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4.0 OXFORD COUNTY WATER QUALITY RISK ASSESSMENT

Three municipal groundwater systems (**Table 4-1)** are located within the portion of Oxford County that falls within the Long Point Region Source Protection Area: Dereham Centre, Oxford South (as of 2013, includes Norwich, Springford and Otterville) and Tillsonburg. There is also a municipal groundwater source that supplies water to Mount Elgin; however, the source is located in the Upper Thames Region Source Protection Area.

Table 4-1: Oxford County Municipal Residential Drinking Water Systems in the Long Point Region

DWS Number	DWS Name	Operating Authority	GW or SW	System Classification[1]	Number of Users served
260001510	Dereham Centre	Oxford County	GW	Small municipal residential	48
220000601	Oxford South (includes Otterville/ Springford and Norwich)	Oxford County	GW	Large municipal residential	4753
220000683	Tillsonburg	Oxford County	GW	Large municipal residential	16,340

1 as defined by O.Reg. 170/03 (Drinking Water Systems) made under the *Safe Drinking Water Act, 2002.*

The description of each of these systems is included in **Sections 4.4 to 4.7**.

The annual and monthly average pumping rates are provided for each well or in **Table 4-2**.

These sections outline the common methodology that was used to delineate wellhead protection areas, vulnerability and threats assessment, and Issues and uncertainty evaluations for each of these systems.

4.1 Oxford County Wellhead Protection Areas and Vulnerability Assessment

The delineation of Wellhead Protection Areas (WHPAs) represents the foundation of a municipal groundwater protection strategy. WHPAs associated with the municipal water supply represent the areas within the aquifer that contribute groundwater to the well over a specific time period. According to the *Clean Water Act, 2006* Technical Rules (MOECC, 2017), four WHPAs are required, one a proximity zone and the three others time-related capture zones:

- WHPA-A 100 m radius from wellhead
- WHPA-B 2-year Time of Travel (TOT) capture zone
- WHPA-C 5-year Time of Travel capture zone
- WHPA-D 25-year Time of Travel capture zone

Table 4-2: Annual and Monthly Average Pumping Rates for Oxford County Municipal Residential Drinking Water Systems in the Long Point Region

Well or Intake	Annual Avg. Taking[1] (m^3/d)	Monthly Average Taking[1] (m^3/d)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tillsonburg 1A	821	721	711	685	743	662	1405	925	741	548	926	1027	764
Tillsonburg 2	342	273	284	271	285	287	590	365	293	241	442	441	329
Tillsonburg 4	531	577	582	539	614	418	326	332	729	996	509	297	460
Tillsonburg 5	481	602	692	554	638	622	513	560	210	608	279	198	315
Tillsonburg 6A	90	161	0	201	0	171	0	210	179	0	139	0	0
Tillsonburg 7	0	0	0	0	0	0	0	0	0	0	0	0	0
Tillsonburg 9	1053	1153	1043	1139	1054	1117	1025	1105	977	1075	908	1024	1016
Tillsonburg 10	920	974	956	989	856	992	869	973	909	894	856	829	941
Tillsonburg 11	1053	1153	1043	1139	1054	1117	1025	1105	977	1075	908	1024	1016
Tillsonburg 12	409	508	501	453	527	509	554	306	14	488	431	332	298
Norwich 2	320	387	29	259	364	395	395	380	141	509	413	326	227
Norwich 4	179	134	302	153	201	144	150	154	362	122	149	149	138
Norwich 5	220	163	374	272	202	253	232	214	191	89	189	167	301
Otterville 3	61	15	20	50	37	65	130	61	93	110	44	90	18
Otterville 4	62	45	36	50	33	88	134	98	45	87	43	37	53
Springford 4	7	15	61	17	0	0	0	0	0	0	0	0	0
Springford 5	224	217	171	205	233	231	245	248	244	245	220	172	246
Dereham Centre 2	10	12	13	10	10	9	9	8	8	9	10	10	11

[1] Source: Oxford County annual summary reports, based on 2009 monitoring data.

Note: Tillsonburg Well 7 has subsequently been replaced by Well 7A.

All of the capture zones were delineated using numerical models that were developed for each municipal production well system and calibrated to the available hydrogeological data. The models were developed using the computer programs MODFLOW and MODPATH, and the procedures and results are described in detail in the Phase II Groundwater Protection Study (Golder 2001) report. Otterville capture zones were updated in 2019 using the Long Point Tier 3 model. The specific method used to delineate each of the WHPAs within Oxford County is described in **Section 4.4 to 4.7**.

4.1.1 Vulnerability Scoring

Following their delineation, the intrinsic vulnerability of the aquifer within each WHPA is assessed using one of the methods approved under the *Clean Water Act, 2006* Technical Rules (MOE, 2009a; MOECC, 2017). The resulting maps rank aquifer vulnerability as high, medium or low.

In Oxford County, aquifer vulnerability mapping within the WHPAs was completed using the Aquifer Vulnerability Index (AVI) and Surface to Well Advection Time (SWAT) method (ARL Groundwater Resources Ltd. 2010; Golder, 2005). Both methods are approved under the Technical Rules.

The aquifer vulnerability mapping recognized three overburden units based on depth, with the classification of units as follows: Shallow aquifers occurring from surface to 15 m, intermediate aquifers occurring from 15 – 30 m, deep aquifers occurring at depths greater than 30 m. The bedrock aquifer was also recognized as a fourth unit.

The AVI method involves assigning a numerical score at each known well location that is related to the hydraulic conductivity (K) and thickness of the geological layers (stratum) overlying the aquifer (Golder, 2001). The aquifer vulnerability is classified on the basis of the AVI scoring following the thresholds provided by Technical Rule 38(1): High Vulnerability (AVI score <30), Medium Vulnerability (AVI score >30 and <80) or Low Vulnerability (AVI score >80). The AVI scoring method was used to develop vulnerability maps for each of the four aquifers identified as part of the aquifer mapping (shallow overburden, intermediate overburden, deep overburden, bedrock). The results were also used to develop a composite AVI map for the County. The composite AVI map reflects the vulnerability of the first aquifer present at each well location in the County.

A pilot study of the SWAT (surface to well advective travel-time) vulnerability assessment methodology was performed by Golder (2005). The SWAT approach provides direct estimates of the travel time from the ground surface to the supply wells, and a vulnerability map expressed in units of time. The method requires a determination of the travel time from ground surface to the water table (through the unsaturated zone), and the travel time from the water table to the pumping well completion zone. The two travel times are then added to produce the SWAT values across the WHPA. The results of the SWAT pilot study (Golder 2005) indicated that the method was useful in assessing the relative vulnerability of the municipal wells to surface sources of contamination and therefore, was applied to the Tillsonburg municipal production wells.

The resulting 'low', 'medium' or 'high' aquifer vulnerability rating is then intersected with the four WHPA zones, and translated into an overall vulnerability score ranging from 2 to 10, where a score of 2 represents lowest relative aquifer vulnerability and a score of 10 represents highest vulnerability. **Table 4-3** and **Table 4-4** below summarize the WHPA vulnerability scoring for both the AVI and SWAT methods as stated in the Technical Rules.

Within each of the WHPAs, aquifer vulnerability was assessed using two methods: the aquifer specific AVI method for the Dereham Centre and Otterville-Springford systems (ARL Groundwater Resources Ltd. 2010; Golder, 2001), and the SWAT method for the Norwich and Tillsonburg systems (Golder, 2005). Both methods are approved under the *Clean Water Act, 2006* Technical Rules. Detailed methodologies for each of these approaches can be found in the respective sections for each municipality.

