Regional Water Resources Sydney Coalfield, Nova Scotia

by

Fred E. Baechler

Nova Scotia
Department of the Environment
Honourable Guy J. LeBlanc
Minister
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Deputy Minister

Halifax, Nova Scotia 1986

Province of Nova Scotia
Department of the Environment

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REGIONAL WATER RESOURCES
Sydney Coalfield, Nova Scotia

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EXECUTIVE SUMMARY

Study Objectives

The objectives of the study were to evaluate the occurrence, quality and quantity of both surface and groundwater in the Sydney Coalfield and to review current water resource utilization by rural, municipal, institutional and industrial entities.

Funding Agencies

The Sydney Coalfield Water Resource Evaluation Project, which included an extensive field program (1976-1979) and subsequent data correlation and report generation (1979-1985), was primarily funded by the Nova Scotia Department of the Environment. The first year of the study was jointly funded under the former Agricultural and Rural Development Act (ARDA). This study represents a portion of an overall program by the the Nova Scotia Department of the Environment to evaluate the Province's water resources.

Scope

The study involved the collection, analysis and interpretation of existing and new data in the areas of bedrock and surficial geology, hydrometeorology, hydrogeology, hydrology, water quality and current water resource utilization practices throughout the study area. The acquisition of new data involved: mapping of surficial geological deposits; sampling for and determination of groundwater (100 samples), surface water (64 samples) and precipitation chemistry (24 composite samples); delineation of joint sets within the Morien Group; installation of four hydrometric stations (three temporary, one automatic); a sampling program to determine the erodibility of major soils and till units, installation of two groundwater level recorders and the drilling and pump testing of six wells constructed in the major bedrock aquifers.

RESULTS

SURFICIAL AND BEDROCK GEOLOGY

The review of existing data and augmentation by the extensive field program has resulted in the development of the major project mapping which is found in the sleeve at the conclusion of this report. Map 1 "Bedrock Geology" outlines major geological boundaries, bedding directions, rock outcrops, coal seams and limestone beds, anticlinal and synclinal axes, faults, mineral occurrences and bedrock water well and test well locations. Map 2 "Surficial Geology" outlines the major boundaries of unconsolidated deposits and depicts water well locations with associated overburden depths.

GROUNDWATER

The availability of groundwater in the Sydney coalfield is generally excellent. Wells constructed for domestic use in all hydrostratigraphic units have a 95-98% success rate. The Lower Morien unit is capable of producing adequate water supplies for medium to large institutional, industrial and municipal developments, especially where wells penetrate significant thicknesses of sandstone. Yields from the Upper Morien and Upper Windsor units are somewhat lower. However, in most cases they will be adequate to supply small scale developments. The remaining hydrostratigraphic units in the study area generally will not produce greater than domestic yields. Water quality is generally good, however wells penetrating the Windsor Group or associated rocks may produce relatively hard, mineralized groundwater. Iron and manganese may present an aesthetic problem in all units.

In the study area, the Lower Morien Hydrostratigraphic unit has the greatest areal extent and, as noted, is the best water producer. From the domestic point of view 98 percent of a total of 645 wells surveyed were capable of producing a minimum of 9 L/min. Larger yields were assessed via the review of nineteen 72-hour pumping tests. Yields per 30 m of well saturated thickness range from 24 to 551 L/min. and average 248 L/min. Water quality in this unit is generally acceptable according to the Guidelines for Canadian Drinking Water Quality, 1978. However, minor treatment for iron and manganese may be desirable.

The Upper Morien hydrostratigraphic unit also exhibits excellent potential for supplying domestic water quantities. Of 112 wells surveyed 98 percent had yields in excess of 9 L/min. This unit may also produce relatively large quantities of groundwater. However, data are only available from two 72-hour pumping tests. Yields per 30 m of well saturated thickness range from 47 to 174 L/min. and average 111 L/min. Water quality is generally acceptable. It is described as being moderately hard to hard (90-220 mg/L) and may contain elevated concentrations of iron and manganese.

The remaining sedimentary hydrostratigraphic units in the study area include the Canso Group and the Upper and Lower Windsor Groups. Domestic water production in these units is generally good to excellent. A total of 20 wells were surveyed in the Canso Group. Based on graphical analysis, 98 percent produced a minimum of 9 L/min. In the Upper and Lower Windsor Groups with 381 and 26 wells surveyed, respectively, 98 and 95 percent produced a minimum of 9 L/min. With respect to the potential of encountering relatively large yields, only the Upper Windsor has data base support. Utilizing information from five 72-hour pumping tests, yields per 30 m of well saturated thickness range from 30 to 164 L/min., and average 90 L/min. Water quality in the Upper Windsor Group is extremely variable but is generally described as a moderately hard to hard (77-370 mg/L), corrosive, predominantly $Ca\text{-}HCO_3$ type water. Strong secondary trends towards $Ca\text{-}SO_4$ and Na-Cl type waters are also in evidence. Little water quality information is available for the Canso and Lower Windsor hydrostratigraphic units.

The Basement Complex hydrostratigraphic unit includes all igneous and metamorphic rocks found in the study area. Groundwater availability in this unit is totally dependant upon whether or not a well encounters bedrock fracturing, thus is only generally suitable for domestic purposes. At present, specific data on water quantity and quality in this unit are not available.

The unconsolidated water-bearing units in the study area are divided into two specific entities, namely, the basal till hydrostratigraphic unit and the sand and gravel hydrostratigraphic unit. These units are utilized by some residents for domestic supply via the construction of large diameter dug wells or through the installation of drilled screened wells. Well yields vary widely according to permeability and saturated thickness. Those constructed in the basal till can only be expected to supply domestic quantities; whereas, properly constructed screened wells in coarse sand and gravel may be expected to yield significant quantities of water.

SURFACE WATER

Surface water supplies serve 71% (90,467) of the study area's total population of 127,000. Municipal systems are in place in the communities of Sydney, Glace Bay (including Dominion and Reserve Mines), North Sydney (including Florence, Alder Point and Bras d'Or), New Waterford (including New Victoria and Scotchtown), Donkin, and Birch Grove. A small number of consumers in Coxheath and Westmount also utilize a central system. In total, these utilities utilize an average of 52 ML of water per day and each has a minimum of 33% expansion capability based on identified watershed safe yield. In addition, the systems have been significantly upgraded over the past 15-20 years and therefore are considered adequate to meet both current and projected water requirements.

Major drainage in the study area can be basically resolved into three components: namely, drainage into 1) the saline environment of the Atlantic Ocean; 2) the brackish waters of the Bras d'Or Lakes; and 3) the estuarine-brackish waters of the Mira River. Of these, the ocean is dominant, as a direct receptor for land drainage.

For the purposes of this report, major drainage has been divided into 14 specific watershed areas. Of these, the McAskill Brook watershed, which best represents the natural hydrological conditions exhibited throughout a large portion of the Sydney Coalfield, was chosen to serve as a reference watershed. This enabled the investigation of long term natural processes and facilitated extrapolations to other watersheds. To collect pertinent data, an automatic stream gauging station was installed on McAskill Brook upstream of the reservoir. Data obtained to date yield evidence of seasonal trends whereby peak flows are recorded in March, April and May resulting from spring break-up. Summer recession continues usually until September and fall rains, particularly in November and December, create a second period of peak discharges. This is followed by a decline through January, bottoming in February, due to the onset of the winter season. The mean annual runoff coefficient remains relatively constant averaging 0.038 $m^3/sec/km^2$.

Surface water quality is generally satisfactory according to the Guidelines for Canadian Drinking Water Quality, 1978. The data indicated a fresh (TDS 15 to 70 mg/L), very soft (hardness 1.0 to 16 mg/L), corrosive $Na/Ca-Cl/HCO_3$ type water. The pH is generally acidic ranging from 4.0 to 7.1 and nutrient concentrations are relatively low and consistent, with PO_4 ranging from 0.02 to 0.10 mg/L and Kjel Nitrogen ranging from 0.10 to 0.80 mg/L.

IMPLICATIONS

Surface and Groundwater

Due to relatively high and consistent precipitation and general watershed configurations, the Sydney Coalfield region has significant surface water resources. Municipalities in the area have utilized this resource, and at the present time urban populations are serviced with good quality water. In addition, these water systems have potential for moderate expansion.

Groundwater is also a significant resource in the study area. Rural residents can utilize a wide variety of aquifers with proven yields. In addition to excellent capability for domestic supplies, groundwater in some areas (i.e., Lower and Upper Morien sandstone and conglomerate) will be adequate to supply moderate to large institutional and industrial demands. The overall groundwater quality is generally good. In some areas evaporite deposits of the Windsor Group may impart natural minerals (i.e., hardness, sulfate, etc.) to well water. Iron and manganese concentrations may present aesthetic problems to groundwater users throughout the Coalfield.

Date Base Inventory

In conjunction with the preparation and publishing of the Sydney Coalfield Water Resources Evaluation Project, a Data Base Inventory System has been developed. This subject file and map index (1:15,840) incorporates all the reference material in the report, along with information considered useful for any subsequent investigations. Included are subjects such as 1) well log data, 2) bedrock geologic information, 3) surficial geologic information, 4) aquifer analysis, 5) water quality data, 6) hydrological information, 7) meteorological information, and 8) water resource utilization information. In addition, the data base includes a variety of information on special interest topics such as coal, industrial deposits, bedrock mineralization, air emission and sedimentation. The field work portion of this project devoted a substantial amount of time acquiring sedimentation data. To access this information, interested parties are encouraged to refer to background material contained in the data base.

This report and associated background data are considered unique in that for the first time, a comprehensive water resources data file for the Sydney Coalfield is organized and readily accessible.

RECOMMENDATIONS

With respect to surface water, it is recommended that a concerted effort be made by all levels of government, industry, and the general public to address municipal water supply and watershed management issues. Considering that the vast majority of municipal water supplies utilize surface water and the relative concentration of industrial activity in the Coalfield, watershed protection is deemed a necessity. Existing and potential development must be addressed in relation to the need of all users to be ensured adequate supplies of good quality water.

Concerning groundwater, it is recommended that future planning consider the development of this resource as an economically viable alternative. This recommendation is a result of the identification of groundwater in significant quantities throughout a large portion of the study area. Extraction of this resource through properly constructed wells can be utilized to augment existing municipal, institutional and industrial supplies, or totally supply new medium-sized developments.

With respect to overall water resource management in the study area, it is recommended that this report and the associated data base be extensively utilized, the report and supporting information provide a basis for total water resources management. It is intended to promote the efficient development and wise use of this resource as an integral part of future socio-economic development in the Sydney Coalfield.

CHAPTER 1

INTRODUCTION

1.1 Purpose and Scope

The water resources of "Industrial Cape Breton", centred in the Sydney Coalfield, have been utilized with increasing frequency since the mid-1800's. The coalfield, with 1.8 billion metric tons of proven insitu reserves, is the largest in eastern Canada. As a result, this area became a priority with the Water Resources Planning Section (WRP) of the Nova Scotia Department of the Environment (NSDOE) for the evaluation and documentation of its fresh water resources.

The general objectives of the project were to evaluate the occurrence, quality and quantity of surface and groundwater in the designated study area, and to review current water resource utilization by rural, municipal, institutional and industrial entities.

Associated mapping is presented at a scale of 1:63,360. This is comparable to existing soils and bedrock geology maps, available climatic data and correlates with the scale presently being utilized for the County of Cape Breton's regional development plan.

1.2 General Description of Area

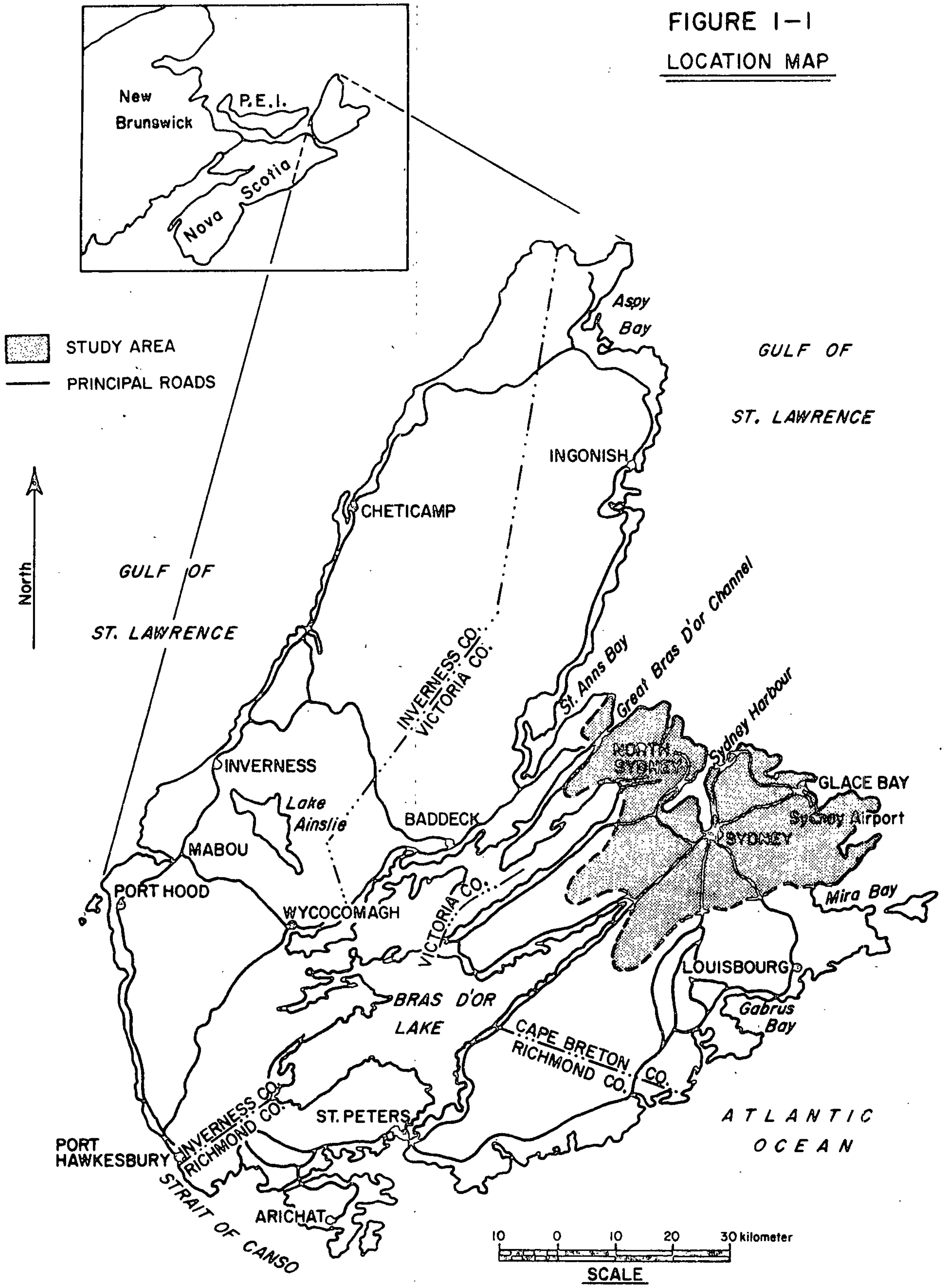
1.2.1 Location, Access and Extent

Encompassing 1145 sq. km the study area borders the Atlantic Ocean and Gulf of St. Lawrence along the northeast coast of Cape Breton Island, Nova Scotia (Figure 1-1). It has a sea frontage of some 56 km. Geographically it is enclosed between 45° 59' and 46° 21' north latitude and 59° 45' and 60° 30' west longitude.

The inland boundary has been delineated by surface water drainage areas and has therefore been extended beyond the geological boundaries of the coalfield proper.

FIGURE I-I

LOCATION MAP



The study area is readily accessible by rail, road, sea and air. Rail access is provided by the main CNR line and road transport is via the Trans Canada Highway north from Truro to its termination at North Sydney. Here, sea transportation to and from Newfoundland is available. Numerous primary, secondary, and logging roads provide fair access to most parts of the map area. Port facilities for medium sized ocean vessels are provided year round at Sydney Harbour. Regional airport facilities are also available at Sydney.

1.2.2 Population and Industry

The population of the study area is approximately 127,000 (1981 data). This is primarily located in five major centres: Sydney (pop. 29,444), Glace Bay (pop. 21,466), New Waterford (pop. 8,808), Sydney Mines (pop. 8,501) and North Sydney (pop. 7,820). Other smaller centres include Dominion, Westmount, Donkin, Port Morien and Florence.

Growth of the area is influenced by coal mining (approximately 2.3 million metric tons a year) and the steel industry. Fishing and forestry provide secondary employment.

Mineral exploration for metallics (Cu, Pb, Zn, Fe, U) and non-metallics (potash, salt, celestite, limestone, dolomite and sand and gravel) has been prevalent. Several mines have been worked briefly, the largest of which included the Coxheath copper mine and the Rudderham limestone quarry. Limestone for the steel industry is mined at New Campbellton. Large scale gravel quarrying occurs along the Sydney River Valley.

1.2.3 Physiography

The Sydney Coalfield forms the major lowland on Cape Breton Island. It is irregularly shaped and is underlain by Carboniferous sedimentary sequences. It is bounded by the sea to the north and east, the Bras d'Or Lakes to the southwest, and by uplands to the west and south. The latter comprises Kelly's Mountain on the northwest, the Boisdale, Coxheath and East Bay Hills to the west and southwest and the Mira Hills to the south. All are remnants of the crystalline basement complex.

The present geomorphic expression of the study area evolved principally from differential erosion associated with subaerial exposure since Late Tertiary time. Glacial erosion and deposition within the study area had only a secondary effect. This has resulted in relief being a function of bedrock type; from the igneous/metamorphics underlying the uplands to the less resistant sedimentary rocks underlying the lowlands.

The coastline is a deeply indented shoreline of submergence due to post glacial sea level rise. The submergence has heavily dissected the coalfield with salt water embayments. The associated coastal erosion has created many baymouth bars and spits.

The study area encompasses 95% of the portion of the Sydney Basin that lies above sea level. The study area, however, forms only approximately 3% of the entire basin, the submarine extension of which lies offshore, forming one of the major geological units of the Scotian Shelf.

1.3 Data Base

The Nova Scotia Department of the Environment continues, as a long term objective, to develop an effective and efficient water resources data base in Nova Scotia. In conjunction with the preparation and publication of this report a data base was set up which allowed for flexibility in the scale of interpretation, was not time dependent and allowed data to be easily recalled. Therefore all data relevant to water resources collected for this report were presented in a versatile format.

This was undertaken by having each piece of data located on maps (1:15,840) and held in associated files. The extent and location of each map sheet within the study area is outlined in Figure 1-2. The data base is held by the Nova Scotia Department of the Environment Sydney Regional Office. A copy of the data base is also kept on file in the Nova Scotia Department of the Environment Halifax Main Office for the use of interested parties.

1.4 Land Survey System

The National Topographic System has been used in the past by the Nova Scotia Department of the Environment for the location of sites within the province. The breakdown is exemplified at the base of each of the two maps accompanying this report.

The trend however has been toward using the more accurate Universal Transverse Mercator (UTM) grid. All locations sited in this report are identified by means of the UTM grid which is superimposed upon the two maps.

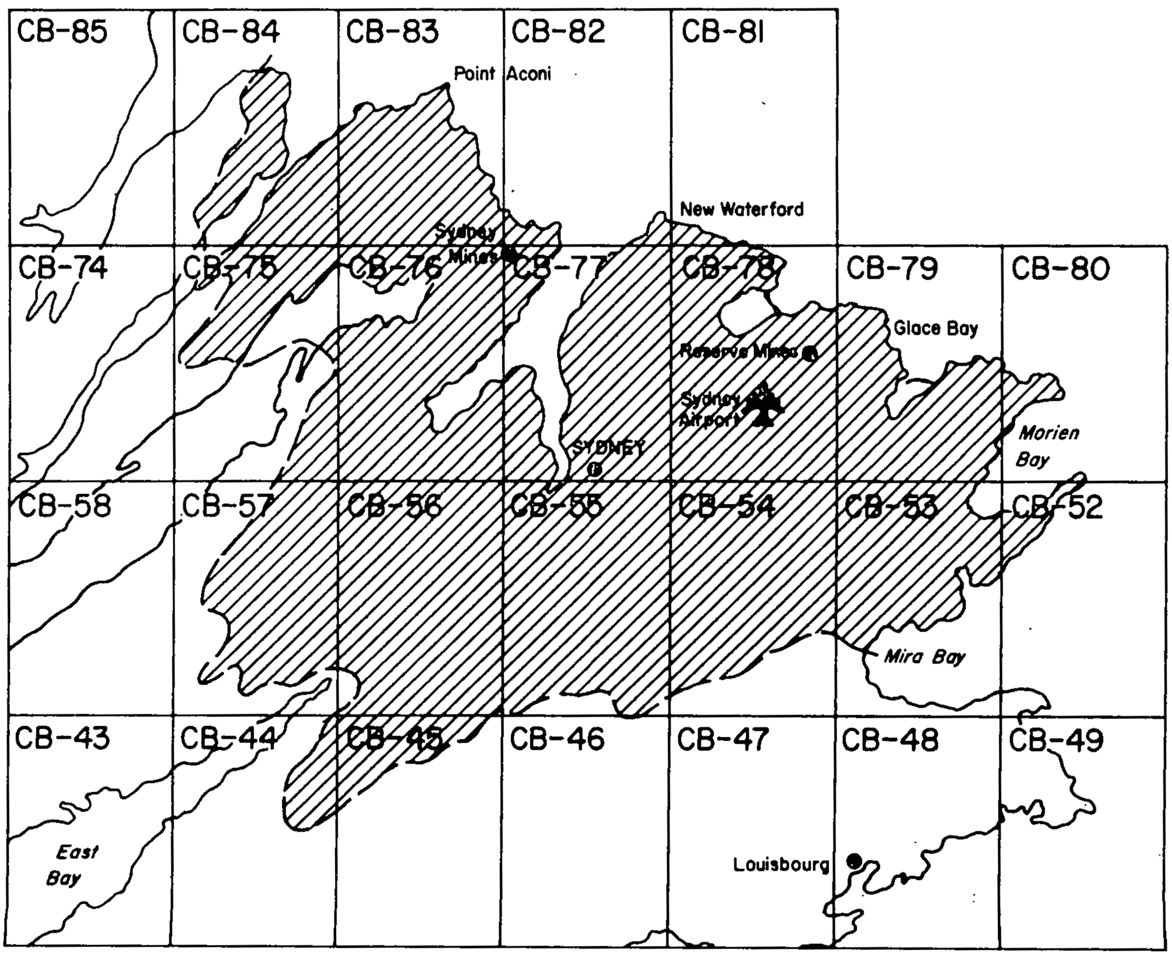


Figure I-2 INVENTORY MAP SHEET COVERAGE FOR SYDNEY COALFIELDS STUDY AREA.

1.5 Field Work and Previous Studies

The field work was carried out during 1976 through 1979, while the author was employed by the Province of Nova Scotia. There were no previous hydrogeological studies carried out in this area, however it has been intensively studied geologically. A number of hydrological studies were available on certain lakes which are presently being utilized for water supplies.

The initial phase of the project, the collection and location of existing data, took approximately two years. All test holes, where subsurface data were available, were checked in the field and their locations placed on the data base maps.

Available data were assessed to determine areas which lacked information and, accordingly, prevented the completion of the regional evaluation. Major programs were designed and implemented to fill these gaps and included: mapping of surficial geological deposits; sampling for and determination of groundwater, surface water and precipitation chemistry; delineation of joint sets within the Morien Group, installation of four hydrometric stations (three temporary, one automatic); a sampling program to determine the erodibility of major soils and till units; test drilling and pump testing of major bedrock aquifers; and the installation of groundwater level recorders.

1.6 Acknowledgments

The study was carried out under the direction of Dr. C. Lin, P. Eng., Chief, Water Resources Planning, Nova Scotia Department of the Environment. Editing of the report was capably handled by Mr. J. Fraser and Mr. A. Cameron of the Nova Scotia Department of the Environment, who also participated in writing various sections of the document.

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CHAPTER 2

BEDROCK GEOLOGY

The bedrock geology of the study area has been mapped previously by Bell & Goranson (1938), Hayes & Bell (1923, 1938), Hayes, Bell & Goranson (1938), Weeks (1957), and studied by numerous authors. Bedrock geology, with modifications resulting from more recent studies, is noted on Map 1; stratigraphy is presented in Table 2-1.

2.1 George River Group (Unit 1)

During the Pre-Cambrian (Hadrynian) a platformal sedimentary sequence of sandstone, claystone, and limestone of the George River Group was deposited over Archean rocks. The now-metamorphosed unit forms narrow zones of outcrop which flank the east side of Kelly's Mountain and the Boisdale Hills.

The group is divided into two members: a quartzite-schist-gneiss member and a carbonate member. The former consists mainly of pure and impure quartzite, schist, phyllite, gneiss, and meta-argillite. The latter member is mainly crystalline limestone or dolomite (Bell & Goranson, 1938).

2.2 Fourchu Group (Unit 2)

This group, also of Hadrynian age, is comprised of a thick sequence of predominately acid volcanic flows and sediments (sandstone, shale, chlorite schist). The relationship with the George River Group is uncertain. The Fourchu rocks are less metamorphosed than those of the George River Group and the metamorphism appears to be restricted to broad zones of considerable shearing. These zones are probably associated with undetected faulting (Weeks, 1957). The group outcrops in the East Bay Hills.

2.3 Cambrian Igneous Complexes (Units 3 & 4)

Large plutons generally consisting of diorite, quartzmonzonite and red

TABLE 2-1

STRATIGRAPHY

ERA		PERIOD OR EPOCH	GROUP & FORMATIONS		LITHOLOGY
Cenozoic		Recent			tidal, stream alluvium, peat, longshore bars, man-made fill
		Pleistocene			till, glacio-fluvial sand and gravel
			UNCONFORMITY		
Palaeozoic	Pennsylvanian	Westphalian D (early Permian?)	Morien Group	Ptychocarpus Unitus Zone	Non-marine: gray arkosic conglomerate, sandstone, siltstone, shale, intercalated red beds, workable coal seams
	Pennsylvanian	Westphalian C	Morien Group	Linopteris Zone Obliqua Zone	non-marine; gray arkosic conglomerate, sandstone, siltstone, shale, intercalated red beds, coal seams, rare thin limestone
	Pennsylvanian			Lonchopteris Zone	non-marine; gray arkosic conglomerate, sandstone, minor siltstone, shale, intercalated red beds
			UNCONFORMITY		
	Mississippian	Namurian to Visean (?)	Canso Group	Cape Dauphin Formation	non-marine, partly brackish; gray shale
	Mississippian			Pt. Edward Formation	non-marine partly brackish; red minor gray sandstone and shale
	Mississippian			CONFORMABLE	
	Mississippian	Visean	Windsor Group	Zones B to E	marine; limestone, anhydrite, gypsum, shale, sandstone, conglomerate
	Mississippian			UNCONFORMITY	
	Mississippian			Grantmire Formation	non-marine; conglomerate, sandstone, shale
			UNCONFORMITY		
		Devonian			granites
			UNCONFORMITY - ACADIAN OROGENY		
Pre-Cambrian		Early-Middle Devonian	McAdam Lake Formation		conglomerate, arkose, shale, tuff
			UNCONFORMITY - TACONIAN OROGENY		
		Early Ordovician			conglomerate, grit, sandstone, shale
			CONFORMABLE		
		Cambrian			pyroclastics, rhyolite, quartz latite, dacite, andesite, quartz diorite, granodiorite, quartz monzonite, granite
			CONFORMABLE		
		Hadrynian	Fourchu Group		volcanic breccia, tuff, lavas, sandstone, shale, chlorite schist
			UNCONFORMITY (?) (GEORGE RIVER AND FOURCHU NOT IN CONTACT)		
		Hadrynian	George River Group		quartzite, schist, gneiss, amphibolite, crystalline limestone or dolomite

After Hayes, Bell, Goranson (1923-1938), Kelly (1967), Bell (1958), and Weeks (1957).

granites intruded both the George River Group and the Coxheath volcanics during the late Pre-Cambrian to very early Paleozoic periods (Clarke et al, 1980). These rock units comprise Kelly's Mountain, the Boisdale Hills and the Coxheath Hills. A variety of pegmatites, granophyre and diabase dykes cut these plutonic rocks in the Boisdale Hills. Granophyre and ceratophyre dykes intrude Kelly's Mountain.

2.4 Cambrian and Ordovician Strata (Unit 5)

A basin of arenaceous and argillaceous, fossiliferous, marine sediments, exists southwest of the Coxheath Hills. The middle Cambrian sediments are mainly sandstones, grits, and sandy shale, with some conglomerate. The upper Cambrian and early Ordovician rocks are mainly black and grey shales; middle Ordovician sediments are conglomerates and black shales. The sediments are tightly folded, striking northeastward (Bell and Goranson, 1938).

