Water Use in the Grand River Watershed

April 2005

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EXECUTIVE SUMMARY

As the Grand River watershed continues to experience both economic and population growth, there will be increased demands on the basin's water resources to supply sufficient water to residential, commercial and industrial consumers. The Grand River Water Quantity Plan is addressing these concerns by quantifying both water availability and water use in an attempt to determine the sustainability of water use within the watershed, while taking into account temporal and spatial variations.

This report is an initial summary of present-day water use within the Grand River Basin. Water use estimates contained within the report will be constantly updated as new water takings come online, or improved data becomes available. Water use was broken into four subgroups: Municipal Water Supply Systems, Agricultural Water Use, Rural Domestic, and Operations on Private Supply (greater than 50,000 L/Day).

Water use estimates were determined using the best available data. Municipalities were contacted directly to establish municipal water use. Census of Population and Census of Agriculture were utilized to determine rural domestic as well as agricultural water use. Lastly the Permit To Take Water (PTTW) database was used to quantify any water uses that did not fall into the previous three groups. This analysis of has identified the following top 15 water uses within the basin.

1. Municipal Water Supply
2. Dewatering
3. Aggregate Washing
4. Aquaculture
5. Remediation
6. Golf Courses
7. Agriculture
8. Agricultural Irrigation
9. Other – Industrial
10. Miscellaneous
11. Manufacturing
12. Food Processing
13. Rural Domestic
14. Cooling Water
15. Recreational

While annual totals are useful for comparison purposes, seasonal and annual temporal changes in water use must be considered for an accurate representation of water taking. While agricultural irrigation is the eighth largest water user on an annual basis, during the month of July, this water use is the second most significant water use. During an extremely dry year, which requires more irrigation than an average year, this effect is much more pronounced.

In order to address a number of limitations in data sources and to increase the accuracy of estimates, a number of recommendations have been made.

1. That the water use estimates generated from this report be combined with estimates of water availability to identify possible water quantity issue areas.
2. While certain sectors, such as municipalities, are well organized and have provided actual water use statistics for use in this study, water use estimates that have been based from the PTTW database should be surveyed to determine if takings are active, and to measure actual water use, levels of consumption, and seasonality of the taking.

3. That consumptive ratios of all major water sectors be determined, as well as water diversions be identified.
4. That investigations into more accurate estimates of irrigated land continue including assessing the use of alternative methodologies such as remote sensing.
5. That development of a central database of water use in the watershed continues. This database would house recent information on municipal water systems as well as other water users.

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ACKNOWLEDGEMENTS

The Authors would like to acknowledge the following organizations and people for their invaluable support in determining water use estimates for the Grand River:

- The Grand River Conservation Authority's member municipalities for their support of this project and for supplying water use information.
- The Ministry of Natural Resources and Ministry of Environment for their support of the Water Budget Project.
- Rob de Loë and Reid Kreutzwiser at the University of Guelph for their work with agricultural water use.
- Rebecca Shortt with Ministry of Agriculture and Food, for crop irrigation support.
- The peer reviewers for the report, including the Water Managers Working Group, Rob de Loë and Rebecca Shortt.

As well as the following Grand River Conservation Authority staff:

- Lorrie Minshall – Project Management.
- Jeff Pitcher – GIS analysis.
- Pat Lapcevic – Groundwater support.
- Graham Smith, Zoë Green – GIS support.
- Mark McKinnon – Database management support.
- Amanda Wong – Data updates, report management support

1.0 INTRODUCTION

The Grand River watershed is approximately 6,700 km^2 is size and is home to over 800,000 residents. The population is expected to grow by 300,000 people in the next 20 years. As the watershed continues to attract both people and industrial enterprises, there will be increased demands on the water resources of the basin to support such growth. Realizing the increased strain on the basin's water resources, the Grand River Conservation Authority is developing a Water Quantity Plan, looking at current and future water use, as well as quantifying the amount of water resources available.

This report details the initial estimate of water use for the watershed, and identifies the major water use sectors. For the purposes of this report, water use has been divided into the 4 groupings, Municipal Supply, Agricultural, Unserviced Population, and Operations on Private Supply (Permits to Take Water). The Permits to Take Water (PTTW) are further broken down into user groups.

At various points throughout this report, cubic metres will be used to quantify water use. To put this into perspective, a household with 3 people will use approximately 1 m^3 per day, as average Canadian use is 0.340 m^3 per day (Environment Canada, 2003).

2.0 DESCRIPTION OF WATERSHED

At 6,700 km^2, the Grand River watershed is the largest watershed in southwestern Ontario. Located to the west of the Greater Toronto Area (GTA), the Grand River begins its 310 km long journey near the village of Dundalk, in the Dundalk Highlands, which is also the headwaters for such other rivers as the Nottawasaga, Saugeen and the Sauble Rivers. The Grand River picks up its major tributaries, the Conestogo, the Speed and the Nith Rivers, as it flows by the urban centers of Kitchener, Waterloo, Cambridge, Brantford. The City of Guelph is another urban centre in the Grand River watershed, located on the confluence of the Speed and the Eramosa Rivers. Downstream of Brantford, the Grand River passes by Six Nations, as well as the towns of Caledonia, Cayuga and Dunnville, before flowing into Lake Erie at Port Maitland. A general map of the watershed is included in Figure 1. The predominant land use in the watershed is agricultural; approximately 5% of the total area is devoted to urban centres.

In a physiographical sense, the Grand River can be divided into three distinct areas, as shown in Figure 2: the northern till plain; the central moraine and sand plains; and the southern clay plain. The northern till plain can be characterized by relatively tight tills, producing significant amounts of runoff, and small amounts of groundwater recharge. This area has very few areas of urban centres, with the dominant land use being agriculture. The central moraine area contains the watershed's three major moraines: the Waterloo, Galt/Paris and the Orangeville Moraines, which are shown in Figure 3. Also included in this area is a portion of the Norfolk Sand Plain, which is located just to the west of Brantford. Numerous sand and gravel deposits are located in this area, allowing significant amounts of groundwater recharge to be produced. It is within this central moraine area that the majority of the watershed's population is located, in the cities of Kitchener, Waterloo, Cambridge, and Guelph. The southern clay plain is the remnants of a previous lakebed. The heavy clays left behind when the lake receded, produce very high amounts of runoff, and do not allow significant water infiltration to produce groundwater recharge. The City of Brantford is located just on the northwestern edge of this area.