Table 4-3: Wellhead Protection Area Vulnerability Scores - AVI

Groundwater Vulnerability Category for the Area	WHPA-A (100m zone)	WHPA-B (2-year time-of-travel)	WHPA-C (5-year time-of-travel)	WHPA-D (25-year time-of-travel)
High	10	10	8	6
Medium	10	8	6	4
Low	10	6	4	2

Table 4-4: Wellhead Protection Area Vulnerability Scores –SWAT

Groundwater Vulnerability Category for the Area	WHPA-A (100m zone)	WHPA-B (2-year time-of-travel)	WHPA-C (5-year time-of-travel)	WHPA-D (25-year time-of-travel)
High	10	10	8	6
Medium	10	8	6	4
Low	10	6	2	2

At the completion of the vulnerability mapping and scoring, Oxford County completed an assessment of transport pathways. The results of the transport pathway assessment were reviewed using professional judgment to determine whether to increase the vulnerability based on the presence of the pathways.

Identification of Transport Pathways and Vulnerability Adjustment

Following a review of the intrinsic vulnerability scoring maps, an assessment of transport pathways was undertaken to determine whether adjustments to the vulnerability assessment were warranted. Technical Rules 39 – 41 address the general process of how transport pathways would increase vulnerability. Constructed preferential pathways for groundwater based drinking water systems include: wells (existing and abandoned), pits and quarries, mines, construction activities, storm water infiltration, septic systems, sanitary sewer infrastructure.

To evaluate the transport pathways, the WHPAs were superimposed on aerial photography available from the County. Well locations in the vicinity of the WHPAs, available from the County well information system (based originally on the MECP Water Well Information System), were plotted on the aerial photograph maps. Information on the location of sanitary sewers, septic systems, storm water infiltration facilities and pits/quarries available from the County information systems were also plotted on the aerial photograph maps. The locations of petroleum wells within 100 m of the WHPAs were plotted on maps, based on information available from the oil & gas well database at the County.

The maps were then reviewed in detail to identify areas where the vulnerability scoring procedure should incorporate the presence of transport pathways. The process was based on professional judgment. The review identified areas on the map where other adjustments to the mapping should be made, such as (a) filling minor gaps/misaligments within the WHPA, (b) smoothing of the contacts between areas with different vulnerability ranking/scores and (c) removing what appear to be anomalies in the scoring that could not clearly be supported by the available hydrogeological information.

Adjusted Vulnerability Scoring

At the completion of the transport pathways assessment, the Technical Rules allow investigators to modify the vulnerability scoring if there is a concern that the identified transport pathways within the WHPAs may increase the vulnerability of the aquifer beyond that represented by the intrinsic vulnerability. Modification of the vulnerability score is performed by increasing the vulnerability of the underlying aquifer vulnerability map from either a low to moderate value or moderate to high value. An intrinsic aquifer vulnerability value of high cannot be increased. The results of the transport pathway assessment and adjusted vulnerability scoring for each municipal system are presented in **Sections 4.4 to 4.7.**

4.1.2 Oxford County Managed Lands and Livestock Density

Managed Lands

Managed Lands are lands to which nutrients are applied. Managed lands can be categorized into two groups: agricultural managed land and non-agricultural managed land. Agricultural managed land includes areas of cropland, fallow, and improved pasture that may receive nutrients. Non-agricultural managed land includes golf courses, sports fields, lawns and other built-up grassed areas that may receive nutrients (primarily commercial fertilizer). Determining the location and percent managed lands, the location of agricultural managed lands, and the calculation of livestock density were used to determine whether the application of agricultural source material (ASM), non-agricultural source material (NASM), and fertilizer were significant threats within the WHPAs.

Calculation of the percent managed lands was done in accordance with Part II, Rule 16(9) of the Technical Rules (MOE, 2009a; MOECC, 2017). Similar to the calculation of impervious surfaces, mapping the percent managed lands area is not required where the vulnerability score for an area is less than the vulnerability score necessary for the activity to be considered a significant threat. Based on this, the percent managed lands were only calculated where the vulnerability score in each WHPA was 6 or greater.

Livestock Density Analysis

The calculation of livestock density is required to determine the amount of Nutrient Units (NU) generated in each vulnerable WHPA scenario. This calculation is only completed when there are building structures that could house livestock on a farm parcel that intersects a vulnerable WHPA. This means that for each farm parcel that has a portion of their land in the WHPA and also has a livestock barn on their property (regardless of whether the barn is in the WHPA), the livestock density in Nutrient Units per acre (NU/ac) is calculated. The Nutrient Units generated by each farm parcel is area weighted to determine the proportion applied in each WHPA. The total amount of Nutrient Units applied in each WHPA is divided by the amount of agricultural managed land in that same WHPA to determine the livestock density. The agricultural managed lands in each WHPA scenario was calculated in accordance with Part II, Rule 16(10) of the Technical Rules (MOE, 2009a; MOECC, 2017), and as previously described. Each parcel of land that intersects each WHPA was assessed for the presence of a livestock barn. The nutrients that are generated by the livestock are assumed to be applied only onto that farm parcel.

Farm parcels intersecting each WHPA, as determined in the previous section, were assessed through air photo interpretation for the presence of barns or other livestock housing facilities. To aid in verifying the livestock type and whether the structure was used to house livestock, all available land use information from Oxford County records and databases were used including incorporating local knowledge from Planners, Township Chief Building Officials (CBO's) and other municipal staff who may have been able to provide local knowledge about a given farm operation. Site visits were also completed by Oxford County and Long Point Region Conservation Authority staff to verify the presence/absence of livestock on several properties in Tillsonburg. After all available knowledge (air photo interpretation and notes/photos from site inspections) was utilized, a reasonable estimation was made about the type of livestock that was housed or could be housed in a particular structure.

Once a livestock barn type was identified, the area of the barn was estimated using measuring tools in ArcMap. The barn area and livestock type were then compared to the Barn/Nutrient Unit Relationship Table (provided by the GRCA in their "Preliminary Technical Memo", issued September 23, 2009). Where the number of livestock is unknown, barn area is used as a surrogate for the number of animals (and consequently the amount of nutrients generated) that could be housed in the farm structure, based on best management practices for barn capacities. A nutrient unit conversion factor can also be used if the number of livestock present on a farm is known, which was the case for farm 1 in Norwich. Each type of livestock has its own NU conversion factor, to determine the number of animals that generate 1 NU. For instance, one beef cow produces 1 NU and requires 100 sq.ft. of barn space, so the relationship for beef barns is 100sq.ft./NU. The ratio assumes that the capacity of each livestock barn is at the maximum to generate or have the potential to generate that amount of nutrients.

4.1.3 Percent Impervious Surface Area in Wellhead Protection Areas

To determine whether the application of road salt poses a threat in Oxford County, the percent impervious surface where road salt can be applied per square kilometre was calculated as per Technical Rules 16(11).

To calculate the percent impervious surfaces for WHPAs within Oxford County, the calculations were performed using a 1 km by 1 km grid centered over each vulnerable area. As this method is a departure from Technical Rule 17, the Director has provided confirmation that they agree to the departure as per Technical Rule 15.1. The Director's letter of confirmation can be found in **Appendix B**. Roadways, sidewalks, driveways and parking lots all receive applications of road salt, and these surfaces were considered impervious.

The application of road salt can only be a threat in areas with a vulnerability score of 6 or greater; therefore the percent impervious calculation was only completed in areas with a score of 6 or greater.

Methodology

Roadways, sidewalks, driveways and parking lots were digitized on screen using ArcMap and 30cm resolution SWOOP orthoimagery from 2006 displayed at a scale of 1:500, to represent impervious surfaces. Grid cells were digitized in ArcMap by establishing the centroid of each WHPA and placing the centre of a 1 km by 1 km grid cell over the centroid.