2.5 McAdam Lake Formation (Unit 6)

This Formation outcrops southwest of the Coxheath Hills. It is of lower or middle Devonian age and consists of grey fresh water arkoses and conglomerates that are generally highly inclined. It is assumed that the base of the formation rests upon Pre-Cambrian granitic rocks and early Palaeozoic sediments of the Coxheath Hills and that the formation is faulted against the Pre-Cambrian rocks of the Boisdale Hills (Bell and Goranson, 1938).

2.6 Devonian Igneous Units (Unit 7)

The rock types mapped as Unit 7 consist of diorite and granite occurring only in the East Bay Hills. There is presently a question of the Devonian age attributed to this unit. However, the Acadian orogeny during the Devonian was responsible for creating the tectonic elements which form the Sydney Coal Basin.

All pre-Windsor Group units are henceforth referred to as the basement complex.

2.7 Windsor Group (Units 8 and 9)

This Group contains the only marine strata in the study area. Where the Windsor Group has not been wholly displaced by faults, it borders the basement complex in a linear surface belt ranging from 425 to 7160 m in width. It consists of two large units, the Marginal Basin Beds (Grantmire Formation) and the Central Basin Beds.

2.7.1 Marginal Basin Beds - Grantmire Formation (Unit 8)

At the base of the Windsor Group is the Grantmire Formation which is of deltaic or piedmont origin. It ranges in thickness from 150 m at Cape Dauphin to approximately 1070 m on the northeast flank of the Coxheath Hills.

It is characterized by a chocolate-red conglomerate which is poorly consolidated, poorly sorted, and composed of sub-angular blocks one metre in diameter downward. Clasts generally comprise volcanics and metamorphics. The most common matrix is a fine conglomerate or coarse grit, possessing very little coherency. The coarser beds predominate but alternate constantly with lenticular or persistent bands of reddish, coarse and fine-grained, jointed, friable sandstone including an occasional layer of impure limestone (Fletcher, 1900).

The northeastern extent of the Grantmire/marine contact around the Coxheath Hills has been extended one kilometre beyond the original assumed contact due to the presence of "red conglomerate" in drilled water wells in Cantley Village and outcrop at UTM 106 100.

2.7.2 Central Basin Beds (Unit 9)

Marine incursion deposited generally a carbonate/evaporate rock sequence. These strata, above the Grantmire Formation, are estimated to be approximately 1060 m thick. Generally this carbonate series consists of thick beds of red and grey argillaceous shales, sometimes calcareous, approaching marls in character and frequently having nodules of limestone and argillaceous iron ore. Associated with them are numerous beds of concretionary, laminated, compact and generally dark-gray or almost-black limestone, sometimes gypsiferous. Beds of red and gray micaceous sandstone, generally slightly calcareous, also frequently occur in this formation, chiefly toward its summit (Fletcher, 1900).

Limestones occur predominately on the Point Edward Peninsula, the aggregate amount exceeding 49 m (Bell, 1958). There are four main limestone members in the Point Edward peninsula. In ascending stratigraphic order they are, Point Edward, Crawley Creek, Rudderham Point, and Dixon Point. On the Point Edward peninsula, the conspicuous absence of the evaporite sequences found in similar strata elsewhere is possibly attributed to lack of outcrop which conceals 70% of the stratigraphic section (McPhee, 1965). Gypsum lenses do, however, occur nearby at Leitches Creek.

Gypsum and anhydrite are restricted in near surface subcrops to a single member lying in the Sydney Forks area (UTM 055 001). A test hole, in the East Bay area (UTM 051 002) unexpectedly encountered gypsum as the uppermost bedrock unit proving the evaporite member to be at least twice as thick as previously mapped.

A major contact change is shown on Map 1. The original assumed Windsor-Morien contact ran east and southeast of the Sydney River from UTM 108 058 to UTM 054 006. The change was based upon:

(a) lithology encountered in water well logs in the Sydney Forks-Howie Centre Area; notably 80 m of sandstone at UTM 105 055, 60-90 m of sandstone at UTM 103 052, 24 m of sandstone with a thin coal seam at UTM 103 051, gray sandstone with coal at UTM 058 008, and 14 m of sandstone with thin shale at UTM 095 500 being indicative of Morien sediments.

(b) groundwater chemistry at UTM 095 500, 058 008, and 102 052 that is indicative of Morien sediments.

(c) lithology encountered in water well logs in the Silverside Subdivision; notably 18 m of soft shale at UTM 105 053, 12 m of red sandstone at UTM 106 053, and 9 m of soft shale at UTM 105 055 are indicative of Windsor Sediments.

2.8 Canso Group (Unit 10)

Offlap sedimentation associated with regression of the Windsor Sea created the non-marine brackish strata of the Canso Group; the basal Pennsylvanian Unit in the study area. It is comprised of two formations both conformable in attitude with the underlying Windsor Group and the overlying Morien Group. The Point Edward Formation (10a), predominately consists of alternating red sandstone and mottled red and green areno-argillaceous shales. The formation is 229 m thick on the Point Edward peninsula, with an additional 183 m concealed under Sydney Harbour (Hayes, Bell, and Goranson, 1938). The Cape Dauphin Formation - (10b) outcropping on the eastern flank of Kelly's Mountain exposes approximately 84 m of dark gray shales.

2.9 Morien Group (Unit 11, 12 and 13)

The Morien Group consists of a thick sequence of transgressive clastic sediments of Pennsylvanian to early Permian age. Although no marine horizons are known in the Morien Succession, the coalfield is genetically a paralytic basin (Hacquebard and Donaldson 1969). The sediments exhibit rapid lateral and vertical variations. Three zonal divisions of the Group are based chiefly on palaeontological characteristics.

2.9.1 Lonchopteris Zone (Unit 11)

The Lonchopteris Zone is composed of 915 m of predominately arkosic grit, gray sandstone and shale with minor zones of red shale southeast of Sydney. In the very basal section, there are approximately sixteen lenticular beds of arkosic grit, carrying abundant calcareous nodules resembling a limestone conglomerate, varying in thickness from 1 centimetre to .6 m (Hayes and Bell, 1923). Thin coal seams are noted but are localized near the base of the zone. Transgressing westward, the zone thins to 518 m and grades into predominately sandstone in the Pottle Lake area and into conglomerate, arkosic grit, and sandstone in Boularderie (Bell and Goranson, 1931). The summit of this zone is arbitrarily chosen at approximately 6 m above the Tracy coal seam at the first appearance of Linopteris.

2.9.2 Linopteris Oblique Zone (Unit 12)

In the Linopteris Zone greater accumulations of shales and siltstones interfinger with sandstones in the eastern portion of the coalfield. Coal seams are more frequent, however, all except the Mullins and Emery occur only in the eastern basin (Gray and Gray, 1941). Of the thirty two carbonaceous seams found in this zone, the majority are only a few centimetres thick. These coal and associated shale units merge laterally into thick (1066 m plus) massive sandstones toward the west-northwest between Sydney and New Waterford. This unit is broken only by thin shale-coal sequences associated with the Gardiner and Mullins coal seams (Hayes and Bell, 1923). The lithology continues to coarsen westwards into conglomerates, arkosic grit, and sandstone on Boularderie Island.

2.9.3 Ptychocarpus Unitus Zone (Unit 13)

The base of this, the most economically important zone, is placed arbitrarily approximately 6 m above the Emery Seam at the first conspicuous presence of the fossil Amthracomya (Hayes and Bell, 1923). The total numer of known coal seams in this zone is 24 of which six are .9 m or greater in thickness. The total average thickness of coal is 14 m (Fletcher, 1900).

The zone is comprised predominately of shale, mudstone, siltstone and coal beds with minor fresh water limestone beds, calcareous shale and fossil bands. The clastic parting between coal seams show high variations in character, degree of fineness and thickness. No rhythmic succession in lithology has been noted. As well, the zone increases in thickness westward rather than decreasing as do the lower units (Gray and Gray, 1941). This unit contains the youngest rock types in the study area.

2.10 Bedrock Structure

Carboniferous deposition over the basement complex occurred in the broad subsiding Fundy Basin in which numerous sub-basins were fed by fault bounded Devonian uplands. For the Sydney sub-basin this included:

Kelly's Mountain and the Cape Breton Highlands to the west, the Boisdale and Coxheath Hills to the southwest, and the East Bay Hills and the Scaterie basement ridge to the south.

The Sydney basin is characterized by gentle undulating folding and minor faulting. The regional strike of the beds is generally northwest-southeast dipping usually from 4-15^{o} toward the north central part of the basin.

2.10.1 Folding

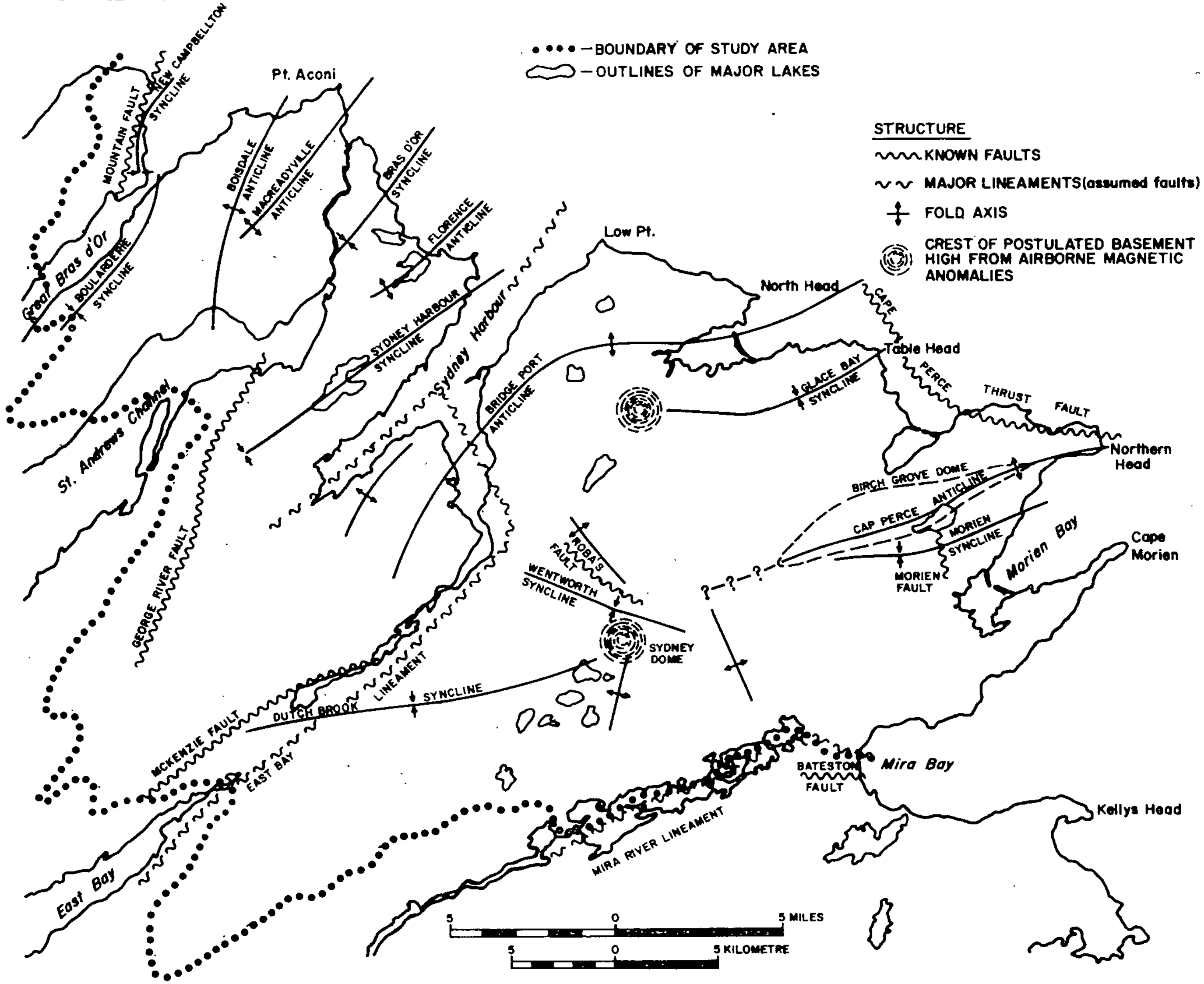
The dominant structural features are a number of gentle, open folds plunging seaward (Figure 2-1). They gradually alter direction from north-northeast in the western part of the field to easterly, then southerly in the eastern section where their axes radiate out from an area near MacDonald Lake.

The Boisdale and Bridgeport anticlines are extensions of the anticlinal folds that raised the crystalline rocks of the Boisdale and Coxheath Hills respectively. The Boularderie syncline is a faulted downfold between the Boisdale Hills and Kelly's Mountain. The western end of the Sydney Harbour syncline is a downfold between the Boisdale and Coxheath Hills. The remaining folds are structures confined to the Morien Group (Bell, 1958).

A minor belt of folding is present immediately southeast of Sydney. The main structure, the Wentworth syncline, is closed and has associated gentle secondary flexures that plunge into it.

The main reason for folding is thought to result from a combination of differential subsidence contemporaneous with sedimentation, accentuated by Permian compressive forces from the northwest (Hacquebard and Donaldson, 1969), post-lithification and faulting. The effect of differential compaction resulted in ancient river channels meandering landward in synclinal areas and outward in anticlinal areas; coal seams are therefore thicker in synclines than anticlines.

Figure 2-1 MAJOR CARBONIFEROUS STRUCTURE WITHIN THE STUDY AREA



The draping of Carboniferous sediments over basement highs may be a secondary reason for the folding. The crest of two such highs have been postulated from geomagnetic anomalies (G.S.C., 1953). The anomaly between Grand Lake and Bridgeport Basin has been interpreted as a basement high lying 1173 m below sea level (Howie and Cumming, 1963). The axial trend of the anomaly to the south leads to another postulated high along Morrison Road east of Dumaresq Lake over which Windsor marine beds are draped at depth of approximately 762 m (Forgeron, 1980).

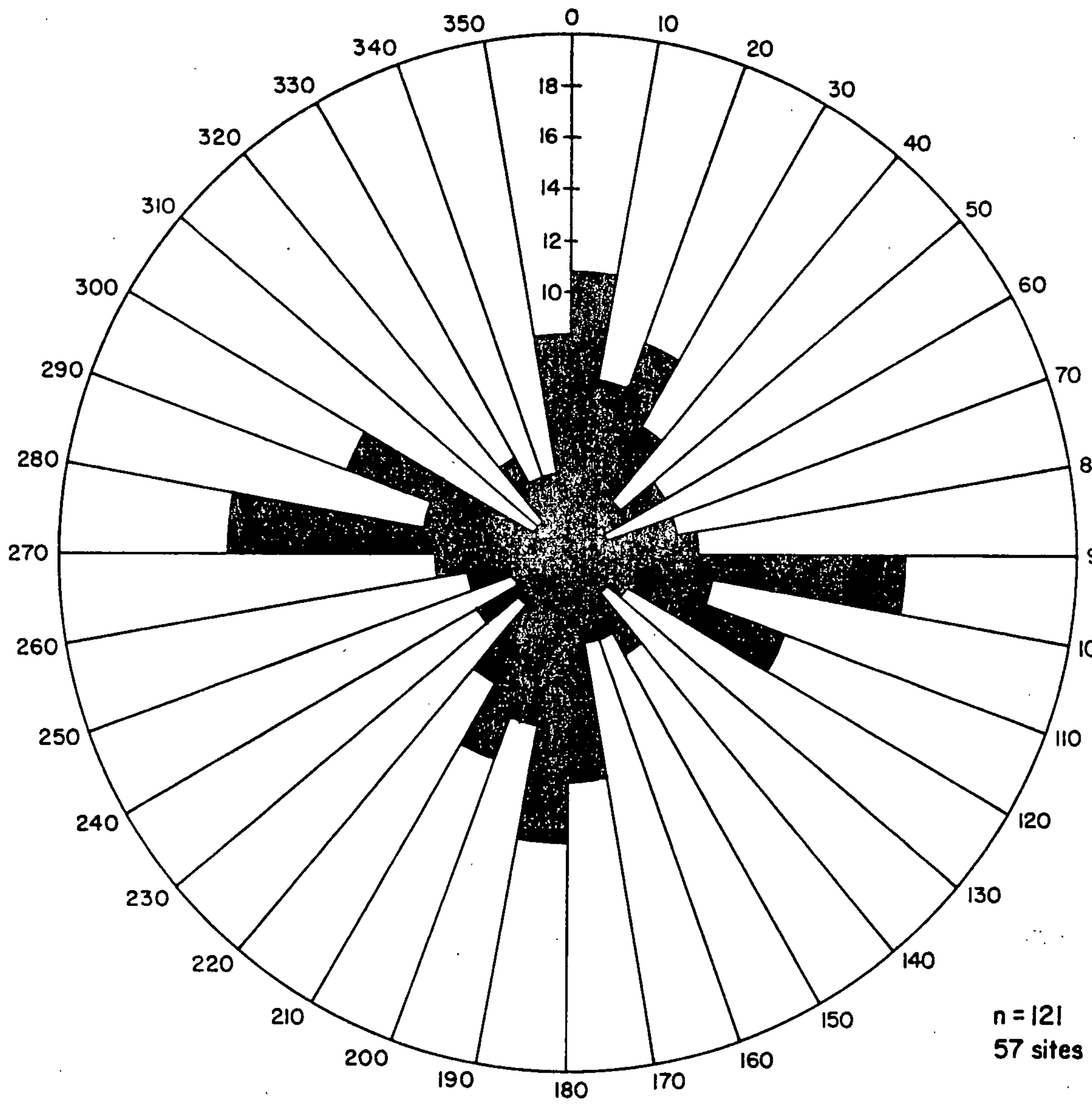
Domes are situated on the summit of two of the Morien folds. The largest is the Birch Grove dome situated on the Cap Perce anticline (Mather et al, 1944). The Sydney dome is expressed in surface outcroppings southeast of Sydney. It is approximately 5 km long trending generally southeast. It could be the western extension of the Cap Perce anticline.

2.10.2 Faulting

Generally Cape Breton Island exhibits the Appalachian northeasterly trending structural grain which controls the main topographic features including the boundaries of the Sydney basin. Resistance of the crystalline basement to folding, resulted in movement along pre-existing faults situated between basement and Carboniferous rocks. Most faults extend very little beyond the crystalline cores and affect only the Lower Carboniferous sediments at the borders of the coalfield. As noted in Figure 2-1, these include: the Great Bras d'Or lineament (mountain fault) along the western rim, the Mira River lineament (Bateston fault) along the southern border, the East Bay lineament and McKenzie fault along the eastern border of the Coxheath Hills and the George River fault following the eastern rim of the Boisdale Hills. Fault lines are readily traced along most of their courses by high angled dips of the Carboniferous strata; however, very little is known about dips or displacements (Keppie, 1976).

Thrust faulting has been noticed in some mines. In all cases the thrust faults strike in a northwesterly direction. The throw and displacements seem to be less in younger beds (Haites, 1952). The major fault is the Cap Perce thrust at Donkin which has been traced over 16 km with normal

Figure 2–2 ROSETTE OF JOINT STRIKES RELATIVE TO BEDDING STRIKE



Rosette of joint strikes in relation to strike of beds (bed strikes rotated to N–S)
92% of all joints dip >60°; 60% >80°; 89% of all beds dip<30°; 52%< 10°

downthrows on the north measurable in tens of metres (Haites, 1952).

Work by the Nova Scotia Research Foundation (1970) indicated that the Sydney Harbour syncline southwest of Pottle Lake is extensively faulted with displacements up to 122 m or more and downthrows generally to the northwest.

Seismic work (McPhee, 1965) confirmed the presence of Robb's fault cutting the Sydney dome east of Sydney (Figure 2-1) with possible stratigraphic displacement in the order of 457 m and a downthrow on the west side of possibly 275 m.

2.10.3 Jointing

Carboniferous sediments are generally well jointed due to the folding. To better define the regional jointing pattern, discontinuities were quantified at 57 sites throughout the coalfield predominately within the Morien Group. A rosette plot of joint strikes in reference to bedding strike (Figure 2-2) indicates a well-defined orthogonal system with the master set nearly paralleling the strike of the beds and the major set at right angles to the first. Both sets dip steeply; the dip of the master set is generally at right angles to bedding dips.

The jointing is well developed in the sandstones, conglomerates and siltstones. They rarely penetrate far into soft siltstones, shales, mudstones.

Cleat is generally well developed in Sydney coals. The two directions are N65^{o}E and N25^{o}W. Both are of equal prominence. They dip at very high angles (80-90^{o}) to bedding. They are far more numerous in coal than are joints in accompanying sediments (Haites, 1951).

CHAPTER 3

SURFICIAL GEOLOGY

3.1 Introduction

The last important geological event in the study area was glaciation. Grant (1972, 1977) discussed his findings on ice movement and the Pleistocene history of Cape Breton Island. In general, the main Laurentide ice sheet did not dominate this region; instead, a locally nourished Appalachian complex was active throughout the Maritimes.

The initial ice movement across the study area was north-northeast originating from an ice-dome of the Appalachian glacier complex centered offshore on the continental shelf during the Wisconsin maximum.

About 14,000 years ago, the Wisconsin ice waned and the sea encroached into the Gulf of St. Lawrence, trapping ice on Cape Breton Island. It is inferred by Grant (1972, 1977) that the center of the offshore ice dome was shifted landward. During the recession, there was a minor readvance which emplaced till over a peat deposit near the head of East Bay dating 10,300 ± 150 years BP (Grant 1972, 1977). It probably was also responsible for creating a belt of humocky terminal moraine stretching from East Bay to Mira Bay just north of the Mira River. The retreat of this ice lobe is further thought to have created the two major fluvial outwash plains associated with the present Sydney and Mira River Valleys.

A regional surficial mapping program was undertaken of the study area for this investigation (Map 2). In general, glacial movement emplaced a thin till cover over greater than 90% of the study area. There was generally little transport of eroded bedrock debris.

Spot thicknesses of surficial deposits are indicated on Map 2 as derived from well logs. The data indicate that the deposits range from 3 - 6 m in thickness over the lowland areas except in the Sydney and Mira River Valleys where thicknesses may locally exceed 30 m. Deposits over the major topographic highs are generally thin (less than 3 m) and discontinuous.

3.2 Glacial Tills

The study area is generally overlain by one basal till emplaced during the main ice advance to the northeast. There are, however, areas where more than one basal till have been recognized. The texture varies considerably, closely reflecting the underlying bedrock lithology. Till contacts lie remarkably close to bedrock contacts with limited spread in a down-drift direction. The tills have been mapped solely on their lithology, which has delineated three major types.

3.2.1 Sandy Silt to Silty Sand Till

This unit is the most widespread of the tills in the study area. It has been developed predominately over the Morien Group as well as in the Cambrian and Devonian sedimentary basins southwest of the Coxheath Hills.

The unit can be generally described as a moderate to dark yellowish brown compact, non-calcareous, stony, sandy silt to silty sand basal till. The matrix exhibits a subangular blocky to at times pseudo-platy structure; no jointing is in evidence. Relevant grain size distributions are shown in Figures 3-1 A and B.

The dominant grain size within the matrix varies from fine sand to silt depending upon the local geology. This is exemplified by the more sandy texture over the lower two zones of the Morien Group and the more silty nature over the upper zone. Vertical variations are also in evidence so that the texture of the till near the bedrock interface more closely resembles the local facies.

The clasts are very poorly sorted and range in size from granules to boulders. Clasts are predominantly sedimentary in composition. The block-like shape and frequency of cobble and boulder-size clasts appear to be a result of the extensive jointing developed in the parent bedrock.

Figure 3-1 REPRESENTATIVE GRAIN SIZE DISTRIBUTIONS

Figure 3-1A

SILTY SAND TILL

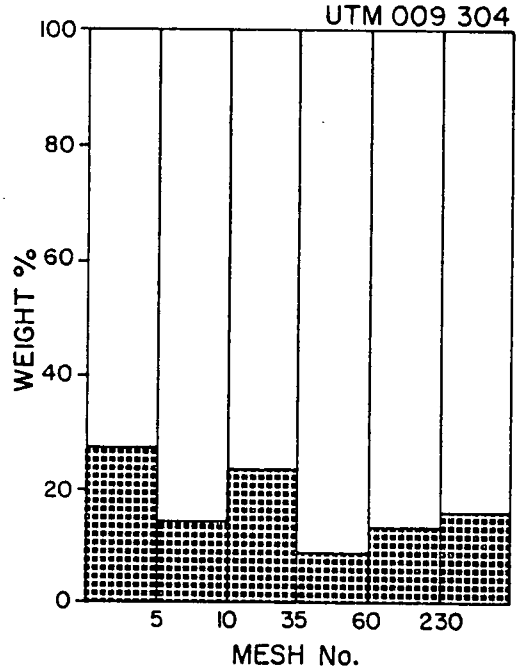


Figure 3-1B

SANDY SILT TILL

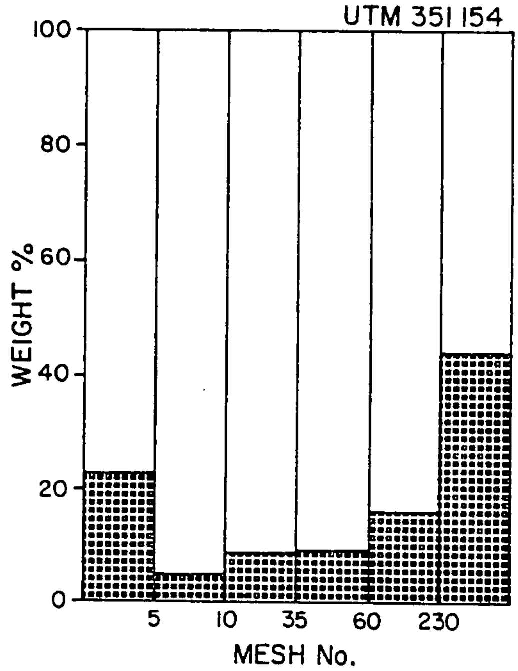


Figure 3-1C

CLAYEY SILT TILL

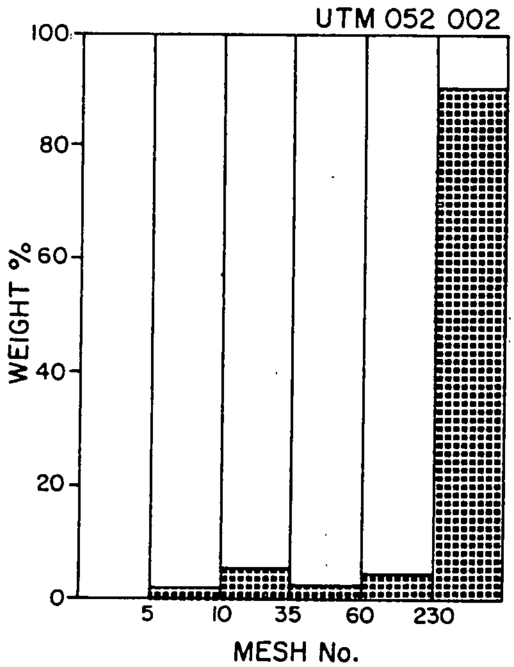
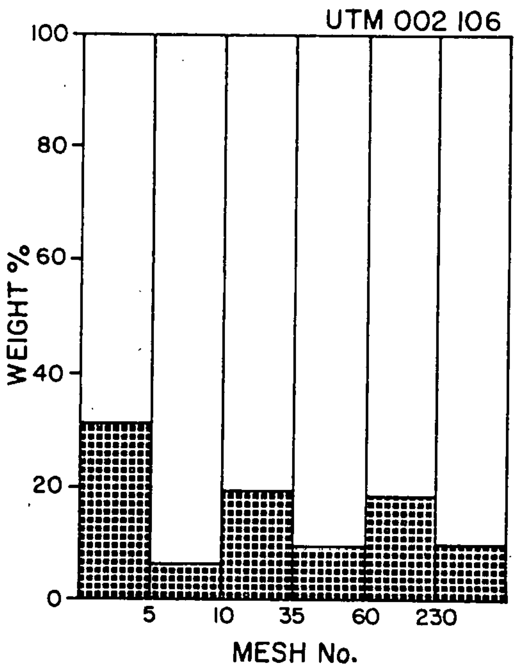


Figure 3-1D

STONY SAND TILL



3.2.2 Clayey Silt Till

This form of the basal till is developed primarily over the Windsor Group central marine beds.

The unit can be generally described as a dark reddish brown, hard, stony, clayey silt till. The matrix exhibits a blocky structure with no signs of jointing. A representative grain size analysis is shown in Figure 3-1 C.

The clasts usually do not attain boulder size and are more rounded due to the absence of jointing and the incompetence of the parent rock.

