Chapter 5
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5 Groundwater Sources

Introduction

This chapter provides information on groundwater within the Mississippi-Rideau Source Protection Region (MRSPR). First is discussion on 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 region.

All municipal wells in the MRSPR, with the exception of the Almonte, Carp, and Westport wells, draw from a combination of the shallow and deep bedrock aquifers found at each site. Carp draws from a sand and gravel aquifer. Almonte and Westport draw water only from bedrock aquifers. All wellhead protection areas (WHPAs) in the MRSPR which are currently delineated are shown in Figure 5-106.

Groundwater is more susceptible to contamination in some areas and these areas have been identified regionally as Highly Vulnerable Areas (HVAs) and Significant Groundwater Recharge Areas (SGRAs). Approximately 90% of the MRSPR has been identified as HVA and SGRAs account for 13.2%.

There are seven municipal groundwater drinking water systems in the MRSPR. The following table shows their location and the number of users.

Municipal Water Supply Location	Estimated Number of Users
Almonte	4,700
Carp	1,500
Kemptville	3,400
Merrickville	1,000
Munster	1,300
Richmond	450
Westport	650
Total	**13,000**

Groundwater Drinking Water Systems

An eighth wellhead protection area for the Town of Lanark has not been completed and it is anticipated that information on the well and associated WHPAs will be included in an updated assessment report.

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 region are discussed in Chapter 6.

Summary of Key Findings

Two thousand three hundred and twenty-nine potentially significant drinking water threats have been identified in the wellhead protection areas of the MRSPR. Summary information on key findings and threats can be found in Tables 5-1 and 5-2.

Two conditions have been identified in the MRSPR, one in Almonte, discussed in Section 5.5.7, and the other in Carp, discussed in Section 5.6.7.

Drinking water issues have been identified in non-municipal drinking water in:

- Beckwith;
- Cranberry Estates;
- Crotch Lake area;
- Village of Constance Bay; and
- Village of Lanark.

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
Impervious Surfaces, 2010	Mississippi-Rideau Source Protection Region staff	not peer reviewed
Groundwater Drinking Water Threats and Issues, 2010	Dillon Consulting	not peer reviewed
Almonte Groundwater Vulnerability Study, 2003, 2008, 2009	Intera Engineering Ltd.	Golder Associates Ltd.
Carp Vulnerability Studies, 2003, 2004, 2008	Golder Associates Ltd.	TAG, Intera Engineering Ltd.
Kemptville Groundwater Vulnerability Study, 2008	Golder Associates Ltd.	Malroz Engineering Incorporated
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.
Westport Groundwater Vulnerability Study, 2009	Malroz Engineering Incorporated	Golder Associates Ltd.

Summary of Groundwater Background Technical Studies

Peer Review

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

Highly Vulnerable Aquifer Study

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

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

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

Significant Groundwater Recharge Areas Study

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

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

- Michel Kearney, City of Ottawa, Infrastructure Planner

Regular meetings were held with the peer review team between early 2006 and 2009. Complete Peer Review records are available for the Mississippi-Rideau Conceptual Water Budget, Tier 1 Water Budget and Water Quantity Stress Assessment Reports and Significant Groundwater Recharge Areas Study (see Appendix A-1).

Groundwater Vulnerability Studies

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

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

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

Data gaps 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. The primary deep aquifer in the region is the Nepean Aquifer, although this is also a shallow aquifer in some areas.

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. Factors that can affect an aquifer's vulnerability are:

- the depth from the ground surface to top of the aquifer;
- the water table depth, if the aquifer is exposed at ground surface; and
- the type of soil and rock between the aquifer and the ground surface.

The delineation of vulnerable aquifers in the MRSPR focused on the shallow aquifers, which is important for private well water supplies.

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.

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.

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.

MOE ISI Process

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.

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 as surface water cannot readily reach it.

Each area is categorized as 'High', 'Medium', or 'Low' vulnerability, based on the ISI value that was calculated in the previous step. ISI values less than 30 indicate high vulnerability, values between 30 and 80 are medium, and values above 80 indicate low vulnerability.

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.

The ISI approach to determining aquifer vulnerability was originally intended by the MOE for use in assessing the vulnerability of unconfined aquifers, which are aquifers that are connected to the surface. However, many of the upper aquifers in the MRSPR are confined aquifers, which are aquifers that have an overlying layer that has low permeability such as a clay, a clay-till or a shaley bedrock.

The ISI approach was modified with permission from MOE to better suit the unique characteristics of the region. This modification was developed in consultation with MOE staff, and the study's technical advisory group. 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 of the Canadian Shield is at or very close to the ground surface for a significant part of the study area;
- this rock is very fractured near surface, so a shallow aquifer is present; and
- significant deposits of sand and gravel are also present in the MRSPR.

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

The final step was to combine the results from the original ISI method with the modified ISI method to delineate the HVAs across the MRSPR. The ISI results were separated into three vulnerability categories, as required by the Technical Rules and are shown in Figure 5-1, MRSPR Aquifer Vulnerability. Figure 5-2 shows a map of the final High Vulnerability Aquifers areas.

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 5-3. Approximately 90% of the region has been determined to fall under the HVA designation. Areas of low to moderate vulnerability are predominantly in flat lying areas which have clay or silt deposits as the surficial geology.

Uncertainty

HVA delineation relies on water well records from the MOE water well database. The reliability of the study results was improved by correcting obvious errors in the database; however, the accuracy of the remaining data still has uncertainty associated with it. Therefore, there is high uncertainty associated with HVA delineation at a local scale.

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. Below are 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

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

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 is regarded as a threat. Impervious surface area calculations are required to determine if road salt application in the vulnerable areas could be a drinking water threat.

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 E1 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 5-4. The results range from 0 to 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 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 labeled) as significant threats within an HVA.

