Grand River Water Management Plan 2013 Update

Livestock Water Use and Future Water Needs

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Introduction

Agricultural water use is the highest seasonal water use in the Grand River watershed, peaking in the summer months of July through September. These months also coincide with low flow season and the potential for water use conflicts amongst 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 removed – or consumed – from the environment to get a more complete assessment of whether the future water needs of the agricultural sector can be sustainably met.

The purpose of this report is to refine water use information available about water needs for livestock watering and general farm operations. With consultation with specialists and the forecasting group at the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA), and the information gathered from Statistics Canada, a more detailed estimate of livestock water needs can be completed.

Projections for future water needs of the Grand River watershed agricultural sector were the focus of consultation with specialists and the forecasting group at OMAFRA, as well as information provided by Agriculture and Agri-Food Canada (AAFC). Water use for agriculture can be categorized into 2 uses: crop irrigation that occurs primarily in the growing season months of May through September (irrigation will be detailed in a separate report) and livestock drinking and washing requirements, which are needed year-round.

Livestock water use to date has been estimated using water use coefficients and Statistics Canada's agricultural census livestock population numbers. The basis for the current water use assessments are derived from this and future projections of water use will be compared to these values.

In the future, various aspects of livestock production numbers and water use may change due to market changes, local preferences and capabilities, and climate change impacts. For example, the agricultural industry may grow or intensify in this region but, at the same time, advancements in water efficiency continue to improve.

Based on these forecasts of future livestock production numbers, scenarios of future agricultural water use are prepared to show how the water use for agriculture may change in the future.

Current Livestock Water Use

Livestock watering accounts for approximately 6% of water consumption in the Grand River watershed and is the 5th highest user of water at approximately 7,500 m^3/year. Water use estimates for livestock watering and farm operations across the Grand River watershed are shown in **Figure 1.** Livestock are most abundant in the west-central portions of the Grand River watershed, encompassing the Conestogo and Nith River basins, or Wellesley, Wilmot and Mapleton townships.

To determine the water needs of livestock, water use coefficients are used to estimate the amount of water needed per animal for drinking, washing and other related uses (i.e. equipment washing). These coefficients have been detailed in work by Ecologistics in 1993, then updated by Ivey (1999) and revised and made available as a spreadsheet by de Loe and Kreutzwiser (2001). The coefficients are applied to Statistic Canada's Census of Agriculture documentation of livestock rolled up on a watershed basis. For the Grand River watershed, the Conservation Authority requested that data from Statistics Canada be rolled up into subwatersheds (instead of townships) to better reflect the watershed's populations. The most recent data available was the 2006 Census of Agriculture and the 2003 spreadsheet of water use coefficients to get the total livestock watering requirements of 7500 m^3/year.

The livestock water use coefficients have recently been altered by OMAFRA staff, updating the original coefficients to better reflect current standards in Ontario (see **Table 1**). The updated coefficients have increased dairy and swine drinking water needs; both livestock types are abundant in the Grand River watershed. The coefficients that were lowered included adult male sheep and some fur bearers, for example, but these are much fewer in number and had very little impact. Overall, the changes in the coefficients increased the overall water use for livestock by 6.5% from the original coefficients when applied to the 2006 Census of Agriculture information. These updated coefficients better reflect the demands of livestock but are increases from previous estimates of water use for livestock.

The new coefficients better reflect the water needs of livestock currently (Ward and McKague, 2007). The last column in **Table 1** shows the estimates by AAFC for the same livestock types, with the bolded values indicating higher estimates than the OMAFRA and deLoe coefficients.

