Water Planning and Management Division Report 75 - 1

HYDROGEOLOGY AND GROUNDWATER FLOW SYSTEMS OF THE SMITHS COVE AREA NOVA SCOTIA

Chang L. Lin

Nova Scotia Department of the Environment
Halifax, Nova Scotia, 1975

PROVINCE OF NOVA SCOTIA
DEPARTMENT OF THE ENVIRONMENT

Water planning and Management Report 75-1

Hydrogeology and Groundwater Flow Systems Of the Smiths Cove Area, Nova Scotia

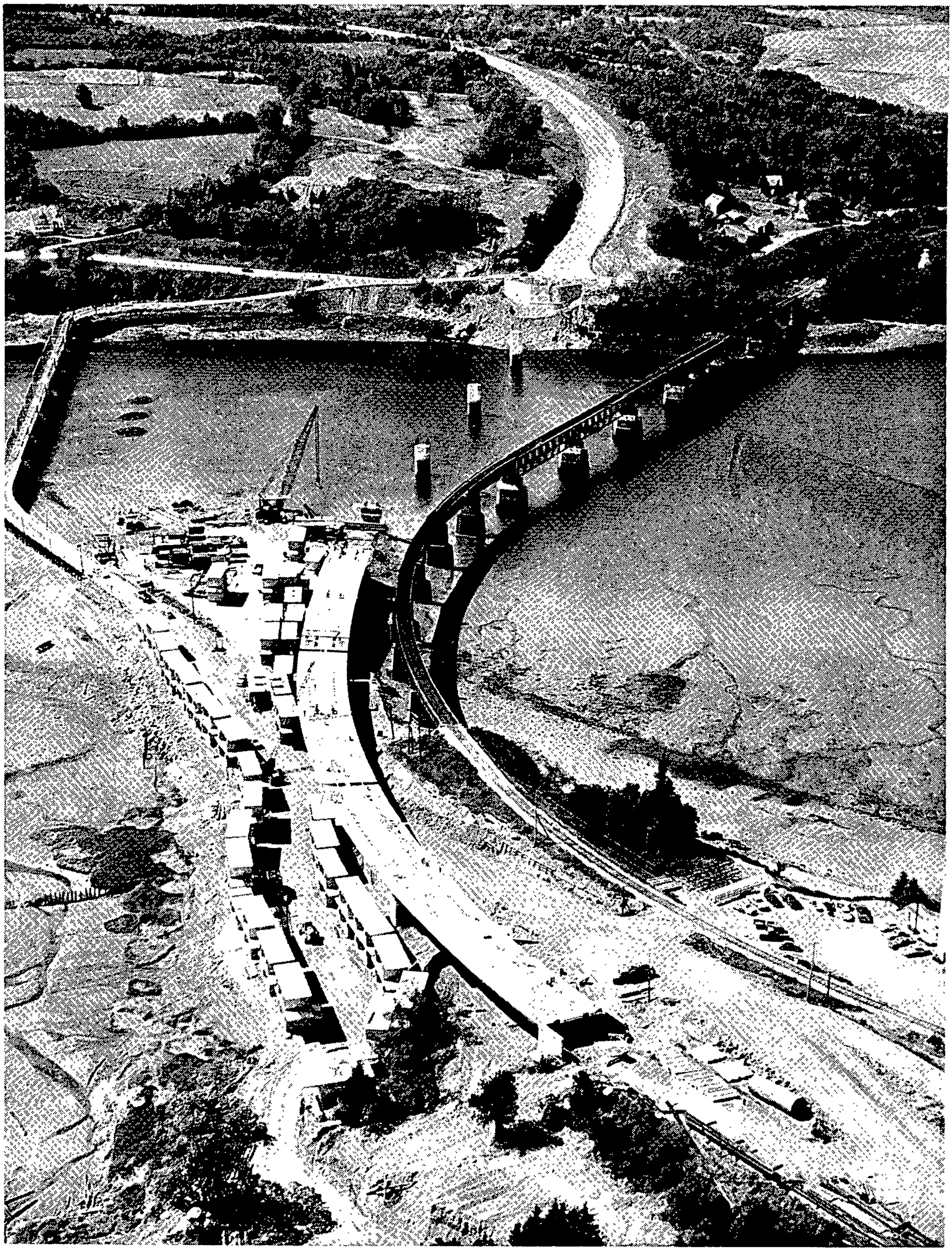
by

Chang L. Lin

Hon. John Hawkins
Minister

John S. Mactavish
Deputy Minister

Halifax, Nova Scotia
1975



Frontispiece: Bear River Bridge and Highway 101 under construction.

CONTENTS

ABSTRACT

More than 80% of the Smiths Cove area is underlain by the high angle, tightly folded slates of lower Ordovician age, which is in turn overlain in the north by sandstones and shales of Triassic age. The entire area is blanketed with surficial deposits of sand, gravel and glacial till of Pleistocene age which vary from less than one foot to over 200 feet thick.

The village of Smiths Cove depends for its water supply entirely on individually owned wells. On a short term basis, wells drilled into the slates may yield from ½ to 6 igpm, whereas the well yields from Triassic sandstone and shale aquifers vary from 1 to 15 igpm. For wells constructed in sand and gravel deposits, a well yield in the order of 5 to 10 igpm can be obtained at shallow depths. In the eastern part of the Smiths Cove area, where the occurrence of many mafic intrusives has reduced at least in half the permeability of the slate aquifers, many shallow wells have been constructed along steep slopes to take advantage of the active groundwater discharge.

A preliminary study of the groundwater flow patterns of the Smiths Cove area indicates the following: (A) The small topographic relief coupled with the steeply folded slate bedrock strongly favours the development of local groundwater flow systems characterized by a series of recharge and discharge zones. (B) The groundwater flow systems of the Smiths Cove area receive little recharge from the South Mountain Upland. Major groundwater recharge occurs along the margins of the upland adjacent to steep slopes. (C) An active groundwater seepage occurs along the northern steep slope of the South Mountain Upland, which is a favorable area for groundwater development in the slate terrain. (D) Exposures of permeable sand and gravel beds and fractured bedrocks along highway 101 pose a potential pollution problem to the wells located below and adjacent to the highway by the de-icing road salt.

INTRODUCTION

Purpose and Scope of the Investigation

The Province of Nova Scotia initiated in June, 1971, the construction of a four-mile section of highway 101 and a new Bear River Bridge at Smiths Cove, Nova Scotia. The placement of the new highway resulted in the loss or interruption of about 20 domestic water supply systems. The Water Planning and Management Division of the Nova Scotia Department of the Environment, formerly the Groundwater Section of the Nova Scotia Department of Mines, was called to investigate the situation and to assist the Nova Scotia Department of Highways in locating an alternate satisfactory water supply for each of those affected by the construction of the new highway.

More than 80% of the Smiths Cove area is directly underlain by hard, dense slates of Halifax Formation of Ordovician age where a thin cover of surficial deposits offers little protection for the underlying bedrock aquifers. The situation is further complicated by the fact that the permeability and the water supply potential of the slate aquifers in the Smiths Cove area have been significantly reduced by the occurrence of many hard, dense mafic rocks which intrude into the slate formation. Consequently, wells drilled into slate bedrock often yield water sufficient only for domestic require ments.

The construction of the new highway required several deep cuts, which exposed fractured bedrock and permeable sand and gravel beds. Hydrogeologically, the placement of the highway cut or fill interrupted the near surface groundwater flow and resulted in the diversion or reversal of local groundwater gradients. The loss or reduction of many well water supplies of the area in 1971 was directly attributable to these changes in the hydrological environment.

In addition to results of geological, hydrological and geotechnical data collected, compiled and evaluated intermittently during the summers of 1971, 1972 and 1973, this report includes the following considerations:

(1) The water supply for domestic and industrial requirements of the area.

(2) The engineering and environmental problems related to the manifestation of groundwater flow systems and the construction of the new highway.

(3) The simulation of the groundwater flow system influenced by the complex permeable, impermeable and hydraulic boundaries.

General Description of the Area

Location and Physiography

The Smiths Cove area lies between north latitudes 44°37' 17.5" and 44°34' 47.5", and west longitudes 65°39'40" and 65°45'00", covering an area of approximately 16 square miles in Digby County, Nova Scotia (Fig. 1).

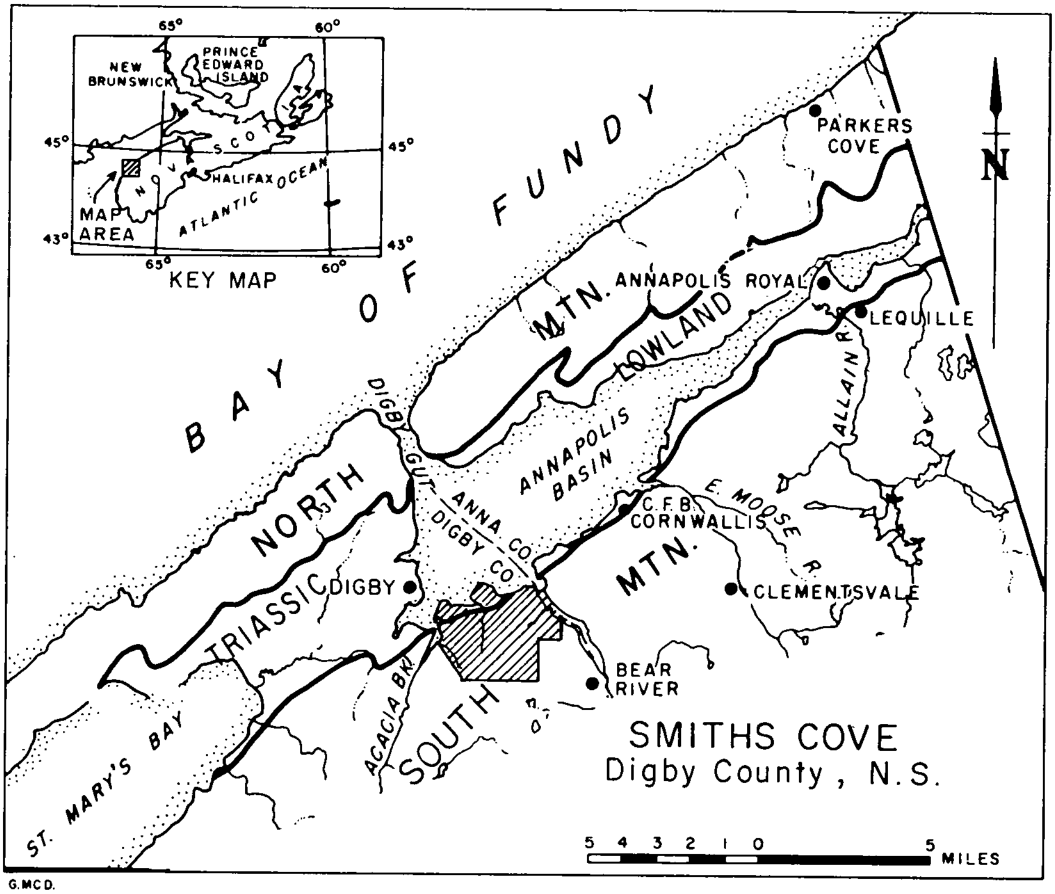


Fig. 1: Location of the Smiths Cove area, Nova Scotia.

It is readily accessible by highways and the Dominion Atlantic Railway from Halifax and Yarmouth, and by a ferry service from Saint John, New Brunswick, via the Digby Ferry Terminal. Many county, farm and logging roads provide access to most rural parts of the study area and to the adjacent communities such as Digby, Bear River, Clementsvale, Conway and Deep Brook.

Physiographically, the Smiths Cove area is situated at the north end of the South Mountain Peneplain with a topographic relief of 475 feet. This landform was slightly modified by glaciation during the Pleistocene age. The ancient Bear River valley is about 160 feet below the present mean sea level, whereas the bottom of a glaciated valley at Joggins is about 90 feet below sea level. The area is drained by three perennial ungraded bedrock brooks, the Roop, the Roach, and the Walsh. Over the highland area, where the relief is small, the drainage is sluggish and the water table is high. Along the Annapolis Basin, where the land slope is steep, groundwater seepage is abundant.

Agriculture and Soils

Sandy clay loam, sandy loam, and gravelly sandy loam, constitute the three main soil types of the area (Table 1). Farming is not common in the Smiths Cove as most of the area is forested.

TABLE 1

SOILS AND THEIR SUITABILITY FOR AGRICULTURE
IN THE SMITHS COVE AREA,
DIGBY COUNTY, NOVA SCOTIA*

Parent Material	Soil	Classes of Land	Limitations
Red Brown Clay Till	Sandy Clay Loam	Good Crop Land	Topography, Stoniness
Brown Sandy Till	Sandy Loam	Good to Poor Crop Land	Topography, Stoniness, Rock Outcrop Occasionally Excessive Drainage
Sand and Gravel	Gravelly Sandy Loam	Fair Crop Land	Excessive Drainage Stoniness

• Modified from Soil Map of Digby County, by Hilchey, J.D., D.B. Cann and J.I. MacDougall (1962)

The sandy clay loam, developed from underlying red brown clay till, is a moderately fine textured, stone-free soil, suitable for a fairly wide range of crops (Hilchey, Cann & MacDougall, 1962). The sandy loam is derived from the brown sandy till and its usefulness as good crop land is limited in places by bedrock outcrops and stoniness. The gravelly sandy loam developed mainly on the outwash sand and gravel deposits is generally a fair cropland where the drainage is not excessive.

Climate

The climate of the Smiths Cove area is temperate and humid, typical of Nova Scotia. Extremes of climate are prevented in part by the proximity of the Bay of Fundy and the Annapolis Basin.

Although there is no weather station at the Smiths Cove area, longterm records exist for Annapolis Royal and Digby at Prim Point, and shorter records are available for Bear River, Clementsvale and Digby at CKDY Radio Station (Canada Dept. of Environment, 1971). Based on climatic records at Bear River, Clementsvale and Digby (Prim Point), the mean temperature at Smiths Cove area is about 43.5 ^{o} F, with an annual precipitation of about 45 inches (Table 2). The following

TABLE 2

MONTHLY NORMAL PRECIPITATION AND TEMPERATURE IN BEAR RIVER, CLEMENTSVALE, AND DIGBY

RECORDS	PRECIPITATION, INCHES			TEMPERATURE, °F		
Station / Month	B^4	C^3	D^6	B	C^3	D^8
JAN	5.68	4.58	4.49		25.4	23.6
FEB	4.97	3.91	4.61		26.2	22.3
MAR	3.87	3.09	3.22		32.8	30.1
APR	4.16	3.72	3.91		41.5	39.6
MAY	3.51	3.86	3.08		50.4	49.7
JUNE	3.27	3.66	2.87		58.4	58.9
JULY	2.79	3.62	2.64		64.6	64.7
AUG	3.32	3.92	3.13		63.5	63.3
SEPT	3.71	3.69	3.54		57.6	56.2
OCT	4.64	4.27	4.71		49.7	47.9
NOV	5.72	5.85	5.57		41.7	39.2
DEC	5.79	4.25	6.01		31.2	28.0
TOTAL	51.43	48.42	47.78			
AVERAGE	4.25	4.03	3.98		45.3	43.6

NOTES:

A. Data taken from "Temperature and Precipitation 1941-1970, Atlantic Provinces", Canada Department of Environment, Atmospheric Environment Service, 1971, 55 pp.

B. Record stations are designated by B: Bear River; C: Clementsvale; D: Digby.

C: Subscripts: 3,4,6 & 8 denote type of normal; 3-20 to 24 years between 1941 and 1970, 4-15 to 19 years between 1941 and 1970, 6-less than 10 years, 8-adjusted.

D: No temperature records are available for Bear River.

climatic data are extrapolated from Chapman and Brown (1966): Actual evaporation, 22 inches; potential evaporation, 22 inches; moisture deficiency, 0 inches; mean frost period, 130 days.

Population and Industry

According to the Dominion Bureau of Statistics, the village of Smiths Cove (Smiths Cove, Lansdowne and Joggins Bridge) had a population of 573 in 1966 and 509 in 1971. The village stretches about four miles along the old highway trunk No. 1 between the Bear River and the Joggins Bridges. Strategically located for the full view of the scenic Annapolis Basin, the Smiths Cove area is an ideal tourist attraction. Many restaurants, cabins, motels, cottages, trailer parks, and camping facilities provide an important income to the area. The recently completed pre-cast, post-tensioned Bear River Bridge, the first of its type constructed in North America, will undoubtedly be an added attraction of the area (Fig. 2).

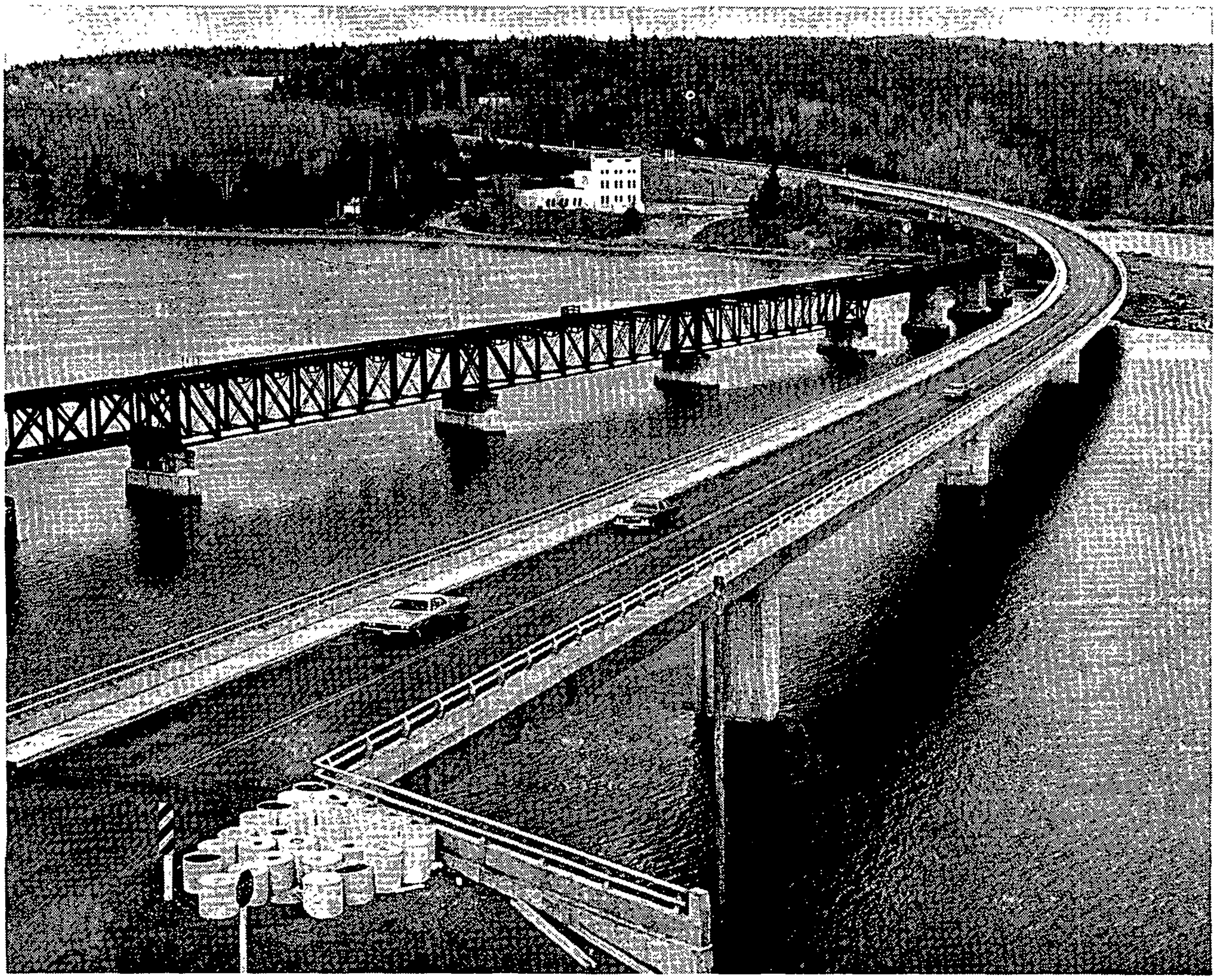


Fig. 2: The Bear River Bridge, Nova Scotia

Field Work, Maps and Grid System

The field work of this project was carried out intermittently during the summers of 1971, 1972 and 1973. A total of 104 mechanical analyses of surficial samples, 83 well logs and 49 chemical analyses of water samples were collected and compiled to assist in the interpretation of hydrogeology of the area (Appendix A, B, & C). Two pump tests of short duration were conducted at wells 53 and 77 in 1971.

