PROVINCE OF NOVA SCOTIA

DEPARTMENT OF MINES
Groundwater Section

Report 69-2

GROUNDWATER RESOURCES AND HYDROGEOLOGY of the WINDSOR-HANTSPORT-WALTON AREA, NOVA SCOTIA

by

Peter C. Trescott

HON. PERCY GAUM
MINISTER

J.P. NOWLAN, Ph.D.
DEPUTY MINISTER

PRICE $1.00

1969

HALIFAX, NOVA SCOTIA

PROVINCE OF NOVA SCOTIA

DEPARTMENT OF MINES
Groundwater Section

Report 69-2

GROUNDWATER RESOURCES AND HYDROGEOLOGY

of the

WINDSOR-HANTSPORT-WALTON AREA, NOVA SCOTIA

by

Peter C. Trescott

HON. PERCY GAUM
MINISTER

J.P. NOWLAN, Ph.D.
DEPUTY MINISTER

Halifax, Nova Scotia
1969

PREFACE

The Nova Scotia Department of Mines initiated in 1964 an extensive program to evaluate the groundwater resources of the Province of Nova Scotia. This report on the hydrogeology of the Windsor-Hantsport-Walton area is an extension of the Annapolis-Cornwallis Valley study reported in Department of Mines Memoir 6.

The field work for this study was carried out during the summer of 1968 by the Groundwater Section, Nova Scotia Department of Mines, and is a joint undertaking between the Canada Department of Forestry and Rural Development and the Province of Nova Scotia (ARDA project No. 22042). Recently the administration of the ARDA Act was transferred to the Canada Department of Regional Economic Expansion.

It should be pointed out that many individuals and other government agencies cooperated in supplying much valuable information and assistance throughout the period of study. To list a few: Dr. J. D. Wright, Director, Geological Division and the staff of the Mineral Resources Section, Nova Scotia Department of Mines, Mr. J. D. McGinn, Clerk and Treasurer, Town of Hantsport, and the Nova Scotia Agricultural College at Truro.

It is hoped that information in this report will be useful for agricultural, industrial, municipal and individual water needs and that the report will serve as a guide for the future exploration, development and use of the important groundwater resources of the Windsor-Hantsport-Walton area.

John F. Jones
Chief, Groundwater Section
Nova Scotia Department of Mines

Halifax, October 1, 1969

CONTENTS

Illustrations

Tables

GROUNDWATER RESOURCES AND HYDROGEOLOGY OF THE WINDSOR-HANTSPORT-WALTON AREA, NOVA SCOTIA

ABSTRACT

This report describes the potential for developing groundwater supplies in the agricultural and mining districts of the Windsor-Hantsport-Walton area. The hydrogeologic map included with this report illustrates at a scale of 1 inch to 1 mile the bedrock and surficial geology of the area and the locations of water wells reported in selected drillers' logs.

Groundwater of good quality can be obtained for domestic use in the areas not underlain by or closely associated with rocks of the Windsor Group. Except for water in some of the basal Windsor limestones and in a few surficial sand and gravel deposits that are recharged locally, groundwaters in the area underlain by Windsor rocks contain up to 1,600 ppm sulphate hardness and are poorly suited for domestic, irrigation and many other uses.

The best aquifers in the area, in terms of both quality and quantity, are the sandstones and conglomerates in the Horton Group and the sandstones in the Scotch Village Formation. Wells in these rocks will yield 20 to 50 gpm per hundred feet of saturated section. The glaciofluvial deposit at Windsor Forks is the best surficial aquifer in the area. Screened wells in this deposit should yield more than 100 gpm with the yield sustained by water induced from the Avon River.

Drilled wells in the lowlands near the sea may penetrate the zone of diffusion between fresh and salt water and yield water with a chloride concentration in excess of 50 ppm. The relatively large chloride concentration in some water supplies, however, is due to pollution from highway salt. Saltwater intrusion may be a problem in the future if wells of high capacity are completed near the sea.

INTRODUCTION

Purpose and Scope of the Investigation

The investigation of the groundwater resources and hydrogeology of the Annapolis-Cornwallis Valley (Trescott, 1968) included the Gaspereau Valley and Avonport. This report extends the investigation into adjacent Hants County to embrace the agricultural and mining districts in the Windsor-Hantsport-Walton area. Included in this report are discussions of: (1) the geology of the area, (2) the yields that can be expected from wells in the various geologic units, (3) the chemical quality of groundwaters, and (4) the potential for developing irrigation, industrial and municipal groundwater supplies.

General Description of the Area

Location, Access, and Extent of the Area

The area of investigation (also called the map-area) lies between north latitudes 44°55' and 45°15', between west longitudes 64°00' and 64°15', and includes a land area of about 210 square miles (Fig. 1). The main access to this area is provided by the Dominion Atlantic Railway, and by highways 1 (Halifax to Yarmouth via Windsor and the Annapolis-Cornwallis Valley), 14 (Chester to Shubenacadie via Windsor), and 15 (Windsor to Shubenacadie via Walton). In addition to the main highways, numerous county, farm and logging roads provide access to many parts of the area. Port facilities for small, ocean-going vessels are provided at Windsor, Hantsport and Walton. The nearest commercial airport is the Halifax International Airport at Kelly Lake.

Physiography and Drainage

The area investigated is mainly in the Hants-Colchester lowland, but it is bounded on the south and east by the South Mountain highland (Goldthwait, 1924). The lowland, which includes the area north of a line from Windsor Forks to St. Croix, is formed on Carboniferous shale, sandstone, anhydrite, gypsum, limestone and a few salt beds. Relief in the gently rolling lowland is generally less than 200 feet; swamps and peat bogs are common. Cheverie Mountain, which rises to an elevation of 420+ feet, is the highest point in the area north of the Kennetcook River. Along the eastern slope of the South Mountain highland west of Hantsport and Falmouth, however, the land rises in places to an altitude in excess of 500 feet.

The South Mountain highland, which is underlain by slate, quartzite and granite, is mostly uninhabited within the map-area. The altitude of much of this moderately rolling highland is above 500 feet; the highest point, found

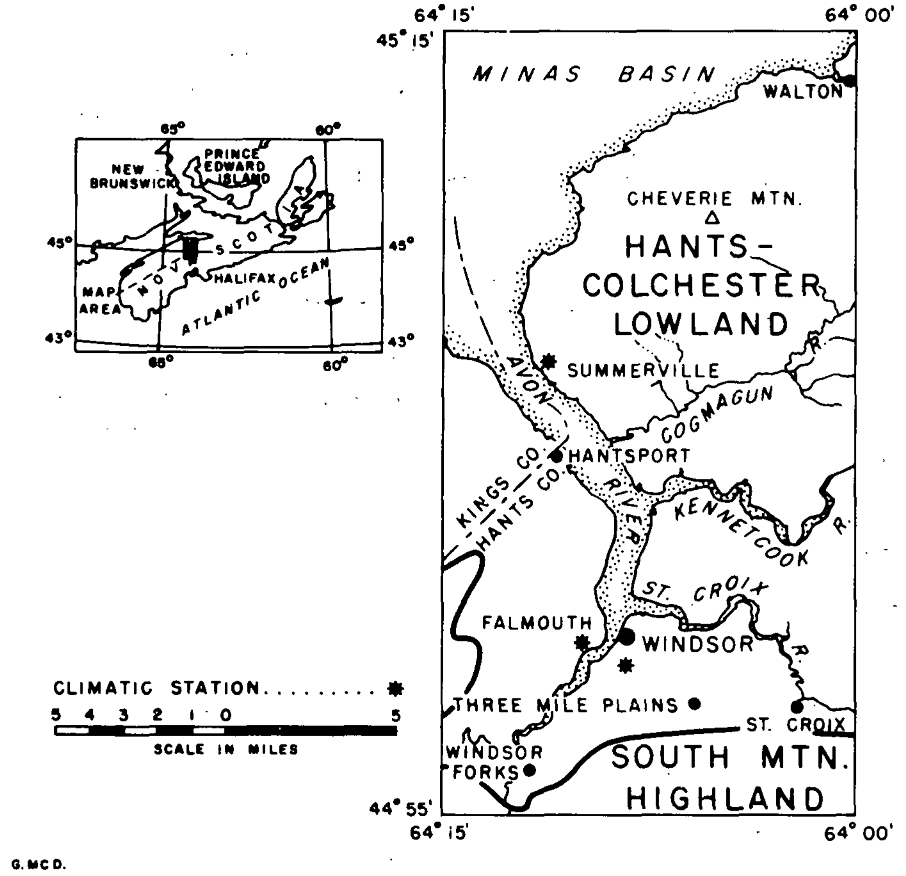

FIGURE 1. Location and physiography of the map-area.

near the southwestern corner of the area, exceeds an elevation of 750 feet. The highland contains a few swamps and lakes. Many of the lakes have been created by dams on the St. Croix River.

Most of the area is drained by the Avon River and its principal tributaries, the St. Croix, Kennetcook, Halfway, and Cogamagun Rivers. The land between Summerville and Walton is drained by a few smaller streams which discharge directly to the Minas Basin. Much of the area underlain by Windsor Rocks is a karst terrane where drainage is internal. The solution of gypsum, anhydrite and salt beds along joints and bedding planes by percolating groundwater has formed sinkholes, many of which contain ponds. Solution does take place at depth, but most of the solution occurs above the water-table (Goldthwait, 1924, p. 52).

Agriculture and Soils

Most of the soils in the map-area developed on deposits of glacial till. Glacial till is composed predominantly of material eroded and deposited within a short distance by glacial ice; consequently it reflects the nature of the underlying bedrock. The soils that have formed on various parent material and their suitability for agriculture are outlined in Table 1.

Table 1. Soils and their Suitability for Agriculture in the Windsor-Hantsport-Walton Area*

Parent Material	Soil	Suitability for Agriculture	Use Restricted in Places by
Granite and quartzite tills	sandy loam	forest only	cobbles and boulders
slate till	sandy loam	fair crop land	topography and stoniness
till developed on Horton rocks	sandy loam to clay loam	fair to poor crop land	poor drainage
till developed on Windsor Group and Scotch Village Fm rocks	loam and clay loam	good to fair crop land	topography and poor drainage
Glaciofluvial deposits	sandy loam	fair to poor crop land	excessive drainage and topography
Dykeland	silty loam	good crop land	poor drainage
Depressional areas	peat and muck	unsuitable	poor drainage

* summarized from Cann, Hilchey, and Smith (1954)

Commercial farming in the map-area consists of dairying, livestock production (including hogs, cattle, sheep and poultry), mixed farming, lumbering, and a large greenhouse complex at Falmouth. Improved land (probably more than 10 per cent of the land in the map-area) is used mainly for pasture and the production of hay. Other crops include grains, potatoes, vegetables, orchards which consist mainly of apple trees, and some cultivated small fruit, chiefly blueberries. Most of the unimproved land can be classified as productive forest (perhaps 75 per cent of the land in the area investigated); the remainder includes depleted forest, unproductive land and forest, strip-mined areas, and swamps (Cann, Hilchey, and Smith, 1954; and N. S. Dept. of Trade and Industry, 1968).

Population and Industry

The population of Hants County, 26,893 in 1966, has been slowly but steadily increasing since 1931 when the population was slightly over 20,000. In the map-area, which contains over half the population of Hants County, this growth has been restricted primarily to the towns of Hantsport and Windsor (see Table 2).

Table 2. Population Changes in the Windsor-Hantsport-Walton area, 1931-1966

Community	Population*				Per Cent Change
	1931	1941	1951	1966	1931-1966
Falmouth	879	1,163		724	- 18
Hantsport	704	907	1,131	1,438	+104
Three Mile Plains				1,247	
Walton	770	453		373	- 52
Windsor	3,032	3,436	3,439	3,765	+ 24
Totals (excluding Three Mile Plains)	5,385	5,959		6,300	+ 17

* Dominion Bureau of Statistics

Those living in the towns of Hantsport and Windsor are classified as urban dwellers; all others in the map-area, perhaps 65 per cent of the population, are classified as rural dwellers.

The economy of the area is based on agriculture, forest products and mining. Agricultural products, chiefly apples, are processed for export at Hantsport. Forest products, mainly pulpwood, piling, lumber and paper products are processed in Hantsport, Newport and Scotch Village and are exported through the ports of Hantsport and Windsor. Anhydrite and gypsum are mined at Wentworth Creek, Miller Creek, and near Walton, mostly for export through the ports of Hantsport and Walton. One company, however, does process gypsum at Windsor to produce a wide range of plaster products. About 90 per cent of the barite produced in Canada is mined and processed southeast of Pembroke for export through the port at Walton. The same mine also produces lead, copper, silver and zinc concentrations. Other manufacturing in the map-area includes chemical fertilizers, feeds and grains, concrete products, granite monuments, textiles, and food products from a bakery, dairy, pastry shop and a confectionary store (N. S. Dept. of Trade and Industry, 1967 and 1968; and Slater, 1967).

Climate

Nova Scotia's humid, temperate, continental climate is modified by the Atlantic Ocean which almost completely surrounds the province and by the Gulf Stream which runs northeasterly parallel to the Atlantic coast. The proximity of the ocean tends to prevent extreme temperatures in the summer and winter and minimizes the number of severe atmospheric storms (N. S. Dept. of Trade and Industry, 1965). The South Mountain highland modifies precipitation, temperatures and winds to some extent in the southern and eastern parts of the map-area.

Long-term climatic records are available in the map-area only for the Windsor (Kings College) station (see Fig. 2 for temperature and precipitation data). Records from this station date from 1871 to 1948 and are continuous except for a few breaks in the period 1871 to 1903. Continuous records have been kept at Falmouth since September 1963 and at Summerville since May 1965. East of the map-area climatic records are available for Wolfville where the mean annual precipitation is nearly identical to that at Windsor. Five miles south of the map-area on the South Mountain highland at Avon, the mean annual precipitation is 55 inches, nearly 13 inches greater than it is at Windsor. The mean annual snowfall at Windsor is 64.5 inches and at Avon is 101.4 inches. The frost-free period at Windsor, based on 50 years of record, is an average of 134 days (Canada Dept. of Transport, Met. Branch, 1956, 1967).

For high yields from fruit and vegetable crops, optimum soil moisture conditions should be maintained during the growing season. Soil moisture deficits during this season, therefore, are of concern to farmers who grow cash crops. Soil moisture is a function of many variables including precipitation, potential evapotranspiration, vegetation, soil infiltration capacity and soil moisture storage capacity. Potential evapotranspiration, that amount of water which would be evaporated and transpired if continuously available, has been calculated for Falmouth using Thornthwaite's (1948) method. These values along with the monthly precipitation have been used to calculate Holmes and Robertson (1959) moisture budgets (Fig. 3) for a sandy loam soil at Falmouth for the years 1965-1968 (calculations were made with a computer program by Freeze, 1967). The Holmes and Roberston (1959) moisture budget considers the fact that evapotranspiration decreases below the potential rate as soil moisture storage is utilized. A moisture surplus is assumed to contribute to groundwater recharge and direct runoff. During the months that have a deficiency of precipitation, the moisture deficit is the monthly average, in inches, below soil field capacity (the amount of water retained in the soil after gravity drainage). Soil moisture deficits during the growing season for loam, clay loam and silty clay loam soils are usually less than that for sandy loam soils because the finer-grained soils have larger moisture storage capacities. If mean monthly precipitation at Falmouth could be depended upon, a significant soil moisture deficit would develop on the average only during the month of August. It is apparent from figure 3, however, that large soil moisture deficits may also develop in July and September in some years. Consequently supplemental irrigation should be available to assure maximum crop yields. A discussion of irrigation requirements for various crops and soil types is beyond the scope of this report. For detailed in-

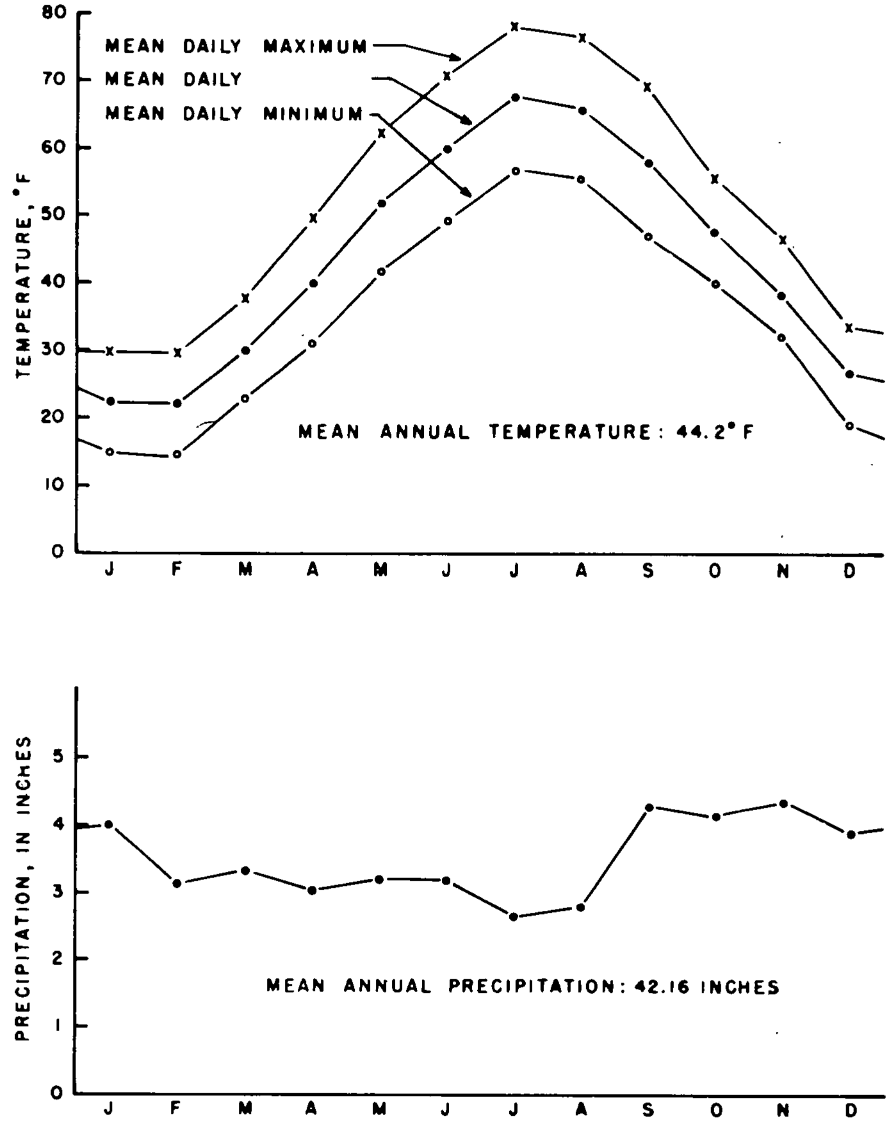

FIGURE 2. Mean temperature and precipitation distribution at Windsor (based on 17-year mean values, Canada Dept. of Transport, Met. Branch, 1967).

