Chapter 5

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5 Groundwater Sources

Introduction

This chapter provides information on groundwater within the Mississippi-Rideau Source Protection Region (MRSPR) and discusses municipal drinking water sources for the Mississippi Valley Source Protection Area (MVSPA). First is an explanation of methodologies used to identify areas where groundwater may be more susceptible to contamination, followed by information on issues, conditions and potential threats. Specific information is included on each of the groundwater sources found in the MVSPA.

There are currently two municipal groundwater drinking water systems in the MVSPA, with an third planned. The following table shows their location and the approximate number of users. It should be noted that these user numbers may vary slightly from those found in the 2008 MRSPR Watershed Characterization report and Table 2-16 as more current information is included in this chapter, where available.

Municipal Water	Estimated Number
Supply Location	of Users
Almonte	4,700
Carp	1,500
Total	6,200

Table 5-i. Groundwater Drinking Water Systems in the MVSPA.

A third wellhead protection area for the Village of Lanark has not been completed and it is anticipated that information on the well and associated WHPAs will be included in an updated Assessment Report.

Carp draws water from a sand and gravel aquifer and Almonte draws water only from bedrock aquifers. All delineated wellhead protection areas (WHPAs) in the MVSPA are shown in Figure 5-8, shown with WHPAs from the Rideau Valley Source Protection Area (RVSPA). Figure 5-9 shows all WHPAs with a vulnerability score of 8 to 10.

Groundwater is more susceptible to contamination in some areas and these areas have been identified regionally as Highly Vulnerable Areas (HVAs).

Approximately 89% of the MRSPR has been identified as HVA. Significant Groundwater Recharge Areas (SGRAs) are areas where a relatively large percentage of water recharges from the ground surface to an aquifer. Approximately 13.2% of the MRSPR has been identified as SGRAs.

General information on aquifers in the MRSPR is provided in Chapter 2 and further background information on threats, issues and conditions may be found in Chapter 4. Municipal surface water intakes in the MVSPA are discussed in Chapter 6.

Summary of Key Findings

Two hundred and thirty potentially significant drinking water threats have been identified in the wellhead protection areas of the MVSPA. Summary information on key findings and threats can be found in Tables 5-1 and 5-2. Table 5-3 is a summary of the potentially significant threats, organized into drinking water threat categories.

One condition has been identified in Carp and is discussed in Section 5.6.7.

Drinking water issues in the MVSPA have been identified in non-municipal drinking water in Beckwith, the Crotch Lake area, and in the villages of Constance Bay and Lanark. The Beckwith issue falls in both the RVSPA and the MVSPA. These issues are discussed in Section 5.1.5.

Technical Studies

Numerous background technical studies were completed for the groundwater sources chapter. The following table summarizes "who did what", including a peer review, if applicable. Further information regarding peer review is included following the table.

Study & Completion Date	**Lead Consultant**	***Peer Review***
Highly Vulnerable Aquifers, 2003	Golder Associates Ltd.	*Technical Advisory Group (TAG) for the Renfrew County – Mississippi – Rideau Groundwater Study*
Significant Groundwater Recharge Areas, 2009	Intera Engineering Ltd.	*Water Budget Peer Review Team*

Study & Completion Date	**Lead Consultant**	***Peer Review***
Managed Lands and Livestock Density, 2010	Dillon Consulting	*not peer reviewed*
Impervious Surfaces, 2010	Mississippi-Rideau Source Protection Region staff	*not peer reviewed*
Groundwater Drinking Water Threats and Issues, 2010	Dillon Consulting	*not peer reviewed*
Almonte Groundwater Vulnerability Study, 2003, 2008, 2009	Intera Engineering Ltd.	*Golder Associates Ltd.*
Carp Vulnerability Studies, 2003, 2004, 2008	*Golder Associates Ltd.*	*TAG, Intera Engineering Ltd.*

Table 5-ii. Summary of Groundwater Background Technical Studies

Peer Review

The highly vulnerable aquifer study, significant groundwater recharge areas study and all groundwater vulnerability studies were peer reviewed by an independent third party. Further information about the peer review process is provided below.

Highly Vulnerable Aquifer Study

In 2003, a Technical Advisory Group (TAG) was established for the Renfrew County – Mississippi – Rideau Groundwater Study. Among other things, the TAG was responsible for the peer review of the aquifer vulnerability component of this regional scale groundwater study. The TAG consisted of the following technical experts:

- John Price, Mississippi Valley Conservation
- Kerry Carnegie, Ontario Ministry of Agriculture and Food

- Bob Putzlocher, Ontario Ministry of the Environment
- Heather Wilson, Private Consultant
- Jacques Sauriol, Private Consultant
- Ian Jarvis, Agriculture and Agri-food Canada
- Paul Moreau, Ontario Ministry of Natural Resources
- Dr. Robert Belanger, Geologic Survey of Canada;
- Dr. Michel Robin, University of Ottawa
- Henry Garcia, Lanark, Leeds & Grenville County Health Unit
- Jean-Guy Albert, City of Ottawa Health Department
- Bob Schreader, Renfrew County Health Unit
- Asher Rizvi, Rideau Valley Conservation Authority

Regular meetings were held with the TAG throughout the duration of the study. A Peer Review record is not available except for the available peer documentation for the Ottawa wellhead protection studies (see background technical documents for the Carp Groundwater Vulnerability study).

Significant Groundwater Recharge Areas Study

In 2006, the Cataraqui Source Protection Area, the Quinte Source Protection Region and the Mississippi-Rideau Source Protection Region formed a joint team for peer review of the conceptual water budget studies and subsequent Tier 1 water budget studies and Significant Groundwater Recharge Areas Study. A Terms of Reference was developed for the peer review process in accordance with the provincial water budget peer review guidance document. The peer review consisted of the following external reviewers:

- Bill Hogg, Private Consultant, Former Climatologist with Environment Canada
- Dr. Ed Watt, XCG Consulting Ltd., Former Professor (Hydrology) at Queen’s University
- Darin Burr, Dillon Consulting Ltd., Hydrogeologist
- Dr. Kent Novakowski, Queen’s University, Hydrogeologist
- Dr. Michel Robin, University of Ottawa, Hydrogeologist
- Michel Kearney, City of Ottawa, Infrastructure Planner

Regular meetings were held with the peer review team between early 2006 and 2009. Complete Peer Review records are available for the Mississippi-Rideau Conceptual Water Budget, Tier 1 Water Budget and Water Quantity Stress

Assessment Reports and Significant Groundwater Recharge Areas Study (see Appendix A-1).

Groundwater Vulnerability Studies

In June 2007, a number of consultants working on groundwater vulnerability studies in the MRSPR were retained to undertake a peer review of each wellhead protection study. The objectives of the wellhead protection studies peer review were as follows:

- to ensure consistency with the expectations of the MOE Technical Guidance modules, which have since been replaced by the Technical Rules;
- to validate the approach for development of groundwater vulnerability studies; and
- to ensure scientifically defensible groundwater vulnerability studies.

The previous table lists the names of consultants who undertook the peer review for each study. Each technical study contains a peer review record.

Knowledge limitations for this and other chapters may be found in Chapter 8. A full list of the groundwater technical reports may be found in Appendix A-1.

5.1 Highly Vulnerable Aquifers

This section provides information on aquifers, including the delineation process used to determine vulnerability, and the process used to determine vulnerability scoring.

An aquifer is an underground layer of sand, gravel, or rock that contains enough water to supply a well. The amount of water available from various aquifers is dependent on size, depth, recharge rate, as well as a number of other factors. Regional-scale aquifers are very large aquifers with a span covering a large part (or all) of the region and potentially beyond. The following regional-scale aquifers have been identified in the MRSPR:

- An Upper Precambrian bedrock aquifer is located in the western portion of the region;
- Nepean Sandstone and Oxford-March bedrock aquifers are located in the central portion of the region; and
- Sand and gravel aquifers are located along the eastern and northern portions of the region.

Different aquifers service different types of wells. For example, shallow aquifers (the first aquifer below the ground surface) are often used for private wells that do not require high volumes of water. Deeper aquifers may transmit more water, and are often used to supply municipal drinking water systems.

The shallow aquifers in the MRSPR are sand and gravel deposits, the Oxford and March Formations, and in the western part of the region, upper Precambrian rock.

5.1.1 What is a Highly Vulnerable Aquifer?

A highly vulnerable aquifer, or HVA, is an aquifer that is susceptible to contamination from sources at the surface. Areas with soils and rock which easily allow water to travel through them to the aquifer are considered to be highly vulnerable. Areas where soils such as clay or unfractured rock are present which do not allow easy movement of water are considered to be less vulnerable to contamination.

5.1.2 Delineation of Highly Vulnerable Aquifers

There are numerous methods available for assessing aquifer vulnerability. All of these methods use the geological properties of the aquifer and some also require estimations of the hydraulic properties of the aquifers.

As per the Technical Rules, HVAs in the MRSPR were delineated using the Ontario Ministry of the Environment (MOE) Intrinsic Susceptibility Index (ISI) protocol. This method was modified to address local conditions and is approved by MOE. The ISI approach assesses the vulnerability of the 'first aquifer', or the aquifer closest to the surface.

Both the MOE ISI protocol and the modified MOE ISI protocol are discussed below. As per the Technical Rules, Directors approval was provided for the use of this alternate method (see Appendix 5-1).

MOE ISI Protocol

The ISI approach is based on determining the intrinsic susceptibility of the aquifer to contamination. The main factors that can affect an aquifer's vulnerability are the depth of the water table and the thickness/type of soil or rock layers above the aquifer. Areas where the protective soil or rock layers are either permeable or thinner than other areas or areas where the water table is shallow will be identified as having relatively higher aquifer vulnerability. In general, the ISI approach as designed by the MOE is used to describe the vulnerability of the 'first aquifer', or the aquifer closest to the surface. The methodology is most suited to assessing the vulnerability of an aquifer from near surface sources of contamination.

