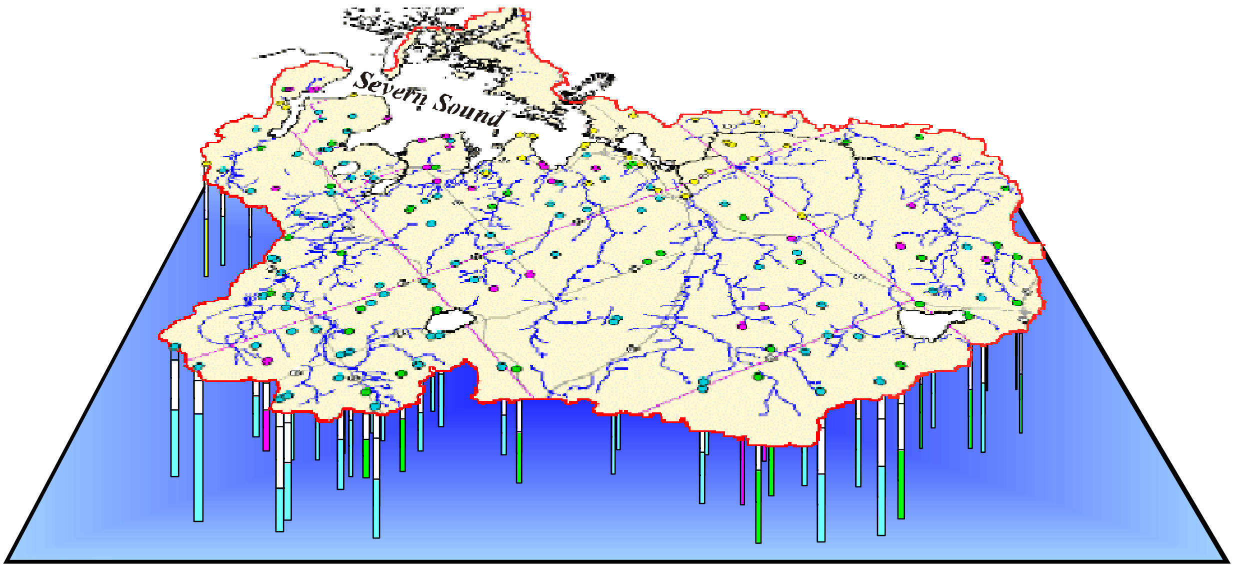
Severn Sound

Remedial Action Plan

THE GROUNDWATER RESOURCES

OF

THE SEVERN SOUND REMEDIAL ACTION PLAN AREA



By

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G. SHIEKH and W. ZAIA

Ontario

PREPARED IN COOPERATION WITH
THE SEVERN SOUND REMEDIAL ACTION PLAN
AND
MINISTRY OF THE ENVIRONMENT
Environmental Monitoring and Reporting Branch

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PREFACE

This report describes the occurrence, quantity and quality of the groundwater resources of the Severn Sound Area of Concern. It provides relevant information related to the geography of the area including topography, physiography, drainage, climate, and soils. The report also includes detailed information related to the area's various bedrock and overburden units.

Data on pumping tests as well as statistical techniques were used in the report to estimate the hydraulic parameters of various bedrock and overburden units. In addition, the report provides a quantitative assessment of the long-term groundwater recharge and discharge as well as an evaluation of surface and groundwater quality.

The report does not address specific situations or local issues within the study area, rather it is intended to provide basic hydrogeologic information that can be used for the wise management of the area's groundwater resources. This report has received technical review by MOE staff. Approval does not necessarily signify that the contents reflect the views and policies of individual agencies nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

The report is prepared in support of the Severn Sound Remedial Action Plan (RAP). For additional copies please contact the Severn Sound Environmental Association Office.

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ACKNOWLEDGEMENTS

This study was carried out under the general supervision of Mr. E. Piché, Director, and Mr. J. Fleischer, Manager, Water Monitoring Section, both of the Environmental Monitoring and Reporting Branch, Ontario Ministry of Environment.

Appreciation is expressed to the Severn Sound Remedial Action Plan for providing administrative and financial support and to the Ministry of Natural Resources for providing financial assistance to this study. In particular, the cooperation and assistance of the late Mr. Roy Alkema, MNR Midhurst District is gratefully acknowledged.

Thanks are due to all the municipal offices in the study area who provided reference materials and assisted in verifying the locations of water wells in the study area. In particular, thanks are due to Mr. W. Crown, Tay Township Planning Department, for providing reference materials and technical advice.

Appreciation is due to staff of the Ontario Geological Survey for supplying maps and information regarding the geology of study area. Also the technical advice of Mr. I. Gray, MOE, Barrie District Office concerning groundwater quality issues within the study area is gratefully acknowledged.

Thanks are due to Mr. B. Kannon for his assistance in compiling information related to the physiography of the study area, and to Mr. C. Chenier and Mr. L. McPhail for their assistance in locating newly constructed water wells and collecting water samples.

The co-operation of the residents of the area, who permitted the sampling of their water wells, is greatly appreciated.

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EXECUTIVE SUMMARY

Groundwater is a valuable resource to the public health and economic well-being of all the people within the Severn Sound Remedial Action Plan Area. Groundwater provides a reliable water supply of high quality water to domestic, public, agricultural, commercial and industrial users. It is also an important component of streamflow, especially during dry weather periods.

Groundwater provides the source for most communal water supplies in the area. In addition, the majority of private dwellings take water for domestic use from private wells. Over 5,000 well records are on file with the Ministry of the Environment for wells constructed in the study up from 1947 to 1995 including over 1,200 well records that were located and added to the data files through this study. In order to protect these resources and to meet the expanding demand for water supply in this area, it is critical to identify its important aquifers and to describe its groundwater flow systems. It is equally important to quantitatively determine the long-term variations in groundwater recharge and discharge within various parts of the study area and to assess the quality of its groundwater resource.

A regional scale study of the groundwater resources of the Severn Sound Area of Concern was conducted from 1995 to 1999 in order to provide a framework for understanding, protecting and monitoring the groundwater in the area. Severn Sound is a group of bays in southeastern Georgian Bay. The study area includes six small watersheds draining from the south into the Sound with some miscellaneous drainage along the north and south coastal areas. The land drainage for the Area of Concern is approximately 1,000 km^2.

The long-term average precipitation within the study area is about 1,110 mm with approximately one-third of the precipitation as snow. The long-term annual groundwater recharge/discharge estimated for the area streams ranged from 41% of the flow in the Wye River to a high of 63% of the flow in the Coldwater River. These values indicate the potential influence that groundwater can have over the quality of water flowing in Severn Sound streams.

The majority of soil series in the area are well drained with poorly-drained muck and marsh soil series near known significant wetlands. The bedrock in the study area consists of Palaeozoic

sedimentary rocks and precambrian rocks. Most of the bedrock within the study area, with the exception of the north and northeastern areas, is obscured by a mantle of unconsolidated overburden deposited during the Quaternary Period.

Five hydrogeologic units were identified within the bedrock in the study area. These units include the Precambrian hydrogeologic unit and the Shadow Lake-Gull River, Bobcaygeon and Verulam hydrogeologic units. This study suggests that the upper 20 m of the Palaeozoic formations are more productive than the lower parts. It also suggests that the Shadow Lake-Gull River and the Bobcaygeon hydrogeologic units have similar water-yielding capabilities. From a practical point of view, however, these units are important as sources of groundwater supplies only in areas where the units are at or close to the surface. In areas where these units are under thick sequences of Quaternary deposits, their significance as sources of groundwater supplies is minor.

The overburden in the study area is composed of glacial, glaciofluvial, glaciolacustrine, and recent deposits. These deposits include clays, silts, sands, gravels, and tills. In general, the availability of ground water in the overburden ranges from poor to good. Most wells in the overburden are used to meet domestic supplies and livestock requirements. Locally, overburden aquifers are the most productive sources of groundwater within the study area and provide a number of urban areas with water supplies. Overburden wells are, in general, more productive that the bedrock wells. Given the heterogeneity of these deposits, however, detailed local investigations including test wells and long-duration pumping tests are necessary to find appropriate water supplies.

Based on the analyses of the specific capacity and related transmissivity distributions of wells completed in various overburden deposits, wells completed in areas where glaciofluvial ice-contact and outwash deposits outcrop at the surface have the highest water-yielding capabilities. This is possibly because these deposits are widespread and extensive especially within the Bass Lake kame moraine. Glaciolacustrine sands and gravels also indicate high water-yielding capabilities. Wells completed in areas where till or glaciolacustrine clays are at the surface are in general less productive. However, it is possible to have highly productive wells completed where till or glaciolacustrine deposits outcrop at the surface due to the fact that the overburden profile is highly variable both vertically and horizontally, and any overburden well may encounter sand or gravel deposits at some depth.

The quality of groundwater in the Severn Sound area was examined through a review of well record information, municipal well sampling results and through a sampling program of selected wells completed in various bedrock and overburden units.

Approximately 99.3% of the 1,816 wells constructed in overburden and with records reporting quality, were reported to yield fresh water, and the remaining 0.7% yield sulphurous, salty or mineral water or water containing gas. In comparison, only 95.0% of the 940 bedrock wells reporting quality were reported to yield fresh water.

The following percentage of samples exceeded the Provincial Drinking Water Objectives in wells of various hydrogeologic units.

	Sodium (Na) >200 mg/L	**Sulphate (SO4)** >500 mg/L	**Chloride (Cl)** >250 mg/L	**Iron (Fe)** >0.3 mg/L	**Total Dissolved Solids** >500 mg/L
Precambrian bedrock	17	7	10	28	41
Palaeozoic bedrock	0	13	4	17	32
Shallow overburden	0	0	3	18	11
Deep overburden	0	0	0	12	0

The highest percentage exceedence for the basic chemical parameters was in precambrian bedrock wells. Deep (>20 m) overburden wells had the least exceedences. Most exceedences were for iron or total dissolved solids. Mean hardness ranged from 173 mg/L in deep overburden wells to 328 mg/L in palaeozoic wells. Longer-term records of quality analyses in municipal wells indicate increases in sodium and chloride concentrations which are likely due to the effect of road salt spreading during winter periods.

Groundwater recharge/discharge into the six streams in the Severn Sound area had a proportionately larger influence on the quality of stream water during low flow or base flow periods (usually the summer months) when surface runoff was reduced. The analysis of the Severn Sound area stream quality examined the long-term trends at the Coldwater River station and base flow quality for the influence of ground water and for trends through time in all six tributaries. Water temperature generally corresponded to groundwater recharge/discharge to streams with the lowest maximum temperature found in the headwaters of the Coldwater River and the warmest in the downstream waters of the North and the Wye Rivers. Median base flow chlorides concentration ranged from a low of 3.6 mg/L in Copeland Creek to 22.1 mg/L in the North River. Chloride concentrations increased with time over a 25-year period in the Coldwater River, leveling off in recent years. Nitrates did not show an increasing trend over the long-term and was generally below 0.5 mg/L with the exception of the Wye River which was influenced by the Elmvale sewage treatment plant discharge and more extensive farming in the area. Total phosphorus concentrations were relatively low, especially in the Sturgeon River, Copeland Creek and the Coldwater River. Based on water quality analysis the streams in Severn Sound were receiving beneficial diluting waters from the groundwater system.

INTRODUCTION

SIGNIFICANCE OF GROUNDWATER RESOURCES

Groundwater is a valuable resource to the public health and economic well-being of all the people within the Severn Sound Remedial Action Plan Area. Groundwater provides a reliable water supply of high quality water to domestic, public, agricultural, commercial and industrial users. It is also an important component of streamflow, especially during dry weather periods.

Where available in sufficient quantity, groundwater offers substantial advantages over surface water supplies. The advantages include:

- minimum treatment requirements in most cases;
- the avoidance of long, costly pipelines for municipal supplies;
- temperature and water quality are usually uniform; and
- with proper protection, the supply is dependable.

Most municipal water supplies within the study area are from groundwater sources. The majority of these supplies are obtained from water wells. Over 3,200 well records are on file with the Ministry of the Environment for wells constructed in the study area between 1947 and 1994. Based on data available for the period 1984 to 1994, it is estimated that between 50 and 200 new wells are being constructed in the study area every year.

The construction of water wells has changed considerably since they were dug with pick and shovel to limited depths. Today, modern drilling equipment allows wells to reach depths of several hundred metres. Similarly, wells and water supply systems today are more reliable than their predecessors. A properly located, constructed and maintained water well will probably never go dry nor be contaminated.

One of the most important attributes of groundwater, which is often overlooked, is its perennial contribution to surface water throughout the year. Within the study area, groundwater contributes substantial volumes to streamflows ranging from 42% to 62% of the long-term, mean annual flows. These contributions are especially important during low flow periods when up to 100% of the flow in these streams consists of groundwater discharge.

In the past, watershed planning studies focused mainly on surface water while groundwater was either ignored or treated in a superficial manner. This attitude, however, is changing as more water managers are coming to the conclusion that the full consideration of the groundwater resources in a watershed planning exercise is not an academic endeavour, but is an essential undertaking that has social, financial, environmental and ecological implications.

Appropriate land use planning in the Severn Sound Remedial Action Plan Area requires a good understanding of its groundwater resources. In order to protect these resources and to meet the expanding demand for water supply in this area, it is critical to identify its important aquifers and to describe its groundwater flow systems. It is equally important to quantitatively determine the long-term variations in groundwater recharge and discharge within various parts of the study area and to assess the quality of its groundwater resource.

LOCATION OF THE STUDY AREA

Severn Sound is a group of bays in southeast Georgian Bay. The Sound was listed as an area of concern by the International Joint Commission because of problems stemming from nutrient enrichment. The Severn Sound Remedial Action Plan (RAP) Area is located in southern Ontario between longitude 79^0 54' 50" and 79^0 24' 30" W and latitude 49^0 31' 02" and 49^0 74' 41" N. The study area contains six small watersheds draining from the south and a miscellaneous area draining land along the north shore of the Sound. The watersheds are those of the North, Coldwater, Sturgeon and Wye Rivers and Hog and Copeland Creeks (Figure 1).

The study area has a total drainage area of about 1,222 Km^2, a maximum length of about 43 km in a northwest-southeast direction and a maximum width of about 46 Km in a northeast-southwest direction. It is bounded on the north by Severn River basin and Georgian Bay, on the east by Lake Simcoe and Lake Couchiching basins, on the south by the Nottawasaga River basin, and on the west by Georgian Bay as well as by a narrow strip of land that drains into Georgian Bay.

Most of the study area lies in Simcoe County whereas a small area in the north is within Georgian Bay Township(Baxter Ward)in the District Municipality of Muskoka. As of 1998 a major restructuring of the northern County of Simcoe municipalities took effect. The original thirteen local municipalities represented within Severn Sound were restructured to form seven municipalities (Figure 1).

The study area contains all or parts of the following municipalities:

OLD STRUCTURE	NEW STRUCTURE
SIMCOE COUNTY:	
Tiny Township	Tiny Township
Flos Township Village of Elmvale	Springwater Township
Town of Penetanguishene Town of Midland	Town of Penetanguishene Town of Midland
Village of Port McNicoll Village of Victoria Harbour Township of Tay	Township of Tay
Township of Medonte Township of Oro	Township of Oro-Medonte
Township of Matchedash Township of Orillia Village of Coldwater	Township of Severn

As many groundwater studies and well records were filed under the old municipal names, they are used throughout the text of this report.

PURPOSE AND SCOPE OF THE STUDY

The purpose of this study is to evaluate the occurrence, quantity, and quality of the groundwater resources in the Severn Sound RAP Area. This includes:

- the compilation, analysis and interpretation of existing information related to physiography, topography, drainage, climate, and soils;
- the assessment of the bedrock and overburden geology of the study area;
- the identification of the geologic conditions under which various groundwater flow systems operate;
- the determination of the hydrogeologic parameters of the various hydrogeologic units;
- the delineation of principal areas of recharge and discharge;

- the evaluation of the long-term groundwater recharge and discharge on a monthly and annual basis as part of water budget analysis; and

- the examination of the surface water and groundwater hydrochemistry and its change over time.

SOURCES OF INFORMATION

The study made extensive use of data contained in the Water Well Information System (WWIS) of the Ministry of Environment. The WWIS is a computer database that was designed in 1972. The system provides for the easy input and retrieval of data describing the characteristics of water wells drilled in Ontario between 1946 and 1984. The WWIS contains approximately 485,000 water well records.

A water well record contains information on up to 212 parameters including:

- surface elevation;

- location: geographic coordinates, county or district, township, borough, city, town or village, lot, concession, and watershed;

- geology: geologic formations encountered during drilling;

- water: depth at which water was found, depth to static level, and the kind of water encountered in terms of being fresh, salty, sulphurous or containing iron or gas;

- pumping test and well yield;

- well construction details: casings, screens, plugs, and seals; and

- date of well completion.

The WWIS database also includes a quality control feature, which assigns to the values of well coordinates and elevations different quality indices. These indices range from 1 for high quality data to 9 for poor quality data. This feature allows the user to select only those data that have the highest degree of accuracy in terms of well location and elevation.

The WWIS indicates that there are 2,011 water wells constructed in the study area prior to 1984. To enhance the available database, a field program was initiated to identify the geographic coordinates and surface elevations of an additional 1,200 wells constructed between 1984 and 1994. Of the total 3,211 water wells in the study area,1,958 wells are in the overburden,1,103 wells are in the bedrock, and the remaining 150 wells are of unknown type.

Information on topography, physiography and geology were obtained from maps produced by the Ontario Geological Survey, Ministry of Northern Development and Mines. Soil information and a digitized soil map were obtained from the Ministry of Agriculture, Food and Rural Affairs. Climatic data were obtained from Environment Canada. Aerial photographs, provided by the Ministry of Natural Resources, were also used to supplement geologic studies.

Daily streamflow data for eight hydrometric gauging stations, being maintained by Environment Canada, were used to determine the variation in baseflow on a daily, monthly and annual basis. The results of the baseflow analyses were used to assess the long-term groundwater discharge and recharge in various watersheds within the study area.

The results of chemical analyses for 177 water samples, collected from wells completed in various bedrock and overburden units, were used to determine the types of groundwater found in these units. In addition, water quality data, collected through the MOE Water Quality Network, and the Severn Sound RAP Tributary Quality Project were used to determine the time and space variations in water quality for various streams within the study area.

THE RAISON GIS SYSTEM AND ARCVIEW 3.1 (R)

In the past, the analysis and interpretation of information obtained from the WWIS database for a given area was done manually. This was a time-consuming process because of the great number of records that had to be considered.

Recent advances in the area of Geographic Information Systems (GIS) made it feasible to consider a large amount of data, to present these data on thematic maps, and to conduct numerous analyses and interpretations within a short time frame. The Regional Analysis By Intelligent Systems On A Microcomputer (RAISON) is such a GIS system, and is suitable for use with the WWIS database.

RAISON is a data analysis tool that was specifically designed for use on personal computers (PCs). It was developed as a joint research project by the National Water Research Institute and the University of Guelph, Ontario (ES Aquatic,1992).

RAISON integrates databases, spreadsheets and GIS capabilities that are particularly suitable for applications involving point data. It provides an environment for displaying the data and analytical results in the context of local geography. In addition, enhanced statistical techniques are included in RAISON and advanced modelling can be performed.

The "RAISON Database" is a subsystem within RAISON that allows the user to maintain files through the use of "Delete Record" and "Edit Record" functions. Data may be exported in dBASE or Lotus 123 formats for use in programs external to RAISON, or for exchange with other users using similar data formats. In addition, data may be imported into RAISON as ASCII files from the mainframe computer or from other software packages.

Normally, data are either entered manually into RAISON or an existing database is retrieved. Using the RAISON Database subsystem, links and basic analyses can be done. Relevant results can then be transferred into a spreadsheet and further analyses can be performed.

The results obtained from various RAISON analyses can be displayed graphically in the form of charts, graphs, maps or cross-sections. As is the case with other GIS systems, RAISON can display the results in colours or symbols so that similar regions can be readily identified. This RAISON capability is extremely useful in conducting hydrogeologic analyses.

Using the mainframe FOCUS software, the water well records for the study area were downloaded from the mainframe computer into a PC. The records were then converted from ASCII type files into dBASE type files. Data were organized in such a way that they can be accessed by the RAISON Database subsystem, retrieved into the RAISON spreadsheet for analysis, or displayed using the RAISON GIS subsystem.

A number of hydrogeologic analytical techniques were developed by MOE staff specifically for the interpretation of the WWIS database in conjunction with RAISON. These techniques allow the user to produce various maps and geologic cross-sections or to perform streamflow separation. At present, the following types of maps can be produced:

- well location,
- well type (bedrock or overburden),
- kind of groundwater in the bedrock,
- kind of water in the overburden,
- bedrock topography,
- overburden thickness,
- groundwater level elevation in the bedrock,
- groundwater level elevation in the overburden,
- specific capacity of bedrock wells,
- specific capacity of overburden wells,
- transmissivity of bedrock wells, and
- transmissivity of overburden wells.

More recent analyses were carried out by MOE and Severn Sound RAP staff of surface and bedrock topography and overburden thickness using ArcView 3.1 (ESRI) with the Spatial Analyst Module.

PREVIOUS INVESTIGATIONS

Numerous investigators have described the climate, physiography and geology of the Great Lakes basin including parts or all of the study area. Brown et al (1968) described the climate of southern Ontario including the study area. The authors identified the major climatic regions in southern Ontario based on the available weather records of temperature, precipitation, sunshine, humidity and wind.

Chapman and Putnam published a number of scientific articles and reports in which they described the physiography of south-central Ontario (1936), the soils of south-central Ontario (1937),the drumlins of southern Ontario (1943) and the moraines of southern Ontario (1943). The classical report by Chapman and Putnam entitled "The Physiography of Southern Ontario" was first published in 1951 and the third edition of the report was published in 1984. This significant publication describes, for the first time, the physiography of southern Ontario including the Georgian Bay-Ottawa Valley Region.

The Precambrian rocks in the study area were described by Deane (1950)and Liberty(1969). Also, Easton (1992) provided a detailed description of the Grenville Province and the Proterozoic history of southern Ontario.

Liberty (1953) published a preliminary map of the Palaeozoic rocks within the Orr Lake area. The map was accompanied by descriptive notes regarding bedrock stratigraphy, glacial geology and structural geology. In addition, Liberty (1969) published a memoir in which he described the Palaeozoic geology of the Lake Simcoe area. The memoir included nomenclatural subdivisions of the Ordovician rocks.

A variety of stratigraphic nomenclature were proposed for the Middle and lower Upper Ordovician strata in Ontario by Wilson (1946),Sanford (1961),Beards (1967),Liberty (1969),Winder and Sanford (1972), Russel and Telford (1983), and Williams(1991). Poor rock exposure, thick overburden and lateral facies changes led various authors to propose nomenclature schemes that emphasized either one or several criteria such as biostratigraphy, lithostratigraphy, subsurface geophysical expression and weathering characteristics.

The stratigraphic nomenclature used in this report is the one currently used by the Ontario Geological Survey (Johnson et al, 1992), which is based on that of Liberty (1969) as modified by Russel and Telford (1983), Williams and Telford (1986), and Williams (1991).

The Quaternary geology of the study area was discussed by many authors as part of compiling the history of the Great Lakes. Johnston(1916) and Goldthwait (1948) traced the Algonquin shoreline in the Lake Simcoe area. Also Stanley (1936, 1937) reported on the lower Algonquin beaches around Georgian Bay.

Deane (1950) described the Pleistocene geology of the Lake Simcoe District. The author also described the various land forms in the area as well as the bedrock and unconsolidated material comprising these forms. In addition, the author discussed in some detail the origin and mode of accumulation of the glacial deposits.

Burwasser and Ford (1974a, 1974c) produced preliminary maps of the drift thickness and bedrock topography of the Orr Lake and Barrie areas. Also, Burwasser and Boyd (1974)compiled a map of the Quaternary geology of the Orr Lake area, which covers the western parts of the study area.

Finmore and Bajc (1984) compiled a Quaternary geology map of the Orillia area, which covers the eastern parts of the study area. Bajc and Paterson (1992)compiled a map of the Quaternary geology of the Penetanguishene and Christian Islands areas. The map covers most of the northern parts of the study area. The same authors compiled in 1992 a map of the Quaternary geology of Gravenhurst area, which covers a small portion of the northeastern corner of the study area.

Barnett (1992) compiled a map of the Quaternary geology of the eastern half of the Barrie and Elmvale map areas. The map covers the central parts of the study area and is based on geological field studies conducted between 1986 and 1989. Also, Barnett (1992)provided a comprehensive description of the Quaternary geology of southern Ontario including the study area in which he summarized Ontario's record of glaciation.

Sibul and Choo-Ying described the water resources of the Upper Nottawasaga River basin, which is located immediately to the south of the study area. The report contains information about the occurrence, distribution, quantity and quality of water in the Nottawasaga River basin. Turner (1982), published a groundwater probability map of the northern portion of Simcoe County, which covers parts of the study area. In addition, Singer et al (1997) described the hydrogeology of southern Ontario which covered most of the study area.

Numerous technical reports dealing with local issues related to water supply have been prepared by government staff and consulting firms. Useful information on the hydrogeology of a number of sites within the study area were reported by Yakutchik and Jeffs (1959), Norman H. Ursel Associates Ltd.(1971),I.D. Wilson Associates Ltd.(1973,1994), Andrijiw (1976), Pawlowski (1978), Belcourt (1980), Dixon Hydrogeology Ltd.(1988,1989,1991), Henderson, Paddon and Associates Ltd.(1990), Trow, Dames & Moore (1991), Midland Public Utilities Commission(1992), Lotowater Ltd.(1992), Jagger Hims Ltd.(1993, 1994), and Proctor and Redfern(1994).

The limestone resources within the study area were described by Derry, Michener, Booth and Wahl and Ontario Geological Survey (1989) as part of a study of the limestone industries in Ontario. In addition, the Ontario Geological Survey (1982, 1984) prepared inventories of the aggregate resources of Flos and Oro Townships.

GEOGRAPHY

TOPOGRAPHY

The topography of the study area is a direct result of the deposition and erosion processes during glacial and post-glacial times. Land surface elevations vary from 177 m above mean sea level (a.s.l.) along the shores of Georgian Bay to 412 m (a.s.l.) in a very small area located within the Bass Lake moraine along the southern topographic boundaries of the study area(Figure 2).

Two distinct topographic regions can be identified within the study area: the flat-floor valleys, rock-knob Precambrian lowlands, and limestone plains topographic region and the elevated, rolling till plains topographic region. The first region varies in elevation from 177 m to 250 m (a.s.l.), while the second region varies in elevation from 250 m to 412 m (a.s.l.).

As Deane (1950) notes, the rock-knob Precambrian lowlands and the limestone plains have little relief, for although the Precambrian topography is rugged and the limestone plains are broken by a few drumlins and escarpments, few of the rock knobs, drumlins, or escarpments rise more than 10 m above the plain on which they occur. Lacustrine deposits, which were left by glacial Lake Algonquin in this area, covered many of the original irregularities of the lake bed, thus subduing the relief.

The till plains topographic region is characterized by rolling hills separated by steep-sided, flat-floored valleys. The hills are encircled by numerous shorelines, indicating that they were islands in Lake Algonquin.

PHYSIOGRAPHY

Chapman and Putnam (1984) identified three physiographic regions in the study area namely, the Georgian Bay Fringe, the Simcoe Lowlands and the Simcoe Uplands (Figure 3).

The Georgian Bay Fringe Physiographic Region

The Georgian Bay Fringe physiographic region area forms a broad belt bordering Georgian Bay and occupying much of Muskoka and Parry Sound. The Georgian Bay Fringe physiographic region occupies an almost continuous strip across the north-eastern parts of the study area and extends further north along the shorelines of Georgian Bay from Matchedash Bay to Beausoleil Island. A major part of this physiographic region within the study area was covered by glacial Lake Algonquin.

The Georgian Bay Fringe physiographic region within the study area is characterized by low relief with surface elevations of 152 to 215 m (a.s.l.), shallow soil, and bare rock knobs and ridges. Deane (1950) notes that the distinguishing feature here is the numerous outcrops of Precambrian granite and gneiss in the form of "*roches mountonneés*" that give a rugged appearance to the landscape.

The Simcoe Lowlands Physiographic Region

The Simcoe Lowlands physiographic region extends from Georgian Bay to Lake Simcoe. Chapman and Putnam (1984) divided this region into two physiographic sub-regions: the Nottawasaga Basin and the Lake Simcoe Basin. The Nottawasaga Basin drains most of the western parts of the Simcoe Lowlands into Georgian Bay via the Nottawasaga River.

Chapman and Putnam(1984) included the lowlands within the Wye River watershed into the Nottawasaga Basin sub-region because of the lack of clear lines of demarcation. Given, however, that the drainage of the lowlands within the study area is towards Georgian Bay mostly via the North, Coldwater, Sturgeon, and Wye Rivers, it is perhaps more appropriate to consider the study area's lowlands as part of the Matchedash-Penetang physiographic sub-region.

The surface elevation of the Simcoe Lowlands physiographic region within the study area ranges from 177 to 250 m (a.s.l.). The region consists mainly of flat-floored valleys, which were flooded by glacial Lake Algonquin. On both sides of the valleys, shore cliffs, beaches and terraces, left during the various stages of glacial Lake Algonquin, can be traced for long distances. The floors of the valleys consist of glaciofluvial sand deposits, glaciolacustrine clays, silts and sands, and recent deposits of mud, peat, and muck.

In addition, large outcrops of Ordovician limestone are found in a number of areas within the North River watershed and are considered part of the Simcoe Lowlands physiographic region. These strata are generally flat-lying, with a low dip of about 5 m per kilometre to the southwest (Deane, 1950).

The Simcoe Uplands Physiographic Region

According to Chapman and Putnam (1984), this physiographic region consists of a series of broad, rolling till plains separated by steep-sided, flat-floored valleys. The surface elevations within this physiographic region range from 250 to 412 m(a.s.l.).

Most of the till plains within the physiographic region are encircled by numerous shorelines, indicating that they were islands in glacial Lake Algonquin. The till plains occur throughout the central parts of the study area. They are also found in the Penetang Peninsula where they were probably submerged in glacial Lake Algonquin.

The Bass Lake kame moraine is also considered a part of the Simcoe Uplands physiographic region. The moraine, which consists mainly of sand and gravel with minor amounts of clay or boulders, is located along the south-eastern boundaries of the study area and is characterized by rolling, kettle and knob topography.

DRAINAGE

There are six main streams in the study area. These streams from east to west are the North River, the Coldwater River, the Sturgeon River, Hog Creek, the Wye River, and Copeland Creek. The streams occupy the flat-floored valleys within the study area and many of them appear to be fed largely by springs along the valley sides.

Due to their small gradients within the flat-floored valleys, the streams have cut shallow channels and their flow at times is very sluggish. These small gradients explain the swampy character of many areas within the valleys. According to Chapman and Putnam (1984), it is probable that the streams within the study area were once even more sluggish, since the water level of Georgian Bay has fallen about 3 m in the last 300 years.

The configuration of the streams within the study area, their respective drainage, and the new municipal boundaries are shown in Figure 4. A summary of the drainage characteristics of the six streams is given in Table 1.

The North River is largest drainage system in the study area. It rises in a hilly plateau to the north of Bass Lake. The river flows in a south-north direction until a point located about 2 km north of Hampshire Mills, where it changes its course into a north-westerly direction until it reaches Lovering. From Lovering, the river flows in a south-westerly direction to its outlet into Matchedash Bay. The river has three major tributaries: Purbrook, Bear and Silver Creeks; 25 second order tributaries, and numerous lower order tributaries.

Table 1. A summary of drainage characteristics of main streams within the study area.

Stream	**Drainage Area * km^2**	**Maximum Elevation m, a.s.l.**	**Main Channel Length km**	**Total Fall m**	**Average Gradient m/km**
North River	315	289	43	112	2.60
Cold-water River	187	358	31	181	5.83
Sturgeon River	102	312	36	135	3.75
Hog Creek	64	305	22	128	5.82
Wye River	217	275	39.5	98	2.48
Copeland Creek	21.8	254	28	77	2.75

* Drainage area above station

The Coldwater River originates near Coulson and flows from south to north before it enters into Matchedash Bay. The river has 22 first order tributaries and numerous second and third order tributaries. The Sturgeon River originates in a hilly plateau near Hillsdale and flows in a northerly direction before it empties into Sturgeon Bay. The river is fed by 10 first order tributaries and a few second order tributaries.

Hog Creek originates in Medonte Township, flows in a northerly direction through Tay Township, and empties into Hog Bay in Severn Sound. The creek has cut a shallow channel in a flat-floored valley and is fed largely by springs along the valley's sides. Hog Creek has 15 first order tributaries and numerous second and third order tributaries.

The Wye River originates to the north of the Cook's Hill area in Flos Township and flows from south to north to its outlet into Georgian Bay. The river has 16 first order tributaries and numerous second and third order tributaries. A major tributary to Wye River is McMahon Creek.

Copeland Creek originates from Lalligan Lake in Tiny Township and flows in a northwesterly direction to its outlet into Penetang Harbour. The creek has 16 small tributaries.

CLIMATE

The climate of the study area is characterized by moderate winters, warm summers, and a long growing season with usually reliable precipitation. It is influenced by the proximity to Georgian Bay and Lake Simcoe. The local differences in climate reflect variations in topography, proximity to large water bodies and prevailing winds. The annual variations are dependent on the nature and frequency of weather systems which cross the area.

According to Brown et al (1968), the study area lies within three climatic regions: Lake Huron-Georgian Bay, Simcoe and Kawartha Lakes, and Muskoka. The Lake Huron-Georgian Bay climatic region consists of a narrow strip along Georgian Bay in which the influence of the Bay is sufficiently marked to differentiate it from the adjacent hinterland. The strip is sharply delimited by topography.

Most of the southern and eastern parts of the study area are within the Simcoe and Kawartha Lakes climatic region. Precipitation in this region is somewhat lighter than that of the areas around it because of the rain-shadow effect created by the western uplands.

The northern and northwestern parts of the study area are within the Muskoka climatic region. The western slopes of this region, facing Georgian Bay, receive heavy precipitation.

Precipitation

Precipitation data are collected at three meteorological stations within the study area. These stations are: Coldwater Warminster, Midland WPCP, and Honey Harbour Beausoleil. In addition, four meteorological stations, where precipitation data are collected, are located in the vicinity of the study area. These stations are: Gravenhurst Booth, Midhurst, Orillia STP, and Thornbury Slama (Figure 5).

Table 2 gives the names of all the meteorological stations and their respective periods of records. The table indicates that the majority of the stations have concurrent records for the period 1977-1993. The records at Gravenhurst Booth station, however, are available for the period 1980-1993, whereas the records at Midland WPCP have a gap during the period 1986-1992.

Table 2. Names and periods of records for the meteorological stations within and in the vicinity of the study area.

Station Name	Period of Record
Coldwater Warminster*	1977-1993
Gravenhurst Booth	1980-1993
Honey Harbour Beausoleil*	1977-1993
Midhurst	1977-1993
Midland WPCP*	1977-1986 1992-1993
Orillia STP	1977-1993
Thornbury Slama	1987-1993

* Climatological stations within the study area

The monthly and annual precipitation as well as temperature statistics as measured at the seven stations for the available periods of records are given in Appendix I. These statistics indicate that all the stations, with the exception of Coldwater Warminster and Orillia STP, registered a maximum annual precipitation during the year 1985. The range of this maximum, however, varied from 1,077.5 mm recorded at Midhurst station to 1,551.3 mm recorded at Midland WPCP station. The minimum annual precipitation of 755.7 mm was recorded at Thornbury Slama station in 1978.

The average, long-term precipitation within the study area is about 1,110 mm. Figure 6 shows the annual variations of precipitation as measured at five meteorological stations.

Approximately one-third of the annual precipitation is in the form of snow, which starts to fall in late September-early October and ends in late March-early April. High amounts of precipitation can occur during any month of the year; however, the months of April, May, June, July and August have usually less precipitation in comparison with other months.

Temperature

Temperature data are collected at the above seven meteorological stations, which are located within or in the vicinity of the study area (Table 2). Appendix I gives the monthly minimum, mean and maximum temperature data as measured at these stations for the available periods of records. In addition, Figure 7 shows the variations in the mean monthly temperatures as measured at five of the seven stations.

The monthly temperature statistics given in Appendix I indicate that the mean minimum monthly temperature of -20.2 ^{0}C was recorded at Gravenhurst Booth station during the month of January 1982. The maximum mean monthly temperature of 28.8 ^{0}C was recorded at Midhurst station in July 1989. Appendix I as well as Figure 7 indicate that lowest mean monthly temperatures are observed during the months of January or February. The mean monthly temperatures start to increase during the month of March and reach their highest values during the months of July or August before they start to fall again.

SOILS

The soil characteristics within an area are determined, by and large, by the type of the parent geologic materials on which they develop. Therefore, knowledge of the characteristics and spatial distribution of soils within an area is useful tool for understanding its surficial geology, the identification of shallow aquifers, and areas that have a good potential for groundwater recharge.

Soils are usually classified into series, types and phases. The term soil series is used to designate a group of soils whose profiles are alike with regard to their general character and appearance, and which were developed from similar parent materials. Soil series are usually given a geographic name from a town, village, township, etc.

The term soil type is used to describe the textural composition of the soil (sand, loam, clay). Finally the term soil phase refers to all the variations that occur in a soil series other than texture, such as stoniness, topography, drainage and erosion.

Based on the soil map published by Canada Department of Agriculture, 1959, 24 soil series have been identified within the study area. These series have been developed on parent materials consisting of silty to sandy tills, outwash sands and gravels, lacustrine clays and sands, and muck and marsh deposits. The majority of the soil series are well drained and cover large areas in Flos, Medonte, and Orillia Townships.

Poorly-drained muck and marsh soil series occur to the southeast of Elmvale in Flos Township, in the southwestern part of Medonte Township, along Purbrook Creek in Orillia Township, around Bass Lake in Oro Township, at Elliotts Corners in Tay Township, to the north of Allenwoodd in Tiny Township, and around Wye Lake and Matchedash Bay in Tay Township.

Figure 8, shows the areal distributions of groups of soils that have similar drainage characteristics. The figure is based on a digitized soil map prepared by the Ontario Ministry of Agriculture, Food and Rural Affairs. Additional details related to the various soil series are given Appendix II.

GEOLOGY

BEDROCK GEOLOGY

The occurrence, flow and quality of the groundwater resources within an area are strongly influenced by its geology. Therefore, it is important in any groundwater investigation to have a full consideration of the characteristics of the geologic deposits within the area under study.

The bedrock in the study area consists of Palaeozoic sedimentary rocks of Middle and Upper Ordovician age resting on a Precambrian basement (Figure 9). Young Quaternary deposits cover most of the Palaeozoic rocks.

A litho-stratigraphic unconformity is defined as a surface separating overlying younger rocks from underlying older rocks and represents a time period of erosion or no deposition. Two such unconformities exist within the study area: one between the Precambrian and Ordovician rocks and the other between the Ordovician rocks and the Quaternary deposits. The existence of an unconformity explains why certain formations are missing within the geologic log of a given area. Also, the unconformity between the Ordovician rocks and the Quaternary deposits provided the window of time necessary for the erosional processes to reshape the bedrock topography before the onslaught of glaciation.

The nomenclature used in this report is the one currently used by the Ontario Geological Survey, which is based on that of Liberty (1969) as modified by Russell and Telford (1983), Williams and Telford (1983), and Williams (1991).

Precambrian Geology

The Precambrian rocks within the study area are mostly obscured by a cover of Palaeozoic and Quaternary deposits. However, these rocks occur at surface or very close to surface within a narrow strip that extends along the northern borders of the study area from Maple Valley in the east to Matchedash Bay in the west, and along the eastern shores of Georgian Bay northward to Honey Harbour and Beausoleil Island.

The surface elevation within the Precambrian strip is generally low, ranging from less than 177 m at Matchedash Bay to over 215 m near Maple Valley. The strip was reshaped by the advancing glaciers during the Quaternary Period and is studded with numerous rock-knob outcrops that give a rugged appearance to the landscape. Minor amounts of drift, left by advancing ice, fill the depressions between the rock-knobs.

The rock-knob outcrops rise from a few metres to over 10 m above the land surface. According to Deane (1950), most of the outcrops have the typical "*roches mountonne*és" form, with a gentle stoss and steep lee ends, and with the long axis parallel with the direction of the ice movement.

Deane (1950) noted that the "*roches mountonneés*" landscape and the small amount of drift, left by the advancing glaciers, indicate that the base of the advancing ice was not overloaded and that mostly scouring action prevailed. The rock structure was the controlling factor. Where folds and fractures were transverse to the direction of ice movement, the plucking action of the ice left very rugged and irregular forms; where the structure parallelled the ice movement, deep grooving and long ridges are common. The load contributed to the glaciers by the Precambrian rocks varied from sand-sized particles to large boulders.

The Precambrian rocks within the study area are part of the Central Gneiss Belt of the Grenville Province. According to Easton (1992), the Grenville Province, which is the youngest part of the Canadian Shield, forms a 300 to 500 km wide by 2000 km long, northeast trending belt that extends from southwestern Ontario to the shores of Labrador. Tonalite, granodiorite, monzonite, granite, syenite, gneiss, anorthosite and gabbro are the main rock types found in the Precambrian rocks within the study area.

Palaeozoic Geology

A succession of Palaeozoic sedimentary rocks of Middle Ordovician age overlies the Precambrian rocks over most of the study area. Limestone outcrops at surface at several locations in Medonte, Orillia and Tay Townships. The rocks form a narrow, limestone plain that extends along the southern rim of the Canadian Shield from the northeastern corner of the study area to Port McNicoll on Georgian Bay.

Due to the fact that the Palaeozoic rocks are much softer than the Precambrian rocks, they were impacted more severely by the advancing glaciers during the Quaternary Period. According to Deane (1950), rock-flour is a typical product of glacial abrasion of limestones and shales, and cobbles and pebbles often make up a large portion of the drift where bedrock lies at or near the surface.

Unlike the "*roches mountonne*és" landscape of the Precambrian rocks within the study area, the landscape of the limestone plain is nearly flat and interrupted by escarpments, which are the result of glacial plucking. Deane (1950) notes that weathering has removed any evidence of fine grooving on exposed surfaces of the limestones, but where these rocks are covered by even a few centimetres of drift the scratches are usually well preserved.

The Palaeozoic rocks within the study area belong to the Basal and Simcoe Groups of the Middle Ordovician age. According to Johnson et al (1992), the rocks of these two groups represent a complex succession of shallow marine carbonate rocks and minor clastic rocks, which were deposited by a marine transgression. Lateral facies changes in this succession have resulted in a plethora of stratigraphic nomenclature for the Middle and Upper Ordovician in Ontario.

Four formations of Middle Ordovician age have been identified within the study area. These formations are: the Shadow Lake Formation of the Basal Group and the Gull River, Bobcaygeon, and Verulam Formations of the Simcoe Group (Figure 9).

According to Johnson et al (1992), the proposed depositional environment for the Shadow Lake Formation in south-central and southwestern Ontario is a supratidal environment. The overlying succession of limestone and shales of the Simcoe Group represents a relatively continuous, depositional environment with a generally deepening shelf. The rock types in this succession range from coarse-grained, bioclastic carbonates to carbonate mudstones, with subordinate calcareous and non-calcareous shales.

Johnson et al (1992) noted that although each unit of the Simcoe Group has general identifying characteristics, precise formational identification in the field is difficult because of repetitive facies and rapid lateral and vertical facies changes.

The following are brief descriptions of the four Palaeozoic formations.

The Shadow Lake Formation

The Shadow Lake Formation is the oldest of the Palaeozoic formations within the study area. Its contact with the overlying Gull River Formation is commonly gradational and is placed at the first significant carbonate bed (Liberty, 1969). The formation unconformably overlies the Precambrian basement and occurs at surface as a thin, narrow band to the east of Maple Valley and to the north of Carlyon in Orillia Township as well as at Waubaushene in Tay Township. Due to its relative thinness, the Shadow Lake Formation and overlying Gull River Formation are commonly portrayed as a single unit (Figure 9).

The Shadow Lake Formation consists of shale, sandstone, limestone and conglomerate. Its thickness differs from place to place. In Tay, western Matchedash, and Medonte areas, the formation ranges in thickness from 0.0 to 12 m (Derry et al, 1989).

The Gull River Formation

The Gull River Formation is the oldest unit of the Simcoe Group and it conformably overlies the rocks of the Shadow Lake Formation throughout the Simcoe County area. The unit represents deposition within a supratidal to intertidal, flat environment with coarser-grained beds representing storm deposition.

Armstrong and Anastas (1992) tentatively subdivided the Gull River Formation into two informal members, the lower and upper, which approximately correspond to the lower and middle members of Liberty (1969). Strata previously recognized as the upper member of the Gull River Formation by Liberty (1969) have been reassigned to the Bobcaygeon Formation (Derry et al,1989).

Within the study area, the lower member of the Gull River Formation consists of argillous, green-grey and grey-brown, fine-grained, dolomitic limestones and dolostones; grey-brown, very fine-grained, fossiliferous limestones; grey-brown, medium-to coarse-grained, bioclastic limestone; and light grey to grey-brown, micritic to very fine-grained, sparsely to very fossiliferous limestones. This lower member is well exposed in the Cook, Port McNicoll, and Uhthoff quarries, in outcrops on Quarry Island, and in a road cut on Highway 400 near Waubaushene.

The upper member of the Gull River Formation consists of light grey to light grey-brown, micritic to very fine-grained, sparsely fossiliferous limestone (lime mudstone). This upper member is completely exposed in the Medonte and Uhthoff quarries (Armstrong and Rheaume, 1993).

The Bobcaygeon Formation

The Bobcaygeon Formation overlies the Gull River Formation and it is generally more fossiliferous. The fauna, grain size and sedimentary features of the formation suggest a shallow, subtidal, depositional environment (Johnson et al,1992).

Liberty (1969) subdivided the Bobcaygeon Formation into three members: lower, middle and upper. As indicated above, most of Liberty's (1969) upper member of the Gull River Formation is tentatively included within the lower member of the Bobcaygeon Formation. According to Armstrong and Rheaume (1993), this interval is transitional in nature between the lime mudstones of the upper member of the Gull River Formation and the fossiliferous limestones of the lower Bobcaygeon Formation.

The lower member of the Bobcaygeon Formation consists of 6 to 8 m of grey-brown, very-fine- to coarse-grained, moderately fossiliferous limestones. The middle member consists of about 6 m of light to medium brown, fine- to coarse- grained, moderately fossiliferous limestones, which are interbedded with grey-green, calcareous shales. This member is exposed in a single outcrop, located less than 2.5 km southwest of Uhthoff Quarry. The upper member consists of approximately 10 m of light grey-brown to blue-grey, fine- to coarse-grained, fossiliferous, limestones (wackestones to grainstones) with shaley partings (Armstrong and Anastas,1992, and Armstrong and Rheaume,1993).

The Verulam Formation

Conformably overlying the Bobcaygeon Formation are the interbedded limestones and shales of the lower member of the Verulam Formation. This unit occurs in a very small area to the southwest of Allenwood in Flos Township where it is covered by a thick mantle of Quaternary deposits. Its distribution in this area has been established from well records (Liberty, 1969).

BEDROCK TOPOGRAPHY

The topography of the bedrock within the study area was determined based on the surficial distribution of Precambrian and Palaeozoic rocks and the records of 1,079 water wells and exploration boreholes. The locations of the wells and boreholes are shown on Figure 10.

Figure 11 shows the bedrock elevations within the study area. The figure shows that the bedrock elevations range from over 250 m to less than 120 m (a.s.l). Highest elevations are found in the northeastern parts of the study area where the Palaeozoic rocks are either at or very close to the surface. They are also found within three dome-like structures located immediately north of Bass Lake. The lowest bedrock elevations are found in the southwestern part of the study area. Figure 11 indicates that the study area contained two major drainage systems before the onslaught of the Great Ice Age.

The two systems were separated by a series of dome-like structures that extended in an east-westerly direction immediately to the north of Bass Lake and then continued in a north-westerly direction to Sturgeon Bay. Surface water to the south and south-west of the bedrock ridge drained towards an extensive bedrock valley known as the Laurentian Channel (Figure 12). The channel extended from Georgian Bay towards Cook Bay on Lake Simcoe and further to Lake Ontario (Singer et al, 1997).

Surface water to the north and north-east of the bedrock ridge within the study area drained river systems that overlap mainly the current North River systems and parts of the Coldwater and Sturgeon River systems. Minor bedrock structures ranging in elevation from 180 to 190 m (a.s.l.) occur to the east of the Wye River and extends to Paradise Point. Another structure extends from Penetang Lake to Midland Point.

QUATERNARY GEOLOGY

Most of the bedrock within the study area is obscured by a mantle of unconsolidated sediments, known as the overburden, which was deposited during the Quaternary Period. The Quaternary Period has been subdivided into the Pleistocene (Great Ice Age) and Holocene (Recent) epochs. The Pleistocene Epoch is the period when great ice sheets covered parts of Ontario several times. The Holocene Epoch includes postglacial times, up to and including the present.

The Quaternary deposits in southern Ontario are associated with the two main glacial stages of the Pleistocene Epoch: the Illinoian and Wisconsinan as well as with the interglacial Sangamonian Stage and the Holocene Epoch. The Laurentide Ice Sheet is the name given to the continental glacier that occupied about 80% of Canada during the Wisconsinan Stage of the Pleistocene Epoch. Exposures of sediments deposited prior to the Late Wisconsinan substage in southern Ontario are rare and are observed only in natural or man-made excavations. Exposures of sediments of the Late Wisconsinan, on the other hand, are widespread and have been extensively investigated (Barnett, 1992).

The Late Wisconsinan deposits within the study area occur mainly in the Simcoe Uplands and Simcoe Lowlands physiographic regions. The dominant land forms include broad rolling till plains, drumlins, a large interlobate moraine (Bass Lake kame moraine) of glaciofluvial origin, steep, flat-floored valleys filled mostly by glaciofluvial and glaciolacustrine deposits; and shoreline sediments and associated bluffs, beach bars and spits. The till plains formed islands within proglacial Lake Algonquin and are surrounded by abandoned beaches.

The Late Wisconsinan deposits, which outcrop extensively at surface within the study area, were likely laid down during and after the Two Creeks Interstade. Older, Wisconsinan deposits may occur at depth within the study area, however, it is not possible to assign an age to them.

The Two Creeks Interstade was mainly a period of ice recession during which the margin of the ice sheet, which occupied the northeastern part of the study area, receded northward, leaving most of southern Ontario including most of the study area free of ice about 12,000 years ago. The recession of the ice margin, however, was not a one way process, rather it was an oscillating process during which the ice margin advanced and receded several times.

Due to the oscillation of the ice margin, minor advances and retreats of the ice took place during the Two Creeks Interstade. The advancing ice scoured the solid rocks on which it passed and transported the loose material lying in its path for varying distances, either by pushing the material ahead of it or by incorporating the material in its lower parts. As the ice retreated from the study area, it left behind on the land surface glacial deposits mainly in the form of ground moraine and drumlins. During periods of temporary halts or readvances of the ice, the Bass Lake Kame Moraine as well as ice-contact and outwash deposits were left to mark the position of the ice front.

The amount of drift left, where the Precambrian rocks are near the surface within the northeastern and northern parts of the study area, is very small and is confined to depression areas between the rock-knob outcrops. The drift thickness, however, increases gradually over the Palaeozoic rocks in a southwestern direction.

About 12,000 years ago, as a result of the retreat of the Laurentide Ice Sheet, separate lakes formed in Lake Ontario and Lake Erie basins, and the waters of Lakes Huron and Michigan basins coalesced to form glacial Lake Algonquin. According to Barnett (1992), the history of Lake Algonquin which occupied most of the study area is commonly divided into 4 parts:

- an Early Lake Algonquin south-draining phase;

- a Kirkfield low water phase when the outlet of Lake Algonquin changed to the east (Fenelon Falls outlet), allowing glacial meltwater to bypass the Lake Erie basin;

- Main Algonquin phase (high lake water)when drainage again became southward after the closing of the Kirkfield outlet; and

- an Algonquin-Stanley phase of falling water levels which occurred as more outlets were uncovered to the northeast across Algonquin Park and into the Ottawa River Valley.

Within the study area, the remarkable record of abandoned shoreline deposits and features, combined with the distribution of fine-grained glaciolacustrine sediments, provide evidence for the glacial Lake Algonquin record (Barnett, 1992).

Glacial Lake Algonquin ended at about 10,400 to 10,000 BP and the Holocene Epoch probably started in this part of Ontario. As Barnett (1992) indicates, the division between the Late Wisconsinan and the Holocene Epoch in Ontario is somewhat arbitrary since most of northern Ontario remained covered by ice 10,000 years ago, while low level lakes existed in the Lake Michigan, Georgian Bay, Lake Huron, Lake Erie, and Lake Ontario basins.

As the land surface in Ontario became ice-free, it began to rise isostatically, recovering from the weight of the ice sheet. This isostatic rebound affected the water levels in the Great Lakes basin as well. According to Barnett (1992), the water levels in the Great Lakes basin were almost within the present lake shoreline following the opening of the North Bay outlet. Approximately 5,000 years ago, however, as the outlet at North Bay rose differentially to the levels of the Chicago and Port Huron outlets, the Nipissing Great Lakes system came into existence in the basins of Lakes

Superior, Huron, Michigan, and Georgian Bay. The Nipissing Great Lakes system left minor shoreline features within the study area. Eventually, the water level within the Nipissing Great Lakes system started a series of falls to that of the present Upper Great Lakes.

By comparison to the Pleistocene Epoch, the Holocene Epoch was mainly a period when erosional processes were dominant within the study area. This postglacial erosion during the Holocene Epoch has resulted in extensive slope failures, gullying, and the formation of theatre-like scarps within the study area. Except for some muck and minor deposits associated with the Lake Nipissing Great Lakes, the deposits of the Holocene Epoch are of little significance.

Glacial Deposits - Surficial Tills

The glacial deposits within the study area consist of various tills. According to Dreimanis (1972), till is a sediment that has been transported and deposited by or from glacier ice, with little or no sorting by water. The general appearance and composition of till depends on the mode of glacial transport, the depositional environment and the processes and sources of glacial debris. Post-depositional weathering also affects till appearance and some of its characteristics (Barnett,1992).

From a hydrogeologic point of view, knowledge of the type and spatial distribution of tills within an area is extremely important. Compact tills with high clay content are characterized by low hydraulic conductivity values. When such tills are found at the surface they would impede the vertical infiltration of water which results in reduced groundwater recharge. On the other hand, when these tills occur at depths, they will act as hydraulic barriers forcing groundwater to move laterally within the overlying more permeable formations. By contrast, loose sandy tills can be highly permeable. When such tills occur at the surface, they will allow water to pass through them freely to recharge underlying formations, and under certain hydrogeologic conditions, these tills can become good aquifers.

As indicated above, the land forms associated with the glacial deposits include broad, undulating to rolling, till plains consisting of ground moraine, a drift that is not terminal moraine nor drumlin and has not been reworked by water. The till plains, which are part of the Simcoe Uplands physiographic region, are broken here and there by rock outcrops and drumlins. They are separated by steep-sided, broad, flat-floored valleys as well as by low-lying areas of clay plains, which constitute the Simcoe Lowlands physiographic region. The difference in elevation between the Uplands and the Lowlands is up to 100 m in some places.

A thin layer of ground moraine covers the bedrock in parts of the Precambrian, rock-knob terrain and limestone plains in the northeastern and northern parts of the study area. The greater part of the drumlin-field areas, the swales between the drumlins, and the gently rolling hills that are not definite enough to be called drumlins are also classified as ground moraine. Deane (1950) notes that many of the swales between the drumlins are floored with clay deposits laid down in temporary lakes during deglaciation or carried down from the slopes of the drumlins by sheet erosion, but are not thick enough nor extensive enough to warrant distinction as a separate unit.

Most of the drumlins occur along the eastern boundaries of the study area in Orillia Township. A few drumlins occur also in the areas between Sturgeon Bay and Hog Bay, and between Hog Bay and Midland Bay in Tay Township. The drumlins are composed mainly of till with some stratified sand and gravel on the top, ends, or sides. The orientation of the long axes of the drumlins is northeast to southwest, which reflects most probably the orientation of the ice movement during the last readvance of the glacier.

The shape and size of the drumlins vary considerably. In areas where the thickness of the overburden is small, many are long, thin, ridge-type drumlins with lengths of 1,000 m and widths up to 350 m. In areas where the thickness of the overburden is large, the drumlins have semi-elliptical to circular forms and are much smaller in size (50 to 100 m).

Figure 13 is a preliminary map of the surficial geology of the study area. The figure is a compilation of the following five geologic maps, scale: 1:50,000:

- S Quaternary geology of the Orr Lake area (western half) - Nottawasaga area (eastern half), southern Ontario; Ontario Div. Mines, Prelim. Map P.975 by Burwasser, G.J. and Boyd, S.T.,1974.

- S Quaternary geology of the Orillia area, southern Ontario; Ontario Geological Survey, Map P. 2697 by Finamore, P.F. and Bajc, A.F.,1984.

- Quaternary geology of the Penetanguishene and Christian Island areas, southern Ontario; Ontario Geological Survey, Map 194 by Bajc A.F. and Peterson, J.T.,1992.

- Quaternary geology of the Gravenhurst area, southern Ontario; Ontario Geological Survey, Map 195 by Bajc, A.F. and Paterson, J.T.,1992.

- S Quaternary geology of the east half of the Elmvale area, Ontario; Mines and Mineral Division, Ontario Geological Survey, Geology by Barnett,1986,1988,1989, issued 1992.

As can be seen from the above, the five geologic maps have been prepared by different authors between 1974 and 1992. Due to the fact that the authors of the maps have worked in different areas and at different times, it is not surprising that they ended up using different names and symbols to identify what appears to be the same till.

To avoid confusion, all the till units that occur at the surface within the study area have been combined in Figure 13 into two undifferentiated tills, which correspond to "map unit 19" and "map unit 21" on the Ontario Geological Survey (OGS) Map 2556 (Barnett et al, 1991). The till of "map unit 19" is undifferentiated, predominantly sandy silt to silt till, commonly rich in clasts, and often high in total matrix carbonate content. The till of "map unit 21" is undifferentiated, fine-grained, commonly clast poor till with a predominantly silty clay to silt matrix, which is high in carbonate content. A full discussion of the tills within the study area is found in Appendix III.

Glacial Deposits - Buried Tills

Available data indicate that additional tills occur under the surface within the study area. Barnett (1991), in a preliminary report on the stratigraphic drilling of Quaternary sediments in the Barrie area, Simcoe County, described the geologic logs of 5 deep boreholes drilled in Medonte and Oro Townships. Three of these boreholes (OGS-90-5,OGS-90-7 and OGS-90-14) reached the bedrock and provide complete profiles of the Quaternary section.

Till-like, diamicton materials, separated by thick sequences of gravel, sand, silt and clay, were found at different depths in all the boreholes. The exact number of buried tills within the study area, however, is not known. A full discussion of these buried tills is given in Appendix III.

Glaciofluvial Deposits

Glaciofluvial deposits are accumulations of large amounts of debris of various grain sizes that have been carried, assorted, and deposited by large volumes of meltwater discharged by glaciers. Glaciofluvial deposits are either laid down in immediate contact with the glaciers or at short distances beyond the glaciers' borders.

The term "ice-contact deposits" is used to describe those glaciofluvial deposits that were laid down in immediate contact with ice and include kame moraines, kames, kame terraces, and eskers. The make-up of the ice contact deposits is highly variable both laterally and vertically and consists mainly of discontinuous layers of sand and gravel with some silt, clay and till.

The term "outwash deposits" is used to describe those stratified sands and gravels that were laid down a short distance from the ice margin. Gravels are usually deposited closer to the ice margin, whereas sands are found further downstream. Deltas formed by meltwater streams at their entrance into glacier-fed lakes are also considered outwash deposits.

One of the most important ice-contact deposit within the study area is the "Bass Lake kame moraine", which can be found at or near the surface south of Bass Lake. The moraine, which occupies the southern half of the study area and continues beyond its boundaries, is approximately 25 km long with a maximum width of 8 km.

The Bass Lake kame moraine extends in a southwesterly direction and forms the surface divide where the highest surface elevations in the study area are found. The surface elevation of the moraine ranges from about 275 to 412 m (a.s.l.). It is characterized by a hummocky topography with extensive kettles and knolls, tunnel channels, small dunes, and steep ice-contact slopes along its northern boundaries.

According to Deane (1950), the Bass Lake kame moraine was deposited under maximum water of fluvial rather than lacustrine conditions. The material of the moraine is mainly sand and gravel with only minor amounts of clay or boulders, and is water sorted to varying degrees. Deane (1950) further notes that stratification is observable in many parts of the moraine, but elsewhere it appears to be a uniform, structureless mass of sand and gravel, which when analysed shows the presence of clay and silt.

Other ice-contact deposits are found to the north of Warminster and south of Fair Valley in the Coldwater River watershed, at various locations within the Sturgeon River watershed, and around Midland Park Lake. These deposits consist of fine to coarse-grained sand, gravelly sand and gravel with minor amounts of silt, clay, and flow till.

A small outwash deposit of well sorted, very fine to coarse-grained sand with minor gravel, silt and clay is found in the headwaters of the Coldwater River adjacent to the Bass Lake kame moraine. Other outwash deposits consisting mainly of medium to coarse sand with some boulders occur to the south and north of Orr Lake around earlier "Algonquin Islands", and also west of Midland Park Lake. The Coldwater River, Hog Creek, and Wye River have cut channels through these outwash deposits.

The origin of the outwash deposits is fluvial or deltaic. As the glacier melted, streams loaded with sediment flowed away and deposited their load of sand and gravel in valleys or in deltas. Compared to the ice-contact deposits, the outwash deposits are generally more uniform. Their texture varies from silt to fine sand to coarse gravel, and their bedding is generally horizontal.

The flat to undulating topography of the outwash deposits has been modified by subsequent actions of Lake Algonquin waters producing boulder strips and some depressions on the surface. According to Burwasser and Boyd (1974), much of the outwash sand between the "Algonquin Islands" in the Orr Lake sheet has been reworked so completely that it is mapped as lacustrine sand. On the edges of the "Islands" and below the Algonquin bluff is a deposit, mapped as winnowed outwash, of medium to fine sand. These sands contain numerous boulders, some exceeding 2 metres in their longest dimension.

Glaciolacustrine Deposits

Glaciolacustrine deposits are stratified sediments that have been carried largely by glacial meltwater and subsequently laid down in glacial lakes. Some of the material could have been derived from eroding shore bluffs or were carried by streams that drained deglaciated areas.

Most of the glaciolacustrine deposits within the study area were laid down in Lake Algonquin. A small amount, however, were deposited in Nipissing Lake. These deposits include beach sands and gravels that were laid down along the shorelines, and lacustrine sands, silts and clays as well.

The records of water wells, drilled within the study area, indicate that the thickness of the glaciolacustrine deposits is highly variable. Within the Precambrian, rock-knob lowlands in the northern parts of the study area, the deposits are generally thin, but can vary greatly within short distances. In areas, where the Palaeozoic rocks are close to the surface, the deposits are thin and uniform. In other areas, where deep boreholes were drilled in Medonte and Orillia Townships (Appendix III), the total thickness of the glaciolacustrine deposits is over 60 m.

Generally, the lacustrine sands were deposited close to the shoreline in areas of shallow water. These sands grade into silts some distance off shore and those, in turn, grade into clays in deeper water. This lateral gradation of the sediments was affected by the fluctuations of the water levels of Lake Algonquin and its successive stages, with each stage giving a lateral sequence of gravel, sand, silt and clay. The geologic logs of deep boreholes within the study area reflects these water levels fluctuations, revealing vertical sequences of sands interbedded with layers of gravel, silt or clay.

The glaciolacustrine deposits within the study area are part of the Simcoe Lowlands physiographic region. Landforms include steep-sided, broad, flat-floored valleys; abandoned shore bluffs, beaches, bars or spits; and sand and clay plains that occupy large low-lying areas. The surface elevation of these sediments ranges from 180 to 250 m (a.s.l.).

Clay flats of glaciolacustrine origin are most common in the depressions within the study area, and are found in the middle sections of the North, Coldwater and Sturgeon Rivers and the Hog Creek. These glaciolacustrine clays also cover a large area extending from the south of Wye Marsh to the headwaters of the Wye River. In addition clay deposits that are varved with silt are found in the low central part of the Orr Lake area along the Wye River (Figure 13).

The thickness of the clay deposits vary from place to place. The records of water wells drilled for the Village of Elmvale indicate that the clays in some locations extend to depths of over 38 m (Andrijiw, 1976). The well records in the vicinity of the Village of Coldwater show that the clay deposits are 6 to 20 m thick (Jagger Hims Ltd. 1993). Fine-grained silts and clays, 23 m thick, were also reported in water wells to the south of Silver Creek Mobile Home Park in Orillia Township.

Extensive deposits of glaciolacustrine origin occur at surface within the study area. They consist of very fine to medium-grained sand with silt and minor clay. These horizontally bedded deposits are found mainly in the headwaters of the North and Coldwater Rivers, over most of the valley of the Sturgeon River, around Orr Lake, and along the western boundaries of the study area (Figure 13).

The records of many water wells as well as the geologic logs of deep boreholes that were drilled in the study area (Appendix III) indicate the presence at various depths of thick layers of sands separated by layers of clay, silt or diamicton. The total thickness of these sands, which are most likely of glaciolacustrine origin, can be in excess of 47 m.

Abandoned beaches and ridges consisting of gravel, sandy gravel and gravelly sand are found around the "Algonquin Islands" within the study area. In his manuscript of the Pleistocene geology of the Lake Simcoe area, Deane (1950) identified a number of beaches associated with the Early Lake Algonquin, a beach associated with the Main Lake Algonquin, and seven beaches associated with the falling stages of Lake Algonquin.

At many places within the study area, the abandoned shorelines are poorly developed, but in many other places one, two or three levels of well developed beaches can be traced for long distances. These cascading beaches can be found particularly around Orr Lake, along both sides of the valleys of Hog Creek and Wye River, and to the southwest of Midland Park Lake.

Most of the beaches within the study area were probably formed during the lower stages of Lake Algonquin when the water levels were lower than those of the Main Lake Algonquin and islands existed in the lake. A few beach deposits, identified by Deane (1950) to be of Lake Nipissing age, are found at Waubaushene. In addition, some raised beaches of glaciolacustrine sands, which are found along Nottawasaga Bay, have been mapped by Burwasser and Boyd (1974) as post-Nipissing deposits.

Recent Deposits

Accumulations of organic matter of mud, peat, muck and marl are found in many low, inadequately drained parts of the study area. The largest such deposits are found in Tiny Marsh, which is located in the southwestern corner of the study area and covers a surface area of about 8 km^2 of open marsh land (Figure 13).

According to Burwasser and Boyd (1974), the peat and muck within Tiny Marsh overlay varved, lacustrine clay and have a maximum thickness of 0.6 m. The Wye Lake, which has a surface area of about 5 km^2 of marshland and lake, also contains up to 0.6 m of muck deposits overlying silty sand around the edges of the lake (Burwasser and Boyd, 1974). Similar peat and muck deposits are found within the deltas of the North and Coldwater Rivers around Matchedash Bay, within the valley of the North River in the New Uhthoff area, and also to the north and southwest of Bass Lake.

Modern alluvium deposits of gravel, very fine to coarse-grained sand, silt and clay occur along stream channels within the study area. These deposits are probably composed of reworked glacio-lacustrine sediments.

OVERBURDEN THICKNESS

Figure 14 shows the spatial distribution of overburden thickness within the study area. The figure is based on data obtained from the geologic logs of deep boreholes and the records of 1,536 water wells that either penetrated the bedrock or were deep overburden wells. To obtain additional accuracy, the surface elevations of those areas where the bedrock outcrops at surface were also used in the compilation of Figure 14.

As expected, the thickness of the overburden in areas where the Precambrian and Palaeozoic rocks are at or close to the surface is small and ranges from 0 to less than 20 m. The thickness of the overburden increases gradually along a front extending in an easterly-northwesterly direction. This front extends from areas located to the north of Bass Lake in the east to areas located west of Midland in the northwest.

The maximum thickness of the overburden (120 to over 140 m) is found along an axis that extends from the southern boundaries of the study area through Orr Lake until it reaches the western boundary. To the southwest of this axis, the overburden thickness starts to decrease to a range of 80 - 120 m. Other thick overburden deposits are found within the area of the Bass Lake kame moraine. The maximum thickness of the overburden in this area ranges from 80 to 100 m along an axis that extends in a north-southerly direction to the west of Bass Lake.

To illustrate the regional distribution of the overburden, a map of the overburden thickness within central Ontario was compiled (Figure 15). The map is based on a map prepared by Singer et al(1997)of the overburden thickness in southern Ontario. Figure 15 indicates that the axis of maximum overburden thickness in central Ontario extends from Georgian Bay in a southeasterly direction towards Kempenfelt Bay and continues southward to link with the Oak Ridges moraine.

HYDROGEOLOGY

GENERAL PRINCIPLES AND DEFINITIONS

Subsurface waters occur in two zones below the land surface: the unsaturated zone and the saturated zone. The first zone extends from the land surface down to the water table and includes the capillary fringe. This zone contains liquid water under less than atmospheric pressure, and water vapour and air, or other gases, at atmospheric pressure. In parts of this zone, interstices, particularly the small ones, may be temporarily or permanently filled with water. The second zone (i.e. the saturated zone) is where groundwater occurs. In this zone all voids, large and small, are filled with water under pressure greater than atmospheric (Lohman, 1972). The top boundary of the saturated zone, at which pressure is atmospheric, is called the water table.

GROUNDWATER AND THE HYDROLOGIC CYCLE

The hydrologic cycle is a concept that considers the processes of motion, loss and recharge of the Earth's water (Gray, 1970). Water that evaporates from the land and oceans is carried by the air masses and eventually precipitates either on land or oceans. Some of the precipitation that falls on land may be intercepted or transpired by plants and returns back to the atmosphere, some may run off over the land surface to ditches, streams, ponds or lakes, and the remainder may infiltrate into the ground.

The infiltrated water may be temporarily retained as soil moisture or move laterally as interflow within the soil to the nearest stream. The remainder percolates deeper to the water table to be stored as groundwater. The groundwater, in turn, may be used by plants, or flow out as springs, or seep into streams as baseflow, only to be eventually evaporated to the atmosphere to complete the hydrologic cycle.

From the foregoing it is clear that the hydrologic cycle is made up of several interrelated components (processes). Therefore, in order to study one of these components in detail, it is necessary to consider its relationships with all the other components.

Groundwater is that part of the hydrologic cycle which occurs in the zone of saturation and is subject to continuous movement. The geometry and intensity of groundwater flow are dependent on the hydrologic environment consisting of topography, climate, and geology (To'th,1962, 1963 and 1972). As indicated above, the source of and recharge to groundwater comes from precipitation, directly by infiltration from the land surface or indirectly by surface water leaking under certain conditions from streams, ditches, ponds or lakes.

The land surface topography exerts a controlling influence upon the configuration of the water table, the distribution of flow systems, and consequently groundwater movement. Further, the occurrence, movement, quality and availability of groundwater depends on geologic factors, in particular, lithology, porosity, permeability, and the areal distribution of various deposits.

AQUIFERS

An aquifer is a water bearing material (unconsolidated deposits or rocks) that is capable of storing and transmitting a large quantity of water. Aquifers vary in thickness and areal extent. Some aquifers are small and may only be able to supply water to one or a few households. Others are large ranging in size from a few hectares to hundreds of square kilometres. Aquifers may be found in bedrock and in the unconsolidated materials of the overburden, which overly the bedrock. The more fractures and openings there are in the aquifer, the higher its water yield.

Unconsolidated deposits and rocks that are saturated but have low permeability and, therefore, do not furnish an adequate supply of water are called aquicludes. Examples of aquicludes are clay deposits or poorly-fractured rock formations with a few interconnected pore spaces. An aquifuge is an impermeable rock neither containing nor transmitting water. Solid granite belongs in this category.

An aquifer that is overlain by a confining layer of low permeability is called an artesian or confined aquifer. Groundwater in wells drilled in confined aquifers rises above the point where the water is found and sometimes flows over the ground surface.

HYDRAULIC PROPERTIES OF AQUIFERS

Groundwater occurs in the openings within the aquifer. In the overburden, the openings are in the form of pore spaces between grains of silt, sand or gravel. In the bedrock, on the other hand, the openings are in the form of solution cavities, fissures, fractures, joints, and bedding planes. The ratio of the volume of the openings to the total volume of the water bearing material is called porosity.

In overburden deposits, porosity is controlled by the shape, arrangement, degree of sorting, and cementation of particles. Porosity is high in well sorted deposits such as gravel and medium to coarse sands and low in small grained, poorly sorted or highly cemented deposits such as fine to very fine sands, silts or clay. In bedrock, on the other hand, porosity is dependent on the extent of cementation and the degree of development of the fissure system or the solution cavity openings. Effective porosity refers to the amount of interconnected pore spaces or other openings available for water transmission.

Porosity is not a measure of the amount of water that an aquifer will ultimately yield. The ratio of the volume of water which the rock, after being saturated, will yield by gravity drainage to the total volume of the rock is called the specific yield. The specific retention is the complement of the specific yield. It is the ratio of the volume of the water that the saturated rock will retain against the force of gravity to the total volume of the rock.

The storage coefficient is the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer and per unit change in head. In an unconfined aquifer, the storage coefficient is virtually equal to the specific yield. In a confined aquifer, however, the storage coefficient is less than the specific yield as the water derived from storage comes from expansion of the water and compression of the aquifer. Similarly, water added to storage is accommodated by compression of the water and expansion of the aquifer (Lohman, 1972).

Groundwater flow occurs under a hydraulic gradient which is defined as the change in static head per unit of distance along the ground water flow path. The relative ease with which a water bearing material can transmit water under a hydraulic gradient is a measure of the permeability or hydraulic conductivity of the material, and is a measure of the capacity of this material to transmit water.

Transmissivity is the rate at which water at the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient, and is equal to the product of the hydraulic conductivity of the aquifer and its thickness.

The specific capacity of a well is defined as its yield per unit of drawdown, expressed as litres per minute per metre of drawdown (L/min/m). Dividing the yield of a well by the drawdown for a specific time during a pump test gives the value of specific capacity.

The specific capacity of a well is a function of the type of the aquifer, well diameter, pumping time, partial penetration, hydrogeologic boundaries, and well construction characteristics. Because of the above-mentioned constraints, the specific capacity is not an exact criterion with which to calculate the transmissivity; however, it is a useful index to describe the water yielding characteristics of the well and of the formation(s) the well taps. In general, high specific capacities are indicative of high transmissivities and, consequently, high water-yielding capabilities.

In applied hydrogeology, pumping and recovery tests of wells generally give the most reliable results for the determination of the hydrogeologic constants. Often, however, the only available data for wells in an area are the final drawdowns associated with specific pumping tests of short durations. These data can be used to calculate the specific capacity distributions within an area of interest, estimate the transmissivity distributions, and describe the water-yielding characteristics of the area's aquifers.

ESTIMATING THE HYDRAULIC PROPERTIES OF AQUIFERS USING THE RESULTS OF PUMPING TESTS

The hydraulic properties of a hydrogeologic unit are expressed quantitatively by the coefficients of transmissivity, hydraulic conductivity, and storage. These properties can be estimated using pumping test data.

There are a number of methods to calculate the aquifer constants from pumping test data. The most widely used methods are based on:

- measurement of drawdown in an observation well during pumping,

- measurement of drawdown of the pumped well during recovery, and

- drawdown-distance method, using the drawdowns in the observation and pumped wells at the end of the pumping period.

BACKGROUND INFORMATION RELATED TO PUMPING TESTS WITHIN THE STUDY AREA

Unfortunately, only a few data on pumping tests are available from various hydrogeologic studies conducted in the study area and most of these data are incomplete. The following is a summary of these data.

In a report to the Ontario Water Resources Commission, Yakuchick and Jeffs (1959) described the results of a groundwater survey for the Village of Elmvale. The report described the village's water supply system, which consists of eight wells. Five of these eight wells are flowing. The combined capacity of the wells is 4.05 L/sec.

Yakuchick and Jeffs (1959) examined data for a total of 73 wells and springs within the Elmvale area. The wells, which obtain water supplies from overburden deposits, vary in depth from 3 to 90 m. The records of these wells suggest the presence of two or more aquifers in the Elmvale area. One aquifer, which appears to range in depth from 3 to 25 m gives rise to numerous shallow wells that flow in most cases above ground surface. These shallow wells are predominant in areas north and west of the Village of Elmvale. In areas to the south and east of the village, wells show a gradual deepening from 40 m within the village to 90 m at a distance of about 2.5 km to the east. Indications suggest a south-easterly dipping aquifer that gives rise to numerous flowing wells.

According to Yakuchick and Jeffs (1959), pumping rates are available only for three wells and range from 0.23 to 0.53 L/sec. The authors did not provide any additional details related to the hydraulic parameters of any well or aquifer.

Norman H. Ursel Associates Ltd. (1971) described the results of a pumping test of a well located at the site of Blueberry Beach Development in Tiny Township. The authors reported that the transmissivity of the well, which taps a 30 m thick layer of sand and gravel, is about 1,670 m^2/day.

In a report to the Midland Public Utilities Commission (MPUC), Wilson (1972) described the results of a test drilling program carried out in the vicinity of Evergreen Sideroad to the southeast of Midland Park Lake. The report includes the results of pumping tests at rates of 4,546 and 5,455 L/sec of a production well that taps an overburden aquifer. The results of the tests indicate that the hydraulic conductivity of the well is about 0.002 L/sec, the transmissivity coefficient is about 3,728 m^2/day, and the storage coefficient is about $2.3 * 10^{-2}$ (dimensionless).

According to Wilson (1972), the overburden increases in thickness to south east of Midland Park Lake and becomes more favourable as a source of groundwater along the Evergreen Sideroad. The bedrock in the area is less favourable as a source of groundwater.

In a study of the water resources of the Elmvale area, Andrijiw (1976) reported that only four wells reached the rocks of the Bobcaygeon Formation or penetrated it. The Bobcaygeon Formation in the Elmvale area is about 100 m below the surface.

Two of the four wells were completed at the bedrock-overburden contact, one well penetrated 0.3 m into the bedrock, and one well penetrated 11 m into the bedrock. This later well was abandoned because it produced insufficient water to meet domestic needs. According to Andrijiw (1976), the specific capacities of the four wells ranged from 0.3 to 0.6 L/min/m, which are too low to permit the construction of high capacity wells in the bedrock.

In a report to the Ministry of the Environment on the inspection results of the Wyevale Pines Estates water works system in Tiny Township, Belcourt (1980) states that the system is serviced by a single well. A second well was constructed but no application for a Permit to Take Water from the well was submitted as of 1980. Both wells are rated at 7.58 L/sec. In an Addendum to the report, the results of a 4-hour pumping test conducted on the second well are given. These results indicate that the transmissivity of the aquifer in the area of Wyevale Pines Estate is 129.60 m^2/day. No information related to the aquifer, however, was provided.

In a hydrogeologic report on the Portage Park water works system in Tay Township, Dixon Hydrogeology Ltd. (1988) provided a summary of the characteristics of three wells that supply water to the system. The first well was pumped for 28 hours and shows a specific capacity of 1.68 L/min/m; the second well was pumped for 16 hours and showed a specific capacity of 4.02 L/min/m; and the third well was pumped for 33 hours and showed a specific capacity of 10.80 L/min/m. No information related to any other hydraulic parameters of the wells was provided.

In a report on the construction and testing of a well for Bramhall Park Mobile Homes Ltd. near Elliotts Corners in Tay Township, Dixon Hydrogeology Ltd. (1989) indicated that the well obtained water supplies from a deep overburden aquifer, which is locally unconfined. The well was tested for 24 hours at a pumping rate of 3.18 L/sec. The water level within the well declined 1.394 m during the first minute of the test, and then remained relatively steady. The maximum drawdown during the test was 1.404 m. The specific capacity of the well at the test rate was 2.27 L/sec/m.

Henderson, Paddon and Associates Ltd. (1990) conducted a hydrogeologic assessment of Buffalo Springs area, which is located within the Bass Lake kame moraine in Oro Township. The authors examined the geology of the area, conducted a review of available water well records, and reported on the results of a 61.5 hours pumping test of a deep production well (OW1) at a rate of about 300 m^3/day.

Seven wells (OW2, OW3, OW4, OW5, OW6, OW7 and OW8) were monitored during the pumping test. Table 3 gives estimates of the transmissivity and storage coefficients determined for these wells. The transmissivity coefficients range from 460 to 17,000 m^2/day and the storage coefficients range from $3.4 * 10^{-4}$ to $8.8 * 10^{-3}$.The results of the pumping test are indicative of the water-yielding capabilities of the Bass Lake kame moraine, which is one of the most important groundwater recharge zones within the study area.

Table 3. Summary of pumping test data for a production well and seven observation wells in Buffalo Springs, Oro Township.

Well No.	Data	Transmissivity m^2/day	Storage Coefficient Dimensionless
OW1	Drawdown	491	-
	Recovery	625	-
OW2	Drawdown	460	$2.7 * 10^{-3}$
OW3	Drawdown	6,350	$8.8 * 10^{-3}$
OW4	Drawdown	7,030	$1.1 * 10^{-3}$
OW5	Drawdown	17,000	$2.1 * 10^{-3}$
OW6	Drawdown	11,500	$8.5 * 10^{-3}$
OW7	Drawdown	1,920	$3.4 * 10^{-4}$
OW8	Drawdown	9,750	$3.9 * 10^{-4}$

According to Henderson, Paddon and Associates Ltd. (1990), the records of water wells within the Buffalo Springs area indicate that the wells range in depth from 13 to 53 m, and water supplies are obtained from sand or sand and gravel units within the overburden. Pumping tests conducted on surrounding wells suggest safe yields averaging about 1.3 L/sec and ranging from 0.15 to 3.00 L/sec.

The Buffalo Springs area contains a shallow, water table aquifer and a confined, intermediate aquifer of variable depth and composition located 20 to 30 m below ground surface, which supplies local domestic wells. In addition, there is a deep aquifer that underlies extensive, confining layers of sandy silty till, 50 to 80 m deep.

In an Application for a Permit to Take Water, dated February 3, 1991, for the Penetanguishene water works system in the Town of Penetanguishene, information related to the maximum amounts of water taken from three wells is provided. The amounts taken from the three wells are 38, 46 and 53 L/sec, respectively. No other data related to pumping tests are provided.

In a report to the Penetanguishene Water and Light Commission, Trow, Dames & Moore (1991) provided information related to the drilling, construction and testing of a second well on Payette Drive. The results of a variable rate pumping test indicted that the specific capacity of this second well was 252 L/min/m and remained constant at each step, suggesting that the groundwater flow regime was maintained. The report also includes information on the results of an earlier pumping test performed on the original overburden well on Payette Drive. A 95-hour constant rate pumping test was performed on this well at a rate of 38 L/sec. The calculated value of the transmissivity coefficient for the well was about 1,760 m^2/day, and the coefficient of storage was estimated at 0.03.

According to Trow, Dames & Moore (1991), the town of Penetanguishene is also serviced by two additional wells constructed within the overburden on Robert Street in 1950 and 1961. The well constructed in 1950 is capable of supplying over 100 L/sec, while the well constructed in 1961 flows naturally at a rate of up to 60 L/sec. The two wells are now out of service.

In an Application for a Permit to Take Water, dated February 4, 1992, for the Sunnyside water system in Tay Township, information related to the average flow, maximum flow, and the rated capacities of four wells is provided. The average flow from the four wells ranges 2.31 to 2.55 L/sec; the total maximum flow of the wells ranges from 7.45 to 9.52 L/sec; and rated capacities of individual wells range from 6.32 to 6.43 L/sec. No other information related to pumping tests is provided.

In a study prepared for the Midland Public Utilities Commission (MPUC), Lotowater Ltd. (1992) evaluated the groundwater resources within the Town of Midland and reviewed the aquifer test data for wells within the MPUC operating system. The study includes information related to the geology and hydrogeology of the area, describes the geologic logs of various wells, and provides some data related to pumping tests. The data, however, are given mainly in terms of pumping rates, water levels and drawdowns. No attempt was made to calculate the hydraulic parameters of the tested wells. The study concludes by stating that a perennial groundwater supply of at least 216.9 L/sec is available from the existing MPUC connected wells.

In a Class Environmental Assessment report that is related to upgrading the water works for the Village of Coldwater, Jagger Hims Ltd. (1993) carried out a hydrogeologic study within and in the vicinity of the village. The objective of the study was to show that the Precambrian aquifer in the area was capable of supplying the projected water needs for the Village of Coldwater.

As part of the Class Environmental Assessment, two exploratory production wells were constructed. Both wells were pumped simultaneously for 72 hours at a combined rate of 31.82 L/sec. In addition, step-drawdown tests were conducted on both wells. Based on the results of these pumping tests, Jagger and Hims Ltd. (1993) estimated the transmissivity of the aquifer at 140 to 190 m^2/day, and the coefficient of storage at 0.0017 to $5*10^{-5}$ (dimensionless).

In a hydrogeologic study to provide water supplies to the Caroway Mobile Home Park in Tay Township, I. D. Wilson Associates Ltd. (1994) note that only a few local wells are constructed in the bedrock. The yields of these wells range from 4 to 32 L/min. These water yields range from marginal to more than adequate for individual domestic requirements.

ESTIMATING TRANSMISSIVITIES FROM SPECIFIC CAPACITY DATA

As can be seen from the above, the available information on long-duration pumping tests within the study area is very limited. Fortunately, thousands of specific capacity values, based on short-duration pumping tests, are available for wells within and in the vicinity of the study area. These data have been used extensively in this study to supplement the data on pumping tests.

Theis et al (1963) describe a method for estimating the transmissivity of an aquifer from the specific capacity of a well. Their analysis is based on the Jacob equation, given in consistent units as:

$$T = (Q/12.6\ s) \ln [(2.25\ T * t)/(r^2 * S)] \quad (1)$$

where

T = transmissivity (L^2/t),

Q = discharge (L^3/t),

s = drawdown in the well (L),

t = pumping time (t),

S = storage coefficient (dimensionless), and

r = radius of the well (L).