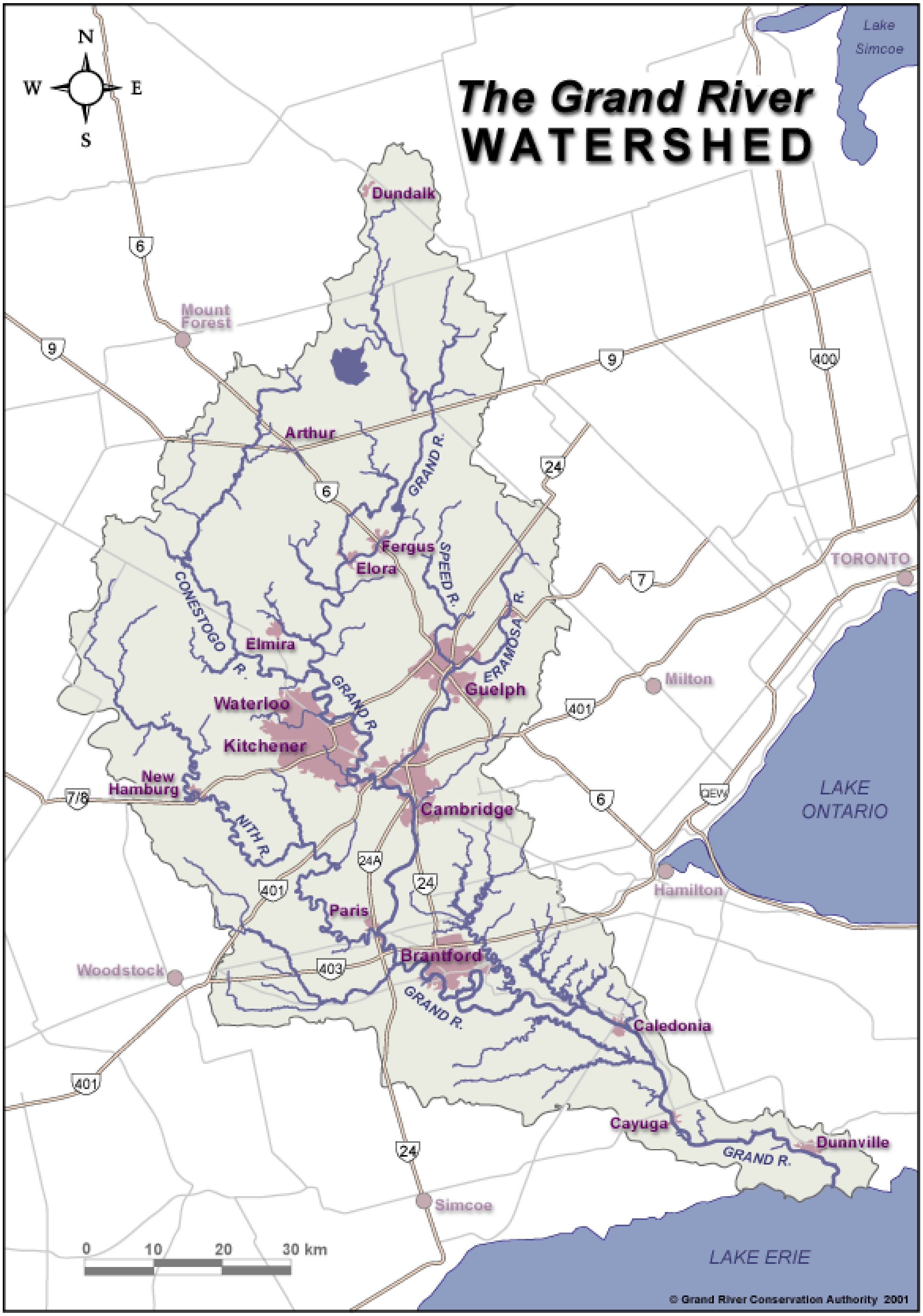

Figure 1: Map of the Grand River Watershed

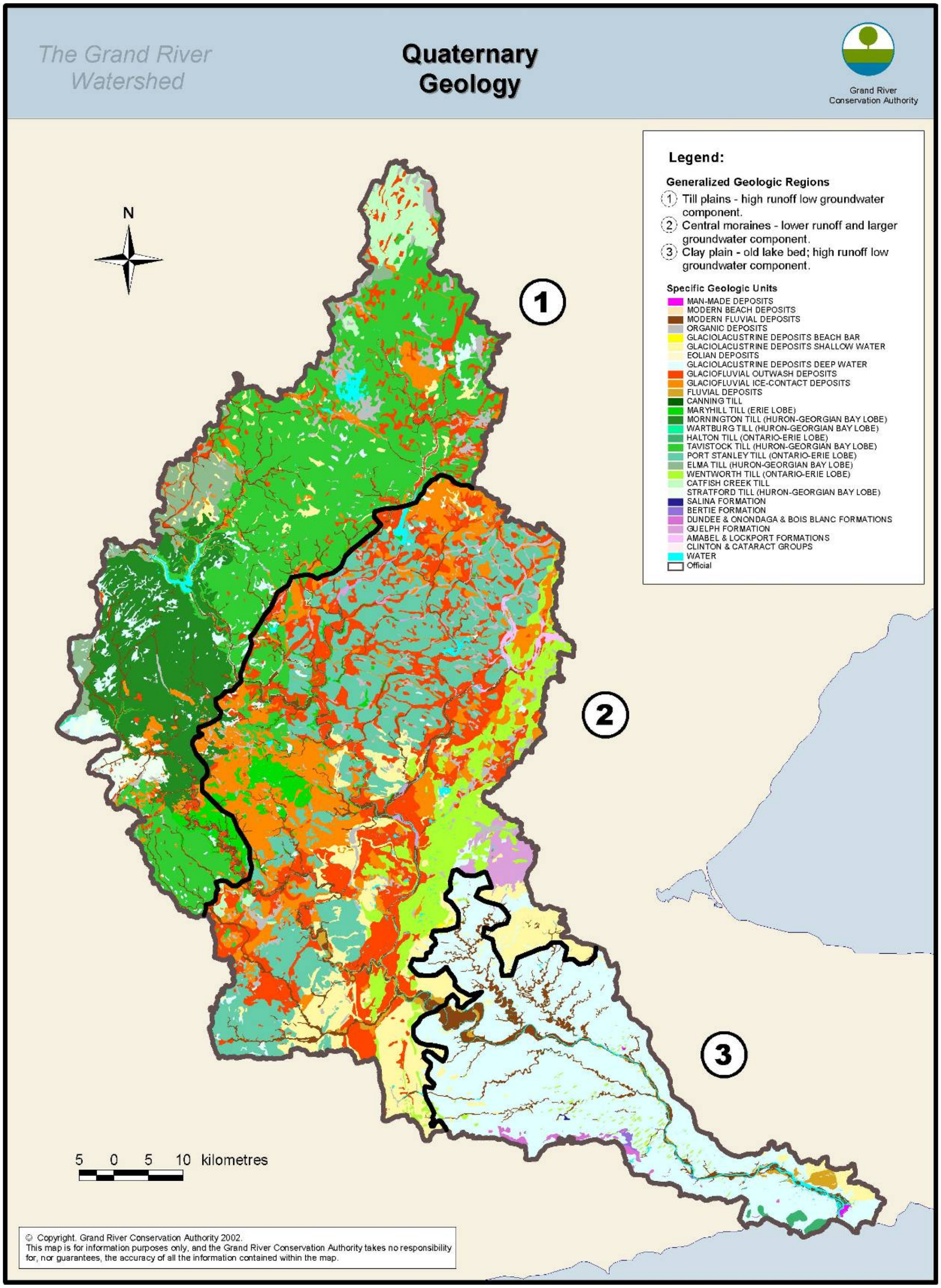

Figure 2: Quaternary Geology of the Grand River Watershed

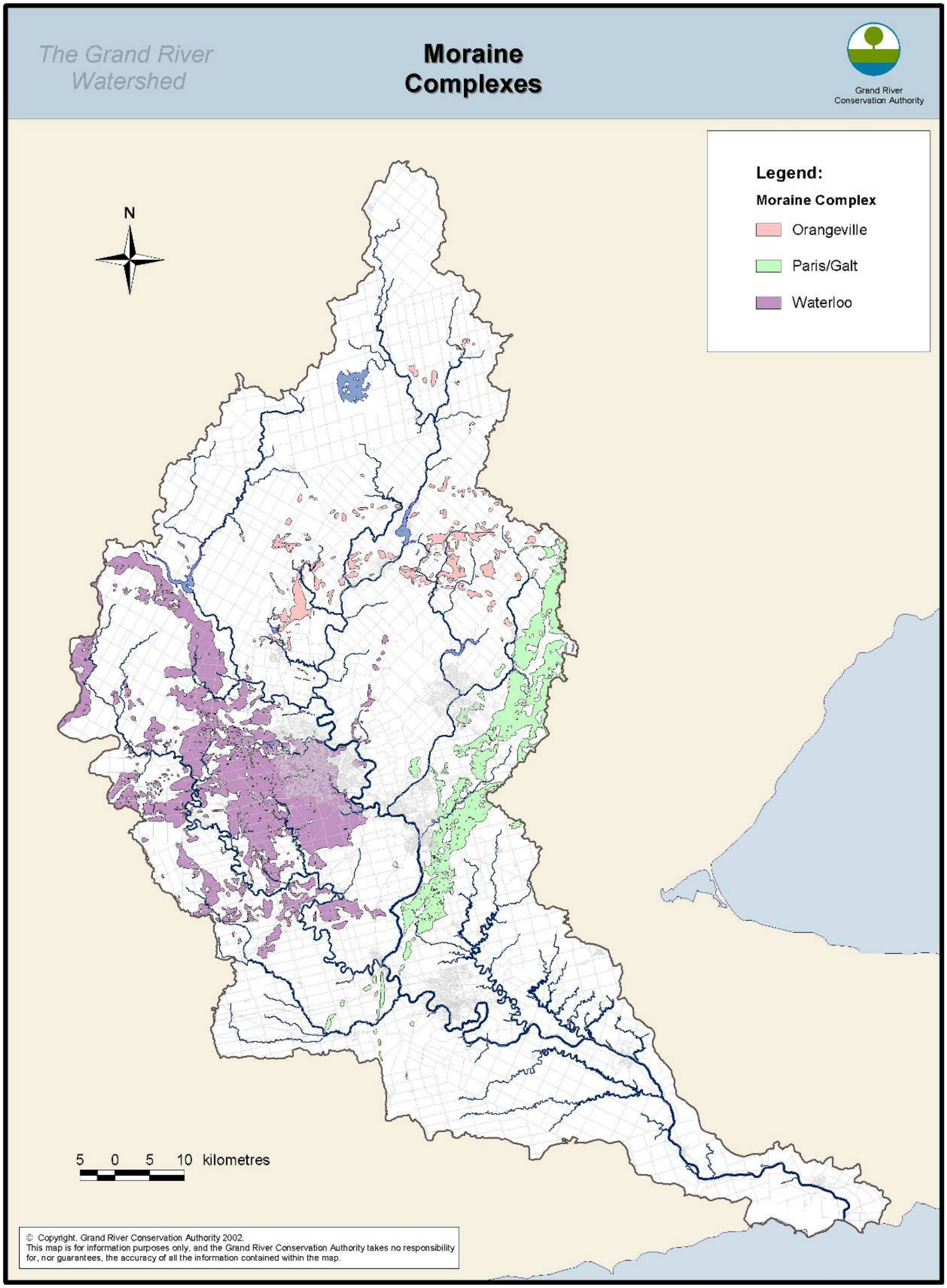

Figure 3: Moraine Complexes

3.0 MUNICIPAL WATER USE

Municipal water use is the supply of water provided through a central distribution system operated by a municipality. Various methods were employed to determine the amount of water municipal systems provided through its distribution. These methods included personal communication with municipal staff, data contained within EA reports, and a municipal water use survey completed in the summer of 1998. A complete picture of municipal water use, including serviced population, average daily demand and maximum daily demand has been produced, as well as the UTM coordinates of the supply wells/river intakes were provided by the municipalities. Figure 4 shows the municipal water supply sources within the watershed.

It is important to note that municipal water use not only includes urban domestic use, whether indoor or outdoor and also includes any industries, institutions or commercial ventures that rely on municipalities for their water supply.

Supply sources, as seen in Figure 4, were from groundwater including shallow, overburden and deep wells, and surfacewater sources such as rivers in the watershed. Municipal groundwater supplies were broken into deep overburden/bedrock wells and overburden wells. This was done to differentiate between wells that draw from large regional aquifers (deep wells), and wells that draw from aquifers that are more local in scale (overburden wells).

Wells that have contributing areas that can be represented by a surface water catchment (local scale aquifers) will be included in the first phase of Water Budget calculations. Deeper wells, which may have contributing areas that reach beyond a particular surface water catchment, or even the particular major basin the well is located in, will be incorporated into later phases of the Water Budget project.

Municipal water takings can be expressed as a depth over the surface water catchment from which the taking is located (see Figure 5). This value is calculated by dividing the total volume of the taking by the catchment area. Depths are useful for comparing water uses to annual average precipitation, ranging from 900-1000 mm in this region, and also provide a consistent basis for comparing various water uses. Subsequent maps will utilize this method of displaying water use across the watershed.

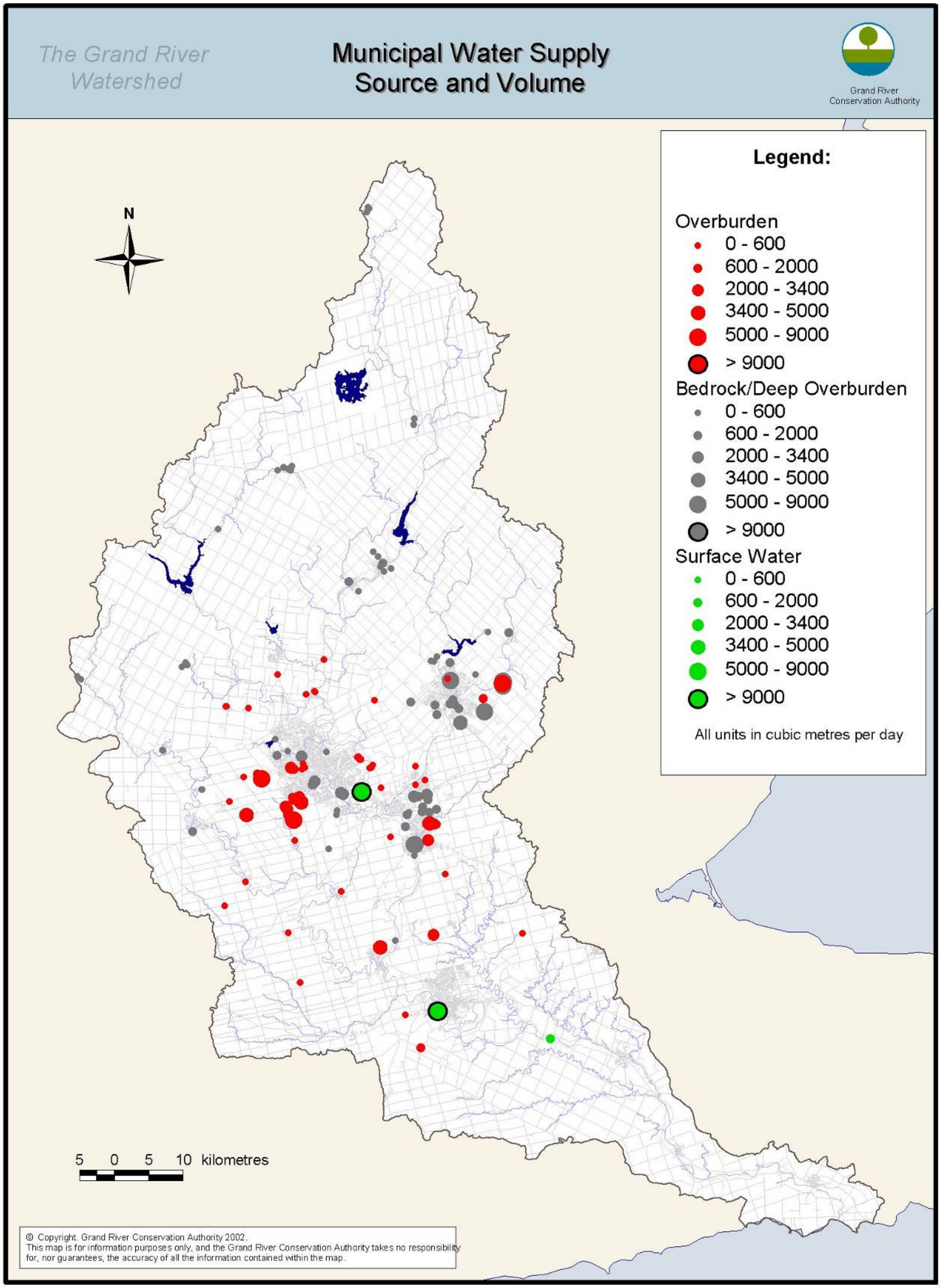

Figure 4: Municipal Water Supply Sources

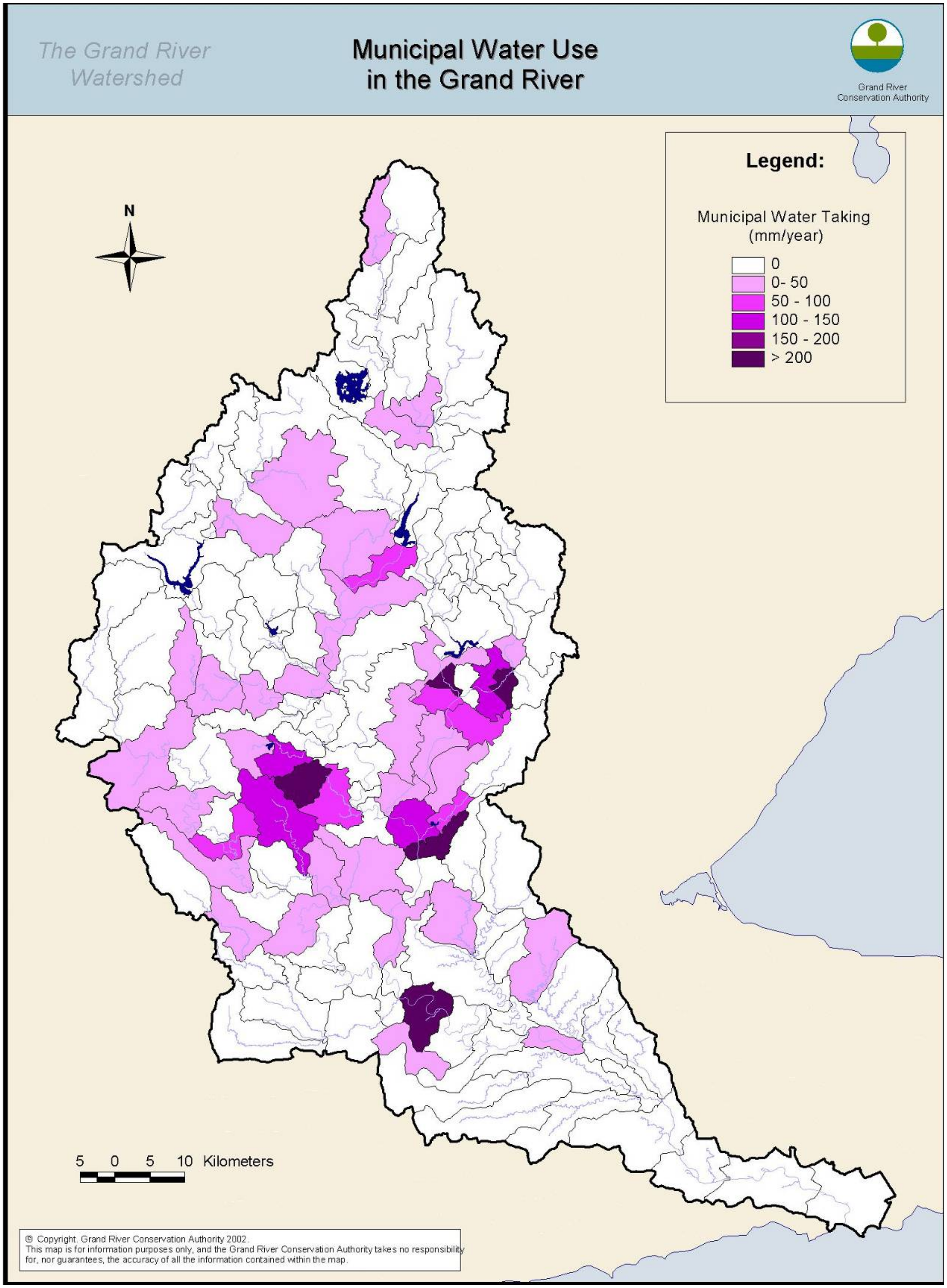

Figure 5: Municipal Water Use in the Grand River Watershed

Each municipal water system in the watershed is listed in Table 1, along with the serviced population, average daily demand, average per capita demand, maximum daily demand and maximum per capita demand. While per capita values are listed, they should not be used to compare between municipal systems, as differing proportions of residential, and Industrial, Commercial and Institutional (ICI) demand may vary widely from municipality to municipality. While most large municipal systems have readily accessible information on the residential (household only) and ICI proportions, many of the smaller systems do not have this information available. For this reason, only residential per capita rates for certain communities are included in Table 2.