Issues and Conditions

Drinking water issues were identified for non-municipal groundwater drinking water systems in the MRSPR. The location of each of the communities is shown in Figure 5-5, with insets providing more information on where issues have been identified within the community. The following non-municipal groundwater drinking water issues may affect some domestic and private wells in those communities. Each of these issues is discussed in more detail below and summarized in Table 5-5.

Beckwith (Former Landfill)

Documented presence of contaminant parameters associated with chlorinated solvents in groundwater in the Township of Beckwith has been attributed to a former private landfill (also referred to as the Levine property) 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-caused) drinking water issue for the purposes of this evaluation.

Cranberry Estates

Since 1984, multiple studies have been performed in the 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 for the purposes of this evaluation.

Crotch Lake Area

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

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

The elevated uranium are interpreted to be naturally occurring, a result of the aquifer geology. Elevated concentrations of uranium in drinking water may present a health-related risk, and are considered to occur relatively infrequently. Thus, the elevated concentrations of uranium are considered to represent a naturally-occurring drinking water issue for the purposes of this evaluation.

Village of Constance Bay

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

Nitrate concentrations were detected in the samples at an average concentration of 5.2 mg/L with 19% of the samples exceeding the Ontario Drinking Water Standards (ODWS) of 10 mg/L as N. These nitrate concentrations appear to be a result of septic loading within the village and are considered to represent an anthropogenic drinking water issue for the purposes of this evaluation.

Village of Lanark

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

These issues are, at least in part, likely attributed to the relatively high density of septic systems in the area. The elevated concentrations of nitrate and bacteriological parameters are considered to represent anthropogenic drinking water issues for the purposes of this evaluation.

5.2 Significant Groundwater Recharge Areas

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

5.2.1 What are Significant Groundwater Recharge Areas?

A significant groundwater recharge area, or SGRA, is an area where a relatively large percentage of water recharges from the ground surface to an aquifer. SGRAs represent important areas for groundwater to recharge the water table.

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 SGRA:

- 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 is listed below.

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

At this stage, 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 could be a 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 5-6.

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.

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 5-7.

Eskers

Eskers in the region are composed of sand and gravel. Eskers have been identified as important groundwater features. Some of the esker areas have steep slopes and were not identified by Method 2 as a SGRA. Given the importance of eskers in the region, all above ground eskers as mapped by the Ontario Geologic Survey were identified as SGRAs, and included in Figure 5-8.

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 5-8.

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.

Vulnerability Scoring

The next step was to determine a vulnerability score for the SGRAs in accordance with the technical rules. For SGRAs, the scoring process depends on the vulnerability of the aquifer. 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

Vulnerability Scoring

For SGRAs, the scoring process depends on the vulnerability of the aquifer that was shown in Figure 5-1. The vulnerability scores from the HVA mapping were overlaid by the final SGRA map, Figure 5-8 in order to produce the final SGRA vulnerability map, shown in Figure 5-9. SGRAs account for 13.2% of the MRSPR.

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 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

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 is regarded as a threat. Impervious surface area calculations are required to determine if road salt application in the SGRAs 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 SGRAs are shown on Figure 5-10. 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 labeled) 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 5.12 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 WHPA zones are outlined in the Technical Rules. Zone A is the area immediately surrounding the well. Zones B, C and D are delineated by time of travel.

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

WHPA Zone	Description
Zone A	100 m radius from the wellhead
Zone B	2-year time of travel to the wellhead
Zone C	5-year time of travel to the wellhead
Zone D	25-year time of travel to the wellhead
Zones E & F	Protection areas for the wellhead of a GUDI well

WHPA Descriptions

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

5.3.2 Wellhead Protection Area Development Methodology

The following four steps are taken in developing WHPAs.

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 5-11 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). 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'.

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 WHPA zones 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, zones respectively. The final (composite) capture zones 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.

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 Province 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.

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

Risk Thresholds

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.

MOE defines thresholds in order to evaluate the risk of over-application of agriculturally sourced materials:

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

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

5.4 Wellhead Protection Areas in the Mississippi-Rideau Source Protection Region

As discussed in Chapter 2, there are currently seven municipal groundwater-based drinking water protection systems in the MRSPR:

- Almonte (Mississippi Mills)
- Carp
- Kemptville

- Merrickville
- Munster
- Richmond (King's Park)
- Westport.

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

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

5.5 Almonte Water Supply

Almonte, in the Town of Mississippi Mills, obtains water from five drilled wells, wells 3, 5, 6, 7 and 8 shown in Figure 5-12. Wells 1, 2 and 4 are no longer in use. The wells are drilled to depths between 39 and 79 m below ground surface. The wells obtain water from the following bedrock formations: Oxford, March and Nepean. Additionally, Well 6 is completed 2 m into the Precambrian bedrock. The groundwater system supplies approximately 4,700 people.

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

The municipal drinking water system in Almonte is operated by the Ontario Clean Water Agency (OCWA). The Almonte source water quality, on isolated occasions, exceeded guidelines in hardness, organic nitrogen, Total Dissolved Solids (TDS), turbidity, aluminum and sodium. Elevated turbidity at Well 6 has been documented during pumping, especially during high demand. Sodium concentrations are consistently above 20 mg/L, which is the advisory limit set by the MOE above which the operator must notify the MOE and the Health Unit to protect patients on sodium-reduced diets.

5.5.1 Delineation of Almonte Wellhead Protection Area

A cross-section for the WHPA conceptual model is shown in Figure 5-13. On the east side of the Mississippi River, wells 3, 7 and 8 pass through the shallow aquifer rock formations before reaching the deep Nepean sandstone aquifer. On the west side of the Mississippi River, Well 5 passes through a thin layer of soil before reaching the Nepean aquifer. Well 6 travels through soil and the Oxford/March formation before reaching the Nepean aquifer.

