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5 Groundwater Sources

Introduction

This chapter provides information on groundwater within the Mississippi-Rideau Source Protection Region (MRSPR) and discusses specific municipal drinking water sources for Rideau Valley Source Protection Area (RVSPA). 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 RVSPA.

There are currently five municipal groundwater drinking water systems in the RVSPA. 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 Supply Location	Estimated Number of Users
Kemptville	~~3, 400~~ 5,000
Merrickville	1,000
Munster	1,300
Richmond (King's Park)	450
Richmond Western Development Lands	5,800
Westport	650
Total	**~~6, 800~~ 14, 200**

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

~~All municipal wells in the RVSPA with the exception of the Westport well draw from a combination of the shallow and deep bedrock aquifers. The Kemptville and Merrickville systems are undergoing well casing modifications so that water is drawn solely from the deep aquifer. The Kemptville well casing modifications were completed in May 2011, and the Merrickville well casing modifications were completed in November 2011 1.~~ Westport draws water from one bedrock aquifer. All delineated wellhead protection areas (WHPAs) in the MRSPR are shown in Figure 5-10. Figure 5-11 shows all WHPAs with a vulnerability score of 8-10.

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 RVSPA are discussed in Chapter 6.

Summary of Key Findings

There are 782 potentially significant drinking water threats identified in RVSPA wellhead protection areas. Summary information on key findings can be found in Table 5-1. Table 5-2 is a summary of the potentially significant threats, organized into drinking water threat categories.

Drinking water issues in the RVSPA have been identified in non-municipal drinking water in Cranberry Estates and Beckwith. 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
Managed Lands and Livestock Density, 2010	Dillon Consulting	not peer reviewed
Kemptville Managed Lands and Livestock Density, 2019	Dillon Consulting	not peer reviewed
Merrickville Managed Lands and Livestock Density, 2019	Dillon Consulting	not peer reviewed
King's Park, Richmond and Munster Hamlet Managed Lands and Livestock Density, 2018	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
Kemptville Groundwater Vulnerability Study, 2008	Golder Associates Ltd.	Malroz Engineering Incorporated
Vulnerability Study for the North Grenville and Merrickville Water Supply, 2019	Golder Associates Ltd.	Dillon Consulting
Revised Kemptville and Merrickville Groundwater Vulnerability, Threats Assessment, Managed Lands and Livestock	BluMetric Environmental	Dillon Consulting

Density Report, 2021		
Merrickville Groundwater Vulnerability Study, 2008	Golder Associates Ltd.	Malroz Engineering Incorporated
Munster Groundwater Vulnerability Study, 2003, 2008, 2009	Golder Associates Ltd.	TAG, Intera Engineering Ltd.
Richmond – King's Park Groundwater Vulnerability Study, 2003, 2008, 2009	Golder Associates Ltd.	TAG, Intera Engineering Ltd.
Consolidated Groundwater Vulnerability Study, Richmond Village, Kings Park and Munster Well Systems, 2018	Golder Associates Ltd.	Dillon Consulting
Westport Groundwater Vulnerability Study, 2009	Malroz Engineering Incorporated	Golder Associates 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.

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:

- William D. Hogg, Reach Consulting, Hydrometerologist
- 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 by interpolating 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.

High Vulnerability	ISI < 30
Medium Vulnerability	ISI > 30 and <80
Low Vulnerability	ISI > 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 ISI approach mapped bare rock, rock covered with less than 1.5 m 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, 5.6.2, 5.7.2, 5.8.2, and 5.9.2. 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 in the MVSPA as well as the Rideau River Valley and the eastern portion of Ottawa in the RVSPA.

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, 3631 km^2 in the RVSPA. 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 5-4. 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 reduced.

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.
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 across the region. One is situated in both the MVSPA and RVSPA and one occurs in the RVSPA. The identified non-municipal groundwater drinking water issues may affect some domestic and private wells in those communities. Table 5-3 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 in the RVSPA

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.

Cranberry Estates Groundwater Contamination

Since 1984, multiple studies have been performed in this subdivision located immediately west of Kemptville. These studies showed between 32 and 83% of private wells contained coliform bacteria (including 10% of wells with *E. coli*) and between 10 and 20% of homes had nitrate concentrations above the ODWS (10 mg/L). The elevated concentrations of nitrate and bacteria are likely attributed to septic loading, and are considered to represent anthropogenic drinking water issues. The location and approximate extent of the Cranberry Estates 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 5-3.

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 Rideau Valley Source Protection Area Terms of Reference, the circumstances presented in Table 5-3 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 (SGRA). It should be noted that SGRA studies, like HVA studies, were done on a regional scale.

5.2.1 What are Significant Groundwater Recharge Areas?

A 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 recharge 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 and 721 km^2 in THERVSPA. 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 5.10 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. WHPA-A is the area immediately surrounding the well. WHPAs B, C and D are delineated by Time of Travel (ToT).

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 RVSPA were GUDI wells. Therefore, WHPA-E and WHPA-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 WHPAs 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) WHPAs 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 cited at the beginning of this Section.

5.4 Wellhead Protection Areas in the Rideau Valley Source Protection Area

There are currently five municipal groundwater-based drinking water protection systems in the RVSPA. The following table shows the systems' full names, with the name they are generally referred to following.

