HYDROGEOLOGY OF THE SALMON RIVER AND ADJACENT WATERSHEDS, COLCHESTER COUNTY NOVA SCOTIA

by

TERRY W. HENNIGAR

Submitted in partial fulfillment of
the requirements for the Degree of

Master of Science

at

Dalhousie University
Halifax, Nova Scotia
September, 1968

DALHOUSIE UNIVERSITY

Date August 20, 1968

Author Terry Wendell Hennigar

Title Hydrogeology of the Salmon River and adjacent watersheds, Colchester County, Nova Scotia.

Department or School Geology

Degree MSc. Convocation - Fall Year 1968

Signature of Author

ABSTRACT

Large fresh water underground reservoirs are found in east-central Colchester County, Nova Scotia in surficial deposits of sand and gravel and bedrock deposits of Triassic age. These underlie the Town of Truro and adjacent areas to the north and east. It appears that individual screened wells with capacities up to several hundred gallons per minute can be developed at many localities in both the surficial and bedrock deposits.

It was found that the sanitary quality of the Salmon River water deteriorated rapidly downstream from Murray whereas the chemical quality did not vary significantly. Groundwater varied in chemical quality with the geology, but excellent quality water (both bacteriological and chemical) can be obtained from bedrock and surficial aquifers in the study area.

A correlation of the factors (elevation and distance) assumed to be affecting precipitation in the area indicated that neither factor showed a significant linear relationship with precipitation. Data from the precipitation gauge network (density 1 gauge per 10 square miles) indicated coefficients of variation ranging from 9 to 24.

Estimates of the hydrologic budgets for the Salmon River and Fraser Brook watersheds were made for the water year 1966-67. Both estimates revealed that about 70 per cent of the precipitation appears as stream runoff, 23 per cent of this as base flow. The degree of utilization of groundwater in the area was determined, by comparing the base flow (70,555 acre-ft.) with the total volume of groundwater utilized (2,835 acre-ft.) and found to be about 4 per cent. Also included in the study is information on water utilization and aquifer hydraulic characteristics.

CONTENTS

Illustrations

Illustrations (continued)

Illustrations (continued)

Maps

Tables

Tables (continued)

Tables (continued)

INTRODUCTION

Purpose and Scope of Investigation

As population and industry increase in the Truro area, new and larger demands for water will emphasize its key role as to man's existance and progress. To date, very little is known about the potential of this area's water resources and thus its potential utilization. More information is required by the Town of Truro which has mainly a surface water supply source which is not entirely satisfactory. Information is required on the subsurface reservoirs which lie under, or near, the town and which are not being fully utilized at present.

The villages of Bible Hill and Salmon River which lie adjacent to the north and east boundaries, respectively, of Truro are considered highly favourable growth areas. At present their water supplies are obtained through privately owned individual domestic wells: the commercial businesses and industries in these villages likewise obtain their own water supplies from groundwater reservoirs. However, it is possible that each of these villages will construct a central water system. Therefore, information will be required on the geology and hydrology to determine the feasibility of developing large capacity wells as a water supply for these areas.

Although the emphasis of the study was placed on the surficial deposits of the area and the quantity of precipitation available to the watershed for distribution to the various components of the hydrologic cycle, some time was devoted to a hydrochemical evaluation of surface water and groundwater from the various bedrock hydrostratigraphic units within the area.

The buried channel at Murray was the subject of an extensive study because of its geologic setting. All outflow from the Salmon River watershed passes this point, and because discharge records exist at this site, it appeared like the most logical place to measure the subsurface outflow. The Murray site is also a favourable area for study because at this point the river is confined to the extreme edge of the flood plain where its channel is controlled by bedrock Triassic outcrops; thus nearly all subsurface outflow is confined to the one broad channel extending to the opposite side of the flood plain. It was in this channel at Murray that test drilling was carried out to determine the cross-sectional area of the channel and to determine the nature of and the hydrologic characteristics of the materials filling it. It is from these data that the volume of water discharged through the channel and out of the watershed area above Murray can be estimated.

General Description of the Area

Location, Access, and Extent of Area

The area under study, near Truro, Colchester County, is located in the north-central part of the Province. Geographically, the area is enclosed between 62°54' and 63°20' west longitude and 45°37' and 45°17' north latitude in the eastern portion of Colchester County.

Most of the area lies in the lowlands at the head of Cobequid Bay which is the easterly extension of the Minas Basin. The area is enclosed in a square roughly

20 miles wide and includes a total watershed area of about 267 square miles in the east central portion of Colchester County. The lowest topographic area being at Truro is thus the area through which all drainage (surface and subsurface) occurs.

Access from the south to the Truro area is available from Halifax, by Highway 2; this road will soon be augmented by the Trans-Canada Highway which is nearing completion and is expected to be ready by 1969. To the west, Highway 2 links the area with Parrsboro and Amherst, while Highway 4 provides a route north over the Cobequid mountains to the Northumberland shore. Eastward the Trans-Canada Highway joins all of eastern Nova Scotia and passes 2 miles north of Truro and eventually will provide a route directly to Amherst. As of March 31, 1962, there were 225.4 miles of paved trunk and county highways in Colchester county and 374.2 miles were classed as graded and gravel surfaced. Total mileage amounted to 1056.8 miles (Nova Scotia Department of Trade and Industry, 1964). Numerous secondary and unpaved roads, logging and other wood roads provide fairly good access to most parts of the map area.

The Town of Truro is also the hub of the railroad system serving Nova Scotia. The main line of the Canadian National Railways from the west enters Truro and divides; the main line going south to Halifax, and a branch line running east to Sydney. The Dominion Atlantic Railway, a branch of the Canadian Pacific Railway links the Annapolis-Cornwallis Valley to Truro.

The nearest commercial airport is the Halifax International Airport, 39 miles south of Truro on Highway 2. Three smaller airfields serve the area; one military airstrip at Debert, 9 miles west of Truro; a public airfield at Trenton about 40 miles east of Truro; and a Nova Scotia Department of Lands and Forests airfield at Shubenacadie, 23 miles south of Truro on Highway 2.

National Topographic System for Location

The National Topographical System which divides Canada into numbered primary quadrangles, each 4^{o} latitude by 8^{o} longitude, is used by the Nova Scotia Department of Mines for location of areas within the Province. The study area is included in primary quadrangle 11. This quadrangle is further divided into 16 larger scale maps such as 11 E 6 on which the town of Truro is located. This map (scale 1:50000) is further divided into 4 parts, each containing 100 mining tracts of approximately 1 square mile each. Mining tracts are further subdivided with letters into 16 mining clains, each containing about 40 acres. Test holes and water sample locations were indicated to the nearest quadrant of the mining claim.

Physiography

The area under study may be divided topographically into three parts; the Cobequid highland, the Carboniferous upland and the Triassic lowland (Fig. 1). Most of the area is an upland underlain by moderately resistant rocks of Carboniferous age. The northern and higher portion belongs to the Atlantic uplands physiographic division of Nova Scotia (Goldthwait 1924) here referred to as the Cobequid highlands and is underlain by resistant rocks of Pre-Carboniferous age. The Triassic lowlands are confined to the immediate area of Truro.

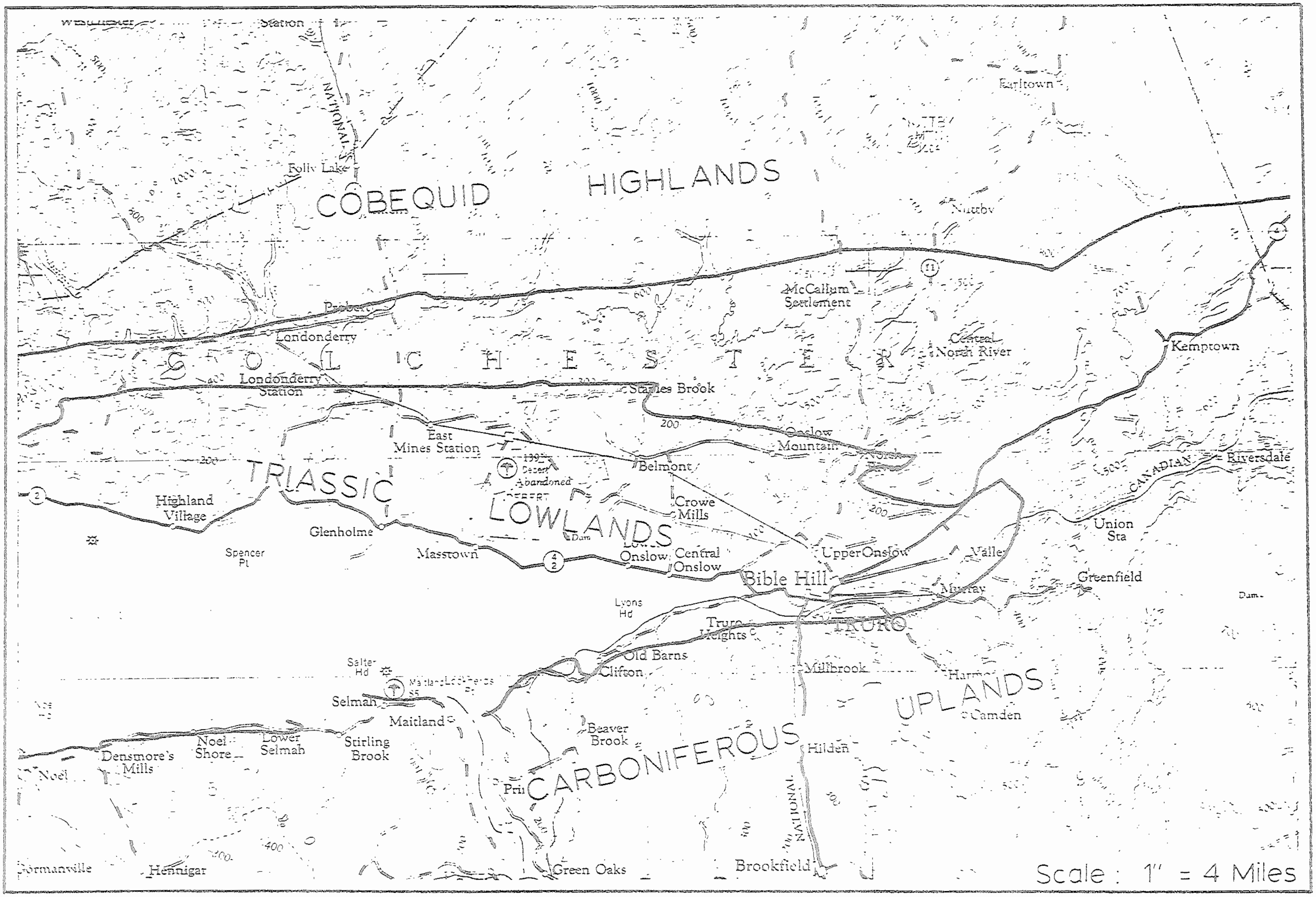


FIGURE 1. Physiographic units in the map area.

Carboniferous Upland

Most of the watershed is underlain by the Carboniferous uplands. These uplands extend westward from Truro on both sides of the Cobequid Bay and eastward from Truro to the Pictou-Antigonish highlands which begin south of New Glasgow. On the south, these uplands extend to the Stewiacke area where they border on the southern upland division of Nova Scotia, which extends from Yarmouth east to Canso.

These uplands are made up of sediments of the Horton, Windsor, Canso, Riversdale and Cumberland and/or Pictou Groups, which include beds of conglomerate, sandstone, shale, limestone, gypsum and anhydrite. The southern watershed boundary follows the Camden ridge which trends northeasterly and is one of the highest features in these upland divisions. Elevations range from about 200 feet to a high of about 800 feet above sea level in the east portion of the system.

Triassic Lowland

The head of Cobequid Bay marks the eastern limit of a syncline that extends from Cape Blomidon to a point 5 miles east of Truro. Thus the area adjacent to the town of Truro is underlain by Triassic sediments consisting of relatively unindurated conglomerates, sandstones and shales which border the Cobequid Bay. These sediments reach a maximum of about 400 feet above sea level where they terminate against the Horton sediments on the east, but generally the contact with Carboniferous sediments is approximately 200 to 300 feet above sea level.

Cobequid Highland

On the north the lowlands are bounded by the Cobequid Mountain highlands which are the surface water divide between the Northumberland Strait and the Cobequid Bay. The Cobequid Mountains are a long narrow remnant of the Atlantic upland stretching 75 miles across Cumberland County from the head of the Bay of Fundy almost to Northumberland Strait. This flat-topped ridge is 8 to 10 miles wide. Broad rounded summits, ranging in altitude from 850 to 1000 feet, blend to form a rolling surface with an average altitude over 900 feet.

These highlands consist mainly of crystalline rocks of granite, syenite, diabase and felsite which are more resistant to errosion than the weak, crumbling sandstone and shale beds of the surrounding lowlands. Infolded and enveloped are masses of contorted schists and slates of Silurian and Devonian age.

Drainage

The map area includes watershed systems, mainly north and east of the Town of Truro, which contribute water to a common point on the Salmon River, just northwest of the town. During its course from the drainage area where it is collected to the Cobequid Bay where it is discharged, the major portion of this fresh water either flows through or underneath the town of Truro (Fig. 2).

Salmon River, the principal river draining the area, flows west and discharges into Cobequid Bay at a point just northwest of Truro. Its largest tributary, the North River, enters the Salmon River immediately north of Truro and only about one mile from the estuary of the Cobequid Bay. Another main tributary, the Black River, joins

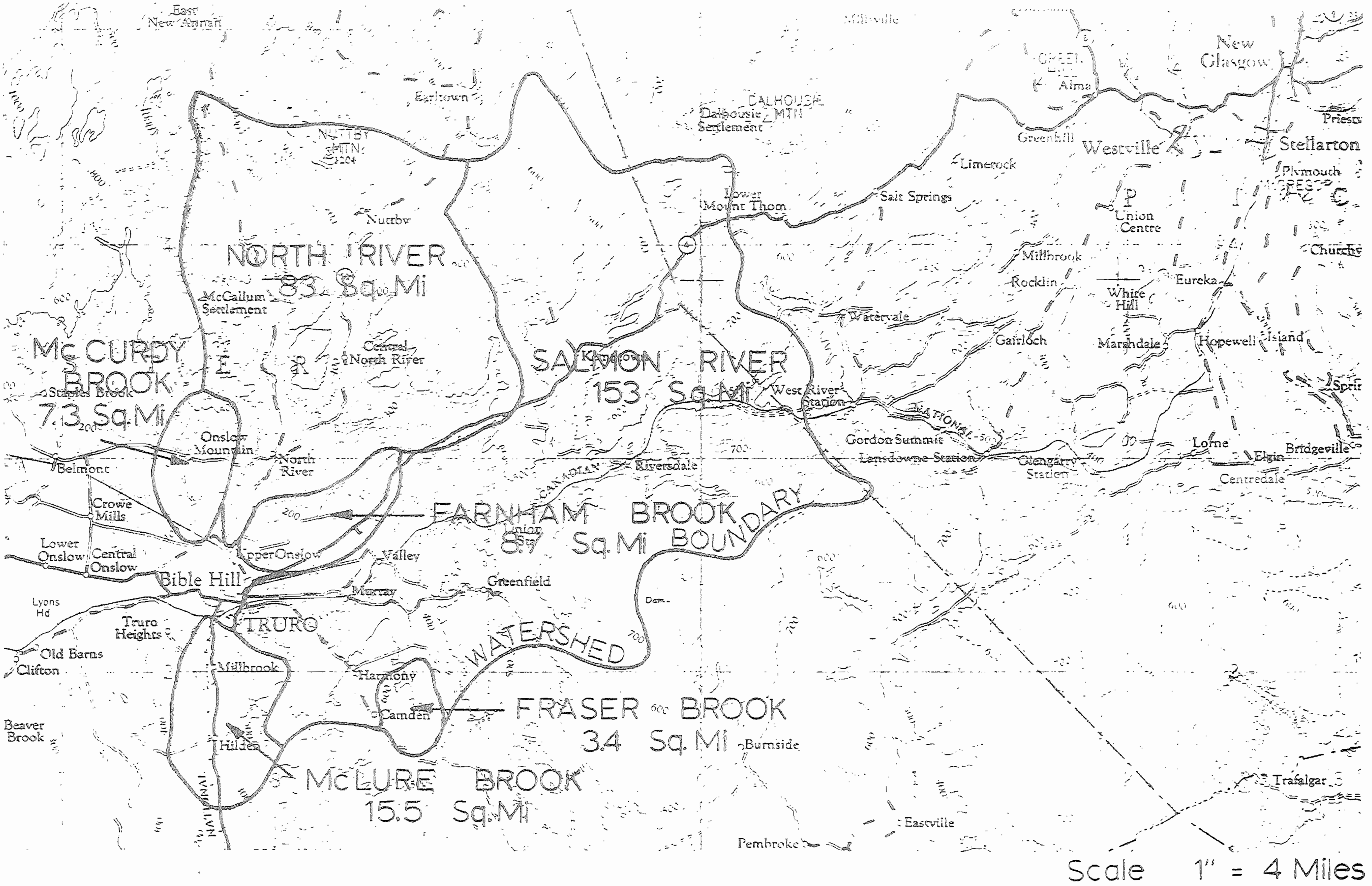


FIGURE 2. Watersheds in the Truro area (showing drainage areas)

the Salmon River at a point between Union and Riversdale. In general, the North River with its headwaters on top of the Cobequid Mountains flows from the north; the Salmon River (main branch) flows from the northeast where its headwaters originate in the Cobequid highlands and the Carboniferous uplands; and the Black River flows from the east where the high Carboniferous strata in that area mark the drainage divide. Drainage from the south in the vicinity of Truro is provided by McLure Brook which discharges directly into the tidal estuary of Cobequid Bay; this brook, therefore, is not considered a component of the Salmon River system in this study. The most westerly watershed in the Salmon River system is drained by McCurdy Brook which flows south immediately adjacent to the North River watershed. Another stream, Farnham Brook, drains the small area between the bottom portions of the North River and Salmon River and enters the latter a short distance above the North River tributary.

Drainage Areas

A watershed or drainage area may be defined as the area from which a lake, stream or waterway and reservoir receives surface flow which originates as precipitation. The drainage area above the eastern extension of Cobequid Bay has been subdivided into the previously mentioned watersheds to segregate these areas as distinct hydrologic units. This is necessary before a quantitative evaluation of a drainage area can be carried out to determine the volume of water expected from a drainage area at any time. The measuring points selected on each stream are just above tidal effect of the Bay at the lowest point on the stream where fresh water may be withdrawn without salt water contamination. The total drainage area of the watersheds outlined in Figure 2 is about 267 square miles.

Table 1 summarizes data on the drainage area, drainage density, and stream profile of the six watersheds outlined. Drainage area refers to the total area contributing to the runoff and sustaining part of all of the flow of the main stream and its tributaries (Dewiest, 1967) and is reported in square miles. Drainage density is the average length of streams per unit area within the basin and is reported in miles per square mile (mi./sq. mi.). Dewiest, (1967), states that the drainage density gives a comparative measure for indicating the degree to which a watershed is drained. He also indicates that a basin with a drainage density of less than 1 mi./sq. mi. is poorly drained whereas a drainage density of about 5 mi./sq. mi indicates very good drainage. An examination of the data in Table 1 shows that the Farnham Brook watershed has the lowest drainage density and thus it is the poorest drained basin under study.

Two other observations from the data in Table I should be noted:

1. With the exception of the Farnham Brook watershed, as the drainage area increases the drainage density generally decreases. Thus the small watersheds tend to be better drained than the larger basins.

2. As the drainage area decreases the mean slope of the stream profile increases. This only applies to the mean slope, whereas the relationship between the drainage area and the gross slope shows no trend.

The Atlantic Upland Plain, according to Goldthwait (1924), was completed by the end of the Cretaceous Period, and the erosion which followed the uplift of this plain produced the modern lowlands and valleys during the Tertiary Period.

When discussing the life history of the Salmon River system, it is found that

Table 1. Physiographic quantities of watersheds

Watershed	Drainage Area (miles^2)	Drainage Density (miles/sq. mile)	Stream Profile Gross Slope (ft./mile)	Stream Profile Mean Slope (ft./mile)
Salmon River				
(a) Above Truro	152.7	1.42	35.7	21.7
(b) Above Murray	140.0	1.41		
North River	83.0	1.60	52.4	36.2
McLure Brook	15.5	1.72	59.4	37.1
Farnham Brook	8.7	1.2	54	38
McCurdy Brook	7.3	2.6	102	51.7
Fraser Brook	3.4	2.60	85	80

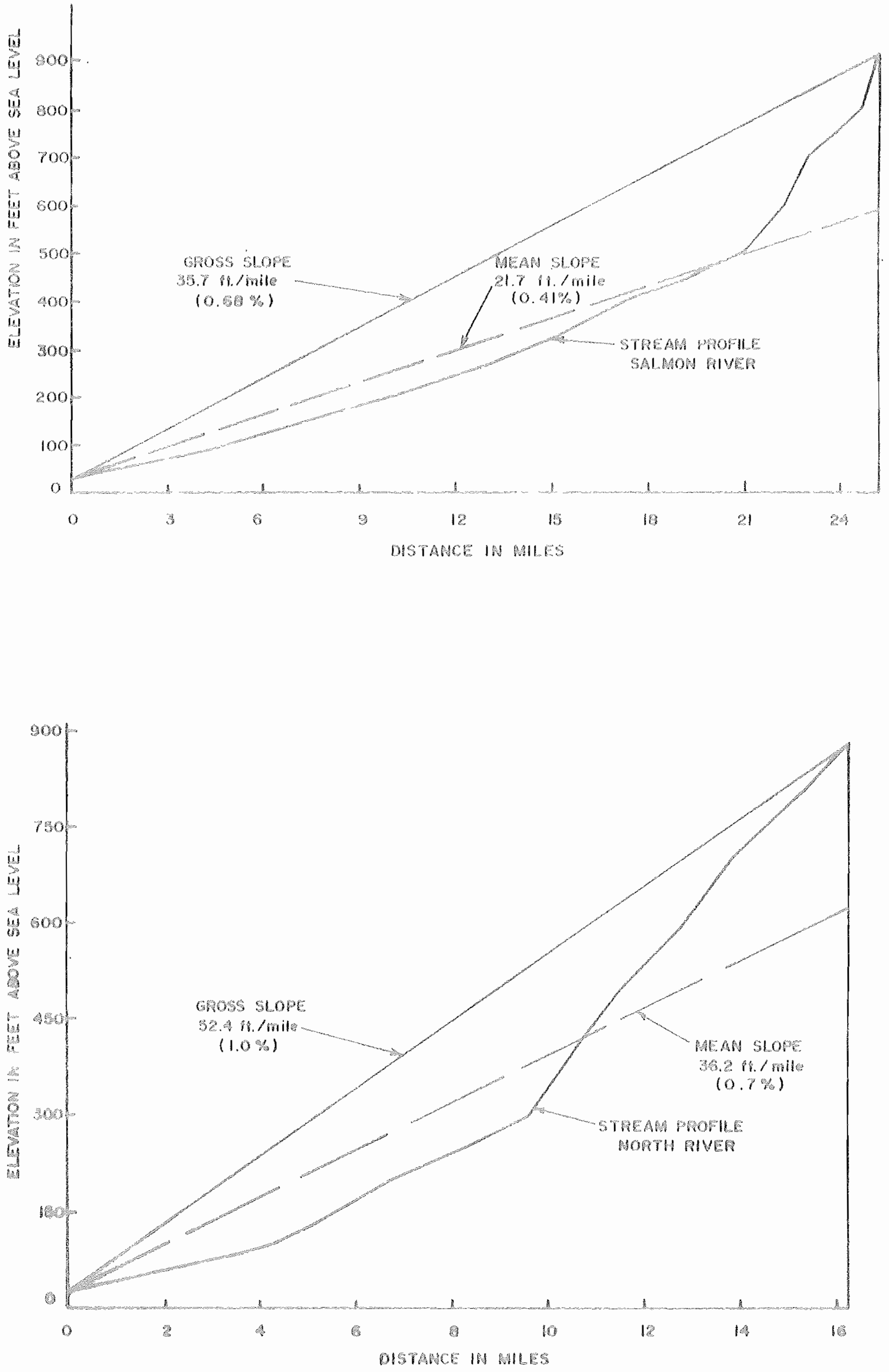
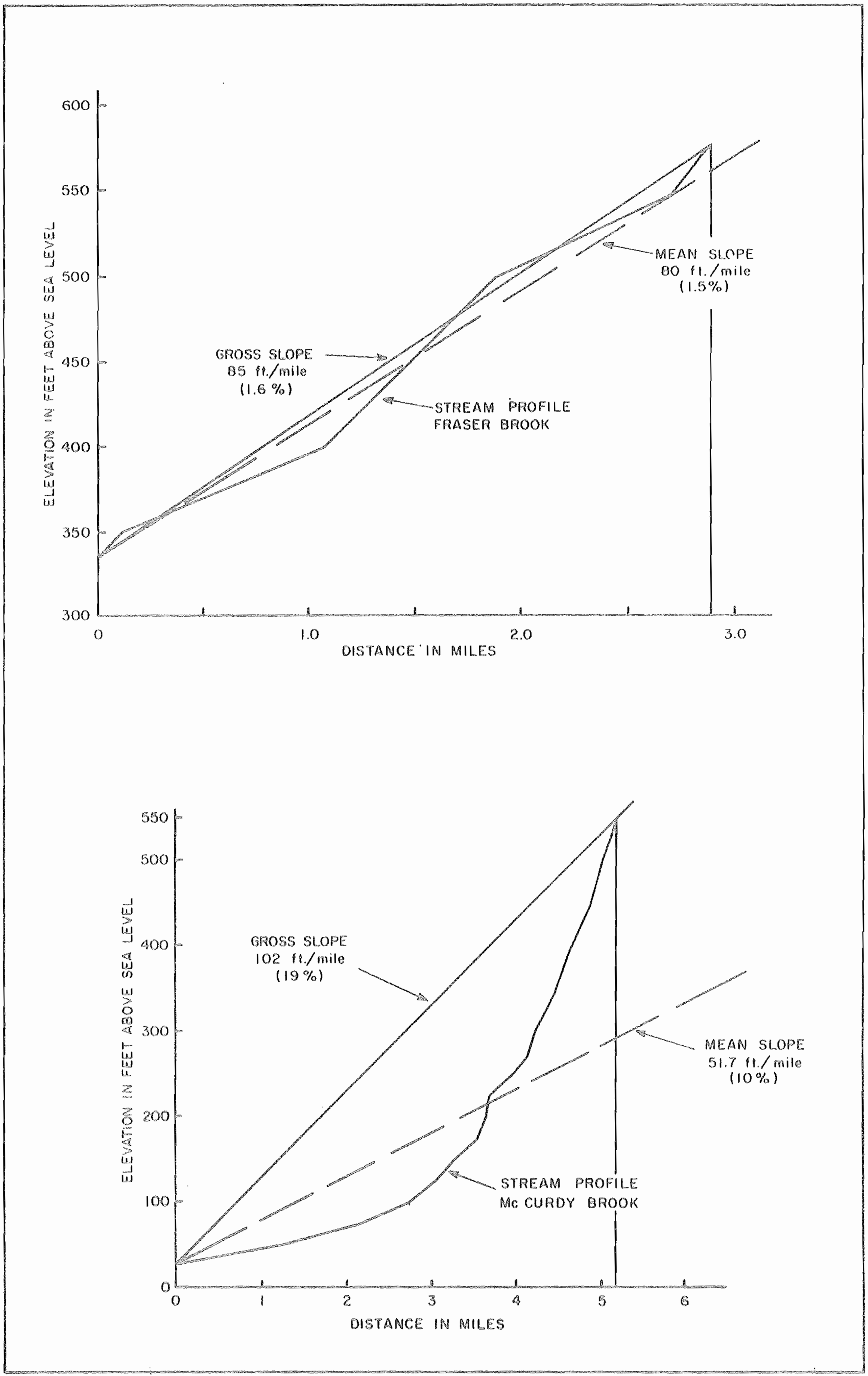
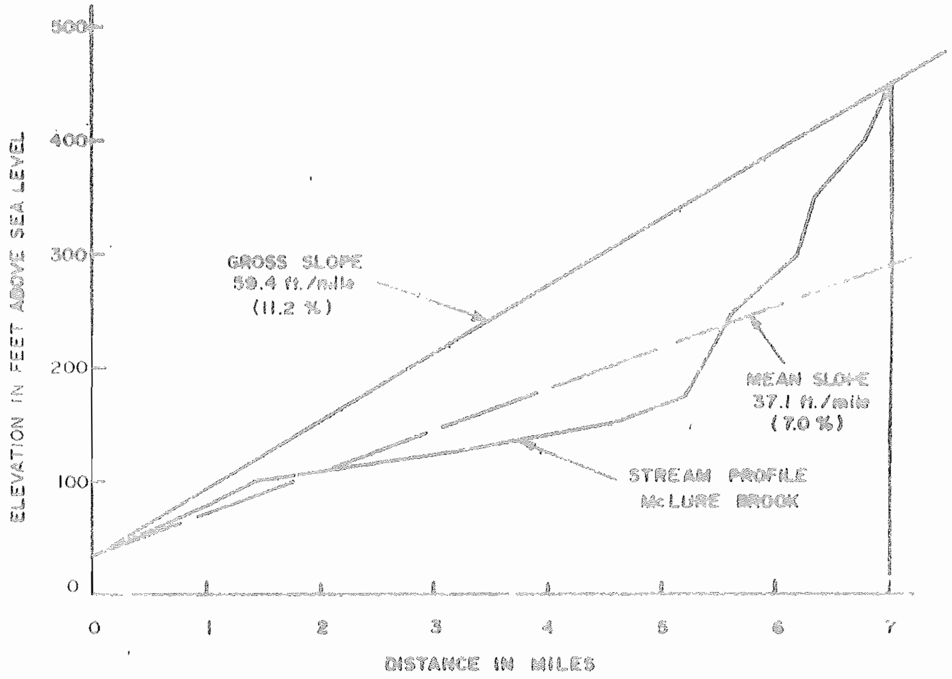


Figure 3. Stream profiles of Salmon and North Rivers.



G.McD.

Figure 4. Stream profiles of Fraser and McCurdy Brooks



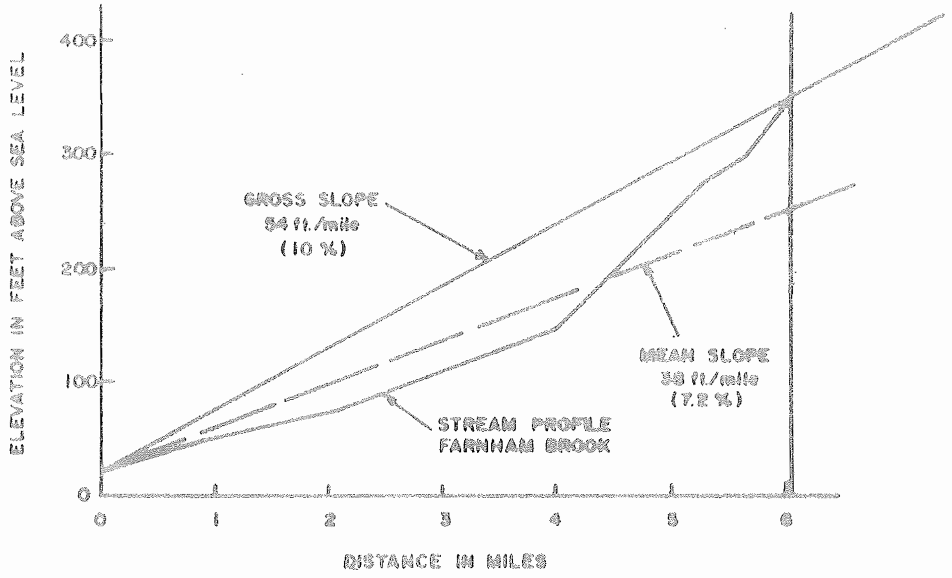


Figure 5. Stream profiles of McLure and Farnham Brooks.

several stages in the life of a river are represented. An examination of the stream profiles in this area indicates that the main channel of the Salmon River appears to be relatively smooth and well graded, whereas most tributary profiles are quite irregular. Leet and Judson (1965) state that valleys sometimes reach different stages of development at different points along the stream's course--maturity in its lower reaches, for example, and youth toward its headwaters. This is also evident in the main channel profile where the irregularities occur near the headwaters. Consideration of the heterogenious geology along the stream course, the most resistant rocks near the headwaters and the less competant sediments in the Triassic lowlands, will help explain the variations in river stage development. Thus it may be concluded that the Salmon River drainage system has reached a stage of late youth in its upper reaches and its tributaries while the lower portion over the Triassic lowlands has reached early maturity.

Drainage Pattern

Most drainage in the area forms a dendritic pattern with small rills and streams following natural depressions in the surficial deposits of the area. In general, geologic bedrock structure and fracture systems do not affect the drainage because of the overlying surficial deposits which have molded present day drainage. A few local isolated areas underlain by Horton sediments, have a rectangular pattern which may reflect the presence of the numerous faults cutting the Horton rocks. In numerous instances these faults form the loci of local drainage gullies, and control in part the channels of some of the larger streams, (Stevenson, 1958).

The Salmon River is evidently a consequent stream, but most of its tributaries are of the subsequent type and follow the less resistant beds of underlying bedrock, (Stevenson, 1958). At several sites along their courses, the streams are superimposed upon glacial and alluvial deposits which conceal the underlying rock strata.

Agricultural and Engineering Soils

Soil is a natural body of mineral and organic constituents, differentiated into horizons of variable depth, which differs from the material below in morphology, physical make-up, chemical properties and composition, and biological characteristics. In agricultural soil science, the term soil is applied only to the thin upper part of the mantle penetrated by the roots of plants, which supply them with the water and other substances necessary for their existence. In civil engineering, soil includes all the loose or moderately cohesive deposits such as, gravels, sands, silts or clays, or any of their mixutres; therefore in this sense the term soil is synonomous with surficial material or deposits as discussed in this study.

Clarification of the term "consolidation" is also required before discussing soils from either a geologic or civil engineering point of view. In geology, consolidation refers to any or all the processes whereby loose, soft or liquid earth materials become firm and coherent. The same term as used in civil engineering and soil mechanics refers to the gradual reduction in volume of a solid mass resulting from an increase in compressive stress. In a saturated soil, it involves the squeezing of water from the pores and a resulting decrease in pore space.

Agricultural Soil Types

The types of farming practised in an area are determined by the soils available, the drainage, climate and native vegetation which also influence the particular type of soil that forms. The most important factor influencing the type of soil in this area is the parent material from which the soil is derived. The most abundant parent material in the area is glacial till. Till is an accumulation of unsorted earth material which may consist of clay, silt, sand and gravel eroded and redeposited by glaciers. Two basic types of till are found in this area; clay till which covers almost 50 per cent of the area and sandy till covering about 30 per cent of the area. The nature of these tills reflect the lithology of the underlying bedrock deposits from which they were derived. The second type of parent material are deposits of glaciofluvial sands, silts and gravels, which cover about 20 per cent of the area.

Wicklund and Smith (1948) state that generally soils in Nova Scotia have a common type of development resulting in a soil collectively called podzols. The process of development known as podzolization has developed certain characteristics as a result of variations in climate, vegetation (including living organisms), parent material and drainage. In Colchester County all the upland soils are classed as podzols. The soil profile of podzols contains highly leached materials which are low in iron and lime and are generally acid. Wicklund and Smith (1948) have classified the soils in associations which include groups of soils developed in the same kind of parent material.

Soils resulting from the weathering of the surficial deposits (parent materials) in the area reflect the nature of the underlying bedrock. The surficial deposits have in turn been derived directly from the underlying bedrock and have not been moved too far. Therefore a change in soil type also indicates a corresponding change in the underlying surficial material and bedrock deposits. As a result soil boundaries often correspond closely with boundaries marking a change in the type of underlying surficial deposits and bedrock contacts. Thus where outcrops are lacking, bedrock contacts may be determined by a careful examination of the soil types. Fletcher (1891) used this method extensively. Drilling in recent years has proved the accuracy of his deductions. While mapping the surficial deposits, the author found that study of both the soil types and bedrock geology was most useful in determining the boundary between the sandy till and the clay till. Sandy till overlies the more granular strata of rocks belonging to the Fundy Group, and the Cumberland and/or Pictou Groups. Granular soils with very good drainage develop on this type of till. Clay till more commonly overlies the fine grained sediments of the Windsor Group, Riversdale Group and Canso Group.

Engineering Aspects of Soils

Soil means to a civil engineer a natural aggregate of mineral grains, with or without organic constituents, that can be separated by gentle mechanical means such as agitation in water. Rock is considered to be a natural aggregate of mineral grains connected by strong and permanent cohesive forces. In reality, however, there is no sharp distinction between rock and soil. Even the strongest and most rigid rocks may be weakened by the processes of weathering, and some intact rocks are as weak and compressible as soils (Peck, Hanson and Thronburn, 1966).

Soils are of interest to the civil engineer because of the dependence of engineering structures and projects on the characteristics and properties of these materials (such as shear resistance and hydraulic properties). These properties are valuable for highway construction, foundation engineering, the design of earth structures (stability of slopes and earth dams) and earth retaining structures (retaining walls and tunnels).

The accompanying Map 1 (Surficial geology of the Truro area, scale 1:50,000) should be of some value to engineers who may require a general idea of the earth materials with which to work in any given area. The deposits can be separated into three distinct categories:

1. Clay till, a compact and cohesive soil. In many cases, it is free of boulders but generally is composed of a mixture of sand and gravel with a high clay content.
2. Sandy till, a loose, sandy and/or gravelly material that in some areas has a fair amount of cohesiveness.
3. Glacio-fluvio deposits of silt, sand and gravel. These materials are very rarely cohesive and are composed of particles with wide grain size distribution.

Land Use and Population

The population of Colchester County (1961) was 34,307 or 4.6 per cent of the Nova Scotia total. The two main towns in the county, Stewiacke (population 1,042) and Truro (population 12,421) account for about 40 per cent of the total county population. The Nova Scotia Department of Trade and Industry (1964) shows that 17,396 (50.7 per cent) of the population in Colchester County is rural. The remaining 16, 911 (49.3 per cent) of the population is classed as urban.

With a total land area of 1,451 square miles (930,000 acres), Colchester County ranks fourth in size in the Province and contains 1,168 cenus farms. Most farming is of the mixed type, with emphasis on vegetable production (cucumbers, carrots), tree fruit farming (apples, plums), small cultivated fruit farming (the leading crop is blueberries), field crops (tame hay, mixed grains). Dairy produce is also of major importance with the county ranking second in the province in numbers of livestock. The sale of lumber provides an added source of income for many of the farmers although very little timber of marketable value remains except in the more inaccessible areas.

Of the 930,000 acres in the county, 259,013 acres or 28 per cent of the total area is classed as farm land; this includes 62,903 acres (6.8 per cent) of improved land. Department of Trade and Industry (1964) show that of this 41,565 acres (4.5 per cent are under crops, 18,322 acres are improved pasture, 235 acres (2.0 per cent) of summer fallow and 196,110 acres (21 per cent) as unimproved land.

In 1961, Colchester County had two fishing districts in which 79 fisherman landed a total value of $57,300 worth of fish.

In 1957, a forest inventory of the county showed 722, 638 acres (80 per cent) as productive forests. Forest production in 1963 indicate the two main products to be softwood and hardwood lumber and chips.

Climate

The northern counties of the Province of Nova Scotia comprise a climatic region within the Maritime Provinces (Wicklund & Smith, 1948). This climate is described in general terms as humid and temperate concurring with the generally continental climate of Nova Scotia as a whole. This continental climate is modified, however, by the Atlantic Ocean which almost completely surrounds the province, and the Gulf Stream which runs north easterly parallel to the Atlantic Coast. The proximity of the province to both the continental land mass and the Atlantic Ocean tend to prevent extreme continental lows in the winter and high temperatures in summer.

The Province of Nova Scotia has been divided into five main climatic regions by Chapman and Brown (1966). The classification is based on temperature zones (based on degree days above 42°F and the frost-free period) and moisture classes (based on average water deficiency and average May-September precipitation). A summation of the regions and climates is given in Table 2.

Precipitation in central Nova Scotia varies significantly as is shown in the chapter on Hydrology but the mean temperatures are much less variable. Truro has an annual precipitation of 11.0 inches less than Halifax (60 miles south) and 0.01 inch less than that of Upper Stewiacke (17 miles southeast).

Measurements at the Truro meterological station have been determined from over 30 years of continuous records. The mean annual precipitation at Truro is 41.72 inches; this consists of 34.93 inches as rain and 67.90 inches snow. The maximum mean monthly precipitation 4.62 inches occurs in the month of November, 4.34 inches of this occurring as rain. The minimum mean monthly precipitation, 2.82 inches occurs during the month of June, the mext lowest value 2.90 and 2.92 occurring for the months of April and July respectively. The maximum mean monthly snowfall 18.10 inches occurs during the month of February. The maximum precipitation

Table 2. Climatic Regions for Agriculture in Nova Scotia

Region	Degree-Days Above 42°F	Potential Evapotranspiration (ins.)	Corn Heat Units	Growing Season		Frost Season (32°F)			Mean Temp. °F			Deficiency	Moisture (inches) Precipitation		Actual Evapotranspiration
				Start	End	Spring	Fall	Period	Annual Min.	Jan.	July		May-Sept.	Annual	
Annapolis Valley	2950	22	2200	April 20th	Nov. 2nd	May 24th	Sept. 30th	130	-10	22	66	0.5	16	41	22
Nova Scotia Interior (map area)	2700	21	1900	April 22nd	Oct. 31st	May 28th	Sept. 25th	120	-15	21	65	0	17.5	48	21
Cape Breton	2500	21	2000	April 30th	Oct. 30th	May 30th	Sept. 25th	115	-10	20	64	0	19	50	21
Northumberland Shore	2700	21.5	2100	April 27th	Oct. 28th	May 25th	Sept. 30th	130	-15	18	65	0.5	15	38	21
South Shore	2800	22	2100	April 30th	Nov. 5th	May 20th	Sept. 30th	130	- 5	25	62	0	> 20	55	22

Adapted from "The Canada Land Inventory," Department of Forestry and Rural Development, Canada, Report No. 3, 1966, By Chapman and Brown.

in a 24 hour period (1931-1958) was 4.60 inches (September, 1942).