The impervious surface percentage in each grid cell was calculated by dividing the total impervious surface area in each grid cell by the total vulnerable area (with vulnerability scoring equal to or greater than 6) in that same grid cell. It should be noted that where a grid cell contains a portion of a Wellhead Protection Area with vulnerability score less than 6, this portion on the Wellhead Protection Area was not used in the calculation of impervious surfaces. For road salt to be considered a significant threat, the percent of impervious surface must be greater than 80%.

The results of the impervious surface calculations are presented in **Sections 4.4 to 4.7.**

4.2 Oxford County Threat Assessment

The Ontario *Clean Water Act, 2006* defines a drinking water threat as "an activity or condition that adversely affects or has the potential to adversely affect the quality or quantity of any water that is or may be used as a source of drinking water, and includes an activity or condition that is prescribed by the regulation as a drinking water threat."

Table 4-5 lists the activities that are prescribed drinking water quality threats. Listed beside the drinking water quality threats are the typical land use activities that are associated with the threat.

Table 4-5: Drinking Water Quality Threats

Prescribed Drinking Water Quality Threats Ontario Regulation 287/07 s.1.1.(1)		**Land Use/Activity**
1	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the Environmental Protection Act.	Landfills – Active, Closed Hazardous Waste Disposal Liquid Industrial Waste
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.	Sewage Infrastructures Septic Systems, etc.
3	The application of agricultural source material to land.	e.g. manure, whey, etc.
4	The storage of agricultural source material.	e.g. manure, whey, etc.
5	The management of agricultural source material.	aquaculture
6	The application of non-agricultural source material to land.	Organic Soil Conditioning Biosolids
7	The handling and storage of non-agricultural source material.	Organic Soil Conditioning Biosolids
8	The application of commercial fertilizer to land.	Agriculture Fertilizer
9	The handling and storage of commercial fertilizer.	General Fertilizer Storage
10	The application of pesticide to land.	Pesticides
11	The handling and storage of pesticide.	General Pesticide Storage
12	The application of road salt.	Road Salt Application
13	The handling and storage of road salt.	Road Salt Storage
14	The storage of snow.	Snow Dumps
15	The handling and storage of fuel.	Petroleum Hydrocarbons
16	The handling and storage of a dense non-aqueous phase liquid.	DNAPLs
17	The handling and storage of an organic solvent	Organic Solvents
18	The management of runoff that contains chemicals used in the de-icing of aircraft.	De-icing
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard.	Agricultural Operations

Table 4-5: **Drinking Water Quality Threats**		
Prescribed Drinking Water Quality Threats Ontario Regulation 287/07 s.1.1.(1)		**Land Use/Activity**
22	The establishment and operation of a liquid hydrocarbon pipeline. OReg.385/08, s. 3; O.Reg.206/18, s.1	Liquid Hydrocarbon Pipelines

The Technical Rules (MOECC, 2017) list five ways in which to identify a drinking water threat:

a) Through an activity prescribed by the Act as a Prescribed Drinking Water Threat;
b) Through an activity identified by the Source Water Protection Committee as an activity that may be a threat and (in the opinion of the Director) a hazard assessment confirms that the activity is a threat;
c) Through a condition that has resulted from past activities that could affect the quality of drinking water;
d) Through an activity associated with a drinking water issue; and
e) Through an activity identified through the events based approach (this approach has not been used in this Assessment Report).

Water quality threats can fall into one of the following four categories:

- Chemical threats can include toxic metals, pesticides, fertilizers, petroleum products and industrial solvents;
- Pathogenic threats are microorganisms that could cause illness; and
- Dense non-aqueous phase liquids (DNAPLs) are chemicals which are denser than water and do not dissolve in water, such as chlorinated solvents.
- Through a condition that has resulted from past activities that could affect the quality of drinking water.

Significant threats to Oxford County groundwater supply were assessed through the development of a desktop land use inventory.

4.2.1 Land Use Inventory

To associate the prescribed drinking water threats listed in with land use activities, Oxford County compiled a land use inventory. The inventory was based on a review of multiple data sources which included previous groundwater-related work undertaken by the County, public records, local knowledge and windshield surveys.

Previous Work

In 2004, Oxford County participated in a groundwater protection pilot project known as the Land Use and Chemical Occurrence (LUCO) Inventory. The objective of the inventory was to identify past and present sources of potential threats that may represent risks to aquifers or are within WHPAs. The inventory was based on the guidelines from the provincial Groundwater Studies' Technical Terms of Reference (2001). Data was obtained primarily through government and commercial databases. This information was used as the starting point for the current threats inventory.

Local Knowledge

Wherever possible, County and Township staff's local knowledge was used to supplement the datasets. Local knowledge was used to confirm road salt application, details of activities undertaken on properties, and type and number of livestock on agricultural properties.

Windshield Surveys

Windshield surveys were conducted to:

- Gain information on current land uses,
- Confirm land uses, and
- Confirm locations of potential drinking water threats.

The survey was conducted within Oxford County between the spring and fall of 2007. The windshield survey was often used for verification of data obtained from various other sources.

Government Databases

Oxford County obtained a number of government and commercial databases during the 2004 LUCO study. Updated versions of these datasets were obtained for the current land use inventory wherever possible.

Other Sources

Data sources other than those described above were primarily used for data verification and improvement. These sources include the County of Oxford On-Line Directory (COOLOxford), the County of Oxford's Land Related Information System (LRIS), the North American Industry Classification System (NAICS), Industry Canada's website, and the Yellow Pages.

The COOLOxford website provides access to a database of public notices, events, businesses, organizations, and services in Oxford County.

The County's LRIS, which is maintained by Oxford County, is a Geographic Information System (GIS) that combines digital maps of the area with related information, such as:

- Property owner and registry,
- Assessment and apportionments,
- Property dimensions,
- Structure locations and characteristics,
- Topographic features including flood plains and vegetation,
- Cultural information including zoning and Official Plan designation, and
- Aerial photography.

For the purposes of the initial threats inventory, NAICS codes were used to determine land use activity names and potential associations with land uses that constitute threats.

Industry Canada provides business and consumer information via the internet. Their website was used to obtain business/industry profiles.

The on-line version of the yellow pages was used to locate businesses and provided links to business websites which helped determine activities undertaken by companies.

Detailed Threat Assessment

Detailed threat assessment commenced in late 2010 to acquire site specific threat information from property owners who had been identified as a potential significant threat using the information described above. The assessment involved contacting property owners directly to obtain site specific threat information which was used to update the significant threat inventory. This detailed threat assessment is on-going and any information collected up until the date of this report was included. The detailed threat assessment will continue throughout the Source Protection Plan development phase and the threats database will continue to be updated as new information is collected.

4.2.2 Methodology

The prescribed threats could pose a threat to drinking water, but only under certain circumstances. Circumstances that would cause an activity to be classified as a significant, moderate or low (risk) threat have been provided in the MOECC Technical Rules, Table of Drinking Water Threats. The Table of Drinking Water Threats accounts for the hazard rating associated with particular substances linked with certain land use activities. Land use activities were further evaluated using professional judgement to determine the likelihood that circumstances are present that would categorize the land use activity as a threat. The circumstances often involve factors associated with the type of contaminant, its volume and consideration of the likelihood of release into the environment.

Activities that have been inventoried were subjected to the process described above to determine their risk category based on their hazard to human health, and the vulnerability of the drinking water source. The risk assessment places activities into one of three risk categories: significant, moderate, or low.

The inventory compiled for this purpose is based on the available data sources described in **Section 4.8**, as well as on assumptions and professional judgement, as described above.