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

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

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

The numerical model calculated WHPA zones A through D for the Almonte system. Figure 5-13 shows the Almonte aquifer wellhead protection area zones around the municipal wellheads. They are made up of a 100 m buffer around the wellheads and the 2, 5, and 25 year times of travel.

Due to geographic location and groundwater flow regimes for the five separate wells, two distinct WHPAs have been established for Almonte (as shown in Figure 5-14). The WHPAs are located on both sides of the Mississippi River. Wells 3, 7, and 8 are located in the northeast WHPA and Wells 5 and 6 are located in the southwest WHPA.

Section 5.3.9 discusses sensitivity analysis in WHPAs. The zones of high and low uncertainty are shown in Figure 5-15.

5.5.2 Aquifer Vulnerability - Almonte Wellhead Protection Area

Once the WHPA is delineated, the aquifer vulnerability is determined using the Intrinsic Susceptibility Index or ISI as shown in Section 5.1.2. 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 WHPA zones. Figure 5-16 shows the results of the aquifer vulnerability determination.

Under the Technical Rules, the presence of transport pathways within a WHPA can increase the intrinsic vulnerability. The presence of water wells, pits and quarries, mines, construction activities, sewer services, septic systems and stormwater infiltration was examined in the WHPA. 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 shown in Figure 5-16, four areas were identified where transport pathways increase the risk to the Nepean aquifer. Two of the areas are bedrock quarries located on the east side of the Mississippi River, close to the limit of the 25 year time of travel zone. In both areas, the aquifer vulnerability was increased from low to medium.

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

5.5.3 Vulnerability Scoring - Almonte Wellhead Protection Area

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

The following table shows the scoring system laid out in the provincial Technical Rules. Possible vulnerability scores are 2, 4, 6, 8, and 10. A score of 10 is highest, indicating an area where drinking water is most vulnerable to contamination. These categories were used to assign vulnerability scores to the areas within the WHPA in Figure 5-17. Figure 5-18 shows a close-up of the vulnerability scoring.

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

Wellhead Protection Area Vulnerability Scores

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

5.5.4 Managed Lands and Livestock Density – Almonte Wellhead Protection Area

Percent managed land and livestock density calculations were carried out according to the methods outlined in Section 5.3.3. Figure 5-19 shows the managed lands and the livestock density in the WHPA zones. The percent managed lands and average livestock densities for each zone are listed in Table 5-6. Note some zones in these tables have two results because the calculation was carried out for each vulnerability score in each WHPA Zone. Also shown in the table is the risk threshold for the over application of nutrients to land and the risk threshold for the over application of ASM to land.

5.5.5 Impervious Surfaces – Almonte Wellhead Protection Area

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

Road salt applied to roads and walkways for winter maintenance is regarded as a potential threat. Impervious surface area calculations are required to determine if road salt application in the vulnerable areas could be a drinking water threat.

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

The percent impervious surfaces results for each grid within the Almonte vulnerable aquifer areas is shown on Figure 5-20. The results range from 0 to 77%.

5.5.6 Potential Water Quality Threats - Almonte Wellhead Protection Area

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

It should be noted that a single land use activity could fall into multiple threat categories. For example, a crop farm could be practicing storage of fuel, application of commercial fertilizer to land, and application of 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 practice fuel storage, 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.

A total of 93 potentially significant drinking water threats were identified in the Almonte WHPA. For WHPAs, significant threats are where the vulnerability score is 8 or 10, or if the activity pertains to dense non-aqueous phase liquids (DNAPLs), anywhere within the 5-year WHPA Zone C. The potentially significant drinking water threats are summarized in Table 5-7. The term “Poly” in the table refers to a polygon, or an area that may contain multiple threats. The term “Point” in the table refers to a point source. Figure 5-21 shows the areas containing potential significant threats in purple and outlines the areas containing potential DNAPL threats in blue. Please see Section 4.3.3 for information on the full list of significant, moderate, and low threats.

Transportation Corridors

A number of transportation corridors exist within the Almonte WHPA where there may be the transportation of dangerous and/or hazardous goods and the potential for a spill exists. Spills within the WHPA have the potential to impair the groundwater quality however they are not included as threats as per the prescribed drinking water threats categories (see Section 4.3).

This Assessment Report provides this key information for municipalities and other agencies to assist in ensuring all available information is accessible for emergency response planning purposes. Transportation corridors can be found on all WHPA maps including the Almonte WHPA map in Figure 5-14.

5.5.7 Issues and Conditions – Almonte Wellhead Protection Area

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

As discussed in Chapter 4, a condition is a situation where past activities resulted in a drinking water threat. Potential conditions in the Almonte WHPA are the sewage lagoons located 200 m from Well 5. Groundwater samples from monitoring wells in the immediate vicinity of the sewage lagoons showed groundwater from one monitoring well exceeded the Ontario Drinking Water Standards for chloride, *E. coli* and total coliforms. Groundwater chloride and bacteria concentrations represent possible migration of the contents of the sewage lagoon, but currently there is no impact to Well 5. As such, the condition associated with the sewage lagoons should be assigned a hazard rating of 6 based on the Technical Rules. Since the vulnerability score for the sewage lagoons is 8, the risk score is 8 x 6 = 48 (risk score = vulnerability score x hazard rating). Thus, the condition is classified as a low drinking water threat.

5.6 Carp Water Supply

The Village of Carp obtains its drinking water from two municipal wells, shown in Figure 5-22, that draw water from a sand and gravel aquifer. The wells are drilled to depths of 27 and 24 m below ground surface. The groundwater system supplies water for 1,500 people in the Village of Carp.

