DRAFT

2019

Backgrounder One: The Physical Environment

MISSISSIPPI RIVER WATERSHED PLAN

Backgrounder Series

Mississippi Valley Conservation Authority

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Note about mapping: All maps in this report that bear the Mississippi Valley Conservation Authority logo were produced in part with data provided by the Ontario Geographic Data Exchange under License with the Ontario Ministry of Natural Resources and Forestry and the Queen's Printer for Ontario, 2019.

The Mississippi River Watershed Plan

Mississippi Valley Conservation Authority (MVCA) completed its first Watershed Plan in 1982 and has since implemented many of its recommendations. A new Integrated Watershed Plan is needed to provide long term guidance for MVCA's activities within the Mississippi River watershed. The new plan will reflect current watershed conditions and anticipated changes related to a changing climate, changes in land use and a changing environment. It will identify issues and challenges and will recommend actions aimed at maintaining a healthy river and watershed while balancing the needs of it many users. The Mississippi River Watershed Plan is set to be completed by the fall of 2020.

This Backgrounder is the first in a series of four that will be used to support the development of the Mississippi River Watershed Plan (MRWP). The Backgrounders examine various characteristics of the Mississippi River Watershed, looking at past and current conditions and, where possible, anticipating future changes on the landscape. The Backgrounders will form the basis for consultation and discussion with key stakeholders, and the broader watershed community, who will be partners in developing the Mississippi River Watershed Plan.

Mississippi River Watershed Plan Backgrounders:

One: The Physical Environment
Two: People & Property
Three: Natural Systems (Biotic)
Four: Asset Management

Climate Change Impacts • Water Management Challenges • Growth & Development Pressures
Water Quality Concerns • Source Water Protection • Infrastructure Considerations

- 6 large floods in the last 21 years (1998 to 2019)
- 4 droughts in the last 7 years (2012, 2016, 2018 and 2019)
- aging infrastructure (7 dams beyond expected life cycle)
- blue green algae occurrences in recent years
- invasive species on the rise
- high growth rates (80% projected increase in Beckwith and Carleton Place by 2038)

As one of the largest river systems in eastern Ontario, the Mississippi River is an invaluable resource, supporting a vast ecosystem made up of countless plants, animals, birds and other organisms. The health of the river and its watershed is vital to the ecological, social and economic wellbeing of its residents. It provides drinking water, replenishes wetlands and groundwater, provides essential habitat for fish and wildlife, supports recreation and tourism, provides water for agricultural crops and livestock, and provides hydroelectric power. A growing list of stressors and challenges impact these functions and values both directly and indirectly. The Watershed Plan will focus on responding to such challenges.

Integrated Watershed Planning

Mississippi Valley Conservation Authority has the responsibility for flood and erosion control, flood forecasting and warning, and providing expertise on, and regulating land use planning matters related to flood and erosion hazards for the Mississippi River watershed. MVCA has provincially assigned responsibilities in monitoring low water events to assist in guiding the local response, as well as a role in the protection of drinking water, both surface and groundwater. MVCA also monitors and reports on water quality and delivers stewardship and education programs aimed at protecting the health of the watershed.

Integrated Watershed Management is the process of managing human activities and natural resources on a watershed basis, considering, social, economic and environmental issues, as well as community interests in order to manage water resources sustainably (Conservation Ontario, 2012). It allows us to address multiple issues and objectives; and enables us to plan within a very complex and changing environment.

The Mississippi River Watershed Plan will provide for integration of these management activities at the watershed scale.

There are many vital resources and complex interactions that occur in a watershed:

- natural stream meanders and floodplains dissipate energy and decrease flow velocity and soil erosion
- water, soils and vegetation provide sustenance and habitat for all life
- wetlands store and filter water, and augment surface and groundwater

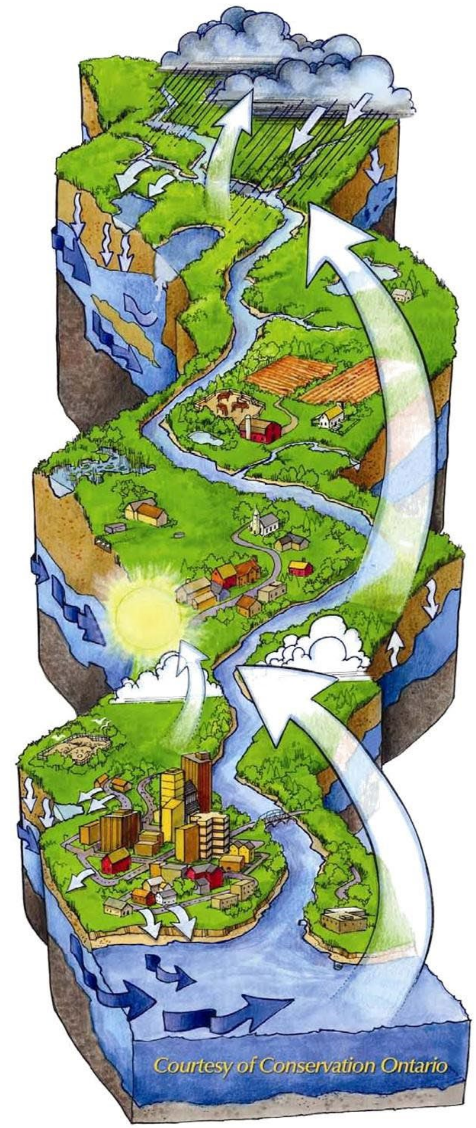

Figure 1: *Watershed Interactions*

The Watershed Scale

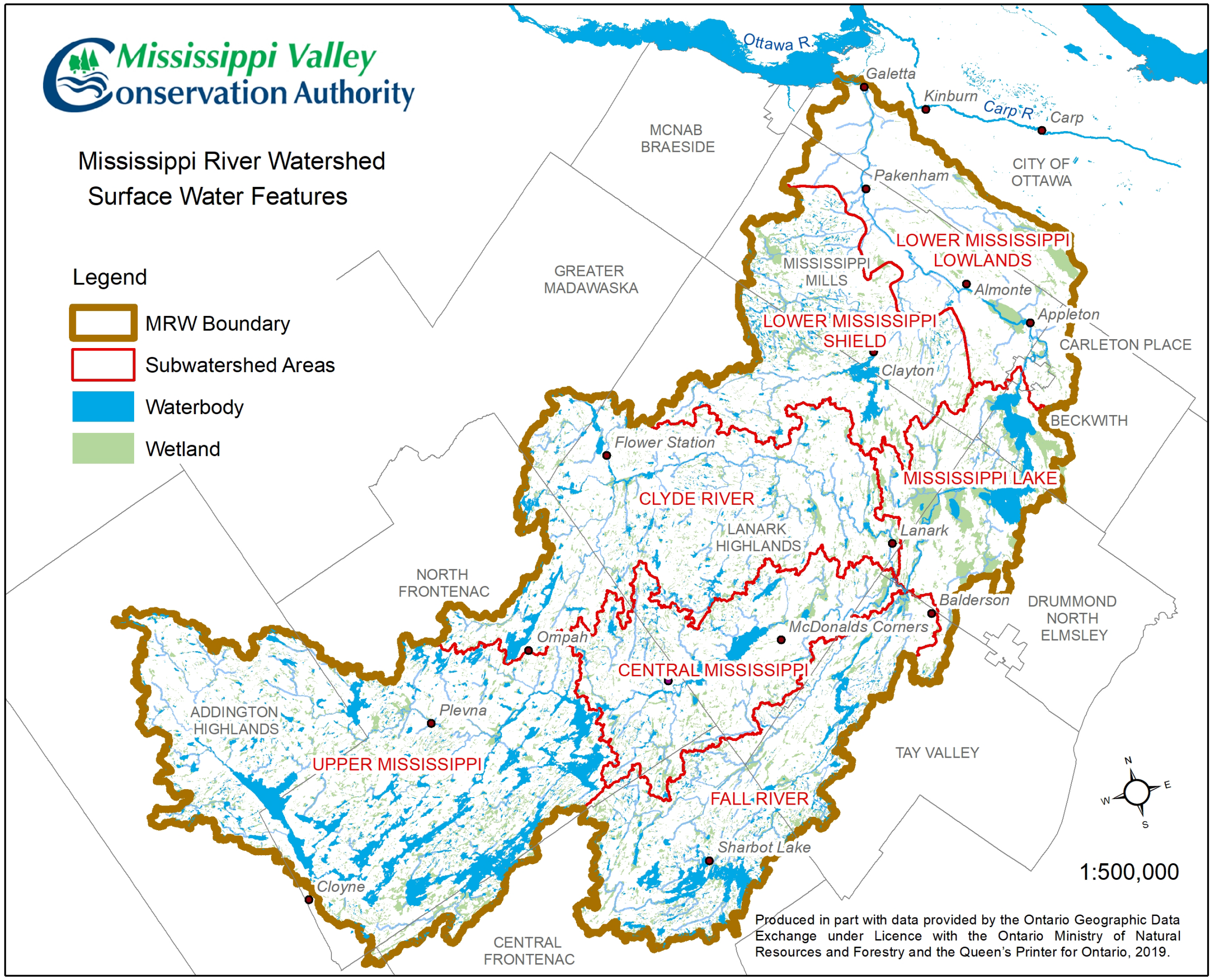

***Figure 2:** Mississippi River Watershed and Subwatersheds*

A watershed is a topographically defined area of land where the water within flows to a common point. Within a watershed, surface and groundwater are generally connected as water flows across the landscape through waterways or vertically through the various layers of soil and substrate. As depicted in Figure 1, watersheds are complex systems whose health depend on the functioning of all of the parts within. Activities and conditions that affect water quality, quantity or flow rate in one part of the watershed may affect locations downstream.

The Mississippi River Watershed[1] is divided into seven subwatershed areas (Figure 2) including the catchment areas for the two largest tributaries, the Clyde River and the Fall River, with the remaining area divided into five "Mississippi River" subwatershed areas: the Upper Mississippi; the Central Mississippi; the Mississippi Lake area; the Lower Mississippi – Shield, and the Lower Mississippi – Lowlands. The subwatersheds are further described on Page 18.

[1] This plan focusses on the watershed area of the Mississippi River and does not include the lands within the MVCA's jurisdiction to the east that drain into the Carp River and smaller watercourses that flow directly into the Ottawa River.

Physiography

KEY CONSIDERATIONS

- Two very distinct physiographic regions, very diverse landscape.
- There is a significant drop in elevation across the watershed with the river dropping 252 metres over its length.
- Shallow soils and overburden – presents limitations (agriculture, drought vulnerability, development challenges).
- Sandy, acidic soils in upper watershed, more variety of soil types in lower

The Mississippi River watershed is 3,765 km^2 in size. It has two distinct geologic regions: the Precambrian Shield (commonly referred to as the “Canadian Shield”) in the west; and the Ottawa-St. Lawrence Lowland basin in the east. The divide between these regions, shown in Figure 3, generally follows a north-south line between Pakenham and Perth. The physical landscapes of these two regions are strikingly different, with a blended transition area between the two. The key physiographic differences are highlighted in Figure 3. Bedrock surface and ground surface topography are shown in Appendix A: Figures 1 and 2.

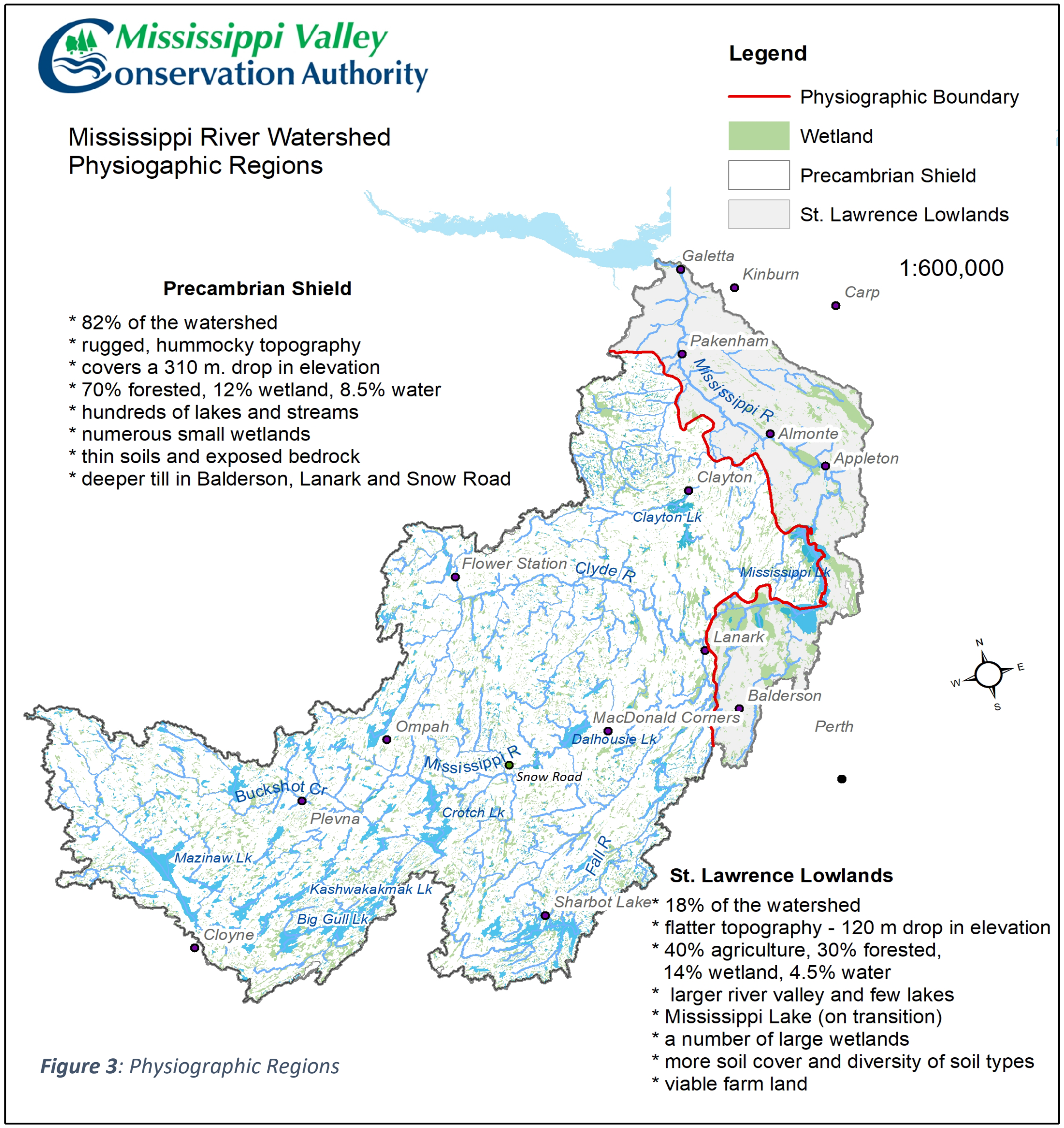

Figure 3: Physiographic Regions

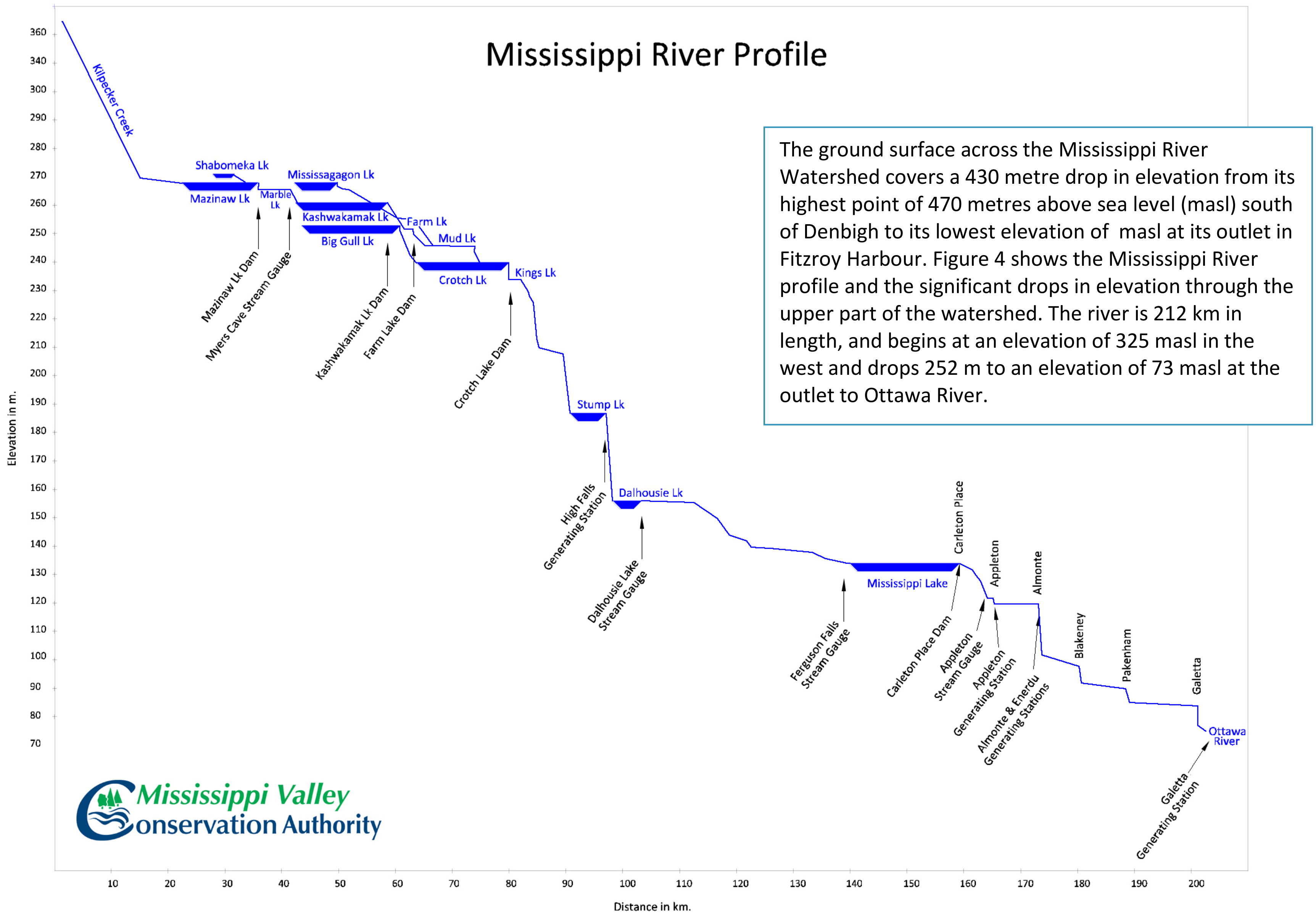

Figure 4: *Mississippi River Profile*

Bedrock, Overburden and Soils

The topography and drainage patterns of the watershed are the result of a long and complex series of geological, glacial and weathering processes. The Shield area provides vast areas for natural water storage in the form of lakes, ponds and wetlands. Softer bedrock was eroded and gouged by glaciers creating deeper trenches that formed long narrow lakes that generally follow a northeast orientation. The last glaciers also left landscape features in the form of moraines, drumlins, eskers and till plains in some areas. Over time, peat and muck deposits have accumulated in poorly drained depressions, creating numerous wetland areas. The flatter sedimentary bedrock in the east and northeast was formed as a result of the sand and marine life deposited by the ancient Champlain Sea following the retreat of the glaciers 12,000 years ago.
See Appendix A: Figure 3 for mapping and descriptions of the bedrock geology throughout the MRW.

Generally, the watershed has thin to non-existent overburden and soils (less than 1 m) with some exceptions near the Ottawa River where bedrock valleys allowed the accumulation of 10-30 m of clays and sands. There is also an area between Lanark Village and Balderson with thick accumulations of till and silt. See Appendix A: Figures 4 and 5 for surficial geology and overburden types throughout the MRW.

Sandy loam makes up about 84% of the soil cover. Found extensively in the upper (southwest) watershed, these soils tend to be acidic with a coarse texture and a low moisture retention capability. They have a very low agricultural capability, classified under the Canada Land Inventory (CLI) as Class 7 soils. See Appendix A: Figure 6 for soil types throughout the MRW.

The soils in the lower (northeast) watershed are more basic (pH), finer textured and generally deeper. In this area the soils vary widely in type and characteristics, with internal drainage also variable, ranging from very poor to good. Soil water retention is generally higher than the upper watershed due to the finer texture and the greater depth of the deposits.

Agricultural capability, a measure of suitability for agriculture based on characteristics of the soils, is higher in this area with high capability areas generally following the Mississippi River, downstream from Mississippi Lake. Farming operations are located mostly on these clay plains which provide high agricultural capability. The clay soils, although poorly drained, are highly productive for agricultural activities when artificially drained.

Hydrogeology

Groundwater is the primary source of drinking water in the Mississippi River Watershed. Approximately 75% of watershed residents draw their drinking water from individual private wells.[2] Mississippi Mills supplies water to approximately 2,900 Almonte residents using five communal wells. Communal systems service 30 other developments and facilities in the watershed (see Appendix A: Figure 7). Groundwater is also used for commercial, agricultural and industrial operations, and plays a vital ecological role in providing baseflow to streams and supporting water levels in lakes and many wetlands.