A summary of the key steps followed to generate an aquifer vulnerability map following the MOE ISI protocol is provided below. Additional details about the MOE ISI protocol is provided in Appendix 5-2.

Prepare Data

Water well records from the MOE water well database were analyzed to determine the aquifer depths and the thickness of each geologic unit (e.g. sand, gravel, and bedrock formations). It is recognized that some records may contain incorrect or incomplete coordinates for well locations, or vary in how the types of rock and soil are described. The reliability of the study results was improved by correcting obvious errors in the database, correcting well location coordinates, or screening out incorrect records altogether.

Map the Water Table

The water well record data was used to determine the depth to water, or water table level, at each well location. Using this information, the overall depth to water for the aquifer is modeled for the region.

Calculate Intrinsic Vulnerability Index

The properties of the soil and/or bedrock overlying the first aquifer were evaluated and assigned an ISI value to each well. Specifically, each soil or rock layer is evaluated in terms of its hydraulic conductivity and associated K-factor – that is, how easily water can travel vertically through it. The K-factor is assigned for each soil or rock layer from the ground surface down to where water is found in the well and a resulting ISI value is calculated.

This process also allows the location and type of aquifers (confined, unconfined, or semi-confined) in the region to be mapped by comparing ISI and water depth information among wells. This information can provide a picture of the depth and extent of an aquifer.

It is important to note that for bedrock wells where little overburden existed, the assumption was made that the top portion of the bedrock aquifer was potentially unconfined. The water table was generated based on kriging the elevation of static water levels in all wells that were less than 15 m deep, and overlain by less than 5 m of overburden, and conditioning this surface to the elevation of surface water features. This assumption was based on the geological model developed for the applicable watersheds, and presented in the regional groundwater study report (Golder and Dillon, 2003).

Categorize Well Vulnerability

ISI results indicate the level of protection that an aquifer has from surface contamination. For example, low ISI results numbers indicate that the geologic materials which are above the aquifer provide little protection as they allow water to flow freely through them, as noted above, meaning the aquifer is very vulnerable. A high ISI number indicates that the aquifer has a large amount of protection and so is not very vulnerable to contamination as surface water cannot readily reach it.

As shown below, each area is categorized as 'High', 'Medium', or 'Low' vulnerability, based on the ISI value that was calculated in the previous step.

Category	ISI Score
High Vulnerability	Score < 30
Medium Vulnerability	Score > 30 and <80
Low Vulnerability	Score > 80

Map Intrinsic Vulnerability Index Values

The calculated ISI values were mapped and regions of similar vulnerability were identified. Mathematical methods were used to find the best way to group the different ISI values from each well together. The end result is a map that shows the vulnerability of the aquifer across the entire region.

Modified MOE ISI Protocol

The MOE ISI protocol was modified with permission from MOE to better suit the unique characteristics of the region. This modification was developed as part of the regional groundwater study in consultation with MOE staff, and the study's technical advisory group. As noted above, documentation of the Provincial acceptance of this methodology is in Appendix 5-1.

The modification uses information about the types of rocks and soils found at the ground surface (called 'surficial geology') as an indicator of vulnerability. The geology of the MRSPR study area is unique in several ways:

- the bedrock is at or very close to the ground surface for a significant part of the study area, especially in the Canadian Shield, though sedimentary bedrock may also be present in many areas;
- this rock is very fractured near surface, so a shallow aquifer is often present; and

- significant deposits of sand and gravel are also present in the MRSPR.

The modified the ISI approach mapped bare rock, rock covered with less than 1.5m of material (soil, glacial till, etc), or bedrock covered by sand or gravel and these were automatically classed as highly vulnerable. All other areas were assessed according to the described MOE ISI protocol.

The final step was to combine the results from the original ISI method with the modified ISI method to delineate the HVAs across the MRSPR.

HVA Delineation – Mississippi-Rideau Source Protection Region

The delineation of vulnerable aquifers in the MRSPR focused on the ‘first aquifer’ or ‘shallow aquifers’, which is important for private well water supplies. The results of the aquifer vulnerability analysis for the MRSPR is presented below, where as the aquifer vulnerability analysis for the wellhead protection areas is presented in Sections 5.5.2 and 5.6.2. It is noted that in some cases, the MRSPR aquifer vulnerability results are different for the wellhead protection areas because many of the municipal wells use groundwater from a deep aquifer instead of the shallow aquifer utilized by most private wells.

Figure 5-1a shows the MOE ISI result for the most reliable well locations. The majority of the wells are classified as ‘High Vulnerability’ (ISI score < 30). However, a significant number of wells were also classified as ‘Medium Vulnerability’ (ISI score >30 and <80) and ‘Low Vulnerability’ (ISI score >80), especially within some parts of the City of Ottawa. The medium and low vulnerability scores include the Carp River Valley, the Rideau River Valley and the eastern portion of Ottawa.

Figure 5-1b shows the areas where the surficial geology maps show either sand/gravel areas or bare rock/shallow overburden areas less than 1.5 m thick. It is evident that a large percentage of the MRSPR is shown as bare rock/shallow overburden areas less than 1.5 m thick and also areas of sand/gravel exist toward the eastern edge of the MRSPR.

Figure 5-1c shows the final MRSPR aquifer vulnerability results for the ‘first aquifer’ or ‘shallow aquifer’, separated into three vulnerability categories (high, medium and low). Figure 5-1d shows a map of the final Highly Vulnerable Aquifers.

Approximately 89% of the MRSPR, about 7663 km^2, has been determined to fall under the HVA designation, 4032 km^2 in the MVSPA. Areas of low to moderate vulnerability are predominantly in flat lying areas which have clay or silt deposits as the surficial geology.

HVA Delineation in Eastern Ontario

Further to the above discussion about HVAs in the MRSPR, a rationale document was developed by the Cataraqui Source Protection Area (Cataraqui SPA) to rationalize the extensive HVA delineation in eastern Ontario. The document is provided in Appendix 5-3. Although the document was developed by the Cataraqui SPA, input was also provided by the Quinte Source Protection Region and the MRSPR. The document includes a discussion of flow and transport in fractured rock aquifers, as well a summary of several studies that show evidence of highly vulnerable aquifers in eastern Ontario. More specifically, the rationale document includes information about: 1) Queen's University research related to groundwater movement in fractured bedrock at the 'Tay River Field Site' located in the MRSPR, and 2) a brief summary of geologic conditions and water quality results for several villages within the MRSPR that rely on private wells that aligns well with the HVA designations.

It is concluded in the rationale documents that the extensive delineation of HVAs for eastern Ontario is appropriate from a scientific perspective, since:

- In most locations there is a limited cover of overburden to prevent contaminants from entering into the groundwater;
- Although our knowledge is incomplete, fracturing has been observed in the shallow and deep bedrock of eastern Ontario, including the Canadian Shield and shallow limestone areas, and it is reasonable to assume as part of groundwater vulnerability assessments that fractures may exist under any location across our source protection areas and that the bedrock is an unconfined aquifer; and
- Research to-date in eastern Ontario has demonstrated that the presence of vertical fractures creates a direct, high velocity conduit to the drinking water aquifer.

Vulnerability Scoring

All of the areas mapped as highly vulnerable were assigned a vulnerability score of 6 as required in the Technical Rules. This is shown in Figure 5-1e.

Data Sources and Limitations

The main data sources for the HVA delineation process were the MOE water well records and government published surficial geology maps. A discussion of each data source, and inherent limitations associated with it is presented below.

Surficial Geology Mapping

Provincial geology mapping was used for the Modified MOE ISI protocol. The rationale was that 1:50,000 scale geology mapping provides a superior accuracy and completeness of geological conditions that can be found through well driller’s records alone. The geological maps are prepared by geologists who specialize in lithological descriptions. It is realized that the mapping shows average conditions over a study areas, and that considerable variability in lithology may be present at larger scales. However, the use of the mapping is deemed to greatly increase the accuracy of the MOE ISI protocol. It is noted that although most of the geological maps were available at a scale of 1:50,000, in some areas a smaller scale was used thus the accuracy of the mapping is reduce.

MOE Well Records

The MOE water well records provide information on subsurface geology, aquifer depths and depths to water. These records are compiled from well logs completed by well drillers whose diligence and knowledge varies greatly. Although significant improvements to the accuracy of the well records have been made, this data source is limited in its accuracy, completeness and representativeness of actual field conditions. A summary of data limitations of the MOE water well records follows.

Limitation	**Possible Effect on Aquifer Vulnerability Mapping**
Error in description and thickness of unit	ISI values could be either too low or too high. Greatest impacts are for wells that have an ISI value near a category boundary.
Error in well location and well elevation	Calculated ISI value not representative of conditions.
Not all wells represented	Data gaps exist. Overburden wells and shallow bedrock wells created by excavation are under-represented.

Limitation	Possible Effect on Aquifer Vulnerability Mapping
Error in depth to static water levels	Possible overestimation of depth to the water table. May result in underestimating the aquifer vulnerability.

Table 5-iii. HVA Delineation Data Source Limitations.

Further to the above discussion about data source limitations, the MOE ISI protocol is based on ISI values that are empirical and not based on groundwater flow dynamics.

Uncertainty

Even though there is high confidence in the HVA classification for the majority of the MRSPR, based on the above data sources and limitations, there is high uncertainty associated with HVA delineation at a local scale.

Limitations

The main limitation of the HVA mapping approach is that all areas of shallow bedrock were conservatively identified as highly vulnerable, when this will not always be the case. In addition, some wells which would have been determined to have low or moderate aquifer vulnerability under the unmodified ISI methodology would be designated as highly vulnerable aquifers under this method. Furthermore, hydraulic data from the Water Well Information System for bedrock wells in areas of thin overburden were not considered with respect to identifying confined or semi-confined aquifer conditions. As a result, some areas in the MRSPR will be conservatively identified as high vulnerability areas, when they may not be. Identifying areas of low or moderate vulnerability conditions in areas of thin overburden would require higher quality data than is currently available for the Assessment Report.