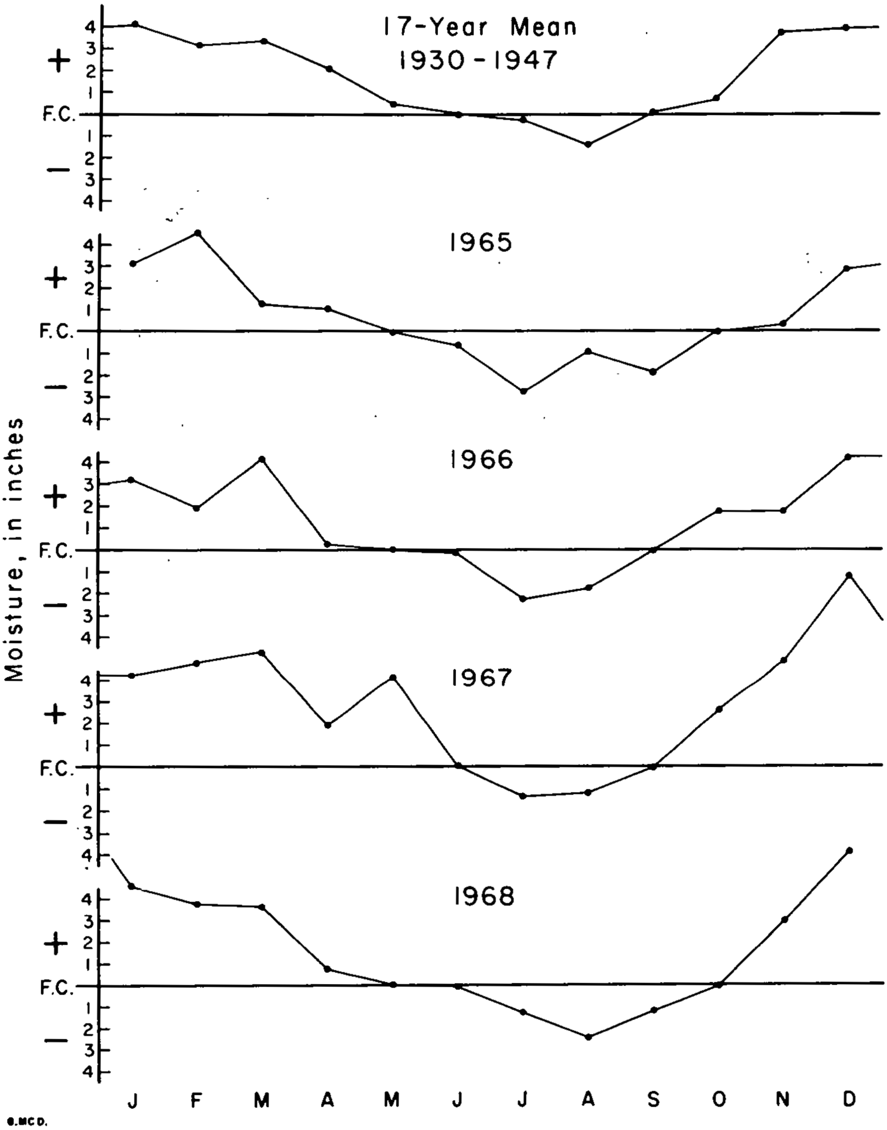

FIGURE 3. Moisture budgets for a sandy loam soil at Falmouth for the years 1965–1968 and mean values for a 17-year period at Windsor (+ = moisture surplus, - = moisture deficit, F.C. = field capacity).

formation refer to pertinent Canada Department of Agriculture publications (e.g. Coligado, Baier, and Sly, 1968).

Land Survey System

The grid system used by the Nova Scotia Department of Mines for locating wells in the province is based partly on the National Topographic System. Under this system, Canada has been divided into numbered primary quadrangles, each 4° latitude by 8° longitude; the map-area is included in primary quadrangle 21. The quadrangles are divided into 16 sections identified by letters, and the sections are divided in turn into 16 standard topographic map sheets identified by numbers. The map-area comprises the eastern half of the Wolfville map (21 H 1) and the northeastern part of the Windsor map (21 A 16). For location by mining tract and mining claim, each map is divided into four reference maps with the letters A, B, C and D. Each reference map consists of 108 mining tracts subdivided with letters into 16 claims, each containing about 40 acres. Figure 4 illustrates the location of a hypothetical well in claim 21 H 1 A 47 H.

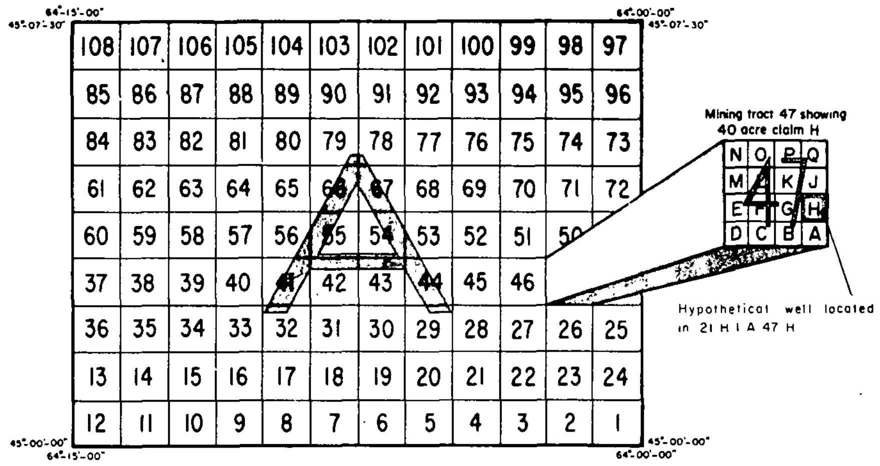

FIGURE 4. Reference map 21 H 1 A subdivided into mining tracts.

Previous Investigations

Aside from climatic records, information on the hydrology of the Windsor-Hantsport-Walton area includes water-well drilling records filed with the Nova Scotia Department of Mines since the inception of the Well Drilling Act of 1965, a groundwater survey of the Falmouth area (Hennigar, 1965), a groundwater investigation for the Town of Hantsport (Bourgeois, 1963), and pertinent information in Trescott (1968). In the Annapolis-Cornwallis Valley, discharge records are available from the Water Survey of Canada for the Annapolis River at Wilmot (since October 1963), the South Annapolis River at Millville (since February 1965), and Sharpe Brook at Lloyds (since November 1966).

Bell (1929) discussed the early contributions to the geology of the area in his memoir describing the stratigraphy and paleontology of Carboniferous rocks in the Horton-Windsor district. Among the more significant contributions are those of Lyell (1843) who recognized that the Windsor and Horton rocks are pre-Coal Measure and Lower Carboniferous in age, and Dawson (1848) who assigned a Triassic age to the sandstones and shales overlying Carboniferous and older rocks around the Bay of Fundy. In his "Acadian Geology", Dawson (1855 and later editions) synthesized the geology of Nova Scotia and included a geologic map of the province. Powers (1916) made the first regional stratigraphic study of Triassic rocks in Nova Scotia and included the Triassic sandstones and conglomerates in the map-area in the Wolfville sandstone member of his Annapolis Formation. Fletcher (1905 and 1911) and Fletcher and Faribault (1909) mapped most of the area at a scale of 1 inch to 1 mile. The Windsor sheet (Fletcher and Faribualt, 1909) is still the only large scale geologic map available for the area between north latitudes 44°55' and 45°00'.

Recent work used as reference material for this report includes three memoirs: one emphasizes the fauna and flora of the Horton Group (Bell, 1960) and the others include descriptions of the geology of the Wolfville map-area (Crosby, 1962) and the Shubenacadie-Kennetcook map-area (Stevenson, 1959). Boyle (1963) studied the geology of the Walton-Cheverie area and made a map which illustrates the structural complexity of Carboniferous rocks in this area. The Wolfville member was raised to formational status and was included along with all other Triassic rocks in the Maritime Provinces in the Fundy Group by Klein (1962). A map of 21 A by Taylor (1962) and the Geological Map of Nova Scotia (Weeks, 1965) were also used during compilation of the map included with this report.

Dawson (1893) made early observations on the glacial features of Nova Scotia. Goldthwait's (1924) description of the physiography of Nova Scotia includes discussions of geomorphic evolution and effects of glaciation in Nova Scotia. Soil maps (Cann, Hilchey, and Smith, 1954; and Cann, MacDougall, and Hilchey, 1965) were used as a guide to the distribution of surficial deposits.

Field Work and Maps

Field work, carried out during the summer of 1968, included mapping of surficial deposits, location of wells reported in selected driller's logs, and collection of groundwater samples for chemical analysis. Mapping was done in the field on aerial photographs (flown 1966) at a scale of 1:24,000 and was transferred to 1:50,000 National Topographic Series maps. Chemical analyses of groundwater samples were made at the Nova Scotia Agricultural College, Truro.

Acknowledgments

This investigation, under the direction of John F. Jones, Chief, Groundwater Section, Nova Scotia Department of Mines, was jointly sponsored by the Canada Department of Regional Economic Expansion (under authority of the Agricultural and Rural Development Act which, until recently, was administered by the Canada Department of Forestry and Rural Development) and the Province of Nova Scotia.

Jim Gunn provided very able assistance in the field. Mapping and gathering of basic data were facilitated by the co-operation of the water-well drillers and many of the residents of the Windsor-Hantsport-Walton area. The hydrogeologic map and illustrations in this report have been drafted by D. Bernasconi and his staff of the Cartographic Division, Nova Scotia Department of Mines.

GEOLOGY

Introduction

This section of the report provides background information for the discussion of hydrostratigraphic units. Description of the bedrock units includes their distribution, thickness, lithology, structural relations, metamorphism and age. Surficial deposits are grouped according to their origin and composition. The structural deformation and geomorphic evolution which are responsible for the present distribution of geologic units are summarized at the end of the section.

Rock Units

Meguma Group

From Ellershouse westward to Fall Brook, South Mountain is formed primarily on rocks of the Meguma Group. The older Goldenville Formation (Lower Ordovician or earlier) underlies most of this area. It is composed of "... alternate bands of quartzite and slate, with slate forming an estimated 5 per cent of the whole" (Stevenson, 1959, p. 11). Regional metamorphism has made these rocks dense and hard, and has produced a distinct cleavage in the rocks where they have been tightly folded. In adjacent Kennetcook map-area, Stevenson (1959, p. 11) assumed the Goldenville Formation has a minimum thickness of 16,000 feet.

The younger Halifax Formation (Lower Ordovician) is present in a syncline south of Ellershouse where the formation's thickness is estimated to be a maximum of 4,000 feet. Stevenson (1959, p. 13) described the Halifax Formation as forming

> "... a monotonously uniform succession of rusty weathering, sericitized, banded slates and argillites, commonly interbedded with relatively narrow bands of siltstones and chloritic, dense quartzites, the quartzites forming probably less than 5 per cent of the whole."

All of these rocks are metamorphosed and steeply folded; the northeast trending cleavage, however, rarely coincides with bedding (Stevenson, 1959). The Meguma rocks were probably deposited in a shallow, gently subsiding marine basin (Stevenson, 1959; and Crosby, 1962), and "the Goldenville-Halifax contact is probably conformable" (Smitheringale, 1960, p. 7).

Granite

South Mountain adjacent to Windsor Forks and Upper Falmouth is formed on the Southern Nova Scotia Batholith of Late Devonian age (Smitheringale, 1960, p. 25). This batholith is typically composed of a quartz-feldspar-biotite granite (often including large phenocrysts of feldspar) which intruded the lower Palaeozoic metamorphic rocks. Contact-metamorphic effects are common in the intruded rock in a zone near the contact with the granite (Crosby, 1962).

FIGURE 5. Basal Horton Bluff Formation sandstones, grits, and conglomerates along Harding Brook (21 H 1 B 51 E; for scale note pick with 2-foot handle in center of photograph).

Horton Group

The early Mississippian Horton Group forms the limbs of a northeast-trending synclinorium in the map-area. Horton rocks unconformably overlie older Palaeozoic rocks and are conformable with rocks of the overlying Windsor Group. Bell (1929) divided the Horton Group into two formations: the Horton Bluff Formation and the Cheverie Formation, but Crosby (1962) was unable to map these formations as separate units because of the scarcity of outcrops and marker beds. Bell (1929, 1960) described the Horton Bluff Formation as consisting of three members: a basal member which includes feldspathic quartz conglomerate, grit, and sandstone interbedded with micaceous, arenaceous shales and quartzitic sandstones (Fig. 5); a middle member consisting mostly of argillaceous and areno-argillaceous shale interbedded with thin quartzitic sandstones and a few thin calcareous beds (test holes 259 and 260*, Appendix A, probably penetrate this member); and an upper member which includes feldspathic, medium- to coarse-grained sandstone and minor feldspathic conglomerate interbedded with arenaceous, micaceous shale and quartzitic sandstone. Bell (1960) gave the thickness of these units as: basal member 600± feet; middle member 1,850 to 3,250+ feet; upper member 400± feet; Horton Bluff Formation 3,500 to 5,000 feet.

The overlying Cheverie Formation consists of reddish coloured siltstones interbedded with greenish grey, micaceous, arenaceous siltstones and shales, argillaceous dark shales, and basal feldspathic and arkosic fine conglomerates (Fig. 6); the formation is 625+ feet thick (Bell, 1960, p. 13).

FIGURE 6. Basal Cheverie Formation feldspathic conglomerates and red shales south of Blue Beach (21 H 1 A 82 M).

Crosby (1962, p. 35) summarized the evidence for the fluvial origin of the Horton Group as the

> "lenticular nature of strata, current ripple-marking, crossbedding, channelling phenomena and other properties ... [such as] abundant plant remains, commonly in situ in fossil soil beds."

---

* Department of Mines test holes are distinguished on Map 1 from drilled wells, dug wells, and springs which were assigned Index Numbers.

Bell (1929) suggested that the ostracod-bearing shales found in the middle member and the associated beds with fish remains found in the middle and upper members of the Horton Bluff Formation are of lacustrine origin, probably within a fluvial environment.

Windsor Group

The central part of the Hants-Colchester lowland in the map-area is underlain by rocks of the late Mississippian Windsor Group. Bell (1929, p. 45) summarized the nature of rocks in the Windsor Group.

> "In composition, the Windsor series comprises a well-defined unit of marine deposits, laid down under peculiarly restricted environmental conditions. There are present four or five distinct stages of calcium sulphate deposits (gypsum and anhydrite), probably none of which is less than 40 feet thick, separated by varying amounts of brick-red argillaceous shale, fossiliferous limestone, thin magnesian sandy shales and oolites. In amount the gypsum may make up almost 20 per cent of the total volume, with red shale 55 per cent and calcareous beds 25 per cent."

Bell (1929, p. 46) subdivided the Windsor Group into two zones and five subzones based on fossil assemblages. Subzone A was subsequently divided by Weeks (1948) into the Macumber Formation, which is characterized by a light grey, fine-grained, well-bedded limestone, and the Pembroke Formation, which consists mainly of a reddish limestone conglomerate. Crosby (1962) was able to distinguish these basal formations only in the northeastern part of the map-area. Elsewhere, Windsor rocks are undivided because of the scarcity of outcrops and marker beds.

Boyle (1963) stated that the Macumber Formation ranges in thickness from 0 to 25+ feet. The Pembroke Formation is up to 100 feet thick and the undivided Windsor rocks are probably about 2,000 feet thick (Crosby, 1962).

The limestones and shales were deposited in a normal marine environment, but the marine basins became more restricted during deposition of evaporite deposits. Crosby (1962, p. 41) suggested that the calcium sulphate beds were deposited originally as anhydrite and were later converted, in part, to gypsum.

Scotch Village Formation

The early Pennsylvanian Scotch Village Formation underlies the Centre Burlington-Scotch Village-Cogmagun River area and probably is present along the eastern boundary of the map-area south of Walton. This formation conformably overlies rocks of the Windsor Group and is characterized by a well-sorted, fine- to medium-grained, cross-laminated, buff weathering, friable sandstone (see Fig. 7) which constitutes about 80 per cent of most outcrops in the Kennetcook map-area (Stevenson, 1959, p. 32). The remaining strata, constituting less than 10 per cent of the outcrops in the Wolfville map-area, are red and grey shales and siltstones (Crosby, 1962). The sandstones are composed mostly of subangular to subrounded quartz grains but may contain up to 20 per cent feldspar; calcite grains are present in some samples, but calcite is not a cementing material (Stevenson, 1959). The evidence that rocks in this formation were deposited in a fluvial environment includes cross-laminations, current ripple marks, channelling phenomena, and abundant plant remains in many of the sandstones and shales (Crosby, 1962). Crosby (1962) estimated that the formation may be more than 800 feet thick.

Wolfville Formation

Rocks of the Upper Triassic Wolfville Formation are found in a narrow belt along much of the Minas Basin shore from Cambridge Cove to Whale Cove. These rocks dip from 5 to 7° to the northwest and overlie deformed rocks of the Horton Group with angular unconformity. The formation is estimated to be a maximum of 100 feet thick in the vicinity of Stubborn Head.