The mean annual temperature recorded at Truro is 42.8°F. The minimum mean monthly temperature is 20.9°F for the month of February, whereas, July has the maximum mean monthly temperature of 64.8°F.

The length of the frost free period in Colchester County ranges from 100 to 120 days, being slightly longer in the northern part of the county. The length of the growing season ranges from 180-190 days (Wicklund & Smith, 1948). The spring season is late because of prevailing northeasterly winds and frequent precipitation which often delays seeding operations until June.

Previous Investigations

Previous to this study, no work on the hydrogeology of the watersheds has been carried out. Although meterological records have been collected at Truro and several other sites in the area for the past 30 years, data on the other phases of the hydrologic cycle were not available. In August, 1964, The Water Survey of Canada, Inland Waters Branch, Department of Energy, Mines and Resources, installed a water level recorder on the Salmon River at Murray, to provide a continuous record of stream flow. In the autumn of 1965, the Fraser Brook watershed, a small component of the Salmon River watershed, was instrumented as an International Hydrologic Decade program representative basin. At Fraser Brook, The Water Survey of Canada erected a composite weir and installed a water level recorder to measure stream flow. The Meterological Branch of the Department of Transport also installed a network of various meterological instruments in the Fraser Brook watershed.

A groundwater probability map of Truro Map Sheet (west half), has been published (Brandon, 1966). The data in this report obtained from numerous geologic publications and three weeks of field work, indicate the probable quality and quantity of water expected from wells drilled into the various geological units of the area.

The earliest scientific description of the rocks of Nova Scotia is found in a paper presented to the "American Journal of Science" by Messrs. Jackson and Alger in 1826 (Stevenson, 1958), in which they refer to gypsum beds outcropping on the Shubenacadie River.

Dr. Abraham Gesnor produced the first comprehensive study of the rock formations and mineral occurrences in Nova Scotia in 1836. In his "Geology and Minerology of Nova Scotia" he attempted to classify the different rock types of the Province by districts. He later published "The Industrial Resources of Nova Scotia" in 1849.

In his book "Travels in North America", Sir Charles Lyell (1843) described his observations on the geology of Nova Scotia based on his visit to the area in 1842. Sir William Dawson in his four editions of "Acadian Geology" (1855, 1868, 1878, 1891) established the foundation of Carboniferous stratigraphy in Nova Scotia. He made a comprehensive description of the Windsor sediments along the Shubenacadie River and was the first to assign a Triassic age to unfossiliferous, limy sandstone beds to the area.

The first detailed mapping of the area was carried out by Hugh Fletcher (1887-1891). These maps, accurate in detail, gave special attention to all mineral showings. Powers (1916) in a report on the "Acadian Triassic" deals mainly with the Triassic rocks in western Nova Scotia and southern New Brunswick. He only briefly discusses these sediments in the Truro area.

In 1927, Dr. W. A. Bell published the first comprehensive report on the Carboniferous stratigraphy of Nova Scotia. L. J. Weeks (1948) in his report on the Londonderry and Bass River map-areas, established a type sequence for the carboniferous rocks in that area, which lie immediately to the west of 11 E 6 Truro map area.

The geology of the Truro map sheet was mapped in detail by I. M. Stevenson and published by the Geol. Surv. Can. in 1958. This report deals in considerable detail with all known deposits of economic interest within the area. In addition, the results of this work have shed new light upon the origin, structure, and age relations of many of the geological formations of the map area.

Dawson (1893) describes some of the glacial features of Nova Scotia, and Daley (1901) dealt in a general manner with the physiography of the Province. The latest publication dealing with the physiography, geomorphology and effects of glaciation in Nova Scotia is the "Physiography of Nova Scotia" by Goldthwait (1924).

Until this report published maps of the surficial geology of the Truro area did not exist. Some unpublished mapping of Colchester County (sponsored by the Nova Scotia Research Foundation) has been done by Professor R. H. MacNeill and his students at Acadia University. The "Soil Survey of Colchester County" by R. E. Wicklund and G. R. Smith (1948), provides a rough idea of the distribution and extent of various surficial geologic deposits.

Field Work and Maps

Field work began in the area during the summer of 1965 when the Fraser Brook watershed was selected as the first representative basin for study under the International Hydrologic Decade in Nova Scotia. During the same summer some water samples were collected from wells in various parts of Colchester County and a water level recorder was installed in a well drilled into the Triassic sediments at Bible Hill.

Mapping in the field was aided with Department of Agriculture Soil Survey reports, maps, air photos and a power auger. Surficial contacts were mapped mostly from the results of the field data. However in the unaccessible areas, contacts were determined by air photo interpretation of the deposits, using mainly drainage, land forms and topography as guides.

A test drilling program to determine the thickness and character of the surficial deposits of the area was carried out during the summers of 1966 and 1967. Drilling was confined mainly to river flood plain deposits but some glacial material was also drilled. A short pump test was carried out on a test well developed in the Canso rocks of Mississippian age at Fraser Brook, and an 80 hour pump test conducted on a screened well developed in the outwash materials filling the Salmon River stream channel. Water level recorders were installed in three wells drilled into the Salmon River flood plain at Murray Siding. Also during the summer of 1967 a precipitation guage network was extablished throughout the Salmon River watershed, and surface water samples were collected to compare the water chemistry of the Salmon River with the river stage. The surficial deposits were mapped to a scale of

1:50,000.

The N. S. Department of Mines supplied a four-wheel drive vehicle, aerial photographs, topographic and geologic maps and other equipment with which to carry out the field work. A rotary drilling rig was used to collect samples of the subsurface strata and to give other pertinent data on the surficial deposits. Preliminary depths of surficial deposits were determined by running profiles with a hammer seismograph owned and operated by the Nova Scotia Research Foundation. A power auger also belonging to the Foundation was utilized in mapping the surficial deposits of the area and in drilling test holes to be used as observation wells during pump tests.

All chemical water analyses were done by the Provincial Laboratory at the Nova Scotia Agricultural College under head chemist G. Byers. Constituents were reported in parts per million by weight. Bacterial examination of the samples collected from the Salmon River were carried out by the Pathology Laboratory at the Colchester County Hospital. A dissolved oxygen determination of the Salmon River water was done on the Direct Reading Engineer's Field Kit developed by Hach Chemical Company. Several of these results were checked at the Agricultural College Laboratory and found to correspond closely.

Acknowledgements

This investigation was jointly sponsored by the Canada Department of Forestry and Rural Development (ARDA) and the province of Nova Scotia under the direction of the Groundwater Section, Geological Division, Nova Scotia Department of Mines.

The writer is indebted to Mr. J. F. Jones, Chief, Groundwater Section, Nova Scotia Department of Mines, who guided the field program and from whom the writer received criticism and direction while writing the thesis. P. C. Trescott and G. F. Pinder provided valuable information when editing the pump test analysis and the statistics, respectively.

Able assistance was given in the field by David Urquhart who helped with the investigation during the summer of 1967 and by the members of the drill crew who carried out the test drilling and pump testing. Y. Turker also was very helpful in preparing the final drafts of the thesis. Most maps and illustrations have been drafted by D. Bernasconi and his staff of the Cartographic Division, Nova Scotia Department of Mines.

Professor R. H. MacNeill, Acadia University, provided valuable assistance and information on the surficial geology of the area and was instrumental in supplying data allowing completion of the surficial deposit map of the area.

Appreciation is also extended to Dr. Morrison and Dr. Handforth, county pathologists, for the arrangement made to have the bacterial examination of water samples done at the Bacteriology Laboratory in Truro.

Without the co-operation, interest and assistance of many of the inhabitants of that area this program would not have been possible. To all these people I am humbly grateful for their kindness and would like to express to them my sincere appreciation.

GEOLOGY

Introduction

The bedrock of the area consists of sedimentary, igneous and metamorphic rocks from Pre-Carboniferous to Triassic in age. The most promising rocks for yielding high capacity wells of good quality water are sandstone and conglomerate beds of Triassic age. Since time did not allow the author to map and study the bedrock units in any detail, all information presented here has been summarized from previous reports by Stevenson (1958), Weeks (1948), Bell (1958) and Brandon (1966).

To date there has been no published literature on the surficial geology of the area. Until more detailed work can be carried out on the distribution and nature of these surficial materials and incorporated in Map 1, the accompanying map should be considered only as being preliminary. The thickness of the mapped materials vary from only a few feet on the uplands where the till cover is very thin to about 130 feet over the Triassic lowlands.

The Carboniferous sediments of this area were deposited in the Minas sub-basin (Bell, 1958) which is part of the larger Fundy geosynclinal area. This sub-basin lies south of the Cobequid highland and north of an upland in southern Nova Scotia and extends from Minas Channel east to the Stellarton structural gap. Carboniferous strata in the Minas sub-basin range in age from early Mississippian (Horton sediments) to late Pennsylvanian (Pictou sediments). They are conformably overlain in Minas Basin area by non-marine late Triassic red sediments.

Table 3. Table of Formations*

Era	Period or Epoch	Group of Formation (approx. thickness, feet)	Lithology
Cenozoic	Recent	0 - 130+	Stream alluvium, tidal flats, salt & marsh: dykeland
	Pleistocene	0 - 70+	Glacial drift, stratified sand and gravel estuarine deposits
		Unconformity	
Mezozoic	Triassic	Fundy Group 1,000	Brick-red, calcareous sandstone, conglomerate, shale
		Unconformity and Basic Intrusions?	
Palaeozoic	Pennsylvanian	Pictou and Cumberland groups 6,500	Brown, green, and grey conglomerate, sandstone, shale
		Riversdale Group 7,000	Grey shale, sandstone
		Unconformity (?)	
	Mississippian	Canso Group (Unknown)	Red and grey sandstone shale
		Disconformity (?)	
		Windsor Group (Upper) 1,300	Grey limestone, red and green shale, gypsum (?)
		Windsor Group (Lower) 1,300	Black and red limestone, red and green shale, gypsum
		Pembroke Formation 100	Red limestone, conglomerate red calcareous shale
		Macumber Formation 30	Grey, arenaceous, laminated limestone
		Minor Disconformity	
		Horton Group 4,000	Red and grey, sandstone, grit, shale, conglomerate
	Devonian ?		Granite, syenite felsite, diorite, acidic porphyritic rocks, aplite dykes, diabase
	Pre-Carboniferous		Argillite, shale, sandstone, chloritic schists, graphitic schist

* Modified with a few additions from Stevenson (1958), Weeks (1948), Bell (1958).

Rock Units

Palaeozoic

Cobequid Complex

The rocks of the Cobequid complex consist of a series of sedimentary and Volcanic rocks that have been intruded by syenite, granite, diabase, and felsite (Stevenson 1958). These igneous rocks intrude volcanic and sedimentary strata of possible Silurian and Devonian ages. The rocks may be divided into two distinct lithological groups. The older group consists of a séries of mixed sedimentary and volcanic rocks whose age relationships are uncertain but lie south of the igneous granitic core. Cutting these rocks is a series of younger intrusive rocks that range in composition from diabase to granite.

Rocks of the sedimentary and volcanic group are the most abundant and have been subjected to severe shearing movements causing chloritization. The rock types of this group consist of fine-grained, purplish argillites, red and grey sandy shales, green, gray and brown sandstones, highly altered chloritic schists and black, graphitic schist.

The main body of intrusive granitic rocks forming the core of the mountains are confined to the extreme northern part of the map area. The rocks have suffered intensely from fault movements that occurred along the southern face of the Cobequid Mountains. The more basic intrusive rocks extend farther south into the pre-Carboniferous sedimentary rocks. These intrusive rocks include minor amounts of granite, porphyritic rhyolite and aplite dykes in diorite and disbase dykes. Weeks (1948) states that the main batholitic intrusive of Cobequid Mountains may be tentatively ascribed a Devonian age. While the minor intrusive may be either Devonian or Carboniferous. The diabasic dykes on Salmon River are post-Mississippian and probably pre-Triassic in age because nowhere in the area are Triassic sedimentary rocks found cut by intrusive rocks (Stevenson 1958, p. 20).

Horton Group

The Horton Group rocks are Mississippian age and in Nova Scotia are the oldest Carboniferous group. They are overlain by the Windsor Group in apparent structural conformity. Horton strata outcrop in the southern part of the map area and are best exposed along Lepper Brook at Truro. These strata consist of a sequence of conglomerate, grit, sandstone, siltstone, and shale beds. The boundary between the Horton rocks and the overlying younger Triassic sediments is exposed in a number of places to a point about a mile west of Christie Brook (5 miles east of Truro) where Horton rocks are faulted against the Canso Group of sediments. Bell (1929) divided the Horton Group into the Horton Bluff and Cheverie Formations. The lower or Horton Bluff Formation consists of grey, feldspathic conglomerates, grits and sandstones, interbeded with dark grey argillaceous shales. The upper or Cheverie Formation consists chiefly of red shale and grey arkosic grits. In the greater part of the Truro area, however, the Cheverie Formation cannot be separated lithologically from the Horton Bluff Formation.

The oldest part of the Horton in the Truro area consists of a series of feldspathic grits, sandy shales, and siltstones which originated as streamlaid deposits (Stevenson, 1958). The presence of cross bedding and current ripple-marks, channelling, lenses of sandstones and conglomerates (linticular strata), rain prints and broken up plant remains, erect plant stems and sun cracks indicate a fluviatile or terrestial environment of deposition. A statistical study of the current ripple-marks indicates the dominance of northeasterly flowing currents (Stevenson, 1958). The minerological composition of the Horton sedimentary rocks offers conclusive proof that they were formed from the Devonian granite batholith and associated Precambrian rocks that lie to the south.

Horton rocks in the area are folded and cut by numerous faults with small stratigraphic displacement.

Windsor Group

A small area about 4 miles northeast of Truro is underlain by undifferentiated marine sedimentary rocks of the Windsor age (Mississippian) that conformably overlie the Horton sediments. The main body of Windsor sediments is present about 4 miles southwest of Truro. The Windsor sediments consist of red sandstone, red and minor grey siltstone, red and green sandy shales, limestone, minor dolomite, anhydrite, gypsum and salt.

The Windsor Group has been subdivided into lower and upper parts. The lower part in the Truro area contains three basic formational units: the Macumber Formation, consisting of grey sandy laminated limestone; the Pembroke Formation of red limestone, conglomerate and red shale; and late Lower Windsor rocks consisting of red and green shales, marine limestone, and gypsum and anhydrite. The upper part of the Windsor Group consists of grey limestone, red and green shale and possibly gypsum.

Canso Group

Upper Mississippian terrestrial sedimentary rocks of the Canso Group underlie the south-central and northeast portions of the map area. These sediments were probably derived in part from an older upland that lay to the south during late Mississippian time and from the Cobequid Highlands in the north. They were deposited in a fluvio-lacustrine environment and consist of sandstones which are interlayered with bands of fissile, chocolate-red shale showing ripple marks, cross bedding, laminations and mud cracks. Stevenson (1958) indicates that narrow bands of conglomerate are present, and quartzites interlayered with massive maroon shales occur in the southern part of the area in Christie Brook. Because of the scarcity of fossils in the Canso sediments and the similarity in lithology between Canso and Horton sediments, accurate separation of the two groups is extremely difficult in the south-central part of the area.

Riversdale Group

Lower Pennsylvanian, non-marine sediments of the Riversdale Group underlie a strip about 3 miles wide and extending eastward across the map area. On the south they make a fault contact with Horton, Canso, Windsor and Triassic sediments; while on the north they are separated from sediments of the Cumberland and/or Pictou Groups by another eastward trending fault. Riversdale sediments consist of grey, fissile sandy shales, grey sandstones interlensed in the shales and black coaly shales. The strata are evenly bedded and show both mud cracks and ripple marks. The sandstones, commonly massive and crossbedded, contain numerous plant remains and petrified tree roots which are often several feet long.

Cumberland and Pictou Groups

Lying in faulted contact to the north of and overlying the Riversdale sediments is a band of upper Pennsylvanian rocks about 3 miles wide extending eastward across the map area. These rocks constitute the Cumberland and Pictou Groups and are in fault contact with older Canso rocks and the Cobequid complex lying to the north. Lithologic similarities and the absence of fossils in the conglomerates and coarse sandstones of the Cumberland and Pictou Groups make it impractical to differentiate between the two. In general these strata are a mixed assemblage of rocks that range in grain size from coarse conglomerates to fine shales. Locally, thin beds of lenticular conglomerate occur in crossbedded sandstones and shales showing ripple marks.

Mesozoic

Fundy Group

Triassic sediments belonging to the Fundy Group lie in the eastern end of a synclinal basin which extends from about the center of the map area westward to the western portion of the Annapolis-Cornwallis Valley. These terrestrial sediments dip about 5° toward the Bay of Fundy and overlie with angular unconformity the older

Carboniferous strata to the south. The Fundy Group is noted for the heterogeneous distribution of its constituents and in the Truro area for their consistent red color. Conglomerates, sandstones, and shales are interbedded at random. Poor sorting, cross bedding, channelling phenomena in the sandstones, and subangularity in shape of the pebbles in the conglomerate are indicative of transportation and deposition by torrential streams. The sediments were probably deposited in the form of flood plains and perhaps in part as broad, alluvial fans.

To the north these strata are separated from older Carboniferous rocks by the Cobequid fault which extends from West Advocate to a point northeast of Truro, a distance of about 90 miles.

The true thickness of the Triassic is not known but there is at least 1000 feet exposed along the Debert River, 10 miles northwest of Truro. A test hole drilled at Bible Hill, northeast of Truro, penetrated over 600 feet of Triassic rocks.

Surficial Deposits

Of the glacial drift in the area, till is by far the most abundant surficial material and covers over 80 per cent of the map area (Table 4). The remaining area is covered by stratified sand and gravel, of recent and glacial ages and recent clay deposits. Generally the deposits are thickest in the lowland areas and consist of stratified sands and gravels, while the topographic high areas are covered with a thin mantle of till.

Carboniferous strata to the south. The Fundy Group is noted for the heterogeneous distribution of its constituents and in the Truro area for their consistent red color. Conglomerates, sandstones, and shales are interbedded at random. Poor sorting, cross bedding, channelling phenomena in the sandstones, and subangularity in shape of the pebbles in the conglomerate are indicative of transportation and deposition by torrential streams. The sediments were probably deposited in the form of flood plains and perhaps in part as broad, alluvial fans.

To the north these strata are separated from older Carboniferous rocks by the Cobequid fault which extends from West Advocate to a point northeast of Truro, a distance of about 90 miles.

The true thickness of the Triassic is not known but there is at least 1000 feet exposed along the Debert River, 10 miles northwest of Truro. A test hole drilled at Bible Hill, northeast of Truro, penetrated over 600 feet of Triassic rocks.

Surficial Deposits

Of the glacial drift in the area, till is by far the most abundant surficial material and covers over 80 per cent of the map area (Table 4). The remaining area is covered by stratified sand and gravel, of recent and glacial ages and recent clay deposits. Generally the deposits are thickest in the lowland areas and consist of stratified sands and gravels, while the topographic high areas are covered with a thin mantle of till.

Table 4. Extent of Surficial Deposits Within the Map Area

Material	Area Square Miles	 Acres	Percent of total area
Sandy till	93	59,500	35
Clay till	125	80,000	47
Glacio-fluvial materials	49	31,300	18

The surficial deposits mapped in this area may be classed into five main divisions: till; ice-contact stratified drift; outwash deposits; estuarine deposits; and recent alluvial deposits. Each group is discussed below.

Pleistocene

Till

Till is unstratified glacial drift, deposited by glaciers without subsequent movement by wind or water. It consists mainly of mechanically broken fragments, ranging from clay to boulders, of nearby bedrock. The proportions of the various sizes of material depend upon the nature of the source rocks (Thwaites, 1957). Till is perhaps the most variable sediment known by a single name. Its outstanding characteristic is that it is not sorted. It may consist of 99% clay particles, or 99% large boulders, or any combination of these and intermediate sizes (Flint, 1963).

The till mapped in the area was divided into two main distinct types: clay till and granular or sandy till. Clay till is the most abundant, covering nearly one-half of the map area, whereas a sandy till covers about one-third the area.

Clay till is generally confined to areas underlain by bedrock units of predominantly silts and shales, i. e. the Riversdale, Canso, and Horton groups.

Wide variations in the compactness of the clay till were experienced throughout the area. Flint (1963) states that most till containing more than 10 per cent clay or more than 40 per cent clay and silt combined tend to be massive and compact. Other factors affecting compaction are physical settling, cementation and static pressure of overlying ice.

The granular or sandy till was mainly confined to areas overlying bedrock units of predominately granites, conglomerate and sandstone, i. e., the Cobequid granites, and Cumberland, Pictou and Triassic sediments. Thwaites (1957, p. 30) states that hard rocks like granite have widely spaced fractures and so break chiefly into boulders and large pebbles. Till derived from sandstone is largely unstratified sand mixed with some pebbles, boulders and silt mainly from other areas.

An excellent correlation between till composition and underlying bedrock types exists in the area where sandy till overlies the Triassic sediments which consist of predominantly conglomerate and sandstone. Nowhere in the map area was a clay till found overlying these coarse Triassic sediments. And along the contact of the Triassic sediments and Riversdale shales, the sandy till-clay till contact almost exactly coincides with the bedrock boundary.

Two areas of hummocky moraine were mapped both of which were over coarse grained or clastic bedrock deposits. One large hummock of sandy moraine materials (see Fig. 6) overlies the coarse-grained granitic area of the Cobequid complex in the northwest corner of the map area (see Map 1). This material, which has the form of a drumlin (see Fig. 7), consists almost entirely of particles identical in color and texture to those comprising the underlying granite. The second area of hummocky moraine material occurs in the east central portion of the map area. Here most of the hummocks are composed of a granular till derived from the underlying sandstones and conglomerates of the Cumberland and/or Pictou Groups.

Hummocky till areas were separated from flat till areas mainly because of its hummocky topography. The flat till areas of ground moraine have low relief and do not show any linear elements, whereas hummocky moraine is an area of knob and kettle topography. The features thus mapped as hummocky moraines are believed to be significant enough to justify this classification, even though some of the features may be closely controlled by bedrock. Hogg (1953) reports that hummocky ground moraine areas in Pictou County, along the flanks of the Cobequids, consist of a gravelly and porous material. Since texture and drainage were also used in classifying the ground moraines in this area, it would appear that this conclusion is valid.

Ice-Contact Stratified Drift

Accumulations of stratified drift built in immediate contact with wasting ice are collectively referred to as ice-contact stratified drift or simply as ice-contact features (Flint, 1963, p. 136). They include eskers, kames, and kame terraces. Thwaites (1957, p. 32) defines glacio-fluvial deposits as glacial drift which was not

Figure 6. Granular till overlying the Cobequid Complex. McCallum Settlement, 11-E-11-B 16 G. (view east)

Figure 7. Moraine hummock overlying Cobequid Complex. McCallum Settlement 11-E-11-B 16 G. (view north)

deposited directly by the ice but was carried, assorted, and deposited by streams derived from the melting of the glacier. Using this definition both ice-contact deposits and outwash deposits may be classed as glacio-fluvial. This may be convenient for a practical reference to the type of materials deposited when their mode of origin is not being considered.

In general, ice-contact deposits of sand and gravel occur in local topographic low areas throughout the map area. These local "low" areas resulted in the accumulation of sediments carried by glacial melt water which came from ablating blocks of ice filling the drainage channels. In some areas, North River in particular, the remnants of these deposits were observed to grade into the surrounding till cover on the slopes of steep valleys (see Fig. 8).

Kames: Kames are irregular-shaped hills or mounds resulting from ice-contact stratified materials deposited by glacial meltwater in crevasses or other openings in ablating ice. They are generally composed of bedded sands and gravels which show extreme variations in sorting both vertically and horizontally (Fig. 9).

The most spectacular kame in the map area is located just south of Riversdale in a small isolated area of ice-contact stratified drift. This feature is roughly oval shaped and about 600 feet long and 300 feet wide at the base. It is steep sided and reaches a height of about 50 feet. In this deposit fine sand is interbedded with coarse gravel both showing excellent cross bedding.

Figure 8. Remnants of ice-contact stratified drift on steep valley slope, North River, 11 E 6 C 72 Q (view east)

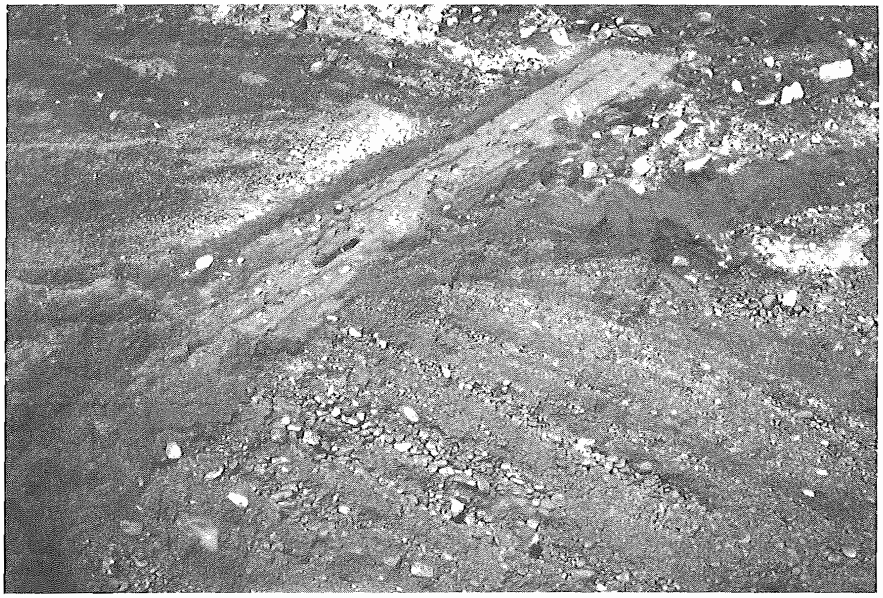


Figure 9. Variations of bedding in kame, Greenfield 11 E 6 A 102 P (view north)

Eskers: The most distinctive form of ice-contact stratified drift is the esker, a long narrow ice-contact ridge commonly sinuous and composed chiefly of stratified drift (Flint, 1963, p. 152). An esker sometimes has distinct tributaries since it is often the deposit of a glacial stream either in an ice tunnel or an open crack. The material composing eskers in the map area is poorly sorted, irregularly bedded sands and gravels which alternate abruptly.

Four eskers occur in the map area: two may be part of the same deposit in the northern part of the area, the other two are in the southern part of the area. All, however, are formed on or near the topographic high of the area (see Fig. 10).

Kame Terrace: Kame terraces are accumulations of stratified drift laid down by streams between a glacier and an adjacent valley wall and left as a constructional terrace after disappearance of the glacier (Flint, 1963, p. 149). They consist of coarse sands and gravels which are poorly sorted and irregularly bedded. The largest and most prominant terraces in this area occur along the main channel of the Salmon River near Kemptown. Here terraces about one-half mile wide border both sides of the river and extend downstream for over two miles. Other terraces exist along the North River valley and on the Black River above Riversdale.

Outwash Deposits

Outwash is stratified drift which has been transported by streams originating within the glacier and deposited beyond the glacier itself. The material is characteristically coarse grained, well sorted and stratified in thin foreset beds. Variations

Figure 10. Cross-section of esker, Archibald, 11 E 6 A 80 K (view south)

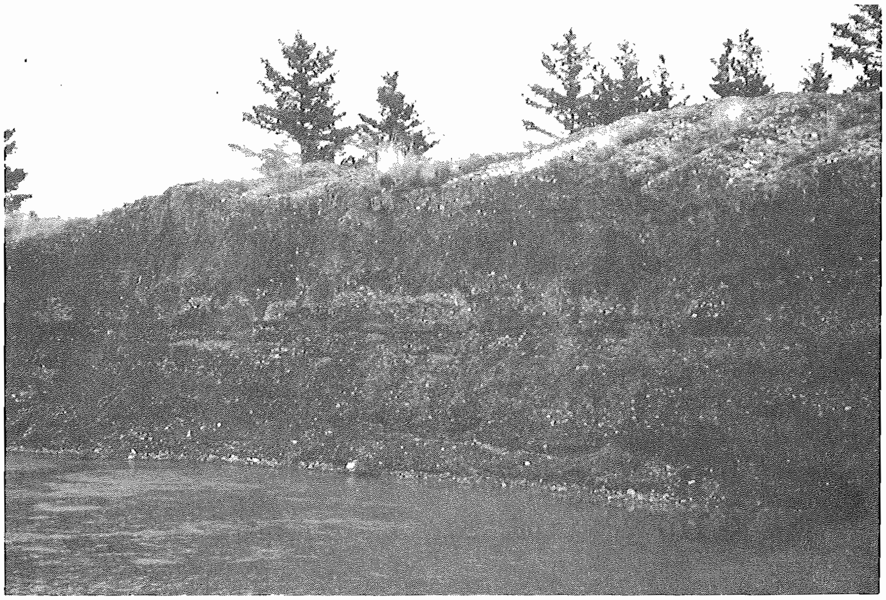


Figure 11. Outwash sand and gravel terrace, North River, 11 E 6 C 24 L (view east)

in grain size are sharp and numerous both horizontally and vertically (Flint, 1963, p. 136).

All outwash deposits in the map area occur in and immediately north of Truro. The largest is a terrace of outwash material flanking the east side of the North River flood plain (see Fig. 11). In this terrace which continues for over two miles, the bedding is well defined, irregular, continuous, and in some places shows very good sorting. The material ranges from crossbedded, well sorted sands to coarse gravels containing boulders in many places.

The town of Truro is located on an irregularly shaped terrace of outwash materials. The more regular eastern portion of this deposit originated from glacial meltwaters draining the Salmon River watershed, but the western portion, which is incised and irregular in form, probably received sediments from both the North and Salmon Rivers during ablation. Cuts in the terrace at Truro indicate a very similar type of material and structure to that in North River.

Recent

Stream alluvium is found along most of the main streams in the area. Along the bottom portions of the North and Salmon river valleys, recent deposits of stream alluvium cover broad flood plains. In general, the material consists of clay, silt, sand and gravel deposited by the stream at periods of high flow when the rivers overflow their normal channels. Deposits along the North River are commonly the coarsest found in the area and consist mainly of material from about 2-6 inches in diameter.

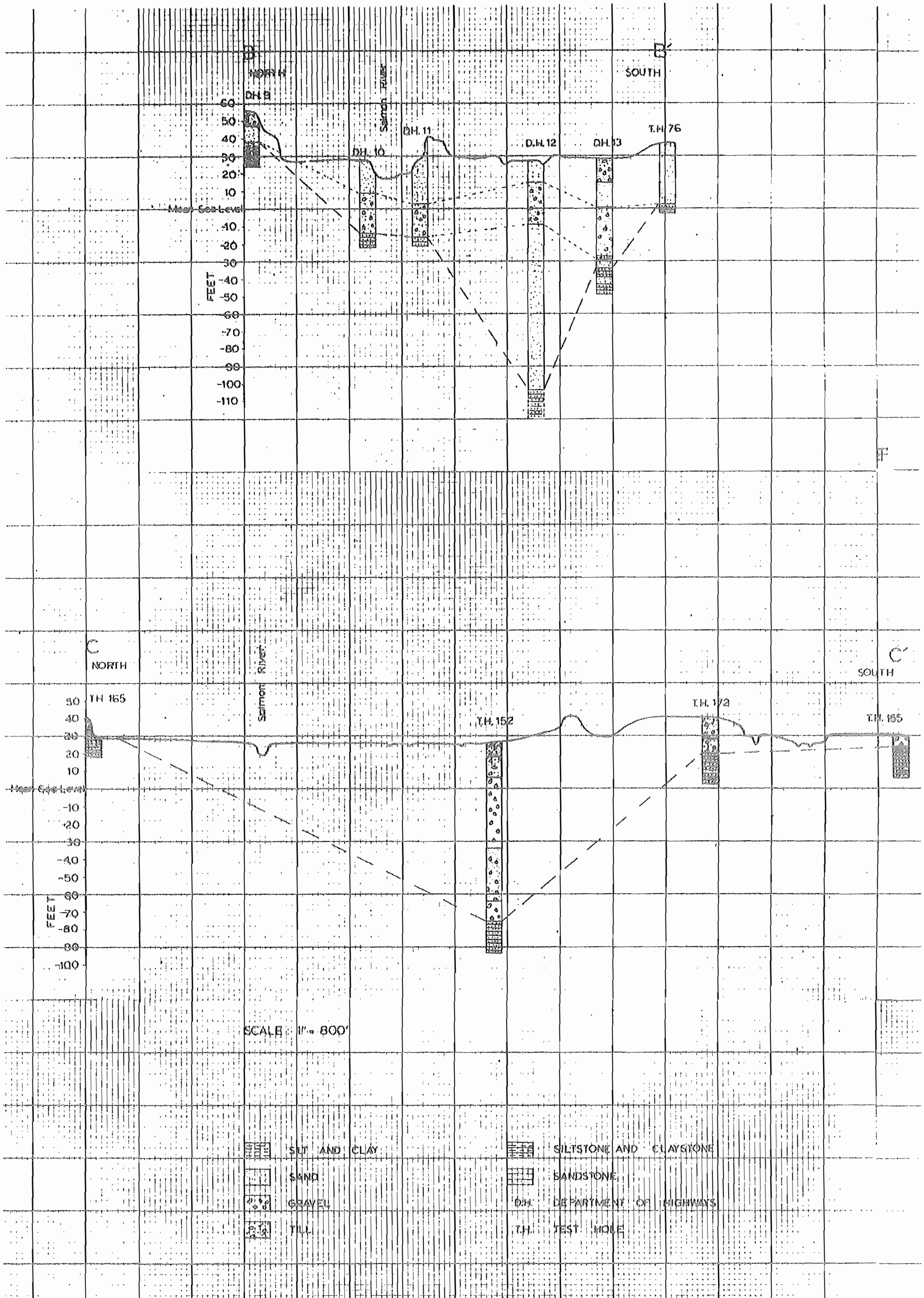
In the lower reaches of the North and Salmon rivers, recent deposits overlie considerable thicknesses of outwash sands and gravels, in which the present rivers have incised themselves. At Murray, on the Salmon River, deposits of sand and silt (up to 6 feet thick) form the recent flood plain which overlies a buried channel filled with outwash sands and gravels (see Map 3).

The tidal estuaries of the North and Salmon rivers have been dyked to protect valuable and rich pasture and hay land. The materials making up the dykelands are fine sediments of sand, silts, and clay deposited by tides or by streams in the salt water at the mouths of the principal rivers. The area is flat, with a small natural slope toward the Bay. These deposits are about 6 feet deep and overlie outwash sands and gravels which are over 130 feet deep.

Buried Channels

Two well-defined buried river channels were found incised in the soft Triassic sediments underlying the area, north and east of Truro. The largest and deepest channel, that of the North River, has been traced for a distance of about 4 miles north from Truro. Surficial deposit test-hole cross-sections illustrated in figure 12 and figure 13 reveal the dimensions of and the distribution of materials filling the North River channel. The second channel, that of the Salmon River (see Map 3) has been traced for a distance of over 5 miles east of Truro. Under the northwest part of the town, the channels appear to merge into a larger channel which continues westward under the Cobequid Bay. Washed deposits of sand and gravel over 80 feet thick fill the North River channel, which reaches a width of about three-quarters of a mile. Similar coarse, water-washed clastics fill the Salmon River channel to depths of over 40 feet. Passing under the town from the east this channel reaches widths of about one-quarter mile. To the west of town, where the dyke lands are constricted to a width of less than three-quarters of a mile, the main channel is over 130 feet deep and narrows to about one-half mile wide. It is suggested than the gradual increase in depth of both channels is quite uniform in a general downstream direction possibly indicating the stream profile or gradient of the preglacial drainage systems. Both buried channels follow the same general flow direction as the present surface streams after which they were named. A common flood plain was shared by the two streams northwest of Truro in the general area of their junction before their river mouths were "drowned" thus creating the present dyke land, which extends inland from the constriction for several miles.

It appears that the area east of the constriction, which begins just west of the Board Landing bridge, was a relatively deep sub-basin before and during the Pliestocene epoch. A sea level only 50 feet lower than the present sea level, combined with very high river flows during an interglacial period could easily account for erosion of the main channel. During a later interglacial interval or later in the same interval, this same basin would be filled with glacial outwash sediments. Drowning of the river mouths during recent time combined with the extreme tides in this area would account for deposition of the silts and clays forming the present day dyke lands.



(Sections are located on Map 2)

Fig. 12 Surficial deposit test-hole cross-sections B-B' and C-C'

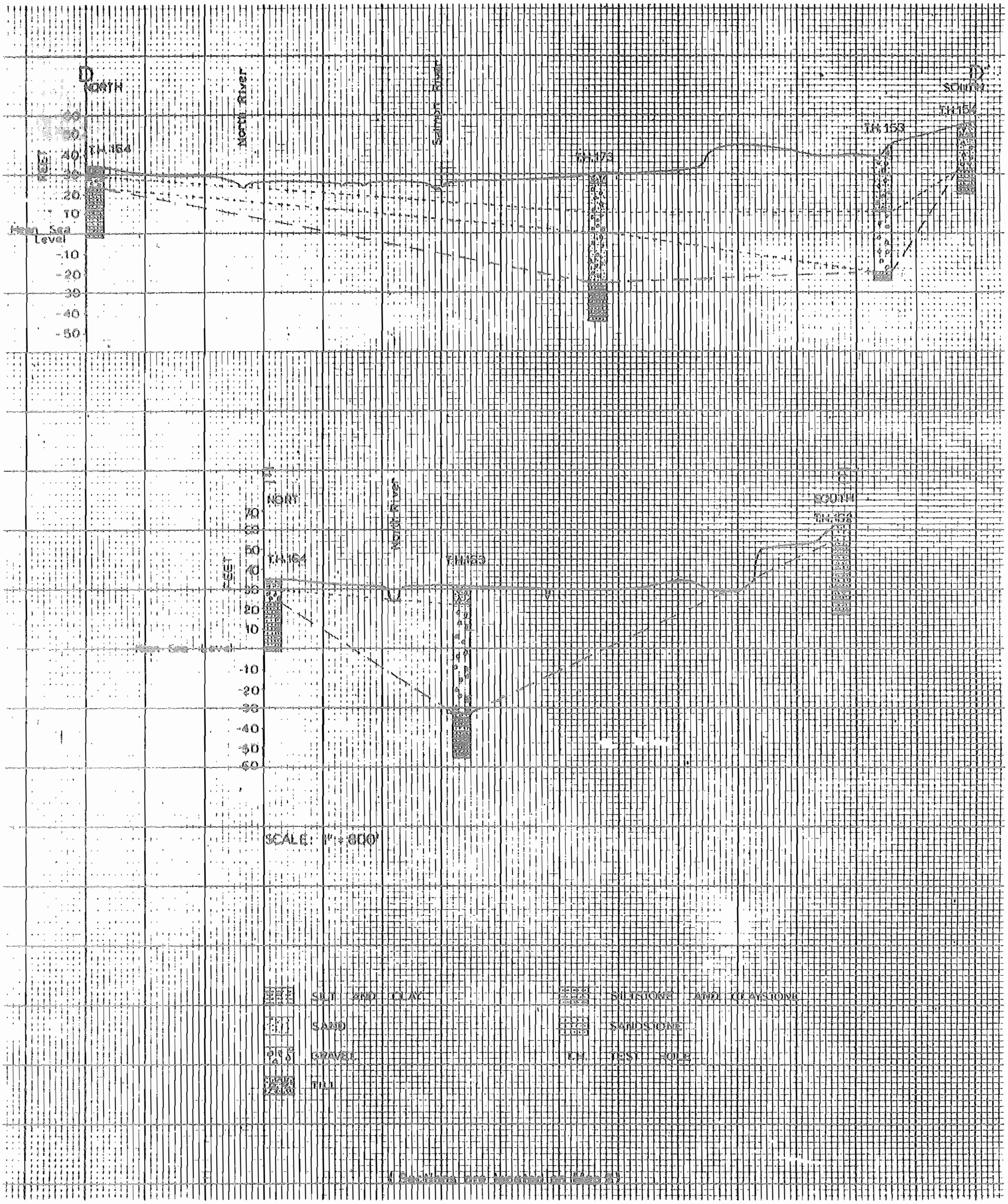


Fig. 13. Surficial deposit test-hole cross-sections D-D' and E-E'

Structure

Bedrock Structure

In general, the strata in the Truro area have been extensively folded and faulted into structural patterns which are evident in the geomorphological make-up of the area.

The younger Triassic rocks, which are only slightly folded, exhibit a low broad synclinal structure which trends in an easterly direction. Major east-trending faults limit the extent of the Triassic in the north but numerous north-trending faults in the sediments result in minor displacement.

Two regional strikes, one southwest for the Mississippian strata, and the other east for the Pennsylvanian strata, indicate the presence of two distinct sets of folds. The early, southwest-trending, set affects the Mississippian sediments in the south part of the map area; while the later east-trending set folded the Pennsylvanian strata lying in the north portion of the area. The major southwest-trending folds in the map area have been named the Truro anticline, which terminates at the Triassic-Horton contact in the southern part of Truro, and the Greenfield syncline, which transverses the Canso sediments just southeast of Fraser Brook (Stevenson, 1958).

Two major east-trending folds were identified in the Pennsylvanian strata in the northern portion of the area (Stevenson, 1958). The axis of the Debert River syncline is enclosed in, and parallels, the Cumberland-Pictou groups, whereas the North River anticlinal axis lies in the Riversdale Group just south of the fault contact with the Cumberland-Pictou group.

Faults in the area form two distinct systems, an earlier west-, and a later north-trending system. The west-trending system, the largest and most important of the two, consists of three major faults: The Cobequid, North River, and the Riversdale Faults. In addition, the strata have been cut by numerous other faults showing irregular attitudes, small displacements and no distinct pattern.

HYDROLOGY

Introduction

From studies of hydrology, man is able to determine the quality and volume of water available to him for use for life, agriculture, and industry. The volume is determined by using the basic hydrologic equation:

$$\text{Inflow} = \text{outflow} \pm \Delta \text{ storage} \qquad (1)$$

This equation expresses the basic principle that, during a given time interval, the total inflow to an area must equal the total outflow plus the net change in storage.

This study includes an evaluation of precipitation on the Salmon watershed, the amount of water lost through evapotranspiration and an estimate of the quantity and quality of water available for utilization from surface supplies and some of the subsurface reservoirs.