Figure 1. Livestock Water Use in the Grand River Watershed

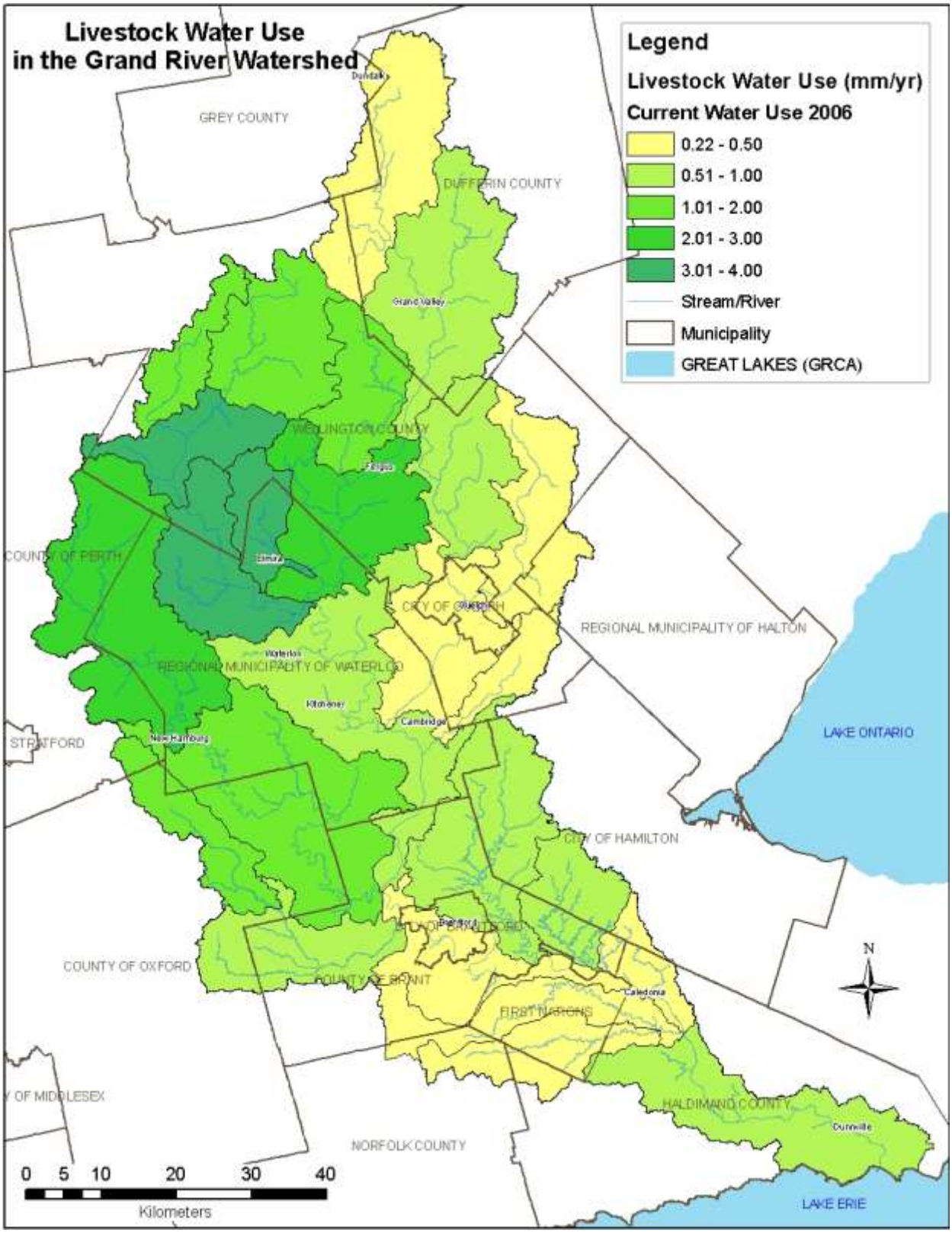


Table 1. Water Use Coefficients for Livestock

Water Use Coefficents	Drinking L/day/animal	Spillage/ Losses fraction of drinking water	Animal washing L/day/animal	Equipment washing L/day/farm	Approximate Water Consumption Levels L/day (AAFC and NRC)**
Poultry					
Hens & chickens	0.28				0.03-0.29
Turkeys	0.45	0.02			0.06-1.0
Other Poultry	0.50	0.02			
Beef					26-66
Bulls	36 (38*)	0.05			36-45
Beef Cows	45.00	0.05			26-66
Heifers (beef, dairy, slaughter and feed)	27.00	0.05			**32-45**
Steers	30.00	0.05			**36-45**
Calves	15.00				**18-27**
Dairy					28-110
Milking cows	90 (115*)	0.05	4.00		68-114
Dry cows	40 (41*)	0.05			**55-68**
Dairy Heifer	30 (25*)	0.05			**32-45**
Swine					
Boars	12.50 (15*)	4.20	1.20		8-17
Sows &bred gilts	20.50	4.20	1.20		15-35
Sows & bred gilts: dry sows	12.50 (15*)	4.20	1.20		5-20
All other pigs	5.00	1.60	0.55		5-10
Sheep					
Rams	7.40 (5.75*)	0.05			
Ewes	7.40	0.05			4-12
Lambs	4.0 (4.4*)	0.05			3.5-4
Other Livestock					
Horses/ponies	42.00	0.00	0.00		5L/ 100kg
Goats	4.00	0.05			3-15
Rabbits	0.20 (0.30*)	0.05		500	
Mink	0.18 (0.23*)	0.05			
Fox	0.23	0.05			

*New OMAFRA coefficients

**http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1259101276424&lang=eng

Bolder values show higher estimates from AAFC and NRC

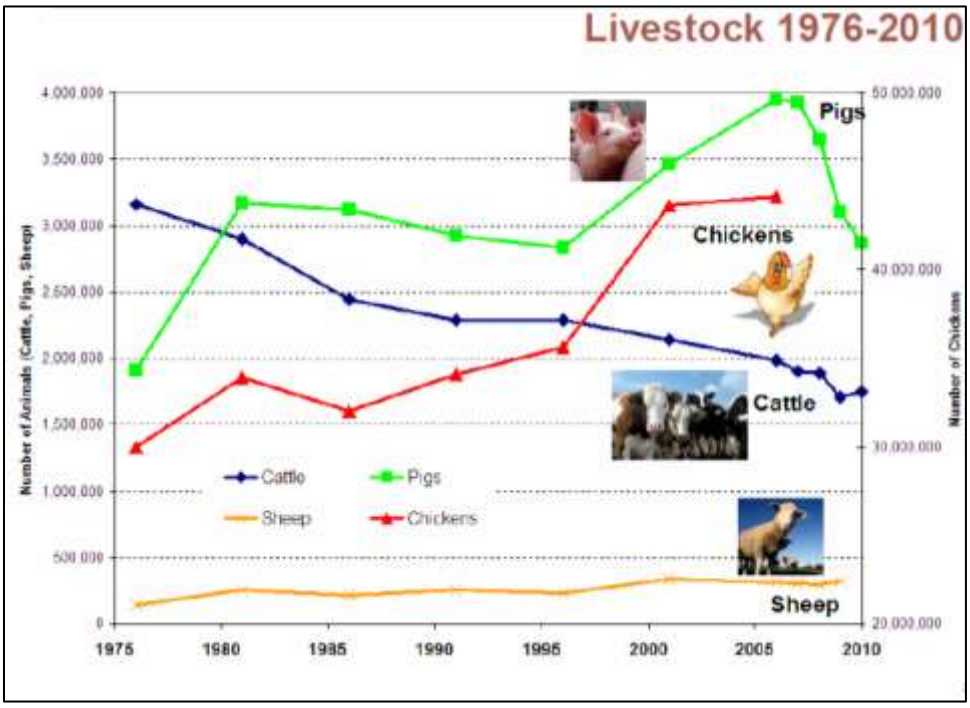
Future Projections: Livestock Water Needs

Agriculture and Agri-Food Canada (AAFC) produced a report entitled *Medium Term Outlook for Canadian Agriculture: International and Domestic Markets, 2012,* which included a section on livestock projections. Many projections are based on population growth, which was projected at 1.2% annually*:*

- Cattle prices are projected to increase, and stimulate rebuilding of the cattle breeding herds. Exports are expected to increase, but domestic beef consumption has decreased over the past decade; no substantial growth is expected domestically in the medium term outlook
- Swine prices and exports are projected to increase only modestly, but the Canadian per capita consumption has been in decline and expected to continue that trend
- Dairy has a mature market in Canada with an aging population which will either maintain or decline the dairy consumption per capita in Canada. Only yogurt has shown an increase in growth, a trend that has continued for the last 20 years
- Poultry consumption in Canada is expected to be stable or decline on a per capita basis
- An aging Canadian population and changing diets are expected to prevent significant growth in Canadian per capita meat consumption over the outlook period

OMAFRA specialists project that populations of livestock in the watershed are likely to increase in the coming decades, thereby increasing the volume needed for drinking water. The trends show increasing populations of chickens, a decrease in cattle and OMAFRA estimates a cyclical pattern for hogs (**Figure 2**).

Figure 2. Livestock population trends in Ontario (OMAFRA, 2012)



However, in terms of washing, new technologies in water efficiency may offset an increase in water use for livestock (OMAFRA, 2012, pers. comm.) With regard to climate change, an increase in evaporative cooling demand, for example cooling stations for livestock due to the increased temperature, would increase water use. Evaporative cooling is not currently considered in water use coefficients and would need to be added as a water use in climate change projections.

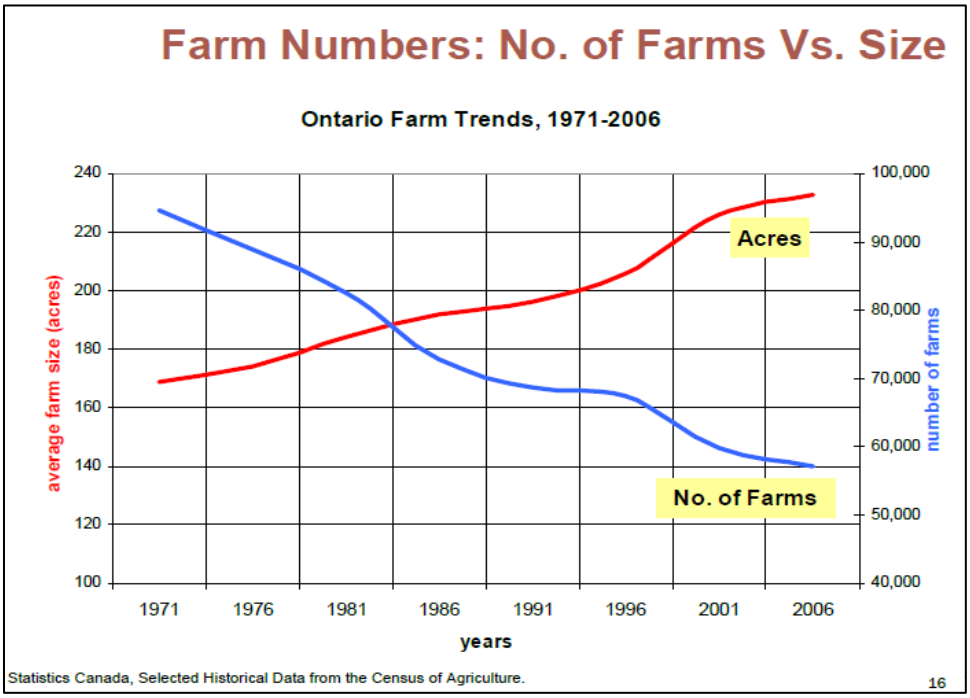
Trends to Consider

Numerous factors influence trends that are both unpredictable and hard to quantify. For example, some trends mentioned by OMAFRA (2012) include:

- Costs of production
- Market opportunities
- Commodity prices
- Fewer farmers and larger farms
- Increased number of retirement and lifestyle farms
- Growth in vegetable and greenhouse sectors
- Increased mechanization
- Value of Canadian dollar
- Market incentives (organic, non-GMO)
- Decrease in farm population
- Crop shifts, rotations

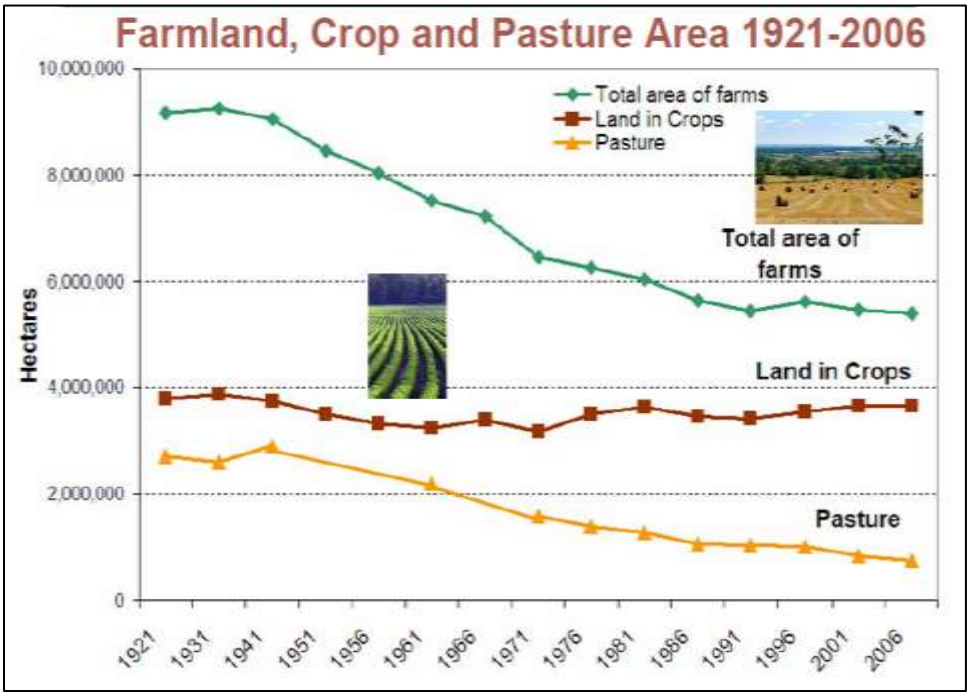
While not all of these trends can be considered, general outlook of certain aspects could be used to determine whether there will be an increase or decrease in water use by livestock. For example, in **Figure 3**, the trend in the past 30 years has been that the number of farms is decreasing but individual farm acreage is getting larger. However, the most recent data shows that this trend is slowing and it is possible that the trend may be reversing (OMAFRA, pers comm, 2012). The thought is that the growing popularity of local food markets may increase the number of smaller sized farms in the future to provide local food to urban areas.

Figure 3. Trends in size and number of farms in Ontario



Other trends show the acreage of farms on a provincial scale. As seen in **Figure 4**, farmland in Ontario is decreasing, with the majority of this decrease occurring in pastureland, while land area in crops seems to be stable. This would imply that the total land area for livestock is decreasing, indicating either intensification or a decrease in livestock production overall in the province.

Figure 4. Trends in total land area in farms, pasture and crops



In terms of water use, these trends would indicate that the higher density livestock farming areas may have more water demands from livestock in the future if intensification will be occurring in the future. In addition, if livestock farming moves to other areas of the watershed, an additional (or increase) in water use for livestock may occur.

Future Water Needs by Livestock Type

The future water needs for livestock are dependent on number and type of livestock as well as their water demands for drinking and cooling. For forecasts of livestock populations, market trends and population forecasts were reviewed. In terms of water demands, the necessities of water include drinking, washing and the likelihood of water used for evaporative cooling (in some livestock types only) in the future due to increased temperature projections based on climate change. In addition, if any water efficiencies are anticipated in the livestock operations, they will also influence the amount of water necessary in the future.

According to several sources (as listed), each livestock type is described below with details on the market trends and influences on populations, the trend for population and water needs.

Cattle:

Market Trends/Influences:

- Prices expected to increase (AAFC, 2012)
- High feed prices will limit sector expansion (AAFC, 2012)

Population Forecasts:increasing

- Modest growth in domestic red meat industry (AAFC, 2012)
- Net export projected to increase (AAFC, 2012)
- Breeding herds increasing

Water Use and Efficiency Forecasts:

- Evaporative cooling water will be needed more often in climate change to combat heat stress

Dairy:

Market Trends/Influences:

- Increased demand will keep prices high

Population Forecasts: increasing

- Reductions in other parts of the world (EU, Australia/NZ) will likely increase North American exports

Water Use and Efficiency Forecasts:

- Increases in water efficiency
- Evaporative cooling water will be needed more often in climate change to combat heat stress

Swine:

Market Trends/Influences:

- Prices expected to increase (AAFC, 2012)
- High feed prices will limit sector expansion (AAFC, 2012)
- Decline in per capita pork consumption

Population Forecasts: cyclical

- Modest increase in medium term,maintain cyclical pattern (AAFC, 2012)

Water Use and Efficiency Forecasts:

- Evaporative cooling water will be needed more often in climate change to combat heat stress

Poultry: Chickens

Market Trends/Influences:

- Market maturity means modest increase only (AAFC, 2012)

Population Forecasts: increasing

- Limited expansion as per capita consumption stable or declining, 1.5% growth/yr (AAFC, 2012)

Water Use and Efficiency Forecasts:

- Increased drinking water needed in hot weather

Poultry: Turkey and Others

Market Trends/Influences:

- Prices increasing to reflect increase in feed prices

Population Forecasts: increasing

- Average growth rate of 1.5% growth/yr maintained (AAFC, 2012)

Water Use and Efficiency Forecasts:

- Increased drinking water needed in hot weather

Sheep

Market Trends/Influences:

- More than 50% is imported from New Zealand and elsewhere

Population Forecasts: slight increase

- Supply of lamb domestically expected to grow (AAFC, 2012)
- Increasing breeding herds

Water Use and Efficiency Forecasts: unknown

Horses

Market Trends/Influences: unknown

Population Forecasts: unknown

Water Use and Efficiency Forecasts:

- Increased drinking water needed in hot weather

Effect of Higher Air Temperatures on Livestock

Agriculture and Agri-Food Canada (AAFC) has published some information on livestock water requirements and discussed also the effect increasing temperature has on various livestock. Water needs increase as temperature increases, as provided by examples in **Figure 5**, **Table 2** and **Table 8** from AAFC, (2009). Generally, higher temperatures in dairy, beef cattle and swine can be combatted via evaporative cooling, while all other livestock including cattle and swine will need additional drinking water to prevent heat stress.

Increased Drinking Water Intake

For most livestock, water intake requirements vary due to ambient temperature, humidity, water loss via sweating/respiration or production parameters (i.e. in dairy and poultry) and water content in feed.

Figure 5 shows that water intake increases at a faster rate as the ambient temperature increases. This may be due to the need for the cooling effect of water to prevent heat stress, in addition to the regular metabolic needs of the animals.