Aquifers and Aquitards

An aquifer is a water-bearing geologic unit that can supply groundwater in usable quantities to wells. An aquitard (confining bed in Figure 5) is a geologic unit having a low capability to supply water to wells. Figure 6 shows the main aquifers and distribution of private wells[3] throughout the watershed.

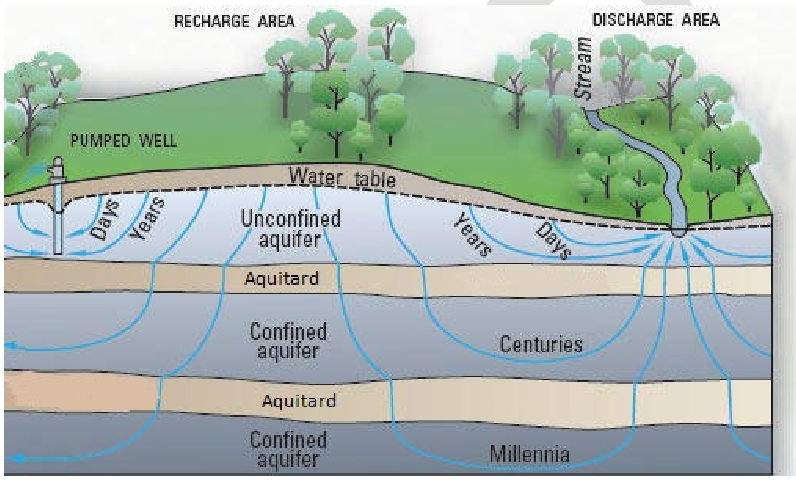

Figure 5: *Conceptualized Diagram showing Aquifers and Aquitards*

KEY CONSIDERATIONS

High reliability on groundwater for drinking water supply (over 75% of population).

Groundwater recharge occurs throughout the watershed.

There is limited information on groundwater discharge areas.

Potentially high vulnerability of groundwater contamination - most of the watershed is highly vulnerable aquifer at a regional scale.

Monitoring data is good at a regional scale but limited at the local level.

Insufficient data for watershed reporting on groundwater quality.

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[2] The Town of Carleton Place draws surface water from the river and some rural waterfront properties also rely on surface water intakes.

[3] The mapping of private wells is derived from Ministry of Environment, Conservation and Parks well record data. These records are incomplete, particularly for older wells. It therefore provides an underrepresentation of the actual number of wells throughout the watershed.

The Precambrian aquifer underlies most of the Mississippi River Watershed that is exposed at the surface or covered by a thin mantle of overlying material. This allows rainfall or snowmelt to directly and easily enter into the aquifer from the ground surface and is termed an “unconfined aquifer” (Figure 5). An unconfined sandstone aquifer lies between Balderson and Almonte.

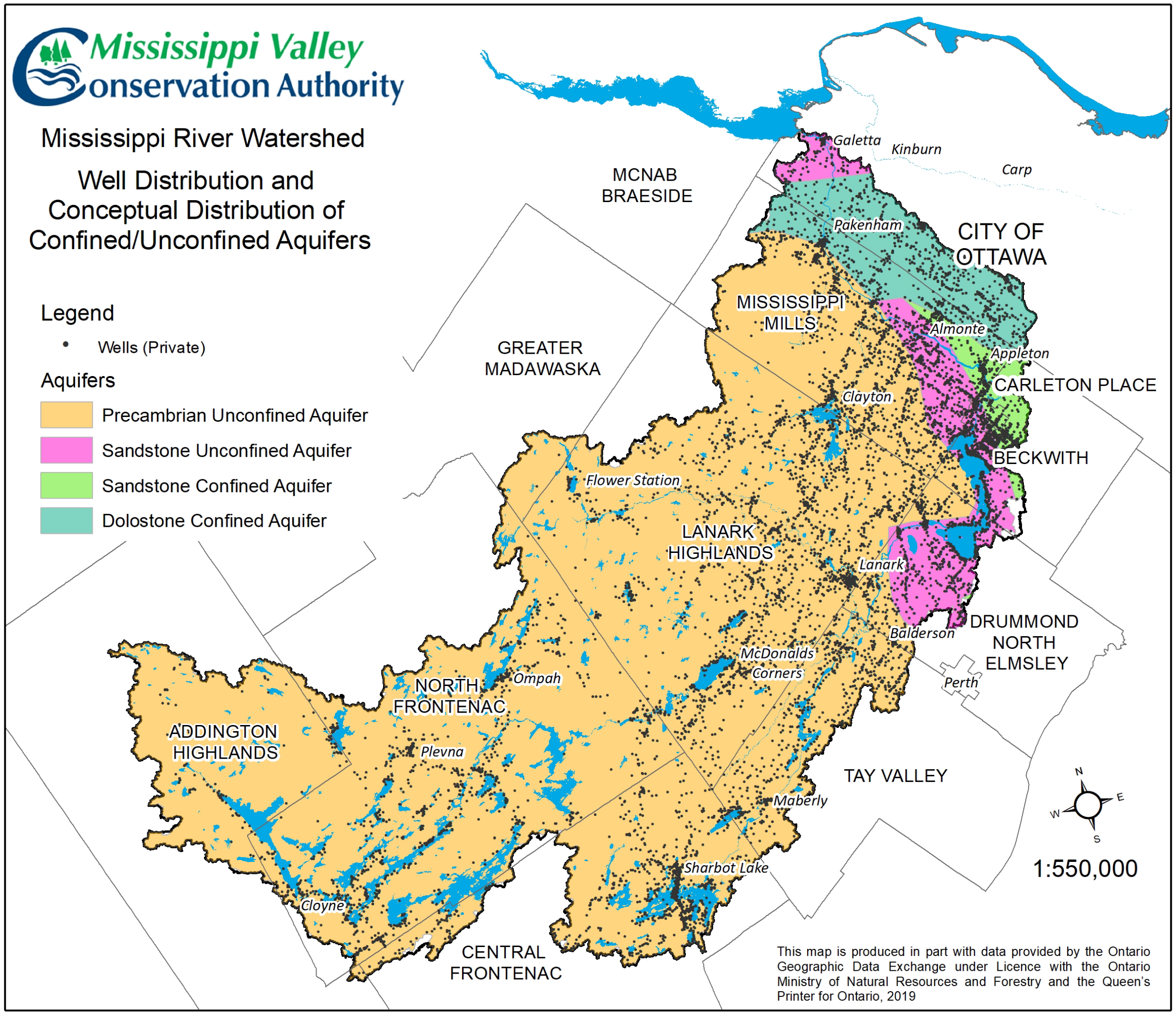

Figure 6: Well Distribution and Conceptual Distribution of Aquifers

Areas east and north of Carleton Place, Almonte and Pakenham, have “confined aquifers” where water movement between surface and ground are slow due to the presence of an aquitard (impermeable or less permeable layer).

Detailed descriptions of the watershed aquifers and aquitards, and other groundwater features and functions, can be found in in the Mississippi Rideau Source Protection Committee 2008. Watershed Characterization - Preliminary Draft Mississippi-Rideau Source Protection Region.

Groundwater Recharge/Discharge

Groundwater recharge, where water moves downward from surface water to groundwater, occurs throughout the watershed. Recharge can impact groundwater supply and should be taken into consideration in land use planning and decisions making.

Groundwater discharge areas, where shallow groundwater flows upward from subsurface to the surface (ex. seeps and springs) are typically found in valleys and other topographic depressions. They provide a significant ecological benefit by maintaining stream flow in many parts of the watershed which then feeds ponds, wetlands and lakes. These features can be difficult to identify and have not been mapped in the Mississippi River Watershed.

Aquifer Vulnerability

Aquifer vulnerability represents how quickly contaminants may move from the ground surface into the uppermost underlying aquifer. A map showing aquifer vulnerability, prepared for the Mississippi-Rideau Source Protection Committee 2008. Watershed Characterization **-** Preliminary Draft Mississippi-Rideau Source Protection Region is presented in Appendix A: Figure 8. All areas that were mapped as having less than 1.5 m of overburden, exposed bedrock at surface or sand and gravel deposits were deemed highly vulnerable. As such, most of watershed has been mapped as high vulnerability. Lower vulnerabilities are associated with areas where thicker low-permeability sediments (clay, till) overly the uppermost aquifers. This includes areas around Balderson, Appleton to Almonte and downstream in the area between Pakenham, Kinburn and Galetta. The vulnerability mapping provides a regional or large-scale interpretation and is not intended to provide for interpretation of groundwater conditions at the local/site level.

Groundwater Monitoring

Regional groundwater level and water quality monitoring is carried out under the Ministry of Environment, Parks and Conservation's (MECP's) Provincial Groundwater Monitoring Network (PGMN) program. It consists of 8 observation wells, 6 in the Mississippi River Watershed and 2 outside. Water level monitoring has been carried out since the early 2000s. Sampling and analysis for water quality also takes place annually in many of the wells and less frequently in others.

The groundwater levels show typical seasonal fluctuations. Groundwater levels generally rise in the spring, through recharge from snow melt and spring rains, and recede during the summer when precipitation is generally intercepted by plants and/or stored in the soil zone. Smaller recharge events occur in most falls and may also occur over the winter during snow melt or rain events. The fall/winter seasons are also times of lowered groundwater levels in many years.

Groundwater level information from the PGMN wells data can be used to assess conditions such as "groundwater drought" which may occur in association with or separate from surface water droughts and, over the long term, to compare the water level changes in response to a changing climate. The water quality component of this program provides limited value because of the sampling infrequency and limitations in extrapolating the localized representation of the well on a broader scale. As such, MVCA doesn't have sufficient data to report on groundwater conditions and trends over time. This represents a shortfall in the MVCA's Watershed Report Card Program reporting which will be discussed in Backgrounder Three: Natural Systems.

See Appendix A: Table 1 for a listing of Existing and Potential Sources of Contamination (to be covered in Backgrounder Two – People & Property)
Note: Groundwater data is also collected under Planning Act requirements through MVCA's plan review function. This provides site specific information relevant to applications for development made under the Planning Act.

Climate

Regional Climate

Climatic elements such as temperature, precipitation (rain and snow), and evapotranspiration (evaporation and transpiration from plants) are key components of the hydrologic cycle (Figure 7). Understanding the patterns of these elements, as well as their interaction, plays a key role in assessing water budgets and in comprehending how the natural systems will respond to changes in climate.

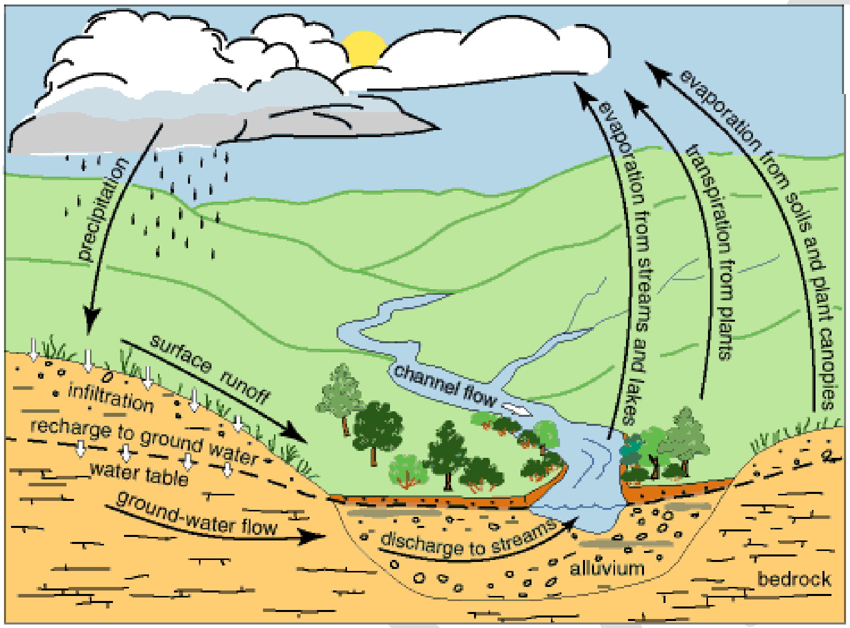

Figure 7: *Water Cycle (Source: Kansas Geological Survey)*

The climate in the Mississippi River watershed has been broadly categorized as a humid continental climate with severe winters, no dry season, warm summers and strong seasonality (Köppen-Geiger classification: Dfb). The topography also has a significant localized influence over temperature and precipitation patterns in the watershed. It is common during a single precipitation event to see marked differences in rainfall and snowfall at various locations throughout the watershed.

KEY CONSIDERATIONS

Three different weather systems across the watershed make weather forecasting a challenge.

Only one weather station (Drummond Centre) has more than 30 years of data and does not represent local or watershed wide conditions.

Weather, soil moisture and related data is needed for flood forecasting and modelling, and climate modelling.

Climate change projections predict more frequent and extreme rainfall events, an earlier spring freshet, prolonged periods of low summer flow, and more frequent drought-like conditions.

Increases in temperature and evaporation rates are expected to offset the increase in precipitation resulting in less water availability.

Runoff increases are projected to occur only in winter and fall and to decrease during the spring and summer.

Spring freshets will generally occur resulting in lower summer flows.

Climate change impacts are already being observed in the Mississippi River Watershed.

Local Climate

The climate of the Mississippi River Watershed is generally influenced by three distinct weather systems (Figure 8):

- Ottawa Valley, which influences weather in the lower (northeast) part of watershed and areas to the east like the Carp River;
- Lake Ontario north to Hwy 7, which affects the southern part of watershed; and
- Highway 41 north which tracks from Peterborough to Plevna and influences the upper (west) part of the watershed.

Generally, the western part of the watershed is slightly colder and wetter, with harsher winters and later springs than the eastern part.

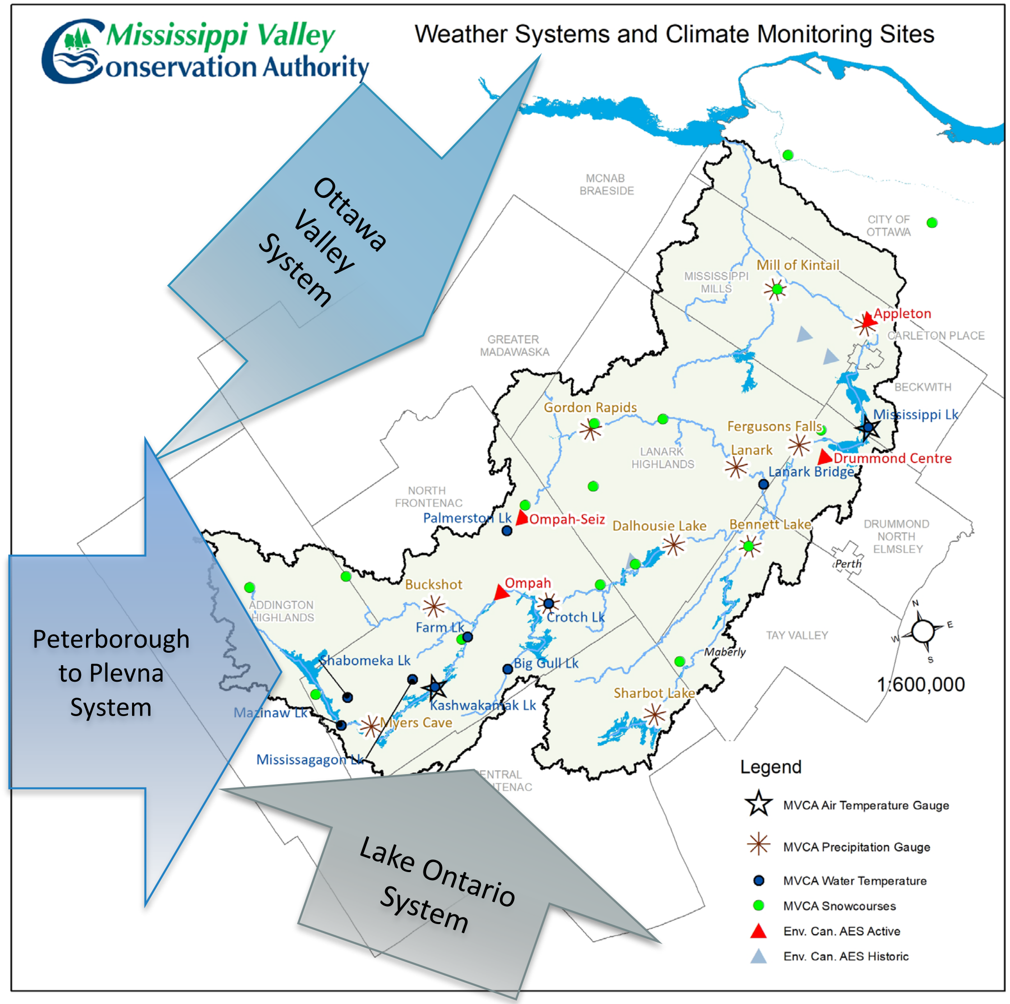

Figure 8: Mississippi River Watershed Weather Systems and Climate Monitoring Sites

Climate Data

The Atmospheric Environment Service (AES) division of Environment Canada has collected climate data in the watershed for over 100 years. Active AES climate stations include Appleton, Drummond Centre, and Ompah –Seitz (Figure 9). Drummond Centre, with the longest period of recent data (1984 to the present), is used for most MVCA climate change modelling.

MVCA, Water Survey of Canada (WSC) and Ontario Power Generation (OPG) also collect precipitation, water temperature, and air temperature data at stream flow and water level monitoring sites throughout the watershed. MVCA operates 16 snow courses to collect data for measuring snow water equivalent (SWE) during the snow season. The climate data collected by MVCA is used primarily for flood forecasting and flood/stormwater modelling. There is a lack of evaporation data for the Mississippi River Watershed, which is needed for developing water budgets and climate modelling. Simplified evapotranspiration rates have been calculated for the watershed for these purposes.

Appendix A: Tables 2 and 3 for the locations and listings of these sites.

Climate Data Trends

Climate data from all four AES stations (current and one discontinued) for a twenty-year period from 1997 to 2016 was used to provide a geographical comparison of climate across the Mississippi River Watershed (Table 1). It shows some geographic differences in climate particularly in comparing the western stations (Ompah and Ompah –Seitz) in the upper watershed to the eastern station (Appleton and Drummond Centre) in the lower watershed. The upper watershed is generally colder and receives more rain and snow. Precipitation is more variable with higher rainfall and snowfall in the western stations.

Table 1: Average Annual Temperature and Precipitation Summary (1997- 2016)

West (Upper Watershed) **East (Lower Watershed)**

Weather Station Location	**Ompah***	**Ompah-Seitz**	**Appleton**	**Drummond Centre**	**Variation (H-L)**
Elevation (metres above sea level)	251	276	133	145	143
Mean Annual Temp (°C)	5.5	6.2	6.6	6.9	1.4
Warmest Month -July (°C)	18.8	19.1	20.6	20.5	1.8
Coldest Month- January (°C)	-9.6	-9.8	-9.6	-10	0.7
Total Precipitation (mm)	967	957	829	915	128
Rain (mm)	763	740	669	731	94
Snow (mm)	204	218	159	183	59
Wettest Month - June (mm)	105	109	96	105	13
Driest Month- February (mm)	53	54	44	55	11

*based on 1997 to 2009 data from EC database, and 2010 to 2016 data provided by same volunteer recorder for this site Source: Environment Canada website

The monthly variation, presented in Appendix A: Table 4, shows that the greatest differences in precipitation were measured in May, November and December. During these months both of the Ompah sites averaged at least 19 mm more precipitation than the Appleton site.

Climate Projections

In 2014, MVCA completed a climate change study on the projected climate and water budget parameters for the MVCA watershed area[4]. Figure 9 shows a generalized depiction of some of the predicted changes in annual averages for key water budget parameters. It shows the differences (increase or decrease) from the baseline average (1970 to 2000) for time horizons projecting into the 2020s and the 2050s[5]. It is predicted that the Mississippi River Watershed will experience a 1.2°C rise in average annual temperature by the 2020s and a 2.5 °C rise by the 2050s. This will be accompanied by increases in precipitation, runoff and evapotranspiration, and decreases in snow amounts and soils moisture content.