In an attempt to obtain a more accurate measurement of precipitation falling on the Salmon River watershed, a network of rain gauges was established. Sixteen sites were equipped with standard rain gauges at various locations throughout the watershed or a density of about 1 rain gauge for each 10 square miles. It was felt that this density was accurate enough for a preliminary estimate of the amount of rainfall on the watershed.

Evapotranspiration (ET), or consumptive use, may be defined as the water lost to the atmosphere by evaporation from soil and water surfaces, and by transpiration from plants during the growing season. Potential evapotranspiration (PE) is that amount of water that would be evaporated and transpired if it were continuously available.

Estimates of potential evapotranspiration (PE) were determined by using a set of nomographs devised by J. A. Turner (1958). Turner's graphs were developed from Thornthwaite's (1948) equations which equate PE with temperature and length of daylight.

Records of stream flow measurements have been collected by the Water Survey of Canada, Inland Waters Branch of the Canada Department of Energy, Mines and Resources, on the Salmon River at Murray and at Fraser Brook. These flows are being measured by recording the river stage at the two stations and entering the recorded value in a stage-discharge relationship, or a rating curve. The rating curve is established by actually measuring the river discharge at various stages and plotting a stage vs. discharge curve on log-log paper. Stage is plotted on the ordinate and discharge on the abscissa.

Precipitation

Precipitation is defined as the various forms of moisture, (rain, sleet, snow, hail, dew, and fog drip) which fall from the atmosphere to the earth. Within the map area rainfall accounts for over 80 per cent of the mean annual precipitation and is thus the main element of discussion in this report. In general, rainfall diminishes with distance from the sea coast and increases with elevation above sea level.

Long term records of precipitation have been kept at four stations in, and adjacent to, the map area. Data in these records cover the period from 1931 to 1960. At Truro and Upper Stewiacke the records are nearly complete for the full 30 year period. At Clifton and Debert from 10 to 24 years of records are available during the same 30 year period (Fig. 14).

At Fraser's Brook, instrumentation was installed under the International Hydrological Decade program. Data from these sites are available from late fall of 1965. The only two sites shown on the accompanying map are those where standard rain gauges were installed which require twice daily measurements.

Temporary precipitation sites were established throughout the Salmon River watershed and instrumented with standard rain gauges in June 1967. The main purpose of this network was to indicate the consistancy of variations in rainfall across the watershed. It was felt that changes in physiography, topography and distnace from the sea shore in this area affected the amount and areal distribution of precipitation in the map-area.

Precipitation instrumentation within the area were therefore placed in three main groups: permanent gauge sites that have been in operation since 1931; instruments installed under the IHD program in 1965; and temporary instruments throughout the Salmon River watershed established in June 1967. A discussion of the various records at these sites is included below.

Precipitation at Truro and Other Established Instrument Sites

Precipitation normals calculated for the permanent sites are listed in Table 5. Note that mean annual precipitation at the Truro site is the lowest of the four.

An examination of mean monthly data however, reveals that only during the months of February, May and August is precipitation at Truro less than at any other site. Also, there is no month during which the mean precipitation at Truro is the greatest of the four stations. Another interesting pattern shows that during the months of September and October, the precipitation is greater at Truro than the average of the four sites. During ten months of the year, records at Truro thus indicate less precipitation than actually does occur on the eastern part of Colchester county.

The mean annual precipitation at Truro, 41.72 inches, is 6.90 inches less than the highest mean annual normal (Debert) and is 2.68 inches less than the mean normal of the four sites which is 44.40 inches, representing a discrepancy of about minus 6 per cent. Therefore the precipitation measured at Truro is about 6 per cent less than that which actually falls on the entire eastern portion of Colchester County. To apply the Truro mean figure to the Salmon River watershed above Murray, for example, would indicate an annual inflow of about 310,000 acre-feet. The Maximum, Debert, data would indicate about 362,000 acre-feet while a mean precipitation of 44.40 inches is equivalent to about 330,000 acre-feet of water in the watershed. From these figures, the Truro data gives an underestimate of 52,000 acre feet per year when compared to the Debert data and about 20,000 acre feet per year less when compared to the overall mean data.

Salmon River Watershed Precipitation Gauge Network

Discussion of the amounts and variations of precipitation over the Salmon River watershed is based on records for a 5 month period from July to November 1967.

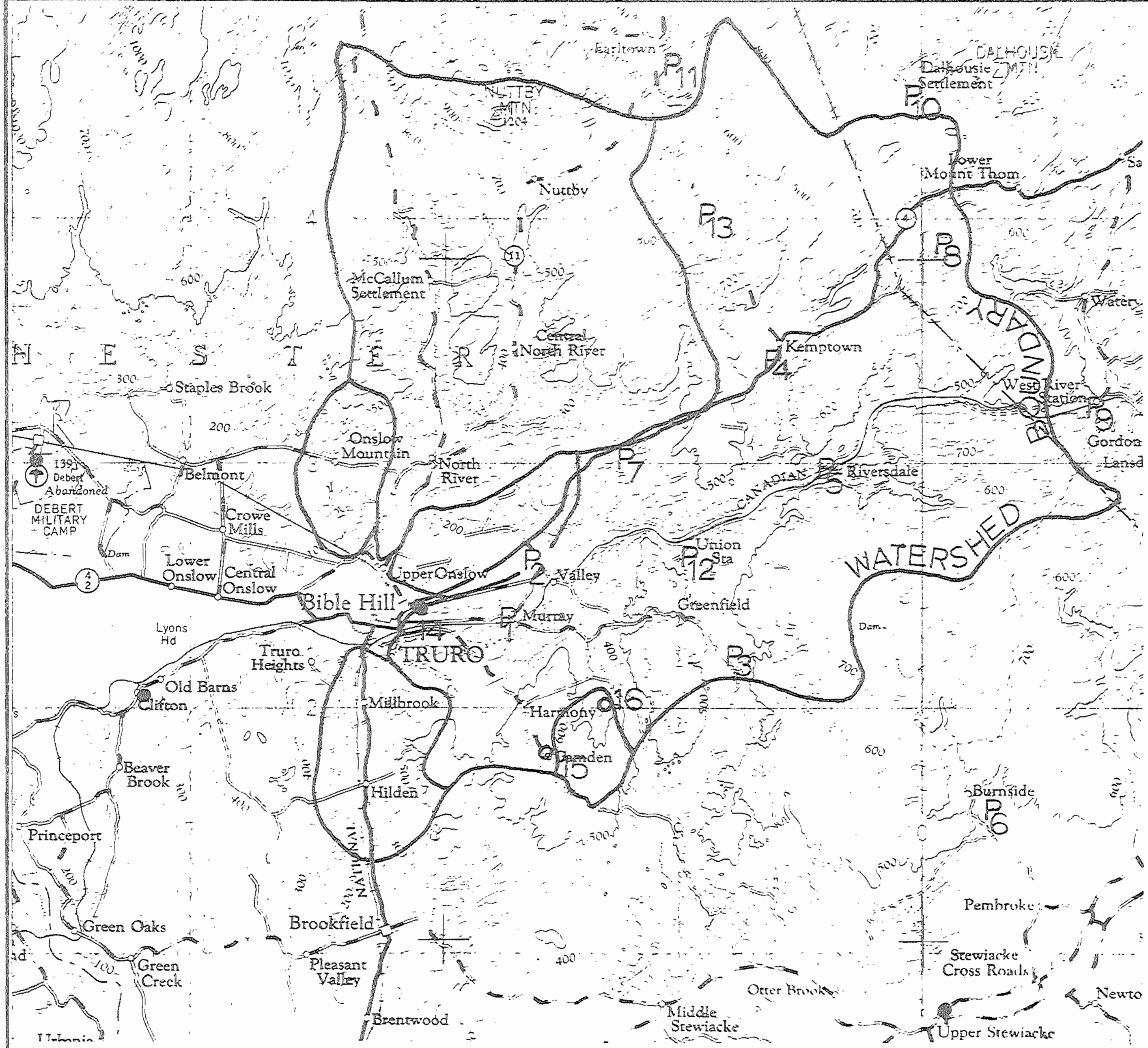


FIGURE 14. Precipitation gauges in the map area

LEGEND

● Site with 10 to 30 years records 1931 - 1960

o Site with 2 years records 1965 - 1967

P Site with 5 months records July - Nov. 1967

Scale: 1" = 4 Miles

Table 5. Precipitation Normals

	SITE				20 - 30 YEARS MEANS		
Month	Truro[1]	Debert[2]	Upper Stewiacke[1]	Clifton[2]	Mean	Median	Range
January	4.16	4.58	3.92	5.38	4.51	4.37	1.46
February	3.47	4.03	3.76	4.24	3.88	3.90	0.77
March	3.10	3.65	3.05	3.71	3.38	3.38	0.66
April	2.90	3.70	2.87	3.35	3.21	3.13	0.83
May	3.13	4.12	3.35	3.30	3.48	3.33	0.99
June	2.82	3.37	2.89	2.30	2.85	2.86	1.07
July	2.92	3.41	3.08	2.72	3.04	3.00	0.69
August	3.37	4.70	3.49	4.16	3.93	3.83	1.33
September	3.94	4.08	3.97	3.44	3.86	3.96	0.64
October	3.40	3.27	3.45	3.09	3.31	3.34	0.36
November	4.62	5.60	4.46	5.38	5.01	5.00	1.14
December	3.89	4.11	3.50	4.47	3.99	4.00	0.97
TOTALS	41.72	48.62	41.79	45.54	44.40	43.67	6.90

N. B. 1. Data from 25-30 years of records between 1931-1960
2. Data from 10-24 years of records during period 1930-1960

* Difference between mean and Truro values = 2.68" = 6%

These records from sixteen locations across the map area show wide variations in the monthly totals (See Table 6). The highest total for the 5 month period was recorded near the south watershed divide at Camden (site 15, Fig. 14) while the lowest total was farther southeast at Upper Burnside (site 6).

Also included in Table 6 are the values at site 14 (where the 30 year mean value of precipitation at Truro was determined) for each 5 months and the mean values for the sixteen sites. These data show that the average precipitation measured over the watershed is less than that at site 14 only for July. These two totals differ as little as 0.09 inch for October, and as much as 1.09 inches for the month of November. The value for November at Truro is only 83 per cent of the average rainfall on the watershed for the same month. For October, the mean at Truro is 98 per cent of the rainfall measured in the gauge network. Also, the precipitation during August measured at Truro is only 64 per cent of that measured at Kemptown (site 13) during the same month.

To give some idea of the magnitude of variation in rainfall at the sites throughout the watershed, the "coefficient of variation" was used. This is a measure of relative variation between the totals at the various sites and the mean. To determine the "coefficient of variation" (V), the standard deviation among the sites is calculated for each month and the average amount of rainfall for each month is determined. V is then determined by the following equation:

$$V = \frac{s_d}{\bar{x}} \times 100 \qquad (2)$$

where s_d is the standard deviation and $\bar{x}$ is the average rainfall. It is apparent from this equation that the coefficient of variation gives the standard deviation as a

Table 6. Precipitation on Salmon River Watershed
Monthly Totals at Gauge Sites
(July to Nov. 1967)

MONTH	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Mean	Median	Range	# 14 30 Year Mean
July	5.26	4.30	4.95	3.70	5.32	2.78	3.91	4.01	2.26	3.64	4.01	4.03	4.37	4.85	6.35	6.08	4.39	4.17	3.73	2.92
August	3.36	4.19	3.42	3.60	3.80	2.84	3.96	3.06	3.78	3.93	3.90	4.07	5.05	3.26	3.93	3.66	3.74	3.79	2.21	3.37
September	4.40	3.70	4.32	4.82	4.63	4.80	4.71	4.57	4.55	6.37	5.45	4.63	5.97	4.43	5.90	5.30	4.91	4.67	2.67	3.94
October	5.27	5.51	6.53	5.99	6.53	6.17	5.52	5.77	5.86	6.71	6.87	5.78	6.23	5.97	6.38	6.24	6.06	6.08	1.60	3.40
November	5.12	5.98	7.24	7.30	7.75	3.77	5.81	6.40	6.70	8.32	6.71	6.58	6.95	5.39	6.95	6.73	6.48	6.71	3.20	4.62
TOTALS	23.41	23.68	27.99	25.41	28.03	20.36	23.91	23.81	23.51	28.97	26.94	25.09	28.57	23.90	29.51	27.01	25.58	25.25	8.15	
Rank of Site	15	13	5	8	4	16	10	12	14	2	7	9	3	11	1	6				

precentage of the mean.

Table 7. Statistical Data on Precipitation in Salmon River Watershed for the Five-Month Period July - November 1967

Month	Mean (inches)	Range	Standard Deviation	V Coeff. of Variation (%)
July	4.39	3.73	1.046	24
August	3.74	2.21	0.509	14
September	4.91	2.67	0.773	16
October	6.06	1.60	0.521	9
November	6.48	3.20	1.045	16

Table 7 is a summary of the statistical data determined on the records obtained in the rain gauge network. Values of V varied from 9 per cent for October to 24 per cent for the month of July. The value of the range in rainfall measurements among the sites is also highest for July and lowest for October. This data indicates that during October rainfall was more uniform over the watershed and thus the value at any one site during this month more closely represents the average amount of rainfall for the entire area. Similarly, rainfall was the most variable or non-uniform on the watershed during July.

Determination of Average Precipitation on the Watershed

Measurements of precipitation with a rain gauge give the depth of moisture in inches that falls on the earth at the site of the gauge. Where several gauges are employed in an area, the values of the points are used to determine an average amount over the area. The instrument accepted by the Meteorlogical Branch, Department of Transport, to collect and measure the amount of rainfall is the standard rain gauge. This gauge consists of a metal (copper) cylindrical container with an intake opening of 10 square inches which is set 12 inches above the ground level.

Large differences in precipitation are observed in short distances in mountainous terrain or during showery precipitation in level country. It is therefore necessary to consider methods of computing the average precipitation over a given area. Two objective methods are applied for areas smaller than 2,000 square miles. For small areas up to 200 square miles and reasonably uniform spacing of the rain gauges, the arithmetic mean is sufficient. For intermediate areas of 200 to 2,000 square miles with small orographic effects, Thiessen's method may be used (DeWiest, 1967, p. 29).

Several factors affect the accuracy of the average value of precipitation, the most important ones being density of the gauge network, spacing of the gauges and orographic effects.

If the precipitation is non-uniform and the stations unevenly distributed within the area, the arithmetic mean may be incorrect. To overcome this error, the precipitation at each station may be weighted in proportion to the area the station is assumed to represent; this is accomplished with the Thiessen network.

> "A Thiessen network is constructed by connecting adjacent stations on a map by straight lines and erecting perpendicular bisectors to each connecting line. The polygon formed by the perpendicular bisectors around a station encloses an area which is everywhere closer to that station than to any other station. The area is assumed to be best represented by the precipitation at the enclosed station. The average rainfall is the sum of the individual station amounts, each multiplied by its percentage area." (Linsley and Franzini, 1964, p. 13.)

Table 8. Average Values of Precipitation in Inches over the Salmon River Watershed as Determined by the Arithmetic Mean and the Thiessen Method

Month	Mean as Determined by Arithmetic Average (inches)	Thiessen Network (inches)	Difference (inches)
July	4.34	4.05	.29
August	3.84	3.82	.02
September	4.95	4.85	.10
October	6.09	6.14	.05
November	6.75	6.98	.23

For a period from July to November, the average precipitation over the watershed was determined by both the arithmetic mean and the Thiessen network. From the results, summarized in Table 8, the mean values differ the most for the month of July. It was also shown earlier that the coefficient of variation was the greatest for July indicating that rainfall during that month varied greatly from one part of the area to another. Since the stations are evenly distributed throughout the watershed, this variation in measurement must be due to non-uniform precipitation in the area. With this assumption and the fact the Thiessen network weights the precipitation and areas, the mean determined by using the network is more accurate. Although there is not enough evidence to show what is causing the variation, it is felt that local showery activity is contributing the major portion of the difference.

Correlation of Factors Affecting Rainfall

Commonly, the two major factors affecting the amount of precipitation on an area are the elevation of the land area, and the distance of that land area from the seashore (Linsley and Franzini, 1964). These data for various precipitation gauge sites are given in Table 9. In Table 9 are as example, site No. 1, which is 82 feet above sea level and 7 miles from the sea shore, had a total of 23.41 inches of rainfall from July to November. Note that the most rain fell at Camden (site 15), which is neigher the highest nor the lowest site. While the highest site (13) at Kempton, had the third highest amount of rainfall.

Figure 15 shows the plot of precipitation verses elevation for instruments in the Salmon River watershed and Figure 16 shows the plot of precipitation verses distance of the site from the sea shore. Butler (1957) indicates that the general relationship between precipitation and elevation is linear. In order to test this hypothesis and to determine whether a similiar relationship exists between distance and precipitation, a linear regression analysis was performed.

If a linear relationship is strong, the points will then lie close to a straight line and the equation for expressing the relationship can be written as:

$$y = a + bx \tag{3}$$

where a and b are numerical constants. Values for y can be found by substituting values of x in (3).

Table 9. Data on Precipitation Gauge Network
Salmon River Waterhsed

Site No.	Elevation in feet (A.S.L.)*	Distance from Sea Shore (miles)	Total P_r (July-Nov. '67) (inches)
1	82	7	23.41
2	195	8	23.68
3	398	13	27.99
4	336	16	25.41
5	337	16	28.03
6	483	20	20.36
7	468	11	23.91
8	735	15	23.81
9	465	23	23.51
10	560	14	28.97
11	534	12	26.94
12	356	12	25.09
13	840	16	28.57
14	120	5	23.90
15	607	9	29.51
16	396	10	27.01

*A. S. L. = Above Sea Level

In regression analysis the method of least squares is used to fit a line to the data that best represents the relationship between x and y. To do this, requires that the sum of the squares of the vertical deviations from the points to the line be a

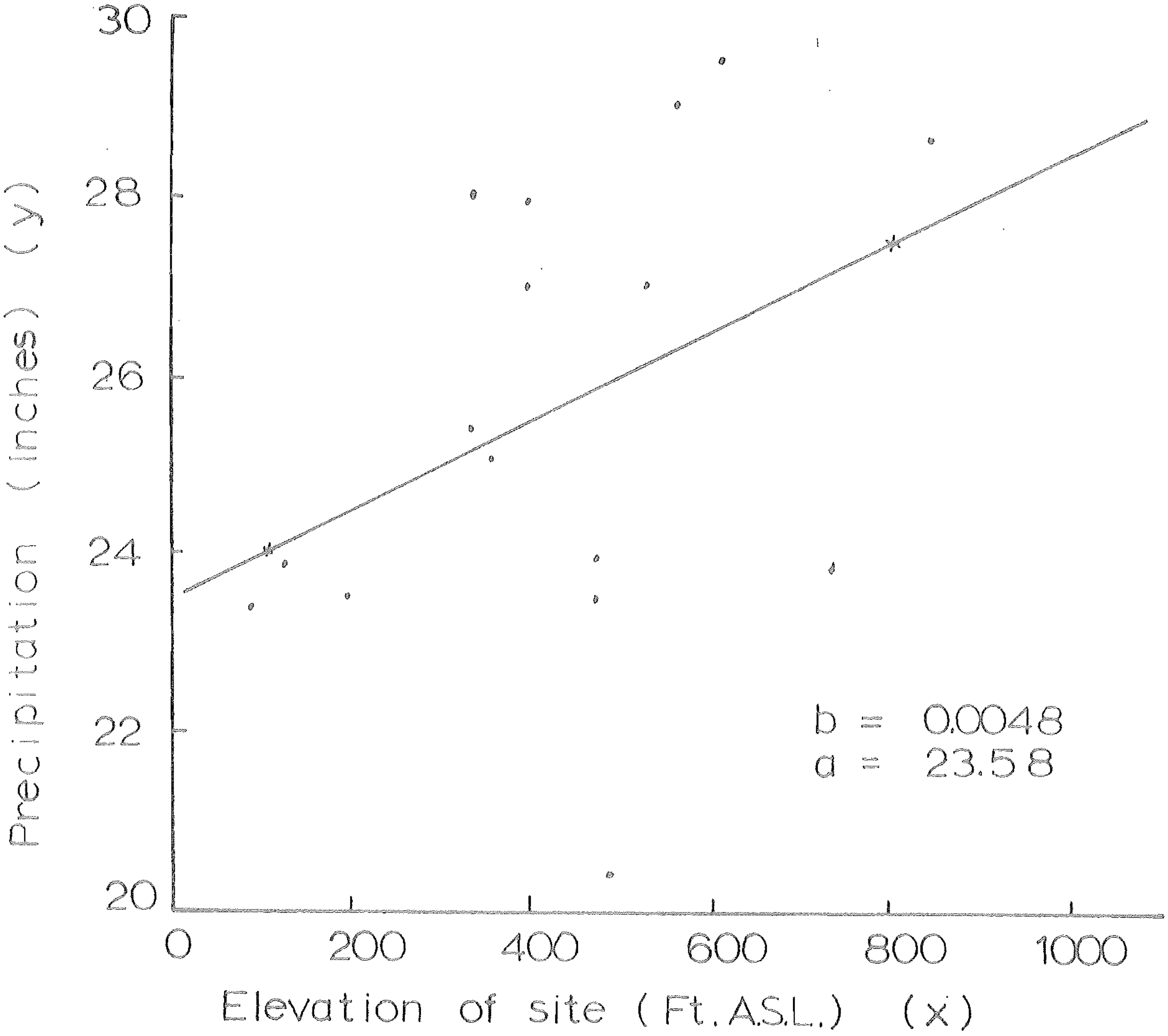


FIGURE 15.

PRECIPITATION Vs ELEVATION

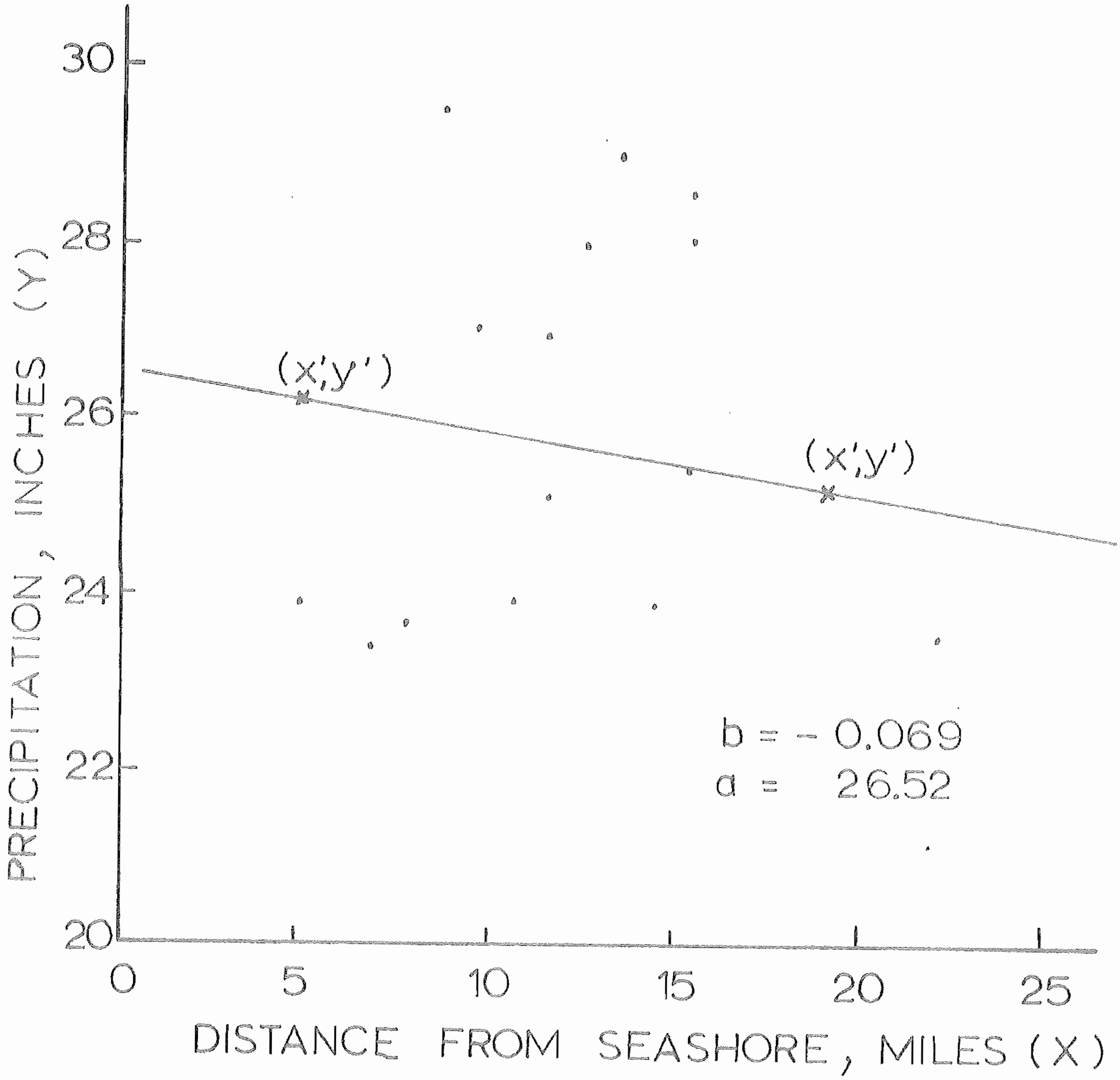


FIGURE 16.

PRECIPITATION Vs DISTANCE FROM THE SEASHORE minimum. Using this method, the constants a and b for the linear equation were determined from equations given in Freund (1965).

To determine whether the relationship between precipitation and elevation, and between precipitation and distance are significant the variance of the regression coefficient (b) in each case was determined and the student t value was computed (see Steele and Torrie, 1960).

The t value, with 14 degrees of freedom, determined for b in the precipitation - elevation relationship is 1.55 and at an α level of 10 per cent this value of t is not significant. The t value determined for b in the precipitation - distance relationship is 0.48 and at an α level of 50 per cent this value of t is not significant. In both cases there is no reason to believe that b is not equal to zero; therefore it can be concluded that there is no linear relationship between precipitation and elevation nor between precipitation and distance with B chance of type II error.

Evapotranspiration

Potential evapotranspiration is one of the more important components of the hydrologic equation. By assuming that all precipitation enters the soil when the soil is below field capacity (the volume of water retained by the soil against gravitational drainage) it is possible to compute the water deficiency and water surplus for an area. In areas where there is a water deficiet (when the soil moisture is less than field capacity) actual evapotranspiration will be less than the potential amount. The Department of Forestry and Rural Development of Canada (1966) assume a soil moisture holding capacity of 4 inches. Thus a moisture deficiency does not exist until the P. E. exceeds the precipitation by 4 inches.

Three basic methods of determining the evapotranspiration of an area are available:

1. empirical methods using climatological data;
2. measuring the actual evaporation at a site and adjusting for the whole area, and
3. balancing the hydrologic equation for E. T. when P_r, R, and S are known.

$$P_r = R + E.\,T. \pm \Delta S \tag{4}$$

where P_r is precipitation, R is runoff; E. T. is evapotranspiration; and Δ S is the change in storage.

The first method used in this report is based on empirical computations derived by Thornthwaite (Turner, 1958). A study in arid and subhumid areas in the United States to correlate the P. E. obtained by several empirical methods (the Thornthwaite method being one) with adjusted pan evaporation measurements indicated several variations in the methods. Results obtained by using the Thornthwaite method were consistently low.

> "Values of potential evapotranspiration computed by the Thornthwaite method were less than the adjusted pan evaporation at all sites used in the study. The differences ranged from -21 to -66 per cent for the entire year and from -10 to -63 per cent for the growing season" (Cruff and Thompson, 1967, p. 19).

In areas where a soil mositure deficiet occurs during the summer months, the amount of moisture actually lost through evapotranspiration during this period is somewhat less than that indicated by the P. E. value.

> "From the beginning in spring "actual" evapotranspiration is accumulated at the potential rate until the soil mositure is all withdrawn, then it is governed by precipitation until this exceeds the potential rate when actual again becomes the same as potential" (Chapman and Brown, 1966, p. 12).

Mean monthly values of P. E. were determined (using the Thornthwaite method) from the data recorded at the Truro weather station (Table 10).

Note that E. T. begins in April, reaches a peak in July and ceases during November. During July the mean P. E. exceeds the mean P_r by 2.18 inches, indicating a heavy withdrawal of the soil moisture content to satisfy E. T.

To determine the hydrologic budget of an area it is necessary not only to know the P. E. but more importantly to know what loss of water is actually occurring as E. T. To determine the actual E. T. for the Truro area a soil moisture holding capacity of four inches was assumed. By determining the accumulated P. E. from the beginning of April (Table 11) it was found that at no time was this value greater than the accumulated P_r by 4 inches. From Fig. 17 it is seen that during June, July and August the tendency exists to evapotranspire more moisture than is available on the surface, thus soil mositure is withdrawn to satisfy E. T. But since the soil moisture reservoir is never depleted then a soil moisture deficiency does not exist and there is always a continuous supply of moisture available for E. T. Under these conditions, the actual E. T. equals the P. E.

At Truro the mean annual P. E. equals 22.47 inches which is 54 per cent of the mean annual P_r. This leaves 19.25 inches or 46 per cent of the total annual precipitation available for runoff and storage in the watershed. Figure 17 shows the graphic relationship between P. E. and P_r for a twelve month Period.

Stream Flow

Stream flow or runoff has two basic components: firstly, direct runoff, that

Ref: J. A. Turner

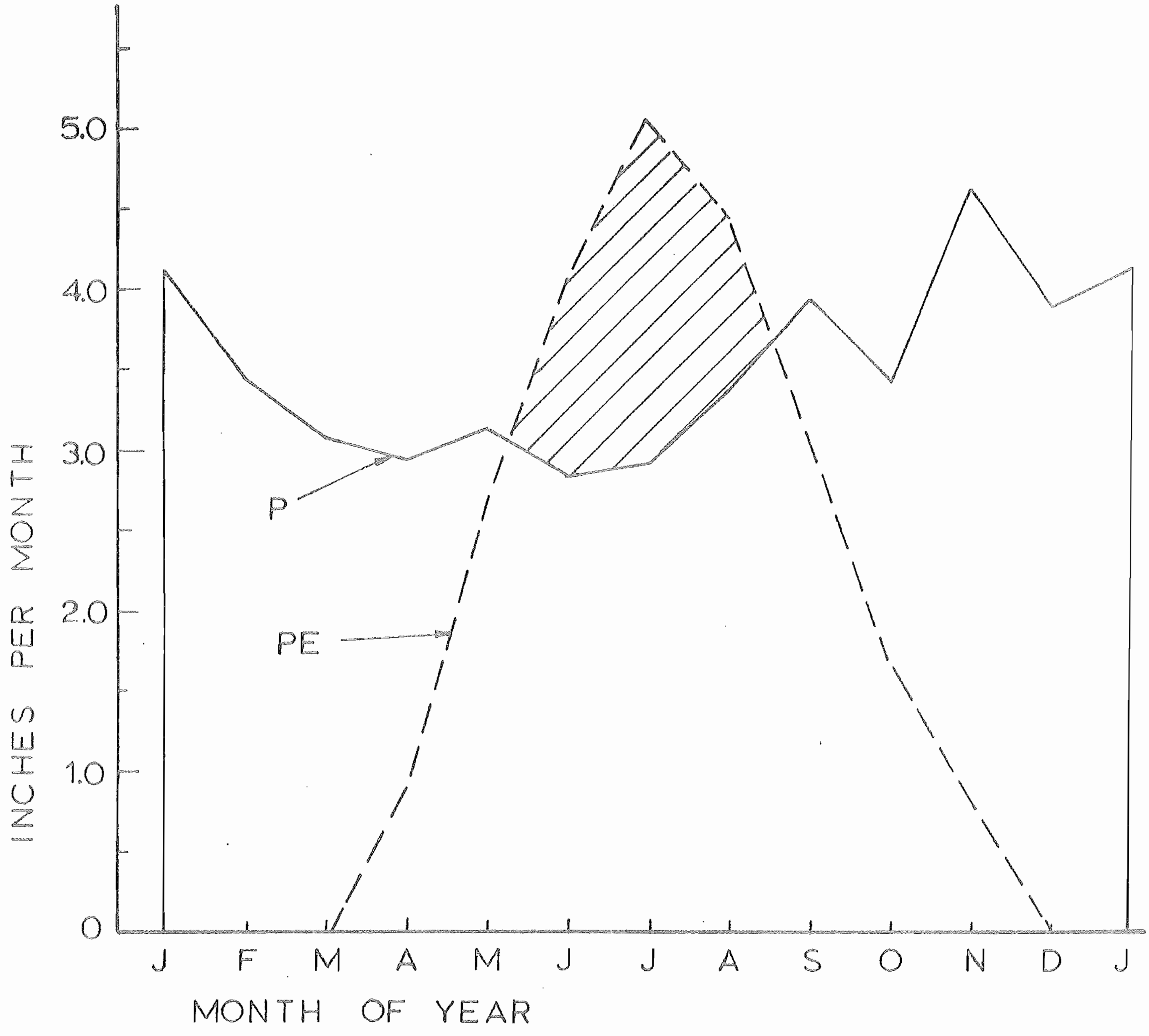
Table 10. Mean Monthly Values of potential evapotranspiration for Truro

Mean Annual Temperature = 42.8°F
Mean Temperature of Coldest Month = 20.9°F
Adjustment to Mean Temperature = + 5°
Adjust Mean Temperature = 47.8°F

Month	Mean Temperature	Unadjusted PE Ins./month	Adjusted PE Ins./month	Mean P_r Ins.	Difference
January	21.4	0	0	4.16	4.16
February	20.9	0	0	3.47	3.47
March	28.5	0	0	3.10	3.10
April	39.2	0.89	.89	2.90	2.00
May	49.1	2.00	2.70	3.13	0.43
June	57.8	2.95	4.01	2.82	-1.28
July	64.8	3.70	5.02	2.92	-2.18
August	63.2	3.50	4.35	3.37	-1.03
September	57.2	2.90	3.08	3.94	0.84
October	47.3	1.79	1.65	3.40	1.70
November	38.3	0.77	.77	4.62	3.82
December	25.3	0	0	3.89	3.89
Totals			22.47	41.72	19.25

% of Annual P_r as PE = $\frac{22.47}{41.72}$ = 54%

54% of P_r is lost
46% available for Runoff + storage



▨ — Period when the tendency to evapotranspire soil moisture exceeds soil moisture recharge

FIGURE 17.

MEAN MONTHLY PRECIPITATION AND POTENTIAL EVAPOTRANSPIRATION AT TRURO

Table 11. Actual Evapotranspiration
Assuming a 4" Soil Moisture Capacity

Month	P. E. (inches)	P_r (inches)	Accumulated P.E. (inches)	Accumulated P_r (inches)	$PE-P_r$	E. T. (inches)
April	.89	2.90	.89	2.90	0	.89
May	2.70	3.13	3.59	6.03	0	2.70
June	4.01	2.82	7.60	8.85	0	4.01
July	5.02	2.92	12.62	11.77	.95	5.02
August	4.35	3.37	16.97	15.14	1.83	4.35
September	3.08	3.94	20.05	19.08	.97	3.08
October	1.65	3.40	21.70	22.48	0	1.65
November	0.77	4.62	22.47	27.10	0	0.77
Totals	22.47	27.10			3.75	22.47

portion of precipitation reaching the stream channel by overland flow, and secondly, base flow, the water discharged to a stream channel as a result of groundwater flow. A stream which continuously receives groundwater flow is effluent, its channel being below the water-table.

Of the total precipitation the proportion which occurs as runoff depends on many factors. The most important are the rainfall intensity, rate of infiltration, soil moisture deficiency, vegetation, geology and physiography of the watershed. The volume of streamflow also varies with size of the drainage area.

The only groundwater that does not reach the streams is (1) that which is evaporated and transpired before it can reach a stream and (2) that portion passing underground beneath the coasts together with underflow in river flood plains, and discharging into the sea without first entering a stream. Although both types of discharge amount to a good many million gallons per day in a large area, in most areas they are in significant in comparison to the groundwater that does reach the streams (McGuinness, 1963). The volume of groundwater discharge as stream flow is large because it supports the dry season base flow of most streams after water has ceased running into them directly over the land surface. The rest comes from lakes and swamps which, like groundwater reservoirs, provide some storage and thus delay runoff.

Rather extreme variations in the percentage of precipitation which occur as direct runoff is evident in different parts of Nova Scotia. The Water Survey of Canada Inland Waters Branch, Department of Energy, Mines and Resources (Personal Communication) has found that in Nova Scotia from 7 to 76 per cent of the precipitation occurs as direct runoff. Variations in this ratio also exist at any particular river during different periods of the year. A storm on the Medway River on July 5, 1951, resulted in only 7 per cent of the water occurring as direct runoff while a storm on the St. Mary's River on June 21, 1959, resulted in 76 per cent of the rainfall occurring as direct runoff. It is also interesting to note that on the Medway River this percentage varies from 7 to 44 per cent while that on St. Mary's River varies from 31 to 76 per cent. However it should be born in mind that the precipitation used for determining these figures was measured at only a few sites and thus may not be an accurate measurement of what actually fell on the watershed. That both these extreme values of direct runoff over precipitation occurred during the summer months when the precipitation is of a showery and scattered nature would suggest possible errors in measurement. For example, if a shower was centered over the inaccessible and uninstrumented portion of the watershed the measured precipitation and the direct runoff-precipitation ratio would appear much higher than it actually is. An incorrect and lower ratio would result if the storm was centered over the instrumented site.

Salmon River Runoff

Since August, 1964, a continuous record of stream flow and river stage has been kept of the Salmon River at Murray, which is the outlet for the river as used in this report and all water flowing out of the watershed does so at this point. The mean daily discharge plotted on semilog hydrograph paper for the complete water year (1966-67) appears in Fig. 18. Included on the hydrograph plot are mean daily

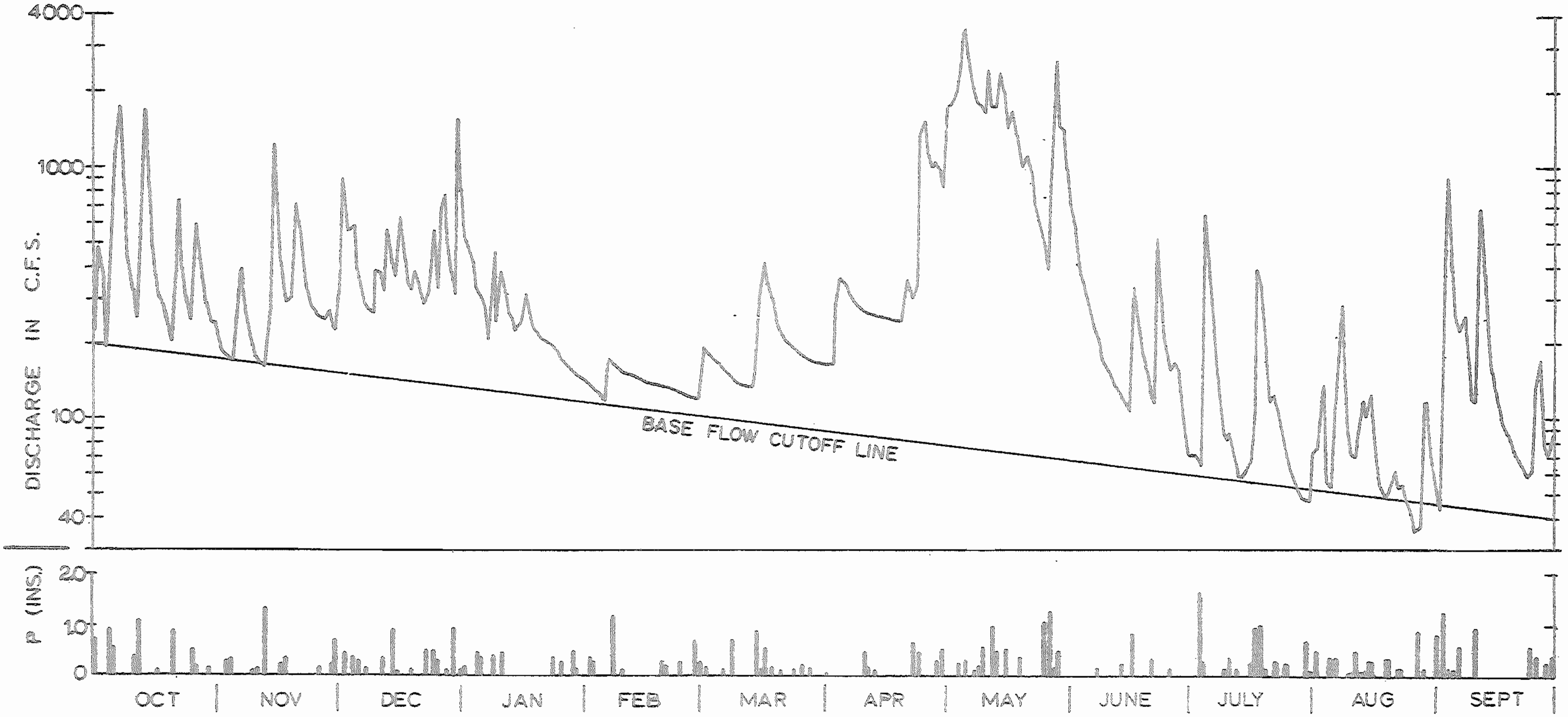


FIGURE 18 MEAN DAILY DISCHARGE OF SALMON RIVER AT MURRAY AND AVERAGE DAILY PRECIPITATION ON THE FRASER BROOK WATERSHED FOR WATER YEAR 1966-67

precipitation values from data collected at the sites in the Fraser Brook watershed; and the base flow cutoff line. This line was used to determine the portion of stream flow contributed by groundwater discharge. Table 12 summarizes flow data of the Salmon River at Murray for the three complete water years beginning in 1964. The hydrograph plot together with the summarized flow data illustrates some interesting relationships between runoff and rainfall.

The lowest mean monthly flow (for the 3 years) was a discharge of 54.7 cfs (cubic feet per second) which occurred during the month of August while the highest flow, 757 cfs, occurred in May. During individual years, however, maximum mean monthly flows occurred during December, March and May while the minimums occurred in September, August and July.