Figure 5. Example of water intake changes as ambient temperature increases

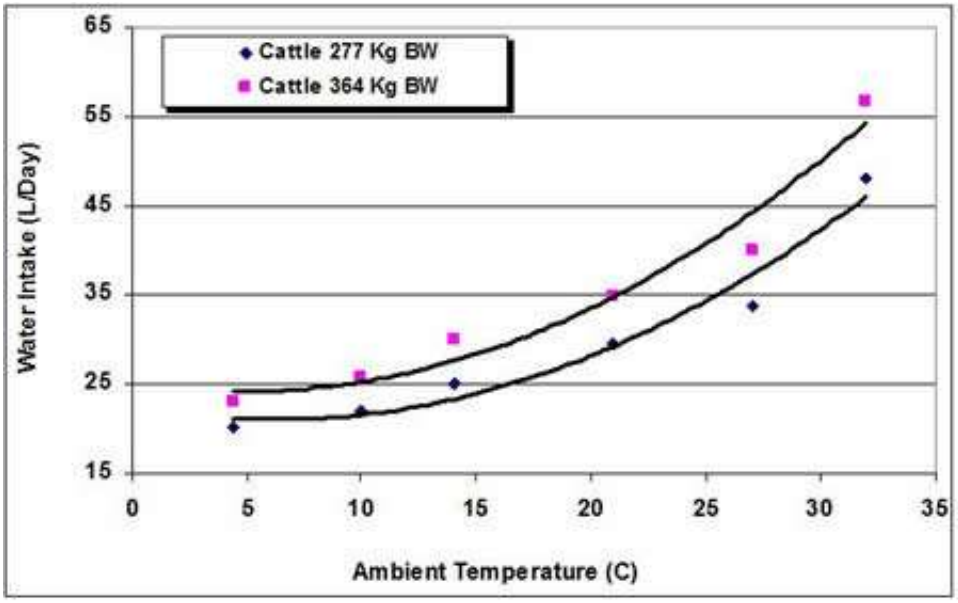


Table 2. Water consumption by beef cattle with reference to environmental temperature

	Water Consumption (Litres per Day at Different Temperature)						Percent Increase from 21.1° C	
Weight (kg)	**4.4° C**	**10° C**	**14.4° C**	**21.1° C**	**26.6° C**	**32.2° C**	**26.6° C**	**32.2° C**
Growing Cattle							**Growing Cattle**	
182	15.1	16.3	18.9	22.0	25.4	36.0	15.5%	63.6%
277	20.1	22.0	25.0	29.5	33.7	48.1	14.2%	63.1%
364	23.0	25.7	29.9	34.8	40.1	56.8	15.2%	63.2%
Finishing Cattle							**Finishing Cattle**	
273	22.7	24.6	28.0	32.9	37.9	54.1	15.2%	64.4%
364	27.6	29.9	34.4	40.5	46.6	65.9	15.1%	62.7%
454	32.9	35.6	40.9	47.7	54.9	78.0	15.1%	63.5%
Lactating Cows							**Lactating Cows**	
409	43.1	47.7	54.9	64.0	67.8	81	5.9%	26.6%
Mature Bulls							**Mature Bulls**	
636	30.3	32.6	37.5	44.3	50.7	71.9	14.4%	62.3%
727	32.9	35.6	40.9	47.7	54.9	78.0	15.1%	63.5%
Data Adopted from National Research Council,1974.								

From the results listed in **Table 2**, the increase in water consumption on the hotter days can be considerably more. The average daily temperature across the watershed currently for the summer months of July and August are between 18 to 21° C, with maximums in the range of 25-27° C. There is a

15% increase in water consumption by cattle at the maximum temperature as compared to a high estimate (21.1° C) of the average temperature. For lactating cows, which have the highest water demands for any type of beef cattle, their water consumption rates rise only slightly (6% compared to 15% and 27% compared to 63%).

As temperatures continue to increase; climate change is expecting increases of between 1 and 6°C; the water consumption required is considerably more. At temperatures of 32.2° C, the daily water consumption requirements for cattle increase by 63% compared to current average day temperatures (21.1° C).

In dairy, the comparison of water intake from spring temperatures to extreme summer temperatures can be seen in Appendix B (**Table 8**). The increase is between 51% to 64% when daily temperatures reach 32°C, from daily temperatures of 10°C.

Water consumption is also attributed to the amount of water in dry matter (DM) feed intake. There are different water requirements for drinking as the thermal environment changes, and as dry feed is ingested (Appendix B, **Table 9**).

For poultry, additional water is required in the summer time as poultry are unable to sweat as a means of regulating body temperature. OMAFRA suggests that as air temperatures exceed 30°C or (87°F), poultry are increasing their water consumption by 50% of normal rates, because panting is their way of regulating their temperature which increases water loss (OMAFRA, 2007).

Evaporative Cooling Demand

In addition to increased drinking water, it was found that evaporative cooling was necessary to prevent heat stress. Generally, a temperature humidity index (THI) over 68 (air temperature and relative humidity rating), causes heat stress. Evaporative cooling using sprinklers at 3.4L/min (approximately 1gal/min) per 80 square feet a few times an hour with fans is effective to cool the animals (OMAFRA, 2011; Pennington and VanDevender, 2006).

For swine, evaporative cooling is effective in temperatures above their optimal of 21-25°C using intermittent sprinklers and fans, similar to cattle evaporative cooling systems.

For poultry, Winfield (1971) found that evaporative cooling was not an effective way to maintain optimal temperatures in barns in the summertime in southwestern Ontario. Generally, additional drinking water and fans are used more effectively to cool for poultry, so the only additional water use would be for drinking water only.

Water use coefficients for evaporative cooling demands were calculated for cattle (beef and dairy) and swine (**Table 3**). These values were not previously available and were calculated for this project.

Table 3. Evaporative cooling demands by livestock type

Cooling Needs		L/day/animal
Cattle	Beef COWS	28.56
	BULLS	40.80
	BFHEIFER	14.28
	STEERS	9.52
	CALF	10.00
Dairy	Milking COW	48.96

	MILK HEIFER	21.42
Swine	BOARS	6.00
	SOWS	12.86
	Other Pigs	3.86

The evaporative cooling demands were calculated based on typical capacity requirements of each livestock type in barns. On average, the sprinklers for evaporative cooling demand are needed for 2-12 minutes per hour, so the average of 7 minutes were used in the calculation, for 8 hours a day (1pm to 9pm).Information from several sources gave the water requirements in terms of sprinkler systems of 3.4L/min or 0.0015L/sqft of barn area (OMAFRA, 2011). It was assumed that heat stress would begin to occur at 25^0C and over as the maximum daily temperature. From climate normals at the Waterloo-Wellington station from 1960-1990, the the average number of days in that period where the maximum temperature was over the threshold was 59.1 days per year, or approximately 2 months over the year that evaporative cooling demand is required. The results of the increased water intake are seen in **Table 4.**

Table 4. Water demand by livestock with and without cooling demands

Livestock Type	Current Water Demand (no cooling) (L /s)	Current Water Demand (with cooling and increased intake)	Percent Increase
Poultry	33.46	36.59	9.35%
Beef	61.90	69.87	12.88%
Dairy	81.84	87.80	7.28%
Swine	56.61	61.43	8.51%
Sheep	2.09	2.29	9.57%
Horses and Other	10.73	11.13	3.73%

Future Livestock Water Use Scenarios

To determine the water demand in the future for livestock, both population growth and climate change were considered.

Scenario 1: Population Growth

Growth estimates for several livestock commodities were suggested by AAFC in their medium term outlook (AAFC, 2012). This information was used to base some growth projections and extrapolate out to 2031 and 2051 horizons (). These growth projections accounts for factors such as international demand for the products, national per capita consumption of the products and also the size of breeding herds, as mentioned previously. The values as found in **Table 5** will be used to determine the growth in water requirements for livestock for the future.

Table 5. Growth projections for various livestock based on AAFC (2012)

Livestock Type	Population Growth Projection (per year)
Cattle - beef	1.2%
Cattle – dairy	2.0%
Swine	1.0%

Poultry	1.5%
Sheep	0.2%
Horses and Others	1.0%

The results of water requirements for future populations of livestock after the population projections are found in **Table 6.** The percent increase from the current water demand is also given, which shows up to 90% more water demand for swine in the 2051 time horizon.

