


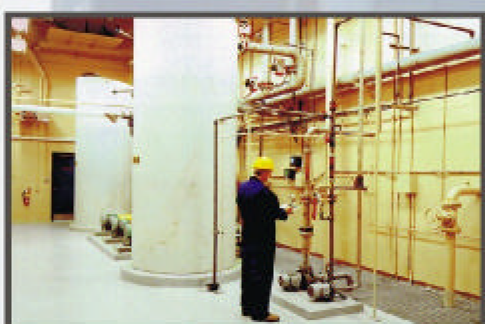

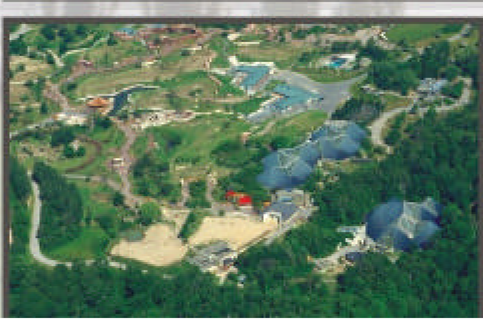

PARTNERS IN PROGRESS 50 YEARS

Final Report

Analysis of Agricultural Water Supply Issues

National Water Supply Expansion Program
Province of Ontario

Agriculture and Agri-Food Canada
Prairie Farm Rehabilitation Administration

Submitted by:

Marshall Macklin Monaghan
PROJECT MANAGERS • ENGINEERS • SURVEYORS • PLANNERS

WESA
A Better Environment For Business

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March 2003

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Attention: **Ms. Sharon Reedyk**
Project Manager

Dear Ms. Reedyk,

Subject: **Final Report - Analysis of Agricultural Water Supply Issues**
NWSEP – Ontario

We are pleased to submit our Final Report for the *Analysis of Agricultural Water Supply Issues – NWSEP – Ontario*. This report describes the results of our literature review, interviews with stakeholders, and stakeholder workshop, and it identifies issues and constraints for Ontario agriculture due to water supply availability. It summarizes work completed by ourselves, Professors Rob de Loë and Reid Kreutzwiser, and Ms. Tifanny Svensson of WESA. This version incorporates the comments made by yourself and your colleagues on the February 24, 2003 draft version of the final report.

We trust that our submission meets your requirements. Should you have any further questions, please do not hesitate to contact the undersigned. We appreciate the opportunity to have been of service on this project and thank you for all your assistance in ensuring its successful completion.

Yours very truly,
MARSHALL MACKLIN MONAGHAN LIMITED

Robert Bishop

Rob Bishop, M.Sc., P.Eng.
Vice President
Water Resources

Table of Contents

1.0 INTRODUCTION 1

2.0 SUMMARY OF FINDINGS 5
- 2.1. Literature Review 5
- 2.2. Mapping Regional Agricultural Water Demand 17
- 2.3. Stakeholder Interviews 22
- 2.4. Stakeholder Workshop 26

3.0 SYNTHESIS OF FINDINGS 29
- 3.1. Regions of Heaviest Agricultural Water Use 29
- 3.2. Areas with Inadequate or Failing Infrastructure 30
- 3.3. Agricultural Regions with Water Supply Constraints 31
- 3.4. Water Supply Constraints/Water Supply Issues Identified 33

4.0 CONCLUSIONS AND RECOMMENDATIONS 34

5.0 REFERENCES CITED 35

APPENDIX A: LIST OF INTERVIEW CONTACTS AND QUESTIONS ASKED

APPENDIX B: WORKSHOP MATERIAL

APPENDIX C: DETAILED DISCUSSION OF ONTARIO HYDROGEOLOGY

List of Figures

No.		Page
1.1	Ontario Municipalities - Southwest Central Ontario	3
1.2	Ontario Municipalities - Southeast Ontario	4
2.1	Mean Annual Precipitation in Ontario	7
2.2	Mean Annual Runoff in Ontario	9
2.3	Groundwater Yields from Bedrock in Ontario	10
2.4	Groundwater Yields from Overburden in Ontario	11
2.5	Estimated Total 2001 Agricultural Water Use in All Sectors	18
2.6	Estimated 2001 Seasonal Irrigation	19
2.7	Seasonal Accumulated Precipitation as a Percentage of Average (July 1, 2002 to September 30, 2002)	20
2.8	Percentage of Lowest Average Monthly Flow, Southern Ontario (September 1-14, 2002)	21
3.1	Locations Identified with Agricultural Water Supply Constraints	32

1.0 INTRODUCTION

Farming is Ontario's second largest economic sector, producing gross annual sales of $6.8 billion and employing well over 600,000 people to grow, harvest, process and market the produce. Ontario farmers produce a great diversity of products for consumers. Of the total farm cash receipts for 2001,

- 16.1% was for dairy products
- 14.4% was for cattle and calves
- 11.3% was for hogs
- 7.3% was for poultry
- 2.6% was for eggs
- 2.9% was for tobacco
- 4.4% was for corn
- 10.5% was for fruit & vegetables
- 10.1% was for floric & nursery
- 5.3% was for soybeans
- 15.1% was for other products.

Geographically, farming activity takes place predominantly in southern Ontario with pockets of productivity in the north around Sudbury, Thunder Bay, New Liskard, etc. Certain areas are known for specific products, e.g. tobacco in parts of southwest Ontario, tender fruits in the Niagara Peninsula. In general, however, the full range of products are found across southern Ontario.

The drought situation experienced in many parts of Canada over the past two to three years has heightened awareness of the importance of reliable water supplies for domestic, industrial and agricultural purposes. Nowhere is this more critical than in the agricultural sector, where water shortages directly limit yields and result in economic hardships. In Ontario alone, crop insurance payments following the 1988 dry spell were $55 million, while livestock producers received $12 million. These figures are dwarfed by the $244 million in drought-related insurance payouts made to producers in Ontario for 2001.

The National Water Supply Expansion Program (NWSEP) is a four year $60 million initiative by Agriculture and Agri-Food Canada (AAFC). It aims to improve the capacity of agricultural producers to deal with drought and other agriculturally-related water constraints through the development and expansion of water supply systems on a cost-shared basis. An initial $10 million was made available in 2002/03 and was targeted mainly to help relieve the water supply situation on the drought-affected Prairies. The remaining $50 million of the NWSEP will be available nationally over the next three years to fund additional infrastructure and strategic water supply studies to address long-term solutions to agricultural water supply problems.

In order to determine the most appropriate uses for the funds, AAFC, through the Prairie Farm Rehabilitation Administration (PFRA), initiated a series of scoping studies across Canada. These were intended to identify the scope of agricultural water needs; to determine the nature and extent of water supply constraints on agriculture; and to identify priorities for agricultural water supply expansion across Canada.

The intent of the *Analysis of Agricultural Water Supply Issues–NWSEP–Ontario* study was to complete the required scoping and to determine future programming options for the Province of Ontario's share of the remaining $50 million of the NWSEP. The results will form the basis for negotiations/consultations with the Ontario government and agricultural stakeholders.

Findings presented in this report are based on a study methodology that involved analysis of pertinent literature on agricultural and rural water demand and supply in Ontario, including recent estimates of 2001 agricultural water use by sector; structured interviews with experts and stakeholders; and a stakeholder workshop. Details regarding each element of the methodology are provided in the appropriate section, below. A key aim in the consultation phase of the study was identification of water supply constraints, and specific areas where constraints are most severe for Ontario agriculture. Through synthesizing findings from these data sources, this report identifies agricultural regions of heaviest water use (current and anticipated future); agricultural regions with inadequate or failing infrastructure; and agricultural regions with water supply constraints. Additionally, water supply constraints and issues identified during the study are highlighted in the report.

Throughout this report, reference is made to numerous counties, towns and regional municipalities in Ontario. Figures 1.1 and 1.2 show the structure of primary agricultural area, i.e. southern Ontario, to the county level.

Figure 1.1: Ontario Municipalities – Southwest Central Ontario

(Source: Ontario Municipal Directory, 2002)

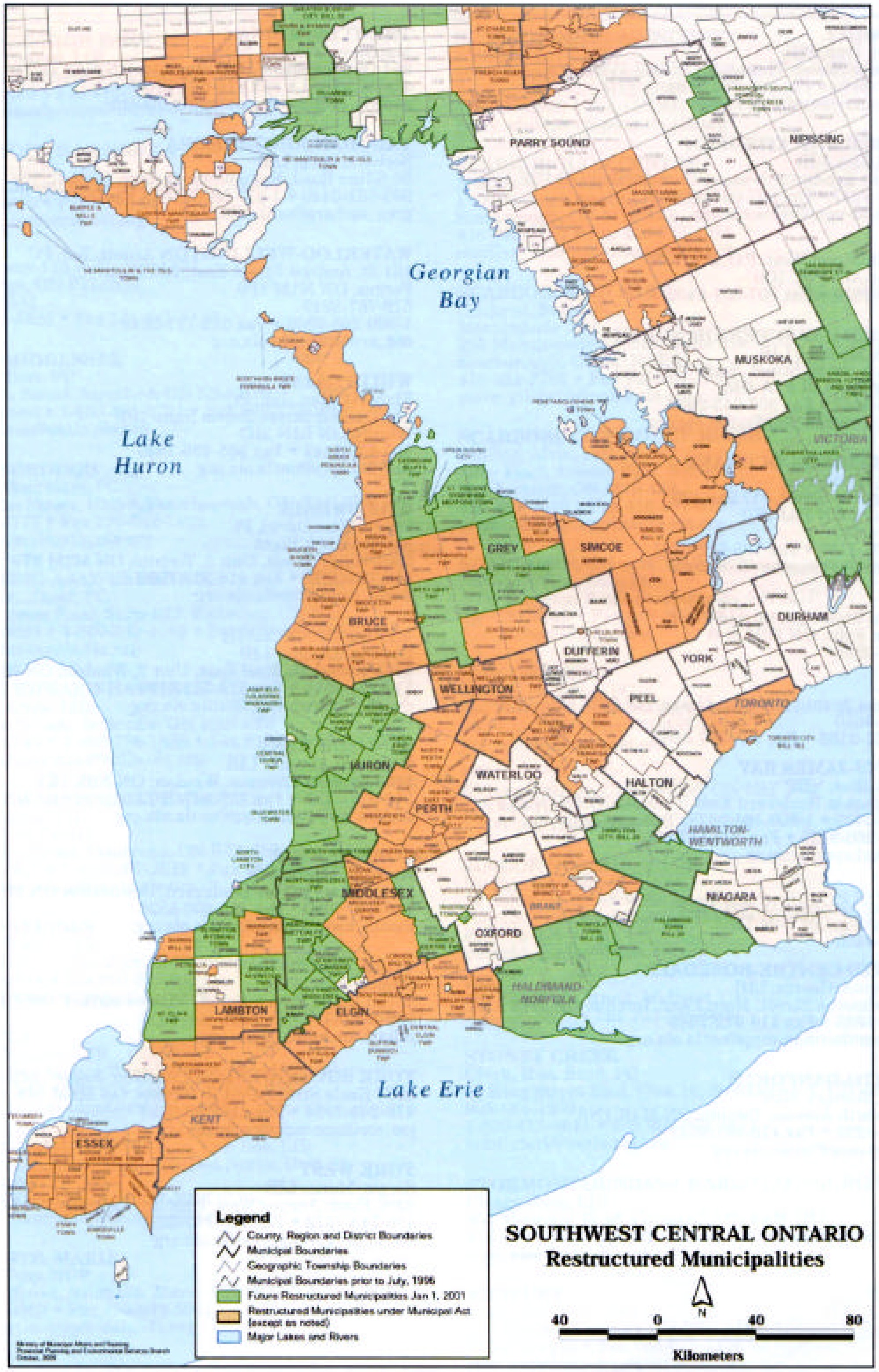
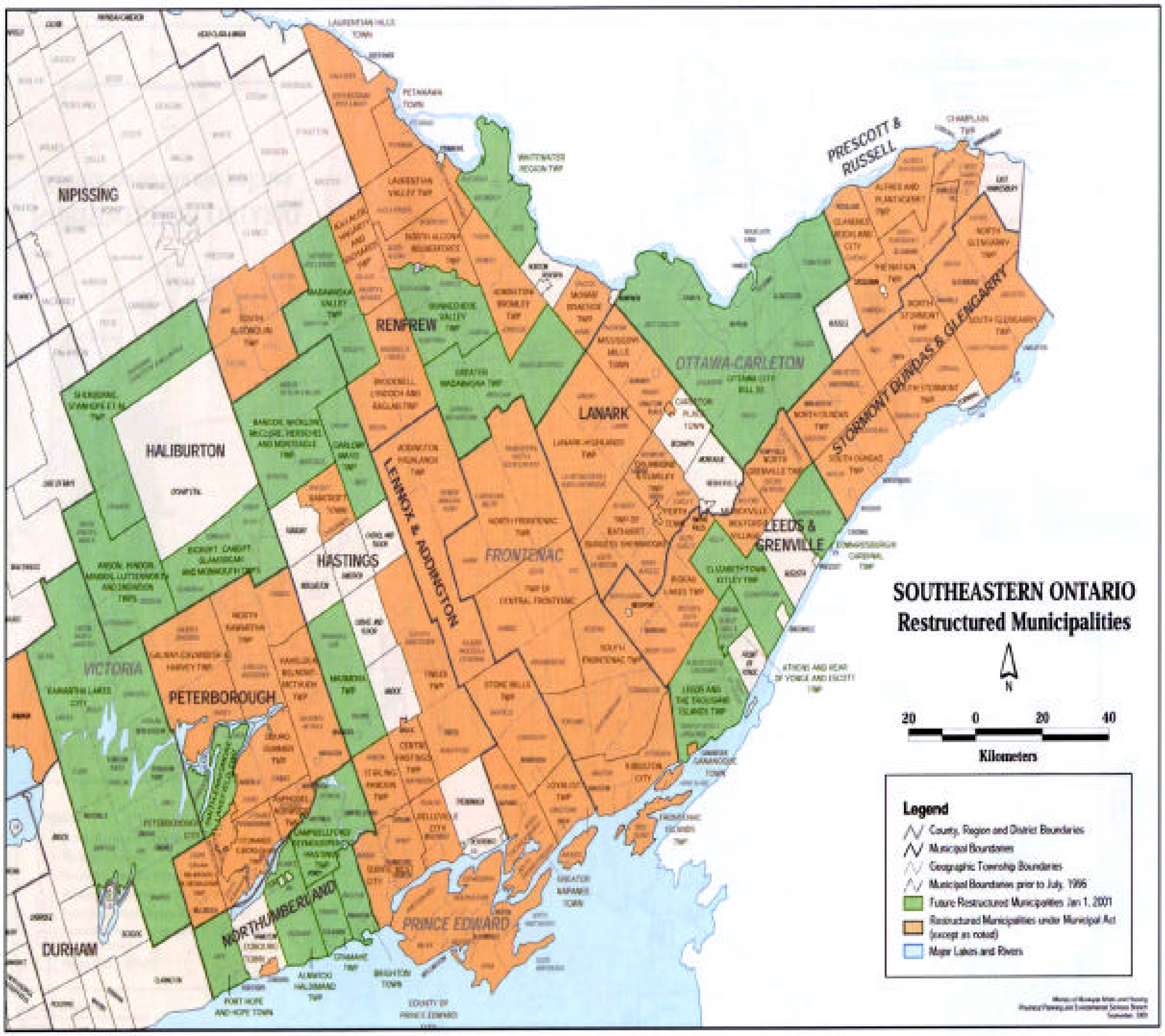


Figure 1.2: Ontario Municipalities – Southeast Ontario

(Source: Ontario Municipal Directory, 2002)



2.0 SUMMARY OF FINDINGS

Findings presented in this section were derived through synthesis of data collected through four phases.

1. A review of available literature (journal articles, reports) was completed to identify broad patterns and trends, and highlight key variables (Section 2.1). This review guided subsequent data collection.

2. Maps of estimated agricultural water demand for 2001 were used to identify regions of Ontario (at the Consolidated Census Subdivision scale) which have high levels of agricultural water use (Section 2.2). Use of large quantities of water is not necessarily a constraint on agriculture. Volumes of water used must be compared to available supplies, and to demands from other sectors. Therefore, in this phase maps of water availability, and knowledge of other sources of demand, were compared to estimated agricultural water demand to highlight potential problem areas.