4.2.3 Conditions

The *Clean Water Act, 2006* Technical Rule 126 requires a list of conditions that are drinking water threats resulting from a past activity to be included in the Assessment Report if the Source Protection Committee is aware of them:

1) The presence of a non-aqueous phase liquid in groundwater in a highly vulnerable aquifer, significant groundwater recharge area or wellhead protection area;

2) The presence of a single mass of more than 100 litres of one or more dense non-aqueous phase liquids in surface water in a surface water intake protection zone;

3) The presence of a contaminant in groundwater in a highly vulnerable aquifer,significant groundwater recharge area or a wellhead protection area, if the contaminant is listed in Table 2 of the Soil, Ground Water and Sediment Standards, is present at a concentration that exceeds the potable groundwater standard set out for the contaminant in that Table, and the presence of the contaminant in groundwater could result in the deterioration of the groundwater for use as a source of drinking water.

4) The presence of a contaminant in surface soil in a surface water intake protectionzone if, the contaminant is listed in Table 4 of the Soil, Ground Water and Sediment Standards is present at a concentration that exceeds the surface soil standard for industrial/commercial/

community property use set out for the contaminant in thatTable and the presence of the contaminant in surface soil could result in the deterioration of the surface water for use as a source of drinking water.

5) The presence of a contaminant in sediment in an intake protection zone, if the contaminant is listed in Table 1 of the Soil, Ground Water and Sediment Standardsand is present at a concentration that exceeds the sediment standard set out for the contaminant in that Table, and the presence of the contaminant in sediment could result in the deterioration of the surface water for use as a source of drinking water.

6) The presence of a contaminant in groundwater that is discharging into an intake protection zone, if the contaminant is listed in Table 2 of the Soil, Ground Water and Sediment Standards, the concentration of the contaminant exceeds the potable groundwater standard set out for that contaminant in the Table, and the presence of the contaminant in groundwater could result in the deterioration of the surface water for use as a source of drinking water.

All of Oxford County's water supply is obtained from groundwater sources. Therefore, only conditions 1 and 3 as listed above are applicable.

4.3 Oxford County's Drinking Water Issues

The *Clean Water Act, 2006* Technical Rules (MOECC, 2017) requires that Issues associated with the drinking water quality for the municipal system be identified. The activities that contribute to identified Issues that have an anthropogenic origin are deemed to be significant drinking water threats.

The water quality data used in this evaluation was compiled by the Oxford County Public Works Department. The data comprises the analytical results taken as part of operating the systems in addition to water quality results received as part of other programs/projects. Ministry sources were not utilized as all those sources obtained their information from the County data. The bulk of the data used in this evaluation is from 2001 to present. Older data has been used where relevant.

The Issues evaluation (County of Oxford, 2009b and Matrix, 2019) for Oxford County focused on the water quality parameter groupings outlined in the Ontario Drinking Water Quality Standards (ODWQS) identified in Ontario Regulation 169/03 under the *Safe Drinking Water Act, 2002* and the related technical support document. These parameters include: a) Pathogens, b) Schedule 1 Parameters, c) Schedule 2 and 3 parameters, and, d) Table 4 parameters.

Parameters have been screened for closer investigation where any of the following criteria have been met:

- Consistent presence of microbiological parameters;

- The parameter has a health related Maximum Acceptable Concentration (MAC) associated with it and the concentration in the raw or treated water exceeds half of the MAC level (with the exception of fluoride); and

- The parameter does not have a health related MAC but the concentration observed exceeds the objective or guideline associated with the ODWS.

Water quality parameters meeting the screening threshold above were further reviewed to determine whether to identify them as Issues. The considerations included:

- Whether the concentration is at or trending towards a health related MAC;
- The frequency with which the parameter meets the screening threshold;
- Capabilities of the treatment facility;
- The ability of the parameter to interfere with/upset the treatment process;
- Whether the parameter is related to Issues raised by the public; and
- Importance of the well to the overall supply.

A detailed evaluation of Issues present for each municipal water supply is presented in **Sections 4.4 to 4.7.**

4.4 Dereham Centre Water Supply

The Dereham Centre water system (**Map 4-1**) is supplied by a single well (Well 2) located in the southeast part of the village. At the time of the Phase II Groundwater Protection Study (2001), the water system was supplied by a different well (Well 1) located approximately 225 m to the north of Well 2. The water well record indicates that the original supply well was screened in gravel (17.1 – 17.7 m below surface) and considered to be part of the Intermediate Aquifer (Golder 2001). The current supply well (Well 2) was constructed in 2000 with a well screen set from approximately 35 – 36 m below surface. The water well record indicates that the screened interval is overlain by fine grained sediments (clay). It is a Small Municipal Water system as defined by Regulation 170/03 and serves a population of approximately 48.

4.4.1 Wellhead Protection Areas and Vulnerability

The MODFLOW groundwater model was used to generate Wellhead Protection Areas for the Dereham Centre system (Golder, 2001). The model covers an area of approximately 28 km^2, and is oriented in a northeast to southwest direction, parallel to the direction of regional groundwater flow in the municipal supply (intermediate) aquifer. The following sections below provide a summary of the groundwater model based on hydrogeological information available at the time of the Golder (2001) study.

The Wellhead Protection Areas developed in the original model were based on Dereham Centre's municipal Well 1. This well is no longer in use and has since been replaced by Well 2. The Wellhead Protection Areas for Well 2 were delineated in 2007 using the same 2001 model. A pumping rate of 9 m^3/day was used to model the Wellhead Protection Area for Well 2.

The following provides a summary of the Dereham Centre Groundwater Flow Model based on hydrogeological information available at the time of the Golder (2001) study.

Stratigraphy

Dereham Centre is primarily underlain by Port Stanley Till, a low permeability silty clay with a sandy silt matrix. The till is approximately 17 m thick in the area of the Dereham water supply well, and there is no Shallow Aquifer mapped in this area. To the north of Dereham Centre, the shallow aquifer is present, and was included in the groundwater model where present. The intermediate aquifer was assigned a thickness of 4 m in the groundwater model. The Dereham

Centre well (Well 2) is screened approximately 35 to 36 metres below ground surface (mbgs). The water well record indicates that the screened interval is overlay by fine-grained clay sediments.

Groundwater Flow Boundaries

Groundwater flow in the intermediate aquifer at Dereham Centre is inferred to occur in a southeasterly direction. To the northeast and southwest of Dereham, the model boundaries follow inferred groundwater contours and were assigned as constant head boundary conditions. To the northeast, a constant head boundary ranging in elevation from 261 metres above sea level (masl) to 275 masl was assigned.

Groundwater will flow into the model across this boundary. To the southwest, a constant head boundary elevation of 260 masl was assigned. Groundwater will flow out from the model across this boundary. To the southeast and northwest of Dereham Centre the model boundaries follow inferred groundwater flowlines, and were therefore assigned as "no flow" boundaries. It was assumed that groundwater flow in the intermediate aquifer does not occur across these boundaries.

Groundwater/Surface Water Interaction

Given the thickness and low permeability of the Port Stanley Till that overlies the intermediate aquifer, the surface water systems are considered to be hydraulically isolated from the aquifer in the Dereham Centre area. Direct intermediate aquifer groundwater and surface water interactions were not included in the model.

Recharge

Recharge into the till, which covers the majority of the model area, was applied at a rate of 20 millimeters per year (mm/yr).

Hydraulic Conductivity and Porosity

There was no record of aquifer tests completed for the Dereham Centre well that would provide an estimate of the local aquifer properties. The hydraulic conductivity of the intermediate aquifer in the model was assigned at 5×10^{-4} m/s, with an effective porosity of 25%. This hydraulic conductivity was established through the model calibration process.