The Hants Facies of the Wolfville Formation is found in the map-area. It consists mostly of roundstone conglomerates and medium- to coarse-grained, poorly sorted, cross-bedded sandstone (see Fig. 8) interbedded with a few claystones (Klein, 1962). The sandstones in the map-area are typically a low-rank greywacke derived from the pre-Triassic rocks to the south. The Hants Facies - based on the lithology and on primary structures such as cut-and-fill, cross, and channel stratification, current ripply marks and mud cracks - was deposited in a transition zone between alluvial fan and flood plain environments (Klein, 1962).

Surficial Deposits

Glacial Till

Glacial till is the surficial deposit that mantles most of the map-area. Its composition and thickness strongly reflect the nature of the underlying bedrock. Thin, sandy tills including numerous boulders are present in areas underlain by quartzite and granite. Relatively thick, heavier-textured tills, usually reddish-brown in colour and sometimes including beds of stratified drift, mantle slate terrane and areas underlain by rocks forming the Hants-Colchester lowland. Drumlins are present in places although few have the classic elongate shape. Several drumlins composed of till and mantled by lenses of stratified drift may be

FIGURE 7. Crossbedded fine- to medium-grained sandstones in the Scotch Village Formation near Center Burlington (21 H 1 A 54 M).

FIGURE 8. Crossbedded and poorly sorted Wolfville Formation sandstones and conglomerates near Pembroke (21 H 1 D 94 M).

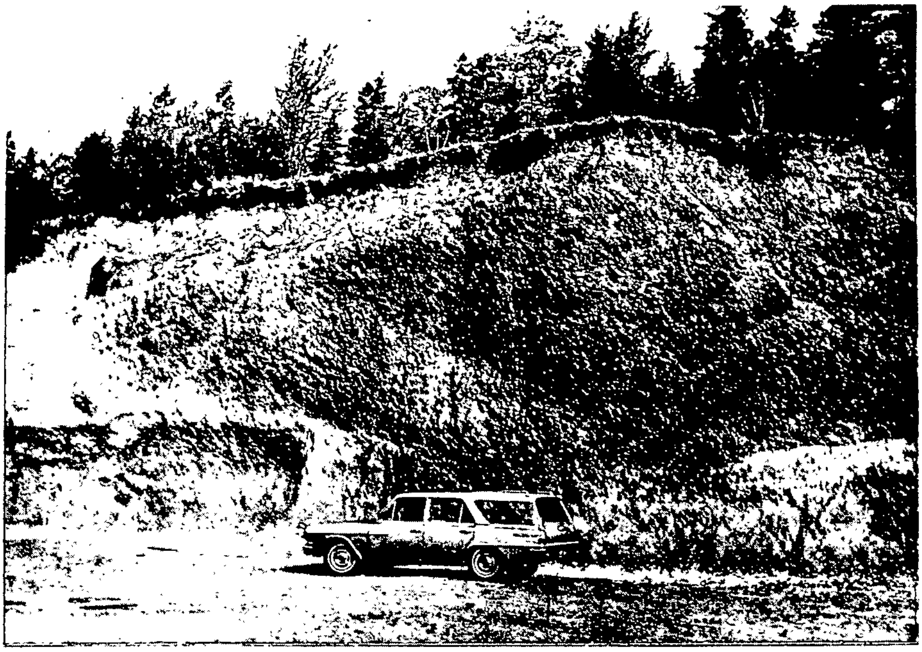

FIGURE 9. Drumlin composed of till and a lens of stratified drift east of St. Croix (11 D 13 C 84 C).

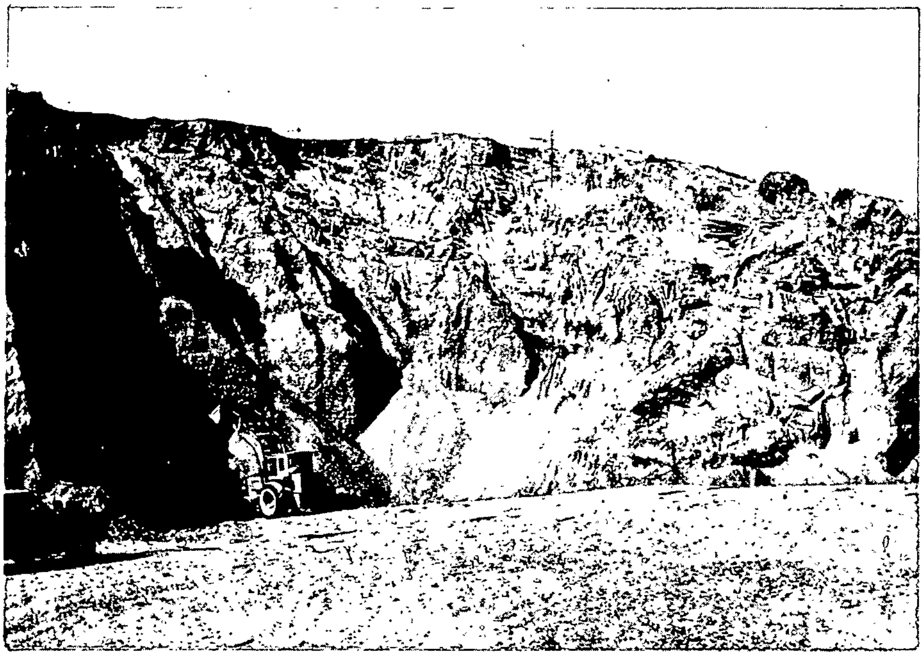

FIGURE 10. Gravel pit in kame at Windsor Forks (21 A 16 D 39 N).

seen east of St. Croix along Thumb Hill Creek (Fig. 9). (For the distribution and composition of various till deposits, see Cann, Hilchey, and Smith, 1954; and Cann, MacDougall, and Hilchey, 1965.) Glacial drift, which includes till and stratified drift, has an average thickness of 40 feet in the area underlain by Carboniferous rocks (the average is based on drillers' logs for fifty test holes and wells selected from Appendices A and B). The maximum reported thickness of drift is 182 feet in a well (Index No. 106) at Lower Burlington.

Glaciofluvial Deposits

Glaciofluvial deposits in the map-area can be classified mostly as ice-contact stratified drift. Such deposits, principally kames and a few eskers, were "... built in immediate contact with wasting ice" (Flint, 1957, p. 136). Kames are mainly irregular hills of stratified sand and gravel, but they usually include some till and interbedded silt and boulders in varying amounts depending on the nature of the source material (Fig. 10). A few sand and gravel deposits at Johnson Cove, Mutton Cove and Pembroke along the Minas Basin shore may actually be raised beach deposits, but the writer did not spend the time required to determine their precise origin. Although only one esker (a subglacial channel deposit) is shown on Map 1, several of the other elongate sand and gravel ridges mapped as kames might be more correctly described as eskers.

Kame deposits in the map-area are mostly small features scattered along stream valleys. The largest deposits, which cover an area up to a square mile, are found adjacent to French Mill Brook at Falmouth and adjacent to the Avon River at Windsor Forks. Figure 10 illustrates the size of the kames at Windsor Forks; the deposits in the Falmouth area are more than 50 feet thick in places (see logs, Appendix A).

Outwash is "... stratified drift that is stream built... beyond the glacier itself" (Flint, 1957, p. 136). The two sand and gravel deposits mapped as outwash at Upper Burlington and Windsor have only poor to fair sorting (Fig. 11). Considering their location on dykeland, these deposits may originally have been kames which have subsequently been beveled by the tides. In the Falmouth area, a few outwash (or ice-contact) deposits up to 60 feet thick are found interbedded with or underlying glacial till (e.g., see test holes 262 and 263, Appendix A; and Index No. 71, Appendix B). The extent of these deposits is unknown, but they are commonly found in the subsurface adjacent to stream valleys, particularly in areas where kames and eskers are exposed at the surface. Department of Highways borehole logs, for example, reveal that sand and gravel deposits underlie the St. Croix River dykeland near the junction with Thumb Hill Creek to a depth of 50 feet below sea level.

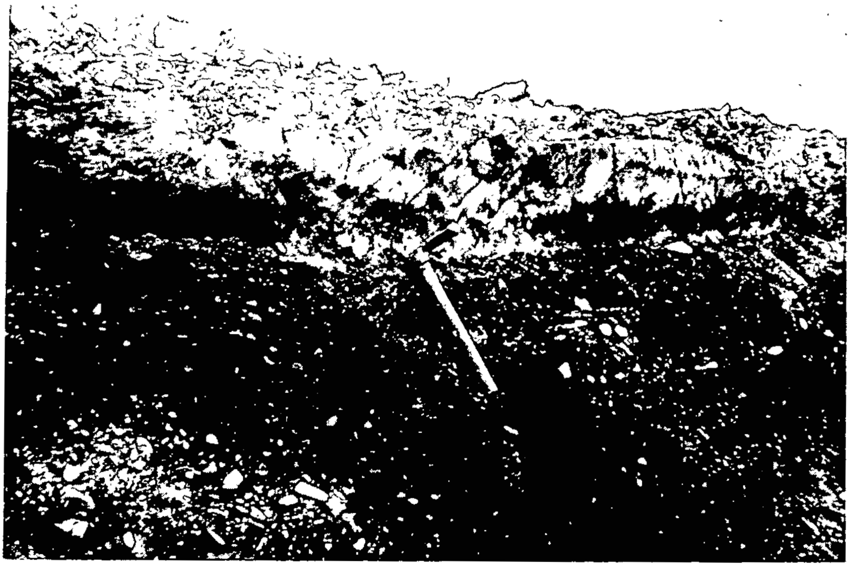

FIGURE 11. Estuarine clay over poorly sorted outwash sand and gravel near Windsor (21 A 16 D 102 P).

Stream Alluvium

Alluvium is being deposited on the flood plains of many streams and rivers above the zone of tidal influence. Most of the alluvial deposits are fine textured, consisting of clay, silt and fine sand. In a few places, for example along Lebreau Creek, alluvium may overlie deposits of stratified drift.

Peat and Muck

Glaciation left much of the drainage in the area, particularly in the lowland but also on South Mountain, deranged. Many shallow lakes soon became swamps and subsequently were filled with deposits of peat and muck.

Dykeland, Salt Marsh and Tidal Flat

Since the sea stabilized at its present level, tidal flats have formed along the estuarine part of the Avon River and its tributaries, partly in response to the large tides experienced in this area (mean tidal range at Avonport, for example, is 39.3 feet). Many of these areas have been reclaimed by dyking to form rich farm land. Active deposition of silt and clay continues on the salt marsh and tidal flat beyond the protection of the dykes and on former dykeland where the dykes have been breached (e.g. along the lower reach of the Cogmagun River).

Structure

> "The Wolfville map-area is structurally complex as regards the Palaeozoic rocks. This is especially apparent in those localized areas where exposures are common, along parts of the shore and in some stream valleys. The general scarcity of outcrops and marker horizons greatly hinders the tracing of structural features inland, particularly in the areas underlain by Windsor and Horton strata. The structural picture of the Windsor Group is further complicated by expansion effects of sulphate beds during hydration and probably by salt solution effects as well. The structure of the Horton Group is more complex to the northeast. On the west side of Avon River, Horton strata have been thrown into sharp-angled recumbant folds and are displaced by innumerable faults [Fig. 12].
>
> "Major folds conform to the northeast Appalachian trend. Pre-Carboniferous folds were accentuated by forces that folded the Carboniferous strata, but fold axes of both correspond. Although many of the minor folds conform to the regional northeast trend, there are many east-west folds as well. Except for minor irregularities, Triassic rocks dip gently to the northwest" (Crosby, 1962, p. 52).

The bedrock geology shown on Map 1 has been generalized from previous work in structurally complex areas. Most of the faults, many of which are assumed, have not been extended beyond the area where they affect geologic boundaries. The reader is referred to the reports listed on Map 1, particularly Boyle (1963), for structural details.

The largest fault in the map-area is the Butler Hill fault (Bell, 1929, p. 12) which probably extends from west of Avon River at Windsor Forks eastward along an undulating line through St. Croix and into the Kennetcook map-area (Stevenson, 1959, p. 40). This high-angle, reverse fault thrusted pre-Windsor rocks against Windsor strata (Bell, 1960, p. 19). "The stratigraphic throw

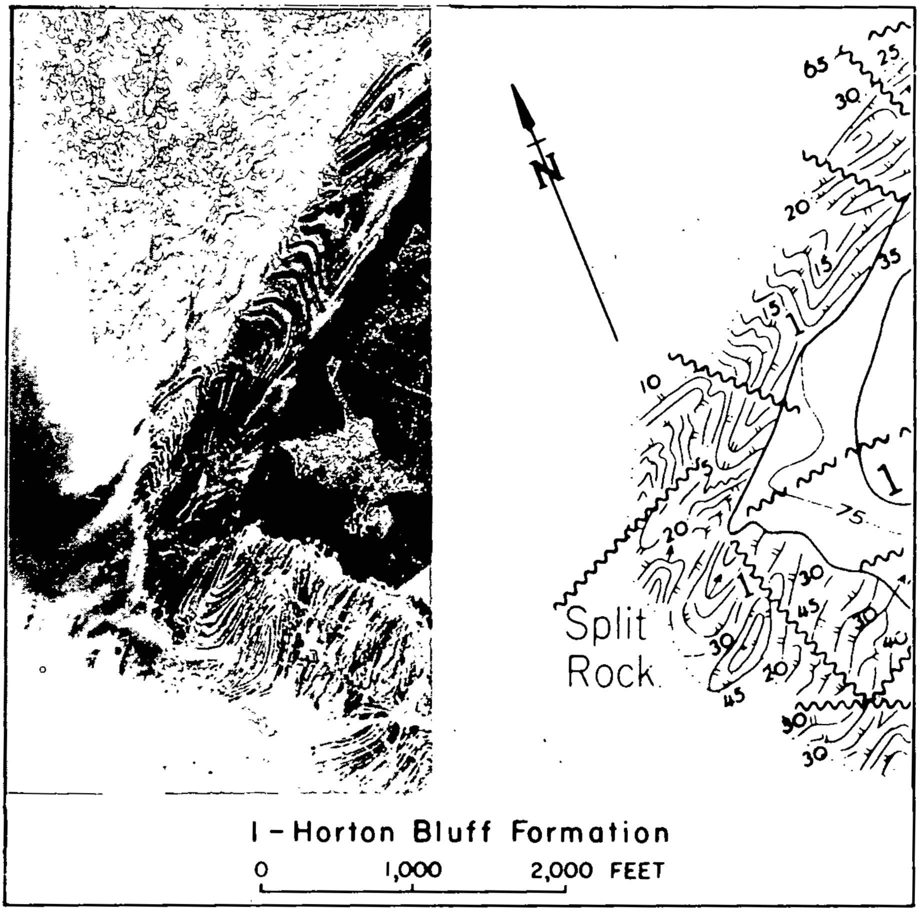

FIGURE 12. Aerial photograph of the shore at Split Rock and Boyle's (1963) interpretation of the geology.

varies in amount at different places and in Windsor district certainly exceeds 1,000 feet and probably is in the neighborhood of 2,000 feet" (Bell, 1929, p. 12). Drillers' logs for wells in this area are sometimes useful for defining the boundary of the fault. For example, a well (Index No. 39) at Three Mile Plains is in gypsum from 105-173 feet and in granite from 173-184 feet. Several wells along Panuke Road and Highway 1 at Five Mile Plains are in [Horton] sandstone in an area assumed by Fletcher and Faribault (1909) to be underlain by Windsor rocks. This interpretation is supported by the chemical quality of groundwaters samples in this area (see discussion on page 37). Consequently the boundaries shown on Map 1 have been modified from those shown on Fletcher and Faribault's (1909) map in this area.

Geomorphology

The South Mountain highland is all that remains in the map-area of a peneplain formed throughout eastern North America in the Cretaceous. Following uplift of this surface in the late Cretaceous or early Tertiary, a second erosional cycle reduced the area underlain by Carboniferous rocks to a gently undulating lowland (Goldthwait, 1924). During some periods in this erosion cycle, major streams in the region eroded their valleys to depths of 150 or more feet below the present mean sea level (information from Dept. of Mines test holes near Cornwallis River and from Dept. of Highways test borings, Allain and Bear Rivers, Annapolis County). Although stratigraphic information is lacking, bedrock near the mouth of the Avon River estuary probably has been eroded to a similar depth.

Local topographic features in the Windsor area are partly bedrock controlled and partly the result of glacial erosion and deposition. Of particular interest is the sink-hole topography developed on gypsum and anhydrite beds of the Windsor Group. Differential solution of these evaporite deposits by infiltrating precipitation and circulating groundwater has produced sinks and left residual hills which are sometimes mistaken for drumlins (Goldthwait, 1924, p. 52). Where kame deposits are associated with gypsum terrane, it is sometimes difficult to distinguish on aerial photographs the knob and kettle topography typical of kames from pitted gypsum topography.

During ablation of the last ice sheet, the sea, for a time, was above its present level in this region. Evidence for this is found adjacent to the map-area in the Gaspereau Valley where silt and clay, probably of estuarine origin, are found to an altitude of 67 feet, and an outwash delta, probably deposited during this period, is present at Walbrook (Trescott, 1968, p. 33). The sea returned approximately to its present level during post-glacial regional uplift. Drowned forests at Grand Pré, Avonport, and Hantsport indicate that the area underwent a slight submergence (at least 33 feet) about 4,000 years ago (Goldthwait, 1924, p. 158; and Lyon and Harrison, 1960). Some of this submergence may have been the result of an increased tidal range (Lyon and Harrison, 1960, Borns and Swift, 1966). Sea level in the last few thousand years, however, has been relatively stable (Goldthwait, 1924, p. 173).

HYDROSTRATIGRAPHIC UNITS

Introduction

A hydrostratigraphic unit is a group of geologic materials which have similar water-storage and water-transmitting properties. The coefficient of storage is defined as the volume of water the aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface (Theis, 1935). Under water-table conditions, the coefficient of storage with time approaches the specific yield, the ratio of the volume of water that can be obtained by gravity drainage to the total volume of the material (common specific yield values range from 0.01 to 0.2). Under artesian conditions, water released from storage is derived chiefly from compression of the aquifer skeleton and secondarily from expansion of the water itself (common values range from 0.0001 to 0.001).