Table 6. Water requirements for livestock, current and future

Livestock Type	Current Water Demand (no cooling) (L/s)	2031 Water Demand (no cooling) (L/s)	Percent Increase from Current (no cooling)	2051 Water Demand (no cooling) (L/s)	Percent Increase from Current (no cooling)
Poultry	33.46	46.01	37.51%	56.05	67.51%
Beef	61.90	80.47	30.00%	95.33	54.01%
Dairy	81.84	122.76	50.00%	155.50	90.00%
Swine	56.61	70.76	25.00%	82.08	44.99%
Sheep	2.09	2.19	4.78%	2.28	9.09%
Horses, Others	10.73	12.59	17.33%	14.61	36.16%

Scenario 2: Increased Water Consumption in Summer and Population Growth

As shown by examples in a previous section regarding the increase in water needs due to increases in ambient air temperature, this second scenario accounts for additional water consumption by livestock.

Ten scenarios of climate change were provided by Ministry of Natural Resources, resulting increased temperatures in all months, up to a maximum of 6.0 degrees Celsius (Shifflett, 2012). One of the 10 suggested scenarios (#65) increased monthly temperatures on average by 3.3^0C between April and September, and represented the highest overall summer increase in temperatures. The scenario increased the number of maximum daily temperature over 25^0C from 59 to 97 days. This scenario provides the most extreme case of temperature of all the 10 scenarios, chosen to test the sensitivity of the watershed to changes in climate.

To calculate the water demand in the future, the increased water intake and additional water for evaporative cooling and increased intake for drinking were added to the daily water demand, for 97 days. The results are in **Table 7.**

Table 7. Livestock water demand due to effects of warmer temperatures, current and future

Livestock Type	Current Water Demand (no cooling) (L/s)	Current Water Demand (with cooling and increased intake)	2031 Water Demand (with cooling) (L/s)	Percent Increase	2051 Water Demand (with cooling) (L/s)	Percent Increase
Poultry	33.46	36.59	65.26	95.04%	79.50	137.60%
Beef	61.90	69.87	90.83	46.74%	105.69	70.74%
Dairy	81.84	87.80	137.43	67.93%	174.07	112.70%
Swine	56.61	61.43	105.21	85.85%	122.04	115.58%

Sheep	2.09	2.29	2.54	21.53%	2.64	26.32%
Horses, Others	10.73	11.13	13.62	26.93%	15.80	47.25%

Poultry, dairy and swine had the highest water demand increase under this high temperature scenario.

Livestock Water Needs by Subwatershed

Figure 6 shows the results of the population projections out to 2031 and 2051, while **Figure 7** includes the effects of climate change on water use for livestock for both projected futures. Appendix A gives the tabular results of each of the scenarios by subwatersheds.

Population growth increases the water use by one third by 2031 and 50% by 2051. Compared to current water use, most subwatersheds could double their water needs for livestock by 2051 with climate change influence.

Implications to the Overall Water Budget in the Grand River Watershed

According to the current Water Use Inventory Report (Wong, 2011), livestock watering accounts for 5.87% of all water consumption in the Grand River watershed. With an increase in summer water demand and animal population growth, all other parameters being equal to current day demand, livestock water use will account for up to 7% of water use by 2031 and 8.4% by 2051.

The largest increases in livestock populations and demand are in subwatersheds that have low groundwater stress and low surface water stress. In the Canagagigue Creek subwatershed, where current water use is moderate, the increase in water use for livestock operations to 2051 would only increase the average annual water use by less than 2%.

Conclusions

Livestock water use in the Grand River watershed is approximately 6% of current day water demand. In the future, it is thought that animal population growth and increased heat stress due to climate change will increase the demands of livestock for drinking water and evaporative cooling demand. By 2031, with both population growth and climate change, the water demand is expected to increase to 7% of total water use in the watershed, with all other water use sectors remaining at current day demand. By 2051, the demand will increase to 8.4%. However, with human population growth, the relative fraction of livestock water demand will likely remain similar to current day.

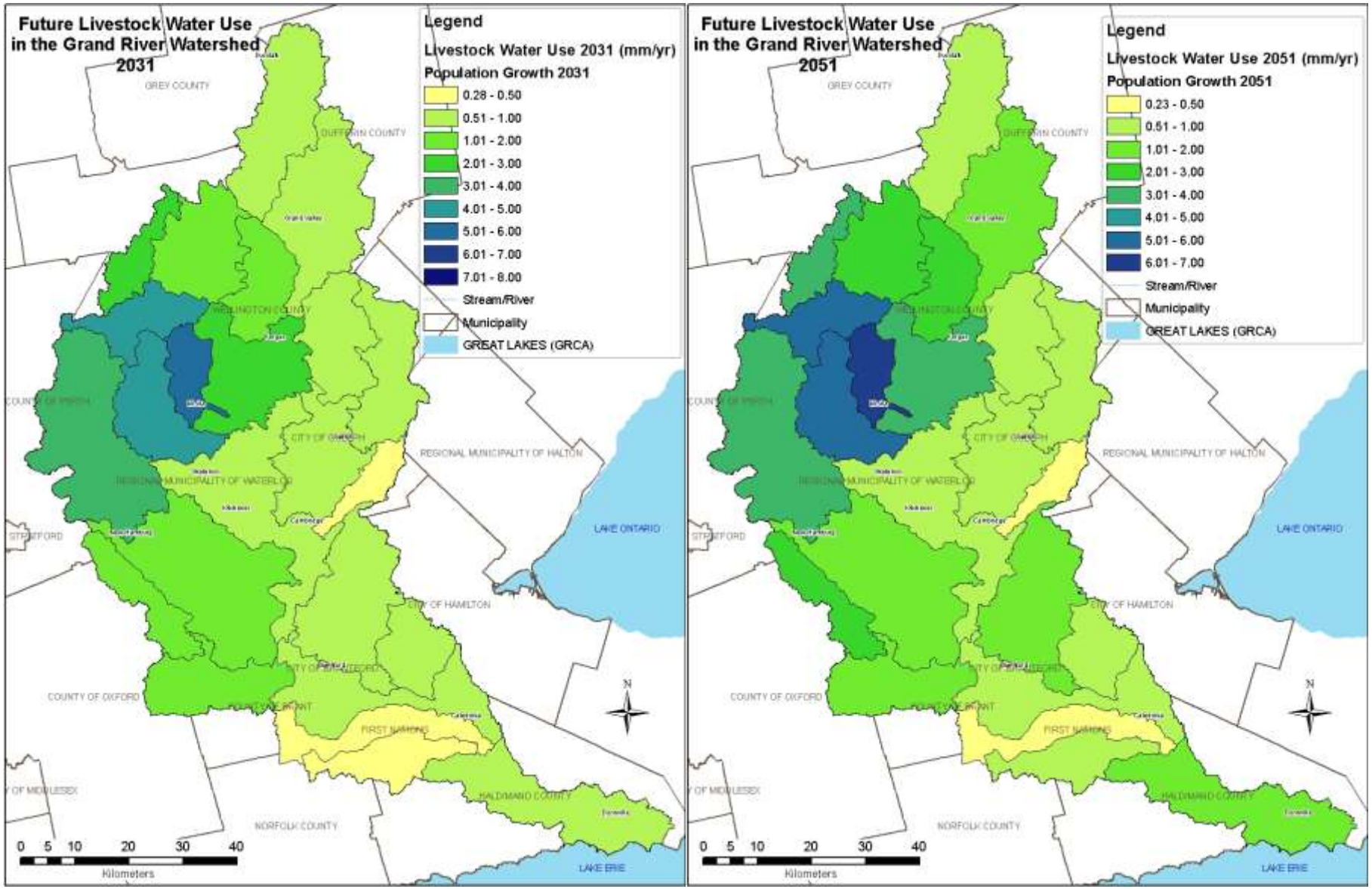


Figure 6. Livestock water use projections for 2031 (left) and 2051 (right)

