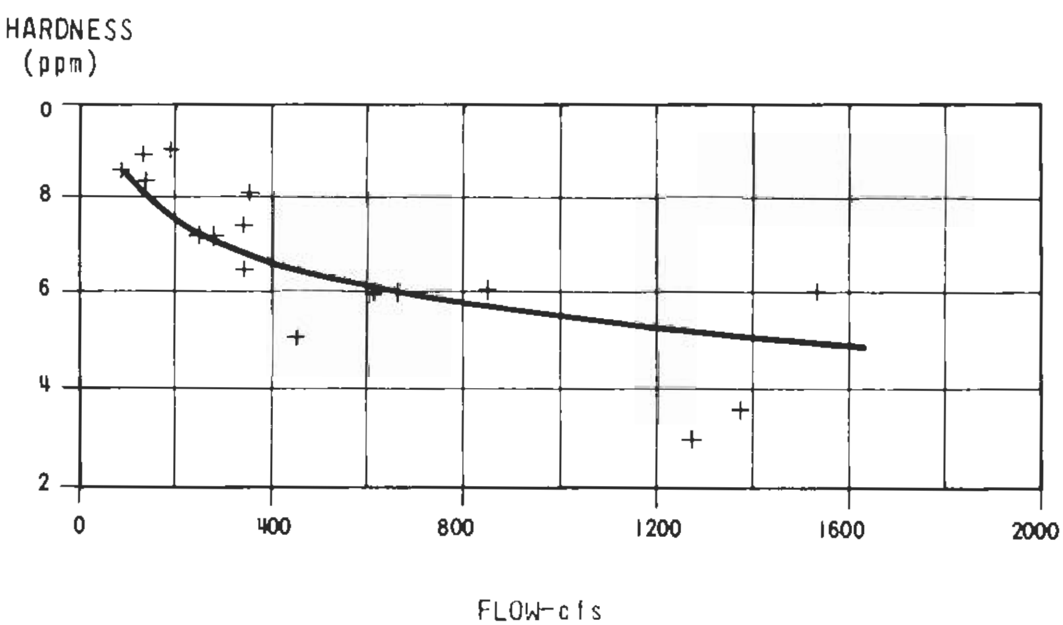
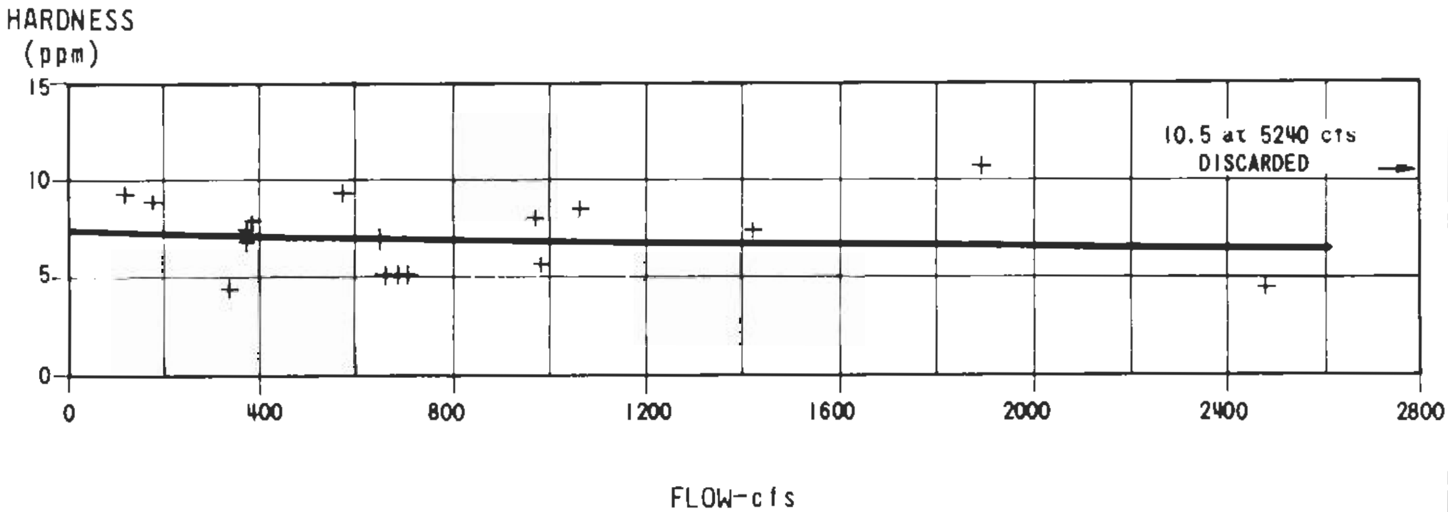


FIGURE 26-4A

NEWFOUNDLAND
VARIATION OF HARDNESS WITH FLOW

PIPERS HOLE RIVER



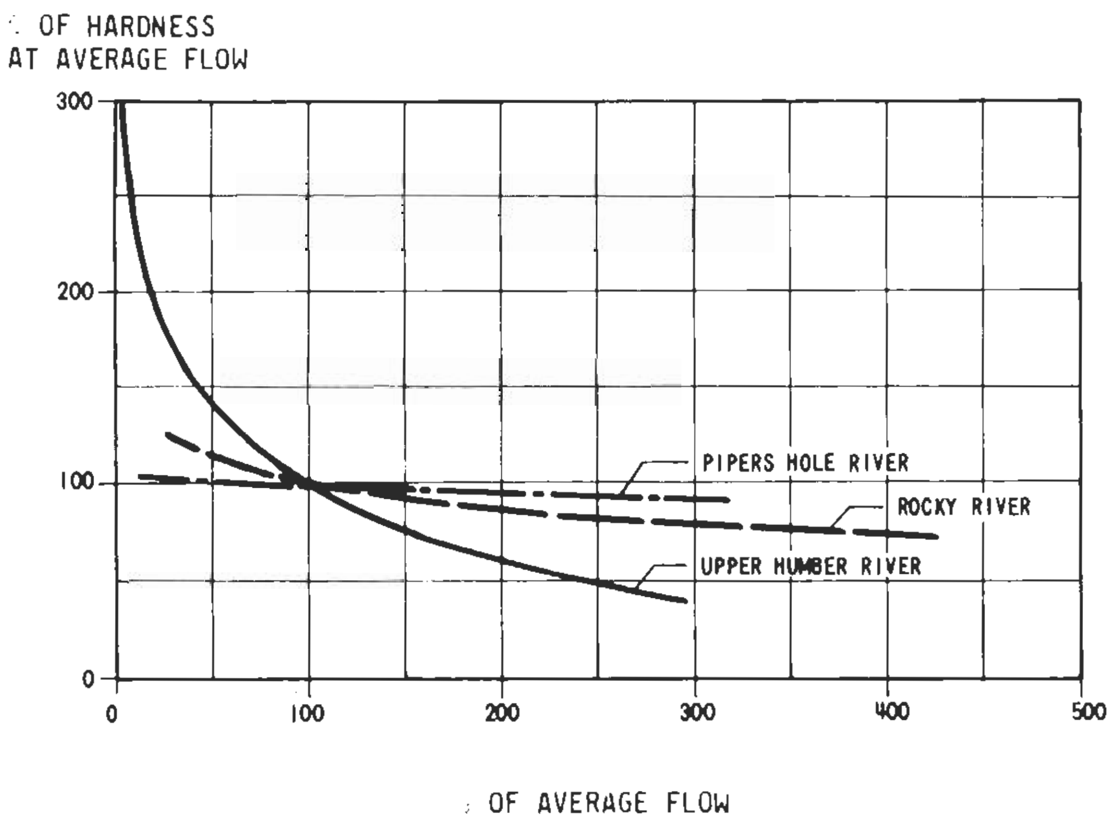
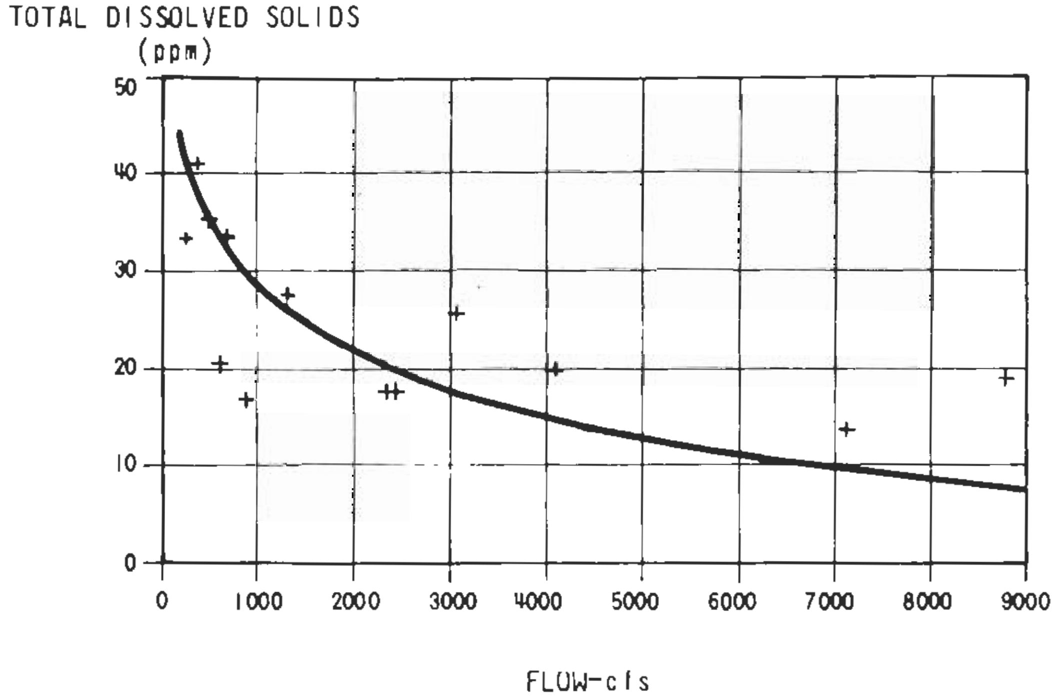


FIGURE 26-4B

NEWFOUNDLAND
VARIATION OF TOTAL DISSOLVED SOLIDS WITH FLOW

UPPER HUMBER RIVER



ROCKY RIVER

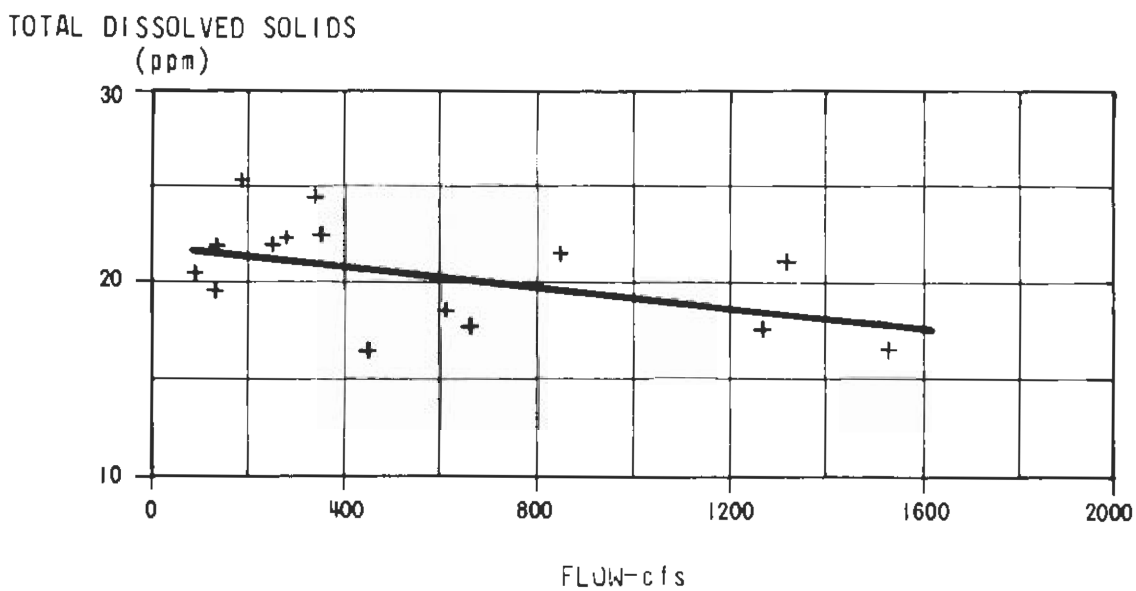
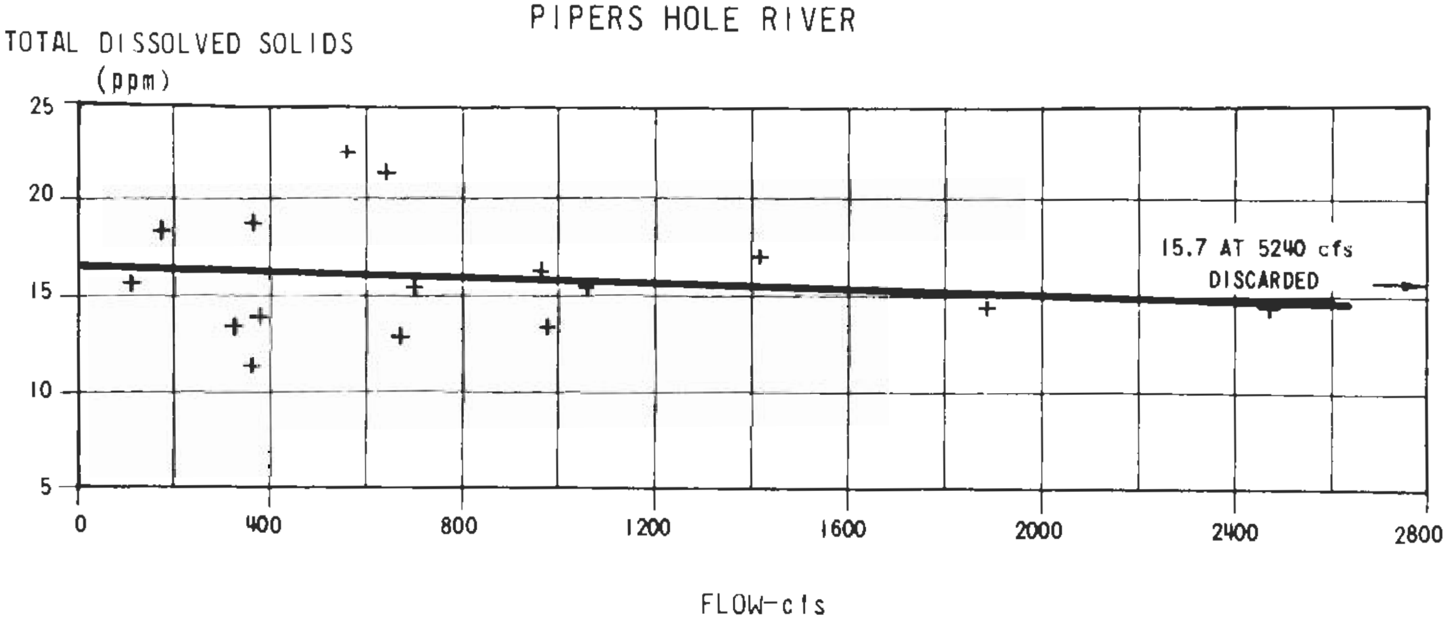