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

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

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

5.6.1 Delineation of Carp Wellhead Protection Area

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

A cross-section for the conceptual model is shown in Figure 5-23. The sand and gravel aquifer that supplies the wells is made up of the fine, medium, and coarse sand and gravel formations. A layer of clay of varying thickness covers the aquifer, however the continuity of this layer is not well known. A layer of limestone bedrock is below the aquifer. The groundwater system for the Carp wells is confined to the shallow overburden. The bedrock does not play a significant role in the groundwater system. Therefore, only the shallow overburden system was considered. An independent third party peer review ensured the approach was accepted by other groundwater experts.

The Carp capture zones were delineated using a forecasted combined flow rate for the two wells of 2,000 m^3/day. This rate is significantly greater than the current flow rate of 400 m^3/day. The forecasted flow rate was chosen based on discussions with the municipality and includes project future growth in Carp, as well as water demands from the potential Carp Airport Development.

The WHPA is made up of a 100 m buffer around the wellheads and the 2, 5, and 25 year times of travel. Results from the numerical model calculated WHPA zones A through D for Carp are shown in Figure 5-24.

Please see section 5.3.1 for information on the uncertainty associated with delineation of the WHPAs. Levels of uncertainty are shown in Figure 5-25.

5.6.2 Aquifer Vulnerability - Carp Wellhead Protection Area

Once the WHPA was delineated, the aquifer vulnerability was determined using the Intrinsic Susceptibility Index or ISI (see Section 5.1.2). 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. he Technical Rules outline the process for categorizing aquifer vulnerability (Low, Medium or High) for the areas within the WHPA zones. Figure 5-26 shows the results of the aquifer vulnerability assignment for Carp.

In Carp, high aquifer vulnerability exists where there is a thin layer of fine sands above the aquifer (close to the municipal wells). Medium aquifer vulnerability exists where there is a thick layer of fine sands above the aquifer (the topographically high area to the southwest of the Carp Ridge). Medium vulnerability also exists where thin weathered clay overlies the fine sands. Low aquifer vulnerability exists where three m of weathered clay and a significant thickness of un-weathered clay is above the aquifer, in the lower lying Carp River valley area. This is shown in Figure 5-26.

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 of water wells, pits and quarries, mines, construction activities, sewer services, septic systems and stormwater infiltration was examined in the WHPA. The review showed transport pathways in the Carp WHPA did not warrant an increase in intrinsic vulnerability.

5.6.3 Vulnerability Scoring - Carp Wellhead Protection Area

The Technical Rules set out a process for scoring vulnerability within a WHPA. It is based on the combination of aquifer vulnerability and overlapping WHPA zones. 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, shown in Figure 5-27 Carp Wellhead Vulnerability Scoring and Figure 5-28 shows the area in more detail.

5.6.4 Managed Lands and Livestock Density – Carp Wellhead Protection Area

Percent managed land and livestock density calculations were carried out according to the methods outlined in Section 5.3.3. Figure 5-29 shows the managed lands and the livestock density in the WHPA zones. The percent managed lands and average livestock densities for each zone are listed in Table 5-8. Note some zones in these tables have two results because the calculation was carried out for each vulnerability score in each WHPA zone. Also shown in the table is the risk threshold for the over-application of nutrients to land and the risk threshold for the over application of Agricultural Source Material to land as described in Section 5.1.3.

The managed lands evaluation 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 – Carp Wellhead Protection Area

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

Road salt applied to roads and walkways for winter maintenance is regarded as a potential threat. Impervious surface area calculations are required to determine if road salt application in the vulnerable areas could be a drinking water threat.

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

The percent impervious surfaces results for each grid within the Carp vulnerable aquifer areas is shown on Figure 5-30. The results range from 0.5-52%.

5.6.6 Water Quality Threat Assessment - Carp Wellhead Protection Area

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

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

The next step was to determine which land use activities and associated threats are occurring where the vulnerability score is high enough to result in 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 practice fuel storage, 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.

A total of 137 potentially significant drinking water threats were identified in the Carp WHPA. For WHPAs, significant threats are where the vulnerability score is 8 or 10, or if the activity pertains to dense non-aqueous phase liquids (DNAPLs), anywhere within the 5-year WHPA Zone C. The potential significant drinking water threats are summarized in Table 5-9. Figure 5-31 shows the areas containing potential significant threats in purple and outlines the areas containing potential DNAPL threats in blue. Please see section 4.3.3 for information on the full list of significant, moderate, and low threats.

Transportation Corridors

A number of transportation corridors exist including a CPR rail line within the Carp WHPA where there may be the transportation of dangerous and/or hazardous goods and the potential for a spill exists. Spills within the WHPA have the potential to impair the groundwater quality however they are not included as threats as per the prescribed drinking water threats categories (see Section 4-3).

This Assessment Report provides this key information for municipalities and other agencies to assist in ensuring all available information is accessible for emergency response planning purposes. Transportation corridors can be found on all WHPA maps including the Carp WHPA map in Figure 5-24.

5.6.7 Issues and Conditions – Carp Wellhead Protection Area

Issues are documented cases of water quality contamination approaching or exceeding acceptable provincial levels. No issues were identified in the Carp WHPA.
As discussed in Chapter 4, a condition is a situation where past activities resulted in a drinking water threat. Based on the criteria, there are no other confirmed conditions in the Carp WHPAs. However, there were two potential conditions noted in the Drinking Water Threats and Issues Technical Report.

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

5.7 Kemptville Water Supply

The Town of Kemptville obtains its drinking water from three municipal wells, shown in Figure 5-32, which draws water from the Nepean Formation sandstone. The three 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 3,400 people.

The local geology in the Kemptville area consists of a thin overburden layer (i.e., less than two m) 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. Total coliform bacteria are detected in Well 1 a few times per year. However, *E. coli* has not been detected in the groundwater, and total coliforms are removed during water treatment. Colour and hardness exceed the Ontario Drinking Water Standards – Operational Guideline Aesthetic Objective; however, these parameters do not affect health.