3. Agricultural stakeholders and experts were interviewed using a structured interview schedule. The aims in this part of the research, which was guided by the first two phases, were to confirm earlier findings, and to identify additional knowledge. Findings are presented in Section 2.3.

4. Finally, a workshop with agricultural stakeholders and experts was convened to review interim findings, and to fill in gaps in knowledge. Findings are presented in Section 2.4.

This section presents findings from each of the four phases. Section 3.0 synthesises the findings, and offers conclusions and recommendations regarding agricultural water constraints in Ontario, and possible programming directions for the NWSEP.

2.1. Literature Review

The literature review phase of the research addressed two main areas. First, literature on Ontario's water resources was reviewed and synthesised. Major data sources included the following: for surface water, the Ontario Ministry of Natural Resources' (1984) *Water Quantity Resources of Ontario*; and for groundwater, a recent review prepared by the National Water Research Institute (MacRitchie, *et al.* 1994). Other useful studies included a recent overview report on water use by watershed in Ontario (Harris and Tate 2002), and a synthesis of water use in Ontario in the report of the Walkerton Inquiry (O'Connor 2002).

Second, literature on agricultural water use in Ontario was reviewed. Key studies include general overviews of rural water use in Ontario and Canada (e.g., Coote and Gregorich 2000) and reports prepared for the National Soil and Water Conservation Program project *Water Quantity Requirements and Challenges for Ontario Agriculture*. Ontario's Low Water Response is an important initiative designed to address water supply limitations.

This is discussed in detail in Section 2, page 9 of this report. An evaluation of this program is another source of recent data on water supply constraints and issues for agriculture (Durley, *et al.* 2003). The aim in the literature review was to identify known and anticipated problems, constraints, and future trends.

Overview of Ontario's Water Resources

Ontario can be descriptively divided into four large physiographic regions that are distinguished based on geologic history and characteristics. These regions are the Great Lakes Lowlands, the Ottawa-St. Lawrence Lowlands, the Canadian Shield and the Hudson Bay Lowlands. The following sections will describe climate and recharge and hydrogeology based on these larger regions.

Climate and Groundwater Recharge

Ontario's climate is mainly influenced by maritime polar and modified continental air masses from the north and maritime tropical air from the south. The Appalachian mountain system generally shields Ontario from any major impact from Atlantic air masses and storms (Phillips, 1990). The Great Lakes provide one of the major climactic controls in the Province (Phillips and McCulloch, 1972).

Southern Ontario (Great Lakes Lowlands and Ottawa St. Lawrence Lowlands) has a humid continental climate with warm summers, mild winters and a long growing season of 180 to 220 days. The range in temperatures in this region is from -45^{o}C to $+41^{o}$C. (Brown et al., 1968). As shown on Figure 2.1, annual average precipitation across the region varies between 660 and 1000 mm per year and is uniformly distributed throughout the year. Higher levels of precipitation are typically found just east of Lake Huron and Georgian Bay as well as the on the Dundalk Uplands of the Niagara Escarpment south of Georgian Bay. The driest area in southern Ontario is southwest of Pembroke in the rain shadow of the Algonquin Park Uplands.

In northern Ontario (Canadian Shield and Hudson Bay Lowlands) the temperatures vary greatly. The mean summer temperature ranges from 12^{o}C in the extreme north to 18^{o}C in the southern part of northern Ontario. The mean winter temperature ranges from -15^{o}C in the south to -28^{o}C in the north (Webber and Hoffman, undated). Mean annual precipitation varies from 1000 mm per year along the slopes facing Lake Superior to a low of 460 mm per year in the extreme north and northwest (see Figure 2.1).

Most recharge occurs during the spring and is associated with snow melt. A second significant recharge period is in the late fall and early winter when evapotranspiration is reduced (MacRitchie et al., 1994). Actual recharge to the groundwater flow system is highly variable and depends on the permeability and thickness of the surficial materials. The Oak Ridges Moraine has a reported recharge rate of 280-380 mm per year whereas the till plain just south of the Moraine has a reduced recharge rate of 150-200 mm per annum (Singer, 1981).

Figure 2.1: Mean Annual Precipitation in Ontario
(from "Water Quantity Resources of Ontario, MNR 1984)

Surface Runoff and Streamflow

Figure 2.2 shows isolines of runoff for the Province of Ontario. The runoff amounts shown on the map are expressed as a depth of water averaged over the drainage basin area. The mean annual runoff depth (mm) is derived from the mean annual flow in cubic metres per second (m^3/s) at the outlet from the basin and the area of the drainage basin (km^2). The isolines were compiled using Ontario streamflow data and the corresponding drainage basin areas.

The total volume of the mean annual runoff is 301 km^3, or about 60 per cent of the volume of water in Lake Erie. If this water was released uniformly throughout the year at one outlet from the Province, the flow would be 9,530 m^3/s. Approximately 68 per cent of the total runoff occurs in the Hudson Bay/James Bay and Nelson River basins. Only 6 per cent of the mean annual runoff occurs in the Lake Erie/Lake Ontario basins where industries and population are concentrated.

Ontario's mean annual runoff is 309 mm or 43 per cent of the mean annual precipitation. The runoff varies from a low of 200 mm in the western part of the Province to a high of 500 mm east of Lakes Superior and Huron. The runoff for the Lake Erie/Lake Ontario basins is below the Ontario average, whereas the precipitation for the same basins is above the Ontario average. This directly reflects the higher amount of evapotranspiration for the Lake Erie/Lake Ontario basins. By comparison, about 20 per cent of Canada has a mean annual runoff in the range of 200 to 500 mm. Comparative annual runoff figures for specific areas in Canada are: British Columbia coast - 1,000 to 3,200 mm, Alberta and Saskatchewan prairies - less than 50 mm; Maritime provinces - 700 to 1,400 mm.

Groundwater and Hydrogeology

Figures 2.3 and 2.4 provide an overview of potential groundwater supply in Ontario in terms of yields obtained from wells drilled in the bedrock and wells drilled in the overburden. The following briefly describes the conditions in the regions of Ontario previously. Since much of the water supply for agriculture is obtained from groundwater, a detailed discussion of this source by region is provided in Appendix C.

As noted previously, the hydrogeology of Ontario is best discussed in the context of four major regions: Great Lakes Lowlands, Ottawa-St. Lawrence Lowlands, Canadian Shield and Hudson Bay Lowlands. The first two regions are the major features of southern Ontario and most relevant to agricultural water supply.

The Great Lakes Lowlands is divided into three sub-regions for discussion purposes: the Southwestern Area, the West Central Area, and the South Central Area.

Figure 2.2: Mean Annual Runoff in Ontario
(from "Water Quantity Resources of Ontario, MNR 1984)

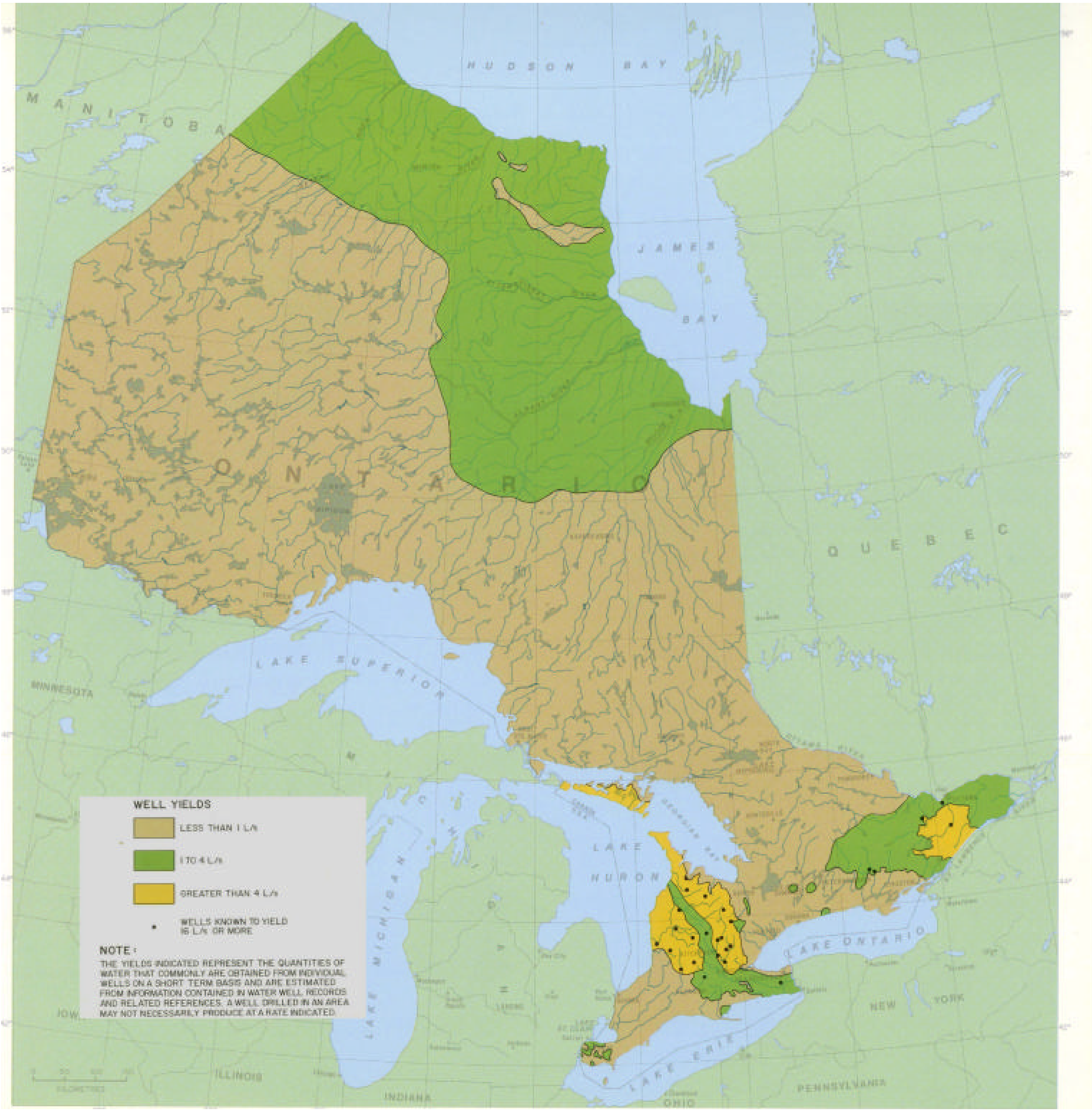


Figure 2.3: Groundwater Yields from Bedrock in Ontario (from "Water Quantity Resources of Ontario", MNR 1984)

Figure 2.4: Groundwater Yields from Overburden in Ontario (from "Water Quantity Resources of Ontario, MNR 1984)

The Southwestern Area has two major bedrock aquifers – the Dundee Formation and the Detroit River Group (Lucas and Amherstburg Formations). The Detroit River Group has the highest permeability of the two but both are widely exploited for domestic, municipal and industrial uses. Yields typically range from less than 0.8 L/s in the Dundee Formation to between 0.8 L/s to 3.8 L/s with occasional yields being as high as 151 L/s (Wang, 1986c). The upper portions of the Detroit River Group is used as a plentiful irrigation supply south of Lake St. Clair. The supply however, can be sulphurous in places.

The Southwestern Area's stratigraphy of the overburden is extremely complex. However, in general two sand and gravel units exist in this area. The majority of wells are completed in a confined basal sand and gravel unit that lies directly on the bedrock or in the upper one m of the bedrock. Although this unit is prolific across the region it varies greatly in thickness and therefore the yield varies greatly from 0.8 to 3.8 L/s. The water quality drawn from this unit is often poor in quality. In the vicinity of the City of London there are excellent yielding aquifers with yields as high as 15 to 50 L/s. A thick weathered clay unit overlies most of the Counties of Lambton, Essex and Kent. Typically residents use large diameter wells in this weathered zone to provide their domestic water supply (MacRitchie et al., 1994). The Cardoc, Norfolk and Bothwell sand plains are the three dominant surficial granular deposits in this subregion. These unconfined aquifers can provide sufficient water for domestic use in these areas, the water, however, is usually very hard.

The Western Central Area contains one of Ontario's most extensive bedrock aquifers and one of Canada's most productive overburden aquifers. This region extends approximately from Stratford in the west to Toronto in the east and from Lake Erie in the south to the northern tip of the Bruce Peninsula.

Three dominant bedrock aquifers exist in this subregion: the Guelph-Amabel aquifer, Guelph-Lockport aquifer and the Salina formation. The largest bedrock aquifer in Ontario is the Guelph-Amabel aquifer. Yields from the aquifer range from 0.8 to 3.8 L/s with some wells capable of yielding 63 L/s in the Guelph area. The Guelph-Lockport aquifer is the bedrock aquifer of the Niagara Peninsula. Although generally of marginal quality, the water is being used for domestic and agricultural purposes. Most of the aquifer only yields 0.4 to 0.8 L/s and in some isolated areas the yield is as high as 15 L/s. The Salina Formation dips to the south and underlies the Onondaga Escarpment north of Lake Erie. The well yields in the southern part of the Salina Formation are generally less than 3.8 L/s with the exception of the municipal well at Caledonia, where the yield is greater than 16 L/s, and north of Kitchener-Waterloo there is a high-yielding aquifer capable of yields greater than 16 L/s (Sibul et al., 1980). The water drawn from the Salina Formation is highly mineralized with excessive sulphate concentrations. This has negative impacts upon its use for agriculture since it reduces yields from dairy herds and causes maintenance problems in equipment.

The overburden is very complex in this subregion. The water supply of the Regional Municipality of Waterloo is provided by one of Canada's best groundwater producing units, the Waterloo Moraine. Wells in this area are capable of yielding up to 76 L/s and altogether the Regional well fields produce approximately 1875 L/s. East of Cambridge and in the vicinity of Elmira wells provide groundwater at an estimated yield of 16 L/s (Sibul et al., 1980). The Haldimand clay plain occupies almost the entire Niagara Peninsula and is not a usable water supply. Just north of Waterloo lies an area of important surficial deposits. Yields from wells completed in these sand and gravel unconfined aquifers range between 0.16 to 3.8 L/s.

The South Central Area is bounded to the west by the Niagara Escarpment, to the northeast and east by the Canadian Shield, to the northwest by Georgian Bay and to the south by Lake Ontario. The major hydrogeologic unit in the area is the Oak Ridges Moraine which is a 200 km long ridge of glacial sediments located north of Toronto.

In general the bedrock shales and limestones of the subregion are poor aquifers that yield a small amount of poor quality water. Where the overburden is thin many need to rely on the underlying bedrock formation for their water supply. For example water wells have been completed in the shales of Georgian Bay and Whitby Formations. The yields in these formations range from 0.08 to 0.20 L/s. The limestones of the Simcoe Group are an important source of water in the Great Lakes Lowlands east of Trenton, on the Napanee plain. The yields average about 0.15 L/s. Adjacent to major water bodies (Lake Simcoe, Georgian Bay) more substantial yields can be achieved (ranging from 0.8 to 5 L/s).

The main overburden feature in this subregion is the Oak Ridges Moraine (ORM) which can be generally described as having two distinguishable aquifer systems. The shallow aquifer system is found at a depth of approximately 76 m. Yields in the shallow aquifer system range from 0.5 to 5 L/s and are used for domestic and livestock purposes. Along the southern parts of the moraine, municipal and industrial wells exist which are capable of yields as high as 53 L/s. The deep aquifers are municipal water supplies for Newmarket, Aurora and Oak Ridges and are capable of sustaining yields of 0.9 L/s.

The aquifers south of the moraine are not heavily exploited and the rivers and streams in the Duffin's Creek-Rouge River drainage basin receive significant groundwater discharge. In the area between Toronto and the Niagara Escarpment a number of buried granular aquifers have been identified with water at a yield as high as 7.6 L/s. North of the moraine lies the greatest accumulation of Quaternary sediment in Ontario. The yields in this area range from 0.38 to 53 L/s depending on the courseness of the granular material and the thickness of the unit. Most of the water in this area is hard and mineralized but is however suitable for domestic and irrigation purposes. The Halton till, found near or at surface from Niagara to Port Hope, can supply adequate water for domestic purposes however the yields are controlled by the storage capacity of the wells (Ostry, 1979b; Funk, 1977b). A variety of local surficial granular deposits are used for domestic water supplies north of the ORM and just east of the Niagara Escarpment.