Sandy tills similar to those previously described have been noted within this unit. Such tills developed over resistant limestone beds principally where the strike is parallel to ice movement (i.e., at Beachmont North, UTM 053 109).

Due to the calcareous nature of the underlying bedrock, the total carbonate content is relatively high. It was measured at 21% (calcite 18%, dolomite 3%) near the Head of East Bay (UTM 052 002).

This form of the basal till is present under the outwash gravels associated with the present Sydney River System.

3.2.3 Stony Sand Till

This form of the basal till has been developed over igneous and metamorphic bedrock types.

It can be described as a moderate brown to pale yellowish-brown, loose to compact, stony to very stony sand till. The matrix exhibits a subangular blocky to coarse angular structure; no jointing is in evidence. A representative grain size analysis is given in Figure 3-1 D.

This unit, it is generally inaccessible and exposures are poor. From airphoto interpretation, field mapping, and bedrock outcrops (Map 1), it would appear to be generally very thin (less than 3 m) and discontinuous. The unit may often contain pods of weathered bedrock.

3.2.4 Till Complex

There are two major areas as delineated on Map 2 where the vertical and horizontal variations in the texture of the basal till(s) become very complex. Given the scale of mapping and limited access, no attempt was made to delineate specific till types within these areas.

In the area north and west of the Coxheath Hills, a wide, relatively rapid areal variation in texture occurs in conjunction with localized occurrences of two or more tills in vertical succession. The basal till found at the surface within this area can range from a clayey silt to a stony sand till. This complexity is enhanced by the presence of an ablation till.

Generally speaking, a sandy to silty till can be found over the Grantmire conglomerate to the north and west of the Coxheath Hills. It becomes noticeably finer to the west as the contact with the Windsor Central marine beds is approached. At a number of locations (UTM 055 101) however, the till resembles a well sorted outwash gravel. Closer inspection indicates reworking of the underlying conglomerate. Over the same unit northeast of the Coxheath Hills near Howie Centre (UTM 104 059) a clayey silt till is present.

A silty sand till is present at the surface on the Point Edward peninsula. However, this can vary considerably from a clayey silt over the mudstone shale sequences to a stony sand over the limestones.

Throughout this entire complex, the colour remains generally consistent, ranging from a grayish red to a dark reddish brown.

The second area of complexity comprises two basal tills in vertical succession. It is located in the southern portion of the study area northeast of East Bay. The lower basal till is generally the clayey silt version previously discussed and complements the underlying Windsor bedrock. The overlying basal till is similar in texture to the sandy silt, silty sand version previously discussed. It does however differ in colour (principally a dark reddish brown) and has a visually higher percentage of igneous and metamorphic clasts.

Drumlins in the area trend northeast-southwest; however, the characteristic stoss and lee form are not well developed.

3.3 Terminal Moraine Complex

This deposit is best described as a complex of local outwash fans deposited on or incorporated between till sheets of varying lithology. Typical kettle and knob topography is found throughout. Gravel ridges are common and glacial mounds form striking landscape features north of the Homeville post office at Broughton and along the Ferguson Road to the Mira River (Hayes and Bell, 1923). The boundaries of this complex have been assumed to follow a distinct humocky topography noted by airphoto interpretation.

3.4 Outwash Sand and Gravel

There are two major outwash channel features in the study area associated with the present day Sydney River. Secondary occurrences are mapped in the Frenchvale River Valley (UTM 002 057), Georges River Valley (UTM 003 150), East Bay area (UTM 008 001) and Gillis Lake area (UTM 002 008). No recognizable tills have been found overlying these gravels.

The Sydney River outwash channel appears to have originated near the foot of the East Bay Hills. Due to inaccessibility and confusion with the Grantmire conglomerate, it was not possible to delineate the southern-most contact. In the vicinity of the Meadows road, quarries indicate 3 - 9 m thick sequences underlain by the clayey silt till. There appear to be a number of small mounds in this plain which are comprised of till draped on all sides by outwash gravels. Although there are recorded thicknesses of 20 - 27 m along the northwest side of the present Sydney River, it is believed these include thicknesses of the underlying Grantmire conglomerate. At Blackett's Lake (UTM 059 051) however, geotechnical drilling indicated what are considered to be true thicknesses of outwash gravel of 33 m+. The unit disappears under Sydney Harbour.

There is evidence of another glacial channel entering the Sydney River system from the east in the vicinity of the present Dutch Brook river valley (UTM 108 054). It is apparently associated with the terminal moraine complex.

The second major outwash gravel feature is associated with the present day Mira River valley. Due to inaccessibility and complexity associated with deposition of the terminal moraine, the boundaries of this former channel are difficult to map. The unit sometimes resembles a poorly sorted sand and gravel while at other spots, it appears more as a well-washed, reworked gravel till or an ablation till. The drill hole data available indicate depths of gravel ranging from generally 3 - 15 m. In one instance, at UTM 354 055, a value of 30 m+ was obtained.

3.5 Ice Contact Stratified Drift

Mappable sand and gravel deposits of this origin are not abundant and are restricted to localized zones associated with the two major outwash channels.

Quarry cuts at UTM 102 051 indicate a poor to moderately-sorted, slightly silty, very fine sand. The clast range is generally bi-modal with the fine gravels moderate to well rounded and sorted and the coarse gravel generally angular-subrounded and poorly sorted; stratification is generally absent. The more linear deposits may be valley trains. There is a distinctive small kame field in the Sydney Forks-Howie Centre area (UTM 108 053).

3.6 Recent Deposits

3.6.1 Colluvium and Weathered Bedrock

This unit is associated with the steep slope transition from the lowland topography of the sedimentary bedrock terrain to the elevated plateaus of the igneous and metamorphic rocks. These areas incorporate bedrock and weathered bedrock at the surface. On the Cape Dauphin mountain, UTM 955 308, a talus cone is present.

3.6.2 Peat Bogs, Organic Deposits

Peat bogs are numerous throughout the study area but are predominantly found east and southeast of Sydney. Most appear to be relatively thin (i.e., less than 3 m). However, sampling of some of the larger deposits indicates thicknesses of 4 to 6 m.

3.6.3 Longshore Bar Complexes

This unit encompasses longshore bars and associated tidal flats and salt marshes. Generally, the units are comprised of loose sand. There are numerous such bars along the coast resulting from the high coastal erosion rate. Only the large scale units have been noted on Map 2.

3.6.4 Stream Alluvium

Alluvial deposits principally of fine sands, silts, and clays are found along most streams in the area. However, only in a few places are they large enough to map.

3.7 Pedology

The soils found within the study area have been mapped at the soil type level by Cann et al (1963) at a regional scale (1:84,480). The reader is referred to that report for detailed descriptions and maps.

The soil profiles have been developed on Wisconsin age glacial deposits over the last 10,000 - 12,000 years. The close association between the texture of the glacial tills and bedrock type is also reflected in the soil types.

There are four major soil groups found within the study area: Podzols, eluviated Gleysols, Organic deposits, Regosols (see Table 3-1). All are acid throughout most of the profile.

TABLE 3-1 - A CLASSIFICATION OF THE SOILS FOR THE STUDY AREA

Parent Material	Lithology	Podsols		Eluviated Gleysols	Regosols		Organic Soils
		Orthic Podzols	Gleyed Podzols	Low Humic Eluviated Gleysols	Orthic Regosols	Gleyed Regosols	
		Good Drainage	Imperfect Drainage	Poor Drainage	Good Drainage	Imperfect Drainage	
Fine-textured glacial till	Red and gray shales and sand-stones	Falmouth	Queens	Kingsville			
	Reddish-Brown sandstone and shale		Millbrook				
	Gray shale and sandstone		Diligence	Joggins			
Moderately coarse textured glacial till	Metamorphic rocks	Thom	Mira				
	Reddish-brown conglomerate	Westbrook					
	Gray sandstone and shale	Shulie	Springhill	Economy			
Coarse-textured Water-Deposited materials	Igneous and Metamorphic rocks	Hebert					
	Gravel over Till		Debert				
	Shaly gravel	Torbrook					
Organic Deposits							Peat

The podzols by far outweigh all others in areal extent. They are generally developed on well-drained, moderately-coarse-textured parent materials. They have an A horizon with a thin layer of partly decomposed organic matter in the upper part. The lower part of this horizon (Ae) is a bleached, light-coloured layer from which alkalies, clay, iron and aluminum compounds have been removed. The B horizon is dark-coloured and usually somewhat finer in texture than the Ae and contains the leached materials from the A horizon. At numerous places within the study area, the B horizon becomes notably indurated and/or cemented by one or a combination of Duripans, Fragipans, Ortsteins, and Iropans (Beke, pers. comm.). These horizons are due in part to cementation by silica, iron, and/or manganese or a high percentage of silt or very fine sand. They are not restricted to the study area but are commonplace with podzols in the cool, humid maritime climate of the Atlantic Provinces. The C horizon is unweathered parent material in various textures, colours, and consistencies but is usually lighter in colour than the B and more firm and dense. The predominant soil types within this group are Shulie, Springhill, and Economy representing the range from good, imperfect to poor drainage. They are developed over the sandy-silt to silty sand till present over the Morien sediments. The Westbrook and Mira are the soil types found over the finer textured till emplaced over the Windsor group. Debert, Herbert, and Torbrook are found over outwash and ice contact gravels.

The next most prevalent soil group in the study area is the organic deposits (See Map 2). They occur in depressional areas and where the soil is saturated with water most of the year. These soils exhibit successive layers of organic material, chiefly moss and sedges, in various stages of decomposition from the surface downwards. Most of these soils are classed as peat.

The eluviated Gleysol and Regosol soil groups are of limited extent in the study area. Eluviated Gleysols have been developed over fine-textured glacial till and generally exhibit poor drainage. Examples of this group include the Kingsville and Joggins soil series. Regosols have been developed over medium textured glacial till and alluvium and exhibit both good and imperfect drainage. Examples of this group include the Cumberland and Bridgeville soil series.

CHAPTER 4

HYDROMETEOROLOGY

4.1 Introduction

The Maritime region is generally situated where practically all cyclonic storms of North America leave the continent. This gives the study area a humid continental climate (Strahler, 1969). According to Thornthwaite (1948), it can be quantified as moist, humid, second order, microthermal with little or no water deficiency.

Excellent long-term, continuous climatic records have been taken for Sydney since 1870. Early observations were taken at the "City" station (UTM 153 108). In April, 1941, the instruments were relocated at the "Airport" with an elevation of 55.5 m (UTM 255 154).

The normals, for 1941-70 where possible, for the major pertinent climatic elements are given in Appendix 1.

4.2 Precipitation

4.2.1 Total Precipitation

4.2.1.1 General

The 1941-70 mean total annual precipitation is 1340 mm ranging between 1021 mm and 1606 mm. The standard deviation is 157 mm. Of the nine selected representative stations throughout the Maritimes, Sydney shows the largest mean number of days with measurable precipitation at 179 days (Gates, 1975).

4.2.1.2 Seasonal Variations

Precipitation has a good seasonal distribution. Minimums occur from May through September with the lowest in June and July. During these months, the concentration of low pressure centered over the St. Lawrence Valley leaves the Atlantic Provinces under the predominate influence of winds from the south, southwest, or west (Montreal Eng. Co., 1969).

Maximum precipitation occurs during the fall rains. This rainfall is caused by frontal convergences of tropical and Arctic air masses as the Arctic front moves south of Nova Scotia. The intensity of migrating storms and rainfalls peak in November and December. The winter months are particularly stormy on the Atlantic coast and severity varies from year to year depending upon the domination of the region by Arctic air. These winter storms often produce violent gales and rains changing to snow resulting in the retention of high precipitation values into January and February.

4.2.1.3. Areal Variations

There are four short-term climate stations in and bordering the study area (Figure 4-1). From the west to east they are Indian Brook (elevation 15.2 m), Coxheath (UTM 101 058, elevation 76.2 m), Port Morien (UTM 358 106, elevation 45.7 m), and Louisbourg (elevation 15 m). Comparison of these data with Sydney "City" and "Airport" stations indicates a number of regional areal variations in total precipitation over the study area.

Isohyets run north-south revealing a decline in mean annual total precipitation from an average of 1729 mm at Indian Brook in the west to 977 mm at Port Morien in the east. Indian Brook was always greater than the "Airport" over five years of record between 1965 and 1977 by an average of 277 mm, ranging from 110 mm to 463 mm. In addition the "City" station was greater than Port Morien 92% of the time over the 25 years between 1873 to 1905; the average was 333 mm, ranging from 29 mm to 730 mm.

4.2.2 Snowfall

Approximately 27% of total precipitation originates as snow, falling over 4.5 months between early December and mid-April. The 1941-70 mean is 2870 mm. A nipher snow gauge was installed to obtain water equivalent in 1954.

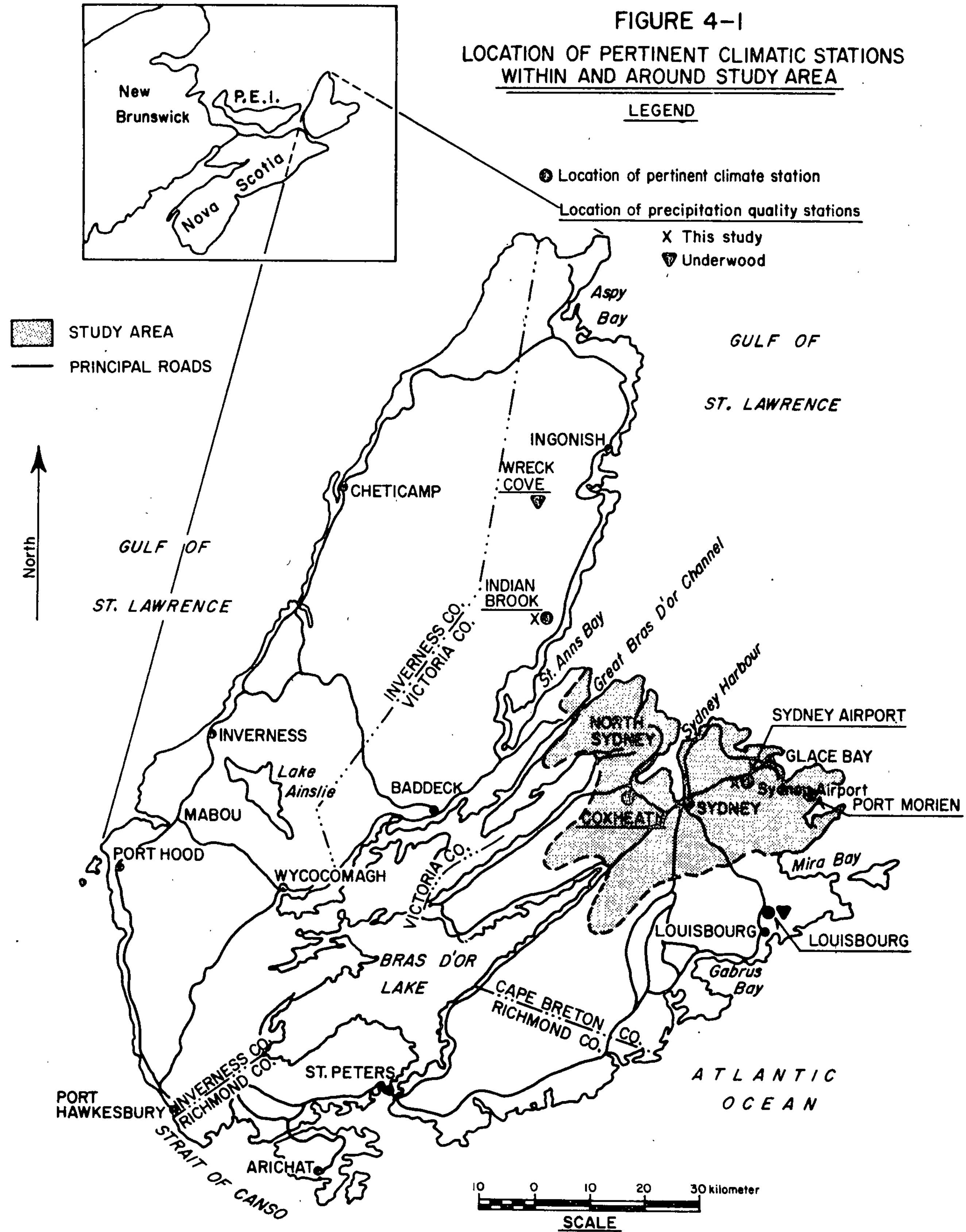


FIGURE 4-1
LOCATION OF PERTINENT CLIMATIC STATIONS WITHIN AND AROUND STUDY AREA

There is considerable variation in the amount of snow in any one place from year to year. The snow fraction can be less than 15% along the coast and up to greater than 30% over the highlands (Gates, 1975). Although snowfall amounts vary considerably and intensities are relatively high, the reliability of snow cover is relatively low. This results from the moderating effect of the Atlantic which vies with Arctic air for domination of the region and determines winter severity.

4.2.3 Intensity

Rainfall intensity-duration-frequency data for the Sydney Airport station are presented in Figure 4-2. The 50 and 100 year event data should be used with caution due to the short period of record. As the most significant portion of the precipitation received results from the passage of major low pressure systems rather than convective storms, the area is generally characterized by long duration-low intensity events.

4.3 Temperature

The mean (1941-70 normal), annual air temperature at the "Airport" is 6.1^{o}C with a standard deviation of 0.7^{o}C. The annual temperature fluctuation at 5.7^{o}C is relatively small being more representative of coastline stations where oceanic moderation depresses the cycle.

The minimum mean monthly temperature of - 5.5^{o}C occurs in February. Mean monthly values below freezing occur during December through March inclusively. The maximum mean monthly temperatures occur in July and August at 17.9^{o}C and 17.8^{o}C respectively.

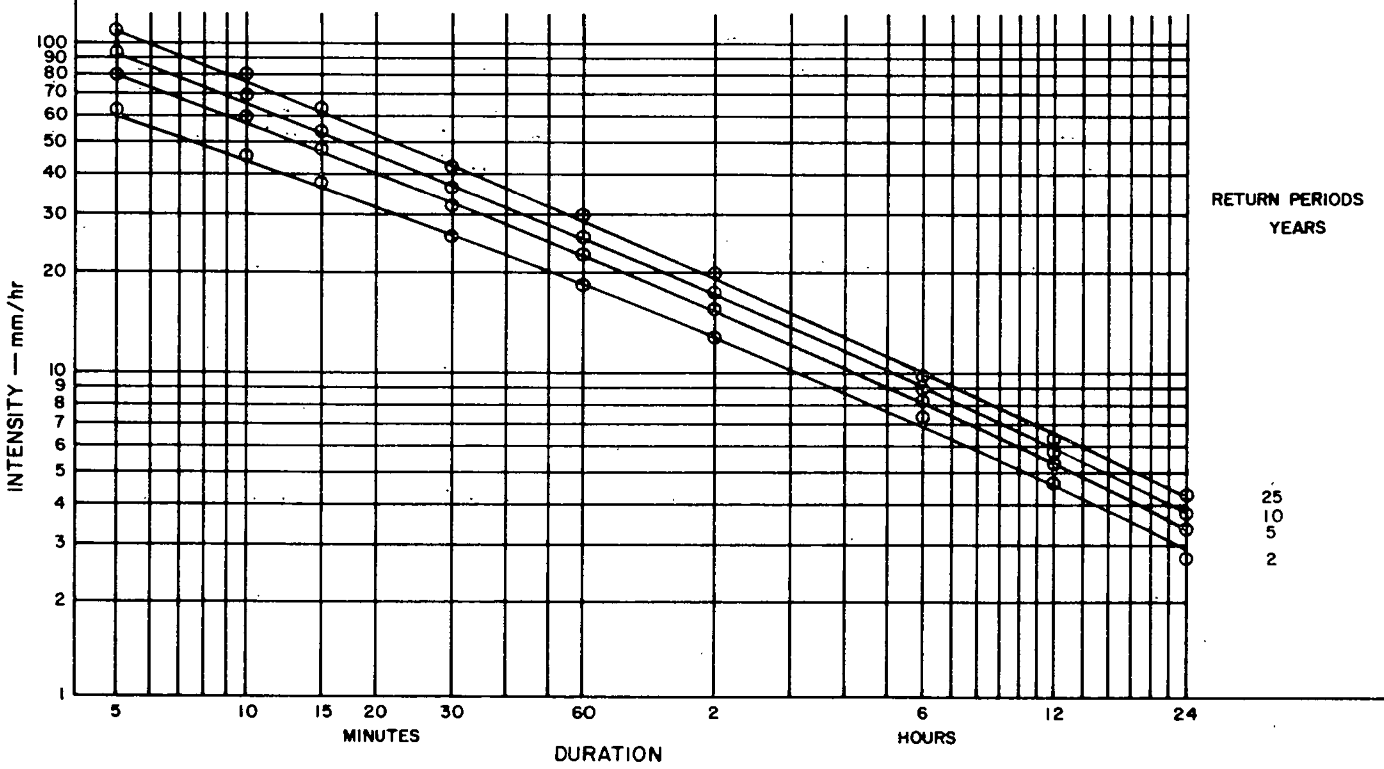
The advent of warmer temperatures is delayed in the spring due to the cold Labrador current and pack ice surrounding the island. Sea ice can be expected from late January to May with the heaviest months being February, March, and April.

Both the current and ice are efficient producers of fog and low cloud when in contact with the warm moist tropical air from the southern latitudes in spring and early summer. At the "Airport" there are 81 days of fog (1941-70 normals) per year with maximums in May (11 days),

Figure 4—2 SHORT DURATION RAINFALL INTENSITY-DURATION FREQUENCY DATA FOR SYDNEY BASED ON RECORDING RAIN GAUGE DATA FOR THE PERIOD - 1961 — 1979, 18 YEARS

50 AND 100 YEAR RETURN PERIOD RATES (mm/hr) WITH 50 % CONFIDENCE LIMITS.

YEARS	5 MIN	10 MIN	15 MIN	30 MIN	1 HOUR	2 HOURS	6 HOURS	12 HOURS	24 HOURS
50	119·1 mm +/-10·8mm	87·6 mm +/-8·0mm	68·3mm +/-5·9mm	45·0mm +/-3·7mm	31·49 mm +/-2·58mm	21·51 mm +/-1·64mm	10·34mm +/-0·56mm	6·79mm +/-0·40mm	4·76mm +/-0·38mm
100	130·4 mm +/-12·7mm	95·9 mm +/-9·4mm	74·4 mm +/-6·9mm	48·9 mm +/-4·4mm	34·18 mm +/-3·02mm	23·23mm +/-1·92mm	10·92mm +/-0·65mm	7·21mm +/-0·47mm	5·16mm +/-0·44mm



June (10 days), and July (11 days).

During September, the Atlantic Ocean reaches its annual temperature maximum. It thus begins to act as heat source delaying the onset of winter. The preceeding processes result in a relatively short frost free period of 145 days and a growing season of 186 days.

4.4 Evaporation

The mean annual lake evaporation (Table 4-1), for the area has been calculated, using 10 years of evaporation pan data (1957-66) and the Christiansen formula, at 535 mm (Ferguson et al, 1970). A more recent review using data from 1967-1978 inclusive, indicated no major deviations from the initial assessment (O'Neill, pers. comm.). There are no data available on the coefficient of variability for this figure (O'Neill, pers. comm.).

The nearest evaporation pan, from which data are utilized in determining the rate, is located in Truro (240 km to the southwest). Although measurements from the pans usually terminate after the first frost, subsequent rates were calculated mathematically and are included in the rate shown.

It should be noted that the calculations assume evaporation from a shallow lake (1-3 m), thereby reducing heat storage to a minimum. The annual mean, however, should not be significantly altered.

The seasonal fluctuations in evaporation (Table 4-1) are extrapolated from the mean evaporation map (Canada Dept. Transport, 1970). They show a regular cycle with a well marked maximum in July.

4.5 Evapotranspiration

Utilizing 1931-70 data and assuming a 300 mm soil deficiency, the Thornthwaite method indicates an annual potential evapotranspiration of 537.7 mm and an actual evapotranspiration of 531.8 mm as noted in Table 4-1. The resultant average annual water deficit is small (5.8 mm),

TABLE 4-1

MEAN MONTHLY EVAPORATION AND EVAPOTRANSPIRATION RATES FOR THE STUDY AREA
*LAKE EVAPORATION (1957-1966 MEANS)

	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPT.	OCT.	NOV.	DEC.	ANNUAL
10-Year Mean Lake Evaporation (mm)				30	90	100	110	95	60	35	15		535
• EVAPOTRANSPIRATION (THORNTHWAITE METHOD) - ASSUMING 300 mm													
Potential Evapotranspiration (mm)				17.3	58.9	89.2	120.7	111.5	79.2	42.9	18.0		537.7
Actual Evapotranspiration (mm)				17.3	58.9	89.2	116.8	109.5	79.2	42.9	18.0		531.8
Deficit (mm)							3.8	2.0					5.8
Surplus (mm)				78.0	40.6					32.0	143.3		293.9

* Meteorological Branch, 1968, 10-Year Mean Annual Lake Evaporation Maps, Climatic Atlas, Canada, Department of Transport

• A. Gates, Climatologist, A.E.S., Pers. Comm., 1977 occurring in July and August. This leaves a large average annual water surplus of 293.9 mm occurring predominately in November.

The accuracy of this empirical value is questionable and difficult to quantify. The most representative comparative study was carried out by Smith (1964), using twenty-six continuous years of data in a similar temperate maritime climate. The annual Thornthwaite potential evapotranspiration was consistently excessive; the 26-year mean annual value being 123% of evaporation pan data. This discrepancy resulted from a reliance on mean air temperatures in the calculation which are depressed in the Sydney area due to coastal proximity and would not represent true radiation. As well the formula does not contain a humidity term, a factor of special significance in this coastal region.

Vaughan and Somers (1980) found that for the Amherst area of Nova Scotia that the Thornthwaite method was generally excessive at an annual level; but of three empirical methods, provided the best correlation coefficient with Truro evaporation pan data although it was only 0.77.

4.6 Wind

The average wind speeds and percent frequency, based on the 1955-1972 period, are given in Appendix 1. It indicates that the predominate wind direction is generally from the southwest.

There is a slight but definite seasonal shift in prevailing winds from the south-southwest during summer (April through September inclusive) to west-southwest in the winter (October to March inclusive). In the latter period, there is also a definite north component during March, April, and May.

Wiltshire (1979), concluded that at Sydney, there was no systematic trend between variations in wind speed with direction. However, there is a seasonal variation indicating a higher average winter speed peaking in December through March inclusive with lows in July and August.

4.7 Precipitation Chemistry

There are two sources of available data for which station locations are noted in Figure 4-1.

a) For this study wet fallout was analyzed at an "urban" (Sydney Airport) and a "rural" site (Indian Brook) on monthly composite samples between August, 1975 and July, 1976 inclusive.

b) A detailed event-based sampling program of wet and dry fallout has been carried out at four rural stations on Cape Breton Island by Underwood, 1984.

4.7.1 Concentrations and Loadings

The average annual ion concentrations, weighted for precipitation, are noted in Table 4-2.

Both the Indian Brook and Sydney Airport sites received a similar Na-Cl dominated precipitation. The total dissolved solids (TDS) ranged from 8-14 mg/L at the rural site to 14 mg/L at the urban site (0.18 to 0.48 meq/L respectively. The reduction at the rural site was a result of declines in sulfate (SO_4), calcium (Ca), chloride (Cl) and sodium (Na) in order of decreasing magnitude.

The resultant average annual loading values (Table 4-2) indicate that TDS ranges from 140 (Indian Brook) to 188 (Airport) kg/ha. The major ions in order of decreased loading are Cl, SO_4, Na, bicarbonate (HCO_3), Ca and magnesium (Mg) at both stations. Although at the rural site Cl and SO_4 are identical as are Na and HCO_3.

Although the average annual TDS concentration at Indian Brook is only 57% of the airport value, the increased precipitation allows the rural TDS loading to reach 77% of the airport site.

Trends during "winter" and "summer" seasons were explained by wind direction. During April through September inclusive, winds are generally from the south-southwest. Between October and March this alters slightly to west-southwest. The resultant concentrations are noted in Table 4-3.