Table 1: Municipal Water System Information

Municipality	Municipal System	Year of Data	Serviced Pop	Average Day		Max Day		System Capacity (approx)	Water Source	Data Source
				Actual	Per Capita	Actual	Per Capita			
				m^3/d	$m^3/d/capita$	m^3/d	$m^3/d/capita$	m^3		
Brant	Paris	2004	9,560	1264	0.1322	1870	0.1958	2271	Groundwater	Communication with Municipal Staff
Brant	Airport	2004	540	225	0.4159	470	0.8704	570		Communication with Municipal Staff
Brant	St. George	2004	2,720	470	0.1726	2820	1.0371	5357	Groundwater	Communication with Municipal Staff
Brant	Mount Pleasant	2004	1,290	589	0.4565	1616	1.2527	450	Groundwater	Communication with Municipal Staff
City of Brantford	City of Brantford	2002	86,000	47,000	0.5465	81,000	0.9419	100,000	Grand River	Communication with Municipal Staff
City of Guelph	City of Guelph	2002	125,416*	52,200	0.4162	65,647	0.5835**	75,000	Groundwater with Enhanced Infiltration with Eramosa River Water	Communication with Municipal Staff
Dufferin	Grand Valley	1998	1,600	400	0.2500	1,676	1.0475	2,246	Groundwater	1998 Municipal Survey
Dufferin	Waldemar	2002	328	200	0.4634	562	1.7134	1,000	Groundwater	Phase 1-2 report for A Class EA for Water Supply for the Community of Waldemar - 2003
Grey	Dundalk	2001	1,902	700	0.3680	1,225	0.6441	1,938	Groundwater	Communication with Municipal Staff
Haldimand	Dunnville	2001		5237		12,385			Lake Erie	Communication with Municipal Staff
Haldimand	Cayuga	2001		687		1,108		2,333	Lake Ontario via City of Hamilton	Communication with Municipal Staff
Haldimand	Caledonia	2003	7,666	3553		5824		13,000	Lake Ontario via City of Hamilton	Communication with Municipal Staff
Oxford	Bright	1999	369	100	0.2710	230	0.6233	412	Groundwater	Communication with Municipal Staff
Oxford	Drumbo	1999	528	200	0.3788	465	0.8807	1,341	Groundwater	Communication with Municipal Staff
Oxford	Plattsville	1998	1,144	500	0.4371	1,342	1.1731	1,964	Groundwater	Environmental Study Report - Plattsville Water and Sewage System - 1999
Perth	Milverton	1998	1,739	800	0.4600	2,000	1.1501	1,432	Groundwater	1998 Municipal Survey

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Municipality	Municipal System	Year of Data	Year of Data	Average Day		Max Day		System Capacity (approx)	Water Source	Data Source
				Actual	Per Capita	Actual	Per Capita			
				m^3/d	$m^3/d/capita$	m^3/d	$m^3/d/capita$	m^3		
Regional Municipality of Waterloo	Integrated Urban System (Cambridge, Kitchener, Waterloo, Elmira, St Jacobs)	2001	411,000*	165,000	0.4015	239,200	0.5995**	260,000	Approx 75% Groundwater, 25% Surface Water	2002 Water and Wastewater Monitoring Report, Region of Waterloo
Regional Municipality of Waterloo	Baden, New Hamburg	2001	7,600	2,200	0.2829	3,664	0.4821	12,000	Groundwater	2002 Water and Wastewater Monitoring Report, Region of Waterloo
Regional Municipality of Waterloo	Ayr	2001	3,770	1,500	0.3870	2,447	0.6491	2,300	Groundwater	2002 Water and Wastewater Monitoring Report, Region of Waterloo
Regional Municipality of Waterloo	Wellesley	2001	1,740	400	0.2385	925	0.5316	1,500	Groundwater	2002 Water and Wastewater Monitoring Report, Region of Waterloo
Regional Municipality of Waterloo	St. Clements	2001	1,320	300	0.2136	647	0.4902	1,750	Groundwater	2002 Water and Wastewater Monitoring Report, Region of Waterloo
Regional Municipality of Waterloo	Branchton Meadows	2001	116	30	0.2241	82	0.7070	130	Groundwater	2002 Water and Wastewater Monitoring Report, Region of Waterloo
Regional Municipality of Waterloo	Roseville	2001	214	90	0.4065	285	1.3320	358	Groundwater	2002 Water and Wastewater Monitoring Report, Region of Waterloo
Regional Municipality of Waterloo	Linwood	2001	604	200	0.3310	477	0.7900	743	Groundwater	2002 Water and Wastewater Monitoring Report, Region of Waterloo
Regional Municipality of Waterloo	Eastgate Meadows	2001	145	30	0.2138	105	0.7240	717	Groundwater	2002 Water and Wastewater Monitoring Report, Region of Waterloo
Regional Municipality of Waterloo	Heidelburg	2001	821	220	0.2667	599	0.7300	829	Groundwater	2002 Water and Wastewater Monitoring Report, Region of Waterloo
Regional Municipality of Waterloo	New Dundee	2001	1,175	340	0.2860	726	0.6180	983	Groundwater	2002 Water and Wastewater Monitoring Report, Region of Waterloo
Regional Municipality of Waterloo	Foxboro Green	2001	432	70	0.1690	145	0.3360	228	Groundwater	2002 Water and Wastewater Monitoring Report, Region of Waterloo
Regional Municipality of Waterloo	St. Agatha	2001	49	20	0.4898	87	1.7760	518	Groundwater	2002 Water and Wastewater Monitoring Report, Region of Waterloo
Regional Municipality of Waterloo	Conestogo Golf Course	2001	233	120	0.5021	361	1.5490	601	Groundwater	2002 Water and Wastewater Monitoring Report, Region of Waterloo

Municipality	Municipal System	Year of Data	Year of Data	Average Day		Max Day		System Capacity (approx)	Water Source	Data Source
				Actual	Per Capita	Actual	Per Capita			
				m^3/d	$m^3/d/capita$	m^3/d	$m^3/d/capita$	m^3		
Regional Municipality of Waterloo	Conestogo Plains	2001	287	120	0.4286	411	1.4320	199	Groundwater	2002 Water and Wastewater Monitoring Report, Region of Waterloo
Regional Municipality of Waterloo	Maryhill	2001	213	40	0.1737	112	0.5260	157	Groundwater	2002 Water and Wastewater Monitoring Report, Region of Waterloo
Regional Municipality of Waterloo	Maryhill Village Heights	2001	132	60	0.4318	190	1.4390	820	Groundwater	2002 Water and Wastewater Monitoring Report, Region of Waterloo
Regional Municipality of Waterloo	West Montrose	2001	154	70	0.4416	177	1.1490	238	Groundwater	2002 Water and Wastewater Monitoring Report, Region of Waterloo
Wellington	Fergus	2001	8,008	4,600	0.5744	6,165	0.7699	8,647	Groundwater	Communication with Municipal Staff
Wellington	Elora	2001	4,122	1,800	0.4367	2,512	0.6094	3,436	Groundwater	Communication with Municipal Staff
Wellington	Arthur	1998	2,200	1,100	0.5000	1,182	0.5373	1,364	Groundwater	1998 Municipal Survey
Wellington	Rockwood	2001	2,973	900	0.2860	2,126	0.7150	1,964	Groundwater	Phase 1, 2 & 3 Class EA for the Development of Additional Water Supply for the Village of Rockwood - 2002
Wellington	Drayton	1998	1,280	500	0.3906	731	0.5710	1,136	Groundwater	1998 Municipal Survey
Wellington	Hamilton Drive	2001	1,000	250	0.2500	683	0.6828		Groundwater	Communication with Municipal Staff
Hamilton	Lynden	2003	400	150	0.3750	375	0.9375		Groundwater	Communication with Municipal Staff

* Winter Populations Used

** For Maximum Day Per Capita, Summer Population Used

Table 2: Residential Per Capita Rates for Selected Watershed Communities

Community	Residential Per Capita Demand (Litres/day/capita)	Unaccounted Water (% of Total)
Brantford	298	13.6
Cambridge	303	15.5
Guelph	188	17.3
Kitchener	235	14.9
Waterloo	197	8.0

In order to illustrate how municipal supply changes from month to month, information on monthly distributions of municipal water use was required. Larger municipalities could provide such distributions, whereas many smaller communities could not. Monthly distributions from larger municipalities were substituted where no distributions were available. Table 3 lists the monthly patterns for the Regional Municipality of Waterloo's (RMOW) Integrated Urban System, smaller systems in the RMOW, the City of Guelph and the City of Brantford. Smaller communities throughout the watershed had monthly patterns assigned to them using the smaller RMOW systems.

Table 3: Monthly Distribution of Average Daily Municipal Water Use

Municipal System	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
City of Brantford	0.89	0.89	0.88	0.92	1.03	1.11	1.29	1.17	1.06	0.94	0.91	0.90
City of Guelph	0.99	0.98	1.00	0.99	1.03	1.04	1.08	1.03	1.01	0.98	0.96	0.91
RMOW - IUS	0.95	0.95	0.96	0.97	1.01	1.05	1.13	1.09	1.04	0.97	0.96	0.93
RMOW Smaller Systems	0.89	0.93	0.92	0.95	0.99	0.99	1.09	1.12	1.10	1.06	1.00	0.94
Smaller Systems	0.89	0.93	0.92	0.95	0.99	0.99	1.09	1.12	1.10	1.06	1.00	0.94

Figure 3 and Table 4 below, illustrates the breakdown of municipal water supply by source. Deep overburden and bedrock sources are more regional in scale than the overburden aquifers, due to the depth of the extraction point. The Grand River, its tributaries and the Great Lakes (mostly Lake Erie) are the surfacewater sources in the watershed.

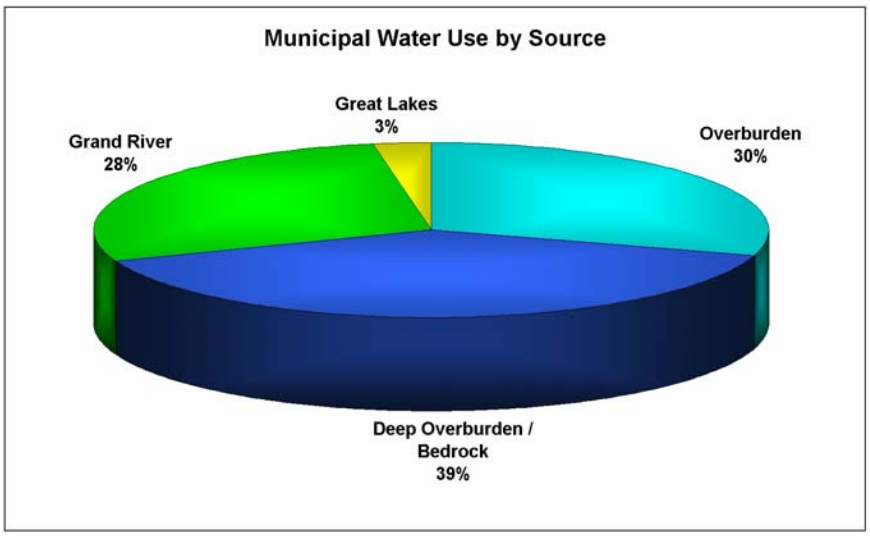


Figure 6: Municipal Water Use by Source

Table 4: Municipal Water Use by Source

Source		Volume of Use
Groundwater	Overburden	32,604,000 m^3
	Deep Overburden/ Bedrock	43,281,000 m^3
	Total Groundwater	**75,885,000 m^3**
Surface Water	Grand River	30,594,000 m^3
	Great Lakes	3,040,000 m^3
	Total Surface Water	**33,634,000 m^3**
TOTAL MUNICIPAL WATER USE		**109,519,000 m^3**

While the majority of municipalities rely on groundwater for their drinking water supplies, surface water is becoming increasingly more significant. The City of Brantford is exclusively dependent on the Grand River for its municipal water supply, with the RMOW now relying on the Grand River for roughly 25% of the water supply to the urban centres of Kitchener, Waterloo and Cambridge. This percentage will continue to increase as the RMOW brings Aquifer Storage and Recovery (ASR) online. The City of Guelph also takes water from the Eramosa River to enhance infiltration in the Arkell area. However, because this water taking is accounted for within the groundwater pumpages for the City of Guelph, it was not included as a surface water taking as well. Supplies from the Great Lakes do not contribute significantly to the total municipal water supply.

4.0 AGRICULTURAL WATER USE

Agricultural water use was divided into two categories, livestock/farming operation water use, and crop irrigation water use. This division was based on the information availability of the 2 categories, as well as their differing water requirements throughout the year.

4.1 Livestock/Farming Operations

Water use for livestock and other farming operations are generally year-round takings, as opposed to crop irrigation, which only occurs during the summer growing season. Water use estimates are more difficult to approximate than other water uses, since a Permit to Take Water is not required for animal watering. The exception to this is water that is taken into a storage facility prior to animal watering, which does require a PTTW. Thus, the estimates would rely on external information and research on livestock daily water needs and the number of livestock in the watershed.

The National Soil and Water Conservation Program recognized the gap in water use estimates, and contracted research out to the University of Guelph to, among other objectives, verify and update agricultural water use data on a sector-by-sector basis. The study, by Kreutzwiser and de Loë (1999), built upon previous work by refining existing water use coefficients for specific farming practices. This study has been updated recently, which will be incorporated into later versions of water use estimates.

A spreadsheet tool was created in the study (Kreutzwiser and de Loë, 1999), which allowed the user to import Census of Agriculture data, and calculate the total agricultural water use for a particular geographic unit. The study has determined various water use coefficients for the different types of information contained within the Census of Agriculture, such as animal populations and farming practices. By multiplying the water use coefficients (e.g. dairy cows consuming 90 L/day) by the number of animals or crop type/area, total agricultural water use for the specific geographic region can be calculated. Data from the Census of Agriculture from 1996 was used to generate water use estimates for this report (Statistics Canada, 1996). Figure 7 displays the results of this analysis.