FIGURE 26-5A

NEWFOUNDLAND
VARIATION OF TOTAL DISSOLVED SOLIDS WITH FLOW

PIPERS HOLE RIVER



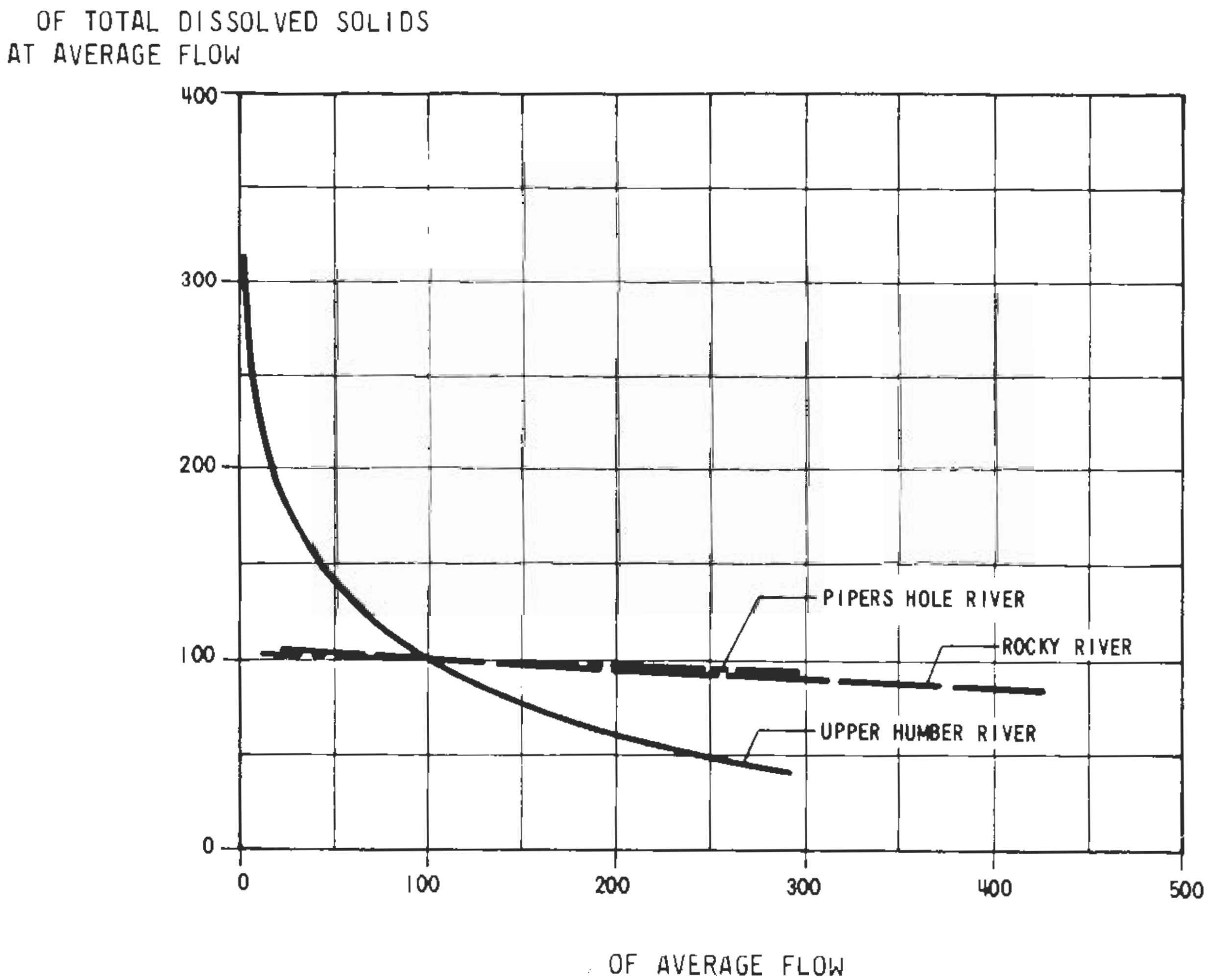


FIGURE 26-58

NEWFOUNDLAND

SUMMARY OF DATA USED IN ESTABLISHING CORRELATIONS BETWEEN FLOW AND WATER QUALITY CHARACTERISTICS

RIVER BASIN CHARACTERISTICS

RIVER BASIN	OVERBURDEN*	HYDROLOGICAL DATA FROM STATION	PHYSICAL-GEOGRAPHICAL DATA: AREA SQ. MI.	PERCENTAGE: LAKE	SWAMP	FOREST	BARRENS
ST. JOHN'S AREA							
Quidi Vidi Lake Outlet	5% Unit 1 95% Unit 2						
Waterford River	15% Unit 1 85% Unit 2		[illegible]	[illegible]		[illegible]	[illegible]
Raymond Brook	25% Unit 1 75% Unit 2	[illegible]	[illegible]	[illegible]			[illegible]
Pierres Brook	15% Unit 1 85% Unit 2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Mobile River	40% Unit 1 60% Unit 2	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]
North Arm River	83% Unit 2 17% Unit [illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Goulds Brook	15% Unit 1 35% Unit 2 50% Unit 3		[illegible]	[illegible]	2	2	[illegible]
Manuels River	3% Unit 1 90% Unit 2 7% Unit 3		[illegible]		[illegible]	[illegible]	[illegible]
Seal Cove	13% Unit 1 87% Unit 2		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
COME BY CHANCE AREA							
Come By Chance River	30% Unit 1 70% Unit 2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
North Harbour River	100% Unit 2		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Black River	100% Unit 2		[illegible]	[illegible]	1	[illegible]	22
Pipers Hole River	18% Unit 2 82% Unit 3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Southeast River	12% Unit 1 88% Unit 2		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Northeast River	25% Unit 1 70% Unit 2 5% Unit 3		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
BURIN PENINSULA AREA							
Grand Bank Brook	100% Unit		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Salmonier River	25% Unit 1 75% Unit 2		[illegible]	[illegible]	1	[illegible]	[illegible]
Tributaries to Great Lawn Brook	100% Unit 2		[illegible]	[illegible]	[illegible]	1	[illegible]
Tides Brook	100% Unit 2		[illegible]	12	[illegible]	[illegible]	[illegible]
Garnish River	40% Unit [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

RIVER BASIN CHARACTERISTICS

RIVER BASIN	OVERBURDEN*	HYDROLOGICAL DATA FROM STATION	PHYSICAL-GEOGRAPHICAL DATA AREA SQ. MI	PERCENTAGE LAKE	SWAMP	FOREST	BARRENS
BONAVISTA PENINSULA AREA							
Trinity River	100% Unit 2		34	22	4	[illegible]	7
River at Lockston	100% Unit 2		28	18	3	58	21
River at Champneys	100% Unit 2		30	13	5.5	77.5	4
River at Port Union	100% Unit 2		28	8.5	8.5	71	12
River at Little Catalina	100% Unit 2		[illegible]	12.5	3	33.5	51
River at Bonavista	100% Unit 2		8	10	0	[illegible]	[illegible]
CONNE RIVER AREA							
Conne River	11% Unit 2 87% Unit 1		[illegible]	[illegible]	4	[illegible]	[illegible]
SALMON RIVER AREA							
Grey River I	4% Unit 2 96% Unit 3	[illegible]	[illegible]	22	[illegible]	29	[illegible]
North Salmon River	17% Unit 2 83% Unit 1		[illegible]	14	[illegible]	42	[illegible]
West Salmon River	54% Unit 2 46% Unit 3		[illegible]	11	0	26	[illegible]
Salmon River	40% Unit 2 60% Unit 1	[illegible]	[illegible]	13	0	[illegible]	[illegible]
BADGER TO BOTWOOD AREA							
Peters Arm Brook	85% Unit 2 15% Unit 5		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Northern Arm Brook	80% Unit 2 20% Unit [illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
GREY RIVER AREA							
Grey River II	17% Unit 1 35% Unit 2 48% Unit 3		[illegible]	[illegible]	2	[illegible]	[illegible]
WHITE BEAR RIVER AREA							
Granite Lake Brook	20% Unit 2 80% Unit [illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Burnt Pond River	7% Unit 2 93% Unit [illegible]		[illegible]	[illegible]	[illegible]	20	[illegible]
White Bear River	45% Unit 2 55% Unit 1		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
EXPLOITS RIVER AREA							
Lloyd's River	46% Unit [illegible] 54% Unit 2		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Victoria River	45% Unit 2 55% Unit [illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Star Lake	100% Unit 2		[illegible]	[illegible]	41	[illegible]	[illegible]
Shanadithit Brook	100% Unit [illegible]		[illegible]	[illegible]	[illegible]	[illegible]	40
Buchans Brook	100% Unit 2		[illegible]	[illegible]	[illegible]	21	[illegible]
Mary March's Brook	100% Unit [illegible]		[illegible]	4	[illegible]	[illegible]	4
Red Indian Lake	100% Unit 2		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Noel Paul's Brook	70% Unit [illegible] 30% Unit [illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Badger Brook	100% Unit [illegible]		[illegible]		7	[illegible]	[illegible]
Great Rattling Brook	24% Unit 2 76% Unit		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Exploits River	45% Unit 2 55% Unit [illegible]	[illegible]	[illegible]	[illegible]	10	[illegible]	2

RIVER BASIN CHARACTERISTICS

RIVER BASIN	OVERBURDEN *	HYDROLOGICAL DATA FROM STATION	····· PHYSICAL-GEOGRAPHICAL DATA ······ AREA SQ. MI.	········· PERCENTAGE ··········· LAKE	SWAMP	FOREST	BARRENS
STEPHENVILLE AREA							
Harry's River	45% Unit 1 21% Unit 2 34% Unit 3		316	5	[illegible]	77	13
Southwest Brook (including Bottom Brook)	2% Unit 4 98% Unit 2		304	7	3	67	23
HUMBER RIVER AREA							
Adies River	86% Unit 1 14% Unit 2		239	3.5	3	69	24.5
Upper Humber River I	100% Unit 3		371	7	1	56	36
Upper Humber River II	4% Unit 1 93% Unit 2	$2YL_1$	275	2	15	79	4
Lewaseechjeech River	100% Unit 2	$2YK_2$	156	9	[illegible]	44	39
Hinds Brook	100% Unit 2	$2YK_4$	195	10	30	33	27
The Main Brook	83% Unit 2 17% Unit 3		614	11	10	64	15
Grand Lake Outlet	93% Unit 2 7% Unit 3	$2YK_1$	548	16	5	58	21
Humber River (Deer Lake)	100% Unit 2		215	14	0	80	6
CAT ARM RIVER AREA							
Cat Arm River	100% Unit 1		272	7	1	80	12
GANDER RIVER AREA							
Northwest Gander River	34% Unit 3 66% Unit 2		575	5	10	70	15
Southwest Gander River	26% Unit 3 74% Unit 2		351	4	15	76	6
Gander Lake	2% Unit 3 98% Unit 2	$2YQ_1$	350	14	5	80	1
Gander River	70% Unit 2 30% Unit 3		370	8	6	85	1
TERRA NOVA RIVER AREA							
Terra Nova River (Upper)	10% Unit 3 90% Unit 2	$2YS_1$	459	10	19	45	23
Terra Nova River	100% Unit 2		274	15	14	65	3

NOTE *

Unit 1 - Predominantly exposed bedrock
Unit 2 - Moderately thick overburden
Unit 3 - Generally thick overburden

Numbers $2YS_1$ etc. are the Department of Energy, Mines and Resources gauging station numbers

27 SUITABILITY OF THE FRESH WATER RESOURCES FOR DIFFERENT USES

27.1 Limits and Criteria

As noted in Section 26, the selected uses which would be used as bases of evaluating the usefullness of waters with the extrapolated qualities were fisheries (suitability of the water as an environment for fish), pulp and paper water supply and domestic water supply.

Having made the projection of the nine parameters, the values of these parameters were then compared with ranges of these values which would render the water good (+), innocuous (0), or bad (-) for the specific use. The results of these comparisons for each square of the vertical columns on Figure 26-1 (the columns represent from left to right, physical, chemical and "biological" characteristics of the water under consideration) were summated and the result transferred to its respective position in the far right hand column. An example of the procedure is given below, following the list of the ranges of the qualities used to determine the acceptability of each parameter for the specific use.

Limits of Acceptability for Various Uses

Parameter	For Fish Survival	For Pulp & Paper Raw Water Supply (kraft paper used as standard)	For Domestic Raw Water Supply
Turbidity (T)	NP	+(< 40) 0 (40 to 100) -(> 100)	+(0 to 10) 0 (10.1 to 250) -(> 250)
Colour (C)	NP	+ (< 25) 0 (25 to 100) - (> 100)	- (0 to 20) 0 (20.1 to 150) - (> 150)
D. O. (O)	+ (> 6 mg/l) 0 (5 to 6 mg/l) - (< 5 mg/l)	NP	6 to 7.5 4 to 6 < 4
pH (pH)	+ (6.8 to 8.5)* 0 (5.0 to 6.8) - (< 5.0)	NP	+ (6.0 to 8.5)* 0 (5.0 to 5.9) - (< 5.0)

* No recorded values of surface water pH > 8.5.

Parameter	For Fish Survival	For Pulp & Paper Raw Water Supply (kraft paper used as standard)	For Domestic Raw Water Supply
Hardness (H)	NP	+ (< 100) 0 (100 to 200 - (> 200)	+ (0 to 50) 0 (50 to 200) - (> 200)
Total dissolved solids (S)	NP	+ (< 300) 0 (300 to 500 - (> 500)	+ (0 to 250) 0 (250 to 500) - (> 250)
Pollution by Sanitary Wastes (P)	NP	NP	+ (0 to 50) E. Coli/100 ml) 0 (50 to 5000) E. Coli/100 ml) - (> 5000)
Oxygen consumed by permanganate (0_2)	NP	NP	+ (0 to 10) - (> 10)
Re-aeration capacity (R)	+ (high 0 (moderate) - (low)	NP	NP

NP = Not pertinent (or significant) under Newfoundland conditions.

The limits quoted in the above table are intended as indicators of a water quality, and were based on discussions with the Canada Department of Fisheries, standards established by the Technical Association of the pulp and paper industry, and recommended standards of the U. S. Department of Health, Education and Welfare. They obviously do not consider total ecological effect which could only be disclosed in detail biological assays and field studies.

The example used to demonstrate the application of the water quality extrapolations to determine the suitability of the water for the three selected uses is the Upper Humber River in the Humber River Basin.

Parameter	Extrapolation	Value Range	Acceptability Rating For: Fish Survival	P & P Supply	Domestic Water
Physical					
Turbidity	+	0 to 5 units	NP	+	+
Colour	-	> 20 units	NP	0	0
D. O.	+	> 6 mg/l	+	NP	+
Effect of Physical Characteristics			+	+	+
Chemical					
pH Field	+	6.5 to 8.5 (6.9)	+	NP	NP
pH Lab.	+	6.5 to 8.5 (6.8)	NP	NP	+
Hardness	+	0 to 50	NP	·	+
Total Dissolved Solids	+	0 to 100	NP	+	+
Effect of Chemical Characteristics			+	+	+
Biological					
Pollution by Population	-	> 1 E. Coli/100 ml (4 calculated)	NP	NP	+
Oxygen Consumed by Permanganate	-	> 10	NP	NP	-
Re-aeration Cap.	0	Moderate	0	NP	NP
Effect of Biological Characteristics			0	NP	0

It should be noted that, based on the data at hand at the time of writing, Buchan's Brook has been until recently chemically unsuitable for fish. The components whose concentration render these waters toxic are copper and zinc. The concentrations of these ions do not appear in the extrapolations on the accompanying figure and therefore, while the pH would render these water satisfactory for fish, the chemical rating is negative. Current indications are that the impoundment of the mine tailings at the Buchan's mine has reduced the copper and zinc to acceptable levels from the point of view of the fish, although insufficient data have as yet been made available to substantiate this. The remedy at Buchans appears satisfactory for the immediate future, but the long term situation is uncertain. The build-up of deleterious sediment can maintain a serious ionic concentration in the lake.

In addition to copper and zinc, the mine tailings contain lead. The only available analyses for lead, carried out by the Department of Energy, Mines and Resources for the Canada Department of Fisheries during 1961, 1962, and 1963, indicated that lead was present in the Exploits River at a maximum concentration of 0.16 mg/l on August 26, 1962, although most analyses since 1963 showed the concentration of lead to be less than 0.005 mg/l. The Canada Department of Fisheries have indicated that such concentrations of lead do not adversely affect the use of the water for fish. It is noted that the USPHS limit for lead in potable water is 0.05 mg/l.

At the time of the writing of the interim report, it was noted that the Shanadithit Brook appeared to have a higher than acceptable copper concentration. This conclusion had been reached on the basis of the grab sampling program. Since then, an analysis of a sample collected in this river by the Canada Department of Fisheries, and analyzed by the Canada Department of Energy, Mines and Resources was received which indicates no such condition obtaining. Since the level of copper which is lethal to Atlantic salmon is very low, 0.032 ppm, it is likely that the concentration determined in the earlier analysis was outside the limits of accuracy of the Hach Test Kit.

28 SURFACE WATER QUALITY IN LABRADOR

Wherever specific references have been made to the water qualities of rivers in Sections 23 to 27, these have been made to the waters of the Island. In order to complete this section of the report, there follows a brief discussion of the surface water qualities of Labrador. This discussion is necessarily briefer than that on the Island because of more limited data available on Labrador. As noted in Section 23, few analyses of the surface waters of Labrador are available, and even those are not on a continuous basis.

In order to maintain a consistency of approach to the surface waters of both areas of the Province, the following is a generalization of the qualities of the waters of Labrador considered under the characteristics used in the water quality extrapolations:

28.1 Turbidity

The turbidities of the surface waters of the southern portion, the main body, of Labrador are expected to be higher than those normally encountered on the Island because of the reported greater proportion of fines present in the glacial materials in Labrador. (Section 35). In general, these turbidities will probably still be less than 10 units. The turbidities of the surface waters of the long northern coastal strip of Labrador would be expected to be at least as low in turbidity as those on the Island because of the low depths of overburden. Exceptionally high turbidities are being artificially introduced into the lakes adjacent to Labrador City and Wabush as a result of the disposal of the iron ore tailings. Efforts are being made by the Canada Department of Fisheries and the mining companies to limit the extent of such pollution.

28.2 Colour

The colour of the surface waters in the main body of Labrador will be high and will be in the ranges encountered on the Island due to similar, or even higher, proportions of swamps and bog encountered. The waters of the long northern coastal strip are expected to be lower in colour due to the shallow depths of overburden.

28.3 Dissolved Oxygen

As with the surface waters of the Island, the concentration of dissolved oxygen should, in general, approach saturation values over the whole of Labrador.

28.4 pH

The pH values of the surface waters of Labrador close to the sea are expected to be slightly acidic, as those encountered in the major portion of the Island's waters. The very low solubility of the rocks of the region will result in the exaggeration of the effects on the pH of swamps and bog lands as is the case over much of the Island. As on the Island, the pH on storage is expected to be generally lower than in flow. Existing analyses indicate that the inland waters of Labrador may have pH's slightly higher than the Island, that is, approaching neutrality at 7.

28.5 Hardness and Total Dissolved Solids

Because of the nature of the bedrock both hardness and total dissolved solids in the surface waters of Labrador will in general probably be very low.

28.6 Pollution by Domestic Wastes

Because of the small and decentralized population of Labrador, and in view of all major municipalities having sewage treatment facilities, pollution from domestic and municipal waste water can be expected to be insignificant.

28.7 Oxygen Consumed by Permanganate

Because of the somewhat greater proportions of swamps and bogs, it is expected that the oxygen consumed values for the surface waters of Labrador will be generally somewhat greater than those for the waters of the Island but not significantly so.

28.8 Re-aeration Capacity

This factor is basically dependent upon topography, but in general it would be expected to vary from good to excellent for the major portions of the surface water systems of Labrador.