Municipal Drinking Water Groundwater Systems as per Terms of Reference	Referred to as:
Kemptville Well Supply	Kemptville
Merrickville Well Supply	Merrickville
Munster Hamlet Well Supply	Munster
King's Park Well Supply	Richmond - King's Park or King's Park
Richmond Western Development Lands	Richmond Western Development Lands
Westport Well Supply	Westport

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

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.

5.4.1 Summary of Amendments

The Assessment Report for the Rideau Valley Source Protection Area (RVSPA) was approved by the Ministry of the Environment, Conservation and Parks (MECP) on December 19, 2011. Chapter 5 of the RVSPA Assessment Report is entitled 'Groundwater Sources' and it provides information on groundwater within the Mississippi-Rideau Source Protection Region (MRSPR), including specific information about each of the groundwater-based municipal drinking water systems in the RVSPA.

The Clean Water Act enables Source Protection Plans and Assesment Reports to be revised using one of four methods:

1. a locally initiated amendment under section 34;
2. a Minister ordered amendment under section 35;
3. an update resulting from the review under section 36; or
4. an amendment under section 51 of O. Reg. 287/07 for minor/administrative revisions.

A description of the amendments are below. None of the other chapters have been updated at this time, however, the following summary figures have been updated:

- All wellhead protection areas within the MRSPR (Figure 5-10)
- All wellhead protection areas within the MRSPR with a vulnerability score of 8-10, including DNAPL zone (Figure 5-11)
- All wellhead protection areas and Intake Protection Zones within the MRSPR (Figure 5-12)

Amendment Number	**System**	**Municipality**	**Description**	**Approval Date**
1	Richmond West	City of Ottawa	New well Impacted WHPAs in Kings Park and Munster	March 11, 2019
2	Kemptville	North Grenville	New well- North East Quadrant Impacted WHPAs in Kemptville and Merrickville	May 21, 2021
3	Kemptville	North Grenville	New well— North Western Quadrant	Pending Approval

5.5 Kemptville Water Supply

The Town of Kemptville obtains its drinking water from ~~four~~ five municipal wells, shown in Figure 5-5a, which draws water from the Nepean Formation sandstone. The ~~four~~ five wells are drilled to depths between 62 and 110 m below ground surface. The wells have casing down to the Oxford Formation (above the Nepean Formation) and are open holes in the Oxford and Nepean Formations. The groundwater system supplies approximately 5,000 people.

The local geology in the Kemptville area consists of a thin overburden layer (less than two metres) in the western half of the area around Kemptville, while in the eastern half, local areas of increased overburden thickness are present (i.e. up to approximately 20 m). The overburden material consists primarily of glacial till deposits, offshore marine clay deposits and near shore fine to medium sand deposits.

The overburden material is underlain by sedimentary rocks of Paleozoic age. The sequence of sedimentary rocks underlying the area is (from oldest/deepest to youngest/shallowest) is Nepean Formation (sandstone), March Formation (sandstone/dolostone) and Oxford Formation (limestone/dolostone).

The Kemptville water system produces high-quality groundwater, the parameters that are tested for have been extremely stable across the testing period. Total coliform bacteria are detected rarely in raw water samples. Any Total Coliform present in the raw water is removed by disinfecting the water via Sodium Hypochlorite and adequate contact time. E.Coli is never detected in the raw or treated water samples.

Hardness and sodium concentrations are typical of the Nepean formation, the average hardness across the ~~four~~ five wells is around 310 mg/L. Typical sodium concentrations range between 30 – 40 mg/L at all wells. 20 mg/L is the advisory limit set by the MOE above which the operator must notify the MOE and the Health Department to protect individuals on sodium reduced diets. Sodium does not exceed any other benchmark, nor does it have human health effects except in a small number of cases that are considered in the advisory limit.

Private wells in the Kemptville area generally obtain water from a bedrock aquifer within the Oxford and March Formations.

In December 2010, the Municipality of North Grenville received funding from the Ontario Drinking Water Stewardship Program to extend the well casing of 3 of Kemptville's municipal drinking water wells (with the exception of the East Quadrant well, which was constructed later). The purpose of the well casing extension project is to ensure that the wells do not draw water from the shallow aquifer, and instead rely only on the deep aquifer. Well casing extensions into the deep aquifer provide an immediate and a cost effective action to reduce the wellhead protection area itself, and reduces the number of properties that would constitute significant threats. The work was completed in April 2011.

5.5.1 Delineation of Kemptville 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. Figures 5-5e show the results of the aquifer vulnerability assignment for Kemptville's WHPA.

5.5.2 Aquifer Vulnerability - Kemptville 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. Figures 5-5e show the results of the aquifer vulnerability assignment for Kemptville's WHPA.

The aquifer vulnerability is generally low because the Nepean aquifer is well protected from the overlying Oxford aquifer, except for some small areas near the northern boundary of the WHPA which is medium as the Nepean aquifer gets closer to the ground surface.

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 on Figure 5-5e, ~~twelve~~ nine areas were identified where transport pathways increase the risk to the aquifer. The transport pathways are due to the presence of aggregate extraction operations. In each case, the vulnerability was increased from low to medium vulnerability because the aggregate extraction reduces the amount of overlying material to filter and/or attenuate contaminants.