Ottawa- St. Lawrence Lowlands extend from the Ottawa and St. Lawrence valleys in to Quebec and are bounded to the west by the Frontenac Arch and to the north by the Canadian Shield. In the Ottawa Valley, average yields of 0.8 L/s in the bedrock in the western end of the area are satisfactory for domestic purposes. Much higher yields of 15 to 50 L/s suitable for small communities are found in areas where well developed fracture networks exist in the faulted bedrock. In the Ottawa St. Lawrence area, the main regional aquifer is capable of yielding 0.4 to 1.1 L/s (Brow, 1967; MacRitchie et al., 1994). The Oxford Formation supplies water to the Smith Falls-Brockville area. The average yield of this formation is 0.4 to 1.1 L/s. The Billings and Carlsbad Formations southeast of Ottawa are limited in extent and provide a small amount of very poor water (Brown, 1967).

Extensive buried overburden aquifers are uncommon in this area. Local small municipal and domestic wells however use limited confined aquifers found in the northern part of the South Nation River basin. The Russell Prescott sand plain is considered an extensive unconfined aquifer for domestic use in the area.

The Canadian Shield is bounded to the south by the Great Lakes Lowlands and to the north by the Hudson Bay Lowlands. Availability of groundwater is controlled on a regional scale by discontinuities including faults, lineaments, dykes and intensely weathered zones. Local flow systems are controlled by the interconnectiveness of the fracture sytems. Bedrock aquifer yields and hydraulic conductivities are therefore highly variable.

Surficial deposits cover approximately 90% of the Canadian Shield. These granular deposits are extensively relied upon as a water supply even though there is an abundance of surface water. Overburden aquifers are extensively used in the cities of Sudbury, Sault Ste. Marie, Iroquois Falls, Blind River, Hornepayne, Callandar, Raymore, Moonbeam and Fauquier (MacRitchie et al., 1994). Yields of wells in the surficial aquifers in these areas are typically 2 L/s. Productive overburden aquifers are also present along the north shore of Lake Superior in the Marathon area.

The Hudson Bay Lowlands is located in the northeast part of Ontario and is a sparsely populated area containing only a few villages. The Hudson Bay Lowlands are a low, poorly drained plain covered with muskeg. The area is of limited relevance in regard to agricultural water supply.

Overview of Agricultural Water Use in Ontario

Agriculture is a major water user in Ontario. This is not immediately apparent when examining withdrawals for all sectors. For example, estimates provided by Vandierendonck (1996) and Ecologistics (1993) indicate that agricultural withdrawals comprise only 0.59 percent of total withdrawals in Ontario, with the vast majority (81.26%) being for thermal power generation. However, agriculture's rate of consumption is high relative to other sectors. Vandierendonck (1996) used the commonly cited figure of 79 percent (which is the mid-range estimate used in a recent evaluation by Harris and Tate [2002]). Based on that figure, agriculture consumes approximately 20 percent of water withdrawn for consumptive use in Ontario, compared to 38 percent for municipalities and 28 percent for industry. The discussions which follow relate to water consumption.

While provincial-scale water use figures such as these provide a useful overview, they can be extremely misleading, especially in the case of agriculture. Agricultural water use is strongly seasonal, varies considerably by sector, and shows strong spatial variability. To address these concerns, de Loë, *et al.* (2001) generated estimates for agricultural water use in Ontario using 1996 Statistics Canada Census of Agriculture data. The methodology used was refined from the one originally developed by Myslik (1991), updated by Ecologistics (1993), and updated again by Kreutzwiser and de Loë (1999) for a project funded by the National Soil and Water Conservation Program (NSWCP). Water use coefficients were applied to Statistics Canada Census of Agriculture data (e.g., number of animals, area of crops) to generate water use estimates by township, county, agricultural region, and Province. The data have seen wide use, including in a recent provincial overview of water use prepared by Harris and Tate (2002), and in maps published by the Ontario Ministry of Natural Resources (MNR). This information is used in Section 2.2 of this report to help identify agricultural regions of heaviest water use.

This mapping isolates irrigation water use, a key component of agricultural water demand. According to de Loë, *et al.* (2001), summer irrigation was estimated at 54 percent of total agricultural water use in 1996. With its significant demand potential and specific time requirements, irrigation water use should be a major concern in any program of agricultural water supply enhancement.

Ontario Low Water Response

Even with its apparent water wealth, Ontario has a long history of drought. Gabriel and Kreutzwiser (1993) documented seven widespread dry spells affecting agriculture during the 1960-1989 period, and noted that localized droughts occur almost every year somewhere in the Province. Agriculture is a sector that is extremely sensitive to drought and variability in water supplies. Crop insurance payments following the 1988 dry spell were $55 million, while livestock producers received $12 million (Gabriel and Kreutzwiser 1993). These figures are dwarfed by the $244 million in drought-related insurance payouts made to producers in Ontario for 2001 (Simkus 2002).

Drought contingency planning and improvements to water allocation systems are an important way of addressing some kinds of agricultural water supply constraints. Ontario's new Low Water Response (OLWR) framework (MNR, 2002) has been identified by numerous analysts as an extremely important tool for addressing shortcomings in the provincial water allocation system (Durley, *et al.* 2003). OLWR encourages the formation of local Water Response Teams (WRTs), which include representatives of water users in a watershed, along with officials from local and provincial governments departments, and conservation authorities. During the summers of 2001 and 2002, WRTs formed in several places in Ontario, and were able to mitigate problems relating to insufficient water supplies. The WRT in the Big Creek area (Long Point Region Conservation Area in the area around Norfolk County) has been identified as particularly effective (Figure 1.1).

Previous and Current Initiatives Relating to Agricultural Water Use in Ontario

Since 1993, the Ontario Farm Environmental Coalition (OFEC) together with the Ontario Soil Improvement Association (OSCIA) and several Provincial and Federal agencies and with financial support from Agriculture and Agri-Food Canada (AAFC) have been delivering the Environmental Farm Plan (EFP) to farmers across Ontario. Soon after the EFP was initiated, the Water Quality Working Group (WQWG) was established to specifically address water issues facing Ontario agriculture. This consists of a diverse group of representatives from various Provincial and Federal agencies including AAFC, Environment Canada, the Ministries of Agriculture and Food, Environment, Natural Resources, the Universities of Guelph and Waterloo, the Conservation Authorities and on a project level municipalities and volunteer agencies. Since its inception the WQWG identified three major water issues facing Ontario agriculture. These include:

- Wellhead protection of farm wells;
- Nutrient loss to groundwater and surface water; and
- Water taking.

The Water Taking Working Group has been working since 1995 to galvanize the debate on a legislative framework for water management in Ontario to protect its interest in the available water resource. OFEC's member agencies such as OFA have been working closely with the Inter-Ministerial Water Management Committee.

Reliable access to fresh water continues to be a priority for agriculture in Ontario. A discussion paper was submitted to the Low Level Response Committee in the summer of 2000 (Ontario Federation of Agriculture, 2000). The paper outlines how critical water is to various sectors of agriculture and how important agriculture is to the Canadian economic and social fabric. Furthermore, the paper responds to issues such as sharing water among other users including municipalities, water bottlers, golf courses, industrial users and aggregate operations, as well as promotion of water use efficiency, water pricing, and the proposed Provincial approach to handling water shortages.

At this time, a limited number of programs provide funding which can be used for addressing agricultural water supply issues. The primary program is the "Healthy Futures for Ontario Agriculture" program through the Ontario Ministry of Agriculture and Food. This is a four-year, $90 million program whose goals include "to improve rural water quality and make efficient use of rural water resources." Various water related programs such as well improvement and decommissioning and rural water quality monitoring programs run by the OFA, have received funding. The Norfolk Water Supply Enhancement Project is another example of a project which received funding from the "Healthy Futures" program. Although not specifically addressed to the agricultural sector, ongoing programs funded by the Ontario Ministry of Environment are improving the knowledge base with respect to water availability and water use in rural and urban areas. These provincially funded groundwater studies have a total budget of $10 million. A parallel program to improve the groundwater monitoring in the province is investing approximately $6 million to install about 400 monitoring wells in 38 watersheds. It is noted, however, that all of the programs mentioned are presently reaching the end of their projected life at the end of the 2002 fiscal year.

Ongoing Ontario MNR-MOE Studies

At this time, five studies are being carried out under the auspices of the MNR and the Ministry of Environment (MOE) relating to water budgets, water allocation and minimum instream flows in Ontario. It is anticipated that these will contain information relevant to the present study. However, it was not possible to review them prior to preparation of this report since they had not been made public.

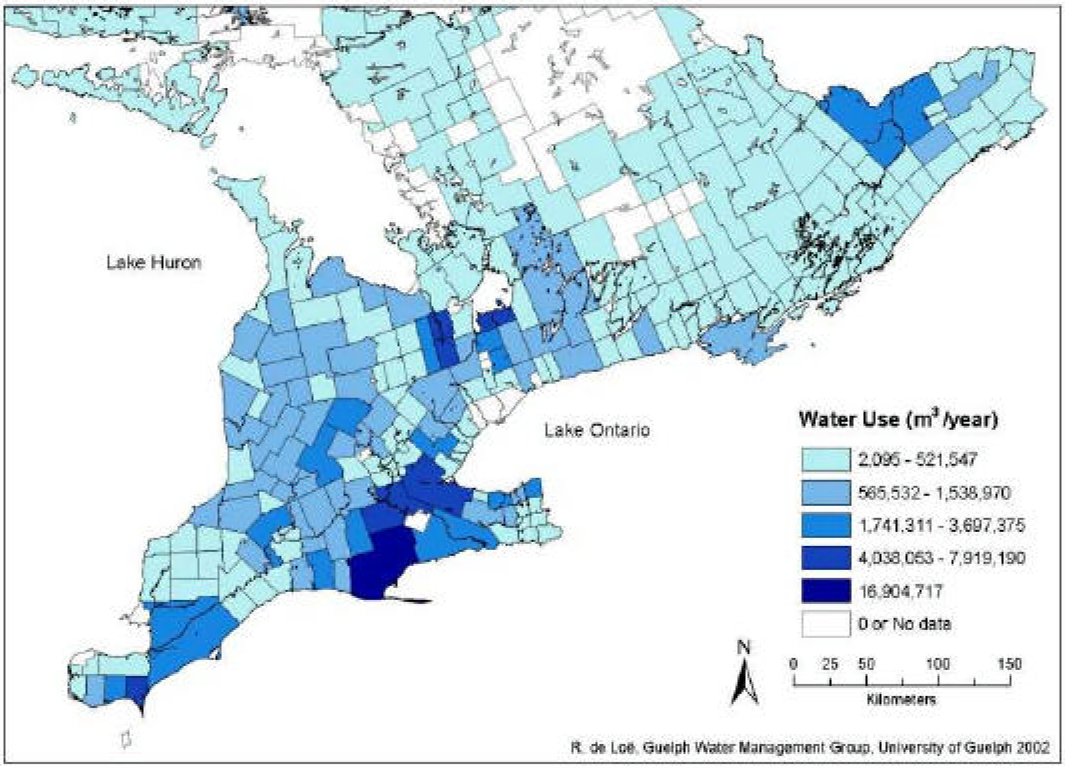
2.2. Mapping Regional Agricultural Water Demand

Maps of agricultural water use for 2001 were used to identify areas of heaviest demand and to target an evaluation of constraints and issues. As noted in Section 2.1, maps of agricultural water demand had previously been generated for the 1996 Census of Agriculture by de Loë, *et al.* (2001). Using the same methodology, agricultural water use estimates for 2001 were created by R. de Loë. Estimates were generated for Census Subdivision and Consolidated Census Subdivisions. This permits an up-to-date evaluation of demand patterns, and highlights areas of high demand by sector, spatial location, and type of water use (especially irrigation). These findings can be compared to data on surface water conditions published by the MNR as part of its water level reporting project.

As illustrated in Figure 2.5, most agricultural production occurs in southern Ontario. Agriculture does occur in northern Ontario. For example, the area around Sudbury has a significant amount of agricultural production in the vegetable sector. Nevertheless, agricultural water demand in Ontario is concentrated in southern Ontario. Indeed, Figure 2.5 can be misleading in that it appears to show agricultural water use occurring evenly across northern Ontario, when in fact it is concentrated adjacent to a few larger centres, such as Sudbury. This is a function of the size of the consolidated census subdivisions (CCS) in northern Ontario. For example, the very large, most northern CCS, “Kenora, Unorganized”, accounts for only an estimated 80,130 m^3 of agricultural water use. In contrast, the “Greater Sudbury” CCS accounts for an estimated 695,144 m^3 of agricultural water use.

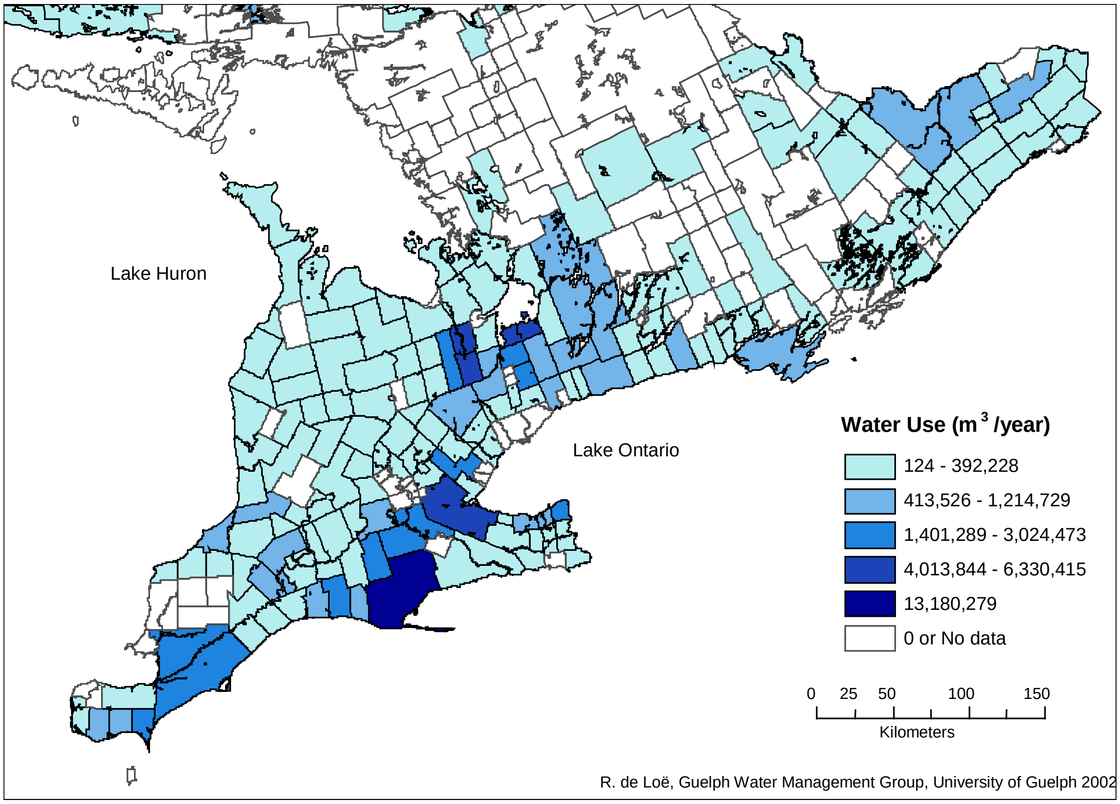
Irrigation is almost exclusively a feature of agriculture in southern Ontario. The CCS with the single largest volume of estimated irrigation water use is Norfolk (Figure 2.6), where tobacco is a major irrigated crop. In this CCS, an estimated 13 million m^3 of irrigation water was applied during the spring, summer and fall of 2001. Other areas of high irrigation water use include Hamilton, New Tecumseth and Georgina -- areas where sod, vegetable and nursery stock are major crops. Leamington is a CCS where considerable year-round irrigation of greenhouse crops occurs.

Figure 2.5: Estimated Total 2001 Agricultural Water Use in All Sectors (Livestock, Fruit, Field Crops, Vegetables and Speciality Crops) in Southern Ontario



Importantly, estimates for irrigation assume "normal" weather conditions. In a dry year, vastly more irrigation water will be applied. For instance, current estimates of tobacco irrigation, reflected in Figure 2.6, assume 2.5 applications of water, 30 mm/ha, per summer. A recent survey of irrigators in Norfolk County during the very dry summer of 2002 found that on average farmers irrigated 10.5 days in June, 17 days in July, 13 days in August, and 10.5 days in September. Anecdotal evidence from the summer of 1988, reported by Kreutzwiser (1996), supports this concern for other sectors such as fruit and vegetables. The irrigation technology used, the size of the farm, and the amount of labour available to the farmer determine how long it takes to apply one application of water. Nevertheless, irrigation water use is likely to be underestimated in Figure 2.6 during dry years.