The bedrock and surficial geological maps accompanying this report are based on the topographic maps of the Smiths Cove and the Bear River sections, prepared in 1960 by the Nova Scotia Department of Highways at a scale of one inch to 400 feet, with a contour interval of five feet. Black and white air photos at a scale of one inch to 1320 feet flown in 1955 were used extensively in the field mapping. On August 24, 1973, a remote sensing flight under Project 73-156 of the Canadian Centre for Remote Sensing was flown over the Smiths Cove - Digby area.

The grid system used for locating wells and samples in this study is adapted in part from the National Topographic System and the Nova Scotia Department of Mines, Mining Tract - Claim System (Fig. 3). The entire Smiths Cove area is covered by Reference Map A of Standard Topographic Map 21A 12 and includes the following mining tracts: 63, 82, 83, 84, 85, 86, 87, 105, 106, 107 and 108. According to the Nova Scotia Department of Mines System, each mining tract consists of sixteen 40-acre claims. In this report, each claim is subdivided into 16 units and each unit contains four 170' x 158' subareas. Therefore, all reported locations in this report are within an accuracy of 80 feet in the field. Figure 3 shows the location of a hypothetical well 37 at 21 A 12 A 107 A H 1.

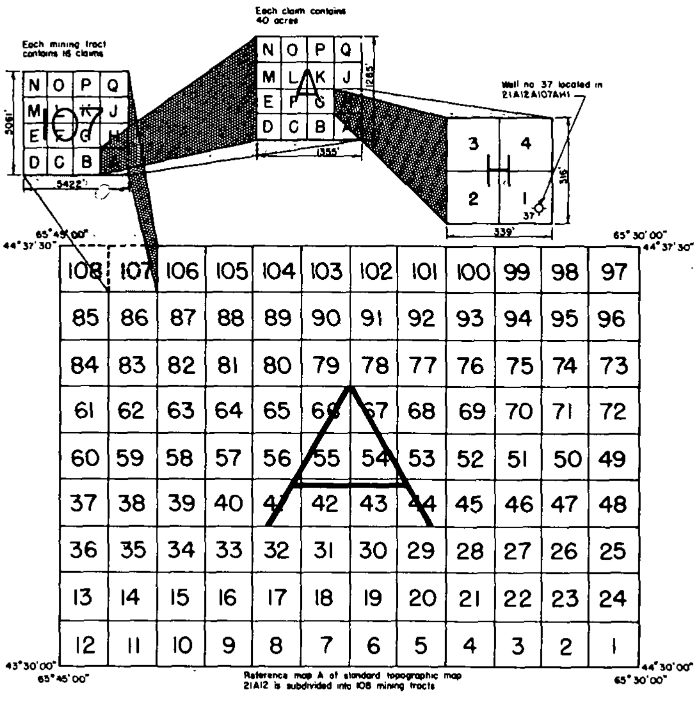


Fig. 3: Grid system used for locating wells, soil and water samples, in the Smiths Cove area, Nova Scotia.

Acknowledgements

The writer is indebted to Mr. Harold Sulis, Sulis Plumbing and Heating Limited, Conway for his recollection of the location and construction details of many unrecorded drilled wells in the Smiths Cove area and to Mr. George Kennedy for donating to the Nova Scotia Department of the Environment four volumes of drilling records of his late father, Mr. O.V. Kennedy. With their assistance, records of many missing drilled wells of the Smiths Cove area have been compiled and verified for permanent reference.

To Mr. Bruce C. Fraser, Claims Agent, Mr. Robert Whitman, Resident Engineer for the construction of the Bear River Bridge and Mr. George Bell, Resident Engineer at the Provincial Materials Laboratory of the Nova Scotia Department of Highways, many thanks for their co-operation, assistance and constructive information rendered freely during the course of this study. All maps and illustrations in this report were prepared by Mr. D. Bernasconi and his staff of the Cartographic Section, Nova Scotia Department of Mines. The photos of the Bear River Bridge were provided by the Nova Scotia Communication and Information Centre. Valuable geotechnical data on the bridge foundations at the Bear River and the Joggins crossings have been kindly provided through the following engineers and consulting firms: Mr. T.J. Boyle, Engineer of Bridge Structures, Canadian Pacific Railways, Montreal, Quebec; Mr. J.A.B. Lovell, P. Eng., A.D. Margison Associates (1973)

Ltd., Willowdale, Ontario; and Mr. U.F. MacCulloch, Urban F. McCulloch Consulting Engineering Services, Beaconsfield, Quebec.

Many findings of Trescott (1969) and Smitheringale (1973) have been incorporated in this report. Of the material quoted, whenever a source is known, credit has been given. Any errors in the interpretations are, however, solely those of this writer. Preliminary results of a model study of groundwater flow patterns in the Smiths Cove area were presented in San Francisco at the 1973 Fall Annual Meeting of the American Geophysical Union.

Field assistance was provided during the summer of 1971 by Ivan Rafuse. From May 1972 to April 1974, very able assistance in the field and laboratory was provided by John C. Fraser. Without the co-operation and assistance of the residents of the area, and many others too numerous to list, this study would not have been possible.

GEOLOGY AND ENGINEERING GEOLOGY

Introduction

The simple general geology of the Smiths Cove area becomes more complicated when studied in detail (Table 3). More than 80% of the area is underlain by Meguma slates (Halifax Formation) of lower Ordovician age. In the northwestern portion of the map area Wolfville sandstones and shales of Triassic age are found (Map 1). This entire bedrock terrain is subsequently blanketed with surficial deposits of sand, gravel, silt, clay, and glacial till of Pleistocene age. Over the upland region the unconsolidated deposits are thin; on the lowland area and glaciated valleys, it may vary from a few feet to over 200 feet thick (Map 2). Described below are the geotechnical properties of the bedrock units and surficial deposits, which have a significant bearing on the hydrogeology and engineering geology of the Smiths Cove area. For other geological details, readers are referred to the publications of Taylor (1969) and Smitheringale (1973).

Bedrock Units

Halifax Formation

The following descriptions of the Halifax Formation of Ordovician Age are taken mainly from Smitheringale (1973, p. 15-20, 66-68). The Halifax Formation is mainly dark grey to black, moderately silty to non-silty slates and phyllites containing laminae of medium to light grey impure quartzite. The thickness of the laminae ranges from less than 0.02 inch to over one inch. The laminae may be continuous, with a uniform thickness of over ten feet, or may be lenticular and discontinuous. The structural pattern of the area is part of a major Torbrook Syncline, located near the village of Bear River, about 3.6 miles southwest of Roop Brook. The Halifax slates in between Roop Brook and the mouth of Bear River contain numerous folds of unknown size. Interpretation of these structures is hindered by a scarcity of continuous outcrops and the absence of horizon markers and fossils. Nevertheless, Smitheringale (1973, p. 19) recognizes a rather distinctive anticline crossing the Bear River about one mile southwest of Roop Brook. This study suggests a syncline between the Roop Brook and the new Bear River Bridge (Map 1).

The axial traces of many folds can be projected precisely from one side of Bear River to the other, a distance of 1,500 feet. The axial planes of these folds plunge 0 to 20 degrees northeasterly and dip 75° SE to vertical, with few exceptions at the new Bear River Bridge that dip steeply northwest.

Major faults are not common in the Smiths Cove area. However, Smitheringale (1973, p. 20) observed several high angle bedding plane displacements along the shore of Bear River and believed that most of them are genetically related to the folding of the area. Most joints fall into one of the three sets: those striking northwesterly; approximately easterly; and N 25° E to N 35° E. All have nearly vertical dips. The joints of approximate attitude N50 W/ vertical form the principal set of joints of the region. The slaty cleavages in Halifax slates consist of many short discontinuous cleavage planes in an en echelon arrangement. These are well defined in thin sections by carbonaceous matter that has been smeared onto the cleavage surfaces. Movement along individual planes ranges from nil to over 0.1 inch. The spacing of the cleavage planes is about 0.001 inch in silty laminae containing rare quartzite and 0.02 inch to over 0.1 inch in quartzite laminae (Smitheringale, 1973, p. 19).

Mafic Intrusives

In eastern Smiths Cove area, the Halifax slates contain numerous mafic sills of Devonian age. Both slates and the intrusives are tightly folded into a series of synclines and anticlines trending about 30 degrees northwest. In this report, modifications in information on the occurrence and the distribution of the mafic intrusives of the area have been based on rock exposures along the new

TABLE 3

STRATIGRAPHY OF THE SMITHS COVE AREA
DIGBY COUNTY, NOVA SCOTIA

ERA	PERIOD or EPOCH	FORMATION or GROUP	LITHOLOGY	
CENOZOIC	RECENT		Stream Alluvium:	Silts and Sands
			Bar and Beach:	Sands
			Peat and Moss:	Organic Matters
	PLEISTOCENE		Glacio Fluvial Deposits:	Sand and Gravel
			Glacial Till:	Red Brown Silty and Sandy, Brown Sandy
	Pleistocene-Triassic (?)		Clean Sand or Gravel Interbedded with Red Clay	
MESOZOIC	TRIASSIC	WOLFVILLE FM.	Sandstone:	Red, White, Hard
			Shale:	Red, Grey, Black; Soft to Hard
PALEOZOIC	DEVONIAN-CARBONIFEROUS (?)		Diorite, Gabbro Metadiorite:	Greenish, Coarse, Crystalline, Both Mafic Minerals and Plagioclase Severely Altered; Reaction to HCl
	LOWER ORDOVICIAN	MEGUMA GROUP HALIFAX FM.	Slate:	Grey, Black, Fine-Grained Occasionally Red, Sandy, and Laminated; Hard

Table 3: Stratigraphy of the Smiths Cove area, Digby County, Nova Scotia

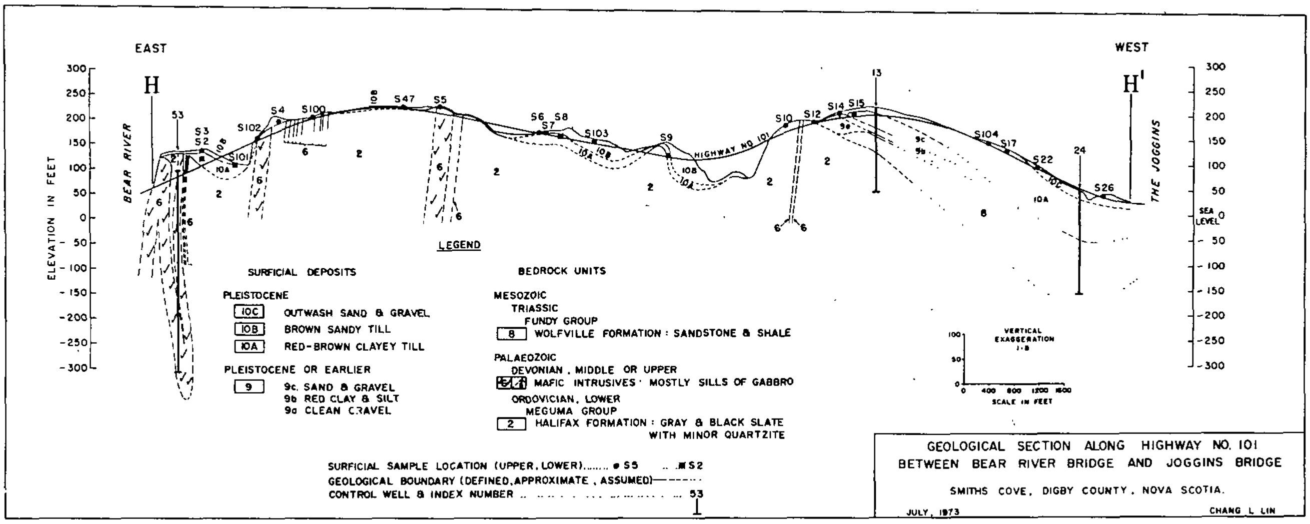


Fig: 4 Geological section along Highway 101, between Bear River Bridge and Joggins Bridge, Smiths Cove, Nova Scotia

highway, drillers' well logs and field mapping (Fig. 4). Four major intrusives, varying in thickness from 100 to 200 feet and in color from dark greenish to olivine grey occur mainly as gabbro sills. Two of them seem to extend more than two miles. Without the aid of a thin section study, these intrusives are easily mistaken for marble, because they are deeply weathered.

The weak zones in the gabbro intrusives are found along the fracture openings and the broken zone on the top. In general, the massive intrusives are dissected by two sets of fractures. The first set, which is parallel to the bedding plane of the slate formation, is a tight fracture, spaced 6 inches to 12 inches apart. Present in between are some en echelon type short fractures spaced 1 inch to 3 inches. All these fractures are discontinuous.

The second set of fractures dips vertically and intersects with the first set of fractures at small angles. Spaced 3 to 5 feet apart, they are discontinuous open fractures with curved surfaces. The second set of fractures appears to be more favorable for the movement of groundwater flow, if they are interconnected. However, it is seldom that such a fracture cuts through the whole intrusive outcrop although most minor intrusives are often segmented.

Wolfville Formation

Occurrence of the Wolfville Formation of Triassic age in the Smiths Cove area was first reported by Trescott (1969) based on records of about 10 drilled wells. The contact between the Wolfville Formation and the Meguma slates shown in Maps 1 and 2 has been modified according to additional well logs and field mapping. The Wolfville formation is about 1700 feet thick in the Annapolis-Cornwallis Valley and dips gently from 6 to 12 degrees to the northwest (Trescott, 1969, p. 13). It consists mainly of poorly cemented, fine grained sandstone, silt-stone and shale of reddish brown or grey color. Occasionally, a thin layer of clean course grained sandstone may be encountered. Based on data from a total footage of 2450 feet of Wolfville Formation encountered by wells drilled at the Smiths Cove area, the ratio between shale and sandstone is about 2:3.

Due to extensive till cover, outcrops of the Wolfville Formation are rare. Hence, a study of the structural relation and other geological details was not possible. However, available well logs suggest that in the Smiths Cove area the Wolfville Formation is thin, with the thickest deposits in the northwestern region.

Surficial Deposits

Sands, Gravels and Glacial Tills

The surficial deposits of the Smiths Cove area include (1) outwash sand and gravel, (2) glacial tills, and (3) organic marine clay interbedded with clean sand and gravel. In addition to the isopach map of the surficial deposits Map 2 shows the distribution of outwash sand and gravel, brown sandy till, and red brown clayey till. The thickness of the surficial deposits is generally less than 50 feet in central and eastern Smiths Cove, whereas in the northwestern region, it may vary from 50 to over 200 feet. At well 29, a total of 247 feet of surficial deposits was encountered in drilling. The well logs in Appendix B provide information on the local stratigraphy and lithology of the surficial deposits.

Results of sieve analyses of 101 soil samples provide useful information on the surface infiltration and permeability of the surficial deposits of the map area (Appendix A). The silt and clay content which relates directly to the permeability of the soils varies considerably among these surficial deposits (Fig. 5). In sand and gravel deposits, the silt and clay content varies from 0% to 26%, with most samples having a silt and clay content less than 10%. Most brown sandy tills contain 7% to 52% of silt and clay, with an average of 23%. The silt and clay content in the red brown clayey till varies from 18% to 62% and averages at 37%, which is at least 10% higher than that reported in the Musquodoboit River Valley (Lin, 1970, p. 16-18). The areas with a silt and clay content in excess of 25% are outlined in Map 2.

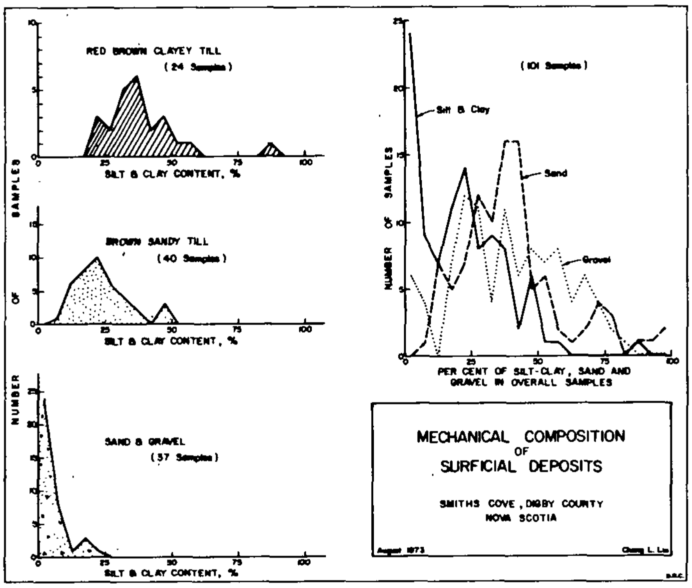


Fig. 5: Graphical results of Mechanical analyses of 101 surficial samples taken from the Smiths Cove area, Nova Scotia

Figure 6 relates the effective grain size, D10, to the permeability of the soil samples, based on Hazen's approximation (Hough, 1957, p. 75). Although the Hazen's approximation assumes well graded filter sands, it provides a quantitative basis on the relative magnitudes of the permeability for various soil samples taken from the Smiths Cove area. According to Figure 6 the permeabilities of the surficial deposits range from 10^{-2} to slightly over 10^{4} imperial gallons per day per square foot.