TABLE 4-2

WEIGHTED AVERAGE ANNUAL CONCENTRATIONS AND LOADING RATES OF IONS IN PRECIPITATION IN THE SYDNEY COALFIELD FROM MONTHLY COMPOSITE SAMPLING OF WET FALLOUT - AUGUST 1975 TO JULY 1976 INCLUSIVE

Location	Na	K	Ca	Mg	Alka-linity as $CaCO_3$	SO_4	Cl	F	Si	Ortho PO_4	NO_2 + NO_3 as N	NH_4 as N	Fe[4]	Mn[4]	Pb[4]	Cu[4]	Zn[4]	TDS	Excess[2] SO_4	Ph (units)	H+	Total[3] Prec-ipita-tion(mm)
1. Indian Brook - Rural (n=11)[1] cation/anion balance = 1% error																						
mg/L	1.1	0.2	0.6	0.3	1.1	2.1	2.1	<0.1	0.2	<0.02	0.2	0.1	0.1	0.06	0.01	0.17	0.03	8	1.8	5.2		1756
kg/ha/yr	19	4	10	5	19	37	37	<2	4	<0.4	<4	2	2	1	0.2	3	0.5	140	32		.11	
meq/m²/yr	84	9.0	50	40	39	77	104	<9		<1	25	13	9	7.7	0.2	9	2		66		11	
2. Sydney Airport - Urban (n=10) cation/anion balance = 2% error																						
mg/L	2.5	0.3	1.4	0.3	1.5	3.1	4.3	<0.1	<0.1	0.02	0.3	0.1	0.2	0.03	0.01	0.1	0.1	14	2.5	5.0		1341
kg/ha/yr	34	4	19	4	20	42	58	<1	<1	0.3	4	1	3	0.4	0.1	1	1	187	34		.13	
meg/m²/yr	150	10	94	30	40	87	160	<7		0.9	29	10	14	2.9	0.1	4	4		70		13	

1 n = number of samples
2 assuming SO_4/Cl = .14 in Seawater
3 total precipitation that fell and used to calculate loadings; not used in weighting concentrations due to missing data
4 values are for total concentrations

Both the Indian Brook and the Airport Stations received Na-Cl dominated precipitation during the winter. This trends toward a $Ca\text{-}SO_4/HCO_3$ type in the summer, being much more pronounced at the airport site.

At the rural site, the concentration of TDS declines by half during the winter. This is possibly due to a reduced ability of snow (compared with rain) to remove substances from the atmosphere (Underwood, pers. comm.).

However, at the airport site the winter TDS concentration remains almost equal to the summer value even with nearly twice the precipitation. The airport winter TDS concentration is almost twice the rural winter concentration due primarily to elevated Na and Cl concentrations.

The resultant loading rates (Table 4-3) indicate that even though winter TDS concentrations are lower than summer values by 54% and 87% for rural and urban sites respectively, the increased winter precipitation allows the loading rates to be higher in the winter by 110% and 157%, respectively.

4.7.1.1 pH

Table 4-2 indicates that the pH's are less than 5.7. The lowest pH's recorded at Indian Brook and Sydney Airport were 4.8 and 4.6, respectively.

Annual loading rates of hydrogen ions indicate a close range from 11-13 $meq/m^2 \cdot yr$ (Table 4-2). This is good agreement with stations at Port Hood (14.3 $meq/m^2 \cdot yr$) and Wreck Cove (8.25 $meq/m^2 \cdot yr$) thereby corresponding with the northeastward decline across the province from 30-40 $meq/m^2 \cdot yr$ in the southwest (Underwood, 1981). Seasonal averages (Table 4-3) indicate an increase in concentrations and loadings in the winter; the latter being five times greater at Indian Brook and nine times greater at the Airport.

4.7.1.2 Sulfate

Sulfate data are reported exclusive of SO_4 from marine aerosols and

TABLE 4-3

WEIGHTED AVERAGE SEASONAL CONCENTRATIONS AND LOADING RATES OF MAJOR IONS IN PRECIPITATION AT INDIAN BROOK AND SYDNEY AIRPORT

Location	Na	K	Ca	Mg	Alkalinity as $CaCO_3$	SO_4	Cl	NO_2+ NO_3 as N	Ammonia as N	Fe	Mn	Pb	Cu	Zn	TDS	Excess Sulphate	Hydrogen	Ph (units)	Precipitation(mm)
1. Indian Brook (rural) April - September (n=5)[5] cation/anion balance = 10% error																			
mg/L[1]	1.1	.1	.9	.3	2.1	2.5	2.8	.2	.1	.1	.08	.01	.36	.05	13	2.1	$2.5X10^{-3}$	5.6	562.6
kg/ha[2]	6.2	.6	5	2	12	14	16	1	.6	.6	.45	.06	2.0	.28	73	12	.01		
meq/m[2] [3]	23	1	22	12	20	25	38	7	-	6	3.3	.05	6.4	.86	-	25	1.4		
October-March (n=6) cation/anion balance = 2.5% error																			
mg/L	1.1	.2	.6	.2	1.0	1.8	2.1	.2	.1	.1	.04	.01	.09	.02	7	1.5	$6.3X10^{-3}$	5.2	1193.8
kg/ha	13	2	7	2	12	22	25	2	2	2	.48	.12	1.1	.24	80	18	.08		
meg/m^2	57	6	36	20	24	45	70	17	-	10	3.5	.12	3.4	.73	-	37	7.5		
Sydney Airport (Urban) April-September (n=5) cation/anion balance = 7.3% error																			
mg/L	1.1	.2	2.9	.2	3.5	3.0	2.5	.3	.3	.1	.06	.04	.31	.02	15	2.7	$3.2X10^{-3}$	5.5	468.9
kg/ha	5.2	.9	14	.9	16	14	12	1	1	.5	.28	.19	1.5	.09	70	13	.02		
meq/m^2	22	2	68	8	33	29	33	10	-	3	2.1	.18	4.6	.29	-	26	1.5		
October-March (n=5) cation/anion balance - 4.4% error																			
mg/L	3.0	.3	.7	.4	1.4	2.6	5.2	.3	.1	.2	.02	<.01	.05	.17	13	1.9	$1.6X10^{-2}$	4.8	872.8
kg/ha	26	3	6.1	4	12	23	45	3	.9	2	.17	-	.44	1.5	110	17	.14		
meq/m^2	110	7	31	29	24	47	128	20	-	9	1.3	-	1.4	4.5	-	35	14		

1. Concentration in milligrams/litre.
2. Loading rate in kilogram/hectare.
3. Loading rate in milliequivalents per sq. metre.
4. Total precipitation that fell and used to calculate loading not used in weighting concentrations due to missing data.
5. Number of samples.

are therefore noted as excess SO_4. As a result excess SO_4 concentrations range from 66 meq/m^2 yr at Indian Brook to 70 meq/m^2 yr at the Airport. These rates are elevated above the background values in Cape Breton of 44.4, 47.1, and 34.7 meq/m^2 yr at Port Hood, Louisbourg, and Wreck Cove, respectively (Underwood, 1981). In addition, it reverses the provincewide trend of declining values from the southwest (i.e., 51.8 meq/m^2 yr at Bridgetown) to the northeast.

Areal variability in excess SO_4 concentrations indicate that the mean annual Airport concentration is 139% higher than Indian Brook. However, the increased precipitation at the latter, decreases this value to only a 106% increase in loading.

Seasonally, both Indian Brook and the Airport indicate higher excess SO concentrations in the summer than the winter by 142% and 140%, respectively. This reverses the pH trend and contradicts what would have been expected due to the burning of fossil fuels.

However, the increased precipitation received during the winter months causes loading rates of excess SO_4 to reverse this trend. They are higher in winter by 135% at the Airport and 148% at Indian Brook.

4.7.1.3 Nitrate

Average annual concentrations of nitrate (NO_3) in the range of 0.2-0.3 mg/L were noted at both sites (Table 4-2). The resultant loading rates are in the order of 25-29 meq/m^2 yr. These are constantly elevated above background values for Cape Breton Island at 7.41, 14.9, and 12.9 meq/m^2 yr for Wreck Cove, Louisbourg, and Port Hood, respectively (Underwood, 1981). Further, these equal and exceed the highest (15-25 meq/m^2 yr) background values for the province in the southwestern sector (Underwood, 1981).

The seasonal data (Table 4-3) show no trends at either station. This is to be expected as a majority of NO_2 emissions come from transportation which would not be expected to vary seasonally (Underwood, 1981).

4.7.1.4 Buffering

The above data indicate that NO_3 and excess SO_4 concenterations have been significantly elevated above background values. However, the resultant potentially very acidic rain is being buffered so that the H+ deposition, although elevated, is in the range expected from provincewide trends. This relationship indicates dust entrainment as air masses pass over the province on northeast storm tracks, rather than washout in controlling H+ deposition. Underwood (1981) also recognized this possibility, a hypothesis which is further supported by data from the Sydney Coalfield where Ca and Mg deposition is 50 and 40 meq/m^2 yr at Indian Brook and 94 and 30 meq/m^2 yr at the Airport. Further, the concentrations are higher in summer than winter (Table 4-3) when dustier conditions prevail and when excess SO_4 concentrations are higher. Buffering is further enhanced by summer increases in alkalinity at both sites (Table 4-3).

The increases in Ca, Mg and HCO_3 result from the bedrock geology in the coalfield. This would not only include the limestones, gypsums, and limy shales of the Windsor Group, but also the carbonate cemented clastic sediments of the Morien Group. The incorporation of the bedrock into overlying tills could provide a widespread source of dust for entrainment into the local atmopshere especially as it is the windiest area in the Maritimes. Another source of Ca and Mg is the steel plant's use of limestone and dolomite in the blast furnaces.

4.8 Long Term Trends

There are two significant long-term climatic trends in evidence within the coalfield.

4.8.1 Precipitation

In the Atlantaic region there has been a slow, fairly uniform trend toward more precipitation over the past 35 years (Thomas, 1975). Specifically, using total annual precipitation recorded at the Sydney Airport, the decadal means centered in the mid 1970's, (1460 mm), are more than 150 mm higher than the decadal means of the mid 1950's, (1300 mm).

Correlations of the running decadal means in total precipitation for each month with the annual total precipitation indicated that the increased precipitation was occurring in the months of December, October, and November (r's = .93, .84, and .82 respectively).

Of special note is the initiation of this rise in the early to mid 1950's. This corresponds closely with data by Munn (1973), where it was noted that since 1953 there has been a significant increase in the number of hours of reported haze at synoptic observation stations in the Atlantic Provinces which is mainly associated with south to southwest winds.

Due to the decrease in particulate emissions in eastern North America during this period, the suggestion is made that the increase in haziness is due to increasing photochemical activity resulting from greater emissions of gases such as hydrocarbons and NO_x from sources throughout Northeastern North America. Interestingly, the increases come during May to October.

4.8.2 Air Temperature

Running decadal means of mean annual air temperature at Sydney Airport from mid 1940's to mid 1970's indicate that a decline commenced again in the mid 1950's (8.6^{o}C) reaching its lowest value (7.2^{o}C) in the early 1970's. There has been a slight rise so that by the mid 1970's the decadal average is 7.3^{o}C. This corresponds to the decline found by Thomas (1975) in the Maritimes, although the rate is somewhat less than that in Ontario and Quebec.

CHAPTER 5

GROUNDWATER HYDROLOGY

5.1 Methodology

To define major hydrostratigraphic units within the study area a number of data sources were analyzed in addition to the geological data previously discussed. Over 1100 domestic wells were located in the field. Twenty-six pump tests and thirty geotechnical studies were reviewed. Water samples were collected from over 100 wells and springs (representative analysis given in Appendix 2). Six test holes were drilled and pump tested within the most important Lower Morien hydrostratigraphic unit.

5.2 Groundwater Quantity and Quality

5.2.1 Lower Morien Hydrostratigraphic Unit

This unit comprises both the Lonchopteris and Linopteris Oblique paleostratigraphic zones of the Morien Group. As such, it is primarily a massive fine to medium-grained sandstone with minor lenticular beds of shale and siltstones and thin continuous carbonaceous seams. As a result of folding and rock competence, discontinuities are relatively frequent, open, well developed, and inter-connected.

Forty-five packer tests in this sandstone unit immediately south of Kilkenny Lake from 1-45 m below rock surface indicated a hydraulic conductivity of 1.0×10^{-4} to 5.0×10^{-4} cm/sec.

There is one known significant exception where the sandstone becomes of minor importance. This area is located in a zone stratigraphically immediately adjacent to and including the Gardiner Coal Seam. In this zone, massive mudstones, shales, siltstones, and coal predominate. Ten slug tests within this zone in the vicinity of Gardiner Mines indicate hydraulic conductivities of 7.2×10^{-4} to 7.1×10^{-6} cm/sec.

In an effort to assess the vertical and areal extent of fracturing, 645 domestic well records were analyzed.

This information indicated a slight trend of declining specific capacity with depth. However, when the data derived from the more accurate pump testing, especially of deeper wells were added, the relationship broke down. Specific capacities in the range of 1-100 L/min/m can be expected at depths of at least 108m and saturated thicknesses of 73m. The absence of such a trend is thought to be related to fracturing being a function of folding associated with compressional forces and differential subsidence rather than expansion from erosional unloading.

Field observations and geotechnical studies indicate a thin, highly-fractured weathered zone at the bedrock surface generally less than 5 m thick. This is thought to be a function of glacial movement. High yields have been encountered in this zone by water well drillers.

To determine the potential of this aquifer to act as a water resource, the domestic records were initially assessed in terms of yield. Table 5-1 indicates that 98% of the wells encountered yields greater than 14 L/min. and 90% of the wells had greater than 23 L/min., a range required for a normal household. Therefore, the unit has excellent potential for supplying domestic yields.

Table 5-1 further suggests that only 10% of wells drilled encountered yield in excess of 90 L/min. This is however not representative, since the driller was only looking for 9-23 L/min., further penetration ceased after that yield or anything greater was encountered.

To assess the potential for obtaining large yields, the records of nineteen constant rate pump tests were assessed (Table 5-2). The pumping rates reflect constraints imposed by hole diameter and volume required; they do not, as a result, necessarily imply the maximum yield obtainable from the aquifer. The data set primarily assesses total well depths of 43-113 m with saturated thickness of 29-90 m. The pumping rates varied over the nineteen tests from 227 L/min. to 1173 L/min. and were generally run for 72 hours at a constant rate. Given the physical

Table 5-1

DOMESTIC WELL YIELDS

% of Wells Drilled Greater Than Stated Value

Hydrostratigraphic Unit	No. of Wells	9 L /min.	23 L /min.	46 L /min.	91L /min.	182L /min.	273L /min.
Lower Morien	645	98%	85%	40%	10%	3%	3%
Upper Morien	112	98%	90%	40%	9%	2%	
Canso	20	98%	80%	45%	n/a*		
Upper Windsor	381	98%	80%	30%	8%	2%	1%
Lower Windsor	26	95%	75%	40%	1%	n/a*	

*not achieved

nature of the aquifer, most drawdown data shows a number of varying slopes; the resultant range in transmissivities is given for each test. The transmissivity of the aquifer over the initial 30-90 m of saturated thickness ranges generally from 1.4 to $14.4X10^{-4}$ m^2/s. There are three notable exceptions: Glace Bay Work Camp ($2.6X10^{-5} m^2/s$), and Haak Industries ($1.9X10^{-5} m^2/s$), and Sydney airport ($9.8X10^{-5} m^2/s$). These wells encountered massive sequences of argillaceous sediments with minor sandstone.

To further assess the unit's potential, six test wells were drilled at four locations: Jacksonville (UTM 100 190), Sydney (UTM 205 060), New Waterford (UTM 215 240), and Port Morien (UTM 404 152). Test sites were selected based upon: proximity to fold axes, predominance of massive sandstones, areas where no large yield pump tests had previously been undertaken, spatial extent over the aquifer, and proximity to communities requiring a new water supply or augmentation of existing sources.

Four 72-hour pump tests were carried out on these wells at three of the locations. The results are summarized in Table 5-3. The assessment of the aquifer's potential at Jacksonville, New Waterford and Sydney was constrained by hole diameter. At these locations the well depth was expected to be 122 m; however, so much water was encountered by 90-107 m that the hammer on the drilling rig became inoperative. The 150 mm diameter restricted the pump size and therefore pumping rate to 910 L/min.; this restricted the total saturated thickness which could be utilized.

The testing indicated values within the previously defined range of transmissivities except at the New Waterford site where values of $4.3X10^{-3}$ and $6.0X10^{-3}$ m^2/s were encountered. Storage coefficients were remarkably similar at $2X10^{-4}$ and $5X10^{-4}$.

To assess the water chemistry of this unit a total of fifty-eight analyses were taken from wells ranging in depth from 10 to 119 m; 80% were less than 46 m.

The data indicate that the unit may be defined as having a fresh (TDS; 51-244 mg/L), soft to moderately hard (hardness: 10-160 mg/L), corrosive, predominately Ca-HCO_3 type water (Figure 5-1). The pH ranges from 6.2-8.1, although it generally lies between 7.0-8.0. Total organic carbon ranges from 1-10 mg/L. Of the 19 metals monitored, only iron (<.02-8.3 mg/L), manganese (<.01-6.6 mg/L), copper (<.01-.25 mg/L), zinc (<.005-2.4 mg/L), and barium (.02-.33 mg/L) frequently appear above the detectable limit.

There are two variations noted in Figure 5-1. One is a mixed Na/Ca-Cl/HCO_3 type water, probably resulting from a mixing of Na-Cl type precipitation with the Ca-HCO_3 type groundwaters. The second is toward a Na-HCO_3 type water. The presence of shale/mudstone units in these wells and associated decline in hardness is believed to be a result of natural softening occurring in the argillaceous sediments.

Investigation of pH and TDS values with total well depth indicate a general increase with depth; however, considerable scatter appears at shallow depths, (i.e., 0-50 m).

TABLE 5-2 RESULTS OF 72-HOUR PUMPING TESTS CONDUCTED IN THE SYDNEY COALFIELD

Location	Hydrostratigraphic Unit	Well Depth (m)	Saturated thickness (m)	Pumping Rate L/min.	Transmiss-ivity m^2/s	Storage Coefficient
N.S. Eastern Institute of Technology	Lower Morien	74.7	61.9	1137	$2.97X10^{-4}$	-
"	Lower Morien	77.7	64.7	490	$4.88X10^{-4}$	-
Car Rail Transport Centre	Lower Morien	63.1	60.4	482	$7.67X10^{-4}$	-
Sydney River Elementary School	Lower Morien	50.3	40.5	284	$2.16X10^{-4}$	$1.7X10^{-4}$
Mayflower Mall	Lower Morien	45.7	32.3	227	$6.89X10^{-4}$	$1.0X10^{-5}$
"	Lower Morien	68.3	54.6	227	$4.61X10^{-4}$	$9.7X10^{-5}$
C.B. County Correctional Centre	Lower Morien	106.7	86.0	250	$5.22X10^{-4}$	-
NSPC Lingan 15 cm well	Lower Morien	73.2	60.4	896	$4.89X10^{-4}$	-
Maritime Trailer Sales	Lower Morien	54.9	45.7	90	$3.52X10^{-4}$	-
Donkin Mine Site Temporary Well	Lower Morien	62.4	49.4	227	$1.89X10^{-4}$*	$5.9X10^{-4}$
Glace Bay Work Camp	Lower Morien	73.1	48.8	105	$2.55X10^{-5}$*	-

TABLE 5-2 RESULTS OF 72-HOUR PUMPING TESTS CONDUCTED IN THE SYDNEY COALFIELD (Cont'd)

Location	Hydrostratigraphic Unit	Well Depth (m)	Saturated thickness (m)	Pumping Rate L/min.	Transmiss-ivity m^2/s	Storage Coefficient
Selminco Well New Waterford	Lower Morien	86.6	72.5	1050	$1.25X10^{-3}$*	$1.7X10^{-2}$
NSPC Dust Control Well	Lower Morien	103.9	86.6	1136	$6.33X10^{-4}$*	$5.3X10^{-3}$
Kyte's Hill Sub-division Well	Lower Morien	41.1	31.7	136	$1.73X10^{-4}$*	$1.5X10^{-3}$
Haak Well	Lower Morien	110.9	85.1	68	$1.94X10^{-5}$*	-
Prince Mine Well	Upper Morien	38.1	23.5	136	$9.12X10^{-5}$*	-
N.S. Housing Comm-ission Port Morien	Upper Morien	56.4	43.0	68	$2.88X10^{-5}$	-
MacCullough's Well	Upper Windsor	56.4	36.6	200	$1.22X10^{-4}$	-
Westmount Subdiv-ision	Upper Windsor	43.3	33.5	91	$7.62X10^{-5}$	-
Senior Citizen Home, Westmount	Upper Windsor	43.6	37.5	118	$5.68X10^{-5}$	-
Point Edward In-dustrial Park	Upper Windsor	61.0	57.9	159	$4.21X10^{-5}$	-
Tim Horton's Res-tuarant, King's Rd.	Upper Windsor	50.0	36.3	36	$2.76X10^{-5}$	-

* Denotes Average Transmissivity

TABLE 5-3

SUMMARY OF TEST DRILLING/PUMP TESTING
PROGRAM - LOWER MORIEN HYDROSTRATIGRAPHIC UNIT

Location	Well Depth (m)	Casing (m)	Saturated Thickness (m)	Pumping Rate L/m	Drawdown (m)	Trans-missivity m^2/s	Storage Coefficient	Well Log
New Waterford West	104.6	6.1	87.1	909	8.3	$4.31X10^{-3}$	$4.5X10^{-4}$	0-3m OB,3m-104.6m grey medium grained sst with thin interbedded shale and coal
New Waterford East	103	6.4	89.4	1137	5.8	$6.04X10^{-3}$	$2.0X10^{-4}$	0-5.5m OB, 5.5m-103m grey and red, fine to medium grained sst, thin interbedded black shale and coal
Sydney	100.6	6.1	94.5	909	10.1	$8.20X10^{-4}$	-	
Jacksonville	89	6.7	69.4	909	16.9	$1.01X10^{-3}$	$5.4X10^{-4}$	0-1.5m OB; 1.5m-89m grey fine to medium sst; with thin interbedded shale and coal

Figure 5—1 HYDROGEOCHEMISTRY—LOWER MORIEN HYDRO-STRATIGRAPHIC UNIT

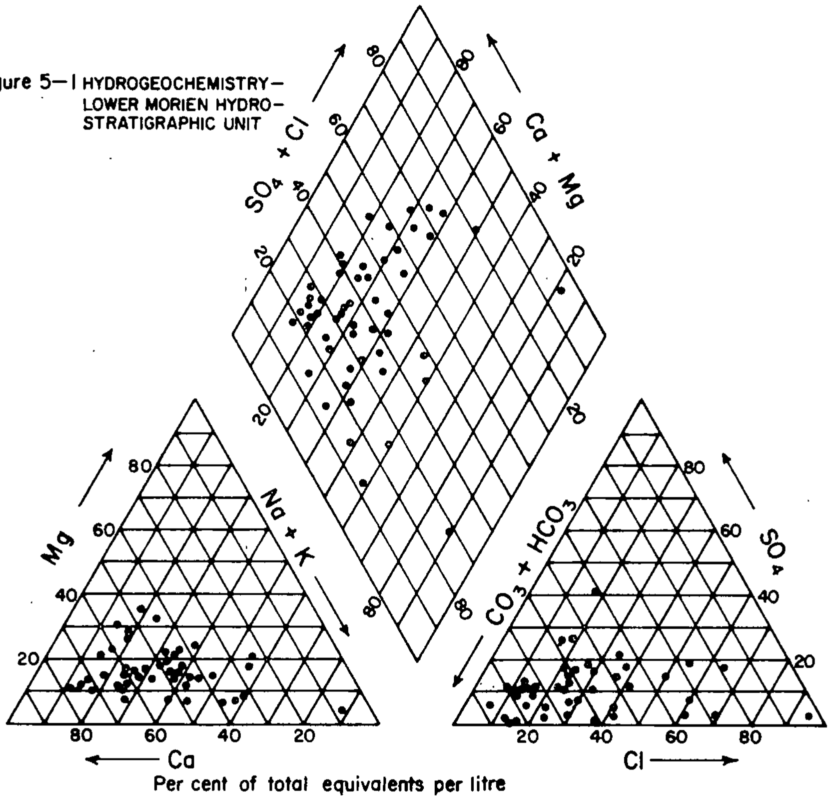
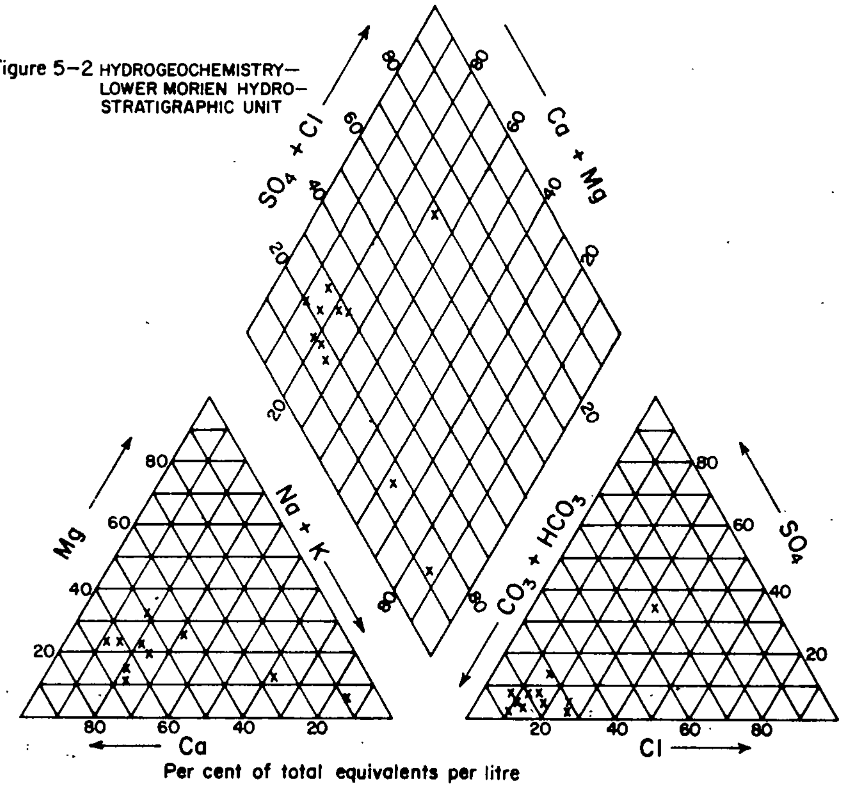


Figure 5—2 HYDROGEOCHEMISTRY—LOWER MORIEN HYDRO-STRATIGRAPHIC UNIT



Comparison with Canadian drinking water quality guidelines indicates that only iron and manganese sporadically exceed the maximum permissible limits.

Given the data on the physical and chemical nature of this aquifer, it is classified as a CLASS 1 Aquifer as delineated by the Nova Scotia Department of the Environment Report on "Groundwater Protection Guidelines in Nova Scotia" prepared by Shawinigan Engineering (1980).

5.2.2 Upper Morien Hydrostratigraphic Unit

This unit comprises the Ptychocarpus Unitus paleostratigraphic zone of the Morien Group. Available geological data indicate the unit is primarily comprised of argillaceous sediments and thick coal seams. Sandstone units are present, however they generally meander and pinch out locally. Due to the relative incompetence of the argillaceous facies, the discontinuities are open but tight, and not well-interconnected.

Packer tests in the Lingan, Gardiner Mines, and the Donkin area in this unit indicate that: (1) the siltstone, shale, mudstone units are characterized by hydraulic conductivities in the range of $3.4X10^{-6}$ to $4.2X10^{-7}$ cm/sec (2) the coal seams range in the order of $1.6X10^{-5}$ to $4.1X10^{-7}$ cm/sec and (3) the sandstone units are $1.0X10^{-3}$ to $1.0X10^{-5}$ cm/sec.

Statistical analysis of 112 domestic well log records indicated a reduction in specific capacity with depth and saturated thickness. The limited pump test data seem to modify this trend in a manner similar to the Lower Morien unit.

Well productivity data produced from the same domestic well data set indicate a similar percentage of low productivities as in the Lower Morien unit. In upland areas this unit shows a slightly higher productivity possibly resulting from the presence of more permeable and resistant sandstone underlying the topographic highs.

The potential of this aquifer to act as a water resource was partially identified by assessing yield data from the 112 domestic well records. The data in Table 5-1 reveal that with 90% of the wells drilled equalling or exceeding 23 L/min., the aquifer, even given the low permeabilities, still has excellent supply potential for domestic purposes.

The pump test data (Table 5-2) indicate that the unit is characterized by transmissivities in the order of $1.4\text{-}14.4 \times 10^{-5} m^2/s$. This is further confirmed by four pump tests carried out at varying intervals stratigraphically adjacent to the Sydney Main Coal Seam at Point Aconi. These tests indicated transmissivities ranging from 0.8×10^{-7} to $2.2 \times 10^{-4} m^2/s$ for mixed mudstones, shales, and siltstones and 1.0×10^{-5} to $5.3 \times 10^{-5} m^2/s$ for the coal seam.