5.5.3 Vulnerability Scoring - Kemptville 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 you are 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 (Figure 5-5f and 5-5g).

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

5.5.4 Managed Lands and Livestock Density – Kemptville Wellhead Protection Area

Percent managed land and livestock density calculations were carried out according to the methods outlined in Section 5.3.3. Figures 5-5h show 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 5-4. 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.

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

5.5.5 Impervious Surfaces – Kemptville 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 Kemptville vulnerable aquifer areas is shown on Figure 5-5i. The results range from 0 to 88%.

5.5.6 Water Quality Threat Assessment - Kemptville Wellhead Protection Area

Water quality threats are existing conditions (i.e. 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 Kemptville WHPA was completed in 2009.

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.

Table 5-7-7 demonstrates where the 22 prescribed activities are a significant threat. Moreover, the Threats Tool, which is a searchable database can be used to identify which of the prescribed threat activities would be a significant threat in the applicable vulnerability scores shown in Figure 5-5f. It is publicly accessible and can be found at the following link http://swpip.ca/. Information from the Threats Tool can be exported into a spreadsheet that can then be sorted either by threat status or vulnerability score. This tool could be used, along with the maps of vulnerability scores, to understand where the 22 prescribed activities are a significant drinking water threat.

Results of Kemptville Wellhead Protection Area Water Quality Threat Assessment

In the Rideau Valley Source Protection Area Assessment Report (2011), a total of 105 potentially significant drinking water threats were identified in the Kemptville WHPA. As of 2019, this number has been further refined to 50 existing and new threats. For the Kemptville WHPA, significant threats are where the vulnerability score is 10 (as there are no 8 scores), 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 5-5. Figure 5-5j shows the areas containing potentially significant threats in red (the vulnerability score is 10). The area containing potentially significant threats is approximately 0.16 km2. The map also outlines the areas containing potential DNAPL threats with a blue dashed line, an area of approximately ~~75~~ 92.6 km2. See Section 4.4.3 and Figure 5-5j 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 Kemptville 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 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 Kemptville WHPA map in Figure 5-5d.

5.5.7 Issues and Conditions – Kemptville Wellhead Protection Area

As discussed in Chapter 4, issues are documented cases of water quality contamination approaching or exceeding acceptable provincial levels. No issues were identified in the Kemptville WHPA.

A condition is a situation where past activities resulted in a drinking water threat. Based on the criteria, there are no confirmed conditions in the Kemptville WHPAs. However, in the Rideau Valley Source Protection Area Assessment Report (2011), there were six potential conditions noted in the Drinking Water Threats and Issues Technical Report.

5.6 Merrickville Water Supply

The Village of Merrickville obtains its drinking water from three municipal wells as shown in Figure 5-6a. Well 1, Well 2 and Well 4 are completed at 35, 49 and 50 m below ground surface, respectively. Well 3 was decommissioned in 2002. All three wells are completed in the Nepean Formation sandstone. The groundwater system supplies water for 1,000 people in Merrickville.

The local geology in the Merrickville area consists of a thin overburden layer (i.e. less than two metres) in the western half of the area around Merrickville, while in the eastern half, local areas of increased overburden thickness are present (i.e. up to approximately 20 m). The overburden material consists primarily of glacial till deposits, offshore marine clay deposits and near shore fine to medium sand deposits.

The overburden material is underlain by sedimentary rocks of Paleozoic age. The sequence of sedimentary rocks underlying the area is (from oldest/deepest to youngest/shallowest) is Nepean Formation (sandstone), March Formation (sandstone/dolostone) and Oxford Formation (limestone/dolostone).

The groundwater has been characterized as having elevated hardness and iron, which do not pose health risks. Elevated turbidity and colour have also been detected in the water, but these are not health risks. The source water has no chemical contaminants. Total coliform bacteria were found periodically between 2003 and 2006. However, E. coli has not been detected in the groundwater, and total coliforms are removed during water treatment.

Private wells in the Merrickville area generally obtain water from a bedrock aquifer within the Oxford and March Formation.

In December 2010, the Village of Merrickville-Wolford received funding from the Ontario Drinking Water Stewardship Program to extend the well casing of all 3 of Merrickville's municipal drinking water wells. The purpose of the well casing extension project is to ensure that the wells do not draw water from the shallow aquifer, and instead rely only on the deep aquifer. Well casing extensions into the deep aquifer provide an immediate and a cost effective action to reduce the wellhead protection area itself, and reduces the number of properties that would constitute significant threats. The work was completed in November 2011.

5.6.1 Delineation of Merrickville Wellhead Protection Area

In addition to the Water Well Information System, geologic and hydrologic data were also obtained from previous studies carried out in the Merrickville area. Also, geologic and hydrologic data was obtained from provincial and federal studies. These data were used to create the conceptual hydrogeological model for Merrickville. Furthermore, observation wells were 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 wells descend through surface layers of clay and glacial till, then through the upper aquifer (the Oxford/March formations), before arriving at the deep Nepean aquifer. Precambrian bedrock lies below the Nepean aquifer. Groundwater from the Oxford/March formation and the Nepean Formation enters the Merrickville wells.

Regionally, groundwater flow in the deep Nepean aquifer is from west to east. Locally, in the Town of Merrickville, groundwater flow in the shallow Oxford and March Formations is from the south and west.