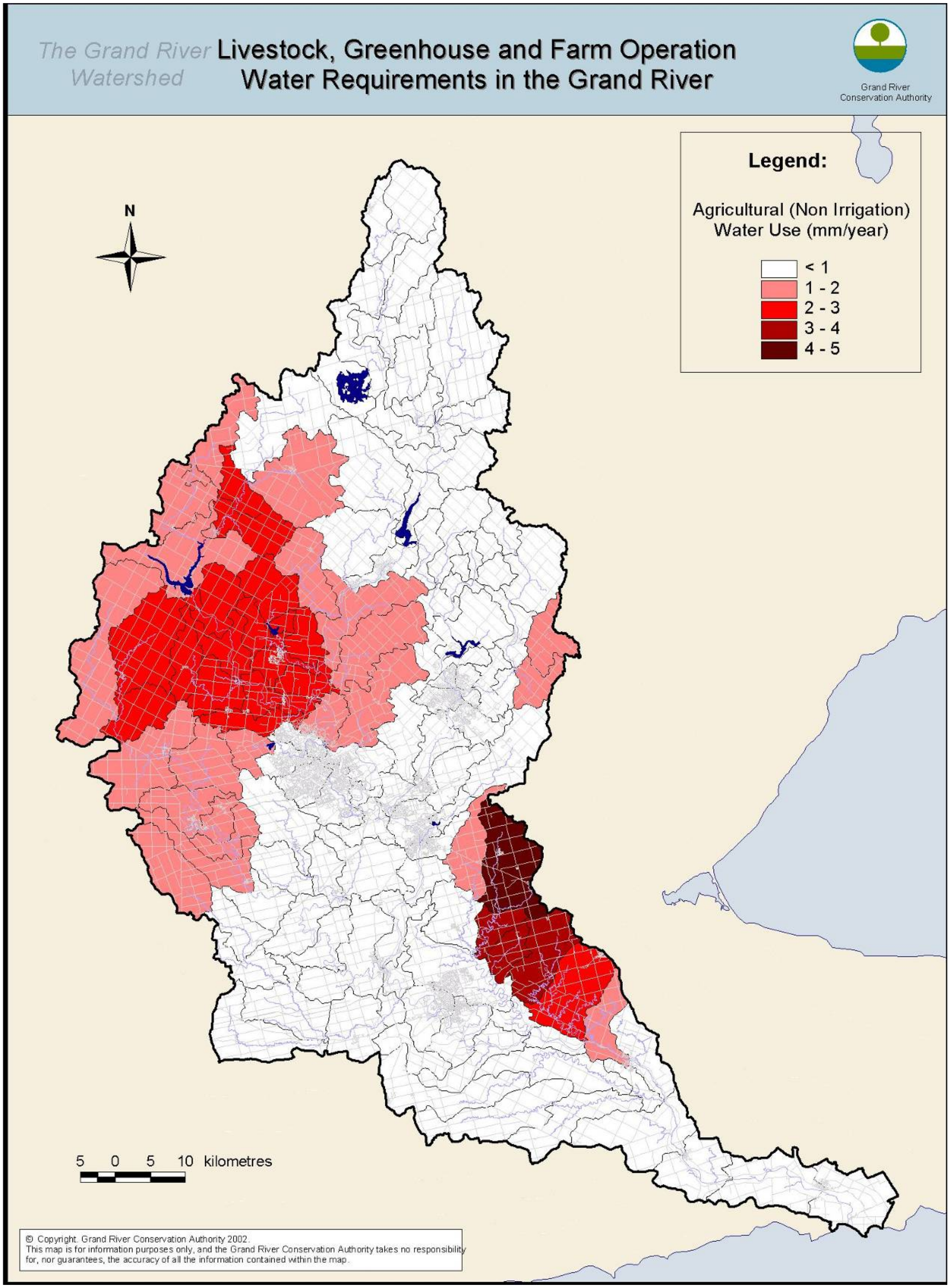


Figure 7: Livestock and Farm Operation Water Requirements

All water use related to crop irrigation (e.g. tobacco, vegetables and sod) was not included in this exercise, as crop irrigation will be accounted for in a separate calculation and discussed in the next section.

Census of Agriculture data, reported on a census consolidated subdivision (CCS) basis, was translated to a surfacewater catchment basis for consistency with other water uses. Weighted averaging was used to translate the data, which assumes that the data is evenly distributed throughout the CCS. This is a significant assumption, and may not hold true when agricultural practices are determined by a specific landform (i.e. geology).

The coefficients derived by Kreutzwiser and de Loë (1999) assume that some agricultural water uses, such as livestock watering, remains constant throughout the year. Water requirements that are specific for a particular season, such as crop washing, are assigned solely to that particular season.

It is estimated that agricultural water uses, other than irrigation, account for 9,645,000 m^3 per year.

4.2 Crop Irrigation

Crop irrigation is the application of supplemental water onto cropped fields when natural precipitation is insufficient. While it is possible to calculate water use for crop irrigation using the technique outlined for livestock/farming operations in the previous section, the need to investigate annual variations in water use required estimation using an irrigation demand model. In order to determine the water requirements for crop irrigation, one must determine both the amount of land irrigated and the number of irrigation events per year.

4.2.1 Area of Irrigated Land

The amount of irrigated land is reported in the Census of Agriculture, and was used for this study to quantify the extent of irrigated land in the watershed. However, transfer of data from the Census reporting units to surface water catchments required the same assumption of uniform distribution as described in the preceding section for other agricultural practices. Because the occurrence of crop irrigation is so dependent to a particular soil type, this assumption may not hold true in all cases. The Grand River Conservation Authority is currently investigating remote sensing methodologies to identify irrigated land, which would negate the reliance on Census of Agriculture data and the governing assumptions.

By investigating the reported amount of irrigated land in the Census of Agriculture, one can identify certain trends. By summarizing the total irrigated land in the Grand River watershed from the 1986, 1991, and 1996 Agricultural Census (Statistics Canada, 1986, 1991, 1996), as shown in Figure 8, one can observe more than a doubling of irrigated land from 2,900 ha in 1985 to 6,100 ha in 1995 (Agricultural Census asks farmers the amount of land they irrigated the previous year).

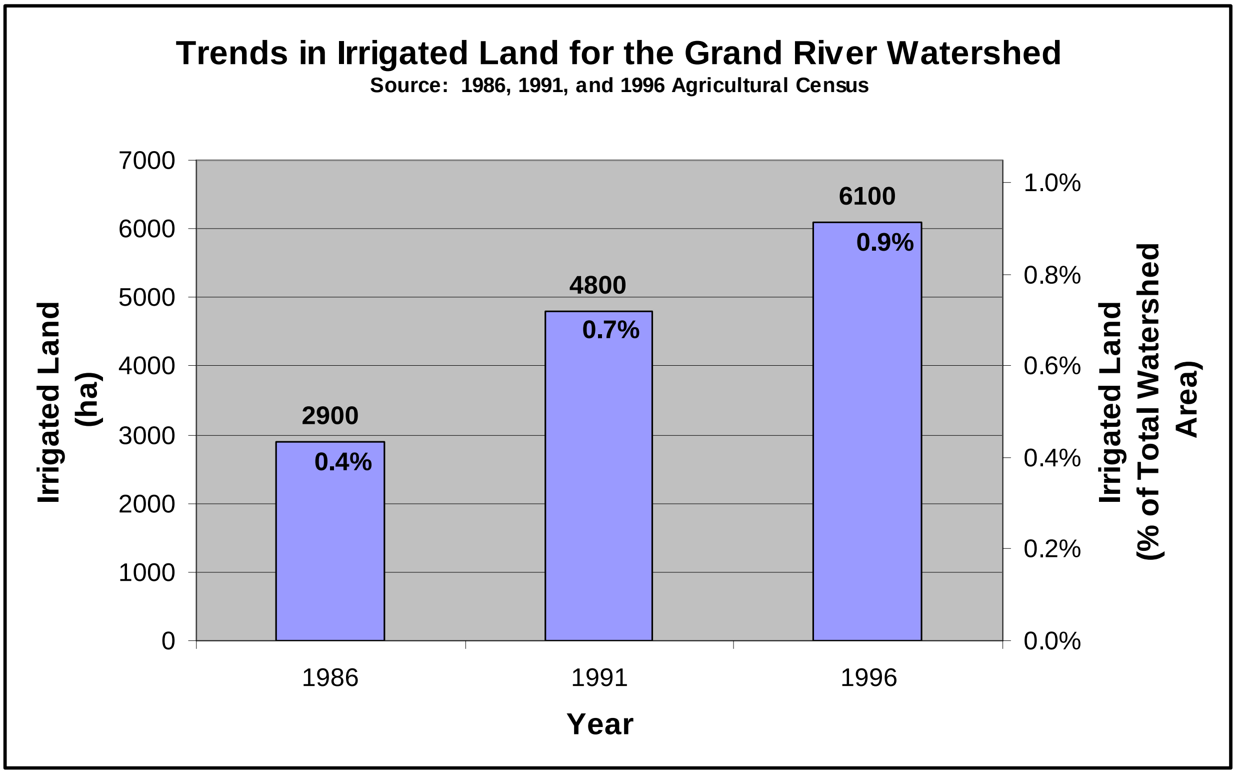


Figure 8: Trends in Irrigated Land for the Grand River Watershed

4.2.2 Number of Irrigation Events

In order to estimate the number of irrigation occurrences, an irrigation demand model was developed that could predict the number of times farmers would be required to irrigate their crops. This model used synthetic daily soil moisture data from the **G**uelph **A**ll-**W**eather **S**equential **E**vents **R**unoff (GAWSER) model, which was generated from the Water Availability component of the Water Budget Project. For further information on GAWSER and its application as a water management tool see GAWSER: A Versatile Tool For Water Management Planning, (Schroeter *et al*., 2000).

The GAWSER model, used for the Water Availability component uses a combination of quaternary geology, land cover, hummocky topography and precipitation to estimate the water cycle at all points in the watershed. The hydrologic model runs continuously from 1961 to 1999 to generate estimates of all aspects of the water cycle. By running in a continuous fashion, it is possible to generate a time series of soil moisture for well drained agricultural land.

The number of irrigation events is calculated based on soil moisture content. It is generally accepted that vegetation becomes stressed when the soil moisture content drops below 55% of the soils water storage (Schwab *et al*., 1981) or halfway between field capacity and wilting point. It is assumed that crops would require irrigation at this point. The GAWSER model requires that the soil moisture remain under this point (55% soil moisture) for an extended period of time to trigger an event, in order to reduce the number of irrigation events that occur just before a large increase in soil moisture (a large rainfall event). The depth of soil that is assumed to be within the active root zone for measuring for soil moisture is 300 mm (AAFC OMAF, 1995). The irrigation demand model tracks soil moisture in the root zone and when it reaches the critical level, an irrigation event is triggered applying 25 mm or 1 inch of water with a 65% efficiency rating (Keller and Bliesner, 1990; Allen, 1991). The irrigation season for this region is between June 20 and September 10, and irrigation events can only be triggered in between these dates. If the soil moisture falls below the critical level outside of these dates, no irrigation event is triggered. The applied water is included to the soil moisture time series, and is evaporated as time moves on. When the soil moisture reaches the critical level again, another irrigation event is triggered.

With this irrigation demand model running continuously from 1961 to 1999, one can determine how irrigation demand changes from year to year.

Included below are Figures 9 and 10, which illustrate the irrigation demand model output, for two different years, 1992 – a wet year, and 1998 – a dry year, respectively. The blue area represents soil moisture, with the yellow areas denoting the soil moisture added by irrigation events.

