GRAND RIVER WATERSHED
Water Management Plan

Grand River Watershed Water Management Plan

Agricultural Irrigation: Forecasts for Future Water Needs

Prepared by: Stephanie Shifflett, Hajnal Kovacs and Amanda Wong
with consultation from Rebecca Shortt

September 2014

Suggested Citation

Agricultural Irrigation: Forecasts for Future Water Needs. Grand River Water Management Plan. Prepared by Stephanie Shifflett, Hajnal Kovacs and Amanda Wong, Grand River Conservation Authority, Cambridge, ON. 2014.

Acknowledgements

Rebecca Shortt from the Ministry of Agriculture and Rural Affairs for her contributions and guidance related to agricultural irrigation requirements and water use.

Abbreviations

GAWSER	Guelph All-Weather Sequential Events Runoff
GCMs	Global Circulation Models
GRCA	Grand River Conservation Authority
IPCC	Intergovernmental Panel on Climate Change
OFA	Ontario Federation of Agriculture
OMAFRA	Ontario Ministry of Agriculture, Food and Rural Affairs
PTTW	Permit To Take Water
T2-WQSA	Tier 2 Grand River Water Quantity Stress Assessment

Contents

List of Figures

List of Tables

Introduction

The Grand River Conservation Authority (GRCA) is facilitating the update of the Grand River Watershed Water Management Plan by municipal, First Nations, provincial and federal partners. One of the goals of the Water Management Plan is to "ensure sustainable water supplies for communities, economies and ecosystems".

Agricultural water use is the highest seasonal water use in the Grand River watershed, peaking in the summer months of July through September. Annually, irrigation is estimated to be the third highest water use in the Grand River watershed, following municipal and dewatering (Wong, 2011). The current and future water needs for agricultural irrigation are being investigated as part of the Water Management Plan update to ensure that the future water needs can be sustainably met. This will also highlight, for future action, any areas that, on a subwatershed basis, have potential for conflict or water use constraint (now or in the future) as a result of the combined water demands by municipalities, the agricultural sector, the aggregate sector and other water users in the watershed.

The Grand River watershed's agriculturally productive land covers approximately 70% of the area,. There are currently around 340 Permits to Take Water for agricultural irrigation purposes in the Grand River watershed, with approximately 125 or 37% of them in Whitemans Creek and 80 or 24% of them in the nearby McKenzie Creek subwatershed.

The peak use months coincide with the low flow season, and the potential for water use conflicts amongst agricultural irrigators or other water using sectors, including the environment, could be a concern. With the uncertainty of climate change affecting both the availability of water and the demand by agricultural irrigation in the watershed, a better understanding is needed to determine how much water is required. The purpose of this report is to develop information and compare available water and water needs for agricultural irrigation.

Projections for future water needs of the Grand River watershed agricultural sector were the focus of consultation with irrigation specialists and the forecasting group at the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) and members of the Ontario Federation of Agriculture (OFA). Water use for agriculture can be categorized into two uses: crop irrigation that occurs primarily in the growing season months of May through September and livestock drinking and washing requirements, which are needed year-round (livestock are detailed in a separate report).

OMAFRA recommended that three future water use scenarios be conducted to assess potential water needs for cropland irrigation. The future scenarios are that irrigated area across the watershed will: remain similar to current day (Scenario 1), increase by 10% (Scenario 2a) and increase by 25% (Scenario 2b). Following further consultation with OFA and county representatives, two additional scenarios were proposed to assess areas of potential high water use for future irrigation. These high water use scenarios assume that 10% of cropland on sandy soils will be irrigated (Scenario 3a) and 5% of all cropland in the Grand River watershed will be irrigated (Scenario 3b). This report provides the results and analysis of each of these future water use scenarios.

Current Agricultural Water Use Estimates

Actual water use for crop irrigation is much less than the amount implied by Permits To Take Water (PPTWs). The estimated volume per year required for irrigation was calculated based on the methodology described in the Grand River Water Use Inventory Report (Wong, 2011). Initial estimates were based on GRCA's existing irrigation demand model and the estimated amount of irrigated land as reported in the 2006 Census of Agriculture data for 2005. These estimates were compared with farmers' reports of actual water use in the watershed.

The estimate for the irrigation season requires on average, 4 irrigation cycles, which matches with the median value for the irrigation demand model and was documented as the average number from local knowledge. Each irrigation cycle lasts 8 days, totaling 32 days of active irrigation per PTTW. The 32-days are spaced throughout the peak demand for water from June through September, having 8 days in June, 12 days in July, 8 days in August and 4 days in September. The extreme dry-year case of the maximum number of irrigation events per year was also estimated at 10 events.

Estimates using the Irrigation Demand Model

GRCA's existing irrigation demand model was used to estimate the number of irrigation occurrences in a season to predict when farmers would be required to irrigate their crops. The model uses synthetic daily soil moisture data from the Guelph All-Weather Sequential Events Runoff (GAWSER) hydrologic model (Schroeter, 2000) of the Grand River Watershed, as documented in the Integrated Water Budget Project (ARI, 2009a).

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 when the soil moisture remains 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 (such as a large rainfall event). 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 to the land with a 65% efficiency rating (Keller and Bliesner, 1990; Allen, 1991). The number of irrigation events predicted from the model (1961-1999) is an average of 4 or a maximum of 10 events per year. The corresponding water taking to apply 25 mm of water with 65% efficiency is 39 mm or 1.55 inches of water per unit area irrigated.

Agricultural irrigation is not entirely consumptive, it is estimated that 5% to 25% of the water should return to its source, depending on the source (ARI, 2009a). For example, runoff and infiltration should return more to the surface water or shallow groundwater source, but deeper confined aquifers will receive less return flow. As most additional agricultural irrigation is assumed to be from groundwater, for this report, the agricultural water use was estimated to be 75% consumptive (ARI, 2009a). This adjustment was applied to all water demand tables throughout the report to reflect how much water is actually consumed by irrigation rather than the amount that was originally taken.

Irrigated area is estimated based on the irrigated land reported in the Statistics Canada's 2006 Census of Agriculture for the 2005 year (Bellamy, 2005).

Table 1 shows irrigated area and estimates of irrigation volumes for the average (normal) 4 irrigation events per year as well as the extreme (dry season) 10 irrigation events per year.

Estimates of current irrigation volume for the watershed in a normal year are currently (2005 estimate) about 7.4M m^3/year for 4 irrigation events. In a dry year, with 10 irrigation events, the estimate jumps to approximately 18.6M m^3/year.

These estimates based on the irrigation demand model do not specify the source of water or differentiate surface water and groundwater takings.

The subwatersheds noted in the **Table 1** are shown on **Figure 3.**

Table 1. Current Estimated Consumptive Water Use for Crop Irrigation by Subwatershed

Subwatershed	Total Subwatershed Area (ha)	Current Conditions			
		Irrigated Area (ha)	% Irrigated Area (of total area)	Average (m^3/year)	Maximum (m^3/year)
Grand Above Legatt	35,872	195.93	0.55%	231,407	578,518
Grand Above Shand	42,405	16.43	0.04%	19,407	48,518
Grand Conestogo to Shand	63,977	41.45	0.06%	48,956	122,389
Conestogo Above Dam	57,095	10.82	0.02%	12,778	31,945
Conestogo Below Dam	24,856	58.39	0.23%	68,961	172,402
Grand Paris to Conestogo	48,865	448.87	0.92%	530,162	1,325,406
Eramosa River	26,093	32.41	0.12%	38,274	95,685
Speed Above Dam	24,209	132.40	0.55%	156,375	390,937
Speed Above Grand to Dam	27,845	190.94	0.69%	225,524	563,811
Mill Creek	9,738	0	0.00%	0	0
Nith Above New Hamburg	54,639	113.75	0.21%	134,345	335,863
Nith Grand to New Hamburg	58,345	376.91	0.65%	445,165	1,112,912
Whitemans Creek	40,378	1969.9	4.88%	2,326,641	5,816,602
Grand York to Paris	32,528	772.99	2.38%	912,978	2,282,444
Fairchild and Big Creek	56,887	551.3	0.97%	651,191	1,627,979
McKenzie and Boston Creeks	37,706	1301.3	3.45%	1,536,986	3,842,465
Grand Dunnville to York	38,432	71.99	0.19%	85,021	212,554
TOTAL	**679,869**	**6285.8**	0.92%	7,424,171	18,560,428

Five subwatershed with the largest irrigation demands

Considerations for Future Irrigation Water Use

Crop Forecasts

Fluctuations in irrigation demand are influenced by the specific commodities that require supplemental water. Traditionally, in Ontario, this includes tobacco, vegetables such as potatoes and fruit. Ginseng is also irrigated in Ontario but it only requires supplemental water in prolonged droughts.

Recent years have shown major fluctuations in the amount of tobacco produced in Brant and Norfolk Counties, with a significant drop after the removal of the quota system. However, there has been a slight recovery with producers and cigarette companies dealing directly with one another. While not likely to increase to production levels seen in the 1960s or 1970s peaks, production has been increasing for the last several years.

In the meantime, vegetables and ginseng have replaced a small fraction of the tobacco acreage. These replacement crops have irrigation demands as well, but the timing and volume may be very different from that of tobacco. Overall, the irrigation volume on the reduced acreage of the vegetables and ginseng has not surpassed that of the tobacco irrigation requirements each year. The projections for tobacco show no documented trend for growth in the future for Brant and Norfolk Counties, instead more fluctuations with market demand.

OMAFRA anticipates that market trends and costs of food delivery will result in an expansion of smaller-scale specialty food production around urban centres. For example, the Mennonite Communities in Waterloo and Wellington Counties could be supplying fruits and vegetables to meet the demands for local food markets. In terms of agricultural water use, this trend will increase water use in these areas for irrigation and washing of fruits and vegetables.