If it is necessary to determine runoff past an ungauged point on a stream and runoff records are available at some other point on the stream, predictions of stream flow at the selected point can be made. This is best done by determining the mean volume of flow from the watershed in relation to a unit area, i. e., volume of flow in acre-feet per day per square mile. Using the mean total annual flow from the Salmon River above Murray (225,000 acre-feet per year from 140 square miles of drainage area) the mean volume per unit area is 4.4 acre-ft. per day per square mile of drainage area. By using this figure, a crude estimate of daily flow can be determined at any point on the stream if the drainage area above that point is known. By using this method a mean daily flow of about 670 acre-feet is expected under the Salmon River Bridge at Truro. This compares with a flow of 616 acre-feet per day under the bridge at Murray Siding. A unit flow of 5.62 acre-feet per square mile

Table 12. Mean Monthly Flow of Salmon River at Murray
Period 1964 - 1967

MONTH

Water Year	Units	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	
Ending 1965	cfs	338	219	858	405	272	294	562	368	181	33.5	46.1	19.1	Mean = 302
	acre-ft	20770	13040	52780	24900	15110	18060	34570	22630	10760	2060	2840	1130	Total = 218600
Ending 1966	cfs	88.5	313	344	137	158	674	573	258	150	32.4	33.3	60.8	Mean = 235
	acre-ft	5260	18620	21150	8410	8770	41440	34080	15870	8950	1990	2050	3620	Total = 170200
Ending 1967	cfs	498	336	487	260	138	194	528	1640	219	136	84.5	197	Mean = 396
	acre-ft	30600	19960	29970	15970	7660	11950	31440	101100	13030	8380	5200	11710	Total = 287000
Means	cfs.	307	289	563	267	189	388	555	757	183	67.5	54.7	92.5	310
	acre-ft	18850	17220	34600	16410	10510	23800	33400	46500	10900	4140	3340	5490	225000

Mean volume = 4.4 acre-ft per day per square mile was recorded for the water year ending in 1967.

Fraser Brook Runoff

Stream flow records for Fraser Brook are complete only for the water year ending in 1967. Table 13 summarizes the flow data recorded at this site since it was instrumented. The minimum monthly flow for this year was 2.35 cfs and occurred in February, while the maximum of 29.3 cfs occurred in May. The unit flow for the Fraser Brook watershed was 5.23 acre-feet per day per square mile during the water year. This figure compares with 5.62 acre-feet per day per square mile obtained for the Salmon River watershed during the same period.

Figure 19 contains the mean daily discharge hydrograph of Fraser Brook and the average daily precipitation on the watershed during the water year 1966-67.

Precipitation - Runoff Ratios

A method offering a direct approach for determining a hydrologic budget of a watershed is available when only precipitation and stream flow are known. The hydrologic equation, an inventory of the water balance of an area, is composed of elements which obviously vary widely from year to year and of elements that are relatively constant. Some of the variable elements are so small that they can be considered insignificant when compared to the overall volumes.

A quantitative estimate of the amount of groundwater available in a watershed after losses due to E. T. can be made if the hydrologic budget for the basin is

Table 13. Mean Monthly Flow (cfs) of Fraser Brook
Period 1965 - 1967

		MONTH												
Water Year	Units	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	
Ending 1966	cfs			7.35	2.98	3.70	16.15	11.5	6.6	3.65	0.33	0.52	1.55	
	Acre-ft			452	183	206	993	684	407	217	20.1	32.2	92.2	
Ending 1967	cfs	9.6	8.4	12.3	6.2	2.35	5.0	14.8	29.3	3.6	5.4	2.9	7.0	Mean = 9.0
	Acre-ft	588	501	757	383	131	306	880	1800	216	331	181	418	Total = 6490

Volume = 159 acre-ft/month/square mile

= 5.23 acre-ft/day/square mile

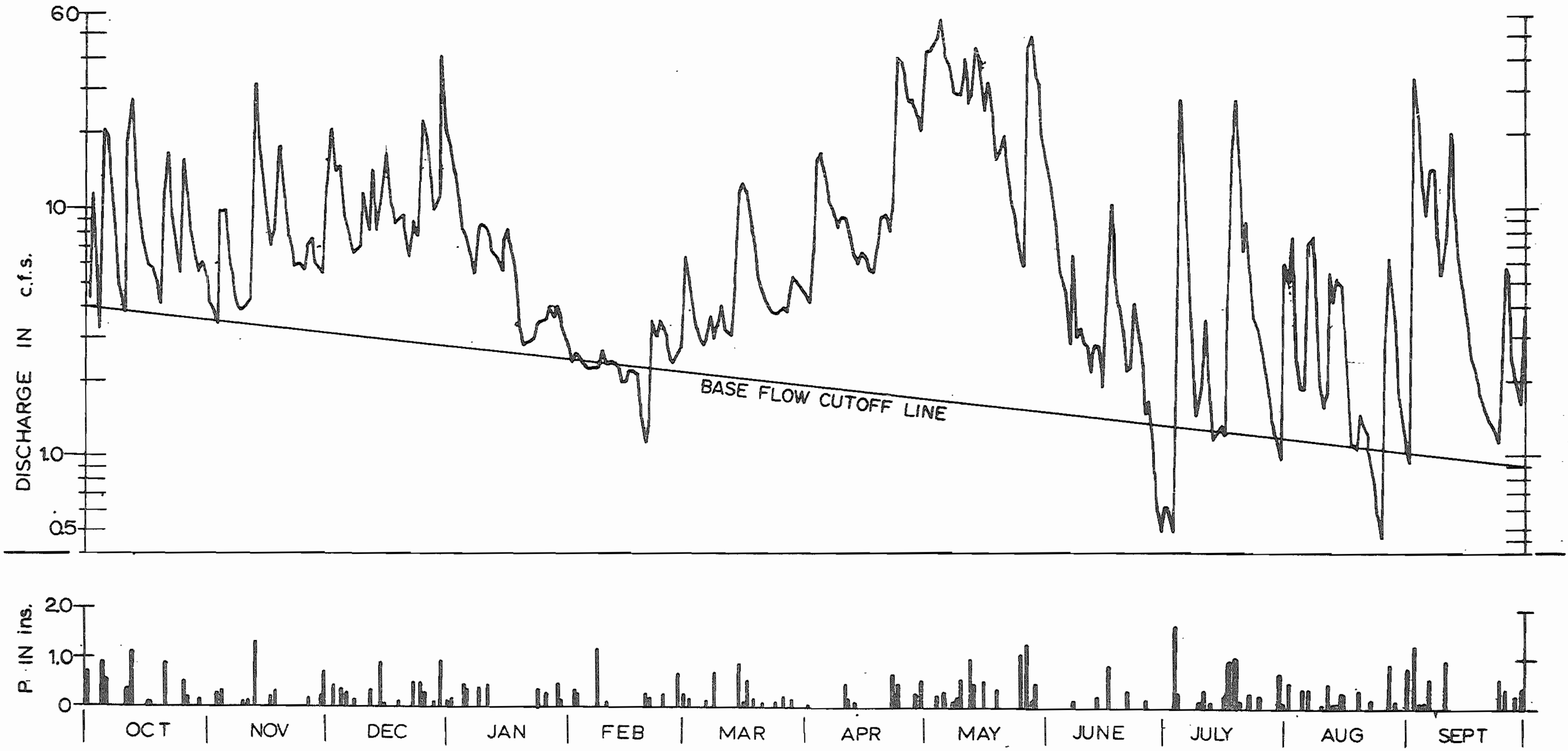


FIGURE 19 MEAN DAILY DISCHARGE OF FRASER BROOK AND AVERAGE DAILY PRECIPITATION FOR WATER YEAR 1966-67

computed.

A comprehensive definition of the hydrolgic budget is given in Schicht and Walton (1961, p. 8):

> "A hydrologic budget is a quantitative statement of the balance between the total water gains and losses of a basin for a period of time. The budget considers all waters entering and leaving or stored within a basin. Water entering a basin is equated to water leaving a basin, plus or minus changes in basin storage."

The hydrologic budget is calculated on the basis of the water year (October 1 to September 30) because surface water discharge and groundwater storage are generally at a minimum at the beginning and end of the period. When stated as an equation including all of the items that may be involved, the hydrologic budget is:

$$P_r + \text{Sur I} + \text{Sub I} + \text{Imp} = \text{R.} + \text{E.T.} + \text{U} + \text{Exp} \pm \Delta\,\text{Soil} \pm \Delta\,\text{Ss} \pm \Delta\,\text{Sg} \qquad (5)$$

where:

P_r = precipitation

Sur I = surface inflow

Sub I = subsurface inflow

Imp = imported water

R = stream flow (surface and groundwater runoff)

E. T. = evapotranspiration

U. = subsurface outflow

Exp = exported water

Δ Soil = change in soil moisture

Δ Ss = change in surface water storage

Δ Sg = change in groundwater storage

Inflow or water gains to a basin are the elements on the left side of the equation. In the Salmon River basin, all elements with the exception of P_r are considered negligible because they contribute little, if any, water to the basin.

On the right side of the equation, the elements may be classified into two main groups: 1. outflow;

2. storage.

Outflow elements include R, E.T., and U. An estimate of the mean U through the buried stream channel under Murray is about 0.36 cfs or about 9.14×10^{-4} times the mean surface runoff flow at Murray. Therefore the subsurface outflow from the watersheds under study is considered negligible and is disregarded in the budget computations.

The remaining elements on the right of the equation are various forms of water storage within a basin. Values for storage will be relatively the same at the end of each water year providing the past water year hasn't been an extremely wet or extremely dry one. In the Beaverdam Creek Basin, Maryland, Rasmussen and Andreasen (1959) show that basin storage was only 3.2 per cent of the total precipitation, while in the Pomperaug River Basin, Connecticut, Meinzer and Stearns (1929) found that basin storage was only 1.4 per cent of total precipitation, an average of 2.3 per cent.

In view of the facts that basin storage may account for only a small per cent of the precipitation and that runoff and evapotranspiration together account for possibly all but a few percent of the precipitation basin storage may be neglected. To obtain a rough estimate of the budgets for water year 1966-1967 on the Salmon River and Fraser Brook watersheds only precipitation, runoff and evapotranspiration were used in the equation. Thus knowing precipitation and runoff from available records, estimates of evapotranspiration were made by:

$$E.\ T. = P_r - R \qquad (6)$$

Table 14 summarizes the data for the budget. The average precipitation for the Salmon River basin was determined from data recorded at three stations: Camden, Harmony, and Truro. The average precipitation for the Fraser Brook Basin was determined only from the data recorded at Camden and Harmony.

By this method evapotranspiration for the year was estimated as only 33 per cent of the precipitation for the Salmon River basin and 26 per cent for the Fraser Brook basin. Both are considerably lower than the 54 per cent value for evapotranspiration as determined by the vapor transfer method set forth by Thornthwaite (Turner 1958).

Computations of base flow by the "low flow cut-off line method" (Chernaya, 1964) indicate similar results for the Salmon River watershed and one of its components, the Fraser Brook watershed (Table 14). Base flow in the Salmon River accounted for 25 per cent of the total stream flow or 18 per cent of the precipitation. The Fraser Brook base flow accounted for 23 per cent of the total flow or 15 per cent of the precipitation.

Table 14. Hydrologic Budgets for Salmon River Watershed and the Fraser Brook Water shed for Water Year 1966 - 1967

			STREAMFLOW								
	PRECIPITATION		SURFACE WATER			BASE FLOW			EVAPOTRANSPIRATION		
	Inches*	Acre-feet**	Inches	Acre-feet	% of Precip.	Inches	Acre-feet	% of Precip.	Inches	Acre-feet	% of Precip.
Fraser Brook Watershed	53.40	9,660	27.8	4,995	52	8.0	1,495	15	17.60	3,180	33
Salmon River Watershed	51.98	386,100	29.0	216,445	56	9.35	70,555	18	13.43	100,000	26

* Inches of Water over the entire basin.

** 1 acre-foot is the volume of water 1 foot deep over an area of one acre.

Aquifers

Introduction

Several potentially productive aquifers exist in the map area which are not being utilized fully at present. The most promising aquifers are the water-bearing geological formations of washed sand and gravel deposits. These materials have favorable porosities and permeabilities for the storage and transmittance of large quantities of groundwater. Porosity is the measure of the void volume of an earth material and is usually expressed as a percentage of the total volume of the mass. Permeability is the rate of flow of a fluid through a unit cross section of a porous media under a unit hydraulic gradient, at a specific temperature. Generally, both the porosity and permeability of unconsolidated earth materials are higher than those of indurated sediments or bedrock units. Thus, soils or surficial deposits are capable of storing and transmitting larger volumes of water than the bedrock units.

Porosity is also an index of how much groundwater can be stored in the saturated material which serves as an underground reservoir. It should be stressed, however, that porosity does not measure the actual volume of water that the earth material will yield nor the rate at which it will be released from storage. The specific yield is the volume of water released from a unit volume of material when drained by gravity and is thus only a fraction of the porosity. It should also be mentioned here that increasing the porosity of a material will not necessarily increase its permeability (see Table 15). Sediments consisting of uniformly sorted gravels generally have the highest hydraulic conductivities. The porosities of these sediments are generally less than those of finer grained materials. The specific yields of these well sorted gravels are generally higher than those for finer and more poorly sorted sediments.

The coefficients of transmissibility and storage are commonly used in groundwater studies to express the hydrological characteristics of an aquifer. The coefficient of transmissibility (T) of an aquifer is the product of the field coefficient of permeability multiplied by the thickness of the saturated portion of the aquifer. Thus it is the rate of flow of water in gallons per day through a vertical strip of the aquifer 1 foot wide under unit hydraulic gradient (Ferris et al., 1962). In this report it has the units of imperial gallons per day per foot (igpd/ft). The coefficient of storage (S) of an aquifer is the volume of water released from storage or taken into storage, per unit of surface area of the aquifer per unit change in head. In water-table aquifers, S, is the same as the specific yield of the material unwatered during pumping (Johnson, 1966). Under artesian conditions where the piezometric surface is lowered by pumping, water is derived from storage by the compaction of the aquifer and its associated beds and by expansion of the water itself, while the interstices remain saturated (Walton, 1962).

The aquifers in the map area fall into the two main categories: confined and unconfined. A confined aquifer is one in which the water is limited above by an impervious of less impervious rock; when that rock is penetrated the water level will rise above the level of the aquifer at that point. Thus a hydrostatic head or pressure exists in the aquifer. An unconfined aquifer is one in which the water is stored at

Table 15. Water Bearing Properties of Common Rocks

	Permeability		Porosity
Highest	Permeability	Highest	Porosity
	Well sorted gravel		Soft Clay
	Porous Basalt		Silt
	Cavernous Limestone		Tuff
	Well-sorted sand		Well-sorted sand
	Poorly sorted sand and gravel		Poorly sorted sand and gravel
	Sandstone		Gravel
	Fractured crystalline rock		Sandstone
	Silt and Tuff		Porous basalt
	Clay		Cavernous limestone
	Dense crystalline rock		Fractured crystalline rock Dense Crystalline rock
Lowest	Permeability	Lowest	Porosity

After S. N. Davis and R. J. M. DeWiest, 1967.

atmospheric pressure. Thus no impervious materials exist between the water table and the ground surface.

Bedrock Aquifers

Triassic

Sediments of Triassic age, those belonging to the Fundy Group, provide the most productive bedrock aquifers in the map area. The good water-bearing sandstone and conglomerate beds of this formation are usually confined by overlying beds of shale and/or siltstone. These conditions are nearly always encountered in the lowland area and flowing artesian wells result.

An examination of the sandstones and conglomerates indicates that these sediments are poorly indurated and show no cleavage or major jointing. It is therefore suggested that movement of water through these rocks occurs mainly through intergranular pore spaces, with a smaller portion flowing through poorly developed joint systems and along bedding plane fractures.

Table 16 lists data obtained from pump tests conducted on wells drilled into these rocks. The coefficient of transmissibility ranges from about 1720 to over 9700 igpd/ft for a 100 foot interval of the aquifer indicating that wells between 200-300 feet deep should yield at least 500 igpm for 20 years of continuous pumping. The hydrograph for the water year 1966-67 recorded in an observation well drilled into these sediments at Bible Hill is shown in Figure 20.

Table 16. Hydraulic Characteristics of the Triassic Aquifer

Location of Well	Depth (ft.)	Static Water Level (ft. below surface)	Pumping Rate igpm	Transmissibility igpd/ft	Permeability igpd/ft^2
Debert Well No. 3	150	21	160	14,600	112
Bible Hill	145	40	26	2,490	24
N. S. A. C. Well No. 1	300	63	200	3,625	15

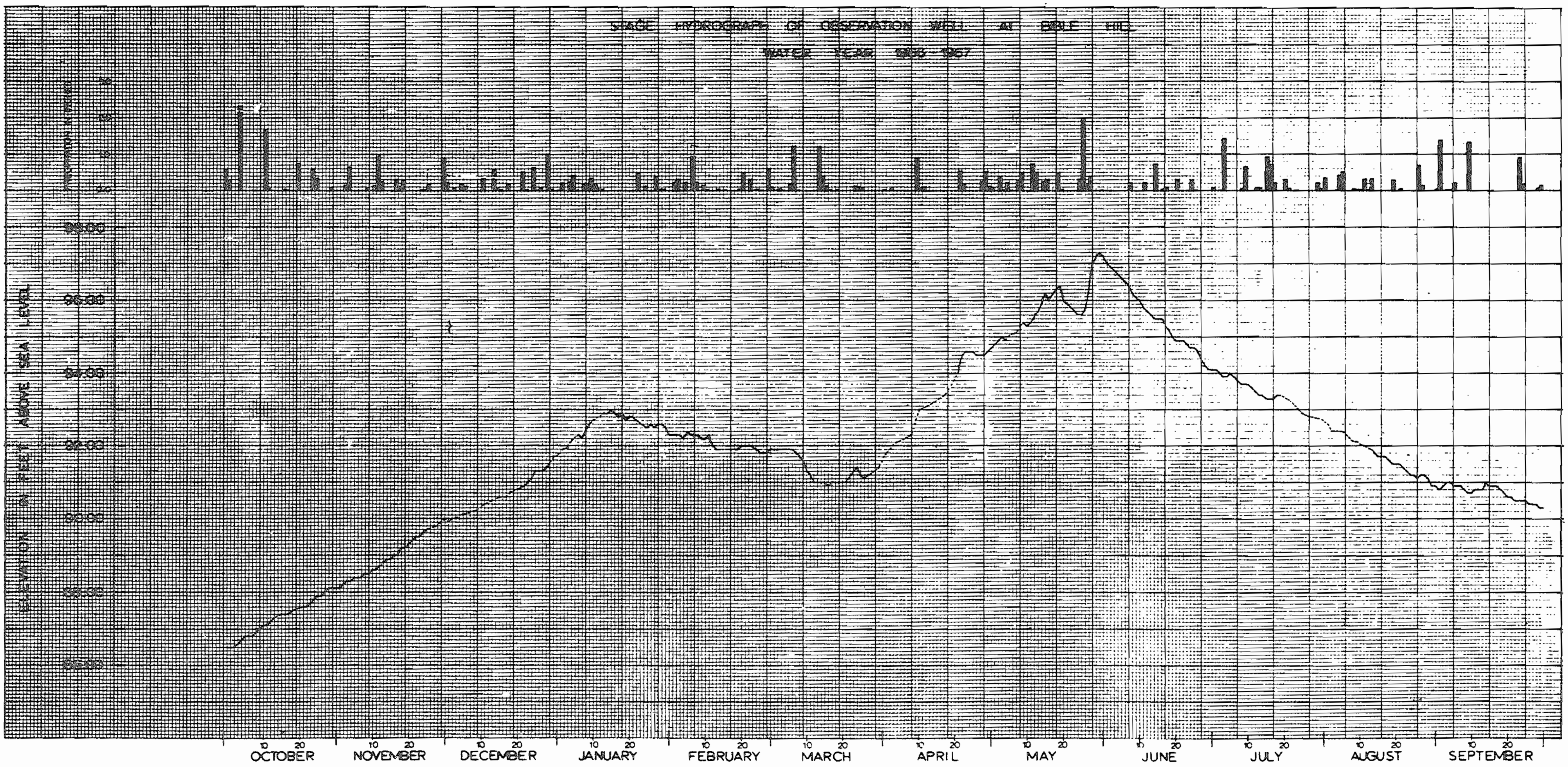


Fig. 20. Stage Hydrograph of Observation Well at Bible Hill (Triassic Aquifer) Water Year 1966–1967.

Canso

Canso aquifers consist mainly of well indurated sandstones and shales, and allow the movement of groundwater mainly along fault planes and through joint systems. As a result, the yields of wells drilled into this aquifer are generally small, varying from 5 to 25 igpm (Brandon 1966). Data obtained from a pump test conducted on a 4 inch - diameter well 60 feet deep at Fraser Brook indicated a transmissibility of about 350 igpd/ft (permeability about 7 igpd/sq.ft.). This indicates that the rock would yield sufficient water for domestic or farm demands. The hydrograph for the water 1966-67 recorded in an observation well drilled into a Canso aquifer at Fraser Brook is shown in Figure 21.

Surficial Aquifers

Outwash Sands and Gravels

At Murray Siding the buried stream channel underlying the Salmon River flood plain is filled with outwash sediments consisting mainly of coarse sand and medium-sized gravel. This outwash material, underlying about 6 feet of recent alluvium consisting of fine sand and silt, has been freed of the finer sediments during deposition and is thus a good water bearing material.

Calculations based on data from a pump test conducted on a screened well developed in this sand and gravel aquifer indicated a T of about 49,500 igpd/ft (saturated thickness 20 feet or Permeability of 2.48×10^3 igpd/sq. ft.) and a S of about 5.5×10^{-2}. Because the saturated thickness of this aquifer is limited to about

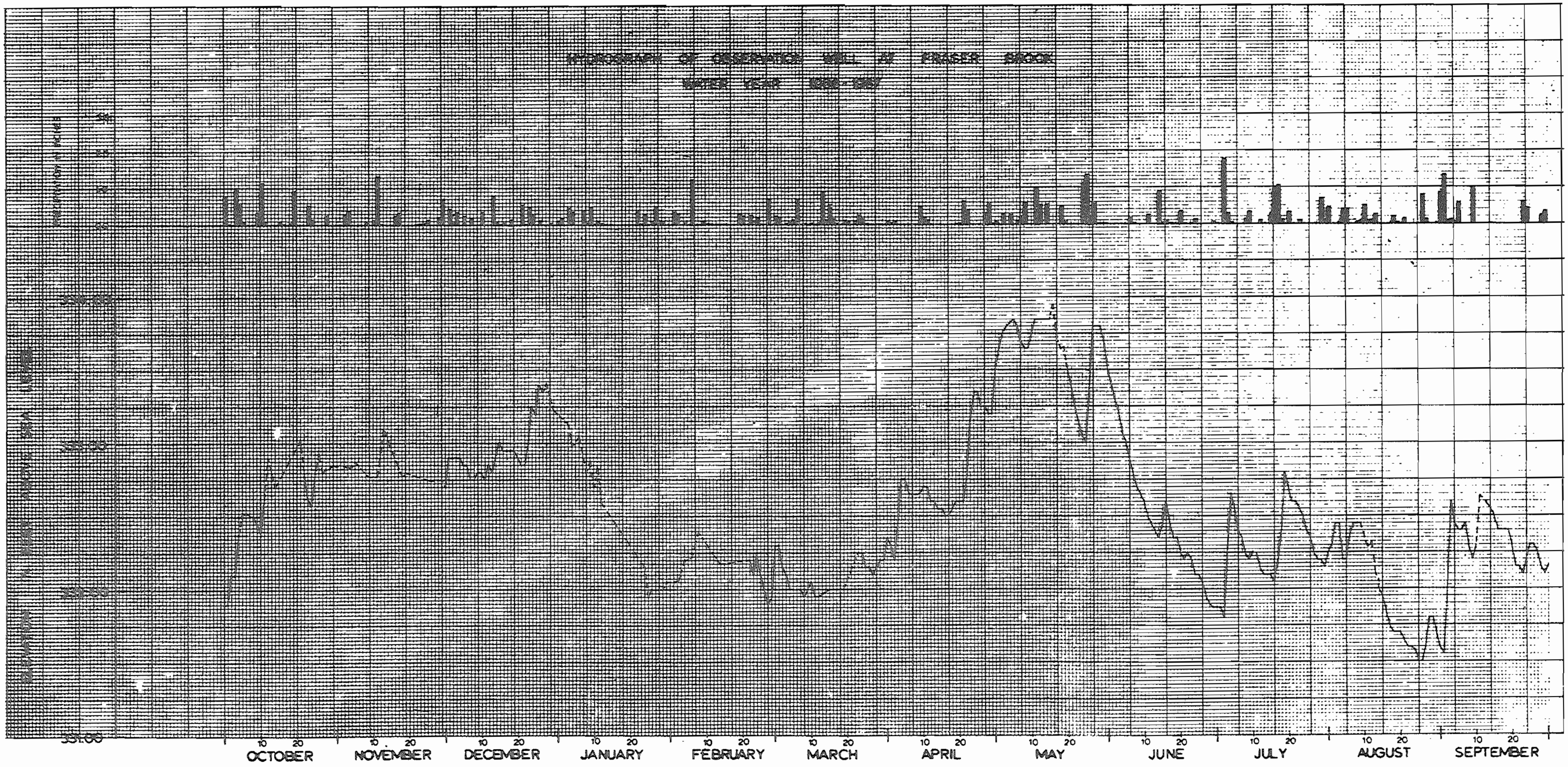


Fig. 21. Stage hydrograph of observation well at Fraser Brook (Canso Aquifer) Water Year 1966-1967.

20 feet (see cross-section of channel, map 3) well yields are limited to about 200 igpm. However, because of the relatively high transmissibility and broad extent of the aquifer, several wells may be developed within about 400 feet of one another, each producing up to 200 igpm. Several wells spaced so that interference among them remains insignificant is the most practical method of obtaining large volumes of water from this type of aquifer. Well fields of this type, developed in aquifers of limited saturated thickness, are capable of yielding great volumes of water. Figure 22 shows the stage hydrographs from three observation wells drilled into this buried channel and of the Salmon River at Murray.

It should be noted, however, that the area of most promising potential based on geology is the North River Channel (Figure 13, cross-section E-E). The channel at this point contains outwash sands and gravels which are about 65 feet deep.

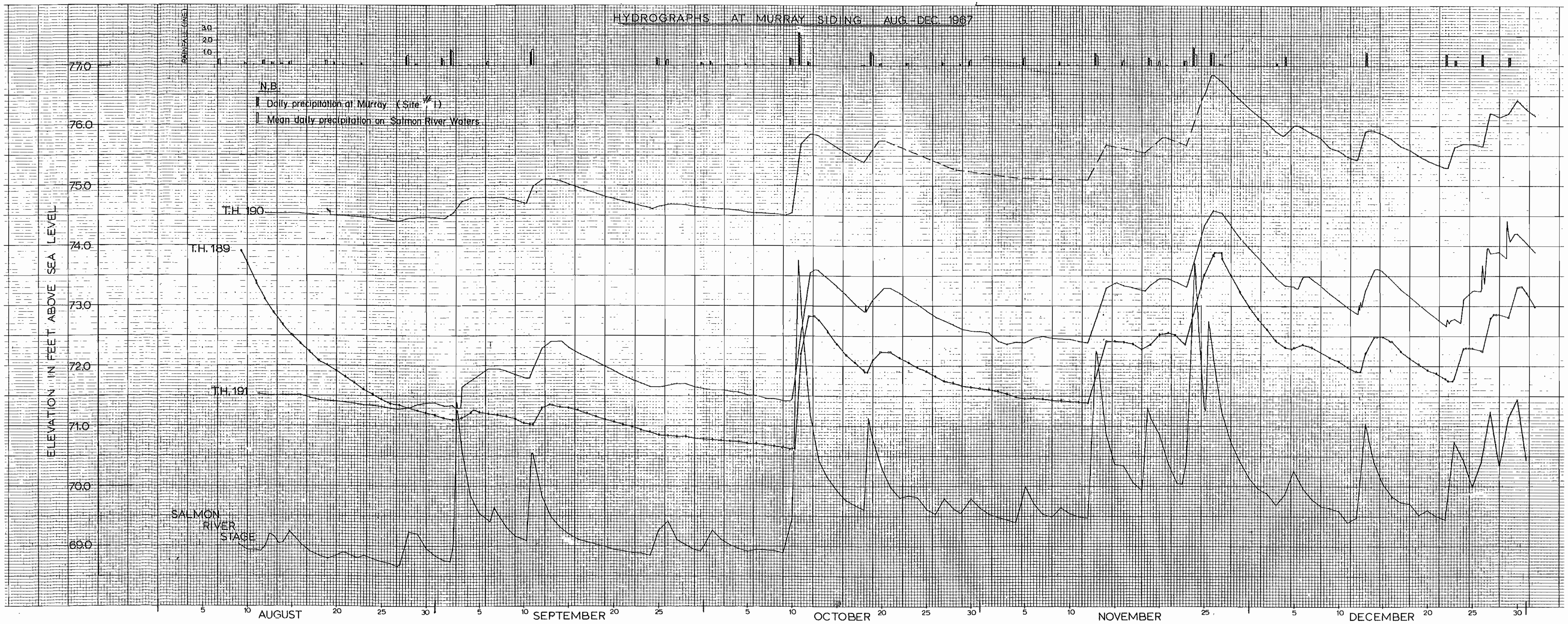


FIGURE 22. Hydrographs recorded from Aug.–Dec. 1967 in observation wells drilled into the buried channel at Murray.

WATER QUALITY

Hydrochemistry

Introduction

The character and amount of chemical constituents found in water depend mostly upon the geologic environment through which the water has passed and the time that the water has been in contact with this environment. Other factors which affect the content of mineral matter dissolved in water are:

1. the solubility of the environmental materials (soils, rocks) and,
2. the pH of the water itself and its ability to dissolve solid matter.

Hem (1959) indicates that the relationship between mineral composition of a natural water and that of the solid materials with which the water has been in contact may be comparatively simple for shallow unconfined aquifers recharged directly by precipitation. A complex relationship usually develops in confined or deeper interconnected aquifers where mixing of waters and continuing chemical reaction occurs.

In the area under study, relatively small variations occur in the dissolved materials of the surface water. In contrast to this, however, a wide range of mineral constituents is present in groundwater derived from the various water-bearing rock units. Analyses of waters collected from surface sources, surficial deposits and from the bedrock aquifers showed a decrease in quality in that same order. The main objectionable qualities of the surface water are colour, turbidity and suspended matter, whereas groundwater derived from the bedrock aquifers contains more dissolved mineral matter. All waters analyzed are suitable for irrigation purposes, and in most cases groundwaters also meet the specifications of the U. S. Public Health Services (1962).

Method of Analyses and Reporting

The methods used to determine the amount of chemical constituents in the water samples were those standardized as outlined in "Standard Methods for the Examination of Water and Waste Water" (American Public Health Association, et. al. 1965). These procedures were determined by the American Public Health Association, the American Water Works Association, and the Water Pollution Control Federation and have been accepted by the American Chemical Society. They are therefore generally accepted as the standard methods for determining and reporting chemcial analysis of water in North America.

Analytical results may be expressed either as milligrams per liter (mg/1) or as parts per million (ppm). Assuming that 1 liter of water weighs 1 kg., the number of mg/1 is equivalent to the number of ppm. In water analysis, "parts per million" is always understood to imply a weight/weight ratio even though in practice a volume may be measured instead of a weight.

In some applications of the results of chemcial analyses, it is necessary to consider not only the weight of the ions but their chemical equivalence (Equation 7). An equivalent per million (epm) is a unit chemical equivalent weight of ion per million unit weights of solution. The equivalents per million of an ion are determined by dividing the concentration of the ion in parts per million by the combining weight of that ion (combining weight equals molecular weight of the ion divided by the ionic charge).

Test results for color and turbidity are recorded in units of color and turbidity. Hydrogen ion concentration is expressed in terms of pH value.

Chemical Analyses and Classifications

Color and Turbidity

Two physical tests were conducted on the samples to determine measurements of the color and turbidity of the water analyzed. Turbidity is caused by the presence of suspended matter such as clay, silt, finely divided organic matter, plankton and other microscopic organisms. It is defined as the optical property of the sample which causes light to be scattered and absorbed. Although turbidity is not necessarily a dangerous characteristic, it is objectionable from the stand point of appearance of water for domestic use of water and its control is essential for many industrial applications. The upper limit for turbidity set by the U. S. Public Health Service Drinking Water Standards is 5 units.

The term "color" means the color of the liquid from which turbidity has been removed. It is usually caused by the presence of organic matter, industrial dyes and colloidal iron compounds. Color is reduced by storage and the bleaching action of sunlight. Any degree of colour is objectionable to water consumers. The U. S. Public

Health Service Drinking Water Standards (1962) recommends that color should not exceed 15 units.

All values of colour and turbidity of groundwaters within the area are well below the recommended limits. In contrast, color and turbidity values for all samples of surface waters tested are above the recommended limits.

Iron and Manganese

The presence of iron and manganese above certain levels are highly objectionable constituents in water supplies for either domestic or industrial use. Their behavior in water is chemically similar and they are discussed together in this section. Iron is distributed freely in nature and is present in nearly all soils, rocks, and vegetation. Both iron and manganese are insoluble in the oxidized state and thus their presence in water requires the absence of dissolved oxygen and a low pH which reduce them to the soluble form.

Iron imparts a brown colour to laundry and containers and affects the taste of beverages. When present in amounts greater than 0.3 ppm it gives a bitter, sweet, stringent taste to the water. Many of the problems related to the presence of iron in water are also in evidence for manganese, except that the latter metal is less common in nature.

The recommended limits (see Table 17) for drinking water set by the U. S. Public Health Service are: 0.3 ppm for iron; 0.05 ppm for manganese, and 0.3 ppm for iron plus manganese.

Table 17. Suggested upper limits for concentrations of various water constituents (Based on U. S. Public Health Service 1962)

Constituents	Concentrations (ppm)
Iron (Fe)	0.3
Manganese (Mn)	.05
Fe + Mn	.3
Sulphate (SO_3)	250
Chloride (Cl)	250
Nitrate (NO_3)	10
Arsenic (As)	0.01
Lead (Pb)	0.05
Zinc (Zn)	5.0
Copper (Cu)	1.0
Cyanide (CN)	0.01
Total Dissolved Solids (TDS)	500

Several of the groundwaters from different source areas contain iron and manganese in concentrations greater than those recommended by these standards (see Appendix C and D). Only the samples of surface water at Riversdale contained amounts of Fe plus Mn greater than 0.3 ppm.

Sodium

Sodium found in water is usually associated with chloride and/or bicarbonate. It may be derived from weathered feldspars, evaporite deposits, or directly through salt water intrusion into a fresh water-bearing zone. Relatively high concentrations are found in hard waters which have been softened by the sodium exchange process (ion exchange resins).

Table 18. Quality Classification of Water for Irrigation
(After Wilcox 1955)

Soluble Sodium Percentage	Calculated Total Dissolved Solids (epm)	Water Class
< 20	< 2.5	Excellent
20-40	2.5-7.5	Good
40-60	7.5-20.0	Permissible
60-80	20.0-30.0	Doubtful
> 80	> 30.0	Unsuitable

The ratio of sodium to total cations is important in agriculture because soil permeability is detrimentally affected by a high sodium ratio. The presence of sodium in drinking water supplies is also important to human pathology since certain diseases require water with a low sodium concentration.

Two methods are available for determining whether the amount of sodium in a water is at a safe level for use of this water as an irrigation water. In place of rigid limits of salinity for irrigation waters, quality is commonly expressed in these terms indicating a relative suitability (Table 18). Sodium content is usually expressed in terms of per cent sodium or soluble sodium percentage (SSP) and is calculated from the following equation:

$$SSP = \frac{(Na + K)\ 100}{Ca + Mg + Na + K} \tag{7}$$

where all ionic concentrations are expressed in milliequivalents per liter, or equivalents per million (epm). The salinity laboratory of the U. S. Department of Agriculture recommends the use of the sodium absorption ratio (SAR) because of its direct relation to the absorption of sodium by soil (Table 19). The SAR is determined from the following equation:

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}} \tag{8}$$

where the concentrations are again expressed in epm.

It should be stressed, however, that the presence of sodium alone in water does not determine its suitability for irrigation. Other factors that determine the suitability of a water for irrigation are:

1. the tolerance of the crops to boron, salinity, selenium, chlorides and other elements present in the water that may be detrimental to the plant itself;

2. soil types, climatic conditions, and the irrigation practices to be applied;
3. and the total concentration of salts present in the irrigation water.

Table 19. Recommended Water Classification for Sodium Absorption Ratio (Richards 1954)

SAR	Water Class
< 10	Excellent
10-18	Good
18-26	Fair
> 26	Poor

Chlorides

Chlorides are found in practically all natural waters. They may come from natural minerals, from sea water contamination of underground supplies, or from pollutants by animal, human or industrial activities. Chlorides in water may impart a salty taste at concentration as low as 250 ppm when present with sodium although in other waters where present with calcium and/or magnesium, 1,000 ppm chloride may give a salty taste.

The tolerance of chlorides by human beings varies with climate and exertion, and chlorides lost through perspiration may be replaced by chlorides in either the diet or drinking water. Individuals adjust physiologically within a few days to increased level of salt intake. In general, it is the cation (Ca, Mg, Na or K) associated with the chloride that produces a harmful affect.

Chlorides also have detrimental effects when present in industrial and irrigation water supplies. McKee and Wolf (1963) suggest that the following concentrations of chloride will not be normally deleterious to the specified beneficial uses:

Industrial water supply-----------50 ppm
Irrigation----------------------100 ppm

Calcium

Calcium salts and calcium ions are commonly encountered in water. The presence of calcium in ground or surface water supplies results from passage through or over, deposits of limestone, dolomite, gypsum and gypsiferous shale.

The human body requires approximately 0.7 to 2.0 grams of calcuim per day as a food element, an amount considerably in excess of the amount normally consumed, even in hard water. It is believed that calcium in water can be used by the body as a supplement to the calcium in the diet. McKee and Wolf (1963) indicate that excess calcium and magnesium in drinking water has been suggested as a contributing factor in the formation of concretions in the body (i. e. kidney, bladder stones).

However, as far as can be determined at the present time, calcium limits are desirable for domestic supplies not because of a hazard to health, but because calcium may be disadvantageous for other household uses, such as washing, bathing and laundering because it tends to precipitate as calcium carbonate on cooking utensils and water heaters.

On the other hand, the presence of calcium in water has several beneficial uses: it tends to inhibit corrosion of cast iron and steel; it is essential for normal plant growth and is desirable in irrigation water, and the presence of calcium in water reduces the toxicity of many chemical compounds to fish and other aquatic fauna.

Nitrates

Nitrates are the end product of the aerobic stabilization of organic nitrogen and,as such,theyoccur in polluted waters that have undergone self-purification or aerobic treatment processes. Nitrates also occur in percolating groundwaters as a result of excessive application of fertilizer, or of leaching from cesspools. In excessive amounts, it contributes to the illness known as infant methemo-globinemia, a disease characterized by certain specific blood changes and by cyanosis. Nitrates are noted among the poisonous ingredients of mineralized waters, with potassium nitrate (KNO_3) being more poisonous than sodium nitrate ($NaNO_3$) (Steyn and Reinach, 1939). The U. S. Public Health Service Drinking Water Standards set a limit of 10 ppm for nitrates mainly because of their dangers to the health of infants in concentrations above 10 ppm.

The presence of nitrates in industrial water supplies is injurious to the dyeing of wool and silk fabrics, is harmful to fermentation processes and cause disagreeable taste in beer. Excess nitrates in irrigation waters tend to reduce soil permeability and they may accumulate to toxic concentrations in the soil. Commonly, in irrigation water nitrates are desirable for their fertilizing value.

Sulphates

Sulphates occur naturally in waters, mainly as a result of leaching from gypsum, and as the final oxidized stage of sulphides, e. g., iron sulphide. They may also be discharged in numerous industrial wasters,such as those from tanneries, sulphate-pulp mills, textile mills, and other plants that use sulphates or sulphuric acid.

The presence of large amounts of magnesium sulphate ($MgSO_4$, epsom salt) and sodium sulphate (Na_2SO_4, glauber's salt) in drinking water often causes a laxative effect on persons unaccustomed to the water. The U. S. Public Health Service Drinking Water Standards (1962) recommend that sulphates do not exceed 250 ppm, except when a more suitable supply is not available.

Sulphates are reported to increase the corrosiveness of water toward concrete. On the other hand, sulphates are somewhat less toxic than chlorides in irrigation waters.

Total Hardness

Hardness of water is caused principally by the elements calcium and magnesium and sometimes by iron, manganese, strontium and aluminum. It is that property of water which prevents or hinders a soap from forming a lather.

Most of the calcium and magnesium present in natural water is in the form of carborates (CO_3), bicarbonates (HCO_3) and sulphates (SO_4). When calcium and magnesium combine with the carbonate or bicarbonate in a water, a carbonate or temporary hardness which may be removed by boiling results. Permanent hardness, or noncarbonate hardness, cannot be removed by boiling and is caused principally by calcium sulphate but may include magnesium sulphate. Both types of hardness are usually present in a water, the predominant one being determined by the soluble minerals in an aquifer.

A relationship exists between the hardness and alkalinity of a water.

> "When the total hardness is numerically greater than the sum of the sum of the carbonate alkalinity and the bicarbonate alkalinity, that amount of hardness which is equivalent to the total alkalinity is called carbonate hardness; the amount of hardness in excess of this is the noncarbonate hardness. Also when the total hardness is equal to or less than the sum of CO_3 and HCO_3 alkalinity all of the hardness is carbonate hardness and there is no noncarbonate hardness. Thus the carbonate hardness of a water is equal to the total alkalinity". (American Public Health Association 1965, p. 146).

Because the hardness of a water does not affect the health of people, there are no recommended upper limits for its occurrence in drinking water supplies. The major detrimental effect of hardness is economic; thus if use of a hard water becomes sufficiently inconvenient it may become more practical to either treat the hard water or to locate another water supply.

Total Dissolved Solids (TDS)

Total dissolved solids in water include all solid material in solution. It does not include suspended material, dissolved gases or colloidal matter. Thus if all dissolved solids were determined by chemical analysis, the numerical sum of all these constituents would be equivalent to the total dissolved solids.

The U. S. Public Health Service Drinking Water Standards (1962) specify that the dissolved solids should not exceed 500 ppm if more suitable water is, or can be made, available. Higher concentrations than this limit in water may impart a taste and may have a laxative effect on new users. Thus its use would be determined on the basis of the local situation, alternative supplies, and the reactions of the local population. Its rejection as a water supply would be based not so much on the TDS value itself as on the presence of constituents contributing to that value.