Figure 2.6: Estimated 2001 Seasonal Irrigation (All Irrigated Crops Excluding Mushrooms and Greenhouse Products)



Comparing agricultural water demand on maps of precipitation and streamflow for 2002 (Figures 2.7 and 2.8) highlights areas where stresses can be anticipated. For example, during the summer of 2002, the areas where the largest moisture deficits occurred frequently coincided with the areas of highest agricultural water demand. This was borne out in discussions with interviewees, who highlighted places such as Norfolk County (Figure 1.1), the New Tecumseth area and Georgina Township as being severely water stressed. Specific watersheds noted were Big Creek, Big Otter Creek, Whitemans Creek and Innisfil Creek. These all fall within areas highlighted as regions of high agricultural water use. In areas of high agricultural water use adjacent to expanding urban areas (e.g., in the Greater Toronto area), further stress is placed by competition from other sources. This is often related to the expansion of golf course operations with their associated irrigation requirements and the expansion of sod farms to service the development industry.

Figure 2.7: Seasonal Accumulated Precipitation as a Percentage of Average (July 1, 2002 to September 30, 2002)

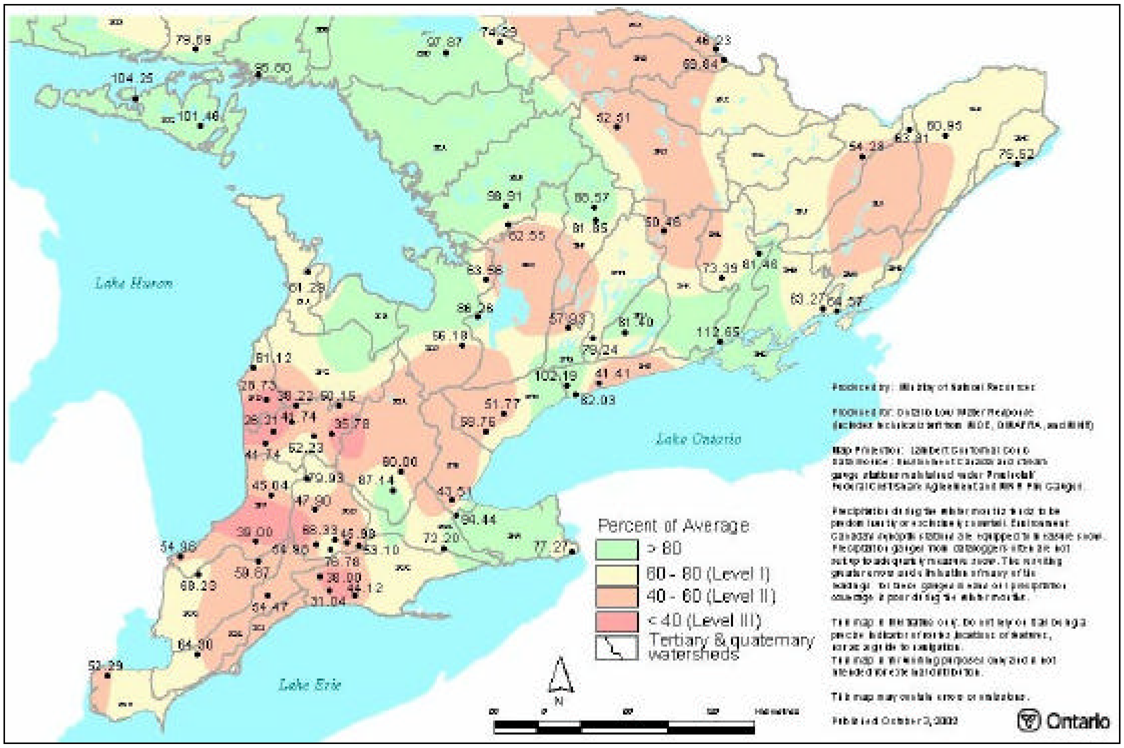
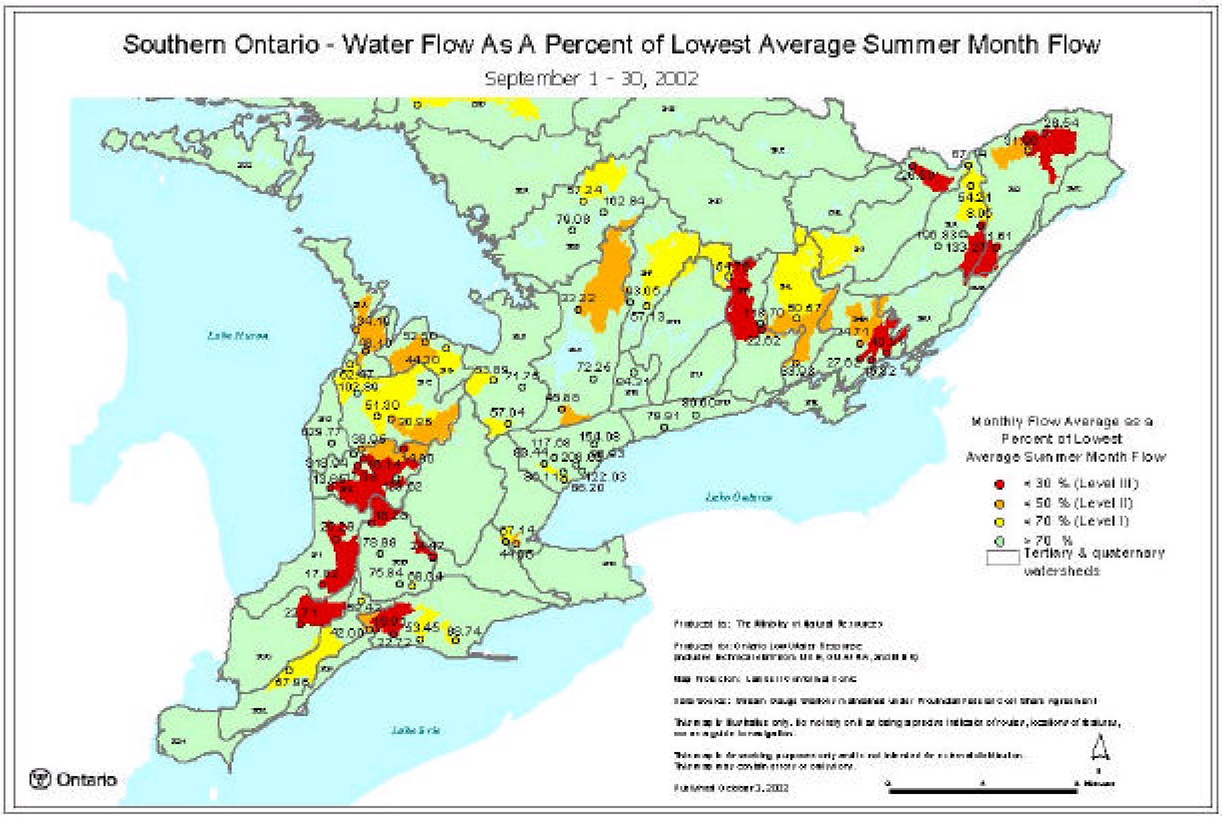


Figure 2.8: Percentage of Lowest Average Monthly Flow, Southern Ontario (September 1 - 30, 2002)



Areas where surface water shortfalls occur are well known. However, as discussed in Section 2.1, the situation for groundwater is different. For example, the MNR does not produce maps similar to Figure 2.8 for groundwater. Additionally, aquifers in Ontario tend to be smaller and less regional in size than in other parts of the world (with the exception of significant features such as the Oak Ridges Moraine) (MacRitchie, *et al.* 1994). Therefore, shortfalls of groundwater tend to be local phenomena, and often are a function of the specific aquifer that different water users are drawing from. Not surprisingly, as is noted in the next section, interviewees again reported that problems of limited groundwater quantity coincided with regions where agricultural irrigation was important. Once again, Norfolk County -- which has high levels of irrigation and shallow aquifers -- was identified as a major regional area of concern. However, local areas of concern where irrigation is dependent on groundwater sources may be expected to exist throughout the Province.

2.3. Stakeholder Interviews

Scoping interviews were held with a select group of key informants representing provincial agencies, producer groups and conservation authorities to permit cross-checking and verification of data from the mapping and literature review phases. The list of potential contacts was developed from several sources: Mr. Jim Myslik of the Ontario Ministry of Agriculture (OMAF), Dr. Mary Jane Conboy of the Ontario Fderation of Agriculture, members of the Ontario Federation of Agriculture's Water Quality Working Group, and Drs. Rob de Loë and Reid Kreutzwiser of the University of Guelph. From an initial list of over 90 names, a subset of 37 names was chosen, and 20 people ultimately were interviewed. (The names of the 20 people interviewed are listed in Appendix A, along with the interview schedule.)

Prior to the interviews, a set of four questions was developed to cover the areas of interest in the study. The questions were purposefully open ended to avoid prompting the interviewees. The list of questions included:

1. Are there any locations where lack of water constrains agricultural activities? If so, please address the following:
    - Where (regions, counties)?
    - What kinds of agricultural activities and crops are constrained?
    - How is "lack of water" a constraint?

2. How should agricultural water supply constraints be addressed, and whose responsibility should it be?

3. What are some anticipated trends that will influence (positively or negatively) the security of agricultural water supplies?

4. What are good sources of information and data to help us answer these questions? For example, can you think of studies and reports, or people that we should contact?

The interviews were conducted either in person or by telephone/e-mail. In the former case, interviewees were shown an introductory letter and the questions and then asked to respond to the questions in sequence. Where the latter approach was used, an initial contact was made to introduce the study, an e-mail containing the questions and an introductory letter was sent and then a follow up telephone call was made to obtain answers to the questions (in some cases respondents sent an e-mail back answering the questions). The introductory letter and question form is included in Appendix A.

The following summary discussion, based upon 20 completed interviews, highlights key points that were raised during the interviews and endeavours to identify unique responses, information and perspectives. Where a number of responses included the same point, this has been emphasized in the text. Opposing points of view have been noted where appropriate.

Where, Why and How Lack of Water Constrains Agricultural Activities

The most frequently noted area where "lack of water" constrains agriculture in Ontario is on the Norfolk Sand Plain and surrounding area. This area stretches across Norfolk County, South Oxford, South Brant and Elgin County (Figure 1.1). Other areas where interviewees suggested that lack of water constrains agricultural activities are located where agricultural operations are near urban centres including the Region of Peel; Region of Waterloo; the City of Guelph, in Wellington County; New Tecumseth, in the southern portion of Simcoe County; the Region of Niagara; City of Hamilton; and the area around the City of Ottawa in the South Nation River Watershed and Kemptville Creek.

Irrigation is the primary agricultural activity that is constrained by lack of water. To a lesser degree, irrigation of the canopy for frost or heat protection is another agricultural activity that is constrained, particularly in tender fruit, vegetable and horticultural operations. It was reported that, on occasion, some livestock operations (dairy and horses) have been constrained due to competition for a limited water supply. This was not reported for all counties.

Farm operations that grow crops that typically rely on precipitation events rather than irrigation in Ontario (corn and soybeans) have been constrained due to lack of precipitation at critical times during the growing season. Furthermore, lack of water constrained some livestock operations recently as forage and food production for the livestock was reduced. In some areas alfalfa crops only yielded two cuts instead of typically three or four cuts during the growing season in Southern Ontario. Irrigation represents an additional input cost making only certain crops economical to grow during unusually dry conditions when irrigation is required.

Lack of water has been a constraint to the agricultural community in Ontario due to a number of reported factors. In some cases, there is simply an insufficient supply to satisfy all demands. In other cases, competition with other users and other requirements is perceived as disadvantaging agricultural production. Examples include:

- competition between sectors within agriculture;
- competition and conflict between agriculture and recreational use (e.g., golf courses);
- conflict with ecosystem requirements;
- competition with aggregate operations;
- competition with industry, e.g., automotive production facilities (Honda and Toyota); and,
- conflict with aggregate operations (dewatering).

Other constraints relate to the availability of information and understanding of the existing water allocation process. These include:

- lack of understanding of the process to acquire a Permit To Take Water (PTTW) (a requirement under the *Ontario Water Resources Act* for most water users taking more than 50,000 litres/day;)
- a fear that agriculture has a lower priority in issuing a PTTW during critical times when typically there is a reduced water supply;
- lack of data and understanding of the local water budget;
- conflict with the general public and their understanding of agricultural water needs.

Agriculture is also expanding rapidly and this demands more water. "Lack of water" therefore constrains the economic growth of the agricultural sector.

It was also reported that some dairy and livestock operations in parts of Brant County and North Oxford face constraints with respect to water in that some shallow wells cannot supply adequate water during dry years. Deeper wells, which help to address this concern, may produce water that is very high in sulphur. High sulphur concentration in the water supply results in reduced intake volumes by livestock that in turn reduces production levels. Furthermore, high sulphur concentration in the water supply readily corrodes and clogs copper and steel piping, such as is used in milking and watering equipment, and therefore adds to the cost of production.

How Should Agricultural Water Supply Constraints Be Addressed And Who Should Be Responsible?

Agricultural water supply constraints should be addressed in a fair, equal and consistent manner across the Province. It was frequently reported that patchwork approaches currently in place across the Norfolk Sand Plain and surrounding area caused frustration within the agricultural community. Farms located within a certain political boundary had access to funding to assist with the cost of additional infrastructure, whereas farms adjacent to this area although suffering from the same dry conditions did not. It was recognized that a local management team was preferred, but that the guidelines, policies, and cost sharing schedules should be the same across the Province.

Specific suggestions as to how constraints should be addressed included:

- An education and awareness effort, such as demonstration projects and workshops to demonstrate efficient irrigation, approaches to conservation, new drought resistant crops, and new equipment, was highly recommended. This would also assist in the implementation of conservation measures on the farm and would engage all users of water to join in the effort to conserve water. The Permit to Take Water (PTTW) workshops held recently in certain parts of the Norfolk Sand Plain were considered to be very successful.

- Programs such as the Norfolk Water Supply Enhancement Project, which provided funding support for on-farm water supply improvements (e.g., ponds and wells), were commended.
- A better understanding of the availability of the water supply was considered highly desirable, coupled with an improved understanding of demand by agriculture as well as other users. It was suggested that this could help water takers to improve their understanding of the impacts of their takings on the resources, as well as their impacts on others. This should be conducted on a watershed level with Provincial, County, and municipal input and management. Interviewees suggested that farmers have the responsibility to cooperate and contribute to the big picture.
- The agricultural community expressed the need for the Ministry of Environment (MOE) to more uniformly and consistently enforce the requirement to have and to follow the conditions of a PTTW.
- It was strongly reported that public funding should be available to support the cost of additional infrastructure as well as to study and monitor the water supply in a given watershed where water demands are high.

Trends That Will Influence The Security of Agricultural Water Supplies

Both positive and negative trends influencing the balance between water supply and water demand for agriculture were noted. Trends, which either increase supply or decrease demand include:

- A frequently noted trend to reduce the area where tobacco is grown.
- More drought resistant varieties of crops are being grown.
- There has been a noticeable trend to move irrigators off streams and increase the use of irrigation ponds and sand point wells in sensitive watersheds.

Trends, which either increase demand or decrease supply include:

- An increasing trend towards irrigation as it is the most cost effective way to increase production of certain crops. This is particularly true for high value crops such as tobacco, tender fruit, and ginseng. However, irrigation is increasing on crops that traditionally have relied on natural precipitation events, e.g. soya beans in Brant County. The increased trend to use irrigation is the result of market demand for high quality produce as drought stressed crops do not give a good investment return.
- Increasing the area growing ginseng and sod and increased levels of aquaculture.
- An increasing trend in developing golf courses resulting in increased demand on local water supplies.
- Increasingly, urban development is encroaching on agricultural land, and this, in turn, increases the risk of conflict over water taking (creating a potential constraint on agriculture).

- Farmers have uniformly noted a change in climate in Ontario over the past ten years. Precipitation events, when they occur, are more intense and not typically timed to the growing season.