29 RECOMMENDATIONS FOR FURTHER INVESTIGATIONS

29.1 Water Quality Data Collection

The Canada Department of Energy, Mines and Resources is the only source of data with continuity of water sampling in the Province, and the following recommendations are in the main oriented to this source of information:

a) The current rate of sampling, on the International Hydrological Decade Stations, is at a maximum of once per month, and this renders it difficult to establish true seasonal trends. An approach to the ideals expressed in Report No. 1 of the series on "Industrial Water Resources of Canada", published by the Department, is desirable. A much more frequent collection of water samples is therefore recommended.

   This would entail the collection of frequent samples (daily if possible) over a two or three-year period, with complete analyses of the type made by the Canada Department of Energy, Mines and Resources being made on composite samples of several days. Such a program would establish a firm base for each sampling point and the sampling could thereafter be reduced to the present rate to check for significant changes.

b) Although the Canada Department of Energy, Mines and Resources' investigations are oriented toward water quality from the point of view of its usefulness to industry, a most significant contribution could be made if the analyses were extended to include parameters which would indicate changes in the pollution load on the river under investigation; for example, determination of biochemical oxygen demand, dissolved oxygen, and more frequent determinations of oxygen consumed.

c) A program of monitoring rivers that may be subject to pollution by the disposal of mining wastes or from other sources is also recommended.

d) With particular reference to the Terra Nova River sampling, a more useful relationship between water quality and flow could be determined, if this is indeed to be one of the aims of the International Hydrological Decade investigations, by relocating the sampling station upstream of Terra Nova Lake relative to the flow gauging station.

PART VI - ESTUARY AND SEA WATER - QUALITY

30 GENERAL CONSIDERATIONS

The physical features of the seacoasts of Newfoundland and Labrador provide a wide variety of hydraulic situations including harbours, lagoons, inshore and intertidal waters, inlets, and estuaries. In each situation the water quality is controlled by characteristics unique to a specific location. However, it is possible and convenient to find sufficient similarity of characteristics so that the innumerable specific situations can be classified into three basic categories: estuaries, coastal waters, and partially-enclosed embayments. Although other categories can be defined, the foregoing are particularly suitable for the ensuing discussions.

Water quality in a body of water is determined by:

a) The qualitative characteristics of the body of water and the materials added to it.

b) The quantitative aspects of the materials and the body of water, the relative movements, and subsequent mixing.

The qualitative characteristics of the body of water and the materials added to it may result in phenomena such as chemical precipitation, flocculation, sedimentation, flotation, die-off of specific micro-organisms, growth of other species of micro-organisms, temperature changes, bio-chemical oxidation, and other changes in the physical, chemical and biological environment. When the foregoing phenomena conflict with an existing or potential desirable use of the receiving water, water quality control is required. Other qualitative characteristics, including density differentials due to chemical properties or temperature, also affect the quality of water, and they also exert their influence in the movement of waters and are discussed elsewhere.

The second fundamental parameter governing water quality is mixing of the materials with the body of water as governed by quantitative characteristics and water movement. It is on this basis that the specific hydraulic situations mentioned previously can be classified.

30.1 Classification of Estuaries

In this study, estuaries are defined as partially-enclosed bodies of surface water which have an influx of fresh water at one end and frequently at many subsurface locations, and which are connected directly to the sea at the other end. The waters within an estuary consist of mixtures of ground and surface fresh water and seawater, the proportions of which may vary from one extreme to the other.

A longitudinal profile of an estuary frequently indicates density stratification due to a layer of fresh water at the surface overlying an intermediate zone consisting of a mixture of fresh and seawater which, in turn, overlies a zone of seawater. The relative volumes of water in each zone are governed by the characteristics of the estuary.

When the fresh water inflow is large compared to tidal movement, the degree of mixing in the zone between the fresh and saline waters is of a relatively low magnitude. Consequently, there is a separation into two layers consisting of a wedge of seawater over which the fresh water flows seaward. As the fresh water moves downstream, the flow volume increases with the entrainment of seawater from the wedge, and its salinity gradually increases. The seawater lost from the wedge is made up by a low upstream flow of almost undiluted seawater. This type of estuary is called a "salt wedge estuary"[1].

A partially-mixed estuary is one in which the tidal movements are large compared to the incoming fresh water flow. The relatively high degree of turbulence at the fresh water/salt water interface promotes vertical mixing such that the boundary between fresh and salt water is not easily identified. The flow is seaward on the surface, and increases in volume as it moves downstream. The consequent loss of salt water from the wedge is made up by a significant inflow of mixed fresh and seawaters along the bottom of the estuary.

A vertically-mixed estuary exists when, with strong tidal currents, the intensity of vertical mixing is such as to promote close to a uniform salinity concentration over the depth of the estuary. Under these conditions, the tidal motion causes the estuary contents to oscillate along the estuary with a net displacement movement towards the sea due to the fresh water influx.

30.2 Water Movement in Estuaries and Coastal Waters

In all estuaries, the oscillating motion of the tide affects the intermixing of the fresh and salt waters. The effect becomes more significant as the situation progresses from a salt wedge estuary to a vertically-mixed estuary. As the water moves past irregularities in the estuary's shoreline, eddies are formed temporarily trapping bodies of water which are slowly displaced through diffusion and hydrodynamic dispersion. When the tide reverses, the process is repeated.

When materials are introduced into an estuary, either in the fresh water influx or through an outfall structure, the subsequent dispersion patterns depend on the method and location of their introduction. When discharged into the salt wedge portion of a salt wedge estuary, materials with a density greater than the receiving body of water will be dispersed very slowly. If the material has a density less than the salt water, it will be rapidly flushed from the estuary within the surface layers.

When materials are introduced into the lower layers of a partially-mixed estuary, they tend to move towards the landward end and are partially dispersed by the oscillatory motion of the tide. The materials will eventually be mixed with the surface layer and will be carried towards the mouth of the estuary. Some of this material is transferred to the lower layers by turbulent diffusion and returns to the head of the estuary.

Materials introduced into the surface layers are initially carried in the net flow towards the mouth of the estuary. Horizontal and vertical dispersion caused by turbulent diffusion distributes a portion of the wastes into the lower layers flowing towards the head of the estuary. Most of the material is ultimately flushed from the estuary in the seaward flow of the surface layers. Part of it, however, may settle at the bottom of the estuary, and some of it may accumulate, thus changing the environmental conditions in the estuary. The proportion of accumulated material, however, is generally small when compared to the corresponding accumulations in partially enclosed embayments.

The tidal movement of coastal waters produces turbulent mixing and advective currents. The effect is strongest in tide-swept channels where intensive vertical mixing disperses the waste and the currents transport the materials from the discharge point. Wind and wave action also have significant effects on water movement and mixing in estuarine and seawaters. A wind blowing over a water surface develops a current in the upper layers of the water; in open coastal waters, this is known as a "drift current" and plays a major part in the dispersal of materials added to the waters. The waves generated by winds also assist in the dispersal of materials by their mixing action, and this accounts for the low proportion of accumulated deposits.

Although the accumulation of deposits may not be very significant in some estuaries, the circulation of water and materials in both directions makes the simultaneous use of an estuary for water supply and waste disposal a difficult problem in some cases.

30. 3 Water and Solids Movement in Partially Enclosed Embayments

Partially-enclosed embayments, such as the frequent barasway formations along the Newfoundland coastline and man-made and natural harbours, are generally relatively shallow bodies of water in which the connection to the sea is restricted by islands, points of land, sand bars, and man-made structures. Water movement between the waters in the embayment and the contiguous seawaters is limited, and materials added to the embayments may reside there for an appreciable time prior to being flushed into open waters. In many cases even large tides are not effective in providing adequate flushing, and materials accumulated may produce significant pollution. Wind effects are often restricted due to the surrounding topography and the drainage area for runoff is frequently relatively small. Therefore, chances of pollution and contamination of water in partially enclosed embayments are much greater than in estuaries.

Although the classifications used have been based upon certain characteristics, it should be noted that this is for convenience only. Specific situations have to be considered individually and the water movement characteristics defined on the basis of the unique factors which affect that movement.

31 ESTUARINE AND SEA WATER QUALITY DATA

Due to the low population density and the relatively small degree of industrialization in Newfoundland and Labrador, there has been little requirement for data on estuarine and sea water quality, and information is extremely limited. That which exists has normally been collected for a specific purpose such as the location of water intakes for manufacturing and processing industries.

Between 1959 and 1963, the Canada Department of National Health and Welfare, Public Health Engineering Division, in conjunction with the Canada Department of Fisheries, carried out several sanitary and bacteriological surveys to assess the quality of sea water which was used or was being considered for use in specific fish processing industries. These surveys included an inventory of both the specific industry and adjacent municipalities, the source and treatment of water, the treatment and disposal of wastes, and the factors which could affect the sanitary quality of water supplies. Most of the situations examined were partially enclosed embayments. The specific data are useful only for the specific location; but, in general, it was observed that insufficient care had been taken in the location of waste outfalls relative to the location of water intakes. The water quality in the area of the intakes deteriorated to such an extent that recommendations to relocate the intakes were made. This can be understood in the light of the discussion in Sections 30. 2 and 30. 3.

In 1942, the Newfoundland Fisheries Research Station at St. John's made a pollution survey of the Humber Arm[2], discussed in Section 32. 1.

The survey referred to is the only one that has been conducted on an estuary in the Province as far as can be determined. The study included a description of the water body and the major source of pollution which is Bowaters pulp and paper mill located in Corner Brook. Analyses were made for temperature, salinity, sulphate, sulphite, and dissolved oxygen at four stations. The data obtained indicated that the effect of the pulp and paper mill wastes on water quality in the Humber Arm was negligible. No dead or distressed fish were noticed during the study. In recent years release of malodourous gases and rising mats of organic material have been observed at the landward end of the estuary in the vicinity of Corner Brook. Observation by members of the study group indicates that this is due to the anaerobic decomposition of bark deposits from logging operations and/or the accumulation of wastes from the pulp and paper mill. In 1968 the Canada Department of Fisheries undertook a preliminary field investigation of the Humber Arm to establish the magnitude of the present pollution problem.

A pollution survey was also carried out on the Exploits River[2] in 1942, and the results indicated that reductions of dissolved oxygen in the river water could be attributed to pollution from the pulp and paper mill located at Grand Falls. No information appears to have been collected on water quality in the Exploits estuary.

Although the general conclusion following the 1942 surveys was that fish life would not be significantly affected by the pollution, the capacity of the pulp and paper mills in both locations has since increased by approximately 50 to 100 percent. Consequently, problems may exist with regard to the quality of water in these water bodies at the present time, but this cannot be confirmed without additional field sampling.

A study is under way of conditions in the Little Codroy River by the Fisheries Research Board, Canada Department of Fisheries. The data being collected include data on estuarial conditions, and it is anticipated that it will be available by the end of 1968.

32 PROBLEM AREAS AND RECOMMENDATIONS FOR FURTHER STUDY

As previously mentioned, the data available on estuarine water quality within Newfoundland and Labrador are extremely limited, and it is difficult to define problem areas. The ensuing discussion should thus be considered as preliminary.

32.1 Problem Areas

32.1.1 Humber Arm

The Humber Arm is almost 15 miles long and, on the average, is approximately 1.25 miles wide; the average depth is approximately 300 feet. The 1942 report indicates that the maximum tidal range is approximately 4.5 feet, and there is an outward flow on the surface of approximately 3 knots at all times, independent of tidal phase. Salinity measurements indicate a relatively distinct stream of fresh water extending from the surface to a depth of about 30 feet at the head of the Arm which gradually decreases downstream until, at the seaward end, uniform salinity with depth exists.

From this information, it appears that the Humber Arm acts partially as a salt wedge estuary; consequently, with good waste outfall design, significant improvement in the disposal of wastes should be possible. However, because of the relatively quiescent zone in the salt water wedge, settleable particles would tend to be removed from the flow quite slowly, creating potentially unsatisfactory conditions on the bottom of the estuary. It is therefore recommended that wastes containing settleable particles should be pre-treated prior to discharge.

For a number of years bark was dumped into the Humber Arm at the mill, but this practice ceased four years ago, and the bark is now being pressed and used for the production of steam. Bark deposits from log-driving are prevented from entering the Humber Arm by means of a "drag boom" situated across the mouth of the Humber River. However, at low tide, banks of decaying organic matter are exposed and unpleasant odours may be detected in lower Corner Brook.

Although the water quality in the Humber Arm estuary as described in the 1942 study was reported as being satisfactory, any further development involving significant quantities of waste which will be discharged to the estuary should be preceded by studies to determine a satisfactory outfall location and/or necessary waste treatment methods.

32.1.2 Exploits River Estuary

Water quality information on this estuary is not available. It is known that the Exploits River is polluted to the extent that certain beneficial uses of the water could be inhibited, but the effect of this pollution on the estuary is indeterminable until further data can be obtained. At the present time, there are no proven problems of water quality in the estuary, although on occasion low dissolved oxygen appears to indicate that significant quantities of bark and pulp fibers from the upstream pulp and paper mill activities are being deposited on the bottom of the estuary. At the present time the bark obtained from the debarking operations is retained and used as fuel, but bark from log-driving and wood fibers from the pulp and paper mill are still providing a source of settleable material in large quantities. This situation possibly presents a problem in the use of portions of the estuary as a fish passage. The particles which settle out destroy the habitat for bottom-dwelling organisms which often serve as food for fish. The decomposition of the sediment utilizes the dissolved oxygen in the bottom waters. In particular situations, for instance, where the water is shallow, the depletion of dissolved oxygen and production of toxic hydrogen sulphide can inhibit the passage of fish. Other potenially undesirable characteristics of such area conditions include increased dredging costs.

32.1.3 Come By Chance Study Area

A phosphate reduction plant has been built at Long Harbour. At the present time development plans for the area include a pulp and paper mill and an oil refinery. As was done at the phosphate plant, the waste water discharge facilities should be designed to ensure no future conflicts with the development of the area.

32.1.4 Stephenville

A proposed linerboard mill, an aluminum reduction plant, and possibly a chemical plant in this area may introduce an esturine, as well as a fresh water pollution problem. If the danger of pollution exists, steps should be taken, at the design stage, to prevent it.

32.1.5 Fish Plants

The disposal of sanitary and processing wastes from fish processing plants commonly takes place directly to the sea or estuary adjacent to the plant. This can lead to the development of bacterial contamination in the salt water, and also to the solid wastes being washed ashore by the tide, causing aesthetic and odour problems. The presence of bacterial pollution in the vicinity of the fish plant necessitates either a high degree of chlorination or the construction of an excessively long and expensive sea water intake, when salt water is required by the plant for processing purposes. The locations at which the disposal of wastes from the fish plants takes place should be selected to ensure the rapid dispersal of the wastes away from shoreline and the plant.

32.1.6 Miscellaneous

Problems of seawater quality have been reported in many localized situations where the discharge of waste from manufacturing operations, or some other sources, such as boats or domestic waste, caused the pollution of a water body to the extent that other uses have been inhibited. Most of these problems occur in partially-enclosed embayments, and it is recommended that, in such instances, waste outfalls be located where adequate dispersion of the waste will occur. To obtain satisfactory location, it will frequently be necessary to discharge the waste outside of the embayment. It would appear at the present time that the disposal of municipal sewage to the sea does not have any adverse effect on the inshore fishery. The source of the oil pollution which has caused repeated water fowl kills[3] should be investigated, and measures to control sea pollution by boats should be sought through international organizations if this proves to be the pollution source.

32.2 Recommendations

The existing data on which quality are not sufficient to define all problem areas in which further investigations are necessary. The absence of this data when considered in conjunction with the proposed multiple use of particular waters indicates the advisability of further water quality investigations to determine whether conditions are suitable for the specified uses. The Exploits and Humber estuaries are cases in question. It is recommended that water quality monitoring stations be established at suitable locations on these estuaries to provide a continuing source of data which can be utilized in the protection of the various uses of the waters. A more comprehensive study of the Exploits River and estuary is recommended elsewhere.

It is generally recommended that the dispersion characteristics of receiving bodies of water be investigated whenever it is proposed to establish a waste outfall. In this way, satisfactory locations can be obtained which will maintain the receiving water quality in a condition satisfactory to fulfill any desired multiple use function.

REFERENCES

1 International Conference on Water Pollution. Proceedings, Volume 3, Advances in Water Pollution Research. Paper presented by K. F. Bowden. The Mixing Process in a Tidal Estuary. New York, Pergamon, 1964.

2 Vavasour, G. R., and Blair, A. A. Pollution Survey of Humber Arm and Exploits River. Journal Fisheries Research Board of Canada. 12(5)-1955.

3 Munro, D. A., and Solman, V. E. F. The Impact of Water Pollution on Wildlife. National Conference on Pollution and Our Environment. Background Paper A-4-1-3. Montreal, The Canadian Council of Resource Ministers, 1966.

PART VII - GROUNDWATER - QUANTITY AND QUALITY

33 ANALYSIS OF AVAILABLE DATA

At the present time there is no program that includes regular gathering of information on groundwater in Newfoundland, but some information is available on specific problems in particular areas.

The information used in the discussions that follow has been obtained mainly from a study of existing wells, and from consideration of geological and other factors that are likely to affect the availability of groundwater. Some information has also been obtained from mining companies.

Although many of the larger towns and municipalities on the Island have developed water supply systems using surface water, the majority of the smaller communities are dependent on groundwater as a source of supply. Most of the groundwater supplies are obtained from an estimated 40,000 shallow dug wells with the remainder obtained from an estimated 700 drilled wells.

Information on groundwater in Labrador is scarce and, as the population of Labrador is small and the development of groundwater to date appears to be small, it was considered uneconomical to attempt to gather any detailed information. In the course of the present study, however, some information on the surficial geology of Labrador was located, which has been incorporated into this section in order to make it more generally accessible.

The groundwater in the Island is discussed below under separate headings, and the economics of groundwater supplies are discussed in Volume Five.