Because T appears twice in equation (1), it cannot be solved directly. Graphical solutions involving matching the specific capacity data to a family of curves were proposed. These solutions, however, have the disadvantage of requiring a different set of curves for every possible combination of well radius, pumping period, and storage coefficient. In addition, any corrections for partial penetration or well loss require additional calculations. A computer program that uses an iterative technique, corrects for partial penetration and well loss, and provides rapid estimates of transmissivities at hundreds of data points, was developed by Bradbury and Rothschild in 1985. This program was modified to accept the format of the MOE water well records, and was linked to the MOE Groundwater RAISON System to allow for the use of contour mapping routines and statistical programs.

Using the above computer program, the transmissivity values for wells completed in various bedrock and overburden hydrogeologic units were determined. To determine the statistical distribution, mean and range of the specific capacities and transmissivity values, a statistical analysis was applied. The specific capacity or transmissivity values in each hydrogeologic unit were listed in ascending order of magnitude and assigned probabilities according to the relationship:

$$F = (100 * m)/ (n + 1) \quad (2)$$

In the case of specific capacities, the parameters in Equation 2 are:

F = percentage of wells where the specific capacities are less than the specific capacity of well with serial number m,

m = serial number of well arranged in ascending order of specific capacities, and

n = total number of wells.

In the case of transmissivity, the parameters in Equation 2 are:

F = percentage of wells where the transmissivities are less than the transmissivity of well of serial number m,

m = serial number of well arranged in ascending order of transmissivities, and

n = total number of wells.

The 10 and 90 percentile values are the specific capacity or transmissivity values not exceeded by 10% and 90% of the wells, respectively. They provide a measure of the dispersion of the specific capacity and transmissivity values; a large difference between the 10 and 90 percentiles indicates a large spread and a high standard deviation.

GROUNDWATER OCCURRENCE IN THE BEDROCK

Within the study area, groundwater occurs in the bedrock primarily in openings such as fissures, fractures, joints, bedding planes, or solution cavities. The availability of water stored in various bedrock units is dependent on the degree of interconnection of these openings.

Five hydrogeologic units were identified within the bedrock in the study area. These units, which are based on the bedrock geology of the study area given in Figure 9, include the Precambrian hydrogeologic unit and the Shadow Lake-Gull River, Bobcaygeon and Verulam hydrogeologic units of Palaeozoic age.

The Precambrian Hydrogeologic Unit

From a hydrogeologic point of view, only those Precambrian rocks that are at or close to the surface within the northern parts of the study area are significant as a source of groundwater supplies. The remaining Precambrian rocks are buried under thick sequences of younger rocks of Palaeozoic and Quaternary ages and, therefore, cannot be tapped for groundwater.

In a groundwater survey which was carried out to upgrade the Waubaushene water supply system, 26 water wells completed in bedrock were examined (Pawlowski, 1978). Of these, 19 wells were completed in Precambrian rocks, six in the Gull River Formation, and one in the Shadow Lake Formation. According to Pawlowski (1978), all the 26 wells encountered sufficient water for domestic use. The author notes that the Palaeozoic rocks in the Waubaushene area are not as productive as the Precambrian rocks. Only 27% of the wells found sufficient water for domestic use in the limestones of the Gull Formation. The low water yield of the limestones indicate that their secondary fractures and solution channels are not completely open and conducive to water movement.

As part of a Class Environmental Assessment of the groundwater resources of a small area within and in the vicinity of the Village of Coldwater, Jagger Hims Ltd. (1993) noted that the bedrock in the area is comprised of Ordovician limestone and Precambrian granite. The author(s) indicated that the bedrock (particularly the Precambrian granites) forms the aquifer which is most often used as a source of groundwater supply by residents of the village.

Two exploratory production wells were constructed as part of the Class Environmental Assessment. Both wells were pumped simultaneously for 72 hours at a combined rate of 31.82 L/sec. In addition, step-drawdown tests were conducted on both wells. Based on the results of these pumping tests, Jagger and Hims Ltd. (1993) estimated the transmissivity of the Precambrian aquifer at 140 to 190 m^2/day, and estimated the coefficient of storage at 0.0017 to $5*10^{-5}$ (dimensionless).

In a study of the hydrogeology of southern Ontario, which included most of the study area, a total of 12,381 wells were identified in areas where the Precambrian rocks outcrop at surface (Singer et al, 1997). Of these, a sample of 7,875 wells was selected to determine the specific capacity and transmissivity distributions for the wells completed in the Precambrian rocks.

According to Singer et al (1997), 5,158 wells in the sample have specific capacity values less than 5.00 (L/min/m). A fair number of wells (2,274), however, show good specific capacity values ranging from 5.00 to 50.00 l/min/m; while a minority of wells (50) have specific capacity values higher than 50.00 l/min/m.

The transmissivity distribution for the wells in the sample was derived from the specific capacity data (Singer et al, 1997). The transmissivity-probability graph for wells in the sample indicates that the sample has log-normal distribution. The 10 and 90 percentile values for the sample were 0.40 and 42.50 m^2/day, and the geometric mean of the sample's transmissivity distribution was 4.20 m^2/day.

Given the large number of wells in the sample, Singer et al (1997) were able to conclude that their sample's transmissivity distribution is representative of the water-yielding capability of the Precambrian rocks. The low value of the distribution's geometric mean suggested that the Precambrian rocks have a poor water-yielding capability.

In this study a total of 808 wells have been identified to obtain water supplies at various depths within the Precambrian Hydrogeologic Unit. Data on short-duration pumping test are available for 202 of these wells. The data were used to assess the specific capacity and transmissivity distributions for the Precambrian wells within the study area.

Since the availability of fractures and fissures within the Precambrian rocks is depth dependent, two suitable samples that reflect the degree of penetration of these rocks were selected from the available data. The first sample consisted of 87 wells whose depths of penetration are less than 20 m, and the second sample consisted of 125 wells whose depths of penetration are more than 20 m.

The specific capacity values for the two samples were plotted against the percentage of wells on a logarithmic probability paper. The specific capacity values plot as approximately straight lines indicating that the samples have log-normal frequency distributions. Therefore, it could be concluded that the most probable specific capacity values for the two samples are equal to their corresponding geometric means. Figure 16 shows specific capacity-probability graphs for the two samples.

The minimum and maximum specific capacity vales for first sample are 0.28 and 596.52 L/min/m, respectively. The 10 and 90 percentile values are 0.88 and 447.39 L/min/m, respectively, and the geometric mean of the first sample is 3.11 L/min/m.

The minimum and maximum specific capacity values for the second sample, on the other hand, are 0.05 and 596.50 L/min/m, respectively. The 10 and 90 percentiles are 0.11 and 15.29 L/min/m, respectively, while the geometric mean for the second sample is 0.65 L/min/m.

The transmissivity distributions for the two samples were derived from their specific capacity data. Figure 17 shows plots of the transmissivity-probability distributions of the two samples.

The minimum and maximum transmissivity values determined for the first sample are 0.50 and 1,484.57 m^2/day, respectively. The 10 and 90 percentiles are 1.48 and 357.14 m^2/day, respectively, and the geometric mean is 5.60 m^2/day.

The minimum and maximum transmissivity values for the second sample are 0.06 and 11,551.86 m^2/day, respectively. The 10 and 90 percentiles are 0.15 and 53.20 m^2/day, respectively, and the geometric mean is 1.01 m^2/day.

Based on the specific capacity distributions and corresponding transmissivity distributions for the two samples, it is possible to conclude that the upper 20 m of the Precambrian rocks within the study area have higher water-yielding capabilities compared to deeper rocks. This is most likely due to the fact that the fracture and fissure system within the upper parts of the Precambrian rocks is more developed, which allows for better conditions for water storage and transmission.

The above analyses also indicate that the water-yielding capability of the Precambrian rocks is highly variable and appears to be a function of the number and size of fractures and fissures encountered by a water well. The openings created by these fractures and fissures are more developed within the upper 20 m of the unit. However, since the openings can begin and end abruptly and since they are usually directional, it is not surprising to have poor water-yielding wells within the upper 20 m range nor it is surprising to encounter high water-yielding wells below this range. The low values of the geometric means for the specific capacity and transmissivity distributions indicate that the Precambrian Hydrogeologic Unit has a poor water-yielding capability.

The Shadow Lake-Gull River Hydrogeologic Unit

The Shadow Lake and Gull River Formations are at or close to the surface within a strip extending from the eastern boundaries of the study area towards the southern shores of Georgian Bay through to the area's western boundaries. Since it is not possible to distinguish between the two formations in the records of water wells drilled in this strip, the formations were combined into one hydrogeologic unit.

An examination of available water well records indicates that 431 wells have been completed in the Shadow Lake-Gull River Hydrogeologic Unit. No long-duration data on pumping tests are available for any of these wells. Suitable, short-duration data on pumping tests are available, however, for 429 wells. These data were divided into two samples. The first sample consists of 301 wells, which penetrate the unit for less than 20 m, and the second sample consists of 128 wells, which penetrate the unit for more than 20 m.

Figure 18 shows graphs of the specific capacity distributions of the two samples. The minimum and maximum specific capacity values for the first sample are 0.08 and 1,278.68 L/min/m, respectively. The 10 and 90 percentile values are 0.69 and 99.42 L/min/m, respectively, and the geometric mean of the first sample's specific capacity distribution is 5.77 L/min/m.

The minimum and maximum specific capacity values for the second sample, on the other hand, are 0.04 and 689.73 L/min/m, respectively. The 10 and 90 percentile values are 0.04 and 596.52 L/min/m, respectively, while the value of the geometric mean of the second sample's specific capacity distribution is 0.88 L/min/m.

The transmissivity distributions for the two samples were derived from their specific capacity data. Figure 19 shows the transmissivity-probability graphs for the two samples. The minimum and maximum transmissivity values for the first sample are 0.11 and 3,174.83 m^2/day, respectively. The 10 and 90 percentile values are 1.12 and 308.79 m^2/day, respectively, while the value of the geometric mean of the sample's transmissivity distribution is 11.57 m^2/day.

The minimum and maximum transmissivity values for the second sample are 0.05 and 1,455.49 m^2/day, respectively. The 10 and 90 percentile values are 0.28 and 42.99 m^2/day, respectively, and the value of the geometric mean of the second sample's transmissivity distribution is 1.84 m^2/day.

By comparing the specific capacity distributions and the corresponding transmissivity distributions of both samples, it is possible to conclude that water wells completed within the upper 20 m of the Shadow Lake-Gull River Hydrogeologic Unit have higher water-yielding capabilities than those completed deeper than 20 m. It is important to remember, however, that a deeper well is often needed when the water supplies within its upper parts are inadequate. What the results of the analyses indicate, therefore, is that the probability of finding more water in this hydrogeologic unit is higher within its upper 20 m.

The upper 20 m of the Shadow Lake-Gull River Hydrogeologic Unit appear to have more openings in the form of fissures, fractures and bedding plains. Given the relatively small water-yielding capability of the Shadow Lake-Gull River Hydrogeologic Unit, however, it is doubtful that the unit contains a well-developed system of interconnected solution cavities. Carbonate aquifers in southern Ontario that have developed extensive systems of solution cavities are usually characterized by excellent water-yielding capabilities.

The Bobcaygeon Hydrogeologic Unit

Rocks of the Bobcaygeon Formation overly the rocks of the Gull-River Formation and cover most of the southern parts of the study area. These rocks are obscured, however, by thick deposits of Quaternary origin.

Available records indicate that 177 water wells have been completed within the Bobcaygeon Hydrogeologic Unit. Suitable, short-duration pumping test data are available, however, for 148 wells. The available data were divided into two samples. The first sample consisted of 84 wells, which penetrated less than 20 m of the unit; and the second sample consisted of 64 wells, which penetrated more than 20 m of the unit.

Figure 20 shows graphs of the specific capacity distributions of both samples. The minimum and maximum specific capacity values for the first sample are 0.09 and 745.65 L/min/m, respectively. The 10 and 90 percentile values are 0.65 and 298.26 L/min/m, respectively, and the value of the geometric mean of the sample's specific capacity distribution is 4.33 L/min/m.

The minimum and maximum specific capacity values for the second sample are 0.06 and 298.27 L/min/m, respectively. The 10 and 90 percentile values are 0.08 and 18.64 L/min/m, respectively, while the value of the geometric mean of the second sample's specific capacity distribution is 0.70 L/min/m.

The specific capacity data for the 148 wells were used to derive the transmissivity distributions for the two selected samples. Figure 21 shows the two transmissivity-probability graphs for the two samples. The minimum and maximum transmissivity values for the first sample are 0.25 and 1,695.67 m^2/day, respectively. The 10 and 90 percentile values are 0.91 and 248.90 m^2/day, respectively, while the value of the geometric mean of the transmissivity distribution is 8.38 m^2/day.

The minimum and maximum transmissivity values for the second sample are 0.08 and 702.86 m^2/day, respectively. The 10 and 90 percentile values are 0.31 and 30.99 m^2/day, respectively, while the value of the geometric mean of the second sample's transmissivity distribution is 4.71 m^2/day.

Again, the analyses of the specific capacity distributions and the corresponding transmissivity distributions of the two samples of wells completed within the Bobcaygeon Hydrogeologic Unit indicates that the probability of encountering higher water-yielding wells within the upper 20 m of the unit is larger than that for deeper wells. The results of the analyses also indicate that the water-yielding capability of the Bobcaygeon Hydrogeologic Unit is, by and large, similar to that of the Shadow Lake-Gull River Hydrogeologic Unit.

The Verulam Hydrogeologic Unit

The rocks of the Verulam Formation occur within a small locality at the southwestern corner of the study area. These rocks are buried under thick sequences of Quaternary deposits and no water wells within the study area tap this formation. Therefore, from a hydrogeologic point of view, the Verulam Hydrogeologic Unit is of little significance as a source of groundwater within the study area.

General Comments Regarding Groundwater Occurrence in the Palaeozoic Rocks within the Study Area

Little background information is available regarding the hydrogeology of Palaeozoic rocks of the study area. As indicated earlier, Andrijiw (1976) reported in his study of the water resources of the Elmvale area that only four wells reached or penetrated the Bobcaygeon Formation, which is present in that area at about 100 m below the surface. Two of the four wells were completed at the bedrock-overburden contact, one well penetrated 0.3 m into the bedrock, and one well penetrated 11 m into the bedrock. This later well was abandoned because it produced insufficient water to meet domestic needs. According to Andrijiw (1976), the specific capacities of the four wells ranged from 0.3 to 0.6 L/min/m, which are too low to permit the construction of high capacity wells in the bedrock.

Pawlowski (1978) reviewed the records of 26 bedrock wells in the Waubaushene area. Of these, 19 wells were completed in the Precambrian rocks, six in the Gull River Formation, and one the Shadow Lake Formation. According to Pawlowski (1978), the limestone of the Gull River Formation was less productive than the Precambrian rocks as only 27% of wells that tapped the limestone encountered sufficient water for domestic use. The primary permeability of the massive limestone and granites in the Waubaushene area is very low and can be compared to that of clay. Therefore the extensiveness of open and well connected joints and fractures receiving recharge will ultimately control the amount of ground water available for development at any particular site.

In a hydrogeologic study to provide water supplies to the Caroway Mobile Home Park in Tay Township, I. D. Wilson Associates Ltd. (1994) note that only a few local wells are constructed in the bedrock. The yields of these wells range from 4 to 32 L/min. These water yields range from marginal to more than adequate for individual domestic requirements.

As can be seen, the number of wells that was considered in the above three studies was too small to arrive at meaningful conclusions. Other hydrogeologic studies, however, that examined the hydrogeologic properties of all or most of the Palaeozoic formations of the study area were conducted. These studies either considered the same Palaeozoic formations outside the study area or examined them in a regional study of the hydrogeology of southern Ontario.

An evaluation of the groundwater resources of the Wilton Creek basin was carried out by Funk (1977). The Wilton Creek basin is located in southeastern Ontario about 20 km west of the City of Kingston. The bedrock in the basin consists of deposits of the Shadow Lake, Gull River, Bobcaygeon, and Verulam Formations. Funk (1977) reported on the results of pumping tests for a number of wells finished in the bedrock. The transmissivity values for these wells range from 1.34 to 58.15 m^2/day.

In a regional study of the hydrogeology of southern Ontario, Singer et al (1997), examined the records of 28,172 wells completed within the Simcoe Group, which includes the Gull River, Bobcaygeon, Verulam, and Lindsay Formations. The rocks of the later Lindsay Formation are not found in the study area. Of the 28,172 wells, a sample of 6,414 wells was selected to determine the specific capacity and transmissivity distributions for the wells completed within the Simcoe Group.

According to Singer et al, 1997, the minimum and maximum specific capacity values for the sample were 0.04 and 1,044.00 L/min/m. The 10 and 90 percentile values were 0.46 and 29.83 L/min/m, respectively, and the geometric mean of the sample's specific capacity distribution was 3.04 L/min/m. The minimum and maximum transmissivity values, derived from the sample's specific capacity data, were 0.053 and 3,062.00 m^2/day, respectively. The 10 and 90 percentile values were 0.71 and 63.84 m^2/day, respectively, and the geometric mean of the sample's transmissivity distribution was 5.70 m^2/day.

Based on the large number of wells in their sample, Singer et al (1997) concluded that it is possible to assume that their sample's transmissivity distribution is representative of the water-yielding capability of the Simcoe Group. The relatively low value of the distribution's geometric mean suggested that the Simcoe Group has fair water-yielding capabilities.

The findings of this study are consistent with the general findings of the study conducted by Singer et al (1997). The specifics of this study, however, suggest that the upper 20 m of the Palaeozoic formations are more productive than the lower parts. It also suggests that the Shadow Lake-Gull River and the Bobcaygeon Hydrogeologic Units have similar water-yielding capabilities (Figure 28). From a practical point of view, however, these units are important as sources of groundwater supplies only in areas where the units are at or close to the surface. In areas where these units are under thick sequences of Quaternary deposits, their significance as sources of groundwater supplies is minor.

Figure 22 shows a comparison between the transmissivity distributions of all the wells completed within Precambrian and Palaeozoic rocks. The geometric mean of all wells completed within the Precambrian Hydrogeologic Unit is 2.78 m^2/day. The geometric means for all the wells completed within the Shadow Lake-Gull River and the Bobcaygeon Hydrogeologic Units are almost identical with values of 7.19 and 7.10 m^2/day, respectively. The two units appear to have identical transmissivity distributions and to have much higher water-yielding capabilities in comparison with the Precambrian Hydrogeologic Unit.

GROUNDWATER OCCURRENCE IN THE OVERBURDEN

The overburden in the study area is composed of glacial, glaciofluvial, glaciolacustrine, and recent deposits. These deposits include clays, silts, sands, gravels, and tills. The grain size varies from tiny particles that are less than 1 mm in size to large boulders that can be a few metres in size. Groundwater occurs in the pore spaces between the overburden grains.

Clays, though highly porous, have such small pore spaces that a large percentage of the water contained in them is bound to the particles by forces of molecular adhesion. As a result, clay-rich sediments are usually described as being impermeable. The coarse-grained sand and gravel deposits, on the other hand, have large pore spaces that allow water to move more freely. These deposits constitute the best aquifers within the overburden in the study area.

The openings between particles within the overburden as well as the degree of the interconnections between the openings are highly variable. Further, the areal distribution of the various water-bearing overburden deposits as well as their thicknesses, geologic settings, and opportunity for being recharged by precipitation are also highly variable. Some sands and gravels in particular have been deposited in a rapidly changing environment, which produced layers of fine sand, silt and clay within them. All these factors have important implications when it comes to the local availability and magnitudes of water supplies, and for the regional movement of groundwater within the study area.

In general, the availability of ground water in the overburden ranges from poor to good. Most wells in the overburden are used to meet domestic supplies and livestock requirements. Locally, overburden aquifers are the most productive sources of groundwater within the study area and provide a number of urban areas with water supplies. Given the heterogeneity of these deposits, detailed local investigations including test wells and long-duration pumping tests are necessary to find appropriate water supplies.

In describing the groundwater occurrence within the overburden, it is important to make the following observations:

- It is extremely difficult to determine with any degree of certainty the hydraulic parameters of individual overburden units from data contained in the water well records. This is due to the fact that the overburden is highly variable in terms of composition and thickness both vertically and horizontally.

- Our experience indicates that the overburden contains various amounts of sands or gravels at different depths and locations. These deposits can be small in size and capable of yielding enough water to satisfy the needs of a single home, or they can be large enough to satisfy the water needs of a village or a town.

- A well could penetrate a number of tills, silts, sands or gravels, and it is not always clear which one of these deposits contributes most of the water to the well.

Faced with these difficulties, the description of groundwater occurrence in various overburden units is provided in terms of the wells that have been completed within various units. The available records of water wells indicate that most of these wells are located in the southern half of the study area where the thickness of the overburden can be substantial.

Figure 13 was used to delineate the geographic boundaries of the various overburden units within the study area. These units include:

- the surficial till deposits,
- the glaciofluvial ice-contact deposits,
- the glaciofluvial outwash deposits, and
- the glaciolacustrine deposits.

Characteristics of Water Wells Completed in Areas Where Glacial Deposits Outcrop at the Surface

Till is a poorly sorted glacial material that often contains clasts of many sizes in a variable finer-grained matrix. Various tills can range from massive, compact clay-types with limited capability to store and transmit water to loose, sandy or sandy silty types, which are more pervious, and allow water to pass through them to recharge lower aquifers or they act themselves as aquifers. Often these later tills contain sand lenses of various dimensions that can provide water in sufficient quantity to meet domestic needs.

Most of the surficial tills within the study area have a sandy silt to silt matrix and are commonly rich in clasts. These tills were mapped by Barnett (1991) as "map unit 19" on the OGS Map 2556. Other tills outcrop at the surface in a few small locals within the study area. These tills are fine-grained, clast poor, and have predominantly silty clay to silt matrices. The tills were mapped by Barnett (1991) as "unit map 21" on the OGS Map 2556.

In a regional study of the hydrogeology of southern Ontario, which includes most of the study area, Singer et al (1997) identified a total of 10,660 water wells in areas where "map unit 19" outcrops at surface. Of these, 115 wells have been reported to be dry. According to Singer et al (1997), a sample of 8,140 of the wells within "map unit 19" was selected to determine the statistical parameters of the sample's specific capacity distribution. The results of the analysis indicated that the minimum and maximum specific capacity values for the sample are 0.09 and 869.00 L/min/m. The 10 and 90 percentile values were 1.32 and 29.83 L/min/m, while the value of the geometric mean of the specific capacity distribution was 5.96 L/min/m.

Singer et al (1997) identified a total of 142 water wells in areas where "map unit 21" outcrops at surface. Of these, 3 wells have been reported to be dry. Of the 142 wells , a suitable sample of 113 wells was selected by Singer et al (1997) to determine the statistical parameters of the sample's specific capacity distribution. The results indicated that the minimum and maximum values for the sample were 0.08 and 89.50 L/min/m, respectively. The 10 and 90 percentile values were 1.14 and 25.94 L/min/m, respectively, while the value of the geometric mean of the sample's specific capacity distribution was 5.26 L/min/m.

In this study, a total of 710 water wells have been identified in areas where till outcrops at the surface (Figure 23). To evaluate the influence of well depth on the water-yielding capabilities of wells completed within the till, five suitable samples were selected, and the statics of their specific capacity and transmissivity distributions were determined. The results indicate that the five samples have similar specific capacity and transmissivity distributions.

The statistical parameters of the specific capacity distribution of a sample consisting of 559 wells completed within the till give a minimum value of 0.26 L/min/m and a maximum value of 894.78 L/min/m. The sample's 10 and 90 percentiles are 1.15 and 35.79 L/min/m, and the geometric mean of the sample's specific capacity distribution is 5.08 L/min/m (Figure 24).

The minimum and maximum values for the sample's transmissivity distribution are 0.27 and 15,784 m^2/day, respectively. The sample's 10 and 90 percentiles are 4.76 and 370 m^2/day, respectively, and the geometric mean of the sample's transmissivity distribution is 44.44 m^2/day (Figure 25).

Characteristics of Water Wells Completed in Areas Where Glaciofluvial Ice-contact Deposits Outcrop at the Surface

Figure 26 shows the surficial distribution of glaciofluvial deposits within the study area. The figure indicates that most of these deposits are of ice-contact type within the Bass Lake kame moraine in Oro Township. As indicated earlier, Henderson, Paddon and Associates Ltd.(1990) conducted a hydrogeologic assessment of the Buffalo Springs area, which is located within the kame moraine.

The authors of the assessment reported on the results of a 61.5 hour pumping test of a deep production well (OW1) in Buffalo Springs at a rate of about 300 m^3/day. Seven wells (OW2, OW3, OW4, OW5, OW6, OW7 and OW8) were monitored during the pumping test (Table 3). The transmissivity coefficients for these wells range from 460 to 17,000 m^2/day and the storage coefficients range from $3.4 * 10^{-4}$ to $8.8 * 10^{-3}$.

According to Henderson, Paddon and Associates Ltd. (1990), the Buffalo Springs area contains a shallow water table aquifer and a confined intermediate aquifer of variable depth and composition located 20 to 30 m below ground surface, which supplies local domestic wells. In addition, there is a deep aquifer that underlies extensive confining layers of sandy silty till, 50 to 80 m deep.

Singer et al (1997) identified a total of 7,908 wells in areas where the ice-contact deposits outcrop at the surface in southern Ontario. Of these, a sample of 5,628 wells was selected to determine the statistical parameters of the sample's specific capacity distribution. The sample's minimum and maximum specific capacity values were 0.07 and 5,384.00 l/min/m, respectively. The 10 and 90 percentile values were 1.29 and 37.28 l/min/m, respectively, and the sample's geometric mean was 5.96 l/min/m.

In this study, a total of 124 wells were completed in areas where the ice-contact deposits outcrop at the surface (Figure 26). The minimum and maximum values of the specific capacity distribution of these wells are 0.49 and 596.52 L/min/m, respectively. The 10 and 90 percentile values are 1.30 and 82.85 L/min/m, respectively, and the geometric mean of the specific capacity distribution is 9.24 L/min/m (Figure 24).

The minimum and maximum values for the transmissivity distribution of 117 of the 124 wells are 1.03 and 10526.30 m^2/day, respectively. The 10 and 90 percentiles are 9.74 and 829.16 m^2/day, respectively, and the geometric mean of the transmissivity distribution is 126.36 m^2/day (Figure 25).

Characteristics of Water Wells Completed in Areas Where Glaciofluvial Outwash Deposits Outcrop at the Surface

Singer et al (1997) have identified a total of 5,227 wells in areas where outwash deposits outcrop at surface within southern Ontario. Of these, a sample of 3,341 wells was selected to determine the statistical parameters for the sample's specific capacity distribution.

The sample's minimum and maximum specific capacity values were 0.12 and 4,823.00 L/min/m, respectively. The 10 and 90 percentile values were 1.86 and 74.57 L/min/m, respectively, and the sample's geometric mean was 10.65 L/min/m.

A total of 154 wells have been completed in outwash deposits within the study area (Figure 26). Of these, a suitable sample of 124 wells was selected to determine the statistical parameters of the sample's specific capacity distribution. The sample's minimum and maximum values are 0.12 and 298.26 L/min/m. The 10 and 90 percentiles are 1.66 and 59.65 L/min/m, and the sample's geometric mean of the specific capacity distribution is 8.03 L/min/m (Figure 24).

A suitable sample of 119 wells was selected to determine the statistical parameters of the sample's transmissivity distribution. The sample's minimum and maximum values are 0.18 and 1,937.38 m^2/day, respectively. The 10 and 90 percentiles are 11.84 and 600.92 m^2/day, respectively, and the geometric mean of the sample's transmissivity distribution is 64.49 m^2/day (Figure 25).

Characteristics of Water Wells Completed in Areas Where Glaciolacustrine Sands and Gravels Outcrop at the Surface

Figure 27 shows areas where glaciolacustrine sands and gravel outcrop at the surface. Unfortunately, only a few data related to long-duration pumping tests are available and it is not clear whether these tests are representative of the hydraulic parameters of glaciolacustrine sands and gravels.

Singer et al (1997), have identified a total of 17,986 wells in areas where sands and gravels of glaciolacustrine origin outcrop at the surface in southern Ontario. Of these, a sample of 8,025 wells was selected to determine the statistical parameters of the sample's specific capacity distribution. According to Singer et al (1997), the sample's minimum and maximum specific capacity values were 0.06 and 2,237.00 l/min/m, respectively. The 10 and 90 percentile values were 1.19 and 49.71 l/min/m, respectively, and the sample's geometric mean was 7.15 l/min/m.

A total of 569 wells, completed in glaciolacustrine sands and gravels within the study area, have been identified. Of these, a suitable sample of 404 was selected to determine the statistical parameters of the sample's specific capacity distribution. The sample's minimum and maximum specific capacity values are 0.26 and 1491,30 L/min/m, respectively. The 10 and 90 percentile values are 1.24 and 49.70 L/min/m, respectively, and the sample's geometric mean is 6.70 L/min/m (Figure 24).

A suitable sample of 383 wells was selected to determine the sample's transmissivity distribution. The sample's minimum and maximum values are 0.33 and 34,802 m^2/day, respectively. The 10 and 90 percentile values are 7.06 and 615.11 m^2/day, respectively, and the sample's geometric mean is 75.70 m^2/day (Figure 25).

Characteristics of Water Wells Completed in Areas Where Glaciolacustrine Clays Outcrop at the Surface

Figure 27 shows areas where glaciolacustrine clays outcrop at the surface. Again, a few data related to long-duration pumping tests are available. A total of 159 wells completed in glaciolacustrine clays have been identified within the study area. An analysis of the specific capacity distribution of these wells indicate that the minimum and maximum values are 0.06 and 357.91 L/min/m, respectively. The 10 and 90 percentile values are 0.75 and 24.86 L/min/m, respectively, and the geometric mean is 4.97 L/min/m (Figure 24).

Of the 159 wells, a suitable sample of 154 wells was selected to determine the statistical parameters of the sample's transmissivity distribution. The minimum and maximum values are 0.14 and 1,262 m^2/day, respectively. The 10 and 90 percentile values are 5.06 and 375.68 m^2/day, respectively, and the geometric mean is 67.14 m^2/day (Figure 25).

A Comparison Between the Water-yielding Capabilities of Wells Completed in Various Overburden Deposits

Based on the analyses of the specific capacity and related transmissivity distributions of wells completed in various overburden deposits, it is possible to conclude that wells completed in areas where glaciofluvial ice-contact and outwash deposits outcrop at the surface have the highest water-yielding capabilities. This is possibly because these deposits are widespread and extensive especially within the Bass Lake kame moraine. Glaciolacustrine sands and gravels also indicate high water-yielding capabilities. Wells completed in areas where till or glaciolacustrine clays are at the surface are in general less productive (Figure 25 and 26). Having said that, it is possible to have highly productive wells completed where till or glaciolacustrine deposits outcrop at the surface. This is due to the fact that the overburden profile is highly variable both vertically and horizontally, and any overburden well may encounter sand or gravel deposits at some depth.

OVERBURDEN AND BEDROCK AQUIFERS

Thick sand and gravel deposits are the most important aquifers within the overburden. To determine the locations and dimensions of these deposits within the study area, a series of parallel, east-west and north-south cross-sections were constructed. Figure 28 shows the locations of these cross-section, Figure 29 shows the east-west cross-sections, and Figure 30 shows the north-south cross-sections.

Figures 29 and 30 show the existence of extensive bodies of sands and gravels within the overburden. The available data do not provide enough control to pin down the exact dimensions of these bodies. Nevertheless, it can be stated that their thickness ranges from less than 1 m to over 40 m.It appears that these sands and gravels are more prevalent in the southeastern and southern parts of the study area.

Figures 31 and 32 show comparisons between the specific capacity and transmissivity-probability graphs for wells completed in the bedrock and the overburden within the study area. The graphs indicate that the overburden wells are, in general, more productive than the bedrock wells.

GROUNDWATER FLOW SYSTEMS

Groundwater is subject to continuous movement, the rate of which is a function of the hydrogeologic characteristics of the material in which it moves, the existing hydraulic gradients and temperature. The existence of a three-dimensional, continuous groundwater domain in a corresponding three-dimensional potential field has been established and developed by Hubert (1940), To'th (1962, 1963), and Freeze and Whitherspoon (1966, 1967).

The groundwater hydraulic potential at a given point in this domain where the flow is at low velocity (Darcian) is given by:

$$H = g * z + (AP - P)/d \qquad (3)$$

where

H = hydraulic potential at a given point in the field,

g = gravity acceleration,

z = elevation at the point above an assumed datum,

AP= atmospheric pressure,

P = pressure at a given point, and

d = density of water.

The hydraulic head equals the hydraulic potential divided by the gravity acceleration and is measured in metres above a datum (usually mean sea level). Because the hydraulic head is obtained by dividing the hydraulic potential by a constant, it is a potential quantity itself and obeys the laws of potential theory. The hydraulic head, therefore, can be used as a potential function to describe the groundwater flow system.

Measurements of the hydraulic head are usually done using a piezometer inserted in an observation well. The piezometer provides readings of the hydraulic head at a given point in the well. A number of piezometers can be inserted at different levels inside the well to provide hydraulic head readings at these levels. This is usually done if the well penetrates more than one aquifer. Many observation wells are needed to provide readings of the hydraulic heads at a given time in order to construct an accurate map of the hydraulic head distribution within a given aquifer. This can be a very expensive operation.

No observation wells are available within the study area. However, data on static water levels from many wells completed in the bedrock or the overburden are available. The water level data were obtained at different times and provide mean readings of the hydraulic heads in various wells. Therefore, they cannot provide an exact picture of the hydraulic head configuration. Nevertheless, given the fact that the differences in hydraulic head readings are small within a well, these data can be used to provide a general picture of hydraulic head (static groundwater level) configuration within the study area.

Knowledge of static water level configuration is of importance in groundwater investigations as it indicates the direction and rate of groundwater flow. Singer et al (1997) in a study of the hydrogeology of southern Ontario showed that Lake Simcoe, Georgian Bay and Lake Huron are the principal water bodies within Simcoe County towards which groundwater flows. Groundwater divides have developed to steer groundwater flow into these three water bodies.

A total of 789 well records were used to construct the groundwater level configuration within the bedrock in the study area (Figure 33). Figure 33 indicates that the configuration of groundwater level in the bedrock within the study area is a subdued reflection of its surface topography. Groundwater divides and local divides coincide closely with the major basin topographic divides and local divides. Groundwater appears to flow mainly towards the valleys of rivers and creeks. These valleys, therefore, represent the main groundwater discharge zones within the study area.

Figure 34 shows the groundwater level configuration in the overburden within the study area. The figure shows similar patterns to those described for the bedrock, but the patterns are more pronounced. Where the overburden is missing, the groundwater flow systems in both the overburden and bedrock become one system.

LONG-TERM GROUNDWATER RECHARGE AND DISCHARGE

SOIL MOISTURE AND GROUNDWATER RECHARGE

The status of moisture within the soil profile is the decisive factor when it comes to groundwater recharge. Precipitation is the primary source of water for the replenishment of soil moisture. Lateral transfer of water over the ground surface from topographic highs to lows and the upward flow of water from the groundwater zone to the unsaturated zone provide further sources of replenishment to soil moisture.

The primary mechanisms for soil moisture depletion are through evapotranspiration and gravity drainage. The magnitude of evapotranspiration is controlled by the soil moisture availability and the climatic conditions. Gravity drainage, on the other hand, occurs in response to pressure gradients either vertically or laterally. Whereas the lateral movement of the soil moisture generates interflow, its downward vertical movement contributes to groundwater recharge (Singer, 1981).

TIMING OF GROUNDWATER RECHARGE

The process of groundwater recharge is completely controlled by the status of soil moisture, provided that there is no gain to the groundwater storage from outside areas. Some people believe that groundwater recharge is limited to certain areas. This is not true. Except in river and stream valleys that constitute the main groundwater discharge zones, groundwater recharge occurs almost everywhere. The rate of groundwater recharge, however, is very high in certain areas and the identification of such areas is very important for the appropriate management of the groundwater resources.

Measurements of static water level variations at observation wells are the best means to determine the periods of groundwater recharge. When discussing groundwater recharge, it is important to keep in mind that the groundwater storage is continually being depleted by discharge to streams. Therefore, when the static water level in an observation well remains steady, the groundwater recharge and discharge are equal. A rise in the static level indicates that recharge is more than discharge; a fall means the reverse is true.

Recharge to groundwater occurs at a maximum rate when the soil is in a state of complete saturation and diminishes when the soil is at the wet limit (field capacity). In southern Ontario, this condition is met mainly during the snowmelt and spring rainfall events, which usually extends from mid March through April and early May.

During this period temperatures start to rise, signalling the arrival of spring. The soil moisture is close to saturation and evapotranspiration is low. The snow pack is sharply depleting until it vanishes completely. A vast amount of liquid water, produced by melting snow and rainfall events, is suddenly available. Part of this water generates high flows and floods. The remaining water infiltrates through the soil and then percolates to the groundwater storage. This is the period of major groundwater recharge in southern Ontario when the water table reaches a maximum height and the groundwater storage is at its peak (Figure 35).

Rainfall events that occur during the period from late October to early December also contribute to groundwater recharge. During this period, the temperature is declining, the growing season is finished, evapotranspiration is low, and soil moisture is being restored to saturation level by precipitation that is mostly in the form of rain. The net result is recharge to groundwater and rising water tables. Finally, some recharge to groundwater could take place during winter warm spells (Figure 35).

During the summer and early fall, the soil moisture is utilized mainly by plants through evapotranspiration and a state of soil moisture deficiency usually prevails. Therefore, most of the infiltrated water from the rain, during this period, is used to satisfy this deficiency with little or no water left to recharge the groundwater. As a result, groundwater levels steadily decline except during heavy rainfall events (Figure 35).

QUANTITATIVE ASSESSMENT OF LONG-TERM GROUNDWATER DISCHARGE AND RECHARGE

It is generally recognized that streamflow consists of the following three components:

- i direct runoff, which is that part of precipitation that flows over the land surface to the streams;
- ii interflow, which is that part of precipitation that flows part of the way underground, but does not become part of the groundwater regime; and
- iii baseflow, which is that part of the precipitation that reaches the streams as natural groundwater discharge, after being a part of the groundwater regime.

One way to estimate the groundwater discharge is to separate the streamflow into different components. Unfortunately, the principles of separating the streamflow into components are not well developed, and in the case of complex streamflow events streamflow separation appears to be somewhat arbitrary. It is believed, however, that if a certain method of streamflow separation is followed consistently, the same error will be committed systematically and, therefore, useful results can be obtained for comparison purposes.

For the purpose of this study, a Streamflow Separation Program was developed. The Program separates streamflow into two components: a surface runoff component consisting of direct runoff and interflow, and a baseflow component.

The Program allows for the processing of a large amount of data in a very short time and ensures consistency in the application of the technique. Six parameters are used in the Program. The first parameter is used to detect the beginning of an event, the second to determine the event period, the third to detect the peak flow, the fourth to determine the value of the groundwater component under the peak, the fifth to determine the relative event limits, and the sixth to determine the absolute event limit.

Daily streamflow data from eight gauging stations, located on various rivers and creeks within the study area, are available for streamflow analyses (Figure 36). One station is located on the North River, one on the Coldwater River at the Village of Coldwater, one on the Sturgeon River near Sturgeon Bay, one on Hog Creek near Victoria Harbour, one on a tributary to the Wye River near Elmvale, two on the main Wye River at Wyevale and Wyebridge, and one on Copeland Creek near Penetanguishene.

Table 4 gives the names of the streamflow gauging stations within the study area, their identification numbers, and their periods of records. Table 4 indicates that the longest daily records of 32 years are available for the station on the Coldwater River. The next longest records of 14 years are available for the station on the Wye River near Wyebridge. The remaining stations have short records of about 10 years.

Table 4. Streamflow gauging stations within the study area.

Station Name	**Station Number**	**Period of records**	**Drainage Area (km^2)**
North River	02ED024	1988-1997	249.00
Coldwater River	02ED007	1965-1997	177.00
Sturgeon River	02ED018	1988-1997	103.00
Hog Creek	02ED017	1988-1997	65.20
Wye River (at Wyebridge)	02ED011	1973-1986	168.00
Wye River (at Wyevale)	02ED013	1987-1997	118.00
Wye River (tributary)	02ED016	1988-1997	15.30
Copeland Creek	02ED019	1988-1997	26.89

Daily streamflow records in excess of 10 years at a given gauging station allow for the determination of the long-term monthly and annual groundwater discharge or recharge within the drainage area of the station. Given that the change in soil moisture storage approaches zero at gauging stations with over 10 years of records, it is possible to assume that the long-term means of monthly and annual groundwater discharges, calculated for such stations, are equal to the long-term means of monthly and annual groundwater recharges.

As Table 4 indicates, only two gauging stations within the study area have daily streamflow records in excess of 10 years. The records at the remaining stations are about 10 years or less. Therefore, the long-term means of monthly and annual groundwater discharges/recharges at these stations are less exact and provide only indications of the magnitudes and degree of the variations of these variables.

All the available daily streamflow data for the eight stations were processed using the Streamflow Separation Program. Table 5 gives the names of the stations and the long-term means of annual groundwater discharge/recharge. Table 5 indicates that the values of these means range from 84.47 to 261.10 mm.

Table 5. Streamflow gauging stations and long-term means of annual groundwater discharge/recharge (mm)

Station Name	Station Number	Long-term Annual Means
North River	02ED024	174.00
Coldwater River	02ED007	260.91
Sturgeon River	02ED018	230.29
Hog Creek	02ED017	131.19
Wye River (at Wyebridge)	02ED011	183.47
Wye River (at Wyevale)	02ED013	140.96
A tributary to Wye River	02ED016	147.94
Copeland Creek	02ED019	84.26

Tables 6, 7, 8, 9, 10, 11, 12, and 13 give the monthly and annual groundwater discharges at the eight streamflow gauging stations and their long-term means. These tables indicate that the long-term monthly means are highest during the months of March, April and

May. The means decrease steadily during the period of June-August and start to recover during the period of September-December.

The monthly and annual groundwater discharge and their long-term means at streamflow gauging station 02ED024, located on the North River, are given in Table 6. The daily streamflow records for this station are nine years and five months long. The length of the records is not enough to assume with certainty that the long-term monthly and annual means of groundwater recharge are equal to their respective long-term means of groundwater discharge. Rather, they give approximate values of the long-term monthly and annual means of groundwater recharge.

Table 6. Monthly and annual groundwater discharges and their long-term means for station 02ED024 on the North River (1988-1997).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1988	---	---	---	---	---	---	---	3.35	4.89	6.22	12.67	9.03	36.15
1989	13.29	7.39	30.35	22.35	14.95	9.02	4.58	4.29	6.28	9.66	19.02	12.88	154.07
1990	11.37	14.60	44.81	21.11	14.82	5.96	4.58	3.96	3.94	6.45	15.50	17.44	164.54
1991	15.64	12.23	40.13	39.83	11.21	5.32	3.91	3.96	3.89	6.31	6.42	10.22	159.08
1992	7.72	6.22	22.17	38.98	11.82	4.52	4.72	8.58	8.67	9.46	38.96	20.57	182.41
1993	28.03	6.75	15.42	38.61	9.65	11.85	5.30	4.31	5.73	10.00	11.00	9.16	155.82
1994	6.84	12.17	16.31	25.63	23.33	8.33	11.83	6.21	4.36	6.00	12.21	14.88	148.10
1995	29.43	10.53	23.13	18.74	15.36	8.90	4.80	5.52	5.34	11.98	26.44	10.40	170.56
1996	19.39	20.00	25.58	28.88	23.62	15.26	11.92	9.57	12.03	19.82	17.80	18.59	222.46
1997	24.73	26.90	33.79	41.29	22.01	12.95	8.00	5.92	5.39	8.34	11.16	8.48	208.96
Mean	**17.38**	**12.98**	**27.96**	**30.60**	**16.31**	**9.12**	**6.63**	**5.57**	**6.05**	**9.42**	**17.12**	**13.17**	**174.00**

Table 6 indicates that the approximate long-term monthly means of groundwater discharges/recharges at station 02ED024 range from 5.57 mm in August to 30.60 mm in April. The approximate long-term annual groundwater discharge/recharge at the station is 174.00 mm, which is 42.22% of the long-term mean annual streamflow. Figures 37 and 38 show the streamflow separation hydrograph and the flow duration graph for station 02ED024, respectively.

The monthly and annual groundwater discharge and their long-term means at streamflow gauging station 02ED007, located on the Coldwater River, are given in Table 7. Given that the daily streamflow records at this station are longer than 27 years, it is possible to assume with a great deal of confidence that the long-term, monthly and annual means of groundwater discharges are equal to their respective long-term means of groundwater recharges.

Table 7. Monthly and annual groundwater discharges and their long-term means for station 02ED007 on the Coldwater River (1965-1997).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1965	---	---	---	---	---	---	---	13.80	14.66	20.50	24.78	27.21	107.90
1966	22.23	22.79	28.71	17.56	16.26	17.69	11.59	11.40	10.82	12.65	17.61	23.74	213.06
1967	21.94	19.79	29.58	30.81	21.05	34.80	27.52	18.12	19.26	27.03	28.58	34.05	312.53
1968	23.99	33.69	41.73	33.70	24.87	18.41	16.08	16.02	16.77	17.23	21.40	30.29	294.20
1969	24.43	20.87	29.93	43.67	45.17	22.39	14.44	12.19	12.63	16.53	20.74	14.87	277.87
1970	15.50	12.94	19.79	39.09	17.08	13.69	20.33	13.82	17.87	22.87	20.74	17.08	230.80
1971	14.36	14.84	25.57	38.31	19.41	14.13	14.49	14.21	13.50	13.56	13.98	19.32	215.70
1972	15.47	15.89	17.50	52.11	22.43	14.73	14.05	13.31	11.33	15.38	19.07	19.05	230.33
1973	22.08	17.68	47.01	22.08	17.86	13.92	12.47	13.05	11.80	15.84	21.89	19.78	235.46
1974	25.15	17.67	29.21	43.24	23.64	14.24	20.78	17.71	17.13	20.96	23.62	19.43	272.78
1975	25.16	20.54	27.40	53.68	21.76	16.73	14.93	16.41	17.40	16.83	16.91	21.06	268.82
1976	17.68	21.56	43.83	23.83	20.70	16.49	19.28	20.19	26.47	26.18	26.07	24.38	286.66
1977	20.68	18.47	51.94	25.50	19.51	16.12	16.26	16.25	18.18	20.87	25.62	22.89	272.29
1978	20.31	17.35	20.32	41.04	23.98	17.29	14.60	14.70	15.51	18.41	17.76	17.68	238.95
1979	17.24	18.99	48.72	30.39	20.44	15.88	15.95	15.88	14.86	21.86	21.36	34.36	275.93
1980	18.35	14.92	39.70	36.89	19.60	22.87	20.82	19.70	18.68	26.85	21.17	32.31	291.85
1981	20.50	50.48	28.61	25.59	31.99	25.36	18.35	20.64	24.05	29.57	27.89	23.43	326.46
1982	20.96	16.60	23.56	55.31	21.84	20.84	16.17	16.96	16.21	16.71	23.45	40.91	289.50
1983	27.87	22.17	26.78	27.04	25.76	16.90	15.21	15.17	15.17	18.04	20.88	18.38	249.36
1984	16.05	26.62	27.81	27.41	20.00	15.56	16.01	14.94	16.73	16.02	19.21	29.66	246.01
1985	20.48	27.91	39.35	44.20	20.14	15.73	15.86	19.22	33.30	27.08	30.61	24.14	318.00
1986	20.48	14.92	36.00	27.03	19.60	16.34	18.89	17.11	29.92	30.70	20.23	20.65	271.86
1987	17.12	13.00	41.86	27.64	16.50	15.12	15.84	14.00	13.80	16.03	19.02	23.91	233.84
1988	21.10	27.15	31.39	24.93	16.64	12.67	12.07	13.33	14.45	15.56	18.87	18.19	226.34
1989	20.53	14.54	35.57	26.53	21.18	16.39	12.12	13.23	15.46	17.25	26.28	20.02	239.10
1990	25.01	19.27	36.57	24.35	20.45	13.72	13.82	12.96	12.82	15.51	21.25	23.27	239.02
1991	21.91	19.42	41.91	44.03	17.10	12.63	13.35	13.27	12.99	15.87	14.56	18.31	245.33
1992	14.43	13.13	31.31	40.07	17.32	12.90	13.70	15.01	14.81	15.77	37.08	18.88	244.41
1993	26.65	13.82	21.81	37.61	16.85	17.20	13.76	13.80	14.93	16.63	16.66	15.09	224.81
1994	14.41	17.77	18.92	27.42	26.75	15.69	16.98	13.91	13.99	16.16	14.82	18.16	214.97
1995	34.16	16.93	29.88	23.74	21.49	16.20	15.27	14.90	13.33	19.86	28.00	16.57	250.33
1996	31.21	27.97	31.59	32.75	31.50	20.75	20.93	19.39	21.38	27.87	26.05	25.95	317.36
1997	31.50	35.83	38.76	39.23	26.46	20.17	17.74	16.56	14.05	16.68	22.57	15.51	295.06
Mean	**21.53**	**20.80**	**32.58**	**33.96**	**22.04**	**17.30**	**16.24**	**15.49**	**16.80**	**19.54**	**22.08**	**22.68**	**260.91**

Table 7 indicates that the long-term monthly means of groundwater discharges/recharges at station 02ED007 range from 15.49 mm in August to 33.96 mm in April. The long-term annual groundwater discharge/recharge at the station is 260.91 mm, which is 63.15% of the long-term mean annual streamflow. Figures 39 and 40 show the streamflow separation hydrograph and the flow duration graph for station 02ED007, respectively.

The monthly and annual groundwater discharges and their long-term means at streamflow gauging station 02ED018, located on the Sturgeon River, are shown in Table 8. The length of the daily streamflow records (9 ½ years) at the station is not long enough to assume with certainty that the long-term monthly and annual means of groundwater discharge are equal to their respective long-term means of groundwater recharge. Rather, these means give approximate values of the long-term monthly and annual means of groundwater recharge.

Table 8. Monthly and annual groundwater discharges and their long-term means for station 02ED018 on the Sturgeon River at Sturgeon Bay (1988-1997).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1988	---	---	---	---	---	---	15.34	16.05	17.49	18.46	20.88	18.58	112.58
1989	20.68	16.76	32.06	26.27	22.90	19.50	12.18	12.42	14.81	15.82	21.30	19.15	233.85
1990	18.15	17.88	35.38	21.27	18.52	13.51	14.49	12.60	12.79	15.73	20.56	20.40	221.27
1991	22.36	17.01	32.89	41.68	15.84	12.22	13.57	13.62	12.30	16.68	16.82	19.60	234.58
1992	15.37	14.36	28.38	33.14	16.44	12.31	13.70	14.94	16.29	18.53	32.06	20.45	235.96
1993	23.11	12.73	16.91	32.36	15.75	16.29	12.54	11.93	15.10	16.92	15.83	14.86	204.32
1994	14.79	19.43	18.60	27.13	24.85	14.73	14.85	12.48	12.38	15.52	15.89	17.48	208.12
1995	25.58	11.98	21.23	21.38	19.10	14.18	14.92	13.65	12.38	18.68	21.94	14.91	209.94
1996	23.84	16.53	20.93	33.30	27.93	18.41	21.05	16.23	17.51	23.02	23.69	21.18	263.61
1997	25.69	28.00	30.67	35.64	23.32	19.55	16.34	15.94	14.18	17.17	19.74	14.75	260.98
Mean	**21.06**	**17.19**	**26.34**	**30.24**	**20.52**	**15.63**	**14.90**	**13.98**	**14.52**	**17.65**	**20.87**	**18.14**	**230.29**

Table 8 indicates that the long-term monthly means of groundwater discharges/recharges at station 02ED018 range from 13.98 mm in August to 30.24 mm in April. The approximate long-term annual groundwater discharge/recharge at the station is 230.29 mm, which is 57.63% of the long-term mean annual streamflow. Figures 41 and 42 show the streamflow separation hydrograph and the flow duration graph for 02ED018 station, respectively.

The monthly and annual groundwater discharges and their long-term means at streamflow gauging station 02ED017, located on Hog Creek, are given in Table 9. The length of the daily streamflow records (about 9 ½ years) at the station is not long enough to assume with certainty that the long-term monthly and annual means of groundwater discharge are equal to their respective long-term means of groundwater recharge. Rather, these means give approximate values of the long-term monthly and annual means of groundwater recharge.

Table 9. Monthly and annual groundwater discharges and their long-term means for station 02ED017 on Hog Creek near Victoria Harbour (1988-1997).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1988	---	---	---	---	---	---	3.12	2.98	4.35	6.40	7.10	6.06	31.23
1989	8.65	5.34	31.31	12.99	9.64	5.28	2.72	2.50	2.47	3.68	11.27	5.93	101.77
1990	11.97	11.12	30.77	10.88	5.87	3.67	4.10	3.21	2.81	5.30	14.36	15.69	119.73
1991	12.21	7.48	26.61	33.98	5.60	2.71	2.99	2.79	3.33	6.16	5.03	8.13	117.01
1992	5.91	5.03	24.27	29.74	7.65	2.85	3.09	4.58	5.95	7.61	26.05	10.44	133.16
1993	24.81	10.72	15.44	33.99	11.66	11.91	4.85	3.81	6.60	9.55	9.65	7.40	150.39
1994	6.26	14.62	25.00	22.19	18.57	7.77	5.75	3.98	4.55	6.16	7.32	8.52	130.70
1995	18.92	4.21	15.30	9.59	10.24	5.45	4.92	3.98	3.40	6.55	12.48	6.70	101.75
1996	19.78	12.37	16.91	17.11	19.24	11.16	11.86	7.40	8.68	12.26	18.77	15.68	171.22
1997	23.30	24.65	22.41	26.53	14.86	9.38	5.93	4.13	3.59	6.09	9.03	5.05	154.96
Mean	**14.65**	**10.62**	**23.11**	**21.89**	**11.48**	**6.69**	**4.93**	**3.93**	**4.57**	**6.98**	**12.11**	**8.96**	**131.19**

Table 9 indicates that the approximate long-term monthly means of groundwater discharges/recharges at station 02ED017 range from 3.93 mm in August to 23.11 mm in March. The approximate long-term annual groundwater discharge/recharge at the station is 131.19 mm, which is 50.46% of the long-term mean annual streamflow. Figures 43 and 44 show the streamflow separation hydrograph and the flow duration graph for station 02ED017, respectively.

The monthly and annual groundwater discharges and their long-term means at streamflow gauging station 02ED011, located on Wye River at Wyebridge, are given in Table 10. Given that the streamflow records at this station are longer than 13 years, it is possible to assume with a great deal of confidence that the long-term monthly and annual means of groundwater discharges are equal to their respective means of groundwater recharges.

Table 10. Monthly and annual groundwater discharges and their long-term means for station 02ED011 on the Wye River (1973-1986).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1973	---	---	---	---	---	---	---	---	---	---	22.33	20.47	49.69
1974	15.72	15.92	35.43	37.84	26.18	11.28	13.27	8.64	8.48	10.93	14.70	11.14	209.54
1975	18.81	13.39	33.45	40.70	13.57	8.41	6.93	7.45	8.65	9.33	8.15	13.47	182.30
1976	8.11	12.37	50.74	15.80	9.43	7.00	8.80	7.92	11.29	12.00	18.17	12.15	173.77
1977	9.25	8.54	64.10	13.92	7.18	5.74	6.16	6.75	9.01	12.41	15.75	16.46	175.25
1978	14.25	9.35	12.46	43.15	12.60	7.86	5.85	5.85	6.09	9.79	9.58	8.54	145.38
1979	11.45	8.32	41.94	20.97	9.68	7.11	6.15	7.00	6.56	9.67	15.81	22.90	167.55
1980	9.81	6.68	29.81	26.54	10.47	16.13	20.82	10.35	9.94	17.27	16.71	23.95	198.48
1981	12.61	41.60	25.32	21.35	21.66	14.85	10.98	17.00	16.32	19.21	18.87	13.83	233.60
1982	13.37	10.77	23.98	55.09	17.40	14.53	9.97	9.14	6.20	5.81	13.74	31.93	211.93
1983	17.64	16.55	18.97	17.78	14.82	7.17	5.18	3.72	4.90	6.80	8.94	6.73	129.20
1984	5.68	23.07	24.40	13.94	8.02	5.22	4.80	4.02	6.06	5.12	8.49	18.91	127.73
1985	15.35	26.24	39.39	34.03	8.23	4.70	4.82	6.18	20.16	16.39	24.94	19.72	220.14
1986	16.23	11.03	39.73	20.20	11.72	9.29	9.85	9.43	29.50	29.62	12.05	11.56	210.23
Mean	**12.94**	**15.68**	**33.82**	**27.79**	**13.15**	**9.18**	**8.74**	**7.96**	**11.01**	**12.64**	**14.87**	**16.56**	**183.47**

Table 10 indicates that the long-term monthly means of groundwater discharges/recharges at station 02ED011 range from 7.96 mm in August to 33.82 mm in March. The long-term annual groundwater discharge/recharge at the station is 183.47 mm, which is 50.33% of the long-term mean annual streamflow. Figures 45 and 46 show the streamflow separation hydrograph and the flow duration graph for 02ED011 station, respectively.

The monthly and annual groundwater discharges and their long-term means at streamflow gauging station 02ED013, located on the Wye River at Wyevale, are given in Table 11. The length of the daily streamflow records (11 years) is long enough to assume with certainty that the long-term monthly and annual means of groundwater discharge are equal to their respective means of groundwater recharge.

Table 11. Monthly and annual groundwater discharges and their long-term means for station 02ED013 on the Wye River near Wyevale (1987-1997).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1987	16.73	13.05	44.03	32.34	7.60	7.17	5.35	4.17	3.75	5.90	10.62	16.04	166.75
1988	14.35	10.16	18.41	14.49	6.29	3.95	3.22	3.56	6.70	7.30	12.30	11.06	111.80
1989	13.99	9.49	35.40	17.33	13.74	12.44	4.03	3.57	4.16	4.95	12.48	13.57	145.17
1990	14.87	15.34	35.57	13.22	6.77	2.83	2.84	2.22	1.94	6.63	17.05	17.07	136.36
1991	12.67	12.30	28.11	29.29	5.36	3.13	4.71	2.73	2.74	6.71	7.11	14.30	129.15
1992	10.52	4.60	37.91	22.52	7.41	3.72	3.67	4.79	5.85	8.59	35.55	13.55	158.69
1993	29.23	4.12	14.60	32.96	4.72	7.12	2.95	2.46	4.25	8.98	7.02	5.38	123.79
1994	3.94	9.51	9.20	16.00	12.69	5.38	4.40	3.59	5.33	4.95	6.36	6.67	88.02
1995	24.85	8.26	15.68	12.53	8.57	4.92	3.80	2.96	2.31	7.46	20.74	8.00	120.09
1996	33.70	15.57	23.85	24.59	23.42	7.77	12.22	3.12	6.98	15.88	25.37	15.33	207.81
1997	24.52	27.20	34.61	21.72	17.44	6.97	6.26	4.35	2.18	3.93	8.51	5.22	162.90
Mean	**18.12**	**11.78**	**27.03**	**21.54**	**10.37**	**5.95**	**4.86**	**3.41**	**4.20**	**7.39**	**14.83**	**11.47**	**140.96**

Table 11 indicates that the approximate, long-term means of groundwater discharges at station 02ED013 range from 3.41 mm in August to 27.03 mm in March. The approximate long-term annual groundwater discharge/recharge at the station is 140.96 mm, which is 40.97% of the long-term mean annual streamflow discharge. Figures 47 and 48 show the streamflow separation hydrograph and the flow duration graph for the station, respectively.

The monthly and annual groundwater discharges and their long-term means at streamflow gauging station 02ED016, located on a tributary to the Wye River, are given in Table 12. The length of the daily streamflow records (about 6 years) is not long enough to assume with certainty that the long-term monthly and annual means of groundwater discharges are equal to their respective means of groundwater recharges. Rather, these means give approximate values of the long-term monthly and annual means of groundwater recharge.

Table 12. Monthly and annual groundwater discharges and their long-term means for station 02ED016 on a tributary to the Wye River below Elmvale (1988-1994).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1988	---	---	---	---	---	---	---	---	---	0.87	5.79	3.04	9.86
1989	11.49	5.98	50.22	13.94	12.69	11.33	---	---	---	---	12.30	7.58	126.87
1990	22.72	15.95	57.28	23.76	8.78	0.49	---	---	---	6.51	18.49	13.22	167.31
1991	6.53	14.58	37.42	29.85	4.01	---	1.45	---	---	2.96	5.10	14.75	117.18
1992	4.74	1.79	47.64	22.91	5.50	0.54	0.62	0.64	5.71	5.60	35.97	16.28	147.94
1993	19.62	4.58	13.79	35.64	3.48	10.11	---	---	---	7.93	4.60	5.38	106.69
1994	1.69	12.82	23.96	19.65	12.91	3.74	---	---	---	---	---	---	76.46
Mean	**11.13**	**9.28**	**38.39**	**24.29**	**7.90**	**5.24**	**1.04**	**0.64**	**5.71**	**4.77**	**13.71**	**10.04**	**147.94**

Table 12 indicates that the long-term means of groundwater discharges at station 02ED016 range from 0.64 mm in August to 38.39 mm in March. The long-term annual groundwater discharge is 147.94 mm, which is 45.72% of the long-term mean annual streamflow. Figures 49 and 50 show the streamflow separation hydrograph and the flow duration graph for the station, respectively.

The monthly and annual groundwater discharges and their long-term means at streamflow gauging station 02ED019, located on Copeland Creek, are given in Table 13. The length of the daily streamflow records (9 ½ years) is not long enough to assume with certainty that the long-term monthly and annual means of groundwater discharge are equal to their respective means of groundwater recharge. Rather, these means give approximate values of the long-term monthly and annual means of groundwater recharge.

Table 13. Monthly and annual groundwater discharges and their long-term means for station 02ED019 on Copeland Creek near Penetanguishene (1988-1997).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1988	---	---	---	---	---	---	2.76	2.72	2.92	5.24	6.30	4.67	27.22
1989	4.60	3.36	12.79	9.07	8.02	5.98	3.76	3.13	3.22	3.95	7.35	5.50	70.73
1990	7.47	6.40	18.86	9.76	6.79	4.07	4.02	3.29	3.48	4.79	8.61	7.50	85.05
1991	5.21	5.59	16.90	22.19	7.19	3.72	3.63	2.97	3.06	5.25	4.95	6.88	87.53
1992	5.59	3.90	12.74	17.61	5.67	3.72	4.07	5.61	5.89	4.74	16.11	6.75	92.41
1993	10.82	4.15	7.89	19.15	7.99	9.29	4.33	3.53	5.16	5.72	4.44	3.83	86.30
1994	4.41	6.01	7.55	10.01	8.40	5.21	6.65	3.93	3.91	4.64	5.22	5.43	71.37
1995	9.01	3.61	8.65	6.68	5.63	3.24	3.27	3.42	3.09	4.81	8.64	4.64	64.69
1996	8.69	5.98	6.98	14.07	14.30	5.79	5.33	4.14	5.35	5.81	7.66	7.73	91.82
1997	9.90	11.14	14.07	22.40	9.64	7.17	5.35	4.96	4.53	5.39	8.66	5.24	108.45
Mean	**7.30**	**5.57**	**11.83**	**14.55**	**8.18**	**5.36**	**4.32**	**3.77**	**4.06**	**5.03**	**7.80**	**5.82**	**84.26**

Table 13 indicates that the approximate long-term means of groundwater discharges at the 02ED019 station range from 3.77 mm in August, to 14.55 mm in April. The approximate long-term mean of annual groundwater discharge/recharge at the station is 84.26 mm, which is 49.14% of the long-term, mean annual streamflow. Figures 51 and 52 show the streamflow separation hydrograph and the flow duration graph for the station, respectively.

LONG-TERM ANNUAL WATER BUDGETS AND GROUNDWATER DISCHARGE AND RECHARGE ZONES

Table 14 gives the long-term mean annual water budgets for various watersheds within the study area. The water budgets are based on the long-term means of annual precipitation as measured at Coldwater Warminster and Midland WPCP meteorological stations as well as on the long-term means of streamflows as measured at the eight gauging stations within the study area. The water budgets for those stations with short streamflow records are the best available estimates at this time.

The above streamflow analyses indicate that large percentages of the streamflows originate from groundwater sources. In essence, the creeks, rivers, lakes and marshes are the major groundwater discharge zones within the study area. Only a small amount of groundwater discharges directly to Georgian Bay.

The streamflow analyses indicate that the gauging stations on the Coldwater and Sturgeon Rivers have the highest values for the long-term means of annual groundwater discharges/recharges. This most likely reflects the presence of the Bass Lake kame moraine and other sands and gravel deposits of glaciofluvial and glacio-lacustrine origin within the drainage areas of these two stations. The gauging station on Copeland Creek has the lowest long-term mean of annual groundwater discharge/recharge which indicates the presence of low permeable deposits within its drainage area (Figure 53).

Figures 26 and 27 show the surficial distributions of sands and gravels of glaciofluvial and glaciolacustrine origin within the study area. As indicated earlier, groundwater recharge can occur anywhere within a watershed. From a practical point of view, however, the most important groundwater recharge areas are those where the high permeable materials are at the surface. In the case of our study area, the sands and gravels of glaciofluvial and glaciolacustrine origin constitute the zones of high groundwater recharge. Given the composition, thickness and large surficial distribution of the Bass Lake kame moraine, it is possible to conclude that it constitutes the main recharge zone within the study area.

The question that is often asked is: "where does the groundwater in an aquifer overlain by low permeable material come from?". The answer is that some of the groundwater may have passed through the low permeable material above or below as most geologic deposits in nature have some permeability to allow water to pass through them. Most of the groundwater in such an aquifer, however, is fed from high permeable materials on the sides of the aquifer, which had access to high groundwater recharge.

The groundwater regime is a system that is controlled by a potential field and is continually on the move due to differential pressure distribution within the field. When groundwater moves it encounters materials of variable permeability. As in the case of electricity, groundwater seeks higher permeable materials to pass through and in the process creates confined conditions.

A water well that passes low permeable materials before it reaches an aquifer will often display confined characteristics and, under certain conditions, the well will be a flowing well. Many flowing wells have been identified within the study area (MOE, 1981). Such wells are indicative of the presence of confining layers of low permeability such as clays, silts and tills in their geologic logs.

Table 14. Long-term annual water budget for various watersheds within the study area.

Gauging Station 02ED024 (North River)
(Precipitation data for Coldwater Warminster Meteorological Station)

Drainage Area (km^2)	249.00
Mean Annual Precipitation (mm)	1060.53
Mean Annual Evapotranspiration (mm)	666.17
Mean Annual Runoff (mm)	394.36
Mean Annual Groundwater discharge/recharge(mm)	174.00

Gauging Station 02ED007 (Coldwater River)
(Precipitation data for Coldwater Warminster Meteorological Station)

Drainage Area (km^2)	177.00
Mean Annual Precipitation (mm)	1060.53
Mean Annual Evapotranspiration (mm)	651.17
Mean Annual Runoff (mm)	408.80
Mean Annual Groundwater Discharge/Recharge (mm)	260.91

Gauging Station 02ED018 (Sturgeon River)
(Precipitation data for Coldwater Warminster Meteorological Station)

Drainage Area (km^2)	103.00
Mean Annual Precipitation (mm)	1060.53
Mean Annual Evapotranspiration (mm)	662.55
Mean Annual Runoff (mm)	397.45
Mean Annual Groundwater Discharge/Recharge (mm)	230.29

Gauging station 02ED017 (Hog Creek)
(Precipitation data for Midland WPCP Meteorological Station)

Drainage Area (km^2)	65.19
Mean Annual Precipitation (mm)	1150.25
Mean Annual Evapotranspiration (mm)	895.95
Mean Annual Runoff (mm)	254.30
Mean Annual Groundwater Discharge/Recharge (mm)	131.19

Table 14 (cont'd)

Gauging Station 02ED016 (Tributary to Wye River)
(Precipitation data for Midland WPCP Meteorological Station)

Drainage Area (km^2)	15.30
Mean Annual Precipitation (mm)	1150.25
Mean Annual Evapotranspiration (mm)	820.25
Mean Annual Runoff (mm)	300.00
Mean Annual Groundwater Discharge/Recharge (mm)	147.94

Gauging Stations 02ED013 (Wye River at Wyevale)
(Precipitation data for Midland WPCP Meteorological Station)

Drainage Area (km^2)	118.00
Mean Annual Precipitation (mm)	1150.25
Mean Annual Evapotranspiration (mm)	821.08
Mean Annual Runoff (mm)	329.17
Mean Annual Groundwater Discharge/Recharge (mm)	140.96

Gauging stations 02ED011 (Wye River at Wyebridge)
(Precipitation data for Midland WPCP Meteorological Station)

Drainage Area (km^2)	168.00
Mean Annual Precipitation (mm)	1150.25
Mean Annual Evapotranspiration (mm)	786.64
Mean Annual Runoff (mm)	363.61
Mean Annual Groundwater Discharge/Recharge (mm)	183.47

Gauging Station 02ED019 (Copeland Creek)
(Precipitation data for Midland WPCP Meteorological Station)

Drainage Area (km^2)	26.89
Mean Annual Precipitation (mm)	1150.25
Mean Annual Evapotranspiration (mm)	983.78
Mean Annual Runoff (mm)	166.47
Mean Annual Groundwater Discharge/Recharge (mm)	84.26

HYDROCHEMISTRY

GENERAL INFORMATION

The suitability of the groundwater for use by agriculture, commerce, industry or for drinking purposes can be assessed by a study of its chemistry. The Provincial Drinking Water Objectives (PDWO) specify the limits for a number of common chemical parameters that ideally should not be exceeded. Some PDWO objectives are aesthetic, while others are health related.

The following are the PDWO objectives for a number of parameters that are routinely found in natural groundwater:

sodium (aesthetic objective)	200 mg/l
iron	0.3 mg/l
chloride	250 mg/l
sulphate	500 mg/l
nitrate as nitrogen	10 mg/l
total dissolved solids	500 mg/l

Although there is no recommended objective for hardness, the following classification scheme is widely used:

Hardness Range mg/l of CaCO3	Type of Water
10 - 60	soft
61 - 120	moderately hard
121 - 180	hard
> 180	very hard

Natural groundwaters have often superior water quality, which makes them highly attractive as sources of drinking water supplies. Unfortunately, certain natural groundwaters do not meet always all the limits set under the PDWO objectives. Some natural groundwaters have high levels of total dissolved solids, hardness, sulphate, hydrogen sulphide or iron. Home treatment devices are available to treat these problems.

Natural groundwaters usually have very low levels of nitrate and are free from bacteria. The detection of high levels of nitrate or any amounts of faecal or total coliform bacteria in a water sample collected from a water well is an indication that the well has been contaminated. Most water well contamination is the result of poor location, inferior construction methods or inadequate maintenance.

The well record includes information related to the kind of groundwater that was encountered in the well in terms of being fresh, salty, sulphurous, or containing iron or gas. This information is submitted to MOE by the well driller as part of the well record. Usually, the driller examines visually a water sample taken from the well for clarity. The driller then smells and tastes the water, and enters his/her observations into the well record.

The information provided by the well driller is very useful especially when the water from the well tastes salty or smells like a rotten egg, indicating the presence of sodium chloride or hydrogen sulphide in the water. This information, however, is subjective and is inadequate for determining the suitability of groundwater for drinking purposes.

Throughout the years, water quality analyses were carried out on many municipal and private wells within the study area. A concerted effort was made during this study to assemble all the available chemical data for further evaluation. In addition a groundwater quality sampling program was conducted as part of this study to augment the historical water quality data.

In order to assess the quality of groundwater within various bedrock and overburden units and determine the types of groundwater in these units, a computer program called: "DUROV Water Quality Analyzer" was used. Water quality data in mg/L are converted by the program into equivalents per million (EPM) and percent EPM values.

The EPM values are used in the DUROV program to calculate the ion balance and determine the percent ion balance. The percent EPM values, on the other hand, are used in the program to determine the dominant ions in each sample and generate a water type table. The percent EPM values can then be plotted on a trilinear diagram to show the dominant cations and anions for all the samples.

GROUNDWATER QUALITY IN THE BEDROCK

General information related to the quality of water encountered in the bedrock is available for 940 wells. The MOE records indicate that the majority of these bedrock wells yield fresh water. A number of wells, however, are reported to have some natural water quality problems. Figure 54 shows the locations of bedrock wells that have been reported to yield fresh, salty, sulphurous or mineral water. The figure indicates that the majority of bedrock wells with natural water quality problems are located in areas where the Precambrian and Paleozoic rocks are at or near the surface.

Figure 55 shows the locations of wells within the study area that were sampled for water quality analyses. The figure indicates that 29 wells completed in Precambrian rocks and 26 wells completed in Paleozoic rocks have been sampled.

Table 15 gives a summary of major ion concentrations for the water samples collected from wells completed in Precambrian rocks. The well geographic coordinates, the identification numbers of the samples, and the results of chemical analyses are given in Appendix IV.

Table 15. A summary of major ion concentrations in water quality samples collected from wells completed in Precambrian rocks.

(All concentrations are in mg/L)

	Sodium (Na)	Sulphate (SO4)	Chloride (Cl)	Nitrate (NO3 as N)	Iron (Fe)	Total Dissolved Solids	Hardness
Number of samples	29	29	29	29	29	27	29
Minimum concentration	4	9	1.60	0.03	0.01	261	31
Average concentration	110	149	132	0.85	0.45	743	267
Maximum concentration	450	600	1500	7.55	6.90	4040	1220
% exceeding PDWO	17	7	10	0	28	41	-

Table 15 indicates that the water quality of samples collected from wells completed in Precambrian rocks is generally good. The mean concentration of total dissolved solids for the samples is 743 mg/L, and the water hardness ranges from moderately hard to very hard. Further, 41% of the water samples exceed the PDWO objectives in terms of total dissolved solids, 28% in terms of iron, 17% in terms of sodium, 10% in terms of chloride, and 7% in terms of sulphate. The sodium and chloride exceedances are most likely connected to salt spreading on roads during the winter.

Table 16 gives a summary of major ion concentrations for the water samples collected from wells completed in Palaeozoic rocks. The table indicates that the general water quality of the samples is good. The mean concentration of total dissolved solids is 557 mg/L, and the water hardness ranges from soft to very hard. The table also indicates that 32% of the samples exceeded the PDWO objectives in terms of total dissolved solids, 17% in terms of iron, 13% in terms of sulphate, and 4% in terms of chloride.

Table 16. A summary of major ion concentrations in water quality samples collected from wells completed in Palaeozoic rocks.

(All concentrations are in mg/L)

	Sodium (Na)	Sulphate (SO4)	Chloride (Cl)	Nitrate (NO3 as N)	Iron (Fe)	Total Dissolved Solids	Hardness
Number of samples	22	23	23	23	23	22	23
Minimum concentration	3.40	7.75	0.50	0.05	0.01	144	45
Average concentration	42	175	53	0.23	0.43	557	327
Maximum concentration	187	1870	394	2.30	3.90	3890	2050
% exceeding PDWO	0	13	4	0	17	32	-

Table 17 shows the percentages of samples exceeding the PDWO objectives in wells of various hydrogeologic units.

Table 17. Percentage of samples exceeding the PDWO in wells of various hydrogeologic units

	Sodium (Na) >200 mg/L	**Sulphate (SO4)** >500 mg/L	**Chloride (Cl)** >250 mg/L	**Iron (Fe)** >0.3 mg/L	**Total Dissolved Solids** >500 mg/L
Precambrian bedrock	17	7	10	28	41
Palaeozoic bedrock	0	13	4	17	32
Shallow overburden	0	0	3	18	11
Deep overburden	0	0	0	12	0

Table 18 provides a comparison among the various bedrock and overburden wells in terms of minimum, maximum and mean levels of hardness.

Table 18. Minimum, mean and maximum levels of hardness of various hydrogeologic units (mg/L)

	Minimum	**Mean**	**Maximum**
Precambrian bedrock	31	267	1220
Palaeozoic bedrock	46	328	2050
Shallow overburden	76	240	456
Deep overburden	22	173	335

Bedrock Groundwater Types

DUROV water type analysis was conducted on 29 samples collected from wells completed in Precambrian rocks (Table 19). The results of the analysis indicate that 8 samples are of calcium-bicarbonate type, 6 are of bicarbonate type, 5 are of sodium-potassium-sulphate-nitrate type, and 3 samples are of calcium type (Figure 56).

Table 19. Bedrock water types generated by the DUROV program

(Wells completed in Precambrian rocks)
(NOTE: X indicates no dominant water type)

Well Number	Dominant Cations	Dominant Anions
20041	Ca	HCO3
27088	X	HCO3
25817	X	HCO3
23911	Ca	HCO3
28202	Na+K	HCO3
21814	X	HCO3
29907	Ca	HCO3
95001	Ca	X
25508	Ca	HCO3
21079	X	HCO3
22681	X	Cl
25823	Ca	X
17207	Ca	HCO3
23411	Na+K	SO4+NO3
29633	Na+K	X
7041	Na+K	Cl
20380	X	X
10083	Na+K	SO4+NO3
4017	Ca	HCO3
4018	Ca	HCO3
24393	Na+K	SO4+NO3
21544	Ca	HCO3
8153	Na+K	HCO3
21544	Na+K	X
28496	X	HCO3
9716	X	HCO3
9953	Ca	X
30356	Na+K	SO4+NO3
27456	Na+K	SO4+NO3

Dominant Water Type		Number of Samples	Percentage
Ca	HCO3	8	28
X	HCO3	6	21
Na+K	SO4+NO3	5	17
Ca	X	3	10
Na+K	HCO3	2	7
Na+K	X	2	7
Na+K	Cl	1	3
Cl	X	1	3
X	X	1	3

Table 19 (cont'd)

(Wells completed in Palaeozoic bedrock)

Well Number	Dominant Cations	Dominant Anions
9263	Na+K	HCO3
25899	X	SO4+NO3
27213	X	HCO3
26763	X	HCO3
25970	X	HCO3
20360	Na+K	HCO3
27693	Ca	HCO3
21662	X	HCO3
27093	Ca	HCO3
23653	Ca	HCO3
22243	X	HCO3
29439	X	HCO3
26389	X	HCO3
22983	Ca	HCO3
23516	X	X
30757	Ca	HCO3
6956	Ca	HCO3
8294	Ca	HCO3
8480	X	HCO3
14028	Na+K	HCO3
29976	X	SO4+NO3
7380	X	HCO3

Dominant Water Type		Number of Samples	Percentage
X	HCO3	9	41
Ca	HCO3	7	32
Na+K	HCO3	3	14
X	SO4+NO3	2	9
X	X	1	4

Table 19 also gives the results of the DUROV water type analysis conducted on 22 samples collected from wells completed in Palaeozoic rocks. The table indicates that nine samples are of bicarbonate type, seven are of calcium-bicarbonate type, and three samples are of sodium-potassium-bicarbonate type (Figure 57).

GROUNDWATER QUALITY IN THE OVERBURDEN

General information related to the quality of groundwater in the overburden is available for 1,812 water wells. Approximately 99.3% of these wells have been reported to yield fresh water, and the remaining 0.7% yield sulphurous, salty or mineral water or water containing gas. In comparison, only 95.0% of bedrock wells have been reported to yield fresh water (Figure 58).

The results of 144 chemical analyses for samples collected from water wells completed in the overburden are available (see Figure 55). The locations of the sampled wells, the identification numbers of the water samples, the results of chemical analyses, and water quality trends in groundwater are given in Appendix V.

Unfortunately, it is not possible to ascribe the quality of a water sample collected from a well completed in an area where a given overburden deposit outcrops at surface to that particular deposit. This is because the well may penetrate a number of various overburden deposits and it is not possible to determine which deposit is contributing most to the water quality of the sample.

The situation, on the other hand, is different in the case of bedrock wells. Logic dictates that the drilling process of a well would not have proceeded into the bedrock unless that was absolutely necessary, either because of lack of water within the overlying overburden deposits or because the amount of water found was inadequate. Although one has to allow for the possibility of some water mixing, the quality of water in a bedrock well represents, by and large, the quality of groundwater within the bedrock hydrogeologic unit, which the well taps.

Faced with these difficulties, the water quality data for overburden wells were divided into two groups. One group consisting of 37 chemical analyses represents shallow wells that are less than 20 m in depth. The second group consisting of 89 chemical analyses represents the water quality of wells that are more than 20 m in depth. The description of groundwater quality of these two groups will be given in terms of parameters and water type rather than in terms of specific overburden units. The parameters that will be considered are: total dissolved solids, hardness, chloride, sulphate, nitrate, sodium and iron.

Total Dissolved Solids

A summary of major ion concentrations in water quality samples collected from wells completed in the overburden is given in Table 20. The table indicates the concentrations of total dissolved solids ranged from 36 to 889 mg/L for the shallow wells and from 92 to 470 mg/L for the deep wells. The table also indicates that about 11% of the samples collected from the shallow wells exceeded the PDWO. All the samples collected from the deep wells, on the other hand, were within the objective.

Table 20. A summary of major ion concentrations in water quality samples collected from overburden wells.

(Water found at depth of less than 20 m)

(All concentrations are in mg/L)

	Sodium (Na)	Sulphate (SO4)	Chloride (Cl)	Nitrate (NO3 as N)	Iron (Fe)	Total Dissolved Solids	Hardness
Number of samples	38	39	39	38	39	36	39
Minimum concentration	1.00	7.41	0.30	0.05	0.01	110	76
Average concentration	8.36	22	18	4.50	0.29	339	240
Maximum concentration	116	59	285	58	4.80	898	458
% exceeding PDWO	0	0	3	11	18	11	-

(Water found at depth of more than 20 m)

	Sodium (Na)	Sulphate (SO4)	Chloride (Cl)	Nitrate (NO3 as N)	Iron (Fe)	Total Dissolved Solids	Hardness
Number of samples	90	96	97	96	97	92	97
Minimum concentration	1.00	0.50	0.40	0.05	0.01	137	22
Average concentration	10.10	16	8.37	0.92	0.14	242	137
Maximum concentration	49	37	85	6.05	1.00	470	335
% exceeding PDWO	0	0	0	12	18	0	-

Hardness

Water hardness ranged from 76 to 458 mg/L for samples collected from the shallow wells and from 22 to 335 mg/L for samples collected from the deep wells. The water in all the samples range from moderately hard to very hard.

Chloride

The concentrations of chloride ranged from 0.30 to 285 mg/L for the shallow wells and from 0.40 to 85 for the deep wells. About 3% of the shallow wells had concentrations of chloride above the PDWO; all the concentrations for the deep wells were within the PDWO.

Sulphate

The concentrations of sulphate ranged from 7.41 to 59 mg/L for the shallow wells and from 0.50 to 37 mg/L for the deep wells. All the sulphate concentrations for both the shallow and deep wells were within the PDWO.

Nitrate

The concentrations of nitrate for the shallow wells ranged from 0.05 to 58 mg/L for the shallow wells and from 0.05 to 6.05 mg/L for the deep wells. About 11% of the samples collected from the shallow wells exceeded the PDWO. All the samples collected from the deep wells were within the PDWO.

Sodium

The concentrations of sodium ranged from 1.00 to 116 mg/L for the shallow wells and from 1.00 to 49 mg/L for the deep wells. All the chloride concentrations for both the shallow and deep wells were within the PDWO.

Iron

The concentrations of iron ranged from 0.01 to 4.80 mg/L for the shallow wells and from 0.01 to 1.00 mg/L for the deep wells. About 18% of the samples collected from the shallow wells and 12% of the samples collected from the deep wells exceeded the PDWO.

Based on the above findings, it is possible to conclude that the water quality within the shallow overburden deposits in the study area is worse than that within the deeper deposits. The exceedances of the PDWO for nitrate and chloride are believed to be the result of human activities.

Overburden Groundwater Types

Durov water type analyses were performed on samples of the two overburden groups (Table 21). The results of the analyses indicate that 30 samples (81%), obtained from the shallow wells, are of calcium-bicarbonate type, two samples (5%) are of bicarbonate type, and two (5%) are of magnesium-bicarbonate type. The results of the analyses also indicate that 68 samples (76%), obtained from deep overburden wells, are of calcium-bicarbonate type, 12 samples (13%) are of bicarbonate type, and nine samples (10%) are of sodium-potassium-bicarbonate type (Figure 59 and 60).

Table 21. Overburden water types generated by the DUROV program.