Dissolved solids in industrial waters can cause foaming in boilers and interference with clearness, colour, or taste in many finished products. The recommended maximum concentrations in water supplies for industrial uses varies considerably with the type of industry.

The TDS values were calculated from the specific conductance readings by the approximate method discussed in that section.

Alkalinity

The alkalinity of water may be defined as its capacity for neutralizing acids and is of interest in water softening, coagulation and corrosion control. Alkalinity is caused by the presence of carbonates, bicarbonates and hydroxides.

That fraction of the total alkalinity contributed by the hydroxide and half of the carbonate is measured by phenolphthalein indicator. Total (methyl orange) alkalinity may be due to any of the three (CO_3, HCO_3 and OH) present in the water. From these two indicators the types and proportions of alkalinities can be determined. For example if the phenolphthalein alkalinity equals zero then the total alkalinity of the water is caused by the presence of bicarbonates. Possible alkalinity conditions in the natural water are listed as follows: (Clark and Viessman, 1965, p. 238)

1. Carbonate alkalinity is present when the phenolphthalein alkalinity is not zero but is less than the total alkalinity.

2. Hydroxide alkalinity is present if the phenolphthalein alkalinity

is more than half the total alkalinity.

3. Bicarbonate alkalinity is present if the phenolphthalein alkalinity is less than half the total alkalinity.

An examination of the chemical analyses listed in Appendix C and D shows that in most waters of the area, both surface and groundwater, bicarbonates account for all the total alkalinity. Only in a few samples of groundwater from bedrock aquifers (mainly Horton and Canso) was any carbonate alkalinity present. In no case was hydroxide alkalinity found. "Alkalinity reported as hydroxide is ordinarily absent from uncontaminated natural water" (Hem, 1959, p. 96). Carbonate alkalinity is more commonly present in waters containing a high portion of sodium in proportion to calcium and magnesium.

In itself alkalinity is not considered to be detrimental to humans but it is generally associated with high pH values, hardness and excessive dissolved solids, all of which may be deleterious.

Alkalinity is detrimental in mnay industrial processes, especially those involving the production of food and beverages. In contrast, alkalinity is desirable in many industrial waters, especially if it serves to inhibit corrosion by creating favourable calcium-carbonate balance.

Excessive alkalinity in irrigation water is detrimental in that it adds to the total salinity and is frequently accompanied by high pH values.

Hydrogen Ion Concentation (pH)

The pH value of a water represents the overall balance of a series of equilibria existing in solution (Hem, 1959, p. 46). The hydrogen ion concentration in a solution is normally expressed in terms of pH, which is the negative logarithm of the hydrogen ion concentration when expressed as moles per liter. pH values of most natural waters fall within the range 4 to 9.

"Solutions with a pH of less than 7.0 are acid and those with a pH greater than 7.0 are alkaline. As pH values deviate from pH 7 the acidity or alkalinity increases exponentially, since pH is a log function. For example, a solution with a pH of 4 is 100 times as acid as one with a pH of 6". (Clark and Viessman, 1965, p. 241).

The pH of a raw-water source for domestic water is important in that it affects taste, corrosivity, efficiency of chlorination, treatment processes such as coagultion, and industrial applications. The pH value enters into the calculation of carbonates, bicarbonates, and carbon dioxide, as well as the corrosion or stability index, and into the control of water treatment processes.

Specific Conductance

Specific conductance (Spec. Cond.) is a measure of a water's capacity to convey as electric current. The Spec. Cond. is related to the total concentration of the ionized substances in water and the temperature at which the measurement was taken. The standard unit of electrical conductance, the mho, is used in reporting the Spec. Cond. of a water sample at a specified temperature. All Spec. Cond. analyses in this report are reported in mhos x 10^{-5} at 25°C.

The specific conductance of a water can be used to make a rough calculation of the total dissolved solids in that sample. In most natural waters specific conductance (in micro mhos/cm at 25°C) multiplied by a factor which ordinarily lies in the range 0.55 to 0.70 is equal to ppm total dissolved solids (American Public Health Association, 1965, p. 37).

To determine the total dissolved solids for all waters in this report, a factor of 0.55 was used, i. e. this gives minimum values for total dissolved solids.

Dissolved Oxygen

Surface waters of good quality should be saturated with dissolved oxygen (DO). Dissolved oxygen is utilized by bacteria to biodegrade the organic matter, which was introduced into streams as sewage and industrial wastes. The concentration of the organic load can be so great that higher forms of life are inhibited because all of the DO in the receiving water is utilized by the bacteria. In view of this, the concentration of DO in water is a significant index of its sanitary quality. A water saturated with oxygen may or may not be polluted, but is not likely to be contaminated with heavy concentrations of oxidizable matter.

The solubility of oxygen in water varies inversely with temperature and directly with pressure and is somewhat reduced by the amount of dissolved solids present in the water (Hem 1959, p. 144).

Three factors (Department of National Health and Welfare, 1962) normally affect the dissolved oxygen levels of a river at a given point with a constant flow. They are:

1. fluctuations in the quantities of oxygen consuming wastes;
2. photosynthesis produced by the action of sunlight on water vegetation;

3. re-oxygenation or re-aeration due to wind or other causes of turbulance during the period.

It should be stressed that the mean value of DO in a stream is not the best statistic to condiser when evaluating that water for fish, purity, etc. Often the minimum value and its duration must be considered since a minimum value, too low for the survival of fish, with a duration of several hours could result in the death of many fish.

Surface Water Quality

Introduction

The quality of surface water varies widely as a result of natural changes in flow, which affect the dilution factor, and man's activity, which usually upsets the natural chemical and bacteriological balance of a water system. Generally, the total dissolved solids in surface waters are less than in groundwaters. Those qualities of surface water that are generally not as suitable as those of groundwater are color, turbidity, temperature, and bacteriological content. These qualities are more variable and place definite limitations on the use of surface water.

Sampling Procedure

Suring the period from July to November, 1967, samples were collected periodically from sites established on the Salmon River. Five Stations, Truro (90), Murray (86), Union (87), Riversdale (88), and Kempton (89) (for locations see map 1) were sampled every two weeks. Samples were analyzed for the regular constituents determined in groundwater samples plus dissolved oxygen and bacterial content.

The DO analyses were conducted in the field at the time of sampling before the sample temperature changed any appreciable amount. Analyses were carried out with a portable chemical kit. The results were checked against several duplicate determinations in the laboratory and found to correlate reasonably well.

The method of sampling and examination of water to determine the bacterial quality is discussed in the section on bacterial quality of surface water.

Discussion of Analyses

Table 20 presents the means of the data collected at each sampling site during the period of study. A consideration of the data at sites 89, 87, and 86, in that order, involves a study of the change in water chemistry in a distance increasing from the headwaters along the course of the main branch of the Salmon River. From these data, it is noted that a steady increase in most chemical constituents occurs in a downstream direction. The same applies to a similar consideration of sites 88, 87, and 86 in that order; site 88 is on the Black River Tributary. The only chemical constituents that do not increase in a downstream direction are iron and chloride.

It should be noted also that turbidity decreases in a downstream direction. The highest mean turbidity (21.4) occurred at the Riversdale site where the high mean value of iron (0.36) was also recorded.

A statistical analysis was performed on the data from these sites in an attempt to determine whether there is a significant difference in the chemistry at the sites

Table 20. Mean Values* of Chemical Constituents in Surface Waters at the Sites Sampled on the Salmon River

Analyses in parts per million

Site	Ca	Mg	Na	Fe	Mn	SO_4	Cl	NO_3	Alkalinity	Total Hardness	Calculated TDS	pH	Color	Turbidi
#89 Kemptown	4.23	0.94	4.55	0.18	0.01	3.5	5.96	T**	12.8	14.6	16	6.98	41	15.4
#88 Riversdale	2.86	1.04	4.97	0.36	0.02	3.75	6.88	T	8.75	11.3	16	6.7	84	21.4
#87 Union	4.96	1.26	9.03	0.23	0.01	3.75	12.2	T	14	17.7	43	7.1	43	13.3
#86 Murray	5.36	1.56	9.6	0.19	0.01	4.5	11.6	T	17	19.7	45	7.13	40	11.6

* means of 12 samples

** T = concentration 0.01 ppm

sampled. The analysis is confined to only one variable; the total dissolved solids in the samples. It is desired to know whether the difference among the mean TDS values at the various sites are significant or whether they may reasonably be attributed to chance. An analysis of variance was made of the mean calculated dissolved solids values by considering the four sampling sites as a group of treatments. The following procedure was used:

1. Hypothesis $\mu 86 = \mu 87 = \mu 88 = \mu 89$. The means of the k treatments are all equal.

2. $\alpha = 0.05$. The confidence level of 95 per cent permits us to be 95 per cent sure that we will not reject a true hypothesis (type I error) i. e. we will not reject the hypothesis when it should be accepted.

3. The statistic used is F, the ratio of the treatment mean square to the error mean square. This test concerning the difference in means was done using the F distribution as obtained from the following equation:

$$F = \frac{(kn\,(n-1)\ .\sum_{i=1}^{k} (\bar{x}_i - \bar{x})^2}{(k-1)\ .\sum_{i=1}^{n} \sum_{j=1}^{k} (x_{ij} - \bar{x}_i)^2} \qquad (9)$$

The value obtained for F is then compared to the theoretical value F .05 under the degrees of freedom determined by K - 1 (numerator) and K(n-1) (denominator).

4. The calculation of F was done on an electronic calculator. An analysis of variance for the group of treatments is given in Table 21.

5. The calculated F is less than F .05. Thus we can assert with β confidence that

Table 21. Analysis of Variance Table for total dissolved solids in Surface Water Samples

	Sum of Squares	df	Mean Squares	F Ratio
Category Means Between Groups	9314	3	3105	$F_{cal.} = \frac{3105}{1630} = 1.91$
Within Groups	71732	44	1630	$F_{.05\,(3,44)} = 2.83$
Total	81046	47		

the mean values for dissolved solids at the different sampling sites are equal.

Groundwater Quality

From the data collected on the water analyses, two basic statements must be made before any definite conclusions can be drawn regarding water chemistry and rock types. Firstly, it must be shown whether the difference in chemistry between any two rock types is significant or not. Secondly, it must be stated whether any significant difference is attributed to the environment provided by the host rock or whether it is attributed to the time that the water has been associated with that particular rock type.

Investigation of both points would require a great deal of work and at this time the results would not warrant the work required to obtain this information. Therefore they will not be considered in this report.

However, it is important and of a great deal of practical value to know what quality of water to expect from a particular source. It is also equally important to know whether different sources will yield water of significantly different qualities. Thus an analysis of variance of the waters sampled was made to indicate whether there is a significant difference in chemistry of the three main classes sampled: 1. surface water; 2. water from surficial deposits; 3. water from bedrock deposits. The analysis was made of the calculated dissolved solids by considering the three source areas as a group of treatments.

Table 22. Mean Values of Chemical Constituents (Total Dissolved Solids) in Parts Per Million for Surface, Surficial and Bedrock waters

	Categories	
Surface Water (S)	Surficial (Sd)	Bedrock (Bd)
45	147	160
43	70	279
16	130	141
16	91	269
	120	425
Totals 120	558	1274
Grand Total		= 1952

Table 22 summarizes the data collected from each source area. The four values under surface water are the mean values of calculated dissolved solids at each of the sampling sites 86, 87, 88, and 89. The figures under "surficial" and "bedrock" in the table are the mean values of calculated dissolved solids for water derived from the various surficial and bedrock aquifers respectively. The analysis of variance was designed to determine whether a significant difference does exist in the chemistry of water from the three sources, streams and surficial and bedrock deposits. From a comparison of the data in table 22, it is seen that there is a difference in the mean values and thus it is desirable to know whether this difference is significant or whether it may be attributed to chance. The following procedure was used:

1. Hypothesis $\mu_s = \mu_{sd} = \mu_{bd}$. The means of the k treatments are all equal.

2. $\alpha = 0.05$. The confidence level of 95 per cent permits us to be 95 per cent sure if we reject the hypothesis on the basis of the test.

3. The statistic used is F, the ratio of the treatment mean square to the error mean square. F was determined by equation (9).

4. The calculation of F was done on an electronic calculator. An analysis of variance for calculated dissolved solids for the group of treatments is given in table 23.

5. An examination of Table 23 indicates that the calculated F is greater than $F_{.05}$. Thus it can be stated with a 95 per cent degree of certainty that the mean values of dissolved solids for surface, surficial and bedrock waters were not equal.

Table 23. Analysis of Variance Table for Dissolved Solids in Surface, Surficial, Bedrock Waters

	Sum of Squares	df	Mean Square	F Ratio
Category Means	118,324	2	59,162	$F = \frac{(59162)}{5118} = 11.6$
Within	56,296	11	5,118	$F_{.05}\,(2,11) = 3.98$
Total	174,620	13		

Bacterial Quality of Surface Water

Introduction

Several different groups of bacteria are found in water. They are mostly derived from contact with air, soil, living or decaying plants, or animals, mineral sources and fecal excrement. Many of these bacteria present are without sanitary significance because they die rapidly in water, come from unknown sources, are widely distributed in air or soil, or have no known or suspected association with pathogenic organisms. However, the presence of the coliform group of organisms in water is regarded as evidence of fecal contamination, with which pathogenic, or disease producing, bacteria may be associated. Thus the presence, above a specified concentration, of the coliform group of bacteria in water renders that water potentially unsatisfactory and of unsafe sanitary quality.

The coliform group of organisms includes, by definition, "all aerobic and faculative anaerobic, Gram-negative, nonspore-forming, rod-shaped bacteria that ferment lactose with gas formation within 48 hours at 35°C" (McKee and Wolf, 1963, p. 308). This group includes organisms of many origins. Most bacteriological examinations report the numbers of coliform bacteria present without regard to their origin, i. e. fecal or non-fecal, because the effect of the coliform group generally is a basis for standards to make the water relatively safer.

However if the bacterial examination is primarily to determine the source and/or type of contamination of a water supply then it will be most useful to determine whether the coliform bacteria are of a fecal or non-fecal origin. Recent investigations (American Public Health Association, 1965) strongly indicate that the portion of the coliform group which is present in the gut or the feces of warm blooded animals generally includes organisms which are capable of producing gas from lactose in a suitable culture medium at 44.5° - 0.5°C.

The presence of another group of bacteria, Fecel Streptococcal, in water is also considered in water resources investigations. The streptococci of this group are indicators of fecal pollution of water inasmuch as the normal habitat of these organisms is generally the intestine of man and animals. Therefore, fecal streptococcal determinations may be of particular value for stream pollution surveys, and for determining the sanitary quality of waters from shallow lakes, bathing areas and wells (American Public Health Association, 1965, p. 618). Although this group is mainly derived from the feces of warm blooded animals and thus presents possible pathogenic dangers, they do not multiply in water as sometimes occurs with the coliform group.

However the presence of the coliform group is in itself enough positive evidence of possible contamination by pathogens, thus creating a danger to the health and well being of water consumers. The N. S. Department of Public Health use the coliform group of bacteria to indicate pollution of water with wastes and thus the suitability of a particular water supply for domestic and diatetic uses. All examinations conducted on samples collected for this study report the numbers of coliform bacteria colonies present in a given volume of water. This numerical count includes those bacterial organisms of both fecal and non-fecal origin.

Method of Sampling and Examination

Samples were collected every two weeks at sampling sites 86, 87, 88, 89 (Map 1) on the Salmon River in prepared sterilized sample bottles provided by the Colchester Hospital. The same procedure used in collecting samples for chemical analysis was adopted when obtaining samples of the river water for the bacteriological examination. All sample sites are located sufficiently downstream from major tributaries to allow mixing of that water with that of the main stream. Also all samples were taken at mid-depth and mid-stream where the overall stream quality is best represented. Site 87, at Union, is approximately 3.5 miles downstream from the tributary of the Black River, Site 89, at Kemptown, is about 3.8 miles above the tributary on the Salmon River, while site 88, at Riversdale, is on the Black River about 2.0 miles above the tributary. Site 86, at Murray, is about 4.5 miles above 87 and about 3 miles above Truro, site 90.

The sampling period from July to November inclusive is long enough to include wide fluctuations in stream discharge which also influence the bacteriological counts obtained. A rigid sampling interval of 2 weeks was strictly adhered to so as to obtain unbiased samples which might be influenced by weather, stream flow, etc.

All bacterial examinations were carried out in the bacteriology laboratory at the Colchester Hospital by using the membrane Filter technique. This technique allows the coliform colonies to be counted directly with the aid of a stereomicroscope. Results of a colony count are reported as the number of coliforms present in 100 mililiters of water.

The Nova Scotia Department of Public Health grade the water in 3 classes, A, B, and C, depending on the number of coliforms present.

Grade A water has a count less than 2 per 100 mls and is considered satisfactory for domestic consumption. Grade B has a count between 2 and 10 per 100 mls of sample and is classed as doubtful for domestic consumption. Grade C water contains more than 10 coliform per 100 mls and is considered unsatisfactory for domestic consumption.

Discussion of Bacteriological Contamination of the Salmon River

The sanitary quality of the Salmon River varies widely at points along its course and with time. Table 24 summarizes the bacteriological data collected during the sampling period. In general, the mean bacteria counts indicate a decrease in sanitary quality of the water in a downstream direction (see Fig. 23). The data also indicate that the water at the two upper sites, Kemptown and Riversdale, is of the highest sanitary quality on the river system. Above each of these sites, contamination contributed to the stream by domestic sewage, is relatively small compared to that entering the stream below Murray.

A comparison of the means of sites, 89, 88, and 87 is interesting in that it shows an increase in sanitary quality of the river water along that reach of the stream. If all contamination at 89 and 88 may be attributed to the influx of domestic sewage, the readings at 87, which is well below the tributary of the Black River, should be more than those at Kemptown and Riversdale. However, the mean at Union is only

Table 24. Coliform Bacteria Counts of Samples Taken from the Salmon River

Site No.	Area	Sampling Period	Mean River Discharge (cfs)	Median	Mean	Min.	Max.	% of Samples with a Count ∠ the mean.
89	Kemptown	July-Nov. '67		29	35	0	150	58
88	Riversdale	July-Nov. '67		30	29	0	72	50
87	Union	July-Nov. '67		27	48	12	140	66
86	Murray	July-Nov. '67	233.4	124	118	0	240	33
90	Truro	Nov. '67		1735	1428	242	2000	25

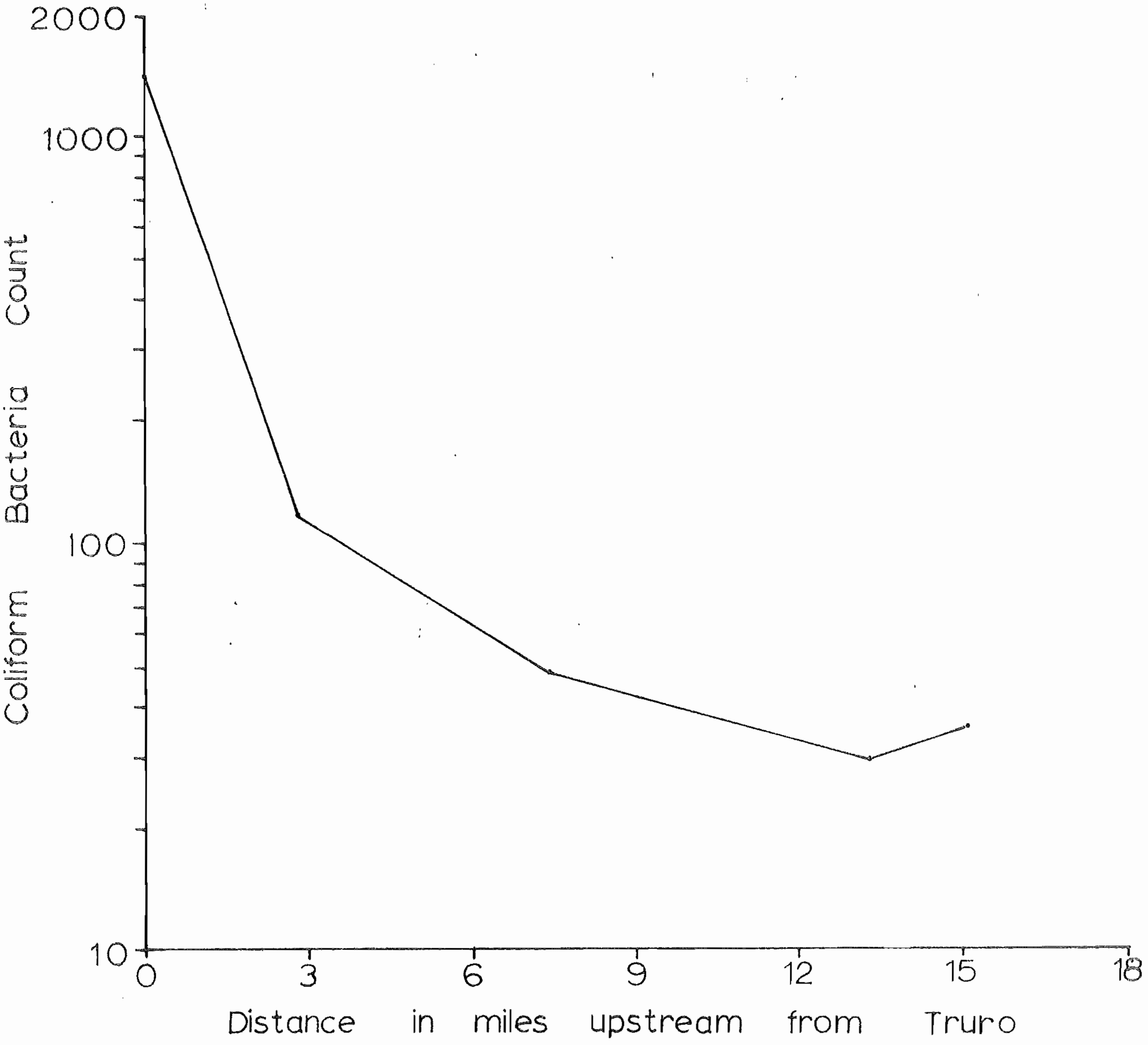


FIGURE 23. Relationship between sanitary quality and distance upstream from Truro on the Salmon River. (Sampling period July - November 1967).

75 per cent of the total of the means at 89 and 88, indicating a 25 per cent reduction in the coliform counts. This decrease in density may be explained by:

1. a self purification action of the stream in that area by which bacteria are destroyed or
2. dilution by a higher quality water, i. e., base flow.

Because of drainage, containing some sewage effluent, from the Manganese Mines and Greenfield areas above site 87, it was expected that the bacterial counts would be higher at this site.

The mean coliform count at site 86 is almost 250 per cent of that at 87. Tributaries between these two sites receive water draining the Manganese Mines area, Valley and Murray areas all of which contribute domestic sewage to the streams.

The increase in coliform bacteria between 86 and 90 is over 1,200 per cent. The mean count at 90 is 12 times the mean count at 86. Site 90 which is subject to bacterial contamination from an increase in domestic sewage is also subject of pollution from effluent from food processing plants and industry.

The tables listed in Appendix D showing the chemical analyses and coliform counts also include the stream flow in cfs at Murray at the time of sampling. These data reveal that the bacteria count does not appear to be directly related to stream flow, possibly because of a dilution factor and/or because there are areas where the bulk of coliform bacteria is being continuously introduced to a stream at a specific point. Thus below these points of influx the coliform density will vary inversely with the stream stage and volume of influx.

There are several interesting relationships between river discharge and coliform count (see Fig. 24). During periods of low river stage only those cesspools discharging directly into streams will contribute sewage discharge to the river. On the other hand after heavy rainfalls surface runoff contributes coliforms derived from all four sources (cesspools, open garbage pits, barnyards and pasture area). Also the higher coliform counts tend to occur when the river discharge is less than about 90 cfs, whereas the lower coliform counts were associated with higher river flows. However, there are few samples collected during high flow periods and before a more reliable interpretation can be made more samples should be collected during periods of high flow. It is suggested that at least as many samples be collected at high flows as there are at low flows to give data from which a reliable interpretation may be drawn.

Several samples indicated an absence of coliform bacteria at the Kemptown, Riversdale and Murray sites. Samples collected on October 18th showed that sites 89, 88 and 86 were all free of coliforms, while the water at 87, the intermediate site, contained 140 coliforms per 100 mls. Table 24 also shows that the water at site 87 had the highest percentage (66 per cent) of samples with a count less than the mean at that site.

Table 25 shows the results of bacteriological examinations carried out on samples collected on December 13th when the river stages was at its peak. River discharge at Murray at this time was 1,440 cfs. The cleanest river at this time with respect to sanitary quality was the North River which contained 184 coliforms per 100 mls. The highest coliform count, 1,930 per 100 mls, was in the Salmon River sample taken just above the Salmon River bridge.

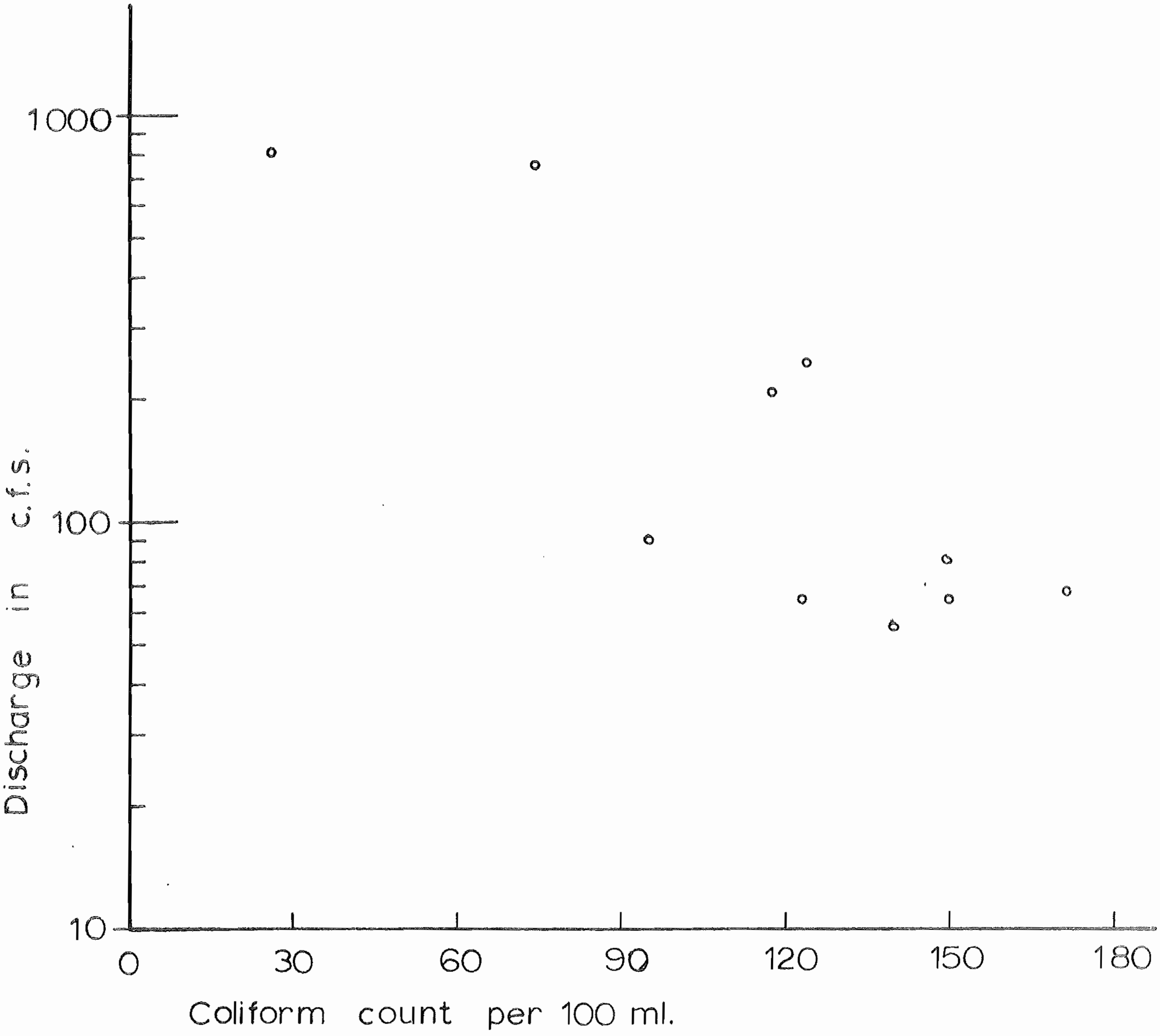


FIGURE 24.

RELATIONSHIP BETWEEN SALMON RIVER DISCHARGE AND COLIFORM COUNT AT MURRAY

Table 25. Coliform Bacteria Counts in Samples from the Various Watersheds when Stream Discharge at Murray is 1440 c.f.s.

Sample No.	Grid Location	Area and Stream	Date Samples	Coliform Bacteria Count per 100 mls.
90	11 E 6 B 98 H North	Truro (Salmon River)	13-12-67 9:50 a.m.	1930
91	11 E 6 C 2 K NW	Bible Hill (Farnham Brook)	13-12-67 10:15 a.m.	1530
92	11 E 6 C 2 D West	Upper Onslow (North River)	13-12-67 10:30 a.m.	184
93	11 E 6 C 3 P NW	Upper Onslow (McCurdy Brook)	13-12-67 10:45 a.m.	770
94	11 E 6 B 94 J North	Truro (McLure Brook)	13-12-67 11:45 a.m.	1450

Classification of the Salmon River

An attempt will be made to classify the Salmon River water on the basis of its sanitary quality and its use for domestic water supplies, industrial uses and swimming and bathing water. Most of the following discussion will be based on material presented in "Water Quality Criteria" (McKee and Wolf, 1963).

Domestic Water Supply

Water used by human beings for drinking and other domestic purposes is the most essential use of water. Such water must also meet the most stringent water-quality requirements that offer people the highest degree of sanitary protection.

For domestic water supplies the U. S. P. H. Service sets an upper limit on the number of coliform organisms present in the supply. These requirements limit the average monthly coliform content to a membrane filter count of one coliform per 100 ml. (McKee and Wolf, 1963, p. 88). Although these standards are accepted and used throughout the U. S., it is criticized as being too strict, arbitrary and impractical for many municipal supplies, on the other hand, it has been held that the standards are not strict enough and that the ultimate goal should be the elimination of all coliform organisms from drinking water (McKee and Wolf, 1963, p. 311).

Using these standards, the water at all sampling sites would be unfit for domestic use without treatment.

Industrial Use

The bacterial requirements for industrial water vary widely depending on the purpose to which the water is put. In the food handling industry, bacterial quality requirements may be more stringent than for domestic water supplies inasmuch as bacterial contamination may result in fermentation, taste changes and/or spoilage. Industries are generally willing to accept, for most processes, water that meets drinking water standards. A few of these, however, require a higher degree of sanitary protection. The largest water consumer meeting these standards is the carbonate beverage industry since fruit juice beverages are particularly susceptable to micro-organism growth. Thus water supplies for other industrial uses are more likely to possess objectionable chemical characteristics such as high turbidity and color which may result in a physical inferiority of the product. Most industrial processes require water with recommended threshold values as high as 10 ppm for turbidity and color. A few, however, can tolerate up to 20 ppm turbidity and 100 ppm color. The mean values for turbidity and color at Truro are 19 and 44 ppm respectively.

The Salmon River water fails to meet even the most relaxed requirements for sanitary quality, turbidity, and color content. Therefore, before this water can be used for industrial purposes, it requires treatment, including filtration and disinfection.

Swimming and Bathing Waters

To be acceptable to the public and the regulatory authorities, waters that are used for swimming and bathing must conform to three general conditions:

1. they must be esthetically enjoyable, i. e. free from obnoxious floating or suspended substances, objectionable color, and foul odors:

2. they must contain no substances that are toxic upon ingestion or irritating to the skin of human beings; and

3. they must be reasonably free from pathogenic organisms (McKee and Wolf, 1963, p. 118).

Because the first two conditions are qualitative rather than quantitative, they have only been defined in general terms by various water standards. The third condition pertaining to pathogenic organisms has, on the other hand, been subjected to strict and definitive bacterial standards in many areas. It is agreed by most investigators that the bacterial quality of waters for bathing need not be as high as that for drinking but that natural bathing water should be maintained reasonably free of bacteria of known sewage origin.

In the United States, coliform concentration of acceptable bathing areas vary widely from 50 to 3000 bacteria per 100 ml. Perhaps the most restrictive standards are those of the states of Utah and Washington which limit the median coliform content of a representative number of samples to 50 per 100 ml. Utah further specifies that not more than 5 per cent of samples should exceed 100 coliform bacteria per 100 ml. (McKee and Wolf, 1963, p. 119). Also used to state the quality of a water for swimming is the per cent of samples that may exceed a stated coliform density. The Nova Scotia Department of Public Health in the Truro area (personal communication) class the surface water of C grade (coliform count > 10 as of doubtful sanitary quality for swimming and bathing.

UTILIZATION AND DEVELOPMENT

Introduction

Water supplies within the map area are derived from both groundwater and surface water reservoirs. Most domestic supplies in the rural areas are from groundwater, whereas the main municipal and industrial water demands are currently supplied from a central surface water system operated by the Town of Truro. This trend, which has developed over the years since the area became settled, has been fairly adequate in the past. However, the feeling is commonly shared by local officials that, although the present system is supplying adequate water to meet today's demands, it will not meet the demands placed upon it as a result of future expansion of the area. It is mainly because of these limitations of the surface system that careful consideration be given to developing the groundwater reservoirs available to this area. Abundant supplies of a good quality water may usually be obtained from drilled wells in the rural areas to supply the domestic and agricultural demands. The exploration program carried out to date also indicated that the occurrence and type of water-bearing rocks within or near the Town of Truro are highly favourable for the withdrawal of large volumes of a good quality groundwater.

Any future efforts to expand the water supply system of the Truro area to meet increased municipal and industrial demands, will best be spent developing the relatively untapped groundwater reservoirs. The selection of groundwater rather than an alternative surface water supply at a considerable distance from the center of consumption has definite advantages in this area:

1. groundwater is available in most areas of town convenient to consumers and to the main distribution system now operated by the town.

2. the yield from wells would be relatively constant regardless of the season.

3. the groundwater quality is not only more uniform with respect to temperature and dissolved solids but is also of a much better sanitary quality and is free of color and turbidity.

4. the cost of developing the groundwater resources in this area will most likely be much less than the cost of impounding, treating and transporting surface water into the area.

Future groundwater exploration programs may be confined to two main systems: the surficial deposit aquifers and the bedrock aquifers. To date there has been almost no utilization of the surficial aquifers. Only a few small domestic supplies are derived from these unconsolidated sands and gravels by using well points. No large producing wells of this type exist in the area and there are only a few large capacity wells (withdrawing over 100 igpm) drilled into the bedrock aquifers. Of these wells none has been evaluated thoroughly enough to indicate the maximum safe pumping rates which may be obtained from the wells or the interference that such pumping rates may have on neighbouring wells. Only after this data is available can the safe yield of the water bearing sediments be determined so that the proper design of more wells and well fields will be possible. The safe yield can be defined as the maximum withdrawal of groundwaters that will be possible without exceeding the rate at which the aquifers are being recharged.

Base Flow as an Index of Safe Yield

Probably the most important factor influencing the groundwater recharge of a basin in a humid area is the character of surficial deposits within that drainage area. For example, the stream flow from basins mantled with permeable sands and gravels generally will be less variable than the flow of streams from an area covered with relatively impervious deposits of clay till. This is best reflected in the mean annual minimum stream discharge. The flow of a stream draining an area covered with permeable sediments will consist of a higher portion of base flow than will the flow of a stream draining an area covered with impermeable sediments.

Thomas (1966) studied the effect of glacial geology upon the time distribution of stream flow in eastern and southern Connecticut. He found that the type and relative extent of glacial drift within an area exert a predominant influence upon the runoff characteristics of streams draining the area.

> "Flow duration curves show that the median annual minimum 7-day average flow (which in Connecticut is equivalent to the stream flow equaled or exceeded about 94 per cent of the time) is 1.30 cfs per square mile from a drainage area underlain exclusively by stratified drift, and only 0.013 cfs per square mile from an area underlain exclusively by till, a ratio of 100 to 1." (Thomas, 1966, p. B209).

In view of this the amount of groundwater runoff from an area is also an index of the amount of groundwater recharge in that basin over a long period of time when the change in groundwater storage is constant. Thus, the base flow from a basin is an index of the safe yield and may be used as a guide to determine the volume of groundwater available for withdrawal. An increase in groundwater utilization may firstly reduce evapotranspiration loss and secondly result in a decrease in groundwater runoff. This is especially true when considering base flow contributed by shallow unconsolidated aquifers. Because of the higher permeability of stratified' glacial sands and gravels, they are more susceptable to higher rates of recharge from precipitation. Walton (1965) found that in Illinois most of the stream base flow consists of groundwater released from the shallow unconsolidated sands and gravels. These deposits permit a large per cent of the precipitation to infiltrate and flow to the stream without it entering the bedrock flow system.

The amount of groundwater withdrawal from the area as a ratio to the amount of base flow is thus an estimate of the degree of groundwater utilization.

Groundwater Utilization in the Salmon River Watershed

The base flow of the Salmon River for the water year 1966-67 was determined by the base flow cutoff line method applied to the discharge hydrograph (see Fig. 18). Base flow was 70,555 acre-feet or 18 per cent (9.3 inches) of the precipitation on the watershed. This compares with a figure of 12 per cent estimated by Trescott (1968) in the Upper Annapolis River Basin, Nova Scotia.

To determine the amount of groundwater withdrawal in the area consumers were classed into three main groups: 1. industry; 2. rural; 3. Town of Truro (see Table 26). The main industries using groundwater from their own supplies are the Maritime Cheese Products, the Meadowvale Dairy and the Nova Scotia Agricultural College. All three obtain water from wells drilled into the Triassic sediments. Although none have records of consumption, estimates are based on the size of the wells

Table 26. Data on Groundwater Consumption in the Map Area

	Consumer	Population	Consumption	Source	General Quality	Capacity	Remarks
Industry	Maritime Cheese Products		35 igpm	1 Well (Triassic)	Hard	Overflow = 35 igpm	5 H. P. pump 8 " well
	Meadowvale Dairy		10 igpm	3 Wells (Triassic)	Hard		Treatment (softening)
	Nova Scotia Agricultural College		60 igpm	4 Wells (Triassic)		250 igpm	Consumption varies widely during year.
Rural	Bible Hill	2,887 (1966)	120 igpm	Individual Supplies	Moderate Hardness		
	Salmon River	1,033	45 igpm	Individual Supplies			
	Other Areas	4,553	190 igpm	Individual Supplies	Variable		
Town of Truro		12,692 (1966)	Average = 1000 igpm	Leeper Brook	Undersirable Color and Iron		An estimate of 50% of the consumption is domestic.
			Peak = 1400 igpm	Four Drilled Wells (Triassic)	Hard	1150 igpm	

and other data supplied to the writer. The total volume of groundwater withdrawal by this class is about 200 acre-feet per year (see Table 27).

Table 27. Utilization of Groundwater in Map Area

Consumer	Volume of Water
Industry	200 acre-ft. per year
Rural	685 acre-ft. per year
Town of Truro	1,950 acre-ft. per year
TOTAL	2,835 acre-ft. per year

Volume of groundwater runoff = 70,555 acre-ft. per year

$$\% \text{ of utilization} = \frac{2835}{70555} = 4\%$$

The second class of consumers includes all domestic users outside the Town and within the map area. To determine the volume of water used by this class, the population of the area and the average daily consumption per capita were used. Figure 25 shows the population distribution of the area and from this data a total of 8,453 people are estimated to be obtaining their water from groundwater sources including springs, dug and drilled wells. These populations are those taken in 1966 by the Dominion Bureau of Statistics (D. B. S.). The areas outlined are the D. B. S. enumeration areas and were supplied by the Director of Technical Services for the Municipality of Colchester. Using a daily average consumption of 60 imperial gallons, the annual use by this class was determined to be about 685 acre feet per year.

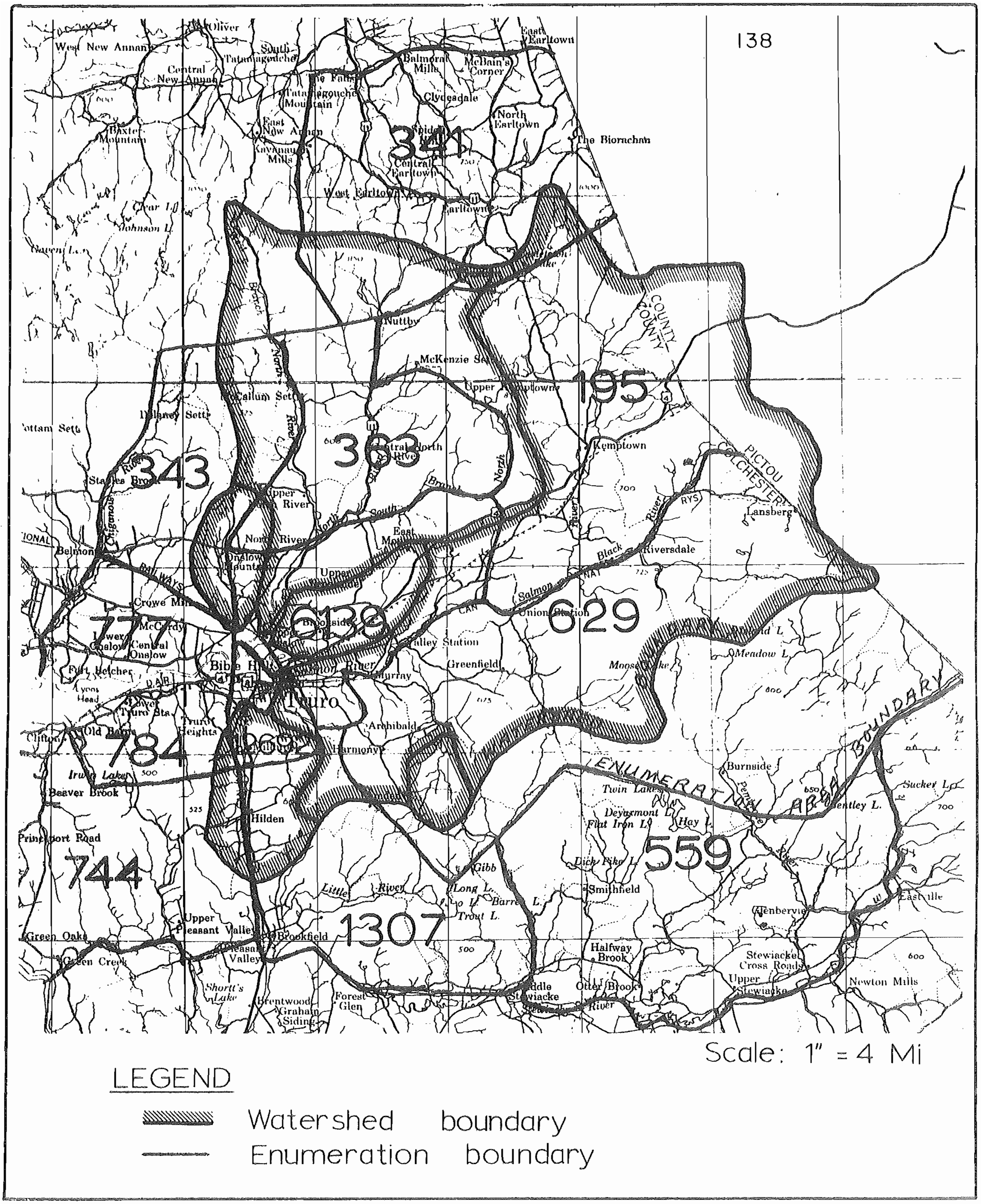


FIGURE 25. Distribution of population in the map area (D.B.S.) 1966

The third class is the Town of Truro which includes domestic, commercial and industrial consumers and is by far the largest single consumer of the three classes. Although most of the town's water is supplied by their surface water reservoir the concumption calculations are based on the assumption that their four auxillary wells, which are capable of yielding about 1.5 mgpd are supplying all their water requirements. Thus if there is any underestimation of withdrawal from the other classes, this assumption should offset the difference and allow a much more practical value of overall withdrawal. From these data the town uses about 1950 acre feet per year.