To assess the water chemistry of this unit, a total of eleven samples were collected from wells ranging in depth from 11-62.5 m. The analyses indicated that the unit could be characterized as having a fresh (TDS: 150-250 mg/L), moderately hard to hard (hardness: 90-220 mg/L), corrosive, predominately $Ca\text{-}HCO_3$ type water which exhibits a pH range from 7 to 7.8. Total organic carbon is in low concentrations ranging from 1 to 4 mg/L. Of the nineteen metals monitored, only three frequently appear above detectable levels; namely, iron (<.02-1.0 mg/L), manganese (<.1-2.4 mg/L) and barium (.06-.25 mg/L). In addition, TDS and pH appear to increase with depth, as such, the unit exhibits similar chemistry to the Lower Morien unit.

There are two other recognizable trends in water typing. The $Na/Ca\text{-}Cl/HCO_3$ type water is believed to result from mixing with recharged Na-Cl type precipitation (see Figure 5-2). The $Na\text{-}HCO_3$ type water is expected to result from natural softening. Due to the high percentage of argillaceous sediments in this unit, it can be expected that this trend will be more predominate than in the Lower Morien unit.

It was initially suspected that due to the pyrite associated with the coal and mudstone/shale units, acid groundwaters would prevail in this unit. However, such was not the case. The alkaline pH's result from

$Ca(HCO_3)_2$ cementing, thin interbedded limestone beds and high static water levels which prohibit oxidation. The latter may prove to be the most important, as a sample of a spring discharging from the coal seam in a de-watered zone near the base of a coastal cliff revealed a pH of 2.7.

Comparison with Canadian drinking water quality criteria indicates that only iron and manganese usually exceed the maximum permissible limits. Hydrogen sulfide gas has also been noted in a number of areas.

This aquifer is classified as a CLASS II Aquifer as delineated by the Nova Scotia Department of the Environment (Shawinigan Engineering, 1980).

5.2.3 Canso Hydrostratigraphic Unit

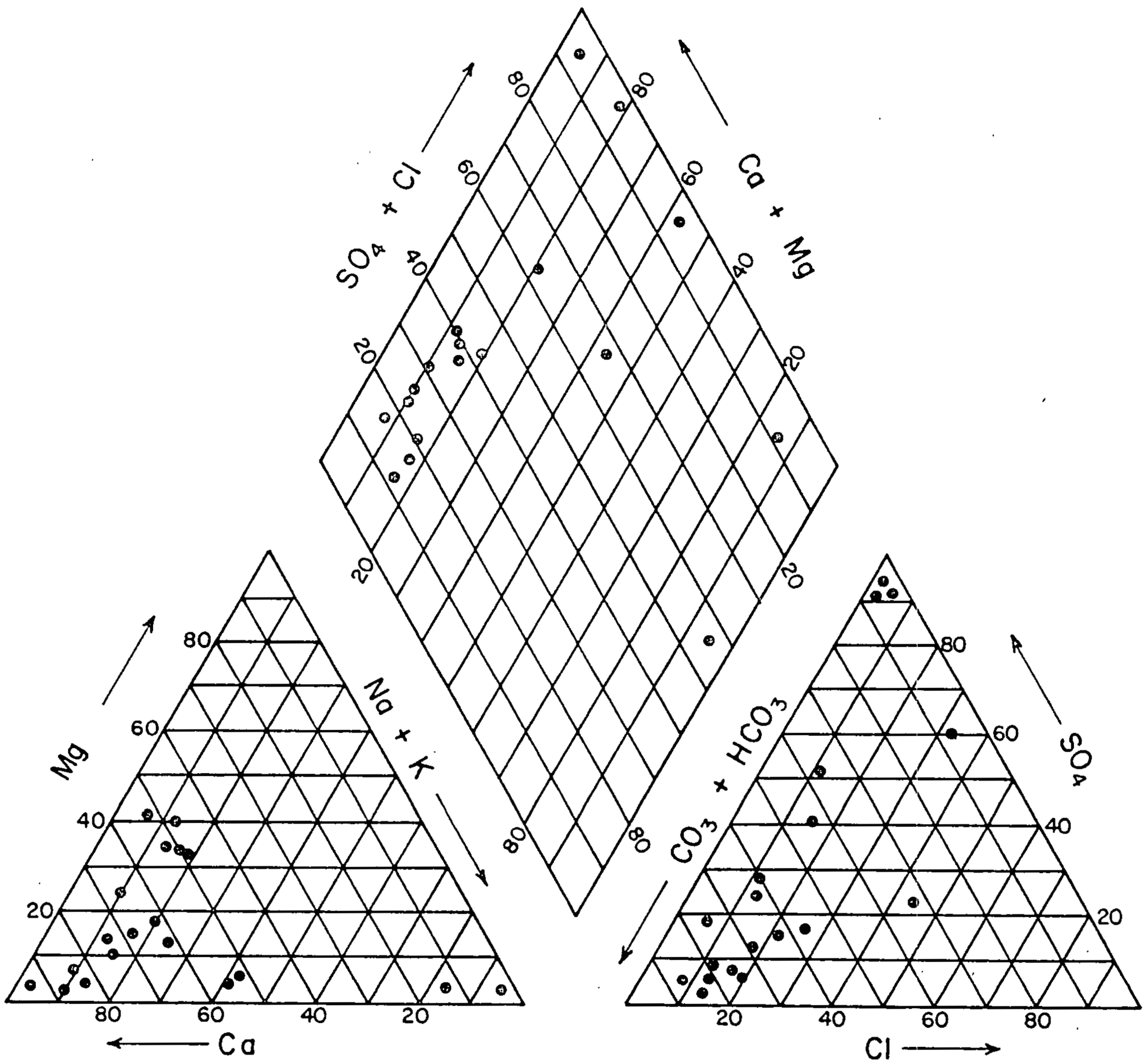
This unit comprises the Canso bedrock group. A summary of available geological data indicates that the unit is primarily comprised of argillaceous sediments. Utilizing yield data from 20 domestic wells drilled into this unit, 80% of the wells drilled encountered greater than 23 L/min. It appears that the unit will yield enough water for domestic supplies. Water quality data for this unit are lacking at the present time.

5.2.4 Upper Windsor Hydrostratigraphic Unit

This unit is defined as encompassing the Central marine basin beds of the Windsor bedrock group. In summary, it comprises interbedded shale/mudstone facies and, depending upon the area, either major limestone and/or evaporite facies.

Structurally, the limestone beds are competent units with generally open, interconnected jointing. The other units are relatively incompetent with associated tight, localized fracturing. Karst topography has been noted associated with the basal Windsor limestone.

Figure 5-3 HYDROGEOCHEMISTRY—UPPER WINDSOR HYDROSTRATIGRAPHIC UNIT



Per cent of total equivalents per litre

Statistical analysis of 381 domestic well records indicates that there is no recognized trend between yield and depth of overburden over a range of 0-44 m of overburden. However, there appears a possible slight trend to decreasing specific capacity with depth as with other units.

Productivity data for upland and lowland areas show rates similar to the Morien Group. Further, there appears a definite trend of uplands being more productive than lowland areas. This is expected given the fact that topography is function of bedrock competence. Therefore, limestone units form the upland areas. The jointing pattern is expected to give a higher permeability and therefore better productivity. Although the limestone units could be encountered at depth under the lowland areas, the greater resultant saturated thickness would reduce the productivity (productivity is measured in L/min./m).

The data from the 381 wells examined indicate that 80% encountered yields greater than 23 L/min. (Table 5-1). Therefore, the unit exhibits excellent potential for supplying domestic needs.

To assess the potential for obtaining large yields, the records of five constant-rate pumping tests were assessed. The wells were drilled principally for commercial purposes. The data set indicates total well depths of 43-61m with saturated thicknesses of 33.5-37.5 m. The transmissivity of the aquifer generally ranges from 1.4 to $14.4X10^{-5} m^2/s$ (Table 5-2).

To determine the hydrogeochemistry of this unit a total of 19 analyses were taken from wells ranging in depth from 9-50 m.

The sampling program indicated that this unit is characterized by a fresh (TDS: 77-370 mg/L), moderately hard to hard (hardness: 73-310 mg/L), corrosive, predominately Ca-HCO_3 type water (Figure 5-3) which exhibits a pH range from 6.5-8.0. Total organic carbon is generally less than 5 mg/L. Of the nineteen metals monitored, iron (<.02-1.0), manganese (<.01-.06 mg/L), copper (<.005-.06 mg/L), zinc (<.01-.19 mg/L), boron (.02-.15 mg/L) and barium (.01-.39 mg/L) are frequently above the detectable limits.

There are strong secondary trends (Figure 5-3) toward $Ca-SO_4$ and Na-Cl type waters. Generally, it is expected that these trends result from interbedded, evaporite deposits within the unit.

This unit is ranked as a CLASS II Aquifer as delineated by the Nova Scotia Department of the Environment (Shawinigan Engineering, 1980).

5.2.5 Lower Windsor Hydrostratigraphic Unit

This unit comprises the Grantmire Formation of the Windsor Group.

Available geological data indicate the unit is comprised of sandstone, conglomerate facies. Very little is known regarding the extent, degree, and orientation of the discontinuities.

From twenty-six domestic well log records, 75% of the wells had yields in excess of 23 L/m (Table 5-1) Therefore, the limited data set indicates that the unit is acceptable from a domestic water supply standpoint.

There is no existing water quality information for this unit.

5.2.6. Basement Complex Hydrostratigraphic Unit

This unit is designed to encompass all igneous and metamorphic rocks of the basement complex.

At present data on water quantity or quality are not available for this unit within the study area.

5.2.7 Basal Till Hydrostratigraphic Unit

This unit comprises the basal till developed over the bedrock units. Given the complexities in texture, the permeabilities can be expected to vary widely. Further, very little data are available since the unit is very rarely utilized as a water supply.

The sand silt to silty sand basal till which has the largest areal extent within the study area can be expected to exhibit permeabilities in the range of $1.0X10^{-6}$ to $1.0X10^{-7}$ cm/sec. as derived from grain size analyses and insitu field testing.

The reddish brown clayey silt till from grain size analyses has permeabilities in the range of $1.0X10^{-7}$ to $1.0X10^{-9}$ cm/sec. Even with these low values, dug wells have developed in this unit due to the frequent occurrence of poor quality in the underlying Upper Windsor Hydrostratigraphic Unit.

With respect to water quality only three samples are available for this unit from wells 4.6 - 6.1 m deep. The data indicate the unit can be characterized as having a fresh (TDS: 106-632 mg/L) soft to very hard (hardness: 64-437 mg/L), corrosive, Ca-HCO_3/SO_4 type water, exhibiting a pH range of 7.4-7.9. Total organic carbon concentrations are less than 5 mg/L. Of the nineteen metals monitored, only barium (.07-.17 mg/L), iron (.03-.55 mg/L), manganese (.01-.17 mg/L) and zinc (.01-.26 mg/L) frequently appear above detectable limits.

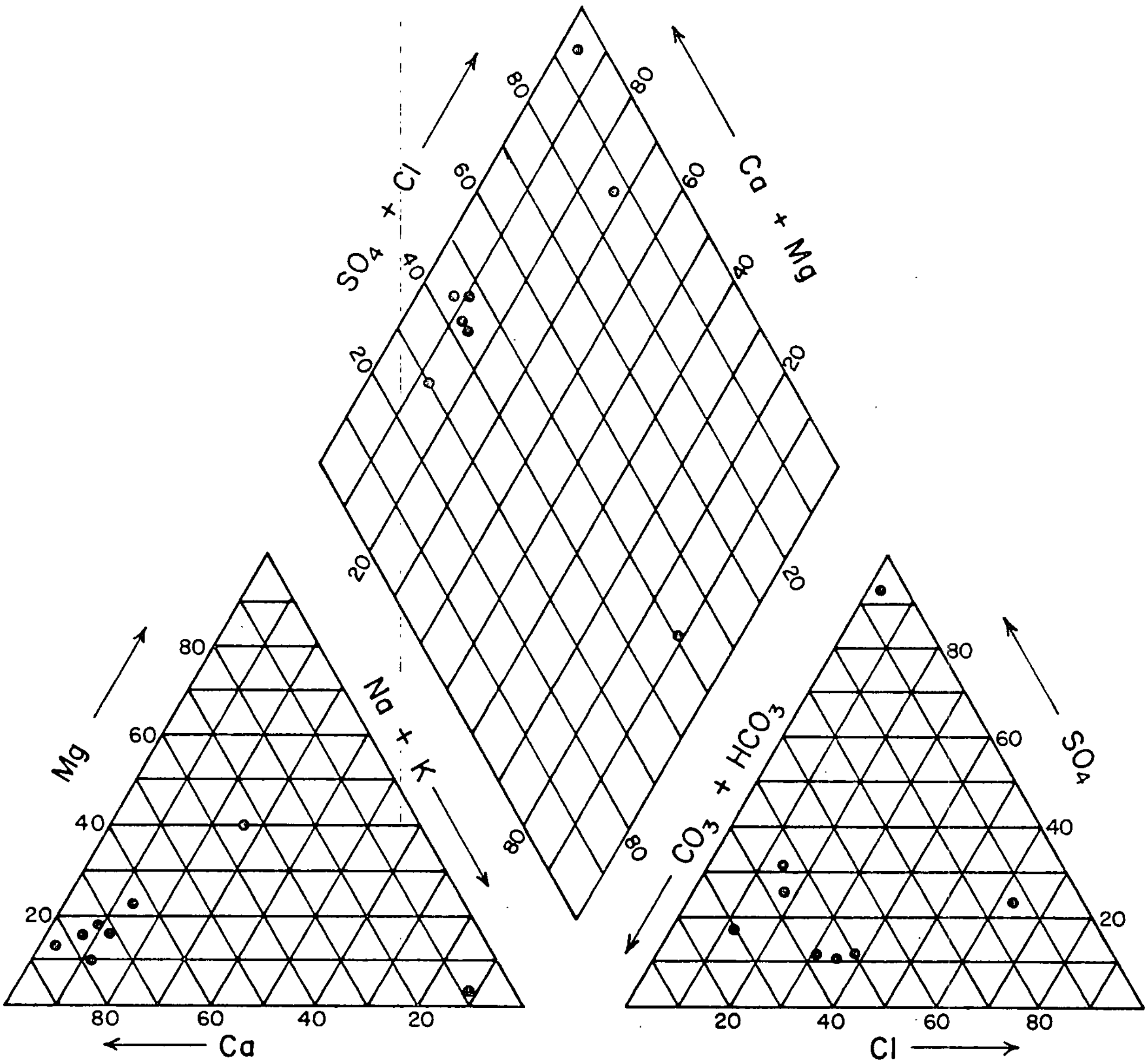
The chemistry appears closely dependent upon the presence of gypsum boulders in the till or in the vicinity of the well and on the well construction which could allow interflow movement to enter and mix with till water chemistry.

The limited data suggests a CLASS II-III Aquifer ranking as delineated by the Nova Scotia Department of the Environment (Shawinigan Engineering, 1980).

5.2.8 Sand & Gravel Hydrostratigraphic Unit

This unit comprises the outwash sand and gravels. Even though permeabilities can be expected to be high, the unit is rarely utilized by local drillers for water supply. The few wells that do bottom in this unit are constructed as open ended casing. The unit is usually cased off in favour of a bedrock well.

Figure 5-4 HYDROGEOCHEMISTRY-SYDNEY RIVER OUTWASH GRAVEL



Per cent of total equivalents per litre

To determine hydrogeochemistry of this aquifer a total of eight samples were collected from wells bottoming in this surficial unit at depths between 1.2 and 32m. The data indicate a fresh to brackish (TDS:213-1,447 mg/L), soft to very hard (hardness: 21-1,700 mg/L), corrosive, Ca-HCO_3/SO_4 type water. It exhibits a pH range of 7.0-8.5. The shallow (1.2 m) well exhibited a low pH of 5.8, indicative of precipitation (See Figure 5-4).

With the positioning of this unit over the groundwater discharge zone of the Sydney River Valley, it can be expected that wells bottoming closer to the bedrock contact would resemble chemistry indicative of the underlying bedrock unit. Since a number of the wells are along the valley slope where the Windsor/Morien contact lies and since evaporite beds, especially one gypsum unit, are interbedded throughout the Windsor Group in this region, chemistries can be expected to be complicated.

CHAPTER 6

SURFACE WATER HYDROLOGY

6.1 Regional Hydrology

The Drainage within the study area (Figure 6-1) can be classified into three components: namely, drainage into 1) the saline environment of the Atlantic Ocean, 2) the brackish waters of the Bras d'Or Lakes and 3) the estuarine-brackish waters of the Mira River. Of these, the ocean is the dominant direct receptor of land drainage.

Numbering of the major watersheds subsequently referred to in the text is based upon Nova Scotia Department of the Environment mapping (1:50,000 scale) and is noted in Table 6-1.

6.2 Drainage Basin and Channel Morphology

The most notable characteristic of the drainage basins within the study area is their relatively small size. The largest is the Sydney River System at 191 km^2. Table 6.1 indicates that the remaining larger basins are in the 10 to 80 km^2 range. The areas adjacent to the coast contain numerous smaller basins which are less than 10 km^2.

This reduced size is the result of two processes:

1) Large, consequent rivers developed on the uplifted, tilted Atlantic upland in pre-Tertiary times must have drained downslope toward the present day southeast. However, due to later subaerial erosion, the basement complex created high northeast trending promontories which transected these drainages at nearly right angles; thereby breaking the large basins down into a series of smaller basins.
2) Immediately after recession of the last ice sheet, existing drainage systems would have extended far to the northeast past present day coastlines due to a much lower sea level. However, these systems have been submerged and eroded as a result of post-glacial sea-level rise over the past 10,000 years.

Figure 6-1 MAJOR WATERSHED DIVISIONS WITHIN STUDY AREA.

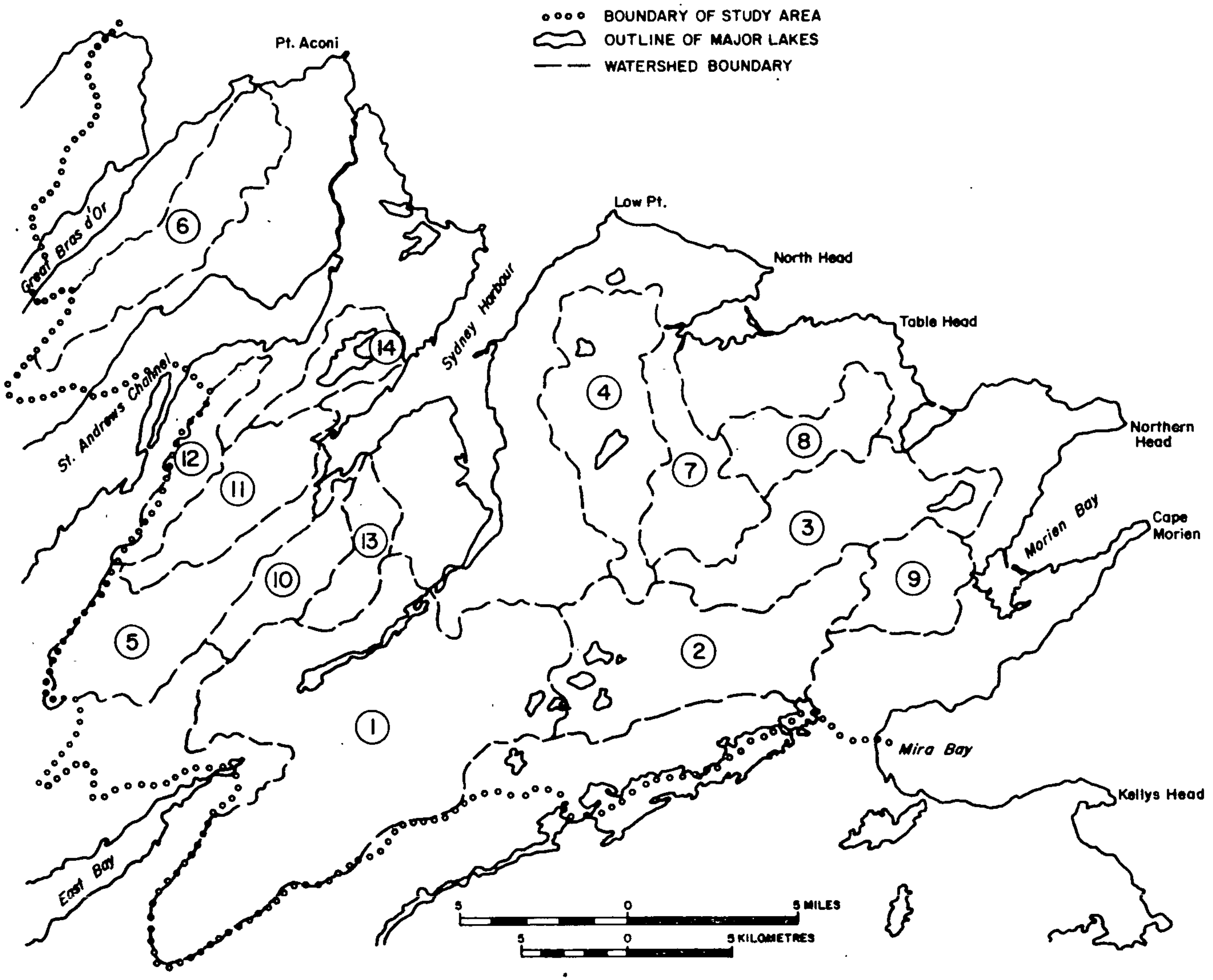


TABLE 6.1

MAJOR WATERSHEDS WITHIN THE STUDY AREA

	WATERSHED NAME	WATERSHED DESIGNATION	TOTAL AREA (hectares)	AREA COVERED BY LAKES hectares	(% of TOTAL)
1.	Sydney River	1FJ-10	19122	626	(3.3)
2.	Black Brook	1FJ-5B	7661	358	(4.7)
3.	McAskill Brook	1FJ-6	5677	224	(3.4)
4.	Northwest Brook	1FJ-9	5604	314	(5.6)
5.	Frenchvale Brook	1FJ-11	4870	54	(1.1)
6.	Point Aconi Brook	1FJ-SD93	4303	38	(.9)
7.	Southwest Brook	1FJ-8	3296	46	(1.4)
8.	Renwick Brook	1FJ-7	2489	0	(0)
9.	Black Brook	1FJ-SD31	2399	82	(3.4)
10.	Grantmire Brook	1FJ-SD52	2295	0	(0)
11.	Leitches Creek	1FJ-SD55	2259	190	(8.4)
12.	Georges River	1FJ-SD66	1796	42	(2.4)
13.	Watson Creek	1FJ-SD50	1774	0	(0)
14.	Smelt Brook	1FJ-12	1725	296	(17.2)

Note Figure 6.1 for location.

Therefore, what is present today are the remnant low order tributaries located in the headwaters of the once larger main rivers that flowed out to a receding sea during early post glacial times. As can be noted from Figure 6-1, most of the watersheds are orientated northeast - southwest thereby paralleling the regional northeasterly trending structural grain of the bedrock.

More in depth analysis of certain watersheds, i.e., Northwest and Southwest Brook in the Gardiner and Lingan areas (Nolan, Davais & Assoc. 1981) indicate a close link between the trend of the main tributary and strike of either the subcropping bedrock or the master joint set as it swings around the plunging Bridgeport anticlinal axis (Map 1). Such bedrock control is facilitated by the relatively shallow overburden. The resultant drainage pattern throughout the Carboniferous lowland is primarily trellised with a secondary dendritic component.

Most of the watersheds noted in Table 6-1 are developed over the Carboniferous rocks underlying the lowland plain. However, some of the major systems transect the steep transition slope and have their headwaters on the high relief of the basement complex.

Given that most of the study area population lives on the lowland plain, drainage basin/channel morphological analysis was restricted to those watersheds solely draining the Morien Group with its overlying sandy silt basal till. The morphology of these basins with data derived from the 1:15,840 scale data base maps is quantified in Table 6-2. A total of eleven basins were studied ranging over two orders of magnitude in drainage area from .38 to 76.6 km^2.

Drainage densities indicate that all watersheds are generally poorly drained. In addition the texture ratios are all low; thereby defining the overall density as coarse textured (Figure 6-2B). The values indicate good agreement with expected values (Strahler, 1957). These low values are believed to be a function of:

- the small watershed size which limits the volume of water moving through the basin.

- the generally long duration/low intensity character of precipitation.
- the generally high resistivity of the terrain to erosion due to the thin overburden, underlying sedimentary rock, vegetation cover and low gradients.

The low drainage density explains the relatively low Shreve stream order number for the main channel. However, even with the low numbers, the theoretical ratios of the length of the main channel to drainage area relationship still appear to be valid (Figure 6-2A).

Generally speaking all the watersheds exhibit a straight (sinuosity ratio 1.5) single channel system for water and sediment transport. The channels have high width/depth ratios when traversing the areas underlain by glacial till. These are reduced significantly in organic terrain.

It has been noted elsewhere (Dunne and Leopold, 1978) that under rural, non-urbanizing conditions in the Appalachian region of the eastern United States, stream channel dimensions at bankful flow are correlated closely with drainage area. This hypothesis was investigated in watersheds 1, 2, 3 (Table 6-2) (Nolan, Davis & Assoc. Ltd., 1981). The study indicated that for all channel parameters in each watershed, the actual field values were always significantly lower than predicted. Further study indicated that the coarse gravel cobble material forming the channel bed was in all likelihood a lag pavement derived from the underlying stony glacial till. This is prevalent in all the streams draining the Morien Group and restricts growth of the channel thereby accounting for the characteristic high width/depth ratios. Therefore, channel development proceeds as degradation through the soil profile until the parent material is encountered. The extent of downcutting in a local area depends upon how quickly the lag pavement sets up; i.e., the degree and size of stoniness of the till, the rate of flow, etc.