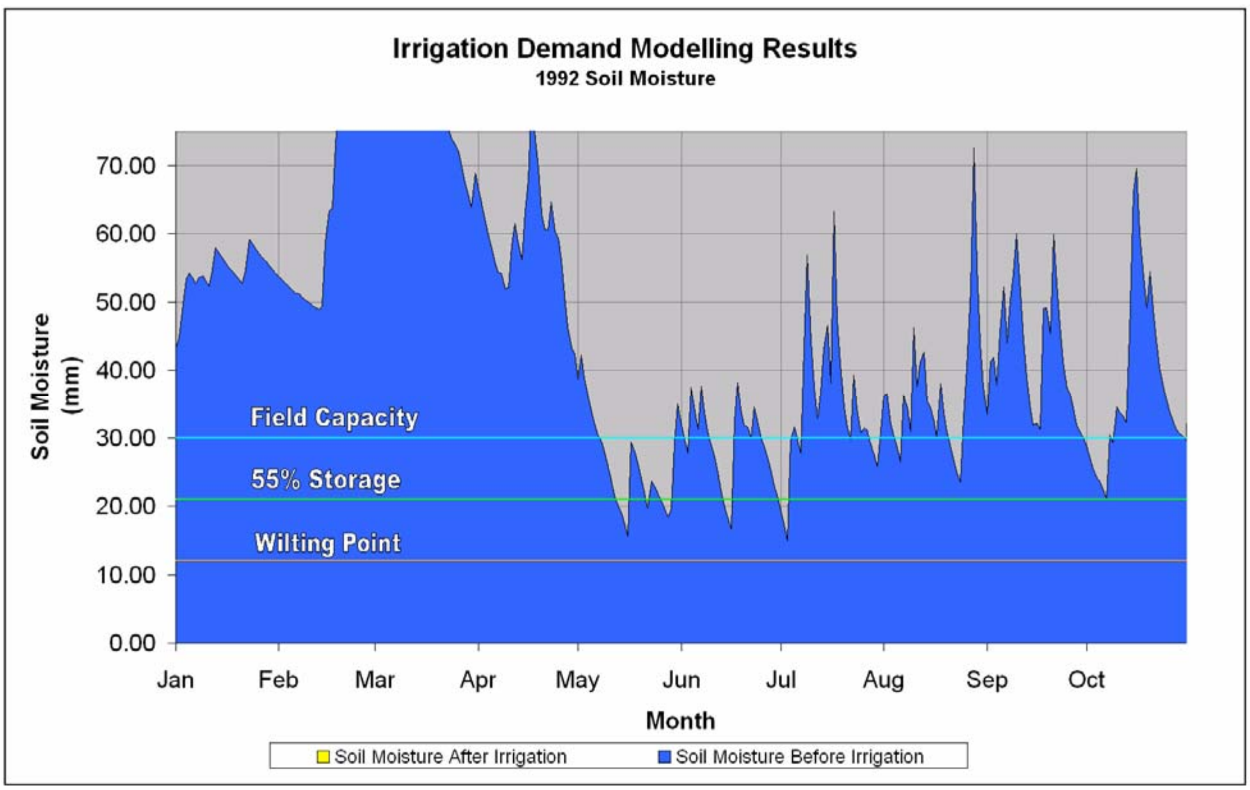


Figure 9: Irrigation Demand Modelling – Wet Year

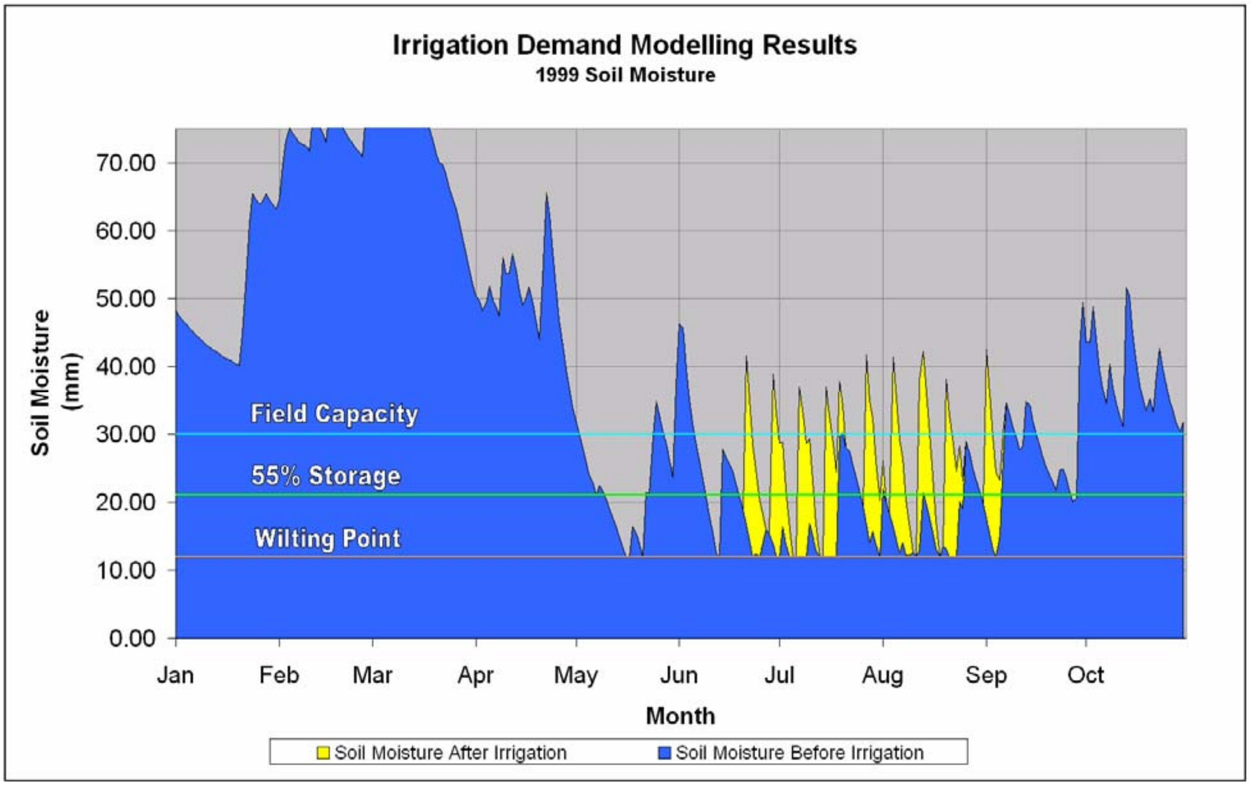
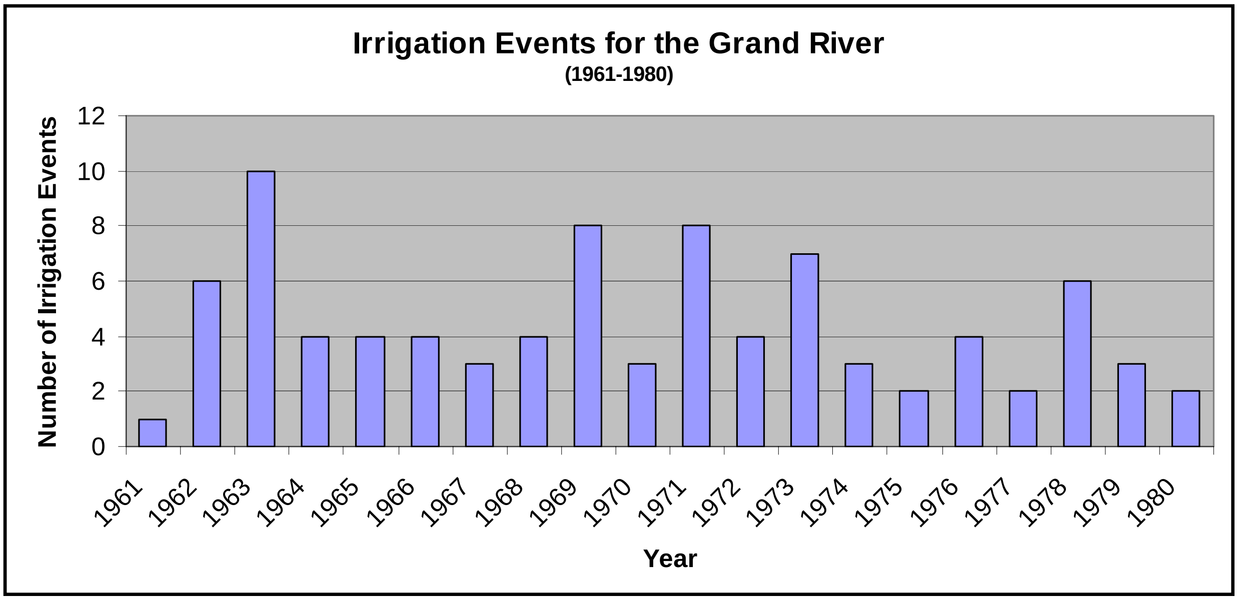


Figure 10: Irrigation Demand Modelling – Drought Year

This type of analysis is useful in determining the temporal variability of irrigation events, and ultimately water demand. Establishing how water use can change with precipitation patterns can be an integral component of water management. The number of irrigation events predicted for each year is included in Figure 11.



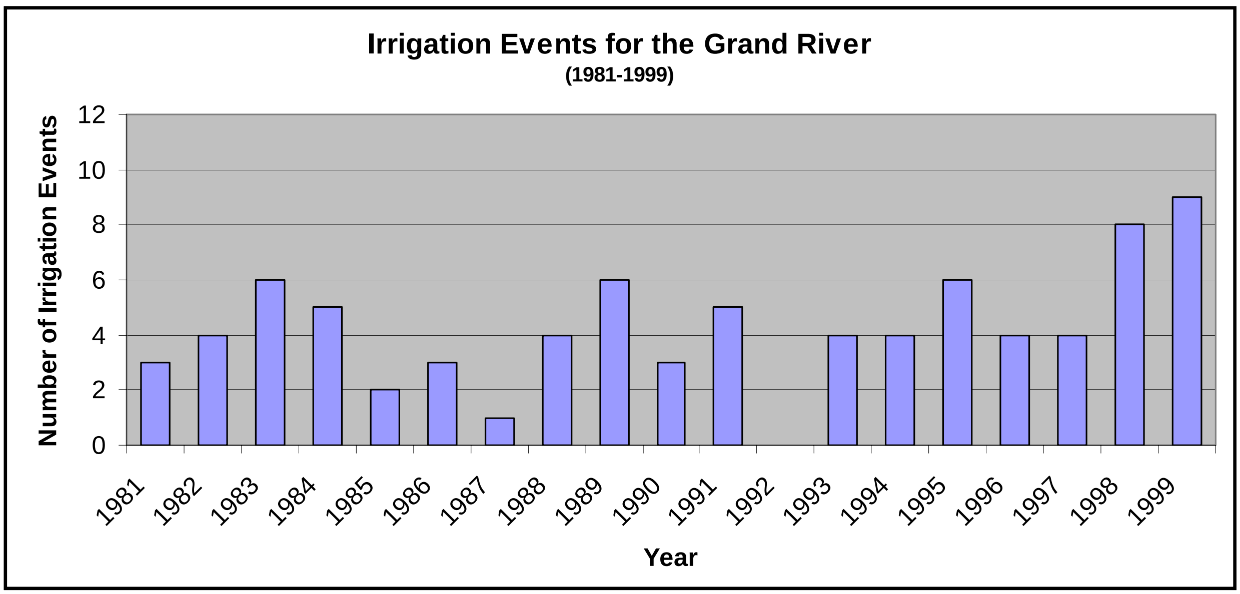


Figure 11: Irrigation Events Predicted 1961-1999

The variability of irrigation events across the years is seen in Table 5, as well as the associated water requirement for the watershed.

Table 5: Range of Irrigation Events and Irrigation Water Demand in 2001

Range	Irrigation Events	Water Demand (cubic metres)
Minimum	0	0
1st Quartile	3	5,242,000
Median	4	6,989,000
3rd Quartile	6	10,483,000
Maximum	10	17,472,000

The irrigation demand model only considers irrigation events meant for maintaining soil moisture at adequate levels for plant growth. Irrigating for climate control, such as spring irrigation to protect against frost, was not considered in this exercise.

The Permit To Take Water database was analyzed to determine a possible breakdown of source of irrigation water. It was determined that from 509 agricultural irrigation sources, 313 were supplied by groundwater, and 196 were supplied from surface water, producing a 61%, 39% split, respectively.

Total annual water demand for crop irrigation (for an average year) is displayed in Figure 12. The majority of irrigation takes place in the southwestern portion of the watershed. This is due to the extensive cash cropping taking place in the Norfolk Sand Plain.

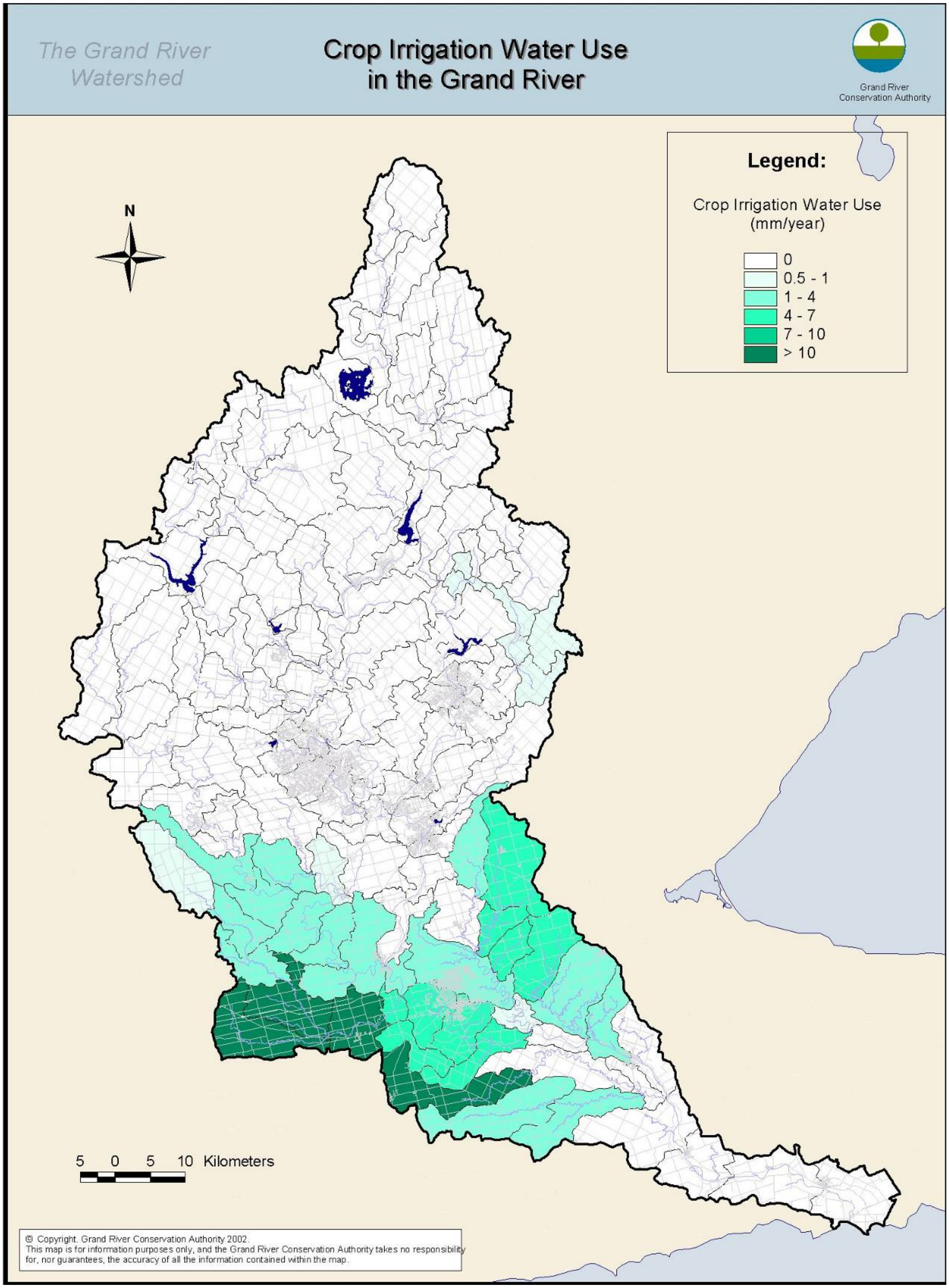


Figure 12: Average Crop Irrigation Water Demand

5.0 UNSERVICED DOMESTIC WATER USE

Unserviced domestic water use is all water uses for domestic (indoor and outdoor residential water use) use that are not on a municipal distribution system. Generally, these are rural communities, and water could be taken from private wells. While a relatively minor component of the overall watershed water use, unserviced domestic water use can represent a significant water use in some localized areas of the watershed.

Census of Population from Statistics Canada provides human population on an Enumeration Area basis. By removing the enumeration areas that are within municipally serviced communities, a total for unserviced population can be determined.

The population across the Enumeration Areas was assumed to be evenly distributed. This assumption allowed the Enumeration Areas to be summarized on a surfacewater catchment basis.

Rural domestic per capita water use has traditionally been much lower than urban domestic use. This can be attributed to rural residents being more aware of the demands placed on their well and/or septic system and less outdoor water use. While the actual rate varies depending on a large number of factors, 160 L/day was assumed to be the rural domestic per capita water use rate (Vandierendonck and Mitchell, 1997). It should be noted that a large percentage of this water is likely returned to the shallow groundwater system via septic systems. This water use is assumed to be relatively constant throughout the year.

This analysis was carried out using 1991 Census of Population data (Statistics Canada, 1991). This process will be repeated with 2001 Census data.

It is estimated through this process that 115,000 people have private water supplies and draw 6,700,000 cubic metres of water per year. It is assumed that the water source for all unserviced homes is groundwater. Figure 13, displays the results of this analysis.