Other Water Takings

No private water takings from the intermediate aquifer were identified in the review of the MOE PTTW Database for the Dereham Centre area. It was assumed that the Dereham Centre water supply well is the only water taking from the intermediate aquifer in this area.

Calibration of the Dereham Centre Groundwater Model involved the adjustment of the recharge rate into the aquifer and the hydraulic conductivity of the intermediate aquifer until there was a reasonable match between the simulated groundwater elevations and the recorded groundwater elevations for Dereham Centre area overburden wells in the MOE Well Record Database. As defined above, the hydraulic conductivity of the intermediate aquifer was estimated to be 5×10^{-4} m/s, with a recharge rate of 20 mm/yr over most of the model area. The average annual pumping rate in 1999 (of 6.6 m^3/day) was used in the calibration process. **Map 4-2** illustrates the Wellhead Protection Areas for the Dereham Centre Water System. The Wellhead Protection Areas extend approximately 3.4 km to the northeast, terminating near the Village of Mount Elgin.

Vulnerability Scoring

The intrinsic vulnerability for the intermediate aquifer (as defined by Golder (2001) and using the AVI method), within Well 2's Wellhead Protection Areas is low for WHPAs A, B, and C and a large portion of WHPA-D has a moderate vulnerability.

The vulnerability mapping within Oxford County was completed using the AVI method (ARL Groundwater Resources 2010; Golder, 2001) with score thresholds of <30, 30-80, and >80 to identify areas of high, medium and low vulnerability respectively.

The assessment of transport pathways within Well 2's Wellhead Protection Areas resulted in a limited number of private wells located within the Wellhead Protection Areas. No adjustments were made to the vulnerability as a result of the assessment. The intrinsic vulnerability is shown on **Map 4-3**.

Final vulnerability scoring is shown on **Map 4-3.** Vulnerability scores range from 10 in WHPA-A, to 6 in WHPA-B, to 4 in WHPA-C and 2 - 4 in WHPA-D.

4.4.2 Managed Lands and Livestock Density

Managed lands and livestock density calculations for Dereham Centre were completed in WHPA-A, WHPA-B. **Table 4-6** provides the results of the calculations, showing that WHPA-A falls into the 'high' percent managed lands category and 'low' livestock density category while WHPA-B is in the 'moderate' percent managed lands category and the 'moderate' livestock density category (**Map 4-6** and **Map 4-7**).

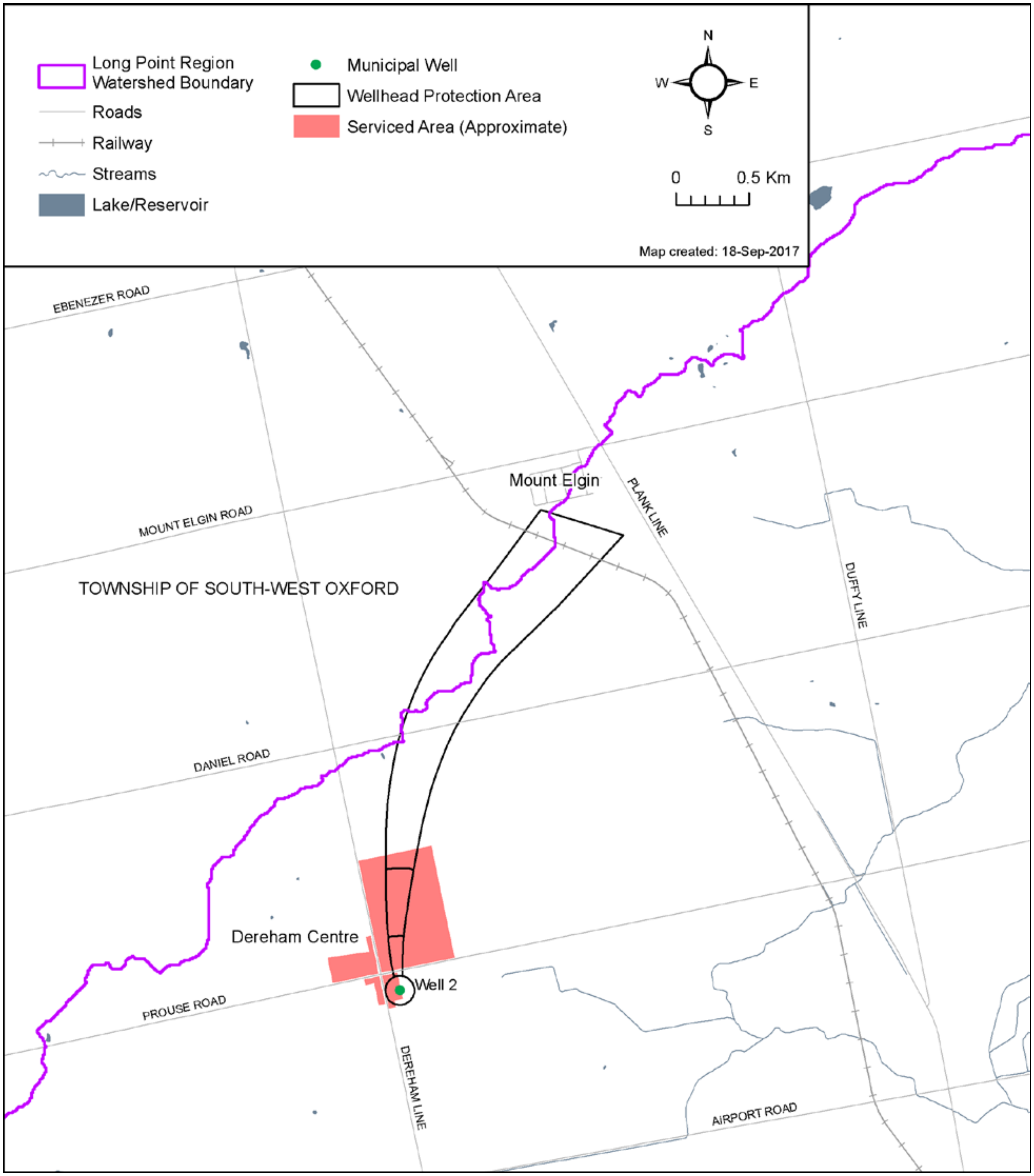
Table 4-6: Managed Lands and Livestock Density in Dereham Centre

WHPA Zone	Percent Managed Land	Livestock Density
	%	NU/acre
Dereham Centre Well 2 WHPA-A	99%	0.0
Dereham Centre Well 2 WHPA-B	79%	0.7