A material's water-transmitting property is termed its permeability. In this report the coefficient of permeability is defined as the rate of flow of water through a one square foot cross-section of aquifer under a gradient of one foot per foot. The permeability of an aquifer times its thickness is the aquifer's coefficient of transmissibility which in this report has the units of imperial gallons per day per foot (gpd/ft.).

The aquifer coefficients of transmissibility and storage, which can be determined from properly run pumping tests, can be used to calculate pumping rates suitable for long-term production and to predict drawdown in the aquifer after given pumping periods. In the map-area, pumping-test data are available for three test wells in Horton rocks and one screened well in glaciofluvial deposits.

For geologic units where no pumping test data are available, well yields have been estimated mainly from drillers' bail tests. Well yield is defined as the discharge which can be sustained for a period of one to twenty years utilizing the full available drawdown. Drillers' tests are most useful if drawdown at the end of the test has been recorded. If information on the drawdown is not available, the discharge rate during the test should be used judiciously as an estimate of the long-term well yield because this rate is often a function of the equipment used and may range from considerably less than to much greater than the long-term well capacity. Furthermore, the tests are usually of short duration (0.25 to 2 hours).

In this report the median well yield in gallons per minute (gpm) per hundred feet of saturated section has been estimated for rock units where fracture permeability predominates. In such rocks the few wells that produce relatively large amounts of water make the average yield much greater than the median yield (Davis and Turk, 1964; and Snow, 1968). Consequently, the median is a better measure of the yield which can be expected from wells drilled at random in fractured rocks (Snow, 1968).

Bedrock Hydrostratigraphic Units

Slate, Quartzite and Granite

Slate, quartzite and granite are dense rocks which, for all practical purposes, yield no water in the unfractured slate. These rocks, however, are all fractured and consequently have some capacity to store and transmit groundwater. The most numerous fractures in slate follow their northeast-trending cleavage, making permeability in these rocks strongly anisotropic. Quartzite and granite commonly are cut by three sets of nearly orthogonal fractures (see Fig. 13) which make permeability in these rocks less anisotropic. Permeability

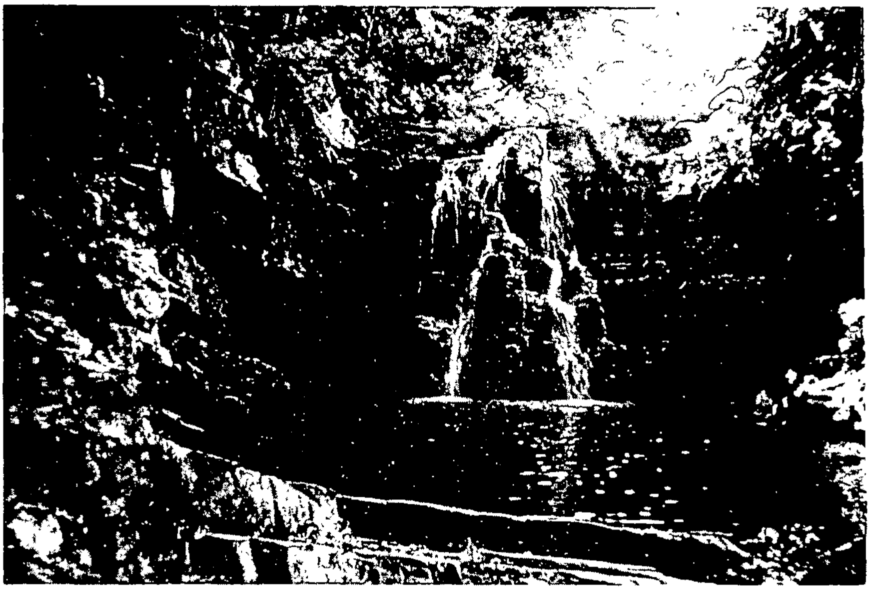

FIGURE 13. Joints in Goldenville Formation quartzite along Fall Brook (21 A 16 D 67 H; falls are 31 feet high).

in fractured igneous and metamorphic rocks is mostly near the surface where the release of confining pressure by erosion of the overlying rock has allowed fractures to open and where weathering has increased the aperture of many fractures. The zone of slightly weathered rock (which is commonly found in Nova Scotia below the glacial drift and above fresh rock) may be ten times more permeable than the unaltered rock (Davis and DeWeist, 1966, p. 320). Drillers, however, often case this zone of 'broken rock' even though water in this zone could be recovered through screens or even perforated casing. From this zone to a depth of about 300 feet the permeability of crystalline rock decreases about three orders of magnitude (Snow, 1968). This is due mostly to the decrease in fracture openings (a result of increasing confining pressure) because permeability varies with the cube of the aperture (Snow, 1968, p. 177). The practical limit of exploration for water in these rocks, therefore, is 250 to 300 feet even though significant water-bearing fractures may be found in places at much greater depths (see Meinzer, 1923; Davis and Turk, 1964; and Snow, 1968).

The median yield of wells in the upper hundred feet of saturated slate and quartzite is estimated to be 1.5 to 2 gpm (based on records for five wells in Appendix B). Where pumping is intermittent (e.g. for domestic demand), pumping at rates of 4 to 5 gpm for a well with a saturated thickness of 100 feet can be sustained for short periods while storage in the well is utilized. No records are available for wells drilled in granite (except for Index No. 39 where granite was reported below gypsum) in the map-area. The writer (Trescott, 1969) estimated that wells in granite in the Western Annapolis Valley yield an average of 2 gpm per hundred feet of saturated section. The yield of wells in granite and metamorphic rocks ranges from less than 0.25 gpm (which Snow, 1968, classified as a failure) to 40 or 50 gpm. For example, a well 86 feet deep in granite near Lawrencetown, Annapolis County, was tested at 45 gpm (Trescott, 1968, p. 41), and a well 250 feet deep in slate at Kejimkujik Park was rated at 50 gpm after a 72 hour pumping test.

Horton Group

The Horton Group contains good sandstone aquifers, but in places where wells penetrate mostly shale, the yield is poor. The grits and sandstones are often silicified to quartzites (Crosby, 1962, p. 31), making their intergranular permeability small compared to their fracture permeability. The permeability in finer-grained siltstones and shales is entirely in fractures and is usually much lower than that in the coarser-grained rocks.

Pumping tests were conducted on three test wells in Horton rocks. The two wells near Falmouth (test holes 259 and 260, Appendix A) penetrated mostly dark grey shale and siltstone with interbeds of fine-grained sandstone. The pumping tests of these wells were difficult to interpret because of variations in the discharge. Consequently the calculated aquifer transmissibilities, 40 gpd/ft. for test hole 259 and 60 gpd/ft. for test hole 260, are only estimates. The long-term yields of test holes 259 and 260 were estimated to be 10 and 15 gpm (2 and

3 gpm per hundred feet of saturated section), respectively. The larger yield of test hole 260 maybe related to the more numerous fine-grained sandstones penetrated in this hole.

A test well (Index No. 80) drilled for the Town of Hantsport was 465 feet deep and penetrated mostly black shale with some sandstone below the casing which was driven to 90 feet (Bourgeois, 1963). The transmissibility of these rocks, based on data from a 36-hour pumping test, is 410 gpd/ft. The long-term yield of this well was calculated to be 100 gpm or about 27 gpm per hundred feet of saturated section. A detailed lithologic log (if one were available) might explain the relatively high yield of this well compared to the yield of test holes 259 and 260 at Falmouth.

The median yield for wells drilled primarily in shale, based on the yields of test holes 259 and 260 and on drillers' bail tests, is estimated to be 2 to 3 gpm per hundred feet of saturated section. The median yield for wells drilled primarily in sandstone is estimated to be an order of magnitude greater (20 to 30 gpm per hundred feet of saturated section). Yields per hundred feet of saturated section will range from less than 1 gpm in some shale areas (e.g. Index No. 142) to 50 or more gpm where wells penetrate Horton sandstones, grits and conglomerates (e.g. Index Nos. 11 and 123).

Windsor Group

Fracture permeability predominates in rocks of the Windsor Group and ranges from very low in shales to very high in limestone and gypsum where solution channels are present. The only data available on the nature of aquifers in these rocks are the drillers' records in Appendix B. From these records, it is estimated that a well drilled at random in Windsor rocks will yield about 10 gpm per hundred feet of saturated section. Yields range from less than 1 gpm in shale and in dense gypsum and limestone where solution channels are absent (e.g. see Index Nos. 3 and 59) to over 100 gpm where solution channels are present. For example, a well (Index No. 57) only 90 feet deep in limestone at Falmouth is pumped at 60 gpm, and a well (Index No. 39) at Three Mile Plains which penetrates mostly gypsum was tested at 60 gpm.

The most important aquifers in the Windsor Group are the limestones because they sometimes contain water of satisfactory quality and are usually fairly productive. A fractured limestone conglomerate in the Pembroke Formation is illustrated in figure 14. Note that the fracture openings shown in this picture are probably at least an order of magnitude larger than they would be in a well at a depth of 50 feet (see Bianchi and Snow, 1969). This formation, based on the log of a well (Index No. 129) at Cheverie, may yield 30 gpm per hundred feet of saturated section. The relatively good quality of water from this well is discussed in the next section.

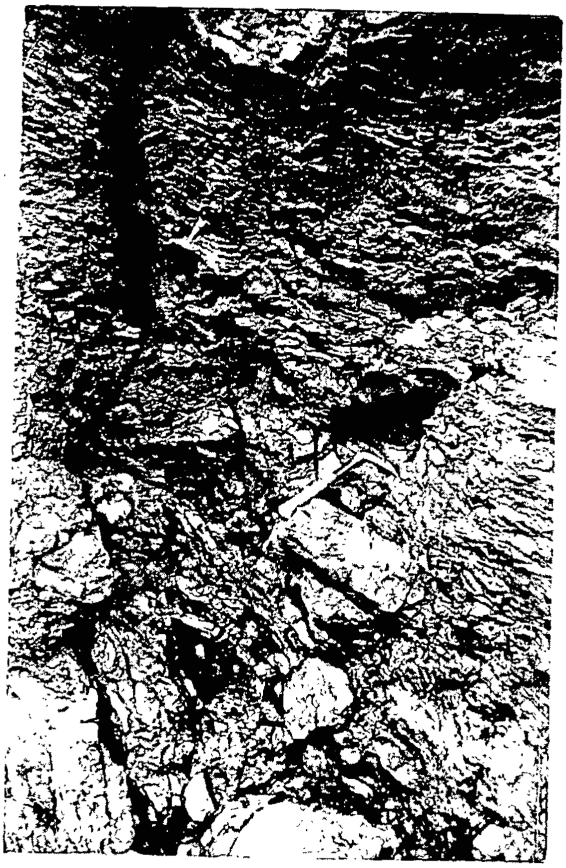

FIGURE 14. Fractured limestone conglomerate in the Pembroke Formation at Cheverie (21 H 1 D 34 A; hammer is in a vug lined with calcite crystals).

Scotch Village Formation

Permeability in sandstones of the Scotch Village Formation may be primarily in fractures, but Stevenson (1959, p. 32) noted that this rock is generally very porous and friable. Thus intergranular permeability may contribute significantly to aquifer transmissibility.

Little is known about the potential of sandstone aquifers in the Scotch Village Formation. It is estimated that the formation penetrated by a well (Index No. 91) at Centre Burlington would yield about 20 gpm per hundred feet of saturated section. The yield per hundred feet of saturated section probably ranges from less than 10 gpm where shale makes up a larger percentage of the section to over 50 gpm, comparable to the best aquifers in the Horton Group.

Wolfville Formation

Clean, well-sorted sandstones and conglomerates in the Wolfville Formation are the best aquifers (except for some glaciofluvial deposits) in the Annapolis-Cornwallis Valley. Wells in this formation yield, on the average, nearly a gallon per minute per foot of saturated section. In the map-area, however, the formation's potential as an aquifer is limited by its thickness and small areal extent. Depending on the saturated thickness, which may be up to 50 feet in a few places, wells in this formation can be completed to yield from 1 to 40 or more gpm. Few, if any, wells have been drilled in the Wolfville Formation within the map-area, but it is apparent that it should be considered a good source for domestic water supplies.

Surficial Hydrostratigraphic Units

Glaciofluvial Deposits

Glaciofluvial deposits are more permeable and store more water per unit volume than any other hydrostratigraphic unit in the map-area. The permeability of these deposits, for example, is from ten to one hundred times greater than that of the best aquifers in the Horton Group, and the storage coefficient often approaches the specific yield of the deposits.

One of the largest glaciofluvial deposits in the map-area is at Falmouth where confined sand and gravel deposits penetrated by test holes 262 and 263 (see logs, Appendix A) are probably connected laterally with the kame field along French Mill Brook. A 24-hour pumping test of a screened well constructed in test hole 262 was used to calculate a transmissibility of 11,000 gpd/ft. for the aquifer at this location. The usefulness of this aquifer, however, is severely limited by the gypsum beds which underlie it (note in Appendix C the deterioration of water quality during the test). Most of the other glaciofluvial deposits in the map-area are also associated with Windsor rocks and consequently contain water of poor quality or would suffer deterioration in quality with time if pumped at a rate of more than a few gallons per minute.

The most promising sand and gravel aquifer in the area is the one at Windsor Forks. The thickness of the deposit is unknown, but it should extent to a depth of at least 50 feet below mean sea level, assuming that the bedrock valley in this location is at least as deep as the one at St. Croix. Although this deposit is limited in extent, the yield of a well field constructed in it would be sustained by infiltration from the Avon River. Up to the present this would have created a water quality problem because the river is affected by the tides in this area. After completion of the Avon River causeway between Falmouth and Windsor, however, a freshwater lake will be formed in this area, assuring a source of good quality water for the aquifer.

Other Surficial Deposits

Except for the scattered glaciofluvial deposits, surficial deposits in the map-area are predominantly fine grained and are poor aquifers. Although intergranular permeability may predominate in the sandy tills which commonly mantle granite terrane, permeability in heavier-textured till and in dykeland deposits is usually confined to joints and thin sandy stringers and lenses.

Probably the majority of domestic water supplies in the map-area are obtained from dug wells constructed in glacial till. Dug wells are usually sufficient to meet domestic demand because of the storage capacity of the well itself, but they may be a problem during dry summers when their storage capacity is reduced due to recession of the water-table.

CHEMICAL QUALITY OF GROUNDWATER

Introduction

The dissolved solids in groundwater depend on the material through which the water passes and on the length of time the water is in contact with these materials. In humid regions like Nova Scotia where groundwater circulation is relatively rapid, groundwaters that pass through rocks of low solubility have a low concentration of dissolved solids. Groundwaters that pass through anhydrite, gypsum, limestone and salt beds, however, usually contain relatively high concentrations of dissolved solids. Sandstones and shales down gradient from soluble rocks in regional or local flow systems also contain poor quality water.

The complete analyses, both in parts per million (ppm) and in equivalents per million (epm), of groundwater samples collected in the Windsor-Hantsport-Walton area are given in Appendix C. Statistical comparisons of the quality of groundwaters among the hydrostratigraphic units were made in a manner described previously by the writer (Trescott, 1968, p. 116). Statements made in the discussion below concerning similarities or significant differences in the chemistry among various units are based on the results of these statistical comparisons. In general, significant differences in chemistry are due to variations in the concentration of calcium sulphate.

The chemical composition of groundwater may be represented on Piper (1944) trilinear diagrams (Figs. 15 to 17). The major cations in groundwater (calcium, magnesium, and sodium plus potassium) are given as per cents of total equivalents per million in one triangular field; in the other, the major anions (carbonate plus bicarbonate, chloride, and sulphate) are given as per cents of total equivalents per million; and the combined chemistry is plotted in the diamond-shaped field. Most groundwaters plotted in figures 15 to 17 may be classified as one of three chemical types: calcium bicarbonate, calcium sulphate, or sodium chloride.

Relationship of Groundwater Quality to Use

The quality of most groundwaters in the Windsor-Hantsport-Walton area is fair to good for most uses. Windsor rocks, however, generally contain waters of poor quality due to the high concentration of calcium sulphate. Salty groundwater is a problem in flat lowlands (e.g. dykeland) where the freshwater lens is relatively thin. Elsewhere, except where deep wells are drilled, salty water is not a problem because the land (and the water-table) rise rapidly away from the sea, insuring a thick freshwater lens over salt water. Even though most of the population in the map-area lives adjacent to the sea, saltwater intrusion (deterioration of water quality due to flow of salt water towards a cone of depression) is not a problem at the present because most wells produce only a few gallons per minute. In the future, however, the possibility of saltwater intrusion near the sea should be considered and evaluated before high capacity wells are installed.

The various ionic constituents and other chemical properties that determine the chemical quality of a water have been discussed elsewhere (see, for example, Hem, 1959; and for a brief discussion, Trescott, 1968). The discussion in this section is limited to those chemical properties that are pertinent to the various uses of the water.

Most groundwater pumped in the Windsor-Hantsport-Walton area is used for domestic purposes. For such use it should meet the mandatory and recommended limits of the U. S. Public Health Service (1962) 'Drinking Water Standards'. The recommended limits for the constituents given in Appendix C are: iron - 0.3 ppm, manganese - 0.05 ppm, sulphate - 250 ppm, chloride - 250 ppm, nitrate - 45 ppm, and total dissolved solids - 500 ppm. Although total dissolved solids were not determined in the analyses, they are approximately related to the specific conductance by

$$\text{specific conductance } (\mu \text{ mhos}) \times 0.55 \simeq \text{total dissolved solids (ppm)}$$

for waters low in dissolved solids. The factor in the equation above, however, may range from 0.5 to 1.0 depending on the concentration and composition of dissolved solids (Hem, 1959, p. 40).

Iron and manganese, which may cause stains and impart an objectionable taste to water, exceeded the recommended limits in several of the water samples. In most cases the samples were contaminated by the corrosive action of high sulphate waters on well casing and plumbing fixtures.