(Water found at depth of less than 20 m)
(NOTE: X indicates no dominant water type)

Well Number	Dominant Cations	Dominant Anions
20986	Ca	HCO3
22326	Ca	HCO3
30398	Ca	HCO3
768	Ca	HCO3
776	Ca	HCO3
828	Mg	HCO3
15723	Ca	HCO3
26427	X	Cl
20104	Ca	HCO3
29978	Ca	HCO3
8025	Ca	HCO3
95002	Ca	HCO3
95003	Ca	HCO3
27499	Ca	HCO3
12992	Ca	HCO3
95004	Ca	HCO3
95005	Ca	HCO3
95006	Ca	HCO3
95007	Ca	HCO3
95008	Ca	HCO3
28360	Ca	HCO3
20365	Ca	HCO3
95009	Ca	HCO3
95010	Ca	HCO3
3914	Ca	HCO3
29975	Mg	HCO3
20183	Ca	HCO3
95011	Ca	HCO3
23973	X	HCO3
4023	Ca	HCO3
13833	Ca	HCO3
27828	X	HCO3
29406	Ca	HCO3
95012	Ca	X
27965	Ca	HCO3
95013	Ca	SO4+NO3
95014	Ca	HCO3

(Water Type Summary for Shallow Overburden Wells)

Dominant Water Type		Number of Samples	Percentage
Ca	HCO3	30	81
X	HCO3	2	5
Mg	HCO3	2	5
Ca	X	1	3
X	Cl	1	3
Ca	SO4+NO3	1	3

Table 21 (cont'd)

(Water found at depth of more than 20 m)

Well Number	Dominant Cations	Dominant Anions
21516	Ca	HCO3
95029	Ca	HCO3
19428	Ca	HCO3
23347	Ca	HCO3
27128	Ca	HCO3
22215	X	HCO3
95030	Ca	HCO3
95031	Ca	HCO3
95032	Ca	HCO3
28238	Ca	HCO3
21615	X	HCO3
95033	Ca	HCO3
95034	Ca	HCO3
95035	Ca	HCO3
20247	Ca	HCO3
15819	Ca	HCO3
22529	Ca	HCO3
9004	Ca	HCO3
27044	Ca	HCO3
12838	Ca	HCO3
8742	Ca	HCO3
23971	Ca	HCO3
95036	Ca	HCO3
15982	Ca	HCO3
25074	Na+K	HCO3
9946	Ca	HCO3
19700	Ca	HCO3
3978	Ca	HCO3
15758	Ca	HCO3
10360	Ca	HCO3
15922	Ca	HCO3
14602	Ca	HCO3
25486	Ca	HCO3
27964	Ca	HCO3
16157	Ca	HCO3
29403	Na+K	HCO3
24580	X	HCO3
4331	X	HCO3
29196	X	HCO3
9709	X	HCO3
22544	Ca	HCO3
10857	Ca	HCO3
25488	Ca	HCO3
30617	Ca	HCO3
29981	Ca	HCO3
850	Ca	HCO3
9930	Ca	HCO3
26976	Ca	HCO3

Table 21 (cont'd)

Well Number	Dominant Cations	Dominant Anions
25652	Ca	HCO3
95015	Ca	HCO3
6992	Ca	HCO3
754	Ca	HCO3
95016	Ca	HCO3
10335	Ca	HCO3
25623	Ca	HCO3
14375	NA+K	HCO3
778	X	HCO3
30001	Na+K	HCO3
24249	Na+K	HCO3
26254	X	HCO3
24061	Na+K	HCO3
831	Na+K	HCO3
21784	Na+K	HCO3
841	X	HCO3
27822	Ca	HCO3
6384	Ca	HCO3
25985	Ca	HCO3
19978	Ca	HCO3
1075	Ca	HCO3
24285	Ca	HCO3
22365	Ca	HCO3
29380	X	HCO3
23920	X	HCO3
25195	Ca	HCO3
23325	X	HCO3
30445	Ca	HCO3
95017	Ca	HCO3
95018	Ca	HCO3
95019	Ca	HCO3
95020	Ca	HCO3
95021	Ca	HCO3
95022	Ca	HCO3
95023	Ca	HCO3
95024	Ca	HCO3
95025	Ca	HCO3
95026	Ca	HCO3
95027	Ca	HCO3
95028	Ca	HCO3

(Water Type Summary for Deep Overburden Wells)

Dominant Water Type		Number of Samples	Percentage
Ca	HCO3	68	76
X	HCO3	12	13
Na+K	HCO3	9	10

Records of chemical analyses over extended periods of time were collected for three municipal wells (PW6, PW7, and PW15) in Midland and one municipal well (PW1) in Penetanguishene. Water quality trend analyses were performed to assess the changes in water quality in these municipal wells over time. Six water quality parameters were considered for the trend analyses. These parameters are: conductivity, hardness, nitrate, chloride, and sodium. Data are not adequate to plot a pH trend. Plots of water quality trends are given in Appendix V. An examination of these plots indicates noticeable increases in the sodium and chloride concentrations over time in all the municipal wells. This is most likely due to contamination from the continued spreading of salt on roads during winter periods. Nitrate concentrations also increased in municipal wells PW6 and PW15. This increase is most likely due to surface pollution in the vicinity of these two wells.

SURFACE WATER QUALITY

The surface water flowing to Severn Sound includes a drainage basin of approximately 7,000 Km2. The Severn River (basin area approximately 5850 Km2), a highly regulated river, discharges into the Sound at Port Severn. Six main, largely unregulated tributary streams drain northward from the immediate watershed south of the Sound (Figure 61). Smaller tributaries and drainage courses drain coastal areas and the north shore.

Two Provincial Water Quality Monitoring Network (PWQMN) stations located within the study area were selected for analysis because of sufficient length of record and lack of lake level effect. Seven tributary mouth stations and four upstream stations have been sampled using a flow-weighted strategy (at least 40 samples each year) through the Severn Sound RAP Office in order to characterize nutrient and basic chemistry and to calculate nutrient loadings following remedial action. The locations of these stations are shown on Figure 61 and the periods of record for each station are shown in Table 22.

To describe the long-term trends in basic surface water quality in the study area, the water quality data for selected parameters at the PWQMN stations were examined using the method of Bodo (1991). Where possible, the RAP station data was used to supplement and extend the record for the analysis. The method first screens the data for outliers and estimates median values for selected parameters. The statistical significance of changes in each parameter through time are then tested using the Spearman test as well as the seasonality of each parameter. Four parameters (water temperature and concentrations of chloride, total nitrate, and total phosphorus) were examined using the available records at all the stations in the study area.

Table 22 Location and period of record of tributary water quality monitoring stations in the Severn Sound Watershed

Stream	Stn	Location	Easting(1)	Northing	Period of Record
Copeland Cr	201	County Rd.60 near Penetang	582,388	4,956,785	1989-present
Wye R	41	Hwy 27 at Hub Motel	590,462	4,936,387	1993-present
	P70-02	County Rd. 6	586,847	4,942,096	1973-1995
	203	Dawson Side Rd. Near Wyevale	586,930	4,944,419	1989-present
	208	at outlet weir of Wye Marsh	591,320	4,953,623	1989-present
Hog Ck	44	County Rd.23 near County Rd.58	596,303	4,945,498	1993-present
	43	County Rd.58	595,727	4,949,699	1993-present
	204	Granny Whites Side Rd	596,691	4,953,016	1989-present
Sturgeon R	205	Tay Twp Reeves Rd	600,603	4,953,531	1989-present
Coldwater R	45	Oro-Medonte Twp Line 9	608,265	4,944,251	1993-present
	206	at PetroCan, Coldwater	607,434	4,951,105	1989-present
	P76-01	at old CNR bridge	607,352	4,951,490	1973-1995
North R	207	at Laughlan Falls	612,485	4,957,896	1989-present

(1) UTM coordinates are for zone 17 in NAD27

The Severn River flow and quality is largely influenced by surface runoff and was not considered in the analysis of groundwater in the immediate Severn Sound watershed. In order to separate the effect of ground water from surface water on tributary quality, the daily flows for streams in the immediate watershed of Severn Sound were divided into two parts: 1. The base flow or low flow period which occurs over most of the year; and 2. The high flow period which may occupy only a small proportion of the year (see Figure 62). Quality during base flow periods may be influenced by ground water input (usually a diluting or dampening effect) or point sources such as sewage plant discharges and farmstead discharges (usually a polluting effect). Quality during base flow periods is not related to increasing flow. Quality during high flow periods can be influenced by erosional sources of pollutants associated with runoff during spring freshet or storm events if the parameter is associated with sediment. In the analysis of the data for the Severn Sound RAP stations we have examined the base flow quality for the influence of ground water and for trends through time.

Water Temperature

Physical conditions such as the degree of shading over a particular reach, stream depth, velocity, and volume can influence in-stream water temperatures. Ground water discharge to surface water has a cooling and moderating effect on water temperature. The combined effect of groundwater discharge and physical conditions at a stream station is reflected in the maximum temperature and the maximum range of daily fluctuation in temperature. Table 23 shows these indicators for streams in Severn Sound. The lowest maximum temperature was found in the Coldwater River (20.9 NC at station 45), an area of known groundwater discharge and dense forest cover.

The Coldwater River remained cool downstream to the Community of Coldwater (22.8 0C at station 206). The headwater area of the North River, Silver Creek, also had a cool maximum temperature (22.9 NC) but the station downstream on the North River, reflecting an open, relatively flat area, had a high maximum temperature (28.1 NC). Sturgeon River had a moderately low maximum temperature (24.8 NC). Hog Creek had similar, moderate maximum temperatures from the headwater area to the mouth (26.0-26.8 NC).

Table 23 Stream temperature (NC) summary
(July 21-Aug 9, 1999)

Stream	Station	Maximum Instantaneous Temperature	Maximum Daily Range
Wye R	41	26.8	7.6
	203	28.2	4.4
Hog Ck	44	26.5	6.0
	43	26.0	6.1
	204	26.8	4.5
Sturgeon R	205	24.8	3.9
Coldwater R	45	20.9	4.6
	206	22.8	2.8
North R - Silver Ck		22.9	3.9
North R	207	28.1	3.6

At PWQMN Station 030076001 on the Coldwater River at Coldwater (near Station 206) the median temperature has not changed significantly through the period of record (1973-1995 , Figure 63A) indicating that no warming trend in the River is evident. The median temperatures ranged from 0.0 to 24.0 NC. The long term seasonal median temperature rises to a peak of 17.4 NC in mid summer and falls off to 0.0 again in late fall (Figure 63B).

Chloride

Generally, surface waters with concentrations of more than 20 mg/L reflect the effects of human activities. Sources of chloride in surface waters include road salt from major transportation corridors and urban roads as well as direct contributions from sewage treatment plants and other waste discharges. Median base flow chloride concentrations at the monitored sites range from a low of 3.6 mg/L in Copeland Creek to 22.1 mg/L in the North River. The chlorides concentrations were lower in upstream stations with the exception of the Wye River. The upper Wye River is an area of intensive agricultural use.

A significant increasing trend in annual median chlorides concentration was found at the Coldwater station 76-01 (Figure 64A). Median values in the mid 70's ranged between 5 and 7 mg/L with a sharp increase starting in 1985 up to 17 mg/L in 1994. The Highway 400 corridor follows the Coldwater River closely from the headwaters to the Coldwater station. According to Ministry of Transportation records Highway 400 was twinned from 1984 to 1985 through the Coldwater River watershed. With the exception of Highway 400, the use of road salt has apparently not increased during the late 80's and early 90's according to area municipalities. The seasonal concentration has a minimum during the summer with high values during the winter and late fall. A similar but less dramatic increasing long-term trend was found in the Wye River (Station P70-02, Figure 64B).

Across the Severn Sound watershed, chloride values reflected the influence of groundwater inputs, highway corridors or significant discharges on the base flow quality (Table 24). Copeland Creek and Sturgeon River had the lowest concentrations reflecting the relatively high proportion of forest cover, lack of major roads and, especially in the case of the Sturgeon River, the influence of groundwater discharge/recharge. Base flow quality in the Wye River was influenced by the Elmvale sewage treatment plant discharge and agricultural operations in the watershed. The North River, with the highest chlorides concentrations, appears to be influenced more directly by the agricultural activities.

Table 24 Median base flow chlorides concentration (mg/L) of Severn Sound streams for the period 1989-1997

Stn	201 Copeland Ck	41 Wye River	203 Wye River	44 Hog Ck	43 Hog Ck	204 Hog Ck	205 Sturgeon River	45 Coldwater River	206 Coldwater River	207 North River
1989	3.6		13.6			5.8	5.4		14.3	16.3
1990	4.5		18.5			6.4	6.0		15.7	16.3
1991	4.8		16.8			6.4	6.0		16.5	17.4
1992	5.4		16.4			7.2	6.4		18.9	15.8
1993	6.8	14.1	18.2	3.8	9.2	7.2	7.0	10.9	15.2	
1994	5.9	14.6	17.6	4.5	13.6	7.9	6.7	10.7	16.9	17.3
1995	6.1	13.6	15.8	4.5	12.8	7.8	6.0	10.4	14.0	22.1
1996	6.6	13.4	16.0	5.0	12.4	7.2	6.4	10.6	13.8	15.4
1997	6.8	15.6	16.2	4.6	10.0	7.2	8.0	10.8	14.6	15.2

Total Nitrate

In natural, pristine environments, total nitrate levels in surface waters are generally less than 0.50 mg/L. Concentrations greater than 0.50 mg/L are generally indicative of the impacts of human activities on surface waters. Typical sources of nitrate include nitrogen-based fertilizers, runoff from manure storage facilities, and discharges from sewage treatment plants.

In the Severn Sound watershed, nitrate concentration in base flow stations was less than 0.60 mg/L (base flow annual median values ranged between with the exception of the Wye River downstream of the Elmvale sewage treatment plant. At station 203 annual median values fluctuated between 0.68 and 1.39 mg/L with no apparent trend (Table 25). There was no significant trend in nitrates at the two long-term stations.

Table 25 Median base flow nitrates concentration (mg/L) of Severn Sound streams for the period 1989-1997

Stn	201 Copeland Ck	41 Wye River	203 Wye River	44 Hog Ck	43 Hog Ck	204 Hog Ck	205 Sturgeon River	45 Coldwater River	206 Coldwater River	207 North River
1989	0.180		0.680			0.263	0.425		0.510	0.290
1990	0.210		1.155			0.265	0.423		0.498	0.403
1991	0.240		0.905			0.280	0.475		0.540	0.355
1992	0.295		0.740			0.255	0.500		0.555	0.340
1993	0.400	0.580	0.905	0.088	0.073	0.230	0.460	0.540	0.468	
1994	0.310	0.633	0.940	0.135	0.180	0.240	0.510	0.580	0.480	0.240
1995	0.345	0.665	0.895	0.058	0.120	0.255	0.510	0.555	0.465	0.220
1996	0.395	0.705	1.390	0.088	0.105	0.260	0.465	0.510	0.460	0.278
1997	0.385	0.758	1.070	0.133	0.150	0.215	0.505	0.590	0.523	0.235

Total Phosphorus

Ground water concentrations of total phosphorus are typically very low (<0.010 mg/L). Elevated or fluctuating concentrations in streams are generally due to surface point or non-point sources. Ground water discharge/recharge to streams will influence the quality during periods of low flow by diluting total phosphorus concentrations. Point sources include discharges from sewage treatment plants (in the case of Elmvale STP on the Wye River) and from agricultural operations (milkhouse wash water and manure stack and barn yard discharges from the farmstead). Non-point sources include erosion and runoff from fields, banks and ditches in rural areas, contributions from faulty septic systems, unrestricted livestock access to streams and storm water runoff.

The base flow median total phosphorus concentrations in the six tributaries are summarized in Table 26. Year to year trends in the median concentrations indicate a decreasing trend in concentration of total phosphorus in the Wye River. This is likely in response to the new Elmvale Sewage Treatment Plant which came into service in 1994. Generally, the total phosphorus objective of 30 ug/L is met during the low flow period for most of the streams with the exception of Wye River and Hog Creek (Figure 65A & B). These two streams have the highest proportion of agricultural land. The Wye River at station 203 is also influenced by Elmvale sewage treatment plant and urban storm water.

Table 26 Median base flow total phosphorus concentration (mg/L) of Severn Sound streams for the period 1989-1997

Stn	201 Copeland Ck	41 Wye River	203 Wye River	44 Hog Ck	43 Hog Ck	204 Hog Ck	205 Sturgeon River	45 Coldwater River	206 Coldwater River	207 North River
1989	0.011		0.103			0.025	0.012		0.013	0.020
1990	0.022		0.075			0.023	0.012		0.013	0.021
1991	0.011		0.067			0.021	0.012		0.015	0.019
1992	0.014		0.093			0.025	0.014		0.018	0.022
1993	0.007	0.022	0.080	0.048	0.037	0.030	0.010	0.016	0.016	
1994	0.010	0.018	0.070	0.034	0.030	0.030	0.010	0.016	0.020	0.025
1995	0.012	0.022	0.054	0.036	0.038	0.034	0.014	0.016	0.022	0.022
1996	0.013	0.020	0.057	0.019	0.036	0.032	0.009	0.016	0.014	0.024
1997	0.011	0.023	0.038	0.027	0.036	0.023	0.014	0.013	0.014	0.018

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PART II

FIGURES

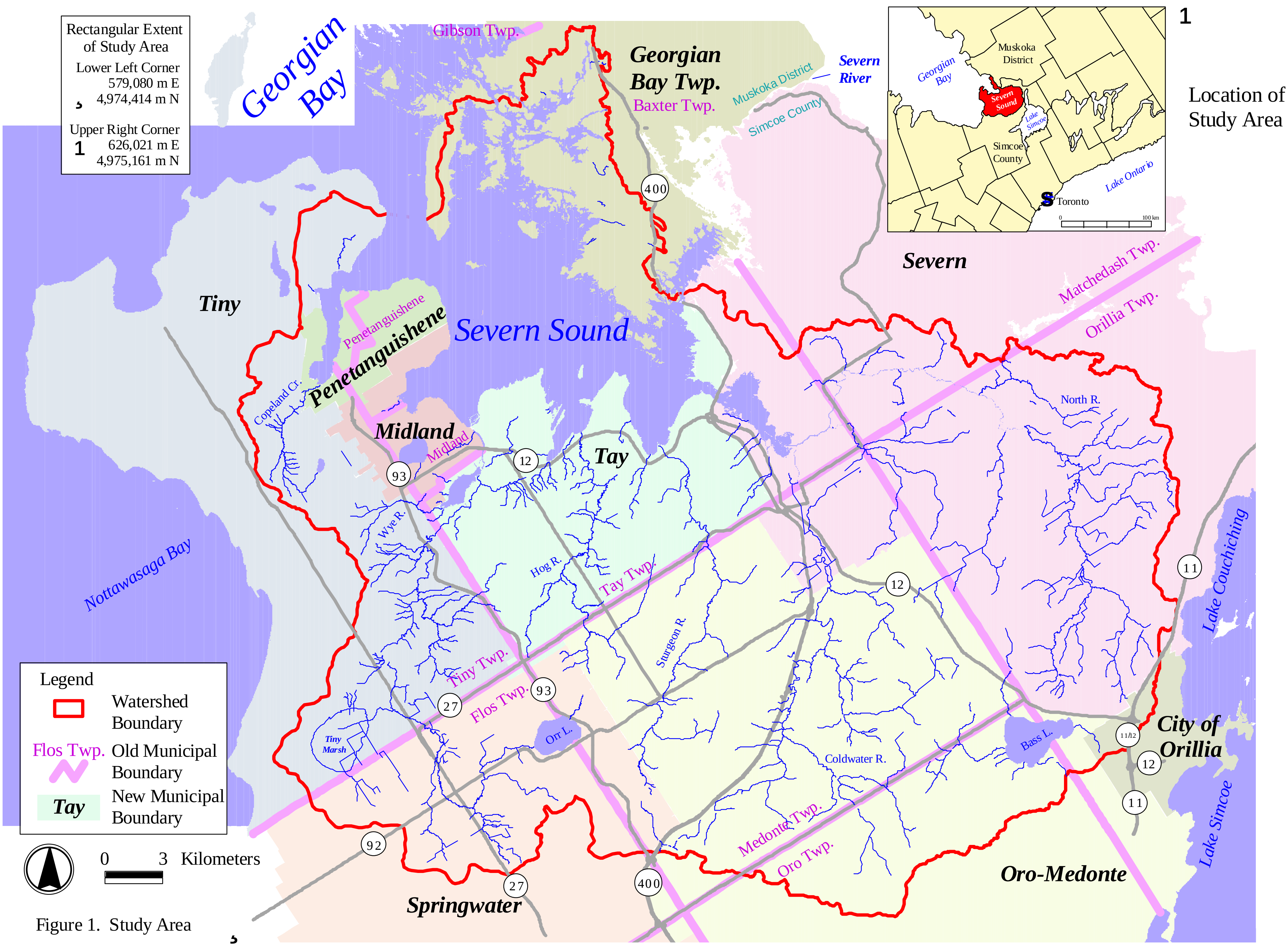


Figure 1. Study Area

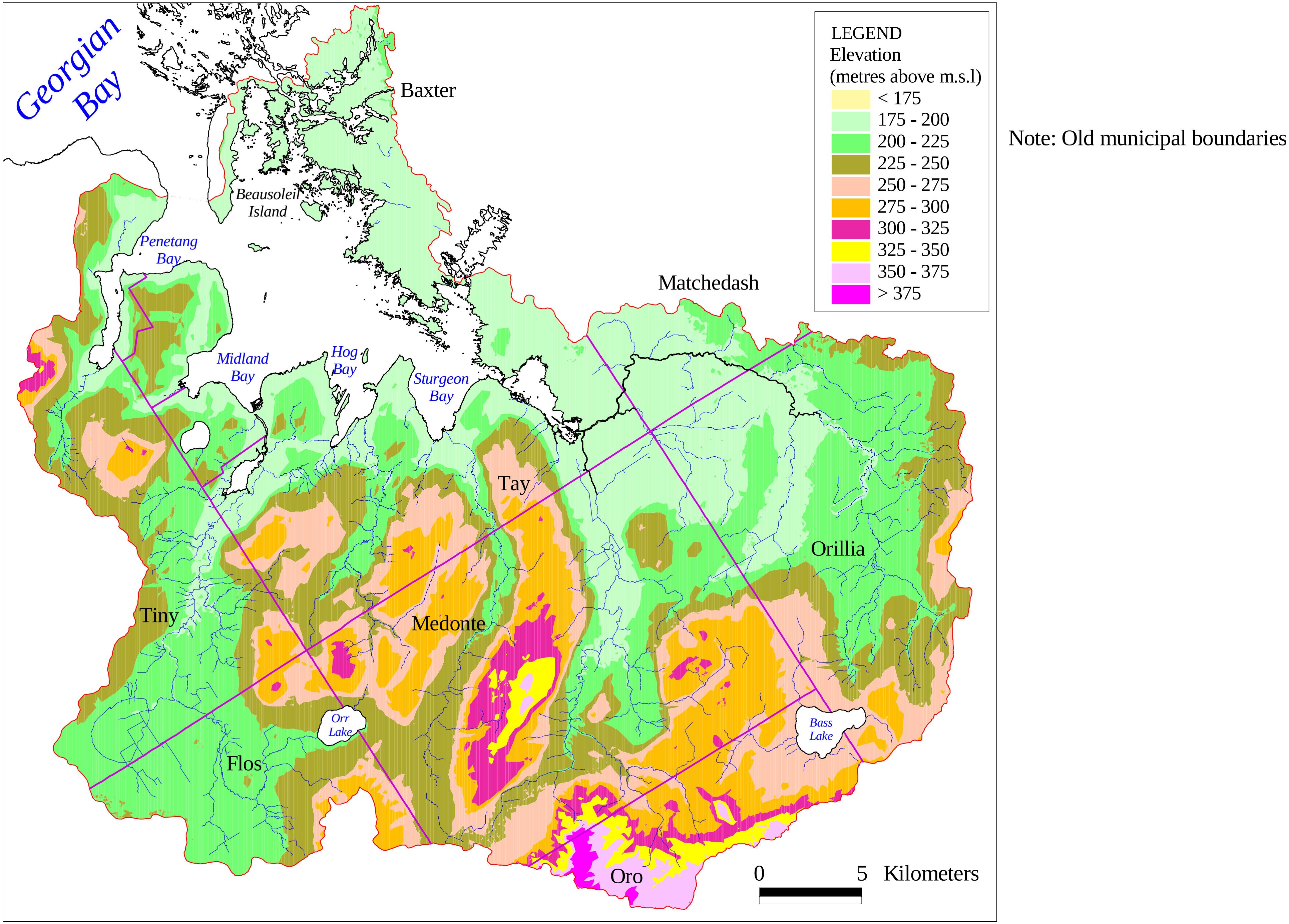


Figure 2. Variations of surface elevations within the study area.

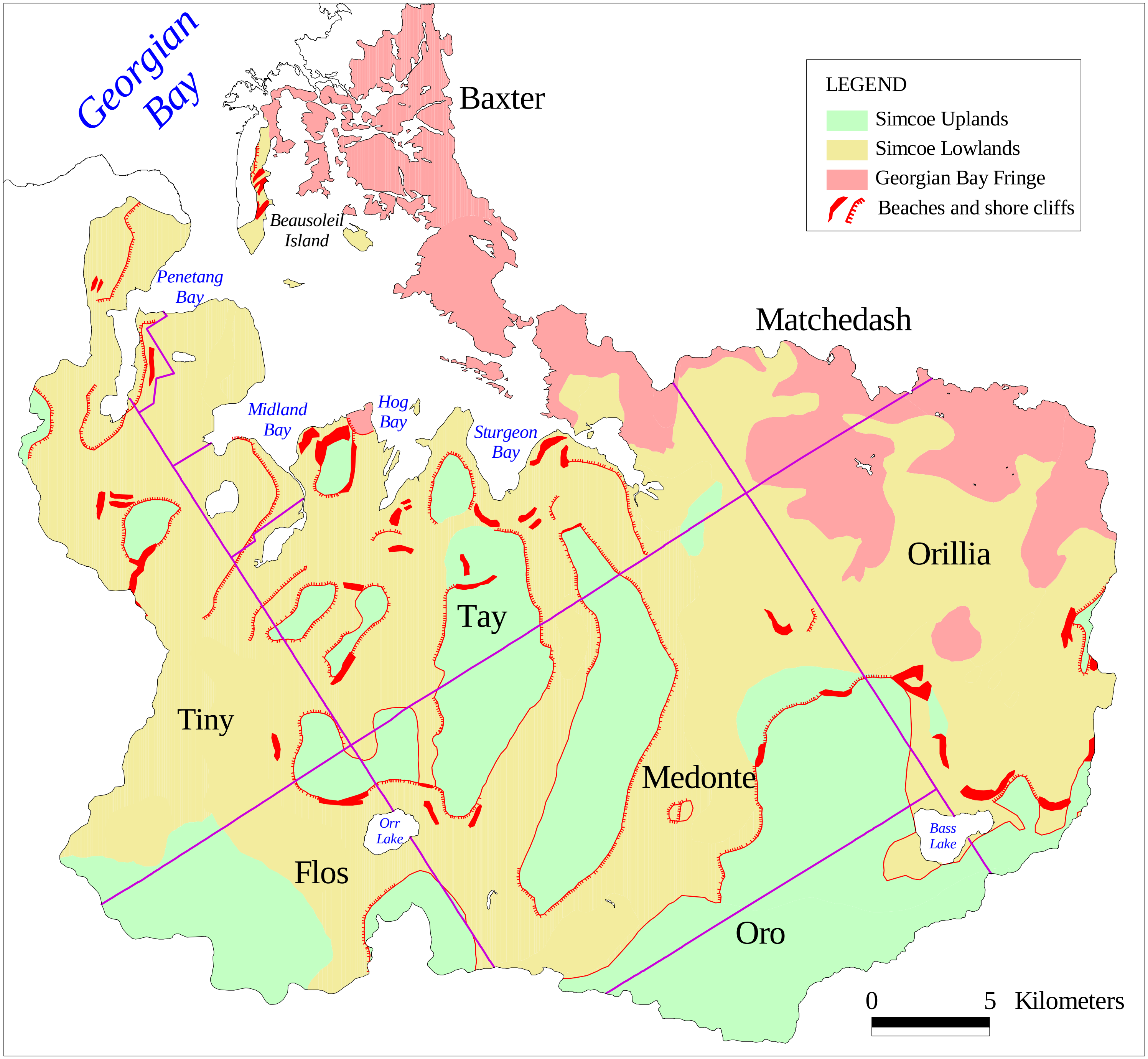


Figure 3. Physiographic regions in the study area.

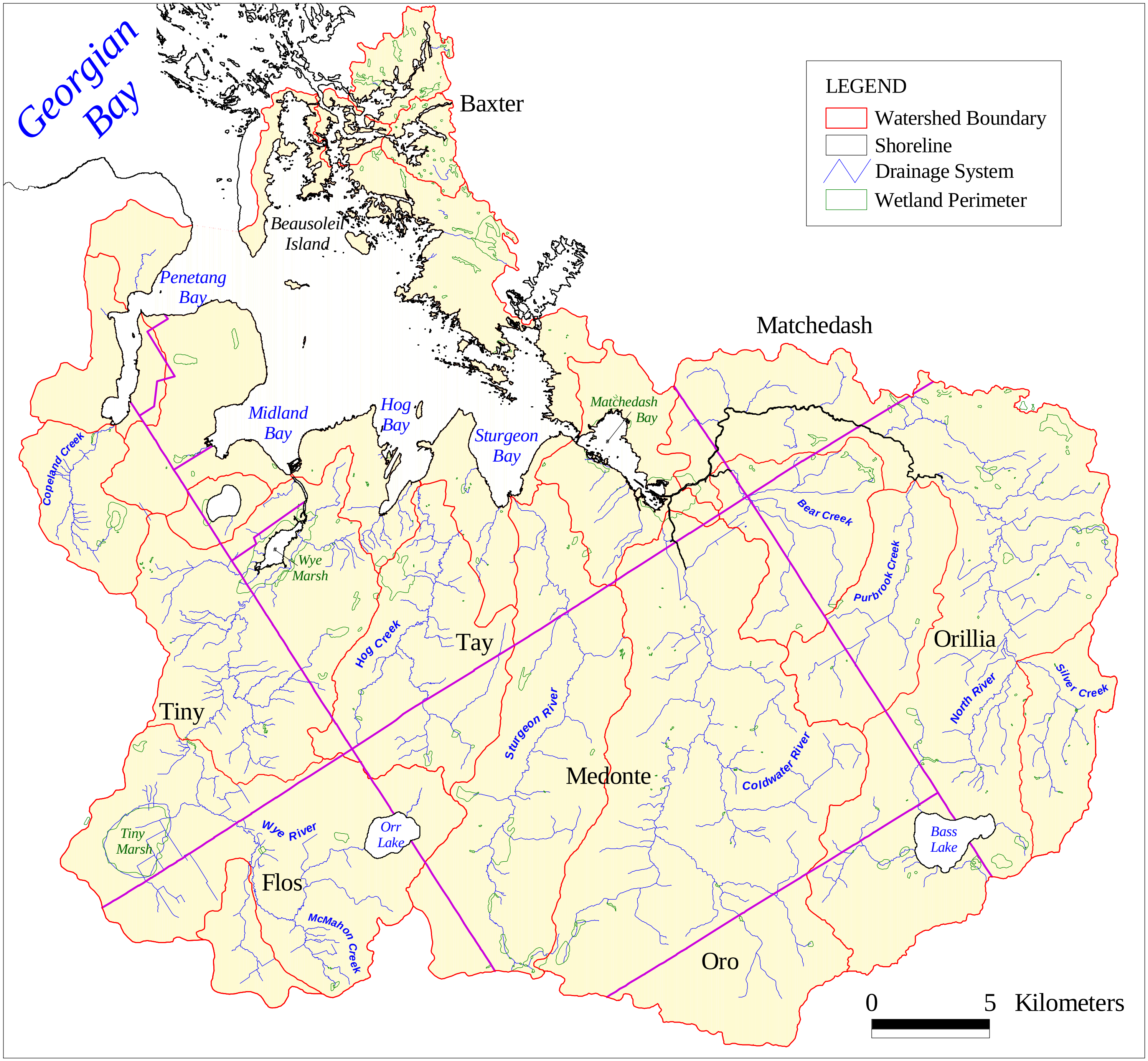


Figure 4. Drainage in the study area

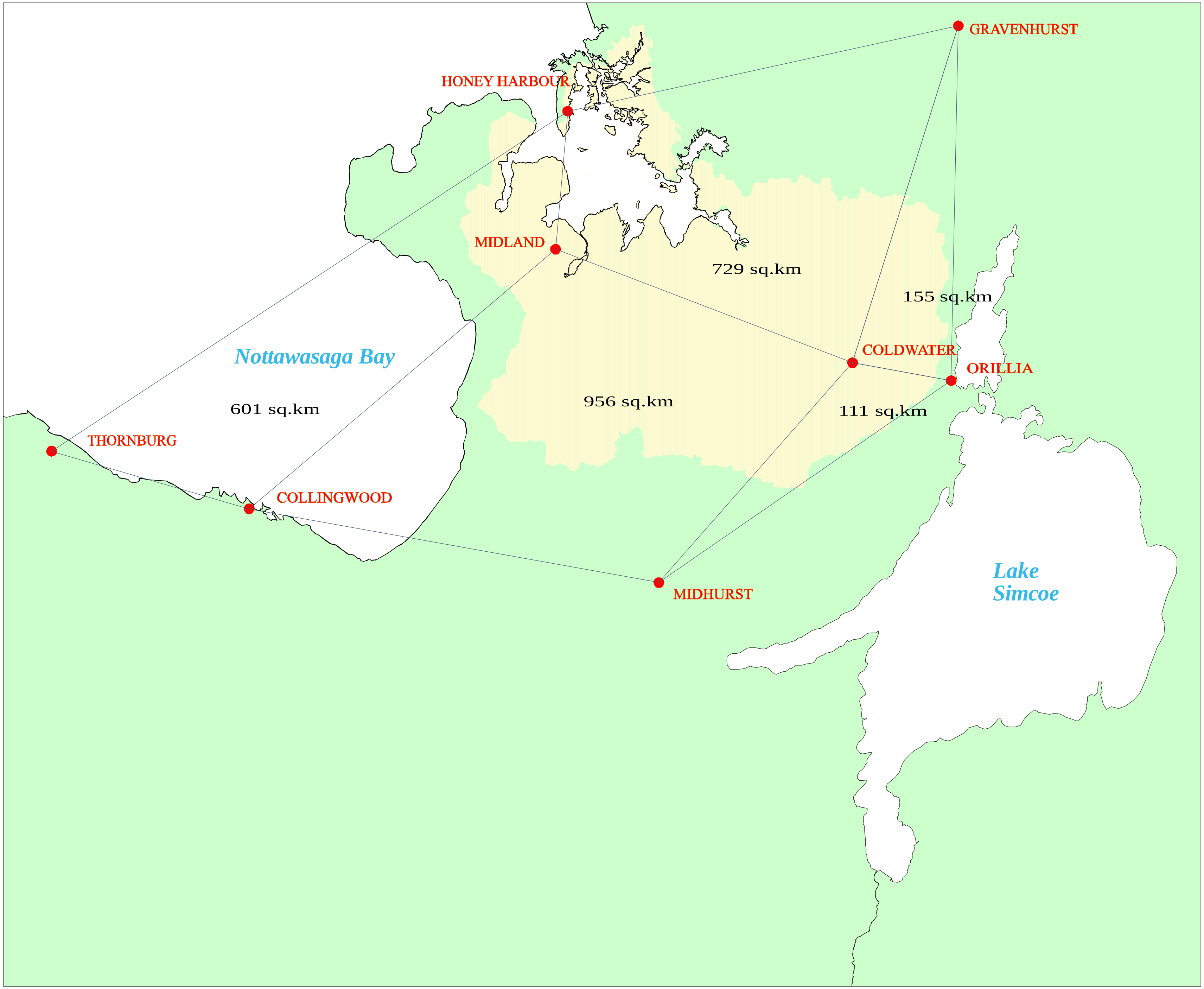


Figure 5. Locations of meteorological stations within and in the vicinity of the study area.

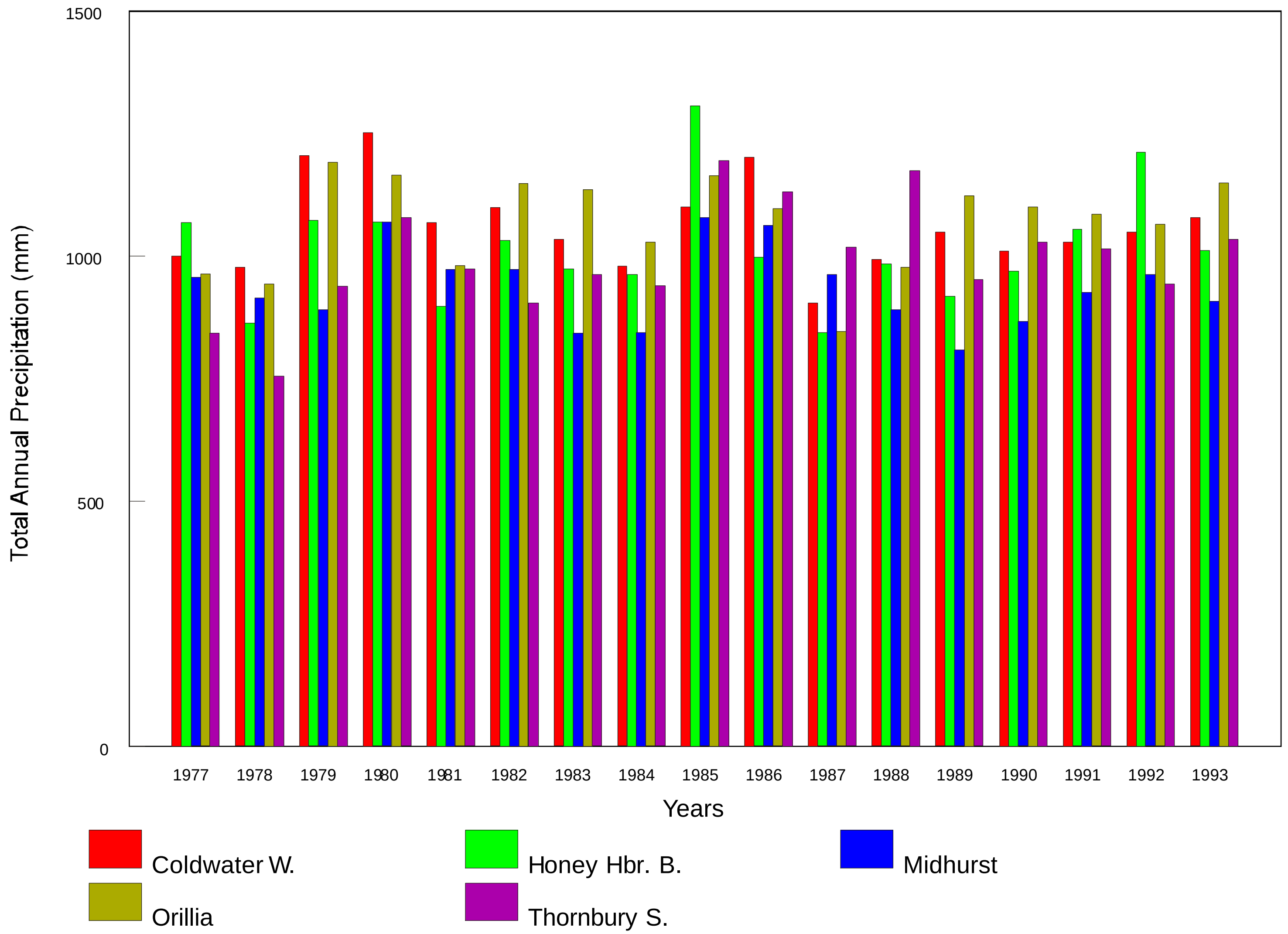


Figure 6. Total annual precipitation variations in and around the study area for the period 1977 - 1993.

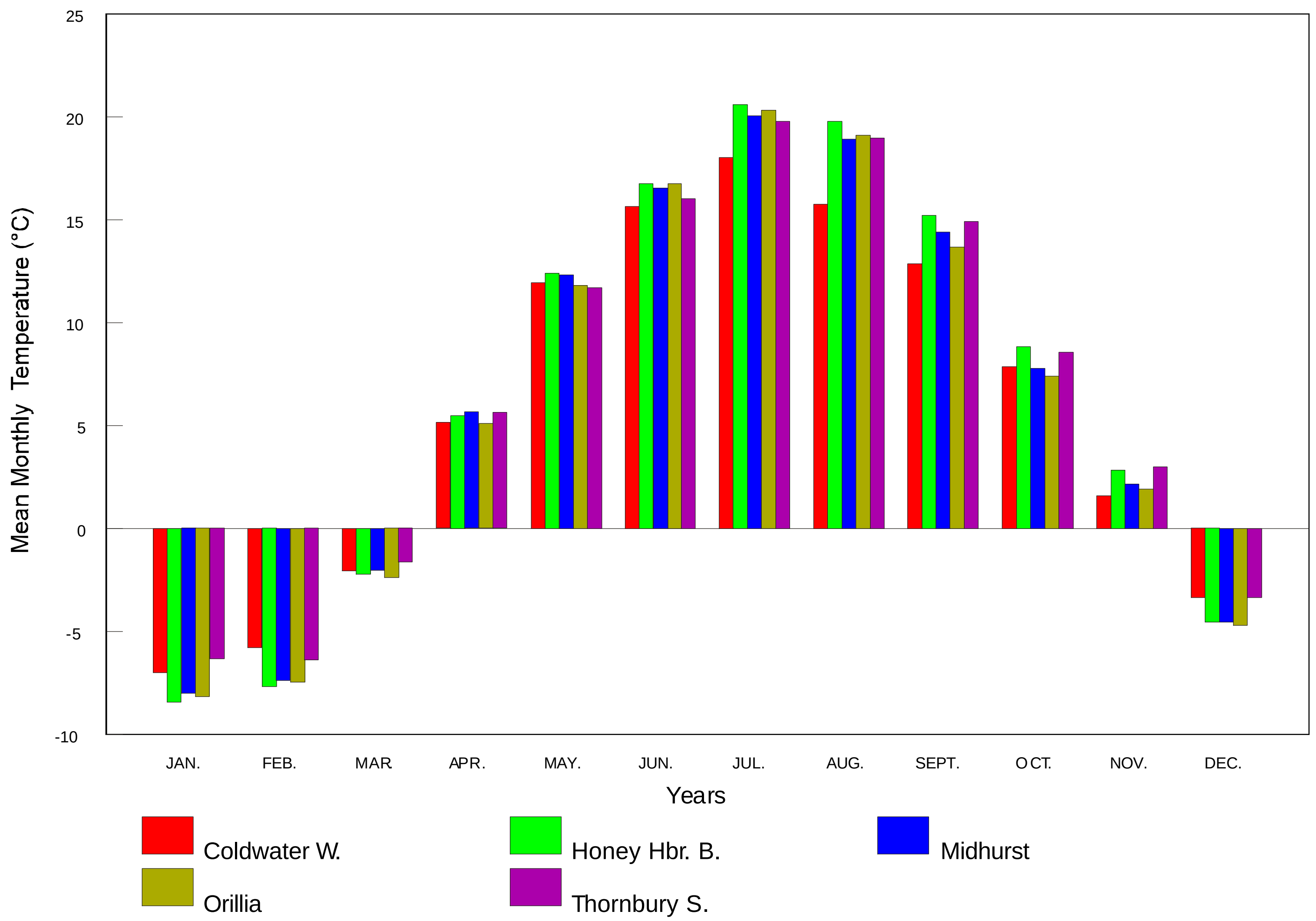


Figure 7. Mean monthly temperature variations in and around the study area for the period 1977 - 1993.

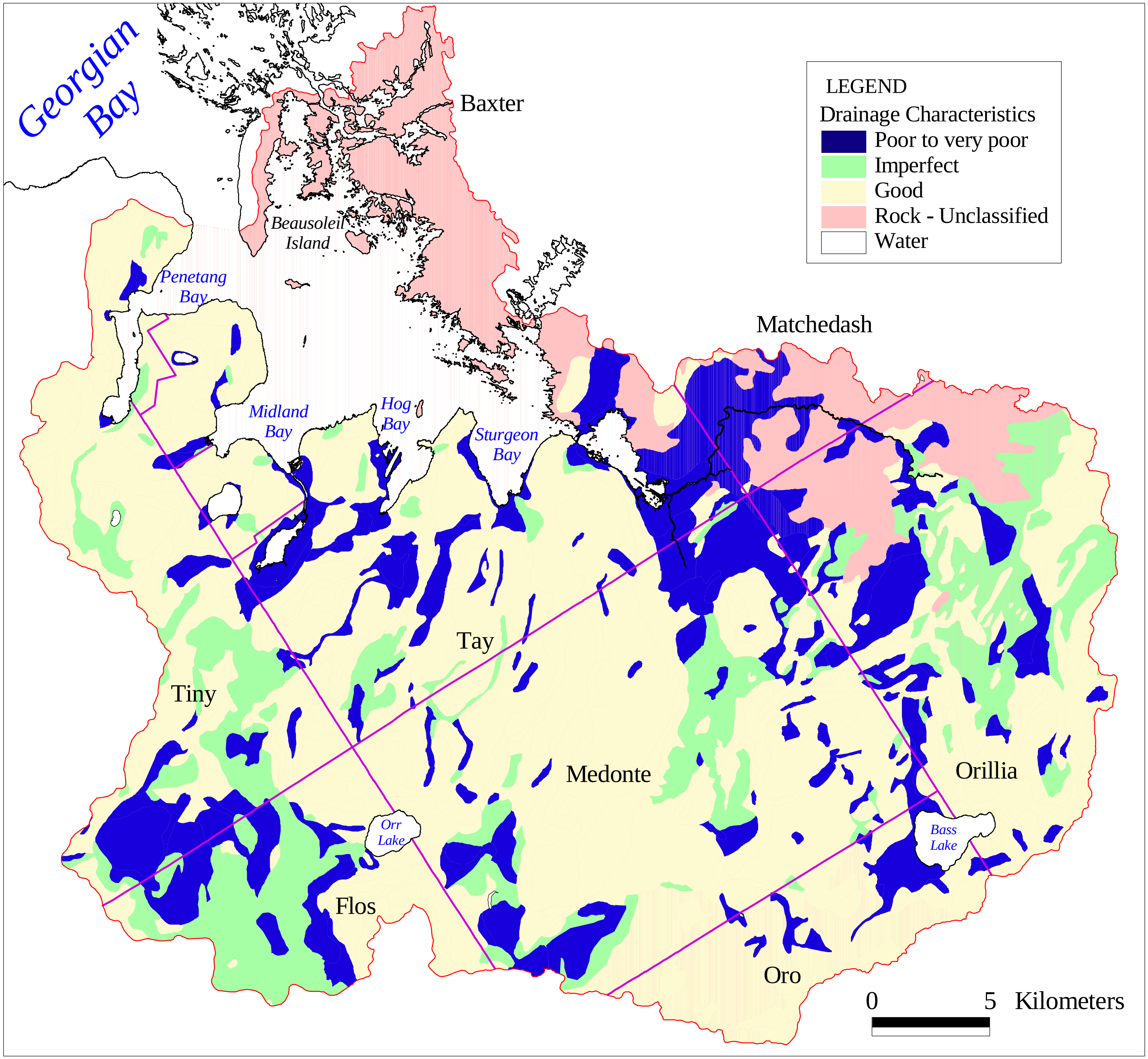


Figure 8. Drainage characteristics of soils within the study area (based on Hoffman, Wicklund and Richards,1992).

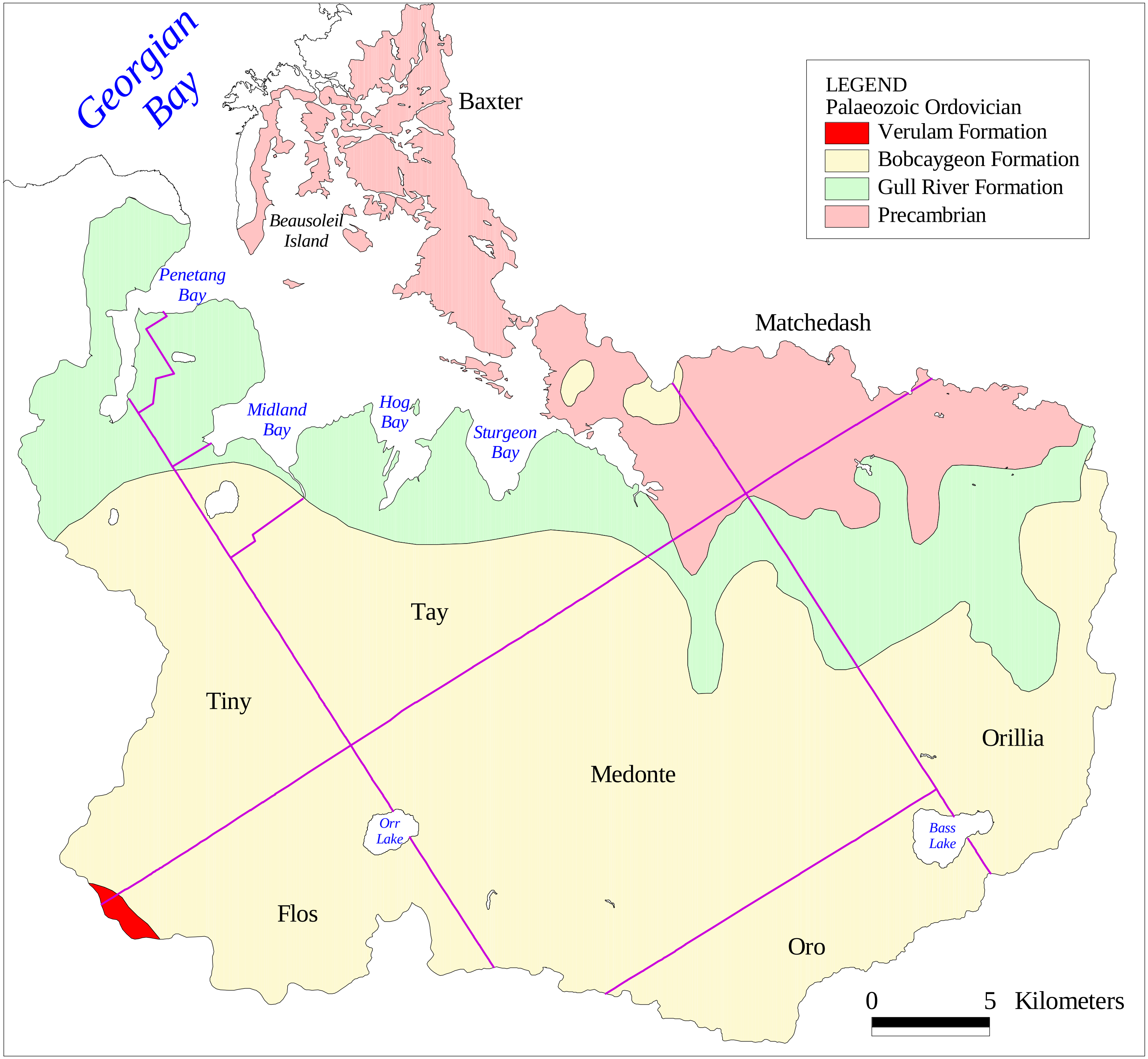


Figure 9. Bedrock geology of the study area.

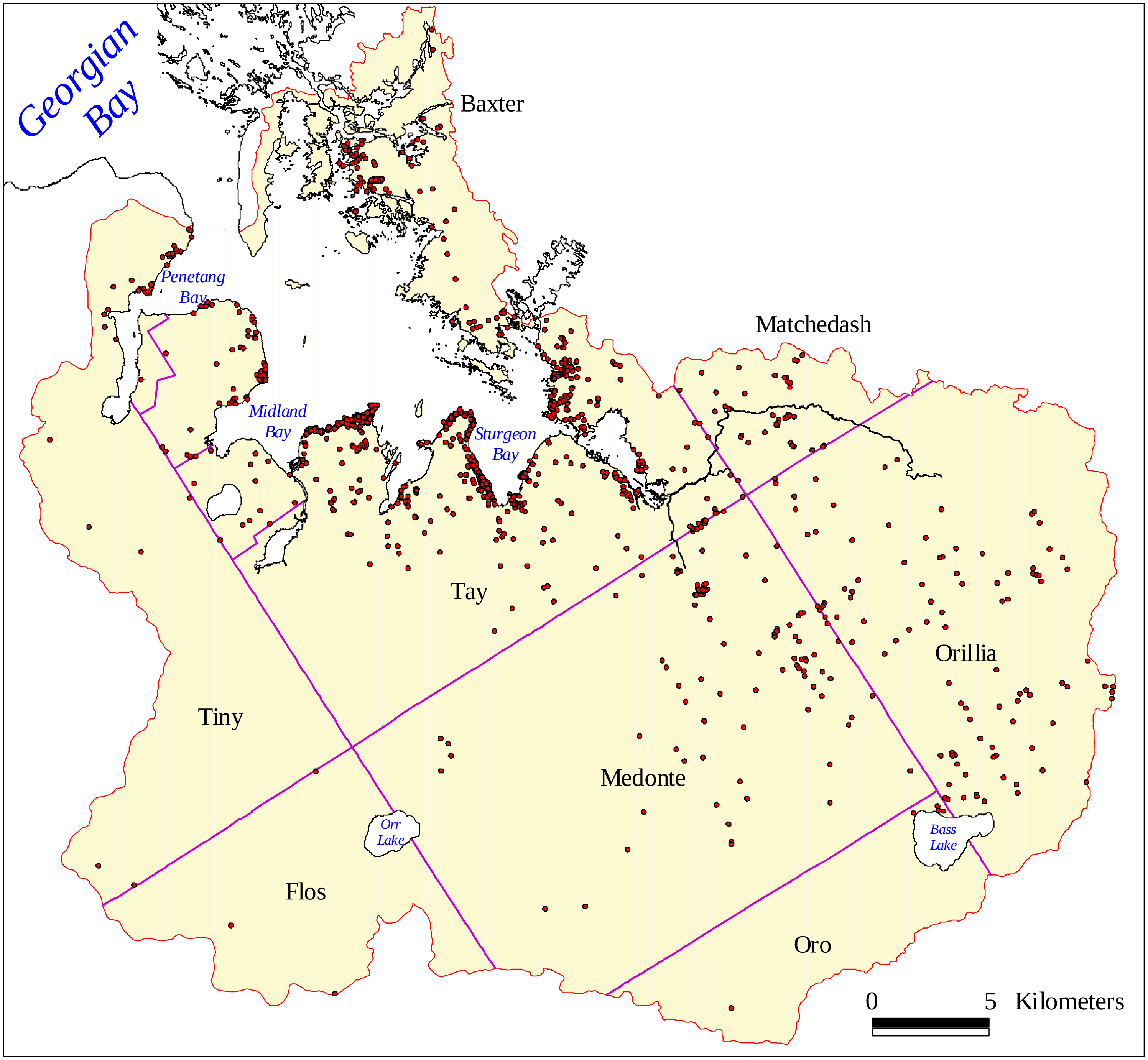


Figure 10. Water wells used in the compilation of bedrock elevation map.

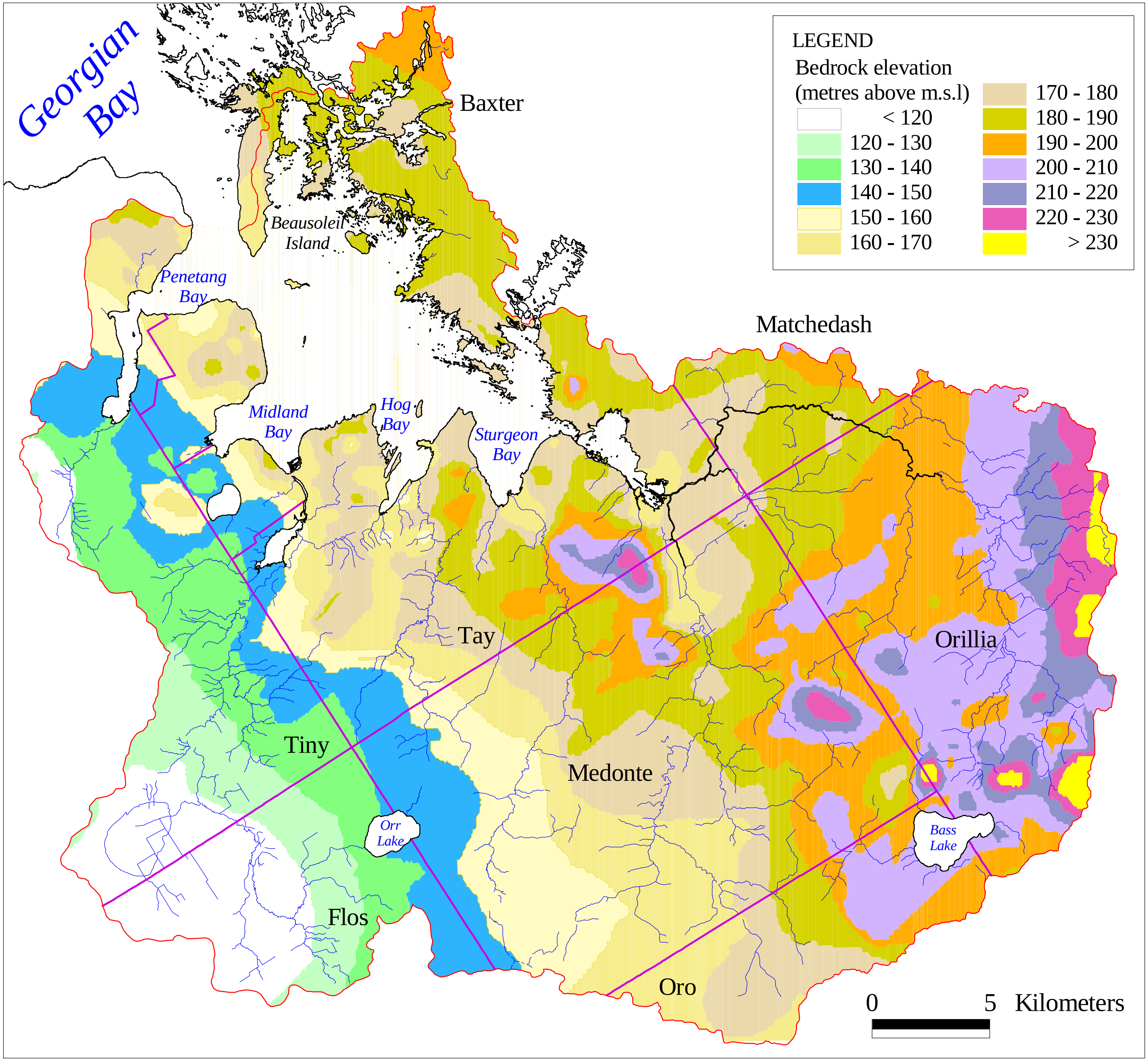


Figure 11. Bedrock elevation within the study area.

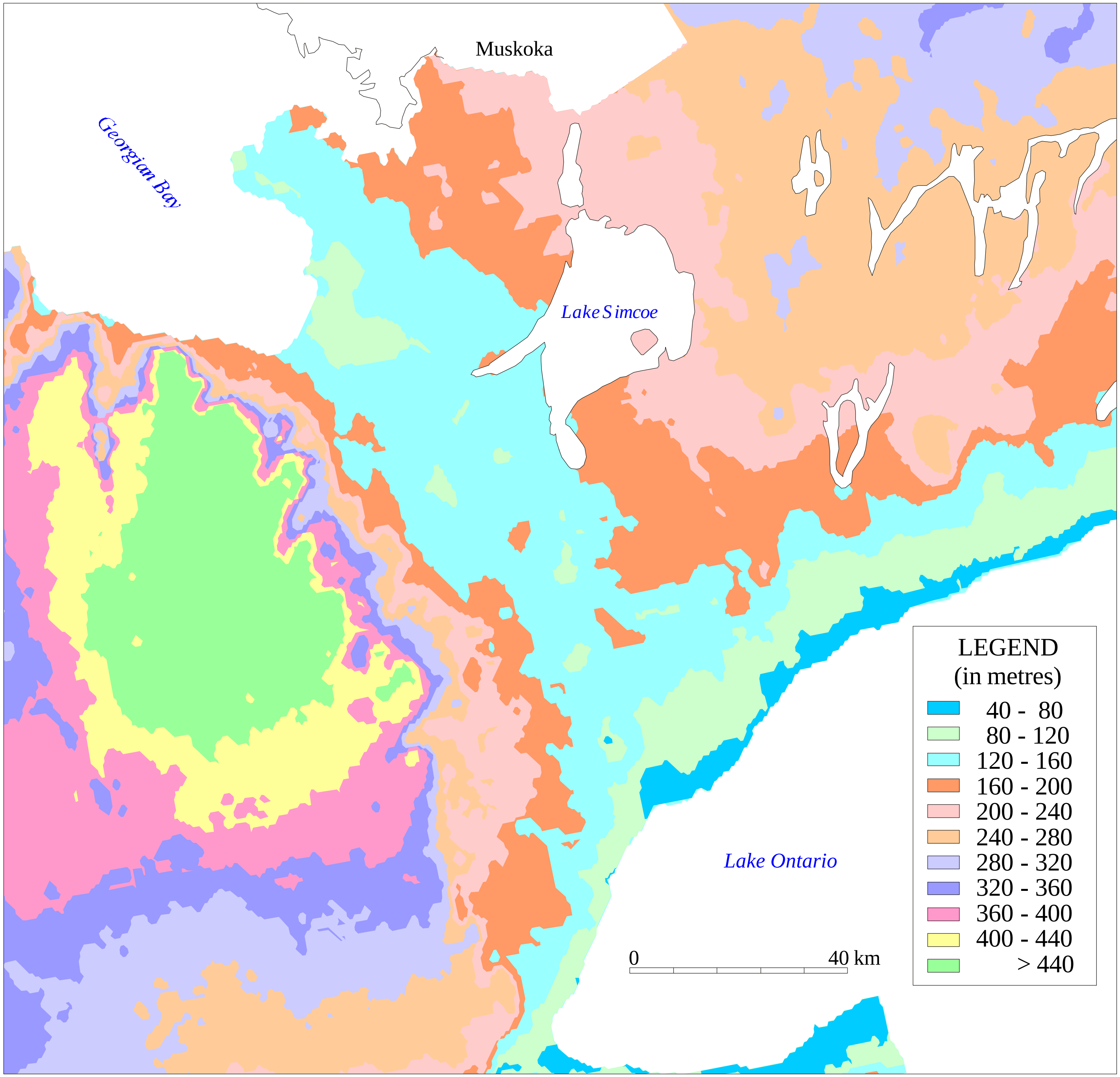


Figure 12. Bedrock elevation within central Ontario.

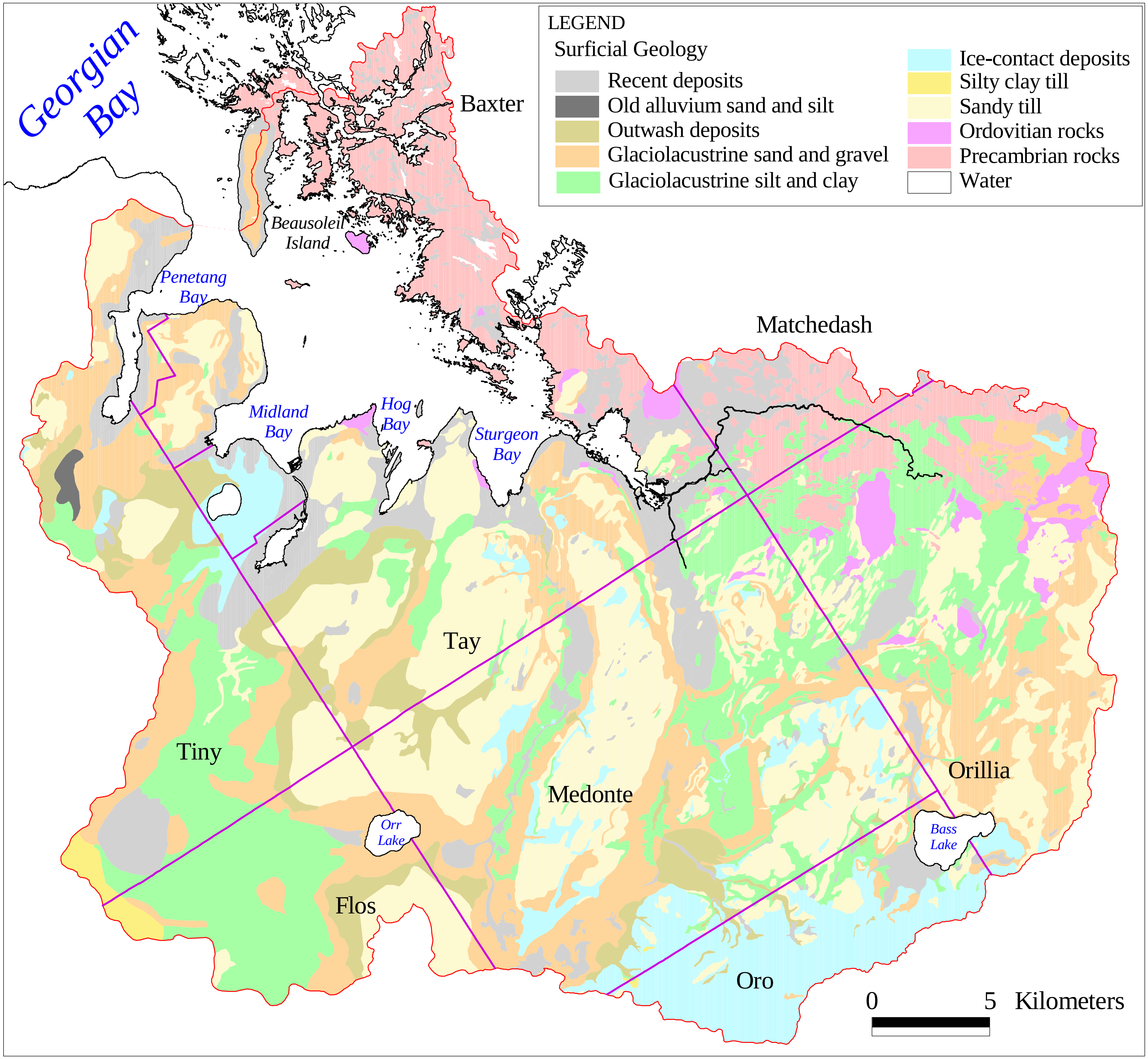


Figure 13. Surficial geology of the study area.

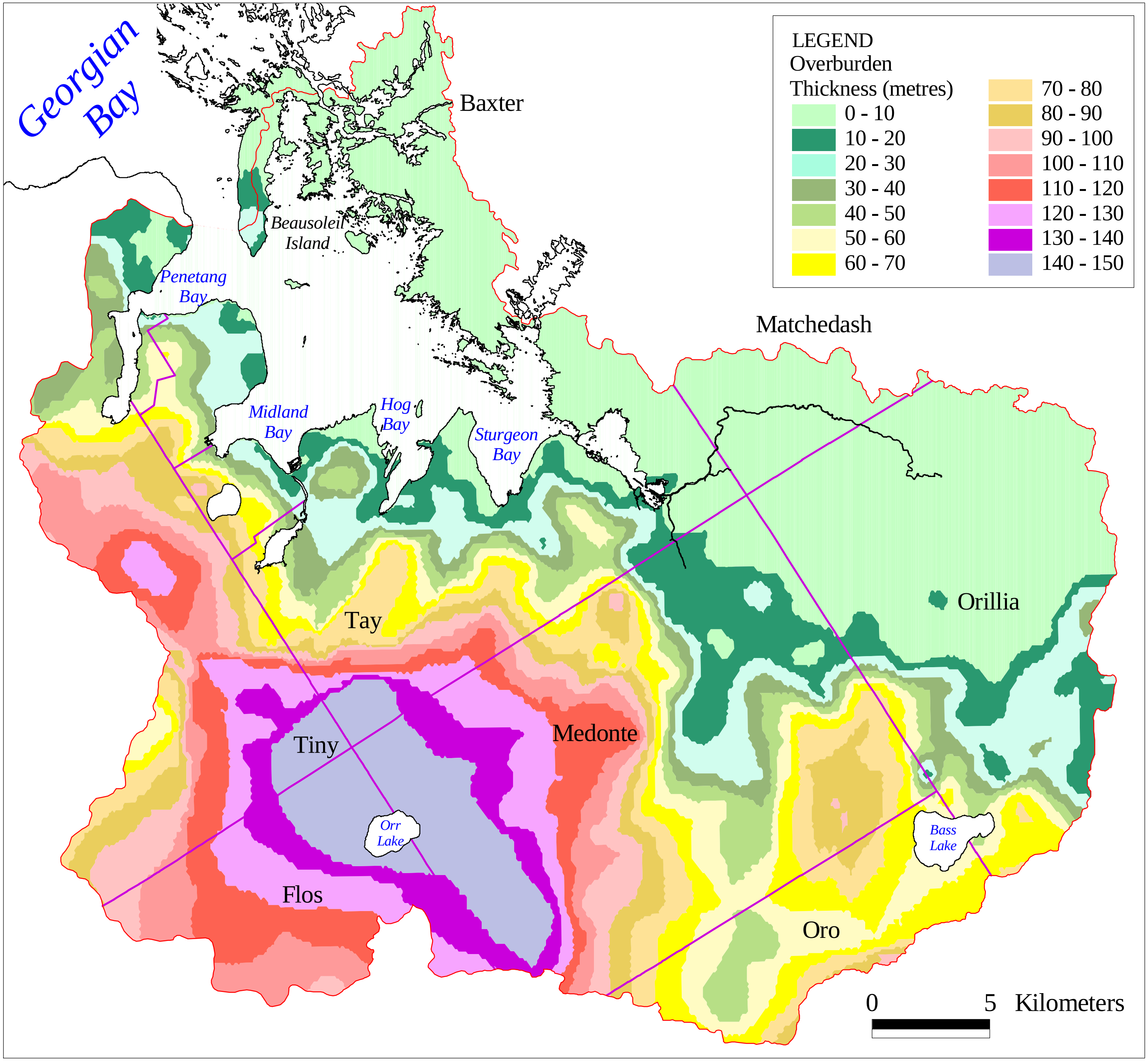


Figure 14. Overburden thickness within the study area.

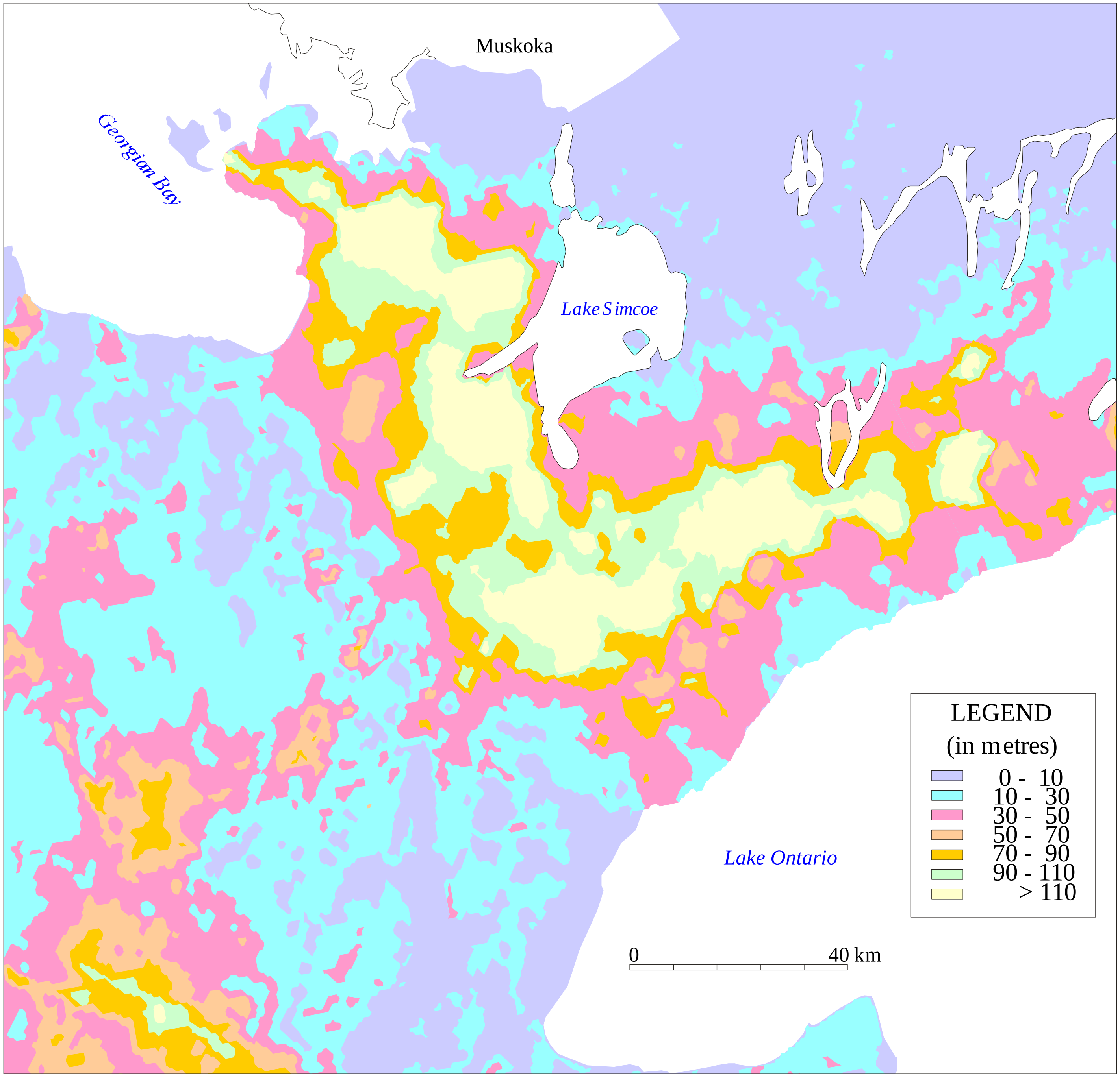


Figure 15. Overburden thickness within central Ontario.

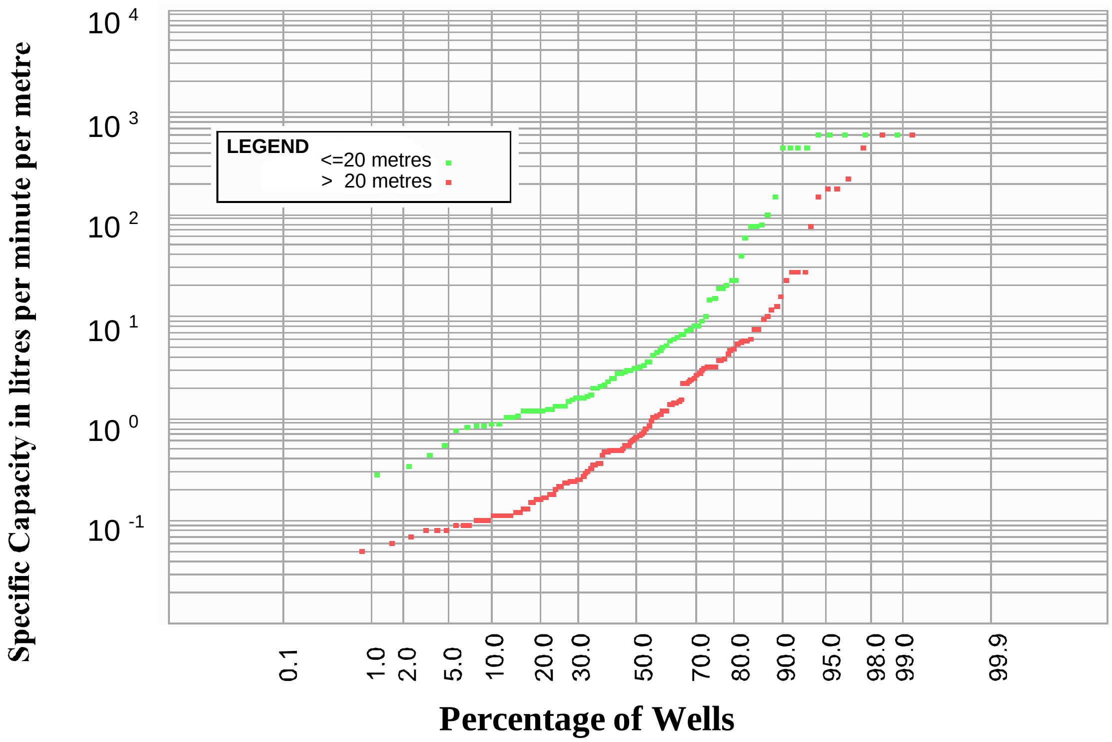


Figure 16. Specific capacity-probability graphs for wells completed in the Precambrian Hydrogeologic Unit.

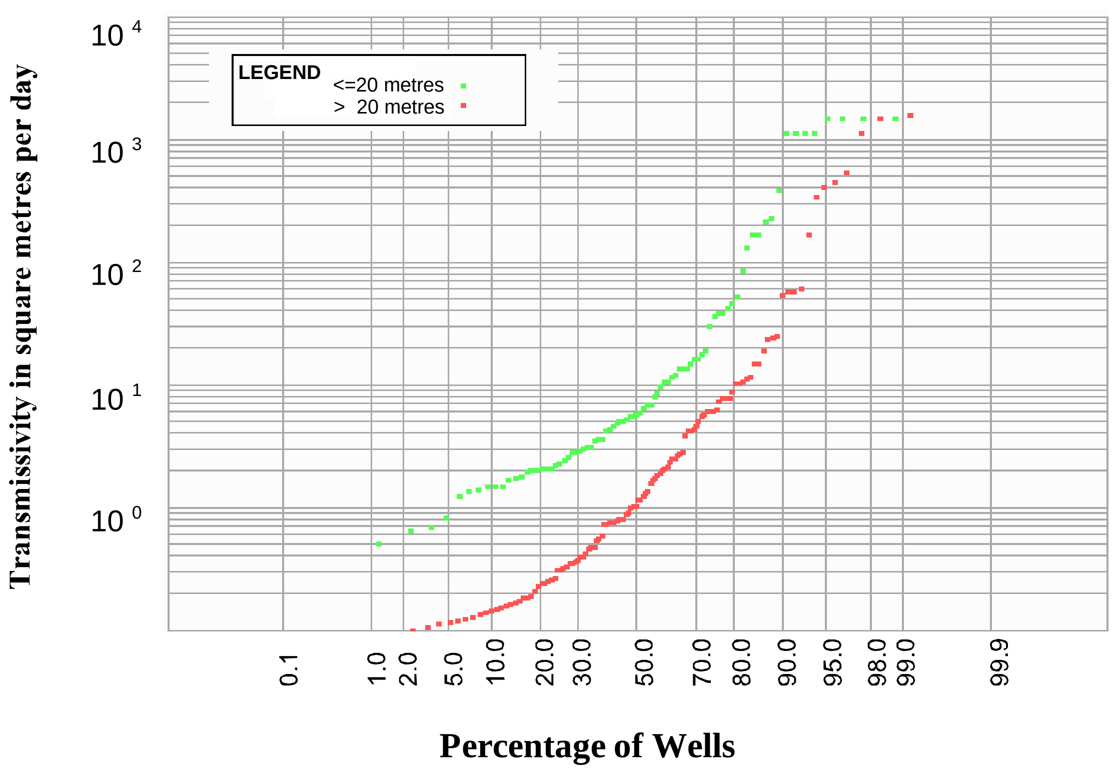


Figure 17. Transmissivity-probability graphs for wells completed in the Precambrian Hydrogeologic Unit.

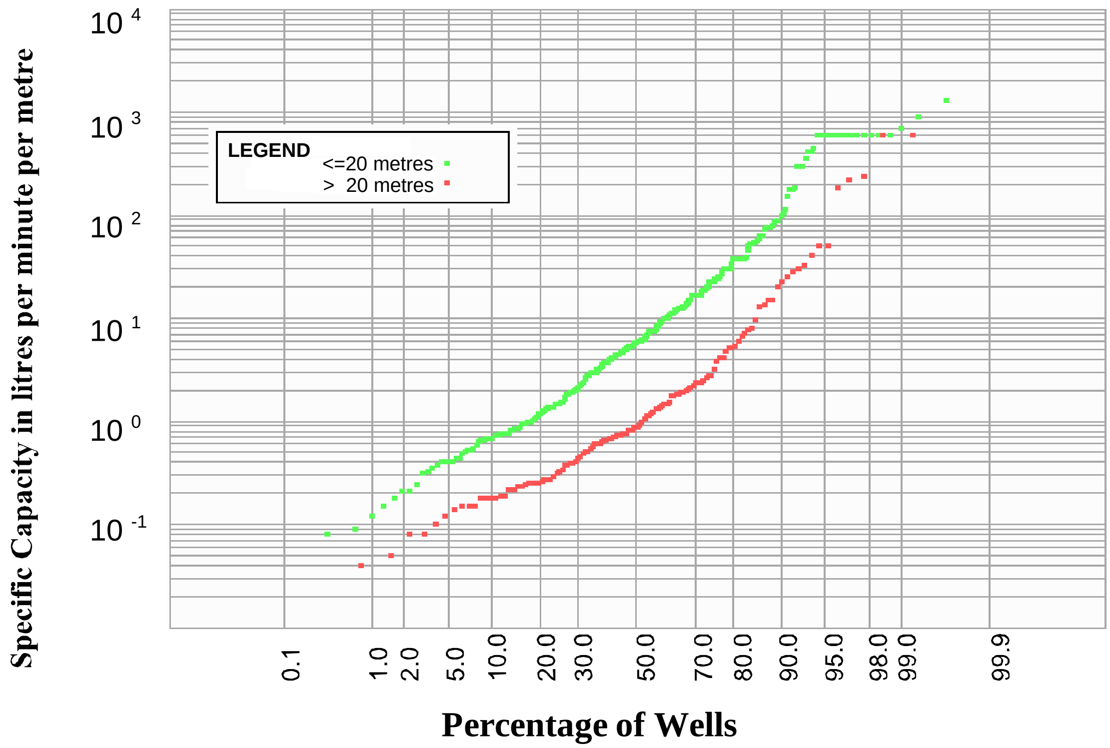


Figure 18. Specific capacity-probability graphs for wells completed in the Shadow Lake-Gull River Hydrogeologic Unit.

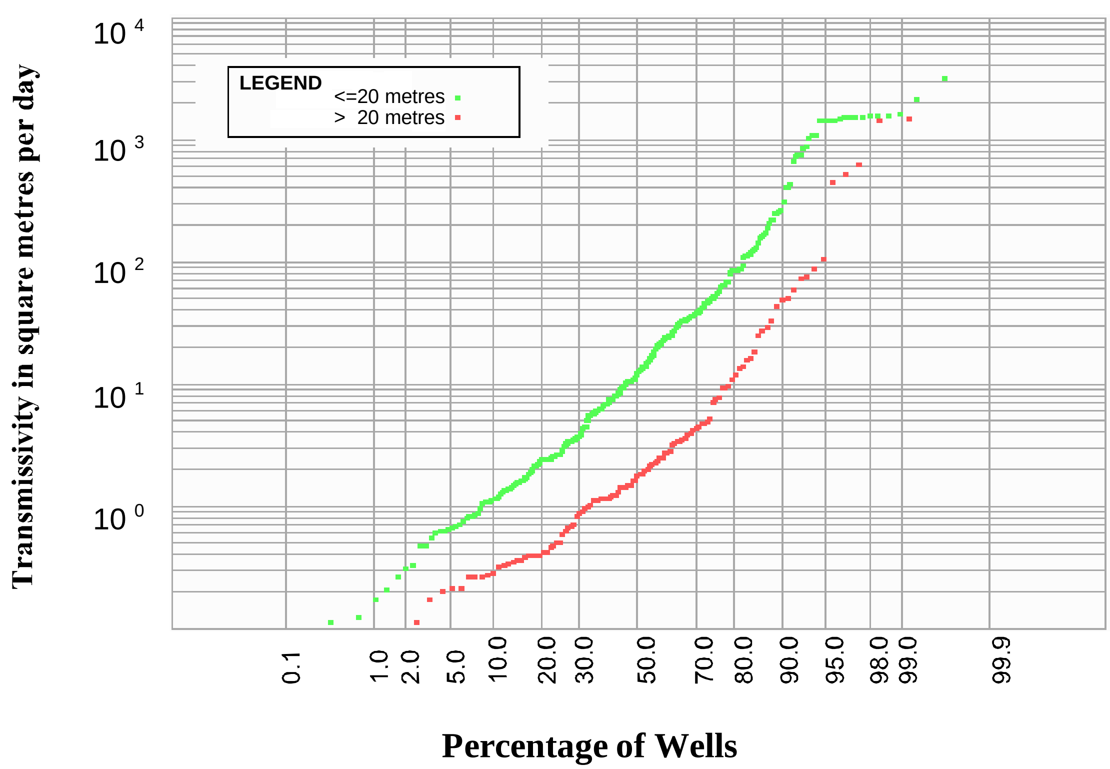


Figure 19. Transmissivity-probability graphs for wells completed in the Shadow Lake-Gull River Hydrogeologic Unit.

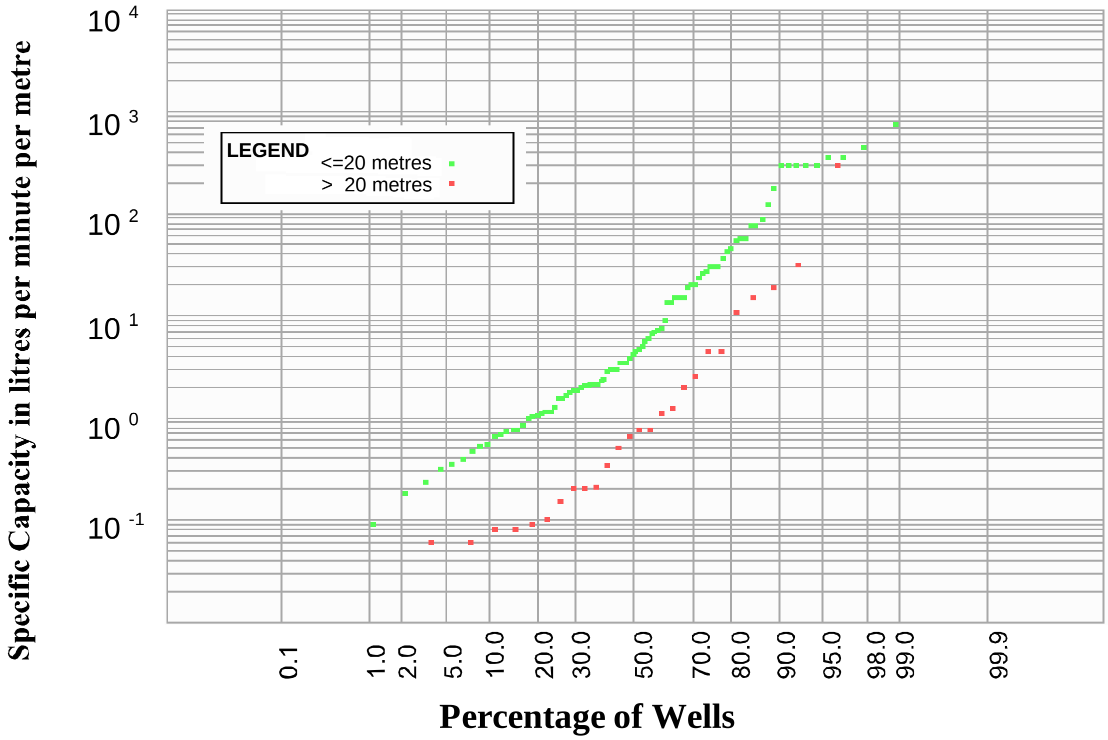


Figure 20. Specific capacity-probability graphs for wells completed in the Bobcaygeon Hydrogeologic Unit.