Table 27 also shows that the total groundwater withdrawal in the map area is about 2,835 acre-feet per year, only 4 per cent of the mean annual groundwater runoff from the area. This indicates that a very small portion of the groundwater which reappears as stream flow is at present being utilized. Since a portion of groundwater leaves the basin as subsurface flow and thus does not appear as stream flow, the per cent of utilization of the total groundwater resources of the area will be somewhat less than the indicated 4 per cent. It should also be mentioned that buried sands and gravelsexist in such a way that they present very favorable conditions for inducing surface water into the groundwater system. Such possibilities of developing large capacity wells from infiltration galleries exist in the outwash sands and gravels adjacent to the North and Salmon rivers. Therefore, groundwater utilization near rivers is not limited by the saturated thickness of these aquifers.

An indication of the well yield to expect from screen wells developed in the outwash sand and gravels is given in the Appendix B. This example is from data obtained during an 80 hour pump test on a screened well drilled into the buried stream channel deposits, 20 feet thick, at Murray Siding, about 4 miles east of Truro. The data from the pump test on this well indicated a T of 4.84×10^4 igpd/ft (P of 2.42×10^3 gpd/sq. ft.) and a safe pumping rate (Q_s) of about 225 igpm over a 20 year period of continuous pumping, assuming no recharge. With recharge from induced infiltration the safe pumping rate of this well would be much higher.

SUMMARY AND CONCLUSION

The surficial deposits within the map area offer a good means through which precipitation may infiltrate and enter the groundwater reservoir system in that area. Over 50 per cent of the area is covered with granular materials which allow a high rate of recharge to the aquifers contained within the surficial deposits. The deepest and most ideal water-bearing strata occur in the areas adjacent to the North and Salmon rivers near Truro. It is in this same area that not only the demand for water resources is now the greatest but also the projected increase in demand through industrial and population growth is also the greatest within that part of Nova Scotia. It has been shown from actual pump test analysis that screened wells yielding over 200 igpm can be developed in the shallower surficial sands and gravels where only 20 feet of saturated thickness is available. Applying the same permeability (2.42×10^3 igpd/ft^2) obtained in the shallow aquifer to the deepest mapped aquifer just north of Truro, which has a saturated thickness of about 70 feet, indicates that a screened well developed in this aquifer should yield over 1,000 igpm. Therefore the surficial deposits within the area are very favorable for withdrawal of large quantities of good quality groundwater by either of two methods. Firstly, large volumes of groundwater may be withdrawn from the shallow surficial aquifers by designing well fields in the most favorable areas, in which the wells are of the screen type. Secondly, large capacity wells may be developed in the deeper portions of the surficial deposits in which screened wells are also utilized.

Underlying these surficial aquifers are the Triassic aquifers which provide groundwater under arterian conditions. Large capacity wells, capable of yielding up to about 500 igpm, can be developed in these aquifers. However, development of bedrock wells of this capacity are limited by two factors. Firstly, the depth and areal extent of the cone of depression resulting from pumping of the Triassic aquifer will result in wider spacing of component wells in a well field. Secondly, the chemical quality of water derived from the Triassic aquifer is somewhat inferior to that derived from the surficial deposits.

It should also be pointed out that, although there is an abundant quantity of surface water in the area, its chemical and sanitary quality renders it unsuitable for most uses without treatment. The presence of coliform bacteria and high contents of color and turbidity in these waters makes them unsafe for domestic consumption and use in most industrial processes.

Other conclusions pertaining to precipitation, water chemistry, sanitary quality of surface water, and utilization of the groundwater resources are listed below:

1. Precipitation varies greatly over the watershed area. At the gauge sites established for this study, the coefficient of variation among the sites was

determined for each monthly precipitation total from July to November 1967. Values for this coefficient varied from 9 for October to 24 for July.

2. No significant change in precipitation was recorded in the area from July to November 1967 as a result of an increase in elevation. The student t of this regression coefficient is 1.55.

3. There is no significant linear relationship between the precipitation and the distance of the site from the sea shore for the period July to November 1967. The student t of this regression coefficient is 0.48.

4. The hydrologic budgets for the Salmon River and Fraser Brook watersheds for the water year 1966-1967 both showed that about 70 per cent of the precipitation appears as stream runoff; the remaining 30 per cent is lost as evapotranspiration.

5. Calculations based on the base flow cutoff line method indicated that 18 per cent of the precipitation appears as base flow which accounts for 23 per cent of the total stream flow.

6. An analyses of variance of the calculated dissolved solids of surface waters at the four sampling sites on the Salmon River indicates that the variation between sites is not significantly greater ($\alpha = 0.05$) than variations in values at the individual sites.

7. An analysis of variance of the calculated dissolved solids in waters from

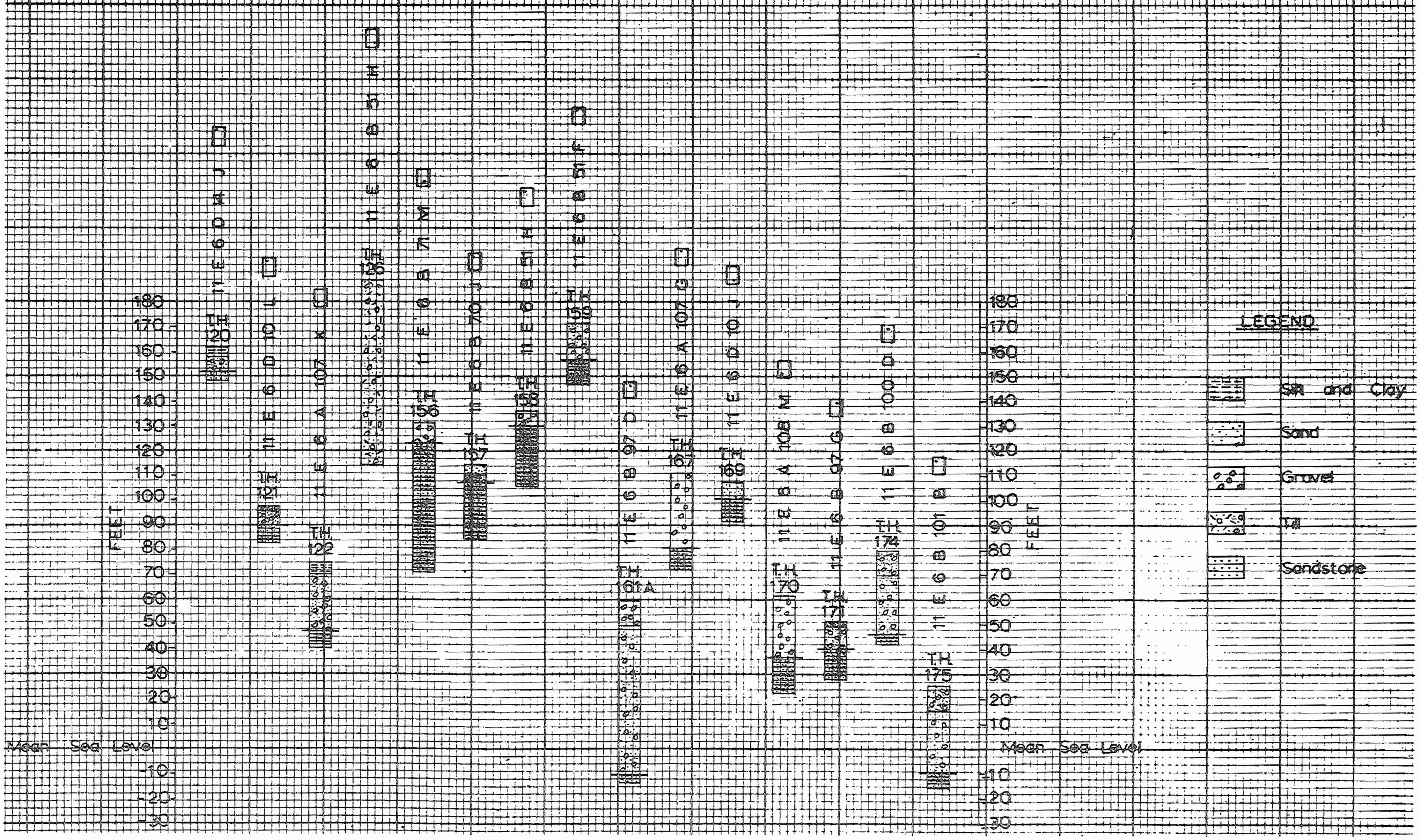
the various sources (surface, surficial, bedrock) indicates that the means of samples from the source areas are significantly different at the 95 per cent level of confidence.

8. The bacterial analyses of samples from sites on the Salmon River indicate a decrease in sanitary quality of the river water in a downstream direction. The most marked decrease in sanitary quality occurring between Murray and Truro, where the coliform bacteria count increases by 1200 per cent.

9. By using the amount of base flow from the area as an index to the amount of groundwater available for safe withdrawal from the area, and estimating the amount of groundwater withdrawal from the area, it was estimated that only 4 per cent of the groundwater resources are presently being utilized. This assumes that all groundwater within the basin can be withdrawn and utilized.

APPENDIX "A" (Figure 26)

Graphic logs of surficial deposit test-holes not illustrated in the cross sections



APPENDIX B

ANALYSIS OF PUMP TEST AT MURRAY

Introduction

Pumping tests are conducted on developed wells for two main reasons. Firstly, to determine the yield and the amount of drawdown resulting from that yield in the well itself. Such data are required to select the proper size pump to be used and to indicate the maximum short term (periodic), or long term, pumping rates expected from the well. Secondly, pump test data are required to determine the hydrologic characteristics of the water-bearing formations. These include the water transmitting capabilities and the volume of stored water whichis released as a result of lowering the water-table or piezometric head.

The foundation of quantitative groundwater studies is based on these principle hydraulic properties of an aquifer influencing water-level decline and the yields of wells. These properties are the coefficients of transmissibility (T), permeability (P), and storage (S). Pump test data can also be used to determine the affect of geohydrologic boundaries on the safe pumping rate of the well, and the amount and extent of drawdown in the vicinity of the pumping well. These data are required to design an efficient well field in a single aquifer or in different aquifers which are hydrologically connected to one another. The information required for the computations and design are obtained in the field by pumping a well at a constant rate and recording the resulting drawdown in the pumping well and several observation wells penetrating the same aquifer. Measurements of the drawdown are taken in accordance with some time schedule (e. g. see Jones 1963, p. 15) as pumping progresses. The data are plotted on logarithmic paper, i. e. drawdown vs. time since pumping started, and the resulting graphs are used to solve equations expressing the relation between T and S of an aquifer and the lowering of water levels in the area of the pumping well.

Hydraulic properties of the aquifer, determined from the pump test at Murray, are given in Table 30. The data and analysis of the pump test are included in this Appendix.

Cone of Depression

As water is pumped from a well the water level is lowered in the area. This lowering is greatest at the well and decreases in all directions, away from the well, resulting in a hydraulic gradient towards the well. The shape of the upper water surface thus forms an inverted cone called the cone of depression, or the cone of pumping depression. It may be defined as:

> "A cone-shaped depression in either the water table in unconfined flow or the piezometric surface in confined flow developed around a well which is being pumped at any given rate of discharge. It has its apex in the well and its base in the water table or piezometric surface. Specially known as "cone of water table depression" and "cone of pressure relief" for non-artesian and artesian wells respectively". (International Commission on Irrigation and Drainage, 1967, p. 501).

The distance from the static water level to the cone at any time measured to a point on the cone is the drawdown at that point. The cone of depression which exists around any pumping well differs in size and shape depending upon the pumping rate, length of pumping period, aquifer hydraulic characteristics, slope of the water-table or piezometric surface and, recharge within the zone of influence of the well. Generally, the shape of the cone is controlled by the coefficients of T and S. With other factors remaining constant, the lower the coefficient of T the steeper will be the gradient of the cone of depression and the greater will be the drawdown in a well. The coefficient of S also affects the shape in that a large coefficient of S yields a given volume of water from storage with a relatively smaller decline in water levels, where as a small coefficient of S requires a greater decline in water levels to supply an equal volume from storage.

With continuous pumping the cone of depression grows in size and depth at a diminishing rate until (1) the lowering of water levels results in increased recharge to, and/or decreased natural discharge from the aquifer and (2) hydraulic gradients are established sufficient to bring from recharge or natural discharge areas the amounts of water pumped (Walker and Walton, 1961, p. 18).

Adjustment of Drawdown Data

Natural Groundwater Recession

The static water level (the level at which water stands in an unpumped well) is subject to change with time. Drawdown measurements are not measured from the

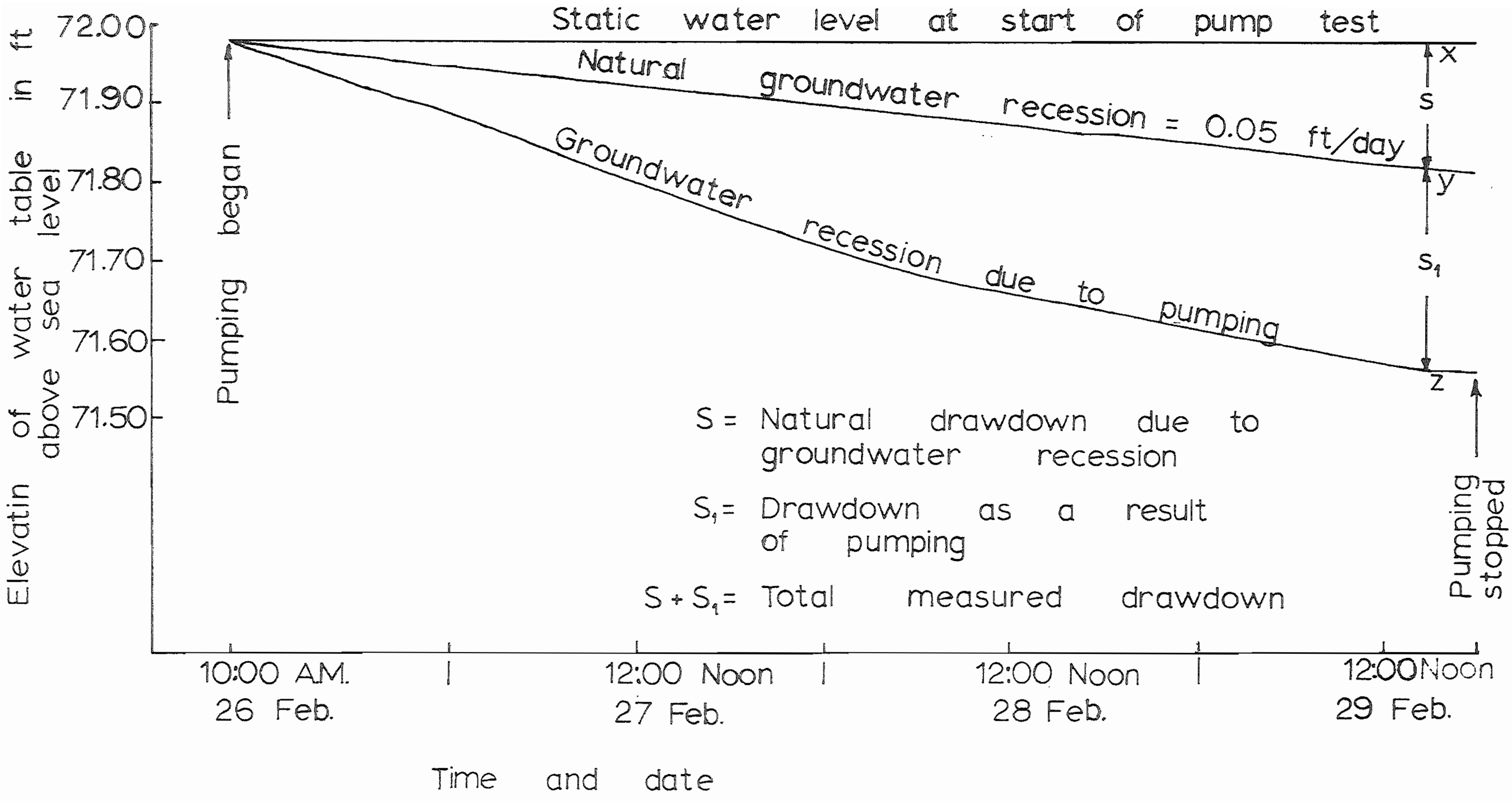


FIGURE 27. Groundwater recession in observation well No. 191 during pump test.

"static" level measured just before the start of the test, but from water level trends extrapolated from measurements made for at least 24 hours prior to the test, and preferably for a longer period. For the pump test at Murray, these water level trends were recorded with an automatic water level recorder installed in observation well No. 191. For the three week period immediately preceeding the pump test, a natural mean daily groundwater recession of 0.05 foot was determined (see Fig. 27) from the groundwater hydrograph in this well. From this figure the correction at any time is equal to s (x minus y) at that time. All drawdown measurements in the three wells were corrected for this natural recession. From Figure 27 the difference between the natural groundwater recession line and the measured water level during the pump test is the drawdown resulting from pumping well No. 368. Also from this figure, S_1 represents the drawdown adjusted to the natural groundwater recession at that particular time shown. This adjusted drawdown value is determined by subtracting the value of y at a given time from the corresponding value of Z . The difference between x and y represents the decrease in water level due to the natural groundwater recession. In this particular example the uniform groundwater recession is attributed to the absence of water on the surface available for groundwater recharge. During the three week period prior to and including the pumping period air temperature were about 0°F and no precipitation fell on the area.

Partial Penetration

One of the assumptions on which the equations used to determine the coefficients of T and S are based is that the well fully penetrates the aquifer. Drawdown measurements in wells only partially penetrating an aquifer are distorted. The approximate distance, r_{pp}, from the pumped well beyond which the effects of partial penetration are negligible is given by the following equation (see Butler, 1957):

$$r_{pp} = 2m\sqrt{p_h/p_v} \tag{10}$$

where:

m = saturated thickness of aquifer in feet.
p_h = horizontal permeability of aquifer in gpd/sq. ft.
p_v = vertical permeability of aquifer in gpd/sq. ft.

Although both observation wells used in the pump test penetrated about one half the thickness of the aquifer, only observation well No. 1 was within the distance r_{pp} determined from equation 10. Therefore adjustments for this condition were made with formulas given in Walton (1962, p. 8) and the corrections applied to the drawdown measurements from observation well No. 1.

The measurements recorded in observation well No. 1 were less than those which would have been recorded if the well had penetrated the aquifer fully. When the pumped well penetrates the bottom of the aquifer and the observation well penetrates the top of the aquifer (as is the case with pumping well 368 and observation well No. 1) the following equation can be used to adjust observed drawdowns for the effects of partial penetration (Walton, 1962, p. 8):

$$s_{fp} = \frac{Cpo}{2\ Cpo - 1} \times s_{pp} \tag{11}$$

where:

s_{fp} = Drawdown in observation wells for fully penetrating conditions, in ft.
Cpo = Partial penetration constant for observation well, fraction
s_{pp} = Observed drawdown for partial penetrating conditions, in ft.

The value of the constant Cpo, found from tables in Butler (1957, p. 161) is 0.995 under the conditions in which the pump test was conducted. Before this table can be used one must know or assume:

1. distance from pumped well to observation well in feet;
2. saturated thickness of aquifer in feet;
3. fractional penetration;
4. horizontal permeability of aquifer in gpd/sq. ft.;
5. vertical permeability of aquifer in gpd/sq. ft.;
6. virtual radius of cone of depression.

The following equation can be used to adjust the observed drawdown in a pumped well for the effects of partial penetration (Walton, 1962, p. 8):

$$s_{fp} = Cpp\ s_{pp} \tag{12}$$

where:

s_{fp} = drawdown for pumped well for fully penetrating conditions in feet.
Cpp = partial penetration constant for pumped well, fraction.
s_{pp} = observed drawdown for partial penetration conditions, in feet.

The value of Cpp can be found from tables in Butler (1957, p. 161) or Walton (1962, p. 8). For the pump test and condition under study Cpp has a value of 0.695.

Equations 10 and 11 give the best results when flow to the well has reached steady-state conditions and when the aquifer penetrated is of small and known thickness (Walton, 1962). Since both of these conditions were satisfied for this pump test the adjustments made are considered justified. It should be noted however that Walton (1962) applies these adjustments only to the drawdown data that is used in the distance-drawdown analysis. In this analysis the adjustments were applied to both time-drawdown and distance-drawdown data. The results (see figures 30 and 31) obtained from the two methods are reasonably close. However, both transmissibility values determined from the time-drawdown data are higher than the values obtained from the distance-drawdown data.

Water-Table Conditions

The equations used to determine the hydraulic characteristics of the aquifer discussed in the next section were derived for artesian conditions (Hantush and Jacob, 1955). Two of the assumptions upon which these equations were developed may be stated as: 1. the S is constant and 2. water is released from storage instantaneously with a decline in head. Neither of these conditions is met in water-table aquifers and therefore the data must be adjusted before used in the equations.

Gravity drainage results in a slow drainage of the interstices in an unconfined aquifer. As a result the S varies and increases at a diminishing rate with the time of pumping. However, Walton (1962) indicated that with long periods of pumping the effects of gravity drainage become small and time-drawdown and distance-drawdown curves conform closely to the nonleaky artesian type curve. He also states that the time after pumping started after which the nonleaky arterian type curve can be used may be expressed by Boulton's (1954) equation:

$$t_{wt} = \frac{37.4\, S_y m}{P} \tag{13}$$

where:

t_{wt} = approximate time after pumping starts when the application of the nonleaky artesian formula to the results of aquifer tests under water table conditions, in days.
S_y = specific yield, fraction
P = coefficient of permeability in gpd/sq. ft.
m = saturated thickness of aquifer in feet.

The above equation is only valid when the distance from the pumping well to the observation well (r) is between about 0.2 m and about 6 m.

Another adjustment is required because of gravity drainage decreasing the saturated thickness and therefore the T of the aquifer. Jacob (1944) derived the following equation to adjust drawdown data under water table conditions for the decrease in T:

$$s_a = s - \frac{s^2}{2m} \tag{14}$$

Where:

s_a = drawdown that would occur in an equivalent nonleaky artesian aquifer in ft.
s = observed drawdown under water-table conditions, in ft.
m = initial saturated thickness of aquifer in ft.

Equations for Determining Aquifer Characteristics

Theis (1935) introduced the nonequilibrium formula which is used to analyze the data collected during testing of an artesian aquifer. This formula, is also used with the adjusted data (after t_{wt}) from a water-table aquifer pump test as discussed above. It may be written as:

$$T = \frac{114.6\,Q}{s} \quad W(u) \tag{15}$$

and:

$$S = \frac{T\,u\,t}{2244r^2} \tag{16}$$

where:

T = coefficient of transmissibility, in gpd/ft.
S = coefficient of storage of aquifer, fraction
Q = discharge in igpm
r = distance from pumped well to observation well in ft.
s = drawdown in observation well, in ft.
t. = time after pumping started, in minutes.
W(u) = the " well function for nonleaky artesian aquifers" (see Wenzel, 1942).

Walton (1962) has drawn a nonleaky artesian type curve with W(u) plotted against 1/u, which was used to solve equations 15 and 16. The adjusted drawdowns from the field data were plotted against t on logarithmic paper. These curves were then matched to Walton's type curve with similar axes kept parallel. The convenient match point coordinates of W(u), 1/u, r and s are then substituted in equations 15 and 16 to determine values for T and S.

The modified nonleaky artesian formula was developed by Jacob (1946) when he recognized that u becomes very small when r is small and t is large. It may be written as:

$$T = \frac{264Q}{\Delta s} \tag{17}$$

where Δs is the drawdown difference per log cycle of time, in feet, and T and Q are as defined above. Values of adjusted drawdown are plotted against the logarithms of time (in minutes) after pumping started on semilogarithmic paper. These data will yield a straight line graph in the region where $u \leq 0.01$, and the slope is used to determine T. This method is most useful for calculating T from pumping well drawdown data.

The Theis recovery formula is used in analyzing the recovery of a previously pumping well and is a very useful check on the T calculated by using equation 15. This recovery formula is written as:

$$T = \frac{264Q}{\Delta s'} \tag{18}$$

where:

$\Delta s'$ = residual drawdown per log cycle of t/t' where t is the time since pumping started and t' is the time since pumping stopped in minutes.

Pump Test at Murray

A six inch diameter screened well (T. H. No. 368) was developed in the outwash sands and gravels which fill the buried stream channel underlying the Murray area east of Truro (see map 2 for location). A 10 foot length of No. 80 slot screen penetrated the bottom half of the aquifer in the interval 20 to 30 feet. The sand and gravel aquifer extends to a depth of 30 feet where it overlies a relatively impervious unit of Triassic shales and grit (see map 3).

The well layout plan is shown in figure 28. Five obsevation wells, drilled into the aquifer, were available in the area from which drawdown measurements could be obtained. Wells No. 190 and No. 191 are equipped with automatic water-level recorders which have been operating since August 1967. Records of the water-table fluctuations in well No. 191 were used to determine the natural groundwater recession trend prior to the pump test. Figure 27 shows graphically the relationship between the water levels due to the natural groundwater recession and those due to pumping during the test period from 26-29 February.

At the end of the 80-hour pump test no drawdown was recorded in wells 190, 192 or 193, indicating that the virtual radius of the cone of depression was something less than 583 feet (see Fig 29). A cross section of the cone of depression as measured in the remaining three wells (pump well No. 368 and observation wells No. 1 and No. 191) is shown in Figure 29. This section (longitudinal to the main axis of the aquifer) shows the natural groundwater gradient in that direction.

Table 28 is a list of the drawdown data and adjustments made to these data from observation well No. 1. The maximum drawdown in this well, which is 100 feet away from the pumping well, is 1.19 feet. An examination of the list of adjustments made reveals that no correction was applied to adjust for partial penetration of the aquifer by this well even though it lies within r_{pp}. It was found that the partial penetration constant (C_{po}), see equation 11, determined for that well

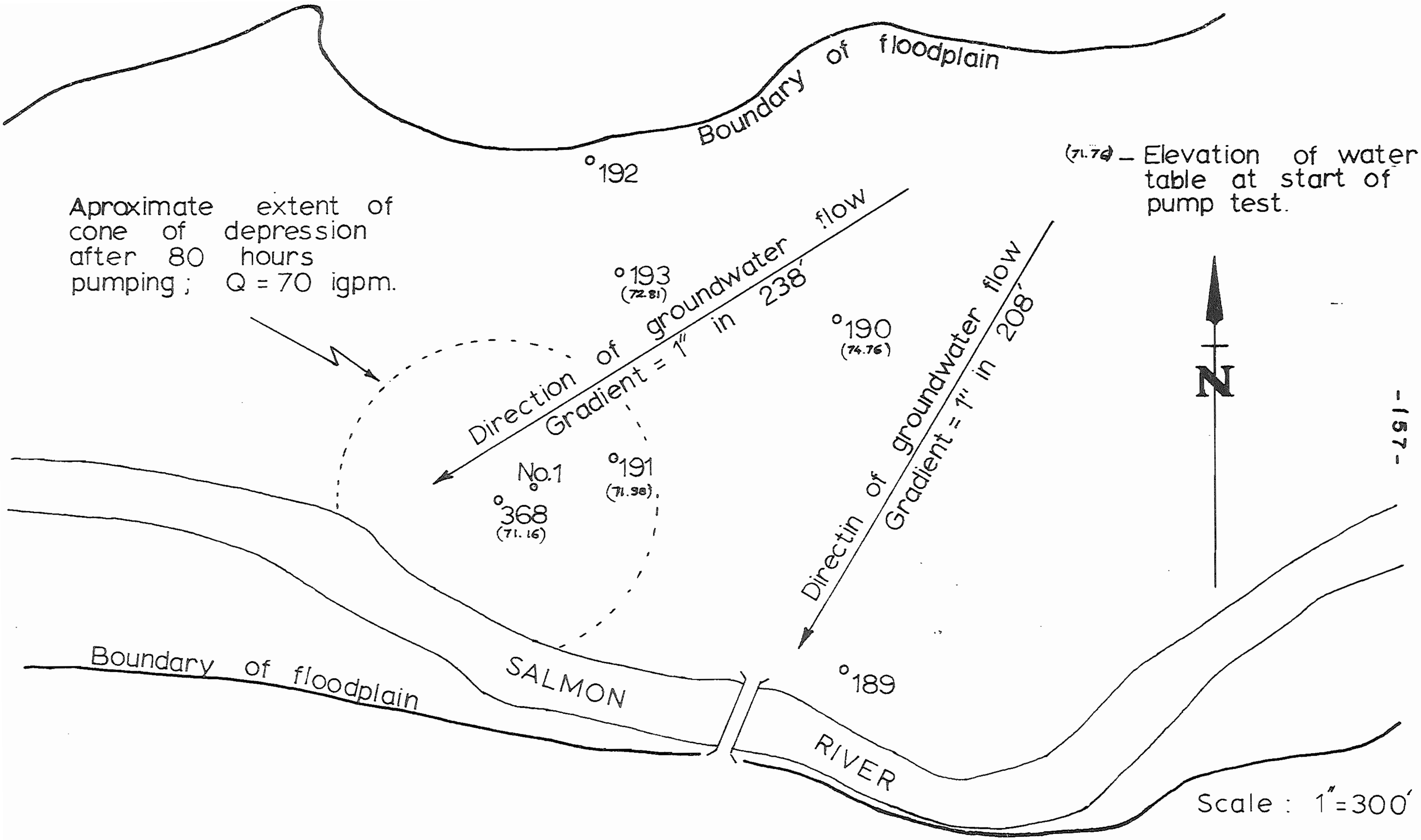
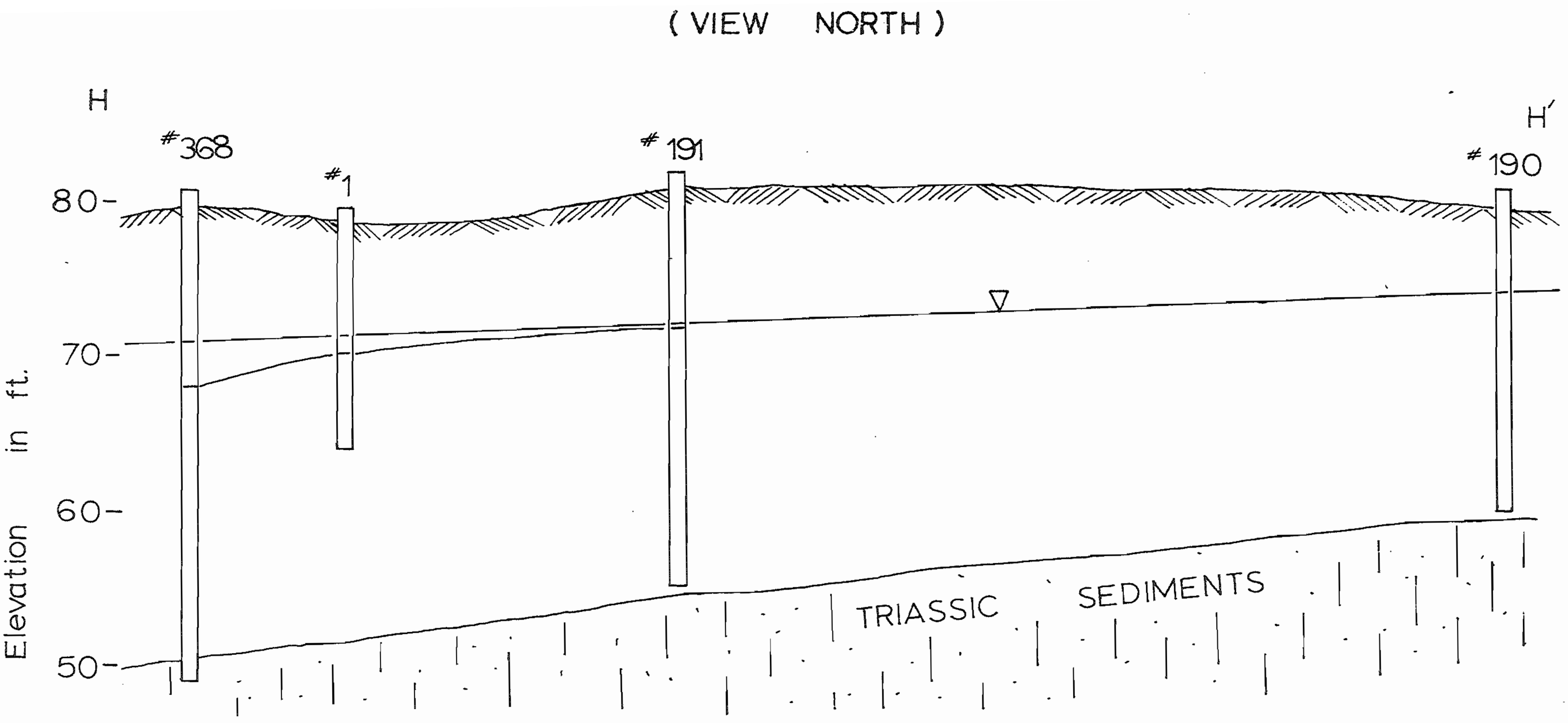


FIGURE 28 Well layout at Murray pumping well No. 368.



Vert. Scale : 1″ = 10′
Horz. Scale : 1″ = 100′

FIGURE 29. Cross section showing cone of depression pump test at Murray

under the prevailing aquifer factors equals 0.995. If the saturated thickness (m) of the aquifer was greater and/or the distance from the pumping well to the observation well (r) was smaller, then C_{po} would have been significantly less than unity and a larger correction applied.

From equation 14, it can be seen that the adjustment made for gravity drainage is very small when the field drawdown measurement is small. Under the conditions in this area, it was found that any adjustment value to a field measurement less than 0.45 feet was insignificant. Thus no adjustments for gravity drainage were made to the data from observation well No. 191 because the maximum observed drawdown in that well was only 0.43 feet. The data from well No. 191 were not adjusted for partial penetration because the distance from the pumped well would make such an adjustment insignificant.

Fig. 30 shows the time-drawdown curve (observation well No. 1) on logarithmic paper plotted from the adjusted data presented in Table 28. These data fit the nonleaky artesian type curve trace very well after a pumping time of about 200 minutes. The early data, as shown on the graph, deviate from the type curve because of late gravity drainage from the aquifer portion being dewatered. The data can be used to fit the type curve after a time of 97 minutes, which is the time t_{wt} calculated from equation 13. In the original fitting only that data after about 150 minutes of pumping were used. If the type curve is matched to drawdown data for values of time equal to and greater than t_{wt} then the solution is judged to be valid (Walton, 1962, p. 6).

Table 28. Adjustments Made to Drawdown Data From Observation Well No. 1

		Adjustments (ft)				
Time Elapsed in Minutes	Measured Drawdown	Natural Recession*	Partial Penetration	Gravity Drainage	Total Adjustments	Adjusted Drawdown
0	0.0	0	0	0	0	0.0
1	.15	0	0	0	0	.15
2	.16	0	0	0	0	.16
3	.18	0	0	0	0	.18
4	.19	0	0	0	0	.19
5	.20	0	0	0	0	.20
6	.21	0	0	0	0	.21
7	.22	0	0	0	0	.22
8	.23	0	0	0	0	.23
9	.24	0	0	0	0	.24
10	.23	0	0	0	0	.23
15	.24	0	0	0	0	.24
20	.25	0	0	0	0	.25
25	.27	0	0	0	0	.27
30	.28	0	0	0	0	.28
40	.27	0	0	0	0	.27
50	.32	0	0	0	0	.32
60	.33	0	0	0	0	.33
75	.35	0	0	0	0	.35
90	.36	0	0	0	0	.36
105	.39	0	0	0	0	.39
120	.45	0	0	0	0	.45
150	.47	-0.01	0	-0.01	-0.02	.45
180	.47	-0.01	0	-0.01	-0.02	.45
210	.48	-0.01	0	-0.01	-0.02	.46
240	.53	-0.01	0	-0.01	-0.02	.51
300	.56	-0.01	0	-0.01	-0.02	.54
360	.62	-0.01	0	-0.01	-0.02	.60
420	.63	-0.01	0	-0.01	-0.02	.61
480	.72	-0.02	0	-0.01	-0.03	.69
540	.75	-0.02	0	-0.01	-0.03	.72
600	.77	-0.02	0	-0.01	-0.03	.74
660	.78	-0.02	0	-0.01	-0.03	.75
720	.79	-0.03	0	-0.02	-0.05	.74
840	.82	-0.03	0	-0.02	-0.05	.77

Elapsed Time in Minutes	Measured Drawdown	Natural Recession*	Partial Penetration	Gravity Drainage	Total Adjustments	Adjusted Drawdown
960	.84	-0.03	0	-0.02	-0.05	.79
1080	.88	-0.04	0	-0.02	-0.06	.82
1200	.91	-0.04	0	-0.02	-0.06	.85
1320	.88	-0.05	0	-0.02	-0.07	.81
1440	.93	-0.05	0	-0.02	-0.07	.86
1680	.99	-0.06	0	-0.02	-0.08	.91
1920	1.02	-0.07	.01	-0.03	-0.09	.93
2160	1.04	-0.08	.01	-0.03	-0.10	.94
2520	1.10	-0.09	.01	-0.03	-0.11	.99
2880	1.12	-0.10	.01	-0.03	-0.13	.99
3600	1.19	-0.12	.01	-0.03	-0.14	1.05
4320	1.21	-0.14	.01	-0.04	-0.17	1.04
4560	1.24	-0.16	.01	-0.04	-0.19	1.05
4800	1.15	-0.17	.01	-0.03	-0.19	.96

* - Recession adjustment equals 0.05 ft./day. Since the magnitude of accuracy is 0.01 ft., adjustments were made every five hours.

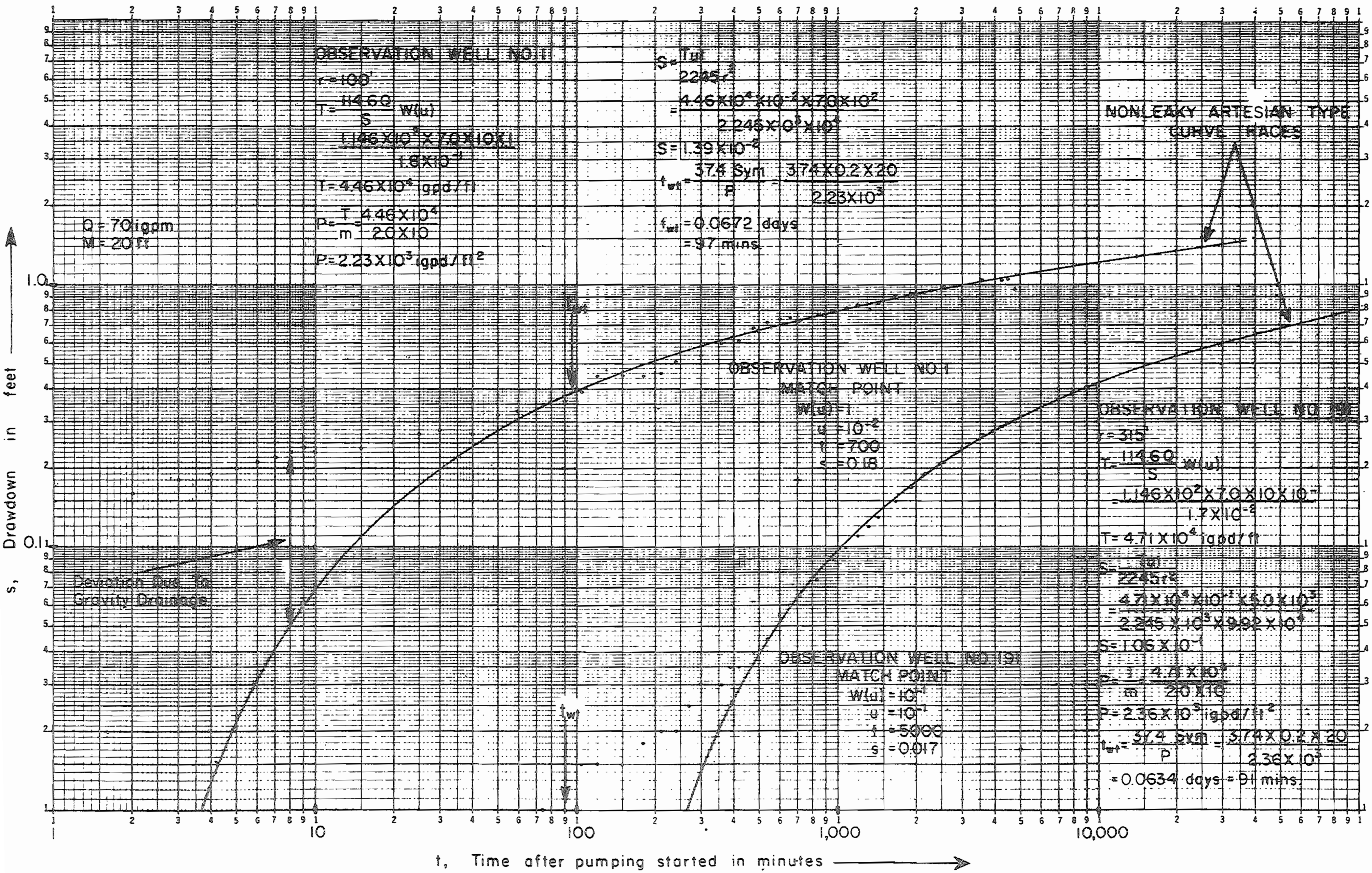


FIGURE 30. Time-drawdown graphs for observation wells nos. 1 and 191

By using equations 15 and 16, the values of T, S, and P were found to be 4.46×10^4 gpd/ft.; 1.39×10^{-2} and 2.23×10^{-3} gpd/ft^2 respectively (see Fig. 30).