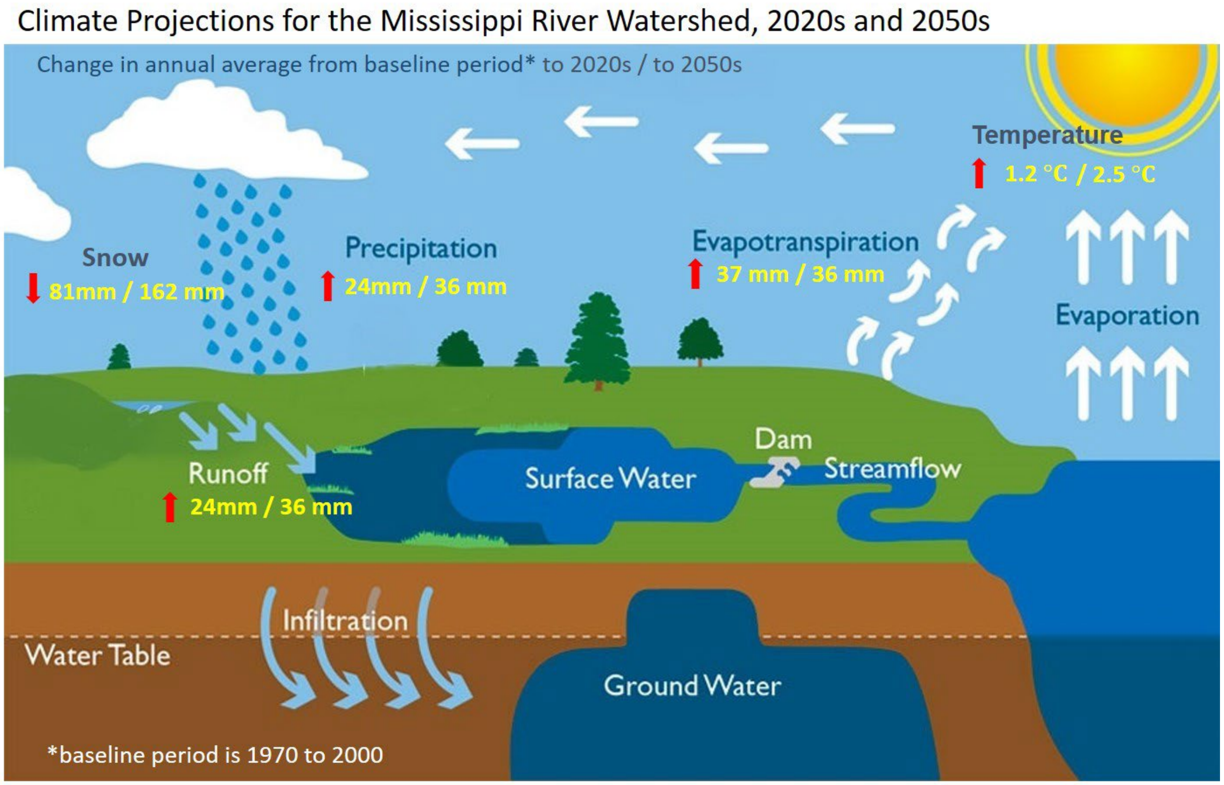

Figure 9: *Projected Climate Change Impacts*

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[4] Based on the IPCC Fourth Assessment Report (AR4), incl. high, moderate and low GHG emissions. Baseline period: 1970 to 2000, 100-year projection (2001-2100).

[5] Projections were calculated for 30 year windows as the 2020s (2011- 2040), the 2050s (2041 to 2070) and the 2080s (2071 to 2100).

The model also predicts an earlier spring freshet with more water, and low water in summer. These trends are already observed with the spring freshet generally 10 days earlier in 1974-02 compared to 1919-73 along with a 43% increase in fall/winter flows. Summer flows also decreased significantly in those same periods (S. Kunjikutty and P. Lehman, 2008). Climate models and IPCC reports are also predicting significant losses in the snowpack.

Table 2 provides a seasonal comparison of projected changes for climate and water budget conditions in the watershed, also using the 2020s and 2050s projections. It shows that the 2.5^{0}C increase in average annual temperature is consistent throughout the seasons, whereas precipitation is projected to show high increases in the winter (186mm) while decreasing in the summer (-7mm). Snow will show a substantial decrease overall. Runoff is projected to increase overall (20 mm), primarily in the winter (34 mm) and will decrease in both spring and summer. Evapotranspiration is projected to increase overall, most substantially in the spring and summer (28 and 34 mm), with smaller increases in the fall and winter (10and 6 mm). See Appendix A: Figures 9 and 10 for graphical representation of the projected changes in monthly temperature and monthly precipitation.

Table 2: Projected Annual and Seasonal Values for Climate and Water Budget Parameters in the Mississippi River Watershed - 2020s and 2050s

	Temperature (°C)*				Precipitation (mm)*				Snow (mm)**				Runoff (mm)**				Evapotranspiration (mm)**			
Period	*Baseline*	2020s	2050s	**Change**	*Baseline*	2020s	2050s	**Change**	*Baseline*	2020s	2050s	**Change**	*Baseline*	2020s	2050s	**Change**	*Baseline*	2020s	2050s	**Change**
Annual Average	***5.8***	**7**	**8.3**	↑	***881***	**905**	**917**	↑	***311***	**230**	**148**	↓	***351***	**354**	**371**	↑	***598***	**635**	**675**	↑
Winter (Jan.-Mar.)	*-6.8*	-5.5	-4	↑	*186*	195	198	↑	*253*	188	68	↓	*179*	193	213	↑	*9.5*	12	15.4	↑
Spring (Apr.-June)	*12.5*	13.7	15	↑	*208*	218	219	↑	*15*	8.6	8.6	↓	*103*	89	70	↓	*230*	243	258	↑
Summer (July-Sept.)	*17.3*	18.5	19.7	↑	*256*	255	249	↓	*0*	0	0		*7.5*	6	4	↓	*313*	330	347	↑
Autumn (Oct.-Dec.)	*0.1*	1.3	2.5	↑	*231*	238	251	↑	*43*	34	26	↓	*62*	67	84	↑	*45.5*	50	55	↑

*monthly average **three month total (red text denotes a negative impact)

Studies suggest that precipitation must increase by 10% to balance evapotranspiration losses resulting from a 4^{0}C increase in temperature (Gleick, 2000). In MVCA, summer precipitation is projected to decrease by 2% while PET is expected to increase by 23% increase, a condition that will worsen the situation in meeting water demand during the summer low flow season.

Appendix A: Note 1 presents a listing of projected climate change impacts for the watershed.

Surface Water Features and Hydrology

The main Mississippi River is 212 km in length from its headwaters above Mazinaw Lake, to where it flows into the Ottawa River just downstream of Galetta. It covers a 252 m drop in elevation with an average slope of 0.1%. (Table 3).

Table 3: Physical Characteristics of the Mississippi River Watershed	
Drainage Area	3,765 km'
River Length	212 km
Upper Elevation	325 m. above sea level
Downstream Elevation	73 m. above sea level
Total Drop	252 m
Average Slope	0.10%

There are more than 30 water control structures (dams) in operation on the river and its tributaries. Most were originally designed and managed for logging and power development. In recent decades the management objectives have shifted to flood mitigation, supporting tourism and recreation, agriculture, municipal services, industry and recreation; with power generation as a by-product.

KEY CONSIDERATIONS

The river has over 30 dams, originally designed for other purposes other than present use (ex. moving timber and mill operations).

The river is fed by an extensive network of rivers and streams totally an estimated 7100 km. in length.

Headwater drainage features make up >75% of total stream length but are not well mapped or studied.

Spring stream flow is about double the annual average, while summer and fall flows are less than half.

Most of the reservoir/water storage in the upper watershed.

Major flood damage centres are located at Dalhousie Lake, Mississippi Lake and Lanark Village.

Major Rivers and Lakes

An extensive network of tributaries feed the Mississippi River, including the Clyde River (catchment area 664 km^2)[6], Buckshot Creek (289 km^2), Fall River (280 km^2), Bolton Creek (158 km^2), Indian River (212 km^2), Indian Creek (162 km^2), Cody Creek (104 km^2) and numerous smaller creeks and streams.

There are more than 250 lakes and ponds concentrated mostly in the upper (southwest) watershed. They cover 11,655 sq.km, representing about 75% of the total surface water area. Mississippi Lake, the largest (surface area 25 km^2)[7] is the only large lake in the eastern part of the watershed. The next largest in terms of surface area are: Big Gull Lake (24 km^2); Crotch Lake (17 km^2), Mazinaw Lake (16 km^2); Sharbot Lake (15 km^2); and Kashwakamak Lake (11 km^2), all located in the upper watershed. See Appendix A: Table 5 for a list of watershed lakes and properties

[6] Catchment areas were derived from MNRF 10m. Digital Elevation Model

[7] Lake surface areas were derived from MNRF “Waterbodies” GIS layer that has been edited using DRAPE 2014 imagery

Smaller Streams and Tributaries

The larger water bodies are fed by thousands of small streams and creeks, many of which flow only in the spring or during large rain events. These smaller **first-order** and **second-order** feeder streams, have a combined length of over 6,500 kilometres and make up 75% of the total stream length within the watershed. Research has shown that these features, referred to as "headwater drainage features" (HDF) for monitoring purposes, have a critical role in the overall health and functioning of the watershed (TRCA, 2007). There is very little monitoring or assessment of HDFs in the Mississippi River Watershed. See Appendix A: Figures 11 and 12, and Table 6, for illustrations and details about headwater drainage features in the watershed.

Stream Flow

Stream flow is measured at a number of sites throughout the Mississippi River Watershed. Table 4 presents average seasonal and annual stream flows[8] for the river and its four major tributaries, listed in order of size. Flows are highest during the spring freshet when the melting snow and ice combines with the spring precipitation. Average spring flows are upwards of double the overall annual average. Flows are at the lowest in the summer and fall when they might be about one third to one half of the overall annual average.

Table 4: Average Seasonal Flow of Major Watercourses in the Mississippi River Watershed

Watershed	Average Annual Flow (m^3/s)	Average Seasonal Flows (m^3/s)				Seasonal Flows as a Percentage relative to Annual Average	
		Winter	Spring	Summer	Fall	Spring	Summer
Mississippi R. (1918 to 2019)	32.4	29.0	67.4	18.1	14.7	208%	56%
Clyde River (1970 to 2019)	7.5	6.4	17.7	3.1	2.6	236%	41%
Fall River (2003 to 2019)	3.8	4.1	7.2	2.0	1.5	189%	53%
Buckshot Creek (1993 to 2019)	2.1	2.1	4.4	1.1	0.7	210%	52%
Indian River (1971 to 2019)	2.3	1.9	5.5	1.0	1.0	239%	43%

A comparison of the monthly runoff (flow per unit area) from each subwatershed is presented in Appendix A: Figure 13. The Clyde River shows the greatest seasonal change with the highest runoff in the spring and lowest in the fall. This reflects the fact that the Clyde watershed has little to no natural storage capacity and functions as an uncontrolled system. As a controlled system, the Mississippi River shows less variation throughout the year.

[8] This data is based on stream flow measured at the gauge located furthest downstream and does not represent the full flow volume that would be measured if the gauges were located at the watercourse outlets.

Subwatersheds of the Mississippi River

The *Mississippi River Water Management Plan* (MRWMP) provides a characterization of the watershed surface hydrology broken out by subwatershed area (Figure 10) to divide the main watershed into manageable portions. Appendix A: Table 7 details the key hydrologic characteristics and features of each of the subwatershed areas.

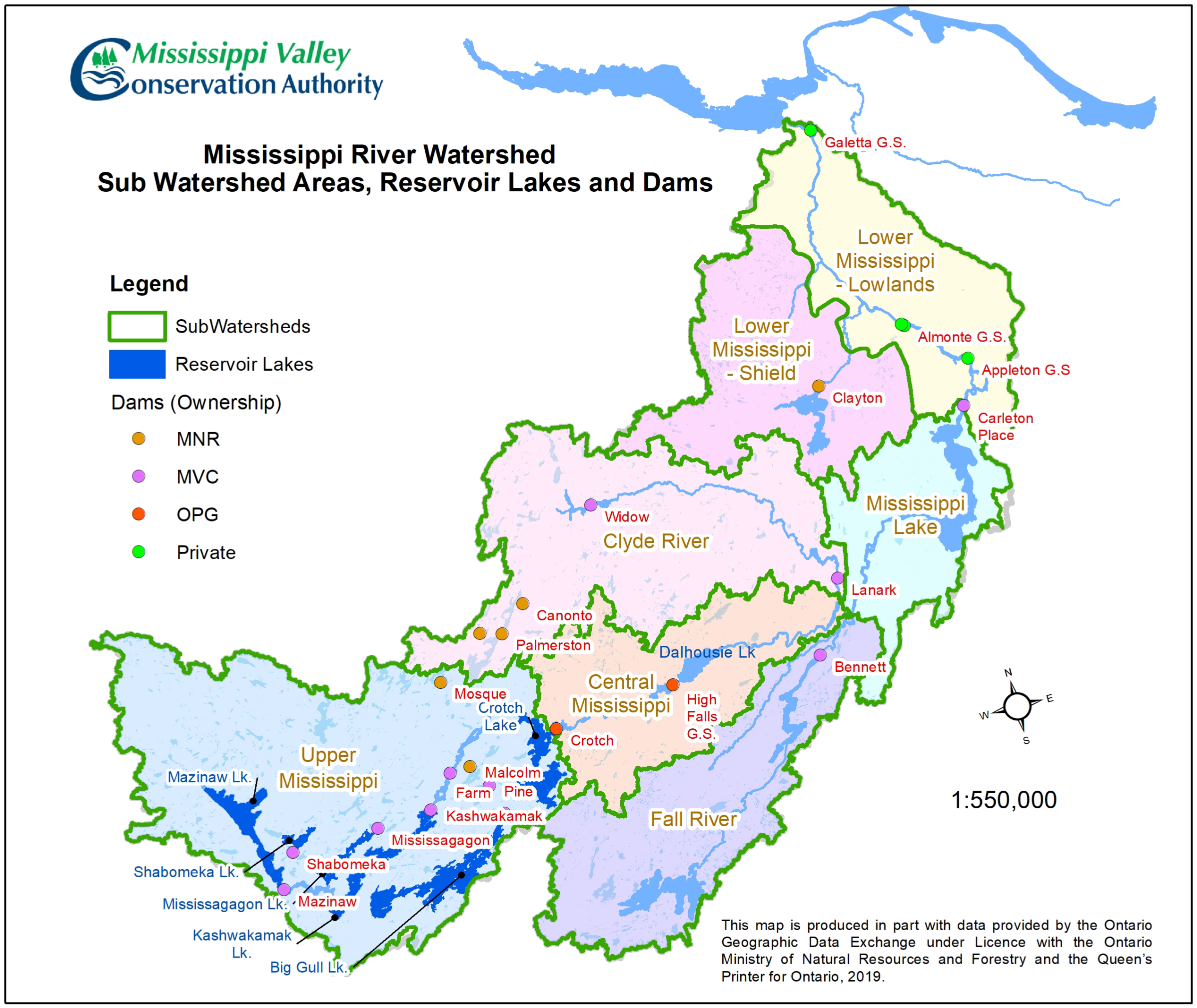

***Figure 10**: Mississippi River Subwatershed Areas, Reservoirs and Dams*

Subwatersheds:

Upper Mississippi (1028 km^2) - has most of the lakes and all available storage for stream flow regulation. Most water management occurs here.

Central Mississippi (395 km^2) - has the High Falls dam hydroelectric generating system (OPG). Flooding issues on Dalhousie Lake.

Clyde River (664 km^2) - has a number of small lakes but no natural storage/reservoir capacity.

Fall River (486 km^2) - has several large lakes and Bolton Creek. Is essentially an uncontrolled system.

Mississippi Lake (294 km^2) - on the transition zone between the Shield and Lowlands. Has Mississippi Lake, the largest, most developed lake and the largest flood damage centre.

Lower Mississippi - Shield (424 km^2) – is the lower part of the system that is on the shield. It has the Pakenham Hills and Clayton-Taylor Lakes.

Lower Mississippi Lowland (432 km^2) –is the lower part of the system that is on the St. Lawrence Lowlands. It has the larger lower valley system of the Mississippi River and it has most of the hydroelectric production.

Water Management

MVCA has been involved in managing water flow and levels along the Mississippi River since the early 1970's. As shown in Figure 11, ownership of the water control structures/dams and generating stations (GS) is currently as follows:

- Mississippi Valley Conservation Authority (MVCA) – 11 structures
- Ministry of Natural Resources and Forestry (MNRF) – 6 structures
- Ontario Power Generation Inc.(OPG) - 2 structures, Crotch Lake dam and High Falls Generating Station (G.S., 2.4 MW capacity)
- Enerdu Power Systems Ltd. - 1 structure, G.S in Almonte (1.0 MW capacity)
- Mississippi River Power Corporation – 1 structure, G.S. in Almonte (4.6 MW capacity)
- TransAlta (Canadian Hydro Developers Inc.) – 2 structures , Appleton G.S. (1.3 MW capacity) and Galetta G.S. (1.6 MW capacity)

In 2006 the *Mississippi River Water Management Plan* (MRWMP) was developed by MNRF, MVCA and the hydro producers in accordance with the *Lakes and Rivers Improvement Act*. The plan documents operating ranges and management strategies for the major hydraulic structures along the river system. It specifies the upper and lower limits of water levels and flows within which the dam/water control structures must be operated to remain in compliance. The plan also includes goals and objectives for protection of species at risk and other ecological features. [9]

See Appendix A: Table 8 for a chronological history of MVCA's role in water control. Appendix A lists MRWMP structures (Table 9) and the other structures (Table 10).

KEY CONSIDERATIONS

MVCA operates 17 of 30 dams and weirs within the watershed.

The dams have limited capacity for flood control – they were designed for other purposes.

The Mississippi River Water Management Plan (MRWMP, 2006) sets operating limits for each of the dams but does not consider the impacts of climate change.

Most reservoir/storage capacity is in the upper watershed with a large amount of "uncontrolled" runoff in the lower watershed.

Dalhousie and Mississippi Lakes are heavily developed with large flood prone areas and no dam at their outlets. The upstream operations strive to alleviate flooding issues.

Crotch Lake is the only true reservoir lake on the system.

The MRWMP sets a summer target of 5 m^2/s* at the High Falls G.S. and a minimum compliance requirement of 1 m^2/s.

Operations must also strive to ensure sufficient flows and levels for spawning fish.

Low water/droughts conditions have occurred more often since 2012. Water usage restrictions during Level 3 drought conditions are voluntary.

[9] The MRWMP terms of reference were restricted to addressing water levels and flows associated with the hydro facilities and main storage reservoirs on the Mississippi River; it therefore does not address issues of water quality, land use or climate change, all of which fell outside of the scope of the plan. The MRWMP is due for review and update, providing an opportunity to consider these additional factors.

Flow and Water Level Monitoring

Water level data and stream flow data are collected from a network of gauges located on rivers, creeks, and lakes throughout the Mississippi River Watershed. The data is used for water management operations, flood forecasting, and low flow assessments and various modelling analyses such as floodplain mapping, nutrient modelling, climate change assessments and hydrology/hydraulic modelling. MVCA partners with Water Survey of Canada (WSC) and MNRF to collect water level and flow data from gauges across the watershed (23 automated gauges and 27 manual gauges, known as "staff gauges"). The automated information is updated daily on the MVCA website for public use. See Appendix A: Figure 14, Table 11 (Automated Gauges), Table 12 (Staff Gauges) and Table 13 (Snow Courses).

Managing Water Levels and Flows

The dams in the upper watershed were originally built to float timber downstream, and the dams in the lower watershed for a variety of milling operations. The management of the dams has since evolved to focus on flood protection, low flow augmentation, ice management, recreation, erosion control, fisheries, tourism and power generation. Six lakes provide primary storage capacity to collect the spring freshet and to alleviate flooding downstream.

Water Management Operating Timeline

RESERVOIR LAKES	SPRING	SUMMER	FALL	WINTER
Shabomeka Lake, Mazinaw Lake, Kashwakamak Lake, Big Gull Lake, and Mississagagon Lake	Lakes are filled to summer target levels for recreation and tourism.	After spring runoff the dams (except Crotch Lake) are operated to slowly release water in order to maintain relatively stable lake elevations for recreation throughout the summer.	The lakes are drawn down to provide storage space for the next year's spring runoff.	The lakes remain drawn down until early spring.
Crotch Lake	The lake is filled with the spring freshet.	Late June to early November the lake is drawn down to ensure flows downstream. This is augmented with the water release from the other dams upstream.	The lake is filled to provide flow through the winter (release from upper dams).	January to mid-March the lake is drawn down providing low flow augmentation over winter and maximize storage for next year's spring freshet.

***A Note about Crotch Lake**

Crotch Lake is the only true reservoir lake on the system. It is predominantly undeveloped as the lands are largely owned by the Crown or OPG. The water level normally fluctuates from 2.5 metres to 3.5 metres over the summer, depending on precipitation. It provides 60 to 100% of the summer flow to the downstream area but does not have the full capacity to buffer the impacts of extreme high or low flow events.

The MRWMP requires a minimum target (compliance) flow of 1 cubic metre per second (m^3/s) at the High Falls G.S. however the plan recognizes 5 m^3/s[10] as the preferred minimum target throughout the year. The water users within the watershed are accustomed to the 5 m^3/s minimum target however, under drought conditions, achieving this target becomes increasingly difficult. In 2001 and 2002, 100% of the river flow downstream of Crotch Lake came from the Lake itself - all other tributaries had virtually dried up.

See Appendix A: Table 14 for a summary of water control structure operational considerations. Appendix A: Note 2 summarized constraints and issues identified through the MRWMP planning process.

Flood Forecasting and Response

Flood forecasting and warning is an integral part of the Authority's flood control program. Responsibilities for flood forecasting and response are shared between the MVCA, the municipalities and the Province.

MVCA is responsible for:	Municipalities are responsible for:	Federal and Provincial Governments are responsible for:
• System and weather monitoring • Predictive analysis/Flood forecasting • Administration of flood warning and notification system • Operation of 17 of 30 water control structures	• Emergency preparedness • Flood response and recovery	• Administration of national Disaster Mitigation and Adaptation Fund (DMAF) – Infrastructure Canada • Administration of Disaster Recovery Assistance for Ontarians (DRAO) and Municipal Disaster Recovery Assistance (MDRA) - Emergency Management Ontario

[10] The 5 m^3/s represents the amount of water that could be maintained, by utilizing all of the storage in Crotch Lake, over a 4 month period with an average amount of rainfall over that same period.