Irrigation Practices

Irrigation practices in recent years have been changing in Ontario, which may impact the volume and rate of water required for agriculture. One change anticipated is the shift from less efficient irrigation (i.e. overhead/spray) systems to more efficient (i.e. drip, drop nozzle centre pivot) systems. The losses to evaporation are much lower with drip delivery under the canopy – as opposed to traditional overhead sprinklers or spray guns – thus delivering a higher percentage of the water to the root system for the plant's uptake. The overall volume of water needed for irrigation may also be lower to meet the crop needs. In addition, drip irrigation systems deliver a lower rate of water over longer periods of time, thus reducing the peak demand from water sources such as creeks and rivers.

A recent article in Ontario Farmer (Reschke, 2012) reports that buried drip irrigation systems have received significant interest in the Ontario Tobacco Belt (Norfolk Sand Plain area), for crops that traditionally have not been irrigated, namely corn and soybean. The 2012 growing season was a very dry year, which spurred this sudden interest in irrigating field crops, as the yields were substantially higher with the buried drip lines and supplemental water. The financial investment is believed to be worthwhile for the farms according to the article, given the high returns on yields. In terms of future agricultural water demand, this trend could drastically increase current water use for irrigation of field crops, especially if this irrigation technique is widely adopted.

The use of technological advancements such as soil moisture monitoring and automatic irrigation systems has also been increasing. These advances are not likely to decrease agricultural water use and may increase water use as the current practice of irrigation shows that most farmers are under-irrigating their crops (Shortt, pers. comm., 2009 and Kovacs, 2014). Often, under-irrigation occurs when farmers delay irrigation if the short-term forecast indicates precipitation, or they may irrigate based on the amount of time the pump is on, not the depth of water that is required by the plant. If more reliance is placed on automatic systems in the future, there may be an increase in the volume of water used for irrigating crops.

Physiography

Irrigated regions of agricultural land are influenced by the surficial geology of the area. The sandy soils, such as on the Norfolk sand plain in the southern portion of the watershed are heavily cropped and require supplemental irrigation to support the crops in these well-drained soils. Portions of Whitemans Creek and McKenzie Creek subwatersheds are in these sand plains. The most extensively irrigated area with the highest concentration of irrigation PTTW is due in part to the sandy soils and the crops that thrive in this type of well-drained soil.

The central portion of the watershed (Waterloo and Wellington Counties) includes moraine areas (kames and spillways) and some agricultural activities, sod farms for example, have irrigation demands.

The till plains, generally found in the northern portion of the watershed are also dominated by agriculture but the tighter soils rarely require irrigation to grow crops. Crop intensification has been projected for the till plains with current pastured fields being seeded with cash crops like corn but likely without the requirement for irrigation.

Agricultural Irrigation

Figure 1 shows the different physiographic regions (MNDM, 1967-1993) and the extent of agricultural irrigation PTTWs.

Irrigation in the future will likely remain limited to the well-drained sand plain, kame and spillway regions, which are already the most intensely irrigated regions of the Grand River watershed. Much of this area is dominated by sandy soils on the surface. Figure 2 displays the extent of these well-drained soils; this map is derived from the Ontario Ministry of Northern Development and Mines surficial geology mapping (MNDM, 1967-1993).

There are 5 main subwatersheds with irrigation that are projected to have significant increasing irrigation demands in the future – Whitemans Creek, McKenzie Creek, lower Nith River (below New Hamburg), Fairchild Creek and the Grand River from York to Brantford . Currently, these areas have a PTTW density of just approximately one permitted source of water per 2 square kilometers on sandy soils. According to Statistics Canada data, the area of irrigated land on these sandy soils is almost 10% in these subwatersheds. The average permitted maximum in the five watersheds is 1,540m^3/day, while in Whitemans Creek the maximum is 2,300m^3/day.

The lower Nith subwatershed currently has a low density of permits but a high percentage of land on sandy soils, indicating that agricultural and irrigation practices may expand in this subwatershed in the future. McKenzie Creek has the highest proportion of sandy soils irrigated, at almost 20%, and also has the highest concentration of PTTWs.

Further details of the 5 subwatersheds with respect to irrigation on sandy soils are found in Table 2.

Table 2. Subwatershed statistics for Agricultural Permits To Take Water and irrigated soil types.

Subwatershed	# Permit Sources *	Permitted Max/ Source (m^3/day)	Total Sub-watershed Area (ha)	% Area That is Sandy Soils	Area of Sandy Soils (ha)	Irrigated Area (ha)	Irrigated Area as a % of Sandy Soils
Nith Grand to New Hamburg	20	1550	58,345	34.43%	20,086	377	1.88%
Whitemans Creek	135	2300	40,378	41.01%	16,559	1,970	11.90%
Grand York to Paris	40	1220	32,528	32.05%	10,425	773	7.41%
Fairchild and Big Creek	40	960	56,887	28.57%	16,255	551	3.39%
McKenzie and Boston Creeks	80	1670	37,706	17.44%	6,577	1,301	19.79%
Total	**315**	**1540**	**225,845**	**30.95%**	**69,903**	**4,972**	**7.11%**

**Active Agricultural permits as of 2013.*

Agricultural Irrigation

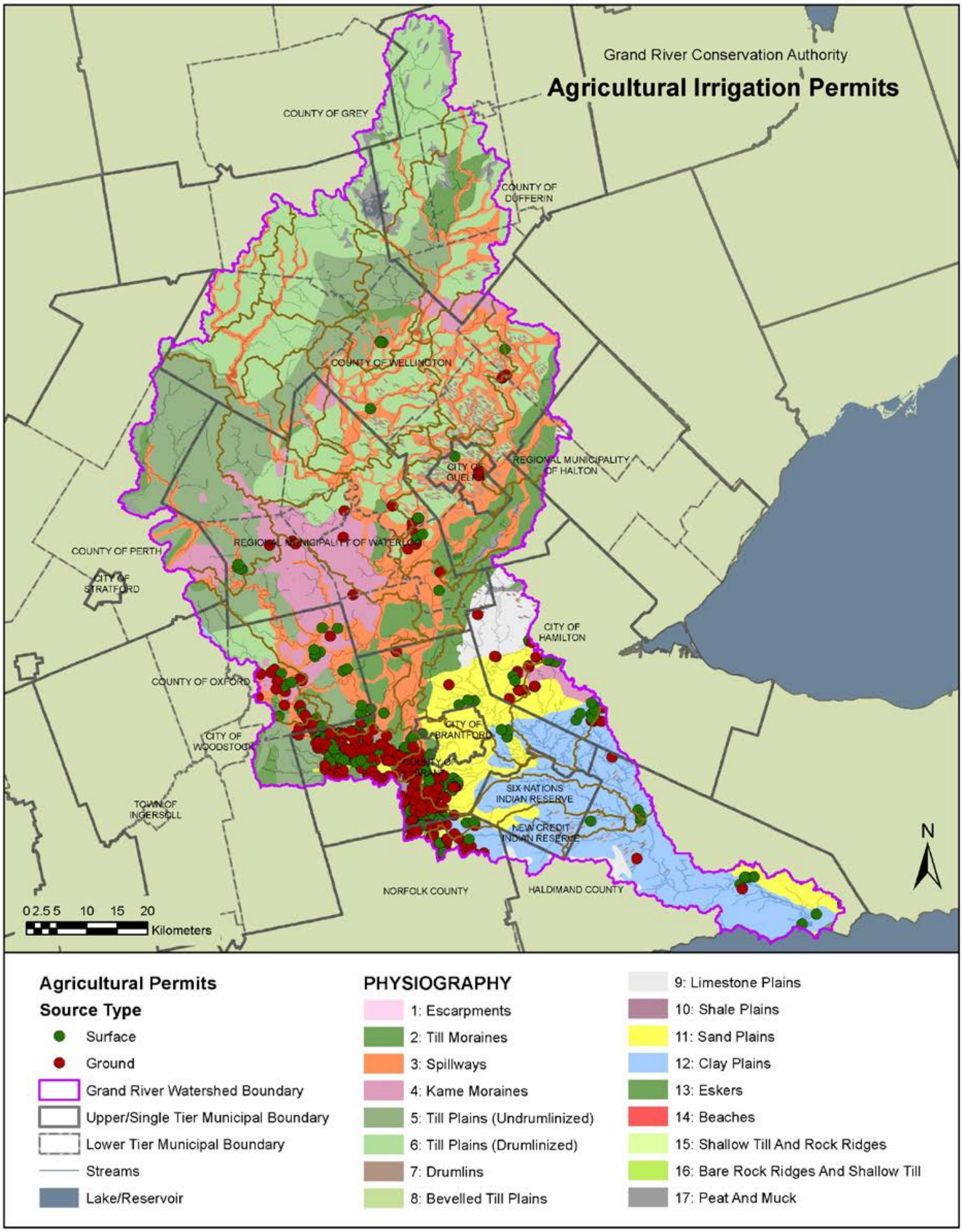

Figure 1: Physiography of the Grand River watershed: Irrigated areas include sand plan, spillway and kame moraine areas.