33.1 Dug Wells

The most common means of obtaining groundwater is by the use of dug wells. Depending on the nature of the ground and the depth of the water table, they are normally sunk to a depth of between 8 to 20 feet and are up to 4 feet in diameter. Normally the wells are sunk to a depth great enough for the bottom of the well to be below the water table during dry periods, but in some areas the thickness of surficial material may be inadequate, and the wells may dry up in a dry summer, such as occurred in 1967. In areas where there is no surficial material, a hollow is excavated in the rock either with crowbars or by blasting, which acts more as a gathering sump for local runoff than as a well since the water table in the rock may be too deep to be encountered in a shallow excavation.

There is practically no quantitative information on the quantity of water withdrawn from dug wells, but as they generally provide a supply for one or two families, it can be assumed that the withdrawal is at least one hundred gallons a day. The greatest reported yield from a dug well is at a ready-mixed concrete plant in St. John's, where about 30,000 gallons a day are being withdrawn from a single well. Owing to the lack of data no detailed analysis has been made of dug wells.

33.2 Drilled Wells

In areas of Newfoundland where dug wells are found to be unsatisfactory, the usual practice is to have a well drilled into the bedrock. There are reasons to doubt that this is justified, and they are discussed in a later part of this report (Sections 39.2 and 39.3).

Drilled wells provide the main source of information on the behaviour of water in the bedrock of the Island; but, unfortunately in the absence of legislation requiring the formal recording of well drilling, as is the case in Nova Scotia, information on wells is scarce and of poor quality. In some cases the drillers estimate the flow of the well either by bailing or by blowing out the water from the hole with an air hose, but neither of these methods give an accurate estimate of the yield. No proper geological logs exist, and the only information that is available from the drillers' records is the total depth of the hole, and sometimes the thickness of the overburden.

The analysis of the behaviour of the water within the ground has been based on the figures obtained from the contractors' records of the depth of the wells since this is considered to be the only factor related to the availability of the groundwater that is known accurately.

Records of the depth of nearly 600 wells have been obtained from three drilling contractors, and this is believed to represent about 80 percent of the drilled wells on the Island.

In order to illustrate the variation that exists in well depths, a series of histograms of well depths in different parts of the Island, and a composite histogram over the whole Island are shown on Figures 33-1A and 33-1B. It is apparent that the distribution of well depths varies in different parts of the Island, and a study of this variation is included in a later section of this report (Section 35.7).

33.3 Mining Operations

A questionnaire was sent to eight active mining companies on the Island, requesting information on the quantity of water encountered during mining operations. Replies were received from six of them giving an estimate of the flow involved. In addition, a visit was made to the fluor-spar mine at St. Lawrence, which was known to have severe groundwater problems, and a copy of a submission by the Newfoundland Fluorspar Company to the Royal Commission investigating the health hazards at the mine was obtained.

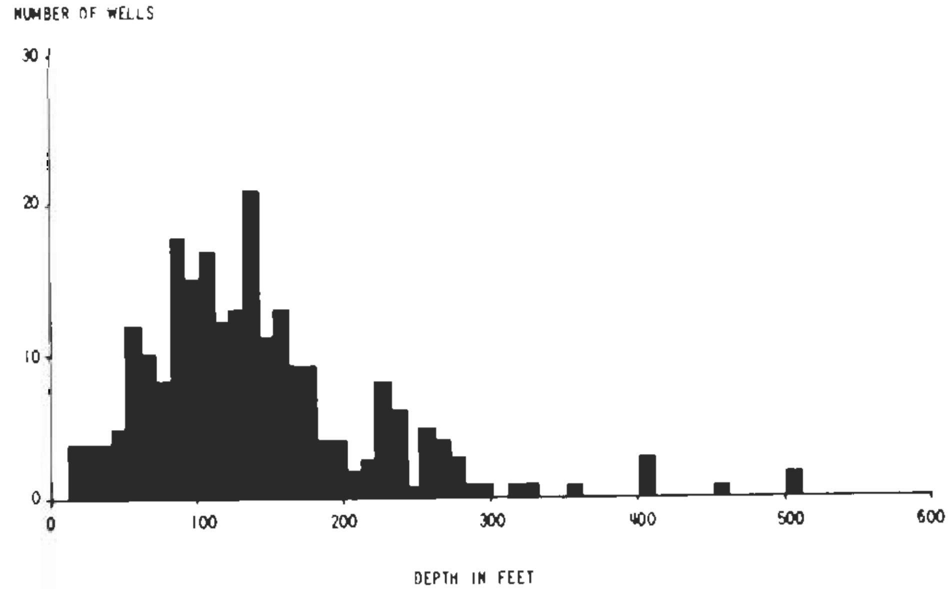
The data obtained from the mining companies was used to assist in the preparation of the hydrogeologic maps. A separate discussion on the problems of the St. Lawrence granite is included in this report (Section 37.5).

33.4 Seasonal Variation

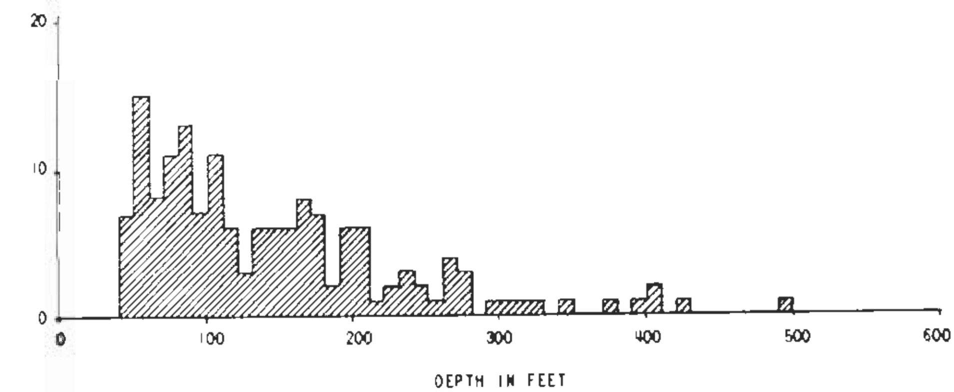
At present no records are being kept of the seasonal behaviour of groundwater in any wells. It is known only that some shallow wells sometimes dry up as the level of the water table falls during periods of low rainfall. It appears highly desirable that some permanent groundwater level recording station should be set up in order to record seasonal fluctuations.

The only quantitative information on the seasonal variation of groundwater flow is provided by the records of the mining companies that have to keep their workings free of water. These records show a variation of up to 30 percent between the amount of water pumped from the mines in the winter and during the spring thaw.

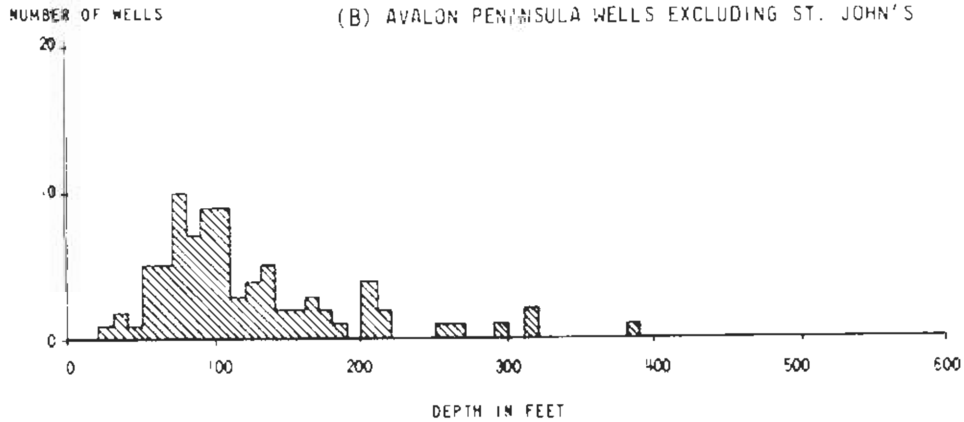
NEWFOUNDLAND
REGIONAL HISTOGRAMS OF WELL DEPTHS



(A) WELLS OUTSIDE AVALON PENINSULA



(B) AVALON PENINSULA WELLS EXCLUDING ST. JOHN'S



(C) WELLS IN ST. JOHN'S

FIGURE 33-1A

NEWFOUNDLAND

REGIONAL AND COMBINED HISTOGRAMS OF WELL DEPTHS

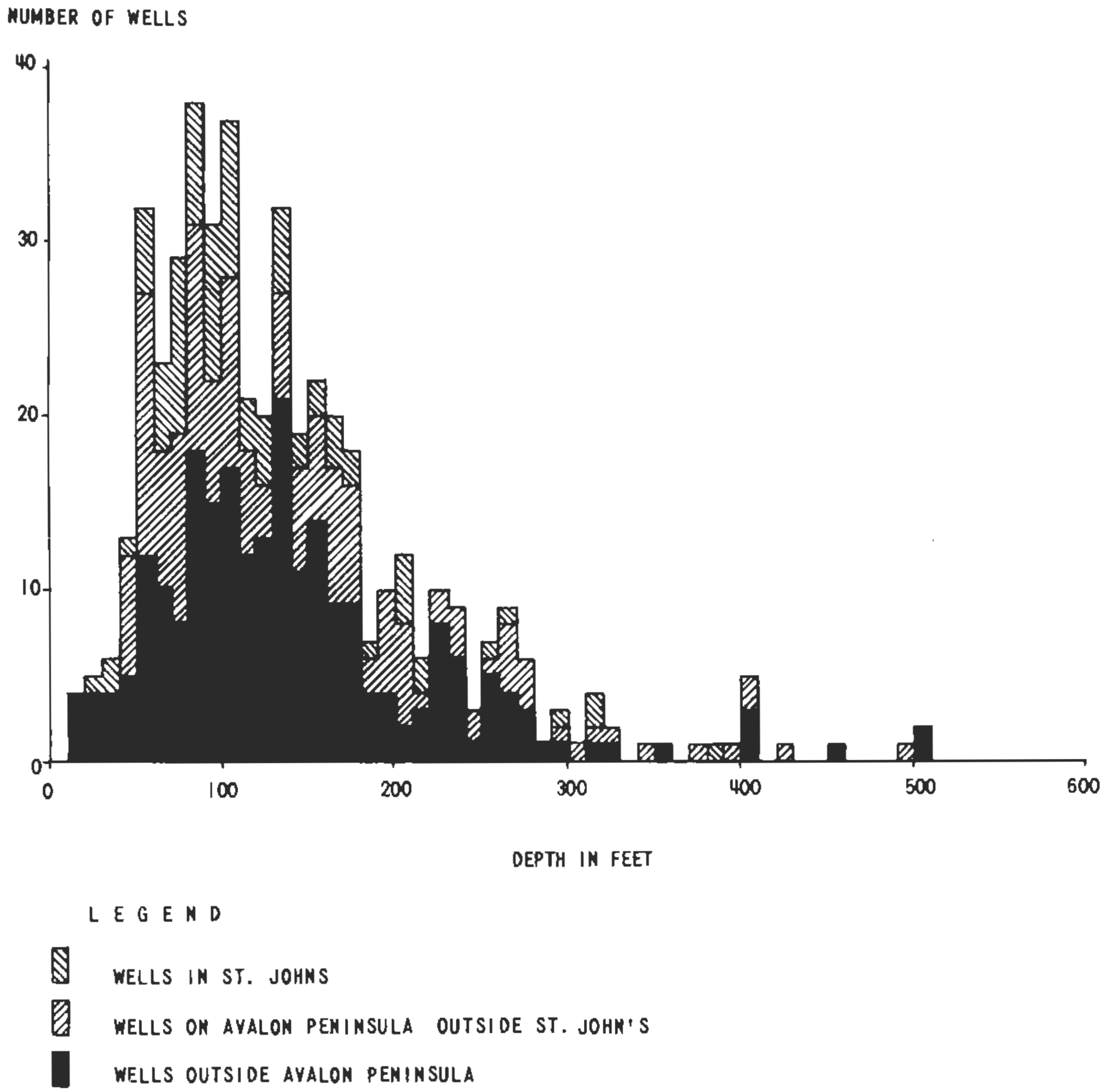


FIGURE 33-1B

34 CHANGES IN GROUNDWATER DUE TO MAN'S ACTIVITY

Changes in the groundwater regime can be brought about by man in three main ways: by the withdrawal of groundwater, by altering the natural recharge pattern, and by contamination of the water in the ground. The first two causes are discussed here, the third will be discussed in Section 36. 3.

34. 1 Withdrawal of Groundwater

As most domestic groundwater supplies are taken from individual wells which supply only one or two families, and the normal pattern in small communities is to have houses separated by at least a hundred feet, it is unlikely that this type of withdrawal causes a significant change in the groundwater regime since the potential recharge in the area of one well will probably be several times as great as the withdrawal. Withdrawal for domestic use is only likely to affect the groundwater regime where drilled wells are put down to supply a large number of houses or an entire community.

There are a number of wells situated close to the shoreline where salt water intrusion has been reported. Some of these are shown on Figures 24-1 and 24-2 and are referred to in Sections 36 and 37.

The largest quantities of groundwater are being withdrawn by mines in order to keep the workings dry. At the Director Mine at St. Lawrence some 2500 US gpm have been pumped from the mine for many years, and the groundwater level in the vicinity of the workings is reported to have dropped. This is the only case so far discovered on the Island where the groundwater level has lowered over any significant area.

34. 2 Alteration of Recharge Pattern

The extent to which the recharge pattern has been altered on the Island is extremely small. In urban areas, the development of artificial drainage methods to divert the runoff can decrease the proportion of the rainfall that percolates into the ground. However, in this Province the area of urban development is a very small proportion of the total land mass, and it is probable that this factor will have an effect only in St. John's, if it has any effect at all.

Although there are no flood control structures as such in the Island, the presence of various dams associated with hydro-electric projects may have some minor effect on the recharge pattern.

The removal of the forest cover on the Island by both cutting and fire will tend to increase the runoff and decrease the infiltration of groundwater. Although there has been substantial deforestation, the alteration in recharge is probably not very great, as it is more likely that there was a surplus of water under the original condition than there is a deficiency of water now.

The nature of the bedrock on the Island is such that the overall groundwater storage in rock is fairly low and with normal precipitation only a small percentage of the water available is required to maintain this storage. Any changes in the surface cover due to deforestation, agricultural, urban development, etc., will have little overall effect on this groundwater storage.

35 HYDROGEOLOGY

35.1 Nature of Flow of Groundwater in Surficial and Bedrock Materials

There is a marked contrast between the method of flow of groundwater in the surficial materials and in the bedrock. The surficial materials retain their original porosity, so that the flow of water through them is intergranular. The bedrock materials on the other hand have, with a few exceptions, lost most or all of their original porosity, owing to changes that have taken place in the rocks since their deposition. This means that the flow that occurs in the bedrock takes place through the fault zones, fissures, joint planes and solution channels in the rock rather than through the pores. The classification of materials that follows is based on the true permeability of the surficial materials and the apprent permeability of the rock which depends on the frequency of occurrence of joints, fractures, etc.

35.2 Hydrogeologic Classification of Geologic Materials

Under the prevailing climatic conditions on the Island, with the precipitation fairly evenly distributed throughout the year, there is normally enough water available to provide groundwater recharge. For this reason the determining factor in obtaining water from the ground is the nature of the subsurface material.

Although the selection of a site for the well can only be carried out efficiently by a detailed examination of the area in which water is required, it is felt that the presentation of maps showing the regional variation in groundwater potential can be useful.

Most of the Island is covered by surficial materials, and generally when there is a depth of 15 feet or more of surficial material, a shallow well can be dug that will give an adequate water supply for individual domestic systems. In many areas it is likely that a few properly developed screened wells will produce large enough quantities of water for a small community. The yields obtained from wells in surficial materials in Newfoundland are potentially greater than those obtained in many other parts of Canada as the fines content, which restricts the flow of water in many glacial materials, is generally low.

In contrast, however, the greater portion of bedrock of the Island is characterized by a generally low permeability and porosity because the supplies of water are derived from joints and fractures and not from water stored in the pores of the rock. Some of the Carboniferous sediments in the western part are an exception to this in that their porosity can be high.

Despite the potentially greater value of the surficial deposits as a source of water, it is common practice when the supply from the surficial materials is inadequate to drill a well into the bedrock. While it is true that it is extremely unusual for a well drilled in the bedrock to be dry, it is quite common for the reported yield of a well more than 200 feet deep to be 1 gpm or less, which is substantially less than the yield that probably could be obtained from a properly developed overburden well.

The hydrogeology of the Island is discussed in more detail under two separate headings - surficial deposits and bedrock. It should be recognized that there are certain areas where no surficial deposits are available to provide water and a knowledge of the groundwater potential of the bedrock is required.

It should be borne in mind that the greater part of the population of the Island outside the larger municipalities derive their domestic water supply from shallow wells dug in the overburden, and that there are at present not more than 700 wells on the Island that have been drilled into bedrock.

35.3 Surficial Hydrogeology - Island of Newfoundland

Much of the Island has a cover of glacial material which extends below the water table and, therefore, is a potential source of water. The distribution of surficial materials is shown in Volume Two A, Figures 5-1 and 5-2. As the main sources[1, 2] used in the compilation of the figures showing the main body of the Island and that for the Avalon Peninsula were different, it is necessary to discuss the two figures separately.

It should be noted that there is equivalence between the two figures in units S1, S4, and S5, but that units S2 and SA2, and units S3 and SA3 are not equivalent. However, if the materials represented by S2 and S3 are grouped they then are equivalent to materials represented by SA2 and SA3 combined.

35.3.1 Island (excluding the Avalon Peninsula)

Unit S1 indicates those areas where patches of ground moraine overlie bedrock. This moraine does not provide a major source of groundwater. It includes extensive areas on the south coast and the Northern Peninsula. It is likely that there is more drift present in these areas than in the unit S1 areas on the Avalon Peninsula. Additional substantial patches of moraine may be delineated on maps of the Island in the future since much of the mapping carried out to date has been of a regional nature.