MVCA has in place a Flood Warning System that can be activated in the event of a flood to help in preventing the loss of life, and minimizing property damage. The stream flows, water levels and climate data described on Pages 12 and 20 is used to assist in flood forecasting and warning. When flooding conditions are lower than or equal to average, MVCA maintains its normal system of providing watershed condition updates to the local media and the member municipalities. The flood warning system is only activated if it appears imminent that above average flooding will occur.

The areas within the Mississippi River Watershed most prone to flooding are:

- Lanark Village (Clyde River)
- Clyde River from Cedardale and Lanark
- Snow Road and Dalhousie Lake
- Innisville and Mississippi Lk.
- Carleton Place
- Glen Isle and Appleton (in Mississippi Mills)
- Town of Mississippi Mills (formerly Almonte, Pakenham)
- Areas around Shabomeka, Mazinaw, Little Marble/Marble, Kashwakamak and Big Gull Lakes may also be susceptible to flooding.

Table 5: Past Major Flooding Events in the Mississippi River Watershed since 1998:	
2019 (Apr)	Mississippi Lake just 0.06 m below 1:100 Flood Level[11] Appleton flow second-highest on record at 275 m^3/s Highest flooding in the Upper Watershed.
2017 (Apr)	Appleton flow: 208 m^3/s
2014 (Apr)	Appleton flow: 244 m^3/s (fourth highest on record*)
2008 (Apr)	Appleton flow: 211 m^3/s
2002 (Jun)	Dalhousie Lake reached just 0.14 metres below the 1:100 Flood Level.
1998 (Apr)	Flooding exceeded the 1:100 Flood through parts of the watershed including Mississippi Lake. Appleton flow highest on record at 282 m^3/s.
* Historic data derived from graphs suggest a 3rd highest flood on record occurred in 1928 with flow of 260 m^3/s. (MVCA, 2019)	

Most flooding in the Mississippi River watershed is the result of continuous peak rainfall along with snow melt associated with warmer temperatures. Flooding is also caused by frazil ice, a slushy river ice that forms during extended severe cold periods and filling the river channel and blocking flow. This occurs at various locations throughout the watershed and there are no readily available means to prevent, control or remove it.

Table 5 provides a listing of recent flood events. The two highest floods on record since 1980 occurred more recently only 21 years apart (1998 and 2019) and four other marked flood events occurring very recently in 2002, 2008, 2014 and 2017. The flood with the highest recorded flows (Appleton) occurred in 1998, impacting the flood damage centres throughout the entire system.

[11] The Mississippi Lake 1:100 year flood level was revised from 136.50 metres above sea level to 136.73 masl following 1998 flood

Low Flow and Drought Response

Until recently, extended periods of dry, hot weather and low water levels were relatively uncommon, occurring once every decade or so. In the past seven years, MVCA has experienced four droughts, one in 2012, a severe one in 2016, and drought conditions in both 2018 and 2019.

In 2001, the MNRF established the Ontario Low Water Response Program to assist in coordination and support of local response in the event of a drought. Under the program, drought response is managed through a Water Response Team (WRT) coordinated by MVCA, and made up of representatives of water users: member municipalities, farmers, businesses, recreation and others.

The WRT communicates when necessary to review stream flow information and weather forecasts. Based on the information, the committee may:

- declare a low water condition for the watershed.
- coordinate drought response and share information and resources to deal with Levels I & II drought (minor event).
- declare a Level III drought (major event). Under these conditions there is no mechanism to require water users to lower/cease water usage.

Low water definitions:

- **Low Water Level 1**: early indication of a potential drought condition.
- **Low Water Level 2**: increased likelihood of drought conditions.
- **Low Water Level 3**: high likelihood of drought conditions (does not imply an emergency).

See Appendix A: Table 15 for a summary of Low Flow Response Levels and Thresholds.

Natural Hazards

Natural Hazards include flood hazards, erosion hazards, unstable soils and unstable bedrock. In Ontario, the Conservation Authorities (CAs) are the primary agency responsible for issues pertaining to natural hazards. Where there is no CA, including the area to the north of MVCA and throughout most of Northern Ontario, it is the responsibility of the MNRF.

Flood Hazards

Following provincial standards and guidelines, the flood hazard in the Mississippi River Watershed is defined and mapped based on the 100-Year Flood standard. The 100-Year Flood is defined as a flood event that has a return period of 100 years on average, or has a 1% chance of being equaled or exceeded in any given year.

Extensive work has been done to map floodplain areas within the watershed. Mapping, listed in Table 6 and shown in Figure 11, has been prepared for urban areas, rural built-up areas (i.e. Mississippi Lake) and a number of the other flood susceptible areas listed on Page 23. The mapping is used to identify potential flood risk areas for development review. And to set regulation limits for the implementation of MVCA's *"Development Interference with Wetlands & Alteration to Shorelines & Watercourses Regulation"*, to be examined in Backgrounder 2

Table 6: Flood Plain Mapping in the Mississippi River Watershed

Year Produced	Watercourse/Waterbody
Underway for 2020	Mississippi River Carleton Place to Outlet at Fitzroy Harbour Indian River - Clayton and Taylor Lakes to Mississippi River Cody Creek – Manion Corners to Mississippi River (replacing 1984 mapping for the same stretch of river)
2014	Mississippi Lake and the River downstream to Carleton Place Dam
2003	Dalhousie Lake and Mississippi River to Sheridan's Rapids
1985	Clyde River - Cedardale to Lanark
1984*	Mississippi River - Carleton Place to Ottawa River
	Indian River - Clayton Lake to Mississippi River
	Clayton & Taylor Lakes - entire lake shore
	Cody Creek - Manion Corners to Mississippi River

KEY CONSIDERATIONS

Floodplain mapping (100 Year Flood) is available for major flood risk areas including Lanark Village, Dalhousie Lake and Mississippi Lake.

Flood events close to, or exceeding the 100 Year flood standard have occurred 3 times in the past 31 years (1998, 2002, and 2019).

Current erosion and slope risk mapping is plotted only in areas where there is floodplain mapping available.

Most known slope stability hazards are located in the lower watershed due to the presence of Leda type clay (between Almonte and Pakenham and along Cody Creek).

Areas in the western part of the watershed where substantial flooding is known to occur but floodplain mapping has not been done include areas around Shabomeka Lake, Mazinaw Lake, Kashwakamak Lake and Big Gull Lake.

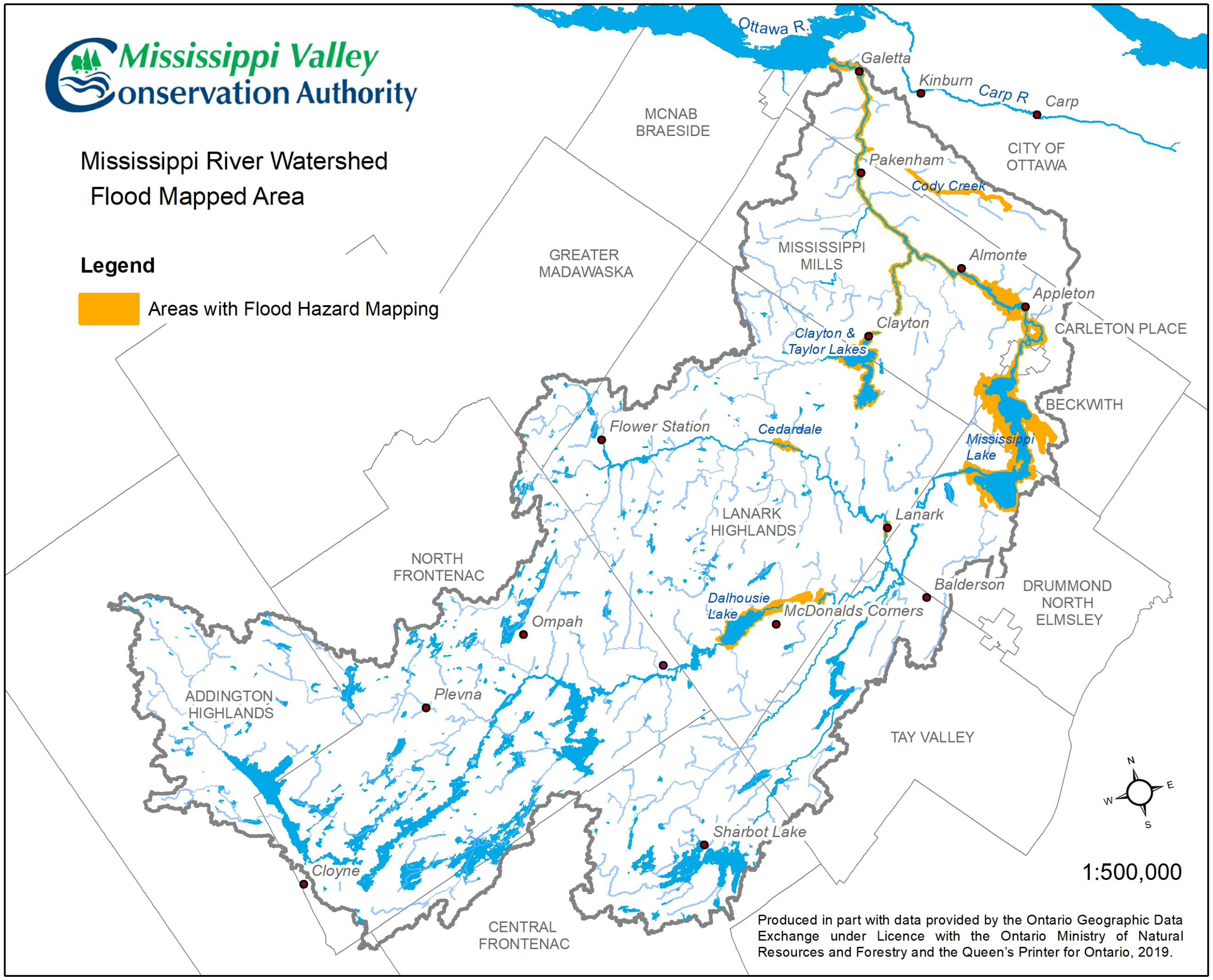

Figure 11: *Mississippi River Watershed Floodplain Mapping*

Conservation Authorities are responsible for the regulation of development in identified hazardous lands. Hazardous land is an area that could be unsafe for development because of naturally occurring processes associated with flooding, erosion, dynamic beaches, or unstable soils (e.g. sensitive marine clay or organic soils); or unstable bedrock (i.e. karst formations). The potential for severe flooding or for catastrophic failures in some areas of unstable soil and unstable bedrock warrant specific studies to determine the extent of these hazardous lands, and therefore the potential for development to be undertaken safely. Conservation Authorities regulate these hazardous lands based on the conclusions and recommendations of such studies. The province's guideline: *Understanding Natural Hazards: and introductory guide for public health and safety policies 3.1, provincial policy statement (2001)*, provides a good overview and descriptions of these hazard features.

Unstable Soil, Landslide and Erosion Hazards

The Mississippi River Watershed has areas that are characterized as being potentially hazardous due to unstable soils, the potential for landslides, and/or potential riverine erosion hazards. Sensitive marine clays (i.e. Champlain Sea clays/Leda type clays which may be prone to catastrophic failure/landslides) and other potentially unstable or highly erosive soil types (sandy or silty soils) are found in the lower watershed. Slope stability mapping studies by Klugman and Chung (1976), Bracken, et.al (1985) and Geological Survey of Canada (2019) identify areas of potentially high instability between Almonte and Pakenham, along substantial parts of Cody Creek and in other parts of the watershed. Potentially hazardous sensitive marine clays are not unique to this watershed. The entire St. Lawrence Valley is prone to landslides. Regionally, the most recent one occurred in 2016, along the Bonnechere River downstream of Renfrew.

Natural Hazard Guidelines to support Section 3.1 of the *Provincial Policy Statement (2020)* set criteria for defining potential riverine erosion hazards based on soil type, slope height, and proximity to the watercourse.[12] Based on those guidelines, more generalized delineations of potential erosion hazards within the watershed are captured within the erosion hazard limits (detailed in Backgrounder 2: People and Property). These erosion hazard delineations are plotted only in the areas where there is floodplain mapping available. Floodplain mapping produced since 2015 identifies slope and meander belt erosion hazards.

Organic soils are also classified as "hazardous sites" or "hazardous lands" under the policies of both the *Provincial Policy Statement 2020* (Section 3.1) and the MVCA Regulation. Organic soils, formed by the decomposition of vegetative and organic matter, usually coincide with wetland areas. They lack structure, erode easily and compress substantially, making them unsuitable for development. Organic soils can also produce methane gas which is highly explosive.

Shown in Appendix A: Figure 15, organic soils are scattered extensively throughout the watershed. In the lower watershed the organic soils coincide mostly with the large wetland areas. Throughout the rest of the watershed, where the topography is dominated by the Canadian Shield, organic soils

[12] Slopes that are steeper than 3:1 (5:1 for sandy soils and clay soils), or where the toe of the slope is within 15 metres of the river or stream bank, are flagged as potentially hazardous due to over steepening and/or susceptibility to erosion at the toe (MNR, 2001). In assessing the hazard, the guidelines further differentiate between watercourses that are confined (apparent) and unconfined or meandering (non-apparent).

are found in numerous small pockets that occupy depressions in the bedrock. Soils Survey mapping is available for all parts for the Mississippi River Watershed however a digital version of soils mapping is not yet available for the extreme western part of the watershed. Site-specific geotechnical studies associated with planning and development applications are also used to confirm the presence or absence of organic soils.

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Appendix A

For Backgrounder One: The Physical Environment

Mississippi River Watershed Plan

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List of Figures

List of Tables

Bedrock and Surface Elevations

Figure 1 shows the ground surface topography and Figure 2 shows the bedrock surface topography (the surface elevation relief pattern of the upper most bedrock unit within the Mississippi River watershed). Due to the shallow overburden deposits throughout the watershed, the ground surface topography is a close reflection of bedrock surface topography throughout much of the watershed. It is only in the north part, at the downstream end of the Mississippi River, where the bedrock topography is considerably lower than the surface topography. This represents an area of deposition with

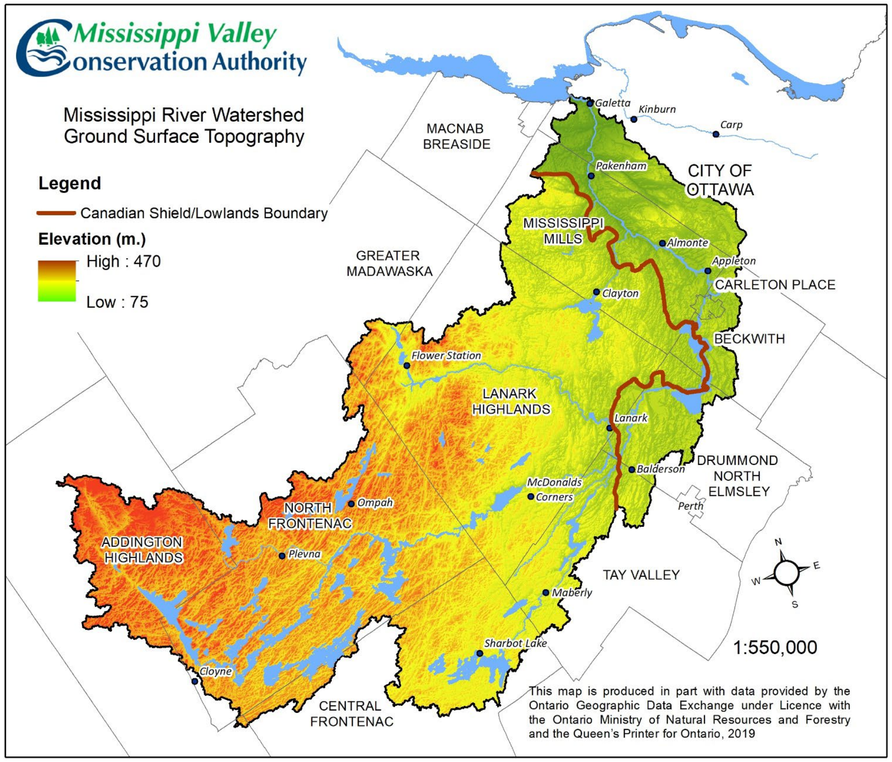


Figure 13: Ground Surface Topography

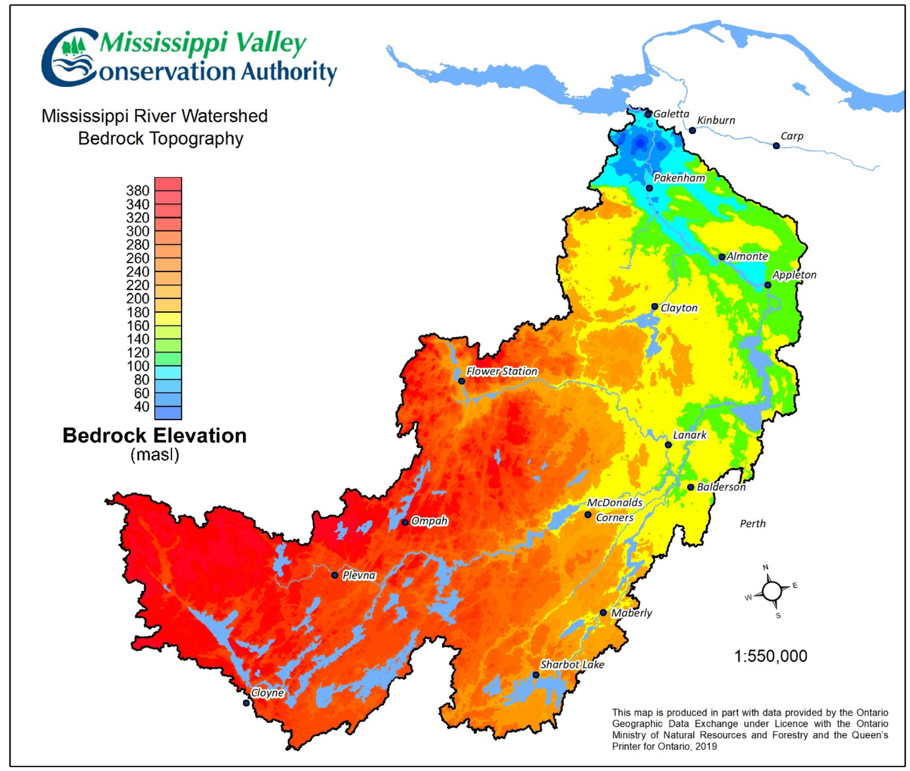


Figure 12: Bedrock Surface Topography

an accumulation of thicker overburden most in the form of clay soils.

The bedrock surface topography is also a reflection of the numerous geological processes including faulting, glaciation, and erosion that have taken place since deposition. Igneous and metamorphic Precambrian bedrock generally has a hummocky topography while sedimentary Paleozoic bedrock was deposited in a marine environment and is generally flat lying. Figure 2 shows the undulating topography in the western and central areas where

Precambrian bedrock is the uppermost bedrock unit, and the generally flatter topography in the eastern portion of the watershed where Paleozoic rocks overly the Precambrian basement rock.

Geological Formations

The Precambrian Shield exists throughout the entire watershed. It outcrops over the majority of the western and central watershed and is covered with Paleozoic-aged sedimentary rocks (Nepean, March, Oxford and younger Formations) east of Perth and east and north of Almonte. The following sections describe each of the bedrock units in greater detail.

Precambrian Bedrock: The geology of Precambrian bedrock within the watershed is extremely complex with many faults, folds, and a mixture of rock types including: marbles, gneisses, quartzites, intruded, deformed and metamorphosed by bodies of granite, syentite and other igneous rocks (Wilson, 1946).

Paleozoic Geology: The Paleozoic Era (~542-251 million ago) comprised a time when an ancient ocean flooded the majority of the North American continent from the east. The series of sedimentary bedrock formations overlying the Precambrian basement were formed as a result of the ancient sea advancing and retreating several times. The Paleozoic bedrock formations generally exist to the east of the Precambrian-Paleozoic interface, which forms a divide roughly coinciding with a north-south oriented line between Pakenham and Perth.