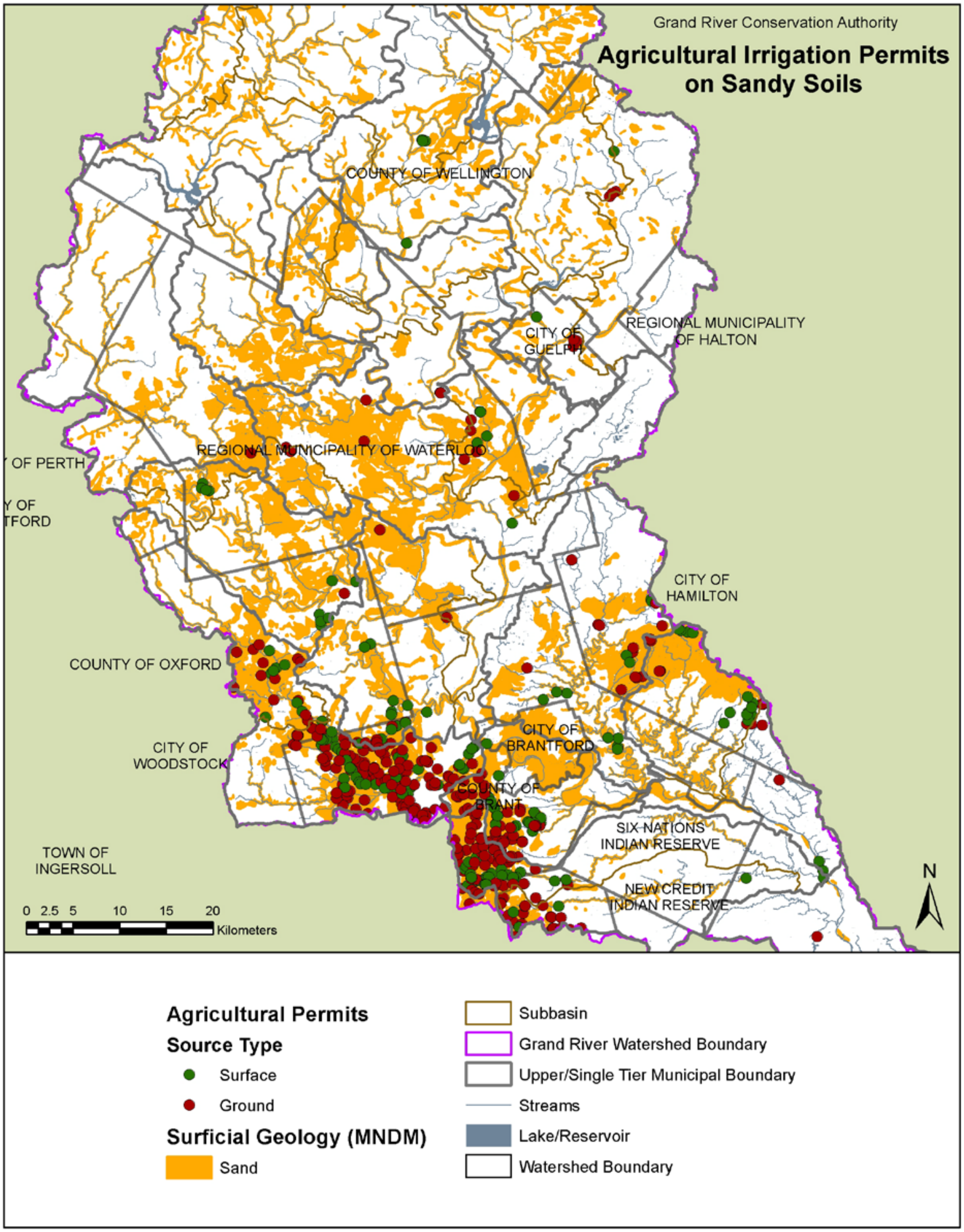

Figure 2: Agricultural irrigation Permits To Take Water and extent of sandy soils in the Grand River watershed.

Future Irrigation Water Use Scenarios

It could be that agricultural crop irrigation will decrease due to market ebb and flow, land conversion or other factors. For the purposes of this report, scenarios of decreased agricultural water use are not investigated and scenarios of future water needs are focused on scenarios of agricultural water supply needs that do increase.

Based on considerations as they appeared in 2011-12, OMAFRA staff have suggested low and moderate agricultural water use scenarios based on modest increases in the amount of cropland that is irrigated in the areas of the watershed where crop irrigation occurs today. In response to the extremely dry season experienced in 2012, OFA representatives subsequently suggested additional scenarios describing expanded use of irrigation for crops that have not traditionally been irrigated (e.g. corn, soybeans). Note that none of these scenarios are based on rigorous forecasting; instead, these scenarios are intended to envelope the future possibilities so that the relative significance of increased crop irrigation can be described.

The five scenarios (low, 2 moderate and 2 high) are described in **Table 3**.

Table 3. Future agricultural irrigation scenarios

1. Low Water Use Scenario:	a. Irrigation demand remains similar to current
2. Moderate Water Use Scenarios:	a. Current irrigation area is expanded by 10% b. Irrigation area is expanded by 25%
3. High Water Use Scenarios:	a. 10% of cropland on sandy soils is irrigated b. 5% of all cropland is irrigated

Scale of Investigation

The Grand River watershed has been divided into 17 subwatersheds for investigation these are shown in **Figure 3**. The investigation results are meant to be interpreted at this regional scale (and not at a local or property scale).

Scenarios of future agricultural water use have been investigated at the surfacewater subwatershed scale, shown in **Figure 3**. However, it is assumed that most of the additional agricultural water demands will come from groundwater sources.

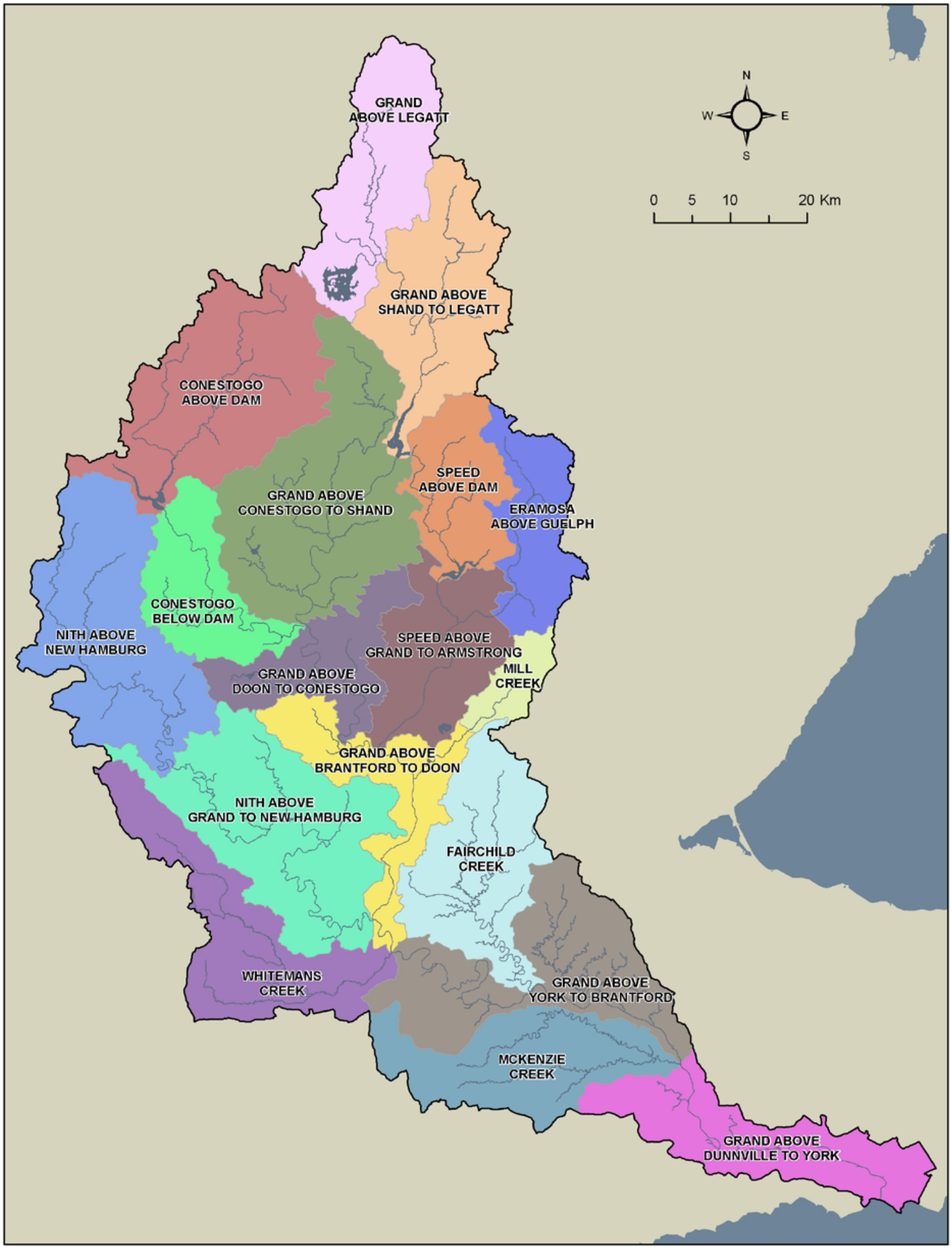

Figure 3: Subwatersheds in the Grand River watershed.

Low Water Use Scenarios

Scenario 1: Irrigation Demand Remains Similar to Current

Future agricultural water use of Scenario 1 is the same as the current day estimates. Under these current conditions, the agricultural water demand in an average year (4 irrigation events) would be 7,424,000 m³/year and during a drought year (10 irrigation events) 18,560,000 m³/year cumulatively across the watershed (**Table 4**).

The water demand of the 5 most irrigated surfacewater subwatershed accounts for 79.11% of the Grand River watershed's irrigational water demands. The consumptive irrigation demands of these 5 subwatersheds are displayed in **Figure 4.**

Moderate Water Use Scenarios

Scenario 2a: Current irrigation area is expanded by 10%

Scenario 2b: Irrigation area is expanded by 25%

In Scenarios 2a and 2b, the current irrigated area was increased by 10% and 25%, respectively, on a subwatershed basis. Therefore, subwatersheds with already high irrigation were increased by a larger amount than areas with low irrigation.

The total amount of irrigated area as a percentage of sandy soils across the subwatersheds would increase from 4.34% to 4.77% and 5.42%, respectively (**Table 5**). The average consumptive agricultural irrigation water demand would be 10% and 25% greater, respectively, than the current and Scenario 1 conditions (**Table 4**).