Sulphate, chloride and the total dissolved solids may have adverse physiological effects and give water an objectionable taste if present in excess of the recommended limits. Except for areas underlain by or associated with Windsor rocks, most groundwaters in the map-area contain these constituents in concentrations considerably less than the recommended limits. For example, the average chloride content of fresh water in the map-area, based on 36 samples from Appendix C, is 20 ppm; the sulphate content of 27 samples that were not affected by gypsum and anhydrite beds averaged 21 ppm; and 24 samples low in sulphate and chloride had an average specific conductance of 390 µ mhos. In areas underlain by Windsor rocks, some people use water with an excess of sulphate as drinking water, but the waters very high in sulphate are used only for flushing toilets.

Drinking water containing a nitrate concentration in excess of 45 ppm may be poisonous to small children. None of the groundwaters collected in the map-area contained nitrate in excess of this amount, but a few waters locally have a relatively high concentration of nitrate (e.g. see Index No. 57, Appendix C) which may indicate pollution from septic tanks, barn yards, broken sewer mains and other sources.

For laundry, cooking and heating purposes, the hardness of water is important. Hardness is caused by calcium and magnesium sulphates and carbonates which form insoluble residues with soap and contribute to incrustations. Since the hardness of water for domestic purposes does not become particularly objectionable until it exceeds 100 ppm (Hem, 1959), waters with a hardness less than 100 ppm are considered to be 'soft' (a category which includes some of the waters in the map-area) and waters with a hardness in excess of 100 ppm are 'hard'. All waters sampled from Windsor rocks and overlying till deposits as well as some waters sampled from other units are hard waters.

In classifying water as to its suitability for irrigation, the important factors to be considered are the total dissolved solids, the concentration of some individual constituents, particularly boron, and the relative concentration of sodium. The sodium or alkali hazard is indicated by the soluble sodium percentage (SSP) which is defined by

$$\mathrm{SSP} = 100\ (\mathrm{Na+K}) \ / \ (\mathrm{Ca+Mg+Na+K})$$

or by the sodium adsorption ratio (SAR) which is defined by

$$\mathrm{SAR} = \mathrm{Na} \ / \ \sqrt{(\mathrm{Ca+Mg})/2}$$

where all ions are expressed in epm. The two commonly used methods of classifying irrigation waters (Wilcox, 1948, and Richards, 1954) both use the specific conductance as an indication of the total dissolved solids or salinity hazard. Water is considered to be good to excellent for irrigation when the SSP is less than 40, the SAR is less than 10 and the specific conductance is less than 750 μ mhos (75 mhos x 10^{-5}). Some groundwaters sampled in the map-area fall in this classification. Groundwaters from the zone of diffusion in Horton rocks have a relatively high concentration of chloride. These waters have a SSP in excess of 40, a salinity usually in excess of 750 μ mhos, and are only fair in their suitability for use as irrigation water. Although high sulphate waters generally have a low sodium hazard, their specific conductance often exceeds 2,000 μ mhos, making these waters poor to unsuitable for irrigation use due to the salinity.

Industrial water quality criteria range widely depending on the use. For example, water exceeding the quality of commercial distilled water is sometimes required for boilers of very high pressure; fish plants, on the other hand, often need large amounts of sea water (for a comprehensive discussion of water quality criteria, see McKee and Wolf, 1963). Except for the groundwaters high in sulphate, many groundwaters in the Windsor-Hantsport-Walton area are of such a quality that they require little, if any, treatment for many industrial uses.

Groundwater is particularly suited for use as cooling water because of its relatively constant temperature. Many of the field temperatures given in Appendix C reflect some heating of the water in the distribution system before sampling. Most groundwaters in the map-area should have a temperature between 46 and 49°F because near-surface groundwater temperatures generally exceed the mean annual air temperature by 2 to 3°F (Collins, 1925).

Chemical Quality of Groundwater in the Hydrostratigraphic Units

Slate, Quartzite and Granite

Groundwaters in slate, quartzite and granite are usually calcium bicarbonate waters low in dissolved solids and hardness (see Fig. 15). Waters in metamorphic rocks are often slightly acid and sometimes contain iron and manganese in objectionable amounts (Trescott, 1968). Of the three water samples

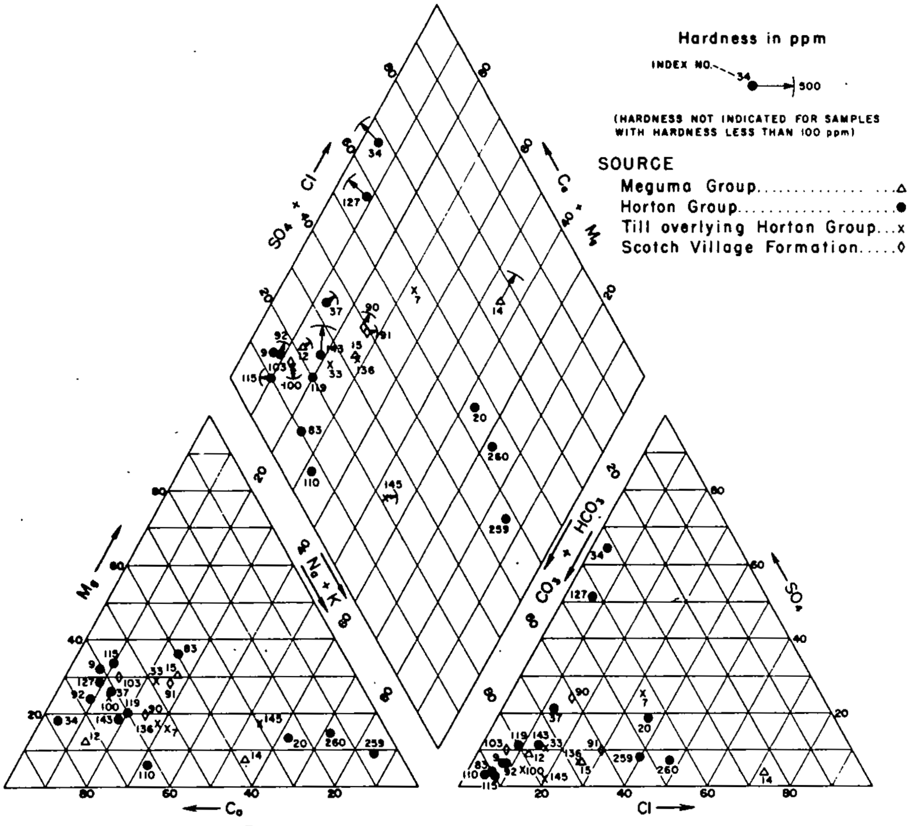

FIGURE 15. Trilinear plot of chemical analyses of water samples collected from the Meguma and Horton Groups, Scotch Village Formation, and till overlying the Horton Group.

collected from these rocks in the map-area, the two from quartzite may be considered typical. The sample from slate (Index No. 14), however, contained an unusually large amount of sodium chloride (289 ppm chloride). The bottom of this well, which is only 94 feet deep, is at least 150 feet above sea level, negating the possibility that the well penetrates the zone of diffusion below the freshwater lens. The high chloride content of this water, therefore, is probably due to pollution, possibly from salt used on the roads in the winter.

No waters from granite were sampled in the map-area, but analyses of samples collected from granite west of the map-area have shown that these waters are usually of good quality although some of them are moderately hard (see analyses in Trescott, 1968 and 1969).

Horton Group

The Horton Group in many places contains good quality calcium bicarbonate groundwaters (low in dissolved solids and hardness, usually low in iron, and generally slightly basic), but there are numerous exceptions (see Fig. 15). Waters with relatively poor quality (generally due to a high concentration of sulphate) are usually found where Horton rocks are down-gradient from Windsor rocks in the groundwater flow system (e.g. see Index Nos. 34 and 127). In a few places groundwaters in Horton rocks contain a relatively large amount of bicarbonate hardness. In some areas this is due to a close association with limestones in the Windsor Group, But in others, such as the water from a well (Index No. 143) at Pembroke, the bicarbonate content is due to the solution of calcareous beds within the Horton Group. No significant difference was found between the composition of waters from till overlying the Horton rocks and waters from the bedrock.

Three of the samples were collected from wells which penetrate the zone of diffusion between fresh and salt water. A well (Index No. 20) at St. Croix is only 78 feet deep, but it is close enough to the St. Croix estuary to yield water with a chloride content of 88 ppm. Test holes 259 and 260, although over two miles from the Avon River estuary, were deep enough (more than 400 feet below sea level) to penetrate the zone of diffusion in this area (see analyses, Appendix C). The third sample from test hole 260, a naturally flowing artesian well, was taken more than a month after the pumping test. Evidently the water flowing from this well is coming mostly from the upper producing zones because the chloride content was only half of that found in the samples taken during the pumping test when a mixture of waters from all producing zones was being discharged. Note the plot of these chloride waters in figure 15.

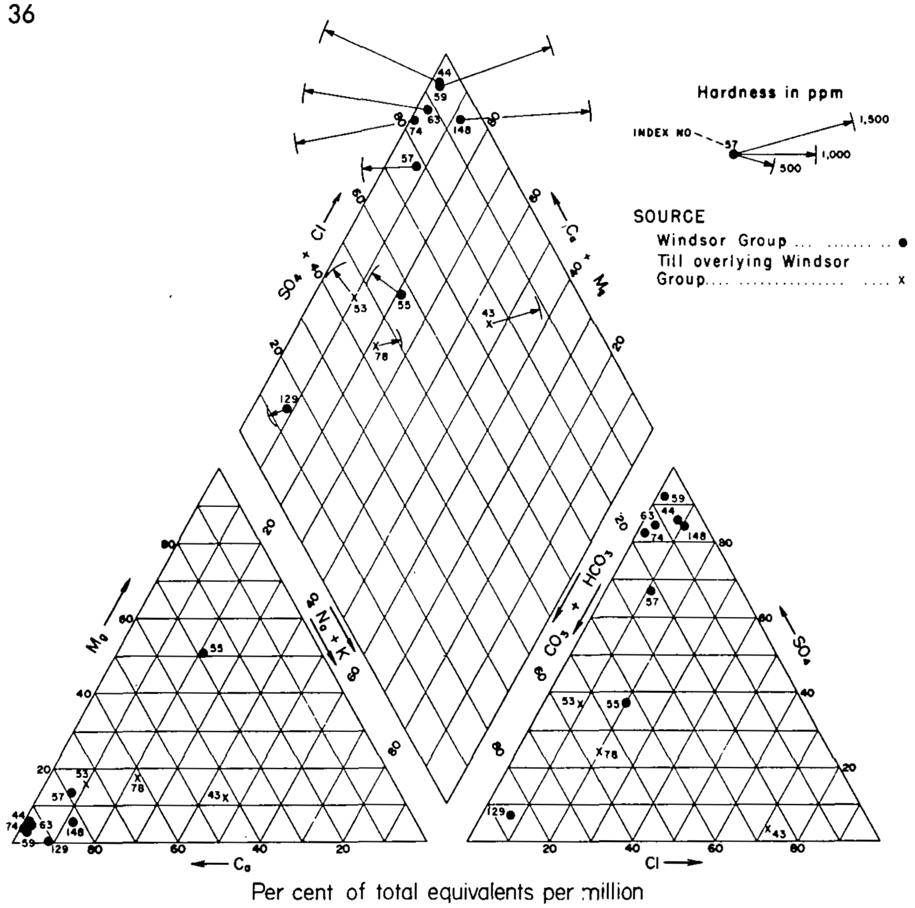

FIGURE 16. Trilinear plot of chemical analyses of water samples collected from the Windsor Group and the overlying glacial till.

Windsor Group

Most groundwaters from gypsum, anhydrite and associated shale in the Windsor Group are highly mineralized calcium sulphate waters which have a hardness ranging from 1,400 to 1,600 ppm (Fig. 16). Although water from these rocks probably contains little iron and manganese (e.g. see Index No. 74) most water samples had large concentrations of iron and manganese due to corrosion of well casing and plumbing fixtures. A few wells (Index Nos. 55 and 148) close to the sea yield water with a relatively high chloride content, indicating that they penetrate the zone of diffusion. The chloride content of water from a 52-foot drilled well (Index No. 44) and from a dug well (Index No. 43) at Upper Falmouth, however, cannot be explained in this manner. Neither may the chloride content be attributed to natural salt beds which are unlikely this close to the surface in a humid climate. This is probably another case of pollution from highway salt because the dug well, which contained water with 356 ppm chloride, is located immediately adjacent to the highway ditch. The nearby drilled well contained water with 124 ppm chloride and is probably affected by the same source of pollution even though it is about 100 feet from the highway.

The best quality groundwaters in the Windsor Group are those from limestones. Except for bicarbonate hardness, which may exceed 200 ppm, their quality is equal to or better than that of most groundwaters in the map-area (see Index No. 129). Unfortunately the quality of water in many limestone aquifers is adversely affected by the proximity of gypsum and anhydrite beds. The affect of sulphate on the relative chemical composition and hardness of waters from limestone may be noted in figure 16 where waters from two wells (Index Nos. 55 and 57) in the Windsor area plot between the high sulphate waters from gypsum and the bicarbonate water from the well (Index No. 129) at Cheverie.

In comparison with waters in gypsum, anhydrite and associated shale, water in till overlying Windsor rocks has a significantly lower calcium sulphate content. Nevertheless these waters have a sulphate (and sometimes bicarbonate) hardness ranging from 300 to 600+ ppm for the three samples collected in the map-area. The choice in these areas, therefore, is between poor quality, but potable water from dug wells in till versus water suitable for little more than flushing toilets from drilled wells in the underlying bedrock.

One sample collected from a well (Index No. 37) on Panuke Road near highway 1 had a composition typical of water from Horton rocks although the well is in an area assumed by Fletcher and Faribault (1909) to be underlain by Windsor rocks. The chemical composition of this water lends support to the drillers who claim the area is underlain by sandstone. Nearby at Five Mile Plains, water from a well (Index No. 34) in sandstone contained 230 ppm sulphate. This well is probably in Horton rocks very close to the fault contact with rocks of the Windsor Group. These examples illustrate the possibility of mapping the boundary of Windsor rocks or other formations containing highly soluble rocks in a drift-covered area by analyzing water from wells. Certainly the Butler Hill fault can be mapped by this method because of the number of wells along the fault trace.

Scotch Village Formation

The three waters sampled from the Scotch Village Formation are fair to good quality waters. Water from one well (Index No. 91) had an excessive amount of iron (5.2 ppm) and manganese (0.3 ppm). This may have been due to corrosion of the well casing or to iron bacteria, but it is not an isolated case because another well (Index No. 103) contained an otherwise good quality water except for an iron concentration of 0.59 ppm. The third well (Index No. 90) may penetrate a zone affected by poor quality water in the Windsor rocks because water from this well had, relative to water from the other two wells, a greater sulphate content and hardness. The waters samples from the Scotch Village

Formation are similar in quality to those sampled from Horton rocks, and like waters in Horton rocks, they are typically calcium bicarbonate in composition (see Fig. 15).

Wolfville Formation

No waters were sampled from the Wolfville Formation in the map-area. In the Annapolis-Cornwallis Valley, the Wolfville Formation contains good quality groundwaters low in dissolved solids and hardness, usually low in iron and usually slightly basic (see analyses in Trescott, 1968 and 1969).

Glaciofluvial Deposits

The waters sampled from sand and gravel deposits in the map-area range from calcium bicarbonate to calcium sulphate in composition (Fig. 17). Many

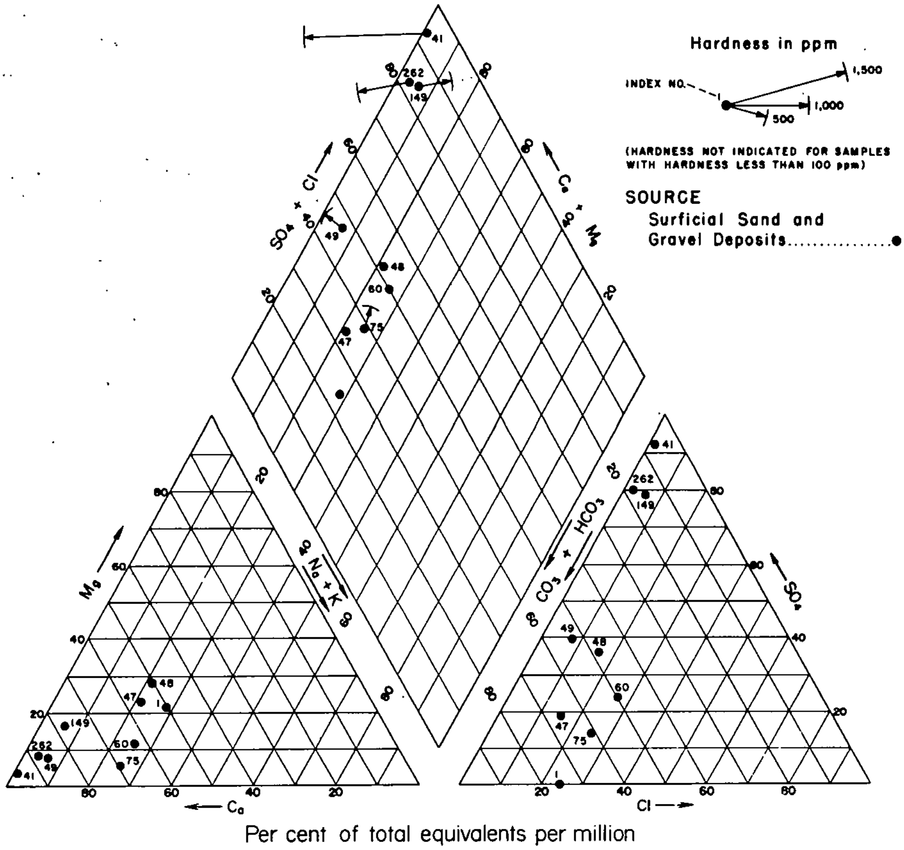

FIGURE 17. Trilinear plot of chemical analyses of water samples collected from surficial sand and gravel deposits.

of the waters in glaciofluvial deposits that overlie Windsor rocks have a high sulphate content due to the proximity of gypsum and anhydrite deposits (e.g. see Index Nos. 41, 49, 149 and test hole 262). Where the sand and gravel deposits are thick and wells receive water from local recharge, the sulphate content of shallow groundwater is low and the quality is generally good (e.g. see Index Nos. 47, 48 and 60). Even where good quality water is found, the quality may deteriorate with time at the site of a pumping well. Note, for example, the increase in sulphate content from 508 to 599 ppm during the pumping of test hole 262.