5.1.3 Managed Lands and Livestock Density in Highly Vulnerable Aquifers

The percentage of managed lands and number of livestock (and the related nutrient units) are indicators of the degree of agricultural activity and other land management activities. In some cases, the storage and application of pesticides, fertilizers, and other agricultural materials associated with agricultural activities may result in pathogen and chemical contamination of drinking water sources.

MRSPR studies on managed lands and livestock density have been completed in accordance with the MOE Technical Guidance Bulletin entitled "Proposed Methodology for Calculating Percentage of Managed Land and Livestock Density for Land Application of Agricultural Source of Material, Non-Agricultural Source of Material and Commercial Fertilizers" issued December 2009.

MOE lists a number of definitions for agricultural operations which fall under the Farm Unit. Following is a summary of definitions. More information may be found at:
http://www.ene.gov.on.ca/en/water/cleanwater/cwdocs/tbmanagedLandsAndLivestock.pdf.

Key Definitions

- Managed lands are lands to which fertilizers and/or nutrient units are, or may be, applied. Managed lands can be broken into two subsets: agricultural managed land and non-agricultural managed land. A managed land includes, but is not limited to, cropland, fallow land, improved or unimproved pasture, golf courses, sports fields, and lawns.
- Nutrient Units (NU) are used to measure how much manure an animal produces annually. MOE has categorized different types of livestock and provides NU conversion factors for each type of livestock. It uses beef cattle as a base (conversion factor of 1 or NU=1) and compares the number of animals in other species which would be required to produce an equal annual amount of manure. From this, nutrient units for livestock of any category can be calculated.
- Livestock density is defined as the number of nutrient units over a given area and is measured in nutrient units per hectare (NU/ha) or nutrient units per acre (NU/ac).
- A farm unit is the area where nutrients generated must be at least the size of the property deed, the generating facility, or all land receiving nutrients. It should include all facilities on other deeds owned by the same person if the nutrients generated there are used on the land of the first deed, and can consist of separate farm units if nutrients are applied to different land bases. The size of a farm unit depends on whether or not the unit generates nutrients. If the farm unit does not generate nutrients, it must be at least the size a single field where nutrients are applied.

MOE has defined thresholds based on the area of managed lands in a vulnerable area to determine the risk of over-application of nutrients causing contamination of drinking water sources as shown in the following table.

Land Use	Risk
<40% of vulnerable area is managed lands	Low potential
40-80% of vulnerable area is managed lands	Moderate potential
>80% of vulnerable area is managed lands	High potential

Table 5-iv. Risk Thresholds.

MOE also defines thresholds based on livestock density in order to evaluate the risk of over-application of agricultural source material (ASM):

- If livestock density in the vulnerable area is less than 0.5 NU/acre, the area is considered to have a low potential for nutrient application exceeding crop requirements,
- If livestock density in the vulnerable areas is over 0.5 and less than 1.0 NU/acre, the area is considered to have a moderate potential for nutrient application exceeding crop requirements, and
- If livestock density in the vulnerable areas is over 1.0 NU/acre, the area is considered to have a high potential for nutrient application exceeding crop requirements.

Method for Calculating the Percentage of Managed Lands

The land area was determined using Landsat imagery of the study areas to identify vegetation types. Agricultural managed land includes areas of cropland, fallow, and improved pasture that may receive nutrients. Non-agricultural managed lands includes golf courses (turf), sports fields, lawns (turf) and other built-up grassed areas that may receive nutrients (primarily commercial fertilizer).

Wooded areas were identified and removed from these calculations as, for the purpose of the study, it is assumed that these areas would not be used for grazing and nutrients would not be applied in these areas.

The percentage of managed lands within HVAs was calculated by summing the total area of managed lands (both agricultural and non-agricultural) and dividing the result by the total land area of the HVA. The same method was used for SGRAs. The total area of managed lands was determined by reclassifying Geobase landcover data into three classes (agriculture, urban and other). One hundred percent of the agricultural land was considered to be managed and sixty percent of the urban land was considered to be managed.

Method for Calculating Livestock Density

The calculation of livestock density within HVAs and SGRAs is based on the calculation of Nutrient Units per acre (NU/ac) of agricultural managed lands.

Livestock density for the region was calculated in 2003 using 1996 Agriculture Canada data, which was the newest available at the time. The data areas were based on clusters of consolidated subdivision enumeration area boundaries. Twenty-two enumeration areas fell within the MRSPR.

In 2009, livestock density was again calculated for the region, with the objective of updating information and determining whether livestock density in the MRSPR was changing. Data areas for the latter period were determined using Agriculture Canada’s 2006 Soil Landscapes of Canada boundaries. Thirty-three soil landscape areas were identified in the MRSPR.

The two data bases were not identical so were adjusted to the same scale to facilitate comparison and provide the opportunity to see whether there were changes in regional livestock density between 1996 and 2006.

Results for HVA Managed Lands and Livestock Density

There was a general decline in livestock density across the region between 1996 and 2006 of just over 25%. Generally the areas with the highest rates of decline of livestock density were in the West Carleton area, the area south of Orleans, and along the Rideau River in the area north of Manotick to Burritts Rapids and the area south through Bishop’s Mills to North Augusta.

The distribution pattern of livestock density was generally similar between 1996 and 2006, with the greatest densities in the far northeast of the watershed, east of Orleans and south of Rockland, and south of Oxford Mills.

The mean nutrient units per area of managed agricultural lands in the HVA were almost exactly the same as the region mean. The HVA covers approximately 90% of the region, which explains the similarity in results.

The regional average livestock density for the HVA in 1996 was calculated as 0.178 NU/ac, and for 2006 was 0.15 NU/ac, both falling in the low “potential for nutrient application exceeding crop requirements” category which is <0.5 NU/ac. The HVA managed lands and livestock density results follow.

Area	Percent Total Managed Lands	Risk Threshold	Livestock Density (NU/acre)	Risk Threshold
HVA	16	Low	0.15	Low

Table 5-v. Total Managed Lands and Risk Thresholds for HVAs and Risk Associated with Over-Application of Nutrients. **Source: Dillon Managed Lands and Livestock Density Technical Report and Agricultural Watersheds Associates Update of Livestock Density Map.**

5.1.4 Impervious Surfaces – Highly Vulnerable Aquifers

Impervious surfaces are primarily constructed surfaces such as roads and parking lots that are covered by impenetrable materials such as asphalt, concrete and stone. These materials are a barrier to groundwater infiltration and generate more runoff during melt or storm events.

Road salt applied to roads and walkways for winter maintenance may enter surface and groundwater systems. Impervious surface area calculations are required to determine if road salt application in vulnerable areas could be a drinking water threat, though the HVA vulnerability scoring system does not allow any activities to be significant threats.

Method for Calculating the Percentage of Impervious Surfaces

The Southern Ontario Land Resource Information System (SOLRIS) was the primary data source used to identify impervious surfaces. SOLRIS is a landscape-level inventory of natural, rural, and urban areas. For the areas without SOLRIS coverage, a combination of the Ontario Road Network (ORN), Ministry of Natural Resources (MNR) built-up areas and some digitized areas were used (e.g., Village boundaries).

Using GIS software, a 1000m x 1000m grid was created to cover the MRSPR. With permission from the MOE, the grid was then shifted so that one of the grid cell intersections overlapped the centroid (centre of mass) of the MRSPR. Appendix 5-1 provides information on the modifications. The use of one grid over the entire MRSPR was to eliminate grid overlap between the Mississippi and Rideau Source Protection Areas. The data sources listed above were then combined into one layer, impervious surfaces. For each grid cell, the amount of impervious surface area is divided by the area of the cell to determine the percentage of impervious surfaces.

The percent impervious surfaces results for each grid within the HVA areas is shown on Figure 5-1f. The results range from 0-99%. The application of road salt cannot be considered a significant threat in HVAs as they are assigned a vulnerability score of 6.

5.1.5 Drinking Water Threats and Issues for Non-Municipal Groundwater Systems

Since HVAs are assigned a vulnerability score of 6 in accordance with the Technical Rules, land use activities are categorized as low or moderate threats in the provincial threats tables. No activities can be scored (or labelled) as significant threats within an HVA.

Issues Identification

Drinking water issues were evaluated for non-municipal groundwater-based drinking water systems that are located in one of the vulnerable areas (i.e. WHPA, HVA, SGRA) in the MRSPR using the methodology outlined below.

Methodology

As per the Technical Rules, the evaluation of non-municipal drinking water issues considered concentrations of contaminants that have exceeded or are increasing and approaching the Ontario Drinking Water Standards, Objectives and Guidelines, and occur over a widespread area. Widespread is interpreted to mean an issue that affects numerous wells within a relatively contiguous area.

To complete the evaluation of non-municipal drinking water issues, various documents and other resources were reviewed, including:

- Mississippi-Rideau Watershed Characterization Report (Draft, March 2008);
- Interviews with local Ontario Ministry of the Environment staff;

- Available historical reports, including groundwater studies, groundwater monitoring reports, etc.; and
- Information request and interviews with municipality staff.

The evaluation of non-municipal drinking water issues was limited by the availability of documents and resources (listed above). Consideration was only given to groundwater which is currently a source of drinking water. While the definition of a drinking water issue, as defined by the Technical Rules, may include situations where increasing trends in parameter concentrations are observed, the available water quality data typically did not include a sufficient number of data points to accurately identify concentration trends.

Both naturally occurring and anthropogenic sources of drinking water impacts were considered; however, the evaluation was focused on health-related drinking water issues with anthropogenic causes. Natural groundwater mineralization is a common occurrence in the MRSPR, often resulting in elevated concentrations of inorganic parameters. Thus, water quality issues have been limited to:

- documented contamination that may be related to anthropogenic activities and relating to a health-based standard (either directly or indirectly); and,
- documented contamination that is naturally occurring but unusual in its occurrence (i.e. not a commonly detected parameter) and relating to a health-based standard (either directly or indirectly).