Trends which influence the management of water allocation rather than increase or decrease the supply/demand include:

- Formation of locally based Irrigation Advisory Committees to assist in the management of allocations during times of low water availability. These are thought to reduce conflict and facilitate more effective water allocation.
- Development of the Ontario Low Water Response with its associated Low Water Response Teams designed to manage implementation at the local level. As in the case of Irrigation Advisory Committees, Low Water Response teams are seen as a way of reducing conflict and improving water allocation.
- There has been a decrease in the number of public servants in the provincial government to deal with the issues on a local level, such as conflict over use of a limited resource.

Overall, local workshops that highlight the need for a PTTW and local water supply conditions are contributing to public awareness of water supply issues. Nevertheless, some interviewees expressed a fear that agriculture is being given a diminished priority relative to other water using sectors and activities.

Additional Sources of Information and Data

Additional sources of data and information were provided by several interviewees. Individuals or agencies mentioned by interviewees during the interview process that were not previously contacted were added to the contact list.

2.4. Stakeholder Workshop

As part of the consultation process for the study a one day facilitated workshop was held with key stakeholders. The workshop had three objectives: (1) to confirm findings from the telephone surveys and literature review (described above), (2) to identify new information, for instance, areas of the Province where water supply is a constraint on agriculture, but which were not identified during the telephone surveys or mapping exercise, and (3) to identify and prioritise programming options.

A total of twenty-one participants attended the workshop, which was held in Guelph, Ontario on January 10, 2003. Participants included representatives from the Ontario Ministry of Agriculture and Food; Ontario Ministry of Natural Resources; the Grand River, Long Point Region, and Credit Valley Conservation Authorities; Ontario Federation of Agriculture; Agricorp; and industry representatives of potato, dairy, tobacco and sod producers. Officials from the Ontario Ministry of the Environment were invited, but were unable to attend. The full list of participants is included in Appendix B.

Workshop participants were grouped into three tables, which include a balanced mix of representatives for the different agencies and industry sectors. Each table had its own facilitator from the study team. The workshop was organized as follows:

- Brief overview of the National Water Supply Expansion Program and of the interim report established the context;
- Break out session to discuss agricultural water supply issues, focused on trends, issues and constraints in different regions;
- Break out session to discuss potential solutions and priorities and criteria for solutions; and
- Brief plenary after each break out session to report on responses from the tables.

Workbooks were distributed to each participant, and maps of Ontario showing the regions where telephone survey participants identified issues of concern were made available to each table. The workbook provided an outline of instructions for the break out sessions, and provided space for participants to list trends, issues and constraints for the regions identified on the maps already, as well as for any other region for which they had knowledge and potential solutions and criteria for implementation. Participants at each table were asked to discuss the topics as a group and complete one workbook that consolidated all of the input from individuals. The workbook included space for participants to list the top 3 trends, issues and constraints, and the top 3 criteria for implementation. Appendix B provides a brief summary of the discussion at each table, along with a copy of the workshop workbook.

The results of the table discussions generally confirmed the concerns for the regions identified in the interim report. However, some workshop participants believed that the urban areas of Waterloo, Guelph and Peel should not be listed. It was suggested that although the rural areas around Waterloo and Guelph were identified as areas of concern, concerns related to competition from other water using sectors, such as golf courses and urban development. Discussion within the groups in general revealed that all regions across Ontario were susceptible to agricultural water supply issues for various reasons ranging from variability of water demands for crop types to soil conditions and weather patterns.

The discussion of issues at the three tables revealed that workshop participants considered the following issues to be most important:

- Need for long term planning coordinated by the three levels of government; federal, provincial and local;
- Need for a better understanding of weather patterns, crop type water usage and opportunities for storage and irrigation. The groups suggested that the agricultural industry was becoming highly dynamic. Changes in crop types were not necessarily regionally dependent, but more a function of the individual choices of farmers. They

also noted that the recent years of irregularity in rainfall largely affected crops and there are inconsistent approaches to storage of water for irrigation; and

- Need for better management and coordination of the Provincial water permitting system. Group discussions identified that in many cases throughout the Province, the cumulative effects of water taking by permit are not clearly documented or understood.

The discussion of solutions identified a need for the following:

- Funding for studies to better understand water systems/capacities;
- Short term solutions focused on infrastructure improvements where immediate change/improvement can be achieved; and
- Programs to increase education and voluntary water efficiency.

Workshop participants believed that much could be gained from instituting programs such as the Water Supply Enhancement Program and Irrigation Advisory Committee in Norfolk County to achieve short-term solutions and education for agricultural water usage. Many workshop participants also believed there is a need for better understanding of water systems and capacities to support a focus on water drainage, supply and management infrastructures. It was recognized that the Permit to Take Water Program should be revised, or implemented more effectively.

Two of the workshop tables explicitly discussed criteria for program design and implementation. Synthesizing the discussion produces the following desirable characteristics of any NWSEP program in Ontario:

- Programs should be led by local stakeholders and involve partnerships
- Existing institutional arrangements and resources should be used whenever this is possible
- Programs that produce immediate results are most desirable
- Measures that increase the efficiency of water use are most appropriate
- Programs should have positive benefit-cost ratios
- Initiatives that fill knowledge gaps are desirable
- Programs that encourage water storage during times of adequate supply (both structural and non structural) should be emphasized

3.0 SYNTHESIS OF FINDINGS

Water acts as a constraint on agricultural production when it is not available in sufficient quantities, or when its quality is unacceptable. Insufficient quantity can be a function of several factors, including inadequate surface or groundwater supplies, and demand that exceeds supplies (a version of the previous constraint). Insufficient quality of water also is a concern (whether or not enough quantity is available). Institutional or technological constraints also exist (whether or not enough quantity is available). These all are constraints that could be addressed by the NWSEP.

Regarding water quantity, a distinction needs to be drawn between agricultural activities that depend on precipitation to provide water for plant growth (e.g., growing grain corn), those which rely on irrigation, or use irrigation to supplement water from precipitation, and those which use water in livestock production (de Loë, *et al.* 2001). This distinction is important because the type of crop grown can determine whether or not producers in an area are facing constraints. For example, the research identified several counties that were facing constraints from water shortages in Ontario. For the most part, these were areas where irrigation was important (e.g., the Norfolk Sand Plain and surrounding areas). In the livestock sector, a different group of counties appears to have experienced drought impacts in 2002. In February, 2003, the Canadian Customs and Revenue Service established a one-year tax deferral for owners of breeding livestock in the counties of Bruce, Cochrane, Elgin, Halton, Kent, Lambton, Middlesex and Peel (Agriculture and Agri-Food Canada 2003). This deferral is available to breeders who were forced to sell all or part of their herd in 2002 due to drought conditions. While there is some overlap between locations where water supply was identified as a constraint in this study and those where the tax deferral for livestock breeders applies, several regions are unique to one sector. This highlights the need to consider the specific agricultural sector when developing any water supply enhancement program.

The following provides a synthesis of the findings from the analyses presented in the previous section. It highlights agricultural regions of heaviest water use (current and anticipated future); agricultural regions with inadequate or failing infrastructure; agricultural regions with water supply constraints; and water supply constraints/water supply issues that were identified.

3.1. Regions of Heaviest Agricultural Water Use

Based upon the mapping of demand discussed in Section 2.1, and the responses to the first question of the survey, the following regions have been identified as having the highest levels of water use:

- The Norfolk Sand Plain and surrounding area. This area stretches across Norfolk County, South Oxford, South Brant and Elgin County.
- New Tecumseth.

- Georgina Township.
- The Niagara Peninsula and the City of Hamilton region.
- The Essex region around Leamington.

In all areas, there are trends towards greater demands and potential conflicts between users in the future.

3.2. Areas with Inadequate or Failing Infrastructure

Infrastructure has been interpreted as both physical works, which are involved in agricultural water supply and non-structural aspects such as institutional arrangements or regulatory systems. In this context, the following area of failing or inadequate infrastructure are noted:

Physical Infrastructure

During the study, no specific examples of failing physical infrastructure have been identified. ("Failing" is interpreted as deterioration of an existing "structure" to the point that it is at risk of not performing the function for which it was designed.) This probably reflects the fact that most irrigation systems in Ontario are small scale on farm systems which withdraw water from local water courses or wells. Major irrigation systems involving diversion structures, storages and canals, such as those found in western Canada, do not exist in Ontario.

In those areas (listed below) where water supply has been found to constrain agricultural production, inadequate physical infrastructure could be considered to be a contributory factor. In some areas, e.g., the Norfolk Sand Plain, additional on farm storage or additional wells have recently been constructed to improve the management of surface water supplies or to supplement surface water supplies. This has improved the ability of farmers to deal with low water situations. In this sense, the existing infrastructure in these areas can be seen as inadequate to support the existing and future demands. Similarly, in the New Tecumseth area, the construction of a pipe line to Lake Huron to supply additional industrial and municipal water has relieved the conflicts with agricultural demand to some extent. There are many other areas where it may be feasible to draw water from the Great Lakes to supplement water supply for municipalities or other purposes. Again, it could be concluded that the infrastructure is inadequate in those areas since a potential source exists which cannot presently be accessed because a pipeline does not presently exist.

Institutional Arrangements and Regulatory Systems

During the study, many instances of inadequate management systems, information systems and regulatory systems have been noted, in particular, the Permit to Take Water program. These tend to have been inadequate across all geographic areas rather than in specific locations. In light of recent low water conditions, various measures have been initiated to address these inadequacies. In particular, these involve:

- formation of Irrigation Advisory Committees to manage demand at the local level;
- formation of Low Water Response Teams to implement the Ontario Low Water Response program;
- studies to determine the extent of water taking under the provincial Permit to Take Water Program;
- water balance studies of individual watersheds; and,
- installation of additional monitoring networks to measure surface and ground water availability.

Many of these programs are pilot projects covering relatively small geographic areas (e.g. the Big Creek watershed). Where such measures have not been taken, the management system can be considered to be inadequate, and considerable potential for improvements can be expected if similar approaches were adopted. Unfortunately, as noted by Durley, *et al.* 2003), local capacity for implementing such measures is variable across Ontario.

3.3. Agricultural Regions with Water Supply Constraints

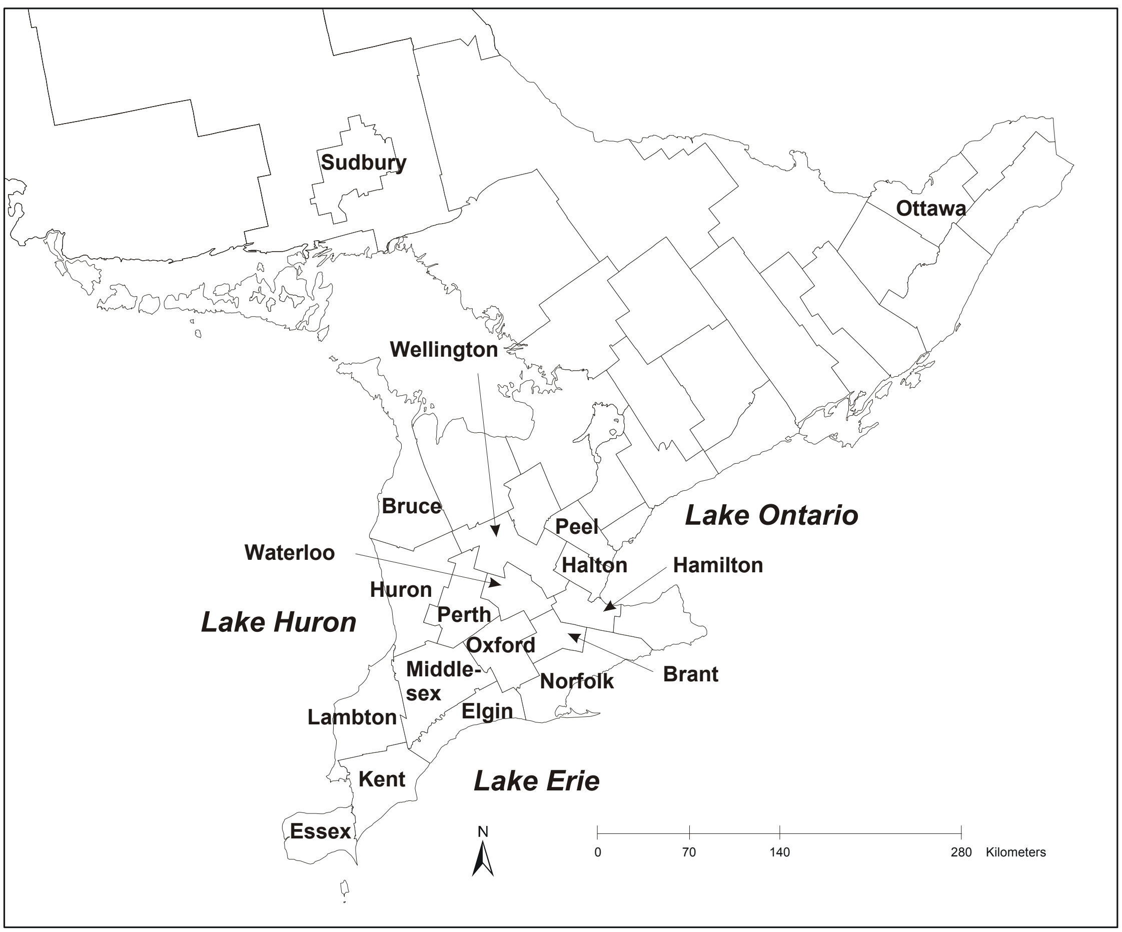
Regional variations in the extent to which farmers face agricultural water supply challenges are a function of factors such as soil conditions, moisture deficits, crop type, farming practices, availability of ground and surface water, competition, and the administration of the water allocation system. Based upon the literature review, analysis of maps of water demand, interviews and stakeholder workshop, the following regions have been identified as having water supply constraints which impact agricultural production:

- the Norfolk Sand Plain and surrounding area (stretching across Norfolk County, South Oxford, South Brant and Elgin County). This includes speciality crops such as tobacco and ginseng where irrigation supply is inadequate and other crops such as hay where irrigation is not practised;
- the Town of New Tecumseth in Simcoe County. This includes inadequate irrigation supply for potatoes and other crops;
- the Niagara Peninsula and the region around the City of Hamilton. This impacts tender fruit production due to lack of supply and livestock production due to poor quality water;
- the Essex region around Leamington. This affects production of soya beans and fruit and vegetable crops due to inadequate irrigation supply and livestock operations du to poor water quality;
- the South Nation River watershed and Kemptville Creek near Ottawa. Primarily dairy operations are constrained by lack of water;

- rural areas in the Region of Waterloo. Livestock and poultry operations are the primary agricultural activities constrained by lack of water;
- the rural area around the City of Guelph in Wellington County. Constrained activities are the same as those in the Region of Waterloo;

Figure 3.1. highlights the locations of these areas. Importantly, as noted earlier, sectoral water needs vary widely. Thus, specific agricultural sectors in other regions also may be experiencing water-related constraints on production. This was highlighted by the example of the counties that received tax deferrals for livestock breeders due to the 2002 drought. In designing a water supply enhancement program, it will be important to develop criteria that are sensitive to sectoral needs.

Figure 3.1: Locations Identified with Agricultural Water Supply Constraints



3.4. Water Supply Constraints/Water Supply Issues Identified

The agricultural water supply constraint/issues identified during the study included the following:

Insufficient Water To Meet Demand in Periods of Low Water – in those regions noted above, the supply is inadequate to meet current demand resulting in reductions in water taking at critical periods. Potential ways in which the NWESP might help address this issue/constraint include:

- support for studies of the feasibility and benefit-cost of supplementing supplies through communal systems;
- support for programs such as the Norfolk Water Supply Enhancement project to help improve management of surface water supplies (on farm storage) and to supplement local supplies from groundwater; and,
- support for education programs which encourage water conservation and possibly programs to convert to new technologies to reduce water usage.

Inadequate Management of Available Water Supply and Demand – in some or all of those regions noted above, adequate mechanisms do not exist to ensure the most effective management of the available resources. Potential ways in which the NWESP might help address this issue/constraint include support for the geographical expansion of Irrigation Advisory Committees or similar bodies designed to improve local water allocation in the agricultural sector.

Inadequate Knowledge of Available Water Supply and Demand – in some or all of those regions noted above, information on the availability of water at critical times and of the actual demand does not exist. This hampers the effective management of the available resources. Potential ways in which the NWESP might help address this issue/constraint include:

- support for studies to understand actual level of water taking vs. the permitted levels of water taking under the Permit to Take Water program;
- support for studies of the water balance of watersheds; and,
- support for additional monitoring of surface and ground water supplies (possibly through Water Survey of Canada).