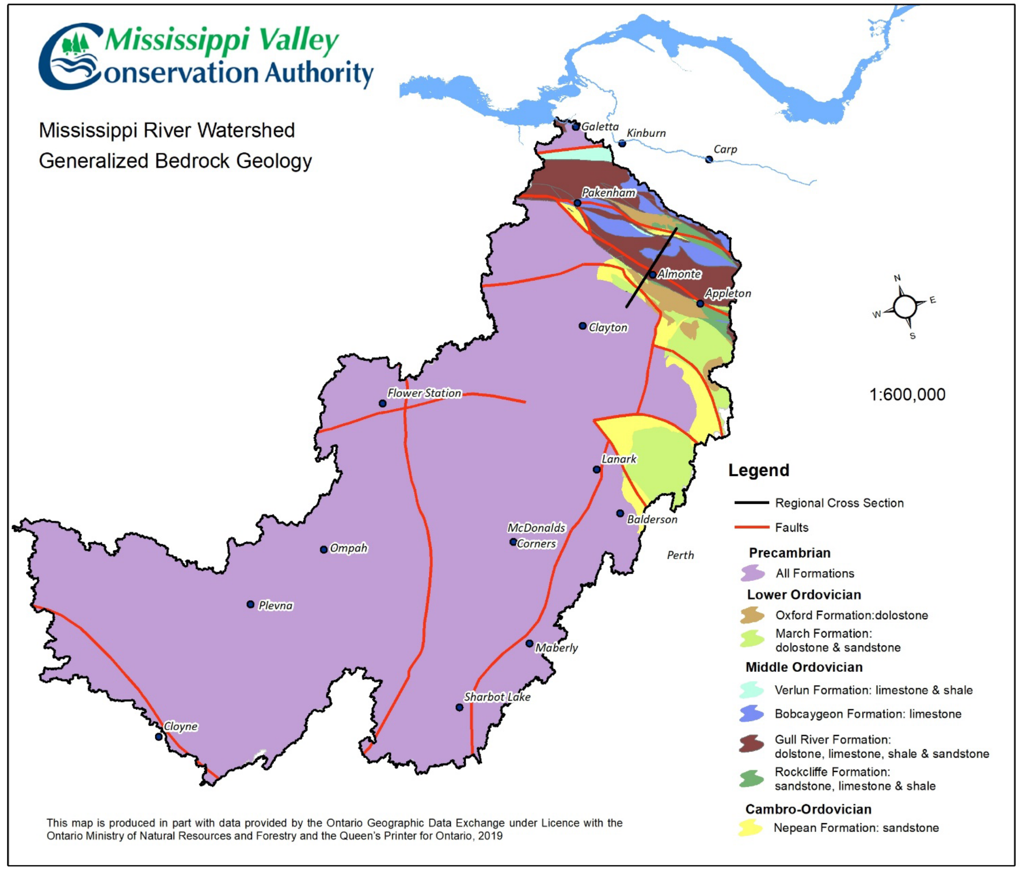


Figure 14: Generalized Bedrock Geology

Bedrock Faults: The Earth's crust continually shifts due to natural stresses imposed on it resulting in the extension and shortening of the Earth's tectonic plates (large sections of the Earth's crust). Although Eastern Ontario is located in a stable continental region within the larger North American Plate, seismic activity (faulting) still occurs in regions of weakness in the earth's crust.

The Mississippi River watershed is situated in a historically active fault zone called the Western Quebec Seismic Zone (National Resources Canada (NRC), 2006) which includes the Ottawa Valley rift zone. Its tectonic history has resulted in many steeply dipping normal faults and fault zones that are evident in both the Precambrian and Paleozoic bedrock formations (Williams, 1991). A simplified version of this fault network is shown in Figure 3 which shows only the major faults characterized by a vertical displacement greater than 200 metres.

Overburden Type and Thickness

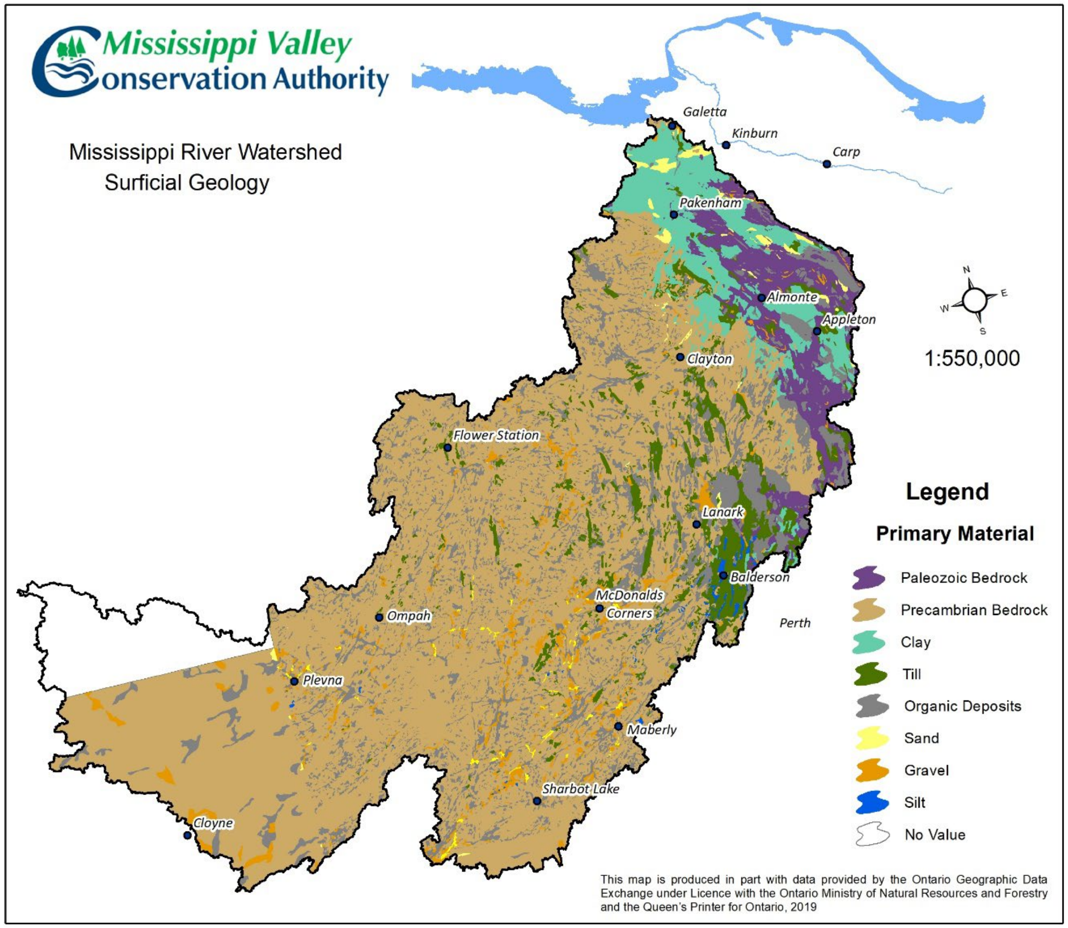


Figure 15: Surficial Geology

Surficial Deposits: Precambrian Bedrock outcrops across 64% of the watershed, dominating the western and southern areas, and in the north eastern part, across 5% of the watershed. This results in very sparse, disconnected overburden deposits, covering less than 30% of the watershed.

Organic Deposits: described as muck and other organic rich soils, generally found in poorly drained/ wetland areas. They cover 15% of the watershed with larger areas around Mississippi Lake, Carleton Place and Almonte. Numerous small pockets are scattered throughout the Precambrian bedrock areas where surface waters collect on the impermeable bedrock.

Clay Deposits: are primarily found in low lying areas the deposits range from non-existent in the west, to >30 m thickness, increasing in thickness towards the east.

Sand and Gravel Deposits: exist in isolated locations throughout the watershed. One notable feature is an esker found south of McDonalds Corners. Sand deposits exist throughout the MRW as both continuous sand layers and discontinuous pockets.

Till and Silt Deposits: Tills exist throughout the watershed as ground moraines, end moraines and drumlins and are characterized by stony and sandy with silt and clay. Thickness ranges from non-existent to ~ 10 m. A concentration of these deposits is found in the area between Lanark Village and Balderson.

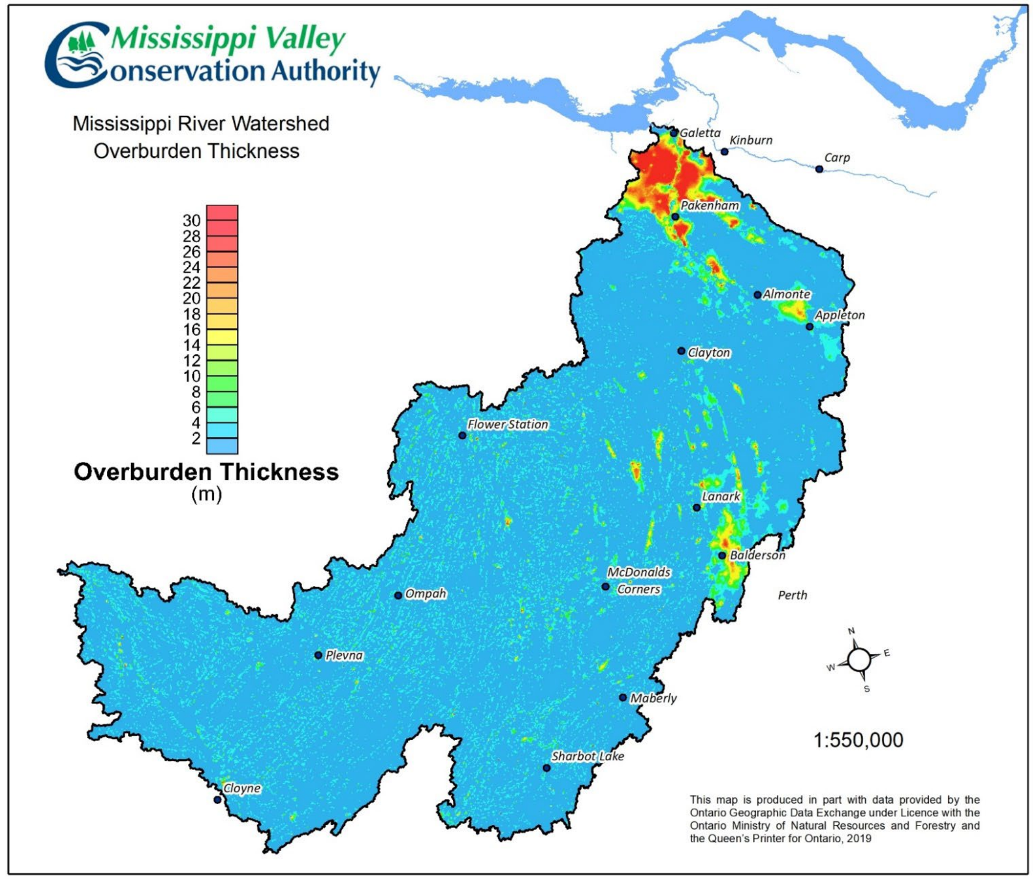


Figure 16: Interpreted Overburden Thickness

Soils

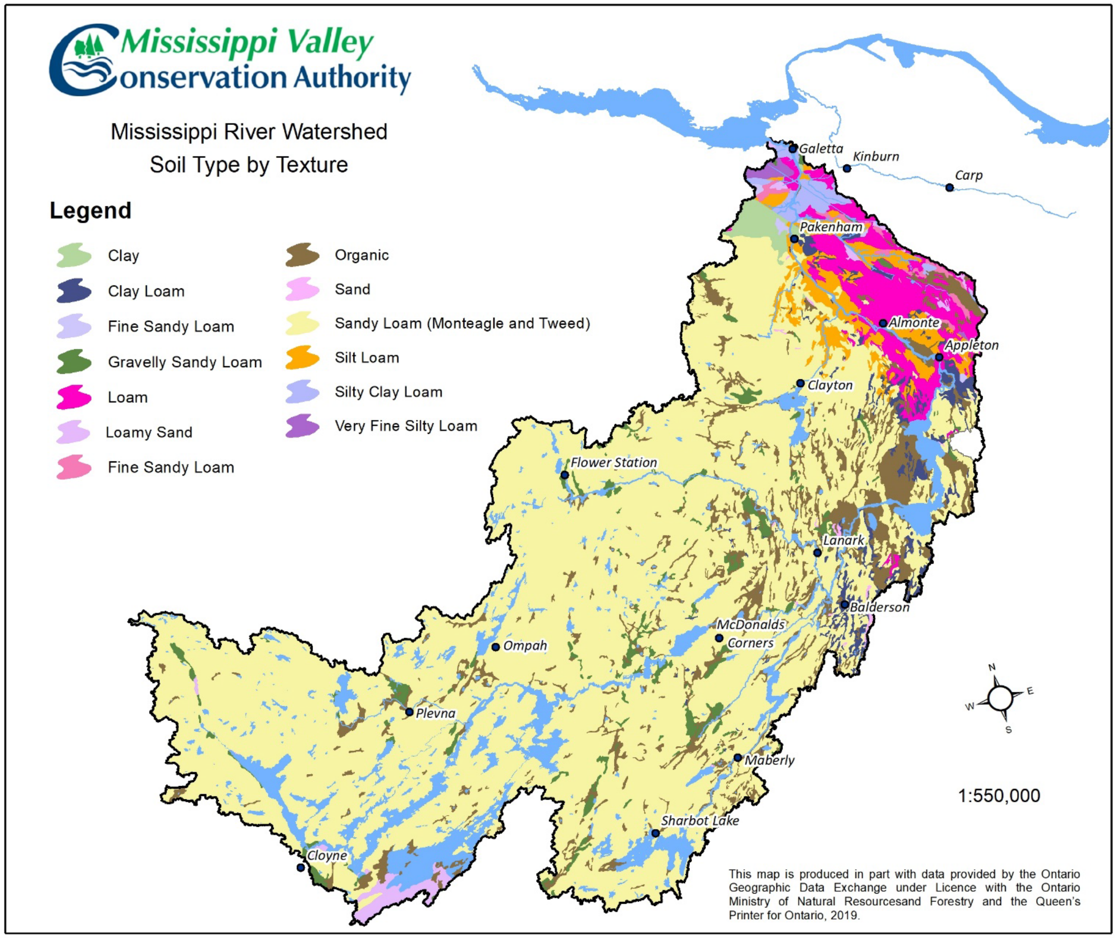


Figure 17: Soil Types

Communal Wells

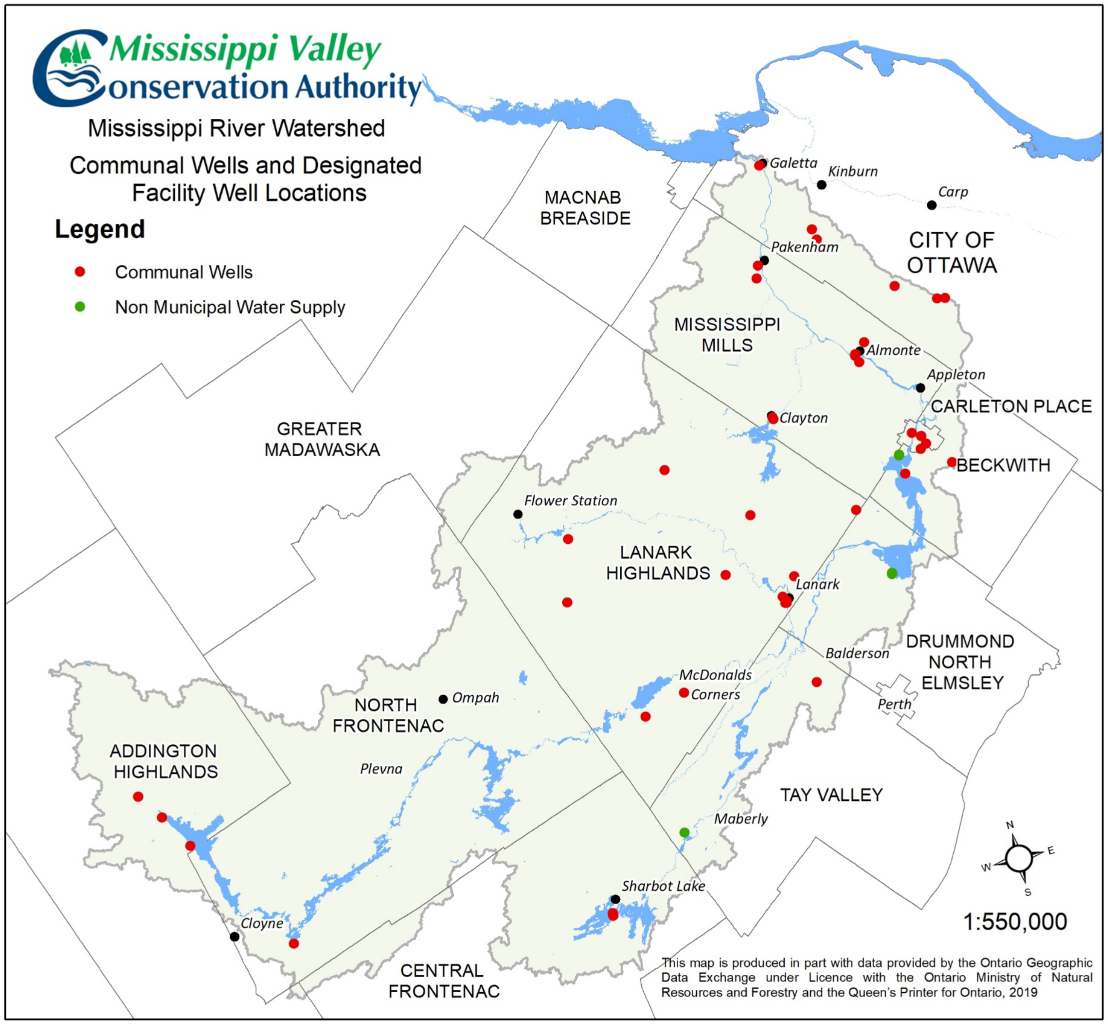


Figure 18: Communal Wells

Aquifer Vulnerability

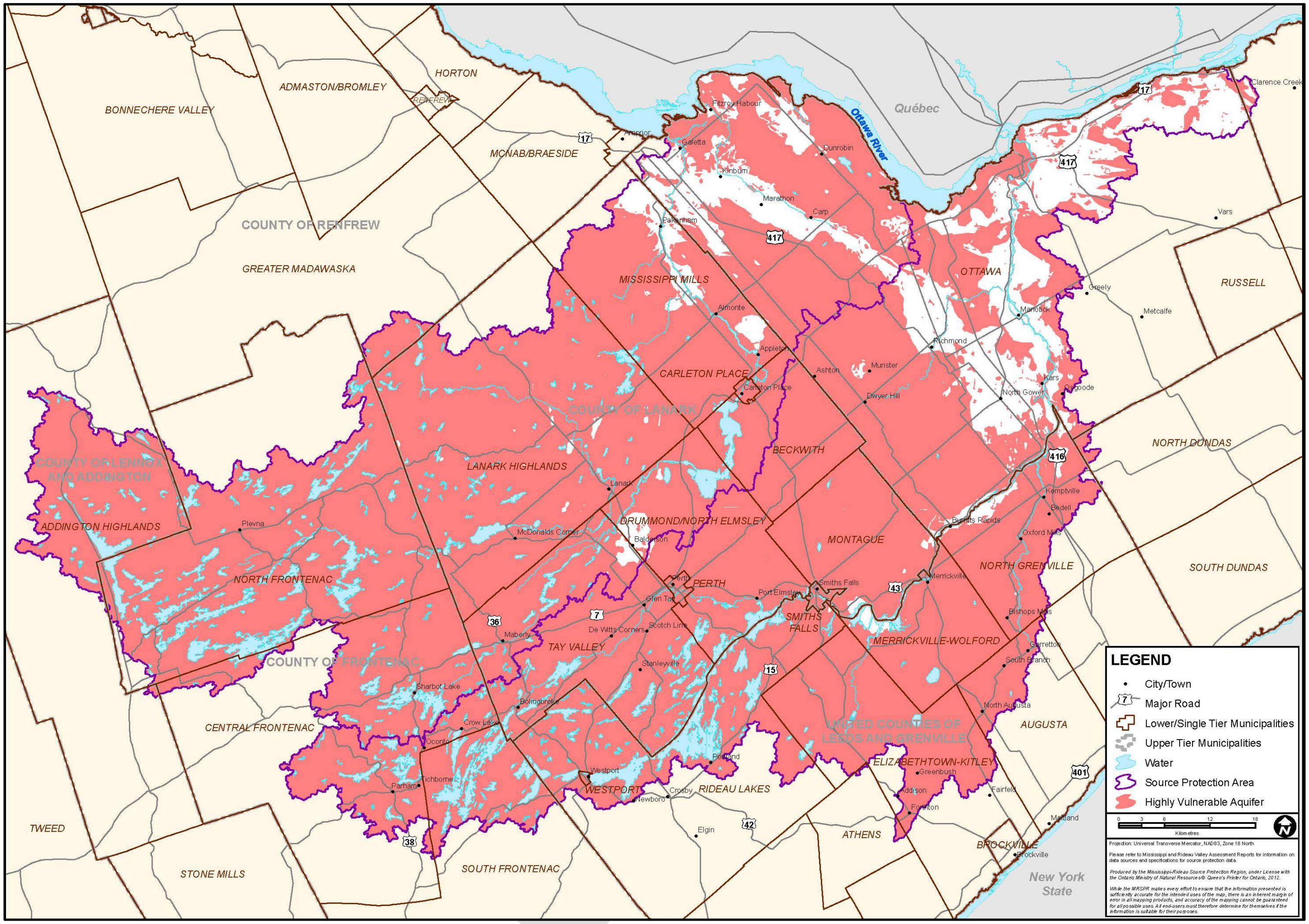


Figure 19: Highly Vulnerable Aquifer

The criteria used for delineating the highly vulnerable aquifer areas are described in the Mississippi Valley Source Protection Area Assessment Report (2011)

Mapping Source: Mississippi Rideau Source Protection Plan (2014, revision 1.2 May 2020)

Groundwater Monitoring

Regional background ground water level and water quality monitoring is carried out under the Ministry of Environment, Parks and Conservation’s (MECP’s) Provincial Groundwater Monitoring Network (PGMN) program. The PGMN consists of 8 observation wells, 6 in the MRW and 2 outside. One well is completed into a sand/gravel aquifer overlying Precambrian bedrock (W260-1 Buckshot Lake), two into the Precambrian aquifer (W331-1 Sharbot Lake; W399-1 Lanark), two wells near Carleton Place are completed into the Sandstone aquifer (318-1 and 319-1) and one well near Kinburn (402-1) is completed into the Dolostone aquifer.