The Merrickville WHPAs were delineated using a forecasted combined flow rate for the three wells of 520 m3/day. This flow rate is slightly greater than the five year average flow rate of 515 m3/day presented in Table 2-17 of Chapter 2.

The numerical model calculated WHPA A through D for the Merrickville system for the aquifer systems. Figure 5-6c shows the Merrickville wellhead protection areas around the municipal wellheads. It is made up of a circle with a 100 m radius around the wellheads and the 2, 5, and 25 year times of travel. The total area of the Merrickville WHPAs is approximately ~~160~~ 182.6 km2.

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

5.6.2 Aquifer Vulnerability - Merrickville 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. Figures 5-6e show the results of the aquifer vulnerability assignment, for the Merrickville WHPA.

The aquifer vulnerability is generally low because the Nepean aquifer is well protected from the overlying Oxford aquifer, except for some small areas near the northwest boundary of the WHPA which is medium as the Nepean aquifer gets closer to the ground surface.

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 on Figure 5-6f, ~~eight~~ six areas were identified where transport pathways increase the risk to the aquifer. The transport pathways are due to the presence of aggregate extraction operations. In each case, the vulnerability was increased from low to medium or medium to high vulnerability because the aggregate extraction reduces the amount of overlying material to filter and/or attenuate contaminants.

5.6.3 Vulnerability Scoring - Merrickville 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 you are 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 (Figures 5-6f and 5-6g).

5.6.4 Managed Lands and Livestock Density – Merrickville 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 show 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 5-6. 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.

The data for the managed lands evaluation was 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 – Merrickville 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 Merrickville vulnerable aquifer areas are shown on Figure 5-6i. The results range from 0 to ~~88~~ 46%. ~~The higher values found in this area are attributed to the Town of Smiths Falls.~~

5.6.6 Water Quality Threat Assessment - Merrickville Wellhead Protection Area

Water quality threats are existing conditions (i.e., 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 Merrickville WHPA was completed in 2009.

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.

Table 5-7 demonstrates where the 22 prescribed activities are a significant threat. Moreover, the Threats Tool, which is a searchable database can be used to identify which of the prescribed threat activities would be a significant threat in the applicable vulnerability scores shown in Figure 5-6f. It is publicly accessible and can be found at the following link http://swpip.ca/. Information from the Threats Tool can be exported into a spreadsheet that can then be sorted either by threat status or vulnerability score. This tool could be used, along with the maps of vulnerability scores, to understand where the 22 prescribed activities are a significant drinking water threat.

Results of Merrickville Wellhead Protection Area Water Quality Threat Assessment

Results of Merrickville Wellhead Protection Area Water Quality Threat Assessment

In the Rideau Valley Source Protection Area Assessment Report (2011), a total of 24 potentially significant drinking water threats were identified in the Merrickville WHPA. As of 20~~19~~21, this number has been further refined to ~~5~~ 1 existing threats. For the Merrickville WHPA, significant threats are where the vulnerability score is 10 (as there is no 8 scores), 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 5-7. Figure 5-6j shows the areas containing potentially significant threats in red (the vulnerability score is 10). The area containing potentially significant threats is approximately 0.04 km2. The map also outlines the areas containing potential DNAPL threats with a blue dashed line, an area of approximately ~~57~~ 32.6 km2. See Section 4.4.3 and Figure 5.6j 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 Merrickville 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 Merrickville WHPA maps in Figures 5-6c and 5-6d.

5.6.7 Issues and Conditions – Merrickville Wellhead Protection Area

As discussed in Chapter 4 issues are documented cases of water quality contamination approaching or exceeding acceptable provincial levels. A condition is a situation where past activities resulted in a drinking water threat. No issues or conditions were identified in the Merrickville WHPA.

5.7 Munster and Richmond Water Supplies

Munster

Munster Hamlet obtains its drinking water from two municipal wells as shown in Figure 5-7-1a. The Munster water supply system currently serves the entire Hamlet and obtains its water supply from two bedrock aquifer wells: Munster

Well No. 1 (MW1) and Munster Well No. 2 (MW2). MW1 and MW2 are completed to a depth of 116 m and 122 m, respectively. Both wells are completed in the Nepean Formation sandstone. The groundwater system supplies approximately 1,300 people.

The local geology in the Munster area consists of limited overburden material (less than five metres) made up of sandy till. The overburden material is underlain by sedimentary rocks of Paleozoic age. The sequence of sedimentary rocks underlying Munster (from oldest/deepest to youngest/shallowest) is Nepean Formation (sandstone), March Formation (sandstone/dolostone) and Oxford Formation (limestone/dolostone).

The source water has a moderately high level of hardness (270 mg/L). The groundwater contains a small amount of free ammonia (0.11 mg/L), and fluoride is present at a concentration of approximately 0.60 mg/L. In addition, there is a measurable concentration of bromide (0.22 mg/L) that occurs naturally in the geology. The presence of bromide results in a higher proportion of brominated compounds in the disinfection by-products for this system. The source water also contains iron at a concentration ranging from 0.15 – 0.65 mg/L, which at times is above the aesthetic guideline of 0.3 mg/L. Iron can be oxidized during chlorination and can at times result in rust or iron deposits in the water distribution system. Most importantly, routine bacteriological testing over many years have demonstrated that both Well No.1 and No.2 are clear from the presence of Total coliform or E. coli bacteria.