In areas of high ground this unit may contain extenxive areas of felsenmeer, where frost action has forced up pieces of rock from the bedrock mass and then caused their disintegration. It is probable in most areas, however, that the felsenmeer is too recent in origin to have had time to break down to an extent where it might become a useful source of groundwater. MacClintock and Twenhofel[3] refer to thick felsenmeer in the Lewis Hills in Western Newfoundland, but do not give any actual thickness. It is possible that in some areas of granitic rocks, the felsenmeer is sufficiently developed to be a groundwater source.

Unit S2 on the Island includes ground, ablation, and some end moraine in areas of low relief. It varies widely in thickness with a maximum recorded thickness of 157 feet at the mine workings at Buchans. From the results of test pitting carried out in association with investigations for dam sites in the Island, it would appear that there are lenses of more permeable material present within the moraine. These would provide the best source of groundwater in this unit, but there is no easy way of locating them.

Unit S3 shows the areas of ribbed moraine, where a wavelike surface has developed with a series of ridges often separated by ponds or bogs. The ridged nature of these deposits means that the thickness varies rapidly, and there may be some sorting of the material. The depth to the water table will be greater in the ridges, and less between them, so the storage may not be very great. From the point of view of total quantity of drift present per unit area, which is an important factor in considering the effects of drift on water quantity, the unit S2 areas should contain less material than the unit S3 areas. This unit will also be sensitive to the type of bedrock present, and will probably be slightly more permeable than unit S2.

Unit S4 includes eskers, kames, alluvium, raised beaches, outwash and delta deposits where they are big enough to be shown on a map of this scale. The underlying bedrock will not be a controlling factor with respect to their groundwater yield. There are some large deposits of this unit on the Island, such as the substantial area of outwash near Stephenville on St. George's Bay, and at the mouth of the Codroy River. A series of wells in these deposits at Stephenville were constructed and tested for the US Air Force and yielded 700 gpm, but no permanent system was installed. A number of outwash and delta deposits up to 100 feet in thickness are described in the Terra Nova and Bonavista map areas (Jenness 1963)[4] where there is also reported 100 feet of gravel and sands in a pit dug on a kame terrace.

The gravel and sand deposits are more extensive on the main body of the Island than on the Avalon Peninsula, and the yield of water available from them will be greater. As yet no complete detailed mapping of glacial features has been carried out on the Island, so that although quite a number of eskers, deltas, outwash trains, etc., are shown on Figure 5-1, Volume Two A, it is likely that a substantial number have not yet been identified.

Unit S5 includes the areas of marsh and bog on the Island which were mapped by Mollard and Munn[5] in 1955. These areas have been shown superimposed on top of the other units shown in the figure.

Unit S6 on the map is the area of known marine incursion on the west coast of Newfoundland. In some areas this has led to the deposition of marine clays which are of no use as a source of groundwater, but in other areas a water bearing layer presently underlies the marine deposits. Where the areas of marine incursion presently overlie any units other than unit S1, there will probably be at least some material present that will provide a source of groundwater, but where unit S6 overlies unit S1, the possibility of finding usable quantities of groundwater is remote.

35.3.2 Avalon Peninsula

Unit S1 consists largely of rock outcrop, with a few patches of thin ground moraine scattered over it. These surficial materials are not likely to provide any significant water but they may provide adequate supplies for an isolated house for much of the year, although they are likely to dry up in dry periods as the storage will be very small.

The most widely used unit for providing groundwater supplies is unit SA2, which includes ground, hummocky, and ablation moraines. This till is affected by the nature of the bedrock beneath it, but even where the material overlies shales or slates the proportion of fine material may still be low, since the particles have not travelled far enough, nor have been weathered sufficiently to have been completely broken down. Most of the material in unit SA2 is less than 20 feet thick, but occasionally a depth of up to 40 feet may be present. Most individual house supplies are obtained from dug wells in these moraine materials and a higher yield may be obtained if a reasonable thickness of material is present.

Unit SA3 is composed of end moraine which appears to be more common on the Peninsula than elsewhere on the Island. It differs from unit SA2 in that there is more fine grained material. Yields obtained from unit SA3 are likely to be lower than those obtained from unit SA2. The unit is 50 feet or more in thickness in some areas, so the amount of storage available is greater, also the lower permeability associated with its generally fine grained texture will result in the water table falling more slowly in dry weather than in units SA2 and S4. Within the end moraine some lenses of sand and gravel occur, which are an excellent source of water; unfortunately, the locations of such lenses are not readily predictable.

Unit S4 will generally provide the best yields on the Peninsula as it contains materials made up entirely of sands, gravels, and boulders. This unit includes eskers, kames, outwash deposits, beach deposits, and deposits of recent alluvium. The materials in this unit are not greatly affected by the nature of the bedrock on which they are situated as they are all well sorted materials that have been transported considerable distances, and most of the fines have been lost in the process. The deposits of unit S4 provide a good source of water in the areas around Manuels and Bay Roberts on Conception Bay. Unfortunately, some of the materials in this unit are of no value, either because they exist as sand bars which are intermittently covered by high tides, and therefore contain water of high salinity; or because they have a complete lack of fines and, due to topography, they drain quickly. This is particularly likely to be the case with some of the raised beach deposits.

Unit S5 being composed of bog and marsh deposits is not of importance as a source of groundwater for domestic use. This unit can be underlain by any of the other four units, but water derived from this unit, or any other close to marshy conditions, is not likely to be of suitable quality for domestic use.

35. 3. 3 Surficial Hydrogeology - Labrador

A surficial geological map of Labrador is presented on Figure 5-3, Volume Two A. Although there is practically no information on wells in surficial materials in Labrador, an attempt has been made to interpret the surficial map in hydrogeologic terms. The different units shown on the map are discussed below.

The mapping is intended to show the dominant unit in each area of Labrador; but as the scale of mapping is small, it must be expected that in many areas there will be patches of material of different units within the boundaries given for any one unit.

Unit SL1, which is composed of areas with exposed bedrock, has been subdivided into units SL1a, and SL1b. The areas mapped as unit SL1a have fairly continuous exposure of bedrock with patches of drift occurring only occasionally. Most of the areas concerned are either highland areas in the inland part of Labrador, or are along the coastline. In the highland areas, the main types of cover that occur over bedrock are felsenmeer on the plateau and scree slopes on the steep hillsides. The areas mapped as unit SL1b have frequent outcrops with thin drift present, mainly in the less rugged areas away from the seacoast. The groundwater potential in both subdivisions of unit SL1 is low but slightly greater potential exists in SL1b than in SL1a.

Unit SL2 consists of areas mapped as moraine, excluding ribbed moraine, and also areas where the relief is drift controlled but which have not been included in any other unit. This unit is approximately equivalent to unit S2 on the Island. Most of the material within this unit consists of ground moraine, since there are very few areas of end moraine mapped in Labrador Also included in this unit are areas with numerous drumlins, and areas where numerous boulders are strewn on top of a cover of moraine. The groundwater potential of this unit is low to moderate, and it is expected that the yield from this unit will be slightly lower than from unit S2, as there is reported to be a greater proportion of fine material present in the glacial materials in Labrador than on the Island. The thickness of the material in unit SL2, however, may be greater than the thickness in unit S2; reported thicknesses of ground moraine are from 30 to 60 feet on northern slopes, although in the northern part of the western section of Labrador the thickness is commonly 5 to 10 feet. The drumlins may have a relief of up to 100 feet above the drift plains on which they are situated.

Unit SL3 consists mainly of ribbed moraine which forms areas of sub-parallel ridges several hundred feet apart, composed of bouldery till. The height of the ridges varies but commonly ranges between 30 and 90 feet and the intervening hollows often contain lakes or swamps. This is the equivalent of unit S3, on the Island, and yields from this material will be low to moderate, again possibly lower than from the equivalent Island unit, owing to the greater proportion of fine material.

Unit SL4 consists of deposits of sands and gravels, and other water-borne material, mainly of alluvial, or fluvio-glacial origin. The materials include sand and gravel deposits along the course of many of the rivers in the south and eastern parts of the area, and also some extensive sand plains which may have originated as outwash deposits or as sandy lake deposits. As most of the mapping has been carried out from aerial photographs, it is possible that some silty and clayey deposits may have been included among the materials mapped in this unit. Also included in this unit are two areas of knob and kettle topography to the south of Lake Melville. This unit is approximately equivalent to unit S4 on the Island of Newfoundland, but is much more widespread in Labrador. The groundwater potential should be moderate to high.

Unit SL5 consists of marshes and swamps, the same materials as those included in unit S5 on the Island. It is possible that marshy conditions are even more widespread than indicated on the map, as these conditions prevail around the margin of many of the lakes in Labrador, but have not always been mapped. Unit SL5 occurs on all the units represented on the map, and causes poor quality water in the other surficial materials in the vicinity.

Unit SL6 represents the area of maximum post-glacial marine overlap in the vicinity of Lake Melville. Over much of the area occupied by this unit, sand and gravel deposits are present, with swampy surface conditions. It may be expected that some marine clays will also be present among the deposits in this unit, therefore the groundwater potential will be extremely variable, as in unit S6 on the Island.

Unit SL7 consists solely of eskers, which were included with unit S4 on the Island, but which are more widespread in Labrador particularly in the southern and western parts. They are steep sided ridges of sand and gravel, with crests up to 100 feet or more above the surrounding terrain. They are shown separately on the map, as locally there are often associated sand deposits, particularly at the end which, while they are too small to map on the scale used here, may be an important local source of groundwater.

As discussed in Section 6 of Volume Two A, there is some permafrost in Labrador. The permafrost boundaries shown in Figure 6-2, Volume Two A should be considered in conjunction with any study of the hydrogeology of Labrador.

The map, Figure 6-2, Volume Two A, was mainly derived from sources which used aerial photography to compile a topographic base map. In making the present compilation discrepancies in the positions of lakes and rivers of the order of tens of miles have been encountered. The base map used was the 16 miles to one inch map published by the Provincial Department of Mines and Resources in 1960. The positions of the various boundaries on the map have been plotted relative to the position of the nearest lake or river on the assumption that the original mapping also related the boundaries to the drainage pattern. It should be appreciated, however, that as a result of this procedure some errors in positioning must exist and for this reason the compilation should be regarded as a reconnaissance map only.

35.4 Yield from Surficial Materials

In the absence of quantitative data it is extremely difficult to estimate the yield that can be obtained from the surficial materials. An attempt has been made in the following table to estimate the possible yield, but it should be realized that very large variations from these figures may occur.

Surficial Hydrogeologic Unit		Range of yield expected (gpm)	
		Minimum	Maximum
S1	(SL1)	0	5
S2	(SL2)	10	50
SA2		10	50
S3	(SL3)	5	50
SA3		5	50
S4	(SL4)	50	1000
S5	(SL5)	Not relevant	
S6	(SL6)	1	100

NOTE: These are estimates only, and will depend on local conditions. They are based on the assumption that a properly installed 8-inch or larger well screen will be used. The Labrador units are bracketed as there is no information on which to base yield estimates for Labrador. The figures are based solely on comparison with the Island, where conditions are believed to be similar, except that yields are probably higher on the Island in units S2 and S3 than they are in Labrador in units SL2 and SL3.

35.5 Bedrock Hydrogeology

35.5.1 Island

As already discussed in the section on bedrock geology, the rocks of Newfoundland were all formed prior to the end of the Carboniferous period. With the exception of a few sediments laid down during the Carboniferous period, nearly all the rocks have undergone some degree of alteration by metamorphism, either associated with the intrusion of igneous rocks, or with the periods of folding that have affected the Island. As a result of this metamorphism, none of any original interstitial porosity remains in these rocks. Their present water bearing capacity depends on the faults, fissures, and joints in which water can be stored, and through which water can flow.

In order to clarify the water availability within the bedrock, Figure 4-2, Volume Two A, has been prepared on which the rocks of the Island have been divided into different units, based on their estimated water storage capacity. As far as possible the different units have been defined in a similar way to that used by Carr[6] in his discussion of groundwater in the Atlantic provinces; but, whereas Carr is dealing with solely time-based units which he has termed hydrostratigraphic units, in this study the rocks have been differentiated by type as well as age, and the term hydropetrologic units is more applicable.

The geological information used in the preparation of this figure was compiled from published and unpublished maps prepared by the Geological Survey of Canada and Newfoundland Geological Survey, together with other maps on file with the Provincial Department of Mines, Agriculture and Resources.

Nine different hydropetrologic units have been indicated and a discussion of the significance of the differences between the units is given in Section 35.7 of this volume. In addition to showing the hydropetrologic units, the maps also show all those faults which are indicated on available maps, together with all the lineaments that could be detected on air photos at a scale of approximately two miles to one inch, as these can be important sources of groundwater. South of latitude 47 degrees on the Avalon Peninsula air photos on a scale of about four inches to the mile have been examined to locate lineaments. On the Avalon Peninsula the fold axes have also been marked as the joints will tend to be more open on the axis of a syncline or anticline than along their limbs, and water should be more readily available along these axes. It should be noted that the concentration of lineaments found by an examination of individual larger scale air photos is greater than that shown on the rest of the map, and it is not unreasonable to expect that a similar increase in frequency would be found elsewhere on the Island if a similar detailed study were made.

The locations of the drilled wells together with the mean depth of wells in each community, for which records are available, are also shown on this figure. These data form the basis of the statistical analysis of the hydropetrologic units that is discussed in Section 35.7.

Some reference is made below to the quality of water encountered in some of the units. Unfortunately insufficient data is available at this time to include an estimated quality for each unit; and the water quality is only mentioned where specific instances of unusual chemical characteristics have been found that can be related to bedrock geology.

Hydropetrologic unit R1 includes all major igneous intrusions with the exception of the St. Lawrence granite. The great majority of the rocks in this unit are granites, which, although they may be weathered near the surface are less jointed than most other rock types on the Island.

The main non-granitic intrusions included in this unit are the mafic and ultramafic intrusions on the west coast, near the Bay of Islands, and in the Long Range Mountains where about 30 percent of the unit R1 rock is mafic. There is also one major intrusion south of the Bay of Exploits with a string of minor mafic intrusions to the south of it, and other smaller intrusions scattered over the Island. These are not necessarily very different from the granites in the quantity of water that can be supplied, but they tend to have a significant effect on the quality. In general, the groundwater derived from them has a high iron content except for waters derived from serpentinites which will have a high magnesium content.

Hydropetrologic unit R2 is largely made up of Pre-Cambrian sediments, together with some rocks which are probably of Cambrian age. The unit R2 rocks on the east side of White Bay, which are termed the Fleur de Lys group, may belong in this latter category; and there are also some rocks of probable Cambrian age in the area of unit R2 rocks to the west of Grand Lake. There are probably substantial areas of volcanic rocks that should be included with the unit R2 rocks, particularly on the Burin Peninsula where some areas have been marked as dominantly volcanic on Figure 4-1, Volume Two A. In fact, the difference between units R2 and R3 in hydropetrologic terms is probably not very great, as the original petrology of the rocks has been extensively modified by metamorphism, and in fact the difference between the two units is as much due to the degree of metamorphism as to the mode of origin.

In principle, the rocks of hydropetrologic unit R3 are dominantly volcanic rocks of Pre-Cambrian age, but as mentioned before there is a considerable overlap with unit R2. The unit R3 rocks should in the overall sense be capable of slightly greater yields than those of unit R2, as it has been possible to establish a statistically significant difference in the yield from the two units on the Avalon Peninsula and only the two patches of unit R2 rocks on the west coast cannot be correlated to some extent with the Avalon rocks.

Hydropetrologic unit R4 is composed of highly metamorphosed rocks which are of Cambrian to Devonian age. In the Long Range area this unit also includes some igneous intrusives which have not been separated out in the geological mapping carried out up to now. The exact boundaries of a unit of this type are hard to define. Where severely metamorphosed there is a very great difference between the rocks of unit R4 and those of units R5 and R6, while there is a range of slightly metamorphosed sedimentary and volcanic rocks that could belong either in unit R4 or unit R5. The area in which the differences are more poorly defined is around and between Gander Lake and Round Pond.

Hydropetrologic unit R5 is mainly composed of relatively unmetamorphosed volcanic rocks of Cambrian to Devonian age. These rocks occur largely in the northern part of central Newfoundland; and much of the mineralization of the mobile belt is in this unit. The presence of mineralization does not affect the quantity of water available, but it is likely to affect the quality of the groundwater. It is probable that both surface and groundwaters on the Burlington Peninsula will have relatively high concentrations of metals. In volcanic rocks the water availability is likely to be even more variable in other units. There is a greater variation in volcanic rock types from glassy rhyolitic materials which originally would have no interstitial porosity to volcanic breccia and other pyroclastic deposits which could have high porosities and permeabilities.

Hydropetrologic unit R6 consists essentially of relatively unmetamorphosed sedimentary rocks of Cambrian to Devonian age, but excludes those groups which have either limestone or dolomite as their dominant rock type. It is also to be expected that there will be some volcanic rocks of unit R5 occurring as minor constituents of unit R6 and rocks of unit R6 as minor constituents of unit R5. It can be expected that yield of water will be rather greater from this unit on the Avalon Peninsula and on the west coast than in the mobile belt in the centre of the Island. These rocks are slightly more metamorphosed in the mobile belt while on the Avalon and the west coast they are relatively unaltered from their original condition. Some members of this unit, for example, on Bell Island, have well developed jointing occurring at very close spacing. The quality of the water obtained from rocks of this unit on the south side of Conception Bay tends to be poor. This is possibly due to the breakdown of some of the shales in the Cambrian succession.