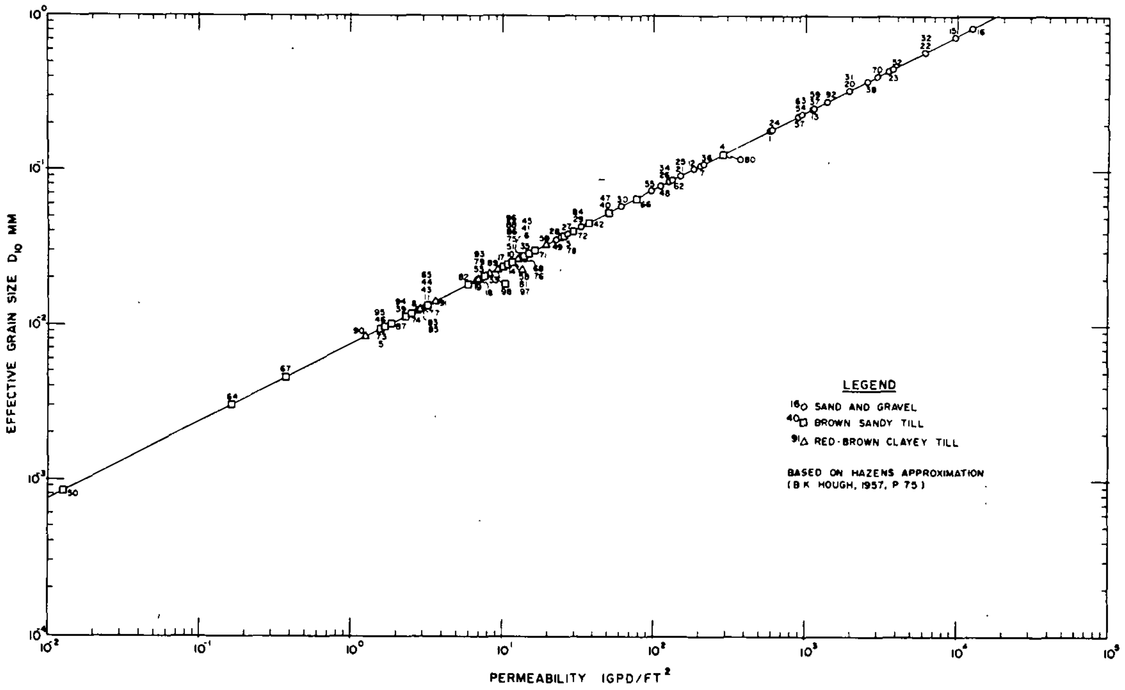
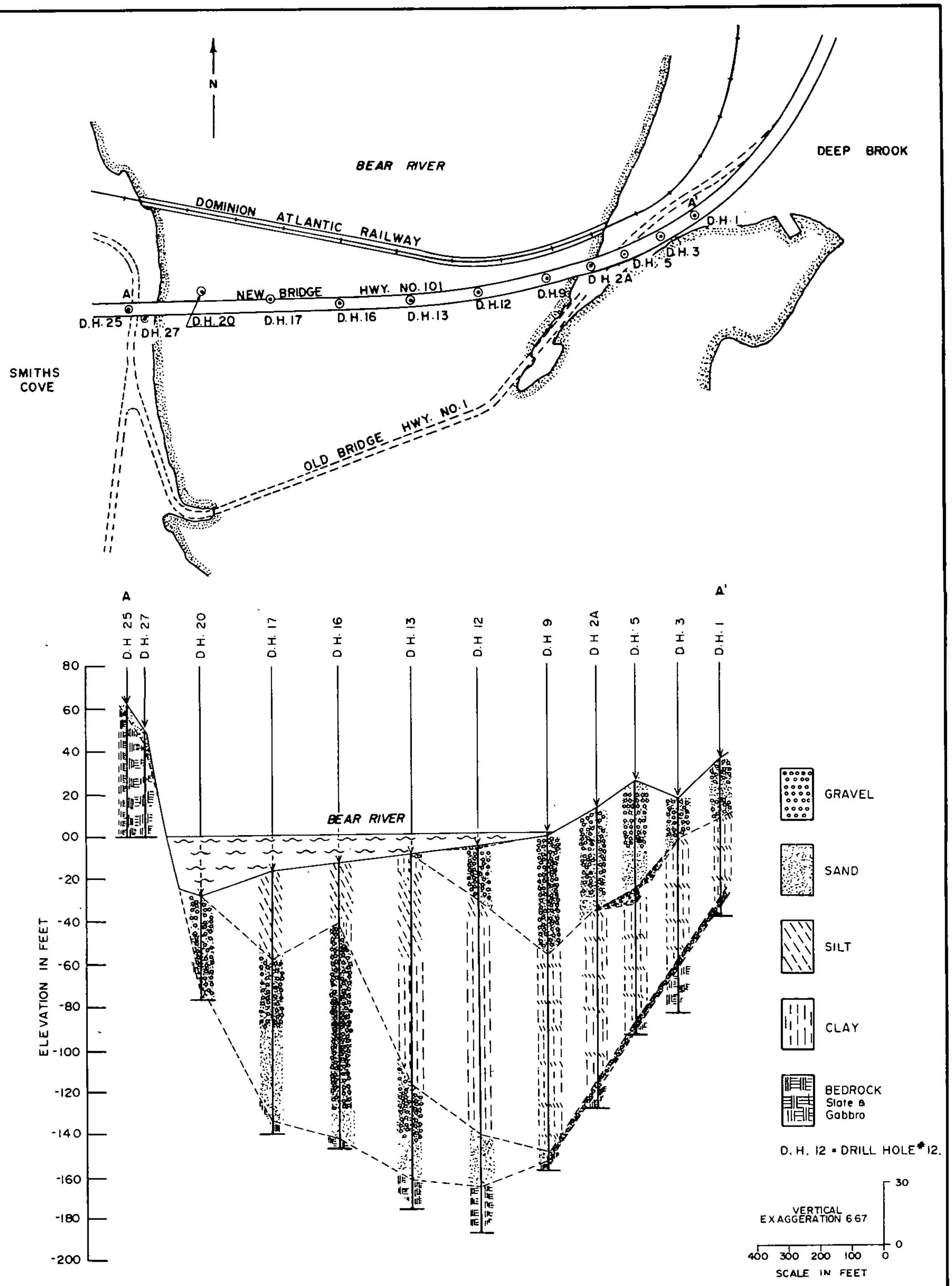


Fig. 6: Permeability of the surficial deposits based on Hazen's approximation

Organic Marine Clays

An organic marine clay was encountered at the bridge foundation of the Bear River and of the Joggins Crossings and at a highway cut in the vicinity of surficial sample No. 13. Presence of the soft silty organic marine clay generated considerable concern in the design and construction of the railway and highway bridges. At the Bear River Bridge foundation, the surficial deposits consist of three main strata. They are from top to bottom: (1) sand and gravel layer (east side) 60 feet, (2) soft silt and clay layer, 90 feet, (3) sand and gravel layer, (west side), 75 feet (Fig. 7). According to the Unified Soil Classification System (Terzaghi and Peck, 1967) the soft silt and clay is termed an organic marine clay (OL), whereas the sand and gravel deposits are classified as the silty gravelly sand (SMD). The index properties of the organic marine clay are as follows: wet density: 106-112 pounds per cubic foot or pcf, dry density, 80 pcf; water content, 24.5 - 37%; liquid limit, 34-47%; plastic limit, 25-28.5%; shear strength, 773-1810 pounds per square foot or psf (N.S. Dept. of Highways, Materials Laboratory, 1970).



GEOLOGICAL SECTION AND PLAN
ALONG BEAR RIVER BRIDGE, HIGHWAY NO. 101
SMITHS COVE, NOVA SCOTIA.

NOTE: BASIC INFORMATION ON
DRILL HOLES TAKEN FROM
N. S. DEPT. OF HIGHWAYS
FILE NO. B-70-6,
DRAWING NO. 2293-313 (JULY 1970).

CHANG L. LIN 1973

Fig. 7: Geological section and plan along Bear River Bridge, Highway 101, Smiths Cove

At the Joggins Bridge, the overburden is approximately 75 feet thick and can also be subdivided into three substrata (from top to bottom): (1) soft silty clay, 30 feet; (2) alternate layers of dense, angular, sand, gravel and sandy clay, 15-20 feet; (3) small boulders, sand and gravel in a matrix of very stiff reddish clay, 20-30 feet (Fig. 8). According to Racey, MacCallum and Associates Ltd., (1957), the silty clay contains wood, roots, shells and other organic matter and has the following engineering properties: wet density, 91-117 pcf; water content, 30-65%; liquid limit, 27-62%; plastic limit, 18-31%; plasticity index, 8.5-31%; shear strength, 280-800 psf. In the final design, the cohesive strength of the organic marine clay was considered as 500 psf. It is also interesting to note that the bottom stratum is a very dense glacial till, characterized by the following properties: water content, 10-18.5%; dry density, 111 pcf; shear strength, 5530 psf (Spencer, White and Prentis of Canada, Ltd., 1952).

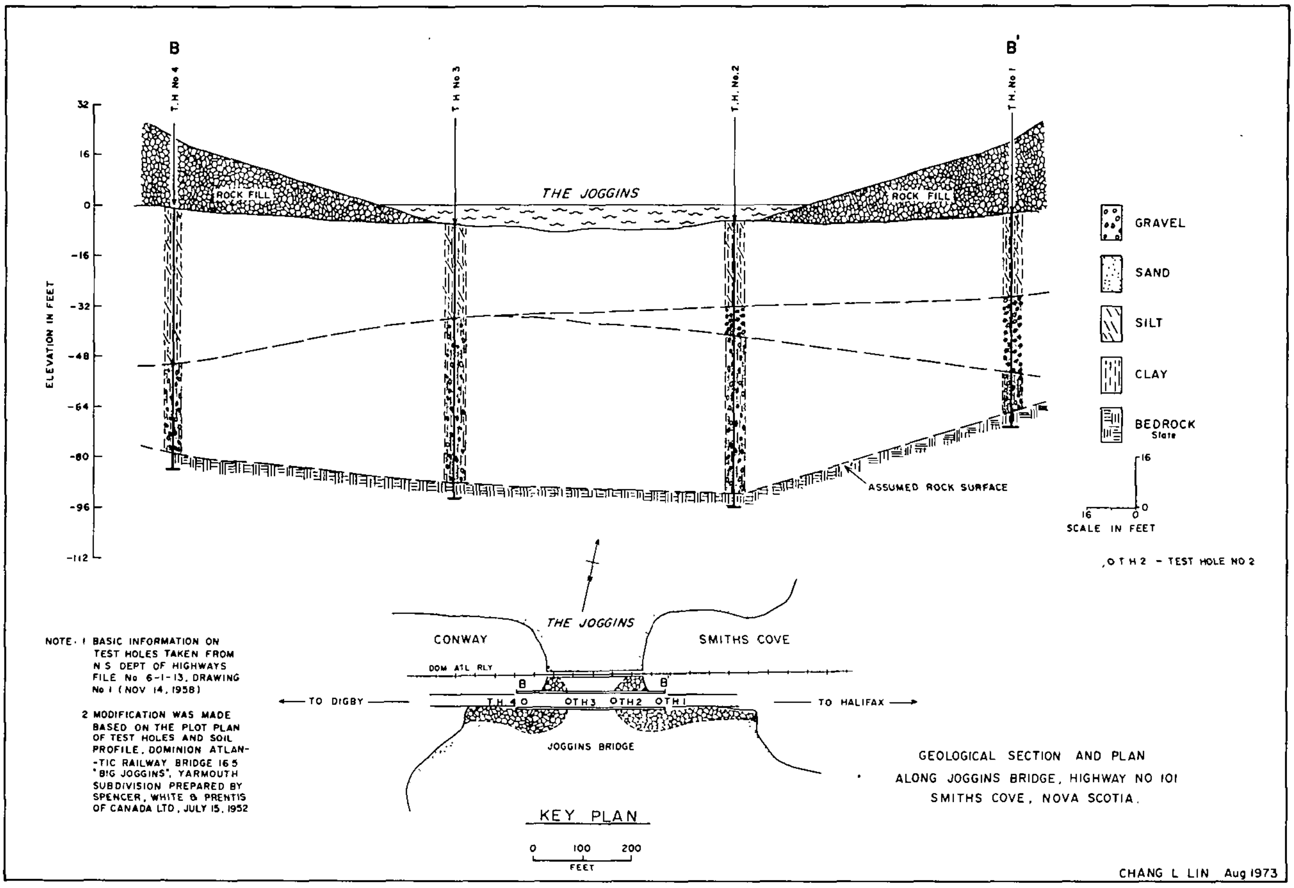


Fig. 8: Geological section and plan along Joggins Bridge, Highway 101, Smiths Cove, N.S.

GROUNDWATER RESOURCES AND DEVELOPMENT

GROUNDWATER RESOURCES POTENTIAL

The village of Smiths Cove has no central water supply system and depends for its water supply entirely on individually owned wells (Appendix B). Figure 9 relates well depth and well yield to the type of aquifers based on available well logs of the Smiths Cove area.

No potential aquifers for large water supplies are present in the eastern part of the Smiths Cove village. Wells drilled into the slates provide smaller yields because of the presence of many mafic intrusives in the slate aquifers (Lin, 1973b). Although the outcrops of most gabbro intrusives and the slates display distinctive fractures, well yields are consistently lower and have a depth greater than those wells drilled into intrusive-free slate aquifers. To evaluate the difference in aquifer properties, two short term pump tests were conducted. At well 53 which is drilled 412 feet deep into massive gabbro sills, the coefficient of transmissibility was found to be one (1) imperial gallon per day per foot. However, about 150 feet away, a coefficient of transmissibility of at least 7.5 imperial gallons per day per foot was obtained from well 77 which is drilled 102 feet deep mainly into a slate aquifer. According to Figure 9, a minimum of 200 feet of well depth would be required to yield one igpm. As a matter of fact, none of the wells in this category yields more than one igpm and the well yield does not seem to increase with depth below 200 feet. A comparison between lines C and D suggests that the presence of the mafic intrusives at the eastern part of Smiths Cove has resulted in a reduction of at least 50% in the well yield and of the permeability of the slate aquifers (Lin, 1973b). This basically confirms with our experiences in Nova Scotia that in fracture media a

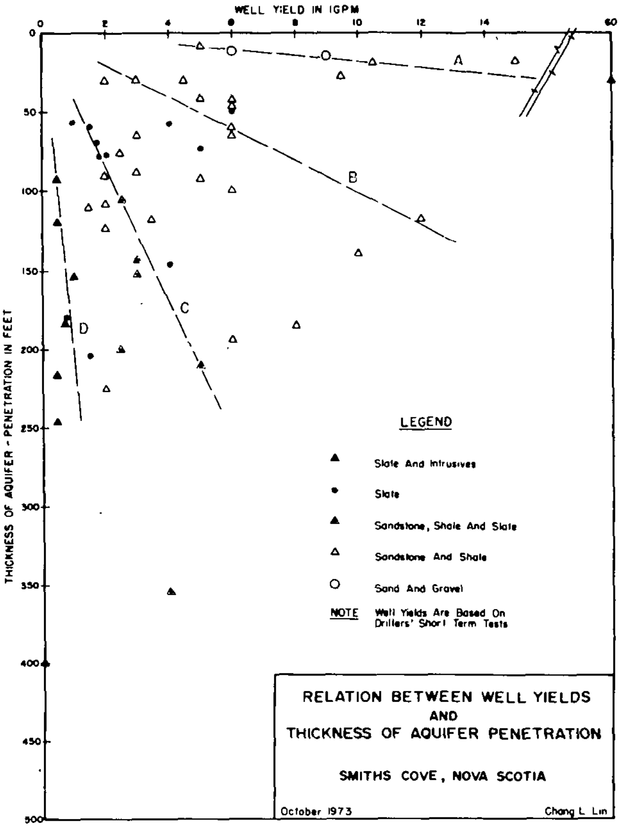


Fig. 9: Relation between well yields and thickness of aquifer penetration, Smiths Cove, Nova Scotia

well is not recommended to be drilled deeper than 250 feet and 300 feet would be a maximum because the fracture openings through which the groundwater moves close rapidly with depth (Trescott, 1969, p. 26). To cope with the situation, many dug wells have been constructed along the sloping area where groundwater seepage is prevalent, and have proved satisfactory to meet domestic requirements. Some of the shallow well systems are gravity fed into the houses.

The north central part of the village is underlain by sandstone and shale of the Wolfville Formation. Except for two small areas, the sandstone and shale are close to the ground surface and a well of 40 to 50 feet deep is generally sufficient to provide a satisfactory water supply for domestic requirements. In sloping areas where the overburden is dense and thick, wells drilled into the sandstone and shale may encounter flowing artesian conditions. Six such wells have been reported in the vicinity of Well 39. Wells drilled into sand and gravel deposits and some highly permeable sandstone aquifers are represented by line A. On an average, a well penetration of two feet will yield one imperial gallon per minute (igpm). The highest recorded well yield is 60 igpm, with only 30 feet of penetration into the sandstone aquifer. For most wells drilled into sandstone and shale, however, a minimum of 10 feet of aquifer penetration is required in order to yield one igpm of water (see line B, Fig. 9). The scattering of the data points reflects the proportion of the sandstone and shale in the makeup of the Triassic aquifers. According to Trescott (1969, p. 22), the aquifer transmissibility of the Wolfville Formation may be up to 2,600 gallons per day per foot (gpd/ft) with a coefficient of of storage in the order of 1.2×10^{-4} and the average long term well yield in the Annapolis-Cornwallis Valley is about 95 gpm per hundred foot of saturated section of the Wolfville Formation. In the Smiths Cove area, well yield is limited due to poor sorting and an insufficient saturated thickness of the sandstone and shale aquifer. Line C represents most wells drilled into the less permeable slates and shales. For a yield of one igpm, an aquifer penetration of 40 to 100 feet is necessary in these rocks. Salt water intrusion can be a problem if the well is located too close to the sea. Adequate water supplies may also be obtained from dug wells constructed into outwash sand and gravel deposits, if there is a sufficient saturated thickness.

In the western part of the village, the unconsolidated deposits vary in thickness from 50 to more than 200 feet, and consist of outwash sand and gravel, glacial tills, and red clay and silt interbedded with clean sands and gravels. To develop a water supply from the underlying bedrock aquifers, longer casing and deeper drilling are required in these areas of thick overburden. The thickness of the surficial deposits therefore becomes an important factor to be considered in well drilling. However, as indicated in the well logs in Appendix B, the presence of permeable sand and gravel lenses below and above the glacial till is common. Higher well yields may be obtained from a properly designed screened well constructed in the sand and gravel beds. Although the outwash sand and gravel deposits above the glacial till are usually thin, their potential water supply for domestic requirements and small commercial ventures is high. The clean sand and gravel beds below the red brown glacial till appear to be quite extensive in the western part of the village. Although the water levels are low, larger well yields may be possible. The so-called "underground lake" or "underground river" encountered during drilling in the vicinity of well 19 is indicative of such a groundwater occurrence. Efforts should be made to develop its groundwater potential.

In summary, the almost untapped groundwater resources in the permeable sand and gravel deposits and the sandstone and shale bedrocks in the western part of the village are probably the most valuable natural resources of the Smiths Cove area.

WATER QUALITY AND USES

Water Quality Criteria

The groundwater chemistry depends upon the types of geological formations through which the water passes and the length of time the water is in contact with these environments (Trescott, 1969, p. 26). The quality of groundwater for various uses, is measured by chemical, physical and bacteriological standards recommended by various health and regulatory authorities.

The complete analyses of 49 water samples including three surface water samples taken from the Smiths Cove area are summarized in Appendix C. For domestic purposes, the Canadian Drinking Water Standards and Objectives, 1968, recommended by Canada Department of National Health and Welfare (1969) are used as the water quality criteria in the development and management of water resources (Table 4). For other uses, the readers are referred to publications by the Federal Water Pollution Control Administration (1968), and that by McKee and Wolf (1971). Local public health authorities should be contacted to determine the bacteriological quality of the water supply.