Hardness and sodium concentrations are typical of the Nepean formation. Typical sodium concentrations range between 30 – 40 mg/L at all three 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.

5.7.1 Delineation of Kemptville 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 Kemptville area. Also, geologic and hydrologic data was obtained from Provincial and Federal studies. These data were used to create the conceptual hydrogeological model for Kemptville. 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 Kemptville's conceptual model is shown in Figure 5-33. The well 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 Kemptville wells. Therefore, WHPA analyses were carried out for shallow (Oxford/March) and deep (Nepean) groundwater systems. An independent third party peer review ensured the approach was accepted by other groundwater experts.

The Kemptville capture zones were delineated using a forecasted combined flow rate for the three wells of 4,488 m^3/day. This flow rate is greater than the five year average flow rate of 1,492 m^3/day. The forecasted flow rate was chosen based on discussions with the municipality, which is currently experiencing growth pressures, and is equal to the maximum allowable rate under the current Permit To Take Water for the three wells. When the municipal demand for water exceeds this rate, it is likely that one or more additional supply wells will be required and the wellhead protection study will need to be updated.

The numerical model calculated WHPA zones A through D for the Kemptville system for the shallow and deep aquifer systems. Figure 5-34 shows the Kemptville shallow aquifer wellhead protection area zones around the municipal wellheads. It is made up of a 100 m buffer around the wellheads and the 2, 5, and 25 year times of travel. Figure 5-35 shows the Kemptville deep aquifer wellhead protection area zones around the municipal wellheads. It is made up of a 100m buffer around the wellheads and the 2, 5, and 25 year times of travel. As indicated on Figure 5-34, a small area of the deep WHPA-D is located within the Raisin-South Nation Source Protection Region.

See Section 5.3.2 for information on determining uncertainty. Figures 5-36 and 5-37 show Kemptville's Shallow and Deep Wellhead Protection Area Uncertainty.

5.7.2 Aquifer Vulnerability - Kemptville Wellhead Protection Area

Once the WHPA was delineated, the aquifer vulnerability was determined using the Intrinsic Susceptibility Index or ISI (see Section 5.1.2). 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 WHPA zones. Figures 5-38 and 5-39 show the results of the aquifer vulnerability assignment for Kemptville's shallow and deep aquifers, respectively.

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 of water wells, pits and quarries, mines, construction activities, sewer services, septic systems and stormwater infiltration was examined in the WHPA.

Three areas were identified where transport pathways pose a risk to the deep aquifer in Figures 5-38 and 5-39. The vulnerability of all three areas was increased from medium to high vulnerability because of the presence of bedrock quarries. No changes were made to the shallow aquifer because the vulnerability of the shallow aquifer was already high.

5.7.3 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 WHPA zones. 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 for the shallow (Figure 5-40) and deep (Figure 5-41) groundwater systems. The final vulnerability scoring is based on the highest of the combined scores for the deep and shallow aquifers and is shown in Figures 5-42 and 5-43.

5.7.4 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 5-44 and 5-45 show the managed lands and the livestock density in the WHPA zones. The percent managed lands and average livestock densities for each zone are listed in Table 5-10. Note some zones have two results because the calculation was carried out for each vulnerability score in each WHPA Zone. 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.

5.7.5 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 is regarded as a threat. Impervious surface area calculations are required to determine if road salt application in the 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 5-46. The results range from 0 to 89%.

5.7.6 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 practicing storage of fuel, application of commercial fertilizer to land, and application of agricultural source material to land. Each of these activities is a separate threat category in the provincial table, and so is therefore a separate threat.

The next step was to determine which land use activities and associated threats are occurring where the vulnerability score is high enough to result in 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 practice fuel storage, 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.

A total of 1150 potentially significant drinking water threats were identified in the Kemptville WHPA. For WHPAs, significant threats are where the vulnerability score is 8 or 10, or if the activity pertains to dense non-aqueous phase liquids (DNAPLs), anywhere within the 5-year WHPA Zone C. The potentially significant drinking water threats are summarized in Table 5-11. Figure 5-47 shows the areas containing potential significant threats in purple and outlines the areas containing potential DNAPL threats in blue. Please see

Section 4.3.3 for information on the full list of significant, moderate, and low threats.

Transportation Corridors

A number of transportation corridors, including Highway 416 and a CPR rail line exist within the Kemptville WHPA where there may be the transportation of dangerous and/or hazardous goods and the potential for a spill exists. Spills within the WHPA have the potential to impair the groundwater quality however they are not included as threats as per the prescribed drinking water threats categories (see Section 4-3).

This Assessment Report provides this key information for municipalities and other agencies to assist in ensuring all available information is accessible for emergency response planning purposes. Transportation corridors can be found on all WHPA maps including the Kemptville WHPA maps in Figures 5-34 and 5-35.

5.7.7 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, there were six potential conditions noted in the Drinking Water Threats and Issues Technical Report.

5.8 Merrickville Water Supply

The Village of Merrickville obtains its drinking water from three municipal wells as shown in Figure 5-48. 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 2 m) 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.

5.8.1 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 5-49. 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. Therefore, WHPA analyses were carried out for shallow (Oxford/March) and deep (Nepean) groundwater systems. An independent third party peer review ensured the approach was accepted by other groundwater experts.

The Merrickville capture zones were delineated using a forecasted combined flow rate for the three wells of 520 m^3/day. This flow rate is slightly greater than the five year average flow rate of 515 m^3/day presented in Table 2-14 of Chapter 2.