Hydropetrologic unit R7 is made up entirely of Carboniferous sediments. These are less altered than the Cambrian to Devonian succession, particularly in the higher part of the Newfoundland Carboniferous succession, which occurs on the south eastern side of Grand Lake and Sandy Lake, at the south western end of Red Indian Lake, and on the eastern side of Deer Lake. In these areas there are some sandstones which are virtually unaltered and still retain their original interstitial porosity and permeability. There are some gypsum and anhydrite deposits in the Carboniferous succession, particularly in the area south of St. George's Bay. It is likely that some of the water that could be obtained from the Carboniferous rocks will not be usable, at least for drinking purposes, because of the high content of dissolved salts. Some salt springs have been reported in this area, as well as sulphurous and hydrogen sulphide rock springs. In addition, there are solution channels developed in some of the Carboniferous materials.

Hydropetrologic unit R8 is made up of groups of rocks which contain limestone and dolomite as the dominant rock type. Groups containing significant quantities of limestone and dolomite occur mainly among the Ordovician rocks of Newfoundland. Although there are some other limestones among the rocks, such as the Smith Point limestone, they are not sufficiently extensive to influence the quantity of the ground-water available over a significant area. On the Northern Peninsula, it is reported that there are some areas in which solution channels have formed in the limestone, leading to the drainage of some streams and ponds underground. Unfortunately, no detailed mapping is available of the limestone areas of the Northern Peninsula so the extent of this type of feature is uncertain. This unit also has an important effect on the quality of the water derived from it in that both surface and underground waters show a substantial increase in total hardness anywhere on this unit while the magnesium hardness is high in areas where dolomite occurs.

Hydropetrologic unit R9 is composed solely of the St. Lawrence granite. This granite has been separated from the unit R1 granites because of its known ability to yield large quantities of water due mainly to the nature of the jointing and fracturing. The town well at St. Lawrence yields 115 gallons per minute without pumping, while the fluorspar mine at St. Lawrence has to pump water out of its workings at a rate of 2500 US gpm, which is much higher than the rate recorded in other mines. The quality of water that is taken from this unit is also exceptional in that it contains fluorides and radon, presumably derived from fluorspar veins and uranium minerals respectively, which occur in the granite.

35.5.2 Labrador

No attempt has been made to prepare a bedrock hydrogeologic map of Labrador, owing to a lack of information on bedrock groundwater potential. Practically the whole of Labrador is underlain by rocks that would be included in hydropetrologic units R1 and R2. The only exceptions are two small patches of Lower Paleozoic sediments on the coast by the Strait of Belle Isle, which would probably belong to unit R4.

35.6 Yield from Bedrock Materials

Although in many cases a yield is quoted by drillers for bedrock wells, this figure is based on either a bailing test of a few minutes duration, or an estimate of the amount of water blown out of the hole by an air compressor, neither of which gives a valid figure for the yield. It is even more difficult to estimate the yields from bedrock units than from the surficial units as the yield is controlled by the size and frequency of the fractures, etc, encountered in the hole, and it is possible to encounter a major fissure in any hole that could produce 100 gpm or more. However, for the sake of completeness, an attempt has been made to estimate the average yields that may be expected from a well 200 feet deep in each of the described units in the following table. It must again be emphasized that large deviations from these figures can be expected in individual cases.

Bedrock Hydropetrologic Unit	Potential Range of yield expected (gpm) Minimum	Maximum
R1	0	40
R2	0.5	10
R3	1	10
R4	1	20
R5	1	30
R6	1	20
R7	1	30
R8	1	50
R9	1	100
Any major fissure, fault, or fracture below the water table	5	200
Solution channels (in R7 and R8)	20	>1000

It will be seen that in all cases the variation is large, and that even with the relatively high yielding units it is possible to get only low yields. The apparent anomaly of the high maximum yield assigned to the R1 unit, which is considered to be the lowest yielding unit of all, is due to the nature of the fractures that exist in some to the granites of the Island, where there are few large fissures which are widely separated, so that a 200-foot hole could be dry or produce plenty of water. It should also be noted that the potential yields are much lower than in the surficial materials.

35.7 Statistical Analysis of Bedrock Wells

The bedrock hydrogeological map was based on geological conditions only, and it was considered desirable to make some check on it from the data available on drilled wells. As the data provided on yields by the drillers is considered to be inaccurate, a statistical analysis has been made of the depth of the drilled wells. The reason for doing this was that the factor that is most important in selecting the site of most of the wells is the location of the house requiring water. This means that the wells are drilled at random in the different units, and as most of the holes are drilled to get a yield of about 5 gpm, in the driller's estimation, the depth of the hole is considered to be proportional to the difficulty in obtaining water in a particular geologic material.

A number of factors exist which will tend to interfere with obtaining a significant result, such as the thickness of overburden, the existence of various contractors with drillers of different degrees of competence, and different ideas as to what 5 gpm looks like. It can be shown that each of the principal contractors will tend to drill a different depth of hole in the same material to obtain the same supply of water. There are also some indications that there is a relationship between the depth of the hole drilled and the distance of the driller from his home base. One further factor is that Federal Government drilling contracts normally specify a depth of 200 feet in advance, which is drilled regardless of yield. Obviously, in view of the large number of factors involved in the well drilling, as well as the distribution of the fissures, etc., that carry the water, it can be expected that there will be a large variation in well depth within each unit.

In order to remove some of the complicating factors, the analysis has been made on the mean depth of wells in each community; this is necessary, as otherwise an excessive weight might be put on a local factor where a community has a lot of wells (St. John's has more than 70). The following table gives the mean depth for the wells in the communities in each unit, together with the standard deviation and the standard error of the mean depth. One set of wells on the Avalon Peninsula has been omitted as these were by one contractor who had drilled in some of the same communities as the contractors analyzed, and an analysis of the overlap showed that the mean depth of his wells was 40 percent less than the depth of wells drilled by other contractors in the same community. As the difference in depth drilled by the other contractors was small, it was felt that the introduction of the additional wells and about 10 more communities in units 2 and 3 was not justified.

Hydropetrologic Statistical Data on Well Depth

Hydro-petrologic Unit	Number of Communities with Wells	Mean Depth of Wells	Standard Deviation (I)	Standard Error of Mean (I)
R1	5	159	± 59	± 27
R2	45	158	± 60	± 9
R3	10	138	± 89	± 30
R4	2	113	± 23	± 23
R5	7	88	± 49	± 20
R6	23	127	± 41	± 9
R7	13	121	± 23	± 6
R8	13	106	± 22	± 6

It should be noted that there are not enough data on wells in unit 9 for it to be included. It can be seen from the table that in some other units the number of communities with wells is too small to place much significance on the mean obtained, as with units 1, 4, and 5. However, if a further analysis is made of the figures in the table by a standard statistical method, it is possible to show which difference between units may not be due to chance, even with the limited data available. The results of this analysis are shown in the following table:

Compared Units	Difference	Standard Error of Difference	Probability that Difference Due to Chance
1 and 2	1	± 28	Greater than .5
1 and 3	21	± 40	Greater than .5
1 and 4	46	± 35	Greater than .2
1 and 5	71	± 34	Less than .03
1 and 6	32	± 28	Less than .3
1 and 7	38	± 28	Less than .2
1 and 8	53	± 28	Less than .07
2 and 3	20	± 31	Greater than .5
2 and 4	45	± 25	Less than .08
2 and 5	70	± 22	Less than .0015
2 and 6	31	± 13	Less than .02
2 and 7	37	± 11	Less than .001
2 and 8	52	± 11	Less than .0001
3 and 4	25	± 38	Greater than .5
3 and 5	50	± 36	Less than .17
3 and 6	11	± 31	Greater than .5
3 and 7	17	± 31	Greater than .5
3 and 8	32	± 31	Greater than .3
4 and 5	25	± 30	Greater than .4
4 and 6	14	± 25	Greater than .5
4 and 7	8	± 24	Greater than .5
4 and 8	7	± 24	Greater than .5
5 and 6	39	± 31	Greater than .2
5 and 7	33	± 21	Greater than .1
5 and 8	18	± 11	Less than .1
6 and 7	6	± 11	Greater than .5
6 and 8	21	± 11	Greater than .04
7 and 8	15	± 8	Greater than .06

The results of the analysis show enough significant differences between units, considering the limited quantity of data available, to suggest that it is justified to separate hydropetrologic units in the manner described.

35.8 Storage

A quantitative estimate of the storage available in some of the basins has been obtained from studies of the base flow with recession curves. The data obtained are discussed in Part IV of this volume.

Owing to the fact that the bedrock carries water in fissures and cracks only, and not in the pores of the rock, the storage of groundwater in the bedrock is small. In the overburden, where the porosity is very much higher, there will probably be a much greater total storage than in the bedrock. The high porosity of the surficial materials will more than compensate for the greater thickness of bedrock materials. Where organic material is present in bogs and swamps, the storage available will be large within the organic materials themselves.

35.9 Amount of Flow

No quantitative information is available on the flow of groundwater on the Island except for the information on the base flow of rivers, which is described elsewhere. Although most of the storage of groundwater takes place in the overburden, most of the flow, at least to the sea, must take place through the bedrock, as the surficial materials are only in contact with the sea at a few localities.

Indirect evidence suggests that there is a considerable net outflow of groundwater to the sea. Although there are a few wells that are affected by saltwater intrusion (Section 36.3) there are many more examples of wells close to the shoreline that are obtaining large quantities of fresh water from the bedrock. At the Golden Eagle Refinery at Holyrood yields of up to 60 gpm have been obtained within three hundred feet of the shore. At the Town of St. Lawrence, the Municipal well yields 115 gpm and is situated only 50 feet from the original shoreline, though recent land fill has moved the shore to 200 feet away. This well has occasionally gone slightly saline, but this seems to have been related to abnormally high tides that inundated the actual site of the well.

Also situated at St. Lawrence is the Director Mine of the Newfoundland Fluorspar Company, which has workings several hundred feet below sea level, within a mile of the sea. Water has been pumped from this mine at an average rate of about 2500 US gpm for twenty years, and although the water table in the area of the mine appears to have gone down, there is no indication of salt water being drawn into it.

REFERENCES

1 Prest, V. K., Grant, D. R., Rampton, V. N. Newfoundland from Glacial Map of Canada (in press 1968).

2 Henderson, E. P. Surficial Geology, St. John's, Newfoundland. Map 35-1959. Canada. Department of Energy, Mines and Resources. Geological Survey of Canada.

3 MacClintock, Paul, and Twenhofel, W. H. Wisconsin Glaciation of Newfoundland. Geological Society of America. Bulletin. Vol. 51.

4 Jenness, S. E. Terra Nova and Bonavista Map-Areas, Newfoundland. Geological Survey of Canada. Memoir 327.

5 Mollard, J. D., and Munn, L. C. Report on Classes of Land in Newfoundland. Appendix I, Report of Newfoundland Royal Commission on Agriculture. 1955.

6 Carr, P. A. Appalachian Hydrogeological Region. Economic Geology Report No. 24. Ottawa, Canada. Department of Energy, Mines and Resources (in press 1967).

36 GROUNDWATER QUALITY

Groundwater quality is important for both domestic and industrial use since the concentration of dissolved materials is generally much higher than in surface water.

36.1 Groundwater Quality Analysis Results

The quality of the groundwater is affected by three main agents: the geological environment from which the water is removed, contamination by population, and the proximity of the sea which can cause salt water contamination. Figure 24-2 of this volume shows a graphical presentation of the groundwater analyses that have been collected during the present study; the analyses in tabular form together with the source of the different analyses are given in Tables 36-1 and 36-2, and a discussion of the analyses is included in Section 23 of this volume.

The graphical presentation shows only the amounts of calcium, magnesium, sodium plus potassium, carbonate plus bicarbonate, sulphate, and chloride ions in equivalents per million. The concentrations of all the ions except sodium and potassium were measured directly; the concentrations of sodium and potassium were obtained by subtracting the total of determined cation equivalents from the total determined anion equivalents. This procedure may have given rise to an error where an unexpected ion was present in major amounts. In a few of the analyses, those determined by the Department of Energy, Mines and Resources, the sodium and potassium have been determined directly. A careful study of the reliability of the results has been made and where some doubt exists about the accuracy of an analysis this is noted on the figure.

The samples which were collected for chemical analysis were not selected in a random manner, in that several wells which had been reported as having atypical properties were sampled. This applies to the wells at Bauline, Winterton, Topsail, and St. John's. There was also one well sampled at Bay Roberts where the total dissolved salt content was too high to be represented on the same scale as the other samples, and it was omitted from the figure. Since this well was situated below the high tide level, the presence of salt in its water is not unexpected.

The most striking feature of groundwater quality as presented is the large variation in total dissolved solids. The proportion of the six major ions is also highly variable from place to place. There is a considerable variation in the quantity of dissolved material due to geological factors even allowing for the fact that in some areas the water quality is affected by the intrusion of sea water.

In order to establish which variations are due to which factors, some criteria have to be established for sea water intrusion and contamination by population. Brandon[1] has used as a criterion of salt water intrusion in groundwater of Prince Edward Island a ratio of chloride to bicarbonate in equivalents which are greater than 0. 5. If the same criterion is used in Newfoundland, it would result in the implication of sea water intrusion in areas such as at Deer Lake and at Whitbourne, which is unreasonable as both are remote from the sea. An alternative criterion that might be applied to the Island would be a chloride bicarbonate ratio greater than one where the total dissolved solids content is greater than 6 equivalents per million. This rather high concentration standard may eliminate some analyses where slight intrusion has occurred, but it should also avoid including any that have not suffered sea water contamination.

On this basis, it would appear that sea water intrusion is taking place at St. Lawrence, Bonavista, Winterton, Bauline, Bay de Verde, and St. John's. The apparent sea water intrusion at St. John's is based on one analysis only, taken at a location a substantial distance away from the shoreline, and is almost certainly due to some other cause than the incursion of the sea. Both this well and the well at Topsail with high sodium, potassium, carbonate, and bicarbonate concentrations showed a significant content of hydrogen sulphide. Further investigation of sea water intrusion is required, and a discussion of it in more detail is given in Section 36. 3.

With the exception of those analyses with indications of sea water intrusion, calcium is generally the dominant cation in the water analyses obtained from the Island exclusive of the Avalon Peninsula. On the west coast of the Island where there is some minor limestone among the Carboniferous sedimentary sequence, the calcium content is generally high. The lowest relative calcium content encountered was at Baie Verte where the dominant cation is magnesium. The most likely source of high magnesium concentration at Baie Verte is from the ultra basic rocks in this area which may have undergone some serpentinization. Another area where the magnesium content might be expected to be high is in the Northern Peninsula where there are substantial quantities of dolomite present in the Ordovician sediments.

On the Burin Peninsula, the analyses at St. Lawrence were all taken at different times from the same well. The three St. Lawrence analyses all show evidence of salt water intrusion in the high concentrations of sodium and chloride ions, yet the concentration of magnesium which tends to be increased relative to the concentration of calcium by sea water intrusion appears to have decreased relative to the calcium content. Three of the analyses at Stephenville Crossing were taken from the same well over a period of several years, and they show very similar chemical characteristics for each determination, although the absolute quantities have varied.

In addition to the major constituents which are present, there are some variations in minor constituents. There is a high iron content at Cataline (3. 9 ppm); St. Lawrence (1. 7 ppm); Long Pond (3. 8 ppm); and Bauline (1. 3 ppm). There is a high nitrate content at Bay de Verde (3. 7 ppm); Winterton (16. 2 ppm); and O'Regans (4. 5 ppm). Hydrogen sulphide was detected in wells at Catalina, Topsail, and St. John's. A high fluoride content (3. 3 ppm) was recorded in one analysis at St. Lawrence, although other analyses in the same well have shown only 2 ppm. Nitrite which can be an indication of recent pollution by population or of an anaerobic condition in the ground, was detected in significant amounts at Baie Verte (0. 2 ppm), at one well in Holyrood (0. 3 ppm), and at one well in Bauline (0. 125 ppm).

Although the presence of significant amounts of manganese has not been recorded in any of the analyses, it is anticipated that this may be found to be present when more analyses are made. It is most likely to occur in hydropetrologic units R5 and R6.

The wells at St. Lawrence, Holyrood, and Bauline will be discussed further in a later section.

The majority of the underground water samples taken had low turbidities and were colourless. There were some exceptions to this, such as the sample at Long Pond which had a turbidity reading of 180; this value was the result of the development of brownish colour in the sample on standing which was due to the presence of iron in the water. A similar condition was responsible for the turbidity of 25 at Bauline.

Due to the intimate contact between the groundwater and the rocks, the range of pH recorded in the well samples was wide, from a low value of 5. 2 at Bay de Verde to a high value of 10 at Baie Verte. This is in marked contrast to the surface waters which show a range from about 6. 3 to 7. 5.

The values of dissolved oxygen determined in the groundwater samples should be viewed with reservation, as the rate of oxygen uptake varies directly as the dissolved oxygen deficit. In the case of dissolved-oxygen-free water in the ground, by the time the sample has been collected, however much care was taken, some oxygen will have been taken up from the air. A problem can also arise with the measurement of the carbon dioxide content as the solubility of the gas in water is much lower at atmospheric pressure than at the sample depth in the ground, and it also varies inversely with the temperature.

36. 2 Contamination of Groundwater

In many localities on the Island the groundwater has been contaminated, either by the introduction of sewage wastes into the water, or by the intrusion of sea water. The two types of contamination are considered separately. There are also some natural materials in the ground which make the water in some areas unsuitable for drinking purposes; these are discussed in the section on groundwater quality.