4.0 CONCLUSIONS AND RECOMMENDATIONS

Water is a constraint on agricultural production in many areas of the Province. Areas where shortages are most pronounced are those where irrigation demand is highest, notably portions of counties on the Norfolk Sand Plain. Nevertheless, as demonstrated by the case of tax deferrals for livestock producers who experienced drought in 2002, water shortages can be a constraint on agriculture in other areas. Rather than identifying regions that are eligible, it is more appropriate to develop a set of criteria that can guide the development and implementation of a National Water Supply Enhancement Program (NWSEP) initiative in Ontario.

Funds can be spent in numerous ways, ranging from support of structural measures (such as on-farm ponds), to data collection, studies, and seed money for local initiatives. For individual agricultural water users, a program that provides funds to permit construction of small scale water storage facilitates, or to promote non-structural storage using wetlands, is appropriate. Successful examples of such programs were identified during the research, and include the Norfolk Water Supply Enhancement Program. Addressing different concerns but still relevant, the Province's Healthy Futures for Ontario Agriculture program is another example.

Large-scale initiatives, such as pipelines from the Great Lakes, are not recommended in most cases. Pipelines are expensive, and difficult to justify -- especially in light of the fact that producers may be unwilling, or unable, to pay the full cost of providing the water. Instead, more appropriate initiatives are the kind that permit agricultural water users to solve problems locally, for instance, through irrigation advisory committees. The NWSEP could play an important role by providing seed money to permit local water users to enhance their ability to participate on Low Water Response teams and irrigation advisory committees. This is consistent with major themes emerging from the research: the need for locally-driven solutions; the need for immediate progress; and the need to fill local knowledge gaps.

A partnership with the provincial government is essential. The Province of Ontario allocates water under the *Ontario Water Resources Act*, and has the most direct responsibility for water management. Therefore, while it is appropriate to consider ways in which water allocation can be enhanced in Ontario, this should not be done without the full cooperation of the Province of Ontario. One opportunity to tie into existing provincial initiatives was identified in the previous paragraph, in other words, provision of seed money to local organizations to enhance their ability to play a role in provincial initiatives such as Low Water Response.

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APPENDIX A

LIST OF INTERVIEW CONTACTS AND QUESTIONS ASKED

Name of Interviewee	Title	Organization
Cameron, Ian	Models Development Engineer, Water Unit	Ontario Ministry of Natural Resources
Caukell, Gordon	Chairman	Dairy Farmers of Ontario
Conboy, Mary Jane	Water Resource Policy Analyst	Ontario Federation of Agriculture
Davis, Larry	Brant Director and Dairy Farmer	Ontario Federation of Agriculture
Dorsey, Wayne	Chair	Ontario Potato Board
Emiry, Keith	Member Service Rep (Dufferin Waterloo, Wellington, Northern Ontario)	Ontario Federation of Agriculture
Gilvesy, George	Past President Tobacco Board, International VP for the Tobacco Board	Ontario Flue-Cured Tobacco Growers's Marketing Board
Gilvesy, Valerie	Member Service Rep (Elgin Oxford)	Ontario Federation of Agriculture
House, Harold	Agricultural Engineer	Ontario Ministry of Agriculture and Food
Lisckai, Janet	Member Service Rep (Brant, Haldimand, Norfolk)	Ontario Federation of Agriculture
Myslik, Jim	Engineer, Water	Ontario Ministry of Agriculture and Food
Oliver, Jim	Manager	Long Point Region Conservation Authority
Reid , David	Stewardship Coordinator Norfolk County - Aylmer District	Ontario Ministry of Natural Resources
Semeniuk, Betty	Poultry Producer	Ontario Federation of Agriculture, Water Quality Group
Shortt, Rebecca	Engineer, Irrigation Water Management	Ontario Ministry of Agriculture and Food
Simpson, Hugh	Environmental Management Specialist, Rural Groundwater	Ontario Ministry of Agriculture and Food
Stevenson, Don	OFA Member Service Rep (Peel, Simcoe, York)	Ontario Federation of Agriculture
Swierenga, Henry	OFA Member Service Rep (Halton, Hamilton, Niagara North and South)	Ontario Federation of Agriculture
Wales, Mark	Chair Low Water Response Team for Big Otter in Elgin, South Oxford, and Norfolk. Chair Big Otter/ Catfish Watershed Irrigation Options Project	Ontario Federation of Agriculture
Wilson, Jeff	Fruit and Vegetable Producer	Ontario Fruit and Vegetable Grower's Association

Marshall
Macklin
Monaghan
CONSULTING ENGINEERS - SURVEYORS - PLANNERS

WESA
A Better Environment For Business

Professor Rob de Loë
Professor Reid Kreutzwiser
University of Guelph

November 2002

Dear Colleague,

In recognition of recent drought conditions, Agriculture and Agri-Food Canada has initiated the National Water Supply Expansion Program (NWSEP), a four year $60 million initiative. The Program aims to improve the capacity of agricultural producers to deal with drought and other agriculturally-related water constraints through the development and expansion of water supply systems on a cost-shared basis. An initial $10 million was made available in 2002/03 and was targeted mainly to help relieve the water supply situation on the drought-affected Prairies. The remaining $50 million of the NWSEP will be available nationally over the next three years to fund additional infrastructure and strategic water supply studies to address long-term solutions to agricultural water supply problems.

As a pre-requisite to the distribution of the available funds, a scoping study is being completed. This will identify the scope of agricultural water needs; determine the nature and extent of water supply constraints on agriculture and identify priorities for agricultural water supply expansion across Canada. Marshal Macklin Monaghan Ltd in association with Water and Earth Sciences Associates Ltd and Professors Rob de Loë and Reid Kreutzwiser of the University of Guelph have been retained to complete the scoping study in Ontario.

The most significant component of the involves consultation with agricultural water users and managers in Ontario. The first stage of this consultation is to ask a key group of stakeholders a series of questions related to the issue. We are contacting you in advance to let you know that we will be phoning you in the next few days to include you in our survey. So that you can be better prepared, we have listed the questions we will be asking on the next page.

We look forward to talking with you shortly and thank you in advance for your cooperation.

Yours Truly,

Rob Bishop
Project Manager
MARSHAL MACKLIN MONAGHAN LTD

Tiffany Svennson
Principal Investigator
WESA

Questions for Task 1 Interviews
November 2002

Name: ______________________________

Date: ______________________________

Agricultural water use estimates for 2001 are presented in a series of maps on this website:

http://www.uoguelph.ca/~rdeloe/AAFC-PFRA/water_use/ag_water_use.htm

If time permits, please visit this website prior to responding to these questions:

____

(1) Are there any locations where lack of water constrains agricultural activities? If so, please address the following:

- Where (regions, counties)?
- What kinds of agricultural activities and crops are constrained? (e.g., livestock watering, crop spraying, irrigation)
- How is "lack of water" a constraint? For example, is it due to insufficient water supply (surface or ground); competition and conflict; weaknesses in the water allocation system; lack of infrastructure or inadequate infrastructure (e.g., dug wells); insufficient water quality

(2) How should agricultural water supply constraints be addressed, and whose responsibility should it be?

(3) What are some anticipated trends that will influence (positively or negatively) the security of agricultural water supplies?

(4) What are good sources of information and data to help us answer these questions? For example, can you think of studies and reports, or people that we should contact?

APPENDIX B
WORKSHOP MATERIAL

List of Workshop Participants

Name of Workshop Participant	Title or Specialty	Organization
Bellamy, Sam		Grand River Conservation Authority
Blake, Gertie	Member Services Rep, Grey Bruce	Ontario Federation of Agriculture
Brander, Debby	Dairy Farmer	
Conboy, Mary Jane	Water Resource Policy Analyst	Ontario Federation of Agriculture
Cudmore, Paul	Director of Operations	Agricorp
Davies, Steve		Credit Valley Conservation
Dorsey, Wayne	Chair	Ontario Potato Board
Elshayeb, Monalisa		Ontario Fruit and Vegetable Grower's Association
Emiry, Keith	Member Service Rep (Dufferin Waterloo, Wellington, Northern Ontario)	Ontario Federation of Agriculture
Garlough, Gordon	Member Services Rep, Eastern Ontario	Ontario Federation of Agriculture
Jackiw, Randy	Chief Executive Officer	Agricorp
Meulemeester, Diane	Farmer and Regional Director	Norfolk Federation of Agriculture
Myslik, Jim	Engineer, Water	Ontario Ministry of Agriculture and Food
Oliver, Jim	Manager	Long Point Region Conservation Authority
Radburn, Trish		Ontario Ministry of Natural Resources
Reid, David	Stewardship Coordinator Norfolk County - Aylmer District	Ontario Ministry of Natural Resources
Schiedel, Ron	Sod Farmer	
Semeniuk, Betty	Poultry Producer	Ontario Federation of Agriculture, Water Quality Working Group
Shortt, Rebecca	Engineer, Irrigation Water Management	Ontario Ministry of Agriculture and Food
Simpson, Hugh	Environmental Management Specialist, Rural Groundwater	Ontario Ministry of Agriculture and Food
Wilson, Jeff	Fruit and vegetable farmer	Ontario Fruit and Vegetable Grower's Association

Agricultural Water Supply Study Workshop Summary

Overall Summary

Issues	Need for long term planning – coordinated Federal/Provincial/local Need for better understanding of weather patterns, crop type water usage and implementation of storage opportunities and irrigation Need for management and coordination of water permitting system and impacts of permits Regional emphasis focused on need to be an overall Ontario priority – different issues in all areas
Solutions	Increased emphasis on agriculture for Ontario Funds for studies to better understand water systems/capacities – manage permitting Short term solutions should focus on infrastructure improvements where immediate change/improvement can be achieved Funds spent on programs to increase education and voluntary water efficiency
Criteria	Programs should be led by local stakeholders and involve partnerships Existing institutional arrangements and resources should be used whenever this is possible Programs that produce immediate results are most desirable Measures that increase the efficiency of water use are most appropriate Programs should have positive benefit-cost ratios Initiatives that fill knowledge gaps are desirable Programs that encourage water storage during times of adequate supply (both structural [e.g., on-farm ponds] and non structural [e.g., wetlands]) should be emphasized

Workshop Table 1

Issues	Healthy agriculture industry in rural areas is only true long term sustainable issue – produce food where it is consumed Can agriculture be enhanced by ensuring water supply Need plan for (20years) how to optimally supply water for agriculture Irrigation systems using municipal water Groundwater quality – need for treatment for potable water
Regions	Noted issues for Norfolk, Niagara Peninsula, Hamilton Wentworth, Essex, South Nation River, Waterloo All regions of Ontario – all regions have issues whether mild/moderate or severe, lots of water but great variability due to soil type (sand), microclimates Northern Ontario (Thunder Bay) – surface water quality issues, depth of wells and pressure – yield from bedrock aquifer, drainage is key, can have variability in weather and changes in agriculture and changes in water requirements. Water issues due to politics – i.e., great lakes, rural infrastructure
Top Issues	Agriculture is not an issue on municipal, provincial, federal agenda (get economist to look at value to consumers) Long term plan is lacking
Solutions	*Short term* Solutions to help producers meet Ontario regulations Coordinated management of water supply on hand as per current understanding Funds for immediate needs *Long term* Make agriculture a priority in Ontario Long term plan for water drainage/supply/management infrastructures Education Funds for long term continuity

Workshop Table 2

Issues	Large number of permit holders Large number of permit takers Experience low rain weather patterns Don't know basic minimum stream flow requirements Agricultural, industrial and municipal competition Severe drought Overall problem is weather rainfall, induced How do we predict/project matters like growth of greenhouse production centres like Huron County (Exeter area) How do we predict/project crops being moved into high water use category (potatoes, seed corn, tomatoes (processing) The Ontario Permit to Take Water program makes no distinction between a permit for 10l/day for 10 days in June, July, August compared to a 10l/day permit for 365 days (water bottling) Adverse weather is putting pressure on demand and supply at the same time There is a trend towards more crops moving into the irrigation category.
Regions	Noted issues for Norfolk, New Tecumseth, South Nation River Other regions included: Durham – moratorium on water taking permits Lambton (south east) – low rainfall pockets 4 of 5 years Grey – water bottling activities (permits)
Top Issues	The natural change of rainfall patterns The Ontario Permit to Take Water process is presently unmanaged The need for knowledge/facts on irrigation technologies and movement of new crops into irrigation
Criteria	Bottom up – user driven or managed programs like Norfolk Water Supply Enhancement program, and Norfolk irrigation advisory Committee and like EFP Programs that use existing arrangements, for example: Drainage Act is existing legislation used to facilitate related water supply enhancement efforts Programs that use existing public resources like Army Corpse of Engineers

	in USA Programs that encourage water storage during times of adequate supply (both structural and non structural) Programs that increase water use efficiency/education Programs with best cost/benefit relationship

Workshop Table 3

Issues	Soil type and recharge – whether is replenishes soil or ground (drainage) Impact of drainage/holding capacity Rate of water taking and timing Storage opportunities and consistent use of irrigation Crop change to high water usage – sod Competing demand – development, aggregate industry Lack of overall water planning Permit to take water system – not accountable or prioritizing
Regions	Comments noted to Norfolk, Georgina, Niagara Peninsula, Hamilton Wentworth, Essex, South Nation River, Waterloo, Guelph, Peel Region Other Areas identified included Grey Bruce and Tweed
Top Issues	Lack of studies (don't know water availability) No consistent approach to planning/organization Allocation system for permits from competing users Alternative management practices
Solutions	Coordinated planning approach Permit system Need for studies - water budget studies, instream needs, irrigation techniques and water distribution, similar to Environmental Farm Plans, Funds to CAs to support studies Short term solutions – implement infrastructure solutions (ponds etc) in problem areas, plan for residual problems through studies in less critical areas Research for impact of irrigation practices vs. productivity Funds to disseminate knowledge from other jurisdictions

	Voluntary on farm water monitoring Permit enforcement Priority areas – level III stream flows/precipitation areas South Nation, Brant, Elgin, Oxford, Alliston
Criteria	Immediacy of results Contribution to filling knowledge gaps Spatially related where large impact could be achieved Degrees to which project improves water use efficiency Regional benefit to recharge/storage Degree of coordination with existing programs Degree of partnership with other stakeholders.

Workshop Workbook

Analysis of Agricultural Water Supply Issues
National Water Supply Expansion Program (NWSEP)-Ontario
Stakeholder Workshop

JANUARY 10, 2003

Agenda

1. Introduction – What is NWSEP? Who's participating in the Workshop? (10:00)
2. Brief overview of interim report (10:05 - 10:30)
3. Questions of clarification/instructions for break out sessions (10:30 – 10:45)
4. Break out Session I on agricultural water supply issues (10:45 – 12:00)
   - Confirm/identify critical regions (p. 15/17 of interim report)
   - Confirm/discuss nature of supply issues/constraints in identified regions
   - Review trends affecting agricultural water supply
5. Lunch (12:00 – 1:00)
6. Break out Session II on solutions/priorities (1:00 – 2:30)
   - Confirm/identify potential solutions (p.18 – interim report)
   - Discuss regional priorities/discuss priorities for funding solutions
   - Discuss criteria for implementation of solutions
7. Plenary session to report on break out sessions (2:30 – 3:00)
8. Refreshment break (3:00 – 3:15)
9. Final summary of workshop findings (3:15 – 3:30)
10. Questionnaire on severity of recent drought conditions (3:30 – 4:30)

General Instructions

This workbook provides an outline of instructions for the workshop break-out sessions. It is to be used in conjunction with the *Interim Report*, *Analysis of Agricultural Water Supply Issues – NWSEP-Ontario*, and the maps provided in this workbook (Full size colour maps will be available for each group). Each person should use the workbook to identify their thoughts and then as a group, respond to the questions, combining the input of all group members in one copy.