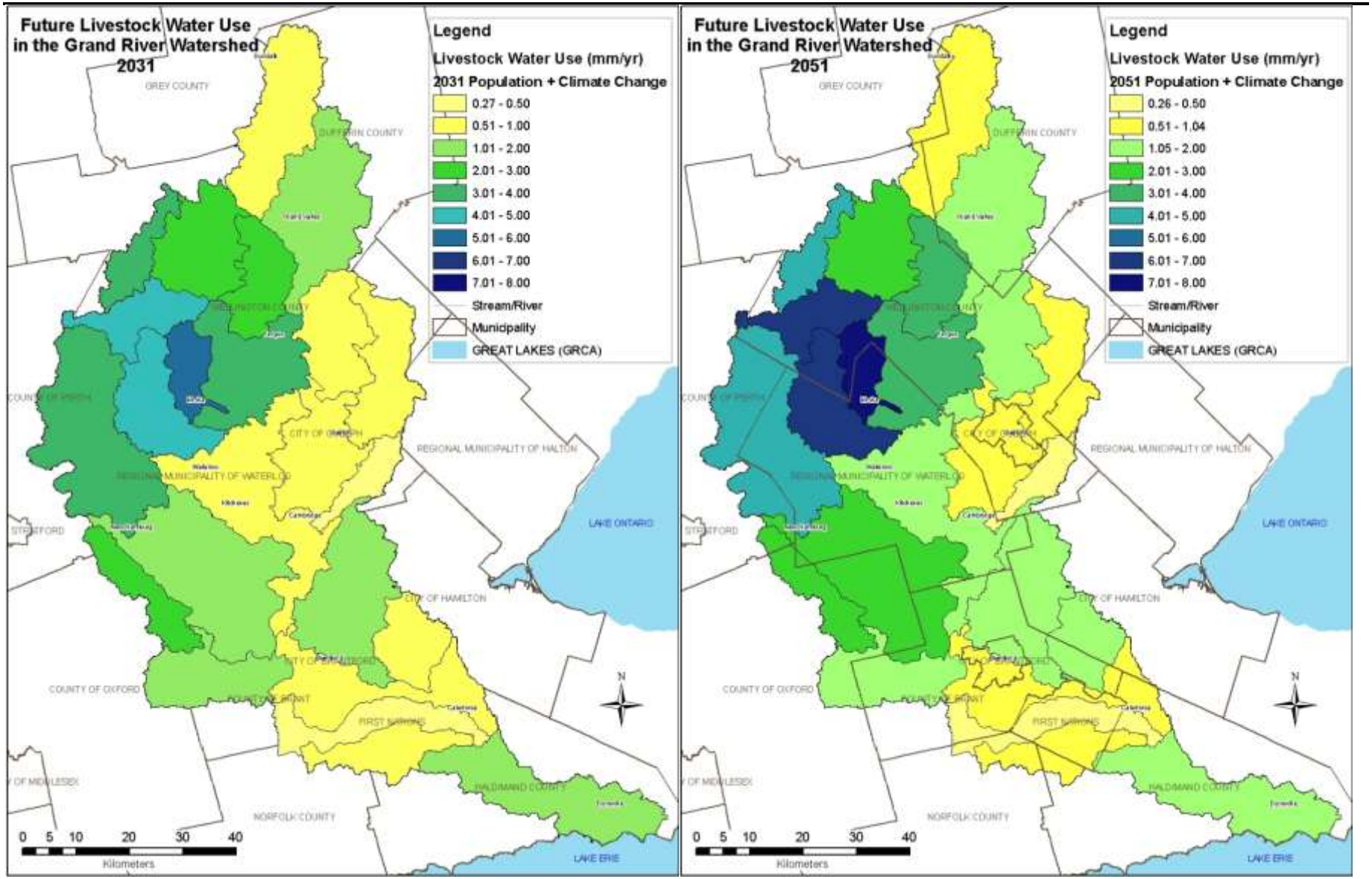


Figure 7. Livestock water use projections with climate change impacts for 2031 (left) and 2051 (right)

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Appendix A

Current Water Use

watersheds Code	SUBBASIN_NAME	Total Current Annual Water Use (m^3/s)						
		Poultry	Beef Cattle	Dairy	Swine	Sheep	Horse/ Others	All Livestock
2GA-01-01	Grand Above Paris to Conestogo	1.58	1.98	3.53	1.14	0.08	0.32	8.63
2GA-01-02	Below Shand to Conestogo	3.52	6.26	6.71	4.30	0.11	0.51	21.41
2GA-01-03	Canagagigue Creek	1.20	4.42	6.37	1.88	0.02	0.27	14.16
2GA-01-04	Irvine Creek	0.46	1.57	2.51	4.26	0.10	0.22	9.13
2GA-01-05	Grand Above Shand	0.43	3.32	3.18	2.34	0.33	0.54	10.14
2GA-01-06	Grand Above Legatt	0.10	2.30	1.48	0.85	0.25	0.28	5.26
2GA-02-01	Nith Above Grand to New Hamburg	2.93	3.62	8.95	3.90	0.13	0.54	20.07
2GA-02-02	Nith Above New Hamburg	4.27	9.08	12.07	13.20	0.19	1.47	40.27
2GA-03-01	Mill Creek	0.10	0.35	0.00	0.00	0.02	0.29	0.75
2GA-04-01	Speed Above Grand to Dam	0.94	0.99	1.24	0.38	0.04	0.33	3.92
2GA-04-02	Speed Above Dam	0.75	1.95	1.25	0.64	0.08	0.58	5.26
2GA-05-01	Eramosa Above Guelph	0.38	1.31	0.51	0.38	0.09	1.08	3.74
2GA-06-01	Conestogo Below Dam	1.87	10.38	6.78	6.29	0.12	1.19	26.63
2GA-06-02	Conestogo Above Dam	3.37	2.93	6.00	4.01	0.04	0.16	16.49
2GA-06-03	Conestogo Above Dam 2	1.75	1.25	2.52	1.95	0.02	0.15	7.63
2GA-06-04	Conestogo Above Dam 3	1.90	2.43	3.98	3.97	0.09	0.37	12.73
2GB-01-01	Grand Above Dunville to York	1.81	2.00	2.29	1.54	0.08	0.28	7.99
2GB-01-02	Grand Above York to Paris	0.31	0.85	1.91	0.33	0.02	0.39	3.81
2GB-02-01	McKenzie Creek	0.55	0.31	0.40	0.06	0.00	0.08	1.39
2GB-02-02	Boston Creek	0.68	0.35	0.53	0.21	0.02	0.11	1.89
2GB-03-01	Big Creek	0.71	0.54	1.16	0.53	0.02	0.42	3.37
2GB-04-01	Fairchild Creek	1.84	1.62	2.97	1.05	0.14	0.78	8.40
2GB-05-01	Lower Whitemans Creek	1.12	1.07	2.93	0.83	0.04	0.27	6.25
2GB-05-02	Upper Whitemans Creek	0.92	1.02	2.58	2.57	0.07	0.12	7.28
TOTAL		**33.46**	**61.90**	**81.84**	**56.61**	**2.09**	**10.73**	**246.63**