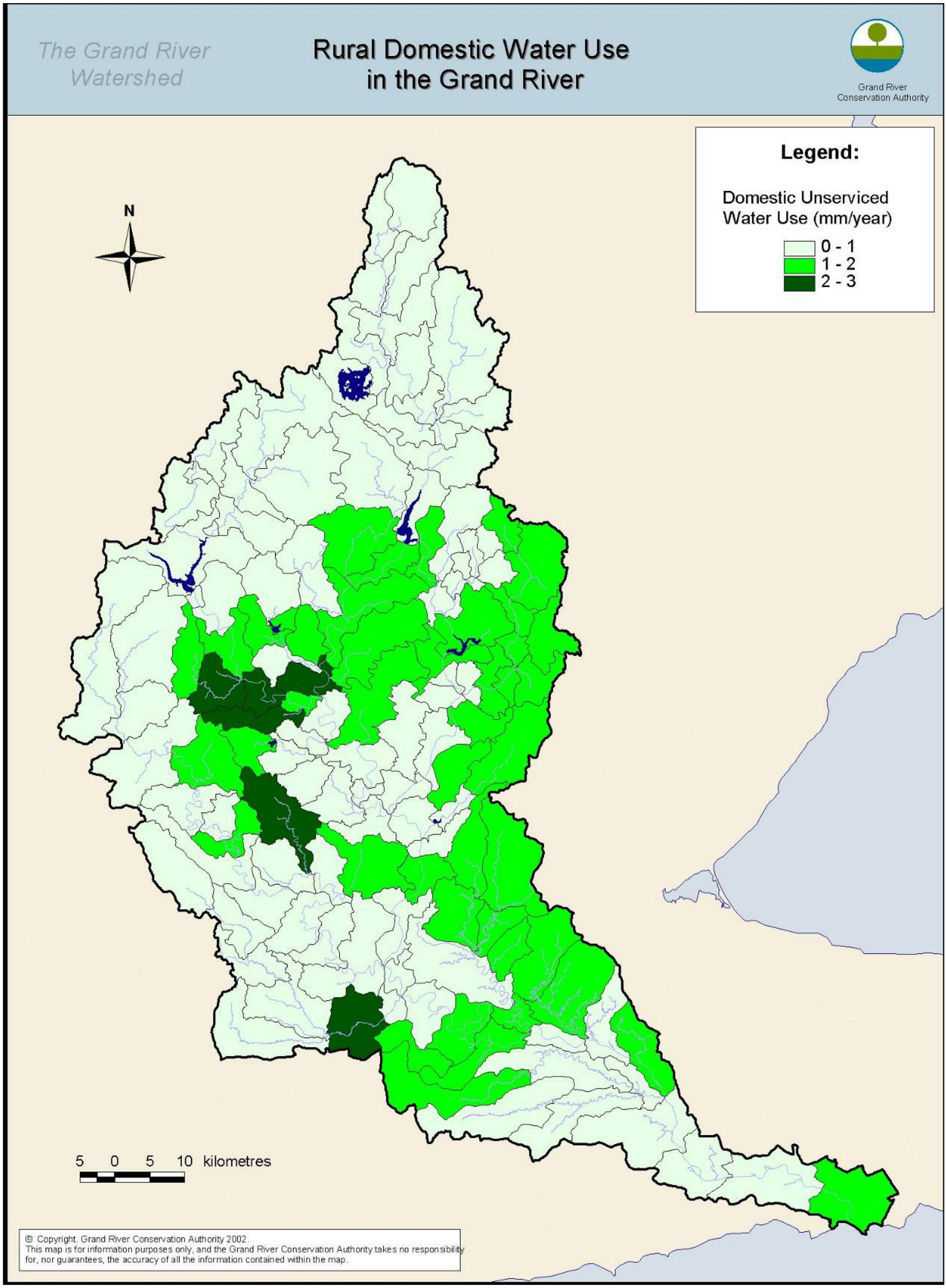


Figure 13: Rural Domestic Water Demand

6.0 OPERATIONS ON PRIVATE SUPPLY

For water uses that did not fall into the 3 previously mentioned categories (municipal, agricultural and rural unserviced), the Ministry of Environment (MOE) PTTW database was used. The MOE requires any person taking greater than 50,000 of waterlitres on any day of the year (animal watering, domestic usage and firefighting excluded) to apply for a PTTW and declare the maximum volume of water they may take. Reporting maximum permitted, but not actual water taking, is a shortcoming of the PTTW program, when used for estimating actual water use. In many cases, the applicant applies for a quantity much greater than they would actually use. In addition, it is not known how many days the permit holder is actively taking water, or even during which season. It should be noted that MOE has recognized this issue with the PTTW program, and is currently considering amendments, which would require permit holders to submit actual water use statistics to the MOE.

6.1 Adjustments to the PTTW Database

In order to address this deficiency in the database information collection, monthly adjustment factors were applied to permitted volumes to more accurately reflect actual water usage, as shown in Table 6. For the most part, these adjustment factors simply determine when the taking is active. For the water supply permits (not including campgrounds) monthly patterns were assumed to be the same as the Regional Municipality of Waterloo's pattern for smaller communities, as described in Section 1.0, with the maximum permitted flowrate being the August monthly water use.

Table 6: Permit To Take Water Adjustment Factors

General Purpose	Specific Purpose	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Commercial	Aquaculture	1	1	1	1	1	1	1	1	1	1	1	1
Commercial	Bottled Water	1	1	1	1	1	1	1	1	1	1	1	1
Commercial	Golf Course Irrigation	0	0	0	0	1	1	1	1	1	1	0	0
Commercial	Mall / Business	1	1	1	1	1	1	1	1	1	1	1	1
Commercial	Other - Commercial	1	1	1	1	1	1	1	1	1	1	1	1
Commercial	Snowmaking	1	1	0	0	0	0	0	0	0	0	0	1
Dewatering	Other - Dewatering	1	1	1	1	1	1	1	1	1	1	1	1
Dewatering	Other - Industrial	1	1	1	1	1	1	1	1	1	1	1	1
Dewatering	Pits and Quarries	1	1	1	1	1	1	1	1	1	1	1	1
Industrial	Aggregate Washing	0	0	0	0	1	1	1	1	1	1	1	0
Industrial	Cooling Water	1	1	1	1	1	1	1	1	1	1	1	1
Industrial	Food Processing	1	1	1	1	1	1	1	1	1	1	1	1
Industrial	Manufacturing	1	1	1	1	1	1	1	1	1	1	1	1
Industrial	Other - Industrial	1	1	1	1	1	1	1	1	1	1	1	1
Institutional	Other - Institutional	1	1	1	1	1	1	1	1	1	1	1	1
Miscellaneous	Heat Pumps	1	1	1	1	1	1	1	1	1	1	1	1
Miscellaneous	Other - Miscellaneous	1	1	1	1	1	1	1	1	1	1	1	1
Recreational	Recreational	0	0	0	0	0	1	1	1	1	0	0	0
Remediation	Groundwater	1	1	1	1	1	1	1	1	1	1	1	1
Water Supply	Campgrounds	0	0	0	0	1	1	1	1	1	0	0	0
Water Supply	Communal	0.80	0.75	0.82	0.82	0.89	0.86	0.97	1.00	0.95	0.95	0.87	0.84
Water Supply	Other - Water Supply	0.80	0.75	0.82	0.82	0.89	0.86	0.97	1.00	0.95	0.95	0.87	0.84

For months that the permit is assumed to be active, the taking is assumed to be occurring continuously. While it is unlikely that most water takings will be active continuously during the month, there is no data available to support an analysis to determine the period of taking for each purpose.

Another concern with the PTTW database information is the issue of over-accounting the same permitted limit when there are multiple supply sources. For instance, a permit having several sources such as a number of ponds or wells could collectively have one maximum permitted amount for the one permit owner. However, when searching the PTTW database, that collective maximum amount appears beside every source of supply, thus over-accounting the amount of water estimated for use in Table 7, by multiples. Unfortunately, there is no way to distinguish these volumes from other permitted users who may have applied to have 2 sources of water supply and 2 permits, each with the same volume. Thus, it is uncertain where over-accounting has occurred and where the estimates of watershed water use are erroneously elevated.

Due to the assumption of continually active water takings, the maximum permitted water takings and the multiples of some permits, the water use estimates for these categories will be the absolute maximum, and do not represent actual conditions. A recommendation from this report will be to survey all major water users identified to gain insight into actual water takings as well as taking characteristics.

It is recognized that within certain water use sectors, compliance with the PTTW program may be an issue. This raises more issues with the accuracy of water use estimates. The MOE has held a number of PTTW clinics attempting to increase compliance with the program.

In addition to the monthly adjustment factors, the PTTW database was queried to remove any permit that has been expired for longer than 10 years, as well as cancelled permits or temporary permits. Any permits from the database that represent water uses that have been determined from the above 3 categories were also dropped from consideration (e.g. municipal, agricultural and rural domestic permits).

Furthermore, permits that were felt not to represent true water takings were also removed from consideration. The most common type of permit that was excluded were those representing Ducks Unlimited wetlands. These constructed wetlands are built to capture runoff during the spring period, and can therefore have very high water taking volumes associated with them. Because these structures will only utilize their full water taking during the initial filling, they were assumed not to be sustained water takings, and were therefore dropped from consideration.

Figures 14 and 15, illustrate all permits included in the analysis, broken down by source, and are proportional to the size of the permitted water taking, and the depth of water use on a surface water catchment.

Excluding any permits that have been expired greater than 10 years, cancelled, temporary, agricultural or municipal water supply permits, 313 PTTW remain in the Grand River watershed. These 313 Permits have a total of 462 sources associated with them. It is worthwhile to note that there may be more than one source associated with a particular Permit. Of the 462 sources, 343 rely on groundwater, and 119 draw from surfacewater bodies, relating to 74% and 26%, respectively.