36. 2. 1 Contamination by Sewage

As the majority of the smaller communities on the Island have no piped sewage disposal system, the disposal of sewage can cause pollution of the water in the ground. These communities normally do not have a water supply system, and obtain their water supply from wells, which in turn often draw on polluted water. In many areas the normal lavatory facilities consist of an outhouse which may have a bucket system which is emptied, or a pit or primitive septic tank. A survey carried out in 1967 by the Provincial Department of Health, in the vicinity of Kelligrews and Chamberlins at the head of Conception Bay, found that about 70 percent of the septic tanks were improperly installed, and that half of them are not working properly. This would indicate that in many cases raw sewage is going into the ground or into drainage ditches, where it may be further spread by the effects of heavy rainfall. In the same area, near St. John's, out of 317 water samples taken from wells only 47 percent were considered to be satisfactory, the remainder were contaminated. In many sea coast communities the cesspools are connected by a pipe to the sea, which provides a means of disposal less likely to cause groundwater contamination.

The degree to which contamination of groundwater takes place mainly depends on two factors, the nature of the ground and the housing density. Where there is a reasonable thickness of surficial material present and the water table is well below the ground surface, and provided that well and outhouse are not situated side by side, as is regrettably often the case, the natural filtering action of the sand, silt, and clay in the ground will tend to prevent pollution. Where the surficial material consists of gravel or coarse sand, however, the filtering effect will not exist and contamination will take place. A further problem is caused by the construction of the wells, which are often simply holes in the ground, without adequate seals at the ground surface and the upper 10 feet. This results in the surface runoff draining into the well directly, without filtering through the ground, and this is a very common cause of pollution. The lack of adequate garbage disposal facilities, resulting in the disposal of refuse in a haphazard manner, may also act as a source of pollution to surface runoff which subsequently drains into wells.

Pollution is generally far more serious in areas where there is practically no overburden. As discussed elsewhere in this report, the flow of water through the bedrock takes place almost entirely through fissures in the rock; and, whereas water that has travelled not less than 50 feet through the overburden should be fairly free from contamination, contaminated water can readily travel for thousands of feet through fissures in the rock without a significant improvement in its quality. In addition, the construction of the shallow wells, which are characteristic of the less developed communities, is more difficult in rock. Often the well consists of a depression a few feet deep which has been excavated by blasting or with crowbars, and which acts more as a gathering basin for local runoff than as a well; and as mentioned earlier the runoff is frequently contaminated. In communities situated on exposed rock, even the drilling of deep wells can result in the production of contaminated water as the percolating water from the surface will still be contaminated when it reaches the water table in the rock, which may be a hundred feet or more from the surface.

The problem is compounded by the site normally selected for a deep well which is normally in the center of the community. While this is convenient from the point of view of access to the well for drinking water, it also means that there is probably polluted water entering the ground at a point upstream from it, so that the well itself is contaminated.

An important factor which affects pollution is the density of the housing. In many of the outport communities the houses were originally built some distance from each other, so that the only factor liable to cause pollution of a well was the sewage from the same house, and in most cases the well and septic tank were not close together. As some of the communities have grown the housing density has increased so that contamination is possible from several sources, and there is less space available on a particular property for the separation of wells and septic tanks. One advantage of close settlement is that it makes the installation of communal sewage and water lines an economic proposition, whereas with the widely separated houses, the cost of installing a water and sewage system is prohibitive.

From the surficial hydrogeologic maps, Figures 5-1 to 5-3, Volume Two A, it is possible to see which areas are most likely to have problems with pollution of groundwater. They are those areas on unit S1 which contain little or no surficial material so that flow of groundwater will largely be through the fissured bedrock; those areas on unit S4 where the surficial material is coarse and granular so that there will be little filtration in the ground; and those areas on unit S5 where swampy conditions prevail and the water table may rise above ground level after heavy rain, leading to the spread of polluted water.

A discussion on the construction of a well so as to minimize costs and contamination is given in Section 38 of this volume.

36. 3 Salt Water Intrusion

In view of the high rainfall and the generally low rate of withdrawal, it might be expected that there would be no salt water intrusion on the Island of Newfoundland. However, owing to the nature of the flow of water through the bedrock, there are numerous examples of wells on the Island that have become contaminated with salt water.

It has been shown theoretically that in a porous medium at a sea coast there will be a fresh water lens overlying salt water, with a thickness of fresh water of about 30 to 40 times the height of the groundwater surface above mean sea level. This relationship, however, is dependent on the existence of a porous medium and, while this is a correct description of the surficial materials that occur on the Island, it is not applicable to the type of rock that occurs along the greater part of the sea coast of the Island. The experience of well drillers has shown that sources of water in wells in the bedrock of the Island are discrete zones of fractured rock, or individual fissures within the rock. The capacity of a particular fissure to produce water for a well depends on the size of the fissure, it's linear extent, and the availability of recharge to it. In normal well drilling practice no proper testing is carried out and it is completed as soon as enough fissures have been encountered to produce the required yield in a bailing test of a few minutes duration. The great majority of fissures encountered by drilling have a sufficient flow of water through them towards the sea to provide the required quantity of water without difficulty, but in some cases the recharge from the landward side of the well may be inadequate, and the result is that water is drawn up the fissure from the seaward side, and ultimately salt water reaches the well. In this context it should be borne in mind that, as the great majority of Newfoundland communities are at the sea coast, many of the wells drilled into the rock are only a few hundred feet from the sea. The fact that salt water intrusion can take place in this manner is known to the drilling contractors, and it is a normal practice when salt water is encountered in a drill hole to cement off the level at which the water is coming in, and then to carry on drilling until a fresh water fissure zone is encountered at greater depth. In one instance at Bay Roberts, in a well situated on an artificial wharf projecting into the sea, fresh water has been obtained at a depth of 300 feet below sea level after four zones of salt water had been encountered and sealed off; however, the water eventually became saline. There are other examples of wells at the shoreline, for example Holyrood, where salt water has been cemented off and yields of 30 gpm or more of fresh water obtained from a lower level without salt water intrusion taking place.

It is almost impossible in most cases in Newfoundland to predict, in advance of a well being drilled close to the shore, whether it will suffer from salt water intrusion. It should occur more frequently at industrial wells than at domestic wells, but this would be expected as the withdrawal will be much greater at the former. The only example of intrusion due to tides is the intrusion at the St. Lawrence Municipal well after an excessively high tide.

Where a well is being installed close to the shoreline, it should be pump tested for a minimum period of 24 hours, and for 72 hours, if possible, at a rate considerably in excess of the proposed longterm withdrawal. Throughout the test the salinity of the water should be monitored, and if no change in salinity takes place during retest, the well will probably be able to maintain the required yield without a chloride increase.

REFERENCES

1 Brandon, L. V. Groundwater Hydrology and Water Supply of Prince Edward Island. Geological Survey of Canada. Ottawa, Canada. Department of Energy, Mines and Resources, 1966.

37 SPECIAL AREA CONDITIONS

There are areas on the Island where specific problems or unusual conditions have been identified which are not totally covered elsewhere in this report. Each of these areas is discussed below.

37.1 Community of Bauline

At Bauline two wells have been drilled in the bedrock to depths of 165 and 170 feet. One of the wells is situated close to the shoreline at the bottom of the steep hill on which the community is situated, the other is in the middle of the community, about 100 feet higher.

Chemical analyses have been made of the water at both of these wells, see Table 36-2. The upper well contains 312 ppm of chloride and 1.35 ppm of dissolved iron, while the lower well contains 55 ppm of chloride and 1.05 ppm of dissolved iron. The upper well also contains significant quantities of both nitrate and nitrite ions. Bacterial analysis showed 550 coliforms per 100 millilitres at the upper well, and none at the lower.

This is an area with practically no surficial material present and no sewage system. Many of the houses have holes excavated into the rock which are used as cess pits and from which raw sewage can escape into cracks in the rock and percolate down to the water table with no change in properties. The analysis of the upper well clearly indicates the presence of such contamination. It would also appear that the fissure system from which the upper well derives its supply is in contact with the sea, as the chloride content is fairly high for contamination by sewage alone.

The fact that the lower well contains no bacteriological contamination or significant chloride concentration, although it is much closer to the sea and situated in an area where there is potential sewage contamination from the whole community instead of only half the community at the upper well, is an indication of how difficult it is to predict in advance what will be encountered in a well in fissured rock. Both wells are badly sited, but the upper well site is theoretically better on both counts, yet gives poorer water.

Unfortunately there is high turbidity in the lower well which makes it aesthetically unacceptable for drinking purposes. The water in the upper well is clear and appears to be good, but has been posted as not fit for drinking purposes. Water from both wells tends to produce brown stains on clothing when used for washing. As a result, it is a common practice for the residents of the community to travel two miles inland to collect water for most purposes from a river. The water in the river is almost certainly as contaminated as the upper well water, but has not been tested.

The safe solution to the problem would be to chlorinate the supply from a well, and make it potable. This, however, would require the organization of a council and tax structure to pay for the plant and treatment which is difficult in a small community with a low per capita income.

37.2 Holyrood - Golden Eagle Refinery

At the Golden Eagle Refinery, five wells have been drilled, all within about 200 yards from the sea, on a site that is less than 50 feet above sea level. The wells are all within half a mile of each other, and as the history and depth of the individual wells is interesting, they are separately described below.

Well 1, drilled in 1966, is 6 inches in diameter, 125 feet deep and is reported to yield 25 gpm. The short analysis made in October 1967 showed 15 ppm of chloride and a conductivity of 135 micromhos.

Well 2, drilled in 1961, is 8 inches in diameter and 200 feet deep; on completion the well was reported to yield less than 2 gpm of saline water, and was never used. The short analysis in October 1967 showed 28 ppm of chloride, and a conductivity of 253 micromhos. The lack of salinity indicated from the 1967 analysis is probably in part due to the fact that the sample was bailed from the well, and represented fresh water which had accumulated locally but which is not available in sufficient quantity for continuous pumping.

Well 3, drilled in 1961, is 8 inches in diameter, 100 feet deep, and on completion water flowed from the top of the casing. The reported yield from this well was 100 gpm for some months during the construction of the refinery. After blasting had taken place in the vicinity the well is reported to have gone saline and was subsequently abandoned. It was not possible to obtain a sample from this well in 1967, so its present condition is unknown. In view of the very high yield, by local standards, being obtained from this well, and in view of its closeness to the sea in a low storage environment, it is surprising that it did not go saline almost immediately. It is possible that the cause of the salinity has been wrongly blamed on the blasting, and that it was in fact a consequence of overwithdrawal.

Well 4, drilled in 1961, is 8 inches in diameter and 60 feet deep; on completion the reported yield was 60 gpm. During the drilling salt water was encountered at shallow depths and was cemented off. After blasting had taken place in the vicinity this well also went saline, and was abandoned. An analysis in October 1967 showed 20 ppm of chloride, and a conductivity of 144 micromhos. As with well 3, it is possible that overwithdrawal was the real cause of the well going saline, as the water quality is now good since the well is not being used and has had a chance to recover.

Well 5, drilled in 1963, is 8 inches in diameter and 225 feet deep; the reported yield is 25 gpm. An analysis of the water in October 1967 showed 43 ppm of chlorides with a conductivity of 400 micromhos. This analysis showed a total carbonate figure of 120 ppm whereas none of the other wells showed carbonate over 50 ppm. This well is in continuous use as a source of drinking water.

From the descriptions of the individual wells it can be seen that the yield varies widely from place to place even on one site which is mapped as being of the same geological material throughout. If the number of feet drilled for each gpm of yield is computed it will be seen that it ranges from 1 foot per gpm at wells 3 and 4 to 100 feet per gpm at well 2. It is also shown that the quality can vary widely at one site, and that salt water intrusion can occur where over-pumping takes place.

37.3 Deer Lake Airport

Deer Lake Airport is situated on deposits of fluvioglacial sands, gravels, and clays forming part of the delta at the north end of Deer Lake. In principle it should be possible to drill and develop a well with no difficulty. Up to the end of 1967, three drilling contractors in turn have drilled holes at the site without bringing in a producing well. The latest attempt involved drilling to 200 feet in sands, gravels, and clays. Initially, water flowed from the cased well but it is reported that as soon as a pump was put on the flow ceased; attempts to get a steady flow by installing screens have been unsuccessful.

It is possible that the installation of a gravel pack and well screen in one of the sandy horizons would result in a satisfactory well.

37.4 Bay Roberts

The wells at Bay Roberts illustrate the type of variation that occurs on the Island. One well has been drilled in gravel and cased, with no screen. This well is reported as having an unlimited yield which probably means in excess of 100 gpm. A number of wells in the town have been put into bedrock yielding up to 10 gpm from holes up to 200 feet deep. In addition a well was put down on a wharf, beyond the level of the mean tide mark, which encountered three zones of salt water before encountering fresh water 300 feet down. The fresh water rose to the top of the casing and flowed out at a height of about 10 feet above sea level. After being used for some time the water from the well became brackish and then saline, and the well was abandoned. This again illustrates the inconsistency of behaviour in wells in fissured rock.

37.5 St. Lawrence

In the St. Lawrence area there are several unusual features associated with the groundwater derived from the St. Lawrence granite. The quantity of water derived from the granite in this area can be higher than from any other hydropetrologic unit on the Island. In the fluorspar mine, the water which enters through cracks and fissures in the rock is presently being pumped from the mine at a rate of 2500 US gpm which is five times the volume being pumped from a given area of workings in any other mine on the Island. In the municipal well for the town of St. Lawrence the flow was 115 gpm from the top of the casing on completion.

Although the mine workings extend several hundred feet below sea level and are close to the sea, there has been no indication of saline water being drawn into the mine. In fact the salinity of water in newly opened workings tends to fall off with time, as the connate water is more saline than that percolating down from the surface to replace it. In the Municipal well, intermittent problems due to salt water intrusion, with concentrations of 600 ppm of sodium chloride being reached for short periods, have been experienced; but this appears to be due to submergence of the well, which is located close to the shoreline, by particularly high tides.

The groundwater also carries radon that is derived from the decay of radioactive materials in the rock, either in accessory minerals in the granite or from zones of uranium mineralization. (See Volume VII - Burin Peninsula Study Area.)

A further problem is caused at St. Lawrence by the high concentrations of fluoride that occur in the groundwater. The source of the fluoride in the groundwater is the fluorspar within the St. Lawrence granite. The water with the highest fluoride content is that derived from wells put down into the granite, such as the municipal well that provides the present town water supply. Concentrations as high as 3.3 ppm have been recorded from this well, though levels of between 2 and 3 ppm are more common. Some evidence of dental fluorosis is present in the population of St. Lawrence, where water with the high fluoride content has been in use for more than 10 years.

A number of samples collected from wells in the vicinity of St. Lawrence and elsewhere on the Burin Peninsula, for analysis of fluoride content are listed in the table on page 37-6. Most of the wells sampled were in the overburden, and the high fluoride content in some of them suggests that there is an interchange of groundwater between the bedrock and the overburden. It is also clear from the figures from neighbouring communities that the high fluorides are found only in the vicinity of St. Lawrence and not elsewhere on the Burin peninsula.

37.6 Stephenville

In 1960 and 1961 a project to supply the USAF base at Harmon Field, Stephenville from a groundwater source was considered. The base is sited on extensive sand and gravel deposits which should be suitable for producing 2,000,000 gallons per day. Six test wells were drilled in 1961, and tests were carried out which indicated that it was perfectly feasible to obtain the 2,000,000 gpd required from three wells. No further work was carried out and no permanent pumping system was installed, but this does indicate the potential of some of the gravel deposits of the Island as a source of groundwater.

37.7 Mine Dewatering

A questionnaire was circulated to all the operating mines on the Island which requested information on water encountered in the mines. The only mine which indicated major water problems was the one at St. Lawrence, discussed above. It is an indication of the general water-tightness of the bedrock on the Island and that much of the water encountered in the mines enters through exploratory drill holes put down prior to mine development, which let water from the surface percolate down. At Gullbridge Mine some grouting of water bearing fissures in rhyolite has been carried out, and the total quantity being pumped from the mine is only 100 gpm.

FLUORIDE CONCENTRATIONS IN GROUNDWATER

BURIN PENINSULA

St. Lawrence (since 1960)	St. Lawrence (pre 1960)	Little St. Lawrence (August 1960)	Elsewhere (August 1960)
1.10	1.6(3)	0.76	Burin
4.30	2.0(1)	0.42	0.08
1.90	4.9	0.57	0.23
1.30	2.0(3)	0.90	0.08
1.30	2.0	0.45	Lewin's Cove
1.80	2.7(1)	0.40	0.31
3.60	2.7(3)	0.65	0.11
4.80	1.4	0.51	Corbin
1.33		0.98	2.4
0.68		1.20	Lawn
1.60		0.50	0.37
2.10		0.53	0.79
1.30		0.96	0.72
1.20			0.16
2.50			0.35
3.30			0.57
2.60			Lord's Cove
2.90			0.15
0.87			0.28
2.50			
4.30			
2.50(1)			
0.79(2)			

Notes: (1) Municipal well
(2) Hospital
(3) Mine water

Remainder are private dug wells.
All values in ppm of Fluoride.

38 FUTURE WELL DEVELOPMENT

As a result of the investigations carried out on the ground-water resources of the Island, it has been observed that there are areas where an improvement could be made in the method of provision and construction of wells. Some of the main points are discussed below.

38.1 General

A small community may request the Provincial Government to provide them with a well. If the request is granted, then the full cost of having a well drilled is met by the Government. The normal procedure is for a drilling contractor to be instructed to go to the community and drill a well; the only other action normally taken by the Government is to pay the bill after the well has been completed. No attempt is normally made by the provincial authorities to ensure that the most favourable site is selected for the well, and no supervision of the drilling contractor is provided.