Under Scenario 2a conditions (10% increase in irrigated area), the agricultural irrigation water demand in an average year (4 irrigation events) would be 8,167,000 m³/year and during a drought year (10 irrigation events) 20,416,000 m³/year cumulatively across the watershed (**Table 4**).

Under Scenario 2b conditions (25% increase in irrigated area), the agricultural irrigation water demand in an average year (4 irrigation events) would be 9,280,000 m³/year and during a drought year (10 irrigation events) 23,201,000 m³/year cumulatively across the watershed (**Table 4**).

The average amount of irrigated area across the 5 highest agriculturally water demanding subwatersheds would increase from 8.87% of irrigated sandy soil area to 9.76% in Scenario 2a and 11.09% in Scenario 2b(**Table 5**). The consumptive demands of these 5 subwatershed are presented in **Figure 4** and the increased irrigated areas are displayed in **Figure 5.**

High Water Use Scenarios

Scenario 3a: 10% of cropland on sandy soils is irrigated

Scenario 3b: 5% of all cropland is irrigated

As requested by the OFA and County representatives, two agricultural water use scenarios are investigated to capture the high range of increased need for irrigation that may occur in the future.

For these scenarios it was assumed that, irrigation will likely increase in subwatersheds where irrigation is already prevalent to a larger amount than areas with low current irrigation levels. The increased agricultural water demand under each scenario was distributed proportionally across the 17 subwatersheds rather than distributing the increases uniformly. Details of how water demand was distributed are included below for each scenario.

Agricultural Irrigation

The first high agricultural water use scenario, Scenario 3a, is based on an increase in irrigation to cover 10% of sandy soils across the entire Grand River watershed (i.e. soils where crops are most in need of irrigation). This would increase from the current 4.3% of sandy soils being irrigated and is considered to be a significant increase in agricultural water demands.

Cropland extent was determined from the 1999 Landsat data to include the land use categories of row crops (including bare cultivated soil), small grains and forage (GRCA, 2013). It was assumed that irrigation would increase faster in areas that already have irrigation compared to new areas of the watershed. 10% of the total amount of sandy soils was calculated and then portioned to various subwatersheds based on the proportion of current irrigated land in that subwatershed compared to the total for the Grand River watershed. The proportional increases in irrigated sandy soil areas for all subwatersheds are shown in (**Table 6**).

The average consumptive agricultural water demand under these conditions would be 130% greater than the current and Scenario 1 conditions (**Table 4**). The agricultural water demand in an average year (4 irrigation events) would be 17,108,000 m^3/year and during a drought year (10 irrigation events) 42,771,000 m^3/year cumulatively across the watershed (**Table 4**).

Currently, Whitemans and McKenzie Creeks are the only subwatersheds with higher than 10% of sandy soils being irrigated (11.9% and 19.8%, respectively), while all other subwatersheds are well under 10%, with an average of 4.05%. In the 5 subwatersheds with the greatest agricultural water demands, Scenario 3a would increase the average amount of irrigated sandy soils from 8.87% to 20.45% of sandy soils (**Table 6**). The increased irrigated areas of these 5 subwatersheds are displayed in **Figure 5** and their consumptive water demands are presented in **Figure 4**.

The second high use scenario, Scenario 3b, is an estimate of the water demand if 5% of all cropland in the Grand River watershed were irrigated. This would account for approximately 3% of the entire Grand River watershed land area being irrigated, whereas the estimate from the 2006 Census information is that 1.72% of the watershed is irrigated. This scenario assumes an extreme increase in agricultural water demands if 5% of the cropland was irrigated and **Table 7** shows the resulting increase in irrigated area of each subwatershed.

It was assumed that irrigation would increase in sandy areas first, so the starting point was Scenario 3a. It was then determined how much more area should be irrigated to bring the total irrigated cropland across the watershed to 5%. This extra land was portioned throughout the watershed based on percentage of cropland in each subwatershed. So the total amount of irrigation across the watershed is 5% of all crop land, but some subwatershed have as high as 20% of the land irrigated and others have as low as 1%.

Under these conditions, the consumptive agricultural water demand would be 190% greater than the current (Scenario 1) conditions (**Table 4**). The agricultural water demand in an average year (4 irrigation events) would be 21,564,000 m^3/year and during a drought year (10 irrigation events) 53,910,000 m^3/year cumulatively across the watershed (**Table 4**).

In the 5 subwatersheds with the greatest agricultural water demands, Scenario 3b would result in an increase of average irrigated land from 4.72% to 11.92% of sandy soils (**Table 6**). The increased irrigated areas of these 5 subwatersheds are displayed in **Figure 5** and their consumptive agricultural water demands are presented in **Figure 4**.

Table 4. Consumptive demand for the low (1), moderate (2a and 2b) and high (3a and 3b) future agricultural water use scenario of the 17 surfacewater subwatersheds.

Surfacewater Subwatershed	Total Sub-watershed Area (ha)	Current Irrigated Area (of total area)	Consumptive Use (1000m³/year)									
			Scenario 1		Scenario 2a (10% Increase in Irrigated Land)		Scenario 2b (25% Increase in Irrigated Land)		Scenario 3a (10% of all Sandy Soil Irrigated)		Scenario 3b (5% of all Crop Land Irrigated)	
			4 Events	1 0 Events	4 Events	10 Events	4 Events	10 Events	4 Events	10 Events	4 Events	10 Events
Grand Above Legatt	35,872	196	231	579	255	636	289	723	533	1,333	691	1,726
Grand Above Shand	42,405	16	19	49	21	53	24	61	45	112	292	730
Grand Conestogo to Shand	63,977	41	49	122	54	135	61	153	113	282	673	1,681
Conestogo Above Dam	57,095	11	13	32	14	35	16	40	29	74	543	1,359
Conestogo Below Dam	24,856	58	69	172	76	190	86	216	159	397	375	937
Grand Paris to Conestogo	48,865	449	530	1,325	583	1,458	663	1,657	1,222	3,054	1,414	3,535
Eramosa River	26,093	32	38	96	42	105	48	120	88	220	214	535
Speed Above Dam	24,209	132	156	391	172	430	195	489	360	901	506	1,266
Speed Above Grand to Dam	27,845	191	226	564	248	620	282	705	520	1,299	612	1,531
Mill Creek	9,738	-	-	-	-	-	-	-	-	-	23	58
Nith Above New Hamburg	54,639	114	134	336	148	369	168	420	310	774	781	1,953
Nith Grand to New Hamburg	58,345	377	445	1,113	490	1,224	556	1,391	1,026	2,565	1,435	3,588
Whitemans Creek	40,378	1,970	2,327	5,817	2,559	6,398	2,908	7,271	5,362	13,404	5,689	14,224
Grand York to Paris	32,528	773	913	2,282	1,004	2,511	1,141	2,853	2,104	5,260	2,294	5,736
Fairchild and Big Creek	56,887	551	651	1,628	716	1,791	814	2,035	1,501	3,752	1,832	4,579
McKenzie and Boston Creeks	37,706	1,301	1,537	3,842	1,691	4,227	1,921	4,803	3,542	8,855	3,736	9,340
Grand Dunnville to York	38,432	72	85	213	94	234	106	266	196	490	453	1,132
TOTAL	**679,869**	**6,286**	**7,424**	**18,560**	**8,167**	**20,416**	**9,280**	**23,201**	**17,108**	**42,771**	**21,564**	**53,910**
Increase from current agricultural water demands			**0%**		**10%**		**25%**		**130%**		**190%**	

Five subwatershed with the largest irrigation demands

Table 5. Percent increase in irrigated area for moderate Scenarios 2a and 2b.

Subwatershed	Sandy Soils Area (ha)	Current Irrigated Sub-watershed Area (ha)	Irrigated Area as % of Sandy Soils	Scenario 2a (10% Increase in Irrigated Land)		Scenario 2b (25% Increase in Irrigated Land)	
				Irrigated Area (ha)	Irrigated Area as % of Sandy Soils	Irrigated Area (ha)	Irrigated Area as % of Sandy Soils
Grand Above Legatt	3,055	196	6.41%	216	7.06%	245	8.02%
Grand Above Shand	13,247	16	0.12%	18	0.14%	21	0.16%
Grand Conestogo to Shand	9,528	41	0.44%	46	0.48%	52	0.54%
Conestogo Above Dam	7,489	11	0.14%	12	0.16%	14	0.18%
Conestogo Below Dam	5,341	58	1.09%	64	1.20%	73	1.37%
Grand Paris to Conestogo	13,247	449	3.39%	494	3.73%	561	4.24%
Eramosa River	1,083	32	2.99%	36	3.29%	41	3.74%
Speed Above Dam	3,689	132	3.59%	146	3.95%	165	4.49%
Speed Above Grand to Dam	5,931	191	3.22%	210	3.54%	239	4.02%
Mill Creek	169	-	0.00%	-	0.00%	-	0.00%
Nith Above New Hamburg	7,814	114	1.46%	125	1.60%	142	1.82%
Nith Grand to New Hamburg	20,086	377	1.88%	415	2.06%	471	2.35%
Whitemans Creek	16,559	1,970	11.90%	2,167	13.09%	2,462	14.87%
Grand York to Paris	10,425	773	7.41%	850	8.16%	966	9.27%
Fairchild and Big Creek	16,255	551	3.39%	606	3.73%	689	4.24%
McKenzie and Boston Creeks	6,577	1,301	19.79%	1,431	21.76%	1,627	24.73%
Grand Dunnville to York	4,356	72	1.65%	79	1.82%	90	2.07%
TOTAL	679,869	6,286	4.34%	6,914	4.77%	7,857	5.42%
	Average of all 17		4.05%	120	4.46%	137	5.06%
	Average of top 5 (green)		8.87%	1094	9.76%	1243	11.09%

Five subwatershed with the largest irrigation demands

Table 6. Percent increase in irrigated area of sandy soils in high Scenario 3a with significant agricultural irrigation expansion.