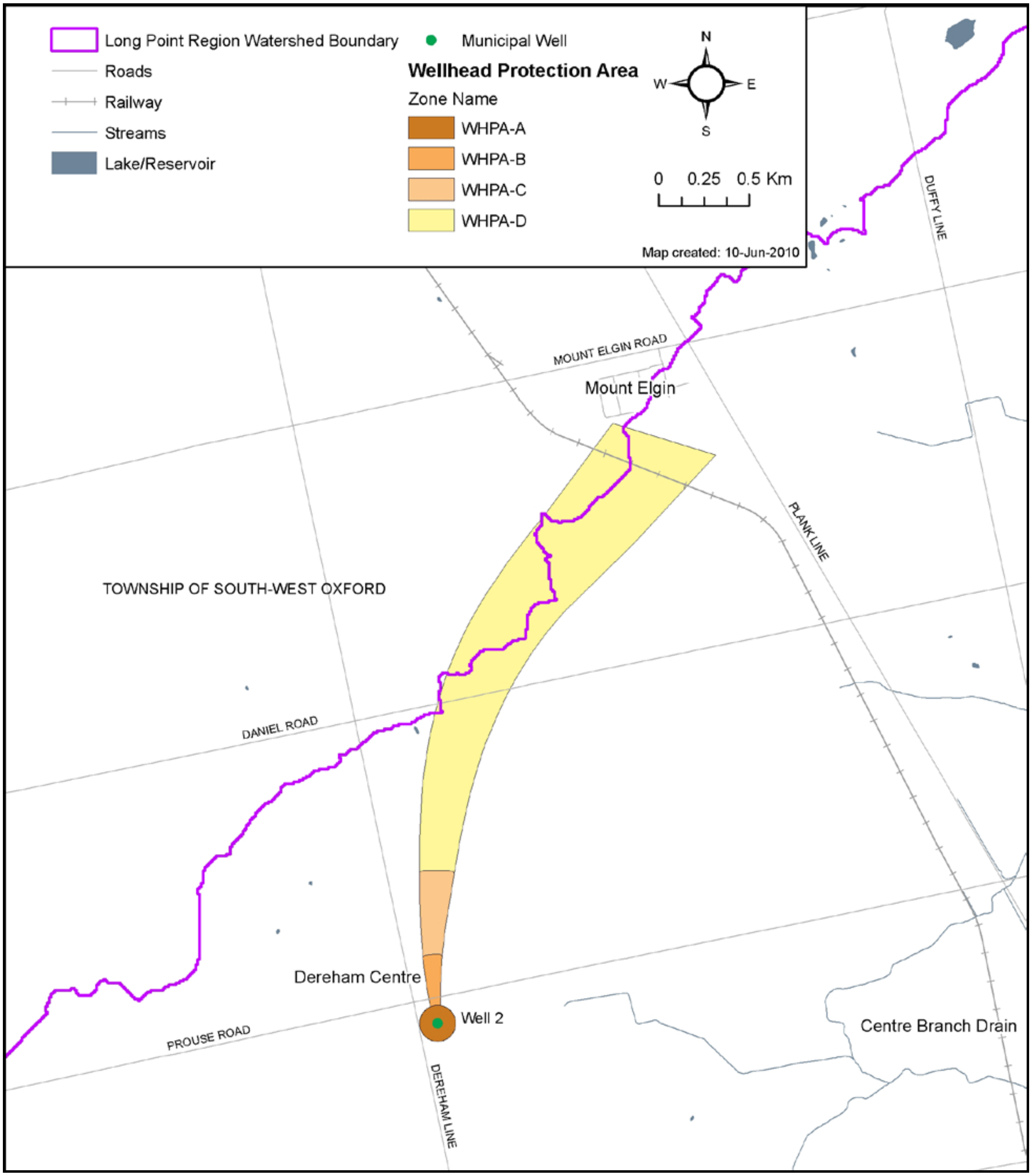
Percent Impervious Surface Area in Wellhead Protection Areas

For Dereham Centre, the impervious surfaces were calculated in WHPA-A and WHPA-B. In cases where only portions of a Wellhead Protection Area had a vulnerability score higher than 6, impervious surfaces were clipped to these areas. The results show that due to the low percent impervious surfaces the application of road salt would not be a significant threat (**Map 4-8**).

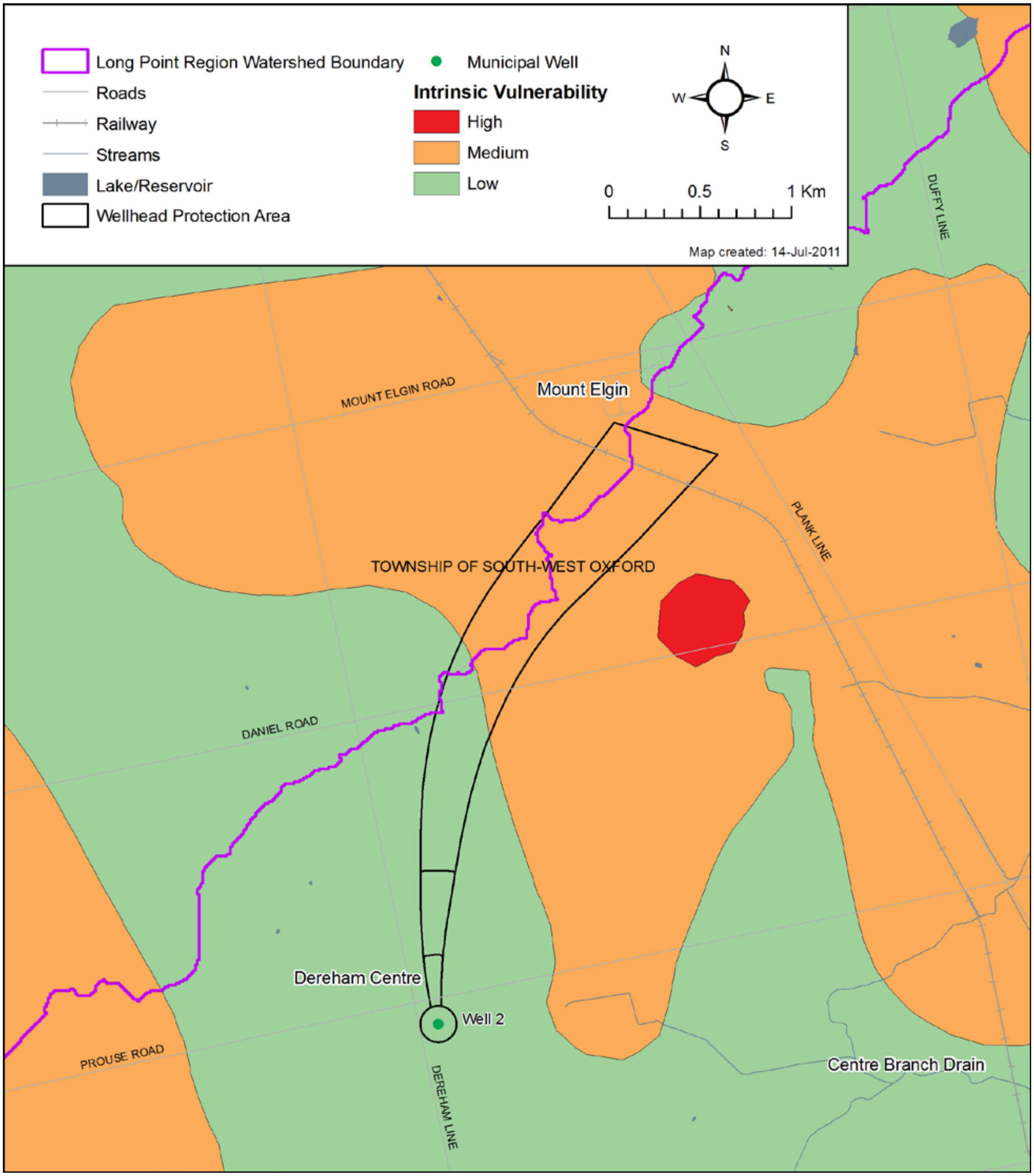
Map 4-1: Serviced Areas for the Dereham Centre Water Supply