MVCA has partnered with MECP to maintain and monitor these wells. Water level monitoring has been carried out since the early 2000s. Sampling and analysis for water quality also takes place annually in many of the wells and less frequently in others.

Groundwater Contamination in the MRW

Table 1: Known Historic Contamination Sources

Site Name and Location	Contaminant and Extent of Spill	Status
Beckwith Township, Black's Corners Area/Lanark County	TCE-plume approximately 9.5 km by 3 km, from former landfill	Interim water supplies and/or treatment in place at 250 homes. Ongoing monitoring at over 230 homes. Class EA study underway to assess water supply solutions.
Carleton Place Industrial Park/Lanark County - Industrial Avenue, north shore of Mississippi River	TCE - approximately 1.5 km by 0.5 km	MOE has retained consultant to determine source of TCE contamination.
Carleton Place – 115 Emily Street (Old DRS Building)*		Not confirmed but likely to contain contamination
Carleton Place – Findlay Foundry*		Not confirmed but likely to contain contamination
Carleton Place - McCarthur Island*		confirmed
Carleton Place - Edward Dive (from Macs Milk)*		confirmed
Ottawa- Former Kingdon Mine/Ottawa - West Carleton on island in Galetta	Lead from mine tailings - extent unknown	Site owners developing Remedial Action Plan for on-site contaminants
Mississippi Mills - Lot 16, Concession 10 Pakenham Township, Lanark County- Closed Waste Disposal Site	Leachate plume has been delineated	Leachate plume has been delineated and the site is subject to ongoing monitoring in accordance with MECP regulations
Mississippi Mills - Lot 6, Concession 4 Ramsay Township, Lanark County-Closed Waste Disposal Site	Leachate - extent of groundwater impact evaluated	Report submitted, periodic monitoring.

Mississippi Mills - Ramsay Road Garage, 3131 Old Perth Road/Mississippi Mills	Inorganic contamination from historic salt storage - late '80s to present.	Issues unresolved according to municipality.
Mississippi Mills – Federal Fire Research Centre on Concession 8	Perfluoroalkylated substance (PFAS), were discovered in the groundwater from drill sites close to the facility's border.	Site owned by the National Research Council. in 2013 Residual sources of PFAS have been eliminated and an impermeable layer to limit further migration of PFAS has been installed. Impacted residences 5 homes are receiving bottled water and/or have accepted charcoal filtration systems
Tay Valley Twp - Five (5) Landfill Sites (locations not described) Township of Bathurst Burgess	Leachate	Issues unresolved according to municipality.
North Frontenac Twp - Municipal Building, 6648 Road 506/Township of North Frontenac	Inorganic contamination from salt storage	Unknown

Source: Golder and Assoc. 2003, *Source: Town of Carleton Place, Planner

Table 2: Atmospheric Environment Service (AES) Stations

Station name	Station ID	Elevation	Period of Record	Status	Total Years
Appleton	6100285	133	1992-present	Active	24
Drummond Centre	6102J13	145	1984-present	Active	32
Ompah-Seitz	6105762	276	1994-present	Active	22
Ompah	6105760	251	1994-2010	Recent	16
Dalhousie L - High Falls	6101955	160	1923-1983	Historic	61
Carleton Place	6101250	145	1984-1999	Historic	16
Carleton Place	6101249	137	1948-1976	Historic	29
Almonte	6100226	125	1912-1980	Historic	69

*the Ompah station was operated as a volunteer AES station from Aug 1994 to Jan 2010. The station is no longer an AES station but the volunteer continues to collect weather data which is shared with MVCA

Table 3: Other Precipitation and Temperature Monitoring Sites in the MRW

Name	Catchment	Station	Gauge Type	Data Collected		
				Precipitation	Water Temp.	Air Temp.
Myers Cave/Marble Lake	Mississippi River	WSC-02KF016	SF	✓		
Buckshot Ck./Plevna	Buckshot Creek	WSC-02KF017	SF	✓		
Fergusons Falls	Mississippi River	WSC-02KF011	SF	✓		
Appleton	Mississippi River	WSC-02KF006	SF	✓		
Gordon Rapids	Clyde River	WSC-02KF013	SF	✓		
Lanark @ Herrons Mills	Clyde River	WSC-02KF010	SF	✓	✓	
Mill of Kintail/Blakeney	Indian River	WSC-02KF012	SF	✓		
Bennett Lake outlet	Fall River	WSC-02KF018	WL & SF	✓		
Dalhousie Lake	Mississippi River	WSC-02KF019	WL & SF	✓		
Sharbot Lake	Fall River	WSC-02KF020	WL & SF	✓		
Mazinaw Lake	Mississippi River	MVCA	WL		✓	✓
Shabomeka Lake	Mississippi River	MVCA	WL	✓	✓	
Kashwakamak Lake	Mississippi River	MVCA	WL		✓	✓
Farm Lake	Mississippi River	MVCA	WL		✓	
Mississagagon Lake	Mississippi River	MVCA	WL		✓	
Big Gull Lake	Mississippi River	MVCA	WL		✓	
Crotch Lake	Mississippi River	OPG	WL	✓		
Mississippi Lake	Mississippi River	MVCA	WL			✓
Palmerston Lake	Clyde River	MVCA	WL	✓	✓	✓
Canonto Lake	Clyde River	MVCA	WL		✓	✓
Lanark Bridge	Clyde River	MVCA	WL		✓	

WSC: water Survey of Canada Station SF: Stream Flow WL: Water Level

*data is collected in a stilling well - may not be representative of the actual lake water temperature but can be used to monitor changes in temperature

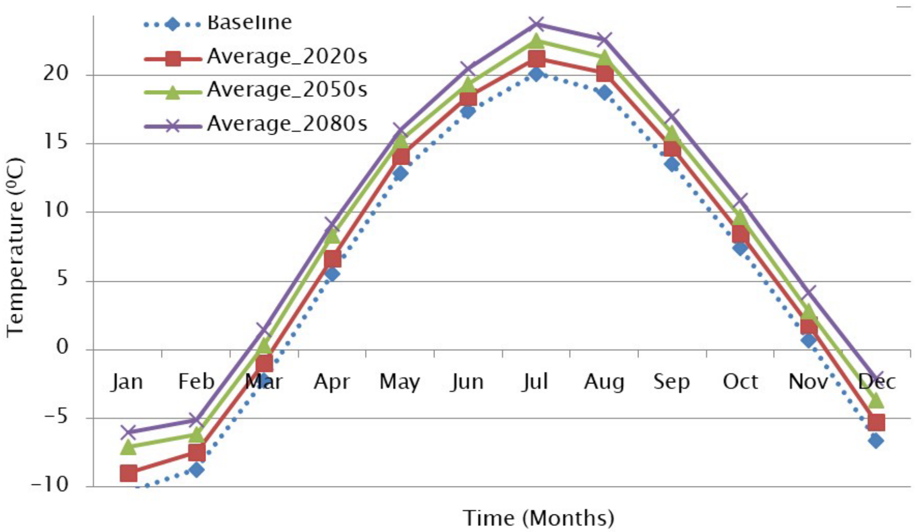
Table 4: Comparison of Monthly Average Daily Mean Temperature and Monthly Average Total Precipitation 1997 to 2016,

	Average Daily Mean Temp (°C)					Average Monthly Total Precip (mm)				
Month	**Appleton**	**Drummond Centre**	**Ompah***	**Ompah-Seitz**	**Variation**	**Appleton**	**Drummond Centre**	**Ompah***	**Ompah-Seitz**	**Variation**
January	-9.6	-9.3	-10.0	-9.6	0.7	57	67	75	75	18
February	-8.0	-7.5	-8.1	-7.7	0.6	44	55	53	60	16
March	-1.9	-1.4	-3.0	-1.9	1.6	56	64	75	73	19
April	6.0	6.3	4.9	5.7	1.4	66	69	69	68	3
May	13.5	13.6	11.5	13.1	2.1	57	72	76	80	23
June	18.2	18.3	17.2	17.7	1.1	96	104	105	110	14
July	20.6	20.5	18.8	20.2	1.8	74	86	79	87	13
August	19.7	19.6	18.1	19.4	1.6	85	75	80	91	11
September	15.6	15.5	14.0	15.3	1.6	91	96	95	100	9
October	8.7	8.5	7.1	8.0	1.6	72	80	78	86	14
November	2.1	2.3	1.4	1.9	0.9	67	71	91	88	24
December	-5.2	-4.8	-6.2	-5.5	1.4	65	77	86	84	21

Source: Environment Canada website (date accessed)

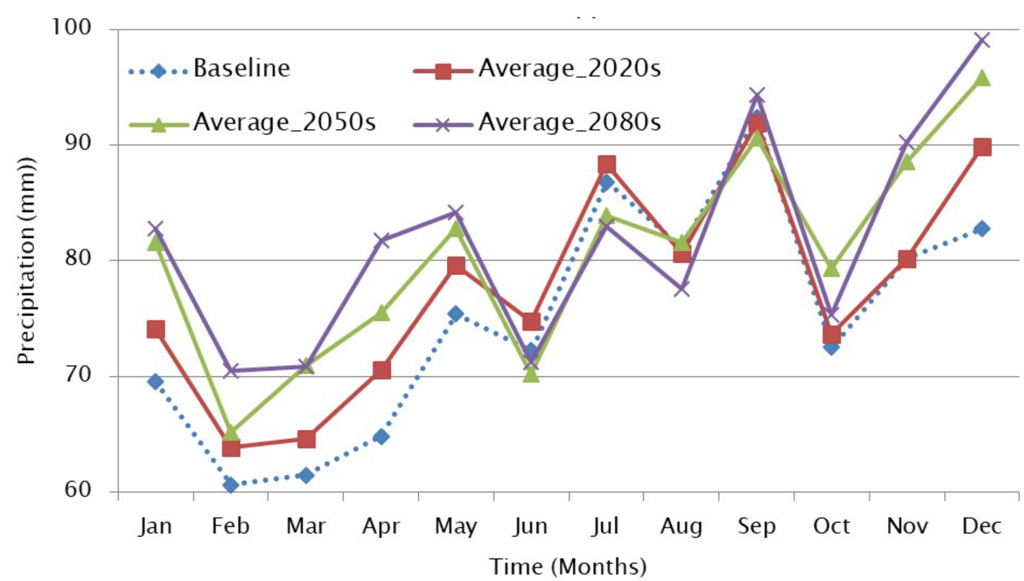
* 1997 to 2009 data from EC database and 2010 to 2016 data provided directly to MVCA by volunteer recorder for same site

Figure 21: Comparison of Mean Monthly Temperature, 2010 to 2100



(Source: Kunjikutty, 2015)

Figure 20: Comparison of Mean Monthly Precipitation, 2010 to 2100



Note 1: Climate Change in the Mississippi Watershed

Water Quantity

Shifting patterns in streamflow, spring freshet, precipitation, melting of ice, increasing temperature and evapotranspiration rate will affect surface and groundwater levels throughout the year. Lake levels expected to decline due to less ice cover, warmer temperatures, and variability in precipitation (amount, timing, forms, and frequency).

Flooding:

- Extreme storm/flood events will be more frequent and more difficult to predict.
- Extreme flood events could occur in any season, rather than the traditional spring flood.
- More frequent heavy rain events may increase erosion, sedimentation and localized flooding.
- Spring flood risk might be lower but the fall/winter flood risk will have implications for the reservoir drawdown regime.
- Flood-prone areas will expand to encompass a broader range of flood-prone areas.

Low Flow/Drought:

- Decreased streamflow in summer with prolonged low-flow periods.
- Midsummer low flow conditions will result from earlier spring freshet (already observed in the MRW 10 days earlier in 1974-02 period than from 1919-73)
- Increased frequency of extreme events. Summer drought-like conditions would become more common in the future (already observed).

Water Supply

- Sufficient flows/water might not be available to meet the needs of fisheries, cottagers, tourists, recreational activities, hydroelectric generation, communities, agriculture, and ecosystem.

Groundwater

- A loss of surface water will deplete the shallow groundwater and may negatively affect groundwater recharge to deeper aquifers.
- Fractured bedrock areas and the shallow and unconfined aquifers will be most affected.
- Potential water availability impact for residents/water users who rely on groundwater supply.

Water Quality:

Increase in predicted surface temperature and evaporation rates will increase the water temperature. The projected decrease in water levels, variability in precipitation, and warmer water temperature, shorter ice cover and longer open water periods will affect water quality.

- Increase algae blooms, including harmful green-blue algae and cyanobacteria.
- Impacts to lake stratification regimes resulting in impacts to oxygen levels/distribution.
- Conditions will favor the spread of certain aquatic species.
- Extreme rain events will result in more pollutants and nutrients flushed into surface waters.
- Waterborne pathogens thrive more readily in warmer water temperatures.
- Reduced river flows will reduce capacity for waste water assimilation.
- Lower streamflow and increasing depth to well water might impose hard water issues for public who depend on the well water.

Water Management:

Reservoir Capacity and Operation

- Pre-1960, MRW streamflow consistently remained above the minimum 5 m^3/s outflow, however post-1960, fell below eleven times and twice below 4 m^3/s (1999 and 2001).
- Existing water control/reservoir infrastructure may not have the capacity to satisfy the current water 5 m^3/s objectives. The projected shift in the timing and distribution of streamflow may be incompatible with current reservoir operation policies.
- Generally, recreational interests could be met on the upper reservoirs; however, the existing reservoir capacity might not be sufficient to meet downstream low flow augmentation objectives under summer extreme conditions.
- Additional reservoir volumes may be required to satisfy all objectives and various users' interests.
- Studies show there will be 0.2 to 12.9 days advancement in river/lake ice break-up (Magnuson et.al, 2000), an increased duration of the open water period (MNR, 2014) and a decrease in ice thickness.
- The MVCA management strategy mostly depends on snowmelt/spring freshet - watershed could see a great certainty in higher winter flows and earlier ice-breakups. The current reservoir fall drawdown strategy is expected to pose a flood and shoreline erosion risk as streamflow during this period are expected to increase by 74% on an average.
- The projected streamflow might cause near flood stage on flood susceptible areas of the watershed for much of the fall and winter periods. May need to assess whether to discontinue or reduce the fall drawdown, though restricting reservoir drawdown to reduce the fall/winter flood risk might subsequently put those flood-prone areas at risk from spring freshet.
- Though there is a higher uncertainty, higher water levels in these reservoirs in winter might pose flood vulnerability and risk of erosion on reservoir lakes. A flood-risk based reservoir management option should be considered in our watershed management plan.

Wetland/Ecosystem:

Increased air temperature and variability in the amount/timing of precipitation will have an impact on wetlands within the MRW:

- Most of the wetlands in the watershed may experience mid to high vulnerability due to shrinkage or drying (C.Chu et.al, 2014).
- Predicting a mid-high vulnerability impact on wetland-dependent species like American Coot. (C.Chu et.al, 2014).
- Runoff or inflow-fed ponds, wetlands and the ecosystem species associated with the wetland are at greater risk with the reduction in water depth.
- Low flows and change in water level will negatively influence the function of the wetland.
- Warmer water temperature also might change the ecosystem with shift to other species that are more suited to warmer conditions, putting pressure on the existing ecosystem.

Economy

Tourism and Recreation

- Warmer temperatures and longer ice free periods may increase the use of lakes and rivers for boating and fishing. Increased heat waves and intense rain events in the summer might influence negatively.
- Ice cover changes may impact ice related tourism; safety issues for ice fishing, snowmobiling, etc.
- Recreational pattern might change to favour spring and fall for water activities.

- MVCA will face challenges with maintaining recreational water levels.

Agriculture

- There would be an increase in the growing season for agriculture; however, water demand for irrigation will affect/increase conflict in meeting various water users' demands.
- Depletion in soil moisture content and the water deficit will increase significantly, placing stress on plants/agriculture and on the water supply.
- Drought-tolerant tree species might do better with the warming temperature year-round.

Fisheries

- Lower water levels during the spawning period will likely result in loss of traditional pike spawning habitat.
- Fluctuations in water levels, might be extreme for some aquatic and riparian species (fish, amphibians, etc.).
- Average recruitment of warm winter species such as 'bass' might increase 15 to 20% in the future, however, the cold water fish like 'Lake Trout' recruitment will decrease by approximately the same amount by 2100. (Casselman, 2008)

Table 5: Mississippi Watershed Lakes

Name	Subwatershed	Municipality	Surface Area (km^2)	Perimeter (km)	Max Depth (m)	Max Length (m)	Waterfront Properties*	Thermal Classs.
Mississippi Lake*	Mississippi Lake	Miss. Mills/ Beckwith/ Drummond North Elmsley	24.5	67.6	9.2	13124.2	1044	warm
Big Gull Lake	Upper Mississippi	North Frontenac/ Central Frontenac	24.2	168.9	26.0	17400.0	475	warm
Mazinaw Lake	Mazinaw	North Frontenac/ Addington Highlands	16.2	54.7	144.8	13997.8	392	cold
Sharbot Lake	Fall River	Central Frontenac	15.0	92.3	31.1	9450.4	578	warm (east) cold (west)
Crotch Lake	Upper Mississippi	North Frontenac	14.8	98.7	24.2	10088.8	34	warm
Kashwakamak lake	Upper Mississippi	North Frontenac	11.5	98.2	22.0	14938.3	616	warm
Dalhousie Lake	Mississippi Lake	L. Highlands	6.2	15.5	13.4	5042.5	229	warm
Palmerston Lake	Clyde	North Frontenac	5.4	28.3	56.4	6444.9	228	cold
Mississagagon Lake	Buckshot	North Frontenac	5.3	39.6	24.0	8004.0	145	warm
Bennett Lake	Fall River	Tay Valley	4.6	32.1	12.2	9934.9	216	warm
Buckshot Lake	Buckshot	North Frontenac/ Addington Highlands	4.5	26.2	33.0	4735.0	174	cold
Clayton Lake	Indian	L. Highlands/ Miss. Mills	4.3	39.3	10.7	4257.9	150	warm
White Lake	Fall River	Central Frontenac	3.1	20.1	29.6	3251.2	43	warm
Taylor Lake	Indian	L. Highlands	2.8	19.0	3.0	3460.8	37	warm
Shabomeka Lake	Mazinaw	North Frontenac	2.5	15.1	32.0	3766.6	107	cold
Silver Lake	Fall River	Tay Valley/ Cl Frontenac	2.5	11.1	24.4	4121.7	87	cold
Canonto Lake**	Clyde	North Frontenac	2.3	19.7	21.4	4858.2	89	warm
Malcolm Lake	Upper Mississippi	North Frontenac	2.1	14.6	4.6	3075.5	110	warm
Pine Lake	Upper Mississippi	North Frontenac	1.9	12.3	17.7	2628.4	63	warm
Shawenagog Lake	Buckshot	North Frontenac	1.8	18.1	28.0	3503.3	91	warm
Marble Lake	Mazinaw	North Frontenac	1.8	10.8	18.3	2882.5	87	warm
Sand Lake	Buckshot	North Frontenac	1.8	10.9	21.3	2893.8	69	warm

Patterson Lake	Mississippi Lake	L. Highlands	1.6	11.7	15.8	3660.7	113	warm
Grindstone Lake	Buckshot	North Frontenac	1.6	15.5	19.0	12665.3	64	warm
Mosque Lake	Upper Mississippi	North Frontenac	1.5	14.3	34.1	2624.9	51	cold
Clyde Lake	Clyde	L. Highlands/ Greater Madawaska	1.1	10.7	12.2	3660.7	37	warm
Flower Round Lake	Clyde	L. Highlands	1.0	6.1	12.8	1830.7	50	warm
Ardoch Lake	Upper Mississippi	North Frontenac	0.9	5.8	17.4	1894.4	29	warm
Kishkebus Lake	Upper Mississippi	North Frontenac	0.9	5.3	32.9	1909.5	2	
Robertson Lake	Clyde	L. Highlands	0.7	9.5	30.5	2137.0	91	warm
Kerr Lake	Clyde	L. Highlands	0.7	6.2	32.9	2007.2	25	warm
Joes Lake	Clyde	L. Highlands	0.6	5.5	4.3	1476.8	24	warm
Sunday Lake	Clyde	North Frontenac	0.5	7.9	15.8	2002.8	50	warm
Black Lake	Fall River	Central Frontenac	0.4	3.7	19.2	1252.0	19	warm
Clear Lake	Fall River	Tay Valley/ Central Frontenac	0.4	3.8	4.5	1520.4	35	warm
McCausland Lake	Mazinaw	North Frontenac	0.4	3.8	23.0	988.2	7	cold
Horne Lake	Clyde	L. Highlands	0.3	4.1	5.0	1219.9	23	warm
Blue Lake	Buckshot	North Frontenac	0.3	2.8	30.0	1035.7	5	cold
Upper Park Lake	Clyde	L. Highlands	0.3	6.1	13.7	1157.6	8	warm
Mackavoy Lake	Mazinaw	Addington Highlands	0.3	3.3	19.8	1300.9	14	warm
Fawn Lake	Upper Mississippi	North Frontenac	0.2	4.5	9.0	1907.5	0	warm
Widow Lake	Clyde	L. Highlands	0.2	3.7	6.1	3494.7	47	warm
Paddy Lake	Clyde	L. Highlands	0.1	2.4	7.9	820.5	1	warm

* within 35 metres of shore (2012)

Stream Order and Headwater Classification

In mapping representations, because of the high density of watercourses, most watershed and subwatershed scale maps will only show the larger watercourses. The Strahler stream order classification provides a way to separate out those larger watercourses for mapping purposes. It provides a measure of the size and strength of specific watercourses within the stream networks which can help in making decisions related to monitoring and water management. It also provides a method to feature and quantify the smaller watercourses as a way to look at headwater conditions within the watershed.