Subwatershed	Sandy Soils Area (ha)	Current Irrigated Sub-watershed Area (ha)	Irrigated Area as % of Sandy Soils	Proportion of Increased Demand	Scenario 3a (10% of all Sandy Soils)	
					Total Sand Irrigated (ha)	Total % Sand Irrigated
Grand Above Legatt	3,055	196	6.41%	3.12%	451	14.78%
Grand Above Shand	13,247	16	0.12%	0.26%	38	0.29%
Grand Conestogo to Shand	9,528	41	0.44%	0.66%	96	1.00%
Conestogo Above Dam	7,489	11	0.14%	0.17%	25	0.33%
Conestogo Below Dam	5,341	58	1.09%	0.93%	135	2.52%
Grand Paris to Conestogo	13,247	449	3.39%	7.14%	1,034	7.81%
Eramosa River	1,083	32	2.99%	0.52%	75	6.89%
Speed Above Dam	3,689	132	3.59%	2.11%	305	8.27%
Speed Above Grand to Dam	5,931	191	3.22%	3.04%	440	7.42%
Mill Creek	169	-	0.00%	0.00%	-	0.00%
Nith Above New Hamburg	7,814	114	1.46%	1.81%	262	3.35%
Nith Grand to New Hamburg	20,086	377	1.88%	6.00%	869	4.32%
Whitemans Creek	16,559	1,970	11.90%	31.34%	4,539	27.41%
Grand York to Paris	10,425	773	7.41%	12.30%	1,781	17.09%
Fairchild and Big Creek	16,255	551	3.39%	8.77%	1,271	7.82%
McKenzie and Boston Creeks	6,577	1,301	19.79%	20.70%	2,999	45.59%
Grand Dunnville to York	4,356	72	1.65%	1.15%	166	3.81%
TOTAL	144,852	6,286	4.34%	100.00%	14,485	10.00%
	Average of all 17		4.05%		852	9.34%
	Average of top 5 (green)		8.87%		2292	20.45%

Five subwatershed with the largest irrigation demands

Table 7. Percent increase in irrigated area if 5% of all crop land was irrigated in high Scenario 3b with extreme agricultural irrigation expansion.

Subwatershed	Crop land (ha)	Current Irrigated Sub-watershed Area (ha)	Irrigated Area as % Crop Land	Proportion of Increased Demand	Scenario 3b (5% of all Crop Land)			
					Total Sand Irrigated (ha)	Additional Irrigated Cropland (ha)	Total Irrigated Cropland (ha)	% Crop Land Irrigated
Grand Above Legatt	12,894	196	1.52%	3.53%	451	133	585	4.53%
Grand Above Shand	20,277	16	0.08%	5.55%	38	209	247	1.22%
Grand Conestogo to Shand	45,875	41	0.09%	12.56%	96	474	569	1.24%
Conestogo Above Dam	42,126	11	0.03%	11.54%	25	435	460	1.09%
Conestogo Below Dam	17,697	58	0.33%	4.85%	135	183	317	1.79%
Grand Paris to Conestogo	15,770	449	2.85%	4.32%	1,034	163	1,197	7.59%
Eramosa River	10,315	32	0.31%	2.82%	75	107	181	1.76%
Speed Above Dam	11,955	132	1.11%	3.27%	305	124	429	3.59%
Speed Above Grand to Dam	7,587	191	2.52%	2.08%	440	78	518	6.83%
Mill Creek	1,894	-	0.00%	0.52%	-	20	20	1.03%
Nith Above New Hamburg	38,636	114	0.29%	10.58%	262	399	661	1.71%
Nith Grand to New Hamburg	33,543	377	1.12%	9.19%	869	347	1,215	3.62%
Whitemans Creek	26,869	1,970	7.33%	7.36%	4,539	278	4,817	17.93%
Grand York to Paris	15,611	773	4.95%	4.28%	1,781	161	1,943	12.44%
Fairchild and Big Creek	27,127	551	2.03%	7.43%	1,271	280	1,551	5.72%
McKenzie and Boston Creeks	15,915	1,301	8.18%	4.36%	2,999	164	3,163	19.88%
Grand Dunnville to York	21,063	72	0.34%	5.77%	166	218	383	1.82%
TOTAL	365,152	6,286	1.72%	100.00%	14,485	3,772	18,258	5.00%
	Average of all 17		1.95%		852	222	1,074	5.52%
	Average of top 5 (green)		4.72%		2292	246	2,538	11.92%

Five subwatershed with the largest irrigation demands (green shading)

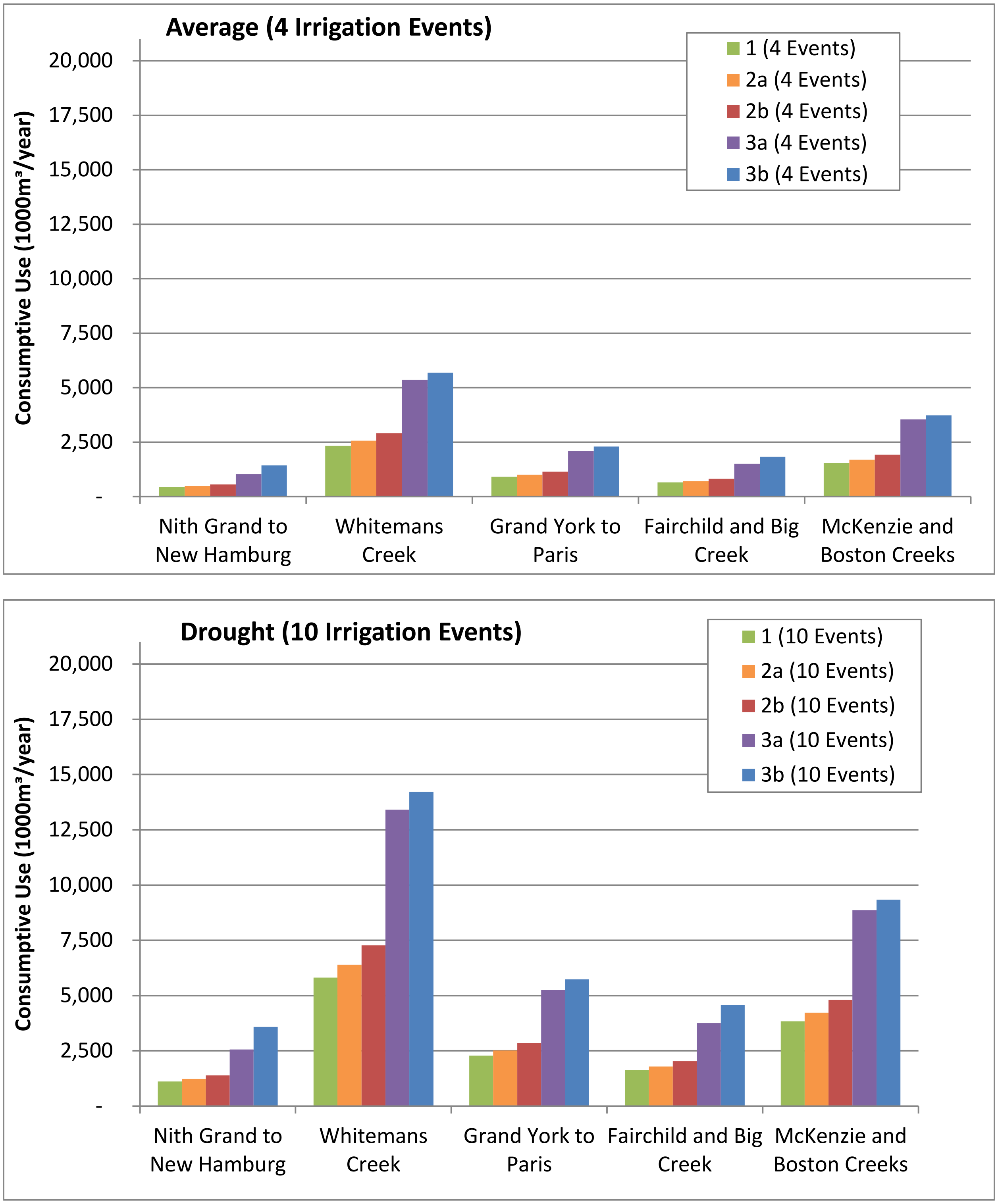

Figure 4: Consumptive irrigation water demands for the low, moderate and high future agricultural water use scenarios of the 5 highest agriculturally water demanding subwatersheds in the Grand River watershed.