The time-drawdown curve plotted from the drawdown data recorded in well No. 191 is also shown in Fig. 30. Here the calculated value of t_{wt} is 91 minutes. Measurements prior to this time include data too early to use for fitting the type curve. Since the fit shown uses data all measured after 91 minutes, the solution is considered valid. Values computed from these data for T, S and P are 4.71×10^4 gpd/ft, 1.06×10^{-1} and 2.36×10^3 gpd/ft^2.

Figure 31 shows the distance-drawdown graph plotted with the data recorded from observation wells 1 and 191. The data from this plot were used in equations 15 and 16 to determine values for T, S, and P which are 2.50×10^4, 1.42×10^{-1} and 1.25×10^3 respectively.

Table 29 lists the time, drawdown and adjustments for the data on the pumping well. Since this well only penetrated about one half of the aquifer adjustments were required for partial penetration as well as for natural groundwater recession and those for gravity drainage. The semi-logarithmic, time-drawdown plot of this data is shown in Fig. 32. Computed values of T and P by using the modified non-equilibrium equation (17) are 7.70×10^4 gpd/ft and 3.85×10^3 gpd/ft^2 respectively.

The computed values of the hydraulic characteristics of this unconfined aquifer are tabulated in Table 30. An examination of this data indicates rather consistant values of T as determined from the data collected at the wells. It is evident from a consideration of the relatively high T of 4.84×10^4 igpd/ft (mean value) and the shape of the cone of depression (Fig. 29) that the geohydrologic properties of

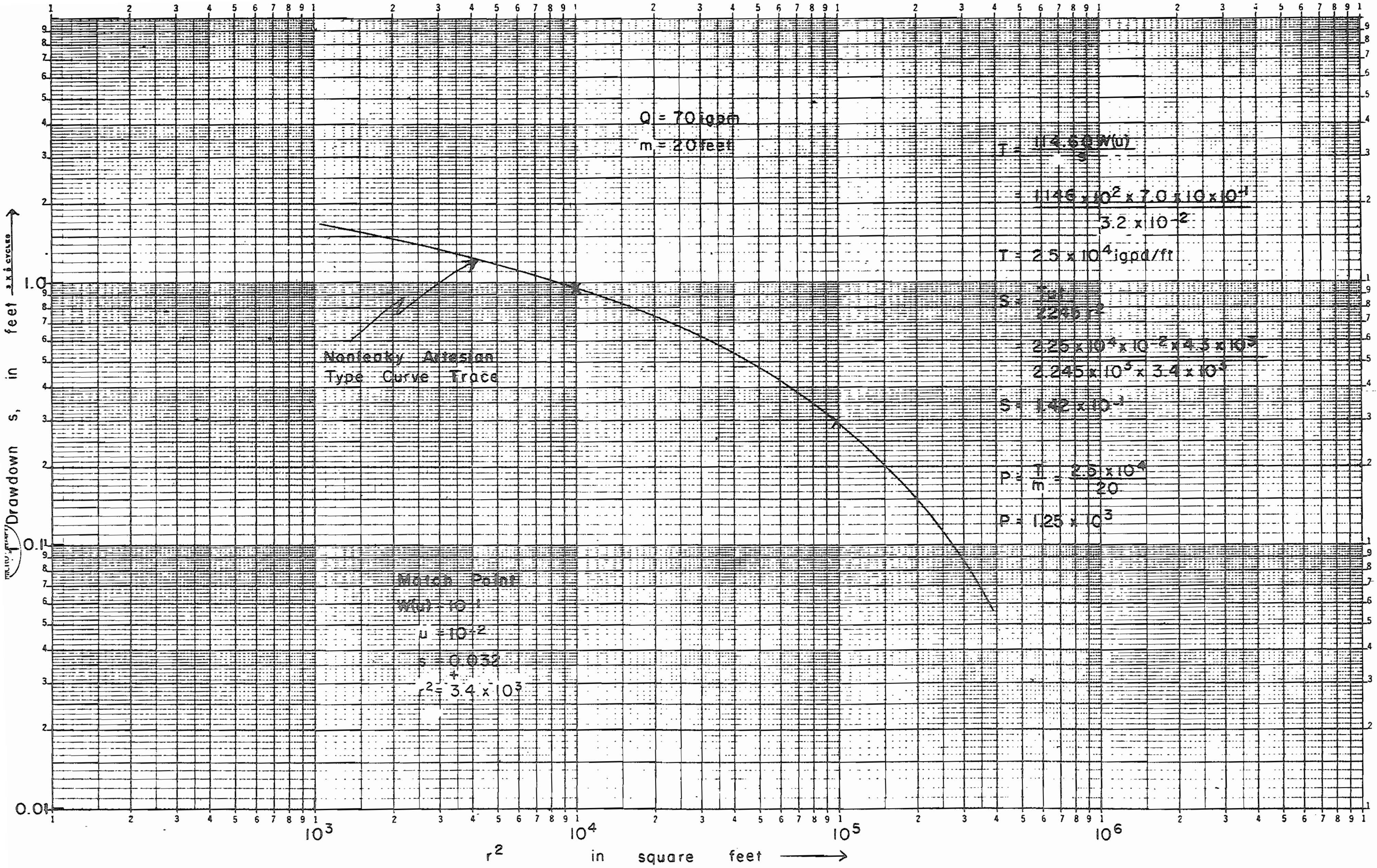


FIGURE 31 Distance—drawdown graph for obervation wells Nos 1 and 191

Table 29. Adjustments Made to Drawdown Data from Pump Well No. 368

Time Elapsed in Minutes	Measured Drawdown	Adjustments (ft)				Adjusted Drawdown
		Natural Recession	Partial Penetration	Gravity Drainage	Total Adjustments	
0	0	0	-0	0	0	0.0
1	.93	0	-0.29	-0.02	-0.31	0.62
2	1.07	0	-0.33	-0.03	-0.36	0.71
3	1.29	0	-0.40	-0.04	-0.44	0.85
4	1.35	0	-0.41	-0.05	-0.46	0.89
5	1.60	0	-0.49	-0.06	-0.55	1.05
6	1.75	0	-0.54	-0.08	-0.64	1.11
7	1.85	0	-0.57	-0.09	-0.66	1.19
8	1.85	0	-0.57	-0.09	-0.66	1.19
9	1.65	0	-0.51	-0.07	-0.58	1.07
10	1.60	0	-0.49	-0.06	-0.55	1.05
15	1.78	0	-0.55	-0.08	-0.63	1.15
20	1.76	0	-0.54	-0.08	-0.62	1.14
25	1.80	0	-0.55	-0.08	-0.63	1.17
30	1.80	0	-0.55	-0.08	-0.63	1.17
40	1.84	0	-0.57	-0.08	-0.65	1.19
50	1.89	0	-0.58	-0.09	-0.67	1.22
60	1.91	0	-0.59	-0.09	-0.68	1.23
75	1.93	0	-0.59	-0.09	-0.68	1.25
90	2.00	0	-0.61	-0.10	-0.71	1.29
105	2.05	-0.01	-0.63	-0.10	-0.74	1.31
120	2.07	-0.01	-0.63	-0.11	-0.75	1.32
150	2.10	-0.01	-0.64	-0.11	-0.76	1.34
180	2.16	-0.01	-0.66	-0.12	-0.79	1.37
210	2.25	-0.01	-0.69	-0.13	-0.83	1.42
240	2.25	-0.01	-0.69	-0.13	-0.83	1.42
300	2.26	-0.01	-0.69	-0.13	-0.84	1.42
360	2.26	-0.01	-0.69	-0.13	-0.83	1.43
420	2.26	-0.01	-0.69	-0.13	-0.83	1.43
480	2.31	-0.02	-0.71	-0.13	-0.86	1.45
540	2.42	-0.02	-0.74	-0.15	-0.91	1.51
600	2.42	-0.02	-0.74	-0.15	-0.92	1.50
660	2.42	-0.02	-0.74	-0.15	-0.91	1.51
720	2.42	-0.03	-0.74	-0.15	-0.92	1.50

		Adjustments (ft)				
Time Elapsed in Minutes	Measured Drawdown	Natural Recession	Partial Penetration	Gravity Drainage	Total Adjustments	Adjusted Drawdown
840	2.45	-0.03	-0.75	-0.15	-0.94	1.51
960	2.48	-0.03	-0.76	-0.15	-0.94	1.54
1080	2.57	-0.04	-0.79	-0.16	-0.99	1.58
1200	2.60	-0.04	-0.80	-0.17	-1.01	1.59
1320	2.58	-0.05	-0.79	-0.17	-1.01	1.57
1440	2.75	-0.05	-0.84	-0.19	-1.08	1.67
1680	2.69	-0.06	-0.87	-0.18	-1.11	1.58
1920	2.69	-0.07	-0.87	-0.18	-1.12	1.57
2160	2.75	-0.08	-0.84	-0.19	-1.11	1.64
2520	2.75	-0.09	-0.84	-0.19	-1.11	1.64
2880	2.78	-0.10	-0.85	-0.19	-1.14	1.64
3600	2.85	-0.12	-0.87	-0.20	-1.19	1.66
4320	2.85	-0.14	-0.87	-0.20	-1.21	1.64
4560	2.85	-0.16	-0.87	-0.20	-1.23	1.62
4880	2.85	-0.17	-0.87	-0.20	-1.24	1.61

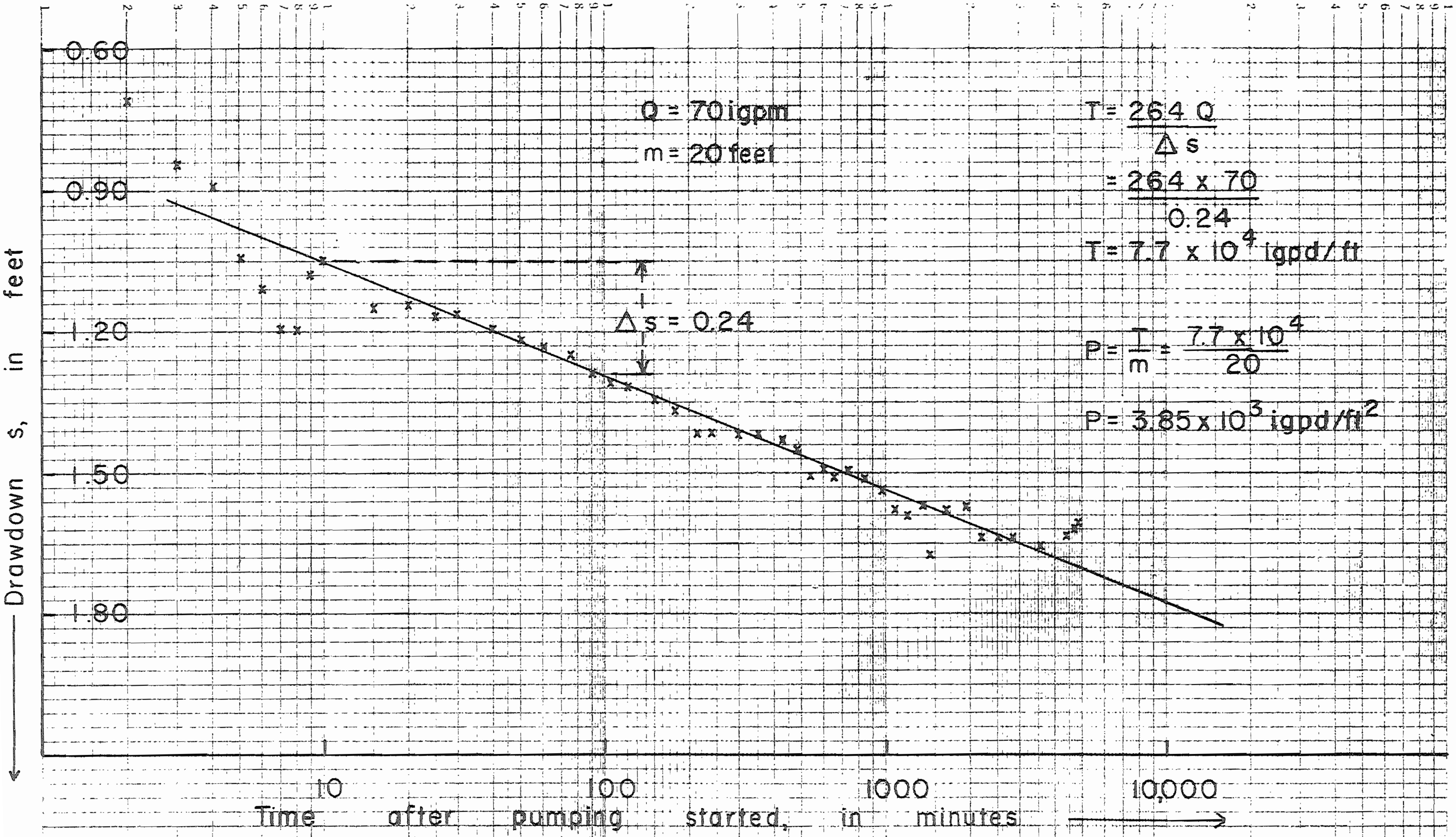


FIGURE 32. Time-drawdown graph for pumping well No. 368

this aquifer are well suited for development of a well field capable of producing large volumes of groundwater. Wells making up such a well field and spaced at about 400 feet apart will result in relatively little interference with on another when each is pumping less than about 200 igpm. However, to efficiently design such a well field, with proper spacing which would allow maximum yields and minimum well interference, will require a complete analysis of interference calculations performed with the data of this aquifer test.

Table 30. Aquifer Hydraulic Characteristics from Pump Test Data

Values	Well 368	Time-Drawdown Plots		Distance-Drawdown Plot on wells 1 and 191	Mean Values
		Well 1	Well 191		
T	7.70×10^4	4.46×10^4	4.71×10^4	2.50×10^4	4.48×10^4
S		1.39×10^{-2}	10.60×10^{-2}	14.20×10^{-2}	8.73×10^{-2}
P	3.85×10^3	2.23×10^3	2.36×10^3	1.25×10^3	2.42×10^3
t_{wt}		97	91		94

T = transmissibility in imperial gallons per day per foot
S = storage coefficient (dimensionless)
P = permeability in imperial gallons per day per square foot
t_{wt} = time in minutes after pumping began that the nonequilibrium equation can be applied to data obtained under water table conditions.

APPENDIX "C" CHEMICAL ANALYSES OF GROUNDWATERS IN THE MAP AREA

(East Central Colchester County)

						Analyses in parts per million (ppm)								Alkalinities										Ions in equivalents per million (epm) Cations			Anions				
Field Sample No.	Grid Location	Area	Depth of Well (feet)	Aquifer	Date Sampled	Ca	Mg	Na	Fe	Mn	SO_4	Cl	NO_3	Phenolphthalein as $CaCO_3$	Methyl Orange	Hardness	Ignition Loss	Total Dissolved Solids	Suspended Matter	Specific Conductance (mhos. $\times 10^{-6}$)	pH	Colour	Turbidity	Ca	Mg	Na	SO_4	Cl	NO_3	SSP *	SAR *
24	11E6D34 A-NE	East Mountain	204	Triassic	29/6/66	32.5	2.9	7.9	.02	T	4	12.4	T *	0	130	94.2			T	23	7.8	<5		1.62	0.24	0.34	0.08	0.34	0	0.154	0.322
26	11E6D14 N-S	Brookside	39	"	29/6/66	14.4	4.1	35.2	0.10	0.03	4	55.0	10	0	8	54.1			T	21	5.4	<5		0.72	0.34	1.53	0.08	1.53	0.16	0.590	2.101
34	11E6D12 F-N	Bible Hill		"	30/6/66	23.2	0.7	4.8	0.08	T	10	7.1	T	0	48	62.1			T	16	8.0	<5		1.16	0.06	0.20	0.21	0.20	0	0.140	0.256
35	11E6D10 K-NW	Valley	33	"	30/6/66	20.0	3.2	7.9	0.07	T	2	12.4	T	0	82	64.1			T	17	7.1	<5		1.00	0.26	0.34	0.04	0.34	0	0.212	0.428
36	11E6A107 K-SE	Murray	77	"	30/6/66	23.2	1.2	5.7	0.01	0.01	12	8.9	T	0	60	64.1			T	16	6.0	<5		1.16	0.10	0.25	0.25	0.25	0	0.165	0.315
38	11E6C4 G-East	Central Onslow		"	14/7/66	74.9	3.9	12.5	0.05	T	8	19.5	15	6	184	201.4			T	48	8.6	<5		3.74	0.32	0.54	0.17	0.54	0.24	0.117	0.379
39	11E6C7 B-North	Lower Onslow	55	"	14/7/66	35.5	0.2	9.1	0.26	T	2	14.2	8	0	86	89.2			T	22	8.0	<5		1.76	0.02	0.395	0.04	0.40	0.13	0.181	0.418
40	11E6C12 Q-NW	Masstown	75	"	14/7/66	46.1	0.5	7.9	0.04	T	15	12.4	6	0	106	117.2			T	30	8.2	<5		2.30	0.04	0.34	0.31	0.34	0.10	0.126	0.314
42	11E6C36 H-NE	Debert		"	14/7/66	22.4	0.2	5.7	0.05	T	2	8.9	T	0	66	57.1			T	14	8.0	<5		1.12	0.02	0.25	0.04	0.25	0	0.179	0.331
44	11E6C63 K-SW		42	"	14/7/66	88.2	9.7	77.8	0.15	0.1	7	121.5	50	0	116	260.5			T	77	8.3	<5		4.40	0.80	3.38	0.15	3.38	0.89	0.393	2.096
45	11E6C55 F-NE	Belmont	71	"	14/7/66	55.6	3.2	12.5	0.03	T	5	19.5	6	6	124	130.3			T	33	8.4	<5		2.77	0.26	0.54	0.10	0.54	0.10	0.151	0.439
46	11E6C45 J-NE	Onslow Mountain	75	"	14/7/66	16.4	2.9	13.6	0.18	0.04	8	21.3	14	0	14	55.1			T	22	7.0	<5		0.83	0.24	0.59	0.17	0.59	0.23	0.355	0.807
47	11E6C47 A-N	North River	50	"	14/7/66	18.0	1.2	11.3	0.04	T	7	17.7	10	0	42	49.1			T	16	7.7	<5		0.90	0.10	0.49	0.15	0.49	0.16	0.328	0.693
48	11E6C23 E-NE	Upper Onslow	82	"	14/7/66	24.4	1.5	10.2	0.03	T	6	16.0	6	0	64	66.1			T	20	7.7	<5		1.22	0.12	0.44	0.12	0.44	0.10	0.247	0.537
51	11E6B91 Q-SE	Lower Truro	240	"	29/7/66	42.9	1.7	10.3	0.01	T	12	16.0	10	0	88	114.2			T	24	7.6	<5		2.14	0.14	0.44	0.25	0.44	0.16	0.161	0.412
52	11E6B90 D-Center	Old Barns	50	"	29/7/66	63.3	4.8	13.6	0.02	T	60	21.3	10	0	102	178.4			T	35	7.8	<5		3.16	0.39	0.59	1.25	0.59	0.16	0.142	0.442
53	11E6B80 E-East	Clifton	31	"	29/7/66	57.3	7.8	19.3	0.03	T	18	30.1	3	0	152	176.4			T	35	7.9	<5		2.86	0.64	0.84	0.37	0.84	0.05	0.193	0.635
54	11E6B62 F-Center	Black Rock	80	"	29/7/66	44.1	1.7	12.5	0.02	T	8	19.5	T	0	124	117.2			T	24	7.8	<5		2.20	0.14	0.54	0.17	0.54	0	0.187	0.499
63	11E6B97 Q-SW	Bible Hill	145	"	11/8/66	20.4	0.2	11.3	0.05	T	38	17.7	2	0	48	52.1			T	14	8.2	<5		1.00	0.08	0.50	0.73	0.50	0.03	0.316	0.681
70	11E6B100 F-Center	Truro	90	"	3/9/66	91.9	1.8	29.7	0.41	T	17	46.1	10	0	204	237.2				60	7.5	<5		4.58	0.15	1.30	0.35	1.30	0.20	0.215	0.845
73	11E6C9 G-NE	Lower Onslow	100	"	3/9/66	32.4	2.5	2.3	0.66	T	3	3.5	T	0	112	91.4			T	24	7.4	<5		1.62	0.21	0.10	0.06	0.10	0	0.051	0.104
7-	11E6C27 F-Center	Onslow Mountain	250	"	3/9/66	44.7	0.4	16.0	0.17	T	18	24.8	12	0	174	113.4			T	46	7.6	<5		2.23	0.03	0.70	0.37	0.70	0.24	0.236	0.658

*N.B. T = Concentration <0.01 ppm SSP = Soluble Sodium percentage SAR = Sodium Absorption Ratio

Field Sample No.	Grid Location	Area	Depth of Well (feet)	Aquifer	Date Sampled	Analyses in parts per million (ppm)																		Ions in equivalents per million (epm)							
														Alkalinities										Cations			Anions				
						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^{-6})	pH	Colour	Turbidity	Ca	Mg	Na	SO_4	Cl	NO_3	SSP	SAR
75	11E6C53 C-South	Belmont	121	Triassic	3/9/66	34.3	2.8	17.2	0.12	T	10	26.6	18	0	88	97.2			T	32	5.9	<5		1.71	0.23	0.75	0.21	0.75	0.36	0.278	0.762
80	11E6A108 C-Center	Truro	87	"	5/9/66	41.9	0.3	4.6	0.06	T	7	7.0	T	0	124	106.2			T	26	7.6	<5		2.09	0.025	0.20	0.146	0.20	0	0.086	0.194
81	11E6D13 E-South	Brookside		"	6/9/66	35.7	1.6	13.7	0.11	T	11	21.2	2	0	28	96.8			T	27	6.7	<5		1.78	0.13	0.60	0.229	0.60	0.04	0.239	0.614
82	11E6D15 E-SE	Valley		"	6/9/66	48.3	0.6	8.0	0.06	T	18	12.4	10	0	176	123.4			T	32	7.8	<5		2.41	0.005	0.35	0.375	0.35	0.20	0.126	0.318
90	11E6880L	Old Barns		"		50.5	6.3	21.6	0.03		12.00	33.7	T		58	152.3		269			6.6			2.52	0.518	0.940	0.250	0.960	0.0		0.764
88	11E6889C	Old Barns		"		55.3	2.4	14.7	T		22.00	23.0	18.0		62	148.3		275			7.4			2.76	0.197	0.639	0.458	0.650	0.290		0.527
89	11E6D14J	Valley		"		49.7	2.4	17.0	0.02		17.0	26.5	14		54	134.3		205			7.5			2.48	0.197	0.739	0.208	0.757	0.226		0.641
41	11E6C60 H-Center	Debert	18	Surficial Deposits overlying the Triassic	14/7/66	10.4	4.4	12.5	0.14	0.02	7	19.5	15	0	20	44.1			T	18	7.0	<5		0.52	0.36	0.54	0.15	0.54	0.24	0.380	0.814
49	11E6C32 G-N.W.	Belmont	25	"	15/7/66	44.1	3.4	18.2	0.08	T	13	28.4	30	0	98	124.3			T	44	8.3	<5		2.20	0.28	0.79	0.27	0.79	0.48	0.241	0.709
79	11E6C65 M-Center	Belmont		"	3/9/66	19.4	2.9	2.3	0.17	T	2	3.5	3	0	112	60.4			T	18	7.4	<5		0.97	0.24	0.10	0.04	0.10	0.06	0.076	0.128
96	11E5C26L	Londonderry		"		12.8	3.4	23.8	0.02	T	6.0	37.2	3		16	46.0		103			6.3			.639	.280	1.02					1.505
85	1E6D76P	Kemptown		Cumberland Formation		2.4	1.5	61.2	0.12		105	95.7	T		128	12.0		608			9.0			0.120	0.123	2.66	2.19	2.71	0.00		7.6
95	11E7C65 C-N.W.	West River Station	400	"	18/10/67	119.3	44.4	920.0	19.0	0.10	80.0	1420	1	0	44	481.4				500	7.3	>350	320	2.74	0.36	40.0	1.66	40	0.016		
31	11E6D86 D-South	Central North River		"	29/6/66	37.7	8.8	126.0	T	T	36	196.8	T	0	112	130.3				78	7.7	<5		1.88	0.72	5.48	0.75	5.48		0.678	4.815
18	11E6D76 F-S.W.	Kemptown	8.3	Surficial Deposits overlying the Cumberland	29/6/66	6.6	2.9	9.1	0.01	T	12	14.2	12	0	6	27.1			T	14	5.2	<5		0.33	0.24	0.395	0.25	0.40	0.19	0.409	0.741
19	11E6D93 F-N.E.	"		"	29/6/66	30.9	2.9	1.7	T	T	17	2.7	2	0	70	87.2			T	23	7.5	<5		1.54	0.24	0.07	0.30	0.07	0.03	0.037	0.074
20	11E6D100 H-S.W.	"	16.2	"	29/6/66	4.8	1.2	10.2	0.25	T	5	16.0	T	0	20	15.0			T	<10	6.6	<5		0.24	0.10	0.44	0.10	0.44	0	0.564	1.067
32	11E6D107 G-North	Central North River	12	"	29/6/66	4.4	1.2	9.1	0.02	T	5	14.2	3	0	22	16.0			T	<10	5.9	<5		0.22	0.10	0.395	0.10	0.40	0.05	0.552	0.987

						Analyses in parts per million (ppm)																		Ions in equivalents per million (epm)							
														Alkalinities										Cations			Anions				
Field Sample 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^{-6})	pH	Colour	Turbidity	Ca	Mg	Na	SO_4	Cl	NO_3	SSP	SAR
78	11E6C97 L-Center	McCallum Settlement	22	Surficial Deposits overlying the Cumberland	3/9/66	8.1	1.4	4.6	0.28	T	2	7.0	1	0	78	26.2			T	9	6.7	<5		0.40	0.11	0.20	0.04	0.20	0.02	0.281	0.396
43	11E6C84 E-East	Debert		"	14/7/66	4.4	1.2	8.5	0.03	T	3	13.3	T	0	20	16.0			T	<10	7.2	<5		0.22	0.10	0.37	0.06	0.37	0	0.536	0.925
93	11E6C968	McCallum Settlement				4.2	4.9	21.6	0.05		11.0	33.7	15.0		14.0	48.0		128			6.0			.210	.403	.940					1.70
84	11E6D76P	Manganese Mines				11.2	2.4	12.5	0.50		7.0	19.5	2.0		22.0	38.0		71			6.9			.559	.197	.544					0.885
29	11E6D59 F-N.E.	North River		Riversdale	29/6/66	50.9	8.8	6.8	1.4	0.02	160	10.6	T	0	152	164.3				55	7.4	<5		2.54	0.72	0.30	3.33	0.30	0	0.084	0.235
60	11E6D46 H-North	Riversdale	205	"	5/8/66	45.7	4.1	12.5	0.06	T	66	19.5	T	0	100	131.3			T	15	7.9	<5		2.28	0.34	0.54	1.37	0.55	0	0.170	0.472
33	11E6D61 D-Center	North River	95	"	29/6/66	12.4	T	61.3	0.05	0.01	130	17.7	1	0	74	31.1			T	38	6.7	<5		0.62	..00	2.69	2.71	0.49	0.01	0.812	4.838
30	11E6D62 P-S.E.	" "	95	"	29/6/66	45.6	3.1	34.0	2.3	0.3	60	53.2	3	0	148	170.3				46	7.2	<5		2.28	0.25	1.45	1.25	1.45	0.03	0.364	1.290
77	11E6C71 O-South	" "	50	"	3/9/66	38.2	8.6	12.6	0.24	0.02	13.	19.5	T	0	142	130.6			T	32	7.9	<5		1.91	0.71	0.55	0.27	0.55	0	0.173	0.480
76	11E6C51 G-North	Onslow Mountain	100	"	3/9/66	196.6	4.8	2.3	2.5	T	540	3.5	T	0	172	511.4				118	7.4	<5		9.81	0.39	0.10	11.24	0.10	0	0.009	0.044
92	11E6C48Q	North River		"		0.6	4.4	14.7	0.02		15.0	23.0	2.0		14.0	42.0		90.0			6.2			0.479	0.362	0.640	0.312	0.649	0.032		0.987
14	11E6D46 D-N.E.	Riversdale	16	Surficial Deposits overlying the Riversdale	28/6/66	44.5	6.3	7.9	0.02	0.01	10	12.4	40.	0	24	158.3			T	42	6.7	<5		2.22	0.52	0.34	0.21	0.34	0.65	0.110	0.290
15	11E6D52 F-Center	"		"	28/6/66	5.6	1.0	4.5	0.01	T	2	7.1	T	0	16	19.0			T	<10	6.6	<5		0.28	0.08	0.20	0.04	0.20		0.357	0.471
16	11E6D54 J-N.E.	"		"	28/6/66	24.4	2.4	18.2	T	T	3	28.4	3	0	52	72.1			T	22	6.7	<5		1.22	0.20	0.79	0.06	0.79	0.05	0.357	0.938
17	11E6D45 O-West	"	9.5	"	29/6/66	6.4	0.7	6.8	0.02	T	3	10.6	T	0	16	20.0				<10	6.3	<5		0.32	0.06	0.30	0.06	0.30		0.441	0.689
22	11E6D40 J-N.W.	East Mountain	12.1	"	29/6/66	53.3	2.4	11.9	0.02	T	5	18.6	5	0	128	144.3			T	34	7.0	<5		2.66	0.20	0.52	0.10	0.52	0.08	0.153	0.435
86	11E6D46H	Riversdale		"		18.4	4.9	20.4	0.75		14.0	31.9	T		70.0	66.3		268			7.7			.918	.403	.887					1.09

						Analyses in parts per million (ppm)																		Ions in equivalents per million (epm)							
														Alkalinities										Cations			Anions				
Field Sample 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})	pH	Colour	Turbidity	Ca	Mg	Na	SO_4	Cl	NO_3	SSP	SAR
28	11E6D40 B-East	East Mountain	160	Canso	29/6/66	53.3	15.6	28.9	0.07	0.01	48	45.2	9	0	136	200.4			T	54	7.4	<5		2.66	1.28	1.26	1.00	1.26	0.15	0.242	0.898
13	11E6D30 N-S.E.	Manganese Mines		"	28/6/66	23.2	7.6	7.9		0.02	12	12.4	4	0	50	90.2				25	7.5	<5		1.16	0.63	0.34	0.25	0.34	0.06	0.159	0.359
11	11E6A77 N-N.E.	Greenfield	130	"	28/6/66	12.3	8.9	7.9	5.5	0.08	18	12.4	10	0	32	54.1			T	18	6.6	<5		0.62	0.40	0.34	0.27	0.34	0.16	0.250	0.476
10	11E6A101 L-Center	"		"	28/6/66	24.8	8.5	7.9	0.13	0.02	8	12.4	2	0	88	98.2			T	24	7.8	<5		1.24	0.70	0.34	0.16	0.34	0.03	0.149	0.345
8	11E6A40 O-N.E.	Camden	83	"	24/6/66	6.4	2.2	9.1	0.22	0.02	22	14.2	1	0	22	26.1			T	<10	6.6	<5		0.30	0.18	0.40	0.46	0.40	0.015	0.835	0.817
7	11E6A58 K-East	"		"	24/6/66	30.5	10.3	30.7	0.24	0.04	27	47.9	25	0	24	119.2			T	42	5.9	<5		1.52	0.85	1.34	0.56	1.34	0.40	0.566	1.230
6	11E6A63 E-East	"	63	"	24/6/66	24.0	2.2	10.2	0.02	T	12	16	8	0	68	91.2			T	21	7.2	<5		1.20	0.18	0.44	0.25	0.44	0.13	0.318	0.530
4	11E6A81 L-N	Archibald	67	"	24/6/66	30.9	4.2	10.2	0.02	T	19	16	2	0	84	97.2			T	21	7.8	<5		1.54	0.35	0.44	0.40	0.44	0.03	0.232	0.452
1	11E6A81 Q-S.E.	"	60	"	9/8/66	18.8	7.3	11.3	2.0	0.04	12	17.7	T	6	150	77.2				21	8.8	<5		0.94	0.60	0.49	0.25	0.49		0.318	0.558
1(a)	"	"	"	"	11/8/66	19.6	7.1	20.4	0.28	0.03	4	31.9	T	4	132	78.2				21	8.3	<5		0.98	0.58	0.89	0.08	0.89		0.570	1.008
12	11E6D19 E-West	Union Station		Surficial Deposits overlying the Canso	28/6/66	5.2	1.9	7.9	0.07	T	2	12.4	T	0	22	22.0			T	<10	6.4	<5		0.26	0.16	0.34	0.04	0.34		0.447	0.742
9	11E6A104 E-South	Greenfield		"	28/6/66	20.8	4.4	12.5	0.12	0.01	12	19.5	15	0	46	71.1			T	30	6.3	<5		1.04	0.36	0.54	0.25	0.54	0.24	0.278	0.645
5	11E6A82 G-N.W.	Archibald		"	24/6/66	7.2	2.8	22.1	0.20	T	4	34.6	T	0	4	30.1			T	12	5.1	<5		0.36	0.23	0.96	0.08	0.96		1.627	1.767
3	11E6A88 B-N	"		"	24/6/66	21.2	0.4	8.5	0.05	0.03	21	13.3	T	0	56	56.1			T	14	7.2	<5		1.06	0.03	0.37	0.44	0.37		0.339	0.501
2	11E6A80 F-N.W.	"		"	24/6/66	6.0	3.0	8.5	0.05	T	11	13.3	T	0	102	28.1				23	8.3	<5		0.30	0.25	0.37	0.23	0.37		0.706	0.673
1(b)	11E6A	"		"	10/6/66	6.4	3.4	5.2	0.65	1.00	3	8.0	T	0	32	34.0				<10	6.9	50		0.319	0.280	0.226	0.062	0.226			
87	11E6D34Q	East Mountain		"		38.5	3.9	10.2	0.16		4.0	16.0	T		58.0	112.3		109			7.2			1.92	.321	.444					0.443
56	11E6B72 E-South	Truro	65	Horton	29/7/66	28.9	8.0	15.9	0.04	0.2	7	24.8	3	0	96	105.2			T	26	7.3	<5		1.44	0.66	0.69	0.15	0.69	0.05	0.247	0.673
55	11E6B95 B-N.E.	"	65	"	29/7/66	41.7	11.7	21.6	0.06	0.01	56	33.7	9	0	184	147.3			T	46	7.8	<5		2.08	0.96	0.94	1.17	0.94	0.15	0.236	0.762

Field Sample No.	Grid Location	Area	Depth of Well (feet)	Aquifer	Date Sampled	Analyses in parts per million (ppm)																		Ions in equivalents per million (epm)						SSP	SAR
														Alkalinities										Cations			Anions				
						Ca	Mg	Na	Fe	Mn	SO_4	Cl	NO_3	Phenol-phthalein as $CaCO_3$	Methyl Orange	Hardness	Ignition Loss	Total Dis-solved Solids	Suspended Matter	Specific Conductance (mhos. x 10^{-5})	pH	Colour	Turbidity	Ca	Mg	Na	SO_4	Cl	NO_3		
59	11E6875 Q-S.E.	Truro	100	Horton	29/7/66	7.6	1.0	182.7	0.08	T	78	285.5	T	16	140	23.0				135	8.7	<5		0.38	0.08	7.95	2.04	7.95		0.945	16.597
83	11E6D32 M-North	Manganese Mines	70	"	6/9/66	40.3	1.5	2.3	0.40	T	12	3.5	3	0	114	107.0			T	26	7.2	<5		2.01	12	0.10	0.249	0.10	0.06	0.044	0.096
23	11E6D41 D-Center	" "	120	"	29/6/66	10.8	2.2	9.1	T	T	3	14.2	T	0	44	37.1			T	11	6.4	<5		0.54	0.18	0.395	0.06	0.40		0.354	0.658
97	11E6875A	Truro		"		17.6	6.3	13.6	0.16		18.0	21.3	T		74.0	70.3		244			8.3			0.878	0.518	0.592	0.375	0.611	0.00		0.685
69	11E6840 5-Center	Beaver Brook	100	Windsor	3/9/66	40.0	7.6	9.1	0.16	T	6	14.1	14	0	148	131.0			T	34	8.1	<5		2.00	-0.63	0.40	0.12	0.40	0.28	0.132	0.349
71	11E6844 A-Center	Hilden	100	"	3/9/66	303.0	7.4	4.6	0.06	0.02	800	7.09	T	0	60	787.6				152	7.4	<5		15.12	0.61	0.20	16.66	0.20		0.012	0.071
27	11E6D35 O-S.E.	Upper Brookside	125	"	29/6/66	58.9	6.1	11.3	2.3	0.06	85	17.7	T	0	122	173.3				46	7.7	<5		2.94	0.50	0.49	1.77	0.49		0.124	0.373
82	11E6823E	Brookfield		"		30.5	25.3	14.7	0.05		22	23	T		84	188.5		256			7.8			1.52	2.08	0.639	0.458	0.650	0.00		0.477
65	11E685 G-Center	Upper Pleasant Valley		Surficial Deposits overlying the Windsor	2/9/66	16.6	4.8	3.4	0.30	T	4	5.3	T	0	68	61.0			T	16	6.5	<5		0.83	0.39	0.15	0.08	0.15		0.109	0.192
66	11E6816 C-East	Green Oaks		"	2/9/66	30.2	4.1	3.4	5.0	0.01	13	5.3	T	0	92	92.0			T	23	7.2	<5		1.51	0.34	0.15	0.28	0.15		0.075	0.156
67	11E6810 O-Center	" "		"	2/9/66	31.0	1.1	3.4	0.03	T	4	5.3	T	0	100	82.0			T	24	7.9	<5		1.55	0.09	0.15	0.08	0.15	0.02	0.083	0.165
68	11E6835 O-Center	Princeport		"	2/9/66	55.8	3.3	13.7	0.18	T	19	21.2	T	0	12	153.2			T	47	7.2	<5		2.78	0.27	0.60	0.39	0.60		0.164	0.486
64	11E682 C-Center	Brookfield		"	2/9/66	39.0	6.0	13.7	0.71	1.5	22	21.2	T	0	116	122.6			T	55	7.5	<5		1.95	0.49	0.60	0.46	0.60	[illegible]	0.197	0.543
98	11E682 H-Center	"	14	"	7/12/67	23.5	1.2	6.0	0.22	0.01	51	12.4	1	0	22	63.6				21	6.3	<5	0	1.17	0.10	0.26	1.06	0.35	0.02		
99	11E682 H-East	"	22	"	7/12/67	25.4	1.0	7.0	0.28	0.01	59	21.3	1	0	27	68.4				24	6.2	<5	0	1.27	0.08	0.30	1.23	0.60	0.02		
69	11E7B16D	Upper Stewiacke		"		25.7	2.9	14.7	0.02		47.0	23.0	T		16.0	76.3		134			6.3			1.28	.239	.639					0.932
81	11E682G	Brookfield		"		62.5	4.9	30.7	0.02		15.0	47.9	14		66.0	176.3		307			7.6			3.12	.403	1.34					1.07
96(a)	11E6A2H-East	"	30	"	13/1/68	17.5	2.2	2.1	0.04	T	21	6.2	T	0	27	52.8				15	6.6	<5	7	0.87	0.18	0.09	0.44	0.18	0		
96(b)	11E6A2H-East	"	30	"	15/1/68	17.3	2.0	2.4	0.05	T	18	8.0	T	0	26	51.4				15	6.6	<5	10	0.86	0.16	0.10	0.37	0.23	0		

Mean Values

		Analyses in parts per million (ppm)																		Ions in equivalents per million (epm)							
										Alkalinities										Cations			Anions				
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})	pH	Colour	Turbidity	Ca	Mg	Na	SO_4	Cl	NO_3	SSP	SAR
Triassic		41.60	2.51	14.96	0.01	0.015	12.5	23.3	7.7	0.5	94	114		160	T	29	7.5	<5		2.08	0.21	0.65	0.25	0.65	0.14	0.21	0.61
Cumberland		53.2	18.2	369	6.38	0.04	73.7	580	0.34	0	95	207					8.0			1.58	0.40	16.05	1.53	16.1			
Riversdale		55.7	4.83	20.6	0.94	0.06	140.5	21.0	0.86	0	114.5	169		279		50.67	7.25			2.85	0.40	0.90	2.9	0.6	0.006	.269	1.19
Canso		24.4	7.4	14.5	0.85	0.03	13.4	22.6	6.1	1.0	78.6	93		141		25.7	7.4			1.22	0.58	0.63	0.37	0.54	0.10	0.36	0.67
Horton		24.5	5.12	40.8	0.13	0.04	29.0	63.9	2.51	3.2	109	82		269		48.8	7.6			1.22	2.40	1.78	0.67	1.78	0.05		3.24
Windsor		107.9	11.6	9.9	0.64	0.03	228	15.5	4.67	0	104	320		425		77.3	7.8			5.39	0.95	0.43	4.76	0.44	0.09	0.089	0.32
Surficial Deposits over the Triassic		24.16	3.53	14.2	0.10	0.01	7.0	22.2	12.7		61.6	68.7		147	T	26.7	7.6	<5		1.08	0.29	0.61	0.15	0.48	0.26	0.23	0.79
Surficial Deposits overlying the Cumberland		9.3	2.4	9.7	0.14	T	7.8	15.1	4.4	0	31.5	34		70	T	12.7	6.5			0.47	0.21	0.42					0.85
Surficial Deposits overlying the Riversdale		25.6	2.95	11.6	0.14	0.01	6.18	18.2	9.6	0	51.1	80		130		23.6	6.84			1.27	0.24	0.51	0.09	0.43	0.16	0.28	0.65
Surficial Deposits overlying the Canso		15.02	2.83	10.69	0.19	0.18	8.15	16.8	2.15	0	45.7	50.6		91		16.5	6.78	12.5		0.752	0.233	0.46	0.18	0.47		0.57	0.68
Surficial Deposits overlying the Windsor		31.2	3.05	9.12	0.62	0.14	24.8	16.1	1.55		52	90.7		120		21.8	6.9			1.56	0.24	0.40	0.40	0.27			