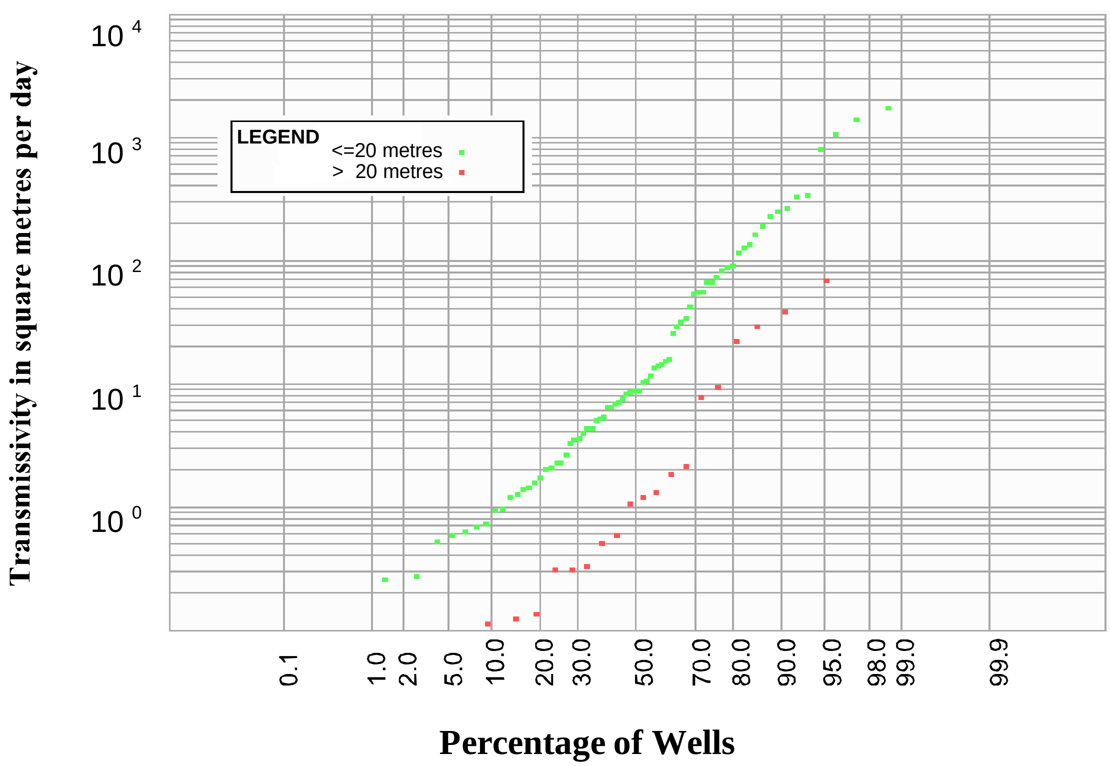


Figure 21. Transmissivity-probability graphs for wells completed in the Bobcaygeon Hydrogeologic Unit.

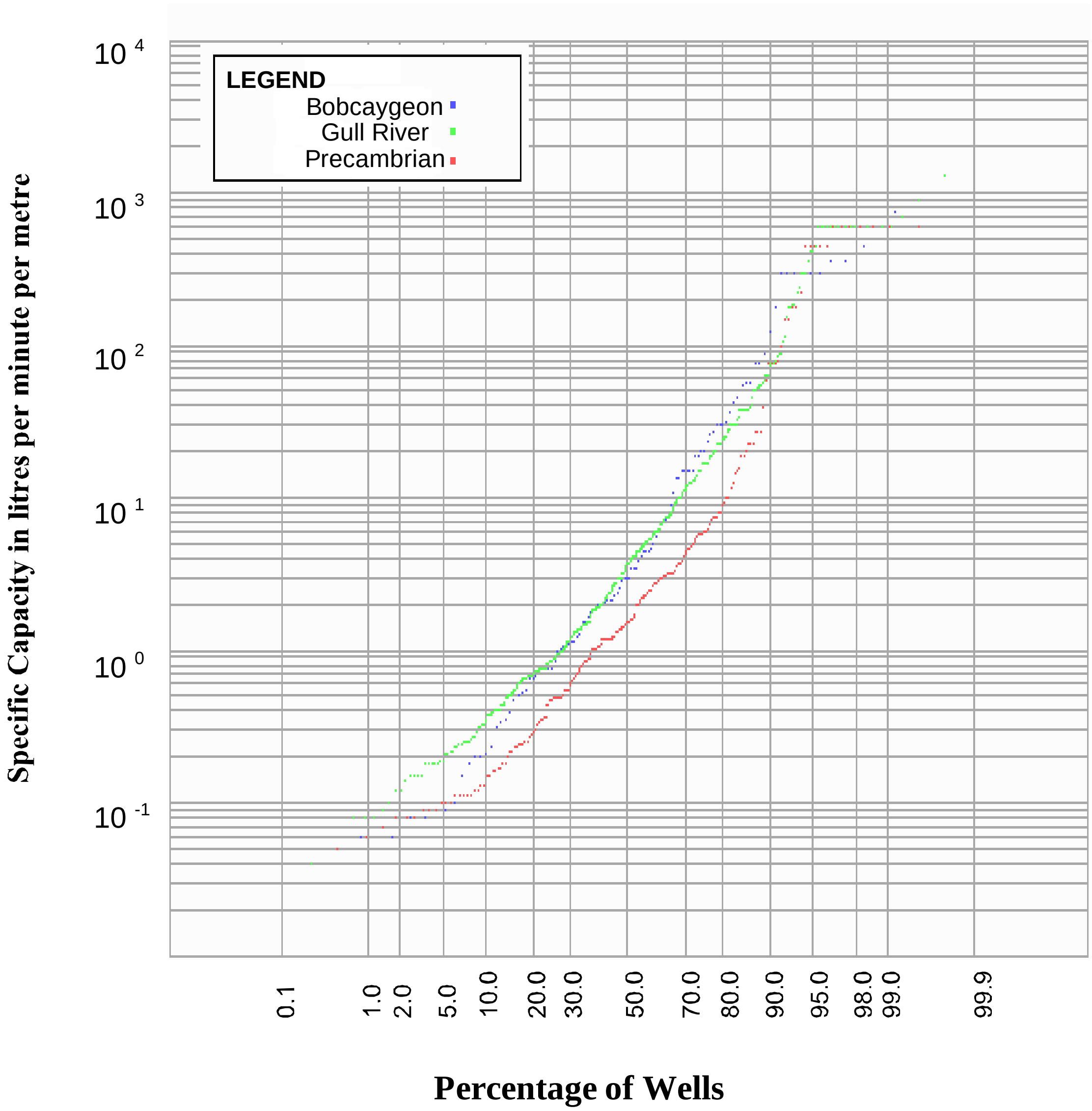


Figure 22. A comparison between the specific capacity-probability graphs for wells completed in various bedrock hydrogeologic units.

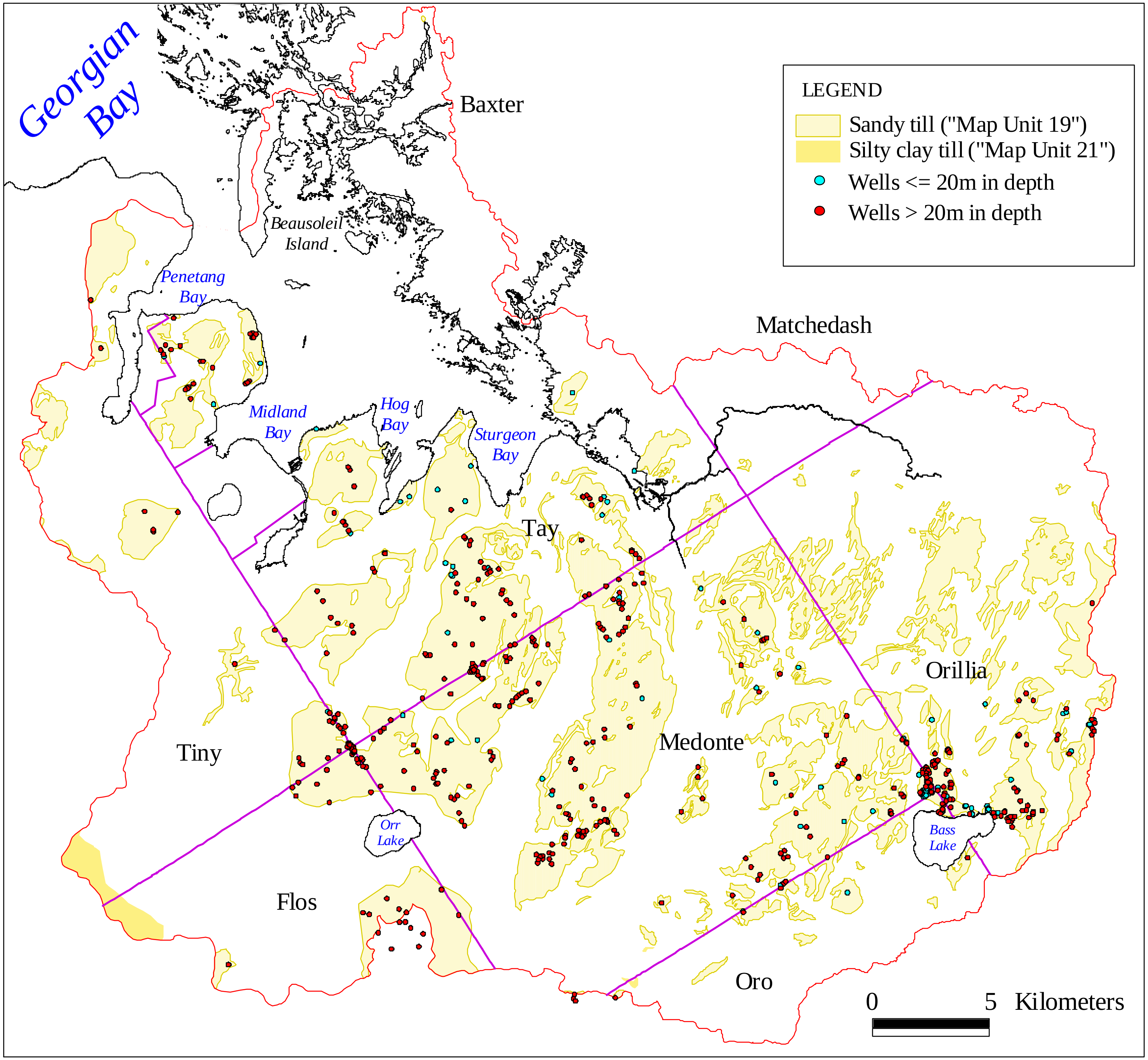


Figure 23. Areas where till deposits outcrop at the surface within the study area.

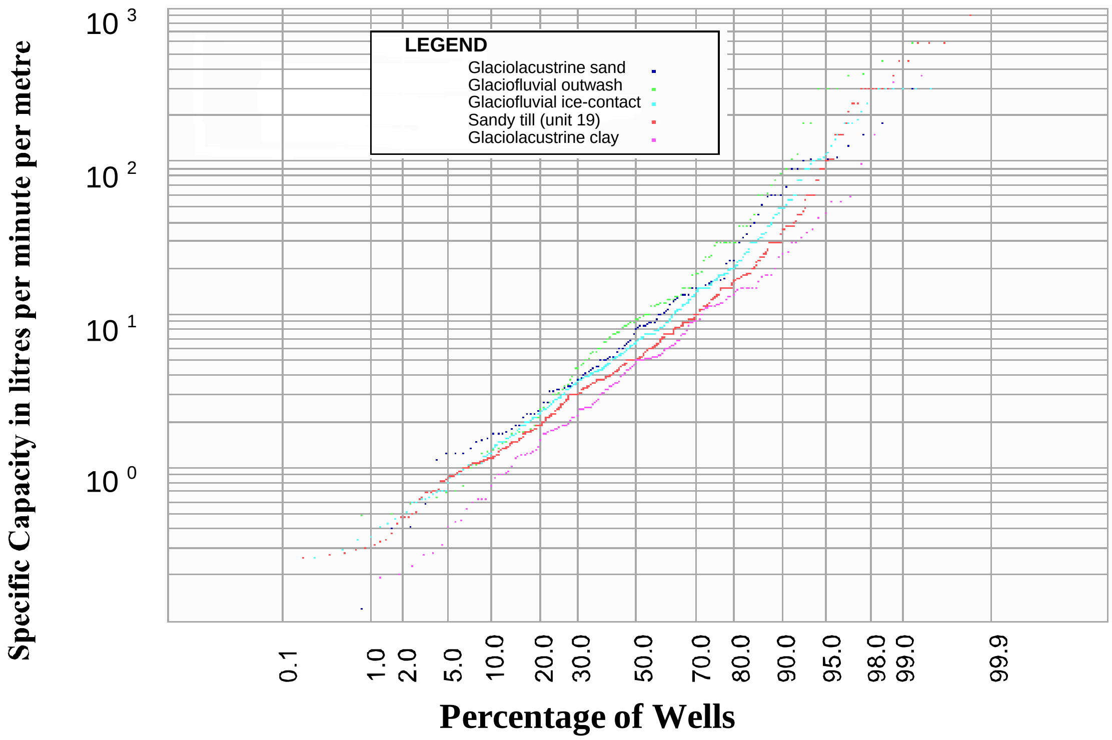


Figure 24. Specific capacity-probability graphs for wells completed in various overburden deposits.

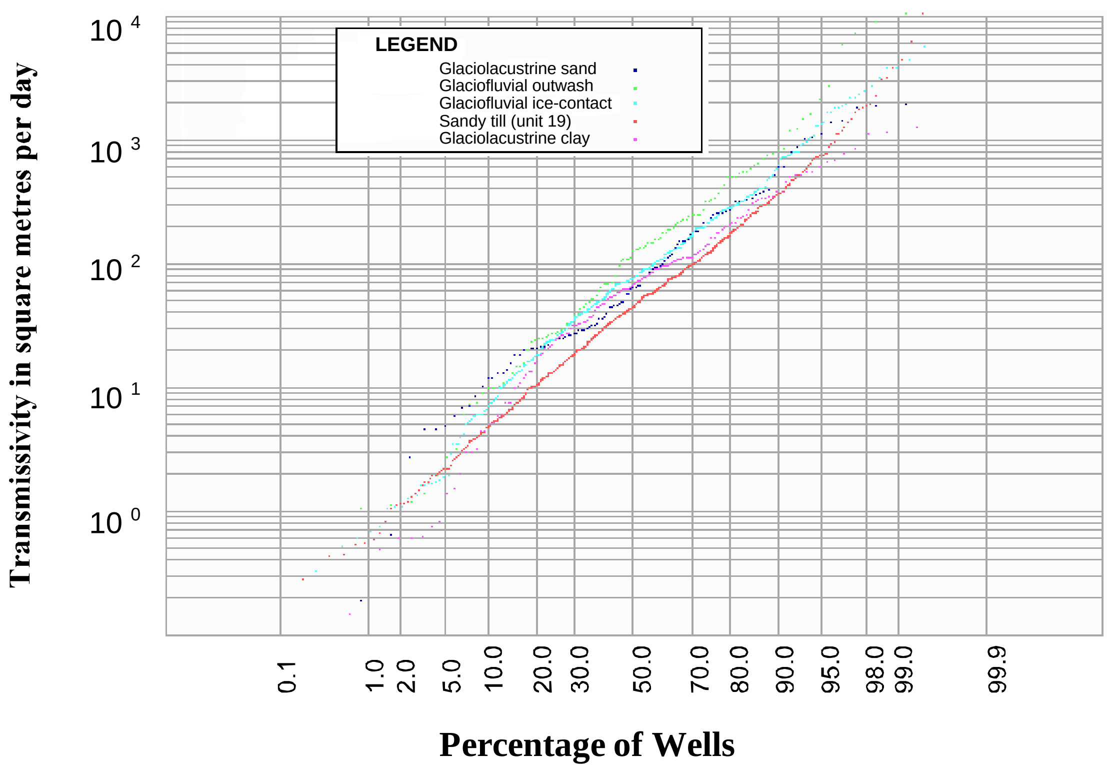


Figure 25. Transmissivity-probability graphs for wells completed in various overburden deposits.

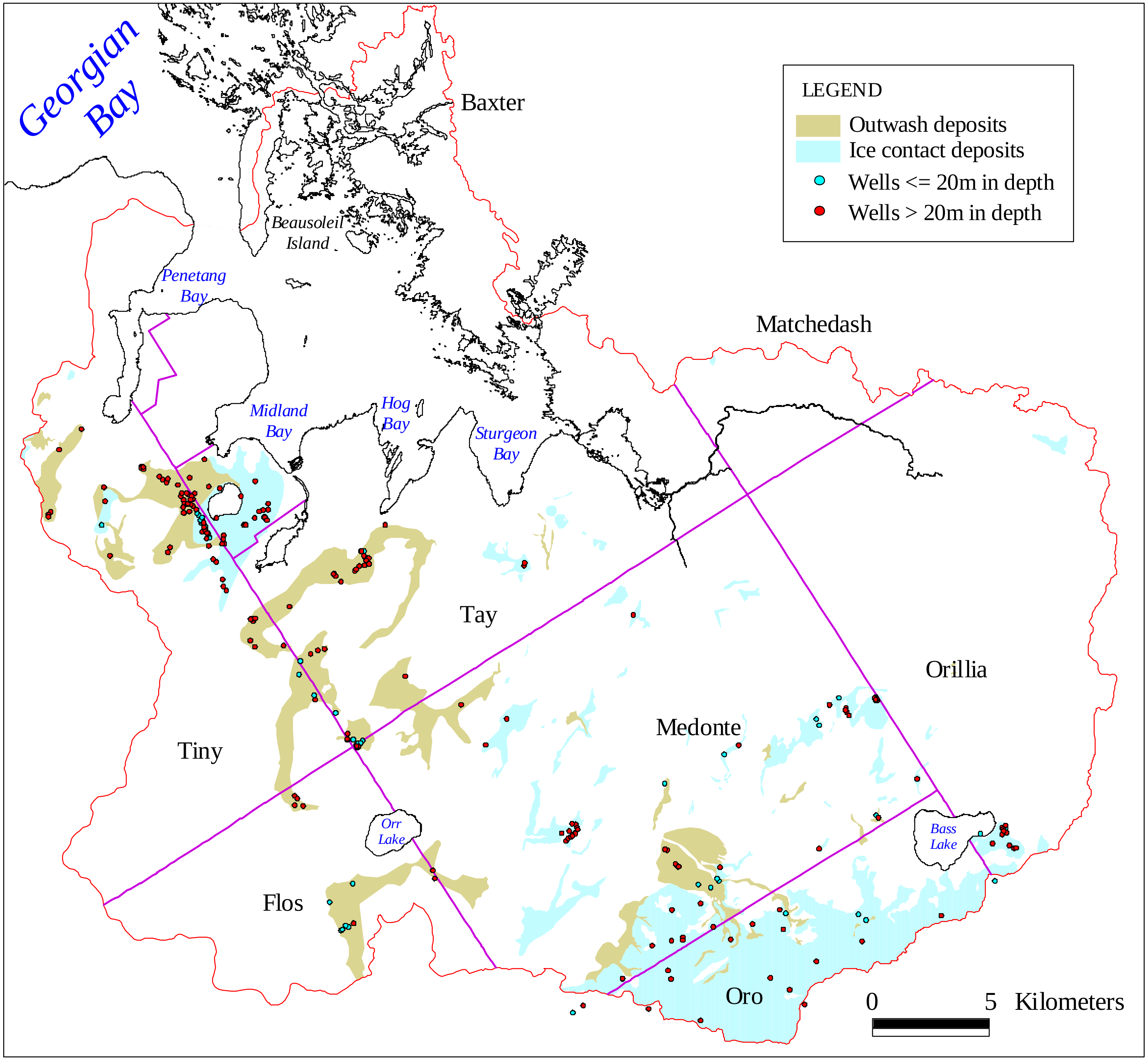


Figure 26. Areas where glaciofluvial deposits outcrop at the surface.

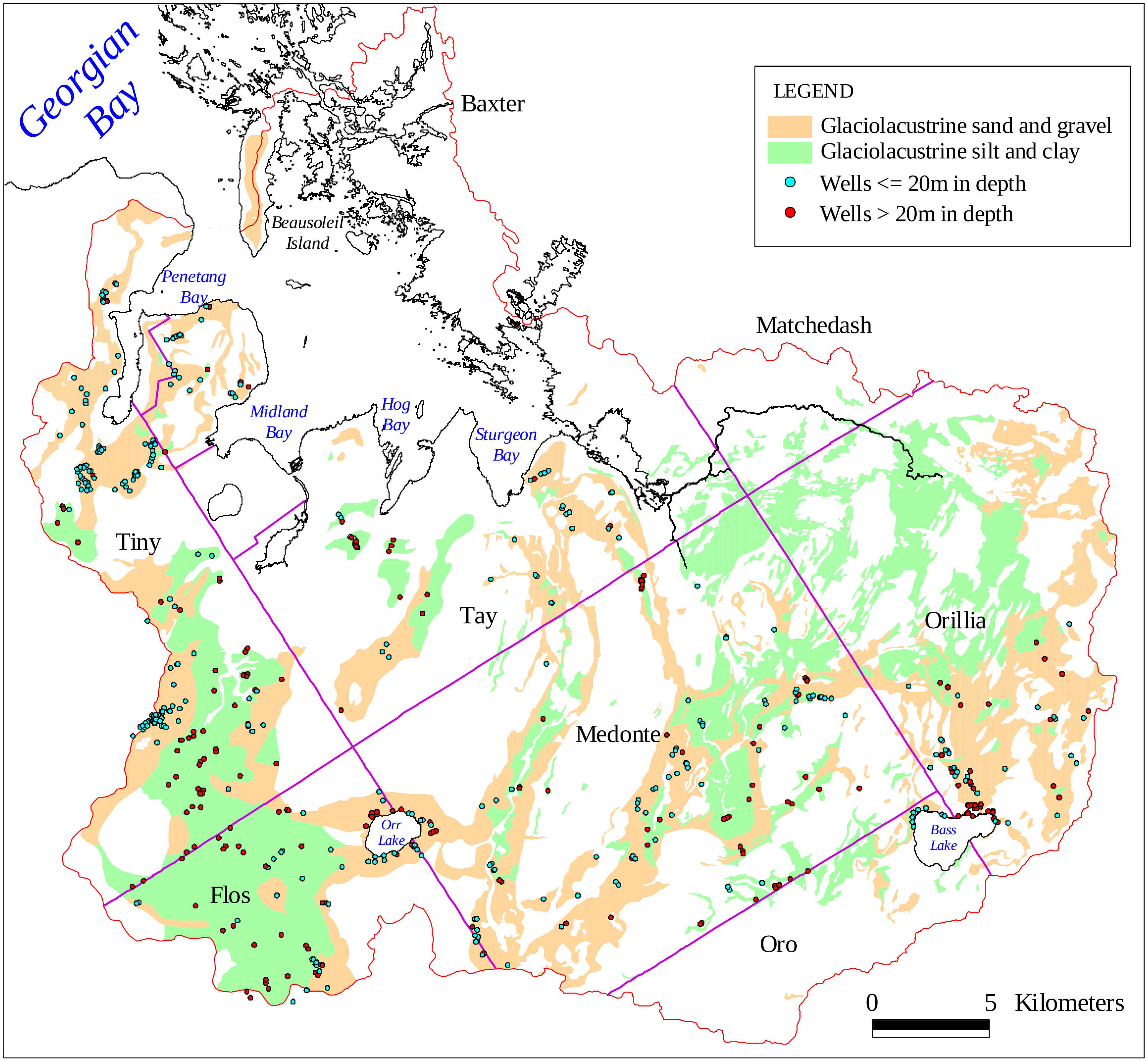


Figure 27. Areas where glaciolacustrine deposits outcrop at or near the surface.

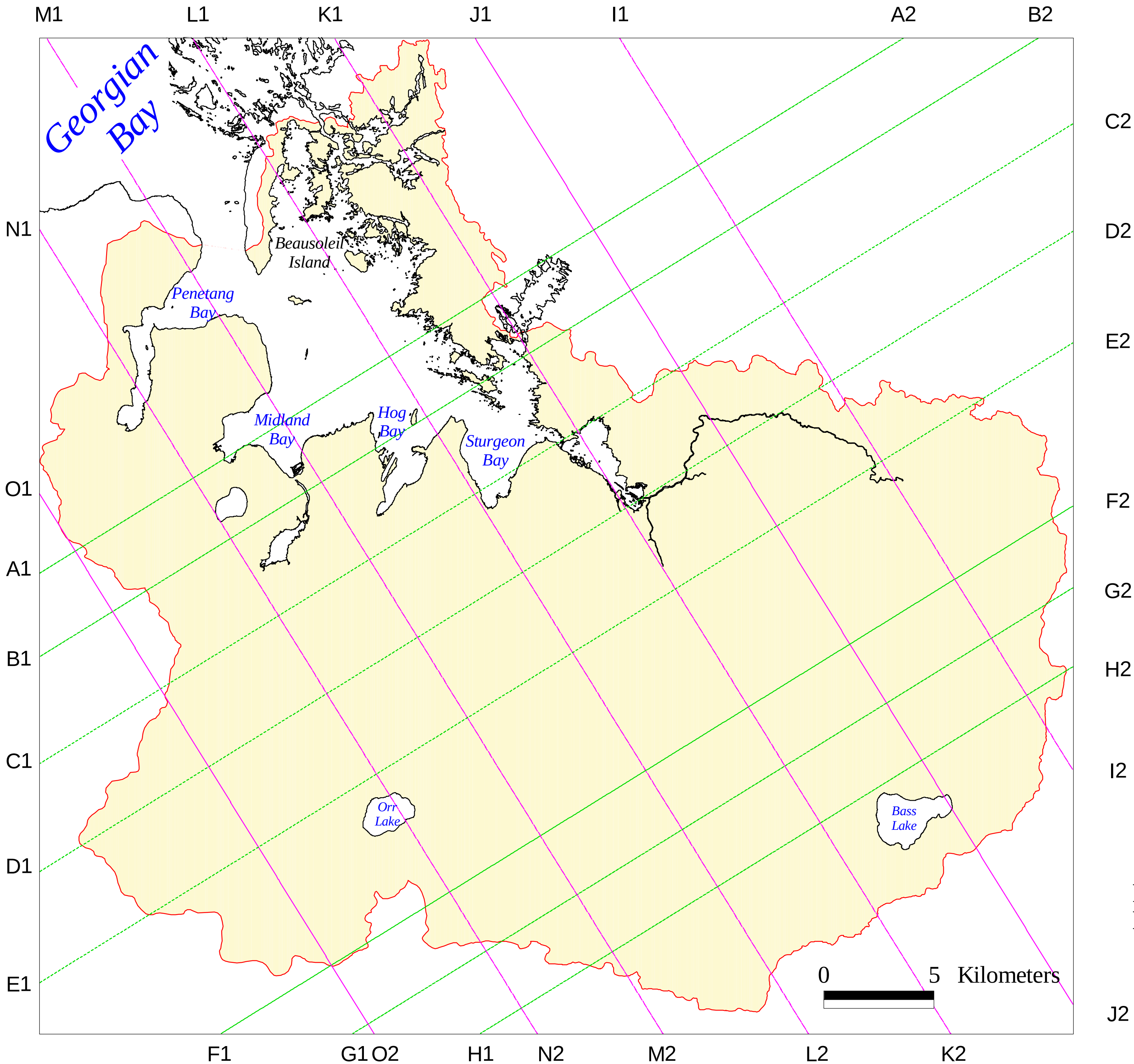


Figure 28.
Location of cross-sections.

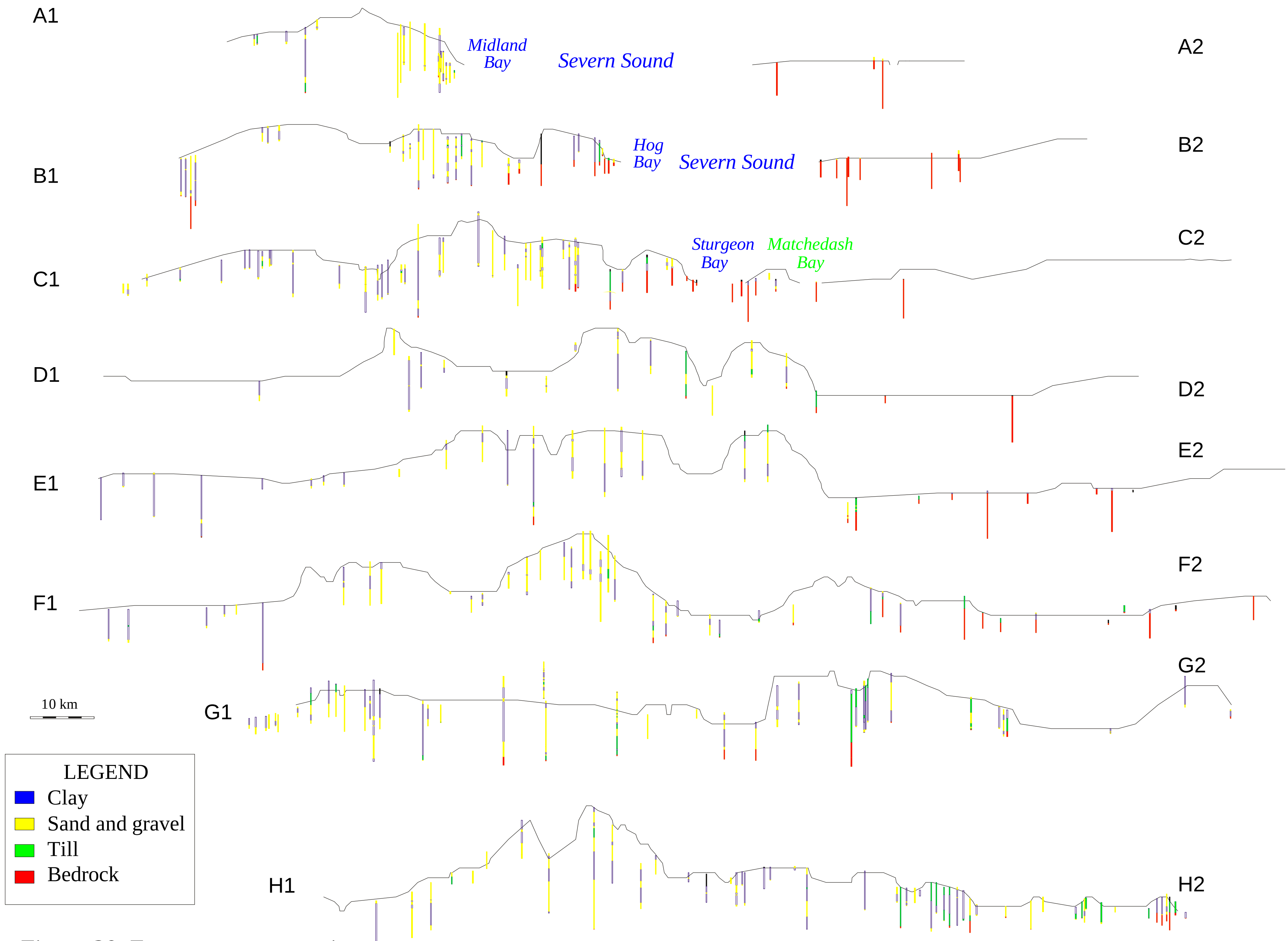


Figure 29. East-west cross-sections.

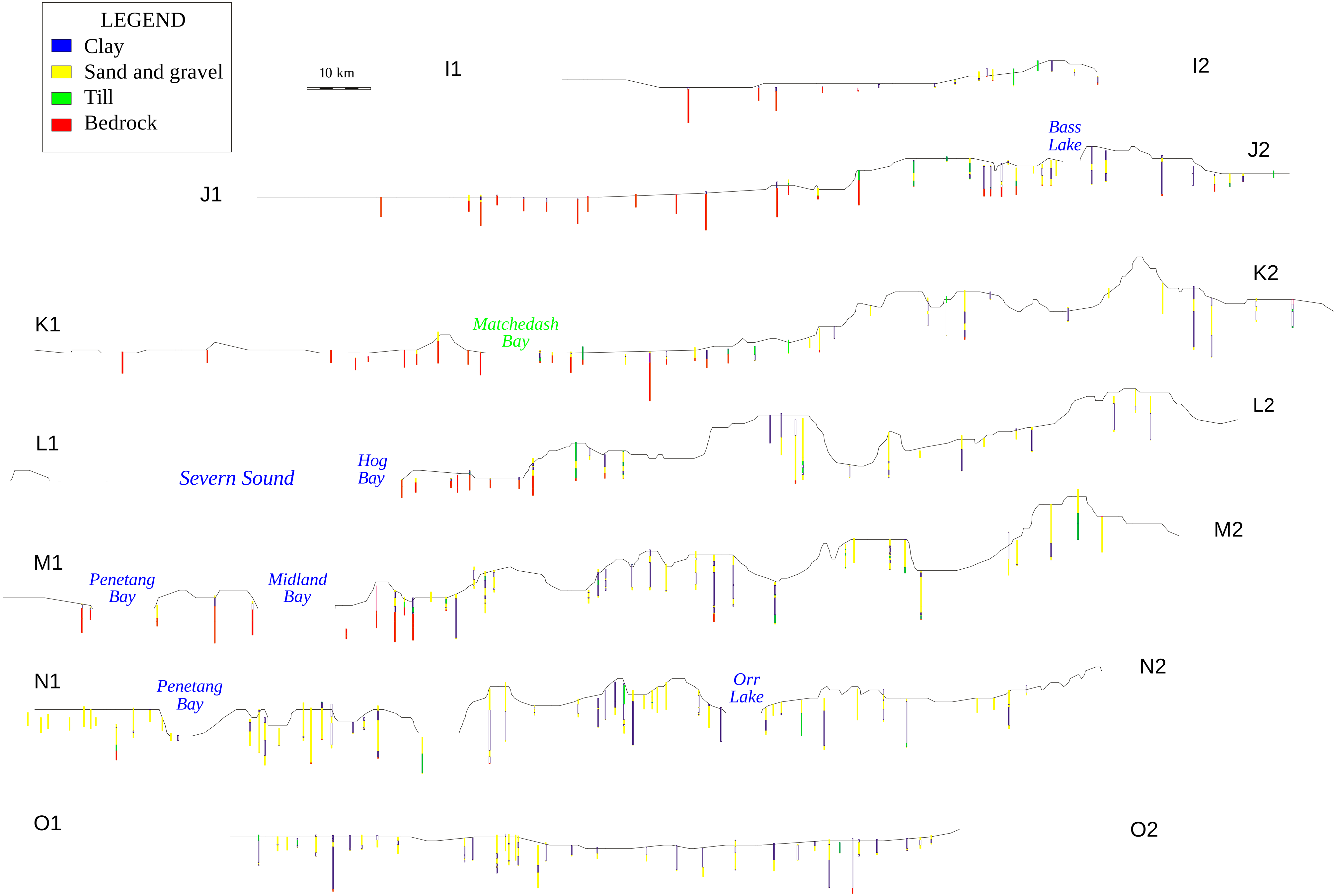


Figure 30. North-south cross-sections.

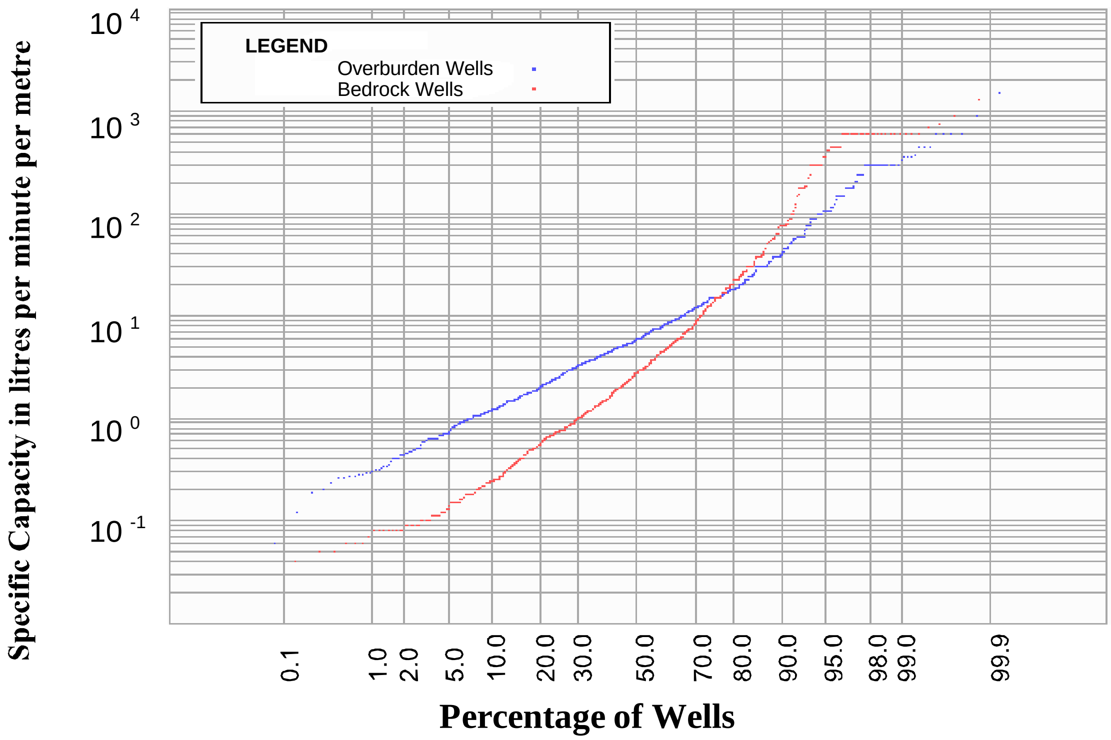


Figure 31. A comparison between the specific capacity-probability graphs for wells completed in the bedrock and the overburden.

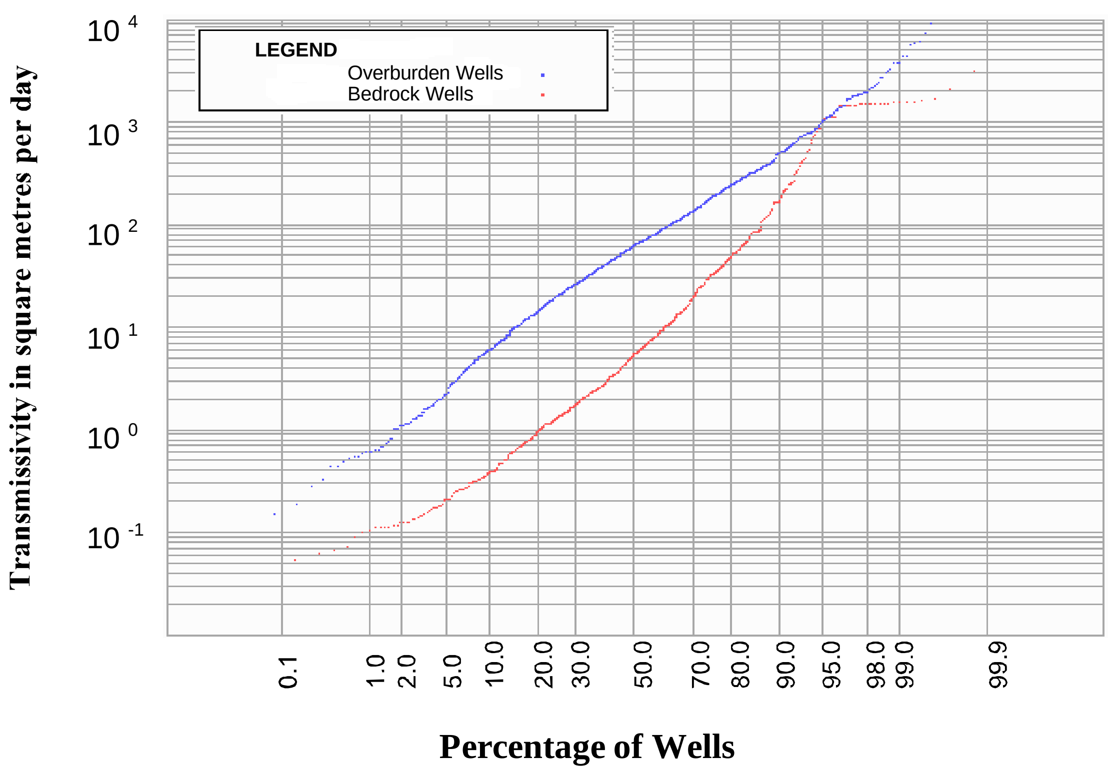


Figure 32. A comparison between the transmissivity-probability graphs for wells completed in the bedrock and the overburden.

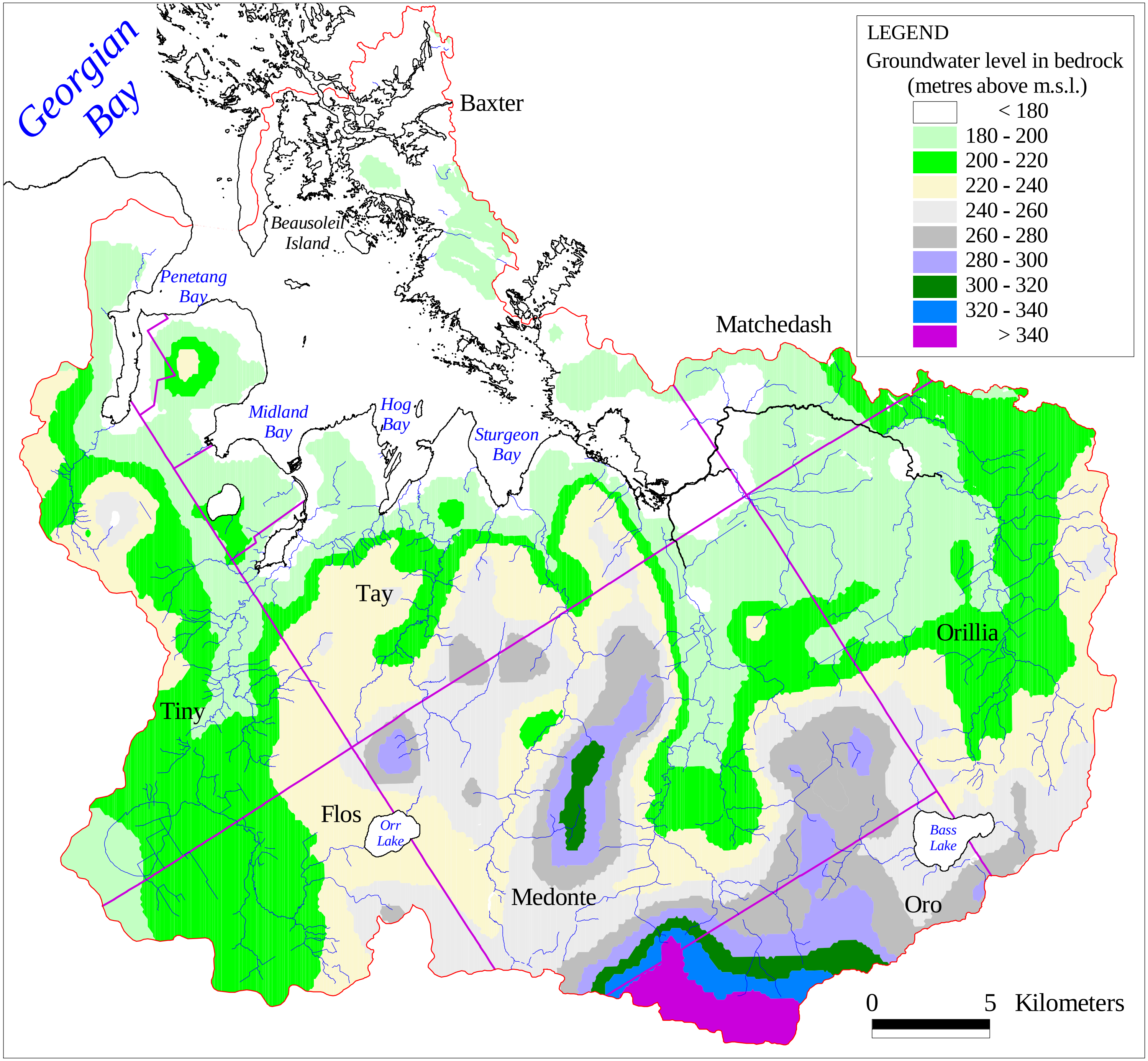


Figure 33. Groundwater level in the bedrock within the study area.

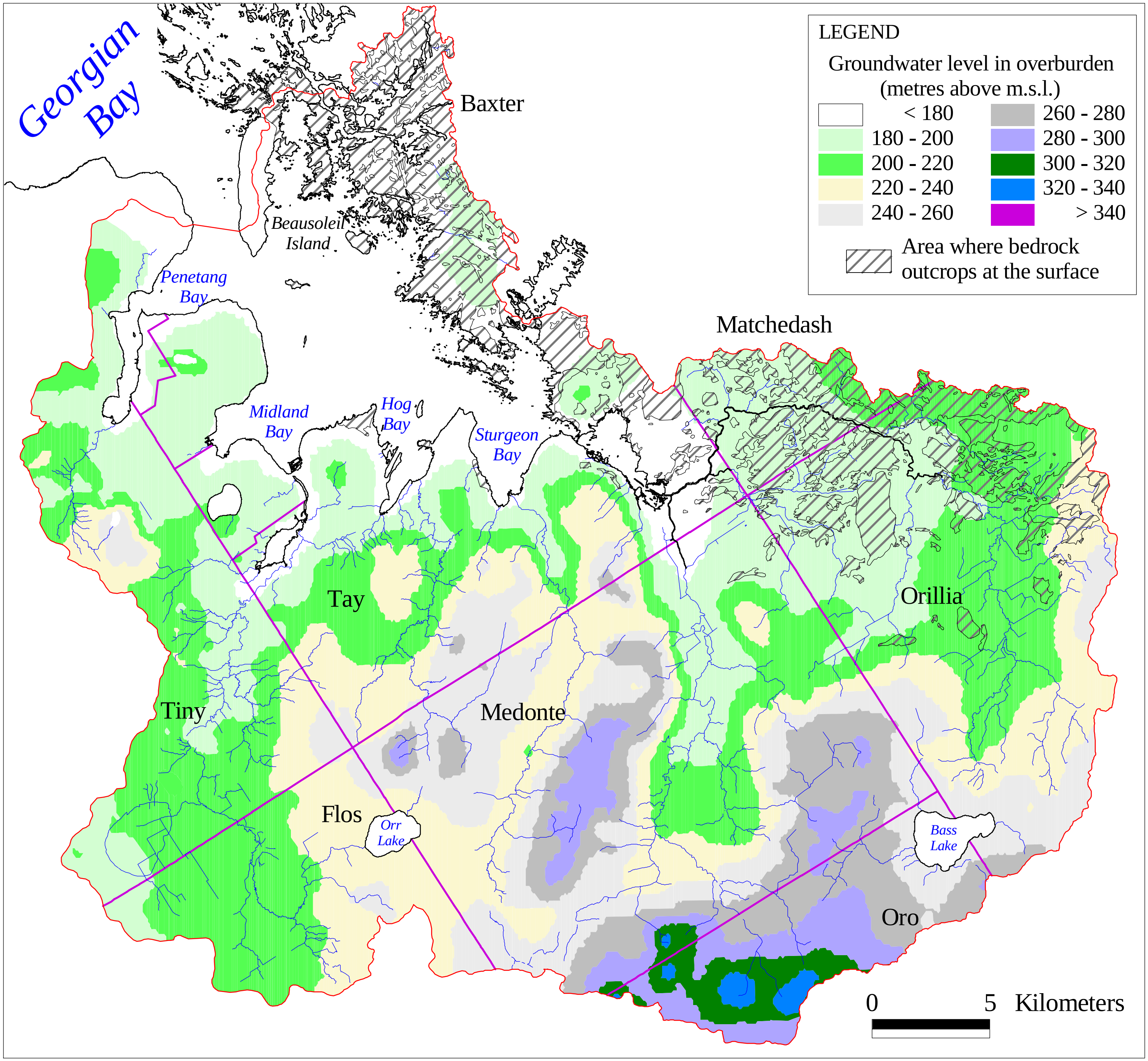


Figure 34. Groundwater level in the overburden within the study area.

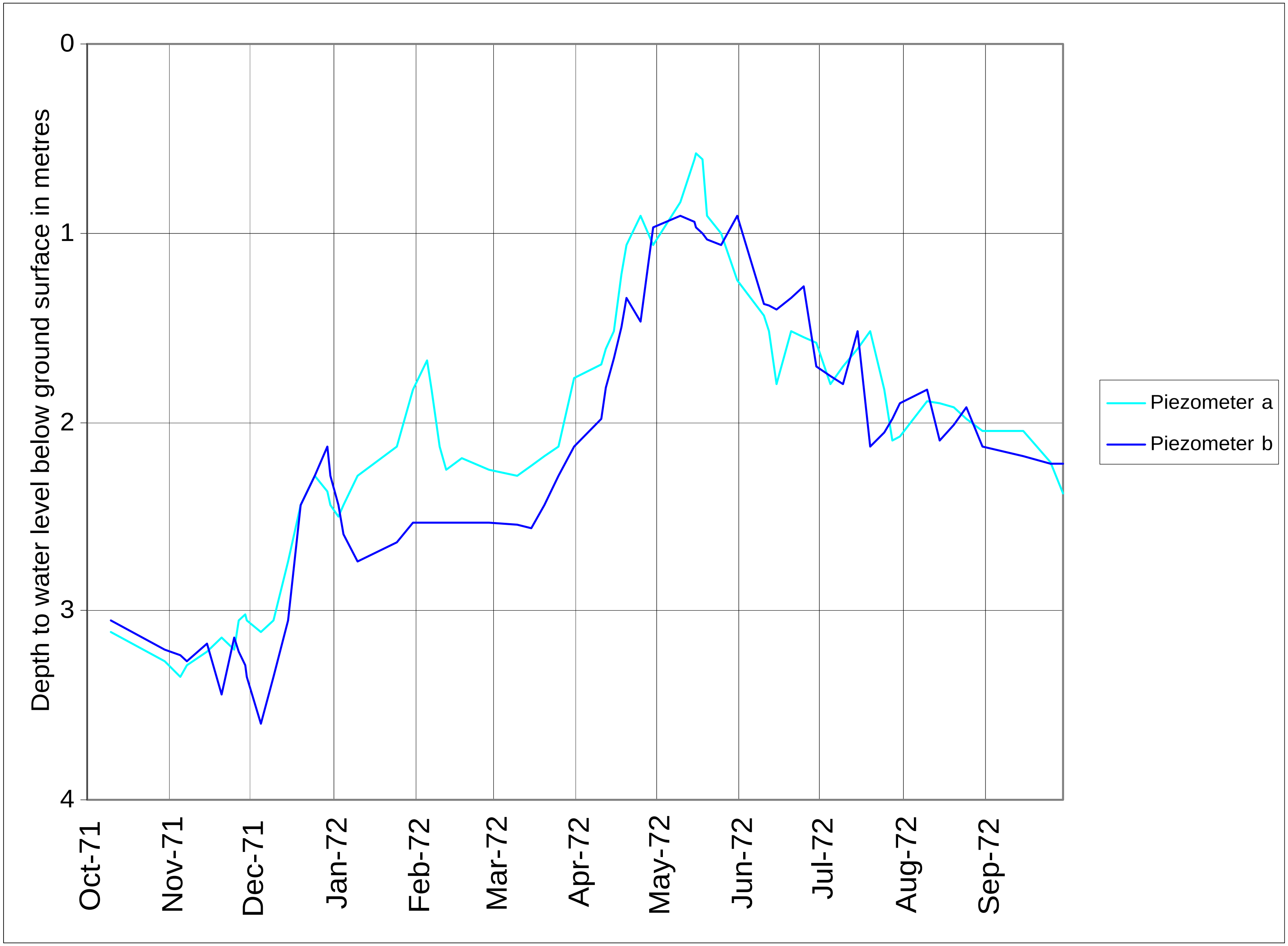


Figure 35 Hydrographs of water level fluctuations in observation well W-5A (piezometers a and b) during water year 1971-1972 (from Singer, 1974)

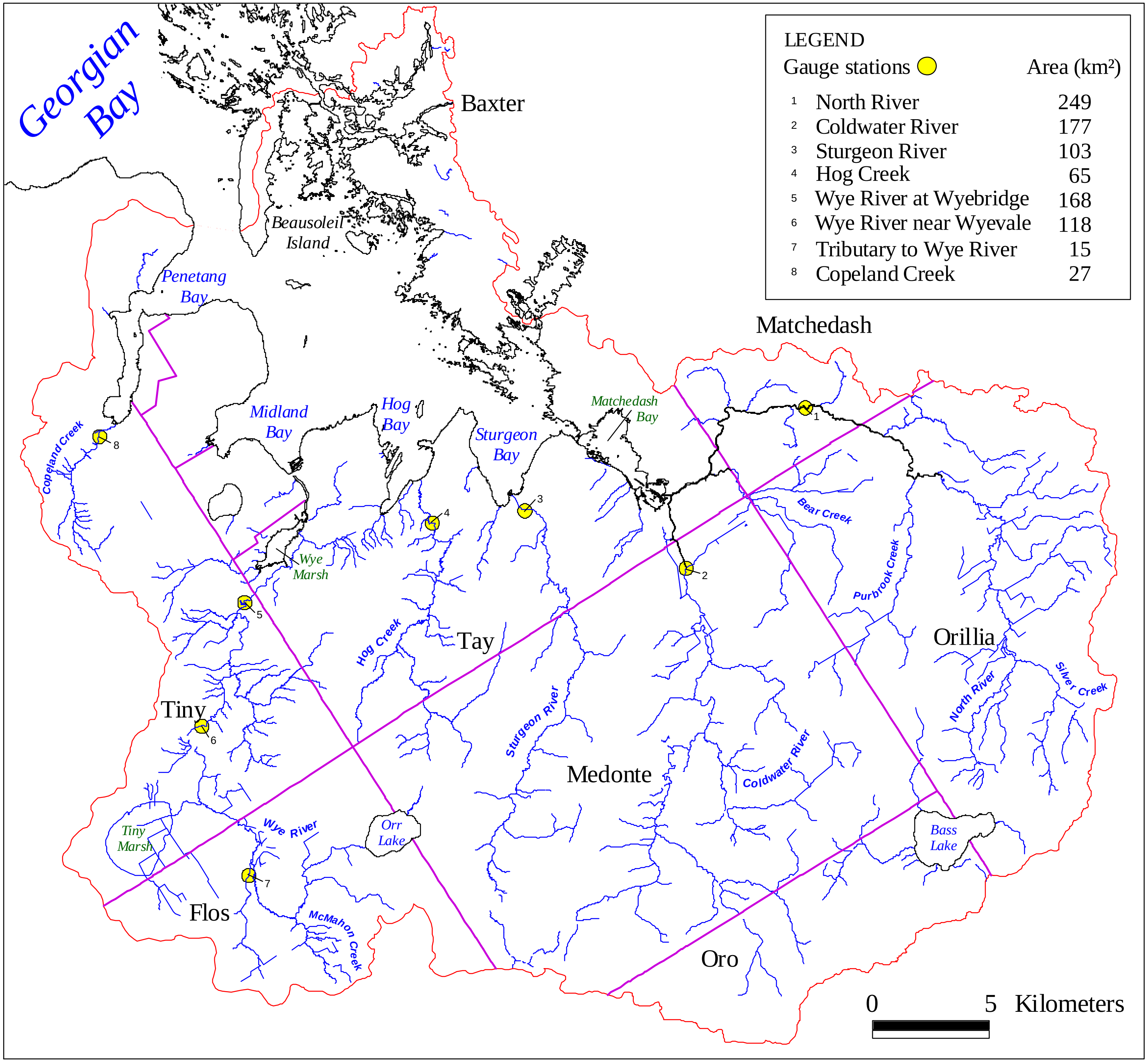


Figure 36. Locations of hydrometric gauging stations within the study area.

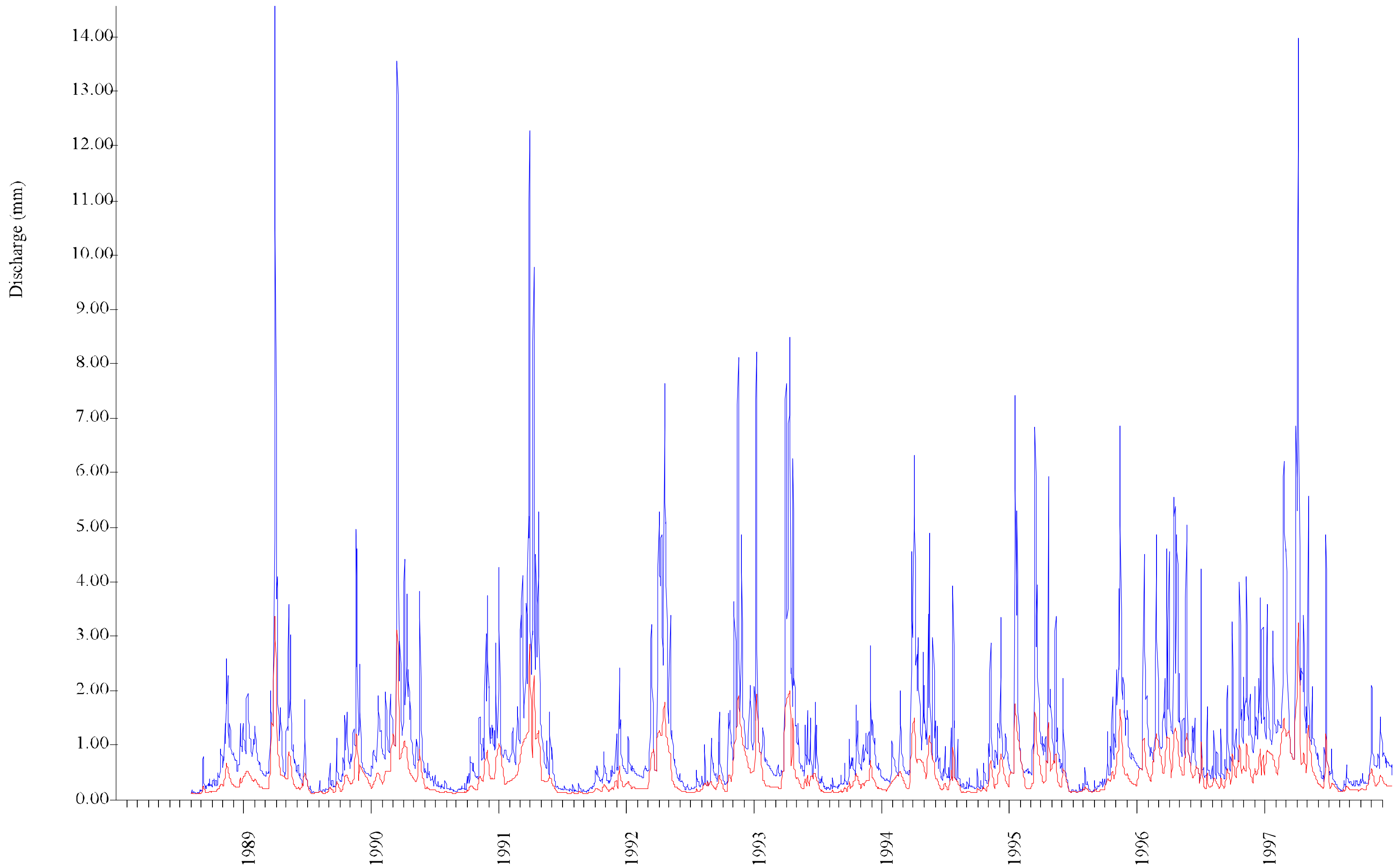


Figure 37. Streamflow separation hydrograph for station 02ED024 on the North River (1988 - 1997).

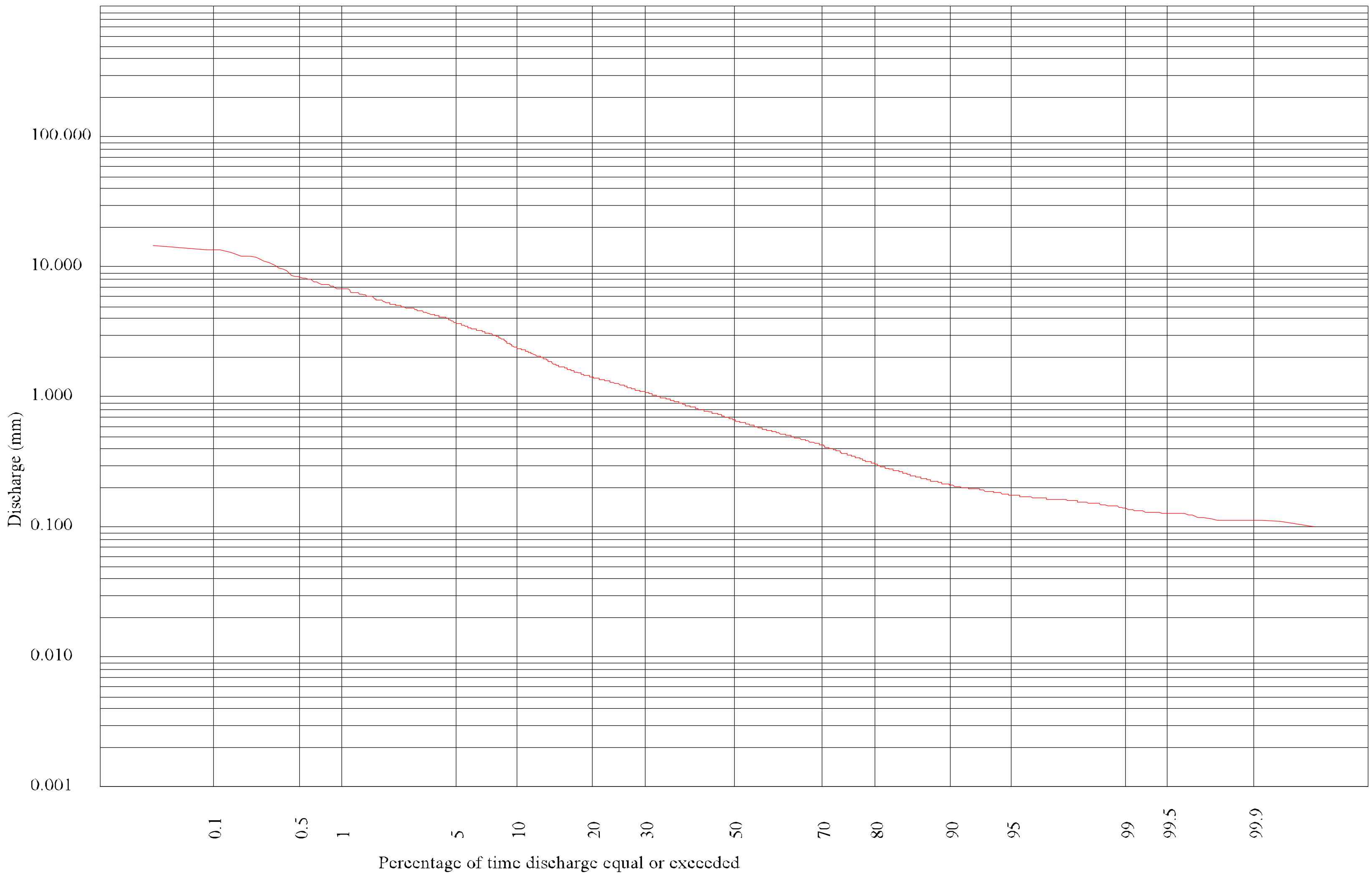


Figure 38. Flow duration graph for station 02ED024 on the North River (1988 - 1997).

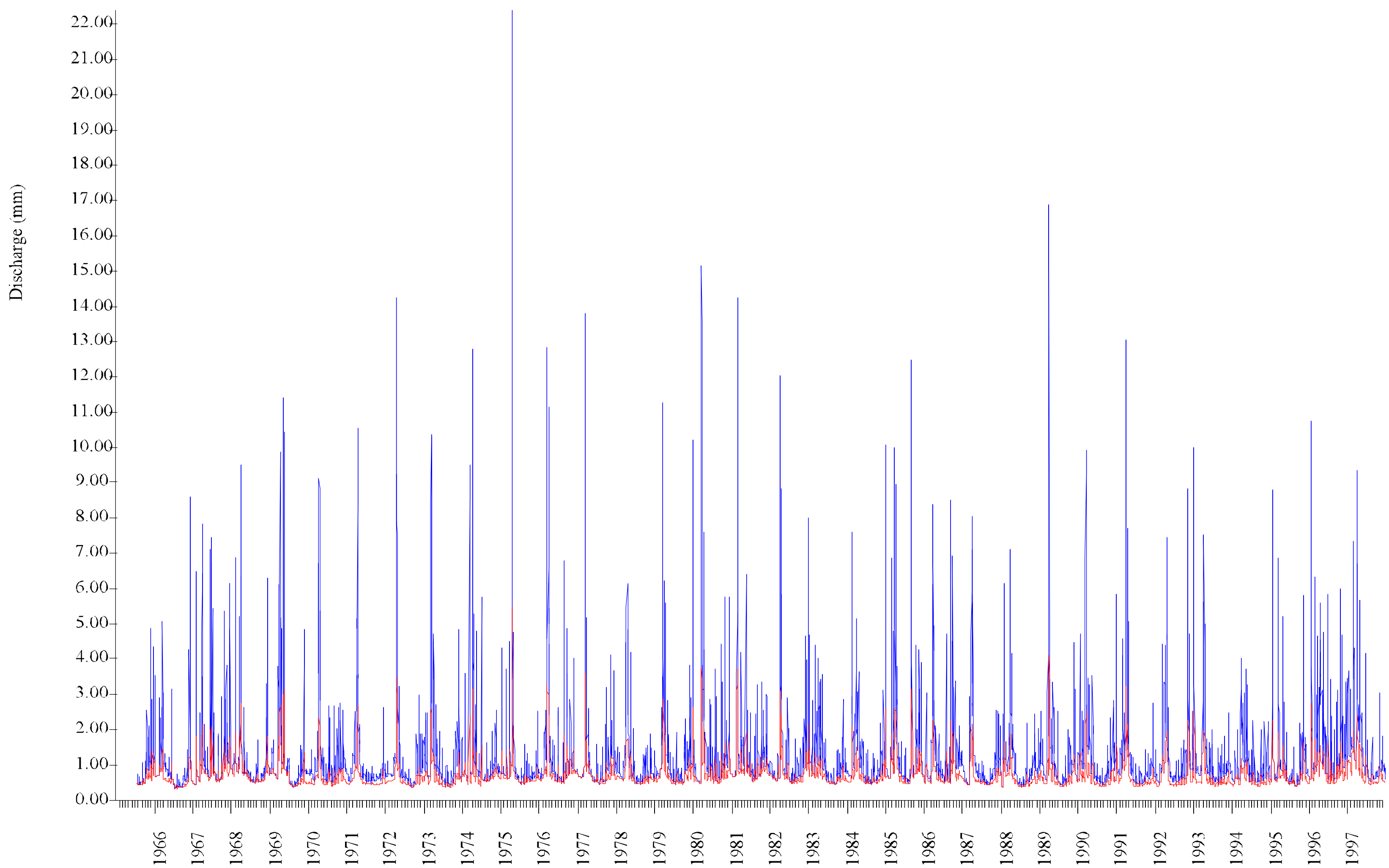


Figure 39. Streamflow separation hydrograph for station 02ED007 on the Coldwater River (1965 - 1997).

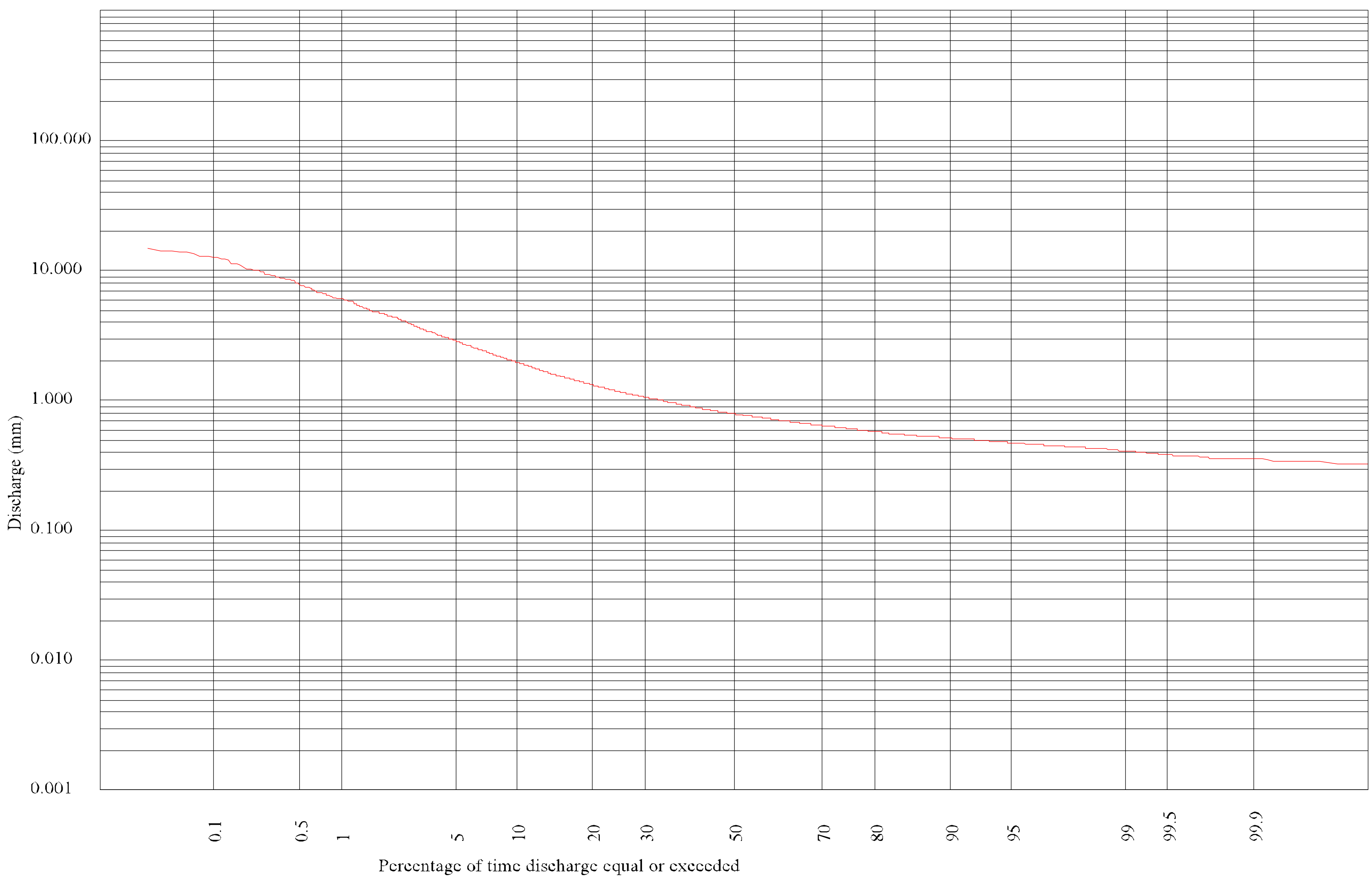


Figure 40. Flow duration graph for station 02ED007 on the Coldwater River (1965 - 1997).

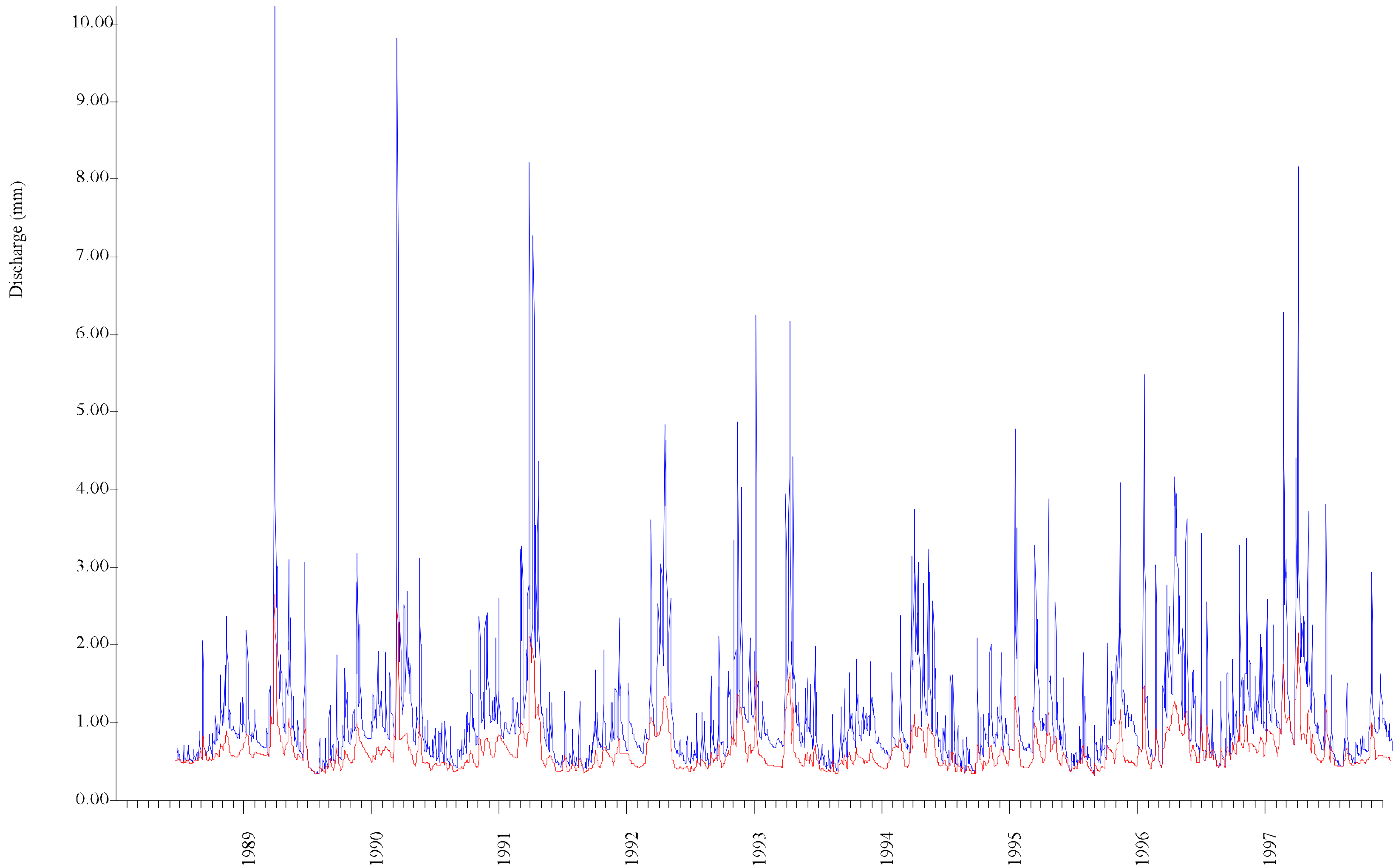


Figure 41. Streamflow separation hydrograph for station 02ED018 on the Sturgeon River (1988-1997).

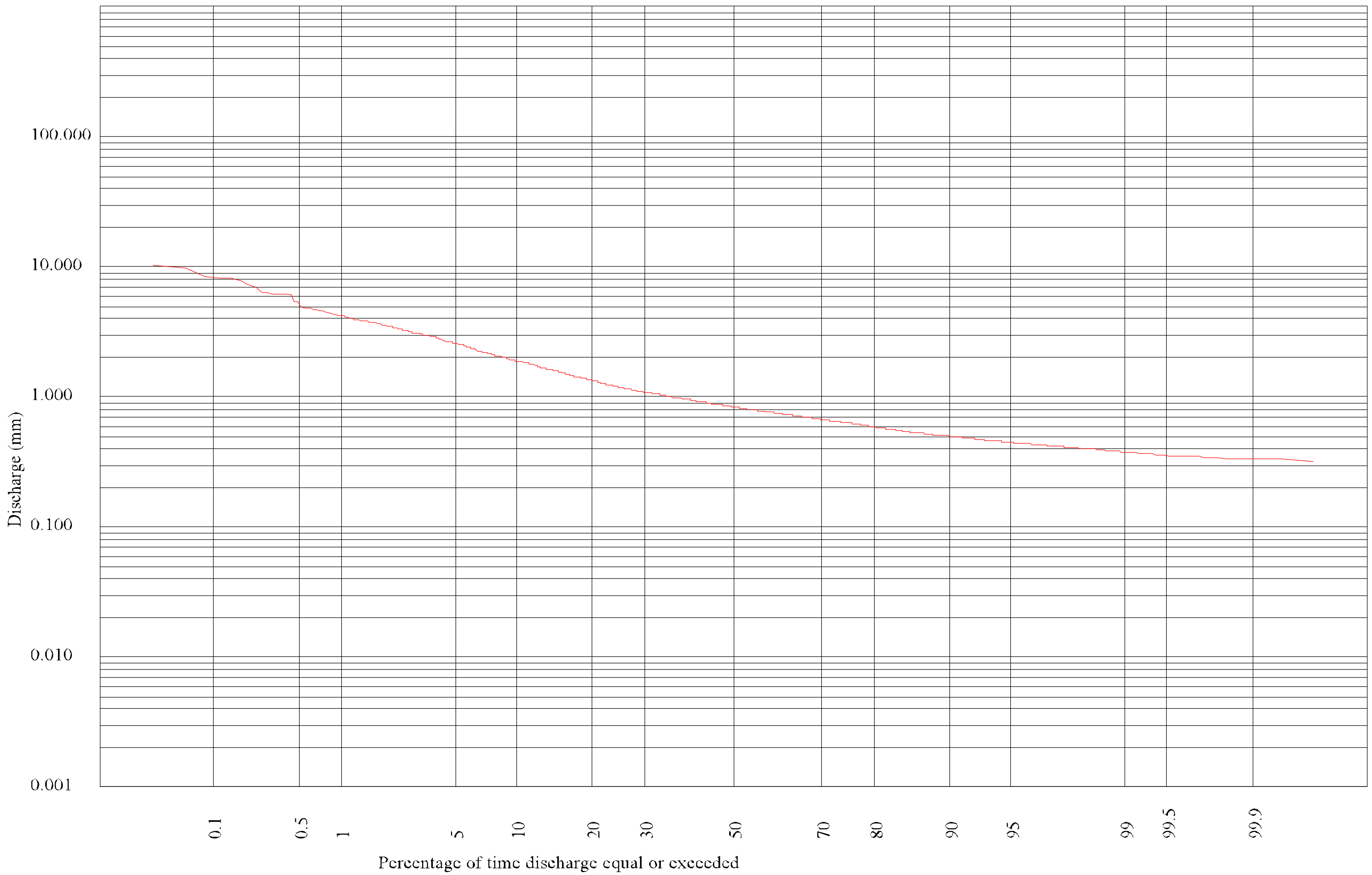


Figure 42. Flow duration graph for station 02ED018 on the Sturgeon River (1988 - 1997).

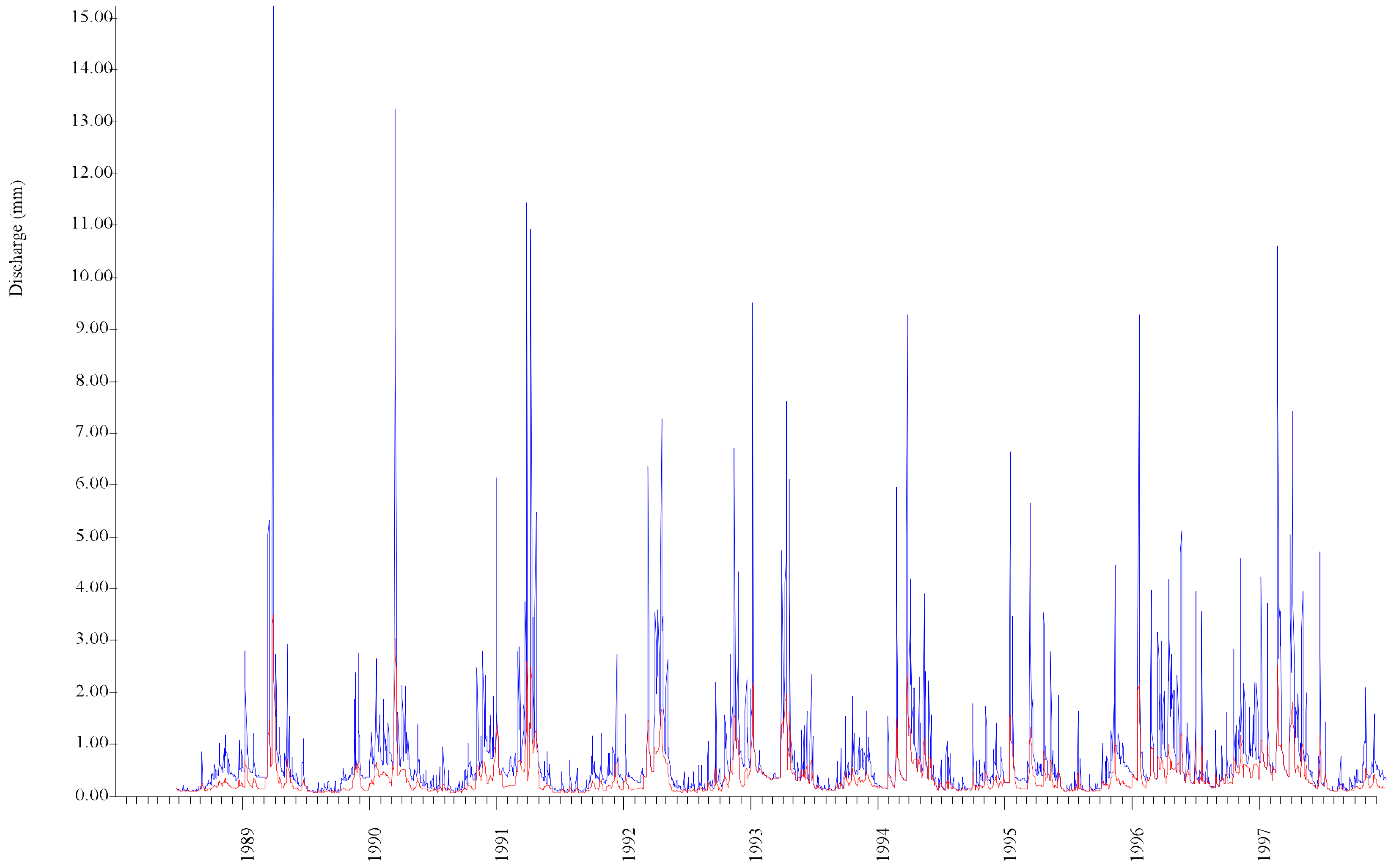


Figure 43. Streamflow separation hydrograph for station 02ED017 on Hog Creek (1988 - 1997).

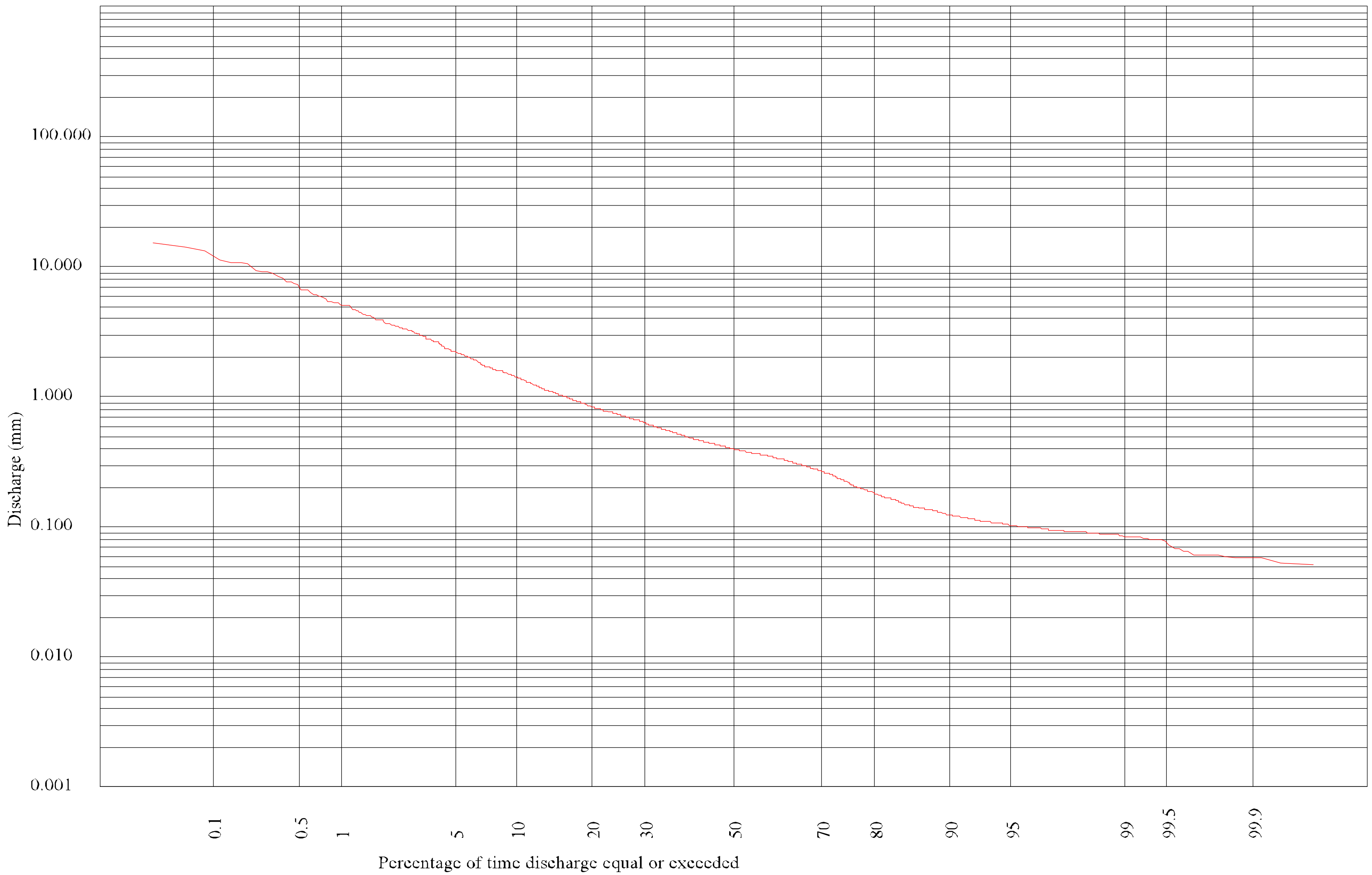


Figure 44. Flow duration graph for station 02ED017 on Hog Creek (1988-1997).