The best quality water sampled in the map-area came from a locally recharged sand and gravel deposit at Windsor Forks (see Index No. 1). The quality of water from the main body of sand and gravel at Windsor Forks should be good because the deposit is underlain by Horton rocks and granite. When this aquifer is fully utilized, the quality of water produced will depend, in part, on the composition of water induced from the Avon River.

GROUNDWATER UTILIZATION AND DEVELOPMENT

Introduction

Groundwater, one of the important freshwater resources in the Windsor-Hantsport-Walton area, is utilized at present primarily for individual domestic supplies. The largest groundwater supplies (which yield less than 60 gpm when in use) have been constructed by the Town of Hantsport to supplement its surface water supply and by a few small industries such as McKenzie Creamery in Windsor and the greenhouses in Falmouth. Future growth and development of the area will depend, to a large extent, on the availability of adequate freshwater supplies for municipal, industrial and irrigation use. In this section, therefore, are summarized the possibilities of developing groundwater supplies in rural areas and in the vicinity of the towns and larger communities in the Windsor-Hantsport-Walton area.

Domestic and Livestock Water Supplies

Daily domestic and livestock water requirements have been estimated by Anderson (1963) to be: 100 gallons per day (gpd) for each member of a family, 10 gpd for each horse, 12 gpd for each steer or dry cow, 25-30 gpd for each cow producing milk, 2 gpd for each hog, 1.5 gpd for each sheep and 4 gpd for each 100 chickens. Normally a well that will yield 1 to 3 gpm on a long-term basis is sufficient to meet the average domestic and livestock watering requirements if adequate surface storage is available. With rare exceptions, it should be possible to construct drilled wells with such a capacity anywhere in the map-area. Even in metamorphic and igneous rock terrane where a few wells may be failures, it is often possible to construct a successful well elsewhere on the same property. In many locations dug wells are sufficient to meet domestic requirements.

The chief problem with groundwater supplies in the map-area is not well yield, but water quality in the areas underlain by the Windsor Group. The high sulphate waters produced from drilled wells in these rocks are often unsuitable for domestic use. The only alternative for many people is poor quality, but usable water from dug wells in till. In a few places good quality groundwater can be obtained from dug wells, sand points, and springs in glaciofluvial deposits.

Another problem with rural groundwater supplies is proper well location and construction to avoid pollution of the supply. Very few dug wells are properly constructed to deep out surface runoff or are in the best location to avoid subsurface seepage from septic tanks, barn yards and other sources of pollution such as salt used on the highways in the winter (see the discussion on page 36 of Index No. 43). Drilled wells are no less subject to pollution if they are improperly constructed and located, particularly in areas where the cover of glacial drift is thin and the underlying aquifer has fracture permeability. Rock fractures have - relative to granular materials - little filtering effect on bacteria and other pollutants. Note, for example, the discussion on page 35 of the chloride pollution of a well (Index No. 14) in slate at Ellershouse. In these areas surface casing should have a minimum length of 20 to 25 feet and preferably the annular space between the casing and borehole should be cement grouted. To minimize the chance of pollution of both dug and drilled wells, Department of Public Health regulations and regulations under the Well Drilling Act should be strictly observed.

Irrigation Water Supplies

Irrigation is not a common practice in the Windsor-Hantsport-Walton area. As noted in the introduction to this report, however, optimum soil moisture conditions can be maintained during some periods of the growing season only by supplemental irrigation. Except for watering gardens, irrigation usually requires a water source which will yield several tens to a hundred or more gallons per minute. On the South Mountain highland and in areas underlain by Horton shales and Windsor rocks, natural lakes and ponds created by damming perennial streams are the only sources that will yield water of satisfactory quality and quantity for extensive irrigation projects. The limitation in areas underlain by igneous and metamorphic rocks and Horton shales is quantity because individual wells rarely will yield more than 10 gpm. Wells in Windsor rocks, however, will yield relatively large quantities of water in many places, but the quality generally will be poor to unsuitable for irrigation.

Only in areas underlain by Horton, Scotch Village, and Wolfville sandstones, in a few areas underlain by basal Windsor limestones, and in the glaciofluvial deposits at Windsor Forks can individual wells be expected to yield 100 or more gpm of good quality water for irrigation. Wells in sand and gravel deposits will have to be screened, but it should be possible to complete irrigation wells in the bedrock aquifers as open boreholes because the formations are generally well consolidated. Sand erosion could be a problem, however, in high capacity wells producing from Scotch Village sandstones because these rocks are usually porous and friable.

Municipal and Industrial Water Supplies

The towns of Hantsport and Windsor and the community of Falmouth have central water systems supplied mostly from surface water sources. Existing data on these water-supply systems were summarized by Jones (1967). This section outlines the potential for developing groundwater supplies to support future urban and industrial growth near the towns and larger communities in the map-area.

Falmouth

Falmouth is in a poor location for the development of large groundwater supplies. Wells in the limestone, gypsum and shale beds underlying Falmouth produce poor quality water (see Index Nos. 57, 59, 148). The sulphate beds also affect the quality of water in closely associated glaciofluvial deposits (see analyses for test hole 262). The only wells which produce good quality water in the Falmouth area are the shallow dug wells (Index Nos. 47, 48, 49 and 60) in glaciofluvial deposits along French Mill Brook. Additional dug wells and sand points can be installed to produce fresh water from the upper zone of these deposits for domestic supplies and for watering small gardens, but any large producing well would bring in high sulphate waters from below or from areas where the sand and gravel deposits are in contact with gypsum. It is unlikely that a significant amount of water could be induced into these deposits from French Mill Brook because the flood plain of this stream is composed of silt and clay of low permeability (see logs for test holes 256 and 258, Appendix A).

The pumping of test holes 259 and 260 west of Falmouth along French Mill Brook revealed that the Horton rocks near the contact with the Windsor Group are poor aquifers in this area (see previous discussions in the sections on geology, hydrostratigraphic units and groundwater chemistry).

Hantsport

Hantsport is in the most favorable location of any of the towns and larger communities in the map-area for developing additional groundwater supplies. The groundwater investigation reported by Bourgeois (1963) demonstrated that the flood plains of the Halfway River and its tributaries are poor aquifers, but that wells capable of producing up to 100 gpm may be completed in the Horton bedrock (see discussion of Index No. 80 on page 27). Note, however, that some wells in this area, for example Index No. 84, may produce as little as 5 gpm per hundred feet of saturated section. The scarcity of outcrops and the possibility of bedrock structures that cannot be observed at the surface make it difficult to predict where the best producing zones will be found. In general, it will be necessary to drill test holes and conduct pumping tests to evaluate the water-bearing potential of the Horton rocks in various places and to determine the proper well spacing to minimize interference among wells. The quality of water from the Horton rocks in this area is good except for a few places where groundwaters contain a moderate amount of hardness (see Index Nos. 83 and 92).

The Town of Hantsport is built partly on a glaciofluvial deposit adjacent to the Avon River. Although sand points and small screened wells would produce fresh water, a large supply is probably not possible from this source because of its limitated thickness and its hydraulic connection with the salt water of the Avon River estuary.

Newport-Brooklyn

The communities of Newport and Brooklyn are underlain by rocks of the Windsor Group which contain groundwaters of poor quality (see Index Nos. 63 and 74). Where available, surface water is the best source of supply in this area (note analysis for water from a small lake at Brooklyn, Appendix C). Groundwater of fairly good quality in quantities adequate for individual domestic supplies can be obtained from springs and dug wells in scattered glaciofluvial deposits found in this area (see Index No. 75). Water from dug wells in till has fair to poor quality, but this water is better than that from the underlying bedrock.

Three Mile Plains-St. Croix

The communities of Three Mile Plains, Five Mile Plains, Newport Station and St. Croix straddle the Butler Hill fault. Those who live south of the fault (including most of the residents of Five Mile Plains and St. Croix) are able to obtain adequate amounts of good quality water from the underlying basal sandstones of the Horton Group. Most of the residents of Three Mile Plains and Newport Station reside north of the fault where drilled wells produce high sulphate waters from gypsum, and dug wells in till yield only slightly better quality water. It may be possible to obtain domestic supplies of good quality water from scattered glaciofluvial deposits which are found along and probably underlying the floodplain of Lebreau Creek. Where these deposits are in contact with gypsum, however, they will contain waters with a high concentration of sulphate (see Index No. 41).

A central water system, based on groundwater from wells in the Horton sandstones along the flank of South Mountain, could be constructed for these communities. The sandstones underlying the Panuke Road area, for example, may yield up to 50 gpm per hundred feet of saturated section (see drillers' logs, Appendix B). A proper evaluation of the groundwater potential of this area, however, must be based on a test-drilling program and pumping tests.

Walton

Little is known about the water-bearing potential of the Horton rocks that underlie most of Walton. The average permeability of these rocks may be lower than that found, for example, at Hantsport because of the more intense deformation in the Walton area. As a consequence, the best wells in this area may not yield more than 5 to 10 gpm per hundred feet of saturated section. Individual wells 100 feet deep should yield, on the average, between 1 and 3 gpm.

The area southeast of the central part of Walton is underlain by rocks of the Windsor Group. Wells completed in these rocks may be fairly productive, but the water quality probably will be poor.

Windsor

The Town of Windsor is underlain by Windsor rocks from which only poor quality water can be produced (see Index No. 55). Even if sulphate beds were not present, a well field in this low-lying area probably would be affected by saltwater intrusion. The only good quality groundwater at Windsor is in the scattered glaciofluvial deposits which should yield enough water to dug wells and springs to satisfy domestic requirements.

The most promising aquifer near Windsor is the glaciofluvial deposit which occupies the bedrock valley at Windsor Forks. Although it may not be practical to utilize this distant source as a supplemental supply for the town, this location would be valuable as the site for an industry that requires large amounts of fresh water.

SUMMARY AND CONCLUSIONS

The economy of the Windsor-Hantsport-Walton area, largely a rural area, is based on agriculture, forest products, and on the mining of gypsum, anhydrite and barite. The slow growth of this area could be accelerated if advantage were taken of favorable soil and climatic conditions to expand the agricultural segment of the economy. Much of the area, for example, is mantled by soils which make fair to good crop land. Precipitation is adequate during most of the growing season except during August and sometimes during July and September. This is not a problem, however, if supplemental irrigation is available for use during periods deficient in rainfall. Expanded agricultural activity would justify the establishment of additional food-processing industries in the area.

The South Mountain highland, which forms the lightly populated southern and southwestern parts of the map-area, is formed on early Palaeozoic quartzites and slates that have been intruded by Devonian porphyritic granite. These rocks are overlain unconformably by Carboniferous rocks which form the Hants-Colchester lowland. The Mississippian Horton Group, which forms the limbs of a northeast-trending synclinorium in the map-area, consists mainly of dark grey shales and siltstones but includes basal and interbedded sandstones, grits and conglomerates. Conformably overlying the Horton Group are the gypsum, anhydrite, shale and limestone beds of the Mississippian Windsor Group. Pennsylvanian fine- to medium-grained sandstones and a few interbedded shales of the Scotch Village Formation are found in the center of the synclinorium. Carboniferous rocks are overlain unconformably along the southern shore of the Minas Basin by gently dipping sandstones and conglomerates of the Triassic Wolfville Formation. Bedrock in the area is mantled mostly by glacial till which has an average thickness of 40 feet in the lowland. Glaciofluvial deposits, consisting of kames and a few outwash deposits, are generally small features found mainly along stream valleys.

The water-storage and water-transmitting capacity of most rocks in the map-area is found in their fractures. The fractures in slate, quartzite and granite are more numerous and have larger apertures near the surface due to weathering and release of confining pressure. The decrease in fracture permeability with depth is such that the practical limit of exploration for water is 250 to 300 feet. Most wells 100 feet deep in these rocks yield 1.5 to 2 gpm. A few wells yield less than 0.25 gpm and can be classified as failures, but, at the other extreme, some are known to yield 50 or more gpm.

Shales in the Horton Group, Windsor Group and Scotch Village Formation are poor aquifers. Wells drilled in shale yield from less than 1 to 3 gpm per hundred feet of saturated section.

The best bedrock aquifers in the Windsor-Hantsport-Walton area are the sandstones, grits, and conglomerates in the Horton Group, Scotch Village and Wolfville Formations, and the limestone and gypsum beds in the Windsor Group. Many of the sandstones and conglomerates have mostly fracture permeability; but the coarse clastics in the Scotch Village and Wolfville Formations may have significant intergranular permeability. Yields per hundred feet of saturated section in these rocks commonly range from 20 to 30 gpm but in places may be more than 50 gpm. Yields from wells in limestone and gypsum depend chiefly on the number of solution-enlarged fractures penetrated. Wells in fractured limestone often yield about 30 gpm per hundred feet of saturated section, but well yields range from a few gallons per minute where wells penetrate dense limestone and gypsum to more than 100 gpm where wells penetrate solution channels.

The larger glaciofluvial deposits at Falmouth and Windsor Forks may yield more than 100 gpm to screened wells. Smaller sand and gravel deposits in the area can be used as sources for domestic water supplies but generally are not large enough to yield more than 10 gpm to wells on a long-term basis. Dug wells in till are often sufficient for domestic supplies if adequate storage is provided.

Groundwaters from all hydrostratigraphic units except the Windsor Group and units closely associated with the Windsor Group have a chemical quality that is good to fair for most uses (low in hardness and dissolved solids, a low sodium hazard, and usually low in iron). Groundwaters in most of the area underlain by the Windsor Group have a sulphate hardness (up to 1600+ ppm) that severely restricts their usefulness. High sulphate waters are also found in Horton Group and Scotch Village Formation rocks and in glaciofluvial deposits where they are down-gradient from Windsor rocks in the groundwater flow system. Relatively good quality groundwater can be obtained in areas underlain by Windsor rocks from shallow wells in the upper saturated zone of many glaciofluvial deposits. Where glaciofluvial deposits are absent, poor quality but potable water usually can be obtained from dug wells completed in the overlying glacial till. The only large glaciofluvial deposit that does not overlie Windsor rocks in the map-area is found at Windsor Forks. If this aquifer is fully utilized, the quality of water produced from it will depend largely on the chemistry of water induced from the Avon River.

Wells in the lowlands near the sea may be affected by the zone of diffusion between fresh and salt water. Two 500-foot test holes more than two miles from the sea at Falmouth yielded water containing 80+ ppm chloride (average chloride content of fresh water in this area is 20 ppm). Closer to the sea on the dykeland, even shallow wells may be affected. Of the groundwaters sampled in the map-area, three domestic supplies contained relatively high concentrations of chloride due to pollution from highway salt. These cases emphasize the need for proper well location and construction.

Of the towns and larger communities in the map-area, Hantsport is in the most favorable location for expanding its water system by constructing wells which, in places, may yield 100 or more gpm from aquifers in the Horton Group. The string of communities from Three Mile Plains to St. Croix could construct a central water system based on wells in the Horton sandstones along the flank of South Mountain. Although Walton overlies Horton rocks, it may not be possible to construct wells which will yield more than 5 to 10 gpm per hundred feet of saturated section in this area. Windsor, Falmouth, and Newport-Brooklyn overlie Windsor rocks and have little prospect of finding convenient sources of good quality groundwater.

REFERENCES

Anderson, K. E., (ed.), 1963, Water Well Handbook: Missouri Water Well Drillers Assoc., 281 pp.

Bell, W. A., 1929, Horton-Windsor District, Nova Scotia: Geol. Survey of Canada, Mem. 155, 268 pp.

__________, 1960, Mississippian Horton Group of type Windsor-Horton District, Nova Scotia: Geol. Survey of Canada, Mem. 314, 112 pp.

Bianchi, L., and Snow, D. T., 1969, Permeability of crystalline rock interpreted from measured orientations and apertures of fractures: Arid Zone Research Assoc., Annals of Arid Zone, v. 8, no. 2.

Borns, H. W., Jr., and D. Swift, 1966, A raised Pleistocene terrace in northern Nova Scotia: Paper presented at the Philadelphia meeting, Northeastern Section, Geol. Soc. America.

Bourgeois, P. O., 1963, Ground water investigation, Town of Hantsport: Int. Water Supply Ltd., unpublished report.

Boyle, R. W., 1963, Geology of the barite, gypsum, manganese, and lead-zinc-copper-silver deposits of the Walton-Cheverie area, Nova Scotia: Geol. Survey of Canada, Paper 62-25, 36 pp.

Canada Department of Transport, Met. Branch, 1956, Climatic Summaries - Volume III.

__________________________, 1967, Temperature and precipitation tables for Atlantic Provinces, v. VI, 28 pp.

Cann, D. B., Hilchey, J. D., and G. R. Smith, 1954, Soil survey of Hants County, Nova Scotia: N. S. Dept. of Agri. and Canada Dept. of Agri., Rept. 5, 65 pp.

Cann, D. B., MacDougall, J. I., and J. D. Hilchey, 1965, Soil survey of Kings County, Nova Scotia: N. S. Dept. of Agri. and Canada Dept. of Agri., Rept. 15, 97 pp.

Coligado, M. C., Baier, W., and W. K. Sly, 1968, Risk analysis of weekly climatic data for agricultural and irrigation planning, Kentville, Nova Scotia: Canada Dept. of Agri., Tech. Bull. 19.

Collins, W. D., 1925, Temperature of water available for industrial use in the United States: U. S. Geol. Survey Water-Supply Paper 520-F, pp. 97-104.

Crosby, D. G., 1962, Wolfville map-area, Nova Scotia (21 H 1): Geol. Survey of Canada, Mem. 325, 67 pp.

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

Davis, S. N., and Turk, L. J., 1964, Optimum depth of wells in crystalline rocks: Ground Water, v. 2, no. 2, pp. 6-11.

Dawson, J. W., 1848, On the New Red Sandstone of Nova Scotia: Quart. Jour. Geol. Soc. London, v. 4, pp. 50-58.