Break-Out Session I: Agricultural Water Supply Issues

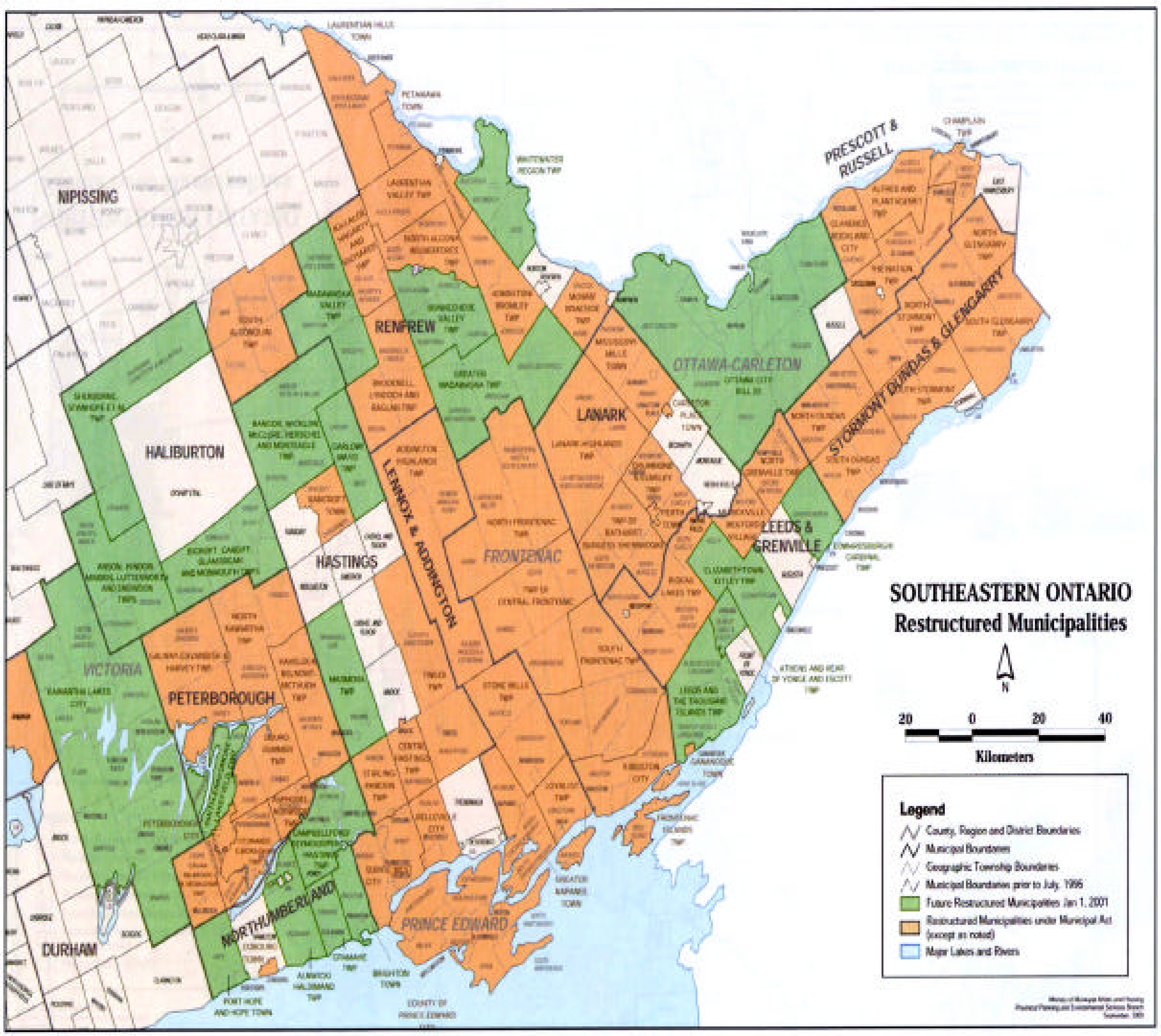
1hr 15 minutes to complete

1. Regions affected by heavy agricultural water use and water supply constraints are identified on the map provided in the Interim Report. Add to the table any other regions and issues/constraints that you are aware of.
2. Review the map and the Interim Report findings to identify a long list of trends in agriculture and/or issues /constraints for each of these regions.

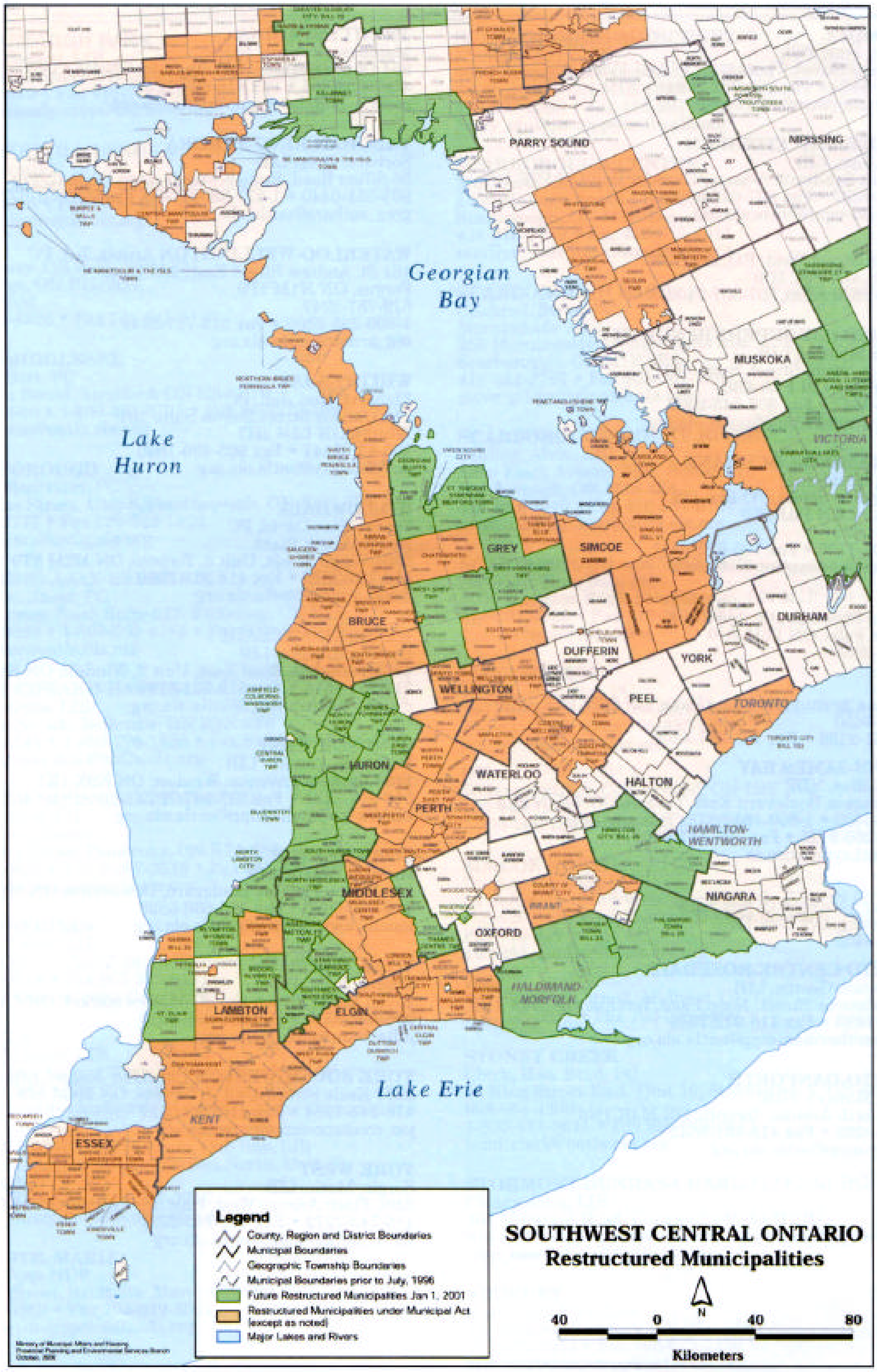
Region	Trends/Issues/Constraints
1. Norfolk Sand Plain	
2. New Tecumseth	
3. Georgina Township	
4. Niagara Peninsula, Hamilton Wentworth	
5. Essex Region	

Region	Trends/Issues/Constraints
6. South Nation River	
7. Kemptville Creek	
8. Region of Waterloo	
9. City of Guelph	
10. Region of Peel	
Others Regions	**Issues/Constraints**

Region	Trends/Issues/Constraints



source: 2002 Municipal Directory



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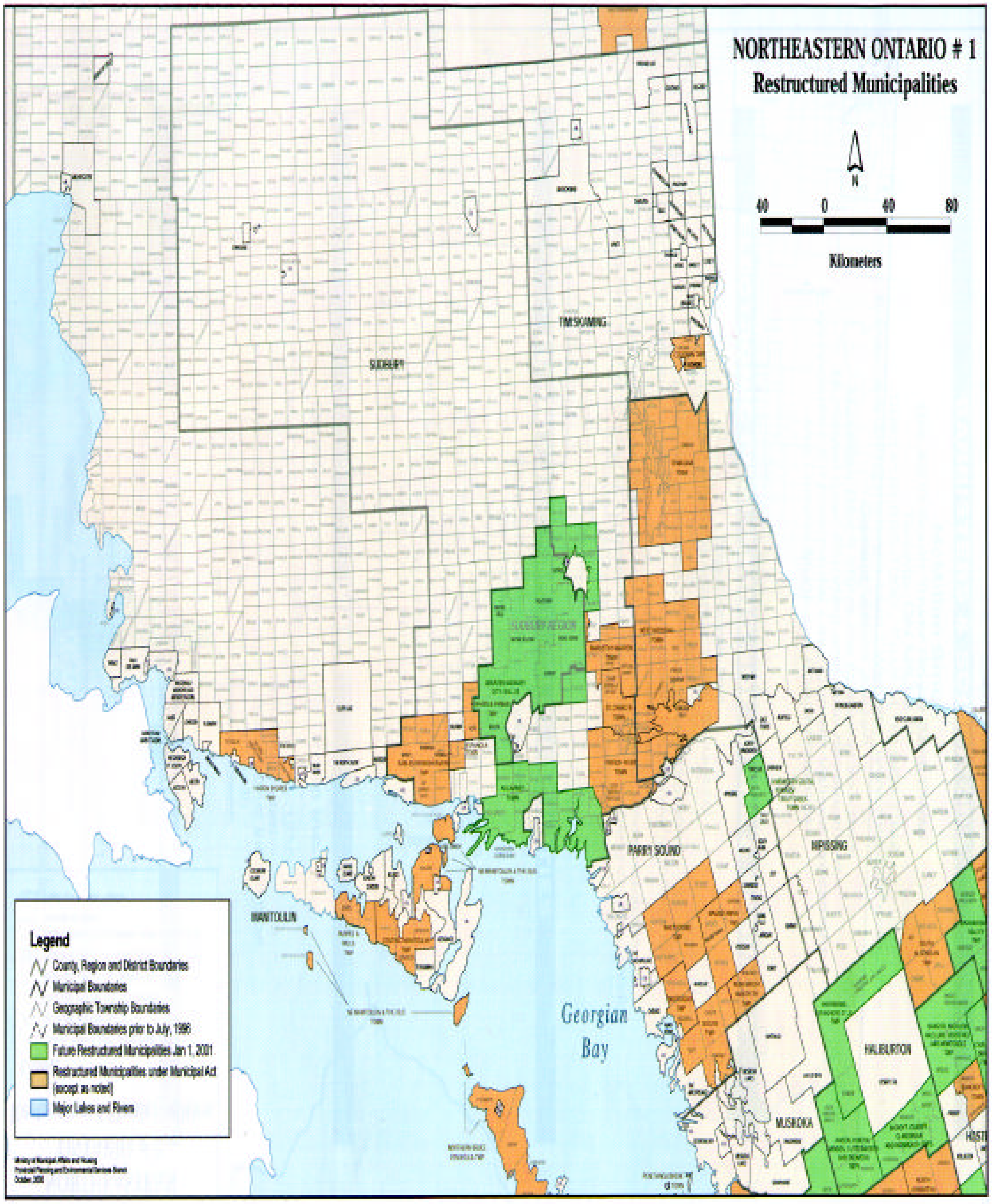
NORTHEASTERN ONTARIO # 1
Restructured Municipalities
N
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SUDBURY
TIMISKAMING
SUDBURY REGION
MANITOULIN
PARRY SOUND
NIPISSING
Georgian Bay
HALIBURTON
MUSKOKA
Legend
County, Region and District Boundaries
Municipal Boundaries
Geographic Township Boundaries
Municipal Boundaries prior to July, 1996
Future Restructured Municipalities Jan 1, 2001
Restructured Municipalities under Municipal Act (except as noted)
Major Lakes and Rivers

3. Review the trend/issues/constraints affecting agricultural water supply listed previously on page 2 and as a group, identify the top three trends/issues/constraints.

Top 3 Trends/Issues/Constraints	
1.	
2.	
3.	

Break-Out Session II: Solutions/Priorities

1 hour 30 minutes to complete

The agricultural water supply issues/constraints and possible solutions identified in this phase of the study are as follows:

Issue:

Insufficient Water to Meet Demand in Periods of Low Water – in those regions noted above, the supply is inadequate to meet current demand resulting in reductions in water taking at critical periods.

Potential Solution
(ways in which the NWESP might help address this issue/constraint):

- support for studies of the feasibility and benefit-cost of supplementing supplies through communal systems, e.g., pipe lines to bring water from Great Lakes sources or regional storage schemes;
- support for programs such as the Norfolk Water Supply Enhancement project to help improve management of surface water supplies (on farm storage) and to supplement local supplies from groundwater;
- support for education programs which encourage water conservation, and
- possibly programs to convert to new technologies to reduce water usage;

Issue:

Inadequate Management of Available Water Supply and Demand – in some or all of those regions noted above, the mechanisms do not exist to ensure the most effective management of the available resources.

Potential Solution
(ways in which the NWESP might help address this issue/constraint):

- support for the geographical expansion of Irrigation Advisory Committees or similar bodies designed to improve local water allocation in the agricultural sector

Agriculture and Agri-Food Canada
Prairie Farm Rehabilitation Administration

Issue:

Inadequate Knowledge of Available Water Supply and Demand – in some or all of those regions noted above, information on the availability of water at critical times and of the actual demand does not exist. This hampers the effective management of the available resources.

Potential Solution
(ways in which the NWESP might help address this issue/constraint include):

- support for studies to understand actual level of water taking vs. the permitted levels of water taking under the PWTP;
- support for studies of the water balance of watersheds;
- support for additional monitoring of surface and ground water supplies (possibly through Water Survey of Canada)

1. Based on the preliminary trends/issues/constraints identified on the first table in Session I, discuss as a group and create a list of other possible solutions.

Other Possible Solutions – List

2. Discuss and group solutions identified above, based on regional settings and priorities for funding solutions.

Region	Potential Solutions

3. Based on the solutions as grouped regionally above, discuss criteria for implementing these solutions. **Identify a list and the top three criteria for solutions.**

Criteria for Implementing Solutions (include regional references where necessary) – List

Top 3 Criteria for Implementation	
1.	
2.	
3.	

APPENDIX C
DETAILED DISCUSSION OF REGIONAL HYDROGEOLOGY

APPENDIX C
DETAILED DISCUSSION OF REGIONAL HYDROGEOLOGY

As discussed in Section 2 of the main report, the hydrogeology is best discussed in the context of four major regions: Great Lakes Lowlands, Ottawa-St. Lawrence Lowlands, Canadian Shield and Hudson Bay Lowlands. The hydrogeology is further discussed on the basis of major bedrock and overburden formations and deposits for each of these major regions. Gartner Lee Associates (1984) introduced a methodology for broadly grouping extremely complex overburden hydrostratigraphy into three generalized units for the South Central Area of the Great Lakes Lowlands. This methodology will be used to describe all of Ontario but is best applied to southern Ontario. The deepest of the three generalized units is labelled as “buried granular deposits” and consists of sands and gravels, intermittently separated by silts and clays. The other two units are glacial till and surficial granular deposits.

The major physiographic and hydrogeologic features of southern Ontario are the Great Lakes Lowlands and the Ottawa-St. Lawrence Lowlands.

Great Lakes Lowlands

There are a variety of hydrogeologic environments in this region as well as an abundance of hydrogeologic information compared to the other regions. For this reason this region is divided further into three sub-regions for discussion purposes. These three sub-regions are the Southwestern Area, the West Central Area, and the South Central Area.