TABLE 4

CANADIAN DRINKING WATER STANDARDS*

	Chemical Constituent	Objective ppm	Acceptable limit, ppm	Maximum Permissible ppm
Chemical Standards	Arsenic	not detectable	0.01	0.05
	Chloride	<250	250	-
	Copper	<0.01	1.0	-
	Iron	<0.05	0.3	-
	Lead	not detectable	0.05	0.05
	Manganese	<0.01	0.05	
	Nitrate and Nitrite	<45.0	<45.0	-
	Sulfate	<250	500	-
	Total dissolved	<500	<1000	-

	Parameter	Objective	Acceptable limit
Physical Standards	Turbidity	<1	5 (Jackson Turbidity Unit)
	Color	<5	15 (Platinum-Cobalt Scale)
	Odor	0	4 (Threshold Odor Number)
	Taste	inoffensive	inoffensive
	pH	-	6.5 - 8.3

	Grade	MPN/100 ml	Rating
Bacteriological Standards**	A	<2	satisfactory
	B	2 - 10	doubtful
	C	>10	unsatisfactory

*Modified from "Canadian Drinking Water Standards and Objectives 1968" by the Canada Department of National Health and Welfare, 1969.

**Bacteriological standards used by the Nova Scotia Department of Public Health.

Results of laboratory analyses of water samples taken during this study indicate that the groundwater resources of the Smiths Cove area are of excellent chemical and physical quality and, according to Canadian Drinking Water Standards and Objectives, 1968, are suitable for domestic use with little or no treatment. Of all dissolved solids present in groundwater, the constituents discussed below have significant bearing on the domestic uses of the groundwater resources of the Smiths Cove area.

Iron and Manganese

Both iron and manganese when present in excessive amounts often result in a brownish stain in laundered goods and plumbing fixtures, and impairs the taste of beverages. The recommended limit of iron is 0.3 ppm. High iron is usually associated with slate formation. The highest iron reading, 4.0 ppm, is from an abandoned well drilled into slate and gabbro. A few manganese readings from shallow wells are slightly high. These wells are located in active discharge areas and in swampy environments. The manganese content of the groundwater is usually less than the recommended limit of 0.05 ppm. Generally speaking, both iron and manganese contents are well below the limits set forth in the Canadian Drinking Water Standards and Objectives, 1968.

Total Hardness

According to McKee and Wolf (1971, p. 195), the term "hardness" refers to the soap neutralizing power of water. Soap will not cleanse, or lather, until all of the hardness is precipitated as insoluable salts of the fatty acids. In groundwater, hardness is attributable principally to calcium and magnesium ions. According to Swenson and Baldwin (1965, p. 17), the hardness of water may be rated according to the combined compounds of calcium and magnesium:

0 - 60	Soft
61 - 120	Moderately Hard
121 - 180	Hard
>180	Very Hard

The hardest water encountered in the area is 220 ppm from a dug well located in a discharge area underlain by a very dense till. With three exceptions, however, the groundwater hardness readings are less than 120 ppm and usually softening is not required in the Smiths Cove area.

According to McKee and Wolf (1971, p. 196), although the causative factors remained unexplained as of 1961, soft water has been shown to be associated with higher death rates from degenerative cardiovascular disease in Japan, England, South Africa, the Canary Islands, Australia and the United States, Furthermore, contrary to common belief, there is no conclusive proof that hardness causes, stomach disorders, urinary concretions or other diseases of the kidney or bladder.

Sulfate and Chloride

The sulfate content ranges from a trace to 17 ppm, with an average of 12 ppm. Sulfate in excess of the recommended limit of 250 ppm in drinking water may cause a laxative effect. Because both calcium and magnesium sulfates are very soluble, boiling of water will not cause sulfates to precipitate.

No chloride contents exceed the recommended limit of 250 ppm. Except for two samples (Wells 17 and 79), all chloride readings are below 50 ppm. The higher chlorides are from wells located in active discharge areas close to the sea. It is also possible that salt water has found its way into local pumping wells close to the sea.

Nitrate

Nitrate concentration can be a sensitive indicator of groundwater contamination or pollution from sources such as agricultural fertilizers, barn yards and septic tank effluent. The recommended health limit for nitrate is 45 ppm. Reduction of high NO_3 to NO_2 in the intestinal tract may be poisonous to infants (0-3 months) and can be responsible for the methaemoglobinemia in new born babies (Swenson and Baldwin, 1965, p. 16). The nitrate content in groundwater generally decreases with the depth of well penetration so that high nitrate occurs mainly in shallow wells. The highest nitrate observed in the study area is 14 ppm from a dug well, constructed in glacial till. At present, the groundwater resources at the Smiths Cove area are free from nitrate pollution.

Total Dissolved Solids

The total dissolved solids include all chemical constituents in groundwater, with the exception of suspended sediments, colloids or dissolved gases. The water may be classified according to its total dissolved solids as follows: Fresh water (0-1,000 ppm), brackish water (1,000-10,000 ppm), salty water (10,000-100,000 ppm) or brine (>100,000 ppm) (Davis and DeWiest, 1966, p. 118).

The acceptable limit of the total dissolved solids in drinking water is 1,000 ppm according to the Canadian Drinking Water Standards and Objectives, 1968. However, a concentration in excess of 500 ppm may result in undesirable taste and laxative effects. It is recommended by the Canada Department of National Health and Welfare (1969, p. 29) that the total dissolved solids of drinking water should be assessed in terms of individual dissolved constituents which may have health, aesthetic and economic significance. No water sample taken from the Smiths Cove area has a total dissolved solids in excess of the acceptable limit of 1,000 ppm. Only two water samples exceed 500 ppm due to high sodium chloride.

Color and Turbidity

The color of water measured after the suspended matters have been removed is due to substances of organic and inorganic origin in solution. The organic substances include humic materials, peat, plankton, rooted and floating aquatic plants and tannins. Inorganic substances consist of metallic substances such as iron and manganese compounds and chemicals, and dyes (Federal Pollution Control Administration, 1968, p. 48). Except samples from two wells and two brooks, the color readings are less than the recommended limit of 15 units. The highest reading is 55 units from Roop Brook.

Turbidity is caused by the presence of suspended matter such as clay, silt, lime, organic matter, bacteria, plankton, and other microscopic organisms (Federal Pollution Control Administration, 1968, p. 46). There are five water samples showing a turbidity value in excess of the recommended limit of 5 units, and the highest reported concentration is 12.2 units.

Lead, Zinc and Copper

Consumption of groundwater with lead in quantities in excess of certain relatively low "normal" limits may result in serious illness or death due to cumulative poisoning (U.S. Dept. of Public Health Service, 1962, p. 43). Both zinc and copper in small amounts are essential and beneficial elements in human metabolism. However, zinc in water produces undesirable aesthetic effects such as a milky appearance and a metallic taste to water (Canada Dept. of National Health and Welfare, 1969, p. 30; U.S. Dept. of Public Health Service, 1962, p. 55). Copper will impart undesirable taste to water. Large doses of copper have been known to produce emesis and prolonged ingestion may result in liver damage (Canada Dept. of National Health and Welfare, 1969, p. 26; U.S. Dept. of Public Health Service, 1962, p. 39).

No water sample taken from the Smiths Cove area exceeds the recommended limits of 0.05 ppm for lead, 5.0 ppm for zinc and 1.0 ppm for copper in the Canadian Drinking Water Standards and Objectives, 1968. The maximum recorded concentrations for these three elements are 0.04 ppm (lead) 4.8 ppm (zinc) and 0.1 ppm (copper). Available information does not seem to indicate a definite relation between the metal contents and the type of aquifers. As many wells have been in existence for years, piping and plumbing fixtures in the water supply are probably the principal sources of these elements in most well waters.

REGIONAL GROUNDWATER CHEMISTRY

Figure 10 is the trilinear plot (after Piper, 1944) of the results of chemical analyses of all water samples. Plotted in the left hand triangle are percents of the total equivalents per million of the cations whereas the anions are in the right hand triangle. The combined chemistry is projected on the diamond shaped field.

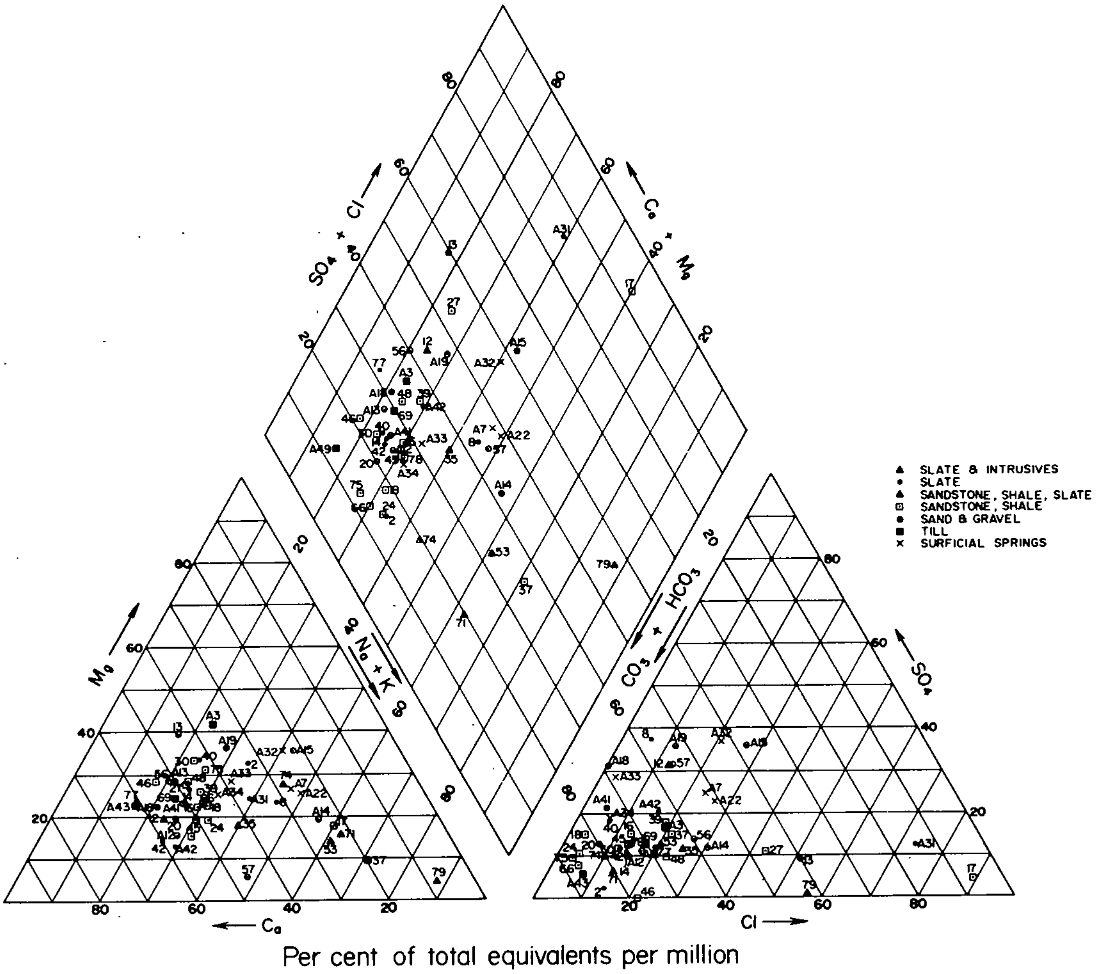


Fig. 10: Trilinear diagram for groundwater chemistry of the Smiths Cove area, Nova Scotia

The water samples taken from shallow wells located in active discharge areas and the drilled wells in the regional flow field are scattered over the right hand side of the diamond shaped field. Wells located close to known recharge areas are concentrated in the left hand corner. In essence, despite the complexity of the geology of the area, the chemistry of groundwater tends to vary from a calcium, magnesium, bicarbonate water in the recharge areas to magnesium, sodium chloride water in the discharge areas as demonstrated by Chebotarev (1955). Most waters are basically calcium, magnesium, sodium bicarbonate waters. Because most wells are concentrated in the north end of the Smiths Cove area, a comprehensive assessment of the groundwater chemistry in relation to the groundwater flow system is not possible at the present time.

GROUNDWATER FLOW SYSTEMS

INTRODUCTION

Groundwater is derived mainly from precipitation and is constantly in motion, with gravity as its driving force. Unlike surface water, groundwater exists almost everywhere below the water table in the zone of saturation. The groundwater flow system describes the movement of groundwater through earth materials from an area of recharge to an area of discharge and is an integral part of the hydrologic cycle.

The water table which defines the upper limit of the groundwater flow field takes a subdued replica of the landform. Both Hubbert (1940) and Toth (1962) have eloquently demonstrated the importance of the topography on the groundwater flow pattern in an isotropic homogeneous medium. Under natural conditions, the stratigraphy and structure of the subsurface strata exert a great influence over the details of the groundwater flow pattern (Freeze and Witherspoon 1967). The groundwater constantly carries, dissolves and precipitates mineral matters in solution or suspended form in equilibrium with changes in the chemical, physical and hydrogeological environments. The quality and quantity of groundwater at any point within the flow system reflect the combined effect of all these factors. Hence, understanding of the local as well as the regional groundwater flow systems is indispensable in the exploration, development and conservation of groundwater resources. Additionally, groundwater is a major engineering problem encountered during the design and construction stage of many projects. For example, ignorance of the presence of enormous pore water pressure beneath construction sites, the seriousness of subsurface erosion, and the occurrence of large quantities of groundwater flow has led to high costs, long delays, structural failures and sometimes even loss of life in engineering works and construction projects. The development of modern computer technology has made possible the study of the three dimensional aspects of groundwater flow through earth materials. Aquifer modelling has become a useful tool in the management of complex water resources systems under various natural or man-made stresses in Nova Scotia (eg., Pinder and Bredehoeft, 1968; Trescott, et al, 1970; Lin, 1972, 1973 a,b).

MODELLING OF GROUNDWATER FLOW SYSTEMS

The groundwater flow systems in a given flow field can be obtained by numerical methods if the dimension of the flow field, the water table configuration, and the permeabilities of the hydrostratigraphic units are known (Freeze 1969, p. 2). Four north-south vertical sections were constructed to study the influence of the complex permeable, impermeable and hydraulic boundaries on the groundwater flow patterns and the potential impact of the new highway on the water resources of the Smiths Cove area (Map 1). The two dimensional, steady state model developed for anisotropic, nonhomogeneous flow field by Freeze (1967), was adapted with slight modification for use by the CDC 6400 Computer at Dalhousie University, Halifax.

The adoption of the flow model carries the implied assumptions as follows:

(1) The three dimensional natural groundwater flow system can be adequately represented by a two dimensional groundwater flow field which is bounded on the bottom by a horizontal impermeable basement, on the top by the ground surface, and on both sides by impermeable vertical boundaries.

(2) The upper boundary of the flow system is the water table, whose configuration coincides with the topographic surface.

(3) All hydrostratigraphic units above the horizontal basement are permeable and a reasonable estimate of permeability contrasts can be made.

The implications of these assumptions and other details have been discussed at length by Freeze and Witherspoon (1966, p. 642-643).

In numerical analysis, the principal components of permeability tensors are assumed to coincide with Cartesian coordinates. In regions of flatlying rocks, such as the Prairie region of Western Canada studied by Freeze (1969), the permeability along the horizontal coordinate direction (Kh) is the greatest permeability, whereas the permeability along the vertical coordinate direction (Kv) is the smallest permeability. At Smiths Cove, Nova Scotia, the slates and the mafic intrusives are characterized by high angle, tight folds. The bedding planes, the intrusive contacts and the major fractures which serve as the main conduits of the groundwater flow, are almost vertical. It is, therefore, necessary to assume that the greatest permeability in the slates and intrusive bodies is along the vertical coordinate direction, whereas the smallest permeability is along the horizontal coordinate direction.

Under natural conditions, a hydrostratigraphic unit is seldom isotropic or homogeneous. Technically as well as economically, it is not feasible to obtain the actual permeability variation in each unit. However, in the absence of such measurements, each hydrostratigraphic unit is assumed to be homogeneous, but anisotropic. However, the anisotropy expressed as the ratio between the smallest permeability and the greatest permeability seldom exceeds 1:50 in the field (Maasland, 1967). In his study of the Old Wives Lake Drainage Basin, Saskatchewan, Freeze (1969) employed the ratios of 1:20 and 1:100 in seven type areas. Near Berwick, Nova Scotia, Trescott (1970) found a ratio of 1:25 provided reasonable results. A ratio of 1:25 was adopted for each hydrostratigraphic unit present in the Smiths Cove area because of its geological similarity with Berwick. In the final analysis, the permeability contrasts between adjacent units ranges from 1 for the least permeable glacial till to 25,000 for the most permeable sand and gravel deposits. All permeability contrasts used in this modelling study are listed below:

Unit	Permeability Contrasts, Kv/Kh
Glacial Till	1/25
Mafic intrusives	125/5
Slates	250/10
Red clay, silt & gravel	50/1250
Sandstone & shale	100/2500
Sand & gravel	1000/25000

Discussed below are four regional groundwater flow patterns typical of the Smiths Cove area (Fig. 11). Many problems of engineering, hydrological and environmental significance which are related to the manifestation of the groundwater flow systems are identified and elaborated for each model section (Maps 1&2). The groundwater flow is considered important only to a depth of 1000 feet below the mean sea level, because the fracture permeability decreases rapidly with depth. A relaxation factor of 1.85 was used in all model sections. To avoid distortion, all groundwater flow patterns are constructed on a 1:1 basis in both vertical and horizontal scales. To further simplify the situation, no salt water intrusion was considered in this study.