As required by the Technical Rules, where drinking water issues were identified and could be attributed in whole or in part to anthropogenic activities, an Issue Contributing Area was identified, along with the activities and circumstances considered likely to have caused or contributed to the issue. The activities and circumstances are taken from the Threats Tables discussed in Section 4.4.3.

Results for Issues Identification

Several non-municipal drinking water issues were identified within the HVAs. One is situated in both the MVSPA and RVSPA and three are in the MVSPA. The identified non-municipal groundwater drinking water issues may affect some domestic and private wells in those communities. Table 5-4 provides a summary of the identified non-municipal drinking water issues and where applicable, a list of activities and circumstances considered likely to have caused or contributed to the issue.

Identified Issues in Non-Municipal Systems

Beckwith Groundwater Contamination (MVSPA and RVSPA)

Documented presence of contaminant parameters associated with chlorinated solvents in groundwater in the Township of Beckwith has been attributed to a former private landfill located near Black's Corners. Groundwater investigations in the area have been conducted since 1999 and have identified compounds including benzene and chlorinated solvent parameters (trichloroethylene and its associated degradation products, 1,1-dichloroethene, cis- and trans-1,2-dichloroethene and vinyl chloride).

The studies indicated the presence of chlorinated solvent parameters in some private wells, with some concentrations in excess of ODWS criteria. Of the 76 wells sampled seven exceeded the ODWS for trichloroethylene (50 μg/L), 11 exceeded for vinyl chloride (2.0 μg/L) and two exceeded for 1,1 dichloroethene (14 μg/L).

As a result of the water quality sampling program, residences with impacted wells have been provided with bottled water and/or granular activated carbon (GAC) treatment systems.

The elevated concentrations of chlorinated solvent parameters in drinking water are considered to represent an anthropogenic (human-related) drinking water issue. The location and approximate extent of the Beckwith groundwater contamination is shown in Figure 5-2a and the approximate Issue Contributing Area is identified in Figure 5-2b. The activities and circumstances considered likely to have caused or contributed to the issue are outlined in Table 5-4.

As per the Technical Rules, since this drinking water issue relates to private wells not associated with a municipal system drinking water systems included in the approved Mississippi Valley Source Protection Area or the Rideau Valley Source Protection Terms of Reference, the circumstances presented in Table 5-4 are considered to represent a moderate drinking water threat. Any other activity/circumstance listed in the Threats Tables, and taking place within the approximate Issue Contributing Area, that is associated with trichloroethylene, vinyl chloride and 1,1 dichloroethene that may contribute to this issue would also be considered to present a moderate drinking water threat.

Crotch Lake Area Elevated Uranium

Crotch Lake is located in North Frontenac County, north of Coxvale and south of Ompah. Mississippi Valley Conservation sampled 98 wells in the Crotch Lake area in order to measure the concentration of uranium in groundwater for the region. The mean concentration was 11 μg/L, with a maximum of 170 μg/L. Of the samples collected, 12 samples exceeded the ODWS for uranium (0.2 μg/L).

Of these samples, two exceeded the ODWS by 500% and six wells exceeded the ODWS by 50%.

The elevated uranium are interpreted to be naturally occurring, a result of the aquifer geology. Elevated concentrations of uranium in drinking water may present a health-related risk, and are considered to occur relatively infrequently. Thus, the elevated concentrations of uranium are considered to represent a naturally-occurring, or non-anthropogenic, drinking water issue. The location and approximate extent of the elevated uranium concentrations in groundwater is shown in Figure 5-2a. Because this is considered a naturally-occurring or non anthropogenic drinking water issue, no Issue Contributing Area or activities/circumstances considered likely to have caused or contributed to the issue have been identified.

Village of Constance Bay Groundwater Contamination

The Village of Constance Bay is located in the north-western portion of the City of Ottawa, adjacent to the Ottawa River. Land use in the village is predominantly residential, with most residences located along the waterfront and within a central residential area. Originally many of these properties were developed as seasonal cottages. A groundwater study for the village was completed during the summer of 2005 and involved the sampling of 69 water wells at selected residential properties, with an attempt to obtain a valid cross section of data.

Nitrate concentrations were detected in the samples at an average concentration of 5.2 mg/L with 19% of the samples exceeding the Ontario Drinking Water Standards (ODWS) of 10 mg/L as N. These nitrate concentrations appear to be a result of septic loading within the village and are considered to represent an anthropogenic drinking water issue. The location and approximate extent of the Constance Bay groundwater contamination is shown in Figure 5-2a and the approximate Issue Contributing Area is identified in Figure 5-2b. The activities and circumstances considered likely to have caused or contributed to the issue are outlined in Table 5-4.

As per the Technical Rules, since this drinking water issue relates to private wells not associated with a municipal system drinking water systems included in the approved Mississippi Valley Source Protection Area Terms of Reference, the circumstances presented in Table 5-4 are considered to represent a moderate drinking water threat. Any other activity/circumstance listed in the Threats Tables, and taking place within the approximate Issue Contributing Area, that is associated with nitrate or nitrogen that may contribute to this issue would also be considered to present a moderate drinking water threat.

Village of Lanark Groundwater Contamination

The Village of Lanark (now part of the Township of Lanark Highlands) is located along the Clyde River. All properties in the community are currently serviced by private wells and septic systems. Multiple well sampling programs have shown that between 17 and 51% of residential wells contained coliform bacteria, and approximately 17% of the wells contained nitrate concentrations above the ODWS upper level of 10 mg/L.

These issues are, at least in part, likely attributed to the relatively high density of septic systems in the area. The elevated concentrations of nitrate and bacteriological parameters are considered to represent anthropogenic drinking water issues. The location and approximate extent of the Lanark groundwater contamination is shown in Figure 5-2a and the approximate Issue Contributing Area is identified in Figure 5-2b. The activities and circumstances considered likely to have caused or contributed to the issue are outlined in Table 5-4.

As per the Technical Rules, since this drinking water issue relates to private wells not associated with a municipal system drinking water systems included in the approved Mississippi Valley Source Protection Area Terms of Reference, the circumstances presented in Table 5-4 are considered to represent a moderate drinking water threat. Any other activity/circumstance listed in the Threats Tables, and taking place within the approximate Issue Contributing Area, that is associated with nitrate or nitrogen and bacteriological parameters that may contribute to this issue would also be considered to present a moderate drinking water threat.

5.2 Significant Groundwater Recharge Areas

Groundwater recharge is the process by which water moves from the ground surface to the water table, or aquifer. This section provides information on areas which have been determined to be Significant Groundwater Recharge Areas.

5.2.1 What are Significant Groundwater Recharge Areas?

A significant groundwater recharge area, or SGRA, is an area where a relatively large percentage of water recharges from the ground surface to an aquifer. SGRAs represent important areas for groundwater to recharge aquifers. These areas are not necessarily associated with individual aquifers, but are considered to be areas where groundwater recharge is important at a regional scale.

5.2.2 Delineation of Significant Groundwater Recharge Areas

The Technical Rules outline two acceptable methods for delineating SGRAs:

- Method 1 identifies SGRAs as areas where annual groundwater recharge is 1.15 times greater than average annual groundwater recharge.
- Method 2 identifies SGRAs as areas where annual groundwater recharge is greater than 55% of the average regional water surplus.

Method 1 is typically applied in areas where the ground cover (geology, vegetation, etc.) are similar throughout the Source Protection Area/Region. Method 2 is more applicable to areas with a wide range of ground cover, which is the case for the MRSPR, therefore, Method 2 was used to delineate SGRAs in MRSPR. The data used to carry out these calculations was obtained from the Tier 1 Water Budget and Stress Assessment (Chapter 3). The methodology to delineate SGRAs follows.

Determine Annual Water Surplus

Annual water surplus is the term used to identify how much precipitation is not lost to evapotranspiration (ET). It is an estimate of how much water is available for runoff for filling lakes and rivers and recharge to underlying aquifers and is based on precipitation (rain or snow) and ET values. ET is the water lost from the ground surface to the air by evaporation and transpiration (water used by plants). Precipitation and ET are outputs from the water budget study.

Using these datasets, the water surplus was calculated, where:

Water Surplus = (Precipitation – Evapotranspiration)

Determine Groundwater Recharge

Groundwater recharge is an estimate of how much water travels from the ground surface to become groundwater. This calculation uses the water surplus and considers soil type, surface slope and vegetation cover to calculate the annual groundwater recharge. Calculations were performed on 25 m × 25 m area (or cell) to reflect the variability of groundwater recharge in the region.

Groundwater recharge was determined as part of the water budget in Chapter 3.

Identify Preliminary SGRAs

Method 2 was used to identify areas that may be SGRAs. Method 2 compares water surplus values to groundwater infiltration values on a cell-by-cell basis. A cell where groundwater infiltration is greater than 55% of the average regional water surplus falls in the category of preliminary SGRA. The average water surplus value for the MRSPR was calculated (as part of the water budget) as 346 mm/yr. Any cell where infiltration is greater than 190 mm/yr (346 x 0.55 = 190) is identified by Method 2 as a preliminary SGRA, shown in Figure 5-3a.

Refine Preliminary SGRAs

The next step is to refine the preliminary SGRA areas that were identified by the MOE Method 2 according to local conditions and professional judgment related to the following items.

Size

The initial output from the Method 2 approach shows a ‘paint splatter’ effect, because all cells that meet the criteria are selected.

The first refinement was to filter out single cells from consideration - any cell not adjacent to another SGRA cell was excluded.

The second set of refinements is based on the total size of adjacent SGRAs. Five different threshold values were examined: areas > 1, 10, 25, 50, and 100 hectares (ha).