Southwestern Area

Bedrock

The southwestern area can be described as having two major bedrock aquifers – the Dundee Formation and the Detroit River Group (Lucas and Amherstburg Formations). These formations are limestone and dolomites between which are grey and black shales (Hamilton, Kettle Point, and Port Lambton formations). Both formations depend on secondary permeability and porosity of interstitial openings produced by fracturing and dissolution. The Detroit River Group has the highest permeability of the two but both are widely exploited for domestic, municipal and industrial uses (Goff and Brown, 1981). Yields typically range from less than 0.8 L/s in the Dundee Formation to between 0.8 L/s to 3.8 L/s with occasional yields being as high as 151 L/s (Wang, 1986c). Pumping tests in the Walkerton area indicate that transmissivities are about 10^{-4} m^2/s (Wang, 1986a). The upper portion of the Detroit River Group is used as a plentiful irrigation supply south of Lake St. Clair. The supply however, can be sulphurous in places. Similarly a large number of wells in the Dundee Formation are dry or have high levels of sulphur and total dissolved solids (Mellary and Nakashiro, 1970). From an agricultural use perspective, livestock will resist drinking water with high sulphur concentrations and therefore production levels will be reduced. This is particularly an issue with dairy farming. Furthermore, some pesticides, herbicides and insecticides will not mix well for spraying purposes if the water has a high TDS (Total Dissolved Solids) value including a high sulphur concentration.

Overburden

The Southwestern Area’s stratigraphy of the overburden is extremely complex. Only the prominent hydraulic units and their properties will be summarized in this report. In general two sand and gravel units exist in this area. The majority of wells are completed in a confined basal sand and gravel unit that lies directly on the bedrock or in the upper 1 m of the bedrock (MacRitchie et al., 1994). Although this unit is prolific across the region it varies greatly in thickness and therefore the yield varies greatly from 0.8 to 3.8 L/s. The water quality drawn from this unit is often poor in quality. The water is hard, usually exceeding the recommended concentration of iron, and sometimes those of chloride and fluoride. In Elgin County the water often contains hydrogen sulphide (Mellary and Novakovic, 1971). In the vicinity of the City of London several buried granular units make excellent yielding aquifers with yields as high as 15 to 50 L/s. The City of London used these aquifers up until 1967 when it switched to a pipeline supply that draws water from Lake Huron (MacRitchie et al., 1994). Further east towards Woodstock, similar confined aquifer units yield about 0.16 to 3.8 L/s (Goff and Brown, 1981).

A thick weathered clay unit overlies most of the Counties of Lambton, Essex and Kent. This clay is part of the St. Clair clay plain and is the dominant hydrostratigraphic unit in the local area. The upper 5 to 10 m of clay is the hydraulically active zone (Ruland, 1991). Typically residents use large large diameter wells in this weathered zone to provide their domestic water supply (MacRitchie et al., 1994).

The Cardoc, Norfolk and Bothwell sand plains are the three dominant surficial granular deposits in this subregion. The Cardoc sand plain is located just west of the City of London and is about 10 m thick. The water table usually lies between 3 and 5 m below surface and the hydraulic conductivity is generally about 10^{-5} m/s (MacRitchie et al, 1994). The Norfolk sand plain lies south east of the City of London and is typically 3 to 10 m thick, however is as thick as 18 m in some places. The hydraulic conductivity of the Norfolk sand plain ranges between 10^{-5} to 10^{-4} m/s. The Bothwell sand plain lies east and north of Chatham and is between 3 and 10 m thick. The water table is found between 1 and 2 m below ground surface and the hydraulic conductivity ranges from 10^{-6} to 10^{-5} m/s. These unconfined aquifers can provide sufficient water for domestic use in these areas, the water, however, is usually very hard (MacRitchie et al., 1994).

Western Central Area

This subregion contains one of Ontario's most extensive bedrock aquifers and one of Canada's most productive overburden aquifers. The subregion extends approximatley from Stratford in the west to Toronto in the east and from Lake Erie in the south to the northern tip of the Bruce Peninsula.

Bedrock

Three dominant bedrock aquifers exist in this subregion. These are the Guelph-Amabel aquifer, Guelph-Lockport aquifer and the Salina formation.

The largest bedrock aquifer in Ontario is the Guelph-Amabel aquifer. This aquifer extends from Hamilton to the Bruce Peninsula. Several municipalities including Guelph, Cambridge, Fergus, and Markdale, as well as industries and irrigators rely on this high yielding confined aquifer using high capacity wells. This bedrock aquifer ranges in thickness from 90 m in the Hamilton area to 120 m near Owen Sound (Turner, 1978 a-c). The specific capacity of this aquifer ranges from 0.25 to 1.25 L/s/m (Wang, 1983). Yields from the aquifer range from 0.8 to 3.8 L/s with some wells capable of yielding 63 L/s in the Guelph area (MacRitchie et al., 1994).

The Guelph-Lockport aquifer is the bedrock aquifer of the Niagara Peninsula. In the upper 3 m, where secondary permeability such as fractures exist, the hydraulic conductivity is about 10^{-4} m/s. Where no notable fractures exist, the conductivity can be as low as 10^{-11} to 10^{-8} m/s. There is a general decline in water quality with depth, and the water quality can become quite saline near the bottom of the Lockport Formation. Although generally of marginal quality, the water is being used for domestic purposes. Most of the aquifer only yields 0.4 to 0.8 L/s, however, in some isolated areas the yield is as high as 15 L/s. The water levels are typically between 0 and 9 m below ground surface (Turner, 1978d).

The Salina Formation dips to the south and underlies the Onondaga Escarpment north of Lake Erie. The Salina Formation also overlies parts of the Guelph-Lockport aquifer formation and negatively influences the water quality in that aquifer. Increased concentrations of sulphide and hydrogen sulphide have been reported where the Guelph-Amabel is overlain by the Salina Formation (Turner, 1978c). In general, proximity to the Salina Formation is a factor that controls sulphate concentrations. The well yields in the southern part of the Salina Formation are generally less than 3.8 L/s with the exception of the municipal well at Caledonia, where the yield is greater than 16 L/s, and north of Kitchener-Waterloo there is a high-yielding aquifer capable of yields greater than 16 L/s (Sibul et al., 1980). The water drawn from the Salina Formation is highly mineralized with excessive sulphate concentrations "over 1000 mg/L" as well as high iron concentrations (Mellary and Aaltonen, 1973).

Overburden

The overburden is very complex in this subregion with several interbedded confined granular units between silt and clay dominated till units. Delineation of the aquifer units is a very difficult task. The water supply of the Regional Municipality of Waterloo is provided by one of Canada's best groundwater producing units (Committee of Regional Water Issues, 1990). The major source of groundwater recharge in the area is provided by the Waterloo Moraine, the primary topographic feature of the area. Wells in this area are capable of yielding up to 76 L/s and altogether the Regional well fields produce approximately 1875 L/s (Water and Earth Science Associates, 1989). The Region currently has 67 wells in an urban setting and 17 wells in a rural small community setting. East of Cambridge, and in the vicinity of Elmira, extensive sequences of medium to course sand of between 7.5 to 9 m thick in Cambridge to up to 24 m thick in Elmira provide groundwater at and estimated yield of 16 L/s (Sibul et al., 1980).

The Haldimand clay plain which occupies almost the entire Niagara Peninsula is the dominant hydrogeologic unit in the area and is not a usable water supply. Local lenses of fine sand and seams of granular material do occur but they are of limited extent. The silts and clays have extremely low hydraulic conductivities (10^{-10} to 10^{-9} m/s) which seriously impedes groundwater flow. Below this clay plain lies the Wentworth till and although it has a higher hydraulic conductivity (10^{-7} m/s) it is still not a good aquifer (MacRitchie et al, 1994).

Just north of Waterloo lies an area of important surficial deposits. These sand and gravel deposits are kame moraines, outwash plains and spill ways. Yields from wells completed in these sand and gravel unconfined aquifers range between 0.16 to 3.8 L/s (Wang, 1983).

South Central Area

This subregion is bounded to the west by the Niagara Escarpment, to the northeast and east by the Canadian Shield, to the northwest by Georgian Bay and to the south by Lake Ontario. The major hydrogeologic unit in the area is the Oak Ridges Moraine which is a 200 km long ridge of glacial sediments located north of Toronto. Several aquifers and aquifer systems are also utilized north and south of the moraine (MacRitchie et al, 1994).

Bedrock

In general the shales and limestones of the subregion are poor aquifers that yield a small amount of poor quality water. In some areas shallow bedrock aquifer wells are capable of producing sufficient water for domestic use. The hydraulic conductivity of the bedrock, however, is typically between 10^{-13} to 10^{-12} m/s (Intera Technologies, 1978b). Domestic wells are therefore typically completed in the upper few metres of bedrock. The specific capacity of these types of wells range from 10^{-3} to 10^{-1} L/s/m.

Where the overburden is thin many need to rely on the underlying bedrock formation for their water supply. Water wells are therefore generally constructed in the shales of Georgian Bay and Whitby Formations. The yields in these formations range from 0.08 to 0.20 L/s. The limestones of the Simcoe Group are an important source of water in the Great Lakes Lowlands east of Trenton, on the Napanee plain. Depth to the static water in this area is between 3 to 4 m below ground surface and the yields average about 0.15 L/s.

Adjacent to major water bodies (Lake Simcoe, Georgian Bay) more substantial yields can be achieved. In these areas fractured bedrock is likely connected to the surface water bodies and thus show yields ranging from 0.8 to 4 L/s (Turner, 1982a). The municipal well in Canington has a yield of 5 L/s (Wang, 1986b).

Overburden

The main overburden feature in this subregion is the Oak Ridges Moraine. Other noteworthy overburden features include the deposits along the Lake Ontario shoreline south of the moraine and north of the moraine in the Simcoe County area.

The Oak Ridges Moraine can be generally described as having two distinguishable aquifer systems. The thick till, that defines the base of the moraine, separates the two aquifer systems within the moraine. The shallow aquifer system is found at a depth of approximately 76 m and has both confined and unconfined aquifers. Yields in the shallow aquifer system range from 0.5 to 5 L/s and are used for domestic and livestock purposes. Along the southern parts of the moraine, municipal and industrial wells, capable of yields as high as 53 L/s, are confined by the Halton till and sometimes artesian conditions exist (Intera Kenting, 1990). The deeper aquifers found at depths between 88 and 125 m are in buried valleys beneath the till. These deep aquifers are municipal water supplies for Newmarket, Aurora and Oak Ridges. Intera Kenting (1990) has suggested that these aquifers alouth not laterally extensive are capable of sustaining yields of 0.9 L/s. The regional water table is typically found at approximately 35 m below ground surface however perched water tables are frequently in place. A major discharge zone from the moraine is located northwest of Stouffville in the Rouge River basin. This discharge provides the baseflow for many wetlands, streams and rivers draining into Lake Ontario and Lake Simcoe (MacRitchie et al., 1994).

The aquifers south of the moraine are not heavily exploited and the rivers and streams in the Duffin's Creek-Rouge River drainage basin receive significant groundwater discharge (MacRitchie et al., 1994). In the area between Toronto and the Niagara Escarpment a number of buried granular aquifers have been identified; one of the most important aquifers is the Brampton esker. The esker once supplied the city of Brampton with water at a yield of 7.6 L/s and currently supplies the municipality of Georgetown. The hydraulic conductivity of this aquifer ranges from 10^{-4} to 10^{-3} m/s (Funk, 1979).

North of the moraine lies the greatest accumulation of Quaternary sediment in Ontario. These sediments can be as thick as 250 m. From north of the moraine to Georgian Bay a series of fine to course sand aquifers form the Alliston aquifer complex. These confined aquifers are generally 3 to 6 m thick. The yields in this area range from 0.38 to 53 L/s depending on the coarseness of the granular material and the thickness of the unit. The Alliston aquifer complex supplies a number of communities in the area west of Lake Simcoe, including the municipal well at Alliston that has a rated capacity of 27 L/s. In 1995, driven by the water demand of high quality and large quantities for local industry (Honda Canada) the Town of New Tecumseth augmented the local groundwater supply with a pipeline from Georgian Bay to Alliston. The Alliston aquifer complex is also a source of water for Aurora, Newmarket and Innisfil. More productive aquifers at higher elevations exist near Barrie and Bradford. Most of the water in this area is hard and mineralized but is however suitable for domestic and irrigation purposes.

The Halton till, found near or at surface from Niagara to Port Hope, ranges in average thickness between 3 and 12 m. Although this till is hydraulically active it has a comparatively low hydraulic conductivity. The Halton till can supply adequate water for domestic purposes however the yields are controlled by the storage capacity of the wells (Ostry, 1979b; Funk, 1977b).

Surficial sand and gravel cover the north shore of Lake Ontario. Domestic water supplies have been developed in these shallow deposits however they are quite vulnerable to seasonal fluctuations in water levels and susceptible to road salt and other surface activities (MacRitchie et al., 1994). A variety of local surficial granular deposits are used for domestic water supplies north of the Oak Ridges Moraine and just east of the Niagara Escarpment (MacRitchie et al., 1994).

Ottawa- St. Lawrence Lowlands

The Ottawa-St. Lawrence Lowlands extend from the Ottawa and St. Lawrence valleys into Quebec bounded on the west by the Frontenac Arch and to the north by the Canadian Shield.

Bedrock

The hydrogeology of the Ottawa valley is stongly influenced by the faults in the region. Average yields of 0.8 L/s in the bedrock in the western end of the area are satisfactory for domestic purposes. Much higher yields of 15 to 50 L/s suitable for small communities are found in areas where well developed fracture networks exist in the faulted bedrock, however significant interference issues between users are noted in this type of environment (MacRitchie et al., 1994).

In the Ottawa area, the Ottawa formation is massive and transmits very little water while in the St. Lawrence area, it has been developed as the main regional aquifer, capable of yielding 0.4 to 1.1 L/s (Brow, 1967; MacRitchie et al., 1994).

The Oxford Formation made up of limestone and shales, occupies about one third of the Ottawa-St. Lawrence area and supplies water to the Smith Falls-Brockville area. The average yield of this formation is 0.4 to 1.1 L/s but some high capacity wells yielding up to 32 L/s have been developed (MacRitchie et al, 1994). The Billings and Carlsbad Formations southeast of Ottawa are limited in extent and provide a small amount of very poor water (Brown, 1967).

Overburden

Large extensive buried overburden aquifers are uncommon in this area. Local small municipal and domestic wells however use limited confined aquifers found in the northern part of the South Nation River basin (Chin et al.; 1980; MacRitchie et al., 1994). Depth to the static water level ranges from 3 to 15 m below ground surface. The till and clay in this area has a very low conductivity at 10^{-10} m/s and provides a good confining layer to the bedrock aquifer in the Ottawa Formation (MacRitchie et al., 1994).

The Russell Prescott sand plain is considered an extensive unconfined aquifer for domestic use in the area. The hydraulic conductivity of the surficial deposits ranges from 10^{-4} m/s for the sand and gravel to 10^{-6} m/s for the fine sand (Woelfe, 1983; MacRitchie et al., 1994).

Canadian Shield

Bedrock

The Canadian Shield is bounded to the south by the Great Lakes Lowlands and to the north by the Hudson Bay Lowlands. Availability of groundwater is controlled on a regional scale by discontinuities including faults, lineaments, dykes and intensely weathered zones. Local flow systems are controlled by the interconnectiveness of the fracture sytems. Bedrock aquifer yields and hydraulic conductivities are therefore highly variable.

Overburden

Surficial deposits cover approximately 90% of the Canadian Shield. These granular deposits are extensively relied upon as a water supply even though there is an abundance of surface water. Since there are often problems with high bacteria levels in surface water, the overburden can provide groundwater for domestic or municipal consumption that does not require extensive treatment. Overburden aquifers are extensively used in Sudbury, Sault Ste. Marie, Iroquois Falls, Blind River, Hornepayne, Callandar, Raymore, Moonbeam and Fauquier (MacRitchie et al., 1994). The deposits are typically less than 40 m thick and commonly the well yields are 2 L/s. One municipal well in Nakina is reported to have a yield of 40 L/s and the municipal wells in Kapuskasing and Cochrane reportedly have yields of 16 L/s. Productive overburden aquifers are also present along the north shore of Lake Superior in the Marathon area. Low permeability clay plains provide good confining units across the area. Examples of such areas include New Liskeard and from Longlac north to Cochrane, extending up to James Bay (MacRitchie et al., 1994)

Hudson Bay Lowlands

Located in the northeast part of Ontario, the Hudson Bay Lowlands are a sparsely populated area containing only a few villages. The Hudson Bay Lowlands are a low, poorly drained plain covered with muskeg.

Limestone and dolomite are the most extensive bedrock types underlying the majority of the Lowlands area. This area and type of bedrock formation has the highest potential for high production wells. Individual wells have been reported to yield 16 L/s. Limited data for less prevalent sandstone formations show a lower yield of 1.9 L/s (MacRitchie et al., 1994). The low permeability lacustrine deposits provide a good confining unit for the underlying bedrock aquifers.