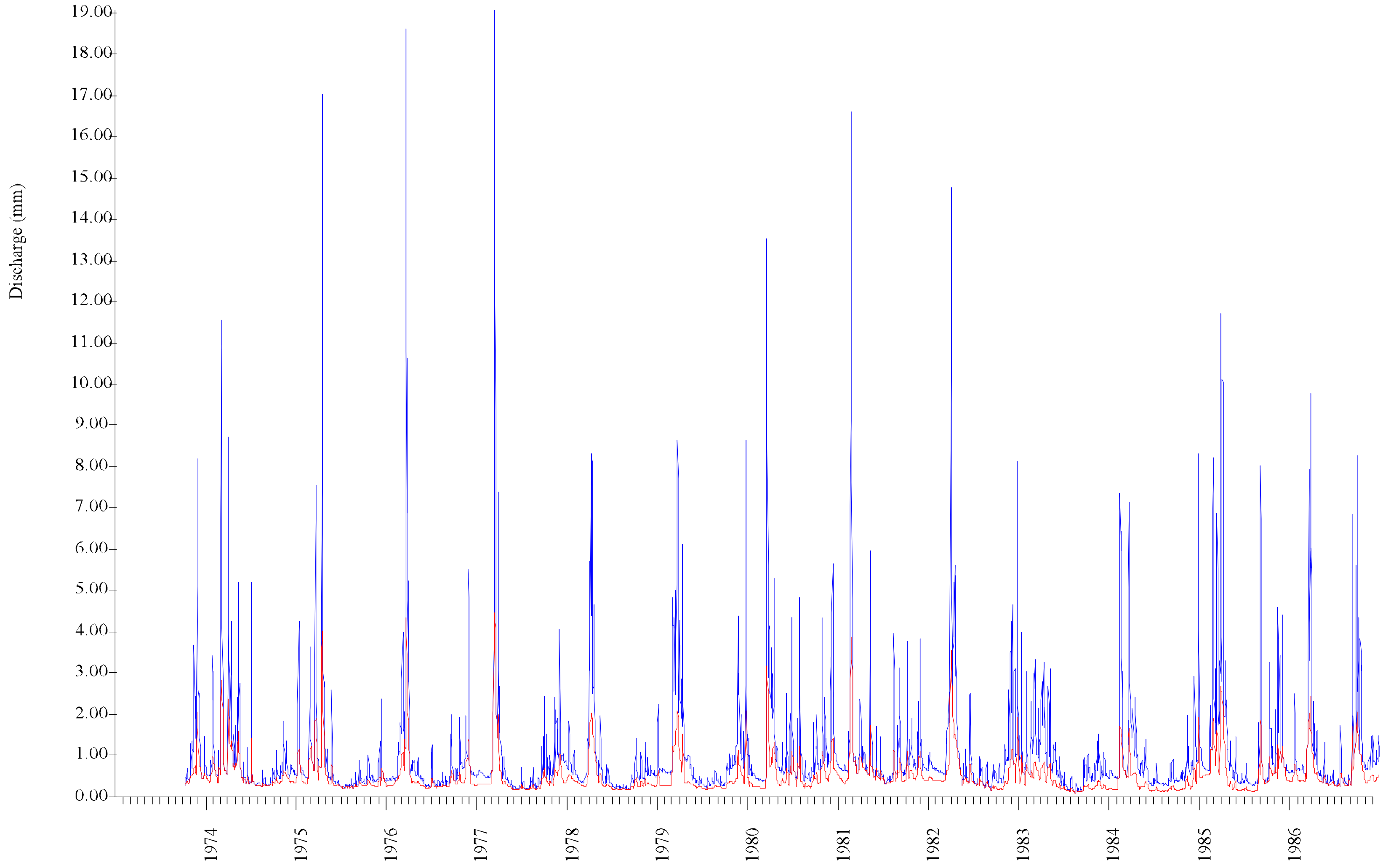


Figure 45. Streamflow separation hydrograph for station 02ED011 on the Wye River at Wyebridge (1973 - 1986).

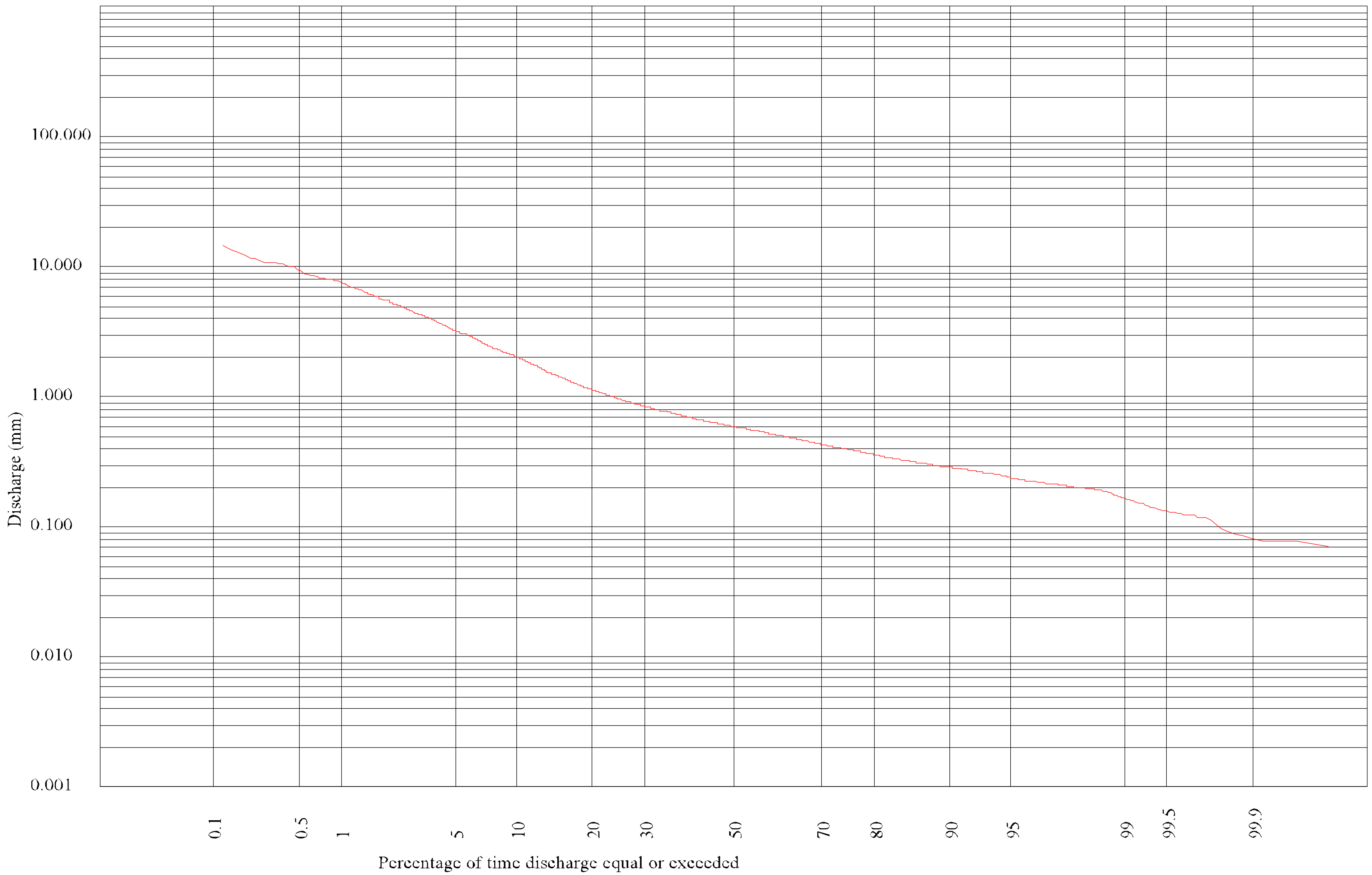


Figure 46. Flow duration graph for station 02ED011 on the Wye River at Wybridge (1973 - 1986).

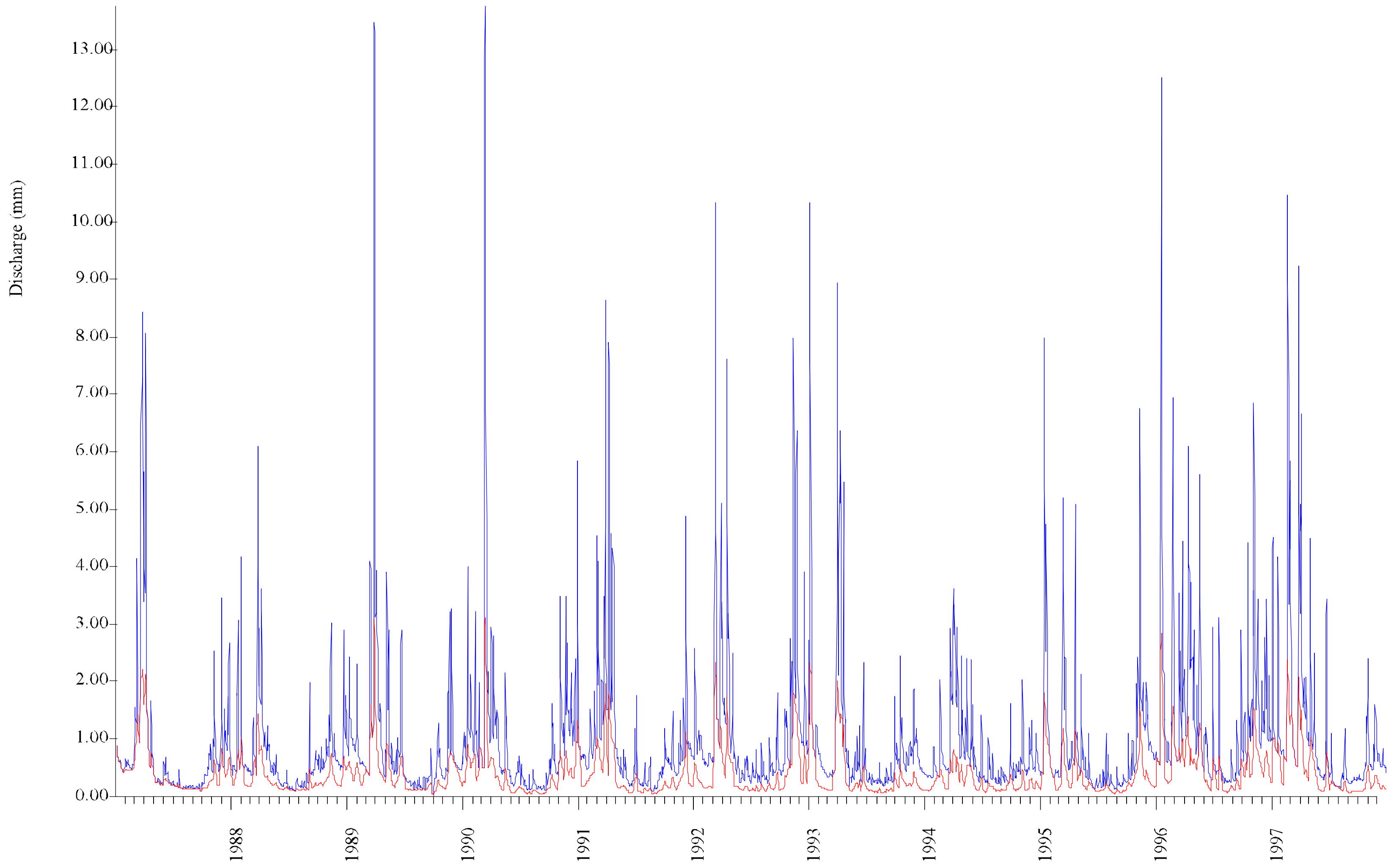


Figure 47. Streamflow separation hydrograph for station 02ED013 on the Wye River near Wyevale (1987-1997).

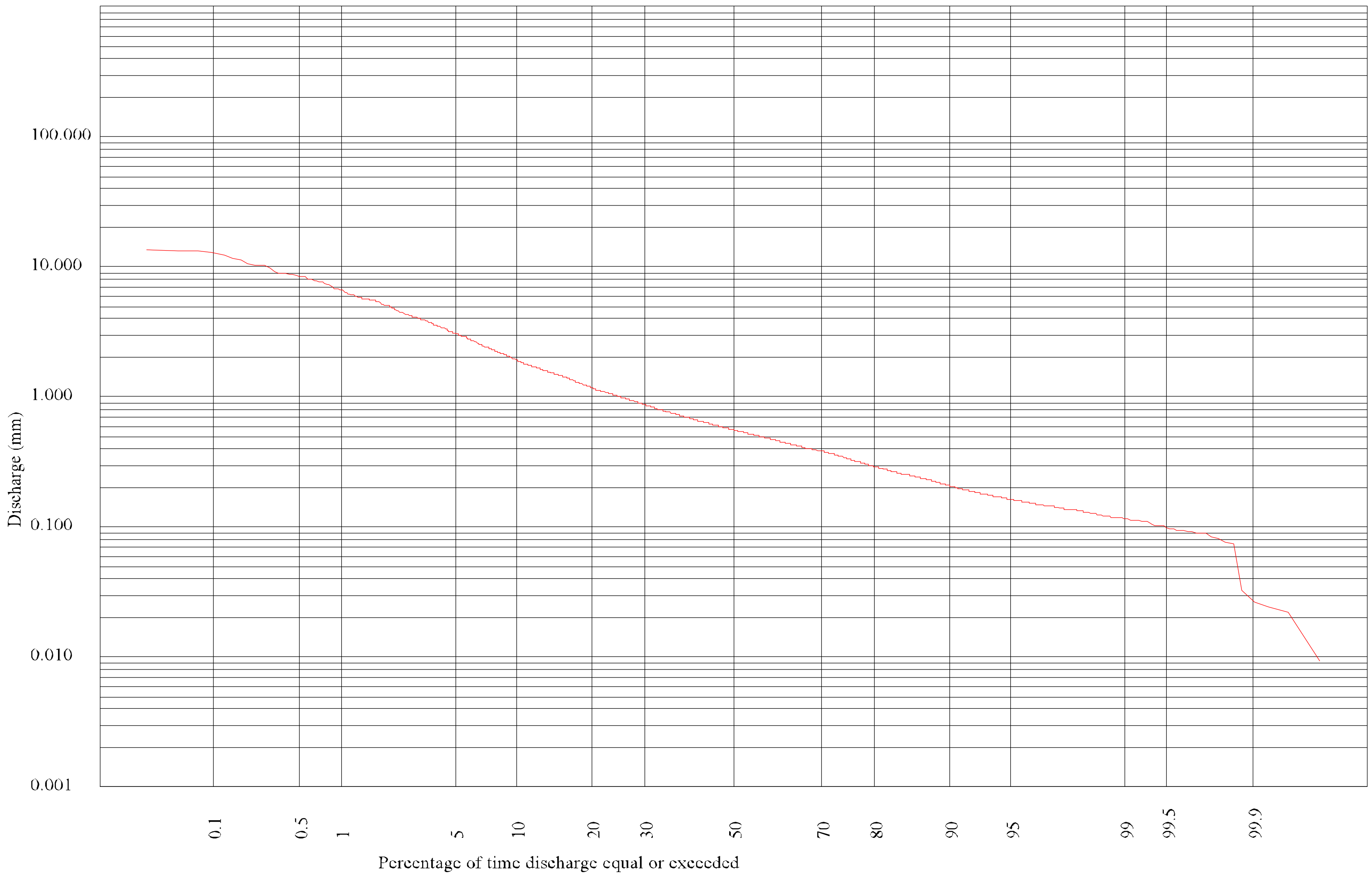


Figure 48. Flow duration graph for station 02ED013 on the Wye River near Wyevale (1987 - 1997).

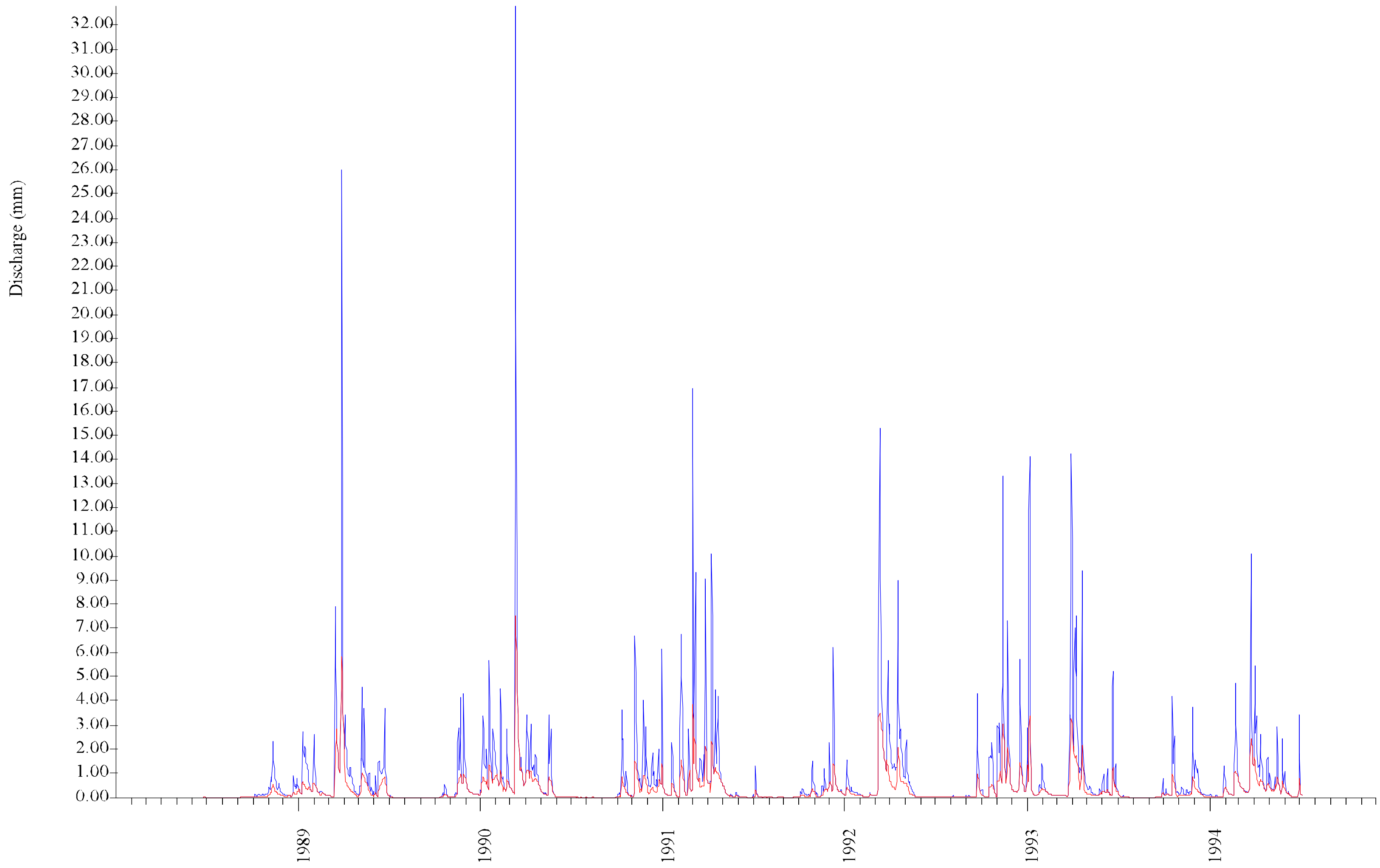


Figure 49. Streamflow separation hydrograph for station 02ED016 on a tributary to the Wye River below Elmvale (1988 -1994).

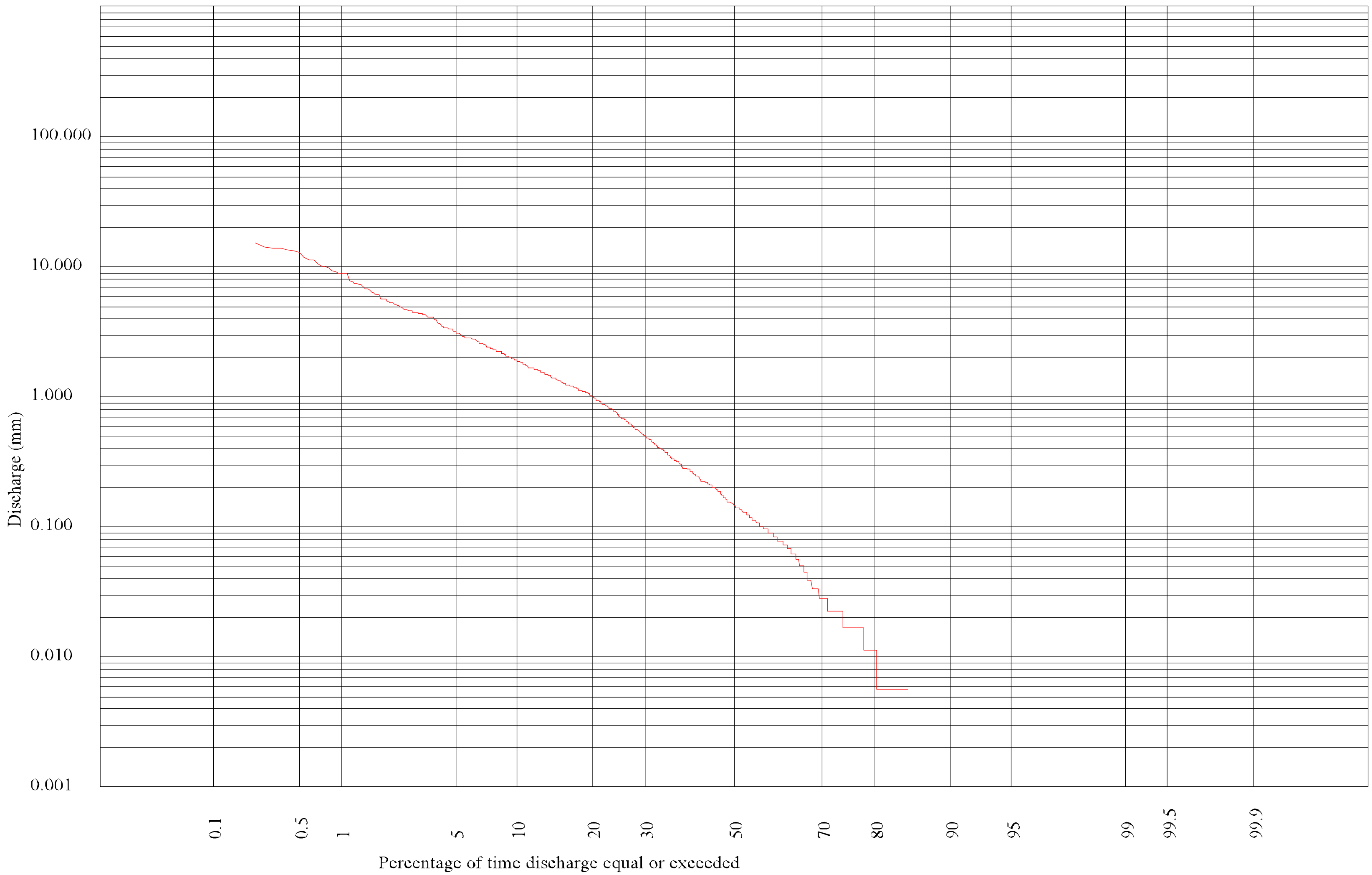


Figure 50. Flow duration graph for station 02ED016 on a tributary to the Wye River below Elmvale (1988 - 1994).

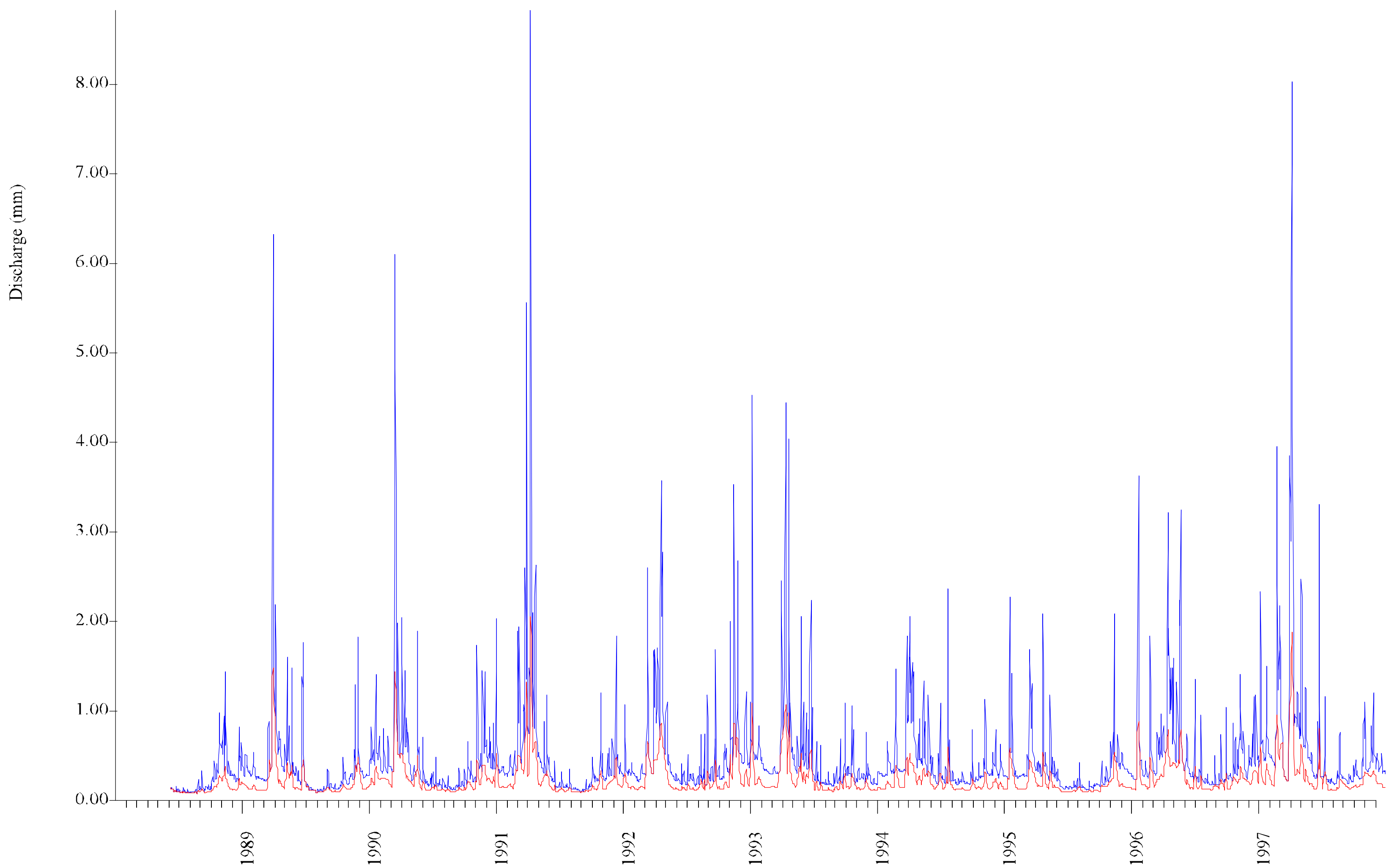


Figure 51.   Streamflow separation hydrograph for station 02ED019 on Copeland Creek (1988 - 1997).

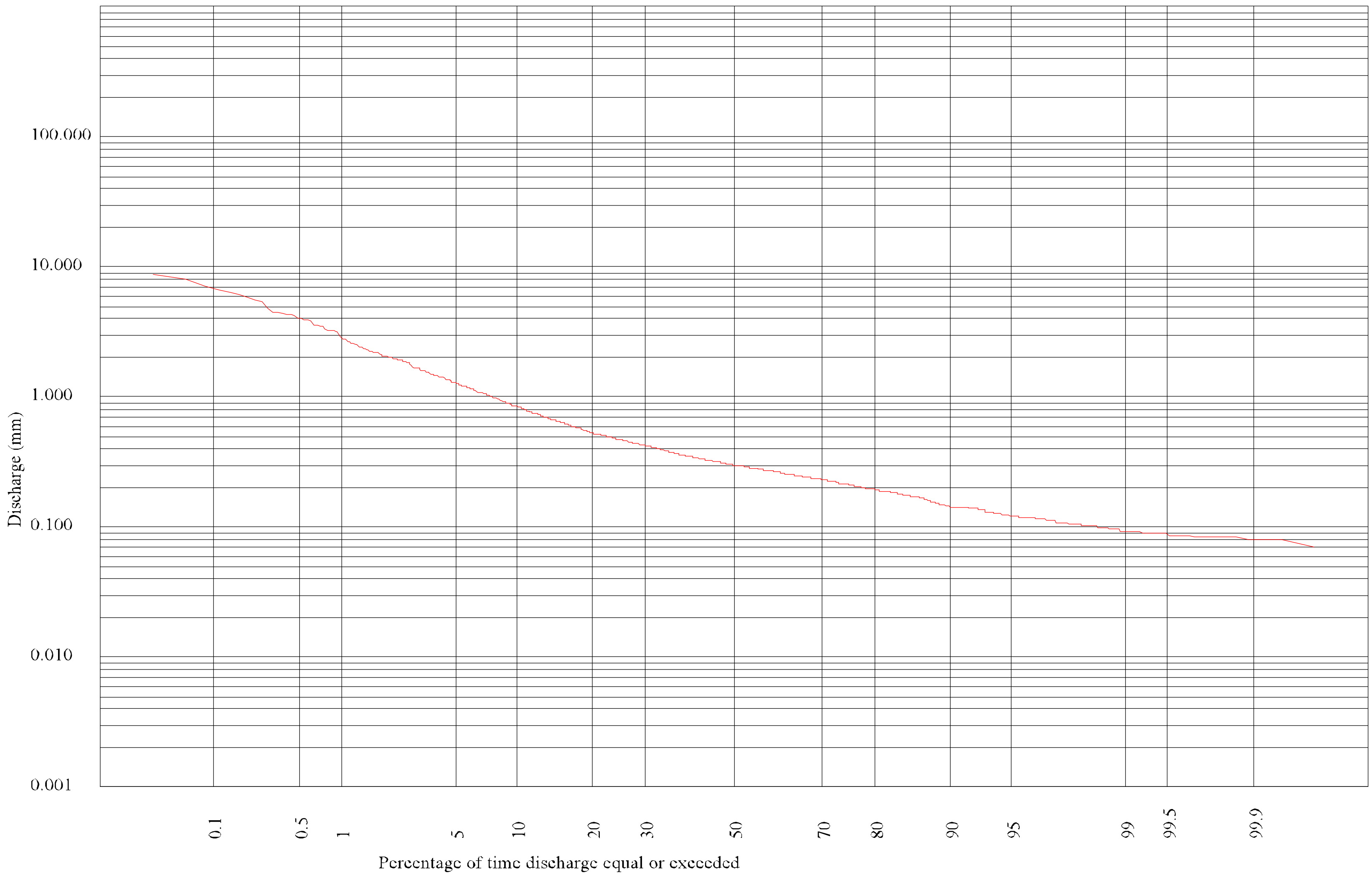


Figure 52. Flow duration graph for station 02ED019 on Copeland Creek (1988 - 1997).

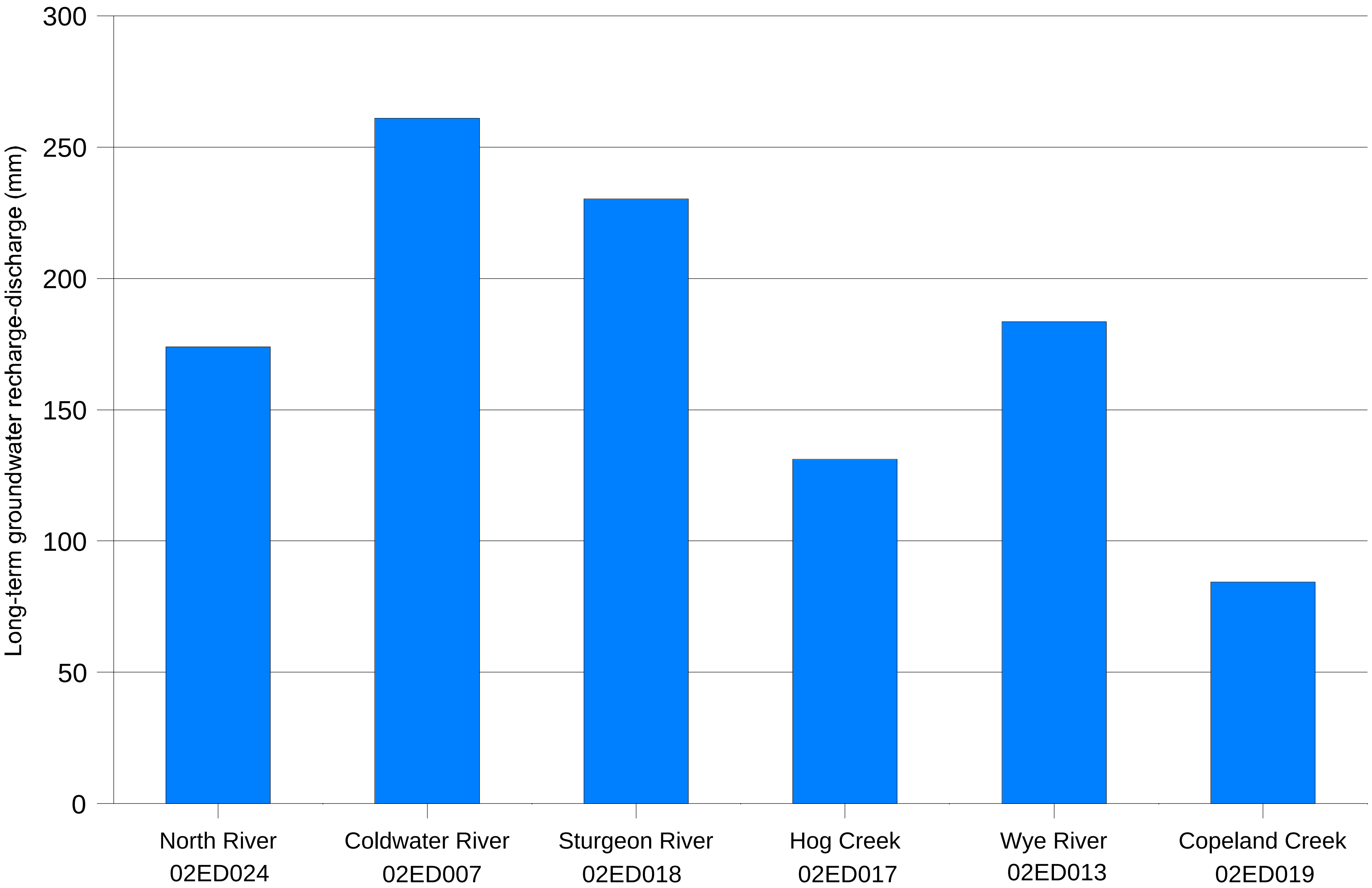


Figure 53. Variations of long-term groundwater recharge and discharge within the study area.

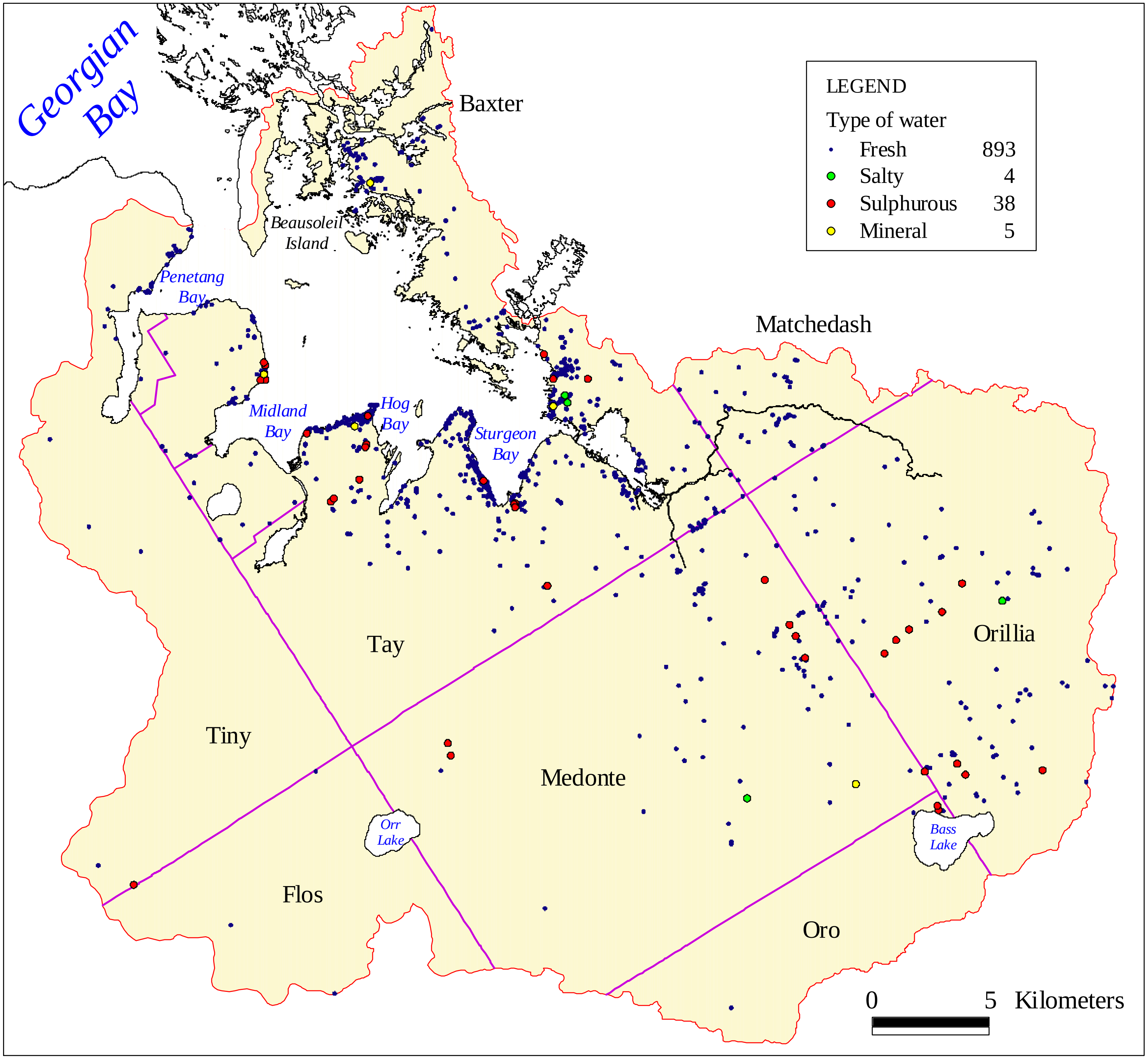


Figure 54. Water quality of bedrock wells based on well records.

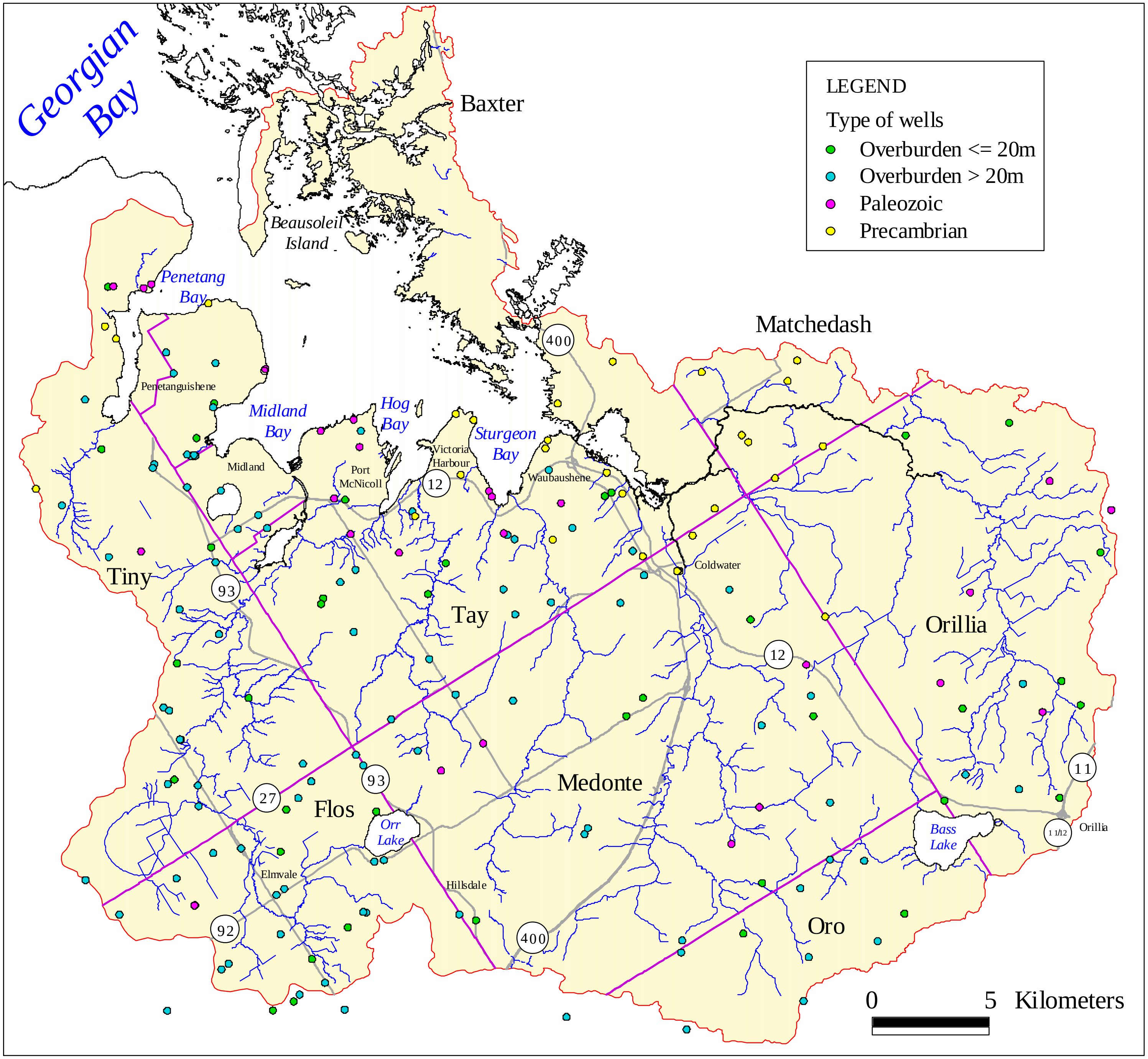


Figure 55. Locations of wells with water quality data.

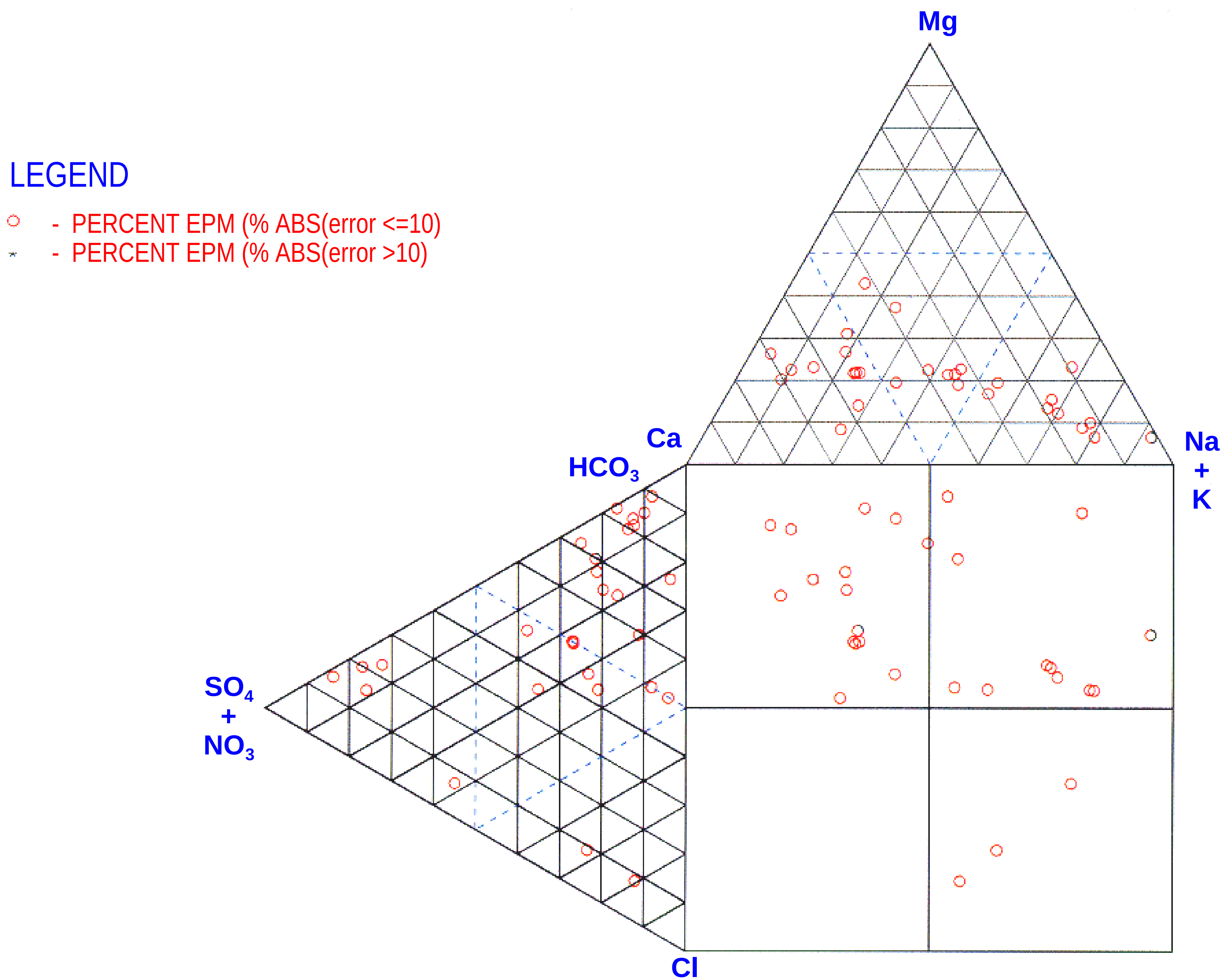


Figure 56. Chemical composition of water in wells completed in Precambrian rocks.

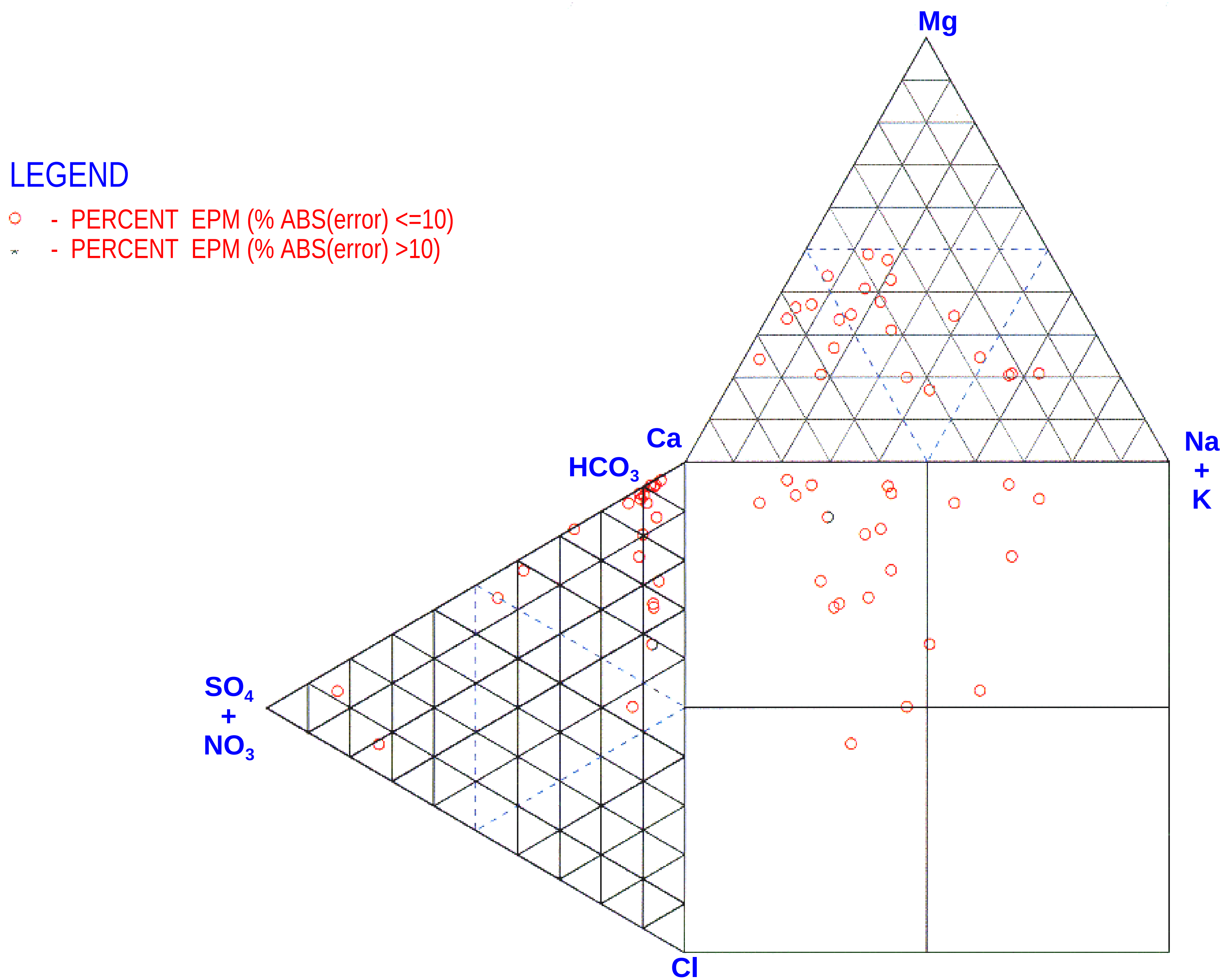


Figure 57. Chemical composition of water in wells completed in Palaeozoic rocks.

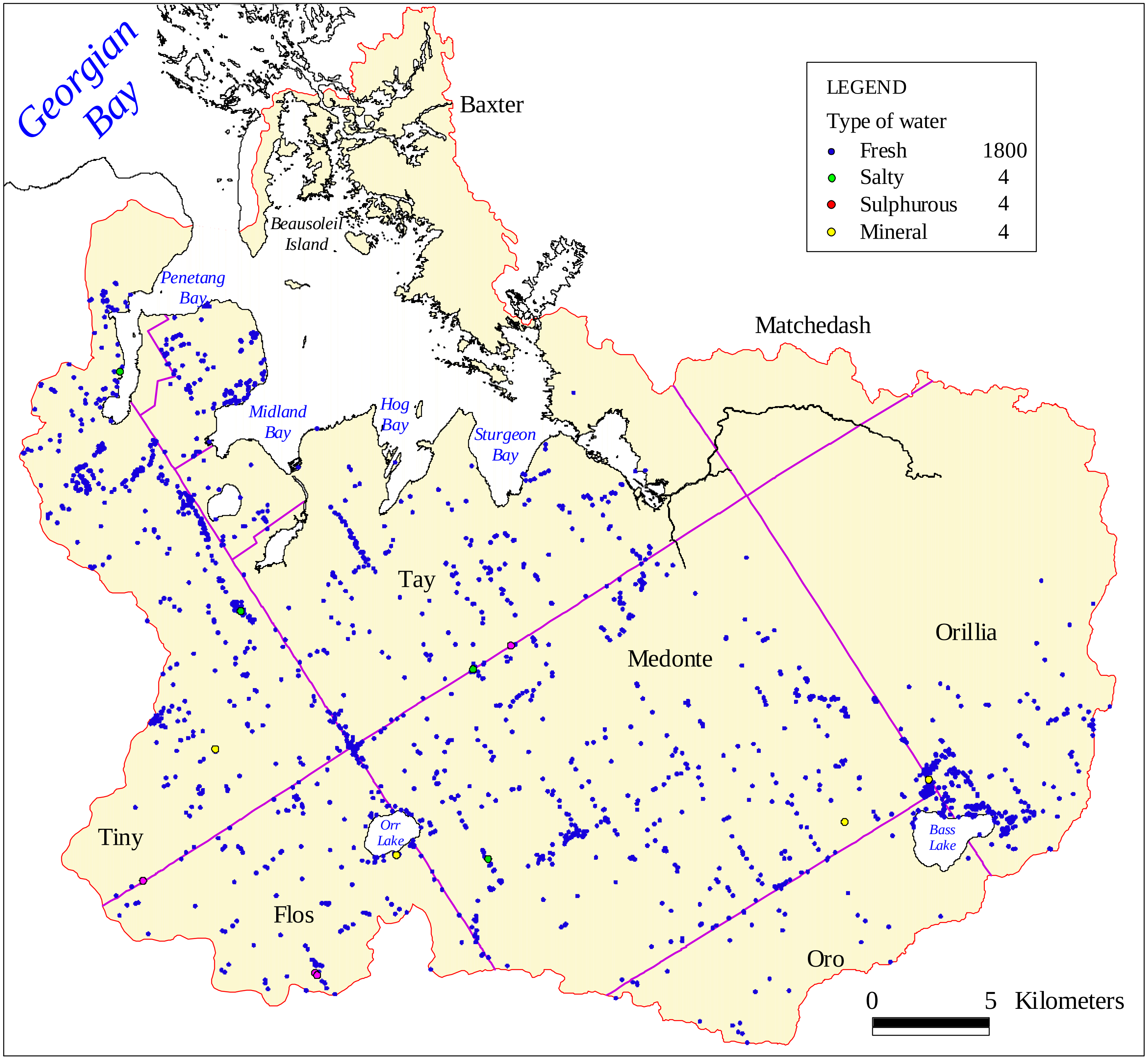


Figure 58. Water quality of overburden wells based on well records.

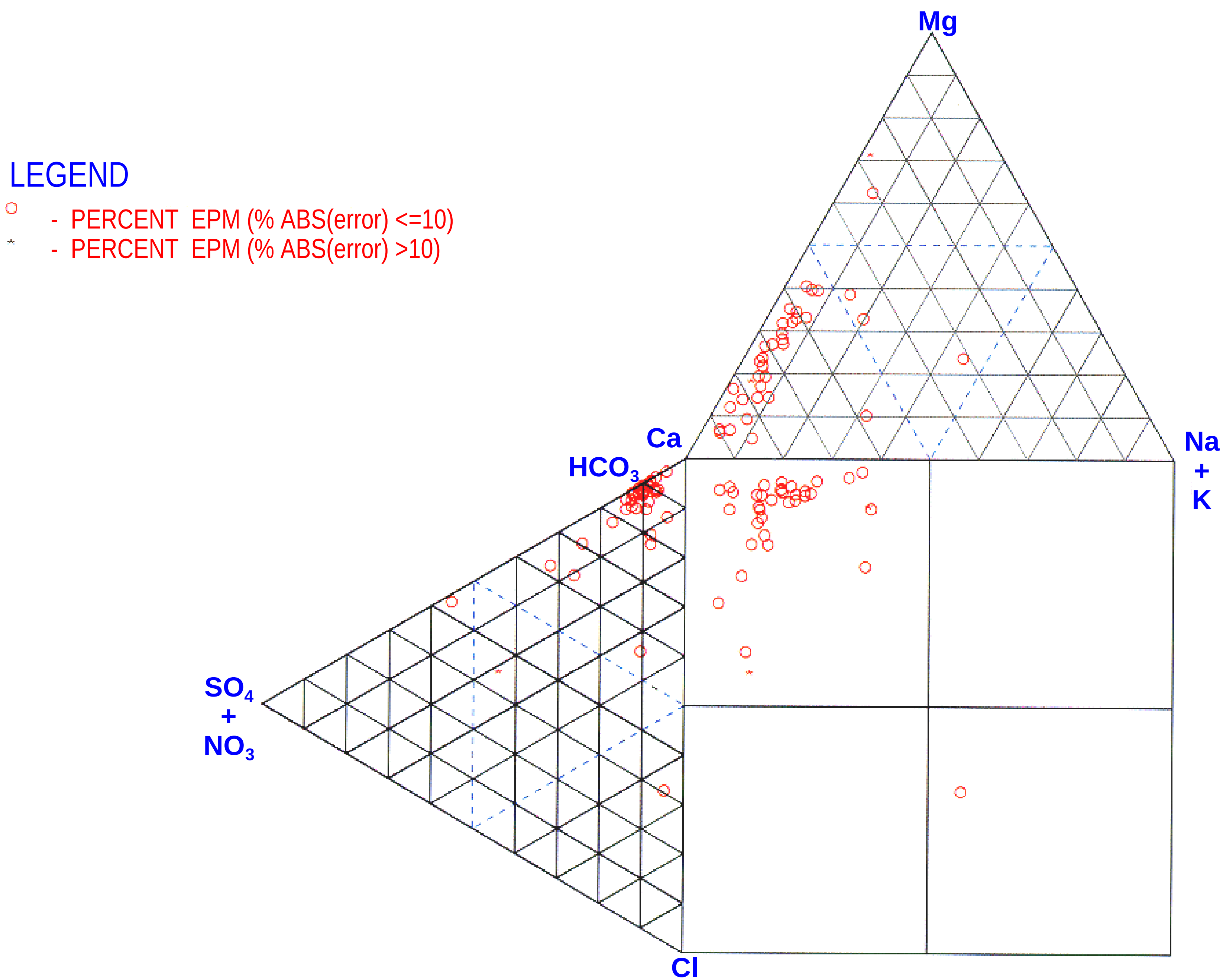


Figure 59. Chemical composition of water in shallow overburden wells.

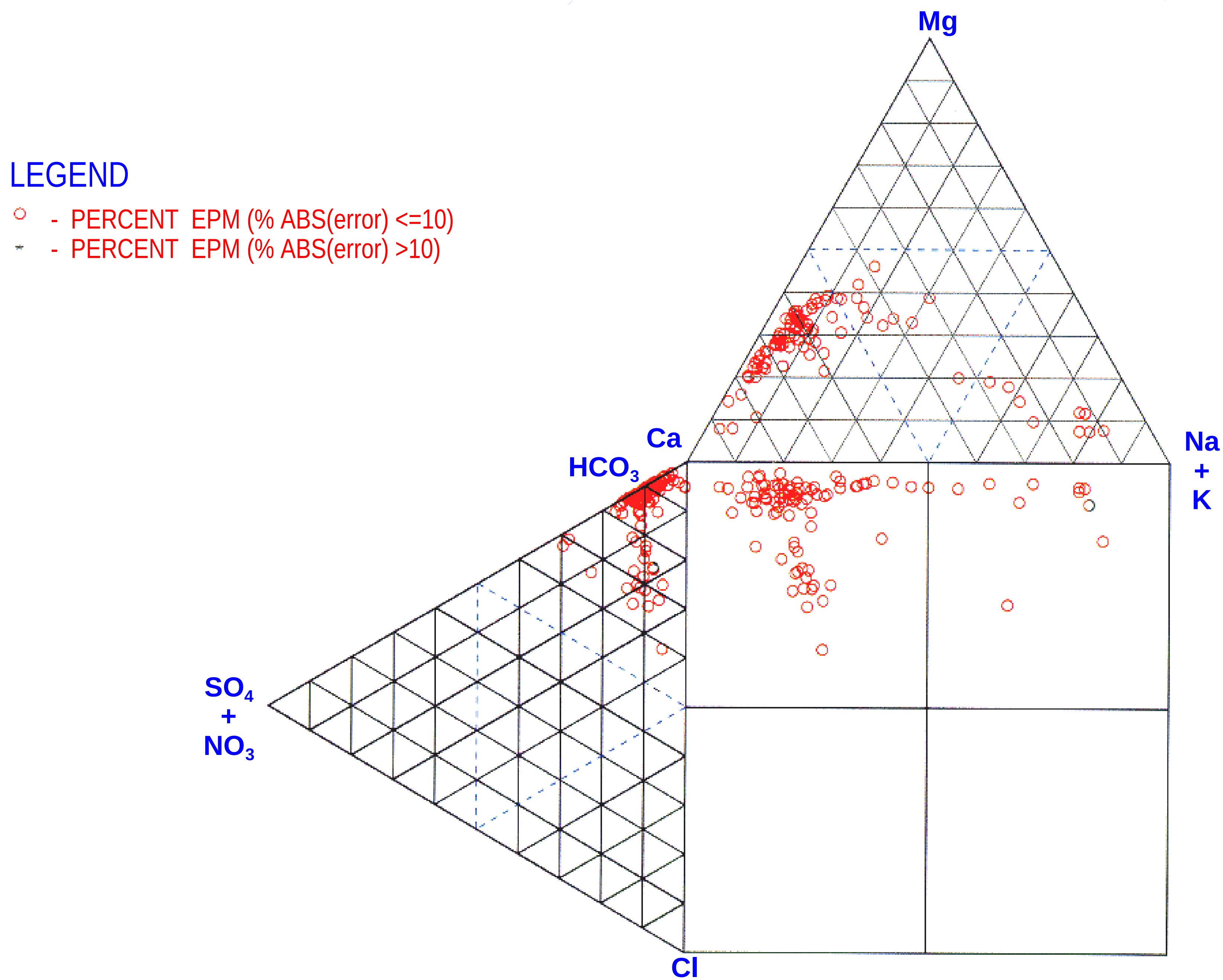


Figure 60. Chemical composition of water in deep overburden wells.

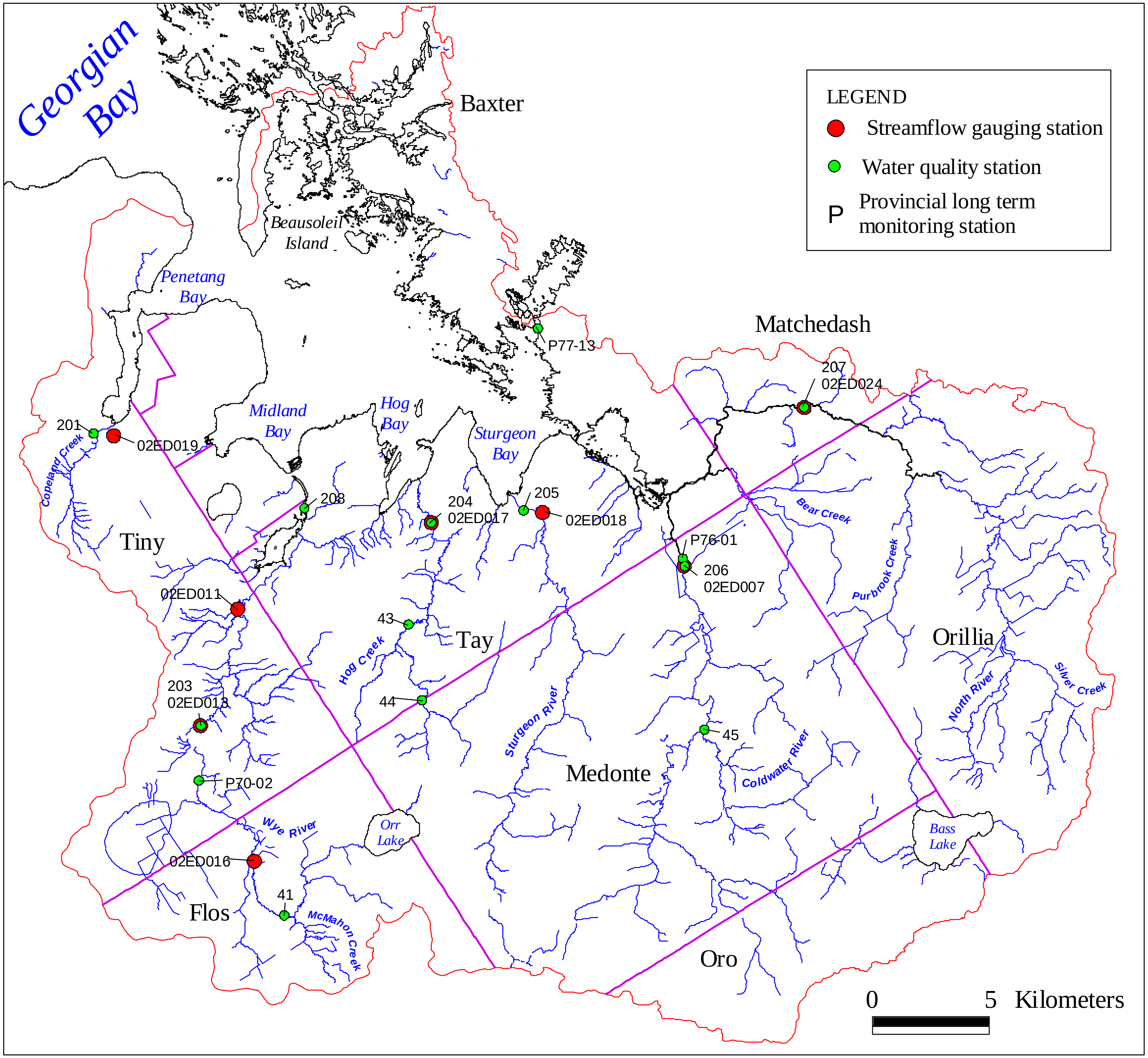


Figure 61. Locations of surface water quality stations within the study area.

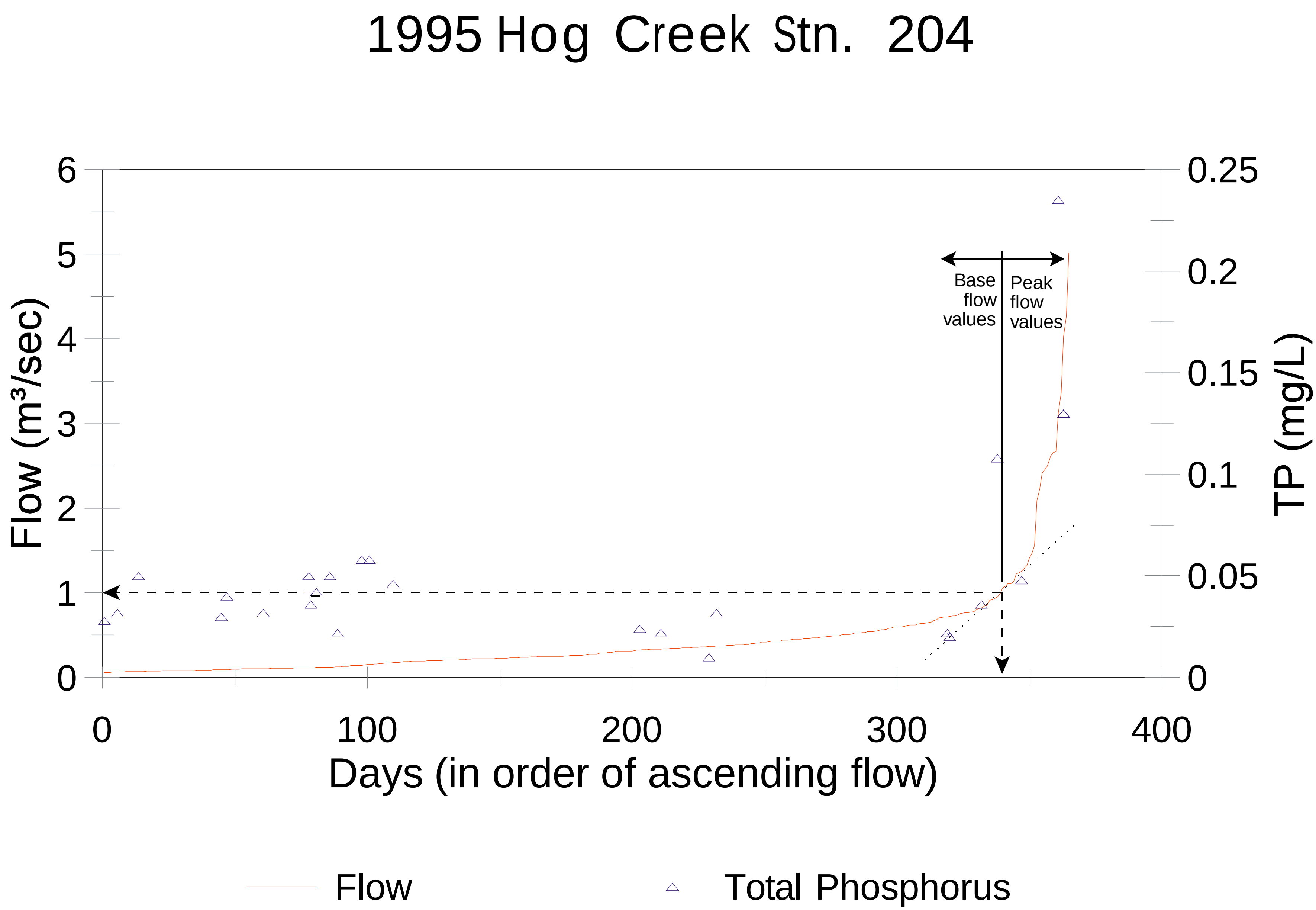
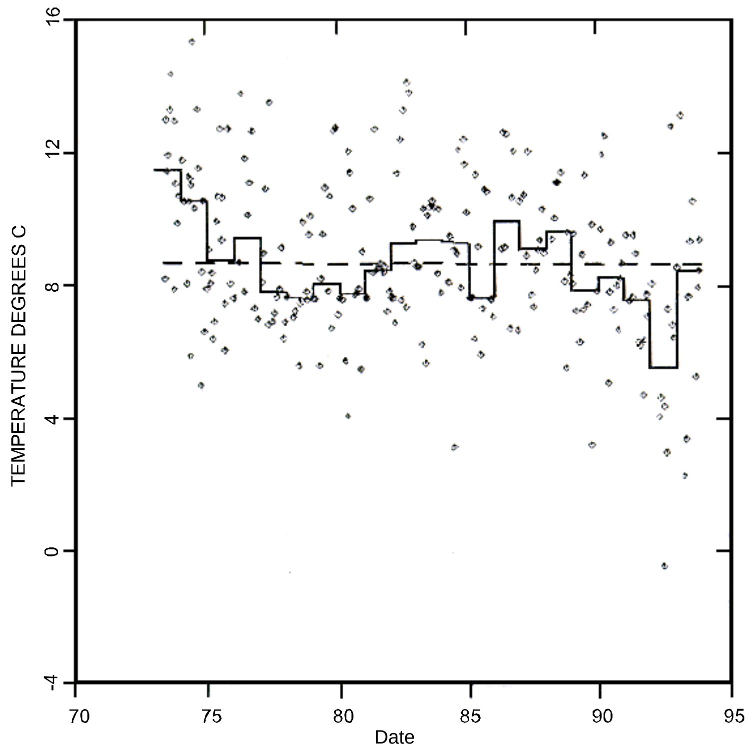


Figure 62. Evaluating annual base vs. high flow

A TRENDS IN DE-SEASONALIZED DATA SERIES

TEMPERATURE C

COLDWATER RIVER AT CNR BRIDGE IN COLDWATER



Run #2: 1 FAR OUTLIER DELETED
Run date: March 10, 1995

Annual Median
Mean annual median = 8.662

Maximum trend @ 1973 = 11.480
Minimum trend @ 1992 = 5.568
Trend range = 5.913

Observations = 237
Series begins @ MAY 15 1973
Series ends @ DEC 7 1993

Iterations = 3
Minimum Window = 1/8 YEAR
Minimum N Per Window = 11

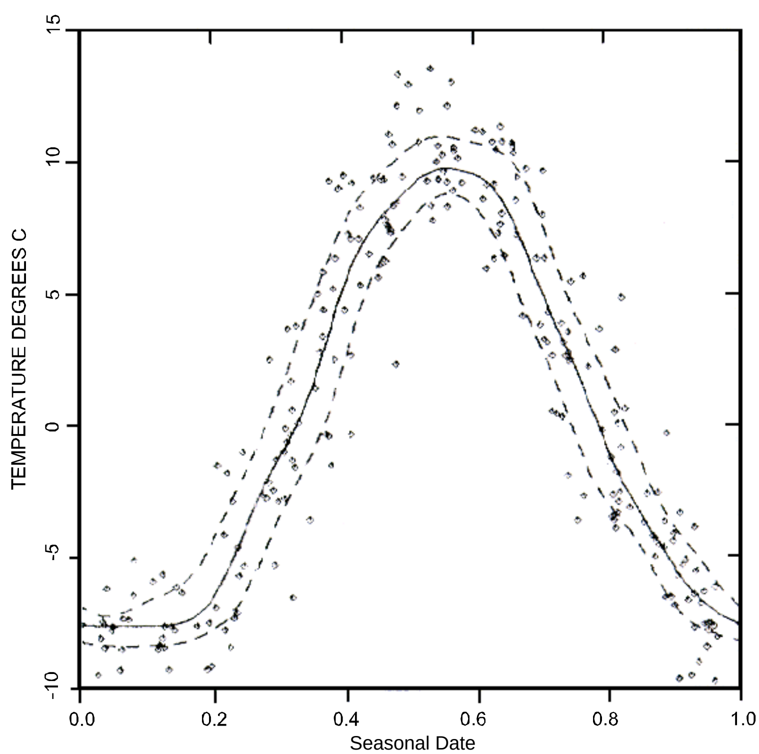
TREND TEST ON ANNUAL MEDIAN
Spearman RHO = -0.357
p(RHO) = 0.112 dof = 19

% Variation due to trend = 17.9

B RELATIVE SEASONALITY IN DE-TRENDED SERIES

TEMPERATURE C

COLDWATER RIVER AT CNR BRIDGE IN COLDWATER



Run #2: 1 FAR OUTLIER DELETED
Run date: March 10, 1995

Seasonal Median
1st & 3rd quartiles

Seasonal Max @ JUL 24
Seasonal Min @ JAN 22
Seasonal Amplitude = 17.4

Iterations = 3
Minimum Window = 1/8 YEAR
Minimum N Per Window = 11

Observations = 237
Series begins @ MAY 15 1973
Series ends @ DEC 7 1993

% Variation due to seasonal = 89.6

Figure 63A & B. Water temperature trend analysis at CNR bridge in Coldwater

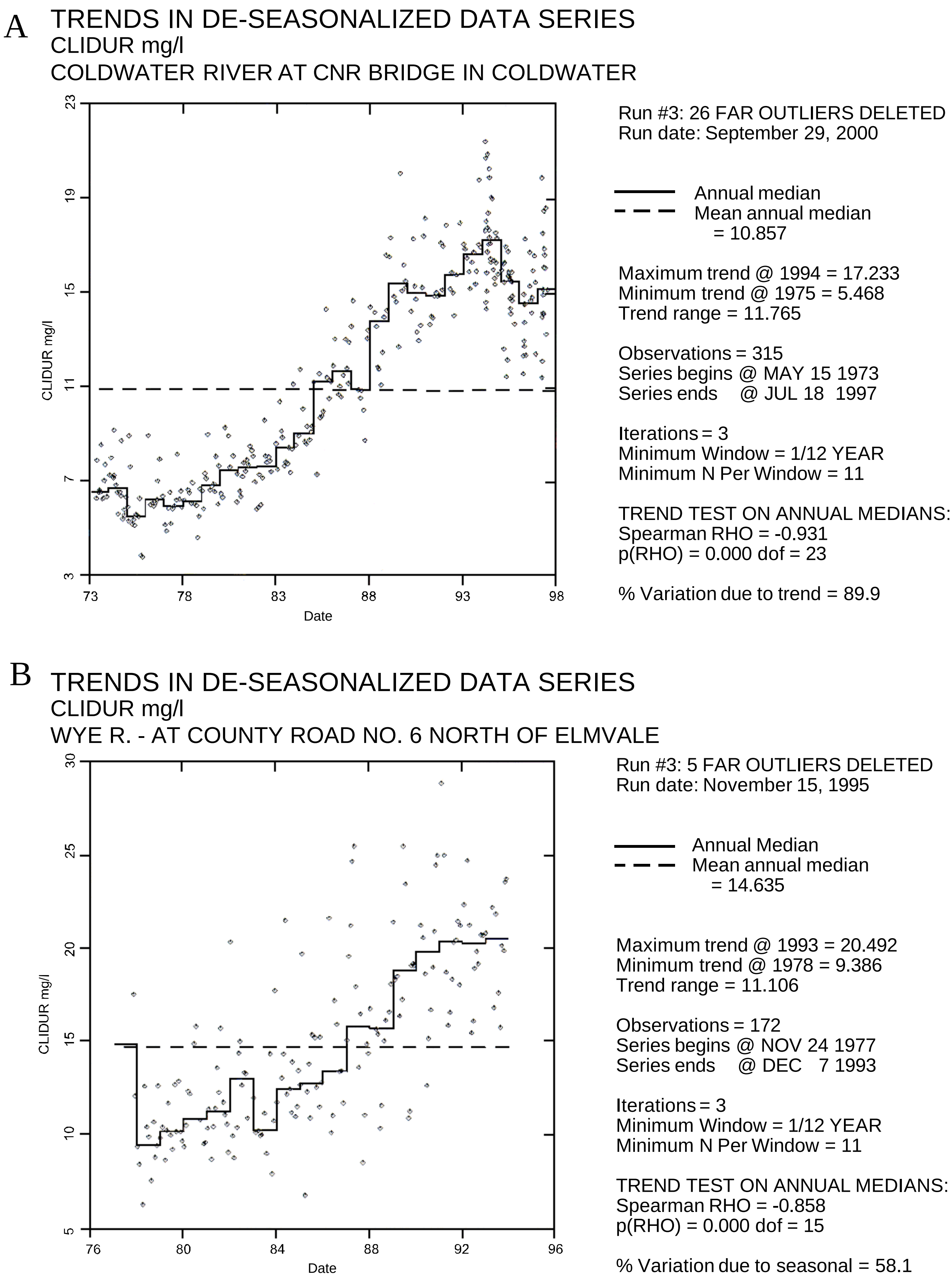
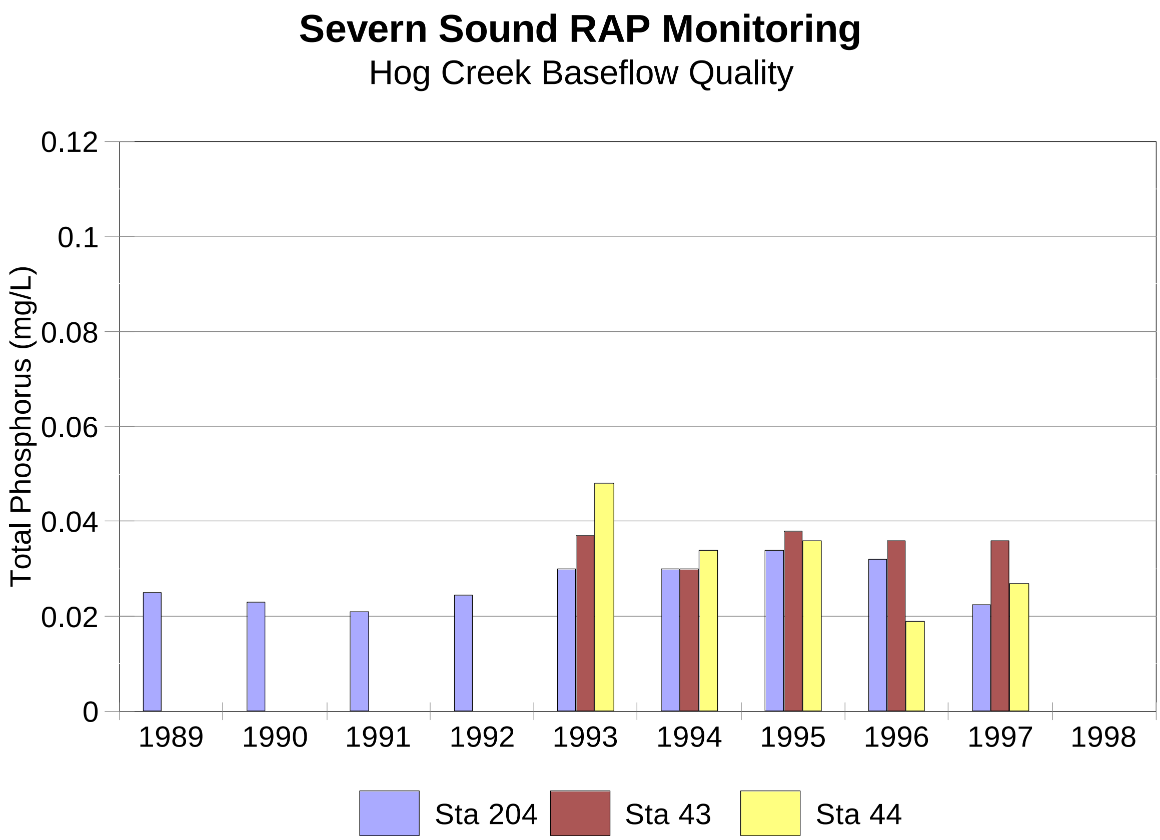


Figure 64A & B. Trend analysis of chlorides at Coldwater and Wye River stations.

A



B

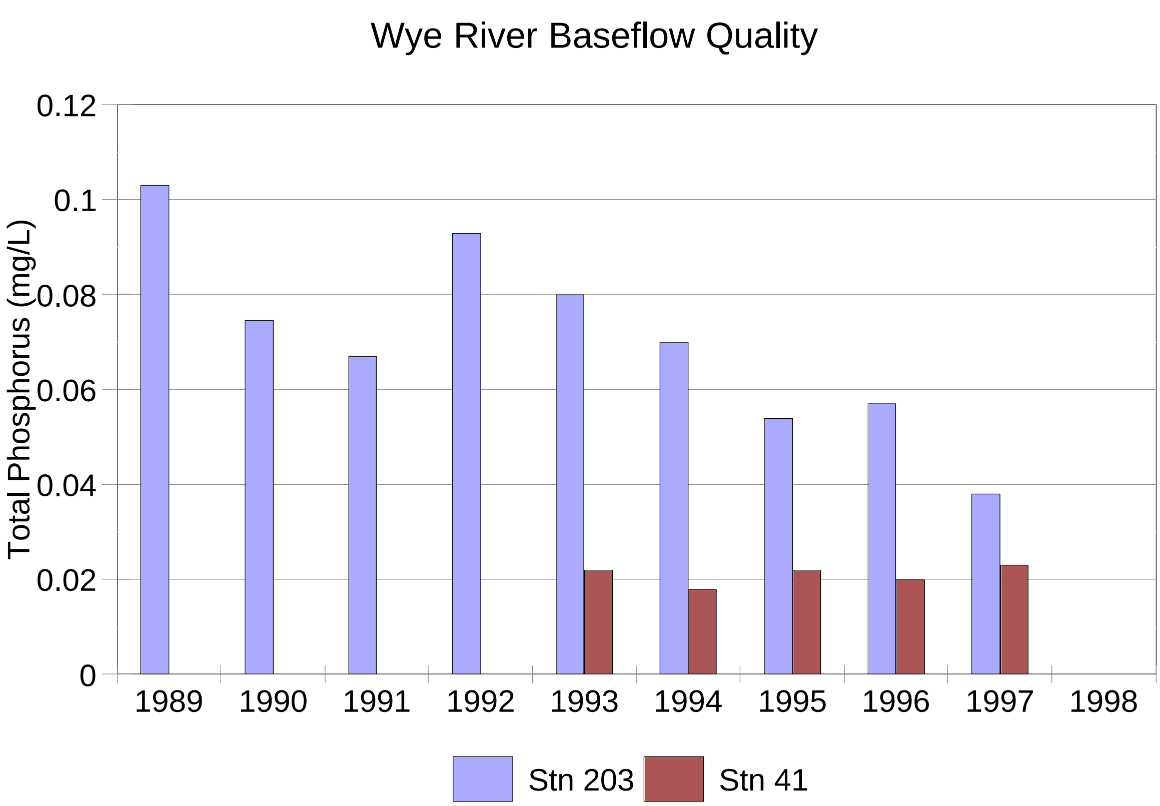


Figure 65A & B. Baseflow total phosphorus concentrations in Hog Creek and Wye River.

PART III

APPENDICES

APPENDIX I

TEMPERATURE AND PRECIPITATION STATISTICS FOR VARIOUS METEOROLOGICAL STATIONS WITHIN AND IN THE VICINITY OF THE STUDY AREA.