Sand and Gravel deposits

Experts compared surface deposits of sand and gravel (as mapped in regional geology data) against the areas identified as preliminary SGRAs. Since sand and gravel deposits on the surface can transmit surface water quickly to the groundwater, they are generally accepted to be important recharge areas.

The comparison revealed that the preliminary SGRAs greater than 25 ha correlate with the location of the sand and gravel deposits. As a result, the SGRAs with an area greater than 25 ha were used as a basis for further refinements shown in Figure 5-3b.

Eskers

Eskers in the region are composed of sand and gravel. Eskers have been identified as important groundwater features. Some of the esker areas have steep slopes and were not identified by Method 2 as a SGRA. Given the importance of eskers in the region, all above ground eskers as mapped by the Ontario Geologic Survey were identified as SGRAs, and included in Figure 5-3c.

Nepean Formation

In the MRSPR, the Nepean Formation sandstone aquifer is the primary aquifer for municipal water supply. The Nepean Formation was the only aquifer considered to be an SGRA because of the regional importance of the aquifer. In several locations in the MRSPR (and specifically along the edge of the Canadian Shield), the Nepean Formation comes to the ground surface (called outcropping). Since these outcrop areas provide a direct pathway to the aquifer they were identified as SGRAs, and included in Figure 5-3c.

Determine Connectivity to Groundwater or Surface Water Supplies

The geology in the region is complicated by numerous soil types, discontinuous bedrock units, and large bedrock faults. Because of the numerous private bedrock wells and abundance of lakes and wetlands in the region, all of the SGRAs which were reviewed were assumed to be connected to a groundwater or surface water supply.

Results for Delineation of Significant Groundwater Recharge Areas

SGRAs cover approximately 13.2% of the MRSPR, an area of 1134 km^2, 413 km^2 in the MVSPA. The final SGRA area is shown in Figure 5-3c.

Vulnerability Scoring

The next step was to determine a vulnerability score for the SGRAs in accordance with the technical rules. Aquifer vulnerability for the MRSPR was completed following the methods outlined in Section 5.1.2 and the vulnerability scoring was carried out using the values in the following table, as outlined by the Technical Rules.

Vulnerability Category	Vulnerability Score
LOW	2
MEDIUM	4
HIGH	6

Table 5-vi. Vulnerability Scoring.

For SGRAs, the scoring process depends on the vulnerability of the aquifer that was shown in Figure 5-1c. The vulnerability scores from the HVA mapping were overlaid by the final SGRA map, Figure 5-3c, in order to produce the final SGRA vulnerability map, shown in Figure 5-3d.

Uncertainty

The calculations used to develop the final SGRA map were carried out at a regional scale using hydrologic, geologic, and land cover data sets that contain uncertainty, therefore there is high uncertainty in the hydrologic data, geologic mapping and the final delineation of the SGRAs. The final SGRA map should be used with caution as there is high uncertainty at a local scale.

5.2.3 Managed Lands and Livestock Density – Significant Groundwater Recharge Areas

Section 5.1.3 describes the analysis used to delineate managed lands and calculate livestock densities. The Technical Rules require that the percentage of managed land and livestock density calculations are carried out for areas where the vulnerability score is greater than or equal to 6. MRSPR calculations were carried out for the entire SGRA, however since 94% of the SGRA has been assigned a vulnerability score of 6 or greater, with the remaining 6% falling primarily in the 4 category, the outcome of the managed land and livestock density calculations would not differ greatly. The SGRA managed lands and livestock density results follow.

Area	Percent Total Managed Lands	Risk Threshold	Livestock Density (NU/acre)	Risk Threshold
SGRA	23.4	Low	0.15	Low

Table 5-vii. Total Managed Lands and Risk Thresholds for SGRAs and Risk Associated with Over-application of Nutrients. **Source: Dillon Managed Lands and Livestock Density Technical Report and Agricultural Watersheds Associates Update of Livestock Density Map.**

Livestock densities for the SGRA, which covers approximately 13.2% of the MRSPR, had an average of 0.190 NU/ac in 1996 and 0.151 NU/ac in 2006.

5.2.4 Impervious Surfaces – Significant Groundwater Recharge Areas

Impervious surfaces are primarily constructed surfaces such as roads and parking lots that are covered by impenetrable materials such as asphalt, concrete and stone. These materials are a barrier to groundwater infiltration. Impervious surfaces also generate more runoff during melt or storm events.

Road salt applied to roads and walkways for winter maintenance may enter surface and groundwater systems. Impervious surface area calculations are required to determine if road salt application in vulnerable areas could be a drinking water threat, though the SGRA vulnerability scoring system does not allow any activities to be significant threats.

For information on methodology for determining percentage of impervious surfaces please see Section 5.1.4 Impervious Surfaces.

The percent impervious surfaces results for each grid within the SGRAs are shown on Figure 5-3e. The results range from 0 to 97%. The application of road salt cannot be a significant threat in SGRAs under the Technical Rules as they are assigned a maximum vulnerability score of 6.

5.2.5 Drinking Water Threats – Significant Groundwater Recharge Areas

Since the vulnerability scores for SGRAs range from 2 to 6, land use activities are categorized as low or moderate threats in the provincial threats tables. No activities can be scored (or labelled) as significant threats within an SGRA.

5.2.6 Issues and Conditions – Significant Groundwater Recharge Areas

There are no issues and conditions identified specifically for SGRAs. Drinking water issues are discussed for non-municipal groundwater drinking water systems in highly vulnerable aquifers in Section 5.1.5.

5.3 Wellhead Protection Areas

This section provides information on Wellhead Protection Areas, called WHPAs, and how they are delineated. Sections 5.5 through 5.13 discuss specific results for each of the MRSPR municipalities that depend on groundwater.

5.3.1 What is a Wellhead Protection Area?

A WHPA is the surface projection of the area of an aquifer that contributes water to a municipal well, and within this area it is desirable to monitor or regulate drinking water threats. WHPA studies aim to provide an understanding of local groundwater conditions and potential sources of contamination surrounding a well or well field that supplies a municipal water system.

The WHPAs are outlined in the Technical Rules. Area A is the area immediately surrounding the well. Areas B, C and D are delineated by time of travel.

Time of travel (ToT) is the distance groundwater travels to the wellhead for a 2, 5 or 25-year time period. These distances are determined using numerical groundwater models.

WHPA	Description
WHPA-A	100 m buffer around the wellhead
WHPA-B	2-year time of travel to the wellhead
WHPA-C	5-year time of travel to the wellhead
WHPA-D	25-year time of travel to the wellhead
WHPA-E, WHPA-F	Protection areas for the wellhead of a GUDI well

Table 5-viii. WHPA Descriptions.

The term GUDI is used for wells where the groundwater that is entering the well is under direct influence of surface water. A review of available records from municipalities and engineers' reports show that no municipal groundwater systems in the MRSPR were GUDI wells. Therefore, WHPAs E and F were not considered in the WHPA analyses.

5.3.2 Wellhead Protection Area Development Methodology

A numbers of steps were used in developing WHPAs. This section lists those steps and provides information about each.

Collection of data and information

Geological and hydrological data was collected from groundwater technical studies, and from federal, provincial, and municipal sources. One of the most important data sources was the Water Well Information System, a database of current and historic well records for Ontario, maintained by MOE. Another key data set was “golden spikes”, which are single high quality borehole logs and water level data, and which may be associated with a provincial or federal database.

Development of a conceptual (theoretical) model

Once data was collected, it was used to develop a general understanding of the local groundwater system, known as a conceptual model. The conceptual model is a representation of the local physical environment showing how water behaves above and below ground. It requires knowledge of geology, how rainfall makes its way beneath the surface (infiltration), and an understanding of the location, depth, and flow direction of water in the aquifer. Figure 5-4 shows a generic conceptual cross-section; specific conceptual cross-sections were created for each WHPA using site specific data. These cross-sections are useful in creating an understanding of the conceptual mode. An independent third party peer review occurred at this stage to ensure the conceptual model for each WHPA was accepted by other groundwater experts.

Selection, development, and calibration of a numerical model

A numerical model is a set of mathematical equations, usually held within a computer program, that represent how water behaves in the physical environment (or hydrogeological system). Using the conceptual model for each WHPA, a numerical model was developed to best represent the hydrogeological system associated with each wellhead. The model was calibrated by adjusting model parameters so that results were consistent with observations (e.g. known well water levels). All WHPA's were modeled using MODFLOW. Often it is impossible to identify a single value for an input parameter, so a range of reasonable values are identified. Using a range of values means a calibrated model run can result in different but equally valid results. This is often called a sensitivity analysis. If results vary greatly when values of an input changes, sensitivity is considered to be high.

Delineation of the Wellhead Protection Areas

For each WHPA, the numerical model determined the speed water travels in the aquifer towards the wells by using a variety of inputs, including municipal water demand values. This information was used to determine WHPA time of travel intervals as discussed above. Since each model had more than one reasonable output (resulting from a range of values for some parameters), the final WHPAs for the shallow and deep aquifers are the combinations, or outer boundaries, of all valid model runs.

Uncertainty

The sensitivity analysis for the numerical model made reasonable adjustments to the aquifer parameters and model assumptions to determine what the WHPAs would look like if the model parameters were slightly different. The results of each of the additional computer simulations were plotted on a map. The area where the results from these additional computer simulations overlapped for the 2 years, 5 years, and 25 years ToT was used to delineate the final WHPA-B, WHPA-C, and WHPA-D, respectively. The final (composite) capture areas are considered to provide a greater degree of protection around the supply wells than would be achieved by using the results from a single model simulation.

The approach to determine uncertainly for all wellhead protection areas, both for delineation and vulnerability scoring, was to give low uncertainty to all areas within the inner limits of all reasonable 5 year time of travel sensitivity runs and to give high uncertainty to all areas beyond this area. This uncertainty approach for both delineation and vulnerability scoring is considered very reasonable based on the fact that more reliable information is generally available closest to the municipal wells and all of the inner limits of the 5 year time of travel sensitivity runs (i.e., areas common to all 5 year sensitivity runs) are classified as low uncertainty.