The numerical model calculated WHPA zones A through D for the Merrickville system for the shallow and deep aquifer systems. Figure 5-50 shows the Merrickville shallow aquifer wellhead protection area zones around the municipal wellheads. It is made up of a 100 m buffer around the wellheads and the 2, 5, and 25 year times of travel. Figure 5-51 shows the Merrickville deep aquifer wellhead protection area zones around the municipal wellheads. It is made up of a 100m buffer around the wellheads and the 2, 5, and 25 year times of travel.

See section 5.3.2 for information on uncertainty. The Merrickville WHPA uncertainty maps are shown in Figures 5-52 and 5-53.

5.8.2 Aquifer Vulnerability - Merrickville Wellhead Protection Area

Once the WHPA was delineated, the aquifer vulnerability was determined using the Intrinsic Susceptibility Index or ISI (see Section 5.1.2). 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 WHPA zones. Figures 5-54 and 5-55 show the results of the aquifer vulnerability assignment.

For the shallow aquifer, the aquifer vulnerability is mostly high with some medium areas (Figures 5-54 and 5-55). The relatively patchy nature of the aquifer vulnerability results from a complex layering of soil in Kemptville. For example, the soil thicknesses varies from zero m to over twenty m with several different soil types present (i.e., sand and gravel, silt and clay, till). For the deep aquifer, 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 north boundary of the WHPA which is medium as the Nepean aquifer gets closer to the ground surface. The three areas adjusted for transport pathways have medium vulnerability.

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 of water wells, pits and quarries, mines, construction activities, sewer services, septic systems and stormwater infiltration was examined in the WHPA.

Three areas were identified for the deep aquifer. Vulnerabilities were increased from low to medium because of the presence of bedrock quarries. For the shallow aquifer, no adjustments were made because the vulnerability rankings were already ranked high.

5.8.3 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 WHPA zones. 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 Table 5-2 were used to assign vulnerability scores to the areas within the WHPA for the shallow (Figure 5-56) and deep (Figure 5-57) groundwater systems. The final vulnerability scoring is based on the highest of the combined scores for the deep and shallow aquifers and is shown in Figures 5-58 and 5-59.

5.8.4 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. Figures 5-60 and 5-61 show the managed lands and the livestock density in the WHPA zones. 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 Zone. 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 – 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 is regarded as a threat. Impervious surface area calculations are required to determine if road salt application in the 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 5-62. The results range from 0 to 88%. The higher values found in this area are attributed to the Town of Smiths Falls.

5.8.6 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 practicing storage of fuel, application of commercial fertilizer to land, and application of agricultural source material to land. Each of these activities is a separate threat category in the provincial table, and so is therefore a separate threat.

The next step was to determine which land use activities and associated threats are occurring where the vulnerability score is high enough to result in 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 practice fuel storage, 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.

A total of 603 potentially significant drinking water threats were identified in the Merrickville WHPA. For WHPAs, significant threats are where the vulnerability score is 8 or 10, or if the activity pertains to dense non-aqueous phase liquids (DNAPLs), anywhere within the 5-year WHPA Zone C. The potentially significant drinking water threats are summarized in Table 5-13. Figure 5-63 shows the areas containing potential significant threats in purple and outlines the areas containing potential DNAPL threats in blue. Please see section 4.3.3 for information on the full list of significant, moderate, and low threats.

Transportation Corridors

A number of transportation corridors, including roads and a CPR rail line exist within the Merrickville WHPA where there may be the transportation of dangerous and/or hazardous goods and the potential for a spill exists. Spills within the WHPA have the potential to impair the groundwater quality however they are not included as threats as per the prescribed drinking water threats categories (see Section 4-3).

This Assessment Report provides this key information for municipalities and other agencies to assist in ensuring all available information is accessible for emergency response planning purposes. Transportation corridors can be found on all WHPA maps including the Merrickville WHPA maps in Figures 5-50 and 5-51.

5.8.7 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.

5.9 Munster Water Supply

Munster Hamlet obtains its drinking water from two municipal wells as shown in Figure 5-64. 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 5 m) made up of clay material in the Richmond area and a sandy till in the Munster area. 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).

The source water has consistently been free of bacteriological and chemical contaminants. Well 1 is used almost exclusively as Well 2 has exhibited turbidity problems since 2001. Historically, conductivity, iron, pH and turbidity have periodically and marginally exceeded drinking water guidelines. The Munster raw water quality has exceeded guidelines for hardness and iron and also identified turbidity issues at Well 2. These parameters do not pose a health risk.

5.9.1 Delineation of Munster 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 Munster area. Also, geologic and hydrologic data was obtained from Provincial and Federal studies. These data were used to create the conceptual hydrogeological model for Munster.

A cross-section for the conceptual model is shown in Figure 5-65. 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 wells. Therefore, WHPA analyses were carried out for shallow (Oxford/March) and deep (Nepean) groundwater systems. An independent third party peer review ensured the approach was accepted by other groundwater experts.

The Munster capture zones were delineated using a forecasted combined flow rate for the two wells of 443 m^3/day. This rate is greater than the five year average daily flow rate of 433 m^3/day. The forecasted flow rate is based on five percent municipal growth projections.

The numerical model calculated WHPA zones A through D for the Munster system for the shallow and deep aquifer systems. Figure 5-66 shows the Munster shallow aquifer wellhead protection area zones around the municipal wellheads. It is made up of a 100 m buffer around the wellheads and the 2, 5, and 25 year times of travel. Figure 5-67 shows the Munster deep aquifer wellhead protection area zones around the municipal wellheads. It is made up of a 100m buffer around the wellheads and the 2, 5, and 25 year times of travel.

See Section 5.3.2 for information on uncertainty. The Munster WHPAs for the shallow and deep aquifers are shown in Figures 5-68 and 5-69.