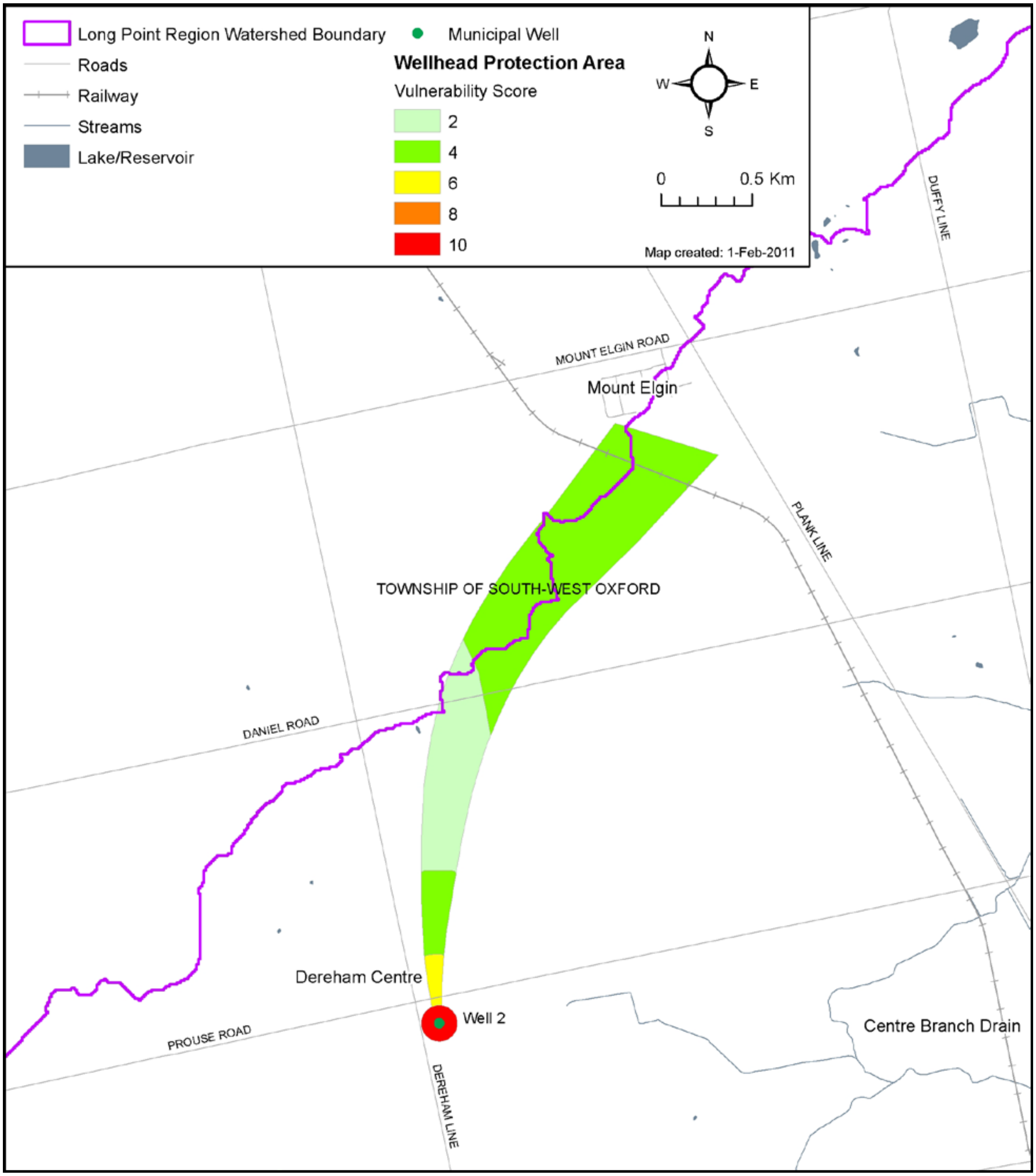
Map 4-2: Dereham Centre Wellhead Protection Areas



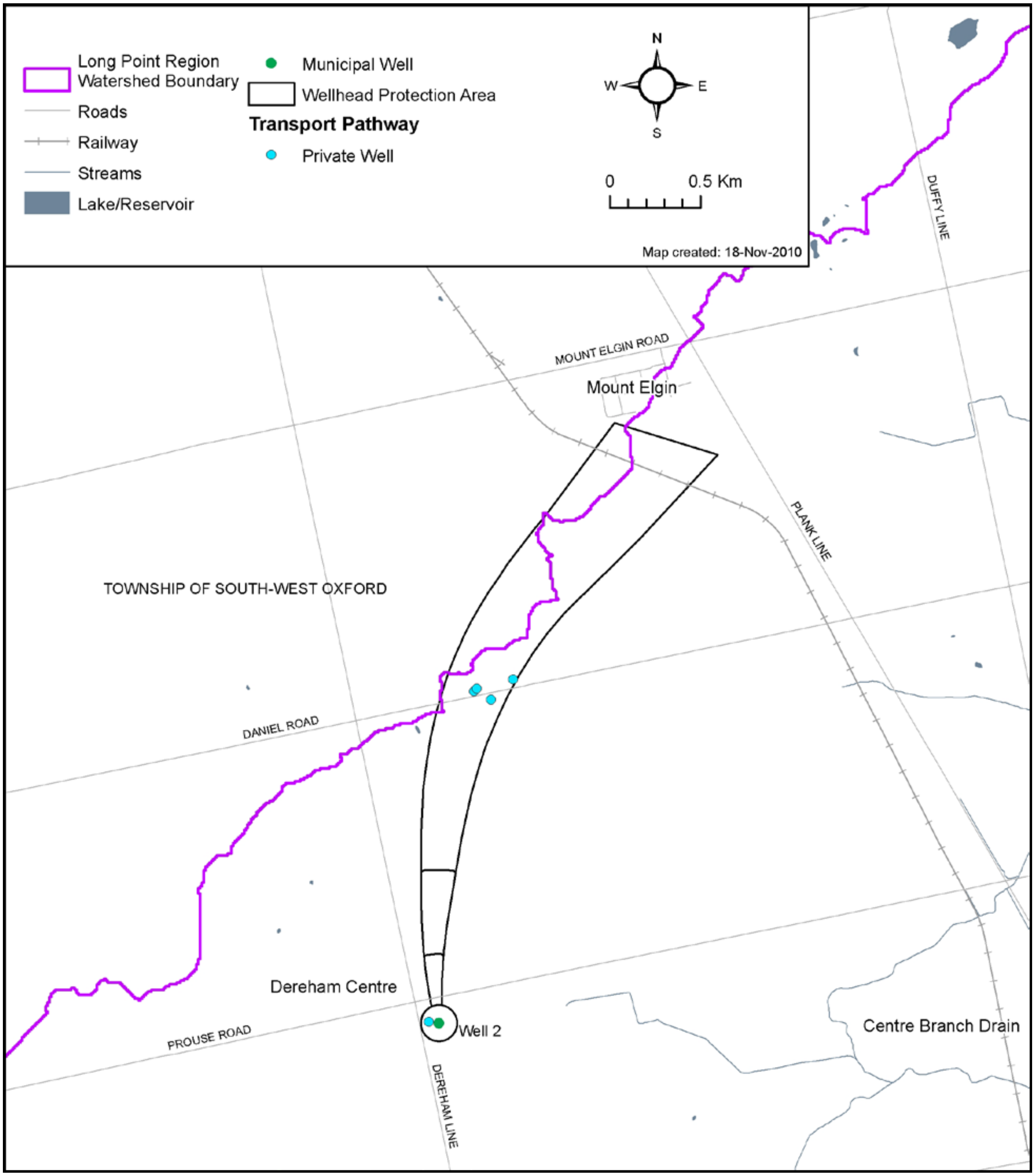
Map 4-3: Dereham Centre Intrinsic Vulnerability