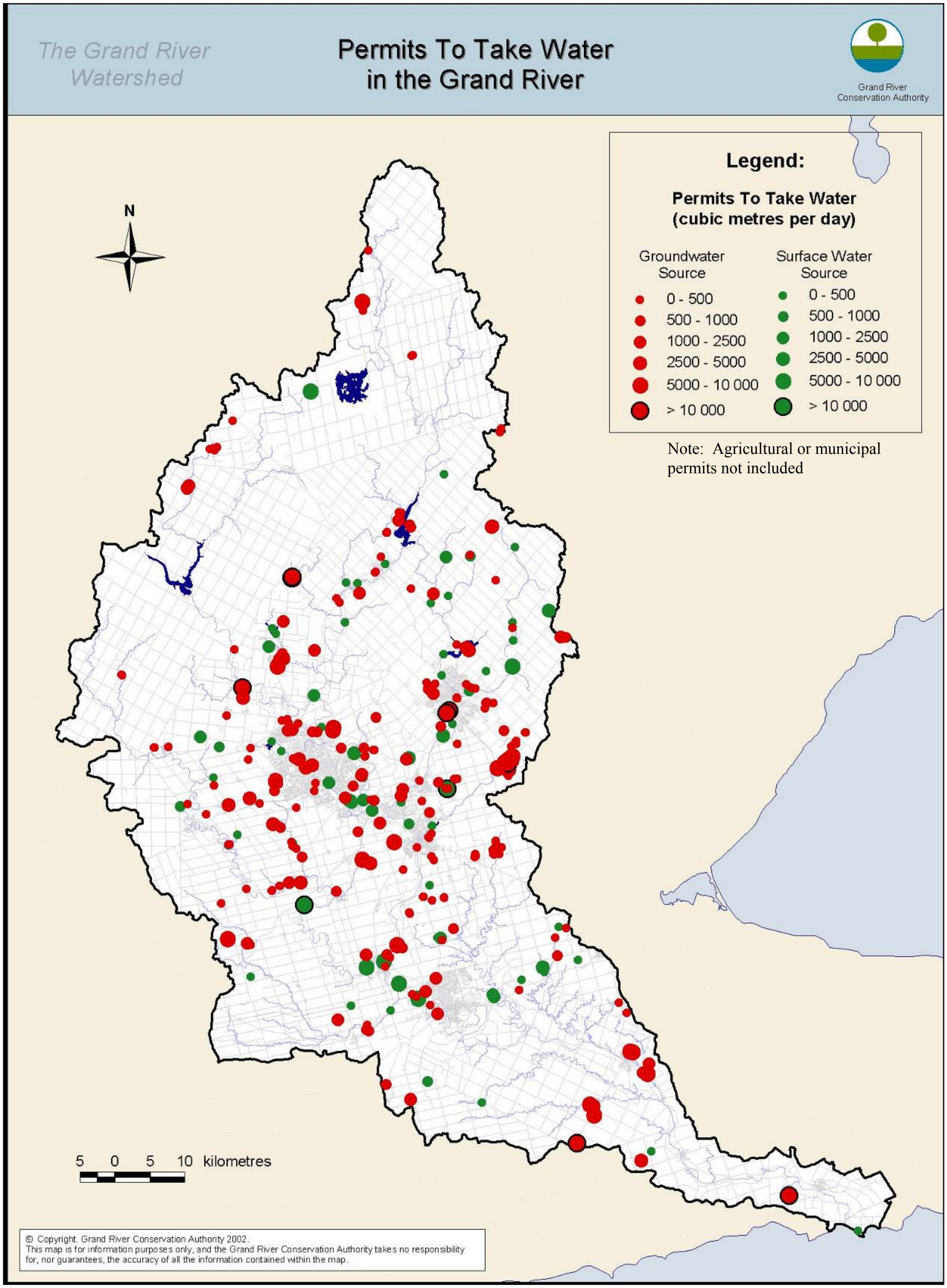


Figure 14: Map of Selected Permits To Take Water, Sources and Amounts

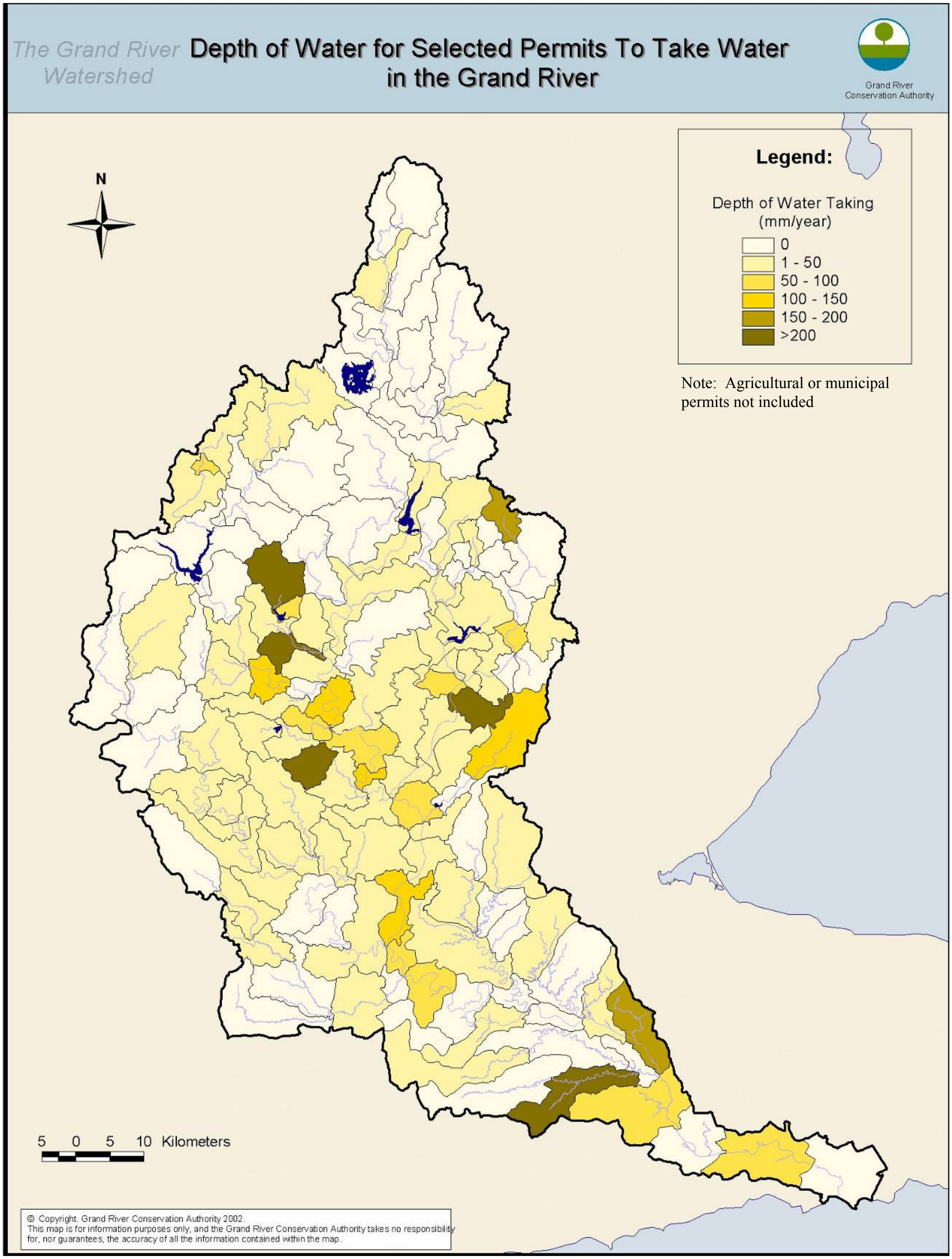


Figure 15: Selected Permits To Take Water – Depth of Water Used

Table 7, included below, quantifies the estimated annual water use for each category listed within the PTTW database. It should be noted that this analysis is limited by the amount of detail included in the database. Many Permits are described as "Industrial – Other", or "Miscellaneous", making it extremely difficult to understand the true purpose or characteristics of the particular water taking.

Table 7: Permit To Take Water Volume – By General Purpose

	January	February	March	April	May	June	July	August	September	October	November	December	**Total**
	(,000's of cubic metres)												
Dewatering	4,030	3,640	4,030	3,910	4,030	3,910	4,030	4,030	3,910	4,030	3,910	4,030	47,490
Aggregate Washing	-	-	-	-	3,330	3,220	3,330	3,330	3,220	3,330	3,220	-	22,980
Aquaculture	1,380	1,250	1,380	1,340	1,380	1,340	1,380	1,380	1,340	1,380	1,340	1,380	16,270
Remediation	1,320	1,200	1,320	1,280	1,320	1,280	1,320	1,320	1,280	1,320	1,280	1,320	15,560
Golf Course Irrigation	-	-	-	-	1,800	1,740	1,800	1,800	1,740	1,800	-	-	10,680
Other - Industrial	780	700	780	750	780	750	780	780	750	780	750	780	9,160
Miscellaneous	680	610	680	660	680	660	680	680	660	680	660	680	8,010
Manufacturing	660	600	660	640	660	640	660	660	640	660	640	660	7,780
Food Processing	640	580	640	620	640	620	640	640	620	640	620	640	7,540
Cooling Water	280	250	280	270	280	270	280	280	270	280	270	280	3,290
Recreational	-	-	-	-	-	670	690	690	670	-	-	-	2,720
Water Supply, Other - Water Supply	210	170	210	200	230	210	250	260	240	240	220	220	2,660
Other - Commercial	180	160	180	180	180	180	180	180	180	180	180	180	2,140
Water Supply, Communal	160	140	170	160	180	170	200	210	190	200	170	170	2,120
Bottled Water	140	130	140	140	140	140	140	140	140	140	140	140	1,670
Water Supply, Campgrounds	-	-	-	-	140	130	140	140	130	140	130	-	950
Mall / Business	40	40	40	40	40	40	40	40	40	40	40	40	480
Snowmaking	90	80	-	-	-	-	-	-	-	-	-	90	260
Heat Pumps	10	10	10	10	10	10	10	10	10	10	10	10	120
Other - Institutional	5	5	5	5	5	5	5	5	5	5	5	5	60
Total	10,605	9,565	10,525	10,205	15,825	15,985	16,555	16,575	16,035	15,855	13,585	10,625	**161,940**

7.0 ANALYSIS

This section will focus on identifying the major water use sectors in the Grand River watershed. Table 8 lists all water uses described in the above sections and compares them against each other, as well as illustrates the monthly and annual variation of water use. Figure 16 shows all the major water uses in the Grand River watershed and how they compare percentage-wise to each other.

Table 8: Total Water Use Comparison

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
		(,000's of cubic metres)												
1	Municipal Supply	8,780	7,340	8,920	8,550	9,520	9,440	11,220	10,630	9,290	9,210	8,390	8,560	**109,840**
2	Dewatering	4,030	3,640	4,030	3,910	4,030	3,910	4,030	4,030	3,910	4,030	3,910	4,030	**47,490**
3	Aggregate Washing	-	-	-	-	3,330	3,220	3,330	3,330	3,220	3,330	3,220	-	**22,980**
4	Aquaculture	1,380	1,250	1,380	1,340	1,380	1,340	1,380	1,380	1,340	1,380	1,340	1,380	**16,270**
5	Remediation	1,320	1,200	1,320	1,280	1,320	1,280	1,320	1,320	1,280	1,320	1,280	1,320	**15,560**
6	Golf Course Irrigation	-	-	-	-	1,800	1,740	1,800	1,800	1,740	1,800	-	-	**10,680**
7	Agricultural	760	760	760	760	760	760	940	940	940	760	760	760	**9,640**
8	Agricultural Irrigation, Average	-	-	-	-	-	2,360	4,730	2,360	-	-	-	-	**9,460**
9	Other - Industrial	780	700	780	750	780	750	780	780	750	780	750	780	**9,160**
10	Miscellaneous	680	610	680	660	680	660	680	680	660	680	660	680	**8,010**
11	Manufacturing	660	600	660	640	660	640	660	660	640	660	640	660	**7,780**
12	Food Processing	640	580	640	620	640	620	640	640	620	640	620	640	**7,540**
13	Rural Domestic	560	560	560	560	560	560	560	560	560	560	560	560	**6,700**
14	Cooling Water	280	250	280	270	280	270	280	280	270	280	270	280	**3,290**
15	Recreational	-	-	-	-	-	670	690	690	670	-	-	-	**2,720**
16	Water Supply, Other - Water Supply	210	170	210	200	230	210	250	260	240	240	220	220	**2,660**
17	Other - Commercial	180	160	180	180	180	180	180	180	180	180	180	180	**2,140**
18	Water Supply, Communal	160	140	170	160	180	170	200	210	190	200	170	170	**2,120**
19	Bottled Water	140	130	140	140	140	140	140	140	140	140	140	140	**1,670**
20	Water Supply, Campgrounds	-	-	-	-	140	130	140	140	130	140	130	-	**950**
21	Mall / Business	40	40	40	40	40	40	40	40	40	40	40	40	**480**
22	Snowmaking	90	80	-	-	-	-	-	-	-	-	-	90	**260**
23	Heat Pumps	10	10	10	10	10	10	10	10	10	10	10	10	**120**
24	Other - Institutional	5	5	5	5	5	5	5	5	5	5	5	5	**60**
	Total	20,705	18,225	20,765	20,075	26,665	29,105	34,005	31,065	26,825	26,385	23,295	20,505	**297,580**

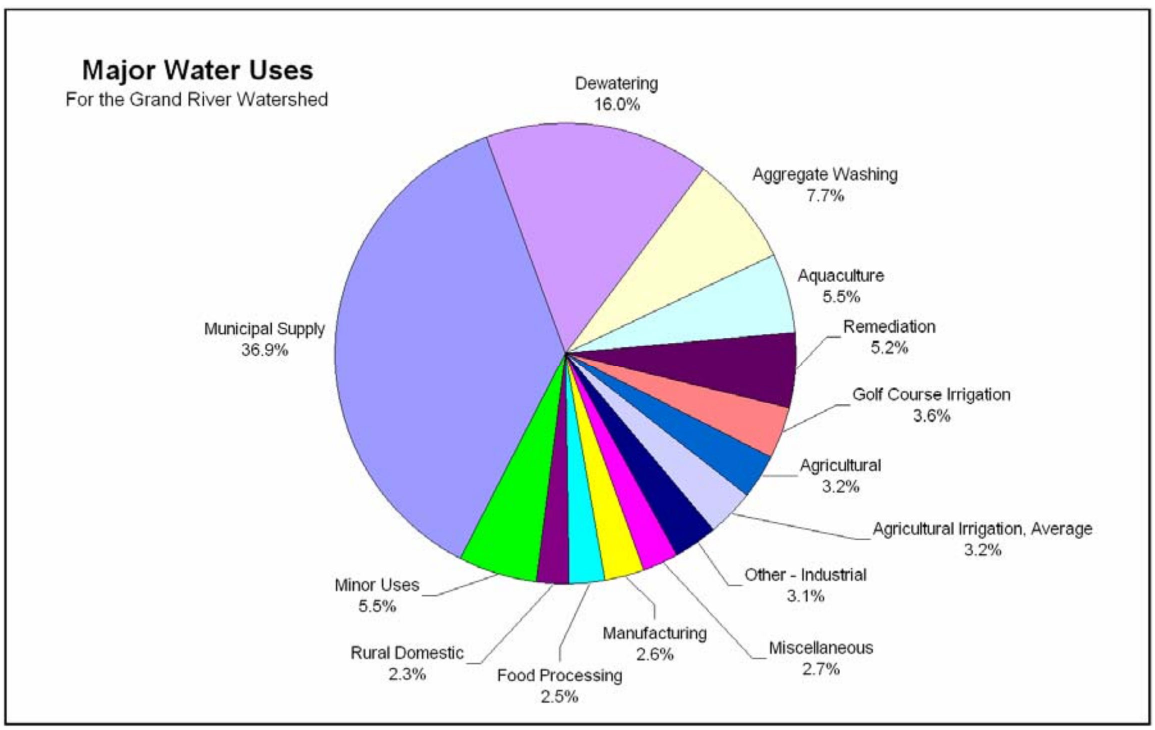


Figure 16: Major Water Uses – Annual Basis

It should be noted that Figure 16 illustrates the annual total water use. While useful for comparing totals, this analysis will under represent the significance of short but intense water uses, such as crop irrigation. The line graph included in Figure 17 illustrates the importance of monthly variability. Agricultural irrigation is the 8th largest water use on an annual basis; however it is the 2nd highest water use for the month of July.

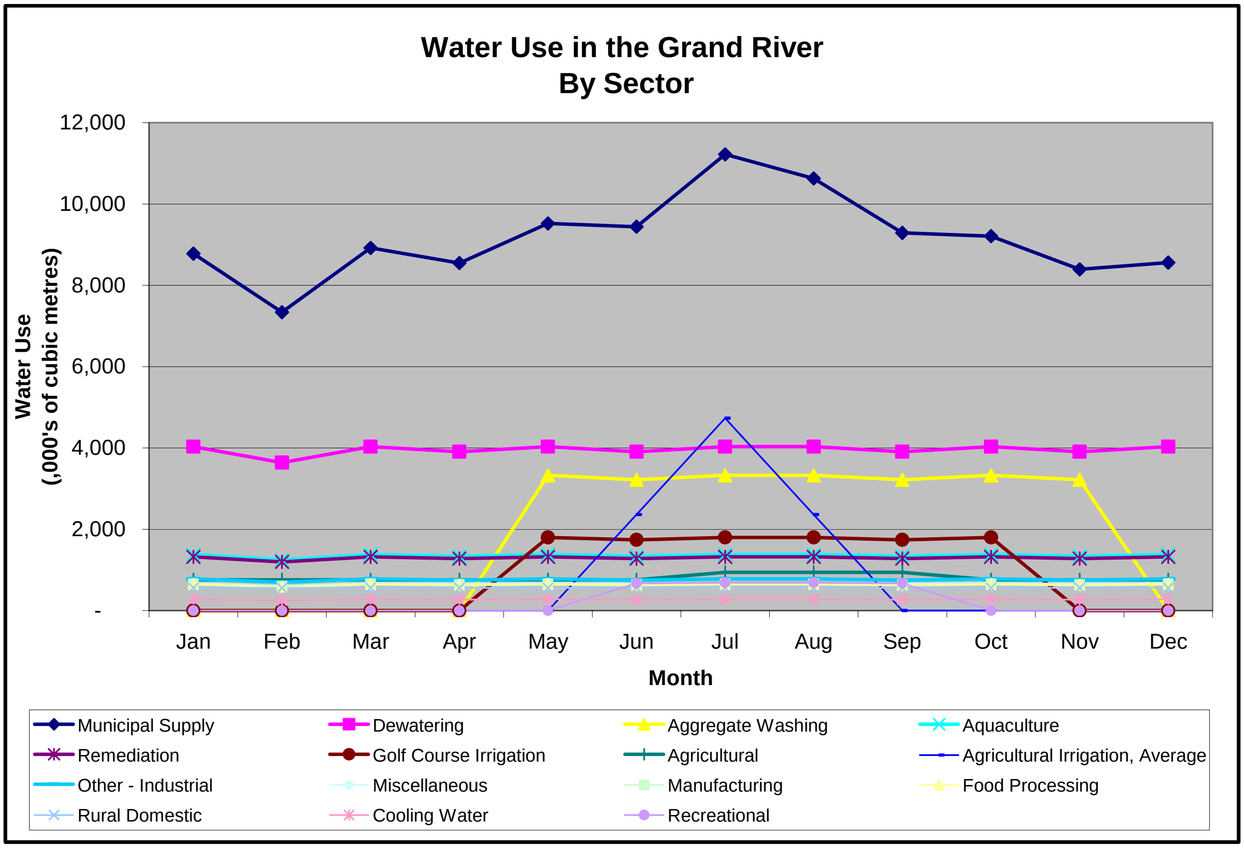


Figure 17: Monthly Variation of Major Water Uses

It should be noted that with regard to Crop Irrigation, the actual water use may be more intense than what is represented by the monthly analysis. Crop Irrigation can be focused into a particular week, depending on climate conditions, making it possibly the highest taking in the watershed, albeit for a short duration.