Appendix A

Scenario 1: Population Projections

watersheds Code	SUBBASIN_NAME	2031 Total Annual Water Use (m^3/s)						
		Poultry	Beef Cattle	Dairy	Swine	Sheep	Horse/ Others	All Livestock
2GA-01-01	Grand Above Paris to Conestogo	2.18	2.58	5.30	1.42	0.08	0.36	11.92
2GA-01-02	Below Shand to Conestogo	4.84	8.14	10.07	5.37	0.11	0.59	29.12
2GA-01-03	Canagagigue Creek	1.66	5.75	9.55	2.35	0.02	0.32	19.66
2GA-01-04	Irvine Creek	0.64	2.04	3.77	5.33	0.11	0.23	12.11
2GA-01-05	Grand Above Shand	0.59	4.32	4.77	2.92	0.34	0.56	13.50
2GA-01-06	Grand Above Legatt	0.14	2.99	2.22	1.06	0.26	0.26	6.92
2GA-02-01	Nith Above Grand to New Hamburg	4.02	4.71	13.43	4.88	0.14	0.62	27.79
2GA-02-02	Nith Above New Hamburg	5.87	11.80	18.10	16.50	0.20	1.76	54.23
2GA-03-01	Mill Creek	0.14	0.45	0.00	0.00	0.02	0.35	0.96
2GA-04-01	Speed Above Grand to Dam	1.29	1.29	1.86	0.48	0.04	0.40	5.35
2GA-04-02	Speed Above Dam	1.03	2.53	1.88	0.80	0.09	0.69	7.03
2GA-05-01	Eramosa Above Guelph	0.52	1.70	0.76	0.48	0.09	1.30	4.86
2GA-06-01	Conestogo Below Dam	2.57	13.49	10.17	7.86	0.12	1.45	35.66
2GA-06-02	Conestogo Above Dam	4.64	3.80	8.99	5.01	0.04	0.18	22.66
2GA-06-03	Conestogo Above Dam 2	2.40	1.63	3.78	2.44	0.02	0.18	10.44
2GA-06-04	Conestogo Above Dam 3	2.61	3.16	5.96	4.96	0.09	0.42	17.21
2GB-01-01	Grand Above Dunville to York	2.48	2.60	3.44	1.92	0.08	0.32	10.84
2GB-01-02	Grand Above York to Paris	0.43	1.10	2.87	0.41	0.02	0.48	5.31
2GB-02-01	McKenzie Creek	0.75	0.41	0.59	0.07	0.00	0.10	1.92
2GB-02-02	Boston Creek	0.94	0.46	0.79	0.26	0.02	0.13	2.59
2GB-03-01	Big Creek	0.97	0.71	1.73	0.67	0.02	0.51	4.61
2GB-04-01	Fairchild Creek	2.53	2.11	4.45	1.31	0.15	0.93	11.47
2GB-05-01	Lower Whitemans Creek	1.53	1.39	4.39	1.04	0.04	0.32	8.72
2GB-05-02	Upper Whitemans Creek	1.27	1.32	3.88	3.21	0.07	0.13	9.88
TOTAL		**46.01**	**80.47**	**122.76**	**70.76**	**2.19**	**12.59**	**334.79**

Appendix A

Scenario 1: Population Projections

watersheds Code	SUBBASIN_NAME	2051 Total Annual Water Use (m^3/s)						
		Poultry	Beef Cattle	Dairy	Swine	Sheep	Horse/ Others	All Livestock
2GA-01-01	Grand Above Paris to Conestogo	2.65	3.05	6.72	1.65	0.08	0.42	14.58
2GA-01-02	Below Shand to Conestogo	5.90	9.65	12.75	6.23	0.12	0.68	35.32
2GA-01-03	Canagagigue Creek	2.02	6.81	12.10	2.73	0.02	0.38	24.06
2GA-01-04	Irvine Creek	0.78	2.41	4.77	6.18	0.11	0.27	14.53
2GA-01-05	Grand Above Shand	0.72	5.12	6.04	3.39	0.36	0.65	16.27
2GA-01-06	Grand Above Legatt	0.17	3.55	2.81	1.23	0.27	0.30	8.32
2GA-02-01	Nith Above Grand to New Hamburg	4.90	5.58	17.01	5.66	0.14	0.72	34.00
2GA-02-02	Nith Above New Hamburg	7.15	13.98	22.93	19.14	0.21	2.04	65.45
2GA-03-01	Mill Creek	0.17	0.53	0.00	0.00	0.02	0.41	1.13
2GA-04-01	Speed Above Grand to Dam	1.57	1.53	2.36	0.55	0.04	0.46	6.51
2GA-04-02	Speed Above Dam	1.26	3.00	2.38	0.93	0.09	0.80	8.47
2GA-05-01	Eramosa Above Guelph	0.63	2.01	0.97	0.55	0.10	1.51	5.78
2GA-06-01	Conestogo Below Dam	3.12	15.98	12.89	9.12	0.13	1.68	42.92
2GA-06-02	Conestogo Above Dam	5.65	4.51	11.39	5.81	0.04	0.21	27.61
2GA-06-03	Conestogo Above Dam 2	2.93	1.93	4.78	2.83	0.02	0.20	12.69
2GA-06-04	Conestogo Above Dam 3	3.17	3.74	7.56	5.76	0.10	0.49	20.82
2GB-01-01	Grand Above Dunville to York	3.02	3.08	4.35	2.23	0.09	0.37	13.14
2GB-01-02	Grand Above York to Paris	0.52	1.31	3.64	0.48	0.02	0.55	6.52
2GB-02-01	McKenzie Creek	0.92	0.48	0.75	0.08	0.00	0.12	2.35
2GB-02-02	Boston Creek	1.14	0.54	1.00	0.30	0.02	0.15	3.15
2GB-03-01	Big Creek	1.18	0.84	2.20	0.77	0.02	0.59	5.60
2GB-04-01	Fairchild Creek	3.08	2.50	5.64	1.52	0.15	1.08	13.97
2GB-05-01	Lower Whitemans Creek	1.87	1.65	5.57	1.20	0.04	0.37	10.71
2GB-05-02	Upper Whitemans Creek	1.55	1.57	4.91	3.73	0.07	0.15	11.97
TOTAL		**56.05**	**95.33**	**155.50**	**82.08**	**2.28**	**14.61**	**405.85**

Appendix A

Scenario 2: Population Growth + Climate Change

watersheds Code	SUBBASIN_NAME	2031 Total Annual Water Use (m^3/s)						
		Poultry	Beef Cattle	Dairy	Swine	Sheep	Horse/ Others	All Livestock
2GA-01-01	Grand Above Paris to Conestogo	3.10	2.94	5.93	2.14	0.09	0.42	13.34
2GA-01-02	Below Shand to Conestogo	6.82	9.10	11.27	7.83	0.13	0.67	31.93
2GA-01-03	Canagagigue Creek	2.34	6.37	10.71	3.42	0.03	0.37	20.51
2GA-01-04	Irvine Creek	0.90	2.29	4.21	8.37	0.13	0.26	15.18
2GA-01-05	Grand Above Shand	0.84	4.89	5.34	4.57	0.40	0.63	14.59
2GA-01-06	Grand Above Legatt	0.19	3.44	2.48	1.67	0.30	0.29	6.97
2GA-02-01	Nith Above Grand to New Hamburg	5.68	5.37	15.02	6.46	0.16	0.68	31.06
2GA-02-02	Nith Above New Hamburg	8.32	13.23	20.26	25.14	0.24	1.95	63.27
2GA-03-01	Mill Creek	0.19	0.52	0.00	0.00	0.02	0.39	0.83
2GA-04-01	Speed Above Grand to Dam	1.83	1.49	2.09	0.77	0.05	0.43	5.96
2GA-04-02	Speed Above Dam	1.47	2.86	2.10	1.09	0.10	0.75	7.05
2GA-05-01	Eramosa Above Guelph	0.72	1.94	0.86	0.68	0.11	1.40	4.63
2GA-06-01	Conestogo Below Dam	3.62	14.97	11.42	12.11	0.14	1.54	37.29
2GA-06-02	Conestogo Above Dam	6.61	4.28	10.07	7.37	0.05	0.20	26.78
2GA-06-03	Conestogo Above Dam 2	3.42	1.85	4.23	3.82	0.03	0.19	12.74
2GA-06-04	Conestogo Above Dam 3	3.71	3.63	6.68	7.28	0.11	0.44	20.30
2GB-01-01	Grand Above Dunville to York	3.51	3.01	3.84	2.95	0.10	0.34	12.46
2GB-01-02	Grand Above York to Paris	0.61	1.28	3.21	0.56	0.03	0.50	5.56
2GB-02-01	McKenzie Creek	1.07	0.47	0.66	0.08	0.00	0.10	2.18
2GB-02-02	Boston Creek	1.34	0.53	0.89	0.30	0.02	0.13	2.96
2GB-03-01	Big Creek	1.39	0.82	1.94	0.94	0.02	0.52	5.19
2GB-04-01	Fairchild Creek	3.59	2.43	4.97	1.76	0.17	0.95	12.72
2GB-05-01	Lower Whitemans Creek	2.17	1.60	4.90	1.37	0.05	0.33	9.71
2GB-05-02	Upper Whitemans Creek	1.81	1.51	4.34	4.52	0.08	0.13	11.76
TOTAL		**65.26**	**90.83**	**137.43**	**105.21**	**2.54**	**13.62**	**391.44**