Due to the low topographic relief over the Morien Group, the longitudinal stream profiles are predominately low. However, very few reveal a normal concave upward profile near their mouths. The reason is due to the relatively rapid coastal erosion rates which appear to be greater than the rate of the stream's regime to reach an equilibrium

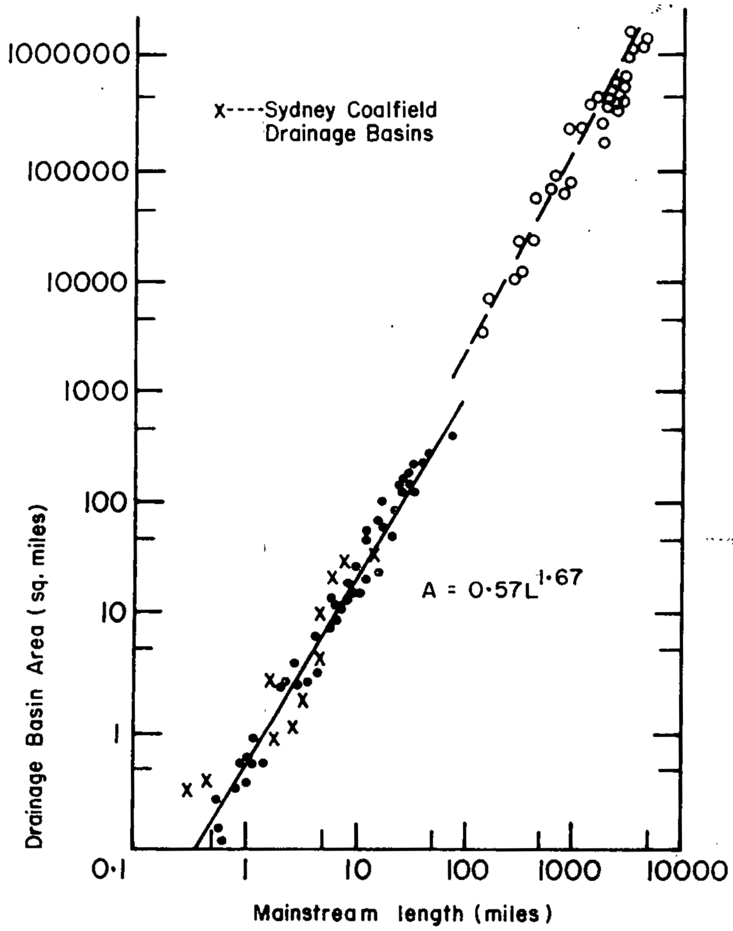


Figure 6-2A RELATIONSHIP OF DRAINAGE AREA TO MAINSTREAM LENGTH
(after Dunne and Leopold, 1978)

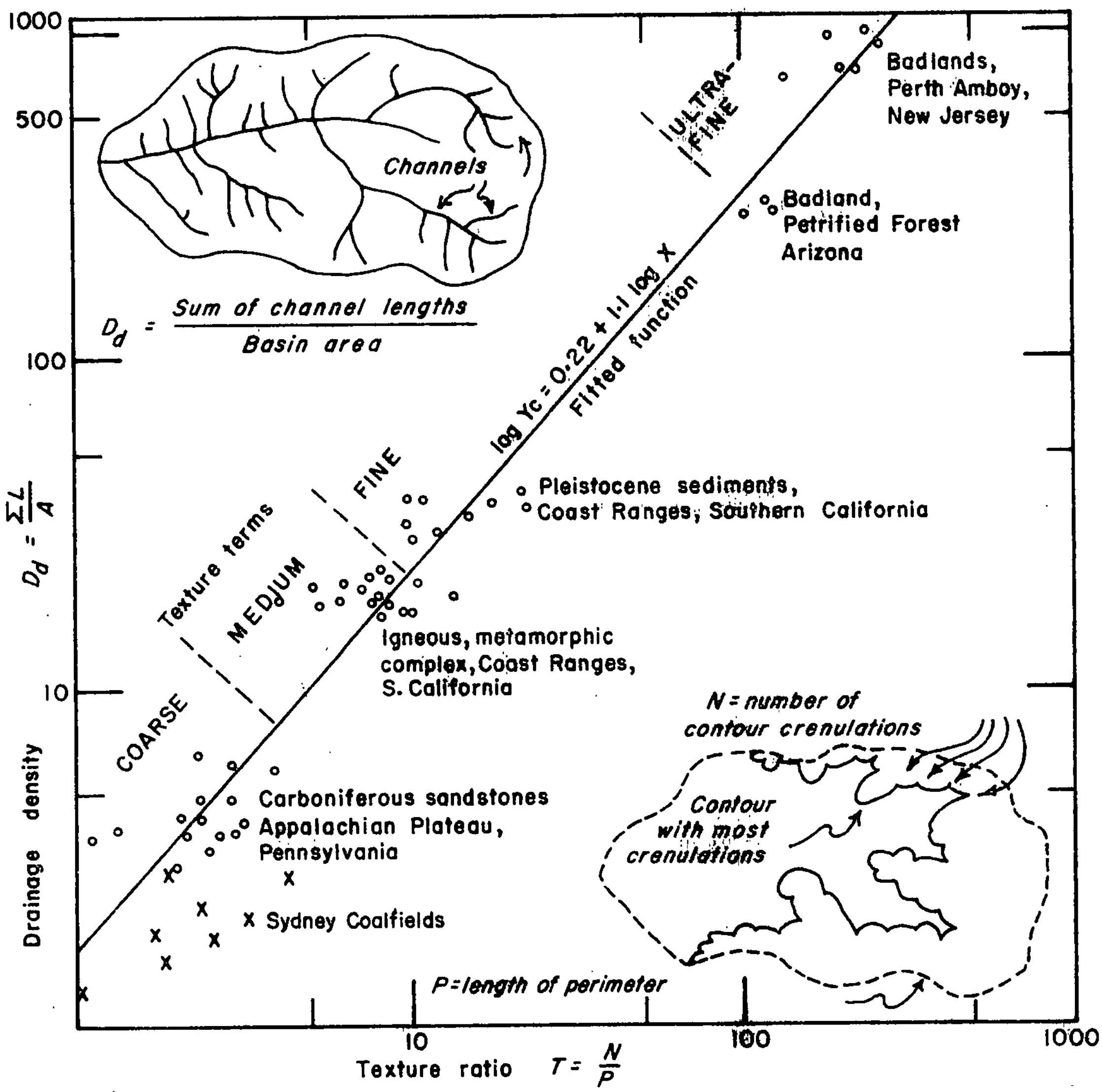


Figure 6–2B DRAINAGE DENSITY VERSUS TEXTURE RATIO (after Strahler, 1957)

TABLE 6-2

DRAINAGE BASIN MORPHOLOGY OF BASINS DRAINING THE MORIEN GROUP

WATERSHED	TOTAL WATERSHED TOTAL[1] AREA km^2	AREA OF LAKES km^2(%)	PERIMETER km	SHREVE STREAM NO. FOR MAIN STREAM AT MOUTH	MAIN[2] STREAM LENGTH	DRAINAGE DENSITY km	TEXTURE[3] RATIO km/km^2	RELIEF RATIO km^{-1}
Black Brook	76.6	2.8(4)	46.4	20	22.1	.72	1.4	
Point Aconi Brook	43.0	.38(1)	42.4	26	19.5	1.1	1.8	
Southwest Brook	33.0	.45(1.4)	33.4	26	15.1	1.3	2.3	
McAskill Brook (above gauge)	17.4	1.0(6)	21.2	8	8.8	0.9	1.3	
Lower Northwest Brook	11.9	0	20.6	7	8.2	1.1	1.0	0.008
Watershed 3	3.70	0	10.9	2	4.7			.014
Watershed 1	3.19	0	8.2	2	3.2			.018
Laffins Brook	2.70	0	7.9	2	2.1	0.78	1.14	0.05
Watershed 2	2.56	0	8.6	2	3.1			0.19
Graces Brook	1.21	0	4.4	1	0.86	0.72	1.36	0.09
Lingan Brook	.38	0	2.5	1	0.60	1.50	2.8	0.18

Note:
1. Area via planimeter on 1:15,840 scale; therefore projected rather than true area.
2. Stream lengths calculated directly from map; therefore, projected and not corrected for slope.
3. Calculated on 1:15,840 scale; does not include extension of channels into contour crenulations.

profile. Thus waterfalls and/or extremely steep slopes are ubiquitous along the coast.

This feature and the absence of a smooth profile are also a function of the presence of only the remnant low stream-order tributaries in which flows are not sufficient enough to erode a smooth profile through the lag pavement created by the till. This is expected to explain why the channels are straight and very little recent alluvium is mapped on the surficial geology map (Map 2).

6.3 Water Discharge

At the time of this study, no water discharge stations had been established within the coalfield. Analysis of surface water runoff within the study area had in the past relied on the long term records established at the Loch Lomond Station some 50 km to the southwest. However, this watershed is underlain primarily by granites and metamorphics with a large lake immediately upgradient of the gauge site. These conditions limited successful extrapolations to the lowland Carboniferous region within the study area where all surface water supplies are presently developed.

Therefore, in 1978 the Water Survey of Canada was requested by the Nova Scotia Department of the Environment as part of this study to install and maintain an automated water discharge gauging station on McAskill Brook (UTM 310 119) upgradient of the reservoir. This particular watershed was selected as it best represented the natural hydrological conditions exhibited throughout a large portion of the Sydney Coalfield, principally those areas underlain by the Morien Group. This thereby served as a reference watershed to investigate long term natural processes at work in the coalfield and facilitated extrapolations to other watersheds. The station commenced operations in March, 1978; records continue to present. Pertinent characteristics of the basin which govern generation and routing of surface flows are given in Table 6.3.

The data obtained from the station are summarized in Table 6-4. Seasonal trends are in evidence whereby peak flows are recorded in

March, April and May resulting from spring break-up. Summer recession continues usually until September. Fall rains, particularly in November and December, create the second period of peak discharges. This is followed by a decline through January, bottoming usually in February, due to the onset of the winter season. The mean annual runoff coefficient remains relatively constant averaging $m^3/sec{\cdot}km^2$.

Given the importance of low flows in: 1) the design of installations to allow surface water resources to be utilized as water supplies, 2) regulating withdrawal rates, 3) design of maintenance flows for fisheries protection, 4) dilution of waste streams, etc., the Water Planning and Management Branch of Environment Canada was requested to estimate extreme low flow conditions in McAskill Brook from available data. The results are given in Table 6-4 (after Smith, 1981). These estimates represent reasonable values for extreme low flows, short of undertaking a complex mathematical modelling study after more data have been collected. However, they could easily be in error by $\pm$ 30 percent.

6.4 Water Chemistry

Only infrequent, short duration spot sampling of water chemistry, was available within the study area. Therefore, a sampling program was initiated at the McAskill Brook gauging station. A total of 64 samples were collected between 1977 and 1980. The frequency was designed to obtain samples over the full range of discharges and to identify gross seasonal trends. Samples were collected over a range of discharges from 0.013 - 6.26 m^3/s. This range varies from the very low base flow to overbank flow.

Generally speaking, the data indicated a fresh (TDS 15 - 70 mg/L), soft (hardness (as $CaCo_3$) 1.0 - 16 mg/L), corrosive, Na/Ca - Cl/HCO_3 type water. The pH is acidic ranging from 4.0 to 7.1. Organic concentrations as delineated by total organic carbon vary widely from 5 to 30 mg/L. Nutrient concentrations are relatively low and consistent i.e. total PO_4 ranges from .02 to .10 mg/L.; Kjel Nitrogen ranges from 0.10 to 0.80 mg/L. Of the eighteen metals usually monitored for, only six appeared consistently above detectable limits including: aluminum (0.11 - 0.30 mg/L), barium (0.005 - 0.30 mg/L), copper (0.005 -

TABLE 6-3

PERTINENT DATA FOR GAUGED PORTION OF
McASKILL BROOK WATERSHED

. Total Drainage Area		$17.4\ km^2$	
. Perimeter		21.2 km	
. Area Covered By Lakes			
	McPherson Lake .3 km^2		
	Cusack Lake .3 km^2..........	0. 6. km^2	(4%)
. Bedrock Hydrostratigraphic Unit - Lower Morien H.U.		$17.4\ km^2$	(100%)
. Surficial Hydrostratigraphic Units			
	- basal sandy silt-silty sand till	$15.3\ km^2$	(88%)
	- organic terrain	$1.5\ km^2$	(8%)
	- recent lake sediment	$.6\ km^2$	(4%)
Pedology			
	Springhill	$11.9\ km^2$	(69%)
	Economy	$1.6\ km^2$	(9%)
	Shulie	$1.8\ km^2$	(10%)
. Vegetation	- hardwoods (76-100% hardwood)	$2.3\ km^2$	(13%)
	- mixedwoods (26-75% hardwood)	$4.7\ km^2$	(27%)
	- softwoods (0%-25%) hardwood	$8.3\ km^2$	(48%)
. Shreve Stream No. For Channel at Gauging Station		8	
. Main Channel Length		8.75 km	
. Tributary Length		6.92 km	
. Drainage Density		$0.9\ km/km^2$	
. Texture Ratio		$1.3\ km^{-1}$	
. Watershed Topographic elevation		24-90 m geodetic	
. Longitudinal Slope of Main Channel		.0002-.0009	

TABLE 6-4

WATER DISCHARGE SUMMARY McASKILL BROOK NEAR BIRCH GROVE
MONTHLY AND ANNUAL MEAN DISCHARGES IN CUBIC METRES PER SECOND

YEAR	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	MEAN
1978			0.502	1.34	0.489	0.274	0.132	0.019	0.072	0.325	0.170	0.630	
1979	0.978	0.408	1.54	0.688	0.317	0.200	0.082	0.256	0.105	0.818	0.694	1.30	0.619
1980	0.458	0.052	0.703	2.07	0.786	0.140	0.339	0.220	0.228	0.658	1.19	1.01	0.655
1981	0.720	0.578	0.516	0.644	1.43	0.195	0.168	0.553	0.237	1.02	0.943	1.27	0.692
1982	0.964	0.787	0.977	2.23	1.12	0.521	0.192	0.057	0.121	0.197	0.403	0.878	0.702

ANNUAL EXTREMES OF DISCHARGE IN CUBIC METRES PER SECOND

YEAR	MAXIMUM INSTANEOUS DISCHARGE	MAXIMUM DAILY DISCHARGE	MINIMUM DAILY DISCHARGE	TOTAL ANNUAL DISCHARGE
1978	5.89 cms at 22:42 AST April 29	4.93 cms on April 30	0.009 cms on Sept. 2-6	
1979	19.9 cms at 06:21 AST Dec. 27	15.7 cms on Dec. 27	0.018 cms on July 27	19,500 cubic decametres
1980	12.3 cms at 06:35 AST May 10	8.28 cms on May 10	0.028 cms on March 3	20,700 cubic decametres
1981	21.4 cms at 05:05 AST May 24	15.3 cms on May 24	0.030 cms on Sept. 15	21,800 cubic decametres
1982	29.9 cms at 19:54 AST April 29	13.3 cms on April 29	0.013 cms on July 28	22,100 cubic decametres

[3] From Water Survey of Canada.

TABLE 6-5

Estimated Low Flows
McAskill Brook Near Birch Grove (after Smith, 1981)
($x10^{-4} m^3/s \cdot /km^2$)

Based on Salmon River Low Flow
Analysis and Short Term Streamflow Data
for McAskill Brook

Recurrence Interval (Years)	2	5	10	20	50	100
Duration (days)						
1	13	7	5	5	4	4
7	17	9	6	5	4	4
30	31	16	10	8	5	5
60	77	34	18	10	6	5
120	146	88	63	50	39	29

Based on River Inhabitants Low Flow
Analysis and Short Term Streamflow
Data for McAskill Brook

Recurrence Interval (Years)	2	5	10	20	50	100
Duration (days)						
1	16	9	5	4	4	3
7	21	12	8	7	7	6
30	33	18	13	11	10	9
60	54	28	21	16	14	13
120	106	67	55	49	46	44

0.110 mg/L), iron (0.17 - 1.0 mg/L), manganese (0.04 - 0.23 mg/L) and zinc (0.005 - 0.230 mg/L).

Loading rates and analysis of other trends were not vigorously examined, and therefore are not discussed in this report.

CHAPTER 7

7.0 Water Resource Utilization and Development

7.1 Introduction

Water resource utilization in the Sydney Coalfield study area is dominated by the provision of surface water. Seventy-one percent (90,467) of the total population of approximately 127, 000 are served directly by Municipal surface water systems. These include the City of Sydney, Glace Bay (inclusive of Dominion and Reserve Mines), North Sydney (inclusive of Florence, Alder Point and Bras d'Or), New Waterford (inclusive of New Victoria and Scotchtown), Donkin, Birch Grove and a small number of consumers located in Coxheath and Westmount.

Only one central supply system located in the study area utilizes groundwater. It serves a total of 40 residents and is located in Gardiner Mines.

The remaining population of approximately 36,493 (29 percent) secure domestic water supply via individual dug- or drilled-well groundwater sources.

Industrial and commercial operations utilize a variety of water sources depending upon their location and relative size. Large industrial users derive their supplies from surface water, either from municipal or privately owned utilities, whereas, small- to medium-sized commercial operations located outside serviced areas utilize groundwater extracted through drilled wells.

The following sections of this report will document existing water utilization patterns in the Sydney Coalfield and provide an overview of potential water supply development.

7.2 Municipal Water Supplies

7.2.1 City of Sydney

The City of Sydney secures its water supply from a series of four lakes and a man-made reservoir located south of the developed area. The watershed encompasses 1785 hectares and includes the City Reservoir and Middle, Dumaresq, Peter and Bray Lakes. All of the above mentioned lakes transmit water to the city reservoir. Bray Lake is connected to the reservoir via a small brook, whereas, Dumaresq, Middle and Peter Lakes are connected via a series of 610 mm diameter transmission mains. The reservoir delivers water to the estimated 120 kilometre-long distribution system via several large diameter mains. The utility also includes a new 13.6 million litre (ML) covered ground level storage reservoir which will be added to the system in the near future.

The Sydney watershed area has an approximate storage volume of 2,542 ML and an estimated safe yield of 20 MLPD. The system currently serves 28,000 individuals with an average daily flow of 15 ML. The available supply and water treatment facilities (i.e., chlorination, pH-adjustment, fluoridation and copper sulfate addition for algae control) are capable of supplying a total of 18.2 MLPD.

The Sydney water supply system, which was originally constructed in 1902, has been continually upgraded over the years and at the present time has the capability of supplying the municipal demand on a year round basis. The system provides good quantity and quality water and has some capacity for moderate expansion. Fire flows are described as generally good; however, as in most systems, undersized distribution mains may cause minor problems (Personal communication, City of Sydney Water Commission, 1985).

7.2.2 Town of Glace Bay

The Glace Bay water supply utility, which also serves the town of Dominion and the community of Reserve Mines, utilizes Sand Lake as its source of supply. Sand Lake, which has a surface watershed area of 389 hectares, supplies water to the distribution system from a dam at the head of the lake through two 406 mm diameter transmission mains. These mains deliver water to a pumping station located on MacAskill Brook which in turn feed to three large diameter mains delivering water to the 109 kilometre long distribution system. The utility also includes a 5.5 ML uncovered ground-level storage reservoir.

Sand Lake has an approximate storage volume of 2,406 ML and an approximate watershed safe yield of 18.2 MLPD. The system currently serves 27,000 individuals with an average daily flow of 11.4 ML. The current supply and water treatment facilities (which includes chlorination, fluoridation and pH adjustment) are capable of serving a design population of 40,000 with a daily design flow of 18.2 ML.

In general, although the Glace Bay and area water supply system was initially constructed in the early 1900's, it has the capability of supplying good quantity and quality water on a year round basis, with significant capacity for expansion. However, certain areas of the system are serviced by undersized water mains and in these areas the current fire flow capacity is described as being inadequate (Nova Scotia Department of Municipal Affairs, 1981).

7.2.3 North Sydney

The North Sydney water supply system, which also encompasses the communities of Sydney Mines, Florence, Bras d'Or and Alder Point, utilizes Pottle Lake as its source of supply. Pottle Lake has a surface area of 262 hectares and an associated watershed of 11.7 square kilometres. Water is delivered to the 41 kilometre-long distribution system via two pumps and two transmission mains (i.e., for the North Sydney system and the Sydney Mines system) with the Florence, Bras d'Or and Alder Point areas being served directly from a transmission main originating at the reservoir. The reservoir (new in 1981) is a 9.1 ML completely enclosed concrete tank.

Pottle Lake has an approximate watershed safe yield of 28.6 MLPD and currently serves a total population of 21,200 with an average daily flow of 20.4 ML. The present supply and water treatment (i.e., chlorination) are capable of serving a design population of 23,550 with a daily design flow of 22.7 ML.

Originally constructed between 1896 and the early 1900's, the Pottle Lake system is still supplying adequate quantity and quality water on an annual basis. In addition, fire flows are described as being generally good (Nova Scotia Department of Municipal Affairs, 1981).

7.2.4 New Waterford

The Town of New Waterford and District Water Commission, which includes the communities of New Victoria and Scotchtown, utilizes Waterford and Kilkenny Lakes as its source of supply. The two lakes have a total watershed area of 316 hectares with water being gravity fed via a 406 mm diameter transmission main 3,609 metres from Kilkenny to Waterford Lake. From Waterford Lake, water is transmitted to the 66-kilometre long distribution system via two 305 mm diameter mains. The system also includes a 9.1 ML covered ground level reservoir.

The Kilkenny-Waterford Lake watershed has an estimated safe yield of 8.2 MLPD and currently serves a total population of 12,650. The average daily flow is 5.5 ML. The present supply and water treatment facilities (i.e., chlorination and fluoridation) are capable of servicing a design population of 18,000 with a daily design flow of 8.2 ML.

Although originally constructed and operated by the Dominion Coal Company in the early 1900's to service local collieries, the New Waterford and District Water Commission has upgraded the utility over the past 10-12 years making the system modern and relatively efficient. At the present time, the water supply is sufficient for year round needs and flows for fire protection are described as being generally good (Nova Scotia Department of Municipal Affairs, 1981).

7.2.5 Donkin

The community of Donkin utilizes an unnamed pond located in the eastern section of the developed area as a source for its water supply. The pond has a total watershed area of 81 hectares with water being fed through a 1.3 kilometre long transmission main to the 7.7 kilometre long distributlon system. The utility also includes a 113,500 L elevated covered reservoir. The Donkin pond has an estimated storage capacity of 45.4 ML (safe yield unknown) and serves a total population of 1087. The average and maximum daily flows are 204,300 and 308,720 L, respectively, with an unknown design daily flow.

The Donkin water system is, at the present time, adequate to meet standard municipal needs. However, with the average daily demand exceeding the storage reservoir capacity, a problem with storage balancing and meeting fire flow requirements is apparent (Nova Scotia Department of Municipal Affairs, 1981).

7.2.6 Birch Grove

The community of Birch Grove utilizes John Allen Lake as its source of water supply. The lake has a watershed area of 64 hecatares with water being pumped via a 203 mm diameter transmission main to the 4 kilometre long distribution system. The utility also includes a 454,000 L covered, ground level reservoir.

The Birch Grove system serves a total population of 280 with an average daily flow of 68,100 L. The maximum and design daily flows are 99,880 and 1.6 ML, respectively.

This utility, which is presently owned and operated by the Municipality of the County of Cape Breton, was originally constructed in the early 1900's. As a result of a series of renovations over the past 10 years (new reservoir, pump house and pumping equipment) the Birch Grove water system is at the present time adequate to meet municipal requirements. Fire flows are described as being generally fair (Nova Scotia Department of Municipal Affairs, 1981).

7.2.7 County of Cape Breton

In addition to the water utilities mentioned previously, which are owned and maintained by the County (i.e., Florence, Bras d'Or, Alder Point, Reserve Mines, Donkin and Birch Grove) two additional systems are in place. One such system involves a 30.5 cm diameter transmission main which extracts water from the Sydney River and delivers it to the Canadian Coast Guard College and the Point Edward Industrial Park. A small number of individuals (approximately 250) and institutions are presently served by this system with direct distribution lines leading from the transmission main. These connections are generally located in Coxheath and Westmount. The system, which is chlorinated, does not include reservoir storage but provides good fire flows along the transmission main. At the present time, the County is planning expansion of this utility to include an additional 150 residents in the Westmount Area.

A second central water supply system being operated by the County serves a total of 13 homes (approximately 40 residents) in the community of Gardiner Mines. This system derives its water supply from a single drilled well which extracts an unknown quantity of groundwater. The transmission main consists of a relatively new 5 cm diameter plastic pipe, lateral shut-offs and individual metering. The system does not include any form of treatment or provision for fire protection. It is suspected that the Gardiner Mines system is being utilized to its utmost capability; however, the recently installed metering should provide estimates of average and maximum daily demands in the near future.

7.3 Rural Water Supply

Water supply provision in the rural regions of the study area is dominated by the use of groundwater via wells. This involves 29% (approximately 36,493 individuals) of the total population.

Domestic water-quantity use is variable from residence to residence depending upon individual lifestyle. In general, rural homeowners utilize an average of 180 L of water per day per person. Therefore, a household consisting of four individuals would consume an average of 720 L of water per day or an average of 0.5 L/min. However, due to required peak use and individual variations it is recommended that a minimum of 1 L/min. is required for a single domestic residence.

Rural water supplies in the Sydney Coalfield are secured from both dug and drilled wells, with drilled wells being the most common.

Dug wells are basically large diameter (i.e., 1 m) storage reservoirs which tap shallow groundwater in unconsolidated overburden. Type of construction varies. However, rocked-up walls are common in older wells while newer wells utilize pre-cast concrete crocks. Depth is the most important consideration when constructing a dug well, since water table fluctuations on an annual basis can be significant in the more common, relatively low permeability, overburden found in the area. These wells should be as deep as possible (up to 8 m) to mitigate water level fluctuations and to provide adequate storage volumes.

Water quality of the shallow groundwaters tapped by these wells is generally good to excellent. However, it may be impaired via the entrance of contaminated surface water caused by inadequate construction techniques.

Drilled wells are commonly 15 cm in diameter and utilize well casing to isolate the unconsolidated overburden and tap the more productive consolidated bedrock aquifers located beneath. Drilled bedrock well depths vary considerably depending upon their location and the rock productivity. However, it is estimated that 98 percent of all wells constructed into these formations will yield adequate domestic water quantity.

Drilled well water quality is highly variable and is generally dependent upon the type of bedrock encountered. For a more detailed discussion of wells and water quantity/quality, the reader is directed to Chapter 5 entitled, "Groundwater Hydrology" and the associated report mapping located in the sleeve on the back cover.

7.4 Industrial and Institutional Water Supplies

A number of industries and institutions which use significant amounts of water in their operation lie outside areas supplied by Municipal systems. Information from N.S. Department of the Environment files on several of the larger users is outlined in the following sections.

7.4.1 Sydney Steel Corporation, Sydney

Sysco utilizes water from Grand Lake and the Sydney River. Water Rights authorizations 25 and 1732 allocated to the company 27 million litres (ML) per day from each of the respective sources.

7.4.2 Point Edward Industrial Park, Point Edward

The Point Edward Industrial Park has been allocated 4.54 ML per day from the Sydney River. This license will be held by the County of Cape Breton upon renewal, January 1, 1986. Since 1980, the license, Water Rights authorization number 1720, has been held by the Cape Breton Development Corporation (DEVCO) and prior to 1980 was held since 1942 by the Department of National Defense. In addition, a 72-hour pump test has been carried out in the Industrial Park on a 30 m deep, 20 cm well at a rate of 7.7 litres per minute. The test indicates the well is capable of much greater yield. For further information refer to Table 5.2.

7.4.3 DEVCO Transportation and Railway Maintenance Center, Victoria Junction

Water Rights authorization 2406 allocates 588,384 litres per day to the Maintenance Center from the groundwater of a 35 m deep, 20 cm diameter well. The well was subjected to a 72-hour pump test at 23.3 litres per minute which indicated a yield in excess of the pumping rate. For more information, refer to Table 5.2.

7.4.4 DEVCO Prince Mine, Point Aconi

The water supply for the Prince Mine is obtained from both surface and groundwater. Water Rights authorization 797 allocates 1,046,016 litres per day (726 L/min.) to the mine. In addition, a 41 m, 15 cm diameter well was subjected to a 72-hour pump test at 136 L/min. The test indicated a long term safe yield of 124.4 L/min. For further information refer to Table 5.2. This well has not been able to meet the demand desired by DEVCO from the groundwater source and there has been recent consideration of the construction of a second well.

7.4.5 Nova Scotia Power Corporation, Lingan

Water Rights authorization 2151 allocates 49,304 litres per day (34 L/min.) to the Nova Scotia Power Corporation from the groundwater of a 98 m, 20 cm diameter well. The well was subjected to a 72-hour pump test at 1135 L/min. The long term safe yield of this well is 981 L/min. However, to reduce local interference, the available head was reduced with the corresponding reduction in safe yield to 341 litres per minute. In addition, the Corporation has a 66 m, 15 cm diameter well that was subjected to a 72-hour pump test at 394 L/min. The test indicated a safe yield of 863 L/min. For further information refer to Table 5.2.

7.4.6 Selminco, Summit Joint Venture, Scotchtown

Water Rights authorization 2183 allocates 1,307,520 litres per day for 260 days a year to Selminco from the groundwater of an 86.6 m deep, 20 cm diameter well. The well was subjected to a 72-hour pump test at 1050 L/min. which indicated a yield in excess of the pumping rate. For more information refer to Table 5.2.

7.4.7 Mayflower Mall, Glace Bay Highway

Water Rights authorization 1925 allocates 158,900 litres per day (114 L/min.) to Norcape Development Limited from the groundwater of two, 15 cm diameter wells. The wells of 54 and 74 m were each subjected to 72-hour pump tests at 227 L/min. The tests indicate safe yields in excess of the pumping rate. For further information refer to Table 5.2.

7.4.8 College of Cape Breton, Glace Bay Highway

This institution, formerly known as the Nova Scotia Eastern Institute of Technology, has a water supply from a groundwater source. Two 20 cm diameter wells of 80 and 84 m supply the school. The latter well was originally drilled and tested as a 15 cm well and later reamed to 20 cm. The wells were subjected to 72-hour pump tests of 1135 and 490 litres per minute respectively. The tests indicate safe yields in the range of 681 litres per minute for both wells. Some interference was reported between the wells. For further information refer to Table 5.2.

7.4.9 Cape Breton County Correctional Center, Gardiner

The institution obtains its water supply from a groundwater source. A 106 m, 15 cm diameter well was subjected to a 72-hour pump test at 227 L/min. The test indicated a much higher yield could be obtained from the aquifer. For further information refer to Table 5.2.

7.4.10 Sydney Airport, Glace Bay Highway

The complex obtains its water supply from a groundwater source. A 121 m, 20 cm well was subjected to a 72-hour pump test at 159 L/min. The test indicated a higher yield could be obtained from the well.

7.4.11 Aggregate Operations, Meadows Road, Sydney Forks

A number of continuing and temporary Water Rights authorizations have been granted to pit operators in the Meadows Road area of Sydney Forks. Permits allow for the extraction of water from surface water sources. The range of the allocations is from 839,900 to 68,100,000 litres per year.

LIST OF REFERENCES

Babich, H., Davis, D., and Stotzky, G., 1980, Acid Precipitation Causes and Consequences. Environment, Vol. 22, #4, p. 6-13.

Bayne, A., 1963, Report on Preliminary Exploration on Property of Mariner Mines Ltd., 15 pgs.

Bell, W., 1958, Possibilities for Occurrence of Petroleum Reservoirs in Nova Scotia, Nova Scotia Department of Mines, 177 pgs.

Bell, W.A., and Goranson, E.A., 1938, Sydney Sheet (West Half), Map 360A, Canada Department of Mines and Resources, Ottawa

Bell, W.A., and Goranson, E.A., 1938, Bras d'Or Sheet (West Half), Map 359A, Canada Department of Mines and Resources, Ottawa

Canada Dept. Transport, 1970, Mean Evaporation Maps, 2 sheets, Meteorological Branch.