For effective water management, one must consider the intensity of water takings, particularly for surface water management. Due to the delayed response associated with groundwater, considering the intensity of water takings is generally less important. However, when considering unconfined aquifers, which are well connected to the surface water system, the intensity of takings may be more significant

In addition to monthly variation, water use also varies on an annual basis. Climate variations play an enormous role in certain types of water use. The longer the watershed goes without receiving rain, the more water that is used to water their lawns, or irrigate agricultural crops.

At this time there is not enough data to support analysis of annual variability for every water use. However this relationship between climate and water use can be illustrated in the Figure 15, below. Figure 18 compares the monthly pumping rate from the City of Brantford for a dry year (1998), with total precipitation of 715 mm, and a wet year (2000), with total precipitation of 1020 mm. The annual average precipitation for this area is 890 mm. One can see a considerable increase in municipal use for 1998 compared to 2000, thought to be largely due to outdoor water use. It should be noted that in recent years, municipalities, including the City of Brantford, have been implementing outdoor water use bylaws in an attempt to reduce this seasonal increase.

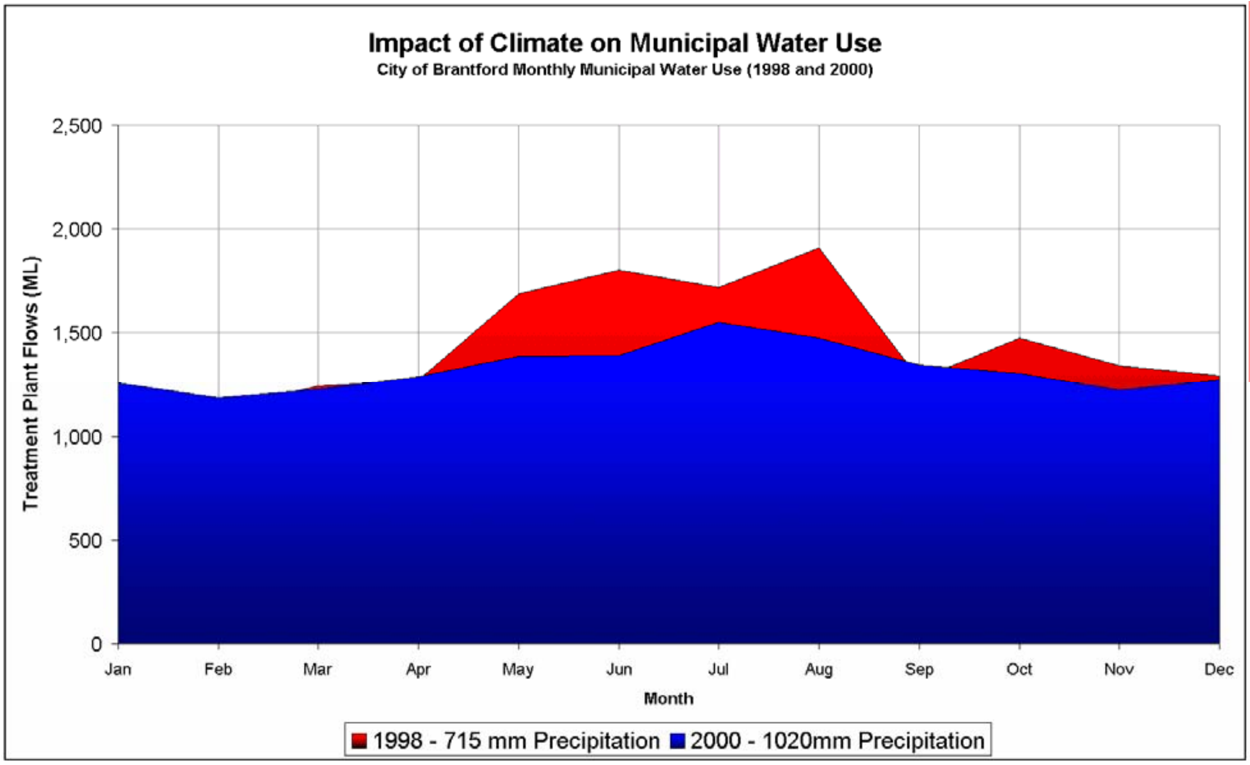


Figure 18: Annual Variation of Municipal Use

Due to the development of an irrigation demand model, employing synthetic soil moisture data from 1961 to 1999, it is possible to investigate individual years, and therefore how irrigation varies with climate. The annual variability of irrigation events is shown in Figure 8, included in Section 2.2. Figure 19, shows the monthly variability of two extremes, 1999 being the dry year and 1987 being the wet year.

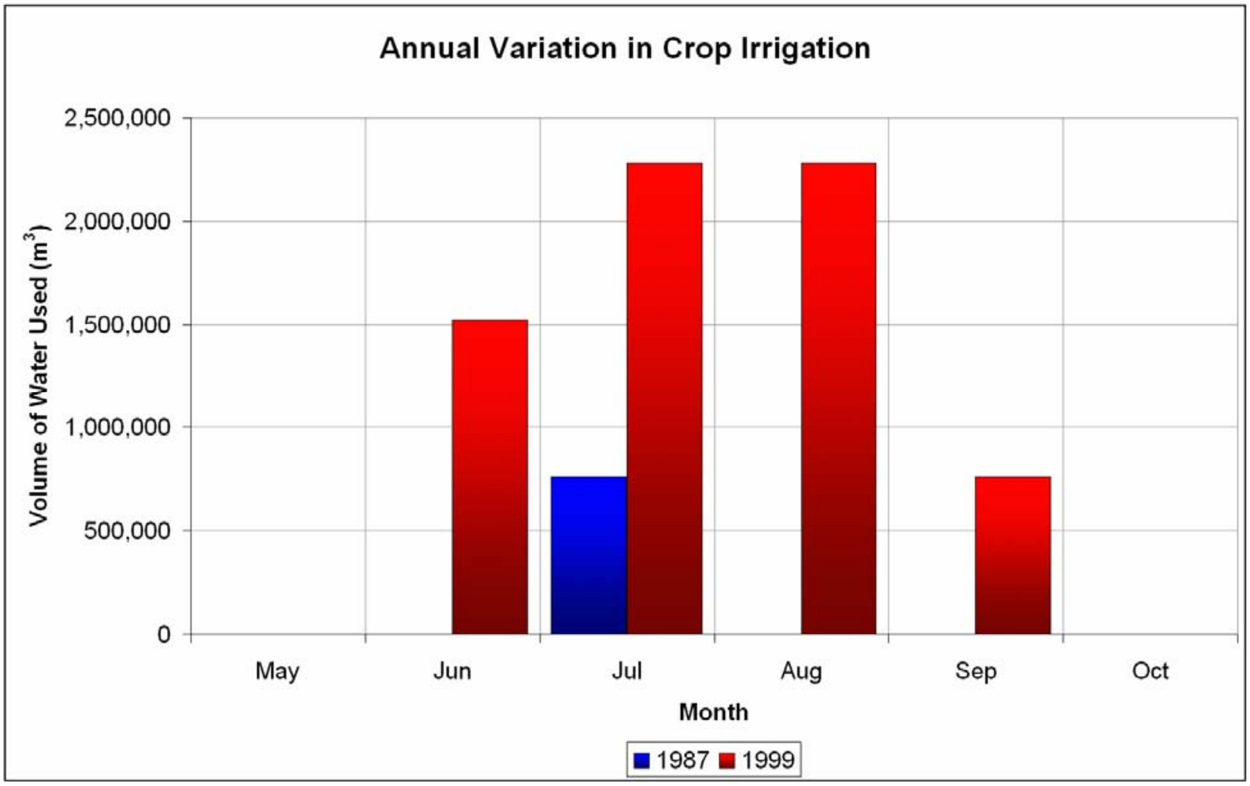


Figure 19: Annual Variation of Crop Irrigation

While the amount of water many water users take is largely dependent on the climate, some water users operate independently of climate. These may include water bottlers, aggregate producers or aquaculture operations. These users require the same amount of water every year for the industrial or commercial processes that produce the product.

While not possible, due to data limitations, to quantify the impact of dry periods on every water user listed in Table 8 one can qualitatively divide water users into climate-dependant and climate-independent subgroups. Table 9 shows this breakdown.

Table 9: Sensitivity of Water Use to Climate Variations

Water Use Category	Climate Sensitive	Climate Insensitive
Municipal Supply	X	
Dewatering		X
Aquaculture		X
Aggregate Washing		X
Remediation		X
Golf Course Irrigation	X	
Agricultural	X	
Agricultural Irrigation, Average	X	
Other - Industrial		X
Miscellaneous	**Unknown**	
Manufacturing		X
Food Processing		X
Rural Domestic	X	
Cooling Water		X
Recreational	X	
Water Supply, Other - Water Supply	X	
Other - Commercial	X	
Water Supply, Communal	X	
Bottled Water		X
Water Supply, Campgrounds	X	
Mall / Business		X
Snowmaking	X	
Heat Pumps		X
Other - Institutional	X	

While the focus of this report is on water use, a critical component of the Water Quantity Plan will be determining the proportion of water use that is not returned to the watershed (i.e. consumptive use). Wastewater discharge, whether it is aquaculture discharge, dewatering discharge, or sewage treatment plant discharge, will all increase the amount of water available in the surface water system. Currently there is not sufficient information to develop consumptive use ratios for all major water uses.

In addition to consumptive water takings, there is a need to identify those takings, which represent a diversion of water from the original source. While not consumptive, a dewatering operation that removes groundwater and discharges it to surface water, represents a diversion of groundwater to surface water. When investigating water takings at an individual source scale (aquifer), these diversions, while not consumptive, do play a significant role in determining the production capacity of the source.

A key recommendation of this report will be that consumptive ratios for significant water takings need to be determined, and water diversions identified. This recommendation will support further work on the Water Quantity Plan.

8.0 CONCLUSIONS AND RECOMMENDATIONS

This report has identified a number of issues with the current water use information, specifically the using the PTTW database to determine actual water use estimates. Water managers who employ the PTTW database to quantify the amount of water use within a specific area may not be using the program for what it was intended. As it stands, the PTTW database does not contain sufficient detail to determine the actual amount of water used, or the seasonal or annual variability of takings. The estimates of the amount of water used, as determined from the PTTW, database are conservative estimates and should be treated as such. It should also be noted that probable low compliance within the PTTW program with certain sectors, further reduces the effectiveness of using the database to determine actual water use.

This study has attempted to use additional information, where possible, to reduce the reliance on the PTTW database, and estimate water uses that are exempt from the PTTW program. For example municipalities were contacted to determine actual water use and Census of Agriculture and Census of Population data were used to determine agricultural and rural domestic water use. An irrigation demand model, using soil moisture data from a continuous hydrologic model, coupled with Census of Agriculture data, has made it possible to determine water demand for crop irrigation and the annual variability of water use.

This report has identified the following water use sectors as being significant in a watershed-wide context.

1. Municipal Water Supply
2. Dewatering
3. Aggregate Washing
4. Aquaculture
5. Remediation
6. Golf Courses
7. Agriculture
8. Average Agricultural Irrigation
9. Other - Industrial
10. Miscellaneous
11. Manufacturing
12. Food Processing
13. Rural Domestic
14. Cooling Water
15. Recreational

While annual totals are useful for comparison purposes, seasonal and annual variations must be considered. While not complete, due to limitations with data sources, examples of seasonal and annual variations were shown. The variations are most significant when considering extremely variable and intense water takings, such as crop irrigation.

This study has identified a number of limitations with water use data available to water managers. In an attempt to address these shortcomings and increase the accuracy of water use estimates, the study has made the following recommendations:

1. While certain sectors, such as municipalities, are well organized and have provided actual water use statistics for use in this study, water use estimates that have been based from the PTTW database should be surveyed to determine if takings are active, and to measure actual water use, levels of consumption, and seasonality of the taking.

2. That the information be gathered from the municipal sector on industrial, commercial, institutional and residential components.

3. That consumptive ratios of all major water sectors be determined, as well as water diversions be identified.
4. That investigations into more accurate estimates of irrigated land continue including assessing the use of alternative methodologies such as remote sensing.
5. That development of a central database of water use in the watershed continues. This database would house recent information on municipal water systems as well as other water users.

REFERENCES

Agriculture and Agri-Food Canada, and Ontario Minsistry of Agriculture, Food and Rural Affairs. 1995. Best Management Practices – Irrigation Management Booklet.

Allen, R. G. 1991. Irrigation Engineering Principles. Utah State University, Agricultural and Irrigation Engineering Dept., Logan, UT.

Environment Canada. 2003. Freshwater Website: Water Use. http://www.ec.gc.ca/water/en/manage/use/e_use.htm. Accessed: July 10, 2003.

Keller, J. and R. D. Bliesner. 1990. Sprinkler and Trickle Irrigation. New York, NY: Van Nostrand Reinhold Pub.

Kreutzwiser, R.D. and R.C. de Loë. 1999. REVISED. Agricultural and Rural Water Use in Ontario. A Report to the National Soil and Water Conservation Program, August 31, 1999. Guelph, Ontario: Rural Water Management Group, Department of Geography, University of Guelph.

Ontario Ministry of Environment. 2003. Permit To Take Water Database.

Schroeter, H.O., Boyd, D.K., Whiteley, H.R. 2001. GAWSER: A Versatile Tool For Water Management Planning.

Schwab, G.O., Frevert R. K., Edminster, T.W., Barnes, K. K. 1998. Soil and Water Conservation Engineering. Third Edition. Toronto.

Statistics Canada. 1986. Census of Agriculture.

Statistics Canada. 1991. Census of Agriculture.

Statistics Canada. 1996. Census of Agriculture.

Statistics Canada. 1991. Census of Population.

Vandierendonck, M., and B. Mitchell. 1997. Water Use Information for Sustainable Water Management: Building Blocks and the Ontario Situation. Canadian Water Resources Journal, 22(4): 395-415.