GROUNDWATER FLOW PATTERNS OF THE SMITHS COVE AREA, NOVA SCOTIA

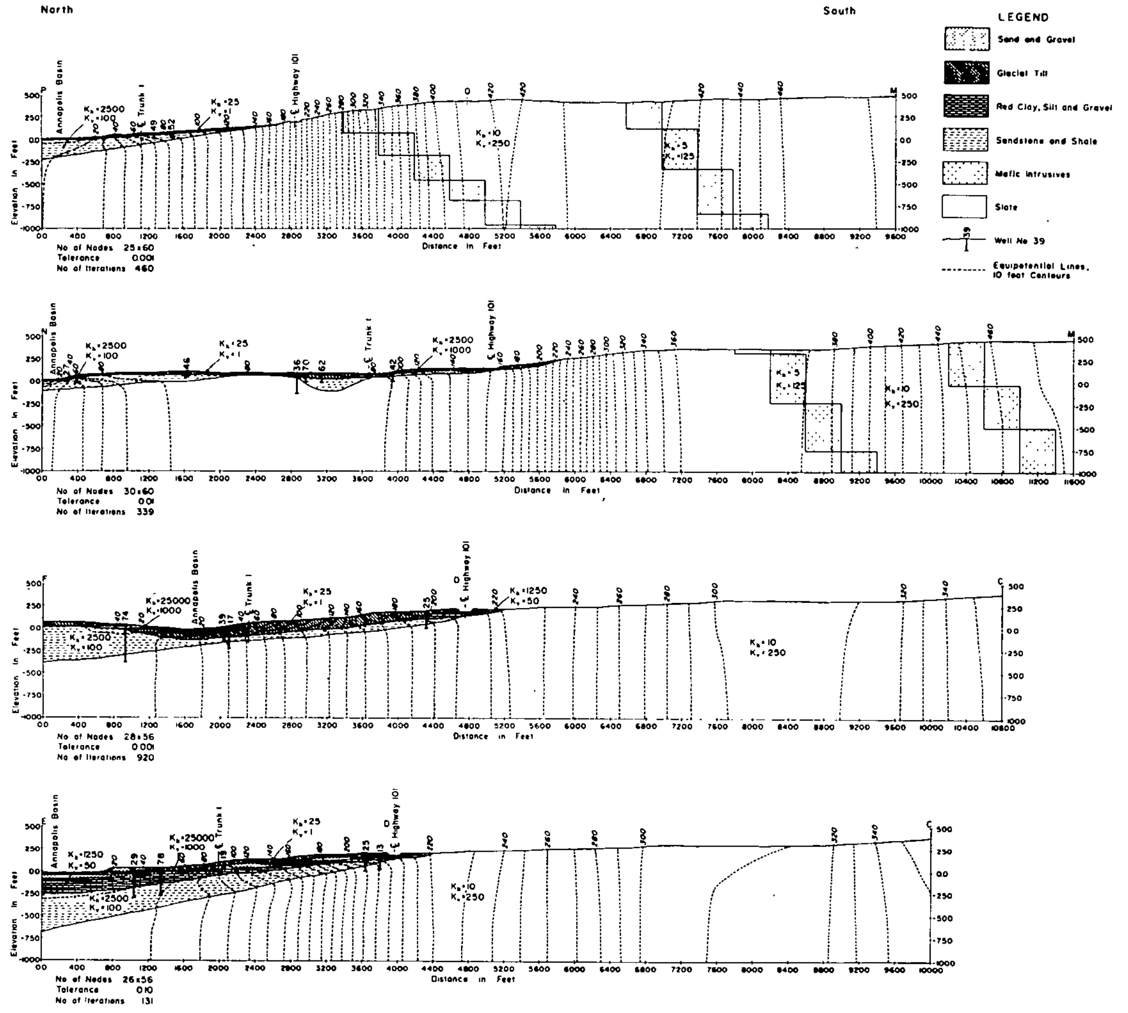


Fig. 11: Regional groundwater flow patterns of the Smiths Cove area, Nova Scotia

Groundwater Flow Patterns and Their Implications

Model Section MOP

Model section MOP, 9600 feet long by 1473 feet deep, consists of 25 x 60 nodes. A total of 460 iterations was required to obtain the groundwater flow pattern with a tolerance of 0.0001. Hydrogeologically, Section MOP is characterized by the presence of two massive mafic intrusives, of sandstone and shale wedge, and of a thin till cover. The model results indicate that at the margins of the slate terrain the equipotential contour lines are nearly vertical and a concentration of the equipotential lines, hence the flow lines, occurs under the steep slope area. This accounts for the occurrence of heavy seepage along this slope. Over the upland, a local topographic depression of only 20 feet results in the total discharge of groundwater flow in a low area between the equipotential lines of 410 feet. Presence of sandstone and shale wedge will result in the convergence of local groundwater flow. Relatively larger well yields can therefore be expected from such permeable aquifers. Unfortunately, permeable sandstone and shale aquifers are absent in the Smiths Cove area east of Model Section MOP. The groundwater flow pattern suggests that (1) there seems to be no active regional groundwater flow through the entire flow field in Model Section MOP and that (2) the sloping area would be the more favourable one for groundwater development. As the groundwater resources potential of the slates in the eastern Smiths Cove area has been significantly reduced by the presence of many mafic intrusives, many dug well systems located along the sloping area have proved to be a practical solution. Some of such water supplies are piped by gravity to the houses.

The specifications for the new highway construction in the eastern Smiths Cove area called for two deep cuts, one to 50 feet into the slates and their mafic intrusives (Fig. 5). The placement of the highway cut along the steep slope blocked off the near surface groundwater flow which resulted in the reversal of the local groundwater gradients. During the excavation phase of the highway construction considerable rock blasting was involved. As discussed by Leet (1960, p. 38-39, and 66) blasting would lead to the opening of the previously existing tight bedrock fractures. Hydrologically, therefore, a higher permeability zone could be formed along the highway cut. Such a hydrological change would account for the lowering of the local water table adjacent to the highway and the resultant loss and failure of at least five shallow well water supplies in 1971. To replace the shallow wells, deep drilled wells were constructed into the slate aquifer. However, because of the presence of many mafic intrusives in the slates, the yields of these drilled wells were very small, generally less than one (1) igpm. A 412 foot well (Well 53) drilled into massive intrusives was abandoned due to an extremely low yield.

From an environmental point of view, the expsoures of the fracture bedrock along the highway cut may pose an additional pollution hazard to the local groundwater flow systems because the deicing road salt could get into the groundwater through fracture openings (Lin, 1974). Fortunately, only a few people live in the east end where the deep cut is located.

Model Section MN

Model Section MN, 11600 feet long by 1473 feet deep, consists of 30 x 60 nodes. A total of 339 iterations were needed to obtain the model solution with a tolerance limit of 0.01. The hydrogeology of the upland area is similar to that of Model Section MOP, except that the groundwater flow above the local depression is not totally discharged in the upland because the depression is shallower. Again, field evidence supports the belief that the area of steep slope would have active groundwater seepage.

In the lowland area, a sandstone and shale bedrock channel developed in the slates becomes the confluence of local groundwater discharge. According to the model results, groundwater stagnation seems to occur at depth between highway trunk 1 and well 46. The groundwater flow system in the lowland is independent of the main flow system from the upland area, and little recharge from the upland is contributing to the groundwater flow in the lowland area. Although the new highway cut was located in a general recharge area, the disruption of local groundwater flow would be small because the cut was small and located in glacial till.

Model Section CDF

Model Section CDF, 10800 feet long by 1375 feet high, consists of 28 x 56 nodes. The groundwater flow pattern with a tolerance limit of 0.001 was obtained after 920 iterations. The hydrogeology of the section is characterized by (1) the exposure of sand and gravel interbedded with red clay and silt along the new highway cut, (2) the presence of a thick dense till cover, (3) the occurrence of six flowing artesian wells in the vicinity of well 39 and (4) the presence of permeable sand and gravel beds below the till.

The groundwater flow pattern over the upland region is similar to Section MN except that (1) there is no concentration of vertical equipotential lines, (2) heavy groundwater seepage is absent, and (3) there is no steep land slope. The digital model has correctly predicted the occurrence of the flowing artesian condition in the vicinity of well 39. Hydrogeologically, it is combination of a thick till cover and a gently sloping terrain.

The new highway cut exposes an outcrop of red clay and silt interbedded with clean sand and gravel deposits, overlain by glacial till. Because the permeability of the sand and gravel is at least 100 to 1000 times greater than that of clay, silt and clay till, the local groundwater flow is expected to converge at the permeable sand and gravel layers. Geotechnically, the placement of a highway cut would result in the washout of the fines and the loosening of the granular packing of the sand and gravel deposits and, ultimately, lead to slump and failure of the highway slopes. Today many local slope failures due to the beheading of the sand and gravel beds still occur, especially after heavy rain. Hydrologically, the water table adjacent to the highway cut was re-established at a lower level and locally the groundwater gradient was reversed. Furthermore, the contaminated surface runoff from the highway could find its way into the groundwater flow system through the permeable sand and gravel out-crops and the nearby fractured bedrocks. As the use of road salt for winter deicing will likely be continued for some time on Nova Scotia highways, salt contamination will be a potential hazard for wells located adjacent to and downslope from the highway cut. The basic groundwater chemistry collected in this study, therefore, serves as an important reference if any future deterioration of groundwater quality of the area occurs. Incidentally, well 13 is a replacement for a dug well water supply disrupted by the highway excavation.

Model Section CDE

Model Section CDE, 10,000 feet long and 1375 feet deep, consists of 26 x 56 nodes. The groundwater flow pattern was obtained with 131 iterations and a tolerance limit of 0.10. The portion of the model section above the new highway is identical to that in model section CDF. The resultant groundwater flow patterns over the upland are in general agreement in both sections. Hydrogeologically, model section CDE is characterized by the presence of a thick sequence of three unconsolidated units and one sandstone and shale unit overlying the slates. Unlike model section CDF, there is no concentration of the horizontal equipotential lines to generate flowing artesian conditions. The equipotentials in the unconsolidated deposits, as well as in the sandstone and shale unit, generally decreases with depth, explaining the low static water level encountered in many drilled wells of the region.

The presence of highly permeable sand and gravel beds below the glacial till may account for the so called "underground river" encountered during drilling in the vicinity of wells 19 and 20. The outwash sand and gravel deposits underlain by glacial till, are very thin and restricted in areal extension, and are located mainly in a recharge area. The near surface groundwater flow is deflected by the underlying less permeable glacial till and occurs as groundwater seepage along the shore line of the Annapolis Basin. The surface water sample station A7 is from one such occurrence.

The foregoing discussions of the groundwater flow patterns typical of the Smiths Cove area and the potential impact of the new highway 101 may be summarized as follows:

(1) The Smiths Cove area receives little groundwater recharge from the South Mountain Upland. Active regional groundwater flow is not likely to exist in the Smiths Cove area.

(2) The presence of a small topographic depression in the upland region may result in total disruption or discharge of the groundwater flow. Such a finding is particularly important because the South Mountain Upland is marked by a series of elongated ridges and grooves left behind by Pleistocene glaciation. Hydrogeologically, such a small topographic relief coupled with the steeply folded slate bedrock strongly favors the establishment of local groundwater flow systems characterized by a series of local recharge and discharge zones.

(3) Active groundwater seepage occurs along the northern steep slope of the South Mountain Upland, which is favourable for groundwater development in the slate terrain. The placement of the present highway 101 along the steep slope has altered the near surface groundwater flow, resulting in the failure of many shallow well water supplies in 1971. Furthermore, exposures of permeable sand and gravel beds and of the fractured bedrock along the highway pose a potential pollution hazard to the local groundwater resources of the Smiths Cove area. Wells located below and adjacent to the highway cut may be contaminated by the de-icing road salts within a few years. Such an environmental

concern may be lessened somewhat by the steep drainage ditches which are found along both sides of the new highway.

(4) The groundwater resources of the Smiths Cove area receive their major recharge from the margins of the upland adjacent to the steep slope. Before any major development such as a new highway is undertaken along the margins of the Upland, the potential environment impact should be thoroughly assessed. Any contamination originating from such a development poses a serious pollution threat to the groundwater resources along the steep slope and in the lowland areas.

(5) Hydrogeologically, there are two areas suitable for a new highway route: (a) the lowland along the shoreline, preferably in an area where a till cover is present, (b) the upland region at least one mile inland away from the edge of the northern steep slope. Because the lowland area is heavily populated and developed, various problems of social, cultural and financial concerns would be involved if the highway were routed through the lowland. Economically, as well as environmentally, the South Mountain Upland seems to be a feasible area for a highway route. Results of the model study tend to suggest that any potential contamination in the upland region would be confined within narrow zones adjacent to the highway and it is very unlikely that the entire groundwater resources of the Smiths Cove area would be seriously contaminated. The implication of this finding should be carefully considered in future selection of highway routes in areas with a similar hydrogeological environment.

If the slate and its mafic intrusives were not characterized by high angle fractures and tight folds, the major groundwater recharge would take place in the upland region and a larger quantity of groundwater flow would, therefore, be transmitted through the Smiths Cove area (Fig. 12).

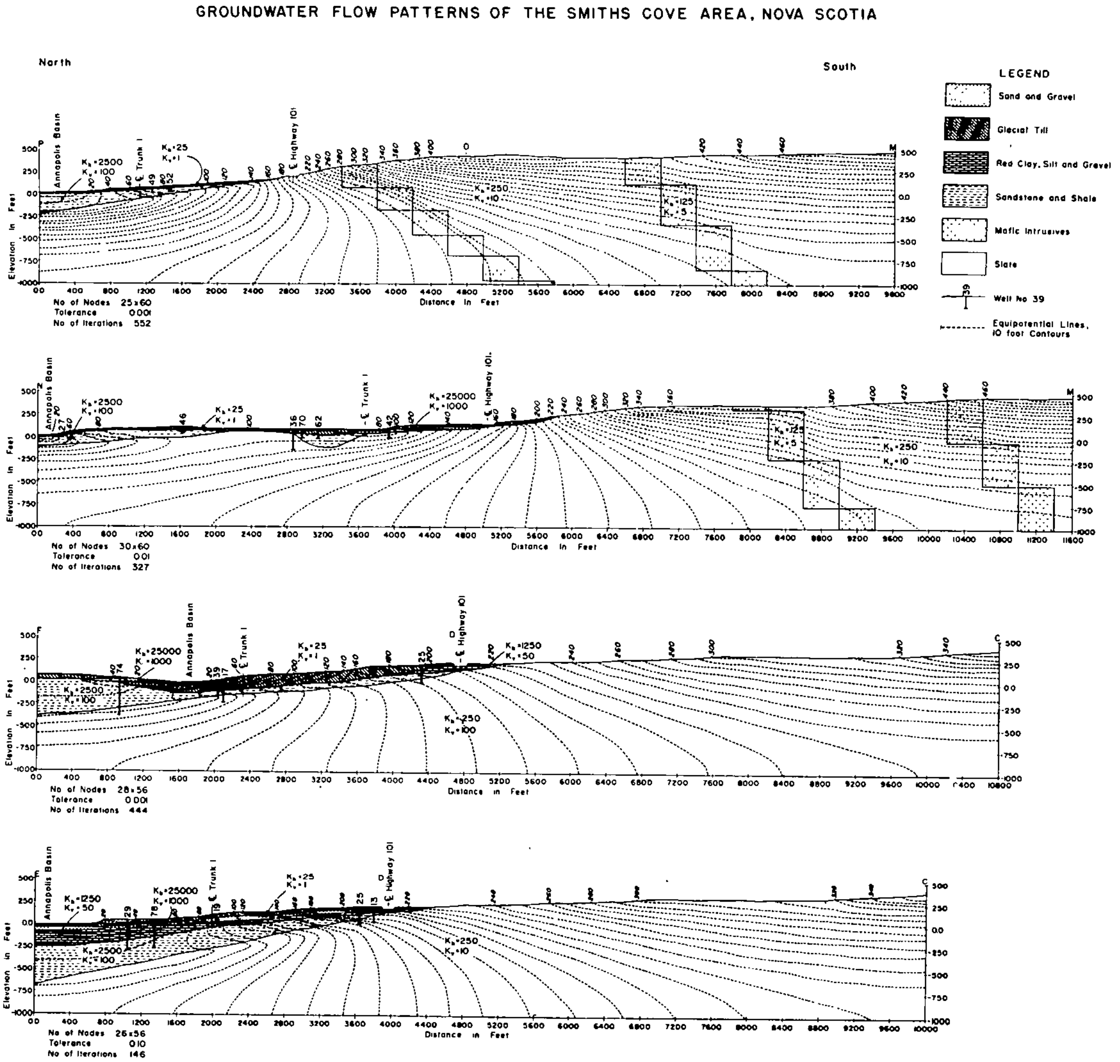


Fig. 12: The would-be-regional groundwater flow patterns of the Smiths Cove area, Nova Scotia

SUMMARY AND RECOMMENDATIONS

The geology of the Smiths Cove area is simple in general, but complicated when studied in detail. More than 80% of the area is directly underlain by high angle, folded slates of lower Ordovician age, which is in turn overlain in the north by sandstones and shales of Triassic age. The entire area is blanketed with surficial deposits of sand, gravel and glacial till of Pleistocene age, which vary from less than one foot to over 200 feet thick.

The village of Smiths Cove has no central water supply system and depends for its water supply entirely on individually owned wells. The groundwater potential of the area varies according to local hydrogeological conditions. Wells drilled into the slates may yield from 6 igpm with 50 feet of aquifer penetration to ½ igpm with 180 feet of aquifer penetration. However, if the slates are interbedded with mafic intrusives, the well yield is significantly reduced to less than ½ igpm with a saturated thickness varying from 100 feet to 400 feet. In the sandstone and shale aquifers, well yields decrease considerably with increasing shale content. The maximum reported well yield of 60 igpm is found in a well constructed in the sandstone aquifer with only 30 feet of aquifer penetration. Generally, the well yields from the sandstone and shale aquifers range from 15 igpm with 20 feet of aquifer penetration to 1¼ igpm with 100 feet of aquifer penetration. Most wells constructed in sandstones and shales are less than 150 feet deep. For wells tapping sand and gravel aquifers, well yields are more than sufficient to meet household requirements. Well yields of 6 igpm and 9 igpm are reported for well 81 and well 13, respectively. Pump test or bail test data on most shallow dug wells are not available for reference.

With few exceptions, results of laboratory analyses of water samples taken during this study indicate that the groundwater resources of the Smiths Cove area are of excellent chemical and physical qualities, and suitable for domestic purposes with little or no treatment. Specifically, the iron and manganese contents in the well waters are well below their respective limits of 0.3 ppm and 0.05 ppm in the Canadian Drinking Water Standards and Objectives, 1968. All hardness readings are less than 120 ppm and the sulfate ranges from a trace to 17 ppm. No chloride contents exceed the recommended limit of 250 ppm. Except for two samples, all chloride measurements are below 50 ppm. No water sample has a total dissolved solid in excess of the acceptable limit of 1000 ppm. Only two water samples due to sodium chloride exceed 500 ppm. Except four samples, from two wells and two brooks, the color readings are less than the recommended limit of 15 units. The highest reading is 55 ppm from the Roop Brook. There are five water samples showing a turbidity in excess of the suggested limit of 5 units; 12.2 units is the highest recorded concentration. Nitrate can be a sensitive indicator of groundwater contamination or pollution from sources such as agricultural fertilizers, barnyard and septic tank effluents. The highest nitrate is 14 ppm from a dug well constructed in glacial till, and is well below the recommended limit of 45 ppm. It is, therefore, fair to state that at present the groundwater resources in the Smiths Cove area are usually free from manmade pollution.

The groundwater in the Smiths Cove area is basically a calcium, magnesium, sodium bicarbonate water. Because most wells are located in the north end of the Smiths Cove area, a comprehensive assessment of the groundwater chemistry in relation to groundwater flow system is not possible at the present time. However, despite the complexity of the geology of the area, the chemistry of groundwater tends to vary from a calcium, magnesium, bicarbonate water in the recharge region to calcium, magnesium, sodium chloride water in the discharge area.

Four N-S vertical sections were constructed to study the influence of the complex permeable, impermeable, and hydraulic boundaries on the groundwater flow patterns and to assess the potential environmental impact of the new highway on the water resources of the Smith's Cove area. The two dimensional steady state digital model developed by Freeze (1967) was adopted with slight modification in the CDC 6400 computer at Dalhousie University, Halifax. Model study of the groundwater flow patterns of the Smiths Cove area resulted in the following conclusions:

(1) In areas underlain by slates, the equipotential lines are nearly vertical. A concentration of the equipotential lines, hence the flow lines occurs under steep sloping areas. This accounts for the occurrence of heavy seepage along the new highway route. Interpreted hydrologically, the sloping area

would be favourable for groundwater development in the slate terrain.

(2) Over the upland, the presence of a local topographic depression, such as a highway cut, may result in a total disruption, or discharge, of the groundwater flow. Under the hydrogeological framework of the Smiths Cove area, existence of an active regional groundwater flow system does not seem likely. In other words, the groundwater flow regime at the Smiths Cove area receives little recharge from the upland region.