Appendix A

Scenario 2: Population Growth + Climate Change

watershed Code	SUBBASIN_NAME	2051 Total Annual Water Use (m^3/s)						
		Poultry	Beef Cattle	Dairy	Swine	Sheep	Horse/ Others	All Livestock
2GA-01-01	Grand Above Paris to Conestogo	3.78	3.42	7.51	2.48	0.10	0.49	16.90
2GA-01-02	Below Shand to Conestogo	8.31	10.61	14.27	9.09	0.13	0.78	41.04
2GA-01-03	Canagagigue Creek	2.85	7.43	13.57	3.97	0.03	0.43	26.81
2GA-01-04	Irvine Creek	1.10	2.67	5.33	9.71	0.13	0.30	18.69
2GA-01-05	Grand Above Shand	1.02	5.69	6.77	5.30	0.41	0.73	18.79
2GA-01-06	Grand Above Legatt	0.24	3.99	3.15	1.94	0.31	0.33	9.37
2GA-02-01	Nith Above Grand to New Hamburg	6.92	6.24	19.02	7.49	0.17	0.79	39.14
2GA-02-02	Nith Above New Hamburg	10.14	15.40	25.67	29.16	0.24	2.26	78.67
2GA-03-01	Mill Creek	0.24	0.60	0.00	0.00	0.02	0.45	0.80
2GA-04-01	Speed Above Grand to Dam	2.23	1.73	2.65	0.89	0.05	0.50	7.35
2GA-04-02	Speed Above Dam	1.79	3.33	2.66	1.27	0.10	0.87	8.78
2GA-05-01	Eramosa Above Guelph	0.87	2.26	1.08	0.79	0.11	1.62	4.92
2GA-06-01	Conestogo Below Dam	4.41	17.46	14.47	14.05	0.15	1.79	48.20
2GA-06-02	Conestogo Above Dam	8.05	4.99	12.76	8.55	0.05	0.23	33.74
2GA-06-03	Conestogo Above Dam 2	4.17	2.15	5.35	4.43	0.03	0.22	15.86
2GA-06-04	Conestogo Above Dam 3	4.52	4.21	8.46	8.45	0.11	0.52	25.28
2GB-01-01	Grand Above Dunville to York	4.28	3.49	4.86	3.42	0.10	0.39	15.76
2GB-01-02	Grand Above York to Paris	0.74	1.48	4.07	0.65	0.03	0.58	6.79
2GB-02-01	McKenzie Creek	1.31	0.54	0.84	0.10	0.00	0.12	2.71
2GB-02-02	Boston Creek	1.63	0.61	1.12	0.34	0.02	0.16	3.67
2GB-03-01	Big Creek	1.69	0.95	2.45	1.09	0.02	0.61	6.09
2GB-04-01	Fairchild Creek	4.38	2.82	6.30	2.04	0.18	1.11	15.49
2GB-05-01	Lower Whitemans Creek	2.65	1.86	6.21	1.59	0.05	0.38	12.15
2GB-05-02	Upper Whitemans Creek	2.20	1.76	5.50	5.25	0.08	0.15	14.62
TOTAL		**79.50**	**105.69**	**174.07**	**122.04**	**2.64**	**15.80**	**471.63**

Appendix B: Additional Water Requirements for Livestock based on Temperature

Table 8. Water intake differences in dairy cows with reference to environmental temperature

Differences in water intake in dairy cows of similar weight, but differing in milk production.			
Lactating Cows (600 kg) Milk Yield (kg/day)	**Water Intake at Temp 10°C**	**Water Intake at Temp 32°C**	**Percent Change in Water Intake**
15	59	89	150.8%
30	92	146	158.7%
45	124	203	163.7%

Table 9. Water consumption estimates for beef cattle related to dry feed and thermal environment

Water consumption estimates for beef cattle in different thermal environments	
Thermal Environment	**Water Requirements**
>35°C	8 to 15 kg water per kg dry matter (DM) feed intake
25 to 35°C	4 to 10 kg water per kg DM feed intake
15 to 25°C	3 to 5 kg water per kg DM feed intake (Young and lactating animals require 10-50% more water)
-5 to 15°C	2 to 4 kg water per kg DM feed intake
< - 5°C	2 to 3 kg water per kg DM feed intake (Increases of 50-100%occur with a rise in ambienttemperature following a period of very cold temperature,e.g., a rise from -20 to 0°C)
Source: Effect of Environment on Nutrient Requirements of Domestic Animals, 1981, NRC.	

Table 10 shows an estimate of the daily water consumption of 1,000 broiler chickens at different stages of growth. It also illustrates the effect air temperature can have on their water consumption rates.

Table 10. Water Consumption of broiler chickens by age

Chicken Broiler Age (weeks)	**Water Requirement (L/1,000 birds/day)**	
	21°C	**32°C**
1-4	50-260	50-415
5-8	345-470	550-770
North, Mack O., Bell, Donald D. Commercial chicken production manual, 4th edition. New York, NY: Van Nostrand Reinhold. 1990.		

Table 11 shows water consumption by season and can be used for estimating average total annual water requirement for broilers (OMAFRA, 2007). **Table 12** and **Table 13** show similar values for turkeys.

Table 11.Water Consumption of Broiler Chickens by Season

Season	Average Typical Water Use[a] (L/1,000 birds/day)
Winter, fall, spring	280
Summer	450

[a] Typical consumption over a year on a daily basis under average agricultural conditions in Ontario.
North, Mack O., Bell, Donald D. Commercial chicken production manual, 4th edition. New York, NY: Van Nostrand Reinhold. 1990.

Table 12. Water Consumption of Turkey by Age

Turkey Age (weeks)	Water Requirement[a] (L/1,000 birds/day)	
	10°C-21°C	27°C-35°C
1-7	38-327	38-448
8-14	403-737	508-1,063
15-21	747-795	1,077-1,139

[a] Includes spillage losses (typically 2% or less of total consumption).
Adapted from Hybrid turkeys: producer guide. Kitchener, ON: Hybrid Turkeys, 2006.

Table 13. Water Consumption of Turkey by Type

Turkey type	Average Typical Water Use[a] (L/1,000 birds/day)	
	Fall/Winter/Spring	Summer
Broiler turkey	296	402
Heavy hens	431	600
Turkey toms	513	723

[a] Typical consumption over a year on a daily basis under average agricultural conditions in Ontario.