5.9.2 Aquifer Vulnerability - Munster Wellhead Protection Area

Once the WHPA was delineated, the aquifer vulnerability was determined using the Intrinsic Susceptibility Index or ISI (see Section 5.1.2). 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 WHPA zones. Figures 5-70 and 5-71 show the results of the aquifer vulnerability study.

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 of water wells, pits and quarries, mines, construction activities, sewer services, septic systems and stormwater infiltration was examined in the WHPA.

Two areas were identified where transport pathways pose a risk to the shallow aquifer, shown in Figure 5-70. One area, located in the centre of Munster, was raised from medium to high vulnerability because of the presence of high groundwater well density and 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. Two areas were also identified for the deep aquifer, shown in Figure 5-71. Vulnerabilities were increased from low to medium because of the presence of bedrock quarries (one active and one abandoned). Both areas are located several kilometres north-west of Munster.

5.9.3 Vulnerability Scoring - Munster 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 WHPA zones. 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 for the shallow (Figure 5-72) and deep (Figure 5-73) groundwater systems. The final vulnerability scoring is based on the highest of the combined scores for the deep and shallow aquifers and is shown in Figures 5-74 and 5-75.

5.9.4 Managed Lands and Livestock Density – Munster Wellhead Protection Area

Percent managed land and livestock density calculations were carried out according to the methods outlined in Section 5.3.3. Figure 5-76 and 5-77 show the managed lands and the livestock density in the WHPA zones. The percent managed lands and average livestock densities for each zone are listed in Table 5-14. Note some zones in these tables have two results because the calculation was carried out for each vulnerability score in each WHPA Zone. 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.

5.9.5 Impervious Surfaces – Munster 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 is regarded as a threat. Impervious surface area calculations are required to determine if road salt application in the 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 Munster vulnerable aquifer areas is shown on Figure 5-78. The results range from 0-25%.

5.9.6 Water Quality Threat Assessment - Munster 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 Munster WHPA was completed in 2008.

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

The next step was to determine which land use activities and associated threats are occurring where the vulnerability score is high enough to result in 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 practice fuel storage, 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.

A total of 219 potentially significant drinking water threats were identified in the Munster 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 Zone C. The potentially significant drinking water threats are summarized in Table 5-15. Figure 5-79 shows the areas containing potential significant threats in purple and outlines the areas containing potential DNAPL threats in blue. Please see Section 4.3.3 for information on the full list of significant, moderate, and low threats.

Transportation Corridors

A number of transportation corridors, primarily roadways, exist within the Munster WHPA where there may be the transportation of dangerous and/or hazardous goods and the potential for a spill exists. Spills within the WHPA have the potential to impair the groundwater quality however they are not included as threats as per the prescribed drinking water threats categories (see Section 4-3).

This Assessment Report provides this key information for municipalities and other agencies to assist in ensuring all available information is accessible for emergency response planning purposes. Transportation corridors can be found on all WHPA maps including the Munster WHPA maps in Figures 5-66 and 5-67.

5.9.7 Issues and Conditions – Munster 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 Munster 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 Munster WHPAs. However, there were two spills noted in the Drinking Water Threats and Issues Technical Report.

5.10 Richmond - King's Park Water Supply

The King's Park community in the Village of Richmond obtains its drinking water from two municipal wells shown in Figure 5-80. 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 30 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. The groundwater system supplies approximately 450 people.

The local geology in the Richmond area consists of limited overburden material (less than 5 m) made up of clay material in the Richmond area and a sandy till in the Munster area. 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).

Raw water quality data collected at the two wells from 2000 to 2005 indicates that the aquifer water quality is very consistent. The source water has consistently been free of bacteriological and chemical contaminants. Sodium was identified during the testing of the aquifer prior to the construction of the communal well system as being naturally elevated. 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.

5.10.1 Delineation of Richmond - King's Park Wellhead Protection Area

A cross-section for the WHPA conceptual model is shown in Figure 5-81. 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 King's Park wells. Therefore, WHPA analyses were carried out for shallow (Oxford/March) and deep (Nepean) groundwater systems. An independent third party peer review occurred at this stage to ensure the approach was accepted by other groundwater experts.

The King's Park capture zones were delineated using a combined flow rate for the two wells of 210 m^3/day. This flow rate is slightly great than the five year average flow rate of 186 m^3/day presented in Table 2-14 in Chapter 2.

The numerical model calculated WHPA zones A through D for the King's Park system for the shallow and deep aquifer systems. Figure 5-82 shows the King's Park shallow aquifer wellhead protection area zones around the municipal wellheads. It is made up of a 100m buffer around the wellheads and the 2, 5, and 25 year times of travel. Figure 5-83 shows the King's Park deep aquifer wellhead protection area zones around the municipal wellheads. It is made up of a 100 m buffer around the wellheads and the 2, 5, and 25 year times of travel.

See Section 5.3.2 for information on uncertainty. Uncertainty related to the shallow and deep aquifer delineation is shown in Figures 5-84 and 5-85.

5.10.2 Aquifer Vulnerability in the Richmond - King's Park Wellhead Protection Area

Once the WHPA was delineated, the aquifer vulnerability was determined using the Intrinsic Susceptibility Index or ISI, as shown in Section 5.1.2. 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 WHPA zones. Figures 5-86 and 5-87 show the results of the aquifer vulnerability assignment.

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 of water wells, pits and quarries, mines, construction activities, sewer services, septic systems and stormwater infiltration was examined in the WHPA.

Three areas where transport pathways pose a risk to the deep aquifer were identified. The vulnerability was raised in these areas from low to medium. In all three cases, these transport pathways are bedrock quarries (two active and one abandoned). The bedrock quarries are located near Fernbank Road. For the shallow aquifer, no transport pathways that warranted an increase in intrinsic vulnerability were identified.