STATION NAME: COLDWATER WARMINSTER ONT.
STATION NUMBER: 6111769
LATITUDE: 44° 38'
LONGITUDE: 79° 32'
ELEVATION: 285 m

Year	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1977	Mean Max.Temp.(C)	-9.5	-4.4	5	12.7	21.1	22	25.2	24.2	17.7	11.9	5.7	-3.1	
	Mean Min.Temp.(C)	-16.5	-11.4	-3	1.4	8.4	10.7	15.1	14.2	10.9	3.5	-0.5	-9	
	Mean Monthly Temp.(C)	-13	-7.9	1	7.1	14.8	16.4	20.2	19.2	14.3	7.7	2.6	-6.1	
	Total Rainfall (mm)	0	15.1	47.5	30.3	15	83.4	58.2	108.4	116.4	83.5	85.1	2.1	645
	Total Snowfall (cm)	112	50.6	23.6	7.9	0	0	0	0	0	0	44.2	117	355.3
	Total Precipitation (mm)	112	65.7	71.1	38.2	15	83.4	58.2	108.4	116.4	83.5	129.3	119.1	1000.3
1978	Mean Max.Temp.(C)	-7	-6.5	-0.3	7	18.9	21.6	25.1	24.23	18.5	11.9	5.4	-1.4	
	Mean Min.Temp.(C)	-15.2	-14.8	-6.2e	-1.6	8.3	11.2	14.3	14.3e	9.5	3.8	-2	-8.5	
	Mean Monthly Temp.(C)	-11.1	-10.7	-1.9	2.7	13.6	16.4	19.7	19.1	14	7.9	1.7	-5	
	Total Rainfall (mm)	25.4	0	22.2	37.9	67.2	82.4	60.8	93.2e	114.6	82.8	40.4	28.8	655.7
	Total Snowfall (cm)	136.5	36.7	20.4	15.5	0	0	0	0	0	0	22.4	89.6	321.1
	Total Precipitation (mm)	161.9	36.7	42.6	53.4	67.2	82.4	60.8	93.2e	114.6	82.8	62.8	118.4	976.8e
1979	Mean Max.Temp.(C)	-7.4	-8.7	2.5	8.9	16.8	22.9	25.5	22.5	20.4	11.2	6.3	0	
	Mean Min.Temp.(C)	-12.7	-17.2	-5.4	0.6	6.7	12.1	14.8	13.5	10	4.5	0.2	-7	
	Mean Monthly Temp.(C)	-10.1	-13	-1.5	4.8	11.8	17.5	20.2	18	15.2	7.9	3.3	-3.5	
	Total Rainfall (mm)	6	11	45.8	78	64	78.1	76.8	103	51.4	155	84.4	48.4	801.9
	Total Snowfall (cm)	128.7	49.9	30.8	28.5	2.5	0	0	0	0	6.8	50.2	106.6	404
	Total Precipitation (mm)	134.7	60.9	76.6	106.5	66.5	78.1	76.8	103	51.4	161.8	134.6	155	1205.9
1980	Mean Max.Temp.(C)	-3.6	-6.2	0.9	10.3	18.8	19.1	24.8	25	18.8	9.5	3.6	-4.9	
	Mean Min.Temp.(C)	-10.1	-13.9	-7.4	1.6	8	9.8	15	15.9	9.9	2.8	-2.4	-13.8	
	Mean Monthly Temp.(C)	-6.9	-10.1	-3.3	6	13.4	14.5	19.9	20.5	14.4	6.2	0.6	-9.4	
	Total Rainfall (mm)	12.4	0	42.6	88.8	70.4	131.4	130.9	91.2	113.8	119.4	51.7	40.5	893.1
	Total Snowfall (cm)	62.2	48	59.5	3.4	0	0	0	0	0	4.4	26.1	155.3	358.9
	Total Precipitation (mm)	74.6	48	102.1	92.2	70.4	131.4	130.9	91.2	113.8	123.8	77.8	195.8	1252

Year	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1981	Mean Max.Temp.(C)	-8.3	1	3.4	11.3	16.7	21.9	25	24.3	17.4	10.1	5.7	-1.8	
	Mean Min.Temp.(C)	-17.4	-7.3	-5	1.9	6.4	12	15.3	14.5	9.9	2.3	-1.3	-7.2	
	Mean Monthly Temp.(C)	-12.9	-3.2	-0.8	6.6	11.6	17	20.2	19.4	13.7	6.2	2.2	-4.5	
	Total Rainfall (mm)	3.8	31.8	27.8	65.4	96.8	125.8	123.8	132.2	113.8	71.6	43.6	7.2	843.6
	Total Snowfall (cm)	27.8	61.5	29	0.2	0	0	0	0	0	25.6	23.4	57.6	225.1
	Total Precipitation (mm)	31.6	93.3	56.8	65.6	96.8	125.8	123.8	132.2	113.8	97.2	67	64.8	1068.7
1982	Mean Max.Temp.(C)	-7.6	-4.3	0.7	8.1	20.5	20	25.5	21.4	19	14.3	6.1	2.3	
	Mean Min.Temp.(C)	-18.2	-11.9	-7.4	-1.6	9.7	10.5	14.6	12	10.6	5.6	0.3	-5.4	
	Mean Monthly Temp.(C)	-12.9	-8.1	-3.4	3.3	15.1	15.3	20.1	16.7	14.8	10	3.2	-1.6	
	Total Rainfall (mm)	8.6	0	19	54	47.8	106	76.1	116.8	76.4	53.8	97.8	98.9	755.2
	Total Snowfall (cm)	133	59.4	70.6	10.2	0	0	0	0	0	0	25.6	44.1	342.9
	Total Precipitation (mm)	141.6	59.4	89.6	64.2	47.8	106	76.1	116.8	76.4	53.8	123.4	143	1098.1
1983	Mean Max.Temp.(C)	-3.3	-1.1	2.7	8.4	14.8	23.8	26.9	25.5	21.7	12.5	4	-1.3e	
	Mean Min.Temp.(C)	-10.2	-8.9	-4.3	0.3	4.7	11.9	16	15.4	11.5	4.5	-1.2	-8.3e	
	Mean Monthly Temp.(C)	-6.8	-5	-0.8	4.4	9.8	17.9	21.5	20.5	16.6	8.5	1.4	-4.8	
	Total Rainfall (mm)	26.4	23.2	34.4	79.8	123.2	45.2	79.2	66.6	95.2	113.4	49.6	27.4e	763.6
	Total Snowfall (cm)	79.8	14	24.2	17.4	0.2	0	0	0	0	0	59.2	75e	269.8
	Total Precipitation (mm)	106.2	37.2	58.6	97.2	123.4	45.2	79.2	66.6	95.2	113.4	108.8	102.4e	1033.4e
1984	Mean Max.Temp.(C)	-6.9	0.5	-1.4	12.1	14.4	23	24.6	25.1	17.8	14.6	5.1	1.9	
	Mean Min.Temp.(C)	-15.2	-6.4	-10.1	2.5	5.1	12.3	14.2	15.5	9.1	5.7	-1.3	-4.3	
	Mean Monthly Temp.(C)	-11.1	-3	-5.8	7.3	9.8	17.7	19.4	20.3	13.5	10.2	1.9	-1.2	
	Total Rainfall (mm)	0	36.4	41.4	57.2	107.4	68.2	71.4	77.4	107.2	75.6	65	51.8	759
	Total Snowfall (cm)	68.8	34	28.1	5	0	0	0	0	0	0	15.8	68.1	219.8
	Total Precipitation (mm)	68.8	70.4	69.5	62.2	107.4	68.2	71.4	77.4	107.2	75.6	80.8	119.9	978.8
1985	Mean Max.Temp.(C)	-4.8e	-3.7	2.4e	11.8	18.5	20	24	24.3	20.8	13.1	4.1	-3	
	Mean Min.Temp.(C)	-11.9e	-9.8	-6.4	1.6	7.6	9.6	13.9	13.9	11.6	5.3	-0.8	-9.6	
	Mean Monthly Temp.(C)	-8	-6.8	-1.7	6.7	13.1	14.8	19	19.1	16.2	9.2	1.7	-6.3	
	Total Rainfall (mm)	13.8e	54.4	35.3e	41.6	82	40.4	74.2	93.2e	135.3	95.4	77.1	8.8	751.5
	Total Snowfall (cm)	90.4e	85.6	31e	25	0	0	0	0	0	0	42.2	75e	349.2
	Total Precipitation (mm)	104.2e	140	66.3e	66.6	82	40.4	74.2	93.2e	135.3	95.4	119.3	83.8e	1100.7e

Year	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1986	Mean Max.Temp.(C)	-4.4	-4.9	4.5	13.4	19.2	21	25	22.9	17.9	12.5	3.1	-0.8	
	Mean Min.Temp.(C)	-12.4	-12.3	-4.9	2.7	9.2	10.3	15.3	12.5	10.2	4.5	-3.2	-6	
	Mean Monthly Temp.(C)	-8.4	-8.6	-0.2	8.1	14.2	15.7	20.2	17.7	14.1	8.5	-0.1	-3.4	
	Total Rainfall (mm)	19.2	3.6	34.6	50.4	86.8	83	157.2	103.2	207.6	76	22.6	17.8	862
	Total Snowfall (cm)	82.2	66	45.6	12.2	0.6	0	0	0	0	0	55	78	339.6
	Total Precipitation (mm)	101.4	69.6	80.2	62.6	87.4	83	157.2	103.2	207.6	76	77.6	95.8	1201.6
1987	Mean Max.Temp.(C)	-3.3	-2	4.5	14.6	19.3	23.8	26.7	24.3	19.7	10.7	5.2	1	
	Mean Min.Temp.(C)	-9.6	-12.7	-4.8	4	8	12.6	16.3	14.3	11.3	2.8	-2.2	-4.2	
	Mean Monthly Temp.(C)	-6.5	-7.4	-0.2	9.3	13.7	18.2	21.5	19.3	15.5	6.8	1.5	-1.6	
	Total Rainfall (mm)	2.2	4.8	42.4	29.4	52.6	80	103.2	60.8	67.2	95.6	68.8	26.8	633.8
	Total Snowfall (cm)	95.6	27.4	39.6	7.6	0	0	0	0	0	0.4	59.6	40.8	271
	Total Precipitation (mm)	97.8	32.2	82	37	52.6	80	103.2	60.8	67.2	96	128.4	67.6	904.8
1988	Mean Max.Temp.(C)	-3.4	-4	2.8	9.9	20.6	23.1	28.9	25.3	19.2	9.4	6.2	-2	
	Mean Min.Temp.(C)	-11.7	-12.8	-7.7	0.9	8.1	11.3	16.3	15.4	9.9	2.7	0.9	-10.2	
	Mean Monthly Temp.(C)	-7.6	-8.4	-2.5	5.4	14.4	17.2	22.6	20.4	14.6	6.1	3.6	-6.1	
	Total Rainfall (mm)	29	6.2	22.6	57.8	40	35.6	68.2	136.8	95.6	106.8	81	7.6	687.2
	Total Snowfall (cm)	95.2	116.2	9.2	8	0	0	0	0	0	12.2	3	61.2	305
	Total Precipitation (mm)	124.2	122.4	31.8	65.8	40	35.6	68.2	136.8	95.6	119	84	68.8	992.2
1989	Mean Max.Temp.(C)	-4.8 e	-3.32e	1.4	8.5	17.8	22.5	27.5	24	19.6	13.7	4.2	-8.6	
	Mean Min.Temp.(C)	-11..9e	-10.9e	-9.1	-0.6	7.1	13.1	14.8	13.9	10	6	-3.7	-17.4	
	Mean Monthly Temp.(C)	-8	-6.13	-3.9	4	12.5	17.8	21.2	19	14.8	9.9	0.3	-13	
	Total Rainfall (mm)	13.8e	14.2e	35.4	19.4	90.4	89.2	3	152.5	92	97.2	99.6	5.2	711.9
	Total Snowfall (cm)	90.4e	50.2e	44.6	13.6	15	0	0	0	0	3.2	42	78	337
	Total Precipitation (mm)	104.2e	64.4e	80	33	105.4	89.2	3	152.5	92	100.4	141.6	83.2	1048.9 e
1990	Mean Max.Temp.(C)	0.4	-1.8	3.7	12.2	16.2	22.5	24.9	25	18.5	12.6	7.5	1.8	
	Mean Min.Temp.(C)	-6.6	-10.1	-4.9	2.8	6.1	12.7	15	13.8	10.3	3.9	-0.7	-6.2	
	Mean Monthly Temp.(C)	-3.1	-6	-0.6	7.5	11.2	17.6	20	19.4	14.4	8.3	3.4	-2.2	
	Total Rainfall (mm)	25.8	28.4	39	59.2	85	95.2	57.8	34	102.4	98.4	80	38.6	743.8
	Total Snowfall (cm)	52.8	66.2	15.4	12.2	2.4	0	0	0	0	0	53.4	64.6	267
	Total Precipitation (mm)	78.6	94.6	54.4	71.4	87.4	95.2	57.8	34	102.4	98.4	133.4	103.2	1010.8

Year	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1991	Mean Max.Temp.(C)	-5	-0.4	3.1	12.5	21.5	25	25.5	25.9	18.8	13.4	5	-1.2	
	Mean Min.Temp.(C)	-12.5	-9.1	-4.7	3.6	10.1	13.3	15.4	15.1	9.2	5.7	-1.8	-9	
	Mean Monthly Temp.(C)	-8.7	-7.5	-1.3	4.9	11.4	16	19.8	20.5	14.6	9.6	1.6	-5.1	
	Total Rainfall (mm)	1.4	6.6	75.8	127	77	15.6	80.6	63.6	104.4	108.6	31	10.8	702.4
	Total Snowfall (cm)	143.6	52.2	17.2	7.8	0	0	0	0	0	1	13.4	91.2	326.4
	Total Precipitation (mm)	145	58.8	93	134.8	77	15.6	80.6	63.6	104.4	109.6	44.4	102	1028.8
1992	Mean Max.Temp.(C)	-4.2	-1.9	1	8.6	18.8	21.4	21.4	22.3	19.2	11	4.3	0.5	
	Mean Min.Temp.(C)	-12.9	-10.6	-8.2	0.2	6.6	10	12.2	12.8	9.8	2.4	-1.5	-6.3	
	Mean Monthly Temp.(C)	-8.6	-7.5	-3.6	4.4	12.7	15.7	19.8	17.6	14.6	7.6	1.8	-2.9	
	Total Rainfall (mm)	26	12.6	31	31	53.4	32	100.2	139.2	88.4	49.8	127.2	17.6	708.4
	Total Snowfall (cm)	113	43.4	11.8	35	0	0	0	0	0	23.8	41.2	73	341.2
	Total Precipitation (mm)	139	56	42.8	66	53.4	32	100.2	139.2	88.4	73.6	168.4	90.6	1049.6
1993	Mean Max.Temp.(C)	-1.9	-5.2	4.3	10.7	17.3	21.7	25.7	25.7	17.2	11.4	4.6	-1.3e	
	Mean Min.Temp.(C)	-10.2	-15.6	-6	1	6.4	11.4	15.7	14.9	8.6	3.3	-1.6	-8.3e	
	Mean Monthly Temp.(C)	-81	-7.5	-0.8	4.8	11.8	16.5	20.7	20.3	12.9	7.6	1.8	-4.8	
	Total Rainfall (mm)	49.6	0	3.8	66.4	76.8	113.4	74.6	105.8	124.2	75	59.8	27.4e	777.6
	Total Snowfall (cm)	120.4	44.6	24.8	21.4	0	0	0	0	0	3.4	11.2	75e	300
	Total Precipitation (mm)	170	44.6	28.6	87.8	76.8	113.4	74.6	105.8	124.2	78.4	71	102.4e	1077.6e

STATION NAME: GRAVENHURST BOOTH ONT
STATION NUMBER: 611C001
LATITUDE: 44° 55'
LONGITUDE: 79° 24'
ELEVATION: 244 m

Year	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1980	Mean Max.Temp.(C)	-4.5e	-2 3e	2.4 e	10.8e	17.9e	19.4	24.8	25	18.9	10	3.8	-1.6e	
	Mean Min.Temp.(C)	-15.2e	-14.0e	-9.6e	-0.8e	5.1e	8.1	12.8	14	7.9	1.6	-3.6	-10.6e	
	Mean Monthly Temp.(C)	-9.8	-8.2	-3.6	5	11.5	13.8	18.8	19.5	13.4	5.8	0.1	-6.2	
	Total Rainfall (mm)	10.9e	3.4e	32.8e	72.1e	92.2e	140.8	143.4	124	83	138.8	55.5	18.6e	915.5e
	Total Snowfall (cm)	88.9e	59.1e	36.3e	9.3e	0	0	0	0	0	0	35.2	100.6e	229.3e
	Total Precipitation (mm)	99.8	62.5	69.2	81.4	92.2	140.8	143.4	124	83	138.8	90.7	119.2	1144.8e
1981	Mean Max.Temp.(C)	-7.3	1.4	3.9	11.8	17.1	22.7	25.7	24.5	17.6	10.3	6.4	-1.2	
	Mean Min.Temp.(C)	-21.1	-9.2	-6.6	0.4	4.4	9.7	12.6	11.9	8.1	0	-3.9	-9.1	
	Mean Monthly Temp.(C)	-14.2	-3.9	-1.4	6.1	10.8	16.2	19.2	18.2	12.9	5.2	1.3	-5.2	
	Total Rainfall (mm)	0	0	25	80.1	81.9	115.2	32	99.4	156.1	63.2	62	8	722.9
	Total Snowfall (cm)	21	34	36	0	0	0	0	0	0	8	15	49	163
	Total Precipitation (mm)	21	34	61	80.1	81.9	115.2	32	99.4	156.1	71.2	77	57	885.9
1982	Mean Max.Temp.(C)	-7.6	-3.4	2.1	8.4	21	20.4	25.4	21.2	19	14	6.7	2.6	
	Mean Min.Temp.(C)	-22	-15.6	-9.9	-4.5	6.7	8.2	10.9	8.9	7.4	2.5	-1.8	-6.9	
	Mean Monthly Temp.(C)	-14.8	-9.5	-3.9	2	13.9	14.3	18.2	15.1	13.2	8.3	2.5	-2.2	
	Total Rainfall (mm)	0	0	24	59.3	48.6	119.1	81.1	66.3	124	80.9	103	78.4	784.7
	Total Snowfall (cm)	144	67	83	18	0	0	0	0	0	0	19	64	395
	Total Precipitation (mm)	144	67	107	77.3	48.6	119.1	81.1	66.3	124	80.9	122	142.4	1179.7
1983	Mean Max.Temp.(C)	-2.8	-0.5	3.6	8.8	15	24.1	27	26.1	21.5	12.5	4.2	-4.5	
	Mean Min.Temp.(C)	-12.5	-11.8	-7	-2.1	2.2	7.8	12.1	11.6	7.4	1.5	-2.7	-15.5	
	Mean Monthly Temp.(C)	-7.7	-6.2	-1.7	3.4	8.6	16	19.6	18.9	14.5	7	0.8	-10	
	Total Rainfall (mm)	22	0	34.6	81.4	158.4	39.2	41.7	48.1	87.3	96.5	43.6	0	652.8
	Total Snowfall (cm)	58	19	25	11	0	0	0	0	0	0	63	164	340
	Total Precipitation (mm)	80	19	59.6	92.4	158.4	39.2	41.7	48.1	87.3	96.5	106.6	164	992.8

Year	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1984	Mean Max.Temp.(C)	-6.9	0.6	-0.8	12.6	14.3	22.8	25.2e	23.8e	17.9	15.4	5.6	2	
	Mean Min.Temp.(C)	-16.7	-7.2	-11.8	2.6	4.4	10.5	12.1e	11.4e	6.3	2.8	-2.9	-6.2	
	Mean Monthly Temp.(C)	-11.8	-3.3	-6.3	7.6	9.4	16.7	18.7	17.6	12.1	9.1	1.4	-2.1	
	Total Rainfall (mm)	0	12	44	88.3	136.7	61.5	78.7e	81e	116.3	57.8	111.5	12	640.1
	Total Snowfall (cm)	76	26	23	0	0	0	0	0	0	0	10	120.2	255.2
	Total Precipitation (mm)	76	38	67	88.3	136.7	61.5	78.7	81	116.3	57.8	121.5	132.2	1054e
1985	Mean Max.Temp.(C)	-6.7	-3	2.3e	11.6	18.4	20.7	24	22.9	20.2	13.8	4.5e	-2.6	
	Mean Min.Temp.(C)	-16.8	-10.9	-9.6e	0	5.2	7.7	11.6	11.1	9.7	3.5	-3.4e	-11.4	
	Mean Monthly Temp.(C)	-11.8	-7	-3.7	5.8	11.8	14.2	17.8	17	15	8.7	0.6	-7	
	Total Rainfall (mm)	0	10	33.4e	91.7	106.4	48.3	144.8	138.6	142.7	131.2	78.2e	12.4	826.1
	Total Snowfall (cm)	113.8	76	39.2e	24	0	0	0	0	0	0	32.2e	216	429.8
	Total Precipitation (mm)	113.8	86	72.5	115.7	106.4	48.3	144.8	138.6	142.7	131.2	110.4	228.4	1438.8e
1986	Mean Max.Temp.(C)	-4.1	-3.5	4.1	14.2	20.1	21.2	25.3	23	18.1	12.2	2.9	-0.3	
	Mean Min.Temp.(C)	-14.6	-14.8	-6.9	1.4	7.4	8.3	13.2	10.4	7.6	2.2	-4	-7.1	
	Mean Monthly Temp.(C)	-9.4	-9.2	-1.4	7.8	13.8	14.8	19.3	16.7	12.9	7.2	-0.6	-3.7	
	Total Rainfall (mm)	10.9	4.2	33.4	53.8	86	111.8	95	95.3	174.8	98.8	11.4	1	776.4
	Total Snowfall (cm)	88.9	43	581	7	0	0	0	0	0	0	33.2	96	326.1
	Total Precipitation (mm)	99.8	47.2	91.4	60.8	86	111.8	95	95.3	174.8	98.8	44.6	97	1102.5
1987	Mean Max.Temp.(C)	-3.1	-1.7	5.9	15.6	19.2	24.1	27.1	25.1	19.5	10.6	4.9	0.6	
	Mean Min.Temp.(C)	-12.5	-16.6	-6.4	2	6.6	10.9	14.3	12.2	9.2	1.5	-2.6	-6.6	
	Mean Monthly Temp.(C)	-8.1	-9.2	-0.3	8.8	12.9	17.5	20.7	18.7	14.4	6.1	1.2	-3	
	Total Rainfall (mm)	0	0	36.9	34.9	56.8	68	56.5	56.5	45.9	109.8	72	39.5	576.8
	Total Snowfall (cm)	57	47	31	6.4	0	0	0	0	0	0	20	69	230.4
	Total Precipitation (mm)	57	47	67.9	41.3	56.8	68	56.5	56.5	45.9	109.8	92	108.5	807.2
1988	Mean Max.Temp.(C)	-3.2	-3.8	2.5	10	20.7	22.8	28.1	25.5	19	9.3	6.1	-2	
	Mean Min.Temp.(C)	-14.2	-15.4	-10.9	-0.3	6.6	8.7	13.5	13.1	7.4	0.8	-1.1	-10.9	
	Mean Monthly Temp.(C)	-8.7	-9.6	-4.2	4.9	13.7	15.8	20.8	19.3	13.2	5.1	2.5	-6.5	
	Total Rainfall (mm)	18	2	19	96.6	51.6	51.8	109.2	123.9	105.2	139	112.3	10	838.6
	Total Snowfall (cm)	117	109.8	20	7	0	0	0	0	0	11	9	78	351.8
	Total Precipitation (mm)	135	111.8	39	103.6	51.6	51.8	109.2	123.9	105.2	150	121.3	88	1190.4

Year	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1989	Mean Max.Temp.(C)	-0.6	-5.1	0.5	7.8	17.7	22.1	27.3	23.9	19.4	12.5	2.5	-9.5	
	Mean Min.Temp.(C)	-12.2	-16.9	-12.9	-3.7	4.6	10.4	11.5	10.8	6.2	1.5	-6.4	-22.4	
	Mean Monthly Temp.(C)	-6.4	-11	-6.2	2.1	11.2	16.3	19.4	17.4	12.8	7	-2	-16	
	Total Rainfall (mm)	14	0	24	40	114	89.8	16.2	67.3	78.4	104.7	97.2	5	650.6
	Total Snowfall (cm)	70	99	36.8	15	0	0	0	0	0	4	70	74	368.8
	Total Precipitation (mm)	84	99	60.8	55	114	89.8	16.2	67.3	78.4	108.7	167.2	79	1019.4
1990	Mean Max.Temp.(C)	-0.8	-2	3.3	11.5	15.5	22.2	24.9	24.2	18	11.6	5.6	-0.6	
	Mean Min.Temp.(C)	-9.5	-13.8	-9	-0.3	2.8	9 9	11.3	10.7	5.9	11	-4.3	-9.6	
	Mean Monthly Temp.(C)	-5.2	-7.9	-2.9	5.6	9.2	16.1	18.1	17.5	12	6.3	0.7	-5.1	
	Total Rainfall (mm)	31	3.4e	27	94.9	92.9	87.3	63.5	21.9	85.2	130.5	53.8	25.5	713.5
	Total Snowfall (cm)	48	53	5	9	0	0	0	0	0	0	46	97	258
	Total Precipitation (mm)	79	53	32	103.9	92.9	87.3	63.5	21.9	85.2	130.5	99.8	122.5	974.9e
1991	Mean Max.Temp.(C)	-5 5	-0.8	2.8	11.8	19.3	22.7	22.3	22.3	14.8	10.1	1.6	-3.8	
	Mean Min.Temp.(C)	-16.9	-14.1	-8.5	-0.2	5.7	8.7	10.5	10.3	4.2	1.4	-5.9	-13	
	Mean Monthly Temp.(C)	-11.2	-7.4	-2 9	5.8	12.5	15.7	16.4	16.3	9.5	5.75	-2.1	-8.4	
	Total Rainfall (mm)	0	5	66.2	117.1	91.8	42.4	74.3	21.6	113.4	126	66.3	19	743.1
	Total Snowfall (cm)	142	75	23	1	0	0	0	0	0	3.6	28	91	363.6
	Total Precipitation (mm)	142	80	89.2	118.1	91.8	42.4	74.3	21.6	113.4	129.6	94.3	110	1106.7
1992	Mean Max.Temp.(C)	-6.3	-3.6	-1.5	5.5	17.9e	20.3	19.9	20.9	18.8	10.7	4	-0.5	
	Mean Min.Temp.(C)	-16.5	-15.6	-15.4	-4.9	5.1e	7.6	10.5	10.2	8	0.8	-2.6	-9	
	Mean Monthly Temp.(C)	-11.4	-9.6	-8.4	0.3	11.5	13.9	15.2	15.5	13.4	5.7	0.7	-4.8	
	Total Rainfall (mm)	16	8	27	42	93.4e	48.3	132.2	110.3	112.1	81	157.3	13	747~2
	Total Snowfall (cm)	93	66	39	29	0	0	0	0	0	16	49	89.5	381.5
	Total Precipitation (mm)	109	74	66	71	93.4	48.3	132.2	110.3	112.1	97	206.3	102.5	1222.1e
1993	Mean Max.Temp.(C)	-2.6	-5.5	2.6	10.8	16.9	22.2	25.7	25.5	16.9	10.7	4.8	-1.6e	
	Mean Min.Temp.(C)	-12.7	-20.2	-9.8	0	4.4	9.2	12.9	12.5	6.6	1.4	-2.7	-10.6e	
	Mean Monthly Temp.(C)	-7.6	-12.9	-3.6	5.4	10.6	15.7	19.3	19	11.75	6.1	1.1	0	
	Total Rainfall (mm)	30	0	33	77.2	95.4	87.9	33	79.8	135.5	49.1	70.9	-18.6	710.4
	Total Snowfall (cm)	127	37	56.1	8	0	0	0	0	0	63.4	21	100.6	413.2
	Total Precipitation (mm)	157	37	89.1	85.2	95.4	87.9	33	79.8	135.5	112.5	91.9	119.2	1123.6

STATION NAME: HONEY HBR BEAUSOLEIL
STATION NUMBER: 6113490
LATITUDE: 44° 51'
LONGITUDE: 79° 52'
ELEVATION: 183 m

Year	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1977	Mean Max.Temp.(C)	-8.6	-4.1	4.7	12.0	19.8	21.4	25.6	22.3	18.2	12.1	7.2	-2.1	
	Mean Min.Temp.(C)	-17.4	-12.1	-3.8	0.6	8.3	11.2	16.0	14.4	12.3	4.9	1.3	-8.2	
	Mean Monthly Temp.(C)	-13.0	-8.1	0.5	6.3	14.1	16.3	20.8	18.4	15.3	8.5	4.3	-5.2	
	Total Rainfall (mm)	0.0	7.9	57.8	54.6	29.4	46.2	50.6	106.8	137.1	80.8	74.6	4.1	
	Total Snowfall (cm)	158.2	47.4	15.3	4.0	0.0	0.0	0.0	0.0	0.0	0.0	38.2	155.3	
	Total Precipitation (mm)	158.2	55.3	73.1	58.6	29.4	46.2	50.6	106.8	137.1	80.8	112.8	159.4	1068.3
1978	Mean Max.Temp.(C)	-6.4	-6.4	-0.4	6.0	17.9	20.9	24.9	24.8	18.5	12.2	6.2	-0.5	
	Mean Min.Temp.(C)	-14.9	-16.2	-10.5	-1.1	8.1	11.3	15.1	15.3	10.7	4.9	-0.8	-7.6	
	Mean Monthly Temp.(C)	-10.7	-11.3	-5.5	2.5	13.0	16.1	20.0	20.1	14.6	8.6	2.7	-4.1	
	Total Rainfall (mm)	5.0	0.0	30.1	44.6	72.2	57.0	47.8	88.6	123.0	73.5	51.0	15.0	
	Total Snowfall (cm)	104.5	16.2	17.0	4.5	0.0	0.0	0.0	0.0	0.0	0.0	17.2	95.5	
	Total Precipitation (mm)	109.5	16.2	47.1	49.1	72.2	57.0	47.8	88.6	123.0	73.5	68.2	110.5	862.7
1979	Mean Max.Temp.(C)	-6.4	-8.1	4.0	8.0	16.2	22.8	25.2	22.7	20.0	11.7	6.9	1.2	
	Mean Min.Temp.(C)	-13.2	-17.8	-4.5	0.8	7.0	12.2	15.5	14.8	11.3	5.5	1.1	-6.2	
	Mean Monthly Temp.(C)	-9.8	-13.0	-0.3	4.4	11.6	17.5	20.4	18.8	15.7	8.6	4.0	-2.5	
	Total Rainfall (mm)	7.0	10.4	44.0	93.4	67.6	70.4	26.2	96.0	67.0	125.7	98.1	27.0	
	Total Snowfall (cm)	145.9	35.2	18.2	14.5	0.0	0.0	0.0	0.0	0.0	0.0	48.0	78.2	
	Total Precipitation (mm)	152.9	45.6	62.2	107.9	67.6	70.4	26.2	96.0	67.0	125.7	146.1	105.2	1072.8
1980	Mean Max.Temp.(C)	-2.9	-5.7	1.0	9.4	16.8	18.5	24.0	24.8	18.9	9.8	4.6	-3.1	
	Mean Min.Temp.(C)	-9.8	-14.9	-7.4	1.5	7.3	9.8	15.4	16.7	10.9	3.9	-1.2	-14.2	
	Mean Monthly Temp.(C)	-6.4	-10.3	-3.2	5.5	12.1	14.2	19.7	20.8	14.9	6.9	1.7	-8.7	
	Total Rainfall (mm)	13.2	0.0	19.0	66.2	77.6	109.0	84.2	97.1	89.7	109.3	53.9	16.6	
	Total Snowfall (cm)	98.5	49.4	20.9	3.0	0.0	0.0	0.0	0.0	0.0	0.0	9.0	152.3	
	Total Precipitation (mm)	111.7	49.4	39.9	69.2	77.6	109.0	84.2	97.1	89.7	109.3	62.9	168.9	1068.9

Year	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1981	Mean Max.Temp.(C)	-7.6	1.4	3.2	10.8	15.8	22.3	25.1	23.8	17.3	10.6	6.2	-1.3	
	Mean Min.Temp.(C)	-18.5	-8.0	-5.3	1.4	6.1	11.8	16.4	15.5	10.9	3.5	-0.5	-7.1	
	Mean Monthly Temp.(C)	-13.1	-3.3	-1.1	6.1	11.0	17.1	20.8	19.7	14.1	7.1	2.9	-4.2	
	Total Rainfall (mm)	0.0	8.2	6.0	59.6	86.0	129.2	29.6	135.9	106.8	103.8	35.5	3.0	
	Total Snowfall (cm)	32.5	48.2	23.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.7	77.0	
	Total Precipitation (mm)	32.5	56.4	29.7	59.6	86.0	129.2	29.6	135.9	106.8	103.8	48.2	80.0	897.7
1982	Mean Max.Temp.(C)	-6.8	-4.1	1.2	7.9	18.7	19.3	25.4	21.0	18.9	14.1	6.7	3.9	
	Mean Min.Temp.(C)	-18.3	-13.0	-8.2	-1.9	8.7	10.6	15.4	13.3	11.5	6.9	1.1	-4.0	
	Mean Monthly Temp.(C)	-12.6	-8.6	-3.5	3.0	13.7	15.0	20.4	17.2	15.2	10.5	3.9	-0.1	
	Total Rainfall (mm)	0.0	0.0	9.4	48.0	35.7	101.6	59.3	68.3	78.1	43.9	102.9	77.6	
	Total Snowfall (cm)	134.5	86.0	81.0	18.0	0.0	0.0	0.0	0.0	0.0	0.0	20.5	67.5	
	Total Precipitation (mm)	134.5	86.0	90.4	66.0	35.7	101.6	59.3	68.3	78.1	43.9	123.4	145.1	1032.3
1983	Mean Max.Temp.(C)	-2.6	-0.9	2.5	7.9	14.2	23.3	27.0	26.4	22.0	13.3	4.9	-2.6	
	Mean Min.Temp.(C)	-10.2	-9.1	-4.6	0.6	5.6	12.3	16.7	16.9	13.0	6.2	-0.2	-11.5	
	Mean Monthly Temp.(C)	-6.4	-5.0	-1.1	4.3	9.9	17.8	21.9	21.7	17.5	9.8	2.4	-7.1	
	Total Rainfall (mm)	15.0	0.0	18.4	75.8	114.9	61.2	37.5	31.2	164.1	100.5	54.3	10.0	
	Total Snowfall (cm)	44.5	19.0	34.0	11.5	0.0	0.0	0.0	0.0	0.0	0.0	27.8	155.0	
	Total Precipitation (mm)	59.5	19.0	52.4	87.3	114.9	61.2	37.5	31.2	164.1	100.5	82.1	165.0	974.7
1984	Mean Max.Temp.(C)	-5.9	0.7	-1.3	11.0	14.0	22.1	24.6	24.8	18.1	14.9	6.0	-0.9	
	Mean Min.Temp.(C)	-15.6	-6.8	-10.4	2.0	5.5	12.5	14.8	16.4	10.2	7.2	-0.2	-8.2	
	Mean Monthly Temp.(C)	-10.8	-3.1	-5.9	6.5	9.8	17.3	19.7	20.6	14.2	11.1	2.9	-4.6	
	Total Rainfall (mm)	0.0	3.2	30.0	83.7	135.1	42.9	66.4	80.6	113.6	53.5	99.0	18.0	
	Total Snowfall (cm)	96.0	12.5	23.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	99.4	
	Total Precipitation (mm)	96.0	15.7	53.5	83.7	135.1	42.9	66.4	80.6	113.6	53.5	104.0	117.4	962.3
1985	Mean Max.Temp.(C)	-5.9	-3.3	3.2	10.3	17.3	19.1	24.2	22.9	20.2	13.4	5.2	-2.2	
	Mean Min.Temp.(C)	-14.9	-9.6	-5.6	0.9	7.5	10.2	15.2	14.9	12.5	6.5	0.3	-9.4	
	Mean Monthly Temp.(C)	-10.4	-6.5	-1.2	5.6	12.4	14.7	19.7	18.9	16.4	10.0	2.8	-5.8	
	Total Rainfall (mm)	3.0	43.2	56.6	68.2	73.5	57.2	82.6	121.3	137.6	120.5	76.2	9.6	
	Total Snowfall (cm)	134.0	64.1	25.1	11.6	0.0	0.0	0.0	0.0	0.0	0.0	34.0	188.6	
	Total Precipitation (mm)	137.0	107.3	81.7	79.8	73.5	57.2	82.6	121.3	137.6	120.5	110.2	198.2	1306.9

Year	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1986	Mean Max.Temp.(C)	-3.9	-4.4	3.7	12.5	18.4	20.7	24.7	23.1	18.1	12.7	4.0	0.3	
	Mean Min.Temp.(C)	-12.1	-12.8	-5.5	2.4	9.0	10.8	15.6	14.3	11.5	5.8	-1.7	-4.5	
	Mean Monthly Temp.(C)	-8.0	-8.6	-0.9	7.5	13.7	15.8	20.2	18.7	14.8	9.3	1.2	-2.1	
	Total Rainfall (mm)	7.6	9.8	33.5	48.9	58.5	65.2	132.7	67.2	175.3	87.3	16.2	4.0	
	Total Snowfall (cm)	98.0 e	58.8	33.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	36.0	60.0	
	Total Precipitation (mm)	106.8 e	68.6	66.5	52.9	58.5	65.2	132.7	67.2	175.3	87.3	52.2	64.0	997.2 e
1987	Mean Max.Temp.(C)	-2.5	-1.9	4.2	13.4	18.4	23.1	26.5	24.4	20.0	11.2	6.1	1.8	
	Mean Min.Temp.(C)	-9.6	-13.3	-4.5	4.0	8.1	13.4	17.5	15.5	12.3	4.0	-0.5	-3.1	
	Mean Monthly Temp.(C)	-6.1	-7.6	-0.2	8.7	13.3	18.3	22.0	20.0	16.2	7.6	2.8	-0.7	
	Total Rainfall (mm)	0.0	11.0	39.0	37.5	47.5	53.2	72.3	90.7	57.2	77.6	59.8	38.7	
	Total Snowfall (cm)	103.3	32.8	28.6	7.0	0.0	0.0	0.0	0.0	0.0	0.0	49.2	38.2	
	Total Precipitation (mm)	103.3	43.8	67.6	44.5	47.5	53.2	72.3	90.7	57.2	77.6	109.0	76.9	843.6
1988	Mean Max.Temp.(C)	-2.3	-3.4	1.6	8.8	19.2	21.9	27.3	25.8	19.6	10.1	7.0	-0.3	
	Mean Min.Temp.(C)	-12.0	-12.7	-8.3	1.1	8.1	11.3	16.7	16.8	10.8	3.9	1.8	-8.4	
	Mean Monthly Temp.(C)	-7.2	-8.1	-3.4	5.0	13.7	16.6	22.0	21.3	15.2	7.0	4.4	-4.4	
	Total Rainfall (mm)	20.8	1.6	19.1	56.2	45.2	44.5	50.0	128.1	89.4	122.0	113.4	6.6	
	Total Snowfall (cm)	62.8	130.2	11.4	0.8	0.0	0.0	0.0	0.0	0.0	3.8	1.0	76.8	
	Total Precipitation (mm)	83.6	131.8	30.5	57.0	45.2	44.5	50.0	128.1	89.4	125.8	114.4	83.4	983.7
1989	Mean Max.Temp.(C)	0.2	-4.5	0.3	7.3	17.0	22.2	27.0	24.5	19.9	14.0	4.5	-8.4	
	Mean Min.Temp.(C)	-9.9	-13.2	-10.3	-1.0	6.7	13.4	16.0	14.8	11.3	6.1	-2.3	-17.5	
	Mean Monthly Temp.(C)	-4.9	-8.9	-5.0	3.2	11.9	17.8	21.5	19.7	15.6	10.1	1.1	-13.0	
	Total Rainfall (mm)	4.7	0.0	27.4	26.6	87.7	97.8	5.0	89.7	56.4	85.4	76.4	1.2	
	Total Snowfall (cm)	63.8	82.6	53.0	10.0	8.2	0.0	0.0	0.0	0.0	0.0	62.6	79.2	
	Total Precipitation (mm)	68.5	82.6	80.4	36.6	95.9	97.8	5.0	89.7	56.4	85.4	139.0	80.4	917.7
1990	Mean Max.Temp.(C)	1.2	-1.1	3.6	11.6	15.4	22.0	24.7	24.5	19.2	13.2	8.1	1.2	
	Mean Min.Temp.(C)	-6.1	-10.4	-5.6	2.8	5.8	12.7	15.5	15.5	11.2	5.4	0.6	-5.1	
	Mean Monthly Temp.(C)	-2.5	-5.8	-1.0	7.2	10.6	17.4	20.1	20.0	15.2	9.3	4.4	-2.0	
	Total Rainfall (mm)	30.7	14.8	28.2	62.0	75.4	67.1	84.3	15.8	97.2	96.2	132.4	18.0 e	
	Total Snowfall (cm)	50.8	70.0	10.6	5.0	0.0	0.0	0.0	0.0	0.0	0.0	11.8	99.4 e	
	Total Precipitation (mm)	81.5	84.8	38.8	67.0	75.4	67.1	84.3	15.8	97.2	96.2	144.2	117.4 e	969.7 e

Year	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1991	Mean Max.Temp.(C)	-4.2	0.2	3.3	13.7	21.8	26.1	28.3	27.0	18.9	13.8	5.4	-0.6	
	Mean Min.Temp.(C)	-12.3	-9.6	-5.2	2.8	9.2	13.4	16.1	16.1	8.7	5.9	-1.2	-7.6	
	Mean Monthly Temp.(C)	-8.3	-4.7	-0.9	8.2	15.5	19.7	22.2	21.6	13.8	9.9	2.1	-4.1	
	Total Rainfall (mm)	0.4	7.4	81.7	133.6	106.1	22.2	90.0	18.6	112.4	137.3	52.0	20.8	
	Total Snowfall (cm)	113.6	53.0	20.2	1.6	0.0	0.0	0.0	0.0	0.0	0.0	14.6	68.2	
	Total Precipitation (mm)	114.0	60.4	101.9	135.2	106.1	22.2	90.0	18.6	112.4	137.3	66.6	89.0	1053.7
1992	Mean Max.Temp.(C)	-3.6	-1.8	2.3	8.9	21.1	23.8	22.1	23.3	19.8	10.7	4.3	-0.9 e	
	Mean Min.Temp.(C)	-11.9	-11.4	-6.6 e	-1.2	5.6	9.0	12.6	12.8	10.2	3.3	-0.8	-8.2 e	
	Mean Monthly Temp.(C)	-7.7	-6.6	-2.2	3.9	13.3	16.4	17.3	18.1	15.0	7.0	1.8	-4.6 e	
	Total Rainfall (mm)	34.8	6.3	33.3 e	29.0	38.4	52.8	139.0	116.2	142.7	51.6	142.9	18.0 e	
	Total Snowfall (cm)	128.9	64.2	27.7	38.6	0.0	0.0	0.0	0.0	0.0	8.0	40.7	99.4 e	
	Total Precipitation (mm)	163.7	70.5	61.0 e	67.6	38.4	52.8	139.0	116.2	142.7	59.6	183.6	117.4 e	1212.5 e
1993	Mean Max.Temp.(C)	-2.1	-5.3	2.9	11.3	17.4	22.4	26.5	25.9	19.3 e	12.4	5.7	-0.7 e	
	Mean Min.Temp.(C)	-9.8	-17.9	-9.1	-0.5	5.7	11.7	16.1	15.9	11.1 e	5.3 e	-0.3	-8.1 e	
	Mean Monthly Temp.(C)	-5.9	-11.6	-3.1	5.4	11.6	17.0	21.3	20.9	15.2 e	8.9 e	2.7	-4.4 e	
	Total Rainfall (mm)	7.2	0.0	5.4	75.1	100.1	122.0	53.4	73.8	107.4 e	92.5	77.6	19.9 e	
	Total Snowfall (cm)	95.9	42.1	24.1	9.5	0.0	0.0	0.0	0.0	0.0	0.8 e	26.0 e	87.3 e	
	Total Precipitation (mm)	103.1	42.1	29.5	84.6	100.1	122.0	53.4	73.8	107.4 e	93.3 e	103.6 e	107.1 e	1020.0 e

STATION NAME: MIDHURST ONT
STATION NUMBER: 6115099
LATITUDE: 44° 27'
LONGITUDE: 79° 46'
ELEVATION: 226 m

Year	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1977	Mean Max.Temp.(C)	-8.4	-3.3	6.1	14.5	22.2	23	26.3	23.3	18.5	12.4	6.7	-2.4	
	Mean Min.Temp.(C)	-16.5	-12.2	-4.7	0.3	5.1	8.1	13.6	11.7	10	2.2	0	-9.7	
	Mean Monthly Temp.(C)	-12.5	-7.8	0.7	7.4	13.7	15.6	20	17.5	14.3	7.3	3.4	-6.1	
	Total Rainfall (mm)	0	14	48.3	22.4	18.5	96.3	61.5	159.7	125.5	66.6	57.9	10.3	681
	Total Snowfall (cm)	97.3	17.6	18.3	0.3	0	0	0	0	0	0	32.3	109.8	275.6
	Total Precipitation (mm)	97.3	31.6	66.6	22.7	18.5	96.3	61.5	159.7	125.5	66.6	90.2	120.1	956.6
1978	Mean Max.Temp.(C)	-6	-6.3	0.2	7.2	19.6	22.9	26.6	25.9	19.4	12	6.6	-0.6	
	Mean Min.Temp.(C)	-14.9	-18.2	-11.1	-2.9	6.5	8.7	12.8	12.1	8.1	2.8	-3.4	-8.1	
	Mean Monthly Temp.(C)	-10.5	-12.3	-5.5	2.2	13.1	15.8	19.7	19	13.8	7.4	1.6	-4.4	
	Total Rainfall (mm)	5.4	0	16	36.8	67.3	72.2	81.2	113.9	108.8	77.6	40.5	15.5	635.2
	Total Snowfall (cm)	133.2	20.8	11.5	0.4	0	0	0	0	0	0	22.1	90.4	278.4
	Total Precipitation (mm)	138.6	20.8	27.5	37.2	67.3	72.2	81.2	113.9	108.8	77.6	62.6	105.9	913.6
1979	Mean Max.Temp.(C)	-6	-7.9	5.3	9.31	17.2	24.3	27.4	24.9	21.4	11.9	7.3	1.3	
	Mean Min.Temp.(C)	-13	-18.6	-4.7	-0.7	5.5	11.1	12.9	12.6	8.3	41	-0.6	-5.7	
	Mean Monthly Temp.(C)	-9.5	-13.3	0.3	4.3	11.4	17.7	20.2	18.8	14.9	8	3.4	-2.2	
	Total Rainfall (mm)	0.8	12.6	40.8	60.8	69	75.6	12.2	80	45.6	147.4	82.6	52.8	680.2
	Total Snowfall (cm)	83.8	35.6	24.2	18.6	0	0	0	0	0	3	10	34.8	210
	Total Precipitation (mm)	84.6	48.2	65	79.4	69	75.6	12.2	80	45.6	150.4	92.6	87.6	890.2
1980	Mean Max.Temp.(C)	-2.5	-5	1.7	11.2	19.3	20.4	25.7	25.7	19.8	9.8	4.5	-3.7	
	Mean Min.Temp.(C)	-10.7	-15.4	-8.5	0.5	5.5	7.7	13.5	15.2	9.1	1.4	-2.8	-13.3	
	Mean Monthly Temp.(C)	-6.6	-10.2	-3.4	5.9	12.4	14.1	19.6	20.5	14.5	5.6	0.9	-8.5	
	Total Rainfall (mm)	7	0	43	91.8	36	125.6	167.4	58.2	112.2	103.6	52.2	41	838
	Total Snowfall (cm)	51	32.6	25.6	0.4	0	0	0	0	0	2.6	11.2	107.8	231.2
	Total Precipitation (mm)	58	32.6	68.6	92.2	36	125.6	167.4	58.2	112.2	106.2	63.4	148.8	1069.2

Year	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1981	Mean Max.Temp.(C)	-7	-1.8	3.6	12	17	22.6	26.3	24.9	18.2	10.4	6.6	-1.5	
	Mean Min.Temp.(C)	-16.2	-7	-5.8	0.6	4	11.4	13.5	13.3	9	1.6	-2	-7.7	
	Mean Monthly Temp.(C)	-11.6	-2.6	-1.1	6.3	10.5	17	19.9	19.1	13.6	6	2.3	-4.6	
	Total Rainfall (mm)	0	29.8	28.2	38.2	112.6	89.6	52	165.8	124.8	73.8	49.2	3.6	767.6
	Total Snowfall (cm)	61.4	33	11.8	0	0	0	0	0	0	31.6	16.8	50.2	204.8
	Total Precipitation (mm)	61.4	62.8	40	38.2	112.6	89.6	52	165.8	124.8	105.4	66	53.8	972.4
1982	Mean Max.Temp.(C)	-6.9	-3.1	1.6	9.4	21.2	20.5	26.6	22.6	19.9	14.6	7	3.2	
	Mean Min.Temp.(C)	-17.6	-12.3	-8.1	-2.7	7.7	9.2	13.8	11	8.3	3.9	0.3	-4.7	
	Mean Monthly Temp.(C)	-12.3	-7.7	-3.3	3.4	14.5	14.9	20.2	16.8	14.1	9.3	3.7	-0.8	
	Total Rainfall (mm)	9	0	31.8	40	47.6	124.4	75.4	89.6	71.2	47.6	111.4	72.8	720.8
	Total Snowfall (cm)	105.8	43	46	5	0	0	0	0	0	4.8	15	32.4	252
	Total Precipitation (mm)	114.8	43	77.8	45	47.6	124.4	75.4	89.6	71.2	52.4	126.4	105.2	972.8
1983	Mean Max.Temp.(C)	-2.1	-0.1	3.7	8.8	15.1	25.1	28.2	26.2	22.5	13.5	5.7	-3.7	
	Mean Min.Temp.(C)	-10.2	-8.6	-4.9	-0.1	4.2	10.4	14.6	15.3	9.2	4.1	-1.3	-11.3	
	Mean Monthly Temp.(C)	-6.2	-4 4	-0.6	4.4	9 7	17.8	21.4	20.8	15.9	8.8	2.2	-7.5	
	Total Rainfall (mm)	20.4	24.2	29.8	71.4	101.8	27.4	65.8	69.6	96.4	90.4	62.2	3.8	663.2
	Total Snowfall (cm)	40	12.4	24.4	7.6	0	0	0	0	0	0	21.2	73.8	179.4
	Total Precipitation (mm)	60.4	36.6	54.2	79	101.8	27.4	65.8	69.6	96.4	90.4	83.4	77.6	842.6
1984	Mean Max.Temp.(C)	-6.1	2.1	0.5	13.3	15.1	25.4	27.1	27.6	18.3	15.3	7.1	3.2	
	Mean Min.Temp.(C)	-15.8	-6.7	-10.4	0.1	3.6	10.5	11.5	14.2	6.9	4.3	-1.7	-5	
	Mean Monthly Temp.(C)	-11	-2.3	-5	6.7	9.4	18	19.3	20.9	12.6	9.8	2.7	-0.9	
	Total Rainfall (mm)	0	79.6	5	53.8	87	46.1	42.2	82.6	121.1	52.4	57.3	42	669.1
	Total Snowfall (cm)	51.6	37.1	30.5	0	0	0	0	0	0	0	51	51	175.2
	Total Precipitation (mm)	51.6	116.7	35.5	53.8	87	46.1	42.2	82.6	121.1	52.4	62.3	93	844.3
1985	Mean Max.Temp.(C)	-5.1	-2	4.5	12.7	19.1	20.2	25.2	24.3	21.9	14	4.9	-1.6	
	Mean Min.Temp.(C)	-13.5	-9.4	-5.7	0.6	5.7	7.9	12.7	11.9	10.4	4.1	-0.7	-8.8	
	Mean Monthly Temp.(C)	-9.3	-5.7	-0.6	6.7	12.4	14.1	19	18.1	16.2	9.1	2.1	-5.2	
	Total Rainfall (mm)	0	27.5	33.4	49.1	91.3	34.4	117.3	147.9	102.5	81.7	77.7	6	768.8
	Total Snowfall (cm)	127.5	4.3	25 5	3.5	0	0	0	0	0	0	30.6	78.6	308.7
	Total Precipitation (mm)	127.5	70.5	58.9	52.6	91.3	34.4	117.3	147.9	102.5	81.7	108.3	84.6	1077.5

Year	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1986	Mean Max.Temp.(℃)	-3	-3.8	5.4	13.3	20	22	25.6	23.4	19.1	12.7	3.7	0.2	
	Mean Min.Temp.(℃)	-11.1	-11.8	-5.3	1.3	8.2	9.5	13.7	9.5	7.3	1	-5.2	-7.1	
	Mean Monthly Temp.(℃)	-7.1	-7.8	0.1	7.3	14.1	15.8	19.7	16.5	13.2	6.9	-0.8	-3.5	
	Total Rainfall (mm)	11.4	9.6	34.4	58.4	67.6	94.9	91	123.7	262.7	72.7	15.1	11.4	852.9
	Total Snowfall (cm)	68.1	46.6	28	0	0	0	0	0	0	0	22.6	34.2	209.5
	Total Precipitation (mm)	79.5	56.2	62.4	68.4	67.6	94.9	91	123.7	262.7	72.7	37.7	45.6	1062.4
1987	Mean Max.Temp.(℃)	-2.4	-1.2	5.3	15.1	20.4	24.6	27.4	24.6	20	11.5	6.1	1.2	
	Mean Min.Temp.(℃)	-11.3	-14.8	-7.4	1.1	5.9	11.7	15	12.7	9.3	1.9	-2.1	-5.3	
	Mean Monthly Temp.(℃)	-6.9	-8	-1.1	8.1	13.2	18.2	21.2	18.7	14.7	6.7	2	-2.1	
	Total Rainfall (mm)	0	0	63.8	38.5	65.1	123.4	108.1	75.2	93.3	80	80.8	30	758.2
	Total Snowfall (cm)	63.2	28.6	30	4	0	0	0	0	0	0	43.1	34.8	203.7
	Total Precipitation (mm)	63.2	28.6	93.8	42.5	65.1	123.4	108.1	75.2	93.3	80	123.9	64.8	961.9
1988	Mean Max.Temp.(℃)	-2.2	-3.2	2.8	10.1	20.5	23.5	29	26.4	20.1	10	7.4	-0.4	
	Mean Min.Temp.(℃)	-11.2	-12.8	-8.8	0	6	8.4	14.7	14.1	9.1	2	0.7	-9.2	
	Mean Monthly Temp.(℃)	-6.7	-8	-3	5.1	13.3	16	21.9	20.3	14.6	6	4.1	-4.8	
	Total Rainfall (mm)	32.2	5.5	13.8	53.8	72.2	51.6	108.7	52	119.8	88.7	59.1	11.6	669
	Total Snowfall (cm)	34	86.4	7.2	5.8	0	0	0	0	0	18.5	1	67.8	220.7
	Total Precipitation (mm)	66.2	91.9	21	59.6	72.2	51.6	108.7	52	119.8	107.2	60.1	79.4	889.7
1989	Mean Max.Temp.(℃)	0.5	-4.1	1.4	9	18.3	23.5	28.8	25.1	20.7	14.3	4.4	-6.8	
	Mean Min.Temp.(℃)	-9	-12.9	-9.5	-2.5	5.7	12.1	14.1	12.6	8.9	4.2	-3.8	-17.5	
	Mean Monthly Temp.(℃)	-4.3	-8.5	-4.1	3.3	12	17.8	21.5	18.9	14.8	9.3	0.3	-12.2	
	Total Rainfall (mm)	21.2	0	13.8	22	85	93.6	2.8	71.1	67.9	92.7	99.8	0.6	570.5
	Total Snowfall (cm)	38.8	46	38.8	4.2	4	0	0	0	0	0	36.6	69.4	237.8
	Total Precipitation (mm)	60	46	52.6	26.2	89	93.6	2.8	71.1	67.9	92.7	136.4	70	808.3
1990	Mean Max.Temp.(℃)	1.7	-0.4	4.8	13.3	17.2	23.3	26	25.8	19.9	13.7	8.4	1.4	
	Mean Min.Temp.(℃)	-6.1	-10.1	-5.1	1.9	5.2	11.3	13.8	13.8	10	3.3	-1.8	-6.6	
	Mean Monthly Temp.(℃)	-2.2	-5.3	-0.2	7.6	11.2	17.3	19.9	19.8	15	8.5	3.3	-2.6	
	Total Rainfall (mm)	6.4	26.7	60.2	44	86.2	102.1	88.3	23.6	85	97.2	85.1	29.6	734.4
	Total Snowfall (cm)	33.2	33.6	6.6	2	0	0	0	0	0	0	8.2	48	131.6
	Total Precipitation (mm)	39.6	60.3	66.8	46	86.2	102.1	88.3	23.6	85	97.2	93.3	77.6	866

Year	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1991	Mean Max.Temp.(C)	-3.3	0.7	3.6	13.1	22.5	26.6	26.8	26.4	20.2	14.8	5.8	0.3	
	Mean Min.Temp.(C)	-11.8	-9	-4.8	2.6	9.2	12.8	14	14.1	8.3	5.3	-1.9	-8.9	
	Mean Monthly Temp.(C)	-7.5	-4.2	-0.6	7.8	15.8	19.7	20.4	20.3	14.2	10	1.9	-4.3	
	Total Rainfall (mm)	0	3	67.8	161.6	76.1	9.2	139.2	63.2	75.5	75.8	39.5	6.3	717.2
	Total Snowfall (cm)	57.6	28	16.1	1	0	0	0	0	0	0	26	80.5	209.2
	Total Precipitation (mm)	57.6	31	83.9	162.6	76.1	9.2	139.2	63.2	75.5	75.8	65.5	86.8	926.4
1992	Mean Max.Temp.(C)	-1.8	-1.5	1.8	9	18.8	22.3	22.1	22.7	20.1	11.6	4.9	1.1	
	Mean Min.Temp.(C)	-11.2	-10.2	-9.1	-0.8	4.2	8.2	11.2	10.6	8.4	0.5	-2.2	-6.7	
	Mean Monthly Temp.(C)	-6.5	-5.9	-3.6	4.1	11.5	15.2	16.6	16.6	14.2	6.1	1.4	-2.8	
	Total Rainfall (mm)	11	17.4	25.6	47.2	64.9	26.4	87	113	119.5	54.9	125.3	25.2	717.4
	Total Snowfall (cm)	69.5	26	15.5	12.5	0	0	0	0	0	3	40.7	77.5	244.7
	Total Precipitation (mm)	80.5	43.4	41.1	59.7	64.9	26.4	87	113	119.5	57.9	166	102.7	962.1
1993	Mean Max.Temp.(C)	-1.5	-5.1	2	11.3e	16.7	21.5	25.5	24.9e	20e	12.6e	6.1e	-0.5e	
	Mean Min.Temp.(C)	-10.2	-17.5	-8.8	-0.1e	5.5	11.5	15.7	12.8e	8.8e	2.9e	-1.8e	-8.5e	
	Mean Monthly Temp.(C)	-5.8	-11.3	-3.4	5.6	11.1	16.5	20.6	18.9	14.4	7.78	2.1	-4.5	
	Total Rainfall (mm)	28.4	0	0.6	55.6e	67.8	85.7	54.1	93.1e	108.2e	81.4e	68.5e	22.6e	666.1
	Total Snowfall (cm)	73	57.5	16.3	4.7e	0	0	0	0	0	3.96e	21.4e	65.1e	241.9
	Total Precipitation (mm)	101.4	57.5	16.9	60.3	67.8	85.7	54.1	93.1	108.2	85.4	89.9	87.7	908e

STATION NAME: MIDLAND WPCP ONT.
STATION NUMBER: 611527
LATITUDE: 44° 44'
LONGITUDE: 79° 53'
ELEVATION: 229 m

Year	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1977	Mean Max.Temp.(C)	-8.4	-3.6	5.7	13.4	21.6	22.7	25.7	22.9	18.5	12.8	6.8	-2.1	
	Mean Min.Temp.(C)	-16.0	-10.9	-3.4	1.3	8.4	11.4	16.4	14.0	12.1	4.4	1.3	-7.8	
	Mean Monthly Temp.(C)	-12.2	-7.3	1.2	7.4	15.0	17.1	21.1	18.5	15.3	8.6	4.1	-5.0	
	Total Rainfall (mm)	0.0	9.2	58.8	47.9	38.1	80.9	112.9	126.7	132.6	101.2	104.5	6.1	818.9
	Total Snowfall (cm)	213.1	54.2	17.6	3.6	0.0	0.0	0.0	0.0	0.0	0.0	23.9	165.4	477.8
	Total Precipitation (mm)	213.1	63.4	76.4	51.5	38.1	80.9	112.9	126.7	132.6	101.2	128.4	171.5	1296.7
1978	Mean Max.Temp.(C)	-6.2	-5.4	0.7	7.5	19.5	22.3	25.8	25.6	18.9	12.4	6.4	-0.3	
	Mean Min.Temp.(C)	-14.7	-15.2	-9.5	-1.1	8.5	11.3	14.7	14.8	10.0	4.8	-1.1	-7.0	
	Mean Monthly Temp.(C)	-10.5	-10.3	-4.4	3.2	14.0	16.8	20.3	20.2	14.5	8.6	2.7	-3.7	
	Total Rainfall (mm)	13.5	0.0	28.0	49.3	61.6	59.8	48.2	63.0	128.6	85.2	57.0	30.8	625.0
	Total Snowfall (cm)	183.6	18.1	18.0	7.6	0.0	0.0	0.0	0.0	0.0	0.0	7.6	112.0	346.9
	Total Precipitation (mm)	197.1	18.1	46.0	56.9	61.6	59.8	48.2	63.0	128.6	85.2	64.6	142.8	971.9
1979	Mean Max.Temp.(C)	-5.9	-7.5	5.2	9.3	17.4	23.8	26.6	23.2	20.8	11.7	7.4	1.1	
	Mean Min.Temp.(C)	-12.0	-17.6	-4.0	0.8	6.7	12.1	15.1	14.1	11.1	5.3	1.1	-5.8	
	Mean Monthly Temp.(C)	-9.0	-12.6	0.6	5.1	12.1	18.0	20.9	18.7	16.0	8.5	4.3	-2.4	
	Total Rainfall (mm)	3.0	10.4	43.8	89.2	83.8	81.8	60.0	91.4	52.0	146.6	96.2	39.2	797.4
	Total Snowfall (cm)	143.0	51.0	14.7	16.0	1.0	0.0	0.0	0.0	0.0	0.0	47.6	52.4	325.7
	Total Precipitation (mm)	146.0	61.4	58.5	105.2	84.8	81.8	60.0	91.4	52.0	146.6	143.8	91.6	1123.1
1980	Mean Max.Temp.(C)	-2.5	-5.4	1.3	10.9	18.6	19.4	24.7	25.4	19.1	10.1	4.6	-3.6	
	Mean Min.Temp.(C)	-9.3	-14.2	-7.3	1.6	7.5	9.9	15.1	16.3	10.4	3.8	-1.4	-13.4	
	Mean Monthly Temp.(C)	-5.9	-9.8	-3.0	6.3	13.1	14.7	19.9	20.9	14.8	7.0	1.6	-8.5	
	Total Rainfall (mm)	8.2	0.0	63.0	83.0	87.6	144.8	98.3	78.2	87.8	128.2	54.2	29.0	862.3
	Total Snowfall (cm)	68.0	31.0	35.2	2.5	0.0	0.0	0.0	0.0	0.0	1.2	13.0	176.0	326.9
	Total Precipitation (mm)	76.2	31.0	98.2	85.5	87.6	144.8	98.3	78.2	87.8	129.4	67.2	205.0	1189.2

Year	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1981	Mean Max.Temp.(℃)	-7.6	1.4	3.5	11.7	16.5	22.7	25.7	24.5	17.8	10.6	6.1	-1.0	
	Mean Min.Temp.(℃)	-18.1	-7.4	-4.8	1.9	6.3	12.0	15.8	14.7	11.0	2.5	-0.9	-6.2	
	Mean Monthly Temp.(℃)	-12.9	-3.0	-0.7	6.8	11.4	17.4	20.8	19.6	14.4	6.6	2.6	-3.6	
	Total Rainfall (mm)	0.0	24.2	26.6	53.6	90.8	138.4	46.2	163.2	96.4	92.6	62.8	10.0	804.8
	Total Snowfall (cm)	42.0	45.6	21.6	0.0	0.0	0.0	0.0	0.0	0.0	4.0	9.0	67.2	189.4
	Total Precipitation (mm)	42.0	69.8	48.2	53.6	90.8	138.4	46.2	163.2	96.4	96.6	71.8	77.2	994.2
1982	Mean Max.Temp.(℃)	-7.4	-4.1	1.4	6.1	17.8	22.2	26.5	21.7	19.4	14.5	6.8	3.4	
	Mean Min.Temp.(℃)	-17.5	-12.3	-7.7	-3.2	7.2	11.5	14.9	12.8	10.9	6.2	1.0	-3.8	
	Mean Monthly Temp.(℃)	-12.5	-8.2	-3.2	1.5	12.5	16.9	20.7	17.3	15.2	10.4	3.9	-0.2	
	Total Rainfall (mm)	7.0	2.0	23.5	64.8	91.0	87.9	57.8	90.4	75.4	57.0	116.2	89.0	761.9
	Total Snowfall (cm)	133.6	78.0	68.0	8.6	0.0	0.0	0.0	0.0	0.0	0.0	9.0	49.0	346.1
	Total Precipitation (mm)	140.6	80.0	91.5	73.4	90.9	87.9	57.8	90.4	75.4	57.0	125.2	138.0	1108.1
1983	Mean Max.Temp.(℃)	-2.3	-0.6	3.6	8.8	14.8	24.6	27.6	26.5	21.8	13.6	5.3	-3.6	
	Mean Min.Temp.(℃)	-10.0	-8.4	-4.4	0.7	4.8	11.9	16.5	16.4	12.1	5.7	0.2	-10.6	
	Mean Monthly Temp.(℃)	-6.2	-4.5	-0.4	4.8	9.8	18.3	22.1	21.5	17.0	9.7	2.8	-7.1	
	Total Rainfall (mm)	43.0	19.0	41.0	92.0	128.0	64.0	49.8	38.4	137.0	98.0	58.0	3.0	711.2
	Total Snowfall (cm)	55.0	20.0	41.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	23.0	162.0	311.0
	Total Precipitation (mm)	98.0	39.0	82.0	102.0	128.0	64.0	49.8	38.4	137.0	98.0	81.0	165.0	1082.2
1984	Mean Max.Temp.(℃)	-5.7	1.6	-0.8	12.3	14.8	23.1	25.0	25.3	18.4	15.0	6.3	1.9	
	Mean Min.Temp.(℃)	-14.4	-6.6	-9.6	2.1	5.8	12.9	15.1	16.7	10.3	6.7	0.0	-4.3	
	Mean Monthly Temp.(℃)	-10.1	-2.5	-5.2	7.2	10.3	18.0	20.1	21.0	14.4	10.9	3.2	-1.2	
	Total Rainfall (mm)	0.0	27.1	39.0	61.0	130.0	70.0	91.6	92.0	111.0	65.0	96.0	39.0	821.7
	Total Snowfall (cm)	58.0	52.0	12.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	83.0	209.0
	Total Precipitation (mm)	58.0	79.1	51.0	63.0	130.0	70.0	91.6	92.0	111.0	65.0	98.0	122.0	1030.7
1985	Mean Max.Temp.(℃)	-5.7	-3.4	3.2	11.6	18.2	20.4	25.0	23.1	21.3	13.9	5.0	-2.2	
	Mean Min.Temp.(℃)	-13.3	-9.3	-5.2	1.5	7.5	10.4	14.8	14.2	12.3	6.3	0.5	-8.7	
	Mean Monthly Temp.(℃)	-9.5	-6.4	-1.0	6.6	12.9	15.4	19.9	18.7	16.8	10.1	2.8	-5.5	
	Total Rainfall (mm)	0.0	72.0	52.0	49.0	92.0	58.2	93.0	123.0	168.0	128.0	86.0	10.0	931.2
	Total Snowfall (cm)	184.1	86.0	45.0	18.0	0.0	0.0	0.0	0.0	0.0	0.0	28.0	259.0	620.1
	Total Precipitation (mm)	184.1	158.0	97.0	67.0	92.0	58.2	93.0	123.0	168.0	128.0	114.0	269.0	1551.3

Year	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1986	Mean Max.Temp.(C)	-3.8	-3.5	5.2	13.8	19.6	21.6	25.7	23.8	18.7	12.6	6.0	-0.6	
	Mean Min.Temp.(C)	-10.9	-11.6	-5.0	2.4	9.5	10.7	15.8	13.6	11.0	4.9	0.0	-7.3	
	Mean Monthly Temp.(C)	-7.4	-7.6	0.1	8.1	14.6	16.2	20.8	18.7	14.9	8.8	3.0	-4.0	
	Total Rainfall (mm)	13.0	9.0	10.6	54.0	97.0	82.0	86.0	113.0	208.0	96.4	85.4	27.6	882.0
	Total Snowfall (cm)	127.0	94.0	25.0	6.0	0.0	0.0	0.0	0.0	0.0	0.7	18.8	118.6	390.1
	Total Precipitation (mm)	140.0	103.0	35.6	60.0	97.0	82.0	86.0	113.0	208.0	97.1	104.2	146.2	1272.1
1992	Mean Max.Temp.(C)	-5.1	-3.2	2.8	10.5	17.8e	22.2	25.8	24.3	19.3	11.6	5.1	0.8	
	Mean Min.Temp.(C)	-13.3e	-11.8e	-6.3	0.7	7.15e	11.5	15.5	14.9	10.9	3.5	-0.3	-5.4	
	Mean Monthly Temp.(C)	-9.3	-7.6	-1.7	5.7	12.5	16.9	20.7	19.6	15.2	7.6	2.4	-2.3	
	Total Rainfall (mm)	12.1	15.7	38.1	64.8	91.0	87.9	71.4	95.4	120.2	62.3	123.3	19.5	801.8
	Total Snowfall (cm)	119.3	52.1	29.7	8.6	0.0	0.0	0.0	0.0	0.0	2.0	25.0	60.1	296.7
	Total Precipitation (mm)	131.4	67.8	62.2	73.4	91.0	87.9	71.4	95.4	120.2	64.3	148.3	79.6	1098.5
1993	Mean Max.Temp.(C)	-0.9	-4.6	2.3	10.7	17.0	21.7	25.9	25.7	17.8	11.6	5.5	-0.6	
	Mean Min.Temp.(C)	-10.7	-17.1	-8.1	0.4	6.5	12.2	16.6	16.0	9.4	3.8	-1.4	-7.3e	
	Mean Monthly Temp.(C)	-5.8	-10.9	-2.9	5.6	11.7	16.9	21.2	20.8	13.6	7.7	2.1	-4.0	
	Total Rainfall (mm)	45.7	0.0	33.2	68.8	100.7	99.5	41.7	70.4	125.8	97.6	50.6	27.6	761.6
	Total Snowfall (cm)	105.0	43.0	28.2	20.0	0.0	0.0	0.0	0.0	0.0	4.0	5.2	118.6	324.0
	Total Precipitation (mm)	150.7	43.0	61.4e	88.8	100.7	99.5	41.7	70.4	125.8	101.6	55.8	146.2	1085.0

STATION NAME: ORILLIA STP ONT
STATION NUMBER: 6115820
LATITUDE: 44° 37'
LONGITUDE: 79° 25'
ELEVATION: 220 m

Year	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1977	Mean Max.Temp.(C)	-3.6	-2.7	2.8	10.7	18.2	21.8	25.5	22.2	18	11.9	6.2	-2.7	
	Mean Min.Temp.(C)	-13.1e	-12.6e	-7.2	0.75e	7.5	10.2	15.8	13.8	11.4	3.7	0	-9.5	
	Mean Monthly Temp.(C)	-8.3	-7.6	-2.2e	5.73e	12.8	16	20.7	18	14.7	7.8	3.1	-6.1	
	Total Rainfall (mm)	0	7.4	66.4	36.8	25.6	59.6	57.3	125.5	83.7	95.1	92.4	13.8	663.6
	Total Snowfall (cm)	101.6	42	24.9	5.1	0	0	0	0	0	0	23.3	102.6	299.5
	Total Precipitation (mm)	101.6	49.4	91.3	41.9	25.6	59.6	57.3	125.5	83.7	95.1	115.7	116.4	963.1
1978	Mean Max.Temp.(C)	-6.6	-6.4	1.1	7.5	19.4	21.7	25.3	25	18.7	11.9	6.31	-0.7	
	Mean Min.Temp.(C)	-15.5	-16	-10.6	-1.2	8.2	10.9	14.7	14.1	8.6	3.1	-2.4	-8.9	
	Mean Monthly Temp.(C)	-11.1	-11	-4.8	3.2	13.8	16.3	20	19.6	13.7	7.5	2	-4.8	
	Total Rainfall (mm)	22.4	0	30.6	54.2	69.5	64.4	45.7	107.4	107.8	89.2	67.4	38.6	697.2
	Total Snowfall (cm)	121.8	17	5.7	6	0	0	0	0	0	0	15	80.8	246.3
	Total Precipitation (mm)	144.2	17	36.3	60.2	69.5	64.4	45.7	107.4	107.8	89.2	82.4	119.4	943.5
1979	Mean Max.Temp.(C)	-6.3	-8.3	4.8	9.1	16.8	23.6	25.8	22.7	20.5	11.6	6.5	1	
	Mean Min.Temp.(C)	-13.7	-18.7	-5	0.9	6.6	11.9	15.3	14.1	10.3	4.4	-0.1	-7.6	
	Mean Monthly Temp.(C)	-10	-13.5	-0.1	5	11.7	17.8	20.6	18.4	15.4	8	3.2	-3.3	
	Total Rainfall (mm)	2	4	37.9	77.1	62.2	56.8	135.2	106.8	67.3	146.9	97.3	57.9	851.4
	Total Snowfall (cm)	113.6	47.2	15.4	21	4	0	0	0	0	4	26.6	108.6	340.4
	Total Precipitation (mm)	115.6	51.2	53.3	98.1	66.2	56.8	135.2	106.8	67.3	150.9	123.9	166.5	1191.8
1980	Mean Max.Temp.(C)	-2.9	-5.4	1.5	10.6	18.9	19.5	25.2	25.1	19	9.7	3.9	-4.3	
	Mean Min.Temp.(C)	-10.8	-15.1	-8.4	0.8	7.9	9.8	15.2	16.2	10.2	2.9	-2.4	-14.4	
	Mean Monthly Temp.(C)	-6.9	-10.3	-3.5	5.7	13.4	14.7	20.2	20.7	14.6	6.3	0.8	-9.4	
	Total Rainfall (mm)	15	0	51.7	98.5	44.1	130.7	90.8	97.1	103.4	146.2	50.2	43.5	871.2
	Total Snowfall (cm)	53.2	51.1	61.2	0	0	0	0	0	0	6	20.4	102.9	294.8
	Total Precipitation (mm)	68.2	51.1	112.9	98.5	44.1	130.7	90.8	97.1	103.4	152.2	70.6	146.4	1166

Year	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1981	Mean Max.Temp.(C)	-8	1.8	3.8	11.4	16.8	22	25.2	24.1	17.5	10.4	6.2	-1.4	
	Mean Min.Temp.(C)	-19.3	-8	-5.3	1.9	6.6	12.1	15.9	15.2	10.2	2.2	-1.7	-7.6	
	Mean Monthly Temp.(C)	-13.7	-3.1	-0.8	6.7	11.7	17.1	20.6	19.7	13.9	6.3	2.3	-4.5	
	Total Rainfall (mm)	0.2	22.6	22.4	68.3	105.4	117.5	58.8	145.2	114.6	74.9	44.6	4	778.5
	Total Snowfall (cm)	27.6	65.6	28.5	0	0	0	0	0	0	29.5	7.6	43.2	202
	Total Precipitation (mm)	27.8	88.2	50.9	68.3	105.4	117.5	58.8	145.2	114.6	104.4	52.2	47.2	980.5
1982	Mean Max.Temp.(C)	-6.3	-3.8	1.2	8.8	19.8	19.9	25.6	21.7	18.9	14.1	6.5	4	
	Mean Min.Temp.(C)	-19.7	-13.6	-8.4	-2.9	9.2	11.5	14.8	12.6	9.7	4.9	-0.7	-5.5	
	Mean Monthly Temp.(C)	-13	-8.7	-3.6	3	14.5	15.7	20.2	17.2	14.3	9.5	2.9	-0.8	
	Total Rainfall (mm)	13.8	0	27.6	62.6	50.9	113.7	113.5	103.6	69.5	37.7	131.3	103.1	827.3
	Total Snowfall (cm)	129.9	53	58.6	11.5	0	0	0	0	0	0	18.4	49.8	321.2
	Total Precipitation (mm)	143.7	53	86.2	74.1	50.9	113.7	113.5	103.6	69.5	37.7	149.7	152.9	1148.5
1983	Mean Max.Temp.(C)	-2.3	-0.6	3.3	8.6	14.7	24.4	27.1	25.6	21.8	13	5.3	-3.4	
	Mean Min.Temp.(C)	-11.9	-9.8	-5.2	0.4	4.6	11.9	16.7	15.9	12	4.6	-0.9	-12	
	Mean Monthly Temp.(C)	-7.1	-5.2	-1	4.5	9.7	18.2	21.9	20.8	16.9	8.8	2.2	-7.7	
	Total Rainfall (mm)	37	22.3	41.6	94.9	125.8	38.6	65.4	108.5	99.7	119.9	79.1	13	845.8
	Total Snowfall (cm)	68.1	8.8	27.4	14	0	0	0	0	0	0	44.5	127.2	290
	Total Precipitation (mm)	105.1	31.1	69	108.9	125.8	38.6	65.4	108.5	99.7	119.9	123.6	140.2	1135.8
1984	Mean Max.Temp.(C)	-5.6	1.1	0	12.3	15.2	23.3	24.9	25.4	17.9	15.1	6	2.4	
	Mean Min.Temp.(C)	-16	-6.9	-10.2	1.8	6.1	12.9	15	16.2	9.9	6	-1.4	-5.4	
	Mean Monthly Temp.(C)	-10.8	-2.9	-5.1	7.1	10.7	18.1	20	20.8	13.9	10.6	2.3	-1.5	
	Total Rainfall (mm)	0	37.8	46.4	55.1	101.2	71.7	98.1	94.41	111.2	56.2	85	47.2	804.3
	Total Snowfall (cm)	72.4	32	19	3.5	0	0	0	0	0	0	9	88.1	224
	Total Precipitation (mm)	72.4	69.8	65.4	58.6	101.2	71.7	98.1	94.4	111.2	56.2	94	135.3	1028.3
1985	Mean Max.Temp.(C)	-5.6	-2.4	4.4	11.6	18.5	20.8	24.9	23.4	21	13.8	5	-1.9	
	Mean Min.Temp.(C)	-15	-10	-5	0.9	7.5	10.4	14.8	14.1	12.2	5.3	-0.6	-10.7	
	Mean Monthly Temp.(C)	-10.3	-6.2	-0.3	6.3	13	15.6	19.9	18.8	16.6	9.6	2.2	-6.3	
	Total Rainfall (mm)	0.4	57.1	46.8	29.2	83	36.2	57	161.6	124.8	85.3	88.1	13.8	783.3
	Total Snowfall (cm)	142	59	31.6	15.8	0	0	0	0	0	0	33.4	99.1	380.9
	Total Precipitation (mm)	142.4	116.1	78.4	45	83	36.2	57	161.6	124.8	85.3	121.5	112.9	1164.2

Year	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1986	Mean Max.Temp.(℃)	-2.9	-3.4	4.8	13.8	20.1	21.8	25.4	23.2	18.2	13.1	4	0.4	
	Mean Min.Temp.(℃)	-11.9	-12.4	-5.9	2.7	9.7	11.5	16.7	13.2	10.6	5.3	-2.5	-5.4	
	Mean Monthly Temp.(℃)	-7.4	-7.9	-0.6	8.3	14.9	16.7	21.1	18.2	14.4	9.2	0.8	-2.5	
	Total Rainfall (mm)	11.4	7.4	46.7	57.3	83.1	91.7	113	125	195.8	58.8	18.1	2.5	810.8
	Total Snowfall (cm)	63.8	54	48	13	0	0	0	0	0	0	36	70.6	285.4
	Total Precipitation (mm)	75.2	61.4	94.7	70.3	83.1	91.7	113	125	195.8	58.8	54.1	73.1	1096.2
1987	Mean Max.Temp.(℃)	-2.4	-1.6	5.3	14.9	20.1	24.6	27.4	24.4	20	10.9	6	1.5	
	Mean Min.Temp.(℃)	-10	-13.8	-4.8	3.3	8.9	13.5	17.7	15.2	11.4	3.2	-1	-4.3	
	Mean Monthly Temp.(℃)	-6.2	-7.7	0.3	9.1	14.5	19.1	22.6	19.8	15.7	7.1	2.5	-1.4	
	Total Rainfall (mm)	0	15	39	27.9	48.3	57.6	92.2	64.2	76.8	77.2	57.4	33.2	588.8
	Total Snowfall (cm)	94.2	20.6	35	5	0	0	0	0	0	0	68	33.8	256.6
	Total Precipitation (mm)	94.2	35.6	74	32.9	48.3	57.6	92.2	64.2	76.8	77.2	125.4	67	845.4
1988	Mean Max.Temp.(℃)	-2.5	-3	2.8	10	20.3	23.9	28.9	25.5	19.3	10.3	6.9	-0.6	
	Mean Min.Temp.(℃)	-11.7	-12.7	-7.6	1.2	9.1	11.1	16.2	15.9	9.7	2.7	0.9	-9.6	
	Mean Monthly Temp.(℃)	-7.1	-7.9	-2.4	5.6	14.7	17.5	22.6	20.7	14.5	6.5	3.9	-5.1	
	Total Rainfall (mm)	32.8	4	23.3	65.8	44.6	24.9	45.2	101.3	102.6	116.3	87.5	21.21	669.5
	Total Snowfall (cm)	77	104.2	12.2	4	0	0	0	0	0	4	0	106	307.4
	Total Precipitation (mm)	109.8	108.2	35.5	69.8	44.6	24.9	45.2	101.3	102.6	120.3	87.5	127.2	976.9
1989	Mean Max.Temp.(℃)	0	-4.3	0.9	7.4	17.2	23	27.5	24	20.1	13.5	5.3	-7.3	
	Mean Min.Temp.(℃)	-10.3	-14	-10.4	-1.3	6.9	12.8	15.7	14.8	10	5.1	-3.1	-18	
	Mean Monthly Temp.(℃)	-5.2	-9.2	-4.8	3.1	12.1	17.9	21.6	19.4	15.1	9.3	1.1	-12.7	
	Total Rainfall (mm)	36.1	0	32	27	118.1	109	0	131.1	87.7	108.6	114.2	1	764.8
	Total Snowfall (cm)	61.6	62.8	92.6	10	0	0	0	0	0	0	50	81.4	358.4
	Total Precipitation (mm)	97.7	62.8	124.6	37	118.1	109	0	131.1	87.7	108.6	164.2	82.4	1123.2
1990	Mean Max.Temp.(℃)	1.3	-0.4	3.8	12.6	16.2	22.8	25.6	24.9	19.3	13.5	8.3	1.4	
	Mean Min.Temp.(℃)	-6.8	-11.6	-6.5	1.8	5.9	12.4	15	14.1	9.4	2.9	-2	-8.2	
	Mean Monthly Temp.(℃)	-2.8	-6	-1.4	7.2	11.1	17.6	20.3	19.5	14.4	8.2	3.2	-3.4	
	Total Rainfall (mm)	20.9	32.4	45.6	87.6	93	105.4	84.7	46.4	104.3	101.3	103.8	28.7	854.1
	Total Snowfall (cm)	49	57.6	10.4	9	0	0	0	0	0	0	40.4	80.2	246.6
	Total Precipitation (mm)	69.9	90	56	96.6	93	105.4	84.7	46.4	104.3	101.3	144.2	108.9	1100.7

Year	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1991	Mean Max.Temp.(°C)	-3.6	0.4	3.8	13.3	21.3	26.1	26.5	26.3	19.8	14.1	5.2	0.1	
	Mean Min.Temp.(°C)	-14.3	-10.7	-5.7	1.6	8.9	12.1	14.9	13.8	7.6	3.6	-2.1	-7.8	
	Mean Monthly Temp.(°C)	-8.9	-5.2	-1	7.4	15.1	19.1	20.7	20.1	13.7	8.9	1.6	-3.9	
	Total Rainfall (mm)	2.4	7.8	91.8	161.1	109.9	13.2	73.1	63.4	114.5	92.8	41.5	23.2	794.7
	Total Snowfall (cm)	130	43.5	18	0	0	0	0	0	0	0	11	87.5	290
	Total Precipitation (mm)	132.4	51.3	109.8	161.1	109.9	13.2	73.1	63.4	114.5	92.8	52.5	110.7	1084.7
1992	Mean Max.Temp.(°C)	-2.8	-1.6	1.2	8.7	18.7	21.5	21.4	21.7	19.2	11.2	5	0.9	
	Mean Min.Temp.(°C)	-12	-11.4	-8.5	-0.3	7	10.8	13	13.4	10.3	3.1	-1.1	-6.3	
	Mean Monthly Temp.(°C)	-7.4	-6.5	-3.7	4.2	12.9	16.2	17.2	17.6	14.7	7.21	2	-2.7	
	Total Rainfall (mm)	17.3	8	29	45.7	53.6	41.2	104.2	128.9	75.5	83.5,	147.7	15.6	750.2
	Total Snowfall (cm)	87.8	47.2	14.1	46	0	0	0	0	0	9	31.2	78.3	313.6
	Total Precipitation (mm)	105.1	55.2	43.1	91.7	53.6	41.2	104.2	128.9	75.5	92.5	178.9	93.9	1063.8
1993	Mean Max.Temp.(°C)	-1.3	-5	2	10.8	17	21.5	25.5	25.8	19.3	12.4	5.7	-0.7	
	Mean Min.Temp.(°C)	-10.8	-17.3	-8.2	0.5	6.4	11.7	15.7	14.9	10.2	3.9	-1.3	-8.8	
	Mean Monthly Temp.(°C)	-6	-11.2	-3.1	5.6	11.7	16.6	20.6	20.4	14.8	18.1	2.2	-4.7	
	Total Rainfall (mm)	47.5	0	2.8	71.9	116.5	116.9	71.2	89.8	102.4e	93.1	81.6e	28.8	922.7
	Total Snowfall (cm)	117.6	51	25	19	0	0	0	0	0	3.3	27.2	83.7	326.5
	Total Precipitation (mm)	165.1	51	27.8	90.9	116.5	116.9	71.2	89.8	102.4e	96.4e	108.7e	112.5e	1149.2e