The Strahler system for stream order classification has been applied to provide a measure of the size distribution of the watercourses throughout the MRW. Watercourses are ranked by size based on their hierarchy within the stream network. Each stream or river segment is treated as a node in a tree, with the next segment **downstream** as its parent (Figure 1). When two **first**-order streams come together, they form a second-order stream. Two second order streams form a third order stream and so on. *(Source: Wikipedia)*

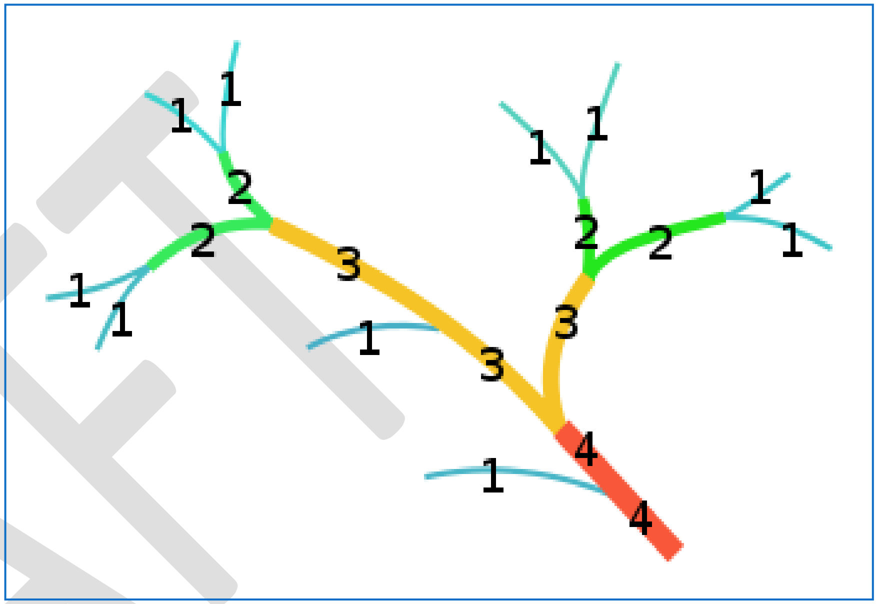


Figure 22: Strahler Stream Order Classification

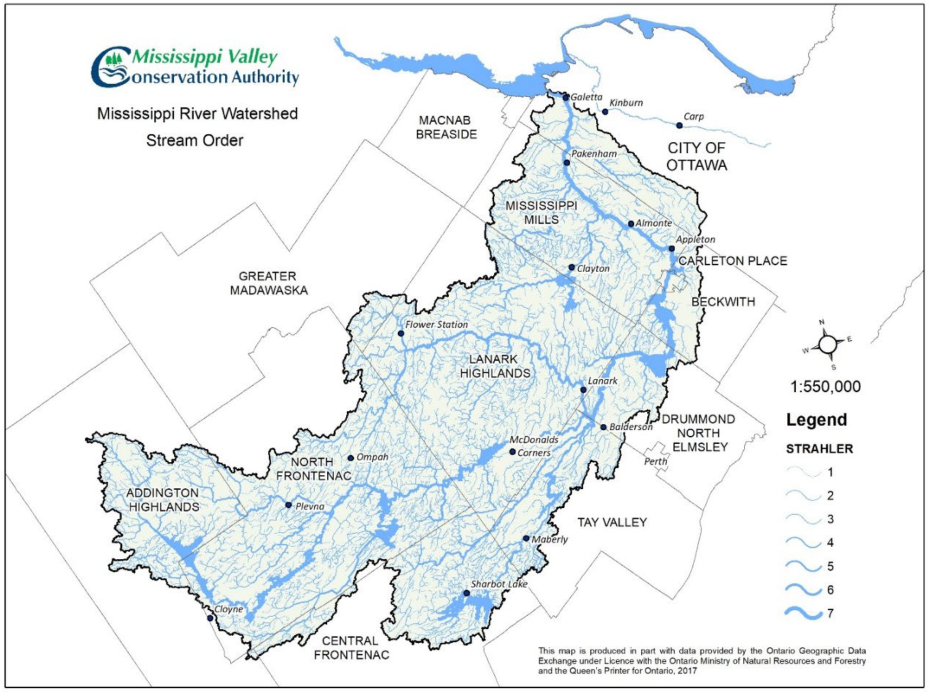


Figure 23: Mississippi Watershed Stream Order

These smaller **first-order** and **second-order** headwater streams make up 75% of the total stream length. As discussed in the next section, these headwater features play an important role in the overall health and functioning of the watershed. The larger stream order classifications including 5th, 6th and 7th order watercourses account for 6% of watercourse throughout the MRW and include the main trunk of the Mississippi River and the six other major tributaries.

Table 6: Strahler Stream Order Summary

Stream Order	Total Stream Length (km.)*	Percent
1	3247	50%
2	1607	25%
3	866	13%
4	407	6%
5	228	3%
6	99	2%
7	75	1%
Total	6529	**100%**

*lake segments have been extracted

Headwaters

It has been determined that the spatial extent of headwater drainage features typically accounts for the majority of the total catchment area (70% to 80%) within a watershed (Gomi, *et al.*, 2002 as cited in TRCA, 2007) and that 90% of a river's flow may be derived from catchment headwaters (Kirby 1978 as cited in TRCA, 2007). Because of this, headwater systems are thought to be important sources of sediment, water, nutrients, and organic matter for downstream reaches. However, due to their small size and because these functions are poorly understood and typically underestimated, headwater drainage features can be vulnerable to impacts resulting from agricultural and urban land uses, such as tile drainage, channel lowering, relocation, and enclosure (i.e. piping). (TRCA March 2007)

As indicated, in the Mississippi River Watershed the smaller **first-order** and **second-order**, headwater streams make up almost 75% of the total stream length. Headwaters are represented by the lowest ordered streams, which include; zero-, first- and second-order streams (Meyer *et al.* 2003, and

Richards 2004 as cited in TRCA, 2007). A *zero-order stream* refers specifically to small, non-permanently flowing intermittent, or ephemeral swales that lack distinct stream banks but still act as conduits of water, sediment, nutrients, and other materials during snowmelt and rainfall (Benda *et al.* 2005, Gomi *et al* 2002, Meyer *et al.* 2003, Richards 2004 as cited in TRCA, 2007). Zero order streams are not captured in the Figure 2 mapping and therefore not included as part of the 75% estimate. It is not known how much the unmapped zero order streams may contribute to the overall stream network throughout the MRW, but it could represent a significant additional contribution to overall stream length and stream flow during snowmelt and rainfall events.

In 2015 MVCA began surveying headwater drainage features (HDF) in the City of Ottawa, primarily in the Carp River watershed. The methodology follows a protocol developed by the Rideau Valley and the Toronto Region Conservation Authorities (TRCA) and adopted as a module into the Ontario Stream Assessment Protocol (OSAP) manual. The initial goal was to gain baseline data on the headwater drainage features (HDFs) within the urban fringe development zone of the City. MVCA adjusted this to perform assessments on HDF's throughout the West Carleton area as well. The City of Ottawa is now requesting proponents of large scale development applications to include an HDF analysis as part of their planning application submissions.

Currently, there is no monitoring or assessment of headwater features outside of the city and/or in areas extending into the MRW.

Seasonal Variations in Stream Flow and Runoff

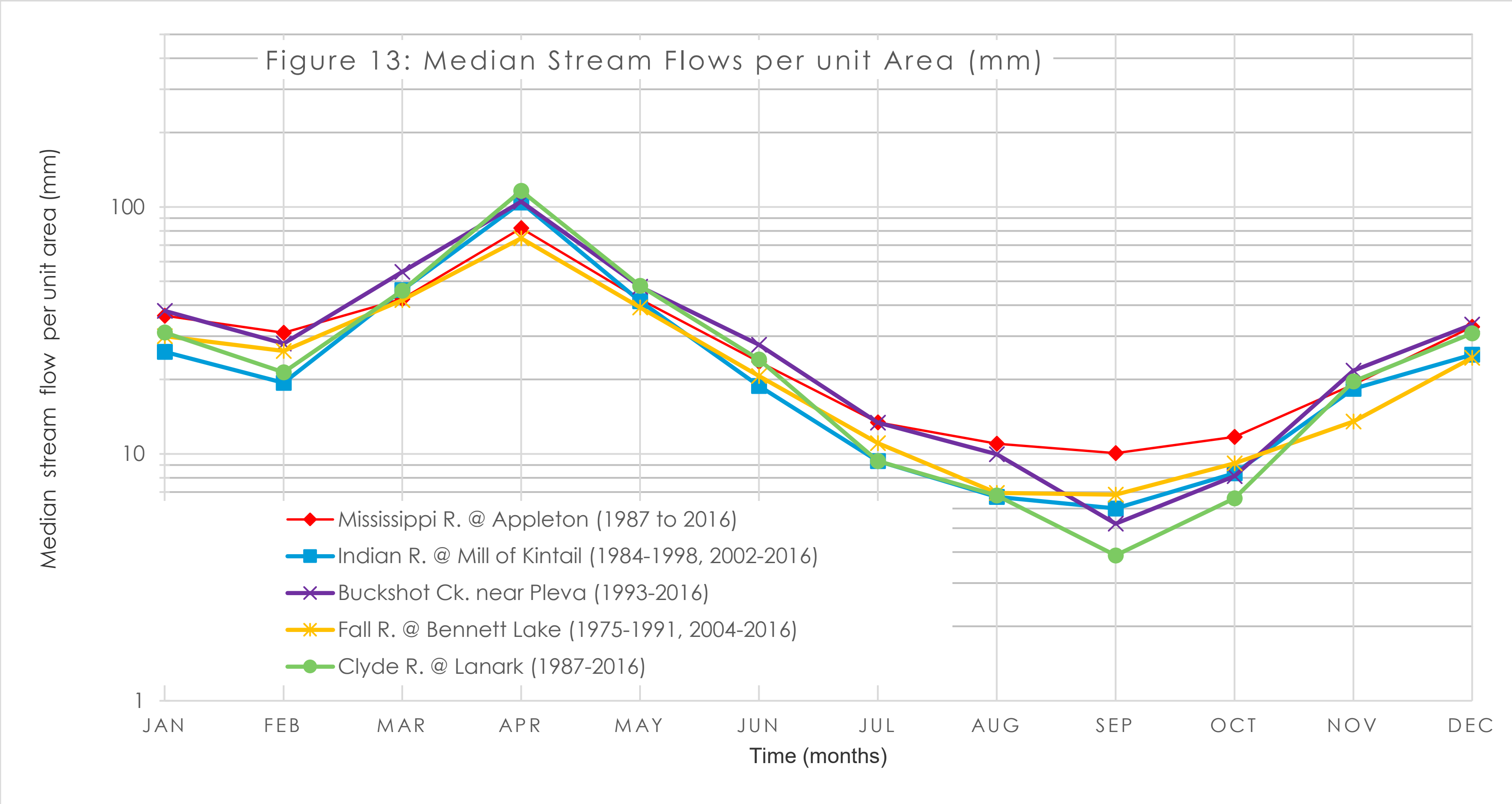


Figure 24: Median Stream Flow per Unit Area

MRW Subwatersheds

Table 7: Mississippi River Subwatershed Characteristics

Subwatershed (area type)	Description	Water Control Structures	Other Key Features
Upper Mississippi (main branch)	Area: 1028 km^2 Main branch from headwaters upstream of Mazinaw Lake to outlet of Crotch Lake Characterized by Precambrian (Shield) bedrock with thin soils. Key considerations in water level operations: • timing on local fish populations (especially on lake trout, walleye and bass), • impact of fluctuations on shoreline vegetation and wildlife, erosion, ice damage • unsafe winter conditions because of variable ice conditions, • access to property and boat launch sites.	Shabomeka Lake* Mazinaw Lake* Mississagagon Lake* Kashwakamak Lake* Big Gull Lake* Crotch Lake* Farm Lake Dam Malcolm Lake Dam Mosque Lake Dam Pine Lake Dam	Includes most of the lakes in the watershed and virtually all available reservoir storage for stream flow regulation. *Six reservoir lakes Wild rice at Ardoch Village - great significance to the Algonquin First Nations who harvest the rice each fall. Lake trout spawning in Mazinaw and Shabomeka (the only lake regulated for fall drawdown prior to lake trout spawning in September.) Walleye spawning - many sites along the reach have had spawning shoal rehabilitation. Whitefish Rapids downstream of Kashwakamak is a key walleye spawning site.
Central Mississippi (main branch)	Area: 395 km^2 Outlet of Crotch Lake to confluence of Clyde R. A transition zone with a combination of lakes and rivers.	High Falls Dam	Dalhousie Lake - Low lands around and downstream of the lake contribute to flooding issues. A natural rock outcrop at the head of Sheridan's Rapids controls levels on Dalhousie Lake, especially during the summer months.
Clyde River (tributary subcatchment)	Area: 664 km^2 Characterized by Precambrian (Shield) bedrock with thin soils.	Summit Lake Palmertson Lake Canonto Lake	Numerous lakes (controlled – no storage available)

	Full Clyde River tributary to confluence with Mississippi R. Largest tributary of the Mississippi with many tributaries of its own	Widow Lake Lanark Village	
Subwatershed (area type)	Description	Water Control Structures	Other Key Features
Fall River (tributary subcatchment)	Area: 486 km^2 Full Fall River tributary to its confluence with the Mississippi R. Nearing the transition to the off-shield arear it is characterized by rolling hills, glacial deposits, and some pasture farms.	Bennet Lake Dam	Bolton Creek (158 km^2) Sharbot Lake Silver Lake Bennett Lake
Mississippi Lake (main branch)	Area: 432 km^2 Main branch from confluence of Clyde R to Carleton Place Dam. Lies on the dividing boundary of two distinct physiographic regions: the Precambrian (Canadian) Shield on the west; and the St Lawrence lowlands on the east.	Carleton Place Dam	Mississippi Lake – the second largest lake in the watershed and the last lake on the system. Developed low lands around the lake contribute to flooding issues – represents the largest flood damage centre in the watershed
Lower Mississippi (main branch)	Area: 432 km^2 Main branch from Carleton Place dam to outlet at Ottawa R. Lies on the dividing boundary of two distinct physiographic regions: the Precambrian (Canadian) Shield on the west; and the St Lawrence lowlands on the east.	Appleton Dam Enerdu G.S.Dam (Almonte) Mississippi River Power G.S. Dam (Almonte) Galetta G.S Dam	Cody Creek tributary (103 km^2) on the east side of the river - flows through a highly erosive clay plain area dominated by agriculture. Indian River (212 km^2), Clayton and Taylor Lakes, on the west side. Indian Creek (162 km^2) on the west side.

Table 8: History of the Hydraulic Structures on the Mississippi River and Tributaries

1909	The Mississippi River Improvement Co. Limited (MRIC) was formed to hold title to the dams at Crotch, Big Gull and Kashwakamak Lakes and operate them to maintain storage capacity.
1909-19	MRIC assumed operation/maintenances of Mazinaw, Shabomeka and Mississagagon Lake dams.
1919	Carleton Place Dam was purchased by the Hydro Electric Power Commission of Ontario (now Ontario Hydro). The Commission also purchased shares in MRIC.
Late1950's to 1970's	The Department of Lands and Forests (now the MNRF) constructed six dams on tributaries of the main Mississippi River, primarily to control water for recreational or fisheries purposes.
1968	Mississippi Valley Conservation Authority was formed
By 1973	Ontario Hydro and the Carleton Place Hydro Commission rebuilt the Carleton Place structure and transferred ownership to MVCA.
1974 to 1978	MVCA with MNRF funding, purchased the Bennett Lake dam (Fall River), Widow and Lanark dams (Clyde River), and Farm Lake dam (Mississippi River).
1981	MVCA completed an inventory of water control structures within the Mississippi River watershed.* Four organizations controlled the major dams on the Mississippi River: MRIC, MVCA, MNRF, and Ontario Hydro (now Ontario Power Generation Inc. (OPG).
1983	Ontario Hydro sold the Galetta Generating Station to Mr. Laurier Dupuis and Mr. Mike Dupuis. They refurbished the structure and began producing power again at the site in 1984.
1983	MVCA "Interim Watershed Plan" was released. It assessed resource management issues within the watershed and proposed programs to address the operation and maintenance of the dams. A key objective was to improve coordination amongst the three primary dam operators.
Mid-1980s	MNRF contracted MVCA to operate all MNRF owned dams. Ontario Hydro contracted MVCA to provide field operations and monitor water levels at the MRIC's Crotch Lake Dam and the Ontario Hydro's High Falls Generating Station. MVCA completed structural surveys on all lakes controlled by dams with a detailed questionnaire regarding water level management.
1989	MRIC completed substantial costly rehabilitation of the Shabomeka Lake Dam.
1989 to 1991	MRIC negotiated agreements to shift responsibilities to MVCA (for Shabomeka, Mazinaw, Kashwakamak, Big Gull, and Mississagagon) and to Ontario Hydro (for Crotch Lake Dam). After these transfers, MRIC was formally dissolved.
1991	MVCA installed automated lake level gauges on Shabomeka, Mazinaw, Kashwakamak, Big Gull and Crotch Lakes to collect detailed water level information
1992	MVCA initiated a dam rehabilitation program with the reconstruction of Mazinaw Lake Dam
1995	The Upper Mississippi Watershed Alliance was created, to address water level concerns across the watershed, specifically from Crotch Lake to Dalhousie Lake. It included residents from Shabomeka, Mazinaw, Kashwakamak, Big Gull, Crotch and Dalhousie Lakes and from the Snow Road and Ardoch communities. A working group of MVCA, MNR, Ontario Hydro and the Alliance was formed to discuss issues and identify opportunities to resolve them with meetings help form 1995 to 1997. It resulted in clarification of key issues and while there were no recommendations to revise current operating policies a variety of fishery related issues were resolved.
1993	The Appleton Generating Station was rebuilt by Merol Power. Merol Power was subsequently sold to Canadian Hydro Developers in spring of 1998.
1995	The Maple Leaf Mills Generating Station in Almonte was reconstructed by Canadian Hydroelectric Components.

* A total of 43 structures were identified, with approximately 20 either derelict or privately owned.