5.3.3 Managed Lands and Livestock Density – Wellhead Protection Areas

Key Managed Lands and Livestock Density definitions may be found in Section 5.1.3.

Method for Calculating the Percentage of Managed Lands for Wellhead Protection Areas

Agricultural managed land includes areas of cropland, fallow, and improved pasture that may receive nutrients. Non-agricultural managed lands includes golf courses (turf), sports fields, lawns (turf) and other built-up grassed areas that may receive nutrients (primarily commercial fertilizer). The following method describes the calculation of each of these values.

The areas of agricultural and non-agricultural lands were determined using land assessment and Municipal Property Assessment Corporation property classifications. The areas were confirmed through analysis of satellite imagery.

The percentage of managed lands within the WHPA was calculated by summing the total area of managed lands (both agricultural and non-agricultural) and dividing the result by the total land area of the WHPA.

The Technical Rules define thresholds based on the area of managed lands in a vulnerable area to determine the risk of over-application of nutrients causing contamination of drinking water sources.

Method for Calculating Livestock Density in Wellhead Protection Areas

Livestock Density is measured in Nutrient Units per acre (NU/ac) to estimate the generation, storage and application of nutrients from agricultural source material

(ASM) in an area. The NU represents amount of manure and biosolids used to fertilize a Farm Unit either produced by animals on the farm or brought from the outside. A farm unit is a single field, the land base that generates nutrients or the land base that receives nutrients.

The calculation of livestock density within WHPAs was based on the calculation of Nutrient Units per acre (NU/ac) of agricultural managed lands. Two values for livestock density were calculated. The first value is the Land Application of Nutrients, which represents the nutrient units applied to crops or turf. The second value reported is for livestock density associated with grazing or pasturing. This value was calculated using the estimated number of livestock in each farm unit or pasture area. The following method describes the calculation of each of these values.

- Determine the number of animals on a farm unit and estimate how many of each type of animals (e.g. poultry – broiler, cattle - cow, or swine - sows) are present. Estimates of the number of animals on a farm were carried out based on building design and size.
- Convert the number of each type of animals to nutrient units using nutrient unit conversion tables supplied by the Province.
- Determine the area of managed lands that are within a vulnerable area (HVA, SGRA or WHPA – see below). For the purposes of estimating the NUs required for the estimation of livestock density in a farm unit, where a portion of a farm unit falls within a vulnerable area, the NUs generated on the entire parcel of land should be factored into the calculations rather than the NUs generated within the portion of land that falls within a vulnerable area.
- Determine the area of land used for pasturing or grazing associated with each farm unit.
- Calculate the livestock density for the application of nutrients to land by dividing the total number of nutrient units by the area of managed lands that are within a vulnerable area.
- Calculate the livestock density for pasturing/grazing by dividing the total number of nutrient units by the area available for pasturing/grazing for each farm unit.

Land Use	Risk
<40% of vulnerable area is managed lands	Low potential
40-80% of vulnerable area is managed lands	Moderate potential
>80% of vulnerable area is managed lands	High potential

Table 5-ix. Risk Thresholds.

MOE defines thresholds in order to evaluate the risk of over-application of agriculturally sourced materials, as shown in the previous table:

- If livestock density in the vulnerable area is less than 0.5 NU/acre, the area is considered to have a low potential for nutrient application exceeding crop requirements,
- If livestock density in the vulnerable areas is over 0.5 and less than 1.0 NU/acre, the area is considered to have a moderate potential for nutrient application exceeding crop requirements, and
- If livestock density in the vulnerable areas is over 1.0 NU/acre, the area is considered to have a high potential for nutrient application exceeding crop requirements.

More information may be found in the MOE Technical Bulletin sited at the beginning of this Section.

5.4 Wellhead Protection Areas in the Mississippi Valley Source Protection Area

As discussed in Chapter 2, there are currently two municipal groundwater-based drinking water protection systems in the MVSPA.

Municipal Drinking Water Groundwater Systems as per Terms of Reference	Referred to as:
Mississippi Mills Water Treatment Plant	Almonte

Municipal Drinking Water Groundwater Systems as per Terms of Reference	Referred to as:
Carp Well Supply	Carp

Table 5-x. Municipal Groundwater Drinking Water Systems in the MVSPA.

Discussions follow for each of the systems and the surrounding areas. There is an explanation of the approach for each in determining the proposed wellhead protection areas and maps of each may be found in the associated figures. Vulnerability scores are discussed and threats for each wellhead are identified.

The Township of Lanark Highlands is currently seeking construction funding and working on the design of a new municipal groundwater-based drinking water system for the Village of Lanark in Lanark County. This planned system has been studied in accordance with the environmental assessment process and is included in the Approved Terms of Reference for the Mississippi Valley Source Protection Area. It is expected that this system, along with associated vulnerability studies and WHPAs, will be included in updated versions of the assessment report.

5.5 Almonte Water Supply

Almonte, in the Town of Mississippi Mills, obtains water from five drilled wells, wells 3, 5, 6, 7 and 8 shown in Figure 5-5a. Wells 1, 2 and 4 were decommissioned in 1992. The wells are drilled to depths of between 39 and 79 m below ground surface. The wells obtain water from the following bedrock formations: Oxford, March and Nepean. Additionally, Well 6 is completed 2 m into the Precambrian bedrock. A monitoring well is present and shown in Figure 5-5a. The groundwater system supplies approximately 4,700 people.

The local geology in the Almonte area consists primarily of silt to clay till and marine deposits and ranges in thickness from 0-25 m. The sequence of sedimentary rocks underlying Almonte (from oldest/deepest to youngest/shallowest) is Nepean Formation (sandstone), March Formation (sandstone/dolostone), and the Oxford Formation (limestone/dolostone). There are numerous bedrock faults in the Almonte area, which complicate the regional hydrogeology.

The municipal drinking water system in Almonte is operated by the Ontario Clean Water Agency (OCWA). The Almonte source water quality, on isolated occasions, exceeded guidelines in hardness, organic nitrogen, Total Dissolved

Solids (TDS), turbidity, aluminum and sodium. Elevated turbidity at Well 6 has been documented during pumping, especially during high demand. Sodium concentrations are consistently above 20 mg/L, which is the advisory limit set by the MOE above which the operator must notify the MOE and the Health Unit to protect patients on sodium-reduced diets.

Private wells in the Almonte area generally obtain water from a shallow bedrock aquifer within the Ottawa Formation or the Oxford and March Formation, or the Precambrian aquifer.

5.5.1 Delineation of Almonte Wellhead Protection Area

A cross-section for the WHPA conceptual model is shown in Figure 5-5b. On the east side of the Mississippi River, wells 3, 7, and 8 pass through the shallow aquifer rock formations before reaching the deep Nepean sandstone aquifer. On the west side of the Mississippi River, Well 5 passes through a thin layer of soil before reaching the Nepean aquifer. Well 6 passes through soil and the Oxford/March formation before reaching the Nepean aquifer.

Groundwater studies show the upper bedrock and overburden units do not contribute a significant amount of water to the Almonte wells. The underlying Nepean Formation aquifer is the primary aquifer for the wells. Therefore, only the deep groundwater system (Nepean Formation aquifer) is considered for this WHPA. An independent third party peer review ensured the approach was accepted by other groundwater experts.

Regional groundwater flow direction in the Nepean aquifer is typically from west to east. In Almonte, however, the Mississippi River affects the local groundwater flow direction. On the east side of the river, the Nepean aquifer flows from east to west, so groundwater flow is towards the river from both the east and west sides.

The Almonte WHPAs were delineated using a forecasted combined flow rate for the five wells of 1831 m^3/day, shown in Chapter 2 in Table 2-14. This flow rate is greater than the five year average flow rate of 1,765 m^3/day. The forecasted flow rate was chosen based on municipal growth projections.

The numerical model calculated WHPAs A through D for the Almonte system. Figure 5-5c shows the Almonte aquifer wellhead protection areas around the municipal wellheads. They are made up of a circle with a 100 m radius around the wellheads and the 2, 5, and 25 year times of travel. The Almonte WHPAs cover a total area of 18.9 km^2.

Due to geographic location and groundwater flow regimes for the five separate wells, two distinct WHPAs have been established for Almonte (as shown in

Figure 5-5c). The WHPAs are located on both sides of the Mississippi River. Wells 3, 7, and 8 are located in the northeast WHPA and Wells 5 and 6 are located in the southwest WHPA.

Section 5.3.2 discusses sensitivity analysis in WHPAs. The zones of high and low uncertainty are shown in Figure 5-5d for both WHPA delineation and vulnerability scoring.

5.5.2 Aquifer Vulnerability - Almonte Wellhead Protection Area

Once the WHPA is delineated, the aquifer vulnerability is determined using the Intrinsic Susceptibility Index or ISI protocol discussed in Section 5.1.2 without the modification. Briefly, the ISI looks at the thickness and types of soil and rock layers above the aquifer, and how easily water can pass through these layers. The Technical Rules outline the process for categorizing the ISI results into aquifer vulnerability (Low, Medium or High) for the areas within the WHPAs. Figure 5-5e shows the results of the aquifer vulnerability determination for the deep groundwater system that supplies the municipal wells. Note that the aquifer vulnerability results are not the same as the aquifer vulnerability for the 'first aquifer' shown in Figure 5-1c.

For the WHPA on the east side of the Mississippi River, the aquifer vulnerability is generally low because the Nepean aquifer is well protected from the overlying Ottawa and Oxford/March Formation aquifers. For the WHPA on the west side of the Mississippi River, the aquifer vulnerability varies from low to high as a result of the variable geology discussed in Section 5.5.1.