(3) The placement of the highway cut perpendicular to the regional landslope has diverted the near surface groundwater flow and has resulted in the reversal of the local groundwater gradients. Furthermore, the use of dynamite during excavation has led to the opening of the previously existing tight fractures. Consequently, the permeability of the bedrock is higher and the water table is lower along the highway cut. Such hydrological changes cannot be accurately quantified without a detailed monitoring program. Nevertheless, exposures of the permeable sand and gravel beds and the fractured bedrocks, pose a potential pollution hazard to the local groundwater flow from the de-icing road salt and surface runoff from the highway. Well water supply systems located adjacent to and downslope from the highway may be subject to road salt contamination within a few years. The basic groundwater chemistry collected during this study would therefore serve as an important data base for any future deterioration of groundwater quality of the area.

The groundwater resources are the valuable subsurface resources of the Smiths Cove area and are at present free from contamination and pollution. The almost untapped groundwater resources in the permeable sand and gravel deposits, sandstone and shale bedrock in the western region of the village are potential aquifers for large groundwater supplies for future needs of the Smiths Cove area. Any unplanned development of the region should be avoided.

The effects of a new highway on the groundwater resources of a given region are complicated environmental problems and require a multi-disciplinary approach and team effort. At present, results from both long and short term research are urgently needed to make the public, the highway engineers, the planners, and the politicians aware of the importance of hydrogeological factors in highway planning. With more public awareness of these problems and more expert participation in the decision making process, groundwater problems due to highway construction and related activities can be minimized.

REFERENCES

PUBLISHED REFERENCES

Canada Dept. of Environment, 1971, Temperature and Precipitation 1941-1970, Atlantic Provinces: Atmosphere Environment Service, 55pp.

Canada Dept. of National Health and Welfare, 1969, Canadian Drinking Water Standards and Objectives 1968; A publication of the Dept. of Natl. Health and Welfare, Canada, 39 pp.

Chapman, L.T. and D.M. Brown, 1966, The Climates of Canada for Agriculture: The Canada Land Inventory Report 3, Dept. of Forestry and Rural Development, Canada, ARDA Rept. 3, 23pp.

Chebotarev, I.I., 1955, Metamorphism of natural waters in the crust of weathering: Geochem. Cosmochim. Acta, v.8, 22-48, 137-170 and 198-212.

Davis, S.N., and DeWiest, R.J.M., 1966, Hydrogeology: John Wiley & Sons Inc., 463 pp.

Federal Water Pollution Control Administration, 1968, Water Quality Criteria: Report 7, the National Technical Advisory Committee to the Secretary, U.S. Dept. of the Interior, Washington, D.C., 234 pp.

Freeze, R.A. and P.A. Witherspoon, 1966, Theoretical analysis of regional groundwater flow: 1. Analytical and numerical solutions to the mathematical model: Water Resources Research, v.2, no. 4, pp. 641-656.

Freeze, R.A. and P.A. Witherspoon, 1967, Theoretical analysis of regional groundwater flow: 2. Effect of water-table configuration and subsurface permeability variation: Water Resources Research, v.3, no. 2, pp. 623-634.

Freeze, R.A., 1967, Program Flopat - 2D: Computer programs in use by the Hydrological Sciences Division, Inland Waters Branch, Dept. of Energy, Mines and Resources, Canada.

Freeze, R.A., 1969, Regional groundwater flow - Old Wives Lake Drainage Basin, Saskatchewan: Scientific Series No. 5, Inland Waters Branch, Dept. of Energy, Mines and Resources, Canada, 245 pp.

Hilchey, J.D., D.B. Cann, and J.I. MacDougall, 1962, Soil survey of Digby County, Nova Scotia: Canada Dept. of Agriculture and N.S. Dept. of Agriculture, Report 11, 58 pp.

Hough, B.K., 1957, Basic Soil Engineering: 2nd ed., Ronald Press Co., 513 pp.

Hubbert, M.K., 1940, Theory of groundwater motion: Jour. of Geol., v. 48, pp. 758-944.

Leet, L.D., 1960, Vibrations from Balsting Rock: Harvard University Press, Cambridge, Massachusetts, 134 pp.

Lin, C.L., 1970, Hydrogeology of the Musquodoboit River valley, Nova Scotia: N.S. Dept. of Mines, Groundwater Section, Rept. 70-3, 60 pp.

Lin, C.L., 1972, Digital simulation of the Boussinesq equation for a water-table aquifer, Water Resources Research, v.8, No. 3, pp. 691-698.

Lin, C.L., 1973a, Digital simulation of an outwash aquifer, Ground Water, v. 11, No. 2, pp. 38-43, March - April.

Lin, C.L., 1973b, Influence of mafic intrusives on groundwater flow at Smiths Cove, Nova Scotia, Canada (Abstract): Presented at the 1973 Fall Annual Meeting of the Am. Geophys. Union held in San Francisco, U.S.A., December 10-14.

Lin, C.L., 1974, Groundwater problems related to highway activities in Nova Scotia (Abstract): Presented at the GAC/MAC Annual meeting, St. John's, Newfoundland, May 19-23.

Maasland, M., 1957: Soil Anistropy and land drainage: in J.N. Luthin, (ed) Drainage of agricultural lands: Am., Soc. Agron, pp. 216-286.

McKee, J.E. and W.H. Wolf (eds)., 1971, Water Quality Criteria: 2nd ed., State Water Resources Control Board, Sacramento, California, Publication 3A, 548 p.

Pinder, G.F. and J.D. Bredehoeft, 1968, Application of the digital computer for aquifer evaluation: Water Resources Research, v.4, No. 5, 1069-1093.

Piper, A.M., 1944, A graphic procedure in the geochemical interpretation of water analyses: Am. Geophys. Union Trans., v. 25, p. 914-923.

Smitheringale, W.G., 1971, Digby, Nova Scotia 21A/12 East Half: 2nd Ed., Open file May 74, October, 1971. Geol. Surv. of Can.

Smitheringale, W.G., 1973, Geology of parts of Digby, Bridgetown and Gaspereau Lake Map-Areas: Geol. Surv. Can., Memoir 375, 78 pp.

Swenson, H.A., and H.L. Baldwin, 1965, A primer on water quality: U.S. Geol. Surv., 27 pp.

Taylor, F.C., 1969, Geology of the Annapolis-St. Marys Bay Map Area, Nova Scotia: Geol. Surv. of Can., Memoir 358, 65 pp.

Terzaghi, K., and R.B. Peck, 1967, Soil Mechanics in Engineering Practice: 2nd ed., John Wiley & Sons Inc., 729 pp.

Toth, J., 1962, A theory of groundwater motion in small drainage basins in central Alberta, Canada: Jour. Geophys. Research., v. 67, pp. 4375-4387.

Trescott, P.C., 1969, Groundwater resources and hydrogeology of the Western Annapolis Valley, Nova Scotia; N.S. Dept. of Mines Groundwater Section Rept. 69-1, 47 pp.

Trescott, P.C., 1970, Piezometer nests and groundwater flow system near Berwick, Nova Scotia: N.S. Dept. of Mines Groundwater Section Rept. 70-1, 29 pp.

Trescott, P.C., G.F. Pinder, and J.F. Jones, 1970, Digital model of alluvial aquifer: Am. Soc. Civ. Eng. Proc., 95 pages 7264, 1115-1128.

U.S. Dept. of Public Health Service, 1962, Drinking Water Standards: Publication no. 956, 61 pp.

UNPUBLISHED REFERENCES

N.S. Communications and Information Center, 1973, New Bear River Bridge fact sheet (June 18, 1973).

N.S. Dept. of Highways, 1958, Test Holes, Joggins Bridge: N.S. Dept. of Highways File No. 6-1-13, Drawing No. 1 (Nov. 14, 1958)

N.S. Dept. of Highways, Materials Laboratory, 1970, Subsurface Investigations, Bear River Crossing (May 6, 1970).

N.S. Dept. of Highways, 1970, Drill holes and plan, Bear River Bridge: N.S. Dept. of Highways File No. B-70-6, Drawing No. 2292-313 (July, 1970).

N.S. Dept. of Highways, Materials Laboratory, 1971, Compaction Data-Contract 71-35, Highway #101, Smiths Cove (August 24 and September 29, 1971).

Racey, MacCallum and Associates Ltd., 1957, Foundation Investigation, Joggins Bridge, Digby County, Nova Scotia (April 17, 1957).

Spencer, White and Prentis of Canada Limited, 1952, Plot Plan of test holes and soil profile, Dominion Atlantic Railway Bridge 16.5 ''Big Joggins'', Yarmouth Subdivision (July 15, 1952).

Spencer, White and Prentis of Canada Limited, 1952, Report of a foundation investigation for proposed railway bridge to replace existing bridge 16.5, Dominion Atlantic Railway, Yarmouth Subdivision, New Digby, Nova Scotia to Canadian Pacific Railway Co., Union Terminal, Toronto.

APPENDIX A

MECHANICAL ANALYSES OF SURFICIAL DEPOSITS IN THE SMITHS COVE AREA, NOVA SCOTIA, CONT'D.

SAMPLE NUMBER	GRID LOCATION	GRAIN SIZE DISTRIBUTION, %			GRAIN SIZE CHARACTERISTICS		REMARKS
		SILT & CLAY	SAND	GRAVEL	EFFECTIVE SIZE (D_{10}) mm	UNIFORMITY COEFFICIENT, D_{60}/D_{10}	
S 57	107LH2	3.0	22.9	74.1	0.224	45.5	Sand and gravel
S 58	107KF1	50.0	45.0	5.0	0.0254	3.2	Red brown clayey till
S 59	107JD2	5.0	28.8	66.2	0.254	26.0	Sand and gravel
S 62	63KK1	9.0	42.3	48.7	0.0865	38.2	Sand and gravel
S 63	63LF4	4.0	32.9	63.1	0.229	51.1	Sand and gravel
S 64	63OK1	38.0	36.0	26.0	0.00303	150	Brown sandy till
S 65	82FF4	25.0	20.0	55.0	0.0135	698	Brown sandy till
S 66	82LL4	10.0	10.9	79.1	0.0661	316	Orange brown sandy till
S 67	87CG2	35.0	32.4	32.6	0.00458	239	Brown sandy till
S 68	86PA1	32.0	44.0	24.0	0.0267	13.3	Red brown clayey till
S 70	86BL2	1.0	27.0	72.0	0.406	62.5	Sand and gravel
S 71	83PL4	34.0	29.4	36.6	0.0303	36.7	Brown sandy till
S 72	83KK3	22.0	27.0	51.0	0.0406	156	Orange brown sandy till
S 73	83GA4	36.0	34.0	30.0	0.00940	59.5	Brown sandy till
S 74	83LK4	25.0	15.0	60.0	0.0119	810	Orange brown sandy till
S 75	86DA1	18.0	10.6	71.4	0.0254	720	Orange brown sandy till
S 76	86DO4	35.0	41.0	24.0	0.0267	11.9	Red brown clayey till
S 77	88LG1	34.0	42.1	23.9	0.0132	23.7	Red brown clayey till
S 78	88FN3	18.0	42.0	40.0	0.0381	42.0	Brown sandy till
S 79	88DN4	25.0	41.0	34.0	0.0203	52.5	Brown sandy till
S 80	84OK1	2.0	74.4	23.6	0.127	4.8	Sand and gravel
S 81	84OK1	86.0	13.7	0.3	0.0254	1.7	Red brown clayey till
S 82	84KP3	28.0	36.0	36.0	0.0183	58.4	Brown sandy till
S 83	84KK1	42.0	36.4	21.6	0.0127	20.0	Red brown clayey till
S 84	84KK1	23.0	38.0	39.0	0.0432	44.0	Sand and gravel
S 85	84HL4	38.0	32.0	30.0	0.0127	24.8	Red brown clayey till
S 86	88MM1	13.0	43.0	44.0	0.0254	125	Orange brown sandy till
S 87	88EM3	34.0	24.0	42.0	0.0102	262	Orange brown sandy till
S 88	87HN4	12.0	7.0	81.0	0.0254	>560	Orange brown sandy till
S 89	82HD2	39.0	42.0	19.0	0.0229	8.6	Red brown clayey till
S 90	63QM1	48.0	75.8	27.8	0.0084	19.7	Red brown clayey till
S 91	63LF2	40.0	32.6	27.4	0.0142	21.4	Red brown clayey till
S 92	83AA4	4.0	27.2	68.8	0.28	25.5	Sand and gravel
S 93	83HG4	20.0	17.5	62.5	0.0211	482	Orange brown sandy till
S 94	83JQ1	25.0	16.1	58.9	0.0112	795	Orange brown sandy till
S 95	87DM2	30.0	12.6	57.4	0.00965	1370	Brown sandy till
S 96	62PE1	54.0	24.6	21.4	0.0254	>100	Brown sandy till
S 97	62OK1	34.0	35.1	30.9	0.0254	15.0	Red brown clayey till
S 98	63KL1	50.0	33.6	16.4	0.0224	5.0	Brown sandy till
S 99	106BJ2	18.4	36.6	45.0			Brown sandy till (Nova Scotia Department of Highways' Materials Laboratory, 1971)
S 100	106BJ2	9.0	36.0	55.0			Brown sandy till (Nova Scotia Department of Highways' Materials Laboratory, 1971)
S 101	106HB2	21.8	38.2	40.0			Red brown clayey till (Nova Scotia Department of Highways' Materials Laboratory, 1971)
S 102	106AO3	4.3	25.7	70.0			Brown sandy till (Nova Scotia Department of Highways' Materials Laboratory, 1971)
S 103	86JJ4	16.1	13.9	70.0			Brown sandy till (Nova Scotia Department of Highways' Materials Laboratory, 1971)
S 104	85HF4	28.8	46.2	25.0			Red brown gravelly clayey till (Nova Scotia Department of Highways' Materials Laboratory, 1971)

APPENDIX A MECHANICAL ANALYSES OF SURFICIAL DEPOSITS IN THE SMITHS COVE AREA, NOVA SCOTIA.

SAMPLE NUMBER	GRID LOCATION	GRAIN SIZE DISTRIBUTION, %			GRAIN SIZE CHARACTERISTICS		REMARKS
		SILT & CLAY	SAND	GRAVEL	EFFECTIVE SIZE (D_{10}) mm	UNIFORMITY COEFFICIENT, D_{60}/D_{10}	
S 1	21 A 12 A - 86QN1	2.0	47.2	50.8	0,182	17.4	Sand and gravel
S 2	106HA1	58.0	20.0	22.0	< 0,0254	> 1000	Red brown clayey till
S 3	106HA1	16.0	45.2	38.8	0,0381	52.6	Red brown gravelly clayey till
S 4	106AN1	22.0	52.0	26.0	0,127	5.6	Brown sandy till
S 5	87OG4	29.0	33.0	38.0	0,00942	187	Brown sandy till
S 6	87MP3	16.0	30.0	54.0	0,028	209	Brown sandy till
S 7	87MP3	7.0	32.5	60.5	0,1065	62.5	Sand and gravel
S 8	87MO2	44.0	39.0	17.0	0,0124	12.0	Red brown clayey till
S 9	86JL2	40.0	40.8	19.2	0,033	5.2	Red brown clayey till
S 10	86FQ4	20.0	11.6	68.4	0,0254	690	Brown sandy till
S 11	86FK3	22.0	34.0	44.0	0,0135	226	Brown sandy till
S 12	86FL4	8.0	39.0	53.0	0,1015	40.0	Sand and gravel
S 13	86FL4	2.0	92.6	5.4	0,2520	1.8	Sand and gravel
S 14	86FM4	46.0	51.0	3.0	0,0247	3.8	Red brown gravelly clayey till
S 15	86EJ1	0.0	40.3	59.7	0,737	7.2	Sand and gravel
S 16	85CA3	0.0	44.5	55.5	0,840	3.8	Sand and gravel
S 17	85HE4	22.0	52.0	26.0	0,0239	16.0	Red brown gravelly clayey till
S 18	84PN2	31.0	32.0	37.0	0,0198	35.6	Red brown clayey till
S 19	85BE2	36.0	39.0	25.0	0,0196	14.3	Red brown clayey till
S 20	85FC3	1.0	80.0	19.0	0,33	1.9	Sand and gravel
S 21	85FM1	12.0	79.3	8.7	0,0915	5.0	Sand and gravel
S 22	85GH2	1.0	24.0	75.0	0,584	12.6	Sand and gravel
S 23	84JP3	1.0	36.0	6.3	0,445	14.2	Sand and gravel
S 24	85OE1	2.0	48.3	49.7	0,183	19.5	Sand and gravel
S 25	85OE1	1.0	22.0	77.0	0,0915	26.0	Sand and gravel
S 26	85GD2	8.0	87.1	4.9	0,084	3.3	Sand and gravel
S 27	85MH2	0.0	95.1	4.9	0,0384	1.63	Sand and gravel
S 28	85MQ3	23.0	52.7	24.3	0,0369	6.1	Red brown clayey till
S 29	85OO1	18.0	72.0	10.0	0,0432	5.8	Sand and gravel
S 30	85OO1	20.0	70.5	9.5	0,0584	3.1	Sand and gravel
S 31	108CG2	3.0	41.5	55.5	0,33	20.0	Sand and gravel
S 32	85PO1	1.0	41.0	58.0	0,584	7.2	Sand and gravel
S 33	85PO1	36.0	45.5	18.5	0,0215	13.3	Red brown clayey till
S 34	85QL3	8.0	68.1	23.9	0,084	5.0	Sand and gravel
S 35	85QK4	46.0	35.9	18.1	0,0229	5.6	Brown sandy till
S 36	86NK1	2.0	97.3	0.7	0,1092	2.1	Sand and gravel
S 37	85QC3	1.0	59.2	39.8	0,254	8.0	Sand and gravel
S 38	85QF2	2.0	73.4	24.6	0,381	3.5	Sand and gravel
S 39	87LB3	26.0	28.6	45.4	0,0114	349	Brown sandy till
S 40	83BE3	14.0	36.6	49.4	0.0534	61.0	Orange brown sandy till
S 41	83GE4	23.0	25.7	51.3	0,028	273	Orange brown sandy till
S 42	83FF2	15.0	16.8	68.2	0.0458	178	Orange brown sandy till
S 43	83MG3	26.0	24.0	50.0	0.0135	397	Brown sandy till
S 44	85AK3	23.0	51.0	28.0	0.0135	94.4	Brown sandy till
S 45	88ON4	14.0	29.4	56.6	0.028	177	Brown sandy till
S 46	88NL1	32.0	23.0	45.0	0.00965	34.2	Brown sandy till
S 47	87PM2	11.0	45.0	44.0	0.0534	47.6	Brown sandy till
S 48	106GQ1	8.0	58.4	33.6	0,0788	16.1	Sand and gravel
S 49	106GD4	18.0	36.9	45.1	0,0356	78.5	Sand and gravel
S 50	106CP3	48.0	26.4	25.6	0,00084	379	Brown sandy till
S 51	106DP1	24.0	39.0	37.0	0,0254	38.0	Red brown clayey till
S 52	106DN1	1.0	60.5	38.5	0.458	3.1	Sand and gravel
S 53	107BC1	26.0	26.4	47.6	0.0208	189	Brown sandy till
S 54	107CG1	2.0	50.4	47.6	0.229	12.7	Sand and gravel
S 55	107DQ4	8.0	65.2	26.8	0.0737	9.7	Sand and gravel
S 56	107FF3	28.0	45.0	27.0	0.0198	16.7	Red brown clayey till

APPENDIX B

SELECTED WATER WELL RECORDS
IN THE SMITHS COVE AREA, NOVA SCOTIA

Records of drilled wells which have been verified in the field are listed along with some dug wells in Appendix B. Some of the questionable well logs have been reinterpreted based on new information obtained during this study.