STATION NAME: THORNBURY SLAMA
STATION NUMBER: 611HBEC
LATITUDE: 44° 34'
LONGITUDE: 80° 29'
ELEVATION: 213 m

Year	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1977	Mean Max.Temp.(C)	-7.8	-3.5	6	12.1	19.9	20.8	25.4	22.3	18.1	12.3	6.5	-1.5	
	Mean Min.Temp.(C)	-14.7	-10.4	-2.9	1.1	7.4	9.6	15.3	12.3	11.3	4.6	1.2	-7.1	
	Mean Monthly Temp.(C)	-11.3	-7	1.6	6.6	13.7	15.2	20.4	17.3	14.7	8.5	3.9	-4.3	
	Total Rainfall (mm)	0	24.1	61.2	31.5	20.6	49.6	72.9	131.2	88.9	81	76	9.1	646.1
	Total Snowfall (cm)	58.8	15.2	12.7	1	0	0	0	0	0	0	23.7	85.3	196.7
	Total Precipitation (mm)	58.8	39.3	73.9	32.5	20.6	49.6	72.9	131.2	88.9	81	99.7	94.4	842.8
1978	Mean Max.Temp.(C)	-5.3	-6.2	-0.5	6.8	17.1	22	24.4	24.4	18.8	12.4	6.9	-0.1	
	Mean Min.Temp.(C)	-11.9	-14.4	-8.7	-1.1	7.6	11.1	13.9	14.2	10.2	5	-0.7	-6	
	Mean Monthly Temp.(C)	-8.6	-10.3	-4.6	2.9	12.4	16.6	19.2	19.3	14.5	8.7	3.1	-3.1	
	Total Rainfall (mm)	3.6	0	19.5	31	46	39.8	61.6	89.8	133.8	73.7	35.8	46.2	580.8
	Total Snowfall (cm)	69.6	25.5	9.7	8.2	0	0	0	0	0	2.8	23.8	35.3	174.9
	Total Precipitation (mm)	73.2	25.5	29.2	39.2	46	39.8	61.6	89.8	133.8	76.5	59.6	81.5	755.7
1979	Mean Max.Temp.(C)	-6.1	-7.5	4.7	8.3	15.4	22.4	24.6	22.5	20.7	12.1	7.6	1.5	
	Mean Min.Temp.(C)	-10.9	-15.9	-4	0.8	5.7	10.9	14.3	13.5	10.2	4.8	0.9	-5.1	
	Mean Monthly Temp.(C)	-8.5	-11.7	0.4	4.6	10.6	16.7	19.5	18	15.5	8.5	4.3	-1.8	
	Total Rainfall (mm)	0	5.6	35.3	93.4	61.6	68.4	32.2	84.6	58.4	130.5	67.2	50	687.2
	Total Snowfall (cm)	125	27.8	11	13.2	0	0	0	0	0	2.5	31.6	40	251.1
	Total Precipitation (mm)	125	33.4	46.3	106.6	61.6	68.4	32.2	84.6	58.4	133	98.8	90	938.3
1980	Mean Max.Temp.(C)	-1.9	-5.1	0.8	10.2	17.3	18.9	24.5	25	19	10.6	5.1	-2.9	
	Mean Min.Temp.(C)	-8.5	-11.6	-6.6	1.4	7	9.2	15	16.2	10.1	3.2	-1	-11.1	
	Mean Monthly Temp.(C)	-5.2	-8.4	-2.9	5.8	12.2	14.1	19.8	20.6	14.6	6.9	2.1	-7	
	Total Rainfall (mm)	12.2	5.2	34.8	75.8	71.4	115.2	209.8	37.4	117	90.9	46	34.2	849.9
	Total Snowfall (cm)	46.6	54.8	31.4	2.8	0	0	0	0	0	0	9	83	227.6
	Total Precipitation (mm)	58.8	60	66.2	78.6	71.4	115.2	209.8	37.4	117	90.9	55	117.2	1077.5

Year	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1981	Mean Max.Temp.(C)	-5.8	0.6	3.5	11.2	15	21.8	24.6	23.5	17.8	10.7	6.9	-0.4	
	Mean Min.Temp.(C)	-14.5	-7	-4.8	2.3	5.7	12	15.3	14.4	11.2	2.6	-0.2	-4.9	
	Mean Monthly Temp.(C)	-10.2	-3.2	-0.7	6.8	10.4	16.9	20	19	14.5	6.7	3.4	-2.7	
	Total Rainfall (mm)	1.4	37	21.8	52	92	125.2	71	155.4	76.2	82.2	64.2	18.2	796.6
	Total Snowfall (cm)	44	24.6	23.4	0	0	0	0	0	0	0	10.2	75	177.2
	Total Precipitation (mm)	45.4	61.6	45.2	52	92	125.2	71	155.4	76.2	82.2	74.4	93.2	973.8
1982	Mean Max.Temp.(C)	-5.5	-3.9	1.2	9	18.8	18.4	24.8	21.3	19.4	15.3	7.7	4.3	
	Mean Min.Temp.(C)	-14.9	-11	-6.8	-1.3	7.5	9.2	14.3	12.4	10.5	5.3	0.3	-3.7	
	Mean Monthly Temp.(C)	-10.2	-7.5	-2.8	3.9	13.2	13.8	19.6	16.9	15	10.3	4	0.3	
	Total Rainfall (mm)	7	1.6	51.4	27.4	60.6	116.8	41.8	74.6	57.1	71.6	90.4	67.8	668.1
	Total Snowfall (cm)	67.2	63.8	38.8	18.2	0	0	0	0	0	0	19	29	236
	Total Precipitation (mm)	74.2	65.4	90.2	45.6	60.6	116.8	41.8	74.6	57.1	71.6	109.4	96.8	904.1
1983	Mean Max.Temp.(C)	-1.6	-0.3	3.1	7.6	13.7	23.1	26.8	25.5	21.9	13.3	5.8	-3.4	
	Mean Min.Temp.(C)	-8.4	-7.4	-4.4	0	4.3	11.4	16	15.5	11.6	5.4	0.1	-9.1	
	Mean Monthly Temp.(C)	-5	-3.9	-0.7	3.8	9	17.3	21.4	20.5	16.8	9.4	3	-6.3	
	Total Rainfall (mm)	32	31.8	43.2	63.3	143.8	26.2	41.6	45	104.6	77.5	73.4	22.4	704.8
	Total Snowfall (cm)	71.8	25.2	26.4	1.6	0	0	0	0	0	0	34	98.2	257.2
	Total Precipitation (mm)	103.8	57	69.6	64.9	143.8	26.2	41.6	45	104.6	77.5	107.4	120.6	962
1984	Mean Max.Temp.(C)	-5.1	1.7	-1.4	10.5	14.1	22.3	24.3	24.4	18.2	14.6	6.7	3	
	Mean Min.Temp.(C)	-12.3	-4.7	-9.4	1.4	5	11.9	13.9	15.1	9.9	5.8	-0.4	-4.2	
	Mean Monthly Temp.(C)	-8.7	-1.5	-5.4	6	9.6	17.1	19.1	19.8	14.1	10.2	3.2	-0.6	
	Total Rainfall (mm)	0.8	27	34.1	80.6	124	33.5	53	102.2	131	59	67.6	52	764.8
	Total Snowfall (cm)	58.8	25.6	23.2	6.8	0	0	0	0	0	0	16	44.4	174.8
	Total Precipitation (mm)	59.6	52.6	57.3	87.4	124	33.5	53	102.2	131	59	83.6	96.4	939.6
1985	Mean Max.Temp.(C)	-5	-3	3.1	12.2	16.6	19	24.3	23	21	14	5.4	-2.5	
	Mean Min.Temp.(C)	-10.8	-9.3	-4.9	1.4	6.6	9	14	13.6	12.6	5.8	0.5	-7.9	
	Mean Monthly Temp.(C)	-7.9	-6.2	-0.9	6.8	11.6	14	19.2	18.3	16.8	9.9	3	-5.2	
	Total Rainfall (mm)	0	31.8	68	57	102	48.4	58.8	129.8	140.6	99.4	80.6	12.2	828.6
	Total Snowfall (cm)	138.6	61.8	16	8.2	0	0	0	0	0	0	42.7	98.6	365.9
	Total Precipitation (mm)	138.6	93.6	84	65.2	102	48.4	58.8	129.8	140.6	99.4	123.3	110.8	1194.5

Year	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1986	Mean Max.Temp.(C)	-2.8	-4	5	12.4	17.8	20.6	24.4	22.9	18.8	12.7	4.7	0.3	
	Mean Min.Temp.(C)	-9.1	-9.5	-4.8	2.2	7.8	9.5	15.4	12.9	10.6	4.8	-1.8	-4.2	
	Mean Monthly Temp.(C)	-6	-6.8	0.1	7.3	12.8	15.1	19.9	17.9	14.7	8.8	1.5	-2	
	Total Rainfall (mm)	15	4.8	49.2	73	71	75.4	117.9	67.2	281.6	88.2	18.5	49.2	911
	Total Snowfall (cm)	70.6	55.4	24.2	9.8	0	0	0	0	0	0	19	42	221
	Total Precipitation (mm)	85.6	60.2	73.4	82.8	71	75.4	117.9	67.2	281.6	88.2	37.5	91.2	1132
1987	Mean Max.Temp.(C)	-1.7	-1.3	4.5	12.7	18.9	23.5	26.3	23.9	20.1	11.2	6.6	1.8	
	Mean Min.Temp.(C)	-7.5	-10.1	-4.1	3	7.3	12.2	16.4	14.2	10.9	3.3	-0.6	-3.5	
	Mean Monthly Temp.(C)	-4.6	-5.7	0.2	7.9	13.1,	17.9	21.4	19.1	15.5	7.3	3	-0.9	
	Total Rainfall (mm)	2.6	12.4	46.8	40.2	34.3	116.2	111.8	132.4	81.2	99	65	18.8	760.7
	Total Snowfall (cm)	92.2	23.6	26.6	1.8	0	0	0	0	0	0	53.2	60	257.4
	Total Precipitation (mm)	94.8	36	73.4	42	34.3	116.2	111.8	132.4	81.2	99	118.2	78.8	1018.1
1988	Mean Max.Temp.(C)	-1.7	-2.8	3.2	8.7	18.2	21.8	27.6	26	19.9	10.3	7.7	0.1	
	Mean Min.Temp.(C)	-9.7	-10.9	-6.6	1	7.2	10.6	15.9	15.7	10.8	3.3	1.4	-7.3	
	Mean Monthly Temp.(C)	-5.7	-6.9	-1.7	4.9	12.7	16.2	21.8	20.9	15.4	6.8	4.6	-3.6	
	Total Rainfall (mm)	26.6	20.6	23.8	55.4	44.4	59.6	69.8	138.4	134.4	143.2	82.8	30.6	829.6
	Total Snowfall (cm)	63	116.8	32.4	5.4	0	0	0	0	0	13.6	0	113.8	345
	Total Precipitation (mm)	89.6	137.4	56.2	60.8	44.4	59.6	69.8	138.4	134.4	156.8	82.8	144.4	1174.6
1989	Mean Max.Temp.(C)	1.1	-4.3	1	7.7	16.2	21.2	25.3	23.9	20.1	14.7	4.5	-6.2	
	Mean Min.Temp.(C)	-7.2	-11.1	-8.1	-0.3	6.2	11.9	14.1	14.2	10.2	5.7	-2.8	-13.8	
	Mean Monthly Temp.(C)	-3.1	-7.7	-3.6	3.7	11.2	16.6	19.7	19.1	15.2	10.2	0.9	-10	
	Total Rainfall (mm)	19.8	0	41.8	24.2	92.2	118.4	16	29.6	39.6	83.8	95.4	4.8	565.6
	Total Snowfall (cm)	71.4	83.6	54.4	4	0	0	0	0	0	0	76.8	96	386.2
	Total Precipitation (mm)	91.2	83.6	96.2	28.2	92.2	118.4	16	29.6	39.6	83.8	172.2	100.8	951.8
1990	Mean Max.Temp.(C)	2	-0.2	4.5	12.5	14.7	21.9	23.8	23.8	18.8	13.3	9.41	1.7	
	Mean Min.Temp.(C)	-4.6	-8.2	-4.7	3.2	4.9	11.7	14.5	14.1	10.6	3.9	0.5	-5.8	
	Mean Monthly Temp.(C)	-1.3	-4.2	-0.1	7.9	9.8	16.8	19.2	19	14.7	8.6	5	-2.1	
	Total Rainfall (mm)	36.4	20	63.2	70.8	72.6	101.6	90.6	31.6	103	121	83	41.8	835.6
	Total Snowfall (cm)	46.6	54.4	10.2	7.8	0	0	0	0	0	0	7.8	67	193.8
	Total Precipitation (mm)	83	74.4	73.4	78.6	72.6	101.6	90.6	31.6	103	121	90.8	108.8	1029.4

Year	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1991	Mean Max.Temp.(C)	-3.4	0.3	3.7	12.1	19.5	23.9	25	25.4	19.4	14.3	5.4	0.8	
	Mean Min.Temp.(C)	-10	-7.3	-4.3	3.5	8.9	12.3	14.9	15.2	9.2	5.5	-2	-6.3	
	Mean Monthly Temp.(C)	-6.7	-3.5	-0.3	7.8	14.2	18.1	19.9	20.3	14.3	9.9	1.7	-2.8	
	Total Rainfall (mm)	6.8	11	60.4	130	65	14.6	197.6	17.2	78	110.6	47.8	24.6	763.6
	Total Snowfall (cm)	98.2	40.8	12	2.4	0	0	0	0	0	0	25.4	72.6	251.4
	Total Precipitation (mm)	105	51.8	72.4	132.4	65	14.6	197.6	17.2	78	110.6	73.2	97.2	1015
1992	Mean Max.Temp.(C)	-1.5	-1.5	0.9	7.8	17.3	19.9	20.7	21.4	20.3	11.9	5.3	1.5	
	Mean Min.Temp.(C)	-9	-8.5	-8.1	-0.4	5.9	8.9	12	12.9	9.6	2.9	-1	-4.5	
	Mean Monthly Temp.(C)	-5.2	-5	-3.6	3.7	11.6	14.4	16.3	17.1	15	7.4	2.2	-1.5	
	Total Rainfall (mm)	20	21	17.6	42.9	39.5	62.4	86.2	104	87.2	41.6	145.4	14	681.8
	Total Snowfall (cm)	79.8	43.2	30.8	26	0	0	0	0	0	5	32	45	261.8
	Total Precipitation (mm)	99.8	64.2	48.4	68.9	39.5	62.4	86.2	104	87.2	46.6	177.4	59	943.6
1993	Mean Max.Temp.(C)	-0.8	-4.9	1.1	10.1	16.2	20.7	25.2	25.1	17.2	12.1	5.8	-0.1	
	Mean Min.Temp.(C)	-8.3	-14.1	-7.5	0.5	5.5	10.5	15	14	8.4	3.6	-1.4	-6.5	
	Mean Monthly Temp.(C)	-4.5	-9.5	-3.2	5.3	10.9	15.6	20.1	19.6	12.8	7.8	2.2	-3.3	
	Total Rainfall (mm)	49.2	0.6	8	65.8	67.6	105.4	52.8	45.2	153.4	79.4	35.8	31	694.2e
	Total Snowfall (cm)	103.6	102.8	29.6	13.6	0	0	0	0	0	0.6	22	67.8	340e
	Total Precipitation (mm)	152.8	103.4	37.6	79.4	67.6	105.4	52.8	45.2	153.4	80	57.8	98.8	1034.2e

APPENDIX II

SOIL SERIES WITHIN THE STUDY AREA

Soil Series Developed on Calcareous Loam Till over Limestone Rock

The Farmington soil is the only member of this category that occurs in the study area. The soil was developed on shallow, calcareous loam till, which overlies limestone bedrock. It belongs to the Brown Forest Great Soil Group. The Farmington soil is slightly stony and has a smooth, very gently sloping topography. It is characterized by a good drainage and has an alkaline surface reaction. The soil occurs in Orillia and Tay Townships.

Soil Series Developed on Pale Brown, Calcareous, Stony Loam Till

The Osprey soil is the only member of this category that occurs in the study area. This soil was developed on pale brown, calcareous, stony loam till, and it belongs to the Brown Forest Great Soil Group. The Osprey soil is very stony, has an irregular, steeply sloping topography, and is characterized by a good drainage and a neutral surface reaction. The soil is found in Medonte and Orillia Townships.

Soil Series Developed on Light Grey, Calcareous and Non-calcareous, Sandy Loam Till

The Vasey soil is the only member of this category that occurs in the study area. The soil was developed on light grey, calcareous and non-calcareous, sandy loam till, and it belongs to the Brown and Grey Brown Podzolic Great Soil Group.

The Vasey soil ranges from moderately to very stony and exhibits moderately to steeply sloping topography. It is characterized by a good drainage and slightly to medium acidic surface reactions. The soil covers approximately 60% of Medonte Township and 70 % of Tay Township. It is also found in Flos, Orillia, Oro and Tiny Townships.

Soil Series Developed on Light Grey, Calcareous, Loam and Sandy Loam Till

Three soils series belong to this category: Bondhead, Guerin and Lyons soils. The three soils were developed on light grey, calcareous, loam and sandy loam till, and are characterized by a neutral surface reaction. The Bondhead and Guerin soils belong to the Grey Brown Podzolic Great Soil Group, whereas the Lyons soil belongs to the Dark Grey Gleisolic Great Soil Group.

The Bondhead soil ranges from slightly to very stony, has a moderately to steeply sloping topography, and is characterized by a good drainage. It is found to the south of Bass Lake in Oro Township.

The Guerin soil is slightly to moderately stony, has a gently sloping topography, and is characterized by an imperfect drainage. It is found in Orillia and Medonte Townships.

The Lyons soil ranges from slightly to very stony, has a very gently sloping topography, and is characterized by a poor drainage. The soil is found in small areas in Medonte Township.

Soil Series Developed on Pale Yellow, Calcareous, Loam and Silt Loam Till

The Wiarton soil is the only member of this category that occurs in the study area. This soil was developed on pale yellow, calcareous, loam and silt loam till, and it belongs to the Grey Brown Podzolic Great Soil Group. The soil ranges from slightly to very stony and has neutral to alkaline surface reactions. It also has a smooth, gently sloping topography, and is characterized by an imperfect drainage. The soil is found in small patches in an area west of Elmvale in Flos Township.

Soil Series Developed on Light Grey, Calcareous, Loam Till

The Otonabee soil is the only member of this category within the study area. The soil was developed on light grey, calcareous, loam till, and it belongs to the Brown Forest Great Soil Group. The soil ranges from moderately to very stony and has a moderately to steeply sloping topography. The soil is characterized by a good drainage and has neutral to alkaline surface reactions. It is found in Flos, Medonte and Orillia Townships.

Soils Series Developed on Grey, Calcareous Outwash Sand

Soils that belong to this category include the Alliston, Tioga, Granby, and Eastport soils. The Alliston and Tioga soils belong to the Podzol Great Soil Group; the Granby soil belongs to the Dark Grey Gleisolic Great Soil Group; and the Eastport soil belongs to the Dry Sands Great Soil Group.

The Alliston soil ranges from stone free to moderately stony and has a smooth, gently sloping topography. It is characterized by an imperfect drainage and a medium acidic surface reaction. The soil occurs in Flos, Medonte, Orillia, Tay and Tiny Townships.

The Tioga soil ranges from stone free to moderately stony. It has a smooth, gently to irregular, steeply sloping topography and it is characterized by a good drainage. The soil occurs in Medonte, Orillia, Oro, Tay and Tiny Townships and is found in association with the Vasey soil in Flos and Tay Townships.

The Granby soil is stone free and is characterized by a level topography, a poor drainage, and a slightly acidic surface reaction. The soil occurs mainly north of Elmvale in Flos Township, near Coldwater in Orillia Township, and around Wye Lake in Tay Township.

The Eastport soil is stone free and has an irregular, moderately sloping topography. The soil is characterized by an excessive drainage and an alkaline surface reaction. It is present mainly in the area of Hog Bay in Tay Township.

Soil Series Developed on Outwash Sand Underlain by Calcareous Loam or Sandy Loam Till

Soils that belong to this category include the Dundonald and Edenvale soils. Both soils are stone free, have slightly acidic surface reactions, and belong to the Grey Brown Podzolic Great Soil Group.

The Dundonald soil has a smooth, gently sloping topography and is characterized by a good drainage. The soil occurs in a small area west of the Hillsdale in Flos Township.

The Edenvale soil has a smooth, very gently sloping topography and is characterized by an imperfect drainage. The soil occurs east of Allenwood in Flos Township and around Lalligan Lake in Tiny Township. A few small exposures also occur to the north of Marchmont in Orillia Township.

Soil Series Developed on Outwash Sand Underlain by Calcareous Clay or Silty Clay Loam.

Three soil series belong to this category: the Bookton, Berrien, and Wauseon. The three soils are stone free and have developed on outwash sand underlain by calcareous clay or silt clay loam at depths of 1 m or less. The Bookton and Berrien soils belong to the

Grey Brown Podzolic Great Soil Group, whereas the Wauseon soil belongs to the Dark Grey Gleisolic Great Soil Group.

The Bookton soil has a smooth, moderately sloping topography. It is characterized by a good drainage and has a slightly to medium acidic surface reaction. The soil occurs south of Orr Lake in Flos Township, along the Sturgeon River in Medonte Township, north of Bass Lake in Orillia Township, and south of Wye River in Tiny Township.

The Berrien soil has a smooth, gently sloping topography. It is characterized by an imperfect drainage and has a slightly acidic surface reaction. The soil occurs in Flos, Medonte, Tay, and Tiny Townships.

The Wauseon soil has a smooth, very gently sloping topography. It is characterized by a poor drainage and has a neutral surface reaction. The soil occurs in Medonte and Tay Townships.

Soil Series Developed on Calcareous, Outwash Gravel

The Sargent soil is the only member of this category in the study area. The soil was developed on calcareous, outwash gravel and belongs to the Brown Forest Great Soil Group.

The Sargent soil is stone free and has a smooth, very gently sloping topography. The soil is characterized by a good drainage and has a neutral to alkaline surface reaction. The soil occurs at the south and west of Orr Lake in Flos Township, at the north of Orr Lake in Medonte Township, and at the north of Bass Lake in Orillia Township. It also occurs at a few places in the southern parts of Tay and Tiny Townships.

Soil Series Developed on Non-Calcareous, Outwash Gravel

The Wyevale soil is the only member of this category that occurs in the study area. The soil belongs to the Podzol Great Soil Group. It is moderately stony and has a smooth, gently sloping topography. The soil is characterized by a good drainage and has a medium acidic surface reaction.

The Wyevale soil occurs south of Wye Lake in Tay Township and around Wyevale in Tiny Township. It also occurs in small patches south of Orr Lake in Flos Township and near Matchedash Bay in Tay Township.

Soils Developed on Calcareous and Non-Calcareous, Lacustrine Material

Three soils have been identified in this group: the Atherley, Lovering, and Medonte. The Atherby soil is a clay to silty clay loam soil. The soil ranges from stone free to very stony and has a gently sloping topography. It is characterized by a poor drainage and a slight acidic surface reaction. The soil is found in the northern and western parts of Orillia Township, in the southern parts of Tay Township, around Elmvale in Flos Township, and in small patches in Tiny Township.

The Lovering soil is similar to the Atherley soil in terms of parent material, stoniness and topography. Unlike the Atherley soil, however, it is characterized by an imperfect drainage and shows slight to medium acidic surface reactions. The Lovering soil is found mainly in Flos, Orillia and Tiny Townships.

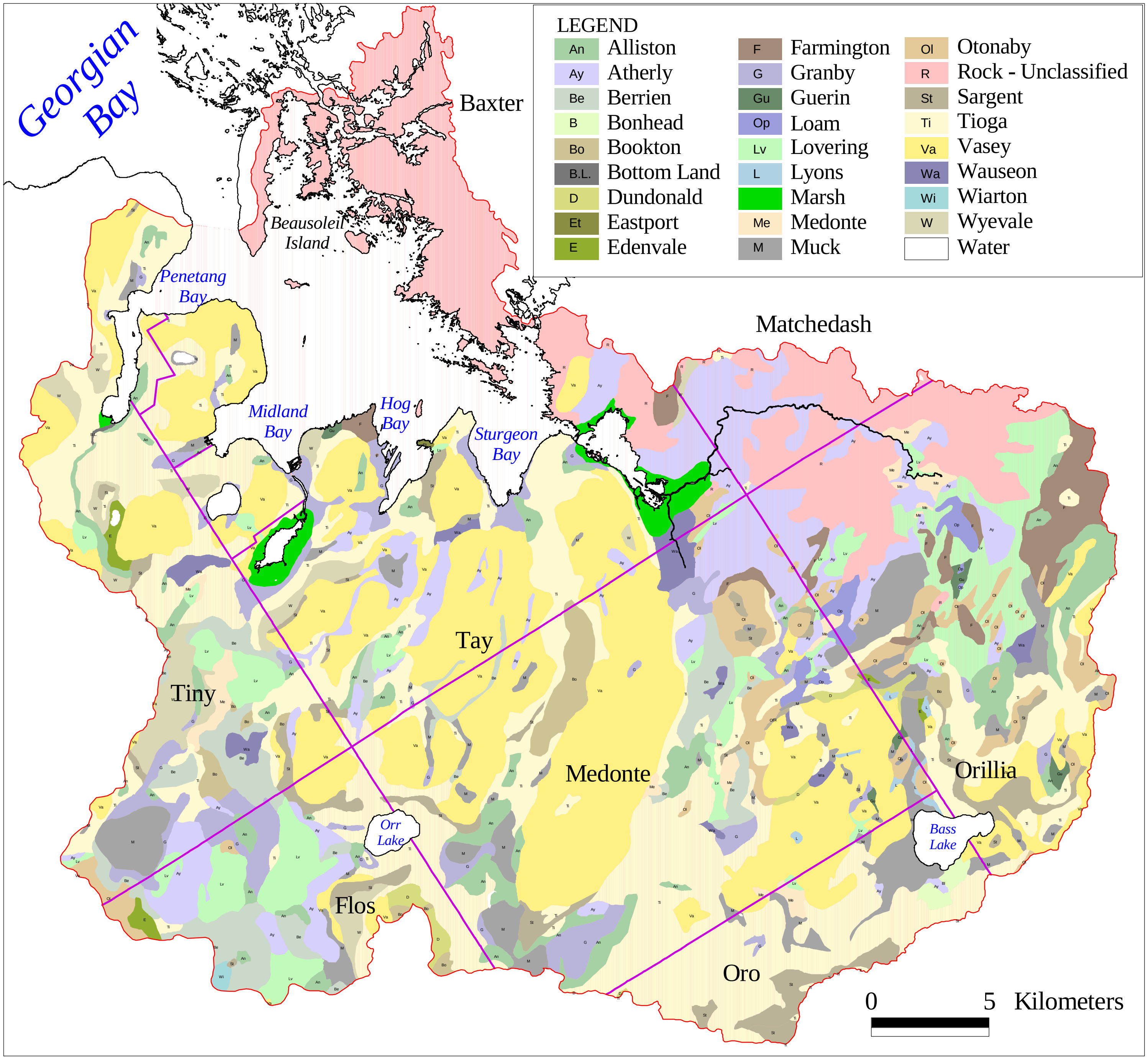
The Medonte soil is stone free and has a moderately sloping topography, a good drainage, and slight to medium acidic surface reactions. The soil is found mainly in the northern parts of Orillia Township and in small patches throughout Medonte Township.

Muck Soil Series

Muck soils of over 30 cm thick have developed on well-decomposed organic material underlain by rock, sand, silt or clay in a number of depressions within the study area. Muck soils are stone free and belong to the Organic Great Soil Group. They are characterized by a depressional type topography, a very poor drainage, and a neutral surface reaction. Muck soils occur to the southeast of Elmvale in Flos Township, in the southwestern part of Medonte Township, along Purbrook Creek in Orillia Township, around Bass Lake in Oro Township, at Elliotts Corners in Tay Township, and to the north of Allenwoodd in Tiny Township.

Marsh Soil Series

Marsh soils have developed in a number of depressions within the study area. These soils are stone free and are characterized by a very poor drainage and a neutral surface reaction. Marsh soils occur mainly around Wye Lake and Matchedash Bay in Tay Township.



Note: Old municipal boundaries

Appendix II - 6. Soil series within the study area.

APPENDIX III

SURFICIAL AND BURIED TILLS IN THE STUDY AREA

SURFICIAL TILLS

Between 1974 and 1992, five authors prepared preliminary surficial geologic maps, scale: 1:50,000, of various parts of the study area. These maps are:

- S Quaternary geology of the Orr Lake area (western half) - Nottawasaga area (eastern half), southern Ontario; Ontario Div. Mines, Prelim. Map P.975 by Burwasser, G.J. and Boyd, S.T.,1974.

- S Quaternary geology of the Orillia area, southern Ontario; Ontario Geological Survey, Map P. 2697 by Finamore, P.F. and Bajc, A.F.,1984.

- Quaternary geology of the Penetanguishene and Christian Island areas, southern Ontario; Ontario Geological Survey, Map 194 by Bajc A.F. and Peterson, J.T.,1992.

- Quaternary geology of the Gravenhurst area, southern Ontario; Ontario Geological Survey, Map 195 by Bajc, A.F. and Paterson, J.T.,1992.

- S Quaternary geology of the east half of the Elmvale area, Ontario; Mines and Mineral Division, Ontario Geological Survey, Geology by Barnett,1986,1988,1989, issued 1992.

Due to the fact that the authors of the above maps have worked in different areas and at different times, it is not surprising that they ended up using different names and symbols to identify what appears to be the same till. The following is a description of the various surficial tills that have been identified by these authors.

In their Quaternary geology map of the Orr Lake area (western half), Burwasser and Boyd (1974)identified three tills. The oldest till (unit 2) is a dark, grey brown, slightly gritty, sand till. It is a massive, very compact till, which develops fissile fractures upon weathering. According to Burwasser and Boyd (1974), this till is nowhere exposed on the surface but is buried under 1 to 2.5 m of glaciofluvial or glaciolacustrine sand.

The second till, which Burwasser and Boyd (1974) named "map unit 3" on their Orr Lake sheet, is a brown, fissile, gritty, sandy silt till that was deposited by the Georgian Bay lobe. Clast content is approximately 5% by weight and is up to 88% limestone pebbles and 10% Precambrian pebbles. The till is found in the southwestern corner of the study area, in a small area along Highway 27 to the northeast of Perkinsfield, and as a narrow band along the middle reach of the Wye River. Burwasser and Boyd's till of "map unit 3" has been mapped by Barnnet et al (1991) as "map unit 21" on the OGS Map 2556.

The third till, which Burwasser and Boyd (1974) named "map unit 4", is exposed on the "Algonquin Islands" in their Orr Lake sheet. It is a brown, sandy silt to sandy loam till laid down from the northeast. Clast content varies between 5 and 10%; limestone pebbles increase from 60% in the north to 90% in the south; and Precambrian pebbles decrease from 20% to 10% in the same direction. The quantity of the sand in the matrix also decreases southward.

According to Burwasser and Boyd (1974), the third till where exposed in section is very compact and massive with a blocky fracture wherever the silt content is high. On the surface it is weathered to a fissile, friable sandy silt. The till in the Orr Lake area is often incorporated into ice-contact deposits and usually overlain by ablation till or ice-contact sand. Burwasser and Boyd's till of "map unit 4" has been mapped by Barnet et al (1991) as "map unit 19" on the OSG Map 2556.

The Quaternary geology map of the east half of the Elmvale Area shows the presence of a till unit, which Barnett (1992) named "map unit 8", was divided, based on grain-size distribution, into three till types: 8a, 8b and 8c. Barnett (1992) suggested, in his unedited manuscript that accompanied the Elmvale map, that "map unit 8" is probably of Late Wisconsinan age. Barnett (1992) describes in the same manuscript two additional older tills, "map units 3 and 4", that may also have been deposited during the Late Wisconsinan or much earlier. The Elmvale map, however, does not show any outcrops of these two tills. According to Barnett (1992), the two tills are exposed along valley walls where they have been truncated during valley formation or subsequent shoreline erosion.

Most of the surficial till within the Elmvale map area belongs to "map unit 8a". Only in the northeastern parts of the Elmvale map does the till described as "map unit 8b" outcrops at surface. The manuscript that accompanied the Elmvale map (Barnett,1992), describes "map unit 8a" as a moderately stony to stony, silty sand to sand till, whereas "map unit 8b" is described as a moderately stony to stony, sandy silt to silt till. The till of "map unit 3" is described as a stony, gritty, silty sand to sandy silt till; whereas "map unit 4" is described as stone-poor, clayey silt to silt till.

By comparing the tills in the Orr area with those in the Elmvale area, it is possible to suggest that Burwasser and Boyd's (1974) till of "map unit 4" and Barnett's till of "map unit 8" are the same till. One may also speculate that Barnett's (1992) till of "map unit 4" is the same as Burwasser and Boyd's till of "map unit 3". Further, one may speculate that Barnett's (1992) till of "map unit 3" is the same as Burwasser and Boyd's (1974) till of "map unit 2". The till of "map unit 8" within the Elmvale area has been mapped by Barnett et al (1991) as "map unit 19" on the OGS Map 2556.

The Quaternary geology of the Orillia area has been mapped by Finamore and Bajc in 1981 and 1982 (Map P. 2697, 1984). Map P. 2697 shows the Quaternary geology of the eastern part of the study area. The map shows a till, which has been identified as "map unit 3a". In the marginal notes that accompany Map P. 2697, Finamore and Bajc (1984) describe map unit 3a as a till that ranges in texture from a stony and gritty, silty, very fine-grained sand to a sandy silt till. Clasts are subangular to subrounded in shape, and Precambrian clast content decreases southward. The till is usually compact and fissile and occurs in the form of drumlins, end moraine and ground moraine.

Within the study area, the till of "map unit 3a" is overlain by a shallow and discontinuous, till-like dimicton. The dimicton is composed of silty clay with some grits and a few pebbles, and it seldom exceeds 1 m in thickness. According to Finmore and Bajc (1984), this structureless dimicton was found above and below the Main Algonquin shore bluff.

The till, identified by Finmore and Bajc (1984) as "map unit 3a" in the eastern part of the study area, is most likely the same till that was identified by Barnett (1992) in the Elmvale area as "map unit 8". Further, Finmore and Bajc's (1984) till of "map unit 3a" is probably the same till identified by Burwasser and Boyd (1974) in the Orr Lake sheet as "map unit 4". The three tills (map unit 3a, map unit 8 and map unit 4) have been mapped by Barnett et al (1991) as "map unit 19" on the OSG Map 2556.

The quaternary geology of the Penetanguishene and Christian Island areas has been mapped by Bajc and Paterson (Map 194, 1992). Map 194 shows the quaternary geology of the northern parts of the study area. The map indicates the presence of a silty sand till, which was identified as "map unit 5b". The till is found to the east and northwest of Matchedash Bay, to the north east of Victoria Harbour, to the northwest of Port McNicoll, and within the Penetang Peninsula. The till of "map unit 5b" appears to be the same till that was identified by Barnett (1992) as "map unit 8b" in the Elmvale area as well as the till identified by Burwasser and Boyd (1974) as "map unit 4" in the Orr Lake area. Barnett et al (1991) mapped this till as "map unit 19" on the OSG Map 2556.

Based on the above discussion, it is possible to conclude that two undifferentiated tills are present at surface within the study area. The first till includes Burwasser and Boyd's (1974) till of "map unit 3", which appears on the OGS Map 2556 as "map unit 21". The second till includes Burwasser and Boyd's (1974) till of "map uint 4", Finamore and Bajc's (1984) till of "map unit 3a", Barnett's (1992) till of "map unit 8", and Bajc and Paterson's (1992) till of "map unit 5b". These four map units appear as "map unit 19" on the OSG Map 2556.

BURIED TILLS

Barnett (1991),in a preliminary report on the stratigraphic drilling of Quaternary sediments in the Barrie area, Simcoe County, described the geologic logs of 5 deep boreholes drilled in Medonte and Oro Townships. Three of these boreholes (OGS-90-5, OGS-90-7 and OGS-90-14) reached the bedrock and provide complete profiles of the Quaternary section.

Till-like, diamicton materials, separated by thick sequences of gravel, sand, silt and clay, were found at different depth in all the boreholes. The following geologic log indicates that seven layers of till-like diamicton were found in borehole No.OGS-90-5.

Geologic log of Borehole No. OGS-90-5

County: Simcoe Township: Medonte Concession: VI
Easting: 500.00 Northing: 3920.00
Surface Elevation: 265.24 m

00.00 - 00.91	SAND	Fine to medium grained, weathered sand.
00.91 - 01.07	SILT	Very fine, sandy silt.
01.07 - 02.13	SILT	Silt horizontally laminated with thin fine sand.
02.13 - 04.72	SAND	Silty, very fine sand, with contorted clay and silty clay laminations. A well sorted, very coarse sand layer reported a depth of 3.35 m, and a fine to medium grained sand layer reported at depth of 4.11 m.
04.72 - 08.53	SAND	Very fine to fine grained sand with heavy mineral lamination.
08.53 - 08.84	DIAMICTON	Massive, stony, sandy silt.
08.84 - 10.06	SAND	Silty, very fine sand with fine sand.
10.06 - 10.97	SAND	Interbedded, medium sand, clayey silt and diamicton layers, highly deformed.
10.97 - 11.89	DIAMICTON	Massive, stony, gritty, silty sand to

		sandy silt (till).
11.89 - 14.94	CLAY	Silty clay with thin contorted silt laminations, rhythmically bedded.
14.94 - 14.97	SAND	Very fine to fine sand, organic?
14.97 - 15.24	DIAMICTON	Massive, clay silt with sand and some gravel.
15.24 - 26.52	SAND	Coarse to very coarse sand with pebbles (1 to 5%).
26.52 - 28.96	SAND	Medium to coarse sand with an occasional pebble.
28.96 - 30.94	DIAMICTON	Massive, gritty, sandy silt (till).
30.94 - 32.93	SAND	Fine grained sand, drill disturbed.
32.93 - 34.45	SAND	Fine sand becoming very fine sandy silt downwards, heavy mineral laminations.
34.45 - 34.75	SILT	Interlaminated clayey silt and silt.
34.75 - 35.67	DIAMICTON	Massive, gritty silt with coarse sand and pebbles (till).
35.67 - 36.58	SILT	Silt to clayey silt, faintly laminated with fine to medium sand.
36.58 - 38.87	SAND	Fine sand with contorted heavy mineral laminations (drill induced?).
38.87 - 39.02	SILT	Massive, gritty silt with the occasional pebble.
39.02 - 39.63	SAND	Silty, fine sand, pebble concentrations in lower 15 cm.
39.63 - 41.76	DIAMICTON	Massive to fissile, slightly clayey silt with minor coarse sand and occasional pebble (till).
41.76 - 42.77	SAND	Well sorted, fine sand with discontinuous wisps of silt.
42.77 - 48.17	SAND	Silty, very fine sand with occasional medium sand layer 5 cm thick.
48.17 - 48.78	SAND	Fine to medium grained sand.
48.78 - 51.83	SILT	Faintly laminated clayey silt, silt, and very fine sandy silt, contorted.
51.83 - 52.44	CLAY	Clay faintly laminated with silt.
52.44 - 59.60	DIAMICTON	Stony, gritty silty sand, massive, clasts break freely from matrix (till).
59.60 - 59.91	CLAY	Silty clay with faint silt laminations.
59.91 - 67.38	SAND	Interbedded, very coarse to coarse grained sand, heavy mineral laminations.
67.39 - 72.36	SAND	Fine to very fine sand becoming finer downwards, interbeds of medium to coarse sand near top, silt drapes at base.
72.36 - 91.46	DIAMICTON	Massive to fissile, very stony, gritty, sandy silt to silt (till).
91.46 - 92.07	SILT	Massive, conchoidal fracture, very few clasts.

92.07 - 93.60	DIAMICTON	Silt, slightly pebbly, massive clast content that increases downward (till?).
93.60 - 93.90	SILT	Massive, conchoidal fractured silt.
93.90 - 100.61	DIAMICTON	Silt, massive to fissile, containing pebbles and cobbles (till).
100.61 -102.44	BEDROCK	Lithographic limestone, very fine to microcrystalline limestone with ostacoda and brachiopoda fossils and thin calcite veins. Gull River Formation.

The first and oldest, till-like diamicton overlies the limestones of the Gull River Formation and has a thickness of 8.53 m and an elevation range between 164.63 to 171.65 m (a.s.l.). The diamicton is composed of massive to fissile silt containing pebbles and cobbles.

The second, till-like diamicton has a thickness of 20.42 m and an elevation range between 173.78 to 193.90 m (a.s.l.). The diamicton is composed of a massive to fissile, very stony, gritty, sandy silt to silt.

The third, till-like diamicton has a thickness of 7.16 m and an elevation range between 205.64 to 212.80 m (a.s.l.). The diamicton is composed of massive, stony, gritty, silty sand, with a clast that breaks freely from matrix.

The forth, till-like diamicton has a thickness of 2.14 m and an elevation range between 223.47 to 225.61 m (a.s.l.). The diamicton consists of massive to fissile, slightly clayey silt with minor coarse sand and the occasional pebble.

The fifth, till-like diamicton has a thickness of 0.91 m and an elevation range between 229.57 to 230.48 m (a.s.l.). The diamicton is composed of a massive, gritty silt with coarse sand and pebbles.

The sixth, till-like diamicton has a thickness of 1.98 m and an elevation range between 234.30 to 236.28 m (a.s.l.). The diamicton consists of a massive, gritty, sandy silt.

The seventh and youngest, till-like diamicton has a thickness of 0.92 m and an elevation range between 253.35 to 254.27 m (a.s.l.). The diamicton consists of a massive, stony, gritty, silty sand to sandy silt.

Borehole No. OGS-90-7, located in Medonte Township, Concession III, also reached the bedrock and provides a complete profile of the Quaternary section. The geologic log of this borehole is as follows:

Geologic Log of Borehole No. OGS-90-7

County: Simcoe Township: Medonte Concession: III
Easting: 320.00 Northing: 3680.00
Surface elevation: 250.00 m

00.00 - 00.30	FILL	
00.30 - 00.91	SAND	Weathered, massive, silty sand.
00.91 - 02.13	SAND	Fine grained sand with minor silt and clay.
02.13 - 02.44	SAND	Interlaminated, silty, fine sand and clay, rhythmites.
02.44 - 03.05	SAND	Fine to medium sand with a rare interbed of very coarse to coarse sand.
03.05 - 11.28	SILT	Laminated silt to clayey silt with clay, rhythmites.
11.28 - 24.39	SAND	Silty, very fine sand with clay laminations, rhythmically bedded.
24.39 - 28.96	SAND	Fine and very fine sand with rare clay layers, beds to 60 cm thick but commonly 20 cm, rhythmites.
28.96 - 39.33	SAND	Very coarse sand and granule gravel with interbeds of very fine sand.
39.33 - 39.63	GRAVEL	Pebble sized gravel.
39.63 - 43.90	SAND	Very fine to fine sand, contains heavy mineral laminations in places.
43.90 - 54.88	SAND	Very coarse sand and granule gravel, some pebbles to 5 cm in diameter, becomes rhythmically bedded with fine to medium sand layers at 47.87 m depth.
54.88 - 55.79	SAND	Pebbly, very coarse sand.
55.79 - 56.09	SAND	Fine to medium sand.
56.09 - 56.86	SAND	Coarse sand with minor medium sand.
56.86 - 57.01	SAND	Very fine to fine sand.
57.01 - 63.41	SAND	Coarse and very coarse sand, a rare pebble.
63.41 - 64.94	SAND	Fine to medium sand with heavy mineral laminations.
64.94 - 66.46	SAND	Very coarse sandy pebble with pebble gravel to 8 cm in diameter.
66.46 - 66.49	SAND	Very silty, fine sand.
66.49 - 67.07	SAND	Very coarse sand and granule gravel.
67.07 - 67.22	SAND	Silty, fine sand.
67.22 - 67.53	GRAVEL	Very coarse, sandy pebble gravel.
67.53 - 68.29	SAND	Fine sand with heavy mineral laminations.
68.29 - 69.05	SAND	Medium sand with pebbles up to 5 cm in diameter.

69.05 - 69.21	SAND	Fine sand with heavy mineral laminations.
69.21 - 71.34	GRAVEL	Very coarse sandy pebble to cobble gravel, clasts up to 13 cm in diameter.
71.34 - 71.65	SILT	Silt to clayey silt rhythmites.
71.65 - 71.80	SAND	Very coarse sand.
71.80 - 72.10	SILT	Silt to clay silt with coarse sand laminations, contains one thin 2.5 cm diamicton layer.
72.10 - 72.25	SAND	Very coarse sand.
72.25 - 72.56	SAND	Medium to fine sand with balls of silty clay.
72.56 - 74.85	SAND	Well sorted, coarse to very coarse sand.
74.85 - 75.30	SAND	Well sorted, medium sand.
75.30 - 81.40	SAND	Fine sand, heavy mineral laminations, and a rare clay layer.
81.40 - 84.91	SILT	Silt, massive to faintly laminated with clay.
84.91 - 86.89	SAND	Silty, fine sand, stony.
86.89 - 93.59	DIAMICTON	Gritty, silty, fine sand, massive, contains a boulder 30 cm in diameter, (till).
93.59 - 95.43	BEDROCK	Fine grained limestone (Bobcaygeon Formation).

The till-like diamicton found in borehole No. OGS-90-7 overlies the limestones of the Bobcaygeon Formation. It has a thickness of 7.71 m and an elevation range between 156.40 to 163.11 m (a.s.l.). The diamicton consists of a massive, gritty, silty, fine sand, containing boulders up to 30 cm in diameter. This diamicton is probably the same as the oldest diamicton found in borehole No. OGS-90-5 at elevation between 164.63 to 171.65.

The geologic log of borehole No. OGS-90-7 does not indicate the presence of any other younger, till-like diamicton. Instead, the geologic log indicates the presence of thick layers of gravel, sand or silt.

Borehole No. OGS-90-14, located in Orillia Township, Concession II, also reached the bedrock. As can be seen in the following geologic log, four layers consisting of till-like diamicton have been reported in this borehole.

Geologic Log of Borehole No. OGS-90-14

County: Simcoe   Township: Orillia   Concession: II
Easting; 1720.00   Northing: 4580.00
Surface elevation: 256.09 m

00.00 - 01.22	SAND	Medium to coarse sand, heavy mineral laminations.
01.22 - 01.52	GRAVEL	Pebble gravel in very coarse, sand matrix, clasts to 4 cm.
01.52 - 02.13	DIAMICTON	Sticky, sandy silt with stones, both angular and rounded, some striated.
02.13 - 02.74	SAND	Very coarse sand with one clay layer at 2.44 m depth.
02.74 - 03.96	DIAMICTON	Sticky, sandy silt with numerous pebbles, loose, becoming dense, gritty, sandy silt with pebbles and cobbles (till).
03.96 - 04.57	DIAMICTON	Pebbly, gritty, silty sand to sandy silt, massive, striated clasts (till).
04.57 - 17.37	DIAMICTON	Compact, thin fissility, stony, gritty, silty sand, several sheared clasts (5-15%) (till).
17.37 - 20.73	DIAMICTON	Massive to fissile, stony, gritty, silty sand to sandy silt.
20.73 - 21.34	DIAMICTON	Thinly bedded, gritty, silty sand diamicton with clay laminations.
21.34 - 23.47	DIAMICTON	Massive to fissile, stony, gritty, silty sand to sandy silt (till).
23.47 - 24.84	DIAMICTON	Vaguely interbedded, pebbly, clayey silty sand with thin layers of coarse to very coarse sand and clay laminations.
24.84 - 25.00	SAND	Well sorted, fine sand.
25.00 - 26.22	DIAMICTON	Faintly stratified, silty sand to sandy silt with pebbles, clay silt, pods and thin, discontinuous layers of sand.
26.22 - 27.44	SAND	Massive, coarse sand with inclusions of clayey silt.
27.44 - 28.96	SAND	Massive, very coarse sand.
28.96 - 32.32	GRAVEL	Clean, well sorted, granule gravel, minor sand and a rare small pebble.
32.32 - 32.77	SAND	Massive, well sorted, medium to coarse sand.
32.77 - 32.93	SAND	Faintly stratified, very fine sand with minor silt.
32.93 - 35.06	SAND	Well sorted, fine sand with heavy mineral laminations.
35.06 - 35.67	SAND	Massive, very fine sand, minor silt.

35.67 - 35.97	SAND	Well sorted, fine sand with heavy mineral laminations.
35.97 - 36.28	SAND	Clean, well sorted, very coarse sand with occasional small pebble.
36.28 - 36.58	SAND	Fine to medium sand.
36.58 - 37.50	SAND	Very fine grained sand with occasional interbed of medium sand.
37.50 - 37.96	SAND	Very fine grained sand with horizontal heavy mineral concentrations.
37.96 - 38.11	SAND	Interlaminated, very fine sand and silty clay.
38.11 - 39.63	SAND	Interlaminated, very fine sand and fine sand with faint, heavy mineral laminations.
39.63 - 40.24	GRAVEL	Pebble gravel in granule, gravel matrix, clasts to 5 cm in diameter.
40.24 - 40.55	SAND	Matrix supported, gravelly sand, fine to medium grained, with clasts to 10 cm.
40.55 - 41.46	DIAMICTON	Poorly sorted, fine to coarse sand with pebbles separated by thin, sand layers.
41.46 - 47.56	DIAMICTON	Massive, poorly sorted sand with pebbles (till?) with gravelly, very coarse sand beds.
47.56 - 49.39	SAND	Fine to very fine sand, containing heavy mineral laminations near the top and silt and clay laminations toward base.
49.39 - 49.84	BOULDER	Fine grained, limestone boulder.
49.84 - 50.61	DIAMICTON	Very stony, clayey silt with sand, massive to colour streaked (till).
50.61 - 52.44	BEDROCK	Fine to very fine grained limestone with minor shale partings.

The first and oldest diamicton in the geologic log of Borehole No. OGS-90-14 overlies the bedrock. It has a thickness of 0.45 m and an elevation range between 205.49 to 205.94 (a.s.l.). The diamicton is a massive to colour streaked, very stony, clay silt with sand.

The second diamicton has a thickness of 7.01 m and an elevation range between 208.54 to 215.55 m (a.s.l.). The diamicton is a massive, poorly sorted sand with pebbles. It contains a very stony, sandy silt to silt bed and gravelly, very coarse sand beds toward the base of the diamicton.

The third diamicton has a thickness of 23.47 m and an elevation rage between 229.88 to 253.35 m (a.s.l.). The diamicton consists from base to top of:

- faintly stratified, silty sand to sandy silt with pebbles and clayey silt, pods and thin, discontinuous layers of sand, 1.22 m thick;

- well sorted fine sand, 0.15 m thick;

- vaguely interbedded, pebbly, clayey silty sand with thin layers of coarse sand and clay laminations;

- massive to fissile, stony, gritty, silty sand to sandy silt; 2.13 m thick;

- thinly bedded, gritty, silty sand with clay laminations;

- massive to fissile, stony, gritty, silty sand to sandy silt, 3.35 m thick;

- compact, thin fissility, stony, gritty, silty sand with 5 to 20% clasts, 12.80 m thick;

- massive, pebbly, gritty, silty sand to sandy silt with striated clasts, 0.61 m thick; and

- sticky, sandy silt with numerous, loose pebbles, becoming dense, gritty, sandy silt with pebbles and cobbles, 0.91 m thick.

The fourth and youngest diamicton is a sticky, sandy silt with stones, both angular and rounded, some striated. It has a thickness of 0.61 m and an elevation range between 253.96 to 254.57 m (a.s.l.).

Borehole OGS-90-6, located in Medonte Township, Concession III, and borehole OGS-90-8, located in Oro Township, concession I, do not reach the bedrock. Both boreholes, however, report the presence of till-like diamicton in their geologic logs.

The following geologic log of borehole OGS-90-6 indicates the presence of a diamicton consisting of loose, fissile, slightly silty, fine to coarse sand with pebbles and cobbles. The diamicton has a thickness of 4.26 m with an elevation range between 276.22 and 280.48 m (a.s.l.).

Geologic Log of Borehole No. OGS-90-6

County: Simcoe   Township: Medonte   Concession: III
Easting: 250.00   Northing: 3780.00
Surface elevation: 312.5 m

00.00 - 00.76	SAND	Slightly silty, weathered, fine sand.
00.76 - 00.91	SAND	Silty, fine sand with rare clast.
00.91 - 01.22	SAND	Fine to medium grained sand.
01.22 - 01.37	SAND	Silty, fine to medium, sticky sand with pebbles.
01.37 - 03.05	SAND	Well sorted, fine sand.
03.05 - 03.66	SAND	Horizontally stratified, fine to medium grained sand.
03.66 - 03.68	SILT	Massive, clayey silt to silt.
03.68 - 04.27	SAND	Medium to coarse sand with rare pebbles.
04.27 - 04.29	SILT	Massive silt.
04.29 - 05.03	SAND	Fine to medium grained sand with heavy mineral concentrations and thin interbeds of very fine, sandy silt.
05.03 - 05.18	SAND	Massive, silty, very fine sand to fine sand.
05.18 - 05.64	SAND	Ripple laminated, fine sand.
05.64 - 05.79	SAND	Pebbly, coarse to very coarse sand.
05.79 - 06.40	TILL?	Fissile, silty fine sand with pebbles (till?).
06.40 - 06.86	SAND	Fine grained sand, faintly stratified to massive.
06.86 - 07.62	GRAVEL	Pebbly, very coarse, sandy gravel with clasts dominantly 3 cm in diameter, up to 5 cm in diameter.
07.62 - 07.65	SAND	Fissile, faintly laminated, silty fine sand.
07.65 - 07.92	GRAVEL	Cobble gravel, washed clean by drilling, clasts to 15 cm in diameter.
07.92 - 09.11	SAND	Fine grained sand with heavy mineral laminations.
09.11 - 09.14	SAND/SILT	Fine sand and silt containing black organic material?
09.14 - 10.43	SAND	Fine sand with some silty, very fine sand and clay laminations, changing to silty, very fine sand at 10.43 m depth.
10.43 - 10.97	SAND	Fine sand.
10.97 - 11.74	SILT	Silt, thinly laminated (flame structures) with clay and fine sand.
11.74 - 12.80	SAND	Interlaminated, fine sand and very fine, sandy silt, rare small pebbles, and thin clay laminations.

12.80 - 14.48	SILT	Silt to very fine sandy silt with laminations of fine sand and clay.
14.48 - 16.46	SAND	Interlaminated, fine sand and silty, very fine sand with wispy laminations. A few clay laminations at 15.40 m depth.
16.46 - 18.29	SILT	Interlaminated silt and clayey silt with minor fine sand laminations.
18.29 - 19.21	CLAY	Interlaminated, silty clay and silt.
19.21 - 23.47	SILT	Clayey silt to silt with contorted, clay laminations and minor fine sand laminations.
23.47 - 24.08	CLAY/SILT	Silty clay to clayey silt with thin, wispy, fine sand laminations.
24.08 - 25.00	SILT	Silt and very fine, sand rhythmites, capped by silty, graded beds with couplets up to 0.5 cm thick.
25.00 - 27.13	SAND	Interbedded, fine and very fine sand with wispy laminations of silt.
27.13 - 30.18	CLAY	Silty clay, thinly laminated with silt.
30.18 - 32.01	SAND	Fine grained sand with one Precambrian pebble, a rare very small pebble.
32.01 - 36.28	TILL	Loose, fissile, slightly silty, fine to coarse sand with pebbles and cobbles (5%), (till).
36.28 - 39.33	SAND	Poorly sorted, fine to coarse sand, minor silt and a few pebbles.
39.33 - 40.24	SAND	Interbedded, silt and fine to medium sand, organics?
40.24 - 44.82	SILT/SAND	Black silt with organics? and fine to medium sand, interbedded with cobbly, coarse sand.
44.82 - 45.43	SILT	Very fine, sandy silt with laminations of fine sand.
45.43 - 46.34	SILT	Massive, conchoidal fracture, silt to very fine, sandy silt with very small pebbles.
46.34 - 46.65	SAND	Fine to medium grained sand.
46.65 - 51.52	SAND	Massive, very fine and fine sand.
51.52 - 54.57	SAND	Dominantly fine sand with heavy mineral laminations and discontinuous, wispy silt laminations.
54.57 - 55.18	SAND	Medium to course sand.
55.18 - 57.93	SAND	Very fine sand to silty, very fine sand, bedding highly contorted (drilling?).
57.93 - 58.84	SILT/CLAY	Clayey silt to silty clay, appears massive.
58.84 - 59.15	SAND	Coarse to very coarse sand with heavy mineral laminations.

Two additional diamicton materials are reported in borehole OGS-90-6. A 0.61 m thick diamicton consisting of fissile, silty, fine sand with pebbles is reported at an elevation range between 306.10 to 306.71 m (a.s.l.) and a 0.15 m thick diamicton consisting of sticky, silty fine to medium sand with pebbles is reported at an elevation range between 311.13 to 311.28 m (a.s.l.).

The following geologic log of borehole OGS-90-8 indicates the presence of four layers of diamicton:

Geologic Log of Borehole No. OGS-90-8

County: Simcoe Township: Oro Concession: VIII
Easting: 1270.00 Northing: 3330.00
Surface elevation: 358.23 m

00.00 - 00.91	SAND	Pebbly, very coarse sand, clasts to 5 cm in diameter.
00.91 - 02.13	SAND	Very coarse to coarse sand with rare, small pebbles to 5 cm in diameter.
02.13 - 02.28	SAND	Silty, pebbly, coarse sand; pebbles to 0.5 cm in diameter.
02.28 - 02.44	SAND	Well sorted, very coarse sand.
02.44 - 02.59	SAND	Fine sand with heavy mineral laminations.
02.59 - 03.35	SAND	Gravely sand, pebbly, fine to medium sand, clast supported, with minor medium sand beds.
03.35 - 03.51	GRAVEL	Pebble gravel in medium to coarse sand matrix, clasts to 5 cm, rounded to angular, clast supported gravel.
03.51 - 03.66	SAND	Well sorted, medium to coarse sand.
03.66 - 05.18	GRAVEL	Pebble gravel in very coarse sand matrix, clasts to 10 cm, average 5 cm.
05.18 - 05.49	GRAVEL	Matrix supported, silty, coarse to very coarse, sandy gravel with rounded clasts 2.5 - 5 cm in diameter.
05.49 - 06.86	GRAVEL	Pebble gravel, 5-8 cm in diameter in coarse to very coarse, sand matrix.
06.86 - 07.77	SAND	Fine to medium sand, heavy minerals.
07.77 - 07.93	SAND	Pebbly, fine sand (gravelly sand).
07.93 - 09.75	GRAVEL	Pebble gravel in fine to coarse, sand matrix, clasts to 5 cm in diameter.
09.75 - 10.67	GRAVEL	Small pebble gravel in very coarse sand, clasts to 2.5 cm in diameter.
10.67 - 10.97	GRAVEL	Open work, pebble gravel, 4 cm diameter.
10.97 - 11.28	GRAVEL	Matrix supported, pebble gravel in very

		coarse, sand matrix.
11.28 - 11.43	SAND	Very coarse sand.
11.43 - 11.58	SAND	Fine to very fine sand.
11.58 - 12.80	SAND	Pea-size gravel and very coarse to coarse sand (gravelly sand).
12.80 - 13.87	SAND	Pebbly, coarse sand, pea-size to 4 cm in diameter (gravelly sand).
13.87 - 15.85	SAND	Slightly silty, fine to very fine sand, massive with a rare small pebble.
15.85 - 16.77	SAND	Fine sand, becoming coarser downward to medium sand.
16.77 - 17.38	SAND	Very fine sand, minor silt.
17.38 - 18.14	SAND	Fine sand and very fine sand.
18.14 - 21.03	SAND	Medium to coarse grained sand with a rare, rounded pebble.
21.03 - 22.83	SAND	Coarse to very coarse sand, rare pebble, and heavy mineral concentration at 22.10 m depth.
22.03 - 22.86	SILT	Fissile silt with minor coarse sand and a rare pebble.
22.86 - 23.17	SILT	Laminated silt with fine sand.
23.17 - 23.78	SAND	Coarse to very coarse sand with thin, wispy laminations of silt.
23.78 - 25.00	SAND	Fine sand with heavy mineral layers.
25.00 - 25.30	SAND	Very fine sand.
25.30 - 26.52	SAND	Medium to coarse sand, minor clast.
26.52 - 27.44	SAND	Fine sand.
27.44 - 28.35	SAND	Well sorted, coarse sand.
28.35 - 29.27	SAND	Dominantly coarse sand, fine to coarse range.
29.27 - 32.62	SAND	Interbedded, fine sand and slightly silty, very fine sand.
32.62 - 33.23	SAND	Thinly interbedded silt and coarse to very coarse sand.
33.23 - 33.54	DIAMICTON	Very poorly sorted silt to very coarse sand with small pebbles (debris flow).
33.54 - 37.50	SAND	Dominantly fine grained sand with minor interbeds of silt and heavy mineral laminations at 35.7 m depth.
37.50 - 37.80	SAND	Well sorted, medium sand.
37.80 - 38.41	SAND	Coarse to very coarse sand.
38.41 - 43.29	SAND	Ripple laminated, fine sand with wispy, silt drapes and heavy mineral laminations at 41.8 m depth.
43.29 - 43.59	SAND	Pebbly (to 5 cm),very coarse sand.
43.59 - 45.12	SAND	Fine grained sand with minor thin beds of medium sand.
45.12 - 46.03	SAND	Fine sand, rhythmically bedded with silt

		to clayey silt.
46.03 - 46.80	SAND	Interlaminated, fine and medium sand with wisps of silt drape, possible ripples.
46.80 - 47.41	SAND	Very coarse sand, becoming small pea-size gravel in lower 15 cm.
47.41 - 47.86	SAND	Heavy mineral laminated, fine sand.
47.86 - 48.78	SAND	Interbedded, coarse sand with fine and medium sand and a rare silt lamination.
48.78 - 50.91	SAND	Fine sand with wisps of silt, containing rounded plates of silt.
50.91 - 53.66	SAND	Interbedded, medium to coarse sand and fine sand, rare lamination of silt or silty clay.
53.66 - 53.96	GRAVEL	Small pebbly gravel in a very coarse, sand matrix, clast to 2.5 cm in diameter.
53.96 - 54.57	GRAVEL	Cobble and pebble gravel in very coarse, sand matrix.
54.57 - 55.49	SAND	Medium sand with horizontal, mineral laminations.
55.49 - 55.94	SAND	Coarse sand with heavy mineral laminations.
55.94 - 56.09	SAND	Pebbly, very coarse sand, clasts to 4 cm in diameter.
56.09 - 58.38	SAND	Coarse to very coarse sand, becoming gravelly in lower 15 cm.
58.38 - 58.53	DIAMICTON	Silt with minor coarse sand and pebbles, poorly sorted (till or flow till).
58.53 - 60.52	SILT	Silt with clay laminations and minor laminations of very fine sand.
60.52 - 62.65	DIAMICTON	Massive silt, minor sands, and contains some pebbles (till?).
62.65 - 64.63	SILT	Silt and very fine sand, faintly laminated with clay (contorted), becoming finer downward, contains 3 inclusions of silt containing clasts, minor sand.
64.63 - 71.34	DIAMICTON	Massive, conchoidal fracture, clayey silt to silt with minor coarse sand and pebbles (less than 2%).
71.34 - 72.56	SLIT/CLAY	Highly deformed silt and silty clay, silt in streaks and small roll-ups.
72.56 - 73.47	DIAMICTON	Massive, clayey silt to silt with pebbles to 1%, minor coarse sand.
73.47 - 80.18	SILT/CLAY	Highly deformed silt and clayey silt with rare small pebbles.

The diamicton layers are:

- a massive, clayey silt to silt with less than 1% pebbles and minor coarse sand, 0.91 m thick;

- a massive, conchoidal fracture, clayey silt to silt with minor coarse sand and pebbles that increase from less than 2% at top to 2-5% at the base, 6.71 m thick;

- a massive silt with minor sand and some pebbles, becoming clay silt with minor sand and about 1% clasts, 2.13 m thick;

- a silt with minor poorly sorted, coarse sand and pebbles (till or flow till), 0.15 m thick; and

- very poorly sorted silt to very coarse sand with small pebbles (debris flow), 0.30 m thick.

Based on the above, it is possible to conclude that till-like materials occur under the surface within the study area. The question: "how many tills are there?" remains, however, unanswered. The possible number of buried tills within the study area ranges from 1 to 7.

APPENDIX IV

WELL LOCATIONS AND IDENTIFICATION NUMBERS OF WATER QUALITY SAMPLES COLLECTED FROM BEDROCK WELLS AND WATER QUALITY DATA FOR BEDROCK WELLS.

Well locations and identification numbers for water quality samples collected from bedrock wells.

Wells completed in Precambrian bedrock

Well Number	County	Town or Township	Conc.	Lot	Well Name	Well Type	Depth Water Found (m b.g.s.)	UTM Zone	UTM Easting	UTM Northing
20041	Simcoe	Matchedash	1	4	-	P	31.4	17	610101	4956431
27088	Simcoe	Matchedash	1	9	-	P	20.1	17	608119	4959389
25817	Simcoe	Matchedash	2	4	-	P	48.8	17	609820	4956726
23911	Simcoe	Matchedash	3	1	-	P	73.2	17	613252	4956258
28202	Simcoe	Matchedash	3	6	-	P	64.0	17	611763	4959017
21814	Simcoe	Matchedash	4	7	-	P	38.1	17	612167	4959886
29907	Simcoe	Medonte	11	21	Coldwater PW 93-1	M	22	17	607080	4950970
95001	Simcoe	Medonte	11	21	Coldwater PW 93-2	M	24.1	17	607120	4950990
25508	Simcoe	Medonte	12	22	-	P	25.3	17	607190	4950980
21079	Simcoe	Medonte	13	24	-	P	20.72, 29.26	17	607740	4952480
22681	Simcoe	Orillia	ND 1	15	-	P	32.0 , 38.1	17	613350	4949044
25823	Simcoe	Orillia	ND 2	24	-	P	3.0	17	611225	4954905
17207	Simcoe	Tay	4	31	-	P	77.7	17	587250	4962300
23511	Simcoe	Tay	5	11	-	P	25.9	17	595991	4953293
29633	Simcoe	Tay	7	12	-	P	47	17	597927	4955051
7041	Simcoe	Tay	8	14	-	P	29.2	17	598470	4957370
20380	Simcoe	Tay	8	16	-	P	24.7	17	597720	4957628
10083	Simcoe	Tay	9	5	-	P	65.9	17	601819	4952297
4017	Simcoe	Tay	10	11	-	P	7.06	17	601606	4956515
4018	Simcoe	Tay	10	11	-	P	9.1	17	601511	4956164
24393	Simcoe	Tay	11	1	-	P	33.8, 176.8	17	605628	4951602
24168	Simcoe	Tay	11	5	-	P	39.6	17	604766	4954252
8153	Simcoe	Tay	11	7	-	P	46.3	17	604100	4955140
21544	Simcoe	Tay	11	13	-	P	72.3	17	602027	4958060
28496	Simcoe	Tay	13	1	-	P	15.2, 54.9	17	608670	4953618
9716	Simcoe	Tay	13	13	-	P	50.3	17	604362	4959838
9953	Simcoe	Tiny	12	13	-	P	119.8	17	579950	4954450
30356	Simcoe	Tiny	15	2	-	P	38.1	17	583345	4960805
27456	Simcoe	Tiny	16	2	-	P	70.1	17	582868	4961330

Wells completed in Palaeozoic bedrock

Well Number	County	Town or Township	Conc.	Lot	Well Name	Well Type	Depth Water Found (m b.g.s.)	UTM Zone	UTM Easting	UTM Northing
9263	Simcoe	Flos	10	10	-	P	91.5	17	586661	4936824
25899	Simcoe	Medonte	PRE 2	69	-	P	158.8	17	597097	4942527
27213	Simcoe	Medonte	3	19	-	P	129.54	17	598880	4943682
25225	Simcoe	Medonte	8	5	-	P	49.1	17	609380	4939421
26763	Simcoe	Medonte	10	6	-	P	48.76	17	610563	4940986
25970	Simcoe	Medonte	13	12	-	P	11.58	17	612551	4947010
20360	Simcoe	Orillia	ND 2	7	-	P	35.1	17	618224	4946243
27693	Simcoe	Orillia	ND 5	1	-	P	20.7	17	622546	4945009
21662	Simcoe	Orillia	ND 5	10	-	P	10.7	17	619487	4950073
27093	Simcoe	Orillia	ND 8	15	-	P	10.4	17	622847	4954779
23653	Simcoe	Orillia	ND 9	11	-	P	9.1	17	625450	4953560
22243	Simcoe	Tay	3	13	-	P	28.4	17	593260	4952537
29439	Simcoe	Tay	4	10	-	P	83.2	17	595317	4951746
26389	Simcoe	Tay	4	15	-	P	34.1	17	592568	4954046
22983	Simcoe	Tay	4	20	-	P	18.9	17	592001	4956897
23516	Simcoe	Tay	4	25	-	P	38.7	17	589662	4959520
21325	Simcoe	Tay	5	17	-	P	34.1	17	593649	4956224
3958	Simcoe	Tay	5	19	-	P	20.4	17	593396	4957380
30757	Simcoe	Tay	7	7	-	P	41.2	17	599751	4952570
6956	Simcoe	Tay	8	10	-	P	10.4	17	599240	4954120
8294	Simcoe	Tay	8	10	-	P	13.1	17	599130	4954360
8480	Simcoe	Tay	10	7	-	P	60.4	17	602170	4953850
14028	Simcoe	Tiny	9	9	-	P	130.5	17	584400	4951800
29976	Simcoe	Tiny	16	1	-	P	66.5	17	583229	4963024
30283	Simcoe	Tiny	16	B	-	P	12.2	17	584829	4963113
7380	Simcoe	Tiny	16	B	Tee Pee Point PW-9	M	45	17	584510	4962950

Wells completed in Precambrian bedrock (all values as mg/L unless otherwise noted)

Well Number	Date Sampled	Sample Type	Report Type	Cl	Fe	Mn	Al	SO4	Ca	Mg	Na	K
20041	Aug 04 1995	R	B	14.0	.036<T	0.0330	0.0061	41.50	84.20	17.10	13.60	1.90
27088	Jul 19 1995	R	B	9.8	.054<T	0.5300	0.0066	35.00	52.40	13.10	41.40	1.55
25817	Jul 21 1995	R	B	4.8	0.100	0.0470	0.0034	21.50	37.80	13.80	51.40	1.50
23911	Jul 19 1995	R	B	42.4	.018<T	0.0640	0.0058	46.00	73.60	26.90	24.60	6.60
28202	Jul 19 1995	R	B	8.6	.036<T	0.0400	0.0049	23.50	13.60	5.05	83.20	0.70
21814	Jul 19 1995	R	B	68.4	6.900	2.5000	0.2700	18.00	29.20	11.20	42.60	1.85
29907	Apr 1993	R	B	54.0	0.160	-	-	85.00	70.20	16.90	33.10	2.40
95001	Apr 1993	R	B	52.4	0.200	-	-	81.00	70.50	17.20	34.20	2.40
25508	Jul 1991	R	B	53.9	0.210	-	-	86.80	71.50	17.70	36.00	3.20
21079	Jun 28 1995	T	B	1.6	0.480	0.0330	0.0028	48.50	46.40	28.90	16.00	5.45
22681	Jul 21 1995	R	B	1500.0	.018<T	0.0120	0.0500	308.00	286.00	122.00	450.00	13.00
25823	Jul 19 1995	R	B	25.0	0.220	0.3500	0.1400	61.00	51.40	7.55	21.40	12.80
17207	Feb 11 1995	R	B	62.7	0.057<T	0.0062	0.0035	9.75	99.20	22.30	24.90	2.61
23511	Feb 03 1995	T	B	12.0	0.016<T	0.0014	0.0043	381.00	33.60	18.20	148.00	3.39
29633	Feb 03 1995	R	B	141.0	0.006<T	0.0220	0.0042	235.00	81.40	28.10	167.00	3.61
7041	Aug 24 1977	R	B	711.0	0.350	-	-	335.00	152.00	68.00	355.00	6.40
20380	Feb 07 1995	R	B	115.0	0.400	0.0380	0.0039	115.00	75.40	44.40	51.90	4.57
10083	Aug 24 1977	R	B	307.0	0.150	-	-	600.00	42.00	64.00	350.00	3.10
4017	Aug 24 1977	R	B	52.0	0.100	-	-	58.00	109.00	19.00	16.00	1.00
4018	Aug 24 1977	R	B	12.0	0.050	-	-	21.00	74.00	17.00	4.00	1.70
24393	Feb 11 1995	R	B	8.8	0.320	0.0130	0.0091	555.00	46.20	19.40	209.00	4.55
24168	Feb 03 1995	R	B	29.8	0.022<T	0.0660	0.0039	75.30	77.40	23.30	30.50	2.20
8153	Aug 24 1977	R	T	81.0	0.050	-	-	42.00	2.00	6.00	160.00	2.00
21544	Feb 28 1995	R	B	182.0	0.048<T	0.0120	0.0024	144.00	33.70	16.70	247.00	2.55
28496	Feb 11 1995	R	B	25.2	0.230	0.0025	0.0100	84.30	58.10	19.30	87.70	2.07
9716	Feb 11 1995	R	B	5.8	0.430	0.0140	0.0250	53.70	32.50	11.30	35.10	2.42
9953	Mar 25 1995	R	B	106.0	.0060<W	.00012<T	0.0029	10.70	84.50	6.63	40.40	2.00
30356	Mar 16 1995	R	B	29.7	1.100	0.0180	0.0066	361.00	27.90	8.62	199.00	2.50
27456	Mar 20 1995	R	B	14.9	0.760	0.0230	0.0019	285.00	32.30	13.70	128.00	3.96

Wells completed in Palaeozoic bedrock

Well Number	Date Sampled	Sample Type	Report Type	Cl	Fe	Mn	Al	SO4	Ca	Mg	Na	K
9263	May 12 1976	R	B	15.0	0.150	-	-	16.00	14.00	8.00	41.00	0.90
25899	Jun 23 1995	R	B	394.0	3.900	0.0700	0.0029	1870.00	477.00	208.00	185.00	10.70
27213	Jun 22 1995	T	B	1.8	0.190	0.0074	0.0110	19.80	15.90	12.20	25.10	1.15
25225	Jun 27 1995	T	B	0.4<T	0.006<W	0.0001<T	0.0056	13.40	0.2<W	0.05<W	85.40	0.40
26763	Jul 12 1995	R	B	1.4	0.054	0.0060	0.0063	11.50	21.60	18.20	12.40	1.15
25970	Jun 29 1995	R	B	16.8	2.100	0.0430	0.0028	19.50	57.20	31.30	9.00	2.05
20360	Jul 15 1995	R	B	2.0	0.160	0.0071	0.0040	13.00	8.00	6.15	34.40	0.95
27693	Jul 13 1995	R	B	3.0	0.770	0.0190	0.0042	20.50	51.60	19.30	3.60	1.90
21662	Jul 13 1995	R	B	23.0	0.140	0.0120	0.0110	264.00	86.00	67.80	32.40	4.65
27093	Sep 23 1995	R	B	1.4	0.084	0.0380	0.0017	14.50	62.40	20.60	3.40	2.50
23653	Sep 23 1995	R	B	7.6	.006<W	.00045<T	0.0020	23.00	80.40	16.30	3.60	0.90
22243	Feb 25 1995	R	B	1.2	0.210	0.0050	0.0023	18.50	29.50	13.30	21.00	1.52
29439	Feb 03 1995	R	B	0.5<T	0.110	0.0097	0.0041	45.30	25.10	14.10	14.40	1.40
26389	Feb 11 1995	R	B	103.0	0.043<T	0.0038	0.0033	25.20	69.50	17.50	80.30	2.38
22983	Feb 03 1995	R	B	58.2	0.056<T	0.0062	0.0061	22.40	92.70	18.80	29.10	2.44
23516	Feb 03 1995	R	B	200.0	0.100	0.0130	0.0025	78.30	111.00	30.40	101.00	3.79
21325	Feb 03 1995	T	B	0.9<T	0.020<T	0.0005	0.0045	23.90	9.40	4.92	37.60	0.97
3958	Jul 16, 1963	R	B	149.0	0.180	-	-	635.00	-	-	-	-
30757	Feb 03 1995	R	B	0.8<T	0.270	0.0120	0.0050	16.00	42.00	17.10	5.50	1.87
6956	Aug 24 1977	R	B	100.0	0.200	-	-	39.00	123.00	36.00	43.00	1.50
8294	Aug 24 1977	R	B	90.0	0.400	-	-	37.00	106.00	42.00	34.00	3.10
8480	Aug 24 1977	R	B	4.0	0.150	-	-	76.00	29.00	21.00	19.00	0.90
14028	Mar 25 1995	R	B	0.9<T	0.200	0.0051	0.0036	7.75	10.60	5.74	29.20	1.52
29976	Mar 16 1995	R	B	33.1	0.006<W	0.0120	0.0026	733.00	91.70	51.30	187.00	7.08
30283	Mar 20 1995	T	B	75.4	0.030	0.0057	0.0016	136.00	4.50	2.51	66.70	246.00
7380	Sep 16 1992	R	B	16.8	0.298	-	-	23.30	40.20	23.50	17.00	2.09

Wells completed in Precambrian bedrock

Well Number	Hardness (as CaCO3)	Conductivity (umhos/cm)	pH	Alkalinity (as CaCO3)	TDS	F	Turb.	Colour	Nitrate (as N)	Nitrite (as N)	Nitrate + Nitirite (as N)
20041	281.0	559	7.9	249	364	-	-	-	-	0.005<W	0.050<T
27088	185.0	505	8.09	239	328	-	-	-	-	0.015<T	0.100<T
25817	152.0	473	8.43	248	308	-	-	-	-	0.005<T	0.100<T
23911	295.0	675	8.09	243	440	-	-	-	-	0.160	7.550
28202	55.0	443	8.42	210	288	-	-	-	-	0.005<W	0.050<T
21814	119.0	467	6.88	116	304	-	-	-	-	0.005<T	0.050<W
29907	245.0	715	8	166	-	0.1	1.45	5	-	<0.010	<0.050
95001	247.0	705	7.9	157	-	-	1.77	7	-	-	<0.050
25508	251.0	561	7.73	167	422	0.37	2	11	<0.030	<0.030	-
21079	234.0	529	8.2	254	344	-	-	-	-	0.005<W	0.100<T
22681	1220.0	4270	7.81	224	4040					0.105	0.800
25823	160.0	459	7.02	109	298					0.305	6.750
17207	340.0	711	8.3	304	462	-	-	-	-	0.005<W	1.550
23511	159.0	994	8.23	103	715	-	-	-	-	0.005<W	0.250<T
29633	319.0	1360	8.26	252	814	-	-	-	-	0.005<W	0.100<T
7041	659.0	2940	7.60	135	2235	-	-	-	<.100	<.0100	-
20380	371.0	926	8.21	234	669	-	-	-	-	0.005<W	0.050<W
10083	367.0	2220	8.00	80	1575	-	-	-	<.100	<.0100	-
4017	350.0	705	7.30	254	514	-	-	-	1.000	<.0100	-
4018	257.0	487	7.60	220	345	-	-	-	3.300	0.340	-
24393	195.0	1380	8.28	100	993	-	-	-	-	0.005<W	0.050<W
24168	289.0	636	8.23	248	413	-	-	-	-	0.005<W	0.050<W
8153	31.0	725	8.80	231	460	-	-	-	0.100	0.110	-
21544	153.0	1410	8.4	310	817	-	-	-	-	0.005<W	0.050<W
28496	225.0	719	8.28	289	467	-	-	-	-	0.035	0.450
9716	128.0	401	8.39	160	261	-	-	-	-	0.005<W	0.100<T
9953	238.0	652	7.78	163	424	-	-	-	-	0.005<W	0.800
30356	105.0	1130	8.28	77	773	-	-	-	-	0.005<W	0.050<W
27456	137.0	869	8.23	93	604	-	-	-	-	0.005<W	0.050<W

Wells completed in Palaeozoic bedrock

Well Number	Hardness (as CaCO3)	Conductivity (umhos/cm)	pH	Alkalinity (as CaCO3)	TDS	F	Turb.	Colour	Nitrate (as N)	Nitrite (as N)	Nitrate + Nitirite (as N)
9263	68.0	290	8.50	116	189	-	-	-	<.1	<.01	-
25899	2050.0	3800	7.83	161	3890	-	-	-	-	0.020<T	0.100<T
27213	89.8	289	8.35	134	188	-	-	-	-	0.0050<W	0.200<T
25225	0.5<W	348	8.51	175	226	-	-	-	-	0.0050<W	0.050<T
26763	129.0	300	8.34	154	196	-	-	-	-	0.095	0.200<T
25970	272.0	526	8.15	259	342	-	-	-	-	0.005<T	0.100<T
20360	45.5	241	8.5	113	156	-	-	-	-	0.005<T	0.100<T
27693	208.0	387	8.28	196	252	-	-	-	-	0.005<T	0.100<T
21662	494.0	969	8.16	308	708	-	-	-	-	0.010<T	0.100<T
27093	241.0	463	8.25	247	300	-	-	-	-	0.005<W	0.050<W
23653	268.0	508	8.09	250	330	-	-	-	-	0.005<W	0.650
22243	128.0	318	8.08	158	207	-	-	-	-	0.005<W	0.050<W
29439	121.0	320	8.4	131	208	-	-	-	-	0.005<W	0.050<W
26389	245.0	797	8.38	258	518	-	-	-	-	0.005<W	2.300
22983	309.0	685	8.26	283	445	-	-	-	-	0.005<W	0.300
23516	403.0	1190	8.05	284	784	-	-	-	-	0.005<W	0.050<W
21325	43.7	256	8.39	111	164	-	-	-	-	0.005<W	0.200<T
3958	550.0	-	7.90	236	-	1.60	-	-	-	-	0.300
30757	175.0	348	8.36	186	226	-	-	-	-	0.005<W	0.050<W
6956	455.0	995	7.30	364	677	-	-	-	<.1	<.01	-
8294	438.0	930	7.40	342	665	-	-	-	<.1	<.01	-
8480	157.0	378	8.10	121	246	-	-	-	<.1	0.080	-
14028	50.1	221	8.44	110	144	-	-	-	-	0.005<W	0.100<T
29976	440.0	1640	8.04	110	1320	-	-	-	-	0.010<T	0.050<W
30283	21.6	1120	8.1	226	714	-	-	-	-	0.005<W	0.050<W
7380	197.0	459	7.89	196	263	0.40	1.30	1.00	<0.1	<0.1	-

Wells completed in Precambrian bedrock

Well Number	Ammonium (as N)	Ammonia (as N)	Ammonium + Ammonia (as N)	Phosphates	TKN	Total Phosphorous	DOC	DIC	Silicon	Bicarbonate
20041	-	-	0.050<W	0.020<W	0.150<T	0.020<W	3.20	70.4	8.30	-
27088	-	-	0.250	0.020<W	0.250	0.020<W	2.80	59.2	7.08	-
25817	-	-	0.150<T	0.020<W	0.150<T	0.020<W	2.10	59.6	5.94	-
23911	-	-	0.100<T	0.020<W	0.500	0.020<W	4.20	63.2	5.00	-
28202	-	-	0.100<T	0.020<W	0.050<T	0.020<W	1.10	51.8	7.02	-
21814	-	-	1.650	0.020<W	2.300	0.020<T	17.10	68.8	5.06	-
29907	-	<0.050	-	<0.010	0.100	-	-	-	-	-
95001	-	<0.050	-	<0.010	-	-	-	-	-	-
25508	-	-	-	-	-	0.070	-	-	-	-
21079	-	-	0.050<T	0.020<W	0.050<T	0.020<W	1.10	61.2	6.70	-
22681	-	-	0.550	0.020<W	0.600	0.020<W	0.50	60.8	3.94	-
25823	-	-	0.150<T	0.020<W	1.100	0.020<T	13.20	49.2	2.96	-
17207	-	-	0.050<W	0.020<W	0.150<T	0.040<T	1.80	74.8	4.46	-
23511	-	-	0.050<W	0.020<W	0.050<W	0.020<W	1.00	22.8	3.64	-
29633	-	-	0.100<T	0.020<W	0.250<T	0.020<W	1.90	62.0	5.68	-
7041	-	0.200	-	-	0.200	-	-	-	-	-
20380	-	-	0.100<T	0.020<W	0.150<T	0.020<W	2.00	58.8	6.66	-
10083	-	0.200	-	-	0.200	-	-	-	-	-
4017	-	<.100	-	-	0.400	-	-	-	-	-
4018	-	<.100	-	-	0.400	-	-	-	-	-
24393	-	-	0.550	0.020<W	0.600	0.020<W	0.200<T	21.6	3.74	-
24168	-	-	0.150<T	0.020<W	0.200<T	0.020<W	0.90	61.8	5.84	-
8153	-	<.100	-	-	0.100	-	-	-	-	-
21544	-	-	0.150<T	0.020<W	0.350	0.020<W	1.20	74.8	6.48	-
28496	-	-	0.050<W	0.020<W	0.150<T	0.020<W	1.40	72.6	4.76	-
9716	-	-	0.050<W	0.020<W	0.150<T	0.020<W	1.80	37.2	5.78	-
9953	-	-	0.350	0.020<W	0.150<T	0.020<W	2.00	39.6	1.86	-
30356	-	-	0.150<T	0.020<W	0.200<T	0.020<W	0.400<T	16.8	3.62	-
27456	-	-	0.250<T	0.020<W	0.350	0.040<T	0.200<T	21.0	3.44	-

Wells completed in Palaeozoic bedrock

Well Number	Ammonium (as N)	Ammonia (as N)	Ammonium + Ammonia (as N)	Phosphates	TKN	Total Phosphorous	DOC	DIC	Silicon	Bicarbonate
9263	-	<.10	-	-	0.200	-	-	-	-	-
25899	-	-	0.900	0.020<W	0.950	0.040<T	0.400<T	37.0	4.80	-
27213	-	-	0.050<W	0.020<W	0.200<T	0.060<T	0.300<T	29.8	5.80	-
25225	-	-	0.050<W	0.020<W	0.050<W	0.020<T	0.200	41.0	8.56	-
26763	-	-	0.050<T	0.020<W	0.350	0.020<T	0.200<T	34.0	6.24	-
25970	-	-	0.050<T	0.020<W	0.050<W	0.020<W	0.500	62.8	8.14	-
20360	-	-	0.050<T	0.020<W	0.200<T	0.020<W	0.200<T	26.4	5.04	-
27693	-	-	0.050<T	0.020<W	0.200<T	0.020<W	0.300<T	48.4	6.06	-
21662	-	-	0.250	0.020<W	0.400	0.020<W	1.000	77.4	12.60	-
27093	-	-	0.050<W	0.020<W	0.100<T	0.020<W	1.400	61.4	3.38	-
23653	-	-	0.050<W	0.020<W	0.050<W	0.020<W	0.800	61.4	5.60	-
22243	-	-	0.050<W	0.030<T	0.150<T	0.020<W	0.100<W	37.4	6.88	-
29439	-	-	0.050<W	0.020<W	0.100<T	0.020<W	0.600	30.4	5.98	-
26389	-	-	0.050<W	0.020<W	0.150<T	0.020<W	1.200	61.4	4.64	-
22983	-	-	0.050<W	0.020<W	0.150<T	0.020<W	2.800	70.4	4.90	-
23516	-	-	0.050<W	0.020<W	0.250<T	0.020<W	1.300	75.4	4.48	-
21325	-	-	0.050<W	0.020<W	0.050<W	0.020<W	0.500<T	25.0	3.64	-
3958	-	-	-	-	-	-	-	-	-	-
30757	-	-	0.050<W	0.020<W	0.050<W	0.020<W	0.700	44.2	6.64	-
6956	-	<.10	-	-	0.100	-	-	-	-	-
8294	-	0.20	-	-	0.200	-	-	-	-	-
8480	-	<.10	-	-	0.100	-	-	-	-	-
14028	-	-	0.150<T	0.020<W	0.100<T	0.020<W	0.200<T	24.6	4.46	-
29976	-	-	0.300	0.020<W	0.400	0.020<W	0.300<T	25.4	4.38	-
30283	-	-	0.050<W	0.020<W	0.200<T	0.020<W	0.800	56.2	6.66	-
7380	-	0.07	-	0.117	0.500	-	0.600	-	-	195

APPENDIX V

WELL LOCATIONS AND IDENTIFICATION NUMBERS OF WATER SAMPLES COLLECTED FROM OVERBURDEN WELLS; WATER QUALITY DATA FOR OVERBURDEN WELLS; AND WATER QUALITY TRENDS IN GROUNDWATER.