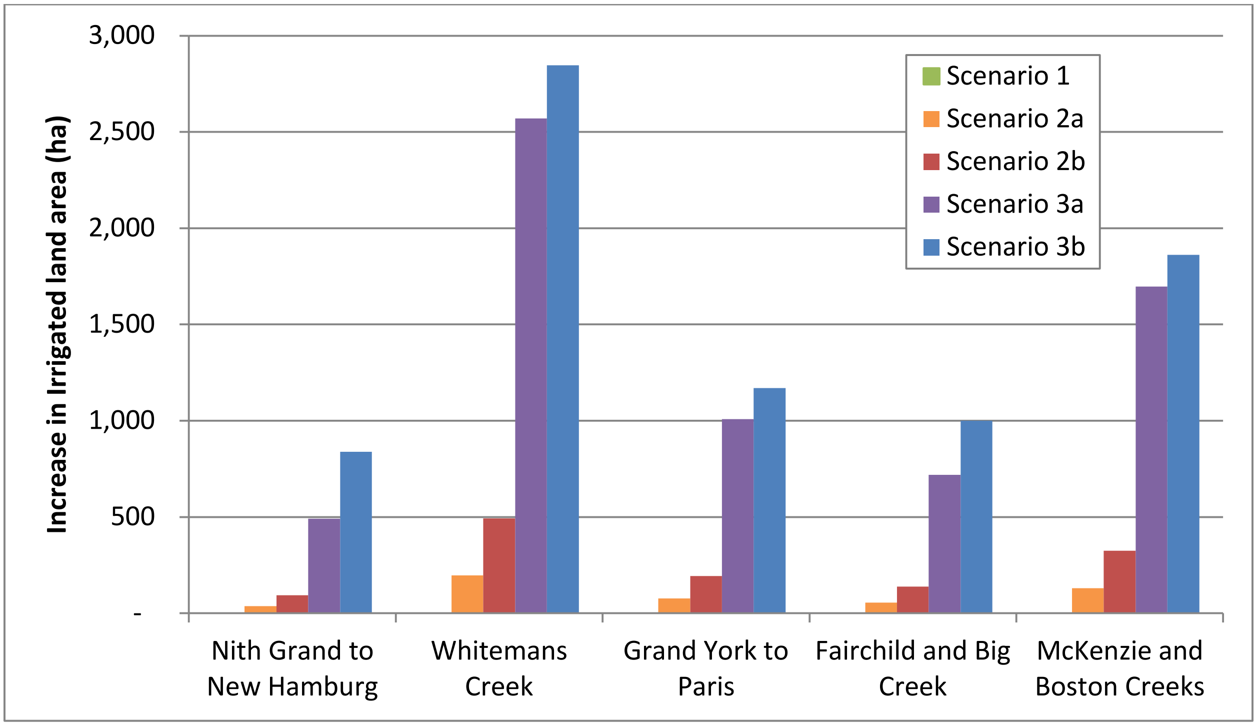

Figure 5: Increase in agricultural irrigated area from current for the low, moderate and high future agricultural water use scenarios of the 5 highest agriculturally water demanding subwatersheds in the Grand River watershed.

Note: Scenario 1 shows no increase in irrigated land area because the irrigated area is assumed to remain the same as current.

This page was left blank intentionally

Interpreting the Relative Significance of Increased Crop Irrigation

Total percent water demand has been used to interpret the relative significance of increased crop irrigation for the purpose of discussing sustainable agricultural water use in the watershed. Percent water demand is the total water demand by all users as a percentage of available water based on the water budget that was developed for the Grand River watershed as part of the Lake Erie Region Source Protection Program.

Percent Water Demand

The Tier 2 Grand River Water Quantity Stress Assessment (T2-WQSA), completed under the Source Protection Program, detailed the current and future assessments of groundwater supply and demand (ARI, 2009b). In the Tier 2 future demand assessment, municipal demand forecasts to 2031 were combined with existing water use in all other sectors. To assess the addition of changes to irrigation water demand, future water demand values were taken from the Tier 2 assessment and applied on a subwatershed basis and then the increase in water demand based on each future irrigation water use scenario was added to the total future demand. It was assumed that there would be one irrigation event for average monthly demand and three irrigation events for the maximum monthly demand. All future additional irrigation water was assumed to be sourced from groundwater.

To calculate the potential for low, moderate or high water use, the same methodology as the T2-WQSA was used, and can be found in detail in ARI (2009b). The percent water demand is calculated as follows:

$$\textit{Percent Water Demand} = \frac{Q_{DEMAND}}{Q_{SUPPLY} - Q_{RESERVE}} \times 100\%$$

The terms are defined below:

- Q_{DEMAND} is equal to the consumptive demand calculated as the estimated rate of locally consumptive takings. (note: demands are grouped into surface and groundwater takings)
- Q_{SUPPLY} is the water supply term, calculated from surface water as the monthly median flow for the area to be assessed, and for groundwater supplies as the estimated annual recharge rate plus the estimated groundwater inflow to a subwatershed.
- $Q_{RESERVE}$ is the water reserve, defined as the specified amount of water that does not contribute to the available water supply. For surface water supplies, reserve is estimated using the 90th percentile monthly median flow, at a minimum (ie. The flow that is exceeded 90% of the time). Groundwater reserve is calculated as 10% of the total estimated groundwater discharge within a subwatershed.

The water use calculation for groundwater systems is carried out for the average monthly demand as well as the maximum monthly demand. The monthly water use for agricultural irrigation was calculated assuming an average month will have one irrigation event and the maximum month will have three irrigation events.

The Percent Water Demand is classified as low, moderate or high according to the thresholds listed in Table 8; the low, moderate, and high threshold colour scheme is used through all percent water demands Tables 9 and 13.

Agricultural Irrigation

Table 8: Percent Water Demand thresholds for Low, Moderate and High

Percent Water Demand Level Assignment	Average Monthly Percent Water Demand	Maximum Monthly Percent Water Demand	Interpretation of Regional Effects
Low	0 – 10%	0 – 25%	Unlikely
Moderate	> 10%	> 25%	Some potential exists
High	> 25%	> 50%	Potential exists

The results of the calculated future Percent Water Demands are detailed in **Table 9** and the Moderate and High conditions are highlighted according to the colour scheme from **Table 8** above. Values in **Table 9** reflect the sum of the future scenarios of agricultural irrigation water use, municipal water use projected to 2031 and current water use levels staying stagnant in all other sectors.

In summary, **Table 9** shows generally Low potential for regional effects on groundwater supplies due to the increased water use scenarios – this is good news. There is no assessment area where the Percent Water Demand increases from Low to Moderate or Moderate to High due to the projected future irrigation water takings.

There are 6 assessment areas where there is Moderate or High Percent Water Demand. These are primarily due to existing and projected municipal water use particularly in the Grand River above Paris to Conestogo and Speed above Grand to Dam (Wong, 2001). Even under the significant/extreme future scenarios (3a and 3b), increased agricultural irrigation only marginally increases the Percent Water Demand.

Comparison of Water Demand by Sector (Scenarios 3a and 3b)

The proportion of total projected water demand by each of the water use sectors for Scenarios 3a and 3b water demand by sector was compared to determine if increased agricultural irrigation would surpass the volumes of water consumed by other sectors. The results are presented in **Table 10** and **Table 11**, respectively. The scenarios include future municipal water demand but existing (un-projected) demand for all other water sectors.

In the original T2-WQSA, agricultural irrigation accounted for 5% of existing water demand and was limited to eight subwatersheds, mostly in the southern portion of the watershed.

High Scenario 3a increases the proportion of agricultural irrigation demand to 7%. The highest irrigation demand still remains in the southern portion of the watershed in McKenzie and Whitemans Creek subwatersheds. The northern till plain areas show some irrigation demand but this demand is small in proportion to other uses.

High scenario 3b increases the proportion of agricultural irrigation demand to 14%, and is spread across all subwatersheds. The highest agricultural demand still remains in the southern portion of the watershed in McKenzie and Whitemans Creek subwatersheds.

Note that in the Central Grand (Grand River above Paris to Conestogo and Speed above Grand to Dam) where the Percent Water Demand is High, agricultural irrigation projections only account for 1% to 2% of consumptive water use due to the large proportion of municipal water takings.

Both Whiteman's and McKenzie Creek Groundwater Subwatersheds have Low Percent Water Demand but a high proportion of that use (43% and 51%) is crop irrigation. The water availability is very high relative to other subwatershed areas because of the geology of this sand plain area.. These two areas currently have water challenges but these challenges may be related more to surface water taking from the creeks and not from high water use in general, given the abundant availability of ground water. This situation warrants further investigation.

Table 9. Groundwater percent water demand for the low (1), moderate (2a and 2b) and high (3a and 3b) future water use in all sectors under future Scenarios of the 17 surfacewater subwatersheds.

Assessment Areas	Groundwater Availability Parameters (L/s)		Future Percent Water Demand									
			Scenario 1: Similar to Current Demands		Scenario 2a: 10% increase in irrigation		Scenario 2b: 25% increase in irrigation		Scenario 3a: 10% of all Sandy Soils		Scenario 3b: 5% of all Cropland	
	Supply	Reserve	Average Monthly	Max Monthly	Average Monthly	Max Monthly	Average Monthly	Max Monthly	Average Monthly	Max Monthly	Average Monthly	Max Monthly
Grand Above Legatt	2,046	162	1%	1%	1%	1%	1%	2%	1%	2%	2%	2%
Grand Above Shand to Leggatt	1,609	207	5%	5%	5%	5%	5%	5%	5%	6%	5%	6%
Grand Above Conestogo to Shand	2,939	217	12%	13%	12%	13%	12%	13%	12%	13%	13%	14%
Conestogo Above Dam	1,969	122	2%	2%	2%	2%	2%	2%	2%	2%	2%	3%
Conestogo Below Dam	1,859	155	3%	3%	3%	3%	3%	3%	3%	3%	3%	4%
Grand Above Paris to Conestogo	2,682	353	56%	69%	56%	69%	56%	69%	56%	70%	56%	70%
Eramosa Above Guelph	1,683	153	19%	23%	19%	23%	19%	23%	19%	23%	19%	23%
Speed Above Dam	1,609	158	2%	4%	2%	4%	2%	4%	2%	4%	2%	5%
Speed Above Grand To Dam	1,521	166	61%	67%	61%	67%	61%	67%	62%	67%	62%	67%
Mill Creek	660	44	13%	19%	13%	19%	13%	19%	13%	19%	13%	19%
Nith Above New Hamburg	2,879	113	2%	3%	2%	3%	2%	3%	2%	3%	2%	3%
Nith Above Grand to New Hamburg	4,101	321	7%	12%	7%	12%	8%	12%	8%	12%	8%	12%
Whitemans Creek	2,787	224	4%	16%	4%	16%	4%	17%	5%	19%	5%	19%
Grand Above York to Brantford	1,285	163	20%	35%	20%	35%	20%	36%	21%	38%	21%	38%
Fairchild Creek	1,831	162	5%	7%	5%	7%	6%	7%	6%	8%	6%	9%
Mckenzie Creek	1,089	86	5%	20%	5%	20%	5%	21%	6%	25%	6%	25%
Grand Above Dunnville to York	1,047	91	10%	12%	10%	12%	10%	12%	10%	12%	10%	13%

Five subwatershed with the largest irrigation demands

Note: *Current climate:* one (1) irrigation event assumed for average monthly irrigation water demand and three (3) events for the maximum monthly water demand.