The following abbreviations are used in the table of Appendix B.

Driller

1. Kennedy, O.V. & Son Ltd.
2. Fisher, John & Son Drilling
3. Trask, S.G. & Sons Ltd.
4. Edwards, Herb and Jodrey, S.J. Well Drilling Ltd.
5. Fox, D.A. Well Drilling
6. Bowmaster, W.L. Well Drilling

Use

D - domestic
P - public

Chemical Analysis

X - chemical analysis available

Well Yield

igpm - imperial gallons per minute
DD - drawdown
Rec - recovered to

Lithologic Log

Adjectives

W - White
B - Black
G - Grey
R - Red
H - Hard
S - Soft
F - Fine grained
M - Medium grained
C - Coarse grained

Nouns

cl - clay
sd - sand
gr - gravel
bldrs - boulders
ss - sandstone
st - siltstone
gb - gabbro
sl - slate
sh - shale

APPENDIX B SELECTED WATER WELL RECORDS IN THE SMITHS COVE AREA, NOVA SCOTIA.

INDEX NUMBER	GRID LOCATION	YEAR DRILLED	PRESENT OWNER	DRILLER	DEPTH (feet)	WATER LEVEL (feet)	HOLE DIAMETER (inches)	CASING LENGTH (feet)	USE	CHEMICAL ANALYSIS	WELL YIELD		AQUIFER	LITHOLOGIC LOG & REMARKS
											PUMP OR BAIL TEST DATA	SPECIFIC CAPACITY (igpm/ft.)		
1	21 A 12 A - 106CE2	1951	John W. Tatem	1	167	0			D		1/2 gpm @ 30' 2 1/2 gpm @ 54' 5 gpm @ 100'	0.0167 0.0463 0.0500	Sandstone	0-74 cl, gr, bldrs; 74-167 ss
2	87OQ3	1953	Mrs. Hugh Oliver	1	245	20			D	X	1 4/5 gpm @ 90'	0.0257	Slate	0-167 cl, bldrs; 167-245 sl
3	106CF3	1957	Mrs. E. MacDonald Mrs. H. MacWilliams Mrs. J. Cossett	1	250	20	10 & 6	39	D		5 gpm @ 200'	0.028	Sandstone and Slate?	
4	86QO1		Mrs. Wendell Robinson		13	10	30		D				Sand and Gravel	0-13 sd, gr
5	106CL4	1946	Tom Milner	1	180	22	6	132	D		1/2 gpm @ 60' 1 1/2 gpm @ 100'	0.0131 0.0192	Slate	0-132 cl, bldrs; 132-180 sl
6	106DA3	1932	Wallis Weir		40 - 50	10	6		D				Sandstone	Sufficient Supply
7	87NM3	1946	Arthur Hill		418		6		D		1 1/2 gpm	0.0075	Slate	0-208 cl; 208-412 sl
8	87MJ4		Gerald Young		150	8	6		D	X			Slate	0-2 cl; 2-150 sl (Gravity Feed)
9	106DB3		Lawrence Comeau		43	10	6		D		5 - 6 gpm	0.261	Sandstone	(little cl)
10	86OL3		Richard Turnbull Mrs. J. Prince	1	185	Overflow			D		2 - 3 gpm	0.0173	Sandstone	0-130 cl, bldrs; 130-185 [illegible]
11	86OK3	1950	Hedley House (Mrs. M. Gott)	1	200	Overflow	6 1/4	100	P		6 gpm @ 75'	0.080	Sandstone & Shale	0-46 cl, bldrs; 46-200 sh, ss
12	86OG2	1970	Weston Pulley	2	240	33	5	85	D	X	1 1/2 gpm DD 120' 1 hr Rec 38' 14 hr	0.0125	Shale & Slate	0-26 cl, bldrs; 26-38 sd, F gr, cl; 38-78 cl, bldrs; 78-105 G sh; 105-140 R sh; 140-240 sl
											3 gpm DD ? 1 1/2 hr Rec 41' 15 min	0.0152		1 1/2 gpm - for well depth of 218' 3 gpm - for well depth of 240'
13	86EP1	1971	Frank Crosby	2	170	38	4	42	D	X	9 gpm DD 4' 3 hr Rec 38' 2 min	2.25	Sand and Gravel	0-12 cl, sd; 12-40 M sd, C gr; 40-43 bldrs; 43-51 cl, gr; 51-55 cl; 55-58 F-C gr; 58-77 R sh; 77-82 R ss; 82-92 R sh; 92-97 B sl; 97-104 R sl; 104-107 G sl; 107-170 sl
14	84PN3	1971	Dr. G. V. Turnbull	1	125	47	6	67	D	X	4 gpm @ 57'	0.400	Slate	0-67 cl, bldrs; 67-125 sl
15	86NJ1		Mrs. F. May		160-180	Surface	6		D				Sandstone	
16	86NJ1		Richard Lynch	1	154	Overflow	6		D	X	1 1/2 - 3 gpm	0.0208	Sandstone	0-125 cl, sd, gr; 125-154 ss
17	86OM3	1949	Capt. J. I. MacPherson	1	265	Overflow	6		D	X			Sandstone & Shale	0-150 cl, gr, bldrs; 150-200 sh; 200-265 ss
18	86MN3		Hector Pothier		200		6		P	X			Sandstone	
19	85JQ1		George Winchester	1	60		6		D					
20	85JJ3	1946	Marshall Turner	1	88 1/2	3	6	88	D	X			Sand & Gravel	
21	85JG4		Gerald Marshall	1	114	93	6		D					

SELECTED WATER WELL RECORDS IN THE SMITHS COVE AREA, NOVA SCOTIA. CONT'D

INDEX NUMBER	GRID LOCATION	YEAR DRILLED	PRESENT OWNER	DRILLER	DEPTH (feet)	WATER LEVEL (feet)	HOLE DIAMETER (inches)	CASING LENGTH (feet)	USE	CHEMICAL ANALYSIS	WELL YIELD		AQUIFER	LITHOLOGIC LOG & REMARKS
											PUMP OR BAIL TEST DATA	SPECIFIC CAPACITY (igpm/ft.)		
22	87NO3	1952	Mrs. E. Morehouse		65	6	6	45' 10"	D		10 1/2 gpm @ 33'	0.389		
23	106DC2		Eric Kinsman		40 - 60	5 - 6	6		D		5 - 6 gpm	0.111		
24	85GF2	1956	Robert Harrison	1	208	45	4	100	D		3 1/2 gpm @ 90'	0.0778	Sandstone	0-100 cl, gr; 100-208 ss
25	86EQ4	1971	Leaman Sarty	2	205	33	4	94	D		2 1/2 gpm DD 85' 2 hr Rec 45' 3 1/2 hr	0.294	Shale and Slate	0-8 cl, sd; 8-10 bldrs; 10-75 cl, sd, gr, bldrs; 75-90 cl, F gr; 90-123 B sh; 123-128 R sh; 128-164 R & G sh; 164-205 B sl
26	86MG1	1928	Dr. W. C. Wermuth	1	200	30	6		D					
27	107KB3	1909	E. V. Perry		70	13	6		D	X			Sandstone	Sufficient Supply
28	86QL4		Neil Adams		12	5			D				Till	cl, gr
29	85QL1	1947	Mountain Gap Inn	1	365	25	6	247	P		4 gpm @ 50' 12 gpm @ 75'	0.160 0.240	Sandstone	
30	106CN1	1970	Lloyd Robinson	2	160	15	4	81	P	X	2 gpm DD 105' 2 hr Rec 26' 5 min	0.019	Sandstone and Shale	0-14 sd, cl, bldrs; 14-33 cl, gr; 33-69 R cl; 69-78 ss, sh; 78-124 ss; 124-160 sh, ss
31	106CL1	1962	Miss D. Henderson	1	105	16	4	49	D		1 gpm @ 55'	0.0256	Slate	0-49 cl, bldrs; 49-105 sl
32	86QL2	1970	John Oickle	2	175	10	4	40 1/2	D		3 gpm DD 35' 2 hr Rec 17' 10 min	0.0857	Shale, Sandstone and Slate	0-31 sd, gr, cl; 31-75 sh; 75-135 F ss; 135-175 sl
33	107BE3	1970	Smiths Cove Trailer Court	2	160	51	4	21	P		2 gpm DD 70' 4 hr Rec 51' 1 hr	0.0286	Sandstone and Shale	0-3 cl; 3-12 gr; 12-36 H cl, gr; 36-160 ss, sh (Not in use)
34	86PQ4		L. Sarty	3	175		8 & 4	80 & 75	D				Slate	0-85 cl, bldrs; 85-175 sl
35	107AD1	1959	Smiths Cove School	1	261	27	6	64	P	X	6 gpm @ 160'	0.0451	Sandstone and Slate?	
36	107AF2		Earnest Thomas	1	220	26	6	150	D		3/4 gpm	0.004	Slate	0-40 cl; 40-220 sl
37	107AH1		Harbour View House & Cottages Ltd. (David Irvine)		180	10	6		D	X	7 - 8 gpm	0.043	Sandstone	
38	86QQ2		Irving Service Station		180				P					
39	86OM4	1952	Capt. J. I. MacPherson	1	194	Overflow	4	152	D	X	2 3/4 gpm @ 45' 5 gpm @ 80'	0.0611 0.0625	Sandstone	0-152 cl, gr, bldrs; 152-194 S ss
40	86LP1	1965	George Bell	3	90	11	6	47	P	X	6 gpm DD 17' 30 min Rec 11' 1 hr	0.353	Slate	0-42 cl, bldrs; 42-90 sl
41	86OA3	1953	Jennie M. Rice	1	175	45	6	105	D		4 gpm @ 60' 5 gpm @ 80'	0.266 0.143	Slate	0-103 cl, bldrs; 103-175 sl
42	86QG4	1966	Howard M. Oliver	4	98	28	6	43	D	X	1 3/4 gpm	0.029	Slate	0-12 cl; 12-29 gr; 29-98 sl

SELECTED WATER WELL RECORDS IN THE SMITHS COVE AREA, NOVA SCOTIA. CONT'D

INDEX NUMBER	GRID LOCATION	YEAR DRILLED	PRESENT OWNER	DRILLER	DEPTH (feet)	WATER LEVEL (feet)	HOLE DIAMETER (inches)	CASING LENGTH (feet)	USE	CHEMICAL ANALYSIS	WELL YIELD		AQUIFER	LITHOLOGIC LOG & REMARKS
											PUMP OR BAIL TEST DATA	SPECIFIC CAPACITY (igpm/ft.)		
43	86QP1	1954	Stan Paxton	1	120	10	6	44	D		2 gpm @ 90'	0.0250	Slate	0-43 cl, bldrs; 43-120 sl
45	87NN3	1965	Harold Sulis	4	63	12	6	59	D	X	DD 5' 3 hrs Rec 12' 40 sec.		Sandstone	0-12 cl, bldrs; 12-63 ss
46	107HD3	1957	Harbour View House & Cottages Ltd. (David Irvine)	1	60	30	6	30	P	X	60 gpm @ 40'	6.000	Sandstone	0-30 cl, gr; 30-60 ss
47	106DB4	1952	John Winchester	1	55	8	4	36	D		15 gpm @ 22'	1.072	Sandstone	0-36 cl, gr; 36-55 ss
48	106DG1	1952	Elmer Weir	1	39	4	4	31	D	X	5 gpm @ 19'	0.333	Sandstone	0-31 cl, bldrs; 31-39 ss
49	106DH3	1951	A. H. Berry	1	70	42	4	46	D		2 gpm @ 50'	0.250	Sandstone	0-40 cl, bldrs; 40-70 ss
50	106CM1	1952	Guy Adams	1	180	19	6	70	D		1 1/2 gpm	0.01	Sandstone	0-70 cl, bldrs; 70-180 ss
51	86PP4		Edgar Sulis		6	3	36		D					cl, gr, bldrs
52	106DH1	1952	E. W. Bryant	1	62	10	6	34	D		9 1/2 gpm @ 35'	0.380	Sandstone	0-34 cl, gr; 34-62 ss
53	107EF3	1971	A. Landers	6	412	15	7	20	D	X	1/5 gpm	0.0005	Slate and Gabbro	0-11 cl, gr; 11-245 gb; 245-257 R sl; 257-412 gb (Abandoned)
54	106HH4	1971	Doug Titus	2	187.	12	4	71	D		1/2 gpm DD 78' 2 hr Rec 44' 12 hr	0.0064	Slate	0-4 cl, gr; 4-68 sd, gr, bldrs; 68-187 sl
55	106GF2		Miss Edith Wightman		11				D					
56	85AE4		Leda Jodrey	1	14				D	X			Sand and Gravel	14' sd, gr
57	85GE1		E. Thomas		12				D	X			Gravel	0-7 cl; 7-12 gr
58	107EE4	1972	Fred Potter	5	253	14	6	15	D		1/2 gpm Rec 65' 12 hr	0.0022	Slate	0-6 gr, cl; 6-184 sl; 184-186 gb; 186-253 sl
59	107EM2	1972	Hoyt Crosby	5	250		6	70	D		3/4 gpm Rec 150' 12 hr	0.0033	Slate	0-26 gr, bldrs; 26-66 gr, cl; 66-250 sl
60	106GA3	1972	John Wightman	5	220	4	6	12	D	X	1/2 gpm	0.0024	Slate	0-4 cl, gr; 4-220 sl
61	85KD1	1940	Clayton Woodman	1	45 - 50	15	4		D	X			Sandstone	
62	107AB2	1963	Katherine Weir	1	110	25	4	64	D		6 gpm @ 50'	0.240	Sandstone	
63	106DB4	1954	Lloyd Durling	1	60	9	4	30	D		3 1/2 gpm @ 30' 4 1/2 gpm @ 40'	0.167 0.145		
64	86QN2		Irene Sarty		7	3			D				Sand & Gravel	
65	86PJ3		Allen Berry		12				D				Till	0-12 cl, bldrs
66	106DC3	1971	Howard Buckley	2	95	4	4	18	D	X	3 gpm DD 60' 2 hr Rec 5' 30 min	0.050	Sandstone and Shale	0-7 sd, gr, cl; 7-13 S-R-C ss; 13-17 F ss; 17-75 R-G sh, ss; 75-86 M-C ss; 86-89 R sh; 89-95 M-C ss

SELECTED WATER WELL RECORDS IN THE SMITHS COVE AREA, NOVA SCOTIA. CONT'D

INDEX NUMBER	GRID LOCATION	YEAR DRILLED	PRESENT OWNER	DRILLER	DEPTH (feet)	WATER LEVEL (feet)	HOLE DIAMETER (inches)	CASING LENGTH (feet)	USE	CHEMICAL ANALYSIS	WELL YIELD		AQUIFER	LITHOLOGIC LOG & REMARKS
											PUMP OR BAIL TEST DATA	SPECIFIC CAPACITY (igpm/ft.)		
67	106DD1		Smiths Cove Post Office						P				Sandstone	
68	106DC4	1970	Elanor Conrad	2	115	Overflow	4	21	D		2 gpm overflow		Siltstone, Sandstone and Shale	0-7 sd, gr, cl; 7-36 F ss; 36-95 st, sh; 95-115 ss
69	86PJ3		Lawrence Berry		3				D	X			Till	0-3 cl, gr
70	107AC4	1965	Victor Dennison	4	117	12	6	68	D		2 1/2 gpm DD 60' 1 hr Rec 12'	0.0417	Sandstone	0-41 cl; 41-117 W ss
71	106FA2	1959	Kelsey Raymond	1	234	15	4	80	D	X	1 gpm @ 77'	0.0161	Slate	0-80 cl, bldrs
72	87NN4		Mrs. M. Harney		65 - 80	9			D		5 - 6 gpm	0.0985	Sandstone and Shale	
73	107KE1		P. E. Prescesky		8 1/2	3 1/2			D				Sand and Gravel	0-8 1/2 sd, gr Flowing spring
74	107CL3	1970	Smiths Cove Trailer Park (R. McGowan)	2	415	60	4	70	P	X	4 gpm DD 50' 1 hr Rec 60' 20 min	0.080	Shale, Sandstone and Slate	0-9 cl, gr; 9-32 M-C gr; 32-60 sd, gr, cl; 60-122 F ss; 122-165 R sh; 165-238 H ss, st; 238-289 sh; 289-313 M-C ss; 313-335 ss, sh; 335-415 sl
75	87NP4	1971	Stan Smith	2	255	30	4	34	D	X	1 gpm DD 70' 2 hr	0.0143	Sandstone and Shale	0-30 cl, gr; 30-40 M ss; 40-45 R sh; 45-74 R sh, F W ss; 74-77 R sh; 77-111 R sh, F W ss; 111-123 M-C ss; 123-185 M ss, sh; 185-255 M ss
											2gpm DD 80' 1 hr Rec 60' 45 min	0.025		
76	106DC1	1971	Irvine Brooks	2	105	16	4	22	D		5 gpm DD 50' 4 hr Rec 20' 10 min	0.100	Sandstone	0-2 cl, gr; 2-9 sd, gr; 9-12 gr, cl; 12-17 C ss; 17-105 F ss, sh
77	105EE4		A. Landers	1	102	7	6		D	X	1/2 gpm	0.0058	Slate	0-10 cl, bldrs; 10-102 sl
78	85QC4	1972	Mountain Gap Inn	5	320	47	5	200	P	X	5 gpm 1 hr 10 gpm 1 hr Rec 51' 2 hr	0.038	Sandstone	0-11 sd, gr; 11-17 cl; 17-33 cl, gr; 33-67 S sd; 67-181 cl, sd; 181-320 ss
79	86OJ3	1972	Kent Vanderput	6	304	30	6	104	D	X	2 1/2 gpm 2 hr	0.0096	Sandstone and Slate	0-104 cl, bldrs, gr; 104-304 ss, sl
80	107CL1	1971	Smiths Cove Trailer Park (R. McGowan)	2	230	35	5	50	P		5 gpm DD 70' 2 hr Rec 39' 20 min	0.071	Sandstone and Shale	0-38 sd, gr, cl; 38-45 cl; 45-135 sh, ss; 135-170 ss; 170-185 sh; 185-225 ss; 225-230 sh
											8 gpm DD 40' 1 hr Rec 35' 4 min	0.200		
81	86OA1	1973	W. K. Burgess	5	81	13	6	72	D		6 gpm 2 hr	0.013	Gravel	0-22 cl; 22-34 cl, sd; 34-69 S sd; 69-81 gr
82	106CF1	1956	MacArthur Morgan	1	198	10	6	51' 8"	D		4 gpm	0.022	Slate	High iron content
83	106DG2		Mrs. Vera Langman		12									Slate near surface -- High iron