APPENDIX "D" CHEMICAL ANALYSES OF SURFACE WATERS IN THE MAP AREA

(East Central Colchester County)

Field Sample No.	Grid Location	Area	Date Sample Taken	Flow c.f.s.	Coliform Bacteria Count . per 100 mls	Analyses in parts per million (ppm)																		Ions in equivalents per million (epm)						SSP	SAR
						Ca	Mg	Na	Fe	Mn	SO_4	Cl	NO_3	Alkalinities		Hardness	Ignition Loss	Total Dis-solved Solids	Suspended Matter	Specific Conductance (mhos. x 10^{-5})	pH	Colour	Turbidity	Cations			Anions				
														Phenol-phthalein as $CaCO_3$	Methyl Orange									Ca	Mg	Na	SO_4	Cl	NO_3		
86	11E6A107K Centre	Murray	28/6/67 10:30 am	81.2	150	3.6	1.6	9.8	0.16	0.03	3	15.0	T	0	16	16.4		49.4	T	9	7.3	25	7	0.18	0.13	0.43	0.06	0.42			
"	"	"	12/7/67 9:45 am	70.2	> 240	5.9	2.14	10.30	0.16	0.02	8	15.9	T	0	28	23.3		66		12	7.9	25	8	.289	.176	.199	.166	.199			
"	"	"	26/7/67 0830	65.4	150	6.7	1.7	13.2	0.24	T	7	20.4	T	0	36	24.4		71.5		13	7.0	30	8	.334	.139	.574	.146	.575			
"	"	"	9/8/67 0900	90.5	95	6.9	1.3	10.1	0.18	T	4	15.6	T	0	20	22.4		66		12	7.2	70	12	.344	.107	.439	.083	.440			
"	"	"	23/8/67 0900	55.7	140	8.0	2.6	11.4	0.16	T	6	17.7	T	0	26	28.4		88		16	7.2	20	7	.40	.22	.50	.12	.50			
"	"	"	6/9/67 0910	209	118	6.4	1.8	8.7	0.17	T	3	8.9	T	0	12	23.5		27.5		5	7.3	115	18	0.32	0.15	.38	.06	.25			
"	"	"	22/9/67 1020	65.4	124	6.4	1.5	9.9	0.04	T	4	13.3	T	0	19	22.3		71.5		13	6.8	5	2	.32	.12	.43	.08	.38			
"	"	"	4/10/67 0930	67.0	172	6.3	1.9	9.0	0.21	T	4	14.2	T	0	20	23.5		66		12	7.2	40	7	.31	.16	.39	.08	.40			
"	"	"	18/10/67 1015	285	0	3.9	1.1	5.3	0.24	0.02	3	1.8	T	0	8	14.2		5.5		1	7.1	35	14	.19	.10	.23	.06	.05			
"	"	"	1/11/67	248	124	4.4	1.3	19.0	0.27	T	3	8.9	T	0	7	16.3		27.5		5	7.0	45	26	.22	.11	.83	.06	.25			
"	"	"	15/11/67 1000	758	74	3.3	1.0	5.0	0.23	T	5	4.4	T	0	6.5	12.4		5.5		1	6.9	40	18	.16	.08	.22	.10	.12			
"	"	"	29/11/67 0930	805	26	2.5	0.8	3.5	0.21	T	4	3.5	T	0	5.5	9.6		0		0	6.6	30	12	.12	.07	.15	.08	.10			
87	11E6D17Q Center	Union	28/6/67 1130	81.2	20	2.2	1.5	8.6	0.26	0.06	3.0	13.3	T	0	12	12.6		38.4		7	7.1	35	3	.11	.12	.37	.06	.39			
"	"	"	12/7/67 1015	70.2	12	4.1	1.41	14.2	0.15		7	17.7	T	0	24	16.0		66		12	8.0	30	9	.204	.116	.338	.146	.34			
"	"	"	26/7/67 0900	65.4	60	4.5	1.5	14.3	0.29		5	22.2	T	0	28	18.0		71.5		13	6.9	30	12	.225	.123	.622	.104	.626			
"	"	"	9/8/67 1000	90.5	43	5.3	1.5	10.8	0.26	T	2	16.8	T	0	16	19.2		60.5		11	7.1	75	18	.264	.123	.470	.042	.474			
"	"	"	23/8/67 0945	55.7	14	5.8	1.3	13.7	0.22	T	6	21.3	T	0	18	19.6		82.5		15	7.1	25	7	.29	.11	.60	.12	.60			
"	"	"	6/9/67 1000	209	32	16.0	1.7	6.2	0.21	T	2	10.6	T	0	18	47.0		38.4		7	7.6	115	20	.84	.14	.27	.04	.30			
"	"	"	22/9/67 1105	65.4	22	3.7	1.3	11.1	0.16	T	4	16.8	T	0	13	14.6		71.5		13	6.9	10	9	.18	.11	.48	.08	.47			
"	"	"	4/10/67 1000	67.0	22	6.3	1.4	9.6	0.27	T	3	14.2	T	0	12	21.5		60.5		11	7.3	45	8	.31	.12	.42	.06	.40			
"	"	"	18/10/67 1015	285	140	2.8	0.9	4.7	0.21	T	3	1.8	T	0	8	10.7		5.5		1	7.1	45	21	.14	.07	.20	.06	.05			

						Analyses in parts per million (ppm)																		Ions in equivalents per million (epm)							
														Alkalinities										Cations			Anions				
Field Sample No.	Grid Location	Area	Date Sample Taken	Flow c.f.s.	Coliform Bacteria Count per 100 mls	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})	pH	Colour	Turbidity	Ca	Mg	Na	SO_4	Cl	NO_3	SSP	SAR
87	11E6D12Q Center	Union	1/11/67	248	96	2.8	1.0	9.1	0.20	T	2	3.5	T	0	6	11.1		11		2	6.8	35	20	.14	.08	.40	.04	.098			
"	"	"	15/11/67 1030	758	104	3.5	1.0	3.1	0.34	T	5	4.4	T	0	7.0	12.9		5.5		1	6.7	45	18	.17	.08	.13	.10	.124			
"	"	"	29/11/67 1030	805	22	2.5	0.6	3.0	0.18	T	3	3.5	T	0	4.0	8.7		0.0		0	6.6	25	9	.12	.05	.13	.06	.10			
88	11E6D46H N.W.	Riversdale	28/6/67 1400	81.2	10	1.8	1.6	4.6	0.32	0.06	2	7.1	T	0	8	12.2		0.0		0	6.7	80	12	.90	.13	.20	.04	.20			
"	"	"	12/7/67 1030	70.2	40	2.8	1.36	6.8	0.32	0.02	7	10.6	T	0	16	12.8		49.5		9	7.4	40	15	.14	.11	.16	.15	.16			
"	"	"	26/7/67 0930	65.4	20	2.7	1.3	9.2	0.58	T	8	14.2	T	0	16	12.8		44.0		8	6.9	80	25	.14	.11	.40	.17	.40			
"	"	"	9/8/67 1100	90.5	44	3.7	0.0	6.8	0.44	T	4	10.6	T	0	8	9.2		11.0		2	6.7	120	22	.19		.30	.08	.30			
"	"	"	23/8/67 1045	55.7	47	4.2	1.1	5.1	0.51	T	5	8.0	T	0	15	14.8		38.5		7	6.8	90	19	.21	.09	.22	.10	.22			
"	"	"	6/9/67 1100	209	72	3.5	1.5	5.2	0.21	T	3	8.9	T	0	6	13.5		0		0	6.5	140	25	.17	.12	.23	.06	.25			
"	"	"	22/9/67 1150	65.4	4	4.4	1.1	6.0	0.39	T	4	8.9	T	0	12	15.5		38.5		7	7.0	70	18	.22	.09	.26	.08	.25			
"	"	"	4/10/67 1045	67.0	48	3.0	1.2	5.2	0.39	T	2	5.3	T	0	8	12.0		11.0		2	7.2	85	21	.15	.10	.23	.04	.15			
"	"	"	18/10/67 1100	285	0	1.9	0.8	2.9	0.37	T	2	1.8	T	0	7	8.0		0.0		0	6.4	80	29	.09	.07	.13	.04	.05			
"	"	"	1/11/67	248	10	2.4	0.9	3.2	0.30	T	2	1.8	T	0	4	8.5		0.0		0	6.4	90	31	.12	.07	.14	.04	.05			
"	"	"	15/11/67 1130	758	40	2.4	0.9	2.2	0.28	0.01	4	3.5	T	0	2.5	9.8		0.0		0	6.6	80	21	.12	.07	.10	.08	.10			
"	"	"	29/11/67 1115	805	8	1.5	0.7	2.4	0.24	0.01	2	1.8	T	0	2.5	6.6		0.0		0	6.1	55	19	.07	.06	.10	.04	.05			
91	11E6C2K N.W.	Bible Hill	13/12/67 1015		1530	9.4	1.2	2.0	0.42	T	8	5.3	T	0	12	28.8		55.0		10	6.3	65	69	.47	.10	.09	.17	.15			
92	11E6C2D West	Upper Onslow	13/12/67 1030		184	1.8	2.2	2.5	0.23	T	16	5.3	T	0	10	13.6		0.0		0	6.6	45	30	.09	.18	.11	.33	.15			
93	11E6C3P N.W.	Upper Onslow	13/12/67 1045		770	5.6	0.6	2.0	0.33	T	6	3.5	T	0	14	16.8		0.0		0	6.5	70	90	.28	.05	.09	.12	.10			
94	11E6B94 J - N	Truro	13/12/67 1145		1450	5.0	0.5	2.2	0.30	T	8	5.3	T	0	8	14.8		5.5		1	6.4	60	55	.25	.04	.10	.17	.15			

Field Sample No.	Grid Location	Area	Date Sample Taken	Flow c.f.s.	Coliform Bacteria Count per 100 mls	Analyses in parts per million (ppm)																		Ions in equivalents per million (epm)							
														Alkalinities										Cations			Anions				
						Ca	Mg	Na	Fe	Mn	SO_4	Cl	NO_3	Phenol-phthalein as $CaCO_3$	Methyl Orange	Hardness	Ignition Loss	Total Dissolved Solids	Suspended Matter	Specific Conductance (mhos. x 10^{-6})	pH	Colour	Turbidity	Ca	Mg	Na	SO_4	Cl	NO_3	SSP	SAR
89	11E6D93K Center	Kemptown	28/6/67 1440	81.2	25	2.2	1.1	4.0	0.14	0.03	3	6.2	T	0	12	11.0		0.0		0	7.1	20	70	.11	.09	.17	.06	.17			
"	11E6D76C Center	"	12/7/67 1100	70.2	0	2.3	1.61	5.03	0.09	0.03	11	7.80	T	0	20	13.0		27.5		5	7.5	25	8	.11	.13	.22	.23	.22			
"	"	"	26/7/67 1000	65.4	150	13.0	1.0	7.4	.22	T	4	11.5	T	0	26	37.3		49.5		9	7.3	25	11	.65	.08	.32	.08	.32			
"	"	"	9/8/67 1130	90.5	47	6.1	0.2	6.3	0.18	T	4	9.7	T	0	18	16.0		33.0		6	7.2	45	10	.30	.016	.27	.08	.27			
"	"	"	23/8/67 1115	55.7	.54	5.1	0.6	4.6	0.18	T	4	6.2	T	0	18	15.2		44.0		8	7.2	25	11	.25	.06	.20	.08	.20			
"	"	"	6/9/67 1145	209	42	3.8	1.3	6.2	0.12	T	2	7.1	T	0	12	14.7		5.5		1	6.6	70	10	.22	.11	.27	.04	.20			
"	"	"	22/9/67 1210	65.4	8	3.5	1.0	4.9	0.09	T	2	6.2	T	0	13	12.8		11		2	7.1	10	7	.17	.08	.21	.04	.18			
"	"	"	4/10/67 1100	67.0	10	3.8	1.3	5.1	0.22	T	2	5.3	T	0	10	14.0		11		2	7.2	35	8	.19	.09	.22	.04	.15			
"	"	"	18/10/67 1130	285	0	3.1	0.8	3.0	0.14	T	2	1.8	T	0	8	11.0		5.5		1	7.0	150	19	.15	.07	.13	.04	.05			
"	"	"	1/11/67	248	32	2.9	1.0	3.1	0.38	T	2	3.5	T	0	7	11.5		5.5		1	6.7	25	18	.14	.08	.13	.04	.10			
"	"	"	15/11/67 1150	758	36	2.8	0.8	2.2	0.19	T	3	2.7	T	0	5.5	10.2		0.		0	6.6	45	11	.14	.07	.10	.06	.076			
"	"	"	29/11/67 1300	805	14	2.2	0.8	2.8	0.18	T	3	3.5	T	0	4.5	8.8		0		0	6.3	20	2	.11	.07	.12	.06	.10			
90	11E6B98H-N	Truro	1/11/67	248	2000	4.4	1.3	5.0	0.28	T	2	8.9	T	0	12	16.3				6	7.0	35	22	.22	.11	.22	.04	.25			
"	"	"	15/11/67 0900	758	1540	3.5	1.0	3.0	0.32	0.06	5	4.4	T	0	8.0	12.9				1	6.7	45	12	.17	.08	.13	.10	.12			
"	"	"	29/11/67 0900	805	242	4.2	0.6	3.0	.29	.01	3	4.40	T	0	7.0	13.0				1	6.5	45	11	.21	.05	.13	.06	.12			
"	"	"	13/12/67 0930	1440	1930	3.2	0.5	2.8	0.27	T	6	7.1	T	0	8	10.4				0	6.8	50	30	.16	.04	.12	.12	.20			

MEAN VALUES

						Analyses in parts per million (ppm)																		Ions in equivalents per million (epm)							
														Alkalinities										Cations			Anions				
Field Sample No.	Grid Location	Area	Date Sample Taken	Flow c.f.s.	Coliform Bacteria Count per 100 mls	Ca	Mg	Na	Fe	Mn	SO_4	Cl	NO_3	Phenol-pthalein as $CaCO_3$	Methyl Orange	Hardness	Ignition Loss	Total Dissolved Solids	Suspended Matter	Specific Conductance (mhos. x 10^{-5})	pH	Colour	Turbidity	Ca	Mg	Na	SO_4	Cl	NO_3	SSP	SAR
86	11E6A107K Centre	Murray	July–Nov.67	233.4	118	5.36	1.56	9.6	0.19	0.013	4.5	11.6	T	0	17	19.7		45		8.25	7.13	40	11.6	0.27	0.13	0.40	0.09	0.31			
87	11E6D17Q Centre	Union	July–Nov.67		48	4.96	1.26	9.03	0.23	0.012	3.75	12.2	T	0	14	17.7		43		7.75	7.1	43	13.3	0.25	0.10	0.37	0.08	0.33			
88	11E6D46H N.W.	Riversdale	July–Nov.67		29	2.86	1.04	4.97	0.36	0.02	3.75	6.88	T	0	8.75	11.3		16		2.9	6.7	84	21.4	0.21	0.09	0.21	0.77	0.18			
89	11E6D93K Centre	Kemptown	July–Nov.67		35	4.23	0.94	4.55	0.18	0.01	3.5	5.96	T	0	12.8	14.6		16		2.9	6.98	41	15.4	0.21	0.08	0.20	0.07	0.17			
90	11E6B98H North	Truro	Nov.67		1428	3.83	0.85	3.45	0.29	0.023	4.0	6.2	1	0	8.8	13.2		11		2	6.75	44	18.8	0.19	0.07	0.15	0.08	0.17			

DAILY PRECIPITATION
on the
SALMON RIVER WATERSHED
July-Nov. '67

APPENDIX E

Date	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#14	#15	#16	Mean
1 July '67	.30	.03			.05		.03	.12				.02	.02	.02	.04
2															
3	1.44	1.28	1.22	1.45	1.43	.64	1.35	1.86	.66	1.19	.73	1.46	1.79	1.77	1.31
4	.15	.13	.22	.15	.19		.15	.14	.04	.11	.12	.01	.23	.34	.14
5	.02	.03	.02	.02	.03	.04	.05			.01	.01	.02	.03	.02	.02
6			.02			.03									.004
7															
8															
9	.08	.06	.07	.05	.05		.05	.07	.04	.07	.04	.05	.10	.15	.063
10	.50	.22	.15	.03	.04	.10		.01				.66	.28	.40	.171
11						.04									
12															
13	.12	.13	.10	.09	.09	.21	.15	.06	.15	.10	.48	.14	.12	.08	.14
14	.01	.01	.03	.05	.02	.04		.03	.03	.02		.02	.03	.03	.02
15		.01			.03	.05	.04					.02			.011
16	.89	.67	.07	.20	.72		.41	.18	.02	.40	.06	.92	.25	.24	.36
17	.65	.70	1.14	.94	1.35		.82	1.03	.70	1.14	1.61	.70	1.04	.94	.91
18	.36	.38	.82	.19	.32	.97	.28	.09	.16			.22	1.10	.84	.41
19			.03			.03							.20	.03	.021
20															
21	.25	.26	.35	.23	.20	.04	.31	.15	.17	.23	.22	.31	.33	.33	.24
22													.01	.01	
23								.01	.07						.006
24	.03	.03	.08	.01	.02	.26	.01		.01		.20	.02	.11	.08	.06
25										.04	.20		.01	.01	.019
26															
27															
28			.01			.24			.02	.05	.17			.01	.036
29															
30	.46	.36	.60	.28	.75		.25	.25	.53	.22	.17	.25	.67	.70	.39
31			.02	.01	.01			.01	.02	.06		.03	.03	.08	.02
Totals	5.26	4.30	4.95	3.70	5.32	2.78	3.91	4.01	2.62	3.64	4.01	4.85	6.35	6.08	4.39

DAILY PRECIPITATION
on the
SALMON RIVER WATERSHED
July-Nov. '67

Date	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#14	#15	#16	Mean
1 Aug'67	.40	.44	.44	.28	.60		.35	.22	1.35	.57	.36	.35	.49	.46	.45
2						.03									
3						.02									
4		.02	.05	.01	.02		.02	.01				.01	.04	.03	.015
5	.38	.54	.32	.78	.38		.77	.58	.21	1.47	1.09	.45	.40	.39	.55
6	.45	.40	.43	.34	.48	.03	.48	.43	.78	.46	.79	.48	.45	.38	.46
7															
8															
9	.10	1.13	.02	.08	.02	.02	.17	.03	.03	.15	.20	.07	.04	.04	.15
10	.03	.02	.08	.04	.04		.03	.02	.03	.26	.30	.03	.07	.07	.07
11	.34	.30	.49	.30	.38		.28	.30	.46	.05	.14	.29	.51	.46	.31
12	.07	.08	.09	.09	.10	1.05	.11	.08	.14	.15	.10	.07	.10	.08	.16
13	.04	.10	.05	.01	.02	.66	.07	.04	.02		.01	.14	.06	.14	.10
14	.25	.15	.28	.28	.28	.01	.20	.21		.01	.20	.19	.31	.22	.185
15						.02									
16															
17															
18	.39														.03
19		.20	.18	.18	.33		.20	.18	.30	.17	.08	.23	.23	.18	.175
20		.03		.02	.08		.04	.02	.32	.02	.05	.07	.01	.04	.05
21	.04					.02									
22		.07	.10	.14	.22		.19	.09	.16	.14	.14	.06	.14	.17	.116
23															
24															
25															
26															
27	.79	.62	.79	.77	.71	.98	.80	.56	.81	.25	.24	.68	.93	.86	.70
28	.08	.09	.10	.28	.14		.25	.29	.17	.17	.16	.14	.15	.12	.153
29														.01	
30															
31										.06	.04			.01	.008
Totals	3.36	4.19	4.95	3.60	3.80	2.84	3.96	3.06	3.78	3.93	3.90	3.26	3.93	3.66	3.68

DAILY PRECIPITATION
on the
SALMON RIVER WATERSHED
July-Nov. '67

Date	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#14	#15	#16	Mean
1 Sept.'67	.44	.55	.55	.32	.52	.49	.45	.99	.67	.81	.36	.77	.70	1.01	.62
2	1.13	.98	1.40	1.56	1.43	.85	1.08	1.14	1.32	1.84	1.62	.76	1.51	1.16	1.27
3		.04	.13	.04	.10	.04	.06	.12	.15	.07	.06	.03	.07	.09	.07
4	.03	.04	.11	.04	.08	.29	.07	.02	.14	.13	.14	.01	.11	.11	.09
5		.03	.04	.06	.10	.03	.08	.21	.19	.32	.23	.02	.04	.03	.10
6	.28	.33		.13	.28	.24	.24	.09		.19	.16	.21	.83	.34	.24
7				.02				.02		.04	.02				.007
8															
9															
10	1.30	.47	.91	1.12	.95	1.20	1.26	.65	.93	1.31	1.58	1.33	.97	.95	1.07
11															
12															
13															
14															
15														.01	
16															
17														.01	
18															
19															
20														.01	
21															
22														.02	
23															
24	.53	.56	.46	.52	.61	.58	.60	.61	.77	.57	.50	.90	.59	.61	.60
25	.44	.46	.11	.48	.16		.46	.29		.52	.33	.17	.49	.37	.31
26															
27														.01	
28															
29	.09	.08	.22	.25	.15	.54	.17	.18	.12	.35	.25	.07	.25	.23	.21
30	.16	.16	.39	.28	.25	.54	.24	.25	.26	.22	.20	.16	.34	.34	.27
Totals	4.40	3.70	4.32	4.82	4.63	4.80	4.71	4.57	4.55	6.37	5.45	4.43	5.90	5.30	4.86

on the
SALMON RIVER WATERSHED
July-Nov. '67

Date	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#14	#15	#16	Mean
1 Oct. '67														.01	
2										.14			.01		.01
3		.08		.01			.03	.18		.05	.03	.02			.03
4	.10	.07	.10	.12	.12		.09	.01	.11	.11	.09	.10	.08	.11	.09
5	.05			.07	.05		.06		.06	.07	.05	.03	.07	.04	.04
6				.02			.04	.02	.03	.14	.09	.03	.02	.03	.03
7		.21	.12	.04	.03			.05		.01		.01	.02	.05	.04
8								.01							
9	.52	.51	.64	.75	.60	1.31	.63	.51	.56	.41	.38	.62	.63	.61	.62
10	2.37	2.35	2.94	2.70	2.85	2.95	2.41	2.58	2.77	2.74	2.72	2.70	3.04	3.01	2.72
11	.20	.23	.36	.15	.31	.38	.30	.30	.33	.26	.35	.15	.26	.17	.27
12															
13		.02					.02			.05	.05	.01	.01	.01	.01
14								.01		.02	.03				.004
15										.01					
16															
17	.04	.03	.05	.01	.03			.01	.03	.04	.07	.03	.05	.05	.03
18	.92	.98	1.20	.95	1.28	.83	1.07	1.05	.79	1.14	1.32	.98	1.15	1.06	1.05
19	.22	.18	.13	.10	.12		.13	.07	.14	.07	.21	.20	.18	.19	.14
20				.01							.01	.01			
21		.18													.013
22	.21		.18	.27	.19	.21	.11	.37	.24	.58	.43	.30	.09	.12	.24
23											.01			.01	
24															
25		.25				.09									.02
26	.24		.34	.32	.38		.24	.10	.35	.41	.35	.32	.30	.32	.26
27					.12									.01	.01
28		.14	.13	.15	.22	.37		.12	.09	.02	.03	.09	.09	.08	.11
29	.40	.28	.17	.29	.23	.03	.30	.31	.36	.40	.44	.35	.37	.36	.31
30			.17	.02						.03		.02			.017
31				.01				.08		.01	.21		.01		.023
Totals	5.27	5.51	6.53	5.99	6.53	6.17	5.52	5.77	5.86	6.71	6.87	5.97	6.38	6.24	6.09

DAILY PRECIPITATION
on the
SALMON RIVER WATERSHED
July-Nov. '67

Date	SITE														Mean
	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#14	#15	#16	
1 Nov.'67					.02					.01	.02	.01	.02	.02	.007
2			.04					.03					.02	.01	.007
3			.02			.11						.02	.02	.01	.013
4	.57	.57	.47	.45	.40	.02	.58	.43	.53	.57	1.09	.53	.54	.51	.52
5											.01				
6															
7			.20					.15	.10	.10		.04	.12	.02	.05
8			.10	.57	.38		.10	.28	.29	.80	.10	.20	.53	.22	.26
9				.78	.40						.10				.09
10			.20		.22		.05	.05			.09	.14	.29	.18	.09
11															
12	.82	1.41	.97	.99	.80	.93	.78	.95	1.23	1.15	1.34	.91	.92	.94	1.01
13											.01				
14					.06					.07	.06		.04	.03	.02
15	.38			.16	.70		.30	.20	.40	.85		.24	.19	.26	.26
16			.22		.18		.10	.20		.15			.07	.13	.08
17			.30	.40							.06				.05
18	.47	1.01	.72	.58	.77	.43	.69	.87	1.10	.55	.48	.30	.61	.66	.66
19	.38				.10		.12		.11	.07	.06	.20	.11	.23	.10
20					.04	.63			.06			.07	.13	.13	.08
21						.03									
22	.38	.28	.71	.45	.38	.35	.37	.21	.33	.41	.46	.37	.36	.44	.39
23	.98	1.61	1.92	1.82	1.91	.36	1.70	1.79	1.05	2.22	1.52	1.34	1.62	1.59	1.53
24			.01		.04	.49		.01	.06	.03	.03	.01	.02	.02	.05
25	1.09	1.10	1.23	.98	1.23	.42	.92	1.13	1.35	1.21	1.17	.96	1.24	1.10	1.08
26	.05		1.15	.02	.04		.10	.07	.09	.07	.09	.05	.10	.21	.15
27				.10	.08			.03		.05					.02
28											.02			.02	
29															
30															
Totals	5.12	5.98	7.24	7.30	7.75	3.77	5.81	6.40	6.70	8.32	6.71	5.39	6.95	6.73	6.52

APPENDIX F

Notation

		Dimensions T = time L = length
a	numerical constant	dimensionless
α	probability of type 1 error; i. e. rejecting a hypothesis that is true.	dimensionless
b	numerical constant (regression coefficient)	dimensionless
β	chance of type II error; i. e. accepting a hypothesis that is false.	dimensionless
Cpo	partial penetration constant for observation well	dimensionless
E.T.	evapotranspiration	L^3
Exp	exported water	L^3
F	ratio of treatment mean square to the error mean square	dimensionless
Imp	imported water	L^3
K	number of treatments	dimensionless
m	saturated thickness of aquifer	L
n	number of samples in a treatment	dimensionless
P	coefficient of permeability	L/T
PE	potential evapotranspiration	L^3
Pr	precipitation	L^3
Q	discharge	L^3/T
R	stream flow	L^3

r	distance from pumped well to observation well	L
r_{pp}	approximate distance from pumped well beyond which the effects of partial penetration are negligible	L
S	coefficient of storage	dimensionless
SAR	sodium absorption ratio	dimensionless
SSP	soluble sodium percentage	dimensionless
SubI	substance inflow	L^3
Sur I	surface inflow	L^3
S_y	specific yield	dimensionless
s	drawdown in an observation well	L
s'	residual drawdown	L
s_d	standard deviation	L
s_a	drawdown in observation or pumped well in an artesian aquifer	L
s_{fp}	drawdown in observation or pumped well for fully penetrating conditions	L
s_{pp}	observed drawdown for partial penetrating conditions	L
T	coefficient of transmissibilty	L^2/T
t	time since pumping started	T
t'	time since pumping stopped	T
t_{wt}	when the application of the nonequilibrium formula to the results of pumping tests under water-table conditions is justified	T
U	substance outflow	L^3
u	$2244\ r^2\ S/Tt$	dimensionless

W(u)	well function for non-leaky artesian aquifers	dimensionless
V	coefficient of variation	dimensionless
X	value of an individual item	dimensionless
$\bar{X}$	mean value	dimensionless
ΔSg	change in groundwater storage	L^3
Δ Soil	change in soil moisture storage	L^3
ΔS_s	change in surface water storage	L^3
Δs	drawdown difference per log cycle of time when drawdown data are plotted on an arithmetic scale versus time on a logarithmic scale	L
$\Delta s'$	residual drawdown per log cycle of t/t'	L
μ	population mean	dimensionless

REFERENCES

American Public Health Association, American Water Works Association, Water Pollution Control Federation (1965): Standard methods for the examination of water and waste water 12th ed., American Public Health Association, Inc., New York 769 p.

American Water Resources Association (1967): Proceedings of the national symposium on ground-water hydrology; P. D. Q. printing service, Urbana, Illinois, proceedings series No. 4, 365 pages.

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

__________, (1958): Possibilities for occurrence of petroleum reservoirs in Nova Scotia: N. S. Department of Mines, 177 p.

__________, (1960): Mississippian Horton Group of type Windsor-Horton district, Nova Scotia: Geol. Survey of Canada, Mem. 314, 112 p.

Boulton, N. S. (1954): The drawdown in the water-table under unsteady conditions near an unconfined formation; Proc. (British) Inst. Civil Engrs., V. 3, Pt. 3.

Butler, S. S. (1957): Engineering hydrology; Prentice Hall, Englewood Cliffs, N. J., 356 p.

California State Water Pollution Control Board, (1954): Report on the invesitgations of travel of pollution: Publication No. 11, 218 p.

Clark, J. W. and W. Viessman (1965): Water supply and pollution control; International Textbook Co., Scranton, Pennsylvania, 575 p.

Davis, S. N., and R. H. M. DeWiest (1967): Hydrogeology: John Wiley and Sons, Inc., New York, 463 p.

Dawson, J. W. (1855): Acadian Geology: London, 1st eds, 833 p.

Department of National Health and Welfare (1962a): Aspects of pollution, Cornwallis River, Nova Scotia: A survey report, 53 p.

__________, (1962b): Aspects of pollution, Annapolis River, Nova Scotia: A survey report, 72 p.

Flint, R. R. (1963): Glacial and pleistocene geology: John Wiley & Sons, Inc., 533 p.

Freund, J. E. (1965): Modern elementary statistics: Prentice-Hall, Inc., 413 p.

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

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

Hogg, W. A. (1953): Pleistocene geology of Pictou County, Nova Scotia; Unpublished report, 50 p.

Johnson, E. E., Inc. (1966): Groundwater and wells: 1st ed. Edward E. Johnson, Inc., Saint Paul, Minnesota, 440 p.

Jones, J. F. (1963): Aquifer-test procedures and other information used in evaluating groundwater supplies in Alberta, Preliminary Report 63-1, 35 p.

__________, (1966): Geology and groundwater resources of the Peace River District, Northwestern Alberta, Research Council of Alberta, Bulletin 16, 143 p.

Linsley, R. K. and J. B. Franzini (1964): Water resources engineering: McGraw-Hill Book Company, New York 654 p.

McGuinness, C. L. (1963): The role of groundwater in the national water situation: U. S. Geol. Survey, Geol. Survey Water-Supply paper 1800, 1121 p.

McKee, J. E., and Wolfe, H. W. (ed) (1963): Water quality criteria: The Resources Agency of California, State Water Quality Control Board Pub. No. 3-A, 548 p.

Meinzer, O. E. (1923): The occurrence of groundwater in the United States: U. S. Geol. Survey Water-Supply paper, 489, 321 p.

Nova Scotia Department of Trade and Industry (1964): Colchester county survey.

________, (1965): Nova Scotia, an economic profile: Econ. services division, V. 4, 71 p.

Peck, R. B. Hanson W. E. and Thornburn, T. H. (1966): Foundation engineering: John Wiley and Sons, Inc., 410 p.

Powers, S. (1961): The Acadian Triassic Jour. Geol., V. 24, p. 1-26, 105-122, 254-268.

Rasmussen, W. C., and Andreasen, G. E. (1959): Hydrologic budget of the Beaverdam Creek Basin, Maryland: U. S. Geol. Survey Water-Supply Paper 1472, 106 p.

Schicht, R. J. and Walton, W. C. (1961): Hydrologic budget for three small watersheds in Illinois: Ill. St. Water Survey, Rept. of investigation 40, 40 p.

Steel, R. G. D. and Torrie, J. H. (1960): Principles and procedures in statistics: McGraw-Hill Book Company, Inc., 481 p.

Stevenson, I. M. (1958): Truro map-area, Colchester and Hants counties, Nova Scotia; Geol. Survey Can., Mem. 297, 124 pages.

Thomas, J. F. T., and Gale R. M. (1965): The upper Great Lakes Drainage Basin in Canada, 1957-63: Department of Mines and Technical Surveys, Water Survey Report No. 14, 137 p.

Thomas, M. P. (1966): Effect of glacial geology upon the time distribution of streamflow in eastern and southern Connecticut: U. S. Geol. Survey Prof. paper 550-B, pages B209-B212.

Thorne, D. W., and H. D. Peterson (1954): Irrigated soils: 2nd ed., The Blaidistan Company, Inc., New York, 392 p.

Thwaites, F. T. (1957): Outline of glacial geology; Edwards Brother, Inc., 136 p.

Todd, O. K. (1959): Ground water hydrology; John Wiley and Sons, Inc., New York, 336 p.

Toth, J. (1962): A theory of groundwater motion in small drainage basins in central Alberta, Canada; Jour. Geophys. Research, V. 67, p. 4375-4387.

Trescott, P. C. (1967): An investigation of the groundwater resources of the Annapolis-Cornwallis Valley, Nova Scotia: Univ. of Illinois Ph.D. Thesis, 269 p.

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

Turner, J. A. (1958): A simplified scheme for computing Thornthwaite's potential evaporation: Canada Department of Transport, Met. Branch, Cir-3118, Tec-284, 12 p.

United States Department of Agriculture (1955): Water; the United States Government printing office, No. 32, 751 p.

United States Public Health Service (1962): Drinking water standards: Publication No. 956, 61 p.

Walton, W. C. (1962): Selected analytical methods for well and aquifer evaluation: St. of Ill., Department of Registration and Ed., Bulletin 49, 81 p.

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

Wicklund, R. E. and Smith, G. R. (1948): Soil survey of Colchester County, Nova Scotia: Dominion Department of Agriculture, Report No. 3, 57 p.

VITA

Terry Wendell Hennigar was born April 6, 1940 in Wolfville, Nova Scotia. He received the first nine years of schooling at Greenwich, Kings County, before entering Wolfville High School from which he graduated in 1957.

Mr. Hennigar entered Acadia University in the School of Engineering, completed two years, then spent two years with Frontier College as a labourer-teacher before graduating from Acadia with a Bachelor of Science Degree (Geology) in 1965. While attending university, he was commissioned in the army Militia, played varsity football and hockey and was active in the Fletcher Geology Club holding the offices of Secretary-Treasurer and President.

Mr. Hennigar married Heather Dianne Allen of Wolfville in 1962. They have two girls, April Lynn and Crystal Beryl and one boy, Allan Wendell.

Mr. Hennigar's professional experience is as follows:

Labourer-teacher, Frontier College, Toronto, Ontario, 1960 to 1962.

Field Assistant, Geological Survey of Canada, Ottawa, Ontario, summer, 1963.

Field Assistant, Nova Scotia Department of Mines, Halifax, summer, 1964.

Groundwater Geologist, Nova Scotia Department of Mines, Halifax, April to August 1965, and from August, 1965 as a permanent employee.

SURFICIAL GEOLOGY
of the
TRURO AREA

SCALE 1:50,000

SCALE IN MILES

LEGEND

CENOZOIC

QUATERNARY
RECENT

☐	Dykeland river outwash sand and gravel.
☐	Stream alluvium.

PLEISTOCENE

☐	Ice-contact stratified drift.
▨	Kame
▨	Kame terrace
▩	Kame field
>>>>	Esker
☐	Outwash sand and gravel (terraces)
☐	Lacustrine silt and clay
☐	Sandy till
▒	Hummocky moraine
☐	Clay till

MESOZOIC

TRIASSIC

7	Annapolis Formation: red sandstone conglomerate

PALAEOZOIC

CARBONIFEROUS
PENNSYLVANIAN

6	CUMBERLAND AND/OR PICTOU GROUP Brown, green, and grey conglomerate, sandstone, shale
5	RIVERSDALE GROUP Mainly grey, fissile, shale; shaly sandstone

MISSISSIPPIAN

4	CANSO GROUP Red and grey sandstone, shale
3	WINDSOR GROUP Grey limestone; red and green shale; gypsum (?)
2	HORTON GROUP Red and grey sandstone, grit, shale, conglomerate

PRE-CARBONIFEROUS (?)

1	Cobequid Complex Igneous, metamorphic and sedimentary rocks

Watershed boundary	
Adjoining watershed boundaries	
Bedrock contact	
Surficial deposit boundary	
Test hole location and number	T.H. 104 ⌖
Sample location of groundwater, drilled well, dug well	⌖5 ○
Sample location of surface water	85 ●
Drill hole (Dept. of Highways)	D.H. 6 ⌖
Road	
Stream	
Lake	
Marsh or swamp	
Building	
Railways	
Contour interval 25 feet	575
Contour interval 50 feet (11 E/11 West half)	500

Bedrock geology taken from maps by I.M. Stevenson, 1950, 1951 (11E6), D.G. Benson, 1960, 1951 (11E7) and L.V. Brandon, 1963.

Surficial geology mapped by T.W. Hennigar, 1966, 1967.

KEY MAP

ISOPACH OF SURFICIAL DEPOSITS
TRURO

LEGEND

QUATERNARY

7 — DYKELAND

6 — STREAM ALLUVIUM

PLEISTOCENE

OUTWASH SAND & GRAVEL

5 — OUTWASH TERRACE

ICE CONTACT DEPOSITS OF SAND & GRAVEL

4 — ICE CONTACT STRATIFIED DRIFT

▨3 — KAME

TILL

2 — SANDY

1 — CLAY

○ T.H. 160 — DEPT. OF MINES TEST HOLE
○ D.H. 10 — DEPT. OF HIGHWAYS TEST HOLE
○ NO. 4 — DRILLED WELL, TOWN OF TRURO
○ W 66 — PRIVATE WELLS DRILLED BY WELL DRILLERS
● NO. 86 — SURFACE WATER SAMPLE LOCATIONS

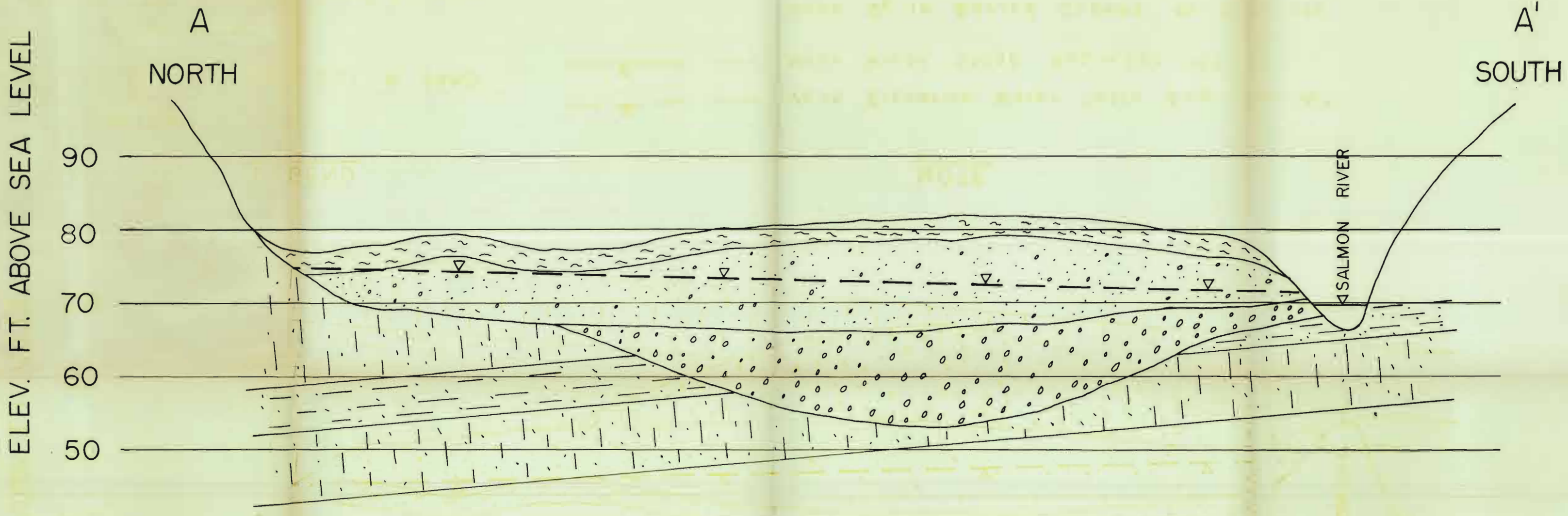
CENTRAL COLCHESTER AREA

SCALE : 1" = 800'

CONTOUR INTERVAL = 5'
ISOLINE INTERVAL = 20'

T. W. HENNIGAR

X SECTION OF SALMON RIVER FLOODPLAIN
AT MURRAY,
COLCHESTER COUNTY



LEGEND

RECENT

≈ — SILT & SAND

PLEISTOCENE

∴ — SAND & GRAVEL

○ — GRAVEL

TRIASSIC

═ — CLAY GRIT

┆ — SANDSTONE

NOTE

— ▽ — — Mean Elevation Water Table Aug.— Dec. /67

—▽— — Mean River Stage Aug.— Dec. /67

Mean Q_S in Buried Channel $\approx$ 0.36 cfs.

Mean Q_R in Salmon River $=$ 396 cfs.

$$Q_S \approx 9.14 \times 10^{-4}\ Q_R$$

HORIZONTAL SCALE : 1" = 100'
VERTICAL SCALE : 1" = 10'

Terry W. Hennigar.

E.E.D.