____________, 1855, Acadian Geology: London, 1st ed., 833 pp.

____________, 1893, The Canadian ice age, being notes on the Pleistocene geology of Canada, with especial reference to the life of the period and its climatic conditions: privately published, Montreal, 301 pp.

Fletcher, H., 1905, Walton Sheet, No. 74, Hants County, Nova Scotia: Geol. Survey of Canada, Map No. 879.

____________, 1911, Kingsport Sheet No. 84, Hants and Kings Counties, Nova Scotia: Geol. Survey of Canada, Map 13 A.

Fletcher, H., and E. R. Faribault, 1909, Windsor Sheet, No. 73, Hants County, Nova Scotia: Geol. Survey of Canada, Map No. 1037.

Flint, R. F., 1957, Glacial and Pleistocene Geology: John Wiley and Sons, Inc., N. Y., 553 pp.

Freeze, R. A., 1967, Program Potev: Computer Programs in use by the Hydrologic Sciences Division, Inland Waters Branch, Dept. of Energy, Mines and Resources, Canada.

Goldthwait, J. W., 1924, Physiography of Nova Scotia: Geol. Survey of Canada, Mem. 140, 178 pp.

Hem, J. D., 1959, Study and interpretation of the chemical characteristics of natural water: U. S. Geol. Survey Water-Supply Paper 1473, 269 pp.

Hennigar, T. W., 1965, Groundwater survey Falmouth area, Hants County, Nova Scotia: N. S. Dept. of Mines, Groundwater Section open file report, 14 pp.

Holmes, R. M. and G. W. Robertson, 1959, A modulated soil moisture budget: Mo. Weath. Rev. v. 67, pp. 101-106.

Jones, J. F., (ed.), 1967, Nova Scotia water resources study, a compilation of existing data: Atlantic Development Board.

Klein, G. deV., 1962, Triassic sedimentation, Maritime Provinces, Canada: Geol. Soc. Am. Bull., v. 73, no. 9, pp. 1127-1146.

Lyell, C., 1843, Travels in North America in the years 1841-42: 1st. ed.

Lyon, C. J., and W. Harrison, 1960, Rates of submergence of coastal New England and Acadia: Science, v. 132, no. 3422, pp. 295-296.

McKee, J. E., and H. W. Wolf, (ed.), 1963, Water Quality Criteria: The Resources Agency of California, State Water Quality Control Board Publication no. 3-A, 548 pp.

Meinzer, O. E., 1923, The occurrence of ground water in the United States: U. S. Geol. Survey Water-Supply Paper 489, 321 pp.

Nova Scotia Department of Trade and Industry, 1965, Nova Scotia, an economic profile: Econ. Services Div., v. 4, 71 pp.

________________________________, 1967, Nova Scotia Directory of Manufacturing, 87 pp.

________________________________, 1968, Hants County Survey.

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

Powers, S., 1916, The Acadian Triassic: Jour. Geol., v. 24, pp. 1-26, 105-122, 254-268.

Richards, L. A., (ed.), 1954, Diagnosis and improvement of saline and alkali soils: U. S. Dept. of Agri. Handbook no. 60, 160 pp.

Slater, R., 1967, Report on industrial minerals, in N. S. Dept. of Mines, Annual Rept. on Mines.

Smitheringale, W. G., 1960, Geology of Nictaux-Torbrook map-area, Annapolis and Kings Counties, Nova Scotia: Geol. Survey of Canada, Paper 60-13, 32 pp.

Snow, D. T., 1968, Hydraulic characteristics of fractured metamorphic rocks of Front Range and implications to the Rocky Mountain Arsenal well: Quarterly of the Colorado School of Mines, v. 63, no. 1, pp. 167-199.

Stevenson, I. M., 1959, Shubenacadie and Kennetcook map-areas, Colchester, Hants and Halifax Counties, Nova Scotia: Geol. Survey of Canada, Mem. 302, 88 pp.

Taylor, F. C., 1962, Geology, Annapolis, Nova Scotia: Geol. Survey of Canada, Map 40 - 1961.

Theis, C. V., 1935, The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using ground-water storage: Trans. Am. Geophys. Union, v. 16, pp. 519-524.

Thornthwaite, C. W., 1948, An approach toward rational classification of climate: Geog. Review, v. 38, pp. 55-94.

Trescott, P. C., 1968, Groundwater resources and hydrogeology of the Annapolis-Cornwallis Valley, Nova Scotia: N. S. Dept. of Mines Mem. 6, 159 pp.

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

United States Public Health Service, 1962, Drinking water standards: Publication no. 956, 61 pp.

Weeks, L. J., 1948, Londonderry and Bass River map-areas, Colchester and Hants Counties, Nova Scotia: Geol. Survey of Canada, Mem. 245, 86 pp.

____________, (consult. geol.), 1965, Geological Map of the Province of Nova Scotia: N. S. Dept. of Mines.

Wilcox, L. V., 1948, The quality of water for irrigation use: U. S. Dept. of Agriculture, Tech. Bull. 962.

APPENDIX B.

SELECTED WATER WELL RECORDS IN THE WINDSOR-HANTSPORT-WALTON AREA

Water well records given in this appendix are mostly those which include a lithologic log. These wells have been located in the field and are shown on Map 1. The lithologic logs have been used as an aid in mapping the geology and for determining the aquifer from which the well is producing. In cases where the lithologic log is questionable for a well drilled near a geologic boundary, the designation of the aquifer may also be in doubt.

The following abbreviations are used in the table:

Driller

1. Atlantic Coast Well Drilling Ltd.
2. Benedict, Edward H.
3. Central Well Drilling
4. Corkum, George
5. Hall, W. C.
6. Kennedy, O. V. & Son Ltd.
7. Lalonde, R. J.
8. Nodland Well Drilling Co.
9. Trask, S. G. & Sons Ltd.

Use

D = domestic
M = municipal
I = industrial
TH = test hole

Pump or bail test

gpm = imperial gallons per minute
DD = drawdown
REC = recovered to

Lithologic log

cl = clay
sd = sand
gr = gravel
dr = drift
sh = shale
ss = sandstone
sl = slate
bldrs = boulders
qtzite = quartzite

Note: Only records for drilled wells are given in this appendix whereas the Index Numbers also include dug wells and springs. Pertinent data on the dug wells and springs are given on Map 1.

Index No.	Grid Location	Area	Year Drilled	Owner	Driller	Well Depth (ft.)	Water Level (ft.)	Hole Diam. (in.)	Csg. Lgth. (ft.)	Use	Chemical Analysis Appendix C	Pump or Bail Test	Aquifer	Lithologic Log & Remarks
3	21A16D57G	Windsor Forks	1965	Mt. Martock Ski Ltd.	4	210	45	6	102	D		1 gpm DD-30'30 mins. REC-45'12 hrs.	Windsor	0-3 cl; 3-25 loose dry sd; 25-75 cl; 75-97 loose dry sd; 97-110 gypsum; 97-200 ss; 200-215 gypsum
8	21A16D68H	Panuke Rd.	1968	Upshaw, Robert	2	75	15	6	21	D		1 gpm DD-50'1 hr. REC-15'20 mins.	Quartzite (?)	0-15 sd & gr; 15-75 ss
9	21A16D68J	Panuke Rd.	1968	Upshaw, Norman	2	125	60	6	70	D	X	1 1/4 gpm DD-75'1 hr. REC-60'12 mins.	Horton	0-65 cl: 65-125 ss
11	21A16D68Q	Panuke Rd.	1968	Smith, Charles	2	50	12	6	25	D		9 gpm DD-0'1 hr.	Horton	0-18 cl; 18-50 ss
12	21A16D72B	Ellershouse	1949	Manley, Joseph	6	140	12	6	8	D	X	3 gpm	Quartzite	
13	21A16D72B	Ellershouse	1968	Wallace, M. L.	2	95	8	6	12	D		4 gpm DD-40'1 hr. REC-8'10 mins.	Quartzite	
14	21A16D72A	Ellershouse	1965	Mosher, Rodger	4	94	12	6	14	D	X	1 gpm DD-31' REC-12'4 hrs.	Slate	0-10 cl; 10-94 sl
15	21A16D72H	Ellershouse	1966	Harvey, Murray	2	52	6	6	15	D	X	3 1/2 gpm DD-42'5 mins. REC-6'8 mins.	Quartzite	0-4 cl; 4-52 qtzite
16	21A16D72H	Ellershouse	1956	Murphey, Maurice	6	71		6		D			Quartzite	
18.	21A16D74E	St. Croix	1958	Allen, Earl	6	103		4	44	D			Horton	
19	21A16D74C	St. Croix	1958	Whiting, Jack	6	97	5	4	24	D		10 gpm	Horton	
20	21A16D74C	St. Croix	1963	Smith, Paul L.	6	78	0	4	29	D	X	9 gpm	Horton	
21	21A16D74G	St. Croix	1963	Cochrane, William	6	122	6	4	47	D		4 gpm	Horton	
22	21A16D74G	St. Croix	1962	Smith, C. L.	6	120	20	6	72	D		4 gpm	Horton	
23	21A16D74G	St. Croix	1962	Dauncey, Elmer	6	69	13	4	38	D		4 gpm	Horton	
24	21A16D74G	St. Croix	1956	Spence, Ella (Miss)	6	85	15	4	23	D		5 gpm	Horton	
25	21A16D74F	St. Croix		Superline Service Station	6	87	13		42	D			Horton	0-42 bldrs & gr; 42-89 ss
26	21A16D74F	St. Croix		Dawson, Miss	6	65	11		22	D		4 gpm	Horton	0-22 bldrs & gr; 22-65 ss
27	21A16D74E	St. Croix	1953	Marsh, Joseph	6	105	30	6	62	D		1/2 gpm	Horton	
28	21A16D74E	St. Croix	1949	Spence, Grayton	6	145	12	4	38	D		1 1/2 gpm	Horton	
29	21A16D74E	St. Croix	1963	Clark, S. H. (Mrs.)	6	135	over flow	4	66	D		6 gpm	Horton	
31	21A16D75E	Newport Stn.		Gibson, Frank	9	47			37	D		3 gpm	Windsor	gypsum
32	21A16D75E	Newport Stn.		Clark, Graham	9	39			39	D		15 gpm	Windsor	gypsum

Index No.	Grid Location	Area	Year Drilled	Owner	Driller	Well Depth (ft.)	Water Level (ft.)	Hole Diam. (in.)	Csg. Lgth. (ft.)	Use	Chemical Analysis Appendix C	Pump or Bail Test	Aquifer	Lithologic Log & Remarks
34	21A16D76L	Three Mile Plains	1968	Lopes, Mr.	2	55	8	6	20	D	X	15 gpm DD-0'1 hr.	Horton (?)	0-4 cl; 4-55 ss
35	21A16D76L	Three Mile Plains	1968	Pemberton, Edward	2	50	25	6	48	D		5 gpm DD-45'30 mins. REC-25'2 mins.	Horton (?)	0-40 cl; 40-55 ss
36	21A16D77H	Panuke Rd.	1968	Caldwell, Jimmy	2	49	12	6	42	D		3 1/2 gpm DD-0'1 hr.	Horton (?)	0-35 cl; 35-49 ss
37	21A16D77H	Panuke Rd.	1968	Spencer, Mr.		50	6	2	10	D	X		Hortor (?)	ss
38	21A16D77H	Panuke Rd.	1968	Caldwell, Cecil	2	75	20	6	29	D		5 gpm DD-0'1 hr.	Horton (?)	0-20 sd & gr; 20-75 ss
39	21A16D77F	Three Mile Plains		School	6	184	39		103	D		60 gpm	Windsor	0-105 cl & bldrs; 105-173 gypsum; 173-184 granite (?)
41	21A16D78H	Three Mile Plains	1968	Allard, Edna (Mrs.)	2	86	15	6	86	D	X	5 gpm DD-0'1 hr.	Sand and gravel	0-80 cl; 80-86 gr
44	21A16D82D	Falmouth	1963	Lyon, Mr.	1	52	5	6	40	D	X		Windsor	gypsum
46	21A16D86J	Falmouth	1945	Alders, E. W.	6	188	15	6	156	D		4 gpm	Windsor	
50	21A16D89P	Windsor	1948	Rafuse, George	6	52	16 1/2	4	34 1/2	D		12 gpm	Windsor	
55	21A16D103O	Windsor	1960	McKenzie Creamery	6	175	27	6	75	I	X		Windsor	
56	21A16D104P	Falmouth		Fina Service Sta.	6	142							Windsor	0-77 cl, gr & sd; 77-142 ?
57	21A16D104E	Falmouth	1956	Loomer, Ralph	6	90	21	8		I	X	60 gpm	Windsor	limestone
59	21A16D106G	Falmouth	1965	Miner, Mrs.	4	87	17	6	50	D	X	3 gpm DD-30'35 mins. REC-17'16 hrs.	Windsor	0-45 sd; 45-82 gypsum
62	21H1A1H	Brooklyn	1956	Smith, Carl	6	65	20	6	29	D		15 gpm	Windsor	sh?
63	21H1A1G	Brooklyn	1957	MacKay, Raymond	6	208	52	6	53	D	X	40 gpm	Windsor	slate & gypsum
64	21H1A1G	Brooklyn	1968	Lidson, Bob	2	60	12	6	50	D		30 gpm DD-0'1 hr.	Windsor	0-30 cl & bldrs; 30-60 ss
65	21H1A1K	Brooklyn	1968	Blackburn, Lennard	2	70	16	6	63	D		5 gpm DD-20'1 hr. REC-16'4 mins.	Windsor	0-25 cl; 25-70 ss
66	21H1A1F	Brooklyn	1951	Hennessey, E. D.	6	120	60	6		D		2 gpm	Windsor	0-33 cl; 33-120 sh
67	21H1A1E	Brooklyn	1968	Filmore, G.	2	110	16	6	25	D		5 gpm DD-20'1 hr. REC-16'4 mins.	Windsor	0-15 cl; 15-110 ss
71	21H1A17F	Falmouth	1966	Wile Fruit Stand	3	200		4	102	D			Windsor	0-40 cl; 40-102 sd & gr; 102-200 limestone

74	21H1A24D	Brooklyn	1967	Keyser, Dr.	2	53	15	6	53	D	X	30 gpm DD-0'1 hr.	Windsor	0-15 cl; 15-53 ss?
76	21H1A24C	Brooklyn	1956	Municipal School	6	260	70	6	160	D		30 gpm	Windsor	
77	21H1A24B	Brooklyn		Parker, John	6	267	80			D		7 gpm	Windsor	BR - 144
79	21H1A36C	Bishopville	1962	Town of Hantsport	7	40		5		TH			Horton	0-1 topsoil; 1-7 sd & gr; 7-40 cl; 40 sh
80	21H1A35O	Bishopville	1962	Town of Hantsport	7	465	29	7 3/8	89	TH		70 gpm DD-119'27 hrs.	Horton	0-1 topsoil; 1-36 cl with gr; 36-46 sd & cl; 46-86 cl & gr; 86-465 sh
82	21H1A38L	Hantsport	1962	Town of Hantsport	7	56		5		TH			Horton	0-3 topsoil; 3-9 sd & gr; 9-56 cl; 56 sh
83	21H1A39F	Hantsport	1968	Minus Basin Pulp & Paper	2	93	0	5	65	D	X	3 gpm DD-20'1 hr. REC-0'2 1/2 hrs.	Horton	0-2 sd; 2-60 broken ss, 60-93 ss
84	21H1A39O	Hantsport	1962	Town of Hantsport	7	225	30	9		TH		12 gpm	Horton	0-2 topsoil; 2-11 cl; 11-23 ss; 23-96 sh & ss; 96-140 ss; 140-225 sh
90	21H1A53L	Centre Burlington	1966	Card, Ralph	2	95		4	80	D	X		Scotch Village Fm.	
91	21H1A53N	Centre Burlington	1967	Sanford, Ellsworth	2	60	6	5	45	D	X	8 gpm DD-45'6 mins. REC-6'10 mins.	Scotch Village Fm.	0-15 cl; 15-50 ss
92	21H1A57A	Hantsport	1965	Benedict, Bob	3	330		6	230	D	X	8 gpm	Horton	0-80 mud; 120-230 gr & sd
94	21H1A57C	Hantsport	1962	Town of Hantsport.	7	38	3	5		TH			Sand and gravel	0-10 soil, decayed veg. & cl; 10-18 cl; 18-32 sd & gr & bldrs; 32-38 cl & gr
95	21H1A58A	Hantsport	1951	Town of Hantsport	1	450		8	175	M		55 gpm	Horton	ss
96	21H1A58J	Hantsport	1959	Town of Hansport		250		8		M		50 gpm	Horton	
97	21H1A58P	Hantsport	1962	Alley, William	6	246	136			D		15 gpm	Horton	11-38 ss; 38-sh
98	21H1A58O	Hantsport		Haliburton, Harold	6	175	92					5-10 gpm	Horton	125-175 sl
99	21H1A69Q	Lockhartville	1967	Hazlett, Morris	9	72	8	4	22	D		5 gpm DD-52'30 mins. REC-8'20 mins.	Horton	0-18 cl; 18-72 sl
102	21H1A63C	Hantsport	1966	Lutz, W. B.	4	66	25	5	60	D		10 gpm DD-10'1 hr.	Horton	0-25 cl; 25-40 sl; 40-60 gr
103	21H1A67C	Centre Burlington	1965	Card, O	2	85		6		D	X		Scotch Village Fm.	
106	21H1A79A	Lower Burlington		Rafuse, Arthur	6	259	42		140	D		8-15 gpm	Windsor	0-182 cl, bldrs, & gr; 182-259 sh
108	21H1A81Q	Summerville	1966	Harrison, W.	3	150		6	103	D		3 gpm	Horton	0-18 cl; 18-150 sl
109	21H1A81P	Summerville	1965	Terfly, Mr.	3	55		6	10	D		3 1/2 gpm	Horton	0-2 sd
110	21H1A83K	Lockhartville	1965	Reddick, Mr	8	150	60	6	55	D	X	5 gpm	Horton	0-4 cl; 4-54 sl; 54-150 ss