APPENDIX C CHEMICAL ANALYSES OF GROUNDWATERS IN THE SMITHS COVE AREA, NOVA SCOTIA

						Analyses in parts per million (ppm)																					Ions in equivalents per million (epm)								
															Alkalinities							pH					Cations				Anions				
Index No.	Grid Location	Present Owner	Depth of Well (feet)	Aquifer	Date Sampled	Ca	Mg	Na	K	Fe	Mn	SO_4	Cl	NO_3	Phenol-phthalein as $CaCO_3$	Methyl Orange	Hardness	Ignition Loss	Total Dis-solved Solids	Suspended Matter	Specific Conductance (mhos x 10^{-5})	Field	Lab.	Field Temp. °F	Colour	Turbidity	Ca	Mg	Na	K	SO_4	Cl	CO_3 HCO_3	SSP	SAR
	21 A 12 A -																																		
2	87OQ3	Mrs. Hugh Oliver	245	Slate	28/6/73	10.8	6.48	12.2	0.9	0.09	0.05	8.9	1.2	1.52	Nil	72.76	53.57		96		14.2	6.95	7.1	48	2.0	2.4	0.539	0.533	0.531	0.023	0.185	0.034	1.19	34.1	0.726
8	87MJ4	Gerald Young	150	Slate	14/6/73	4.8	2.16	6.85	1.7	0.51	0.01	11.18	1.2	0.48	Nil	21.3	20.9		52		5.5		6.7		27.0	12.2	0.239	0.178	0.298	0.0434	0.233	0.034	0.350	45.0	0.653
12	86OG2	Weston Pulley	240	Slate	27/6/73	24	5.04	10.9	0.9	0.10	0.15	15	4.4	0.62	Nil	34.24	80.66		120		17	8.5	7.8	52	3.0	3.0	1.198	0.414	0.474	0.023	0.313	0.124	0.563	23.6	0.529
13	86EP1	Frank Crosby	170	Sand and Gravel	26/6/73	27.6	15.12	11	1.45	1.8	0.56	11	49.6	11.43	Nil	68.5	131		318		27.5	7.0	6.6	50	45	9.4	1.377	1.243	0.479	0.037	0.229	1.400	1.125	16.5	0.409
14	84PN3	Dr. G. V. Turnbull	125	Slate	12/6/73	19.2	6.48	10.6	1.9	0.04	0.015	9.3	8.8	2.1	Nil	80.9	74.6		118		15		6.8	49	2	1.5	0.958	0.533	0.461	0.0486	0.194	0.248	1.325	25.5	0.535
16	86NJ1	Mary R. Lynch	154	Sandstone	27/6/73	15.6	4.32	8.7	3.55	0.07	0.03	10.4	6.4	0.53	Nil	62.06	56.71		93		14	8.0	7.55	50	1.0	3.0	0.779	0.356	0.378	0.091	0.217	0.181	1.02	29.2	0.503
17	86OM3	Capt. MacPherson	265	Sandstone and Shale	26/6/73	40.8	18.72	120	5.9	0.045	0.035	14	249	7.72	Nil	33.38	178.8		651		81	6.5	6.6	54	5.0	1.6	2.035	1.540	5.220	0.151	0.292	7.030	0.547	60.1	3.91
18	86MN3	Hector Pothier	200	Sandstone	14/6/73	9.8	2.88	7.3	0.6	0.05	0.002	7.15	1.2	0.44	Nil	49	35.8		70		8.5	7.2	7.15	47	1.0	2.1	0.489	0.237	0.318	0.0153	0.149	0.034	0.804	31.4	0.528
20	85JJ3	Marshall Turner	88	Sand and Gravel	17/7/73	13.2	2.88	7.0	0.6	0.3	0.002	5.68	2.44	2.44	Nil	44.9	44.8		80		8.9		7.0	46	2.0	4.6	0.659	0.237	0.305	0.0153	0.118	0.069	0.737	33.7	0.456
24	85GE1	Robert Harrison	208	Sandstone	23/8/73	19.0	4.6	13.7	2.5	0.45	0.009	3.4	6.1	2.48	Nil	86.0	66		166		16.2	7.0	7.6	59	8.0	5.0	0.948	0.379	0.595	0.064	0.0708	0.174	1.41	33.2	0.730
27	107KB3	E. V. Perry	60	Sandstone	26/6/73	16.8	5.76	9.0	1.35	0.09	0.05	10.5	30.8	3.9	Nil	57.78	65.62		130		14.2	7.25	7.25	42	2.0	2.4	0.839	0.474	0.392	0.035	0.219	0.870		24.6	0.485
30	106CN1	Lloyd Robinson	160	Sandstone	17/7/73	15.6	7.2	7.6	0.35	0.35	0.02	7.86	5.69	1.77	Nil	64.2	68.5		99		13.5		7.3	51	5.0	4.6	0.778	0.592	0.331	0.088	0.164	0.161	1.05	19.0	0.400
35	107AD1	Smiths Cove School	261	Sandstone and Slate?	29/6/73	16.8	4.32	17.5	0.09	0.09	0.085	10.1	16.8	1.06	Nil	72.76	59.7		125		15.8	8.1	7.7	47	4.0	2.1	0.839	0.355	0.762	0.033	0.210	0.474	1.19	40.0	1.03
37	107AH1	Harbour View Cottages	180	Sandstone	27/6/73	9.6	2.88	38	4.75	0.10	0.012	16	16.8	0.8	Nil	87.74	35.81		156		21.0	8.25	7.9	46	2.0	1.5	0.479	0.237	1.653	0.121	0.334	0.474	1.44	71.3	2.77
39	86OM4	Capt. MacPherson	194	Sandstone	26/6/73	16.8	5.76	10.2	2.9	0.16	0.10	13.6	10.8	0.22	Nil	63.34	65.72		115		16.0	8.0	7.45	52	2.0	2.8	0.839	0.474	0.444	0.074	0.284	0.305	1.04	28.3	0.549
40	86LP1	George Bell	90	Slate	26/6/73	12	5.76	7.6	0.5	0.11	0.006	10	3.2	2.3	Nil	51.36	53.62		90		12	7.05	7.2	49	2.0	2.8	0.599	0.474	0.331	0.013	0.208	0.090	0.844	24.3	0.453
42	86QG4	Howard Oliver	98	Slate	24/7/68	17.8	2.6	8.9		0.01	T	4	14.2	T	8.0	136.0	55.2				39	7.0	8.5	54	<5	0	0.89	0.21	0.39		0.38	0.40	2.503	26.2	0.526
45	87NN3	Harold Sulis	63	Sandstone	17/7/73	21.6	5.04	14.5	1.3	0.06	0.003	10.7	8.53	0.98	Nil	81.3	74.7		130		18.8		7.7	56	1.0	3.7	1.077	0.415	0.631	0.033	0.223	0.241	1.33	30.8	0.731
46	107HD3	Harbour View Cottages	60	Sandstone	24/7/68	16.8	5.4	6.4		0.01	T	T	10.6	T	0	66.0	64.0				20	6.3	8.1	47	<5	0	0.84	0.44	0.28		T	0.30	1.08	18.0	0.35
48	106DG1	Elmer Weir	39	Sandstone	18/7/73	24.0	8.64	13.5	1.2	0.12	0.003	8.93	15.04	5.76	Nil	77.0	95.4		159		18.4		7.1	48	2.0	1.8	1.198	0.711	0.587	0.031	0.186	0.424	1.26	24.2	0.601
53	107EF3	G. Landers	412	Slate and Gabbro	27/1/72	15.5	5.1	40.5	4.5	4.0	0.10	17	21	4.9	3	113	49	32	210	42			8.20				0.774	0.420	1.762	0.115	0.354	0.593	1.955	61.1	2.236
56	85AE4	Leda Jodrey	14	Sand and Gravel	14/6/73	27.6	9.36	11.9	1.35	0.46	0.01	15.2	22	5.3	Nil	85.2	107.4		165		20	7.8	6.9	47	7	8.2	1.38	0.770	0.518	0.0345	0.317	0.621	1.40	20.4	0.484
57	85GE1	Earl Thomas	12	Sand and Gravel	14/6/73	8.4	0.72	11.0	1.20	0.4	0.013	14.26	4.4	2.4	Nil	32	24		73		8.0	5.8	6.5	46	8	7.1	0.495	0.059	0.479	0.0307	0.297	0.124	0.525	47.9	0.910
60	106GA3	John Wightman	220	Slate	29/6/73	13.2	1.48	23.5	2.25	0.46	0.016	10.9	15.6	0.71	Nil	92.07	59.57		135		18.7	7.4	7.4	46	8.0	4.3	0.659	0.122	1.022	0.058	0.227	0.441	1.51	58.0	1.64
61	85KD1	Clayton Woodman	45 - 50	Sandstone	14/6/73	26.4	8.64	11.4	1.2	0.115	0.013	16.48	15.2	3.1	Nil	85.2	101.4		170		18.5	8.1	7.2	51	2	1.8	1.32	0.710	0.496	0.0307	0.343	0.429	1.40	33.9	0.489

CHEMICAL ANALYSES OF GROUNDWATERS IN THE SMITHS COVE AREA, NOVA SCOTIA. CONT'D

						Analyses in parts per million (ppm)																					Ions in equivalents per million (epm)								
Index No.	Grid Location	Present Owner	Depth of Well (feet)	Aquifer	Date Sampled	Ca	Mg	Na	K	Fe	Mn	SO_4	Cl	NO_3	Alkalinities		Hardness	Ignition Loss	Total Dissolved Solids	Suspended Matter	Specific Conductance (mhos x 10^{-5})	pH		Field Temp. °F	Colour	Turbidity	Cations				Anions			SSP	SAR
															Phenolphthalein as $CaCO_3$	Methyl Orange						Field	Lab.				Ca	Mg	Na	K	SO_4	Cl	CO_3 HCO_3		
66	106DC3	Howard Buckley	95	Sandstone and Shale	17/7/73	24.0	7.2	16.5	2.05	0.10	0.005	6.71	3.25	2.81	Nil	92.0	89.5		134		19.0		7.6	44	1.0	2.1	1.198	0.592	0.718	0.052	0.140	0.092	1.51	30.1	0.760
69	86PJ3	Lawrence Berry	3	Till	27/6/73	22.8	6.48	10.9	1.95	0.63	0.005	11.6	11.6	2.75	Nil	81.32	83.57		145		18.0	7.7	7.7	48	1.0	2.1	1.138	0.533	0.474	0.050	0.242	0.328	1.335	23.9	0.519
71	106FA2	Kelsey Raymond	234	Slate	13/6/73	12.0	5.04	33.0	9.55	0.15	0.048	7.8	12.0	Nil	Nil	123.5	50.7		167		20.5	8.5	7.2	52	3	1.5	0.599	0.414	1.436	0.244	0.163	0.339	2.03	62.4	2.02
74	107CL3	R. McGowan (Trailer Park)	415	Shale, Sandstone and Slate	14/6/73	7.2	4.32	11.9	2.2	0.26	0.085	4.93	3.6	0.3	Nil	51.1	35.7		73		9.5		7.0	51	3.0	3.3	0.359	0.355	0.518	0.0562	0.103	0.102	0.838	44.5	0.868
75	87NP4	Stan Smith	225	Sandstone and Shale	17/7/73	19.2	8.64	11.0	5.0	0.28	0.026	7.9	2.03	3.21	Nil	87.7	83.4		127		16.8		7.4	51	2.0	3.0	0.958	0.711	0.479	0.128	0.164	0.057	1.44	26.7	0.525
77	105EE4	G. Landers	102	Slate	23/7/71	33.5	8.0	8.9	2.5	0.18	0.03	14	17	5.5	Nil	110	115	35	155	<1.0	220	7.0		48	5.0	3.0	1.672	0.658	0.387	0.064	0.291	0.480	1.704	16.2	0.358
78	85QC4	Mountain Gap Inn	320	Sandstone	14/6/73	12.0	2.16	7.5	1.3	0.2	0.002	6.7	5.2	2.9	Nil	49	38.9		71		9.0	8.0	6.9	46	2.0	2.8	0.599	0.178	0.326	0.0332	0.140	0.147	0.804	31.6	0.523
79	86OJ3	Kent Vanderput	304	Sandstone and Slate	23/8/73	18.0	5.4	220.0	8.5	0.13	0.045	3.2	169	0.89	Nil	212	66.6		533		75.0	7.3	7.9	53.6	4.0	1.3	0.898	0.445	9.56	0.218	0.0675	4.76	3.48	87.8	12.15
A 3	84PP1	Cecil Jones	11	Till	14/6/73	12.0	8.64	8.7	0.55	0.1	0.002	11.8	10.0	14	Nil	57.5	65.4		114		12.5	6.6	6.9	49	2	1.3	0.599	0.710	0.378	0.0141	0.246	0.282	0.944	23.0	0.467
A 7	108BC2		Spring	Sand and Gravel	14/6/73	4.8	2.88	9.1	0.75	0.31	0.021	9.65	6.8	Nil	Nil	25.6	23.8		50		7.0	6.7	7.15	40	1.0	2.4	0.239	0.237	0.396	0.0192	0.201	0.192	0.420	46.6	0.814
A 12	85GQ2	Fundy Spray Campground (Mr. L. Banks)	14	Sand and Gravel	14/6/73	33.6	5.76	15.5	7.45	0.24	0.025	12.0	13.6	4.8	Nil	117.2	107.6		184.5		22.5		6.9	55	7.0	7.1	1.68	0.474	0.675	0.191	0.250	0.384	1.92	28.7	0.651
A 13	86LO1	Basin View Motel	8	Sand and Gravel	15/6/73	16.8	5.76	8.1	0.6	0.08	0.005	8.7	10.0	2.5	Nil	72.4	65.6		113		13.5		6.8		2.0	2.7	0.839	0.474	0.352	0.0153	0.182	0.282	1.19	21.9	0.435
A 14	107BF2	Phyllis Jefferson	5	Sand and Gravel	15/6/73	10.8	5.04	26.5	2.5	0.12	1.64	12.0	22.8	2.21	Nil	74.6	47.7		144.5		17.5		6.4		4.0	2.7	0.539	0.414	1.152	0.0640	0.250	0.644	1.225	56.0	1.670
A 15	85PF4	Alexander Leighton	6	Sand and Gravel	15/6/73	3.6	3.6	7.5	1.05	0.025	0.014	9.6	5.2	2.9	Nil	12.8	23.8		61		6.5		6.3		3.0	2.4	0.180	0.296	0.326	0.0268	0.200	0.147	0.210	46.6	0.669
A 18	86LK4	George Bell	14	Sand and Gravel	26/6/73	12	2.88	4.8	0.6	0.03	0.002	11	Nil	5.32	Nil	30.51	41.81		77		9.0	6.5	6.7	48	5.0	2.1	0.599	0.237	0.209	0.015	0.229	Nil	0.501	21.1	0.324
A 19	86LJ4	George Bell	9	Sand and Gravel	26/6/73	6.0	3.6	5.1	0.48	0.10	0.004	11.5	2.8	3.54	Nil	21.4	29.76		60		6.5	5.8	6.2	47	5.0	3.0	0.289	0.296	0.222	0.012	0.240	0.079	0.351	28.6	0.411
A 22	107JD1		Spring	Sand and Gravel	26/6/73	9.6	5.76	2.0	2.1	0.14	0.003	15	12.8	2.97	Nil	42.8	47.62		135		19.0	6.7	7.0	42	1.0	2.4	0.479	0.474	0.870	0.054	0.313	0.362	0.702	49.4	1.26
A 31	106BL2	J. D. McClearn		Slate	29/6/73	14.4	5.76	17.5	0.3	0.05	0.035	11	47.2	0.53	Nil	16.26	59.72		218		19.3	5.3	6.15	55	1.0	2.5	0.719	0.474	0.762	0.008	0.229	1.332	0.267	39.2	0.989
A 32	88LJ3	Roop Brook	Stream	Surface	17/7/73	2.4	2.16	4.4	0.4	0.25	0.005	5.93	2.44	3.01	Nil	8.56	14.86		61.5		3.5		6.2	51	55.0	2.1	0.120	0.178	0.191	0.010	0.123	0.069	0.140	40.3	0.495
A 33	86GN1	Roach Brook	Stream	Surface	17/7/73	4.8	2.16	4.6	0.4	0.1	0.004	5.6	0.41	2.73	Nil	17.1	20.9		49.3		4.3		6.75	55	10.0	2.7	0.240	0.178	0.200	0.010	0.117	0.012	0.280	33.4	0.439
A 34	84PD1	Walsh Brook	Stream	Surface	17/7/73	6.0	2.16	5.1	0.2	0.19	0.01	4.82	1.22	1.91	Nil	23.54	23.86		72.5		4.2		7.15	55	45.0	2.1	0.299	0.178	0.222	0.005	0.100	0.034	0.387	32.2	0.455
A 41	86PF2	James Rudolph	12	Sand and Gravel	17/7/73	15.6	4.32	6.0	5.35	0.07	0.05	12.1	2.03	6.87	Nil	53.5	56.7		101		11.8		6.55		4.0	1.5	0.779	0.355	0.261	0.137	0.252	0.057	0.878	26.0	0.348
A 42	87OQ4	Otis Robbins	9	Slate	13/6/72	10.8	1.5	6.0	0.7	0.18	0.10	8.22	4.8	7.0	Nil	33	37		70			6.5			2.0	2.0	0.539	0.123	0.261	0.018	0.173	0.135	0.540	29.6	0.454
A 43	86OJ4	Kent Vanderput	20	Till	10/8/72	63.6	14.4	15.0	8.0	1.98	2.0	11.77	11.4	0.84	Nil	226.8	219.6	39.7	215		40.0	7.64			55	12.0	3.180	1.185	0.653	0.205	0.245	0.322	3.71	16.4	0.443

CONVERSION FACTORS AND SYMBOLS

1 inch (in)	-	0.254 metres (m)
	-	2.540 centimetres (cm)
	-	25.40 millimetres (mm)
1 foot (ft) - 12 in	-	3.048 m
	-	30.48 cm
	-	304.8 mm
1 mile - 5280 ft	-	1.609 kilometres (km)
1 square mile (mile ^{2})	-	2.390 square kilometres (km^2)
1 acre - 43,560 ft^2	-	4.047 x 10^3 square metres (m^2)
1 cubic foot (ft^3)	-	0.02832 cubic metres (m^3)
- 7.4805 U.S. gallons (g)	-	28.317 litres (ℓ)
- 6.233 imperial gallon (ig)	-	28,317 cubic centimetres (cm^3)
1 imperial gallon (ig) - 1.2 U.S. gallon (g)	-	0.00454 cubic metre (m^3)
	-	4.5425 litres (ℓ)
	-	4542.5 cubic centimetres (cm^3)
1 imperial gallon per minute (igpm)		
- 1.2 U.S. gallons per minute (gpm)	-	4.5425 litres per minute (ℓ/m)
1 cubic foot per minute (ft^3/min)	-	0.472 litre per second (ℓ/sec)
1 cubic foot per second (ft^3/sec or cfs)	-	28.3 litres per second (ℓ/sec)
1 imperial gallon per day per foot (igpd/ft)	-	0.0149 m^2/day
1 imperial gallon per day per square foot (igpd/ft^2)	-	0.0488 m/day
1 pound per square inch (lb/in^2 or psi)	-	0.0703 kg/cm^2
1 pound per square foot (lb/ft^2 or psf)	-	4.882 kg/m^2
1 pound per cubic foot (lb/ft^3 or pcf)	-	16.02 kg/m^3