Private wells in the Munster area generally obtain water from a bedrock aquifer within the Oxford and March Formations.

Richmond

There are two communities in the Village of Richmond who are supplied with municipal drinking water. These are referred to as King's Park and the Western Development Lands. Each community obtains their drinking water from two municipal wells (four wells in total) as shown in Figures 5-7-2a and 5-7-3a. Details about each of the well systems is provided below.

The local geology in the Richmond area consists of limited overburden material (less than five metres) made up of clay material. The overburden material is underlain by sedimentary rocks of Paleozoic age. The sequence of sedimentary rocks underlying Richmond (from oldest/deepest to youngest/shallowest) is Nepean Formation (sandstone), March Formation (sandstone/dolostone) and Oxford Formation (limestone/dolostone).

Private wells in the Richmond area generally obtain water from a bedrock aquifer within the Oxford and March Formations.

King's Park

The King's Park Water Supply System consists of two bedrock wells, Well No. 1 (RW1) and Well No. 2 (RW2), which are both approximately 45 years old. RW1 and RW2 are completed to a depth of 66 and 61 m, respectively. The wells penetrate the Oxford and March formations and are completed as open holes in the underlying Nepean Formation sandstone. Two monitoring wells are also present and their locations are shown on Figure 5-7-2a. The groundwater system supplies approximately 450 people.

The source water has a moderately high level of hardness (340 mg/L). The groundwater contains a slight amount of ammonia (0.08 mg/L), and fluoride is present at a concentration of approximately 0.45 mg/L. In addition, there is a substantial concentration of bromide (0.43 mg/L) that occurs naturally in the geology. The presence of bromide results in a higher proportion of brominated compounds in the disinfection by-products for this system. The source water also contains iron at a concentration of 0.4 mg/L, which is above the aesthetic guideline of 0.3 mg/L. Iron can be oxidized during chlorination and can at times result in rust or iron deposits in the water distribution system. Most importantly, routine bacteriological testing over many years have demonstrated that both Well No.1 and No.2 are clear from the presence of Total coliform or E. coli bacteria.

Western Development Lands

The Western Development Lands Water Supply System, also referred to as 'Richmond West Water Supply System', consists of two bedrock wells, Well No. 1 (PW08-1) and Well No. 2 (PW09-1), which were both drilled in 2009. PW08-1 and PW09-1 are completed to a depth of 137 m and 70 m, respectively. The wells penetrate the Oxford and March formations and are completed as open holes in the underlying Nepean Formation sandstone. The groundwater system will supply approximately 5,800 people.

Based on sampling done to assess treatability, prior to construction of the new well system, the source water was found to have a moderately high level of hardness (310 mg/L). The source water also contains iron at a concentration of 0.23 mg/L, which is slightly below the aesthetic guideline of 0.3 mg/L. No Total Coliform or E. coli indicator bacteria were detected in any of the samples taken.

5.7.1 Delineation of Munster and Richmond Wellhead Protection Area

The basic methodology for delineating each WHPA is provided in Section 5.3.2 of the approved RVSPA Assessment Report. In addition to the Water Well Information System, geologic and hydrologic data were also obtained from previous studies carried out in the Munster and Richmond areas. Also, geologic and hydrologic data was obtained from provincial and federal studies. These data were used to create the conceptual hydrogeological model for Munster and Richmond.

A cross-section for the conceptual model is shown in Figure 5-7-1b. The wells descend through surface layers of clay and glacial till, then through the upper aquifer (the Oxford/March formations), before arriving at the deep Nepean aquifer. Precambrian bedrock lies below the Nepean aquifer. Groundwater from the Oxford/March formation and the Nepean Formation enters the Munster and King's Park wells. Therefore, WHPA analyses were carried out for shallow (Oxford/March) and deep (Nepean) groundwater systems. A deeper well casing was installed in the Richmond West wells to prevent Oxford/March formation groundwater from entering the wells. As such, there is only one set of WHPAs for the Richmond West wells.

An independent third-party peer review was carried out for each modeling study to ensure the approach used was accepted by other groundwater experts.

Regionally, groundwater flow in the deep Nepean aquifer is from the northwest. Locally, groundwater flow in the overlying Oxford and March Formations is from the northwest.

The WHPAs were delineated using the following flow rates:

Munster - A combined flow rate for the two wells of 443 m3/day.

King's Park –A forecasted combined flow rate for the two wells of 210 m3/day.

Richmond West – A forecasted combined flow rate for the two wells of 1,630 m3/day which is the anticipated average water demand for the development at full build out.

The numerical model was used to calculate WHPA A through D for each of the Munster and Richmond water supplies, including both the shallow and deep aquifer systems for Munster and King's Park. The Munster (shallow/deep) WHPA zones are shown in Figures 5-7-1c & 5-7-1d; the King's Park WHPA zones are shown in Figures 5-7-2b & 5-7-2c; and the Richmond West WHPA zones are shown in Figure 5-7-3b.