Well locations and identification numbers for water quality samples collected from overburden wells

Shallow overburden wells (water bearing formation <20m deep).

Well Number	County	Town or Township	Conc.	Lot	Well Name	Well Type	Depth Water Found (m)	UTM Zone	UTM easting	UTM Northing
26986	Simcoe	Flos	FRW 1	68	-	F	7.30	17	594356	4940794
22326	Simcoe	Flos	6	5	-	F	11.30	17	591631	4934555
30398	Simcoe	Flos	6	8	-	P	15.90	17	590862	4932758
768	Simcoe	Flos	6	10	-	P	10.7	17	589977	4932382
776	Simcoe	Flos	7	2	-	P	18.3	17	593150	4935900
828	Simcoe	Flos	10	1	-	P	18.0	17	590542	4940881
15723	Simcoe	Flos	10	3	-	P	16.50	17	590300	4939100
26427	Simcoe	Medonte	PRE 1	54	-	P	16.45	17	598568	4936196
20104	Simcoe	Medonte	8	2	-	P	18.89	17	610682	4937778
29978	Simcoe	Medonte	8	16	-	P	15.24	17	605636	4945606
8025	Simcoe	Medonte	8	16	-	P	9.1	17	604935	4944840
95002	Simcoe	Medonte	13	9	-	-	12.2	17	612850	4944840
95003	Simcoe	Medonte	13	17	-	-	9.1	17	610190	4948920
29497	Simcoe	Orillia	SD 1	1	-	P	15.2	17	618394	4941262
27499	Simcoe	Orillia	SD 2	5	-	P	19.8	17	620663	4940342
26019	Simcoe	Orillia	SD 4	5	-	P	11.0	17	623267	4941379
12992	Simcoe	Orillia	SD 6	1	-	FS	5.8	17	624150	4945300
95004	Simcoe	Orillia	ND 2	4	-	-	7.0	17	619160	4945160
95005	Simcoe	Orillia	ND 5	3	-	-	3.0	17	623350	4946320
95006	Simcoe	Orillia	ND 6	23	-	-	4.3	17	616750	4956720
95007	Simcoe	Orillia	ND 8	19	-	-	5.8	17	621130	4957250
95008	Simcoe	Orillia	ND 9	8	-	-	7.6	17	625000	4951760
28360	Simcoe	Oro	7	2		F	6.1	17	609884	4935635

Well Number	County	Town or Township	Conc.	Lot	Well Name	Well Type	Depth Water Found (m)	UTM Zone	UTM easting	UTM Northing
20365	Simcoe	Oro	12	6	-	F	15.2	17	616705	4936482
95009	Simcoe	Tay	PRE 1	89	-	-	5.5	17	592020	4949580
11855	Simcoe	Tay	PRE 1	110	Sunnyside FW	M	7.9	17	586750	4956600
95010	Simcoe	Tay	PRE 2	90	-	-	6.1	17	592110	4949820
3914	Simcoe	Tay	PRE 2	112	Portage Fark FW-2	M	15.9	17	587498	4958077
29975	Simcoe	Tay	4	15	-	F	18.60	17	593037	4953989
20183	Simcoe	Tay	4	25	-	F	8.20	17	589619	4959441
95011	Simcoe	Tay	5	7	-	-	12.2	17	596540	4950000
23973	Simcoe	Tay	6	8	-	F	18.30	17	597292	4951313
4023	Simcoe	Tay	11	6	-	P	16.5	17	604026	4954152
13833	Simcoe	Tay	11	6	-	F	18.30	17	604300	4954300
4479	Simcoe	Tiny	FRW 1	100	-	F	15.2	17	587365	4951983
27828	Simcoe	Tiny	FRW 2	85	-	F	18.0	17	588956	4945601
29406	Simcoe	Tiny	PRW 2	114	-	P	19.8	17	582727	4956131
95012	Simcoe	Tiny	2	15	-	-	9.1	17	585810	4942150
27965	Simcoe	Tiny	6	11	-	F	11.9	17	585925	4947067
95013	Simcoe	Tiny	10	13	-	-	2.4	17	592110	4949820
95014	Simcoe	Tiny	17	1	-	-	6.1	17	583000	4963000

Deep overburden wells (water bearing formation > 20m deep).

Well Number	County	Town or Township	Conc.	Lot	Well Name	Well Type	Depth Water Found (m)	UTM Zone	UTM easting	UTM Northing
443	Simcoe	Elmvale	-	-	-	M	30.0	17	590127	4937274
30617	Simcoe	Flos	PRW 1	55	-	P	60.40	17	597863	4936445
29981	Simcoe	Flos	PRW 1	64	-	P	35.10	17	594671	4938745
850	Simcoe	Flos	PRW 1	65	-	P	24.4	17	594272	4938679
9930	Simcoe	Flos	PRW 1	73	-	P	42.7	17	593803	4942750
26976	Simcoe	Flos	PRW 1	75	-	P	35.40	17	593492	4943195
25652	Simcoe	Flos	PRW 2	74	-	P	36.60	17	591051	4941365
95015	Simcoe	Flos	PRW 2	75	-	-	27.4	17	591600	4942070
6992	Simcoe	Flos	4	5	-	P	26	17	593020	4932420
754	Simcoe	Flos	5	6	-	P	25.6	17	592180	4933553
95016	Simcoe	Flos	6	8	-	-	21.3	17	591110	4933050
10335	Simcoe	Flos	7	1	-	P	39.6	17	593805	4936546
25623	Simcoe	Flos	7	1	-	P	47.30	17	593932	4936526
14375	Simcoe	Flos	7	6	-	P	45.10	17	590300	4935600
778	Simcoe	Flos	7	12	-	P	90.2	17	585511	4932373
30001	Simcoe	Flos	8	10	-	P	111.30	17	588103	4934357
9562	Simcoe	Flos	8	11	-	P	63.7	17	587800	4934120
796	Simcoe	Flos	9	4	-	P	78.0	17	590461	4937531
24249	Simcoe	Flos	9	9	-	P	111.30	17	588204	4935995
26254	Simcoe	Flos	10	5	-	P	21.60	17	588631	4939237
24061	Simcoe	Flos	10	10	-	P	25.3, 34.1	17	586682	4936833
831	Simcoe	Flos	10	10	-	P	72.6	17	585898	4937967
21784	Simcoe	Flos	10	15	-	P	69.80	17	583483	4936431
841	Simcoe	Flos	11	7	-	P	84.7	17	587455	4939040
30611	Simcoe	Medonte	PRE 1	41	_	p	22.86	17	602400	4932100
27822	Simcoe	Medonte	PRE 2	71	_	p	84.73	17	596111	4943365

Well Number	County	Town or Township	Conc.	Lot	Well Name	Well Type	Depth Water Found (m)	UTM Zone	UTM easting	UTM Northing
6384	Simcoe	Medonte	4	23	_	p	21.3	17	597710	4945750
25985	Simcoe	Medonte	5	1	_	p	104.24	17	607296	4935345
19978	Simcoe	Medonte	5	10	-	P	63.70	17	603166	4939842
1075	Simcoe	Medonte	5	11	-	-	50.1	17	603300	4940100
24285	Simcoe	Medonte	5	20	-	P	60.95	17	600139	4945487
22365	Simcoe	Medonte	9	22	-	P	70.10	17	604678	4949627
29380	Simcoe	Medonte	11	3	-	P	78.94	17	613556	4941184
23920	Simcoe	Medonte	11	11	-	P	58.52	17	610656	4944445
25195	Simcoe	Medonte	11	24	-	P	44.19	17	605680	4950794
23325	Simcoe	Medonte	13	11	-	P	50.29	17	612743	4945691
30445	Simcoe	Medonte	13	20	-	P	24.99	17	609291	4950191
1892	Simcoe	Midland	-	-	-	PS	24.3	17	587776	4954383
95017	Simcoe	Midland	-	-	Midland PW-5	M	?	17	586860	4956080
7106	Simcoe	Midland	-	-	Midland PW-6	M	22.2	17	586640	4955890
95018	Simcoe	Midland	-	-	Midland PW-7	M	39.6	17	588500	4952750
95019	Simcoe	Midland	-	-	Midland PW-7B	M	?	17	588600	4952840
95020	Simcoe	Midland	-	-	Midland PW-9	M	49.5	17	586350	4954520
15187	Simcoe	Midland	-	-	Midland PW-11	M	24.4	17	586350	4955900
16076	Simcoe	Midland	-	-	Midland PW-12	M	22.9	17	586500	4955850
16077	Simcoe	Midland	-	-	Midland PW-13	M	25.3	17	586600	4955850
16078	Simcoe	Midland	-	-	Midland PW-14	M	27.4	17	586700	4955850
95021	Simcoe	Midland	-	-	Midland PW-15	M	?	17	589240	4955790
95022	Simcoe	Midland	-	-	Midland PW-16	M	?	17	586550	4955500
95023	Simcoe	Midland	-	-	Midland PW-17	M	?	17	586650	4955750
21516	Simcoe	Orillia	SD 2	1	-	P	23.5	17	619284	4942359
95024	Simcoe	Orillia	SD 3	3	-	-	26.6	17	621550	4941740
19428	Simcoe	Orillia	ND 4	4	-	P	27.4	17	621719	4946207
23347	Simcoe	Oro	4	5	-	P	123.2	17	607487	4931579

Well Number	County	Town or Township	Conc.	Lot	Well Name	Well Type	Depth Water Found (m)	UTM Zone	UTM easting	UTM Northing
27128	Simcoe	Oro	5	1	-	p	135.7	17	607251	4934834
22215	Simcoe	Oro	8	6	-	P	32.90	17	612648	4934635
95025	Simcoe	Oro	8	8	-	-	48.8	17	612430	4932780
95026	Simcoe	Oro	9	2	-	TW	91.2	17	612300	4937550
95027	Simcoe	Oro	11	1	-	-	26.7	17	613550	4938770
28238	Simcoe	Oro	11	7	-	P	78.7	17	615568	4935311
21615	Simcoe	Oro	12	2	-	P	46.0	17	615003	4938712
95028	Simcoe	Penetanguishene	-	-	Payette PW-1	M	?	17	?	?
95029	Simcoe	Penetanguishene	-	-	Payette PW-2	M	76.2	17	?	?
95030	Simcoe	Penetanguishene	-	-	Payette PW-3	M	51.5	17	?	?
26734	Simcoe	Tay	PRE 1	76	-	P	123.8	17	594984	4944702
20247	Simcoe	Tay	PRE 1	99	-	P	29.00	17	589738	4952789
3888	Simcoe	Tay	PRE 1	100	-	P	44.5	17	589357	4953348
15819	Simcoe	Tay	PRE 2	85	-	P	55.8	17	593400	4948400
22529	Simcoe	Tay	PRE 2	117	-	P	54.30	17	585774	4959344
9004	Simcoe	Tay	PRE 2	112	Portage Park PW-3	M	30.5	17	587451	4957900
95031	Simcoe	Tay	PRE 2	120	Sandy Bay PW-1	M	?	17	?	?
27044	Simcoe	Tay	PRE 2	120	-	P	53.40	17	585463	4960222
12838	Simcoe	Tay	3	3	-	P	37.20	17	596600	4947250
8742	Simcoe	Tay	3	10	-	PS	51.8	17	592830	4950500
23971	Simcoe	Tay	3	10	-	PS	58.5	17	593478	4951030
95032	Simcoe	Tay	3	28	-	-	40.2	17	587550	4959770
15982	Simcoe	Tay	4	18	-	P	24.40	17	593700	4956900
25074	Simcoe	Tay	5	12	-	P	21.60	17	595887	4953492
9946	Simcoe	Tay	6	2	-	P	54.00	17	600228	4949139
19700	Simcoe	Tay	7	2	-	P	23.80	17	601750	4949650
3978	Simcoe	Tay	7	4	-	P	54.0	17	599728	4950201
15758	Simcoe	Tay	7	7	-	P	22.00	17	599900	4952500

Well Number	County	Town or Township	Conc.	Lot	Well Name	Well Type	Depth Water Found (m)	UTM Zone	UTM easting	UTM Northing
10360	Simcoe	Tay	8	7	-	P	37	17	600206	4952325
15922	Simcoe	Tay	9	5	-	P	33.50	17	602650	4952800
14602	Simcoe	Tay	10	9	-	P	23.8, 32.6	17	601650	4955250
25486	Simcoe	Tay	11	1	-	p	48.20	17	605207	4951825
27964	Simcoe	Tiny	PRW 1	77	-	P	123.8	17	591251	4942818
4476	Simcoe	Tiny	PRW 1	99	-	IR	37.8	17	587553	4951343
4503	Simcoe	Tiny	PRW 1	110	-	IR	32.0	17	584897	4955342
4505	Simcoe	Tiny	PRW 1	111	-	H	36.0	17	584962	4955493
16157	Simcoe	Tiny	PRW 2	92	-	P	42.4	17	587700	4948300
27968	Simcoe	Tiny	PRW 2	97	-	P	71.6	17	586027	4949353
29403	Simcoe	Tiny	1	14	-	P	21.3	17	586840	4941026
17039	Simcoe	Tiny	1	23	-	P	75.6	17	582050	4937900
24580	Simcoe	Tiny	2	13	-	P	35.1	17	585529	4941958
4331	Simcoe	Tiny	2	14	-	P	24.4	17	586803	4941900
29196	Simcoe	Tiny	4	13	-	P	48.8	17	586093	4943845
9709	Simcoe	Tiny	4	13	Wyevale	M	53.7	17	585596	4945066
12268	Simcoe	Tiny	5	13	Wyevale Pines PW-1	M	83.5	17	585350	4945200
15590	Simcoe	Tiny	5	13	Wyevale Pines PW-2	M	75.6	17	586050	4943850
22544	Simcoe	Tiny	9	11	-	P	24.7	17	583031	4951569
10857	Simcoe	Tiny	12	11	-	P	54.9	17	581050	4953750
25488	Simcoe	Tiny	14	6	-	P	33.5	17	582030	4958226

Water quality data for shallow overburden wells

Shallow overburden wells (water bearing formation <20m deep) (all values as mg/L unless otherwise noted)

Well Number	Date Sampled	Sample Type	Report Type	Cl	Fe	Mn	Al	SO4	Ca	Mg	Na	K	Hardness
26986	May 4 1995	R	B	2.4	0.0072<T	0.0003<T	0.0037	12.70	41.80	8.28	2.00	0.84	138
22326	May 4 1995	R	B	1.9	0.006<W	0.00008<T	0.0019	18.40	59.20	14.00	3.10	1.78	205
30398	May 4 1995	R	B	11.1	4.800	0.1600	0.0110	59.20	110.00	17.10	7.70	1.57	344
768	May 12 1976	R	B	4.0	0.100	-	-	14.00	59.00	16.00	4.00	1.70	210
776	May 12 1976	R	B	4.0	<.050	-	-	11.00	58.00	7.00	<1	0.40	172
828	May 12 1976	R	B	5.0	0.050	-	-	24.00	50.00	80.00	3.00	2.10	198
15723	Jul 25 1995	R	B	3.4	0.018<T	0.0035	0.0043	28.50	55.20	18.00	4.80	2.50	212
26427	Jun 20 1995	R	B	285.0	0.03<T	0.0021	0.0044	18.40	71.90	32.90	116.00	3.11	315
20104	Jun 27 1995	R	B	0.500<T	0.006<W	0.0012	0.0035	11.40	36.60	16.40	4.60	1.85	159
29978	Jun 27 1995	R	B	1.2	0.130	0.0014	0.0028	29.00	50.40	22.20	4.80	2.40	217
8025	Jun 24 1980	R	B	7.0	0.110	-	-	18.00	90.00	17.00	4.00	1.70	297
95002	Jun 24 1980	R	B	19.0	0.030	-	-	16.00	87.00	9.00	5.00	1.20	253
95003	Jun 24 1980	R	B	8.0	0.030	-	-	31.00	128.00	6.00	7.00	4.10	343
29497	Sep 20 1995	T	B	10.8	.012<T	.00005<W	0.0030	12.00	.2<W	.05<W	92.80	0.20<T	.5<W
27499	Jul 10 1995	R	B	27.6	0.078	0.0820	0.0039	15.00	119.00	21.40	7.60	2.05	384
26019	Jul 13 1995	T	B	261.0	.006<W	0.0084	0.0026	13.50	2.80	0.65	73.20	326.00	10
12992	Feb 16 1994	R	B	8.0	ND	-	-	18.00	65.70	22.90	3.36	1.72	258
95004	Jun 26 1980	R	B	62.0	0.040	-	-	20.00	88.00	6.00	8.00	2.70	246
95005	Jun 26 1980	R	B	3.0	0.330	-	-	10.00	29.00	1.00	3.00	2.40	76
95006	Jun 26 1980	R	B	27.0	0.790	-	-	22.00	87.00	10.00	11.00	3.10	257
95007	Jun 26 1980	R	B	13.0	0.160	-	-	28.00	103.00	14.00	9.00	2.40	314
95008	Jun 26 1980	R	B	3.0	0.010	-	-	13.00	116.00	10.00	3.00	2.90	332
28360	Sep 24 1995	R	B	0.4<T	0.012	0.0014	0.0170	10.50	24.80	6.35	1.60	1.40	88
20365	Sep 20 1995	R	B	1.2	0.012	0.0008	0.0043	13.00	56.40	12.80	2.00	1.15	194
95009	Jun 23 1980	R	B	24.0	0.150	-	-	55.00	141.00	15.00	11.00	132.00	412
11855	Sep 21 1990	R	B	2.6	<.006<W	-	-	22.69	43.60	10.75	2.40	1.58	153
95010	Jun 23 1980	R	B	38.0	0.050	-	-	32.00	146.00	23.00	13.00	3.30	458
3914	Sep 21 1990	T	B	1.5	0.150	-	-	20.85	42.40	14.45	5.30	2.09	165
29975	Feb 23 1995	R	B	9.8	1.500	0.0270	0.0030	36.80	38.70	47.40	8.10	3.05	292
20183	Feb 27 1995	R	B	2.9	0.027<T	0.0057	0.0023	25.10	56.20	24.90	3.30	2.92	243
95011	Jun 23 1980	R	B	7.0	0.130	-	-	19.00	120.00	5.00	5.00	1.50	321
23973	Feb 25 1995	R	B	0.4	0.500	0.0220	0.0068	7.41	31.40	13.20	14.00	1.79	133
4023	Aug 24 1977	R	B	3.0	<.050	-	-	19.00	49.00	17.00	4.00	1.60	191
13833	Feb 28 1995	R	B	0.800<T	0.300	0.0490	0.0022	17.10	50.80	15.20	2.40	1.82	189
4479	Jul 18 1963	R	B	9.0	0.120	-	-	24.00					248
27828	Mar 18 1995	R	B	0.300<T	0.350	0.017	0.0028	11.30	29.10	14.40	9.10	1.62	132
29406	Mar 20 1995	R	B	2.2	0.026<T	0.0012	0.0026	15.40	47.70	11.70	4.20	1.68	167
95012	Jun 23 1980	R	B	84.0	0.190	-	-	36.00	120.00	17.00	5.00	4.30	369
27965	Mar 22 1995	R	B	0.800<T	0.260	0.0090	0.0046	22.60	59.90	18.40	4.90	2.16	235
95013	Jun 23 1980	R	B	2.0	0.090	-	-	19.00	65.00	3.00	2.00	1.40	176
95014	Jun 23 1980	R	B	2.0	0.480	-	-	15.00	54.00	6.00	2.00	6.60	157

Well Number	Conductivity	PH	Alkalinity	TDS	F	Turb	Colour	Nitrate	Nitrite	Nitrate + Nitrite	Ammonium
26986	266	8.26	130	173	-	-	-	-	0.005<W	0.500	-
22326	375	8.18	184	244	-	-	-	-	0.005<W	3.200	-
30398	602	7.90	281	391	-	-	-	-	0.005<W	0.050<W	-
768	390	7.80	198	254	-	-	-	0.500	0.010	-	-
776	310	8.00	154	202	-	-	-	0.100	<.010	-	-
828	365	7.90	172	237	-	-	-	0.300	<.010	-	-
15723	430	8.25	209	280	-	-	-	-	0.005<T	0.500	-
26427	1216	8.17	189	898	-	-	-	-	0.005<W	2.800	-
20104	325	8.26	166	212	-	-	-	-	0.005<W	0.850	-
29978	423	8.21	210	276	-	-	-	-	0.005<W	0.050<T	-
8025	535	7.60	248	360	0.10	-	-	-	-	5.300	-
95002	485	7.60	160	400	<0.1	-	-	-	-	14.000	-
95003	622	7.40	287	450	<0.1	-	-	-	-	4.600	-
29497	398	8.45	185	260	-	-	-	-	0.005<W	0.050<W	-
27499	699	7.92	346	454	-	-	-	-	0.005<T	0.600	-
26019	1510	8.28	237	892	-	-	-	-	0.005<T	0.100<T	-
12992	425	7.90	222	391	-	2.00	-	-	-	1.030	-
95004	515	7.50	144	450	<0.1	-	-	-	-	1.800	-
95005	166	8.10	59	110	<0.1	-	-	-	-	2.800	-
95006	530	7.30	225	355	0.20	-	-	-	-	0.200	-
95007	578	7.50	276	370	0.30	-	-	-	-	0.300	-
95008	580	7.20	295	380	<0.1	-	-	-	-	4.300	-
28360	190	8.26	88	124	-	-	-	-	0.005<W	0.050<W	-
20365	374	8.24	189	244	-	-	-	-	0.005<W	1.500	-
95009	1140	7.10	362	800	<0.1	-	-	-	-	36.000	-
11855	-	-	-	-	-	-	-	-	0.025	-	<.05<W
95010	840	7.30	380	560	<0.1	-	-	-	-	1.500	-
3914	327	8.35	153	-	-	-	-	<.050<W	0.005<T	-	<.05<W
29975	533	8.08	275	346	-	-	-	-	0.005<W	0.050<W	-
20183	467	8.12	235	304	-	-	-	-	0.010<T	0.050<W	-
95011	575	7.50	292	375	<0.1	-	-	-	-	0.400	-
23973	302	8.09	164	196	-	-	-	-	0.005<W	0.050<W	-
4023	361	7.80	175	235	-	-	-	<.1	<.010	-	-
13833	378	8.31	195	246	-	-	-	-	0.005<W	0.050<W	-
4479	-	7.50	242	-	-	-	-	-	-	1.500	-
27828	303	8.27	157	197	-	-	-	-	0.005<W	0.050<W	-
29406	351	8.21	170	228	-	-	-	-	0.005<W	1.100	-
95012	720	7.40	192	590	<0.1	-	-	-	-	58.000	-
27965	419	7.97	214	278	-	-	-	-	0.005<W	0.250<T	-
95013	365	7.60	77	235	<0.1	-	-	-	-	22.000	-
95014	304	7.50	142	200	<0.1	-	-	-	-	0.700	-

Well Number	Ammonia	Ammonium + Ammonia	Phosphate	TKN	Total Phosphorous	DOC	DIC	Silicon
26986	-	0.050<W	0.020<W	0.050<W	0.020<W	0.30<T	29.2	4.58
22326	-	0.050<W	0.020<W	0.050<W	0.020<W	0.30<T	44.0	5.54
30398	-	0.100<T	0.020<W	0.300	0.020<W	1.60	68.8	7.52
768	<.1	-	-	-	-	-	-	-
776	<.1	-	-	-	-	-	-	-
828	<.1	-	-	-	-	-	-	-
15723	-	0.100<T	0.020<W	0.050<W	0.020<W	0.50	51.6	5.60
26427	-	0.050<W	0.020<W	0.150<T	0.040<T	0.30<T	43.6	5.96
20104	-	0.050<W	0.020<W	0.050<W	0.020<T	0.40<T	39.2	6.40
29978	-	0.050CW	0.020<W	0.050<W	0.020<W	0.40<T	49.8	5.78
8025	-							
95002	-	-	-	-	-	-	-	-
95003	-	-	-	-	-	-	-	-
29497	-	0.050<W	0.020<W	0.050<W	0.020<W	0.40<T	44.6	8.64
27499	-	0.050<W	0.020<W	0.250	0.020<T	0.30<T	50.6	6.14
26019	-	0.050<W	0.020<W	0.200<T	0.020<W	0.60	49.4	3.94
12992	0.020	-	-	-	-	-	-	-
95004	-	-	-	-	-	-	-	-
95005	-	-	-	-	-	-	-	-
95006	-	-	-	-	-	-	-	-
95007	-	-	-	-	-	-		-
95008	-	-	-	-	-	-	-	-
28360	-	0.050<W	0.020<W	0.050<W	0.020<W	0.30<T	20.0	4.30
20365	-	0.050<W	0.020<W	0.050<W	0.020<W	0.30<T	46.4	5.04
95009	-	-	-	-	-	-	-	-
11855	-	-	-					
95010	-	-	-	-	-	-	-	-
3914	-	-	-	-	-	-	-	-
29975	-	0.050<W	0.030<T	0.150<T	0.020<W	0.20<T	66.0	10.70
20183	-	0.050<W	0.020<W	0.100<T	0.020<W	0.80	64.0	6.08
95011	-							
23973	-	0.050<W	0.030<T	0.150<T	0.020<W	0.10<W	38.4	6.96
4023	<.1	-	-	-	-	-	-	-
13833	-	0.050<W	0.020<W	0.450	0.080<T	0.4<T	47.0	6.40
4479	-	-	-	-	-	-	-	-
27828	-	0.150<T	0.020<W	0.300	0.020<W	0.40<T	37.4	7.58
29406	-	0.050<W	0.020<W	0.100<T	0.020<W	0.10<W	41.0	5.64
95012	-	-	-	-	-	-	-	-
27965	-	0.150<T	0.020<W	0.050<W	0.020<W	0.50<T	51.6	6.14
95013	-	-	-	-	-	-	-	-
95014	-	-	-	-	-	-	-	-

Water quality data for overburden wells

Deep overburden wells (water bearing formation > 20m deep) (all values as mg/L unless otherwise noted)

Well Number	Date Sampled	Sample Type	Report Type	Cl	Fe	Mn	Al	SO4	Ca	Mg	Na	K	Hardness
443	Jul 27 1959	R	B	3.0	0.280	-	-	-	-	-	-	-	151
30617	Jul 27 1995	R	B	11.6	0.460	0.0200	0.0050	31.00	33.20	11.50	2.40	1.70	130
29981	Jul 30 1995	R	B	0.4<T	0.018<T	0.0006	0.0053	12.50	45.60	11.40	2.20	1.80	161
850	May 12 1976	R	B	2.0	<.050	-	-	15.00	49.00	16.00	2.00	1.80	186
9930	May 12 1976	R	B	5.0	0.100	-	-	13.00	50.00	9.00	2.00	1.10	160
26976	May 7 1995	R	B	23.4	0.008<T	0.00046<T	0.0020	15.00	61.30	12.20	7.80	1.36	203
25652	May 7 1995	R	B	2.6	0.069	0.0046	0.0018	17.70	56.10	15.80	3.60	2.16	205
95015	Jun 24 1980	R	B	<1.0	0.070	-	-	13.00	76.00	4.00	2.00	1.30	207
6992	May 12 1976	R	B	3.0	0.250	-	-	18.00	43.00	19.00	8.00	1.50	184
754	May 12 1976	R	B	3.0	0.050	-	-	22.00	50.00	18.00	3.00	1.90	196
95016	Jun 23 1980	R	B	1.0	0.100	-	-	25.00	61.00	12.00	3.00	2.60	203
10335	May 12 1976	R	B	3.0	0.050	-	-	12.00	73.00	14.00	2.00	1.10	236
25623	May 2 1995	R	B	5.1	0.0083<T	0.00045<T	0.0049	16.10	67.10	16.60	3.60	1.98	236
14375	Jul 27 1995	R	B	1.2	0.190	0.0190	0.0026	7.50	14.00	5.85	30.40	0.55	59
778	May 12 1976	R	B	3.0	0.400	-	-	7.00	31.00	18.00	11.00	1.20	148
30001	Jul 25 1995	R	B	4.4	0.030<T	0.0059	0.0095	0.50	5.60	3.40	41.60	0.70	28
9562	May 12 1976	T	B	3.0	1.400	-	-	2.00	12.00	3.00	39.00	0.30	44
796	May 12 1976	T	B	4.0	0.100	-	-	15.00	-	0.00	75.00	0.20	2
24249	May 3 1995	R	B	2.2	0.270	0.0062	0.0065	12.50	5.70	1.97	39.90	0.46	22
26254	Jul 10 1995	R	B	0.8<T	0.006<W	0.0060	0.0052	12.00	22.00	11.90	19.80	1.05	104
24061	Jul 25 1995	R	B	1.8	0.030<T	0.0020	0.0070	37.00	5.20	2.45	49.20	0.70	23
831	May 12 1976	T	B	29.0	0.050	-	-	22.00	18.00	8.00	48.00	0.90	76
21784	May 2 1995	R	B	4.3	0.032<T	0.0033	0.0037	0.500<	6.30	3.57	42.20	0.68	30
841	May 12 1976	R	B	14.0	0.050	-	-	27.00	40.00	18.00	24.00	2.80	170
30611	Jun 27 1995	T	B	0.9<T	0.03<T	0.0006	0.2200	10.10	0.2<W	0.05<W	0.4<T	140.00	0.5<W

Well Number	Date Sampled	Sample Type	Report Type	Cl	Fe	Mn	Al	SO4	Ca	Mg	Na	K	Hardness
27822	Jun 23 1995	R	B	0.6<T	0.500	0.0440	0.0053	10.40	32.00	11.20	10.60	1.39	126
6384	Jun 23 1980	R	B	2.0	0.020	-	-	16.00	65.00	17.00	4.00	2.00	231
25985	Jun 21 1995	R	B	1.1	0.006<W	0.0005	0.0031	15.30	36.60	13.30	2.60	1.44	146
19978	Jul 15 1995	R	B	11.6	0.006<W	0.00040<T	0.0042	12.50	61.60	16.10	3.20	2.10	220
1075	Jun 24 1980	R	B	<1.0	0.240	-	-	11.00	49.00	9.00	3.00	1.70	159
24285	Jun 22 1995	R	B	1.9	0.042<T	0.0016	0.0052	21.60	49.50	16.60	4.30	1.98	192
22365	Jun 28 1995	R	B	1.6	0.048<T	0.0018	0.0030	11.00	28.00	11.00	3.60	1.30	116
29380	Jun 21 1995	R	B	0.8<T	0.170	0.0210	0.0043	10.70	16.70	5.99	25.80	0.64	66
23920	Jun 29 1995	R	B	0.4<T	0.170	0.0110	0.0026	11.50	25.20	12.80	17.60	1.25	116
25195	Jun 22 1995	R	B	0.7<T	0.150	0.0076	0.0011	15.80	27.20	12.60	4.70	1.74	120
23325	Jun 21 1995	R	B	1.4	0.090	0.0070	0.0057	11.80	18.40	14.20	20.20	1.77	104
30445	Jul 6 1995	R	B	0.6<T	0.006<W	0.0009	0.0035	13.00	64.00	12.70	2.40	0.85	212
1892	Mar 25 1964	R	B	13.0	0.130	-	-	19.00	-	-	-	-	250
95017	Feb 1 1995	R	B	17.6	.006<W	0.0023	0.0098	16.90	49.10	15.20	4.58	2.40	185
7106	Jan 20 1981	R	B	8.0	0.010	-	-	-	-	-	-	-	174
7106	oct 28 1981	R	B	10.0	-	-	-	16.00	59.00	21.00	-	-	172
7106	Oct 2 1991	R	B	30.8	<0.006	-	-	-	-	-	-	-	207
7106	Feb 1 1995	R	B	44.2	.006<W	.00009<T	0.0110	16.70	60.80	17.80	10.70	2.50	225
95018	Feb 18 1973	R	B	3.0	<0.05	-	-	13.00	41.00	12.00	3.00	1.9	152
95018	Mar 23 1973	R	B	4.0	<0.05	-	-	15.00	41.00	12.00	3.00	2.00	135
95018	Oct 28 1981	R	B	11.0	0.050	-	-	18.00	54.00	18.00	-	-	176
95018	Feb 20 1991	R	B	23.3	0.016	-	-	23.30	51.90	14.15	6.60	-	188
95018	Oct 2 1991	R	B	22.6	0.023	-	-	-	-	-	-	-	207
95018	Dec 9 1991	T	B	22.6	0.006	-	-	21.96	51.20	15.00	7.30	2.13	190
95018	May 23 1995	R	B	29.3	.006<W	0.0091	0.0047	16.00	58.20	15.40	9.96	2.07	209
95019	Feb 10 1991	R	B	16.7	0.032	-	-	-	-	-	-	-	183
95019	May 23 1995	R	B	27.5	0.036<T	0.0300	0.0048	26.10	47.00	15.30	8.35	2.10	180
95020	Feb 20 1991	R	B	36.1	0.100	-	-	17.89	50.60	20.45	7.10	2.45	210
95020	oct 2 1991	R	B	76.1	0.006	-	-	-	-	-	-	-	272

Well Number	Date Sampled	Sample Type	Report Type	Cl	Fe	Mn	Al	SO4	Ca	Mg	Na	K	Hardness
95020	Dec 9 1991	R	B	88.0	0.0065	-	-	22.64	60.60	26.90	26.30	3.13	262
95020	May 23 1995	R	B	33.2	0.045<T	0.0014	0.0047	20.70	51.60	20.20	12.90	2.44	212
15187	Apr 12 1978	R	B	<1.0	0.060	-	-	-	-	-	-	-	186
15187	Feb 1 1995	R	B	6.2	.006<W	0.0072	0.0100	18.10	50.60	14.50	3.80	2.47	186
15187	Aug 30 1995	R	B	7.6	.006<W	0.0076	0.0029	20.00	47.20	13.70	3.80	2.30	175
16076	Apr 5 1979	R	B	1.0	<0.050	-	-	25.00	44.00	14.00	4.00	2.40	167
16076	Feb 1 1995	R	B	33.0	.006<W	0.0014	0.0100	18.10	50.80	16.50	6.99	2.60	195
16076	Aug 30 1995	R	B	30.8	.006<W	0.0013	0.0032	21.00	48.80	15.00	7.00	2.40	184
16077	Apr 5 1979	R	B	<1.0	<0.050	-	-	25.00	44.00	14.00	4.00	2.30	169
16077	Aug 30 1995	R	B	14.2	.006<W	0.0011	0.0032	19.50	44.80	14.00	4.00	2.20	170
16078	Apr 5 1979	R	B	<1.0	<0.050	-	-	19.00	42.00	14.00	4.00	2.30	163
16078	Feb 1 1995	R	B	22.5	.006<W	0.00032<T	0.0099	16.30	49.00	14.70	4.13	2.25	183
16078	Aug 30 1995	R	B	32.0	.006<W	0.0004	0.0030	18.00	49.60	14.20	5.20	2.20	183
95021	Dec 14 1981	R	B	8.0	0.130	-	-	34.00	66.00	18.00	4.50	2.50	240
95021	Apr 22 1985	R	B	2.2	0.030	-	-	28.00	67.00	20.00	8.80	1.20	250
95021	Oct 2 1991	R	B	27.8	<0.006	-	-	-	-	-	-	-	271
95021	Dec 9 1991	R	B	27.3	0.006	-	-	24.52	62.10	19.90	8.50	2.55	237
95021	May 23 1995	R	B	29.3	.006<W	0.0013	0.0053	24.10	77.00	21.50	10.70	2.61	281
95022	Feb 24 1988	R	B	12.7	0.009	-	-	19.00	44.40	15.40	4.80	2.25	174
95022	Feb 1 1995	R	B	24.0	.006<W	0.0002<T	0.0100	16.50	52.50	17.50	6.78	2.43	203
95022	Aug 30 1995	R	B	30.4	0.012<T	0.0003<T	0.0030	20.00	52.00	17.40	7.40	2.30	202
95023	Feb 24 1988	R	B	18.8	0.068	-	-	20.00	52.00	17.00	3.60	2.25	200
95023	Feb 1 1995	R	B	26.8	.006<W	0.00017<T	0.0100	22.10	60.50	20.80	5.58	2.63	237
95023	Aug 30 1995	R	B	27.8	.006<W	0.00005<W	0.0027	24.50	57.60	19.40	5.60	2.50	224
21516	Jul 13 1995	R	B	4.0	.012<T	0.0009	0.0036	15.00	75.60	9.00	3.00	0.80	226
95024	Jun 24 1980	R	B	10.0	0.070	-	-	15.00	109.00	6.00	7.00	1.60	298
19428	Jul 15 1995	R	B	7.6	.042<T	0.0110	0.0034	17.50	82.00	14.80	2.40	1.05	266
23347	Aug 20 1995	R	B	2.6	0.250	0.0130	0.0062	12.50	45.20	10.10	2.20	0.80	155
27128	Aug 16 1995	R	B	0.4<T	0.170	0.0046	0.0056	16.50	39.20	14.80	4.40	1.55	159

Well Number	Date Sampled	Sample Type	Report Type	Cl	Fe	Mn	Al	SO4	Ca	Mg	Na	K	Hardness
22215	Aug 20 1995	R	B	0.4<T	0.270	0.0300	0.0073	13.00	28.80	13.00	13.80	1.20	126
95025	Jun 24 1980	R	B	2.0	0.020	-	-	13.00	78.00	8.00	1.00	0.80	226
95026	Mar 2 1990	R	B	2.2	0.05	-	-	12.00	42.00	18.00	5.60	1.40	179
95027	Jun 24 1980	R	B	2.0	0.210	-	-	23.00	54.00	17.00	10.00	1.80	207
28238	Sep 19 1995	R	B	2.8	0.066	0.0038	0.0048	11.50	51.80	11.60	2.00	0.95	177
21615	Sep 24 1995	R	B	0.4<T	0.100	0.0300	0.0038	12.50	27.80	13.60	12.00	1.40	125
95028	Sep 17 1981	R	B	<1.0	0.030	-	-	10.00	57.00	12.00	3.50	2.00	192
95028	Sep 19 1990	R	B	4.1	.060<T	-	-	11.28	58.70	12.90	2.70	1.58	200
95028	Mar 20 1991	R	B	6.5	0.020	-	-	12.00	54.50	12.40	2.40	1.50	187
95028	Dec 13 1994	R	B	-	.006<W	.00006<T	0.0022	13.30	70.50	15.10	20.20	1.83	238
95028	Feb 20 1995	R	B	61.8	.006<W	.00005<W	0.0053	12.90	73.70	15.60	24.80	1.84	248
95028	Aug 21 1995	R	B	48.8	.006<W	.00005<W	0.0028	13.00	65.80	14.10	20.80	1.70	223
95029	Mar 20 1991	R	B	2.9	<0.020	-	-	10.00	49.20	14.20	2.70	2.70	181
95029	Dec 13 1994	R	B	-	.006<W	.00006<T	0.0026	11.90	57.70	13.20	6.20	1.83	198
95029	May 15 1995	R	B	30.0	.006<W	.00007<T	0.0025	12.70	56.50	14.00	12.10	1.91	199
95030	Sep 12 1991	R	B	1.9	-	-	-	11.65	57.90	13.10	3.10	1.74	199
95030	Dec 13 1994	R	B	-	.006<W	.00008<T	0.0026	12.40	61.40	13.00	3.11	1.77	207
95030	May 15 1995	R	B	5.2	.006<W	.00007<T	0.0024	12.10	55.00	13.60	3.20	1.77	193
26734	Feb 23 1995	T	B	1.8	0.006	0.0002	0.0250	7.93	0.20	0.05	0.20	139.00	1
20247	Feb 22 1995	R	B	5.0	0.190	0.0180	0.0023	13.70	47.10	14.80	3.30	1.90	179
3888	Jul 18 1963	R	B	8.0	0.200	-	-	26.00	-	-	-	-	190
15819	Feb 22 1995	R	B	0.8	0.026	0.0210	0.0019	14.20	51.60	13.20	4.10	2.01	183
22529	Feb 23 1995	R	B	0.70<T	0.006<W	0.0002	0.0037	5.14	51.40	10.80	1.40	1.15	173
9004	Oct 16 1991	T	B	1.1	0.150	-	-	21.24	43.50	14.20	5.10	2.32	167
9004	Jul 1993	?	B	1.6	0.177	-	-	20.60	39.60	12.70	5.82	1.95	151
95031	Sep 23 1993	R	B	2.2	.0092<T	-	-	15.62	34.62	11.60	4.05	2.06	134
27044	Feb 25 1995	R	B	2.1	0.140	0.0019	0.0025	8.26	37.80	12.50	3.60	2.09	146
12838	Feb 23 1995	R	B	2.3	0.014<T	0.0170	0.0021	9.14	107.00	16.70	3.60	1.35	335
8742	Nov 1988	R	B	2.0	<0.02	-	-	11.00	88.00	14.00	2.30	1.50	278

Well Number	Date Sampled	Sample Type	Report Type	Cl	Fe	Mn	Al	SO4	Ca	Mg	Na	K	Hardness
23971	Jan 1989	R	B	1.0	<0.02	-	-	15.00	52.00	18.00	5.00	1.20	208
95032	Jun 23 1980	R	B	2.0	0.030	-	-	14.00	38.00	3.00	4.00	1.60	110
15982	Mar 12 1995	R	B	3.6	0.014<T	0.0011	0.0043	11.60	66.30	10.60	3.60	1.00	209
25074	Feb 25 1995	R	B	0.500<	0.220	0.0051	0.0018	19.40	12.00	4.39	34.70	1.35	48
9946	Feb 25 1995	R	B	0.800<	0.130	0.0034	0.0017	7.05	57.10	14.20	4.70	1.29	201
19700	Feb 28 1995	R	B	1.1	0.036<T	0.0014	0.0029	12.70	52.00	17.20	3.40	1.67	201
3978	Jun 23 1980	R	B	<1.0	0.060	-	-	17.00	76.00	14.00	4.00	2.30	246
15758	Feb 25 1995	R	B	2.9	0.035<T	0.0092	0.0020	19.50	77.00	20.80	4.30	1.90	278
10360	Aug 24 1977	R	B	3.0	0.650	-	-	24.00	60.00	21.00	4.00	2.00	238
15922	Feb 28 1995	R	B	1.5	0.0078<T	0.0006	0.0032	11.20	42.50	11.90	2.20	1.24	155
14602	Feb 28 1995	R	B	84.9	1.000	0.0820	0.0023	18.60	77.50	20.50	21.80	2.48	278
25486	Feb 28 1995	R	B	0.500<	0.006<W	0.0097	0.0033	17.20	35.40	14.40	4.10	1.94	148
27964	Mar 23 1995	R	B	29.4	0.017<T	0.0009	0.0034	9.90	45.00	13.00	9.70	1.73	166
4476	Jul 18 1963	R	B	5.0	0.250	-	-	16.00	-	-	-	-	166
4503	Jul 18 1963	R	B	10.0	0.150	-	-	-	-	-	-	-	122
4505	Jun 30 1964	R	B	2.0	-	-	-	10.00	-	-	-	-	162
16157	Mar 17 1995	R	B	1.1	0.006<W	0.00012<T	0.0029	30.50	45.00	15.20	4.60	2.79	175
27968	Mar 17 1995	T	B	2.4	0.021<T	0.0068	0.0032	1.74<T	14.70	4.73	50.40	1.52	56
29403	Mar 22 1995	R	B	2.1	0.150	0.0079	0.0063	6.71	6.60	2.00	38.70	0.77	25
17039	Mar 23 1995	R	B	5.4	0.220	0.0090	0.0045	0.500<	14.40	12.50	32.70	1.27	87
24580	Mar 18 1995	R	B	2.3	0.670	0.0330	0.0032	11.50	32.30	16.60	11.50	1.96	149
4331	May 12 1976	R	B	4.0	0.300	-	-	8.00	41.00	30.00	18.00	2.00	224
29196	Mar 27 1995	R	B	0.400<	0.300	0.0400	0.0047	9.59	38.70	18.20	9.20	1.95	172
9709	Sep 17 1992	R	B	1.5	0.189	-	-	12.50	29.90	14.20	7.05	2.94	133
12268	Apr 1 1980	R	B	-	0.750	-	-	24.00	-	-	-	-	-
15590	Apr 1 1980	R	B	1.0	0.700	-	-	23.00	-	-	-	-	199
22544	Mar 16 1995	R	B	0.700<	0.240	0.1100	0.0048	23.20	39.80	16.70	5.70	1.98	168
10857	Mar 25 1995	R	B	1.4	0.690	0.0240	0.0046	19.10	56.80	14.30	6.10	2.37	201
25488	Mar 16 1995	R	B	0.500<	0.410	0.0059	0.0029	19.90	36.80	9.25	2.20	2.14	130

Well Number	Conductivity	PH	Alkalinity	TDS	F	Turb	Colour	Nitrate	Nitrite	Nitrate + Nitrite	Ammonium
443	-	8.00	159	-	-	-	-	-	-	-	-
30617	282	8.26	96	184	-	-	-	-	0.065	0.300	-
29981	320	8.25	163	208	-	-	-	-	0.005<W	0.750	-
850	345	7.90	167	274	-	-	-	0.900	<.010	-	-
9930	295	8.00	134	192	-	-	-	1.200	<.010	-	-
26976	409	8.25	169	266	-	-	-	-	0.005<W	2.000	-
25652	386	8.17	189	251	-	-	-	-	0.005<W	2.750	-
95015	368	7.70	185	240	<0.1	-	-	-	-	1.300	-
6992	355	7.80	175	231	-	-	-	<.100	<.010	-	-
754	360	7.90	174	234	-	-	-	0.200	0.060	-	-
95016	364	7.70	177	235	0.10	-	-	-	-	0.300	-
10335	430	7.80	209	280	-	-	-	3.600	<.010	-	-
25623	437	8.15	204	284	-	-	-	-	0.005<W	6.050	-
14375	244	8.49	124	160	-	-	-	-	0.005<W	0.050<W	-
778	295	8.20	156	192	-	-	-	0.100	<.010	-	-
30001	234	8.43	119	152	-	-	-	-	0.005<W	0.050<T	-
9562	225	8.60	121	146	-	-	-	<.100	<.010	-	-
796	305	8.30	144	198	-	-	-	<.100	<.010	-	-
24249	212	8.65	97	138	-	-	-	-	0.005<W	0.050<W	-
26254	282	8.01	141	176	-	-	-	-	0.005<T	0.100<T	-
24061	269	8.62	97	176	-	-	-	-	0.005<T	0.100<T	-
831	350	8.50	117	228	-	-	-	<.100	<.010	-	-
21784	229	8.64	121	149	-	-	-	-	0.005<W	0.050<W	-
841	400	7.80	171	260	-	-	-	<.100	<.010	-	-
30611	422	8.66	170	274	-	-	-	-	0.005<T	0.650	-

Well Number	Conductivity	PH	Alkalinity	TDS	F	Turb	Colour	Nitrate	Nitrite	Nitrate + Nitrite	Ammonium
27822	296	8.29	156	192	-	-	-	-	0.005<W	0.100<T	-
6384	420	7.60	193	275	0.10	-	-	-	-	5.700	-
25985	298	8.27	146	194	-	-	-	-	0.005<W	0.550	-
19978	431	8.28	208	280	-	-	-	-	0.005<W	1.050	-
1075	291	8.00	147	190	<0.1	-	-	-	-	0.200	-
24285	394	8.23	189	256	-	-	-	-	0.005<W	1.600	-
22365	242	8.31	103	156	-	-	-	-	0.005<W	2.850	-
29380	237	8.46	117	154	-	-	-	-	0.005<W	0.100<T	-
23920	292	8.34	149	190	-	-	-	-	0.005<T	0.050<T	-
25195	262	8.32	125	170	-	-	-	-	0.005<W	0.100<T	-
23325	291	8.35	148	189	-	-	-	-	0.005<W	0.100<T	-
30445	431	8.23	233	280	-	-	-	-	0.005<W	0.150<T	-
1892	-	8.00	194	300	-	-	-	-	-	0.600	-
95017	373	8.24	156	242	0.09	0.01<W	0.20<W	-	0.005<T	0.495	-
7106	335	-	151	-	-	-	-	-	-	-	-
7106	-	-	151	-	0.03	0.67	-	0.080	-	-	-
7106	432	-	159	-	0.04	0.15	0.5	1.100	-	-	-
7106	478	8.25	165	311	0.08	0.01	0.20<W	-	0.001<W	1.490	-
95018	-	8.00	133	150	-	-	-	0.670	-	-	-
95018	298	8.00	135	-	-	0.20	<5	0.500	-	-	-
95018	-	-	153	-	0.03	1.1	-	0.700	-	-	-
95018	411	-	155	211	0.06	-	-	0.550	<0.005	-	-
95018	427	-	172	-	0.04	0.09	0.5	0.700	-	-	-
95018	408	8.38	159	220	0.08	60.00	1.5	0.580	0.013	-	0.146
95018	446	8.1	175	290	0.10	0.04<T	1.6	-	0.008	0.630	-
95019	381	-	154	-	0.06	0.17	1.0	0.350	-	-	-
95019	398	8.13	139	259	0.11	0.15	2.8	-	0.020	0.625	-
95020	451	-	147	233	-	-	-	1.900	<0.005	-	-
95020	632	-	184	-	0.04	0.12	0.5	1.150	-	-	-

Well Number	Conductivity	PH	Alkalinity	TDS	F	Turb	Colour	Nitrate	Nitrite	Nitrate + Nitrite	Ammonium
95020	706	8.35	185	347	0.08	0.29	<0.5	1.510	0.008	-	<.002<W
95020	465	8.15	169	302	0.10	0.18	2.2	-	0.001<W	2.050	-
15187	360	-	185	-	-	-	-	0.200	<0.010	-	-
15187	357	8.28	169	232	0.09	0.01<W	0.20<W	-	0.014	0.360	-
15187	359	8.26	167	232	0.09	0.02<T	0.20<W	-	0.012	0.330	-
16076	324	-	156	210	<0.1	0.22	1.6	0.300	<0.100	-	-
16076	411	8.25	148	267	0.09	0.04<T	0.20<W	-	0.001<W	0.575	-
16076	405	8.23	148	264	0.09	0.04<T	0.20<W	-	0.001<W	0.575	-
16077	322	-	157	210	<0.1	0.23	1.6	0.300	<0.100	-	-
16077	358	8.25	151	232	0.09	0.03<T	0.20<W	-	0.020	0.880	-
16078	310	-	154	200	<0.1	0.23	1.6	0.400	0.010	-	-
16078	373	8.23	147	242	0.08	0.01<W	0.20<W	-	0.002<T	0.510	-
16078	399	8.27	146	260	0.07	0.04<T	1.6	-	0.002<T	0.600	-
95021	450	-	207	295	<0.1	0.15	<1	0.900	<0.010	-	-
95021	495	-	239	-	0.08	0.32	0.5	0.250	<0.005	-	-
95021	541	-	225	-	0.04	0.12	0.5	1.250	-	-	-
95021	537	8.40	199	272	0.06	0.60	0.5	1.440	.003<T	-	.002<T
95021	562	8.17	238	365	0.09	0.08	1.0	-	.003<T	1.410	-
95022	360	-	151	195	0.09	0.08	<0.5	1.000	<0.005	-	-
95022	412	8.29	166	268	0.10	0.01<T	0.20<W	-	0.001<W	0.970	-
95022	434	8.25	167	282	0.09	0.16	0.2<W	-	0.001<W	0.940	-
95023	406	-	165	219	0.08	0.13	0.5	1.000	<0.005	-	-
95023	452	8.30	177	294	0.08	0.01<T	0.20<W	-	0.001<W	1.520	-
95023	449	8.24	175	292	0.08	0.01<T	0.20<W	-	0.001<W	1.500	-
21516	400	8.24	198	260	-	-	-	-	0.005<T	1.700	-
95024	545	7.60	255	370	<0.1	-	-	-	-	5.400	-
19428	481	8.15	244	312	-	-	-	-	.005<W	1.850	-
23347	307	8.15	147	200	-	-	-	-	.005<W	1.500	-
27128	325	8.58	165	212	-	-	-	-	.005<W	0.200<T	-

Well Number	Conductivity	PH	Alkalinity	TDS	F	Turb	Colour	Nitrate	Nitrite	Nitrate + Nitrite	Ammonium
22215	306	8.59	159	200	-	-	-	-	0.025	0.050<W	-
95025	396	7.80	201	255	<0.1	-	-	-	-	1.400	-
95026	351	7.90	170	198	-	0.60	<3.0	-	-	<0.050	-
95027	405	7.80	181	265	0.10	-	-	-	-	<0.100	-
28238	351	8.28	174	228	-	-	-	-	0.015<T	1.400	-
21615	297	8.34	150	192	-	-	-	-	.005<W	0.050<W	-
95028	375	7.80	186	237	<0.1	0.14	1.6	1.500	<0.100	-	-
95028	373	8.30	178	-	-	-	-	1.450	.005<T	-	<.050<W
95028	372	7.90	170	-	-	<0.3	<3.0	-	-	1.800	-
95028	528	8.32	178	343	0.06	0.17	1.6	-	0.001<W	1.540	-
95028	565	8.36	192	367	0.05<T	0.04<T	0.20<W	-	0.002<T	1.390	-
95028	518	8.28	189	336	0.06	0.04<T	0.20<W	-	0.003<T	1.310	-
95029	366	7.90	170	-	<0.1	<0.3	<3.0	1.290	0.010	1.300	-
95029	399	8.42	180	259	0.09	0.01<W	2.0	-	0.001<W	1.520	-
95029	436	8.29	174	283	0.07	0.03<T	0.20<W	-	0.002<T	1.470	-
95030	386	8.15	197	251	-	0.24<T	0.5<W	1.310	0.001<T	-	-
95030	392	8.40	191	255	0.06	0.01<W	2.2	-	0.001<W	2.050	-
95030	358	8.34	185	233	0.06	0.03<T	0.20<W	-	0.002<T	1.980	-
26734	432	8.32	182	281	-	-	-	-	0.050<W	0.050<W	-
20247	339	8.08	170	220	-	-	-	-	0.010<T	0.250<T	-
3888	-	7.90	178	-	-	-	-	-	-	2.000	-
15819	344	8.10	182	224	-	-	-	-	0.010<T	0.100<T	-
22529	318	8.04	174	207	-	-	-	-	0.005<W	0.800	-
9004	330	8.19	158	184	0.10	1.16	2.5	<.005<W	<.001<W	-	<.002<W
9004	311	8.25	152	271	0.20	0.10	7.0	<.100	<.100	-	-
95031	277	8.35	130	-	0.08	0.10	<.2<W	0.315	.002<T	-	.006<T
27044	285	8.07	145	185	-	-	-	-	0.005<W	0.750	-
12838	565	8.00	330	367	-	-	-	-	0.005<W	1.450	-
8742	570	7.90	276	470	0.50	<0.1	<3	3.960	<0.250	-	-

Well Number	Conductivity	PH	Alkalinity	TDS	F	Turb	Colour	Nitrate	Nitrite	Nitrate + Nitrite	Ammonium
23971	445	7.90	215	368	<0.10	<0.3	<3	<0.300	<0.250	-	-
95032	227	8.20	78	150	0.10	-	-	-	-	5.400	-
15982	430	8.20	203	280	-	-	-	-	0.005<W	4.900	-
25074	255	8.18	114	166	-	-	-	-	0.015<T	0.050<W	-
9946	371	8.07	209	241	-	-	-	-	0.005<W	0.150<T	-
19700	386	8.31	198	251	-	-	-	-	0.005<W	1.500	-
3978	436	7.70	227	285	0.10	-	-	-	-	1.000	-
15758	501	7.96	280	326	-	-	-	-	0.005<W	0.050<W	-
10360	445	8.00	224	290	-	-	-	<.100	<.010	-	-
15922	310	8.37	156	202	-	-	-	-	0.005<W	0.750	-
14602	656	8.21	200	426	-	-	-	-	0.005<W	0.050<W	-
25486	315	8.34	155	205	-	-	-	-	0.005<W	0.050<W	-
27964	359	7.71	134	233	-	-	-	-	0.005<W	0.100<T	-
4476	-	7.90	174	-	-	-	-	-	-	-	-
4503	-	8.20	120	-	2.00	-	-	-	-	0.100	-
4505	-	8.10	156	-	0.10	-	-	-	-	0.150	-
16157	369	8.22	171	240	-	-	-	-	0.005<W	0.050<W	-
27968	313	8.24	170	203	-	-	-	-	0.005<W	0.050<W	-
29403	211	8.63	103	137	-	-	-	-	0.005<W	0.100<T	-
17039	290	8.33	156	189	-	-	-	-	0.005<W	0.050<W	-
24580	343	8.24	176	226	-	-	-	-	0.005<W	0.050<W	-
4331	455	7.90	249	268	-	-	-	<.100	<.010	-	-
29196	347	8.13	187	226	-	-	-	-	0.005<W	0.100<T	-
9709	306	8.03	152	261	0.30	0.90	2.0	<.100	<0.100	-	-
12268	375	7.90	-	245	0.10	3.30	-	<.100	-	-	-
15590	373	7.80	197	240	0.10	3.80	-	<.100	-	-	-
22544	359	8.21	176	233	-	-	-	-	0.005<W	0.050<W	-
10857	380	7.98	192	247	-	-	-	-	0.005<W	0.100<T	-
25488	277	8.20	129	180	-	-	-	-	0.005<W	0.050<W	-

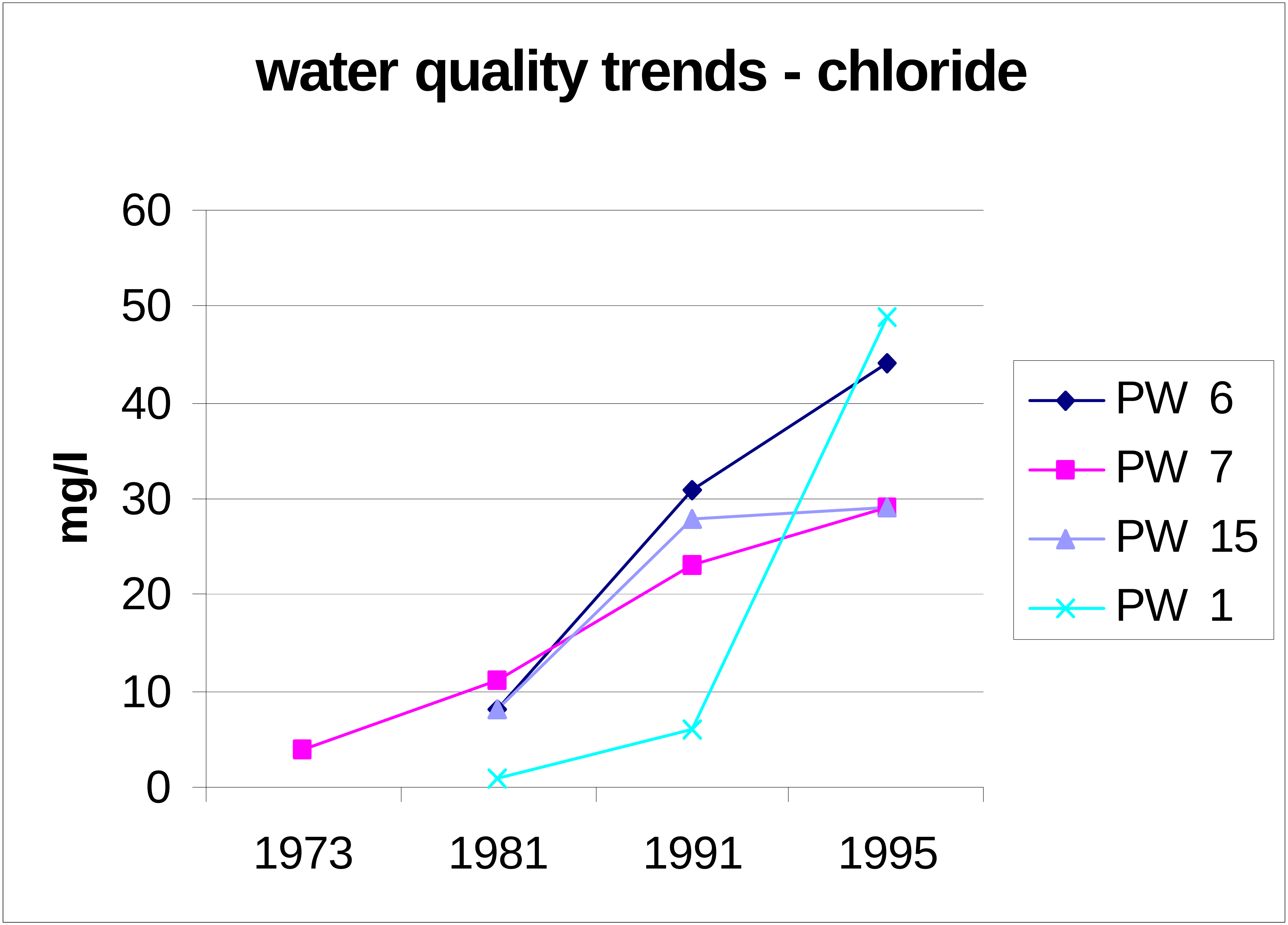
Well Number	Ammonia	Ammonium + Ammonia	Phosphate	TKN	Total Phosphorous	DOC	DIC	Silicon
443	-							
30617	-	0.100<T	0.020<W	0.050<W	0.020<W	0.30<T	23.0	3.46
29981	-	0.100<T	0.020<W	0.050<W	0.020<W	0.40<T	39.4	5.34
850	<.100							
9930	<.100							
26976	-	0.050<W	0.020<W	0.100<T	0.020<W	0.30<T	39.0	5.08
25652	-	0.050<W	0.020<W	0.050<W	0.020<W	0.40<T	44.4	5.56
95015	-							
6992	<.100							
754	<.100							
95016	-							
10335	<.100							
25623	-	0.050<W	0.020<W	0.150<T	0.020<W	0.20<T	48.2	6.08
14375	-	0.150<T	0.020<W	0.100<T	0.020<W	0.50	29.4	4.58
778	0.100							
30001	-	0.150<T	0.020<W	0.150<T	0.020<W	1.20	28.0	5.74
9562	<.100							
796	<.100							
24249	-	0.100<T	0.020<W	0.250	0.020<W	0.60	21.0	4.92
26254	-	0.100<T	0.020<W	0.250	0.020<T	0.20<T	34.0	6.24
24061	-	0.100<T	0.020<W	0.050<T	0.020<W	0.90	22.2	3.98
831	<.100							
21784	-	0.150<T	0.020<W	0.200<T	0.020<W	1.10	26.8	5.68
841	<.100							
30611	-	0.050<W	0.020<W	0.050<W	0.020<T	0.60	39.2	2.22

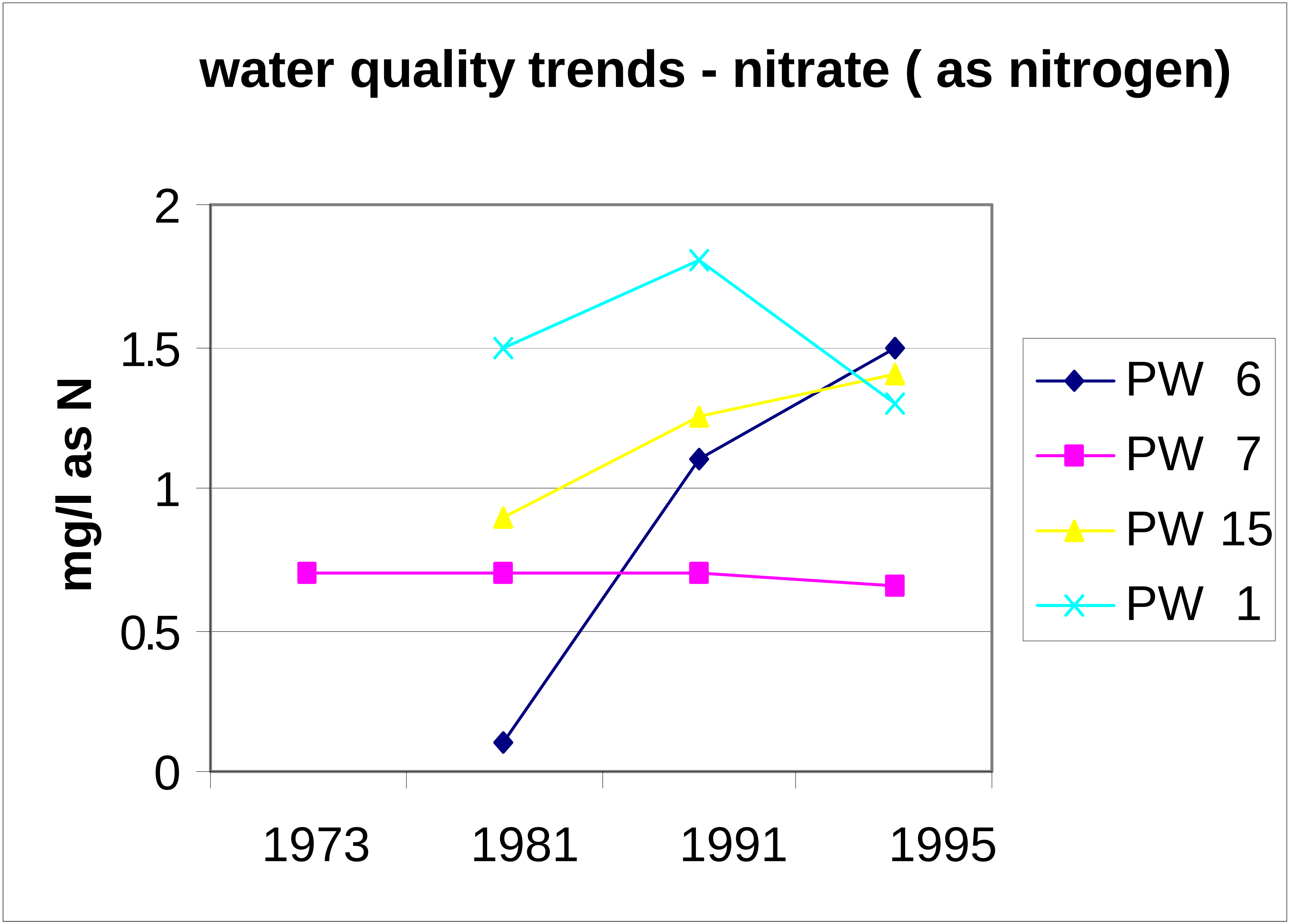
Well Number	Ammonia	Ammonium + Ammonia	Phosphate	TKN	Total Phosphorous	DOC	DIC	Silicon
27822	-	0.050<W	0.020<W	0.300	0.040<T	0.60	35.6	7.02
6384	-							
25985	-	0.050<W	0.020<W	0.150<T	0.040<T	0.20<T	33.2	4.82
19978	-	0.050<W	0.020<W	0.200<T	0.020<W	0.90	51.0	7.44
1075	-							
24285	-	0.050<W	0.020<W	0.150<T	0.060<T	0.40<T	44.0	5.42
22365	-	0.050<W	0.020<W	0.050<W	0.020<W	0.20<T	23.4	5.72
29380	-	0.100<T	0.020<W	0.250<T	0.080<T	0.50<T	25.6	6.44
23920	-	0.100<T	0.020<W	0.050<W	0.020<W	0.30<T	34.8	6.04
25195	-	0.050<W	0.020<W	0.150<T	0.040<T	0.30<T	28.0	5.30
23325	-	0.050<W	0.020<W	0.150<T	0.040<T	0.20<T	33.8	5.54
30445	-	0.050<W	0.020<W	0.200<T	0.020<T	0.40<T	57.6	5.02
1892	-							
95017	-	0.002<W	0.002<T					
7106	-							
7106	-							
7106	-							
7106	-	0.002<W	0.001<W					
95018	-							
95018	-							
95018	-							
95018	<0.050							
95018	-							
95018	-	-	0.003					
95018	-	0.050	0.001<W					
95019	-							
95019	-	0.276	0.001<W					
95020	<0.050							
95020	-							

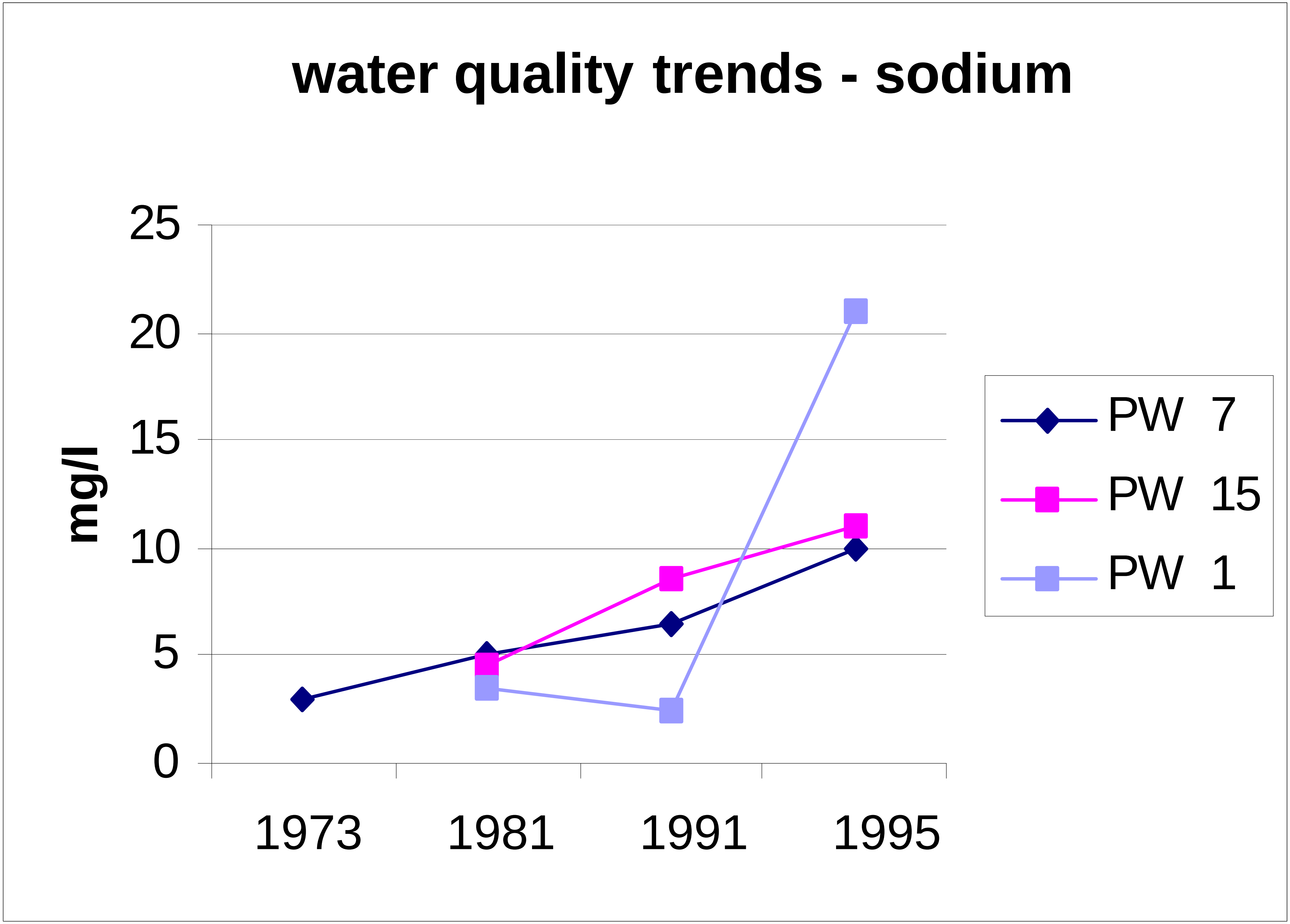
Well Number	Ammonia	Ammonium + Ammonia	Phosphate	TKN	Total Phosphorous	DOC	DIC	Silicon
95020	-	-	.002<T					
95020	-	0.002<W	0.001<W					
15187	<0.100							
15187	-	0.002<W	0.003<T					
15187	-	0.002<W	0.002<T					
16076	<0.100							
16076	-	0.002<W	0.001<T					
16076	-	0.002<W	0.001<W					
16077	<0.100							
16077	-	0.002<W	0.001<W					
16078	<0.100							
16078	-	0.002<W	0.002<T					
16078	-	0.002<W	0.001<W					
95021	<0.100							
95021	<0.050							
95021	-							
95021	0.002	-	.002<T					
95021	-	0.002<W	0.001<W					
95022	<0.050	-						
95022	-	0.002<W	0.002<T					
95022	-	0.002<W	0.002<T					
95023	<0.050							
95023	-	0.002<W	0.003<T	-	-			
95023	-	0.002<W	0.001<T	-	-			
21516	-	0.050<T	0.020<W	-	-			
95024	-							
19428	-	0.050<W	0.020<W	-	-			
23347	-	0.050<W	0.020<W	0.100<T	0.020<W	0.50	34.8	4.50
27128	-	0.050<W	0.020<W	0.050<W	0.020<W	0.30<T	37.8	5.04

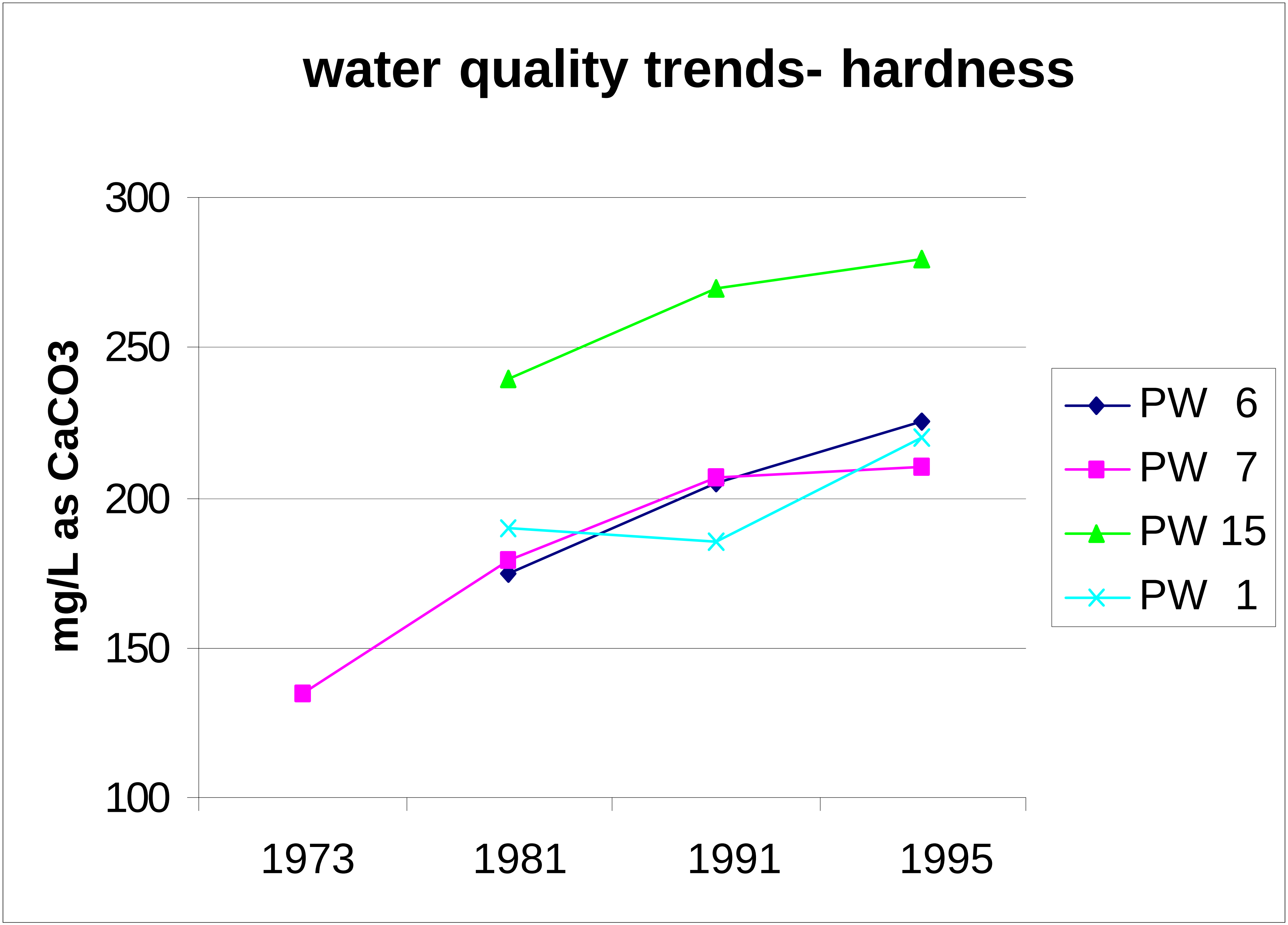
Well Number	Ammonia	Ammonium + Ammonia	Phosphate	TKN	Total Phosphorous	DOC	DIC	Silicon
22215	-	0.050<W	0.020<W	0.050<W	0.020<W	0.50	36.2	7.14
95025	-							
95026	<0.050	-	<0.010					
95027	-							
28238	-	0.050<W	0.020<W	0.050<W	0.020<W	0.30<T	41.4	4.60
21615	-	0.050<W	0.020<W	0.050<W	0.020<W	0.20<T	35.2	5.70
95028	<0.100	-	<0.010					
95028	-	-	-					
95028	<0.050	-	<0.010					
95028	-	0.002<W	0.002<T					
95028	-	0.004<T	0.002<T					
95028	-	0.002<W	0.003					
95029	<0.050	-	<0.010					
95029	-	0.002<W	0.003<T					
95029	-	0.002<W	0.001<W					
95030	0.002<W	-	0.205					
95030	-	0.002<W	0.005					
95030	-	0.002<W	0.001<W					
26734	-	0.050<W	0.020<W	0.100<T	0.020<W	0.30<T	42.8	5.18
20247	-	0.050<W	0.020<W	0.150<T	0.020<W	0.30<T	40.2	4.96
3888	-							
15819	-	0.050<W	0.020<W	0.100<T	0.020<W	0.10<W	43.0	4.84
22529	-	0.050<W	0.020<W	0.050<T	0.020<W	0.10<T	41.2	4.74
9004	-	-	0.004					
9004	<.050	-	0.008					
95031	-	-	.003<T					
27044	-	0.050<W	0.020<W	0.100<T	0.020<W	0.20<T	33.4	5.82
12838	-	0.050<W	0.020<W	0.250<T	0.020<W	1.50	79.4	4.60
8742	<0.050	-	<0.100					

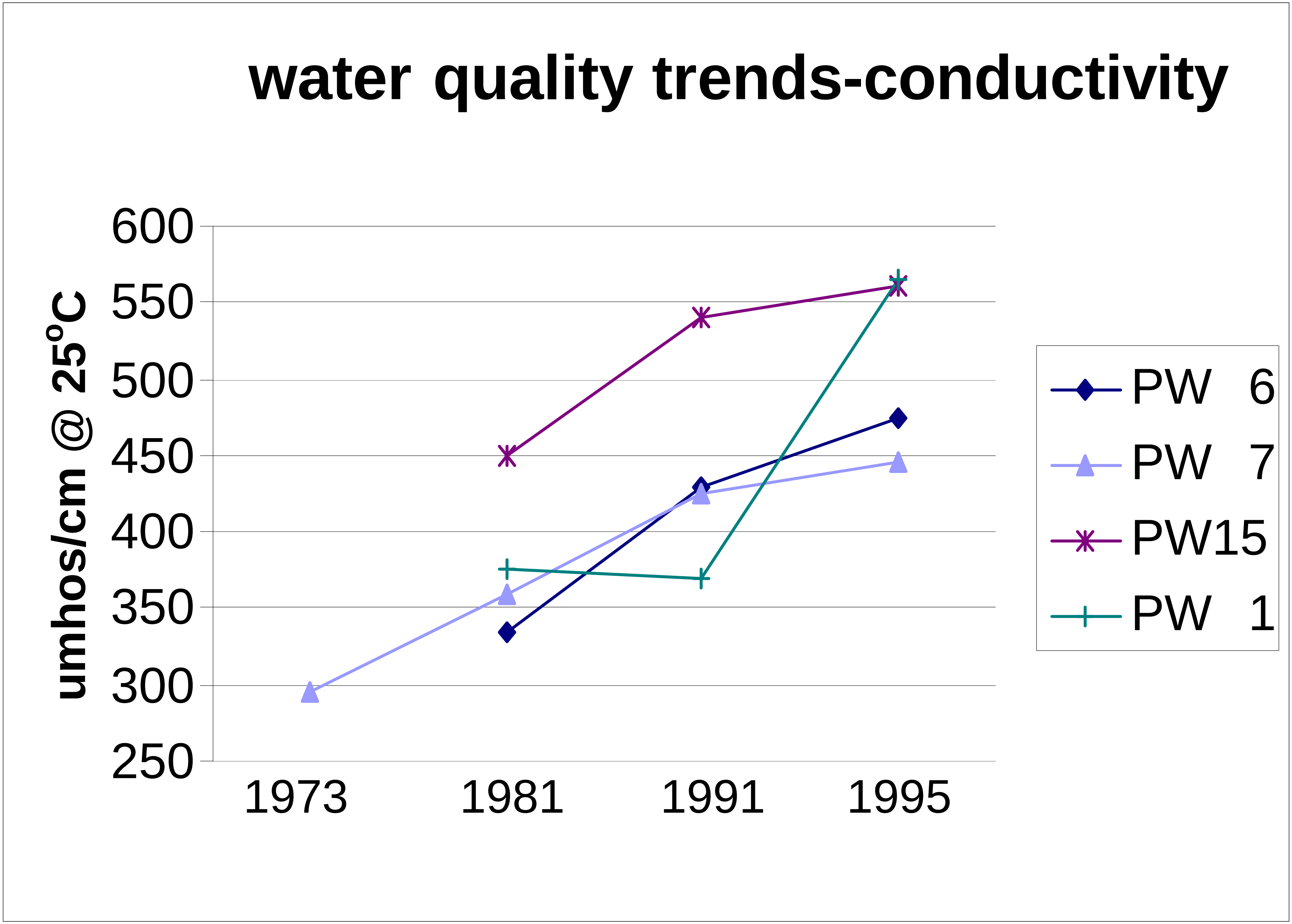
Well Number	Ammonia	Ammonium + Ammonia	Phosphate	TKN	Total Phosphorous	DOC	DIC	Silicon
23971	<0.050	-	<0.010	-	-			
95032	-							
15982	-	0.050<W	0.020<W	0.200<T	0.020<W	0.80	49.4	4.32
25074	-	0.050<W	0.030<T	0.150<T	0.020<W	0.10<W	25.8	4.20
9946	-	0.050<W	0.020<W	0.100<T	0.020<W	0.30<T	49.8	6.66
19700	-	0.050<W	0.020<W	0.100<T	0.020<W	0.20<T	48.2	6.58
3978	-	-						
15758	-	0.050<W	0.020<W	0.100<T	0.020<W	0.60	68.8	6.76
10360	<.100	-						
15922	-	0.050<W	0.020<W	0.100<T	0.020<W	0.20<T	36.0	5.24
14602	-	0.050<W	0.020<W	0.500	0.060<T	0.80	50.8	7.62
25486	-	0.050<W	0.020<W	0.200<T	0.040<T	0.10<W	35.4	5.66
27964	-	0.050<W	0.020<W	0.050<W	0.020<W	0.10<W	33.6	5.44
4476	-	-						
4503	-	-						
4505	-	-						
16157	-	0.050<W	0.020<W	0.150<T	0.020<W	0.40<T	41.2	7.14
27968	-	0.500	0.130	0.700	0.160	1.80	40.6	6.60
29403	-	0.350	0.020<W	0.150<T	0.020<W	1.40	23.2	4.62
17039	-	0.200<T	0.020<W	0.100<T	0.020<W	0.80	36.8	7.36
24580	-	0.050<W	0.020<W	0.150<T	0.020<W	0.50<T	42.2	7.88
4331	<.100	-	-	-	-	-		
29196	-	0.050<W	0.020<W	0.050<W	0.020<W	0.10<W	45.4	7.88
9709	0.100	-	<0.005	-	-	-	-	-
12268	-	-	-	-	-	-	-	-
15590	-	-	-	-	-	-	-	-
22544	-	0.050<W	0.020<W	0.100<T	0.020<W	0.20<T	42.0	7.16
10857	-	1.250	0.020<W	0.050<W	0.020<W	0.30<T	46.8	8.10
25488	-	0.050<W	0.020<W	0.050<W	0.020<W	0.40<T	30.4	3.76


water quality trends - chloride
60
50
40
30
20
10
0
mg/l
1973
1981
1991
1995
PW 6
PW 7
PW 15
PW 1


water quality trends - nitrate (as nitrogen)
mg/l as N
2
1.5
1
0.5
0
1973
1981
1991
1995
PW 6
PW 7
PW 15
PW 1


water quality trends - sodium
mg/l
25
20
15
10
5
0
1973
1981
1991
1995
PW 7
PW 15
PW 1


water quality trends- hardness
mg/L as CaCO3
300
250
200
150
100
1973
1981
1991
1995
PW 6
PW 7
PW 15
PW 1


water quality trends-conductivity
umhos/cm @ 25°C
600
550
500
450
400
350
300
250
1973
1981
1991
1995
PW 6
PW 7
PW15
PW 1