Under the Technical Rules, the presence of transport pathways within a WHPA can increase the intrinsic vulnerability. An area with low vulnerability can increase to medium, and an area with medium vulnerability can increase to high. Areas that are already high cannot be increased. The presence, extent and characteristics of water wells, pits and quarries, mines, construction activities, sewer services, septic systems and stormwater infiltration was examined in the WHPA to determine whether adjustments to the vulnerability scoring were justified.

As shown in Figure 5-5e, four areas were identified where transport pathways increase the risk to the Nepean aquifer. Two of the areas are bedrock quarries located on the east side of the Mississippi River, close to the limit of the 25 year time of travel. In both areas, the aquifer vulnerability was increased from low to medium because they reduce the amount of overlying material to filter and/or attenuate contaminants.

The other two areas (sewage lagoons and a sand/gravel pit) where transport pathways increase the risk to the Nepean aquifer are located on the west side of the Mississippi River. The sewage lagoons are located just west of Wolf Grove Road and the sand/gravel pit is located north of the intersection of Old Perth Road and Concession 8. For the sewage lagoons, the vulnerability was increased from low to medium for those portions of the lagoons which are currently classified as low. The aquifer vulnerability was increased from low to medium for the sand/gravel pit because it reduces the amount of overlying material to filter and/or attenuate contaminants.

5.5.3 Vulnerability Scoring - Almonte Wellhead Protection Area

The Technical Rules set out a process for scoring vulnerability within a WHPA. It is based on the combination of aquifer vulnerability and overlapping WHPAs. The more vulnerable the aquifer and the closer the proximity to the well, the higher the vulnerability score.

The following table shows the scoring system laid out in the provincial Technical Rules. Possible vulnerability scores are 2, 4, 6, 8, and 10. A score of 10 is highest, indicating an area where drinking water is most vulnerable to contamination. These categories were used to assign vulnerability scores to the areas within the WHPA in Figure 5-5f. Figure 5-5g shows a close-up of the vulnerability scoring.

Vulnerability Category (ISI)	WHPA-A	WHPA-B	WHPA-C	WHPA-D
High	10	10	8	6
Medium	10	8	6	4
Low	10	6	4	2

Table 5-xi. Wellhead Protection Area Vulnerability Scores.

On the east side of the Mississippi River, the aquifer vulnerability is all low, with the exception of two small areas which have been increased to medium due to transport pathways. On this side of the river, the Nepean aquifer is well protected by a relatively thick bedrock layer consisting of shale, limestone, and sandstone. On the west side of the Mississippi River, the aquifer vulnerability varies from low to high due the fact that the Nepean aquifer is protected by a relatively thin bedrock or soil layer.

5.5.4 Managed Lands and Livestock Density – Almonte Wellhead Protection Area

Percent managed land and livestock density calculations were carried out according to the methods outlined in Section 5.3.3. Figure 5-5h shows the managed lands and the livestock density in the WHPAs. The percent managed lands and average livestock densities for each zone are listed in Table 5-5. Note some zones in these tables have two results because the calculation was carried out for each vulnerability score in each WHPAs. Also shown in the table is the risk threshold for the over application of nutrients to land and the risk threshold for the over application of ASM to land.

5.5.5 Impervious Surfaces – Almonte Wellhead Protection Area

Impervious surfaces are primarily constructed surfaces such as roads and parking lots that are covered by impenetrable materials such as asphalt, concrete and stone. These materials are a barrier to groundwater infiltration. Impervious surfaces also generate more runoff during melt or storm events.

Road salt applied to roads and walkways for winter maintenance may enter surface and groundwater systems. Impervious surface area calculations are required to determine if road salt application in vulnerable areas could be a drinking water threat.

For information on methodology for determining percentage of impervious surfaces please see section 5.1.4 Impervious Surfaces.

The percent impervious surfaces results for each grid within the Almonte vulnerable aquifer areas is shown on Figure 5-5i. The results range from 0-77%.

5.5.6 Potential Water Quality Threats - Almonte Wellhead Protection Area

Water quality threats are existing conditions (e.g. contaminated sediment, soil or groundwater) or existing or future land use activities that could contaminate a drinking water supply. To determine this, a land use inventory of the Almonte WHPA was completed in 2008.

It should be noted that a single land use activity could fall into multiple threat categories. For example, a crop farm could be storing fuel, applying commercial fertilizer to land, and applying agricultural source material to land. Each of these activities is a separate threat category in the provincial table, and so each is therefore a separate threat.

Land use activities and associated threats that occur where the vulnerability score is high may result in determining it to be a significant threat. In many cases, the specific circumstances that apply to a threat category are unknown. Using the same example, a crop farm may store fuel, but the volume of fuel stored is unknown. Unless additional information was available, it was assumed that enough material was stored for that activity to be a significant threat.

Results of Almonte Wellhead Protection Area Water Quality Threat Assessment

A total of 93 potentially significant drinking water threats were identified in the Almonte WHPA. For WHPAs, significant threats are where the vulnerability score is 8 or 10, or if the activity pertains to dense non-aqueous phase liquids (DNAPLs), anywhere within the 5-year WHPA-C. The potentially significant drinking water threats are summarized in Table 5-6. The term “Poly” in the table refers to a polygon, or an area that may contain multiple threats. The term “Point” in the table refers to a point source. Figure 5-5j shows the areas containing potentially significant threats in red if the vulnerability score is 10 and orange for a vulnerability score of 8. The area containing potentially significant threats is approximately 1.4 km^2. The map also shows the outlines of the areas containing potential DNAPL threats with a blue dashed line, an area of approximately 8.0 km^2. See Section 4.4.3 for information on the full list of significant, moderate, and low threats.

Transportation Corridors

A number of transportation corridors, including major road arteries, exist within the Almonte WHPA. These corridors are not considered an activity under Clean Water Act definitions and, therefore, do not fall within the prescribed list of threats (see Section 4.3). However, there is potential for the transportation of dangerous and/or hazardous goods along these corridors and the potential for a spill to occur. Transportation corridors will thus be considered in the development of the Source Protection Plan to ensure the protection of groundwater sources from potential accidental spills. Transportation corridors can be found on all WHPA maps including the Almonte WHPA map in Figure 5-5e.

5.5.7 Issues and Conditions – Almonte Wellhead Protection Area

Issues are documented cases of water quality contamination approaching or exceeding acceptable provincial levels. No issues were identified in the Almonte WHPA.

A condition is a situation where past activities resulted in a drinking water threat. Based on the criteria, there are no conditions in the Almonte WHPA.

5.6 Carp Water Supply

The Village of Carp obtains its drinking water from two municipal wells, shown in Figure 5-6a, that draw water from a sand and gravel aquifer. The wells are drilled to depths of 27 and 24 m below ground surface. Two monitoring wells are also present and their locations are shown in Figure 5-6a. The groundwater system currently supplies water for 1,500 people in the Village of Carp.

Carp is located in a complex geological setting. The Hazeldean bedrock fault, a significant structural geological feature, is located just northeast of the Village and marks the contact between the near surface Precambrian bedrock to the northeast, and the thick deposits of unconsolidated sediment to the west/southwest. The unconsolidated sediments make up the Carp River Valley and consist of clay soils overlying variable granular deposits and glacial till. Previous studies identified that the aquifer is primarily recharged via infiltration through the extensive sand deposits that come to surface in the higher land adjacent to the Carp Ridge, as well as at the north end of the Village.

The groundwater has been consistently clear of bacteriological and chemical contaminants. Well 2 is the primary well because of identified ammonia issues at Well 1. Well 1 is used as a back-up during periods of high demand. The Carp aquifer consistently had hardness concentrations greater than the 80 - 100 mg/L Ontario Drinking Water Standards – Operational Guideline. Hydrogen sulphide has also been found to be consistently over the aesthetic objective, and is considered to be naturally-occurring and not due to anthropogenic sources.

Naturally elevated sodium levels were found in the water during the testing of the aquifer prior to the construction of the communal well system. Concentrations are consistently above 20 mg/L, which is the advisory limit set by the MOE above which the operator must notify the MOE and the Health Unit to protect individuals on sodium-reduced diets. Sodium concentrations do not exceed the Ontario Drinking Water Standards – Operational Guideline Aesthetic Objective of 200 mg/L, nor does sodium have human health effects except in a small number of cases that are considered in the advisory limit.

Private wells in the Carp area generally obtain water from a bedrock aquifer within the Ottawa Formation.

5.6.1 Delineation of Carp Wellhead Protection Area

The conceptual hydrogeological model for the Carp wellhead was created from the MOE Water Well Information System, as well as geologic and hydrologic data which was obtained from previous studies carried out in the Carp area. Geologic and hydrologic data was also obtained from Provincial and Federal studies. Monitoring wells were also drilled as part of a field campaign to improve the understanding of the geology and hydrogeology of the groundwater system.

A cross-section for the conceptual model is shown in Figure 5-6b. The sand and gravel aquifer that supplies the wells is made up of the fine, medium, and coarse sand and gravel formations. A layer of clay of varying thickness covers the aquifer, however the continuity of this layer is not well known. A layer of limestone bedrock is below the aquifer. The groundwater system for the Carp wells is confined to the shallow overburden. The bedrock does not play a significant role in the groundwater system. Therefore, only the shallow overburden system was considered. An independent third party peer review ensured the approach was accepted by other groundwater experts.

Regionally, groundwater flow in the sand and gravel aquifer is from south-southeast. Locally, in the Village of Carp, groundwater flow directions are affected by pumping at the Carp supply wells and the infiltration areas along the Carp Ridge and in the village there is a south to southwesterly flow.

The Carp WHPAs were delineated using a forecasted combined flow rate for the two wells of 2,000 m^3/day. This rate is significantly greater than the current flow rate of 400 m^3/day. The forecasted flow rate was chosen based on discussions with the municipality and includes projected future growth in Carp, as well as water demands from the potential Carp Airport Development. A rationale for the projected flow rate may be found in Appendix 5-3.