Cann, D.B.; MacDougall, J.I., and Hilchey, J.D., 1963, Soil Survey of Cape Breton Island, Nova Scotia, Report #12, Nova Scotia Soil Survey, Truro, N.S., 85 pgs.

Chatterjee, A., and Oldale, H., 1980, Porphyry Copper - Molybdenum V Gold Mineralization at Coxheath, in Trip 6 Mineral Deposits and Mineralogenic Provinces of Nova Scotia, Halifax 1980, GAC Convention, p., 3-8.

Clarke, D.B., Barr, S., and Donahoe, H., 1980, Granatoid and Other Plutonic Rocks of Nova Scotia, in Proceedings: "The Caledonides in the U.S.A.", I.G.C.P. Project 27: Caledonide Orogeny; Department of Geological Science, Virginia Polytechnic Institute and State University, Memoir #2, p. 107-116.

Cole, L.H., 1961, Report on Drilling for Evaporites in the Sydney Forks Area of Cape Breton, Nova Scotia, Canada. Report for Morton Chemical of Canada Ltd., 11 pgs.

Den Hartog, G., and Ferguson, H., 1976, National Water Balance Maps of Evapotranspiration and Precipitation, Atmoshperic Environment Service, Environment Canada, 14 pgs.

Dunne, T., and Leopold, L., 1978, Water in Environmental Planning, W.H., Freeman and Company, San Francisco, U.S.A., 818 pgs.

Environmental Protection Service, 1978, A Nationwide Inventory of Emissions of Air Contaminants, 1974, Report EPS 3-AP-78-2, E.P.S., Environment Canada, Ottawa, Ontario

Fairbridge, R.N., 1972, The Encyclopedia of Geochemistry and Environmental Sciences, IVA, Van Nostrand & Reinhold, N.Y., 1321 pgs.

Ferguson, H., O'Neill, A., and Cork, H., 1970, Mean Evaporation Over Canada, Water Resources Research, Vol. 6, #6, p. 1618-1633.

Fletcher, H., 1900, Descriptive Note on the Sydney Coalfield, Cape Breton, Nova Scotia, Geological Survey of Canada to accompany revised edition of geological map sheets 133, 134, 135, N.S., #685, 16 pgs.

Forgeron, S., 1974, Report of Work Performed on the Frenchvale Property, Cape Breton County, Nova Scotia, for Kaiser Celestite Mining Ltd., 10 pgs.

Forgeron, S., 1980, Geological Report on the Victoria Junction Claims Property, Cape Breton County, Nova Scotia, Reference Map 11K1D Exploration License #4105, Cape Breton Development Corporation, 15 pgs.

Gates, A., 1975, The Tourism and Outdoor Recreation Climate of the Maritime Provinces, Publications in Applied Meteorology REC-3-73, Met. Applications Branch, Environment Canada, A.E.S., 133 pgs.

Geldsetzer, H., 1977, The Windsor Group of Cape Breton Island, Nova Scotia, GSC Report of Activities Part A, Paper 77-1A, p., 425-428.

Geological Survey of Canada, 1953, Map 227G Airborne Magnetic Survey, Sydney, Scale 1:63,360.

Gibb, J.E., McMullin, K.A., 1980, Regional Water Resources, Pictou County, Nova Scotia, Nova Scotia Department of the Environment.

Golder and Assoc., 1980, Geotechnical Report, Portals for Mine Access Tunnels, Donkin-Morien Development Project, Cape Breton County, Nova Scotia, 35 pgs.

Gorham, E., 1958, Atmospheric Pollution by Hydrochloric Acid, Quarterly Journal, Royal Meteorological Soc., Vol. 84, p., 274-276.

Grant, D.R., 1972, Surficial Geology of Southeast Cape Breton Island, Nova Scotia, Geol. Survey of Canada, Report of Activities, Part A: April to October, 1971, paper 72-1, Part A, p. 160 - 163.

Grant, D.R., 1977, Glacial Style and Ice Limits, the Quarternary Stratigraphic Record, and Changes of Land and Ocean Level in the Atlantic Provinces, Canada, Geogr. Phys. Quat., Vol. XXXI, Nos. 3-4, p., 247-260.

Gray, F.W., and Gray, R.H., 1941, The Sydney Coalfield, Speculation on the Shape and Extent of Its Submarine Extension, and Economic Conclusions, CIMM Transactions Vo.. XLIV, p. 289-330.

Hacquebard, P.A., Cameron, A., and Donaldson, J., 1965, A Depositional Study of the Harbour Seam, Sydney Coalfield, Nova Scotia, GSC Paper 65-15, 33 pgs.

Hacquebard, P.A., and Donaldson, J.R., 1969, Carboniferous Coal Deposition Associated with Flood-Plain and Limnio Environments in Nova Scotia, Geol. Soc. of Am. Special Paper 114, Environments of Coal Deposition, Ed. Dapples, E., and Hopkins, M., p. 143-191.

Haites, T.B., 1949, Splits in the Phalen Seam in the Glace Bay and New Waterford Districts of the Sydney Coalfield, Cape Breton Island, Nova Scotia, Canada Department Mines and Resources, Mines, Forests and Scientific Services Branch, 33 pgs.

Haites, T.B., 1951, Some Geological Aspects of the Sydney Coalfield With Reference to Their Influence on Mining Operations, Can., Inst. Min. and Met. Trans., Vol. 54, p. 215-225.

Haites, T.B., 1952, Conjectural Shape and Extent of the Sydney Coalfield, Annual Meeting Mining Society of Nova Scotia, Trans. Vol. LV, p. 202-212.

Hart, W., 1977, Major Ions in Nova Scotian Precipitation, Ph.D. Thesis, Dalhousie University, 72 pgs.

Hawley, J.E., 1955, Spectrographic Study of Some Nova Scotia Coals, CIMM Transactions, Vol. LVIII, p. 412-426.

Hay, A., 1928, A Description of Coal Mining Operations in the Sydney Coalfield, 61 pgs.

Hayes, A.O., and Bell, W.A., 1923, The Southern Part of the Sydney Coalfield, Nova Scotia, Memoir 133, Canadian Geological Survey, 108 pgs.

Hayes, A.O., and Bell, W.A., 1938, Glace Bay Sheet, Map. 362A, Canada Department of Mines and Resources, Ottawa.

Hayes, A.O., and Bell, W.A., and Goranson, E.A., 1938, Sydney Sheet (East Half) Map 361A, Canada Department of Mines and Resources, Ottawa.

Health and Welfare, Canada, 1978, Guidelines For Canadian Drinking Water Quality, Supply and Services Canada. 77 pgs.

Howie, R., and Cumming, L., 1963, Basement Features of the Canadian Appalachians, GSC Bull 89, 18 pgs.

Kelly, D.G., 1967, Some Aspects of Carboniferous Stratigraphy and Depositional History in the Atlantic Provinces. Geol. Assoc. Can., Spec. Paper No. 4.

Keppie, J.D., 1976, Interpretation of P.P.I. Radar Imagery of Nova Scotia, Nova Scotia Department of Mines, Paper 76-3, 31 pgs.

King, L., and MacLean B., 1976, Geology of the Scotian Shelf, Marine Science Paper 7, Geological Survey of Canada Paper 74-31, 31 pgs.

Landry, A., and Betancourt, O., 1980, SO_2 Emissions and Fuel Use in Nova Scotia Projections for 1980, Nova Scotia Department of the Environment Internal Report, 32 pgs.

Likens, G., 1976, Acid Precipitation, Chemical Eng., p. 29-44.

MacLaren Marex Inc., 1980, An Environmental Impact Assessment Study For Cape Breton Development Corporation For The Donkin Mine, Dartmouth, Nova Scotia, 91 pgs.

MacNeil, C., and O'Neill, A., 1976, Measurements of the Water Equivalent of Freshly Fallen Snow in Canada's Atlantic Provinces, A.E.S., Environment Canada, Bedford, N.S., 14 pgs.

Mather, K., Tulles, E., and Beck, C., 1944, Petroleum Geology of the Sydney Area, Cape Breton Island, Nova Scotia, Sydney Petroleum Co., 48 pgs.

McCurdy, R., 1973, Settleable Particulates Sydney, Nova Scotia, MSc Thesis, University of Minnesota, 98 pgs.

McPhee, J.T., 1965, Geological and Structural Evaluation of Petroleum and Natural Gas Licenses #36, #172, and #173 (Submarine), Sydney Sub-basin Area of Cape Breton Island, Nova Scotia, for Canadian Homestead Oils.

Montreal Eng. Co. Ltd., 1969, Maritime Provinces Water Resources Study, Stage I, Appendix XI, Surface Water Resources for Atlantic Dev. Board.

Munn, R., 1973, Secular Increases in Summer Haziness in the Atlantic Provinces, Atmosphere, Volume II, #4, p. 156-161.

Nolan Davis and Associates, 1981, Environmental Assessment of the Proposed Gardiner Area Surface Mine, Report to Novaco, 140 pgs.

Nova Scotia Department of Municipal Affairs, 1981, Provincial Water and Sewer Inventory, Community Planning Division, Volume 5, Cape Breton Island, 118 pgs.

Nova Scotia Research Foundation, 1970, Seismic Surveys at Leitches Creek, Cape Breton County, for Cerro Mining Co. of Canada, Nova Scotia Research Foundation 2-71, 12 pgs.

Oldreive, C., 1978, Industrial Cape Breton Area Ambient Air Monitoring Annual Report 1978, Internal Nova Scotia Department of the Environment Report, Inspection and Monitoring Division, 29 pgs.

Poole, W., 1967, Tectonic Evolution of Appalachian Region of Canada, G.S.C.

Schmid, C., 1954, Geology of the Coxheath Hills, Cape Breton County, Nova Scotia, BSc Thesis, M.I.T., 16 pgs.

Shawinigan Engineering Limited, 1980, Groundwater Protection Guidelines in Nova Scotia, prepared for the Nova Scotia Department of the Environment, 213 pgs.

Smith, D., 1981, Estimates of Low Flow for MacAskill Brook, Cape Breton, Nova Scotia, Environment Canada Report, IWD-AR-WPMB-81-18, 20 pgs.

Smith, K., 1964, A Long-Period Assessment of the Penman and Thornthwaite Potential Evapotranspiration Formula, Journal of Hydrology, Vol. 2, p. 277-290.

Strahler, A., 1957, Quantitative Analysis of Watershed Geomorphology, Amer. Union Transactions, Vol. 38, No. 6, pgs. 913-920.

Strahler, A., 1969, Physical Geography, 3rd edn., Wiley, N.Y., 733 pgs.

Thomas, M., 1975, Recent Climatic Fluctuations in Canada, Environment Canada, A.E.S., Climatological Studies, #28, 92 pgs.

Thornthwaite, C., 1948, An Approach Towards a Rational Classification of Climate, Geog. Rev., Vol. 38, p. 55-94.

Underwood, J.K., 1979, pH of Precipitation and Annual Deposition of Excess Sulfate, Acidity, and Nitrate on Nova Scotia, in Proceedings of a Workshop on Long Range Transport of Air Pollution and its Impacts on the Atlantic Region, Environment Canada, A.E.S., p. 25-34.

Underwood, J.K., 1981, pH of Precipitation and Annual Deposition of Acidity, Nitrogen and Excess Sulfate on Nova Scotia, Nova Scotia Department of the Environment Report.

Underwood, J.K., 1984, An Analysis of the Chemistry of Precipitation in Nova Scotia, 1977-1980, Ph.D. Dissertation, Technical University of Nova Scotia, 264 pgs.

Vaughan, J., and Somers, G., 1980, Regional Water Resources, Cumberland County, Nova Scotia, Water Planning & Management Division, Nova Scotia Department of the Environment.

Wiltshire, J.F., 1979, The Long Range Transport of Atmospheric Acids: A Sulfur Budget for Nova Scotia, Environmental Protection Service, Environment Canada, EPS-5-AR-79-8, 114 pgs.

Weeks, L.J., 1957, Mira Map Sheet 1056A, Geological Series, Canada Department of Mines and Technical Surveys, G.S.C., Scale 1:63,360.

Zodrow, E.L., and Zentille, M., 1979, Uranium Content of Rocks, Coal and Associated Minerals From the Sydney Coalfield, Cape Breton Island, Nova Scotia, in Current Research, Part C, Geol. Survey of Canada, Paper 79-1C, p. 31-36.

APPENDIX 1

CLIMATIC NORMALS

TABLE A - 1 - 1

CLIMATIC NORMALS
Sydney Airport
Courtesy A.E.S. Environment Canada

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	Period
TEMPERATURE (°C)														
Absolute Maximum	14.4	12.8	17.8	27.2	31.1	34.4	33.3	34.0	32.2	25.0	22.2	16.7	35.0	1941-73
Year	1946	1951	1945	1942	1960	*	*	1944	1942	*	1961	1951	1944	
Mean Maximum	-0.7	-1.3	1.2	6.2	12.8	18.6	23.3	22.7	18.8	13.1	7.6	1.8	10.3	1941-70
Mean Temperature	-4.4	-5.5	-2.4	2.2	7.7	13.0	17.9	17.8	13.9	8.9	4.2	-1.5	6.0	1941-70
Mean Minimum	-8.2	-9.7	6.1	1.8	2.6	7.4	12.6	12.9	9.1	4.6	0.8	-4.8	1.6	1941-70
Absolute Minimum	-23.3	-25.6	-23.9	-13.3	-7.8	-3.9	2.2	2.8	-1.7	-5.6	-9.4	-18.9	-25.6	1941-73
Year	*	1972	1950	1946	1972	1956	1961	1965	1971	1922	*	1955	1972	
% Temperatures 0°C	80.4	88.7	74.5	38.5	5.5	a	-	-	-	2.2	20.6	65.5	30.7	1957-66
% Temperatures -20°C	0.4	1.4	a	-	-	-	-	-	-	-	-	-	0.1	1957-66
% Temperatures 25°C	-	-	-	-	0.4	2.3	6.2	4.4	1.0	a	-	-	1.2	1957-66
PRECIPITATION														
Mean Precipitation (mm)	137.2	118.6	119.4	95.2	99.6	80.8	78.4	99.6	99.0	111.8	161.2	139.8	1340.6	1941-70
Greatest 24 hr. Precip.(mm)	57.2	58.6	67.0	56.2	93.4	72.2	63.8	62.2	91.0	59.0	97.2	60.2	97.2	1941-73
Greatest Rainfall (mm)	204.4	132.6	127.8	180.8	223.2	179.4	174.0	217.6	257.0	252.2	333.8	166.6	1399.0	1941-73
Year	1956	1951	1971	1971	1967	1973	1962	1970	1949	1944	1969	1953	1969	
Mean Rainfall (mm)	71.8	57.2	58.4	68.4	95.0	80.8	78.4	99.6	99.0	110.8	151.6	82.4	1053.4	1941-70
Least Rainfall (mm)	1.6	13.8	7.6	6.6	23.4	23.6	19.4	17.8	34.8	35.8	31.2	3.8	744.0	1941-73
Year	1970	1966	1960	1966	1960	1967	1959	1961	1956	1963	1946	1955	1950	
Greatest 24 hour Rainfall (mm)	57.2	58.4	52.8	56.2	93.4	72.2	63.8	62.2	91.0	59.0	97.2	60.2	97.2	1941-73
Greatest Snowfall (cm)	163.0	135.6	181.6	81.0	28.4	T	-	-	T	27.0	38.6	172.8	542.8	1941-73
Year	1965	1973	1967	1972	1972	*	-	-	*	1972	1955	1964	1964	
Mean Snowfall (cm)	66.8	62.8	60.2	25.6	4.4	-	-	-	-	1.2	9.4	57.6	288.0	1941-70
Least Snowfall (cm)	18.0	17.8	0.2	T	0.0	0.0	-	-	0.0	0.0	T	11.6	143.0	1941-73
Year	1958	1951	1945	1951	*	*	-	-	*	*	*	1957	1953	
Greatest 24 hour Snowfall (cm)	44.4	45.2	37.4	29.2	24.8	T	-	-	T	15.8	21.6	58.6	58.6	1941-73
SNOW DEPTH														
Maximum Snow Depth on Ground at Month End (cm)	58	81	76	5	-	-	-	-	-	-	3	56	-	1946-72
Average Snow Depth on Ground at Month End (cm)	15	23	13	-	-	-	-	-	-	-	-	13	-	1946-72
SUNSHINE														
		301											4478	
Possible No. of Hours	283	290	370	407	464	471	475	437	376	339	285	270	4467	
Maximum	126	161	180	228	277	277	295	296	200	207	93	102	2002	1948-73
Mean	81	106	126	161	204	222	251	225	168	139	74	67	1824	1948-70
Minimum	43	63	75	103	91	160	179	148	98	96	48	37	1482	1948-73
CLOUD COVER														1953-72
Mean Cloudiness (tenths)	7.3	6.7	6.8	6.7	6.6	6.7	6.4	6.3	6.1	6.6	7.7	7.7	-	
% Freq. Clear Skies	6.3	11.3	10.5	12.3	11.2	7.6	8.4	9.9	12.3	10.0	4.8	3.5	-	
% Freq. 1/10-5/10	20.3	23.6	22.2	21.9	23.4	27.0	29.5	27.9	27.7	23.5	15.7	16.8	-	
% Freq. 6/10-9/10	25.9	22.5	22.8	22.5	23.2	27.6	27.7	31.1	27.5	29.1	27.7	29.2	-	
% Freq. Overcast	47.5	42.6	44.5	43.3	42.2	37.8	34.4	31.1	32.5	37.4	51.8	50.5	-	

a = less than 0.1%
* indicates more than one year

TABLE A - 1 - 2

AVERAGE WIND SPEEDS AND PERCENT FREQUENCY
SYDNEY AIRPORT

PERIOD 1955-72 HEIGHT OF ANEMOMETER 33'

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
PERCENTAGE FREQUENCY													
N	5	7	12	11	11	8	5	4	6	6	6	6	7
NNE	3	4	5	5	4	4	3	2	3	3	3	3	4
NE	3	3	5	4	4	4	3	2	3	3	3	3	3
ENE	3	2	3	3	2	2	2	2	2	2	3	2	2
E	4	3	4	4	4	3	4	3	3	2	5	3	4
ESE	2	3	3	2	3	2	2	2	2	2	2	2	2
SE	3	4	3	3	4	4	4	3	3	4	4	4	4
SSE	3	2	2	3	3	4	3	3	3	4	5	3	3
S	6	7	6	8	11	11	14	13	9	9	9	7	9
SSW	6	7	7	8	12	16	19	15	11	10	8	7	11
SW	11	10	9	10	12	18	18	22	18	15	11	12	14
WSW	11	9	7	6	5	6	6	9	9	9	9	12	8
W	16	16	11	9	6	5	7	8	10	11	11	13	10
WNW	9	8	7	6	4	3	3	4	6	6	8	8	6
NW	9	7	7	7	7	4	3	4	6	7	7	8	6
NNW	6	6	8	9	6	4	2	2	4	6	5	6	5
Calm	1	2	1	2	2	2	2	2	2	1	1	1	2
AVERAGE WIND SPEED IN MILES PER HOUR													
N	16.4	15.2	15.6	15.0	14.0	12.9	11.6	11.9	12.9	15.4	17.3	15.1	14.4
NNE	14.4	13.1	13.8	12.3	11.6	11.3	9.8	10.4	11.9	14.1	14.5	14.1	12.6
NE	13.5	13.5	13.3	11.6	10.8	9.9	9.3	10.0	9.8	12.4	13.4	12.7	11.7
ENE	17.2	16.0	15.4	13.6	10.1	10.9	9.2	12.0	10.5	11.9	14.9	13.8	13.0
E	16.5	16.7	16.0	13.7	11.3	10.6	9.8	10.9	10.0	11.6	14.7	15.0	13.1
ESE	19.3	19.9	19.0	14.9	13.4	11.7	10.4	12.2	12.7	13.5	14.0	17.8	14.9
SE	17.6	18.4	16.9	14.8	12.3	12.7	10.4	10.9	11.6	14.7	14.7	17.6	14.4
SSE	16.5	16.5	17.0	14.5	13.6	11.7	12.5	12.1	13.1	15.2	17.1	16.4	14.7
S	14.3	14.3	14.8	14.9	15.0	13.9	13.2	13.0	13.5	13.9	16.1	15.0	14.3
SSW	14.6	14.7	15.0	16.2	14.6	15.2	14.0	13.6	14.4	13.9	14.1	13.3	14.6
SW	12.6	12.8	13.2	14.2	14.0	13.9	12.6	12.3	12.3	12.8	12.7	13.7	13.1
WSW	14.6	14.5	15.4	13.6	13.9	12.1	11.8	11.6	11.8	13.0	14.9	13.8	13.6
WSW	14.6	14.5	15.4	13.6	13.9	12.1	11.8	11.6	11.8	13.0	14.9	15.8	13.6
W	16.6	16.3	15.8	14.7	14.2	12.2	12.8	12.4	12.4	13.6	14.5	16.1	14.3
WNW	16.8	17.2	17.5	15.3	14.5	13.0	13.0	13.2	13.8	14.6	15.4	16.3	15.1
NW	17.0	16.9	15.8	16.0	14.3	12.4	12.3	12.3	13.8	15.2	15.9	16.3	14.9
NNW	19.1	18.5	17.5	17.5	16.1	13.6	11.7	13.1	14.4	16.7	17.7	17.0	16.1
All Directions	15.6	15.4	15.4	14.5	13.7	12.8	12.1	12.1	12.4	13.8	14.9	15.2	14.0

Maximum Observed Hourly Speed 72 SW
Maximum Observed Gust Speed 100

Probably Maximum Gust for
Maximum hourly Speed 99

STATION INFORMATION
The anemometer tower was relocated in August, 1968 from its position in the bog area west of the abandoned runway to a position on the east side runway. The new position is 1200 feet east-northeast of the old one and the equipment is on a standard 30 foot steel tower.

From A.E.S. Environment Canada

APPENDIX 2

PERTINENT SURFACE AND GROUNDWATER

CHEMISTRIES

TABLE A - 2 - 2 SURFACE WATER ANALYSIS - MacASKILL BROOK GAUGING STATION

Sample No.	63335	63806	66673	69660	70457	71544	72840	74285	74281	75272	76363	78186	84285	85514	87446	91514	95092	Detection Limit
Date	13.04.77	19.04.77	11.07.77	11.10.77	14.11.77	04.01.78	28.02.78	14.04.78	25.04.78	30.05.78	23.06.78	24.08.78	06.04.79	24.05.79	16.07.79	31.10.79	06.03.80	
Determinant																		
Sodium[1]	2.9	3.6	2.7	4.0	3.8	4.0	3.8	4.1	2.6	4.0	4.0	6.1	3.4	3.6	5.0	3.4	4.7	
Potassium	0.5	0.4	0.2	0.4	0.3	0.3	0.3	0.5	0.4	0.5	0.3	0.5	0.2	0.3	0.5	0.4	0.4	
Calcium	1.2	1.6	4.4	1.8	2.4	1.0	1.8	1.3	1.3	1.8	1.6	1.8	2.0	2.6	1.8	3.6	2.3	
Magnesium	0.7	1.0	0.9	1.4	1.7	1.0	1.0	0.7	0.7	0.9	1.0	0.9	0.9	1.0	0.7	1.2	1.3	
Alkalinity	2.0	2.5	9.5	2.0	3.4	*	1.6	1.8	1.0	7.0	2.0	4.0	2.0	1.0	3.5	3.5	2.0	*<1.0
Sulfate	2.5	2.0	2.5	5.6	5.0	4.0	3.4	2.0	2.5	3.0	2.5	3.5	3.5	4.0	4.0	2.0	3.0	
Chloride	5.0	5.6	5.8	8.8	8.2	18.	7.1	6.2	4.5	7.2	6.0	8.8	6.5	6.0	6.5	6.2	8.8	
Silica	1.2	1.1	1.9	1.8	1.5	2.0	2.1	1.5	1.0	1.3	1.7	*	1.5	1.3	*	1.8	*	*<1.0
Ortho Phosphate	0.09	*	0.04	0.03	0.05	*	0.03	*	0.03	0.03	*	*	0.03	*	0.08	0.03	*	*<0.02
Total Phosphate	-	-	-	-	-	-	-	-	-	-	-	-	0.08	0.07	0.08	0.06	0.04	
Nitrate + Nitrite(as N)	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	0.1	0.08	*<0.05
Ammonia(as N)	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	0.05	*	*<0.05
Suspended Solids	1.0	2.0	*	1.0	3.0	0.8	2.0	1.0	1.0	2.5	0.8	1.0	1.3	2.3	3.3	1.8	0.5	*<0.3
Total Dissolved Solids	32.	16.	46	.38.	47.	30.	38.	37.	28.	39.	36.	29.	24.	50.	41.	50.	38.	
Colour (T.C.U.)	40.	70.	70.	160.	150.	80.	80.	70.	65.	130.	180.	120.	80.	150.	175.	175.	90.	
Total Organic Carbon	6.0	10.	16.	14.	20.	8.5	6.0	6.5	5.0	11.	15.	9.5	11.	12.	14.	21	11.	
Turbidity	1.6	2.6	2.5	2.8	17.	2.3	0.8	2.0	2.0	1.8	0.63	3.8	1.5	0.48	0.67	1.8	1.6	
Conductivity (micromho/cm)	33.	33.	35.	50.	52.	43.	40.	30.	28.	25.	35.	43.	39.	43.	38.	41.	44.	
pH (units)	5.1	5.5	5.1	4.6	4.7	4.8	5.4	5.1	5.3	5.3	5.9	6.0	5.3	4.6	6.0	4.6	5.1	
Temperature (°C)	2.0	2.5	1.5	10.	10.	0	0	1.0	2.0	11.	15.5	16.0	2.0	10.	17.	6.5	1.0	
Selenium	-	-	*	-	*	*	*	*	*	*	*	*	*	*	*	-	-	*<0.1
Chromium	-	-	*	-	*	*	*	*	*	*	*	*	0.01	*	*	-	-	*<0.01
Aluminum	-	-	0.34	-	0.26	0.17	0.17	0.14	0.12	0.21	0.25	0.16	0.17	0.26	0.44	-	-	
Arsenic	*	-	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*<0.005
Boron	-	-	*	-	*	*	*	*	*	*	*	*	*	*	*	-	-	*<0.02
Barium	-	-	0.01	-	0.01	0.01	0.009	*	*	0.007	0.009	0.007	*	0.01	0.007	-	-	*<0.005
Cobalt	-	-	*	-	*	*	*	*	*	*	0.01	0.02	*	0.02	0.01	-	-	*<0.01
Cadmium	*	-	*	-	*	*	*	*	*	*	*	*	*	*	*	-	-	*<0.002
Copper	-	0.03	0.01	-	*	*	*	*	*	*	*	*	*	*	*	*	*	*<0.01
Nickel	-	-	*	-	*	*	*	*	*	*	*	*	*	*	*	-	-	*<0.02
Lead	*	*	*	-	*	*	*	*	*	*	*	*	*	*	*	*	*	*<0.002
Iron	0.3	0.3	0.63	-	0.43	0.27	0.33	0.27	0.21	0.44	0.61	0.70	0.23	0.46	0.52	0.49	0.49	
Manganese	0.2	0.2	0.15	-	0.17	0.14	0.11	0.09	0.08	0.09	0.10	0.04	0.14	0.16	0.06	0.17	0.14	
Antimony	-	-	*	-	*	*	*	*	*	*	*	*	*	*	*	-	-	*<0.05
Tin	-	-	*	-	*	*	*	*	*	*	*	*	*	*	*	-	-	*<0.03
Vanadium	-	-	*	-	*	*	*	*	*	*	*	*	*	*	*	-	-	*<0.01
Zinc	-	*	*	-	*	0.01	0.02	*	*	*	0.02	*	*	0.02	*	*	*	*<0.01
Fluoride	*	*	*	0.1	*	*	*	0.1	*	0.1	*	*	*	0.1	0.1	*	*	*<0.1
Total (/100 m/s) Coliform	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	800.	8.	
Fecal (/100 m/s) Coliform	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	
Kjeldahl Nitrogen	-	-	-	-	-	-	-	-	-	-	-	-	0.2	0.4	0.31	0.8	0.5	
Tannin and Lignin	1.8	1.8	3.9	20.	2.4	1.6	1.4	1.1	1.0	1.8	2.6	1.5	-	-	-	-	-	
Humic Acids	-	-	-	-	-	-	-	-	-	-	-	19.	18.	28.	20.5	37.	15.5	
Hardness	6.0	7.9	15.	11.	13.	5.9	8.3	6.2	6.2	8.3	8.0	8.3	8.6	11.	7.5	14.	11.	
Discharge (m^3/s)	0.010	0.010	1.079	4.205	3.483	-	0.119	2.931	3.891	0.153	0.391	0.037	2.710	2.064	0.054	5.853	0.273	

1 - All parameters in mg/L unless otherwise noted.