Index No.	Grid Location	Area	Year Drilled	Owner	Driller	Well Depth (ft.)	Water Level (ft.)	Hole Diam (In.)	Csg. Lgth. (ft.)	Use	Chemical Analysis Appendix C	Pump or Bail Test	Aquifer	Lithologic Log & Remarks
112	21H1A84C	Lockhartville	1965	Guptell, B. (Mrs.)	4	102	40	6	102	D		11 gpm DD-22'2 hrs.	Horton	0-35 cl; 35-75?; 75-102 gr
113	21H1A85O	Avonport	1944	Fuller, L. F.	6	144	40	6	53 1/2	D		7 gpm	Horton	
114	21H1A85P	Avonport	1944	Lockhart, Murray	6	103		6	53	D			Horton	
115	21H1A85J	Avonport	1965	Levy, Charley	4	60	8	6	10	D	X	3 gpm DD-3'12 hrs. REC-8'4 hrs.	Horton	0-3?; 3-60 sh
116	21H1A86M	Avonport	1966	Miles, Cecil	4	66	10			D		3 gpm DD-30'12 mins.	Horton	0-3 cl; 3-66 sh
117	21H1A86N	Avonport	1961	Ravine, Vicent	6	215		6	40	D			Horton	
119	21H1A89D	Summerville	1966	Brian, Derick	2	65	10	6	40	D	X	4 gpm DD-50'3 mins. REC-10'4 mins.	Horton	0-35 cl & bldrs; 35-65 sl
123	21H1D10G	Kempt	1968	Crossley, M. (Mrs.)	2	70	15	6	50	D		16 gpm DD-0'1 hr.	Horton	0-30 cl; 30-70 ss
124	21H1D10K	Kempt	1968	Mosher, Raymond	2	90	15	6	64	D		15 gpm DD-0'1 hr.	Horton	0-30 cl; 30-90 ss
126	21H1D16M	Kempt	1968	Girtsen, Harold	2	100	12	6	55	D		5 gpm DD-30'1 hr. REC-12'2 mins.	Horton	0-20 cl; 20-100 ss
127	21H1D16O	Cheverie	1965	Ross, Walter	5	65	9	o	23	D	X	9 gpm	Horton	0-3 cl; 3-23 broken ss; 23-65 ss
129	21H1D33D	Cheverie	1965	Brison, Clifford	5	60	8	6	43	D	X	6 gpm DD-9'3 hrs. REC-8'20 mins.	Windsor	0-36 cl & sd; 36-43 broken ss; 43-60 ss
138	21H1D68M	Cambridge	1966	Lake, R.	3	80	4	6	15	D		2 gpm	Horton	0-7 cl; 7-80 sl
142	21H1D76M	Pembroke	1966	Hiltz, Roy	2	100	50	6	42	D		3 gpm DD-80'5 mins. REC-50'8 mins.	Horton	0-35 cl; 35-100 sl
143	21H1D77A	Pembroke	1966	Mason, B.	3	63	5	6	19	D	X	2 gpm	Horton	0-8 sd; 8-68 sl
148	21A16D104O	Falmouth	1946	MacLellan Bros.	9	154		6	54	I	X		Windsor	

APPENDIX C. CHEMICAL ANALYSES OF GROUNDWATERS IN THE WINDSOR – HANTSPORT – WALTON AREA

Index No.	Grid Location	Area	Depth of Well (feet)	Aquifer	Date Sampled	Analyses in parts per million (ppm)																				Ions in equivalents per million (epm)							
						Ca	Mg	Na	Fe	Mn	SO_4	Cl	NO_3	Alkalinities Phenol-pthalein as $CaCO_3$	Alkalinities Methyl Orange	Hardness	Ignition Loss	Total Dissolved Solids	Suspended Matter	Specific Conductance (mhos. x 10^{-5})	pH Field	pH Lab	Field Temp. °F	Colour	Turbidity	Cations Ca	Cations Mg	Cations Na	Anions SO_4	Anions Cl	Anions NO_3	SSP	SAR
14	21A16D72A	Ellershouse	94	Slate	Sept.4,68	125.0	14.7	201.0	0.07	T	22	289.0	1	8.0	132.0	372.4				139	8.1		54	5	0	5.61	1.21	8.74	0.46	8.15	0.02	54	4.53
12	21A16D72B	Ellershouse	140	Quartzite	Sept.4,68	40.7	3.9	8.0	0.04	T	14	12.4	1	12.0	112.0	117.6				32	7.6		54	5	0	1.83	0.32	0.35	0.29	0.35	0.02	13	0.32
15	21A16D72H	Ellershouse	52	"	Sept.4,68	20.2	8.8	15.1	0.05	T	7	19.5	2	8.0	68.0	86.4				26	7.3		56	< 5	0	0.91	0.72	0.66	0.15	0.55	0.03	28	0.71
9	21A16D68J	Panuke Road	125	Horton	Sept.4,68	25.3	8.0	3.9	0.02	T	8	7.1	T	8.0	112.0	96.0				31	8.5		54	5	5	1.41	0.66	0.17	0.17	0.20		8	0.17
20	21A16D74C	St. Croix	78	"	Sept.4,68	21.6	6.9	60.6	T	T	62	87.9	T	12.0	140.0	82.4				36	8.6		53	5	3	0.97	0.57	2.64	1.29	2.48		62	2.91
34	21A16D76L	Five Mile Plains	55	"	Sept.4,68	97.5	14.2	4.2	0.13	T	230	7.1	T	12.0	108.0	301.6				74	8.3		58	5	1	4.38	1.17	0.18	4.79	0.20		3	0.11
TH259	21A16D107H	Falmouth	420	"	Jan.12,66 4:35 p.m.	7.8	5.1	122.	T	0.02	22.4	80.6	0.20		155.	40.4	25	360	205	64.0		8.3	50	0	77	7.8	5.1	122.0	22.4	80.6	0.2	86	8.4
"	"	"	"	"	Jan.13,66 3:45 a.m.	8.7	4.8	122.	T	0.02	18.4	80.6	< 0.1		158.	41.4	23	364	80	65.9		8.4	50	0	27	8.7	4.8	122.0	18.4	80.6	0.1	85	8.3
"	"	"	"	"	Jan.13,66 3:45 p.m.	8.3	7.6	129.	T	0.02	24.8	85.7	0.1		158.	52.2	9	365	33	65.9		8.3		0	7.7	8.3	7.6	129.0	24.8	85.7	0.1	83	6.9
TH260	21A16D107K	"	500	"	Jan.26,66 3:45 p.m.	18.6	8.4	105.	T	0.1	20.3	105.	< 0.1		134.	81.2	20	356	1595	68.0		8.3	48	0	800.	18.6	8.4	105.0	20.3	105.0	0.1	73	5.2
"	"	"	"	"	Jan.27,66 2:00 a.m.	17.8	10.4	98.	T	0.16	19.5	96.1	0.34		131.	87.1	11	334	282	65.0		7.9	48	0	32.0	17.8	10.4	98.0	19.5	96.1	0.3	61	4.6
"	"	"	"	"	Feb.1,66 9:00 a.m.	13.8	5.8	51.5	T	0.04	19.5	51.	0.38		73.9	58.4	11	198	204	37.4		8.1		0	48.0	13.8	5.8	51.5	19.5	51.0	0.4	65	2.9
83	21H1A39F	Hantsport	93	"	Sept.4,68	18.1	10.	12.4	0.07	T	14.0	14.5	T	28.0	290.0	86.4				66	8.5		55	5	2	0.81	0.82	0.34	0.29	0.55		24	0.58
92	21H1A57B	"	330	"	Sept.3,68	42.3	8.7	6.7	0.18	T	11	10.6	T	16.0	142.0	141.2				38		8.5	51	< 5	1	1.90	0.72	0.29	0.23	0.30		9	0.25
110	21H1A83K	Lockhartville	150	"	Sept.4,68	7.7	0.4	4.4	0.07	T	6.0	7.1	T	16.0	176.0	20.8				42	8.8		56	< 5	0	0.35	0.03	0.19	0.12	0.20		31	0.42
115	21H1A85J	Avonport	60	"	Sept.4,68	34.3	11.8	6.9	0.07	T	7.0	10.6	T	18.0	184.0	134.4				44	8.2		53	< 5	0	1.55	0.97	0.30	0.15	0.30		10	0.26
119	21H1A89D	Summerville	65	"	Sept.5,68	27.7	5.6	10.7	0.01	T	23	14.2	T	20.0	160.0	92.4				46.0	8.5		53	5	6	1.24	0.46	0.47	0.48	0.40		20	0.48
127	21H1D16O	Cheverie	65	"	Sept.5,68	82.2	22.4	14.0	0.24	T	192	19.5	T	8.0	152.0	297.2				76	8.5		53	10	8.	3.69	1.8	0.61	4.00	0.55		9	0.35
143	21H1D77A	Pembroke	63	"	Sept.5,68	101.8	18.6	36.2	T	T	44	40.8	T	22.0	296.0	330.4				83	7.9		61	< 5	7	4.57	1.53	1.57	0.92	1.15		19	0.87
7	21A16D68M	Three Mile Plains		Horton*	Oct.28,65	30.1	5.8	20.9	0.05	T	43	31.9	10	0	73	99.2			T	36		6.7		< 5		1.50	0.477	0.909	0.895	0.900	0.163	31	0.91
33	21A16D76B	Five Mile Plains	Spring	"	Oct.28,65	11.6	4.1	5.9	0.08	T	8	8.9	T	0	58	46.1			T	14		6.5		10		0.578	0.337	0.256	0.166	0.251		22	0.38
100	21H1A62M	Lockhartville	10	"	Sept.4,68	14.1	22.1	8.9	0.04	T	6.0	14.2	T	8.0	118.0	126.0				35	7.9		59	5	0	0.63	1.82	0.39	0.12	0.40		13	0.34
136	21H1D55O	Bramber	10	"	Sept.5,68	42.6	8.2	25.6	0.21	T	14	35.5	T	16.0	120.0	140.0				43	7.0		61	10	8	1.91	0.67	1.11	0.29	1.00		28	0.94
145	21H1D95B	Pembroke	16	"	Sept.5,68	11.2	3.9	22.7	T	T	4	28.4	T	10.0	152.0	44.0				51	8.7		60	5	6	0.50	0.32	0.99	0.08	0.80		53	1.49
37	21A16D77H	Three Mile Plains	50	Horton (?)	Oct.28,65	36.9	9.5	9.4	T	T	34	14.2	T	.0	112	131.3			T	32		7.8		< 5		1.84	0.781	0.408	0.707	0.400		13	0.36
44	21A16D82D	Upper Falmouth	52	Windsor	Sept.4,68	583.2	17.3	8.1	7.40	2	1680.0	124	T	8.0	124.0	526.4				245	8.0		55	160	98	26.19	1.42	0.35	34.99	0.35		1	0.09
55	21A16D103O	Windsor	175	"	Sept.4,68	62.5	66.2	52.4	0.39	T	225	88.1	T	26.0	242.0	428.0				410	8.3		51	15	9	2.81	5.45	2.28	4.69	2.49		21	1.10
57	21A16D104E	Falmouth	90	"	Sept.4,68	230.5	21.8	24.4	3.56	T	490.0	33.7	40.0	10.0	152.0	666.0				142	7.5		51	3.0	31	10.35	1.79	1.06	10.21	0.95	0.65	7	0.41
148	21A16D104O	"	154	"	Sept.6,68	599.3	21.7	100.9	4.90	T	1690.0	150.7	2	8.0	100.0	584.4				310.0	7.7		55	120.0	76.0	26.91	1.79	4.39	35.20	4.25	0.03	12	1.10
59	21A16D106G	"	87	"	Sept.4,68	551.5	8.4	10.8	0.55	3	1550	16.0	T	10.0	112.0	410.4				218	8.3		53	15	2	24.26	0.69	0.47	32.29	0.45		2	0.13

TH = test hole *denotes till overlying this unit T = concentration < 0.01 ppm SSP = soluble sodium percentage SAR = sodium adsorption ratio

CHEMICAL ANALYSES OF GROUNDWATERS IN THE WINDSOR – HANTSPORT – WALTON AREA CONTD.

						Analyses in parts per million (ppm)																				Ions in equivalents per million (epm)							
														Alkalinities							pH					Cations			Anions				
Index No.	Grid Location	Area	Depth of Well (feet)	Aquifer	Date Sampled	Ca	Mg	Na	Fe	Mn	SO_4	Cl	NO_3	Phenol-pthalein 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	SO_4	Cl	NO_3	SSP	SAR
63	21H1A1G	Newport	208	Windsor	Oct.31,68	574.9	20.2	14.6	0.34	0.10	1400	27.5	T	0	210	1518				250	7.5	7.1	55	5	0	28.69	1.66	0.64	29.16	0.78		2	0.16
74	21H1A24D	Brooklyn	53	"	Sept.5,68	560.3	13.4	5.7	0.02	T	660	10.6	T	6.0	132.0	1453.0				219	7.5		52	< 5	7	25.16	1.10	0.25	13.74	0.30		1	0.07
129	21H1D33D	Cheverie	60	"	Sept.5,68	89.5	0	10.6	0.17	T	18	14.2	T	20.0	216.0	223.2				54.0	8.2		57	5	9	4.02	0	0.46	0.37	0.40		9	0.31
43	21A16D82C	Upper Falmouth	12	Windsor*	Sept.4,68	200.4	34.9	261.0	0.08	T	220	356.3	T	8.0	180.0	643.6				170	6.9		55	5	2	9.00	2.87	11.35	4.6	10.05		47	4.48
53	21A16D100E	Wentworth	17	"	Sept.4,68	138.7	16.8	21.2	0.21	T	178	30.1	4.0	24.0	250.0	415.2				94	7.9		56	10	2	6.23	1.38	0.92	3.71	0.85	0.06	10	0.45
78	21H1A27L	Highfield	15	"	Sept.5,68	96.2	17.0	38.8	0.19	T	88	49.6	8	24.0	192.0	310.0				81.0	7.8		54	20	6	4.32	1.40	1.69	1.83	1.40	0.13	21	0.96
90	21H1A53L	Centre Burlington	95	Scotch Village Fm.	Sept.5,68	53.7	11.2	24.7	T	T	68	32.4	T	16.0	164.0	180.0				165	8.6		54	< 5	0	2.4	0.92	1.07	1.42	0.91		23	0.80
91	21H1A53N	"	60	"	Sept.5,68	32.4	8.9	21.3	5.20	0.30	14.0	30.1	T	4.0	84.0	117.2				37.0	7.0		53	110	43	1.45	0.73	0.93	0.29	0.85		28	0.86
103	21H1A67C	"	85	"	Sept.5,68	26.1	7.8	6.0	0.59	T	19.0	8.9	T	12.0	152.0	97.2				44.0	8.4		56	30	6	1.17	0.64	0.26	0.40	0.25		12	0.26
1	21A16D39L	Windsor Forks	3	Sand & gravel	Sept.5,68	6.3	1.6	4.1	0.02	T	T	7.1	T	0	32.0	22.0				10.0	5.7		48	5	0	0.28	0.13	0.18		0.20		29	0.38
41	21A16D78H	Three Mile Plains	86	"	Sept.4,68	577.6	11.7	6.5	1.08	4	1530	10.6	T	8.0	110.0	1489.2				222	8.0		54	25	17	25.93	0.96	0.28	31.87	0.30		1	0.07
49	21A16D88J	Falmouth		"	Feb.10,66	95.6	5.4	7.8	T	T	107	11.7	7.4		147.	261.	30	356		55.5		8.4		0	1.5	6.3	1.6	4.1	0.0	7.1	0.0	6	0.21
47	21A16D88O	"		"	Oct.19,65	16.4	3.9	7.0	0.02	T	18	10.6	T	0	63	57.1			T	18		7.9		< 5		0.818	0.320	0.304	0.375	0.299		21	0.40
48	21A16D88Q	"		"	Oct.19,65	16.8	4.6	8.0	1.42	0.50	53	12.4	T	0	41	61.2			T	22		7.2		15		0.838	0.378	0.348	1.103	0.350		22	0.45
149	21A16D94P	Sweet's Corner	12	"	Sept.4,68	130.3	16.8	12.8	T	T	340	16.0	1	4.0	68.0	394.4				91	5.7		59	5	3	5.85	1.38	0.56	7.08	0.45	0.02	7	0.28
TH262	21A16D105G	Falmouth	117	"	Feb.6,66 9:30 a.m.	231.	14.	9.7	T	0.05	508	6.1	0.25		123.	636.	125	888		115.0		7.9	47	0	3.7	231.0	14.0	9.7	508.0	6.1	0.3	3.2	0.17
"	"	"	"	"	Feb.6,66 9:00 a.m.	255.	16.	10.0	0.05	0.04	583	7.8	0.17		119.	703.	96	1040		123.0		7.9		0	6.1	255.0	16.0	10.0	583.0	7.8	0.2	3.0	0.16
"	"	"	"	"	Feb.7,66 9:00 a.m.	263.	14.	9.6	0.20	0.05	599	7.1	0.23		133.	715.	87	1220		127.0		7.9		0	3.7	263.0	14.0	9.6	599.0	7.1	0.2	2.8	0.16
60	21A16D106K	"		"	Oct.19,65	24.1	2.7	11.7	0.10	0.02	25	17.7	8	0	60	71.2			T	24		7.2		< 5		1.200	0.222	0.509	0.521	0.499	0.129	26	0.60
75	21H1A24C	Brooklyn	Spring	"	Sept.5,68	101.8	4.6	42.2	0.02	T	46	58.5	2	20.0	188.0	273.2				74	6.9		46	< 5	4	4.57	0.38	1.84	0.96	1.65	0.03	25	0.11
	21H1A1D	"	Small lake	Surface water	Sept.4,68	6.1	1.8	1.8	1.80	T	T	3.5	T	0	32.0	22.4				7.0	7.3		60	70	19	0.27	0.15	0.08		0.10			

TH = test hole   *denotes till overlying this unit   T = concentration < 0.01 ppm   SSP = soluble sodium percentage   SAR = sodium adsorption ratio