The WHPA is made up of a circle with a 100 m radius around the wellheads and the 2, 5, and 25 year times of travel. Results from the numerical model calculated WHPA A through D for Carp are shown in Figure 5-6c. The total size of the Carp WHPAs is 5.7 km^2.

Section 5.3.2 discusses sensitivity analysis in WHPAs. The zones of high and low uncertainty are shown in Figure 5-6d for both WHPA delineation and vulnerability scoring.

5.6.2 Aquifer Vulnerability - Carp Wellhead Protection Area

Once the WHPA is delineated, the aquifer vulnerability is determined using the Intrinsic Susceptibility Index or ISI protocol discussed in Section 5.1.2 without the modification. Briefly, the ISI looks at the thickness and types of soil and rock layers above the aquifer, and how easily water can pass through these layers. The Technical Rules outline the process for categorizing aquifer vulnerability (Low, Medium or High) for the areas within the WHPAs. Figure 5-6e shows the results of the aquifer vulnerability assignment for Carp which is generally consistent with the aquifer vulnerability results for the 'first aquifer' shown in Figure 5-1c.

In Carp, high aquifer vulnerability exists where there is a thin layer of fine sands above the aquifer (close to the municipal wells). Medium aquifer vulnerability exists where there is a thick layer of fine sands above the aquifer (the topographically high area southwest of the Carp Ridge). Medium vulnerability also exists where thin weathered clay overlies the fine sands. Low aquifer vulnerability exists where three metres of weathered clay and a significant thickness of un-weathered clay is above the aquifer, in the lower lying Carp River valley area. This is shown in Figure 5-6e.

Under the Technical Rules, the presence of transport pathways within a WHPA can increase the intrinsic vulnerability. An area with low vulnerability can increase to medium, and an area with medium vulnerability can increase to high. Areas that are already high cannot be increased. The presence, extent and characteristics of water wells, pits and quarries, mines, construction activities, sewer services, septic systems and stormwater infiltration was examined in the WHPA to determine whether adjustments to the vulnerability scoring were justified. The review showed transport pathways in the Carp WHPA did not warrant an increase in intrinsic vulnerability.

5.6.3 Vulnerability Scoring - Carp Wellhead Protection Area

The Technical Rules set out a process for scoring vulnerability within a WHPA. It is based on the combination of aquifer vulnerability and overlapping WHPAs. The more vulnerable the aquifer and the closer the proximity to the well, the higher the vulnerability score.

The table shown in Section 5.5.3 has the scoring system laid out as per the Technical Rules. Possible vulnerability scores are 2, 4, 6, 8, and 10. A score of 10 is highest, indicating an area where drinking water is most vulnerable to contamination. The categories in the table were used to assign vulnerability scores to the areas within the WHPA, shown in Figure 5-6f Carp Wellhead Vulnerability Scoring and Figure 5-6g shows the area in more detail.

5.6.4 Managed Lands and Livestock Density – Carp Wellhead Protection Area

Percent managed land and livestock density calculations were carried out according to the methods outlined in Section 5.3.3. Figure 5-6h shows the managed lands and the livestock density in the WHPAs. The percent managed lands and average livestock densities for each zone are listed in Table 5-7. Note some zones in these tables have two results because the calculation was carried out for each vulnerability score in each WHPA. Also shown in the table is the risk threshold for the over-application of nutrients to land and the risk threshold for the over application of Agricultural Source Material to land as described in Section 5.1.3.

The managed lands evaluation is based on property assessment data and refined using satellite imagery. Site activity, including the level of nutrient application, was not known.

5.6.5 Impervious Surfaces – Carp Wellhead Protection Area

Impervious surfaces are primarily constructed surfaces such as roads and parking lots that are covered by impenetrable materials such as asphalt, concrete and stone. These materials are a barrier to groundwater infiltration. Impervious surfaces also generate more runoff during melt or storm events.

Road salt applied to roads and walkways for winter maintenance may enter surface and groundwater systems. Impervious surface area calculations are required to determine if road salt application in vulnerable areas could be a drinking water threat.

For information on methodology for determining percentage of impervious surfaces please see section 5.1.4 Impervious Surfaces.

The percent impervious surfaces results for each grid within the Carp vulnerable aquifer areas is shown on Figure 5-6i. The results range from 0.5-52%.

5.6.6 Water Quality Threat Assessment - Carp Wellhead Protection Area

Water quality threats are existing conditions (e.g. contaminated sediment, soil or groundwater) or existing or future land use activities that could contaminate a drinking water supply. A land use inventory of the Carp WHPA was completed in 2008.

It should be noted that a single land use activity could fall into multiple threat categories. For example, a crop farm could be storing fuel, applying commercial fertilizer to land, and applying agricultural source material to land. Each of these activities is a separate threat category in the provincial table, and so each is therefore a separate threat.

Land use activities and associated threats that occur where the vulnerability score is high may result in determining it to be a significant threat. In many cases, the specific circumstances that apply to a threat category are unknown. Using the same example, a crop farm may store fuel, but the volume of fuel stored is unknown. Unless additional information was available, it was assumed that enough material was stored for that activity to be a significant threat.

Results of Carp Wellhead Protection Area Water Quality Threat Assessment

A total of 137 potentially significant drinking water threats were identified in the Carp WHPA. For WHPAs, significant threats are where the vulnerability score is 8 or 10, or if the activity pertains to dense non-aqueous phase liquids (DNAPLs), anywhere within the 5-year WHPA C. The potential significant drinking water threats are summarized in Table 5-8. Figure 5-6j shows the areas containing potentially significant threats in red if the vulnerability score is 10 and orange for a vulnerability score of 8. The area containing potentially significant threats is approximately 0.7 km^2. The map also shows the outlines the areas containing potential DNAPL threats with a blue dashed line, an area of approximately 1.0 km^2. See Section 4.4.3 for information on the full list of significant, moderate, and low threats.

Transportation Corridors

A number of transportation corridors, including major road arteries, exist within the Carp WHPA. These corridors are not considered an activity under Clean Water Act definitions and, therefore, do not fall within the prescribed list of threats (see Section 4.3). However, there is potential for the transportation of dangerous and/or hazardous goods along these corridors and the potential for a spill to occur. Transportation corridors will thus be considered in the development of the Source Protection Plan to ensure the protection of groundwater sources from potential accidental spills. Transportation corridors can be found on all WHPA maps including the Carp WHPA map in Figure 5-6c.

5.6.7 Issues and Conditions – Carp Wellhead Protection Area

Issues are documented cases of water quality contamination approaching or exceeding acceptable provincial levels. No issues were identified in the Carp WHPA.

As discussed in Chapter 4, a condition is a situation where past activities resulted in a drinking water threat. Based on the criteria, there are is one confirmed condition in the Carp WHPAs, however there were two potential conditions noted in the Drinking Water Threats and Issues Technical Report.

A historic landfill site was identified in Carp. Available groundwater quality results from the site indicate concentrations of sodium and chloride exceeding MOE Table 2 standards. The property is located within the serviced portion of Carp and, thus, no potable water wells are expected to be located near the former landfill site. Based on the site's location and the available information, it is unlikely to affect wells associated with the municipal drinking water system. Further, no evidence of potential off-site impacts related to the historic landfill was identified. As such, the condition associated with the historic landfill site should be assigned a hazard rating of 6 based on the Technical Rules. Since the vulnerability score for the area is 8, the risk score is 8 x 6 = 48 (risk score = vulnerability score x hazard rating). Thus, the condition is classified as a low drinking water threat.

5.7 Lanark Water Supply

This space is reserved for the future Lanark Municipal Drinking Water Supply.

5.8 Summary of Significant Threats to Wellhead Protection Areas

Municipal groundwater drinking water systems in the MVSPA have a total of 230 potentially significant threats. The number of potentially significant threats for each municipal drinking water system in the MVSPA is summarized in the following table.

Municipal Groundwater Drinking Water System	# Potentially Significant Threats
Almonte	93

Municipal Groundwater Drinking Water System	# Potentially Significant Threats
Carp	137

Table 5-xii. Potentially Significant Threats in the MVSPA.

The results, in further detail, may be found in Table 5-2. Table 5-3 lists potentially significant threats in the MVSPA by category. In the table, ‘The handling and storage of fuel’ category has 193 potentially significant threats, so is the category with the largest number of potentially significant threats in the MVSPA.

Figure 5-8 shows all WHPAs within the MRSPR. Figure 5-9 shows all WHPAs within the MRSPR with vulnerability scores of 8 to 10. For further information on the WHPAs within the RVSPA, shown in Figure 5-8, see the RVSPA Assessment Report.

5.9 References

Dillon Consulting. 2010. Groundwater Drinking Water Threats and Issues.

Golder Associates Ltd. 2003, 2008, 2009. Munster Groundwater Vulnerability Study.

Golder Associates Ltd. 2003, 208, 2009. Richmond-King's Park Groundwater Vulnerability Study.

Golder Associates Ltd. 2003, 2004, 2008. Carp Vulnerability Studies.

Golder Associates Ltd. 2008. Kemptville Groundwater Vulnerability Study.

Golder Associates Ltd. 2008. Merrickville Groundwater Vulnerability Study.

Golder Associates Ltd. 2003. Highly Vulnerable Aquifers.

Intera Engineering Ltd. 2003, 2008, 2009. Almonte Groundwater Vulnerability Study.

Intera Engineering Ltd. 2009. Significant Groundwater Recharge Areas.

Malroz Engineering Incorporated. 2009. Westport Groundwater Vulnerability Study.

Mississippi-Rideau Source Protection Region. 2008. Watershed Characterization.

Ontario Ministry of the Environment. 2009. Proposed Methodology for Calculating Percentage of Managed Land and Livestock Density for Land Application of Agricultural Source of Material, Non-Agricultural Source of Material and Commercial Fertilizers, December 2009.