As previously discussed in the approved Assessment Report, the Technical Rules require that levels of uncertainty associated with 1) the delineation of new WHPAs, and 2) their assigned vulnerability scores. The approach applied is described in Section 5.3.2 of the approved RVSPA Assessment Report and includes:

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) WHPAs 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 uncertainty method applied by the Consultant for the Western Development Lands, Munster and Kings Park systems determined that the areas of low uncertainty coincide with the two-year time of travel (TOT). The remaining areas within the WHPAs were mapped as high uncertainty. This was a decision made using professional judgement, as per Appendix 6C in the guidance document.

The decision to assign the areas of low uncertainty to that contained within the two-year TOT capture zone was based on the following, as described in the Peer Review Correspondence (Appendix A) of the Groundwater Vulnerability Study (November 2018):

- High quality data in the form of pumping test information was available near the wells. The data included monitoring well response in both the upper and lower aquifers. This information provided relatively high confidence that the conceptual model correctly represented the aquifer flow systems in the area, as the model was calibrated to the data;

- Considering the relatively low quality and density of data beyond the two-year time of travel (WHPA-B) as compared to that near the wells, the WHPA-C and WHPA-D zones were assigned high uncertainty.

The Munster (shallow/deep) zones of high and low uncertainty are shown in Figures 5-7-1e & 5-7-1f; the Richmond-King's Park zones of high and low uncertainty are shown in Figures 5-7-2d & 5-7-2e; and the Richmond West zones of high and low uncertainty are shown in Figure 5-7-3c.

5.7.2 Aquifer Vulnerability - Munster and Richmond Wellhead Protection Area

Once the WHPAs are delineated, the aquifer vulnerability is determined using the Intrinsic Susceptibility Index or ISI protocol without the modification, as discussed in Section 5.1.2 of the approved RVSPA Assessment Report. 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 to the production aquifer. The Technical Rules outline the process for categorizing aquifer vulnerability (Low, Medium or High) for the areas within the WHPAs.

Figures 5-7-1g and 5-7-1h show the results of the aquifer vulnerability study for the Munster (shallow/deep) WHPA Zones. For the shallow aquifer, the aquifer vulnerability is medium and high. The medium vulnerability is a result of overburden deposits of sand and gravel, glacial till and organic deposits. The high vulnerability is a result of bedrock outcrop areas. For the deep aquifer, the aquifer vulnerability is generally low because the Nepean aquifer is well protected from the overlying Oxford/March Formation aquifers.

Figures 5-7-2f and 5-7-2g show the results of the aquifer vulnerability study for the King's Park (shallow/deep) WHPA Zones. For the shallow aquifer, the aquifer is characterized by mostly medium vulnerability, with some high vulnerability. The area is underlain by clay deposits ranging from about 4 to 8 metres in thickness above the bedrock, with the upper three metres assumed to be weathered clay. The high vulnerability areas are found where the clay thickness is not greater than 4 metres. For the deep aquifer, the aquifer vulnerability is generally low because the Nepean aquifer is well protected from the overlying Oxford/March Formation aquifers.

Figure 5-7-3d shows the results of the aquifer vulnerability study for the Richmond West. The aquifer vulnerability is generally low because the Nepean aquifer is well protected from the overlying Oxford/March Formation aquifers.

As set out in 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. As per the Dillon Consulting Limited 'Drinking Water Threats & Issues Inventory', dated May 2010, 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 transport pathway adjustments discussed below are based on Dillon's report recommendations.

As shown on Figure 5-7-1g, two areas were identified where transport pathways increase the risk to the Munster shallow aquifer. One area, located in the centre of Munster, was raised from medium to high vulnerability because the cumulative impacts of the elevated well density, commercial land use, and the presence of sewer services. In another area, just west of the centre, the vulnerability was increased from medium to high because of the presence of surface water ponds. The till overburden in the pond area is estimated to have a thickness of less than 5 m; thus, these ponds may be resulting in a significant reduction in the overburden thickness. As shown on Figure 5-7-1h, five areas were identified for the Munster deep aquifer. Vulnerabilities were increased from low to medium because of the presence of bedrock quarries because they reduce the amount of overlying material to filter and/or attenuate contaminants.

As shown on Figure 5-7-2g, one area where transport pathways increase the risk to the Richmond King's Park deep aquifer was identified. The vulnerability was raised in this area from low to medium because of a bedrock quarry which reduces the amount of overlying material to filter and/or attenuate contaminants. For the Richmond King's Park shallow aquifer, no transport pathways that warranted an increase in intrinsic vulnerability were identified.

As shown on Figure 5-7-3d, ten areas were identified for the Richmond West aquifer. Vulnerabilities were increased from low to medium because of the presence of bedrock quarries because they reduce the amount of overlying material to filter and/or attenuate contaminants.

5.7.3 Vulnerability Scoring - Munster and Richmond 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 you are to the well, the higher the vulnerability score. The table shown below 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.

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

The categories in the table above were used to assign vulnerability scores to the areas within the Munster and Richmond WHPAs.

Figures 5-7-1i and 5-7-1j show the vulnerability scoring for the Munster (shallow/deep) WHPA Zones. Figure 5-7-1k shows the combined vulnerability score for the Munster shallow and deep WHPA zones (highest vulnerability score).