From the information gathered in this study, it appears that it is possible to select a favourable site for a well on the basis of the geology of an area. It also appears, from the statistical study of the well depths that wells are drilled in a manner that bears no relation to the geology of the area. It is felt that a careful selection of a site for each well drilled could probably save, on average, at least 20 feet in depth for each well drilled. As, in some communities, several holes are put down and the cost of drilling varies between $10 and $15 per foot; the proper selection of sites could save several hundred dollars in each community. There are several geologists who could provide guidance in well site selection but they are in the employ of the Department of Mines, Agriculture and Resources rather than the Department of Municipal Affairs which is the Department responsible for the well drilling.

The fact that there is generally no supervision of the drilling places a considerable responsibility on the drilling contractor. While there is no evidence to suggest any dishonesty on the part of the drillers, there is no guarantee that at some future time the Province may not be charged for a footage in excess of that actually drilled. The drilling contractors have themselves indicated their concern at the lack of supervision they receive.

The communities for whom the wells are drilled are unincorporated and have no means of raising money to provide maintenance for the installed wells. The only facility provided at the well is normally a hand pump, and it is often more difficult to obtain water from the drilled well than from the contaminated dug wells they are intended to displace, so they are often not fully used. It would be preferable if the community were obliged to set up some sort of structure to raise funds so that they could at least partially finance the installation and maintenance of an electric or gasoline pump and a small storage tank. If the community had to contribute to the cost of drilling the well, it is likely that they would take better care of the facility once it was installed.

In the absence of any regulations regarding the drilling of wells, it is possible to have a well drilled so that it removes the supply from a neighbouring property. The introduction of a permit system of some type would aid in more rational well development and would also permit the gathering of more precise data so that a backlog of information is built up which will enable a better understanding in the future of the problems involved.

The economics of water supply to small communities is discussed in Volume 5.

38.2 Wells in Unconsolidated Materials

There is considerable room for improvement in the drilling and development of wells in unconsolidated materials. The drilled wells often go through such materials into bedrock, largely because of lack of understanding of techniques for the development of wells in unconsolidated materials. Where wells are completed above bedrock, it is common for the casing to be left in and no screen installed, so that water is drawn in solely through the bottom of the casing. The correct procedure to develop a well and improve the flow from the surficial material would be to install a well screen surrounded by gravel of suitable grading. One reason which is given for not developing surficial wells is that the water is dirty in the surficials while it is clean in the bedrock. This is because there is often a considerable quantity of silt in suspension in the water of an undeveloped well which gives it a dirty appearance. If the well is properly developed, the water will be clear.

A gravel pack is most useful where the water-bearing deposit is made up of a fine grained material. Details of how to determine the grading of gravel to use, and how to determine the size of slot in the well screen required are given in many standard handbooks, such as "Ground Water and Wells", 1966, by E. E. Johnson Inc.

After installation of the well, it should be pumped out and surged to remove all muddy water and to develop the filter.

38.3 Bedrock Wells

The procedure normally used for drilling bedrock wells is adequate and sensible. The better contractors have learned from experience that by cementing off some of the fissures from which water flows they can often prevent contamination by septic tanks, and in the case of wells close to the sea, prevent salt water entering the well. Little use has been made of techniques of well developments, but it is extremely doubtful if they would be of much assistance. Most of the bedrock wells are uncased and although some attempts to increase fracturing with explosives have been made they have not been very successful.

38.4 Sealing of Wells

Many of the examples of contaminated wells existing on the Island can be traced back to one specific cause, the infiltration of contaminated runoff into the well. This can be prevented quite easily if proper precautions are taken. The top part of the well, even if drilled in solid rock, should be cased, and the casing top should be at least 6 inches above ground surface, or more in areas subject to flooding. The top 10 feet of casing should be surrounded by grout so that there is no possibility of surface runoff running down the side of the casing. In areas where bedrock wells are being installed in communities where the groundwater is known to be contaminated, it may be possible to obtain good water by drilling through the top layers of fissures, cementing off the flow, and then drilling deeper to find a system of fissures carrying uncontaminated water.

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Water Resources Study - Newfoundland and Labrador

PART VIII - CONCLUSIONS ON NATURAL WATER RESOURCES

39 SURFACE WATER AVAILABILITY AND QUALITY UNDER NATURAL CONDITIONS, AND EFFECT OF PRESENT DAY USES

The quantity and quality of the naturally available water was studied on the basis of existing data supplemented by a water quality grab sampling program carried out by the consultant during the fall of 1967. The study has been expanded to the whole Province, but the scarcity of data for Labrador has not enabled a more than general appraisal of the water availability and quality in that area.

39.1 Surface Water Availability

The data available at 25 hydrometric stations on the variation of the levels and flows in the Island of Newfoundland do not cover all the various climatologic (and probably hydrologic) regions. In addition, some of the data are affected by errors related primarily to ice conditions and difficulties in assesing the natural flows at the hydro-electric plants which provide data at eight of the 25 stations considered in the study. Therefore, a special method had to be used to combine all the available climatologic, hydrologic and physiographic data, and thus obtain generalized hydrologic relationships and a preliminary appraisal of the hydrologic characteristics. Although this appraisal can be considered sufficient for the present level of the study, the scarcity and poor quality of data is reflected in some of the results obtained from the generalized relationships, and in the impossibility of assessing in more than an approximate way the subdivision of the Island in hydrologic subregions. This also results in difficulties in estimating the hydrologic characteristics for small basins (smaller than 100 square miles).

The conditions in Labrador are much more difficult than on the Island as only seven hydrometric stations are in operation (for an area almost three times as large as the Island). In addition, the flows at four of the hydrometric stations are affected by changes in storage which cannot be estimated from the available data. Therefore, the hydrologic studies in Labrador were limited to a preliminary estimate of the runoff distribution, which was done using the same technique as for the Island, with additional input from the isohyetal and isothermal maps provided by the Department of Transport. Further investigations, after the completion of a hydrometric network and gathering of data for a period of 4 to 5 years, will be required to bring the hydrologic knowledge of Labrador to the same level as that for the Island.

The analysis of the meteorologic and hydrologic data indicated that the Island has an average annual precipitation of 55 inches, an average annual actual evaporation of 13 inches, and an average annual runoff of 42 inches, which is equivalent to 3.1 cfs per square mile.

Because of the small drainage areas of most of the rivers (only three rivers, the Exploits, the Humber and the Gander, have drainage basins larger than 2000 square miles), the average flows of the rivers are relatively small. For the same reason, and because the groundwater supply to the rivers is not very significant. many rivers have extremely low flows or even dry up during extended drought periods.

From a hydrologic viewpoint, the Island can be divided into four hydrologic regions, having hydrologic regimes characterized as follows:

Hydrologic Region*	Avalon and Burin Peninsulas	South and East Coast	West Coast and Great Northwest Peninsula	Northeast Coast
Maximum size of drainage basin (sq mi)	101	1100	3230***	4400
Average runoff (inches)	40-60	35-50	35-70	25-30
Average runoff (cfs/sq mi)	3.0-4.5	2.6-3.7	2.6-5.2	1.8-2.6
Minimum runoff 1/20 years (cfs/sq mi)**	0.0	0.30-0.10	0.10-0.25	0.05-0.10
Maximum runoff (cfs/sq mi)**				
a) for basins of 1---200 sq mi	30-60	25-50	70-150	30-50
b) for largest basin in region	-	18	19	17

* The limits of the hydrologic regions are indicated in Figure 21-1.
** Correction for sampling errors not included.
*** Next largest basin 390 sq mi.

The climatologic analysis indicated that the four hydrologic regions could be further subdivided into 12 subregions, but the data available are not sufficient to justify such subdivisions at the present time.

Although level variation is influenced by many local conditions, there appears to be a general relationship between the flow variation interval and level variation interval (Figure 20-1), which can be used for a rough estimate of level variation in areas where data on water levels are missing. Ice jams are one of the significant factors disturbing this relationship, and in many cases they are the cause of the maximum levels.

In southern Labrador (south of 56° 30' north latitude) the average annual precipitation is 33 inches, the average annual actual evaporation 9 inches, and the average annual runoff 24 inches or 1.77 cfs per square mile.

The drainage basins are generally larger than on the Island. In addition to the Churchill River (31,500 square miles) another four rivers have drainage basins over 4000 square miles, and another four over 2000 square miles. Because of late snowmelt and large natural storage, the relative variation of the flow for the larger river basins is smaller than that observed in the Island. The small river basins, which are completely ungauged, may, however, present a flow variation which is similar to that observed in the Island.

Since more detailed data are missing, Labrador has been divided provisionally into two hydrologic regions with the hydrologic regime characterized as follows:

Hydrologic Region	Southern Labrador	Northern Labrador
Maximum size of drainage basin (sq mi)	31,500	4806
Average runoff (inches)	20-25	15-25 (est.)
Average runoff (cfs/sq mi)	1.5-1.8	1.1-1.8 (est.)
Minimum runoff 1/20 years (cfs/sq mi)	0.2 (est.)	0.0 (est.)

There are indications that the two regions could be subdivided into at least four subregions, but the data available are not sufficient to justify such subdivisions at the present time.

The data indicated above for the northern Labrador area were estimated from the general climatologic data available and hydrologic records for rivers in similar conditions.

39.2 Surface Water Quality

The quality of the surface water was estimated on the basis of the available data which were correlated, to the extent that this was possible, to the flow data to obtain an estimate of the quality variation in time. Available data were only sufficient to draw valid conclusions on water quality at a very small number of locations. Therefore, an attempt was made to generally relate physiographic and water quality characteristics for the Island, which were then used to roughly estimate the water quality characteristics in rivers for which water quality data were not available. A grab sampling survey was carried out by the consultant to complete the available data and to roughly check the results of these estimates.

From the data available, combined with the estimates of quality changes due to wastewaters, the relationships with flow and the physical characteristics, it was concluded that the water available on the Island can be characterized from the quality viewpoint as follows:

a) The water temperatures vary between about 32°F in winter to about 60°F to 70°F in summer.

b) The turbidity is generally low varying mainly between 0 and 5 units locally and occasionally higher especially during floods and in small deforested areas.

c) The colour is generally high, in most cases being higher than 20 units and seldom as low as 10.

d) The dissolved oxygen in rivers in most cases approaches saturation concentration, and in lakes has variable concentration with depth.

e) The pH is generally low, being less than 6. 5 in most cases, and not exceeding 8. 5 in any of the samples.

f) The hardness is generally low, the total hardness not exceeding 50 ppm as $CaCO_3$. However, in the western region where limestone and dolomite bedrock occur, total hardness of up to 120 ppm as $CaCO_3$ has been encountered.

g) The total dissolved solids content is generally lower than 100 ppm except occasionally in areas where the total hardness is higher than normal.

39. 3 Influence of Present Uses

The main uses which have so far influenced the regime of surface water in a significant way are those for log driving and power. The larger hydro-electric plants (Deer Lake, Grand Falls, Twin Falls) so far have generally had a regulating effect, whereas the smaller plants have occasionally increased the natural flow variation. Large diversions both on the Island and in Labrador have started to change the hydrologic regime on a large scale, but they did not significantly affect the flow data used in the present study.

Withdrawal for industrial and domestic uses has had only a local influence, affecting significantly only very small streams.

From the viewpoint of water quality, only two of the larger rivers have been affected so far by industrial pollution, the Exploits (by a pulp and paper mill) and the upper Churchill (by two mining enterprises). The remaining inland industries discharge their waters into small brooks and rivers whose quality is affected to a varying extent, especially in the case of the mining industry, although this industry impounds its wastewaters before release (sometimes into a natural lake).

The changes induced so far by the release of domestic wastewaters in the inland surface water consist of the increase of organic matter, bacteria, and probably detergents. The major rivers affected by such releases are firstly the Exploits, to a lesser extent the Gander and the Humber, and to an almost negligible extent the Churchill. A number of smaller brooks and lakes in heavily settled areas, particularly the St. John's area, are also contaminated by domestic wastes.

39.4 Recommendations

Recommendations for further investigations on surface water are included in Sections 22 (water quantity), 29 (water quality), and 32 (estuaries).

Further, it is recommended that observational pilot stations for the measurement of lakes, marshes, bogs, embayments, and coastal areas should be installed with a view to expanding them, after gaining the required experience, into a complete network for the Province. Such pilot stations should be established in areas with undisturbed natural conditions as well as in areas where the conditions have undergone changes of various proportions due to human activity, and should be comprehensive in the sense that the observations should, if possible, comprise physical, chemical, bacteriological, and ecological observations, with a view to optimizing the type of data collected at the stations in the trial network to meet the requirements of all interested agencies.

Such pilot stations should be established in both Newfoundland and Labrador, although the rate of expanding them into complete networks will be different in the two cases.

40 GROUNDWATER AVAILABILITY AND QUALITY, AND EFFECTS OF PRESENT USES

40.1 Groundwater Availability and Quality

The groundwater availability was studied on the basis of geologic information, data on dug and drilled wells, and data obtained from mines. The information is mainly qualitative, since data on yields and other hydraulic characteristics were practically non-existent. The data for the Island were sufficient to obtain some estimate of groundwater possibilities, whereas for Labrador the data were limited and the analyses have therefore a much more approximate character. For the Island it was also possible to indirectly estimate the distribution of the combined ground and surface storage from hydrologic data to give an indication of the groundwater storage.

40.1.1 The Island of Newfoundland

As a result of the analysis of surficial groundwater possibilities the Island has been divided into seven surficial hydrogeologic units. The delineation of these units is shown in Figures 5-1 and 5-2, Volume Two A.

Similarly, the Island has been divided from the viewpoint of bedrock hydrogeology into nine units as shown in Figure 4-2, Volume Two A. The yield from a well in bedrock is expected to vary between 0 and 100 gpm according to the type of rock, and more than 100 gpm in major fissures, faults, and fractures, as indicated on the figure. The units R8 and R9 and the major fissures, faults, and fractures present larger groundwater possibilities.

Practically anywhere on the Island of Newfoundland it is possible to obtain a supply of groundwater of reasonable quality, and in sufficient quantity to service a few houses or a small community. In areas where there is a reasonable cover of surficial materials it is possible to develop a supply, and elsewhere water may be obtained from deep wells in the bedrock. Less than 5 percent of all bedrock wells drilled in the Island have failed to find a satisfactory supply, and in cases where drilling has failed it has more often been due to the presence of water of unusable quality, normally saline, though occasionally with other contaminants such as hydrogen sulphide, than due to the absence of water.

Where sand and gravel deposits are present it is possible to develop supplies of several hundred gallons a minute from properly developed wells, and supplies of 50 gallons a minute or more can occasionally be obtained from bedrock wells drilled in fractured rocks.

Data on groundwater quality in natural conditions indicate that the water is generally colourless, with low turbidity, and a large variation in pH (from 5.2 to 10). The major constituent of dissolved solids is generally calcium, and locally magnesium. High salinity which may be related to sea water intrusion was detected in a series of wells near the seacoast, and in some cases at a relatively large distance from the shore (St. John's). Other chemical constituents which may be related to local conditions, such as iron or hydrogen sulphide, or pollution such as nitrites, were detected in a series of wells. The available data indicate that most of the groundwater under natural conditions in the Island is of satisfactory quality. The main sources of poor quality water are the marshes and swamps among the surficial materials, and basic igneous rocks, salt deposits and limestones among the bedrock materials. Salt water conditions are occasionally encountered close to the shoreline.

40.1.2 Labrador

An attempt has been made to interpret the surficial geologic map of Labrador in terms of hydrogeology with units similar to those of the Island (Figure 5-3). The unit with the largest groundwater possibilities (SL4) is shown in Figure 5-3.

The data available have not enabled bedrock hydrogeologic units in Labrador to be delineated. From the available information, it appears that the bedrock possibilities of the area are lower than those of the Island.

40.2 Effect of Present Day Uses

Man's activity has not so far significantly influenced groundwater conditions from the quantitative viewpoint except in areas where mine de-watering has to some extent lowered the groundwater table in surrounding areas. (Mine de-watering flows are indicated in Volume Three, Section 7.5.2).

The increasing population density in some communities has caused contamination of wells by sewage to become widespread. This will lead to an increasing health hazard, which can only be avoided by developing water supply sources from areas where sewage is not permitted to enter the ground untreated, or by treating the groundwater prior to use.

In Labrador, owing to the sparse population and the extensive surface water resources available, little groundwater development has taken place to date.

40.3 Recommendations

a) Legislation should be passed by the Provincial Government to provide for compulsory registration of well drillers for obtaining a permit prior to installing a well and for reporting all data on wells drilled to the Provincial Government.

b) An educational program should be instituted on the proper installation of septic tanks and the sanitary protection of shallow wells.

c) A training program for drilling contractors in the construction and development of wells in the overburden should be instituted and should become a prerequisite for a well driller wishing to operate in the Province.

d) The Provincial Government should review its policy on grants to unincorporated communities for wells, with a view to charging some part of the cost to the community and installing a more convenient pumping system.

e) The Provincial Government should ensure that one of the geologists in their employ is oriented towards the siting of wells and should ensure that all wells are sited by him or some other qualified person.

f) Supervision should be provided when wells are being drilled. If the provision of an inspector is too expensive, then a responsible member of the community should be instructed to carry out specific supervisory tasks.

g) The policy of the Federal Government in specifying a depth of well in advance, regardless of site, is incorrect and should be changed.

h) A properly designed network for the estimation of the groundwater conditions should be developed for the Province. The network can be designed on the basis of the hydropetrologic unit delineation included in Figures 4-5, 5-1, 5-2, and 5-3, with a view to obtaining at least two or three wells in each distinct area of the various units. Furthermore, level records, pumping tests, and water quality sampling are required in at least one well for each distinct area of the various hydropetrologic units.

i) The hydrogeologic maps can be updated and corrected on the basis of the data obtained from these wells. While the establishment of such a network for both the Island and Labrador is required, the groundwater network for Labrador has a lower priority.