Water Control Structures

Table 9: Major Water Control Structures on The Mississippi River

Control Structure	Owner	Operator	Watercourse	Drainage Area (km^2)	Max. Depth (m)	Surface Area (ha)
Shabomeka	MVCA	MVCA	Semi Circle	41	32	268
Mazinaw	MVCA	MVCA	Mississippi R.	339	145	1630
Kashwakamak	MVCA	MVCA	Mississippi R.	417	22	1274
Mississagagon	MVCA	MVCA	Buckshot Ck.	22	24	545
Big Gull	MVCA	MVCA	Mississippi R.	135	26	2540
Crotch	OPG*	OPG, MVCA undertakes operations	Mississippi R.	1030	31	1953
High Falls G.S.	OPG*		Mississippi R.	1233	N/A.	264
Carleton Place	MVCA	MVCA	Mississippi R.	2876	N/A.	3030
Appleton G.S.	TransAlta*	run-of-the-river type structures (generate power based on available flow, no substantial reservoir to	Mississippi R.	2932	N/A.	N/A.
Enerdu G.S.	Enerdu PS		Mississippi R.	3012	N/A.	N/A
Almonte G.S.	Mississippi Power Corp		Mississippi R.	3012	N/A.	N/A
Galetta G.S.	TransAlta		Mississippi R.	3684	N/A.	N/A

Table 10: Other Major Water Control Structures

Control Structure	Owner	Operator	Watercourse
Farm Lake	MVCA	MVCA	Mississippi River
Malcolm Lake	MNR – Bancroft	MVCA	Unnamed creek / Malcolm lake
Pine Lake	MVCA	MVCA	Ward's Creek
Mosque Lake	MNR – Bancroft	MVCA	Mosque Creek
Summit Lake	MNR – Bancroft	MVCA	Dead Beaver Ck. / Summit Lake
Palmerston Lake	MNR – Bancroft	MVCA	Palmerston Lake
Canonto Lake	MNR – Bancroft	MVCA	Sunday Creek / Canonto Lake
Widow Lake	MVCA	MVCA	Clyde River
Lanark	MVCA	MVCA	Clyde River
Bennett Lake	MVCA	MVCA	Fall River
Clayton Lake	MNRF - Kemptville	MNRF	Indian River

Mississippi River Watershed Flow and Water Level Monitoring System

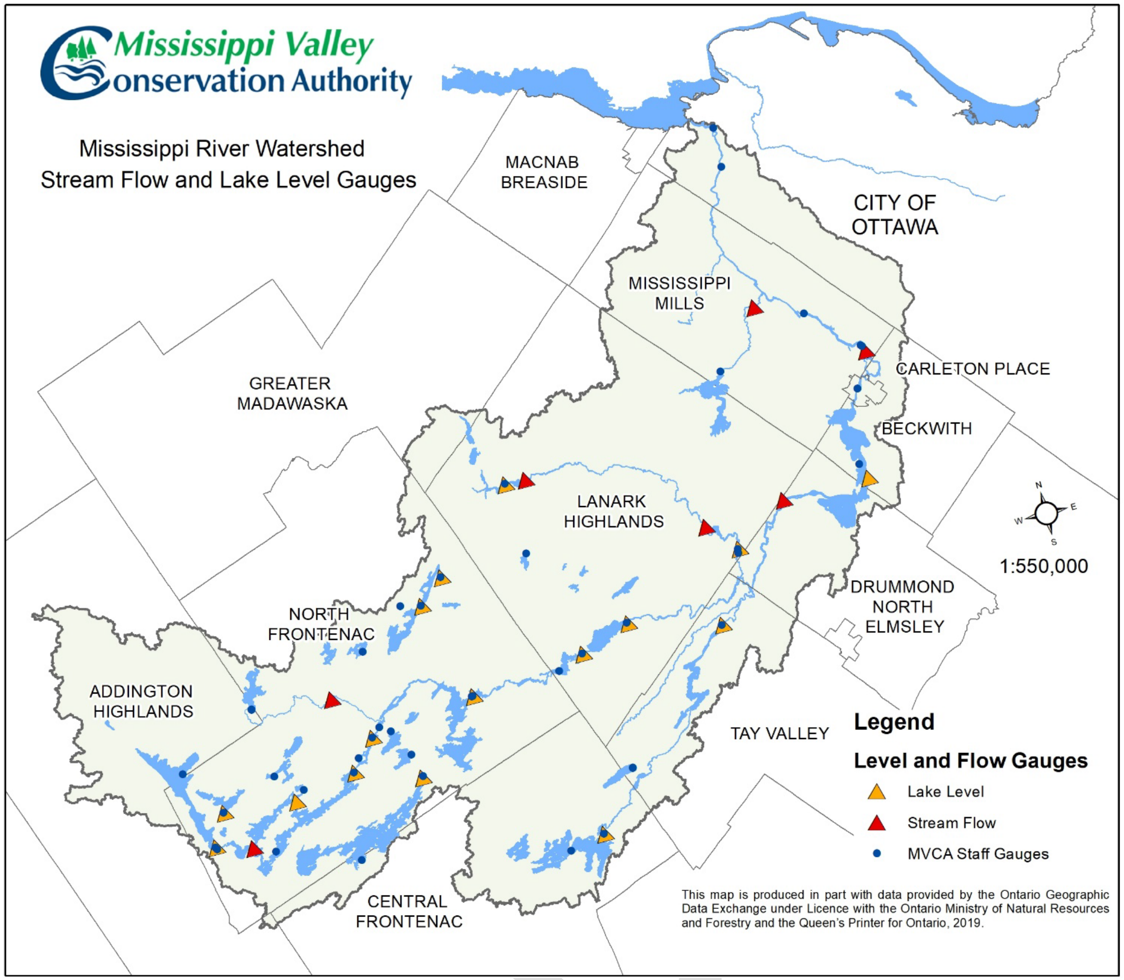


Figure 25: Water Level and Flow Gauges

Table 11: Automated Water Level and Stream Flow Gauges

Name	Waterbody	Subwatershed	Water Level or Stream Flow	Gauge Owner	Rain	Water Temp.	Air Temp.
Shabomeka	Shabomeka Lk.	Upper Mississippi	Water Level	MVCA	yes	yes	
Mazinaw	Mazinaw Lake	Upper Mississippi	Water Level	MVCA		yes	yes
Myers Cave	Mississippi River	Upper Mississippi	Stream Flow	WSC	yes		
Kashwakamak	Kashwakamak Lk	Upper Mississippi	Water Level	MVCA		yes	yes
Farm	Farm Lake	Upper Mississippi	Water Level	MVCA		yes	
Buckshot	Buckshot Creek	Clyde River	Stream Flow	WSC	yes		
Mississagagon	Mississagagon Lk	Upper Mississippi	Water Level	MVCA		yes	
Big Gull	Big Gull Lake	Upper Mississippi	Water Level	MVCA		yes	
Crotch	Crotch Lake	Upper Mississippi	Water Level	MVCA	yes		
Dalhousie Lk	Dalhousie Lake	Central Mississippi	Water Level /Stream Flow	WSC	yes		
Palmerston	Palmerston Lk.	Clyde River	Water Level	MVCA	yes		yes
Canonto	Canonto Lake	Clyde River	Water Level	MVCA			yes
Widow Lake	Widow Lake	Clyde River	Water Level	MVCA			yes
Gordon Rapids	Buckshot Creek	Clyde River	Stream Flow	WSC	yes		
Clyde R. near Lanark	Clyde River	Clyde River	Stream Flow	WSC	yes		
Lanark	Clyde River	Clyde River	Water Level	MVCA		yes	
Sharbot Lake	Fall River	Fall River	Water Level	WSC	yes		
Bennett Lake	Fall River	Fall River	Stream Flow	WSC	yes		
Ferguson Falls	Mississippi River	Mississippi Lake	Stream Flow	WSC	yes		
Mississippi	Mississippi Lake	Mississippi Lake	Water Level	MVCA			yes
C.P. Dam	Mississippi River	Mississippi Lake	Water Level	MVCA			
Appleton	Mississippi River	Lower Mississippi	Stream Flow	WSC	yes		
Mill of Kintail	Indian River	Lower Mississippi	Stream Flow	WSC	yes		

Table 12: Staff Gauges

Location	Related Dam	Subwatershed	Range
Shabomeka Lake	Shabomeka Lake	Upper Mississippi	269 m – 271.5 m
Mazinaw Lake	Mazinaw Lake	Upper Mississippi	266 m – 268 m
Lt. Marble Lake	Mazinaw Lake	Upper Mississippi	265 m – 266 m
Kashwakamak Lake	Kashwakamak Lake	Upper Mississippi	259 m – 261 m
Farm Lake	Farm Lake	Upper Mississippi	247 m – 248 m
Buckshot Lake		Clyde River	291 m – 292 m
Mississagagon Lake	Mississagagon Lake	Upper Mississippi	267 m – 268 m
Ardoch Bridge		Upper Mississippi	241 m – 242 m
Pine Lake	Pine Lake	Upper Mississippi	254 m – 255 m
Malcolm Lake	Malcolm Lake	Upper Mississippi	252 m – 253 m
Big Gull Lake	Big Gull Lake	Upper Mississippi	252 m – 253 m
Mosque Lake*	Mosque Lake	Upper Mississippi	320 m – 321 m
Crotch Lake*	Crotch Lake	Upper Mississippi	236 m - 240.5 m
Dalhousie Lake (outlet)		Central Mississippi	155 m – 158 m
Summit Lake*	Summit Lake	Clyde River	281 m – 282 m
Palmerston Lake	Palmerston Lake	Clyde River	271 m – 272 m
Canonto Lake	Canonto Lake	Clyde River	268 m – 269 m
Widow Lake	Widow Lake	Clyde River	183 m – 184 m
Lanark Bridge	Lanark	Clyde River	143 m – 144 m
Lanark Dam	Lanark	Clyde River	142 m – 144 m
Sharbot Lake		Fall River	191 m – 192 m
Silver Lake		Fall River	178 m – 179 m
Bennett Lake	Bennett Lake	Fall River	152 m – 153 m
Carleton Place	Carleton Place	Mississippi Lake	133 m – 134 m
Almonte Bridge	Enerdu	Mississippi Lake	117 m – 119 m
Clayton Lake*	Clayton	Lower Mississippi	161 m – 162 m
Galetta Dam*	Galetta	Lower Mississippi	
*not on the weekly rotation, read as needed by TranAlta			

Table 13: MVCA Snow Courses in the Mississippi and Carp Watersheds

Name	Catchment	**Years of Data (as of 2019)**
Mackavoy	Mississippi River	28
Bon Echo	Mississippi River	33
Ardoch	Mississippi River	32
Snow Road	Mississippi River	33
High Falls	Mississippi River	0
Innisville	Mississippi River	37
Blakeney	Mississippi River	8
Buckshot	Buckshot Creek	29
Canonto	Clyde River	28
Lavant Station	Clyde River	28
Gordon Rapids	Clyde River	29
Brightside 1/Brightside 2	Clyde River	34 / 8
Maberley	Fall River	39
Fallbrook	Fall River	28
Carp Landfill	Carp	0
Kinburn	Carp	24

Water Control Operations

Table 14: Water Control Structure Operational Considerations and Constraints

Subwatershed (area type)	General Operations	Properties and Access	Fisheries, Wildlife, Wild Rice	Low Flow Augmentation, Power Generation and Other Considerations
Shabomeka	• Spring: Operated early spring to maintain summer levels • Summer: Maintained at 270.90 to 271.10 metres, with virtually no outflow • Fall: Drawdown mid-Sept to min 269.50 by early Nov	• Overtopping of dam has occurred • Flooding of access road • Shoreline flooding • Ice damage	• Lake trout spawning in fall (timing of drawdown could impact spawn survival) • No other known fisheries concerns • Loon nesting in spring require stable levels	• Limited storage volume • Maintain levels below 271.10 to limit erosion • Drawdown used to assist in filling Crotch Lake
Mazinaw	• Spring: Not operated in until levels stabilized from runoff • Logs replaces to bring levels up while allowing adequate flow for Walleye spawning • Summer: Maintained at 267.90 to 267.60 m. with minimal outflow • Fall: Drawdown begins 2nd wk of Nov. (after deer season) to min. level of 266.70 by mid-Jan	• Overtopping of emergency bypass has occurred • Flooding of low properties and docks • Downstream flooding on Little Marble and Marble Lakes • Stable levels at 267.80 (+/- 0.10) m required for access to pictographs, beach at Bon Echo	• Lake trout spawning in fall (timing of drawdown could impact spawn survival) • No other known fisheries concerns • Loon nesting in spring require stable levels • Burrowing reptiles, muskrats, beaver, etc. at risk in fall/winter due to late draw down	• Water access properties can lose access during fall draw down – levels enabling access must be maintained until after hunting season • During drought minimal flow maintained using all of operating range if required • Drawdown used to assist in filling Crotch Lake

Kashwakamak	• Spring: Operated slowly as spring runoff begins to minimize ice movement, but to reach target summer levels prior to walleye spawn (Whitefish Rapids) • Summer: Maintained at 261.00 and 261.20 m with minimal outflow passed • Fall: drawdown after Thanksgiving weekend to approx. 260.20 m by late Oct... Reach a min of 259.65 m by late Feb.	• Flooding of properties and docks • Levels below 261.0 make many bays hazardous to boat access	• Walleye spawning at Whitefish Rapids near main inlet, and on north shore (requires spring level of 260.50 metres. • Bass spawning on shoals addressed through spring target of 261.10 m • Pike spawning at extreme eastern end –no operations concerns • Wild rice – downstream of Ardoch – require minimal outflows after June 1st to Sept.	• During drought minimal flow maintained using all of operating range • Drawdown used to assist in filling Crotch Lake
Crotch	• Lake fluctuates by up to 3 m twice a year. • Spring: levels brought from 237.00 m up to 239.50 to 240.00 m until late June. • July: start of slow release to maintain downstream flow, brought down to 237.00 m by late Sept., while maintaining min 5 cms downstream flow • Fall: after Thanksgiving weekend water levels brought back up to 239.00 to 239.50 m by mid-Jan, while maintaining min 5 cms. downstream flow	• The most significant and only true reservoir lake • Mostly crown land, with some OPG owned land, 3 resorts and a few private properties	• Walleye spawning at Sidedam Rapids (fish sanctuary from Mar 1 to first Mon. of June), Kings Falls and other locations • Spring spawning level must be held for 6 weeks after spawning • Burrowing reptiles, muskrats, beaver, etc at risk in fall/winter due to late draw down	• Filling and drawdown - ice movement risk for snowmobilers • Min. 5 to 15 cms flow needed to address Low Flow Augmentation • Power Generation for High Falls

Note 2: Water Management Activity/Feature and Potential Issues Identified by the Public through the MRWMP

Note: The lake(s) specified in brackets after some identified issues represent the source of the comment but in some cases could be representative of other lakes.

Fall Draw Down:

- Impact to lake trout spawning (Shabomeka)
- Loss of access for boat access properties (Shabomeka, Kashwakamak)
- Is lowering detrimental to shore wildlife (mammals, amphibians, invertebrates, fish, etc.) that inhabit low and marshy areas around lake (Shabomeka, Mississagagon, Crotch)
- Concern over twice annual draw downs on Crotch and whether it could be reduced by drawing upper lakes down less rapidly

Spring Raising of Levels:

- Impacts to nesting loons (Dalhousie, Mississippi)
- Impacts to wild rice from Kashwakamak outflow
- Raising while ice still on lakes – shore erosion, damage to docks
- Reservoir status/Extreme Fluctuations in Water Level
- Water surges downstream of Crotch Lake problematic for downstream residents along river
- "Shock flow erosion" occurs when water is "dumped" out of Kashwakamak (Farm Lake)
- Labour intensive for commercial operation on Crotch Lake needing to remove and install docking systems multiple times throughout the year
- Compensation for problems caused by extremes in twice annual draw downs
- Belief that frequency of flooding has increased (Dalhousie, Mississippi Lake)
- Concerns about fluctuation in levels on Marble Lake during the summer

Low Summer Levels:

- Limit water access to some properties (Kashwakamak)
- Exaggerated where lake has gently sloping bottom (Marble)
- Need to be sufficient to allow access to connecting water bodies (Malcolm/Green Lk, Crotch/Fawn and Twin Island Lakes)
- Impact to boat launch access and navigation (Crotch, Dalhousie, Appleton, Almonte Town ramp)
- General concerns over low summer levels (Big Gull, Mississippi Lake)
- Town water supply (Carleton Place)

Fisheries:

- Which fish species takes priority (lake trout or walleye) if both can't be supported by operating plan? (questions posed by Shabomeka residents but applicable elsewhere)
- Concern over timing of spring water retention and impact to walleye spawning on Crotch and status of Walleye fishery
- Walleye spawning concerns (Crotch Lake, Big Gull, outflow of Dalhousie, Four Step Stone Rapids, Playfairville and Innisville Rapids)
- Bass spawning (Dalhousie, Snow Road, Crotch Lake, Mississippi Lake)
- Are bass and walleye spawning shoals in riverine areas such as Snow Road, Innisville and Appleton also considered in operating plans?

Other:

- Winter ice safety for recreation, can it be stabilized during winter for anglers, snowmobilers and skiers? (Kashwakamak, Mississippi, Marble)
- Is Crotch Lake more economically valuable as a reservoir lake or as a recreation lake? How can this be measured?
- Can the tributaries be managed to stabilize flow in river system; are there possible control structure sites on tributaries and would it make any difference?
- Septic systems, pit privies need more stringent rules (Shabomeka)
- More water sports (large motors, personal water craft) creating problems for wildlife and habitat (Shabomeka)
- Why no floodplain study for this region? (Shabomeka)
- Possibility of hydro generating facility at Mazinaw?
- Concerns about land use planning and impact on shoreline habitat (Mazinaw)
- MRWMP does not deal with water quality, tourism and recreation
- Are the American Eel or River Redhorse Sucker adversely affected by the current operation of the hydro facilities and dams?
- Water quality, weed growth, invasive species and fish tournaments were also raised as concerns.

Table 15: Low Flow Response – Summary of Levels and Thresholds

Condition	Indicator	Goal
Level I – potential water supply problems	Precipitation: <80% long or midterm average	Voluntary conservation - 10% reduction in water use
	Streamflow: <70% lowest average summer month	
Level II – Minor problems, potential major supply problems	Precipitation: <60% long or midterm average	Voluntary conservation and restrictions - Additional 10% reduction (20% in total)
	Streamflow: <50% lowest average summer month	
Level III – Supply fails to meet usual demand, social and economic impact	Precipitation: <40% long or midterm average	Mandatory restrictions will be dealt with at the Provincial Level.
	Streamflow: <30% lowest average summer month	
• Note: A watershed can only enter a Level II from an existing confirmed Level I or Level III. A watershed can only enter a Level III from an existing confirmed Level II.		

The program also developed an Ontario Low Water Response Plan which sets an implementation framework for responding during low water/drought events. Under the response framework:

- The Conservation Authority will confirm and declare a Level I low water condition and establish local Water Response Team* (WRT).
- The Local WRT will provide a coordinated response and share information and resources to deal with Levels I & II.
- The LWR can declare a Level III drought but water conservation is voluntary and there is no mechanism to require water users to lower/cease water usage.

*The Water Response Team, coordinated by MVCA, is made up of representatives of water users: member municipalities, farmers, businesses, recreation and others. The Low Water Response Team communicates when necessary to review stream flow information and weather forecasts. Based on the information, the committee may declare a low water condition for the watershed.

Organic Soils

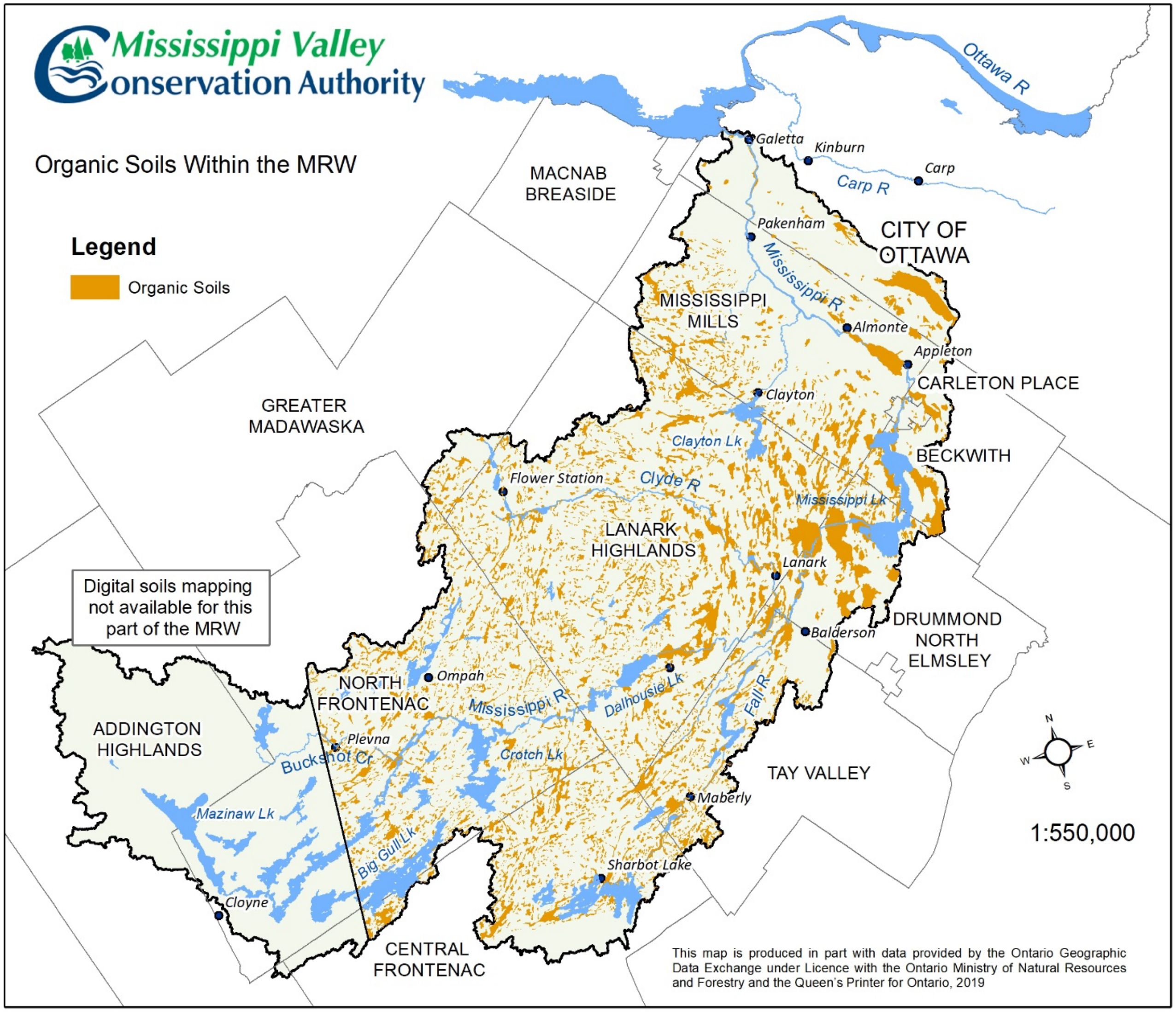


Figure 26: Organic Soils in the Mississippi River Watershed