Figures 5-7-2h and 5-7-2i show the vulnerability scoring for the King's Park (shallow/deep) WHPA Zones. Figures 5-7-2j and 5-7-2k show the combined vulnerability score for the King's Park shallow and deep WHPA zones (highest vulnerability score).

Figures 5-7-3e and 5-7-3f show the vulnerability scoring for the Richmond West WHPA Zones.

The final vulnerability scoring for the combined Munster Richmond WHPA is based on the highest of the combined vulnerability scores and is shown in Figure 5-7-4a.

5.7.4 Managed Lands and Livestock Density – Munster and Richmond Wellhead Protection Area

Percent managed land and livestock density calculations were carried out according to the methods outlined in Section 5.3.3 of the approved RVSPA Assessment Report.

Figures 5-7-1m and 5-7-1n and Table 5-7-1 show the managed lands and the livestock density for the Munster (shallow/deep) WHPA Zones. 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.

Figures 5-7-2l and 5-7-2m and Table 5-7-3 show the managed lands and the livestock density for the King's Park (shallow/deep) WHPA Zones. 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.

Figure 5-7-3g and Table 5-7-5 show the managed lands and the livestock density for the Richmond West WHPA Zones. 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.

Based on the managed lands and livestock density results for Munster, King's Park and Richmond West, it is concluded that there can be significant threats for the application of agricultural source material to land, the application of commercial fertilizer to land, or the application of non-agricultural source material to land.

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

5.7.5 Impervious Surfaces – Munster and Richmond 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 of the approved RVSPA Assessment Report.

The percent impervious surfaces results for each grid within the Munster Richmond WHPA zones is shown on Figure 5-7-4b. Within the village boundaries of Munster and Richmond, the percent impervious surface is either 1 to 8 or 8 to 80. There are no impervious areas greater than 80%.

5.7.6 Water Quality Threat Assessment - Munster and Richmond Wellhead Protection Area

Water quality threats are existing conditions (i.e., contaminated sediment, soil or groundwater) or existing or future land use activities that could contaminate a drinking water supply.

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 Munster and Richmond Wellhead Protection Area Water Quality Threat Assessment

A total of 64 potentially significant drinking water threats were identified in the Munster and Richmond WHPAs, of which 42 are related to sanitary sewer line segments. For WHPAs, this is 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 shown in Tables 5-7-2, 5-7-4 and 5-7-6. Figures 5-7-4c shows the areas containing potentially significant threats in red if the vulnerability score is 10 and orange for a vulnerability score of 8. See Section 4.4.3 of the approved RVSPA Assessment Report for information on the full list of significant, moderate, and low threats. The significant threat counts were determined based on the threats assessment study carried out by Golder Associates Ltd. for this study as well as on-going threats assessment work being carried out by the staff from the Rideau Valley Source Protection Authority.

Table 5-7-7, demonstrates where the 22 prescribed activities are a significant threat. Moreover, the Threats Tool, which is a searchable database can be used to identify which of the prescribed threat activities would be a significant threat in the applicable vulnerability scores shown in Figure 5-7-4c. It is publicly accessible and can be found at the following link http://swpip.ca/. Information from the Threats Tool can be exported into a spreadsheet that can then be sorted either by threat status or vulnerability score. This tool could be used, along with the maps of vulnerability scores, to understand where the 22 prescribed activities are a significant drinking water threat.

5.7.7 Issues and Conditions – Munster and Richmond Wellhead Protection Area

As discussed in Chapter 4 of the approved RVSPA Assessment Report, issues are documented cases of water quality contamination approaching or exceeding acceptable provincial levels. No issues were identified in the Munster and Richmond WHPA zones.

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

5.8 Westport Water Supply

Westport obtains its drinking water from two municipal wells, Well 2 and Well 3 shown in Figure 5-9a, which draw groundwater from the March/Nepean aquifers. The wells are 34 m and 40 m deep respectively and were constructed in 1969 and 2003, respectively. Municipal staff has confirmed that there is no connection between a surface water source and the groundwater flow system that feeds Well 2 and Well 3 at the Westport Well Field. The groundwater supplies approximately 650 people in the village.

The Westport area has rugged terrain with an elevation change of about 75 m. The Village is situated between Big Rideau Lake to the east, Westport Pond to the north and Westport Sand Lake to the west. Within the Village itself, clay soils lie over the March/Nepean aquifer, with sand and/or exposed bedrock over the highlands to the west. Although the March/Nepean aquifer provides the source water for the Village of Westport, the aquifer is localized and is not present just to the north, south and west. Precambrian (Canadian Shield) bedrock is present north, south and west of Westport. Private wells in the greater Westport area may draw water from a variety of different aquifers, such as the March/Nepean or Precambrian aquifer.

Prior to the decommissioning of Well 1, both Well 1 and Well 2 raw water detections of *E. coli* bacteria were common. Following abandonment of Well 1, detection of *E. coli* in Well 2 was infrequent and at lower levels. Treated water has not identified the presence of *E. coli* or total coliform bacteria. Treatment system upgrades are currently being implemented.

Sodium concentrations were 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 Department to protect individuals on sodium-reduced diets. Sodium does not exceed the Ontario Drinking Water Standards – Operational Guideline Aesthetic Objective of 200 mg/L, nor does it have human health effects except in a smaller number of cases that are considered in the advisory limit. The water has high hardness and alkalinity, which do not pose health risks.