TABLE A - 2 - 1 PERTINENT GROUNDWATER CHEMISTRIES

Location	Sample Date	Na	K	Ca	Mg	Hardness as $CaCO_3$	Alkalinity as $CaCO_3$	SO_4	Cl	F	Si	Ortho PO_4	NO_2 + NO_3 as N	NH_4 as N	T.O.C.	T.D.S.	Suspended Solids	Colour	Turbidity	Conductivity	pH	Temp	Al	As	B	Ba	Be	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Sb	Se	Sn	V	Zn	Hg	Well Depth
		mg/L																T.C.U.	J.T.U.	umho/cm	units	°C	mg/L																			m
LOWER MORIEN HYDROSTRATIGRAPHIC UNIT																																										
CB53-13	2/24/76	8.6	0.5	14	1.9	42	44	3.0	14	<0.1	8.6	0.02	<0.1	<0.1		86	10	60	74	138	6.3	7.0	0.05	0.007	<0.02	0.03	<0.005	<0.005	<0.01	<0.01	0.01	0.07	2.3	<0.02	<0.005	<0.05	<0.10	<0.03	0.01	.15		10.1
CB53-28	2/21/76	8.9	1.0	9.9	2.1	34	17	4.5	23	<0.1	6.5	0.03	<0.1	<0.1		67	0	10	1.0	127	6.0	4.0	0.05	<0.005	<0.02	0.008	<0.005	<0.005	<0.01	<0.01	0.04	<0.02	0.15	<0.02	<0.005	<0.05	<0.10	<0.03	<0.01	0.08		30.5
CB54-6	2/21/76	6.0	0.7	25	2.4	71	64	10	7.5	0.1	12	0.04	<0.1	<0.1		103	0	10	0.6	165	7.7	5.0	0.06	<0.005	<0.02	0.03	<0.005	<0.005	0.01	<0.01	0.02	<0.02	0.03	<0.02	<0.005	<0.05	<0.10	<0.03	0.01	0.12		48.8
CB54-9	2/21/76	6.0	0.8	26	2.6	76	68	11	7.5	0.1	10	0.03	<0.1	<0.1		103	1	10	1.0	176	7.6	4.0	0.05	0.006	<0.02	0.04	<0.005	<0.005	0.01	<0.01	0.03	0.28	0.26	<0.02	<0.005	<0.05	<0.10	<0.03	<0.01	0.06		19.8
CB55-12	2/21/76	3.9	0.4	8.8	1.4	28	21	4.0	5.2	<0.1	5.2	0.03	0.3	<0.1		60	0	5	2.5	83	6.4	4.5	0.05	<0.005	<0.02	0.02	<0.005	<0.005	0.01	<0.01	0.008	<0.02	0.01	<0.02	<0.005	<0.05	<0.10	<0.03	<0.01	0.28		30.5
CB55-19	8/8/75	5.5	0.6	9.6	4.2	42	34	7	13	0.2	8.0	0.02	0.2	<0.1		104	20	100	25	133	6.5										0.05	4.4	6.6		0.006					0.02		13.7
CB55-53	3/18/76	4.3	0.5	7.6	1.0	23	15	7.0	9.0	0.1	4	0.06	0.1	<0.1		58	0	5	1.0	74	6.8	9	0.05	<0.005	<0.02	<0.02	<0.005	<0.005	0.01	<0.01	0.01	<0.02	0.01	<0.02	<0.005	<0.05	<0.10	<0.03	<0.01	0.26		29.9
CB55-143	2/20/76	14	1.0	50	4.9	146	103	33	25	0.1	14	0.02	<0.1	<0.1		220	1	20	8.0	341	6.7	7	0.05	<0.005	0.03	0.11	<0.005	<0.005	0.01	<0.01	<0.005	<0.02	1.6	<0.02	<0.005	<0.05	<0.10	<0.03	<0.01	0.02		27.7
CB55-147	2/23/76	14	1.2	20	5.4	72	39	4.5	48	<0.1	8.6	0.02	<0.1	<0.1		132	8	50	25	242	6.5	6	0.05	<0.005	<0.02	0.03	<0.005	<0.005	0.01	<0.01	<0.005	<0.02	1.6	<0.02	<0.005	<0.05	<0.10	<0.03	<0.01	0.11		12.2
CB77-18	2/19/76	36	2.0	41	3.7	119	117	32	36	0.1	12	0.3	<0.1	<0.1	6.5	244	2	5	5.5	387	7.4	6.0	0.05	<0.005	<0.02	0.06	<0.005	<0.005	0.01	<0.01	<0.005	<0.02	<0.01	<0.02	<0.005	<0.05	<0.10	<0.03	<0.01	<0.01	0.0005	57.3
CB77-28	2/19/76	8.1	1.3	21	6.5	79	61	17	15	0.3	8.1	1.2	0.2	<0.1		98	1	5	4.6	197	7.1	4	0.05	<0.005	<0.02	0.08	<0.005	0.02	0.01	<0.01	<0.005	<0.02	0.43	<0.02	<0.005	<0.05	<0.10	<0.03	<0.01	0.28		20.7
CB77-143	2/19/76	8.1	0.9	20	8.7	87	52	13	34	0.2	7.3	0.07	0.1	<0.1		144	6	30	20	234	6.5	5	0.05	<0.005	<0.02	0.02	<0.005	<0.005	0.01	<0.01	0.01	0.38	1.9	<0.02	0.005	<0.05	<0.10	<0.03	<0.01	0.79		15.2
CB77-167	11/24/76	11	1.3	32	4.2	98	100	13	10	0.2	11	0.02	<0.1	<0.1		165	4	10	10	250	7.7	7	0.05	<0.005	<0.02	0.04	<0.005	<0.005	0.01	<0.01	<0.005	0.8	0.3	<0.02	<0.005	<0.05	<0.10	<0.03	<0.01	<0.01	0.0005	182.9
CB77-382	3/17/78	8.3	1.5	29	6.1	97	92	11	11	0.2	12	0.06	<0.1	<0.1	4.5	135	0	10	0.33	230	7.5	6	0.05	<0.005	<0.02	0.12	<0.005	<0.005	0.01	<0.01	0.01	0.05	0.36	<0.02	<0.005	<0.05	<0.10	<0.03	<0.01	0.03		15.2
CB78-32	2/19/76	9.5	1.0	14	3.2	48	40	2	21	0.2	11	0.03	<0.1	<0.1		85	3	30	15	157	6.3	5	0.05	<0.005	<0.02	0.02	<0.005	<0.005	0.01	<0.01	0.008	<0.02	<0.01	<0.02	<0.005	<0.05	<0.10	<0.03	<0.01	0.04		29.6
CB78-105	1/5/78	14	1.6	27	3.4	82	49	21	31	0.1	4.9	0.02	0.6	<0.1	2								0.107	<0.005	<0.02	0.06	<0.005	0.15	0.01	<0.01	0.03	0.2	0.02	<0.02	0.01	<0.05	<0.10	<0.03	<0.01	2.4	0.0005	73.2
CB83-31	3/16/76	4.6	0.5	17	5.5	66	51	22	8.7	0.3	9	0.03	0.1	<0.1		96	0	5	0.7	143	7.2	11	0.05	<0.005	<0.02	0.15	<0.005	<0.005	0.01	<0.01	0.01	<0.02	0.03	<0.02	0.006	<0.05	<0.10	<0.03	<0.01	0.15		39.6
CB84-4	3/16/76	5.9	0.7	3.1	1.2	12	5.5	10	12	0.1	4	0.02	0.2	<0.1		50	49	5	1.5	63	5.5	4	0.05	<0.005	<0.02	0.04	<0.005	<0.005	0.01	<0.01	0.06	<0.02	0.04	<0.02	<0.005	<0.05	<0.10	<0.03	<0.01	0.03		30.5
CB53-17	2/21/76	28	4.3	21	4.9	72	120	5.0	13	0.4	6.1	0.02	<0.1	<0.1		156	1	25	6.7	264	7.7	6.0	0.05	<0.005	<0.02	0.33	<0.005	<0.005	0.01	<0.01	<0.005	<0.02	<0.01	<0.02	<0.005	<0.05	<0.10	<0.03	<0.01	<0.01		11.0
CB54-62	3/12/77	12	2.6	24	3.9	77	84	10	11	0.2	6.1	0.02	<0.1	<0.1	6.5	126	1	5	0.6	210	7.6	5.0		<0.005							0.01	0.1	0.2		<0.005					<0.005		17.7
CB55-136	3/18/76	19	4.4	23	5.1	80	100	14	11	0.2	7	0.02	<0.1	<0.1		140	0	5	1.8	242	7.5	8.0	0.05	<0.005	<0.02	0.13	0.006	<0.005	0.01	<0.01	<0.005	0.27	0.58	<0.02	<0.005	<0.05	<0.10	<0.03	<0.01	0.05		19.5
CB55-153	2/24/76	24	2.3	24	5.1	80	85	17	24	0.1	6.0	0.09	<0.1	<0.1		196	0	20	2.0	273	7.3	5.5	0.05	<0.005	<0.02	0.008	<0.005	<0.005	0.01	<0.01	<0.005	<0.02	0.25	<0.02	<0.005	<0.05	<0.10	<0.03	<0.01	<0.01		13.4
CB76-75	3/3/76	6.6	0.8	22	5.3	77	61	12	10	0.1	12	0.06	<0.1	0.1	4.0	99	2	5	1.5	165	7.6	6.0	0.05	0.006	<0.02	0.03	<0.005	<0.005	0.01	<0.01	0.02	<0.02	0.04	<0.02	<0.005	<0.05	<0.10	<0.03	<0.01	0.02	0.005	32.3
CB77-140	2/19/76	7.3	0.8	3.4	2.4	18	6.0	6	15	0.1	7.3	0.02	0.4	<0.1		46	3	20	17	71	5.3	5	0.05	<0.005	<0.02	0.009	<0.005	<0.005	0.01	<0.01	0.02	<0.02	0.14	<0.02	<0.005	<0.05	<0.10	<0.03	<0.01	0.02		16.8
CB78-2	2/20/76	5.5	0.7	5.4	2.2	23	8.5	6.5	13	0.1	4.3	0.28	0.7	<0.1		50	1	5	0.6	91	5.9	10	0.05	<0.005	<0.02	0.03	<0.005	0.03	0.01	<0.01	0.25	<0.02	0.02	<0.02	<0.005	<0.05	<0.10	<0.03	<0.01	0.08		26.8
CB78-45	1/6/77	12	1.8	28	4.4	89	93	12	13	0.1	11	0.02	<0.1	<0.1		119	1	10	1.0	240	7.9	10	0.05	0.007	<0.02	0.16	<0.005	<0.005	0.01	<0.01	<0.005	0.20	0.34	<0.02	<0.005	<0.05	<0.10	<0.03	<0.01	0.01		20.4
UPPER MORIEN HYDROSTRATIGRAPHIC UNIT																																										
CB77-155	2/19/76	18	2.0	24	7.9	92	45	45	35	0.1	9.4	0.03	<0.1	0.1	4.5	184	3	20	20	308	6.3	5	<0.05	<0.005	0.02	0.02	<0.005	<0.005	<0.01	<0.01	<0.005	0.03	2.4	<0.02	<0.005	<0.05	<0.10	<0.03	<0.01	0.05	0.0006	19.8
CB78-50	2/19/76	8.4	2.0	31	7.3	108	93	15	15	0.2	6.2	0.29	<0.1	<0.1	3.5	145	0	5	6.4	246	7.0	7.0	<0.05	<0.005	<0.02	0.21	<0.005	<0.005	<0.01	<0.01	0.01	<0.02	0.05	<0.02	<0.005	<0.05	<0.10	<0.03	<0.01	0.73	<0.0005	36.9
CB79-5	3/3/76	9.8	7.5	64	15	222	185	19	22	0.1	7.0	0.03	<0.1	0.1		256	2	10	3	429	7.8	5.5	<0.05	<0.005	<0.02	0.15	<0.005	<0.005	<0.01	<0.01	0.007	<0.02	0.01	<0.02	<0.005	<0.05	<0.10	<0.03	<0.01	<0.01		11.0
CB79-18	2/20/76	13	3.6	31	7.0	107	99	9.5	23	0.1	5.5	0.04	<0.1	0.1	3	160	0	10	1.0	275	7.6	8	<0.05	<0.005	<0.02	0.20	<0.005	<0.005	<0.01	<0.01	0.03	0.08	0.12	<0.02	<0.005	<0.05	<0.10	<0.03	<0.01	0.13	<0.0005	42.7
CB80-3	8/12/76	8.9	9.7	36	13.9	160	150	7.5	16	0.1	5.6	0.03	<0.1	<0.1	4	171	2	5	0.7	329	7.8	9	<0.05	<0.005	<0.02	0.06	<0.005	<0.005	<0.01	<0.01	0.006	<0.02	0.05	<0.02	<0.005	<0.05	<0.10	<0.03	<0.01	<0.01	<0.0005	24.4
CB80-14	7/5/77	15	1.7	29	5.9	96	3.2	87	22	0.1	1.2	0.02	1.2	<0.1	4.5	190	2	5	0.3	295	5.3	10	0.51	<0.005	0.06	0.03	<0.005	<0.005	0.008	<0.01	0.04	0.98	0.29	<0.02	<0.005	<0.05	<0.10	0.03	<0.01	0.04		13.7
CB83-3	3/16/76	17	5.2	38	8.6	131	155	7.0	15	0.3	11	0.02	0.1	0.1		184	0	5	1.5	330	7.7	6	<0.05	<0.005	0.13	<0.02	<0.005	<0.005	<0.01	<0.01	<0.005	<0.02	<0.01	<0.02	<0.005	<0.05	<0.10	<0.03	<0.01	<0.01		24.0
CB83-54	3/3/76	5.9	0.3	2.7	1.0	11	5.5	5.5	11	0.1	1.0	0.02	<0.1	0.1		30	1	20	0.6	61	6.5		<0.05	<0.005	<0.02	0.03	<0.005	<0.005	<0.01	<0.01	0.12	<0.02	0.04	<0.02	<0.005	<0.05	<0.10	<0.03	<0.01	0.05		28.0
CB83-8	2/18/77	9.9	8.2	33	8.7	119	140	13	16	0.2	11	0.02	<0.1	<0.1	2.5	164	1	5	2.5	300	7.9	7	<0.05	<0.005	<0.02	0.17	<0.005	<0.005	<0.01	<0.01	0.02	0.1	0.06	<0.02	<0.005	<0.05	<0.10	<0.03	<0.01	0.12	<0.0005	30.5
CB83-145	1/1/78	7.5	0.4	108	23	367	1	395	11	0.4	18	0.04	<0.1	0.2	2.0	592	14	15	7.8	1170	2.7	5	10	0.01	0.005	0.05	<0.005	<0.005	0.71	0.02	0.05	0.52	6.7	0.22	<0.005	0.05	0.16	0.09	0.02	0.54	<0.0005	Spring
CB83-146	1/5/78	32	5.3	22	6.0	80	140	11	12	0.3	10	0.02	<0.1	0.1	12	169	0	5	0.7	290	7.9	6	<0.05	<0.005	0.03	0.15	<0.005	<0.005	<0.01	<0.01	0.007	0.05	0.06	<0.02	<0.005	<0.05	<0.10	0.06	<0.01	0.03	<0.0005	38.1
CB79-228	1/3/78	72	6.1	7.2	2.6	29	181	7.4	16	0.7	6.2	0.02	<0.1	0.2	4.5	231	4	10	4.5	380	8.5			<0.005							0.02	0.20	0.05		<0.005					<0.01		56.4
LOWER WINDSOR HYDROSTRATIGRAPHIC UNIT (MARGINAL BASIN BEDS) GRANDMIRE FORMATION																																										
CB56-18	3/36/76	5.4	1.0	21	1.7	59	53	6	9.5	0.1	8	0.05	0.3	0.1	1.5	82	1	5	1	143	7.8	2	<0.05	<0.005	<0.02	0.17	<0.005	<0.005	<0.01	<0.01	0.08	0.17	0.01	<0.02	0.006	<0.05	<0.10	<0.03	<0.01	0.03	<0.0005	61
CB56-17	2/12/76	7.3	1.5	24	1.9	67	71	6.0	6.0	0.1	9.2	0.02	<0.1	<0.1		92	0	5	0.6	163	7.7	4.5	<0.05	<0.005	<0.02	0.17	<0.005	<0.005	<0.01	<0.01	0.01	0.05	<0.01	<0.02	<0.005	<0.05	<0.10	<0.03	<0.01	0.15		43
UPPER WINDSOR HYDROSTRATIGRAPHIC UNIT (MARINE BEDS)																																										
CB76-147	11/30/77	18	1.4	104	12	310	190	87	27	0.3	16	<0.02	0.1	0.1	4.0	370	0	5	9.9	580	7.9	8		<0.005							0.04	0.3	0.07		<0.005					0.03		18
CB56-1	3/3/76	15	2.7	420	8.3	1084	71	980	16	0.2	5	0.04	<0.1	0.1		1653	2	5	1.5	1765	7.4	5	<0.05	<0.005	0.20	0.006	<0.005	<0.005	<0.01	<0.01	0.06	0.10	0.01	<0.02	<0.005	<0.05	<0.10	<0.03	<0.01	0.60		18
CB56-30	10/24/75	9.7	0.7	56	13	194	147	25	28	<0.1	6.0	<0.02	<0.1	<0.1		282	0	5	1.0	426	8.0	11	0.06								0.02	0.3			<0.005					<0.005		17.6
CB76-2	2/23/76	4.4	0.7	17	2.2	51	49	4.0	5.2	<0.1	6.7	0.03	<0.1	0.1	5	77	1	20	4.5	127	6.8	5.0	<0.05	<0.005	<0.02	0.01	<0.005	0.009	<0.01	<0.01	0.02	<0.02	<0.01	<0.02	<0.005	<0.05	<0.10	<0.03	<0.01	0.19	0.0005	21.6
CB76-7	3/3/76	5.4	0.6	36	17	158	144	5	16	<0.1	8	0.04	0.8	<0.1		175	1	5	2.5	297	7.9	4.0	<0.05	<0.005	<0.02	0.13	<0.005	<0.005	<0.01	<0.01	<0.005	<0.02	<0.01	<0.02	<0.005	<0.05	<0.10	<0.03	<0.10	0.01		21.3
CB76-47	2/23/76	8.0	1.8	64	3.2	174	150	14	23	0.1	7.5	0.02	0.7	<0.1		226	0	5	1.0	385	7.1	3.5	<0.05	<0.005	0.03	0.39	<0.005	<0.005	<0.01	<0.01	0.009	<0.02	<0.01	<0.02	<0.005	<0.05	<0.10	<0.03	<0.01	<0.01		21.0
CB77-61	2/20/76	10	3.8	32	13	136	130	15	13	0.1	8.8	0.02	<0.1	<0.1		164	0	10	2.5	308	7.7	4.0	<0.05	<0.005	0.14	0.13	<0.005	<0.005	<0.01	<0.01	0.008	<0.02	0.01	<0.02	<0.005	<0.05	<0.10	<0.03	<0.01	0.01		40.2
CB77-101	2/20/76	5.4	2.2	30	2.3	84	84	4.5	6.5	<0.1	9.2	0.8	<0.1	<0.1		114	1	5	6.0	187	7.5	4	<0.05	<0.005	0.02	0.21	<0.005	<0.005	<0.01	<0.01	<0.005	<0.02	0.02	<0.02	<0.005	<0.05	<0.10	<0.03	<0.01	0.01		23.8
CB77-261	9/11/73	7.0	1.7	57.6	0.72	146	122	10.3	18	0.18	7.2					213	0	1	3.3	30	8.0	8.5			0.15						0.006	0.07	0.004		<0.005					0.16		43.3
CB77-265	7/26/77	6.5	3.0	35.6	19.2	169	130	24	21	0.2	6.7	0.02	2.5	<0.1		184	12	20	1.4	310	7.7	12	0.51	0.006	0.18	0.08	<0.005	<0.005	<0.01	<0.01	0.06	<0.02	<0.01	<0.02	<0.005	<0.05	<0.10	0.04	<0.01	0.02		43.6
CB77-380	2/24/78	21	3.9	52	20	214	164	45	46	0.3	7.3	0.02	3.0	<0.1		288	10	15	12	390	7.6	8		<0.005							0.01	0.10	0.06		<0.005					0.08		49.7

APPENDIX 3

MAJOR-DOCUMENTED METALLIC

AND NON METALLIC METALLIC MINERALIZATION

MAJOR - DOCUMENTED METALLIC AND NON METALLIC MINERALIZATION

#/Location (See Map 1)	Commodity	Occurrence Name	Description of Occurrence: Primary Commodity	Associated Minerals	Character	Remarks
1	Limestone	Cape Dauphin New Campbellton	Limestone	Dolomite	Lmst-hard, dense, bluish grey and finely crystalline dolomite white-pink coarsely crystalline pure	Limestone is extensive all along entire side of Kelly's mountain from Kelly Cove to Cape Dauphin-6.4 km. Dolomite not continuous along this entire length-intermittent and pinches out, occurrence noted in major dolomite zone. This carbonate band is approx. 300 m wide-maximum, narrows to 1-60 m where only lmst. found - dips steeply to northwest.
2	Coal	Braughin Pits	Coal	-	Lower and Upper Bonnar Coal Seams	Open pit mining - pit on east side of road is finished
3	Coal	Prince Mine	Coal	-	Stubbard coal seam	Initially strip mining then move to underground.
4	Coal	Crawley Brook	Coal	-	Sydney main coal seam	Strip mining - in process of reclamation
5	Coal	Alder Point	"	-	Lower and Upper Bonnar coal seams	Strip mining - in process of reclamation
6	Coal		"		"	Stripped - no reclamation
7	Lead, Zinc	Point Edward - Westmount	Pb-Zn	Cu		Stream & soil sampling revealed anamalous Pb-Zn values around Windsor-Canso contact.
8	Limestone	"	Limestone		Large at Pt. Edward quarry consists of band 8-9 m thick of grey high Ca limestone.	Rudderham Point Lmst. Dixon Point Lmst. Crawley Creek Lmst. Pt. Edward Lmst.- Subcrops & outcrops delineated & named on map. - # of quarries open - not reclaimed
9	Lead	Limestone point	Galena	-	fine galena crystallization in limestone	
10	Strontium	Frenchvale Brook	Strontium Celestite gypsum?		pale white to cream in colour, fine to med. grained crystalline texture, very gritty easily crumbled	0.6 m bed of celestite, - 10 m long dipping at 20°NE, found outcropping within a sst., drilling indicated maximum down dip intersection was 2 m at 23.8% $SrSO_4$.
11	Copper				disseminated	Unconformablly overlying the Grantmire is a 7 to 10 m dark grey-black Lmst. Widespread chalcopyrite and in outcrop malachite occur at the contact between Lmst. and Congl. throughout Basin. Silver in the form of argentite has been found in isolated boulders but nowhere as outcrop.
12	Serpentine	Scotch Lake		Calcite, Pyroaurite hematite, talc, magnetite, tremolite pyrite, graphite, dolomite		Fine grained massive Serpentine occurs in shades of yellowish, yellowish green, olive green, blue, deep red, brown with a variety of patterns producing banded, spotted, streaked & mottled effects.
13	Copper	McDonald + Watson shafts			disseminated	County rock is either a roof pendant or an erosional remanent of the George River Series and is surrounded and interbedded by red granite and cut by baser dykes.
14	Copper	George River	Cu/Chalcopyrite	pyrrhotite pyrite	vein 4-9 m in width with 2 m of very rich sulphide mineralization	mineralization is chiefly pyrrhotite, assoc. with qtz, calcite, chlorite + Serpentine, but pyrite • chalcopyrite are present. Nickel has also been reported. Vein has been traced for several hundreds of metres.
15	Lead	Saunders Cove	Pb/Galena	Zn	Galena in sheared bituminous micrites belonging to a well developed carbonate sequence.	Pb + Zn anomalies in stream sediments
	Gypsum & anhydrite				Granulated gypsum succeeded by green marles, mixed with streaks, veins, nodules of gypsum & selenite; limestone above & below gypsum	5-7 m thick
16	Zinc	Leitches Creek	Zn/Sphalerite	Cu, Pb	In limestone	
17	Limestone	Boulardarie Isl. Graves Point West & George River Stn.	Limestone			Dark grey, hard, fine grained, compact and poorly bedded.
18	Limestone	Balls Creek				Dark grey hard compact fine grained, poorly bedded limestone
19	Limestone					Dark grey hard, fine to med. grained
20	Lead	Leitches Creek	Pb/Cu	Zn	Along contact	Morien & Pt. Edward/Canso Group
21	Limestone					Dark, fine grained, dense
22	Silica	Leitches Creek	Silica/Quartzite			The quartz is overlain by granite and shale. The ore body is considerably cross fissured, the quartzite is white
23	Manganese	Bouladarie Isl MacNeil Prop.	Mn	Ochre		Bog manganese 3-7 mm below overburden thickness 0.6-3 m, ore is completely water saturated

24	Iron		Iron/ magnetite Pyrrhotite pyrite	Cu, Ni, Zn, Pb	2 lenses each 0.6 m thick, parallel to bedding of carbonate rock of George River Group 3 shallower shafts and a # pits. very low grade sulfide zones very lensic in nature.
25	Iron	MacPherson Mine	iron/mag- netite		2 lenses 0.6 m thick, running parallel to the carbonate bedding (in George River Group) and are in close proximity & related to a dyke of red granite. - abandoned mine
26	Dolomite	Black Brook	Dolomite		Light grey, hard, fine grained, very compact and well bedded
27	Limestone	Shawfield Point			Calcium limestone, 14 m thick at Lake level
28	Lead	Scotch Lake Road Group	Pb/galena	Zn/Sphal- erite	Galena traces common in most surface exposures of reefal limestone, lying uncomformably on basement rocks or in juxtaposition with basement along a N-NE trending fault zone. Weak dolomitization.
29	Copper	MacMullen Lake	Cu		Stream anomaly underlain by granodiorites
30	Copper	Frenchvale Leitches Creek	Cu/Mala- chite	Chalcopyrite bornite chalcocite	Disseminated and as platings on conglomerate pebbles
31	Lead	Frenchvale	Pb/galena		Disseminated in carbonates of George River
32	Copper	MacMullin Brook	Cu/chalco- pyrite malachite		Disseminated in Grantmire Conglomerate
33	Lead	MacAdam Lake	Lead/gal- ena	pyrite	Desseminated in Lmst. of George River Group.
34	Lead Zinc Silver	MacAdam Lake	Pb/galena Silver	Pyrite Zn/Sphalerite Cu(Chalcopyrite Au	Pods and lenses banded or in irregular masses in limestone of George River. Iron/hematite lenses 2-3 m wide at surface, pinches out at depth of 4 m, assoc. with limestone
35	Graphite	Frenchvale	Graphite dolomite	Fluorite	Graphite occurs evenly distributed in the form of minute flakes in G.R. Lmst. over thickness of 0.6-1 m Dolomite consists mainly of white to blue-grey, hard, dense & coarsely cyrstalline dolomite with low Silica content.
36	Uranium	MacAdams Lake	Uranium		Anomalous values in shore and stream sediments
37	Limestone	Leitches Creek	Limestone		Light brown to grey, fine, dense & a strong petroliferous odour, quarry abandoned - Silica content too high.
38	Copper	Coxheath	Cu/chalco- pyrite	pyrite, gold, silver, hematite, magnetite, tourmaline, molybdenite	1) Showings within a distance of 130 m on 4 parallel, steeply dipping shear zones in qtz diorite and andesite - Shears followed on surface to 3 km - one is reported up to 11 m wide. 2) Mountain vein - traced on surface for over 300 m & 5 m wide. 5 shafts have been sunk, presently abandoned - Max. depth 105 m.
39	Copper	Coxheath	Cu		Occurrence in outcrop in old pits and trenches.
40	Potash/ gypsum	Sydney Forks	Potash, gypsum		Marine evaporite deposits, beds of gypsum, traces of salt. Gypsum member subcropping and shown on map.
41	Limestone	East Bay area			The subcrop of the limestone is partially shown on the map, the member averages 11-14 m in thickness with a maximum of 18 m. It is composed of a mainly dense textured, high Ca limestone, ranging from sand-brown to bluish grey.
42	Copper	MacKay Showing	Cu/chalco- pyrite		Disseminated throughout the top 06-1 m of a grey calcareous conglomerate forming the lowermost part of the Marine Windsor Group and in a 1-25 m thick zone of dark grey silty to shaly limestone immediately overlying the conglomerate.
43	Celestite	Sydney River	Strontium/ celestite	Calcite dolomite galena	Dark grey-light grey in colour, medium grained, crystalline, granular texture