5.10.3 Vulnerability Scoring in the Richmond - King's Park 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 WHPA zones. 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 for the shallow (Figure 5-88) and deep (Figure 5-89) groundwater systems. The final vulnerability scoring is based on the highest of the combined scores for the deep and shallow aquifers and is shown in Figures 5-90 and 5-91.

5.10.4 Managed Lands and Livestock Density - King's Park Wellhead Protection Area

Percent managed land and livestock density calculations were carried out according to the methods outlined in Section 5.3.3. Figure 5-92 and Figure 5-93 show the managed lands and the livestock density in the WHPA zones. The percent managed lands and average livestock densities for each zone are listed in Table 5-16. Note some zones in these tables have two results because the calculation was carried out for each vulnerability score in each WHPA Zone. 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.

5.10.5 Impervious Surfaces - King's Park 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 is regarded as a threat. Impervious surface area calculations are required to determine if road salt application in the 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 King's Park vulnerable aquifer areas is shown on Figure 5-94. The results range from 0 to 64%.

5.10.6 Water Quality Threat Assessment in the Richmond - King's Park 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 King's Park WHPA was completed in 2008.

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

The next step was to determine which land use activities and associated threats are occurring where the vulnerability score is high enough to result in 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 practice fuel storage, 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.

A total of 70 potentially significant drinking water threats were identified in the King's Park 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 Zone C. The potentially significant drinking water threats are summarized in Table 5-17. Figure 5-95 shows the areas containing potential significant threats in purple and outlines the areas containing potential DNAPL threats in blue. Please see Section 4.3.3 for information on the full list of significant, moderate, and low threats.

Transportation Corridors

A number of transportation corridors, primarily roadways, exist within the King's Park WHPA where there may be the transportation of dangerous and/or hazardous goods and the potential for a spill exists. Spills within the WHPA have the potential to impair the groundwater quality however they are not included as threats as per the prescribed drinking water threats categories (see Section 4-3).

This Assessment Report provides this key information for municipalities and other agencies to assist in ensuring all available information is accessible for emergency response planning purposes. Transportation corridors can be found on all WHPA maps including the King's Park WHPA maps in Figures 5-82 and 5-83.

5.10.7 Issues and Conditions - King's Park Wellhead Protection Area

As discussed in Chapter 4 issues are documented cases of water quality contamination approaching or exceeding acceptable provincial levels. No conditions were identified in the King's Park 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 King's Park WHPAs. However, there were five spills noted in the Drinking Water Threats and Issues Technical Report.

5.11 Westport Water Supply

Westport obtains its drinking water from two municipal wells, Well 2 and Well 3 shown in Figure 5-96, 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. 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 abandonment 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.

5.11.1 Delineation of Westport Wellhead Protection Area

A cross-section for the conceptual model is shown in Figure 5-97. 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.

The Westport capture zones 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 2-14 found in Chapter 2. The forecasted flow rate was chosen based on municipal growth projections.

The numerical model calculated WHPA zones A through D for the Westport system (Figure 5-98). As indicated on Figure 5-98, a small area of the WHPA-D is located within the Cataraqui Source Protection Area.

For information on uncertainly please see Section 5.3.2. Uncertainty for the Westport wellhead area is shown in Figure 5-99.

5.11.2 Aquifer Vulnerability - Westport Wellhead Protection Area

Once the WHPA was delineated, the aquifer vulnerability was determined using the Intrinsic Susceptibility Index or ISI (see Section 5.1.2). 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 WHPA zones. Figure 5-100 shows the results of the aquifer vulnerability assignment.

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. A bedrock quarry located southeast of the intersection of Concession 8 and Salem Road in the Westport WHPA was identified as a potential transport pathway to the March/Nepean aquifer (Figure 5-100). The aquifer vulnerability was increased from low and medium to medium and high for the area near the quarry.

5.11.3 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 WHPA zones. 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 5-101 and 5-102).

5.11.4 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 5-103 shows the managed lands and the livestock density in the WHPA zones. The percent managed lands and average livestock densities for each zone are listed in Table 5-18. Note some zones in these tables have two results because the calculation was carried out for each vulnerability score in each WHPA Zone. 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.

5.11.5 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 is regarded as a threat. Impervious surface area calculations are required to determine if road salt application in the 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 5-104. The results range from 0-37%.

5.11.6 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 practicing storage of fuel, application of commercial fertilizer to land, and application of agricultural source material to land. Each of these activities is a separate threat category in the provincial table, and so is therefore a separate threat.

The next step was to determine which land use activities and associated threats are occurring where the vulnerability score is high enough to result in 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 practice fuel storage, 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.

A total of 57 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 Zone C. The potentially significant drinking water threats are summarized in Table 5-19. Figure 5-105 shows the areas containing potential significant threats in purple and outlines the areas containing potential DNAPL threats in blue. Please see Section 4.3.3 for information on the full list of significant, moderate, and low threats.

Transportation Corridors

A number of transportation corridors, primarily roadways, exist within the Westport WHPA where there may be the transportation of dangerous and/or hazardous goods and the potential for a spill exists. Spills within the WHPA have the potential to impair the groundwater quality however they are not included as threats as per the prescribed drinking water threats categories (see Section 4-3).

This Assessment Report provides this key information for municipalities and other agencies to assist in ensuring all available information is accessible for emergency response planning purposes. Transportation corridors can be found on all WHPA maps including the Westport WHPA map in Figure 5-98.

5.11.7 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.

5.12 Summary of Significant Threats to Wellhead Protection Areas

Municipal groundwater drinking water systems in the MRSPR have a total of 2,329 potentially significant threats. The number of potential threats for each municipal drinking water system is:

- Almonte 93
- Carp 137
- Kemptville 1150
- Merrickville 603
- Munster 219
- Richmond 70
- Westport 57

The results are summarized in Table 5-2.

References

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.