5.8.1 Delineation of Westport Wellhead Protection Area

A cross-section for the conceptual model is shown in Figure 5-9b. The cross-section shows the clay till layer that lies near the ground surface at the location of municipal well MW 3 (in the Village itself). Note the thick clay till layer does not extend throughout the entire Village. Continuing to the southwest, the March/Nepean aquifer is much closer to surface with limited sand cover and/or exposed bedrock. The amount groundwater supplied from the clay/till to the Westport well is considered to be small. Therefore, only the deep groundwater system (March/Nepean aquifer) is considered for this WHPA. An independent third party peer review ensured the approach was accepted by other groundwater experts.

Regionally, the groundwater flow is from the southwest.

The Westport WHPAs were delineated using a forecasted combined flow rate for the two wells of 428 m^3/day. This flow rate is greater than the five year average flow rate of 365 m^3/day presented in Table 2-17 found in Chapter 2. The forecasted flow rate was chosen based on municipal growth projections. The numerical model calculated WHPA A through D for the Westport system (Figure 5-9c). It is made up of a circle with a 100 m radius around the wellheads and the 2, 5, and 25 year times of travel. As indicated on Figure 5-9c, a small area of the WHPA-D, approximately 0.3 km^2, is located within the Cataraqui Source Protection Area. The total area of the Westport WHPAs is 3.3 km^2.

Section 5.3.2 discusses sensitivity analysis in WHPAs. The zones of high and low uncertainty are shown in Figure 5-9d for both WHPA delineation and vulnerability scoring.

5.8.2 Aquifer Vulnerability - Westport 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 5-9e shows the results of the aquifer vulnerability assignment for the 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.

The majority of the WHPA is classified as medium vulnerability with some areas of high vulnerability. The medium and high vulnerability is the result of generally thin overburden cover.

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 on Figure 5-9e, a bedrock quarry was identified southeast of the intersection of Concession 8 and Salem Road in the Westport WHPA where transport pathways increase the risk to the March/Nepean aquifer. The aquifer vulnerability was increased from low and medium to medium and high for the area near the quarry.

5.8.3 Vulnerability Scoring - Westport 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 you are to the well, the higher the vulnerability score.

The table in Section 5.5.3 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. The categories in the table were used to assign vulnerability scores to the areas within the WHPA (Figures 5-9f and 5-9g).

5.8.4 Managed Lands and Livestock Density – Westport Wellhead Protection Area

Percent managed land and livestock density calculations were carried out according to the methods outlined in Section 5.3.3. Figure 5-9h 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 5-12. 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 ASM to land.

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

5.8.5 Impervious Surfaces – Westport 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 Westport vulnerable aquifer areas is shown on Figure 5-9i. The results range from 0-37%.

5.8.6 Water Quality Threat Assessment - Westport Wellhead Protection Area

Water quality threats are existing conditions (i.e. 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 Westport WHPA was completed in 2009.

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 Westport Wellhead Protection Area Water Quality Threat Assessment

A total of 51 potentially significant drinking water threats were identified in the Westport WHPA. For WHPAs, this is 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 5-13. Figure 5-9j 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 0.6 km^2. The map also shows the outlines of the areas containing potential DNAPL threats with a blue dashed line, an area of approximately 0.9 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 Westport 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 Westport map in Figure 5-9c.

5.8.7 Issues and Conditions - Westport Wellhead Protection Area

As discussed in Chapter 4, issues are documented cases of water quality contamination approaching or exceeding acceptable provincial levels. Both Total coliforms and *E. coli* have been detected in the Westport wells. Neither *E. coli* nor total coliforms have been detected in treated water. Scott Bryce (Clerk Treasurer, Village of Westport) has indicated that drinking water treatment upgrades are currently being implemented. More specifically, Mr. Bryce indicated that ultra violet disinfection units will be in place before the end of March 2010. As such, the documented presence of Total Coliforms and *E. coli* is not considered to be an issue for the Westport drinking water system because of the new drinking water treatment upgrades.

A condition is a situation where past activities resulted in a drinking water threat. Based on the criteria, there are no confirmed conditions in the Westport WHPAs. However, there were six potential conditions noted in the Drinking Water Threats and Issues Technical Report.

5.9 Summary of Significant Threats to Wellhead Protection Areas

Municipal groundwater drinking water systems in the RVSPA have 782 potentially significant threats. The number of potentially significant threats for each system in the RVSPA is summarized in the following table.

Municipal Groundwater Drinking Water System	# Potentially Significant Threats
Kemptville	105
Merrickville	24
Munster	256
Richmond	132
Westport	51

Table 5-xi. Potentially Significant Threats in the RVSPA.

The results, in further detail, may be found in Table 5-1. Table 5-2 lists potentially significant threats in the RVSPA by category. In the table, 'The handling and storage of fuel' category has 870 potentially significant threats, so is the category with the largest number of potentially significant threats in the RVSPA.

Figure 5-10 shows all WHPAs within the MRSPR. Figure 5-11 shows all WHPAs within the MRSPR with vulnerability scores of 8 to 10. For further information on the WHPAs within the MVSPA, shown in Figure 5-10, see the MVSPA Assessment Report.

5.10 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.