Table 10 Breakdown of consumptive groundwater demand by sector using future municipal demand and scenario 3a

Subwatershed	Commercial	Dewatering	Industrial	Institutional	Misc	Recreational	Remediation	Private Water Supply	Argi Irrigation	Rural/ Livestock	Municipal	Avg Annual Demand
Grand Above Legatt	32%	0%	0%	0%	0%	0%	0%	4%	30%	7%	27%	42
Grand Above Shand	0%	0%	11%	0%	5%	0%	0%	58%	1%	7%	18%	78
Grand Conestogo to Shand	25%	4%	2%	0%	0%	0%	31%	0%	1%	4%	34%	408
Conestogo Above Dam	0%	0%	7%	0%	0%	0%	0%	5%	1%	20%	68%	52
Conestogo Below Dam	0%	0%	32%	0%	0%	0%	0%	14%	8%	28%	18%	48
Central Grand	6%	4%	11%	0%	0%	0%	4%	5%	1%	1%	67%	2029
Upper Speed	4%	14%	2%	0%	1%	0%	0%	0%	2%	1%	75%	1153
Mill Creek	37%	0%	42%	0%	1%	0%	0%	19%	0%	2%	0%	83
Upper Nith	3%	0%	11%	0%	0%	0%	0%	3%	5%	12%	66%	141
Lower Nith	5%	0%	19%	0%	0%	0%	0%	4%	10%	4%	58%	233
Whitemans Creek	2%	0%	0%	0%	0%	0%	0%	0%	90%	7%	1%	141
Grand York to Paris	16%	0%	9%	0%	0%	0%	0%	0%	52%	4%	19%	97
Fairchild and Big Creek	16%	0%	8%	0%	0%	0%	2%	16%	23%	13%	22%	153
McKenzie and Boston Creeks	0%	0%	0%	0%	0%	0%	0%	0%	94%	6%	0%	89
Grand Dunnville to York	6%	83%	0%	0%	0%	0%	0%	0%	5%	6%	0%	97
Total	8%	7%	8%	0%	0%	0%	4%	4%	8%	3%	56%	4846

Table 11 Breakdown of consumptive groundwater demand by sector using future municipal demand and scenario 3b

Subwatershed	Commercial	Dewatering	Industrial	Institutional	Misc.	Recreational	Remediation	Private Water Supply	Argi Irrigation	Rural/ Livestock	Municipal	Avg Annual Demand
Grand Above Legatt	29%	0%	0%	0%	0%	0%	0%	4%	36%	6%	25%	46
Grand Above Shand	0%	0%	10%	0%	4%	0%	0%	54%	8%	7%	17%	84
Grand Conestogo to Shand	24%	4%	2%	0%	0%	0%	30%	0%	4%	4%	32%	421
Conestogo Above Dam	0%	0%	5%	0%	0%	0%	0%	4%	20%	16%	55%	65
Conestogo Below Dam	0%	0%	29%	0%	0%	0%	0%	13%	17%	25%	16%	53
Central Grand	6%	4%	11%	0%	0%	0%	4%	5%	2%	1%	67%	2034
Upper Speed	4%	14%	2%	0%	1%	0%	0%	0%	3%	1%	74%	1162
Mill Creek	36%	0%	42%	0%	1%	0%	0%	19%	1%	2%	0%	83
Upper Nith	3%	0%	10%	0%	0%	0%	0%	3%	12%	11%	61%	153
Lower Nith	5%	0%	18%	0%	0%	0%	0%	4%	14%	4%	56%	242
Whitemans Creek	2%	0%	0%	0%	0%	0%	0%	0%	91%	6%	1%	149
Grand York to Paris	15%	0%	8%	0%	0%	0%	0%	0%	54%	4%	18%	101
Fairchild and Big Creek	15%	0%	7%	0%	0%	0%	1%	15%	27%	12%	21%	161
McKenzie and Boston Creeks	0%	0%	0%	0%	0%	0%	0%	0%	94%	6%	0%	94
Grand Dunnville to York	5%	78%	0%	0%	0%	0%	0%	0%	10%	6%	0%	103
Total	8%	7%	8%	0%	0%	0%	4%	4%	10%	3%	55%	4952

Climate Change Scenarios

With respect to climate change impacts, the *number of irrigation events* was used as the variable that would change with respect to current day. These scenarios are independent and in addition to the scenarios presented above which altered the land area that would be irrigated.

A number of climate change scenarios were supplied by the Ministry of Natural Resources and Forestry (MNRF), using a 'change field' method, where data is given to alter a base case of historic data (in this study, 1961-1990). These change fields are a result of various Global Circulation Models (GCMs) from the Fourth Assessment Report by the Intergovernmental Panel on Climate Change (IPCC). The change fields represent monthly percentage changes for precipitation (positive or negative), or a monthly degree addition for temperature, to the base case data. All the scenarios showed an increase in temperature projected out to 2050, while precipitation fields were either higher or lower than the base case. Of all the 76 scenarios, each scenario is assumed to have an equal probability of occurring.

Three scenarios (#30, #34 and #65) were chosen from the 10 suggested by the MNRF, to show 3 different potential futures and to determine the differences in irrigation water demand:

- Scenario 65 had a large increase in temperature, annually at 3.5°C, but moderate (3.0°C) in the summer growing season. The precipitation change in Scenario 65 was drastic during the growing season, as much as 28% lower in the month of August from the base scenario.
- Scenario 30 annually had both a small increase in temperature (approximately 2°C) and a slight increase in precipitation, just over 10%, with the summer months fluctuating between high and low increases.
- Scenario 34 was considerably warmer than the base case (3.7°C), just higher than Scenario 65, but with only a slight annual increase in precipitation. The summer months showed a moderate deficit in precipitation, yet not as drastic as Scenario 65. The monthly change fields for temperature and precipitation for each of these scenarios can be seen in **Figure 6.**

For the seasonal months of May through October, the scenarios were run through an irrigation demand model. Modeling had previously been completed in the Grand River Water Use Inventory Report of 2005 and 2011 on current water uses, using climate and soil moisture to trigger irrigation events when precipitation is not enough. To estimate the number of irrigation events required, soil moisture modeling based on climate, soil type and vegetation cover (land use) would estimate how often irrigation events were triggered. Detail regarding this methodology can be found in Bellamy and Boyd (2005). For this study, a hydrologic response unit for sandy soil, low vegetation was employed under the three climate change scenarios (#30, #34, and #65) as well as the base case (1961-1990).

Scenario 65 and Scenario 34 were the most drastic in terms of decrease in precipitation and increase in temperature, respectively. This had a considerable impact on irrigation.

For the base case (1960-1990), an average requirement for supplemental irrigation was modeled at 8 events per year from June through September. The 3 scenarios were also modeled to compare results.

For the different scenarios, Scenario 65 results were the most extreme, followed by Scenario 34 and very little difference for Scenario 30. With the slight increase in precipitation in some months for Scenario 30, the irrigation requirements were actually lower than the base case, despite an increase in monthly temperatures. Scenario 30 most similarly mimics current day. The most extreme result of the 3 scenarios is 50% more irrigation events. The summary of seasonal events can be seen in **Table 12.**

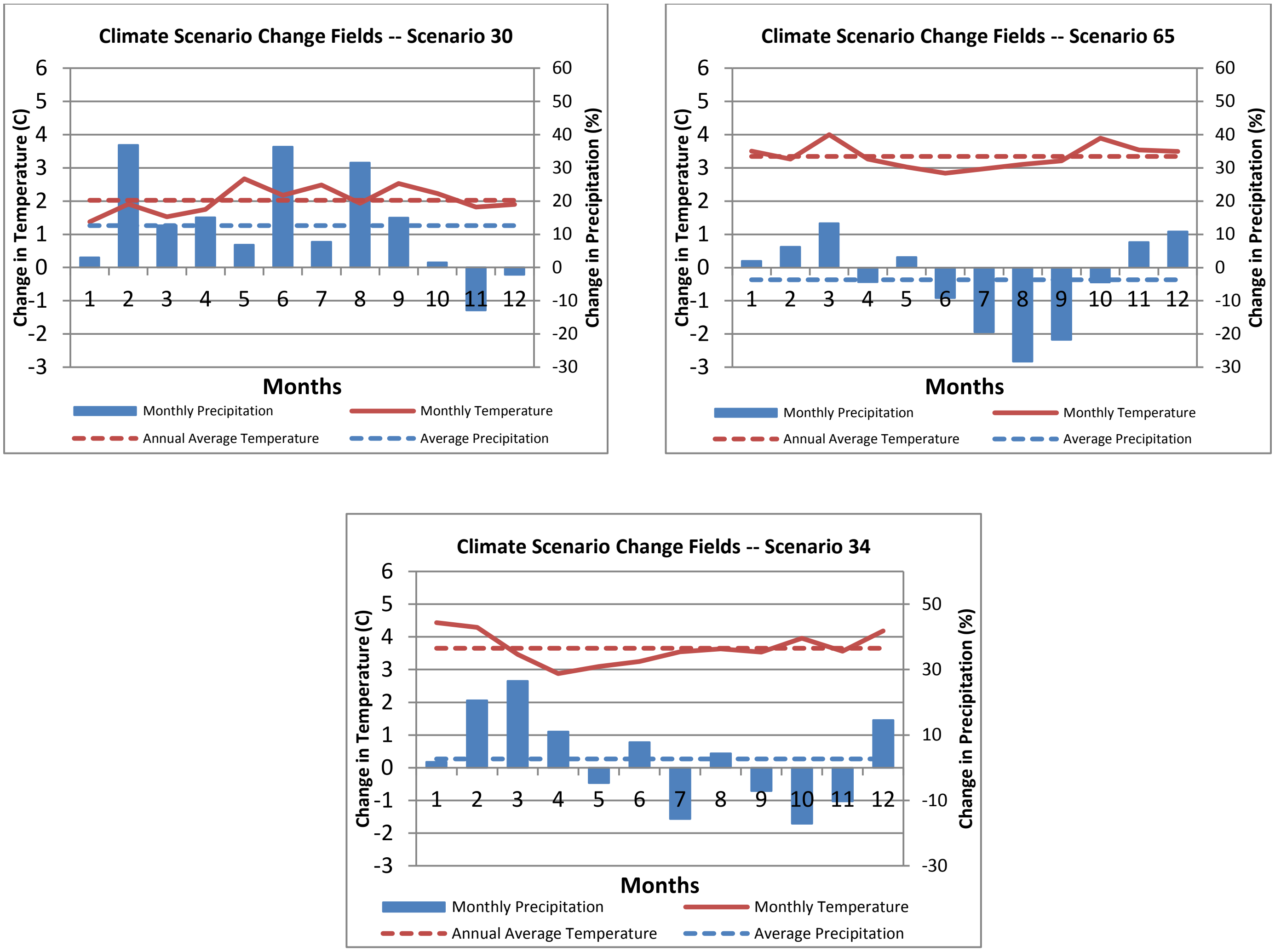

Figure 6: Monthly change fields for 3 climate change scenarios

Table 12: Average number of irrigation events for base case and 3 climate change scenarios

Scenario	Time Period	Average # of Irrigation Events
Baseline	1960-1990	8
65	2050's	12
34	2050's	11
30	2050's	8

Of the 3 climate change scenarios in Table 12, scenario 34 was selected as the moderate worst case scenario and was used to run future percent water demand calculations. This allowed us to look at the impact of climate change on the low, moderate (2a and 2b) and high (3a and 3b) irrigation scenarios. Two (2) irrigation events were assumed for average monthly irrigation water demand and five (5) events for maximum monthly demand. These amounts are higher than the previous percent water demand calculations which used one (1) event for the average monthly calculation and three (3) events for the maximum monthly water demand.

Percent Water Demand

The future percent water demands from the Scenarios combined with climate change are detailed in **Table 13. Table 13** highlights the resulting water use thresholds (similar to **Table 9**) under the effect of climate change.

In summary, **Table 13** does show some increase in water demands under Scenarios 3a and 3b due to the combination of expanded irrigated area and increased irrigation events as a result of climate change. In Scenario 3a, McKenzie Creek develops a moderate Percent Water Demand for the maximum monthly water use and in Scenario 3b, a moderate Percent Water Demand for the average monthly and maximum monthly water use. .

Throughout all scenarios, Grand above York to Brantford shows moderate Percent Water Demands, while in Scenario 3b, the average monthly water use results in high Percent Water Demand.

With and without climate change, both Grand River above Paris to Conestogo and Speed above Grand to dam subwatersheds show high average annual and monthly maximum groundwater use demands throughout all scenarios. The high water use trends in these two subwatersheds are due to the high municipal water demands, not agricultural irrigation (Wong, 2011). Municipal water demands are the reasons most subwatershed are over the moderate Percent Water Demand threshold.

Table 13: Groundwater Percent Water Demand for the Low (1), Moderate (2a and 2b) and High (3a and 3b) Future Water Use in all sectors under future Scenario of the 17 Surfacewater Subwatersheds with Climate Change.

Assessment Areas	Groundwater Availability Parameters (L/s) (Using Supply from Climate Change Scenario 34)		Future Water Demand with Climate Change									
			Scenario 1: Similar to Current Demands		Scenario 2a: 10% increase in irrigation		Scenario 2b: 25% increase in irrigation		Scenario 3a: 10% of all Sandy Soils		Scenario 3b: 5% of all Cropland	
	Supply	Reserve	Average Monthly	Max Monthly	Average Monthly	Max Monthly	Average Monthly	Max Monthly	Average Monthly	Max Monthly	Average Monthly	Max Monthly
Grand Above Legatt	2,380	185	1%	1%	1%	1%	1%	1%	1%	2%	2%	2%
Grand Above Shand to Leggatt	1,698	227	5%	5%	5%	5%	5%	5%	5%	5%	5%	6%
Grand Above Conestogo to Shand	3,111	230	12%	12%	12%	12%	12%	12%	12%	12%	12%	13%
Conestogo Above Dam	2,164	126	2%	2%	2%	2%	2%	2%	2%	2%	2%	3%
Conestogo Below Dam	1,682	154	3%	4%	3%	4%	3%	4%	3%	4%	3%	4%
Grand Above Paris to Conestogo	2,602	336	58%	71%	58%	71%	58%	71%	58%	72%	59%	73%
Eramosa Above Guelph	1,649	148	19%	24%	19%	24%	19%	24%	19%	24%	19%	24%
Speed Above Dam	1,589	152	2%	4%	2%	4%	2%	4%	2%	5%	2%	5%
Speed Above Grand To Dam	1,496	159	62%	68%	62%	68%	62%	68%	63%	69%	63%	69%
Mill Creek	622	40	14%	20%	14%	20%	14%	20%	14%	20%	14%	20%
Nith Above New Hamburg	2,918	105	2%	3%	2%	3%	2%	3%	2%	3%	3%	4%
Nith Above Grand to New Hamburg	3,999	302	8%	12%	8%	12%	8%	12%	8%	13%	8%	13%
Whitemans Creek	2,640	206	4%	17%	4%	17%	5%	18%	6%	22%	8%	25%
Grand Above York to Brantford	1,186	150	22%	38%	22%	38%	22%	39%	23%	43%	25%	45%
Fairchild Creek	1,697	147	6%	7%	6%	8%	6%	8%	7%	10%	8%	11%
Mckenzie Creek	1,003	77	5%	21%	5%	22%	6%	23%	9%	30%	11%	35%
Grand Above Dunnville to York	1,150	83	9%	11%	9%	11%	9%	11%	9%	11%	9%	12%

Five subwatershed with the largest irrigation demands

Note: *Under climate change conditions:* two (2) irrigation events assumed for average monthly irrigation water demand and five (5) events for maximum monthly demand.

Conclusions

It is apparent, based on this analysis, that the future water needs for crop irrigation can be sustainably met at the subwatershed scale, particularly if irrigation is sourced from groundwater and/or storage and not taken directly from surface water. It is important to recognize that throughout all future scenarios, with and without climate change, both the Grand River above Paris to Conestogo and Speed above Grand to dam subwatersheds show high average annual and monthly maximum groundwater use demands. This high water use trend is due to the high municipal water demands, not agricultural irrigation (Wong, 2011). Municipal water demands are the reasons most subwatershed were over the moderate water demands thresholds.

Modest changes in crop irrigation responding to the ebb and flow of market cycles is the most likely scenario. The significant and extreme scenarios investigated in this study represent fairly extreme expansion of irrigated land. However, it was important to confirm that even under these fairly extreme conditions, increased agricultural irrigation demand does not seem to result in moderate or high water supply impacts.

To minimize the potential for local effects and build resiliency for climate change, efficiency in irrigation water use is strongly encouraged. Increases in irrigation water taking should be developed from ground water sources. Regional water management strategies are needed in the Whitemans and McKenzie Creek sand plain areas to deal with current surface water use challenges.

This page was left blank intentionally

References

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

AquaResources Inc. (ARI), 2009a. Integrated Water Budget Report Final Version June 2009. Grand River Conservation Authority. Available online at http://www.sourcewater.ca/swp_watersheds_grand/Grand_2009WaterBudget_final.pdf

AquaResources Inc. (ARI), 2009b. Tier 2 Water Quality Stress Assessment Report. Final version December, 2009. Grand River Conservation Authority. Available online at http://www.sourcewater.ca/swp_watersheds_grand/Grand_2009Stress_Final.pdf

Bellamy, 2005. Water Use in the Grand River Watershed. Grand River Conservation Authority. Available online at http://www.grandriver.ca/Water/2006_WaterUse_complete.pdf

GRCA, 2013. GIS Layers. Produced using information under License with the Grand River Conservation Authority © Grand River Conservation Authority, 2013.

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

Kovacs, H. 2014. Whitemans Creek Subwatershed Drought Contingency Pilot. Available online at http://www.grandriver.ca/lowwater/WhitemansWRAMIPilot_2013.pdf

MNDM Various Authors, 1967-1993, Quaternary and Pleistocene Geology, Southern Ontario, Ontario Geological Survey.

NRVIS. 2013. GIS Layers. Produced using information provided by the Ministry of Natural Resources, Copyright © Queen's Printer, 2013.

Reschke, P. 2012. *100 extra bushels – one drip at a time*. Ontario Farmer, November 20, 2012. Accessed online 28 November, 2012 at http://www.vandenbussche.com/images/content/news-events/sub_irr_corn.pdf.

Schroeter, H.O., Boyd, D.K., Whiteley, H.R. 2000. 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.

Shortt, R., 2009. Personal communication with Rebecca Shortt, Irrigation Engineer with Ontario Ministry of Agriculture, Food and Rural Affairs.

Wong, A.W., 2011. Water Use Inventory Report for the Grand River Watershed. Grand River Conservation Authority. Available online at http://www.grandriver.ca/index/document.cfm?Sec=67&Sub1=1