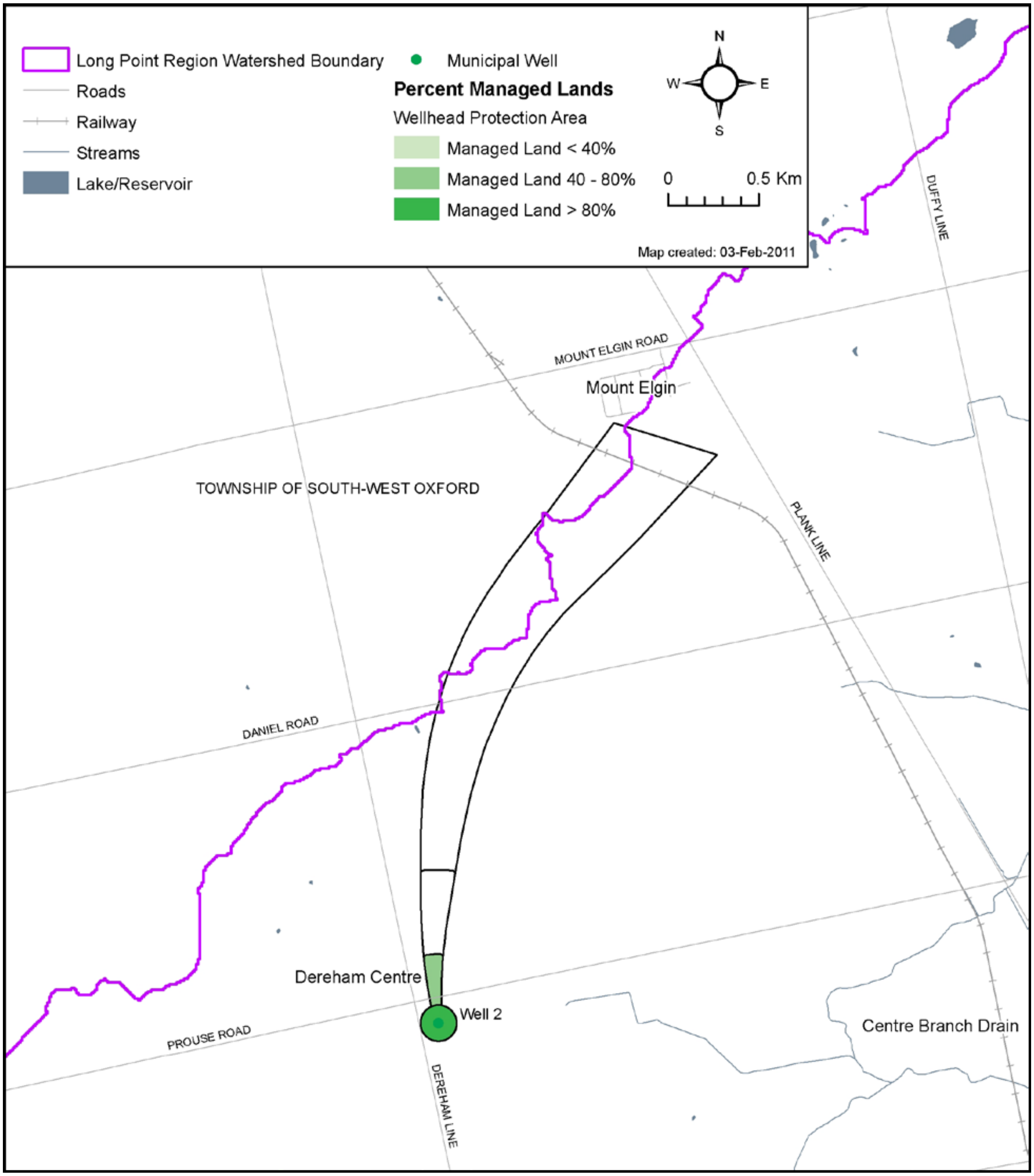
Map 4-4: Dereham Centre Wellhead Protection Area Vulnerability



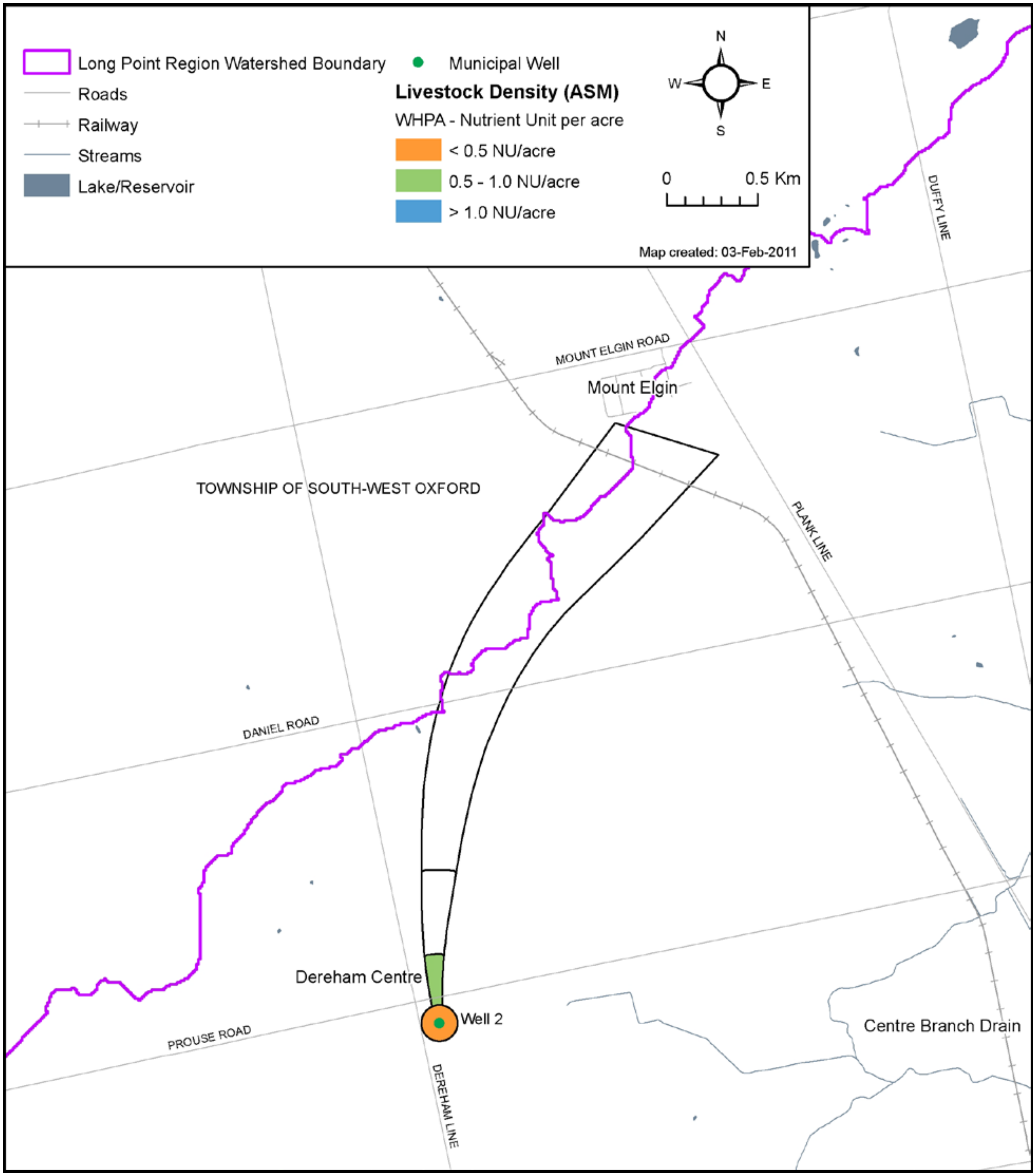
Map 4-5: Dereham Centre Transport Pathways



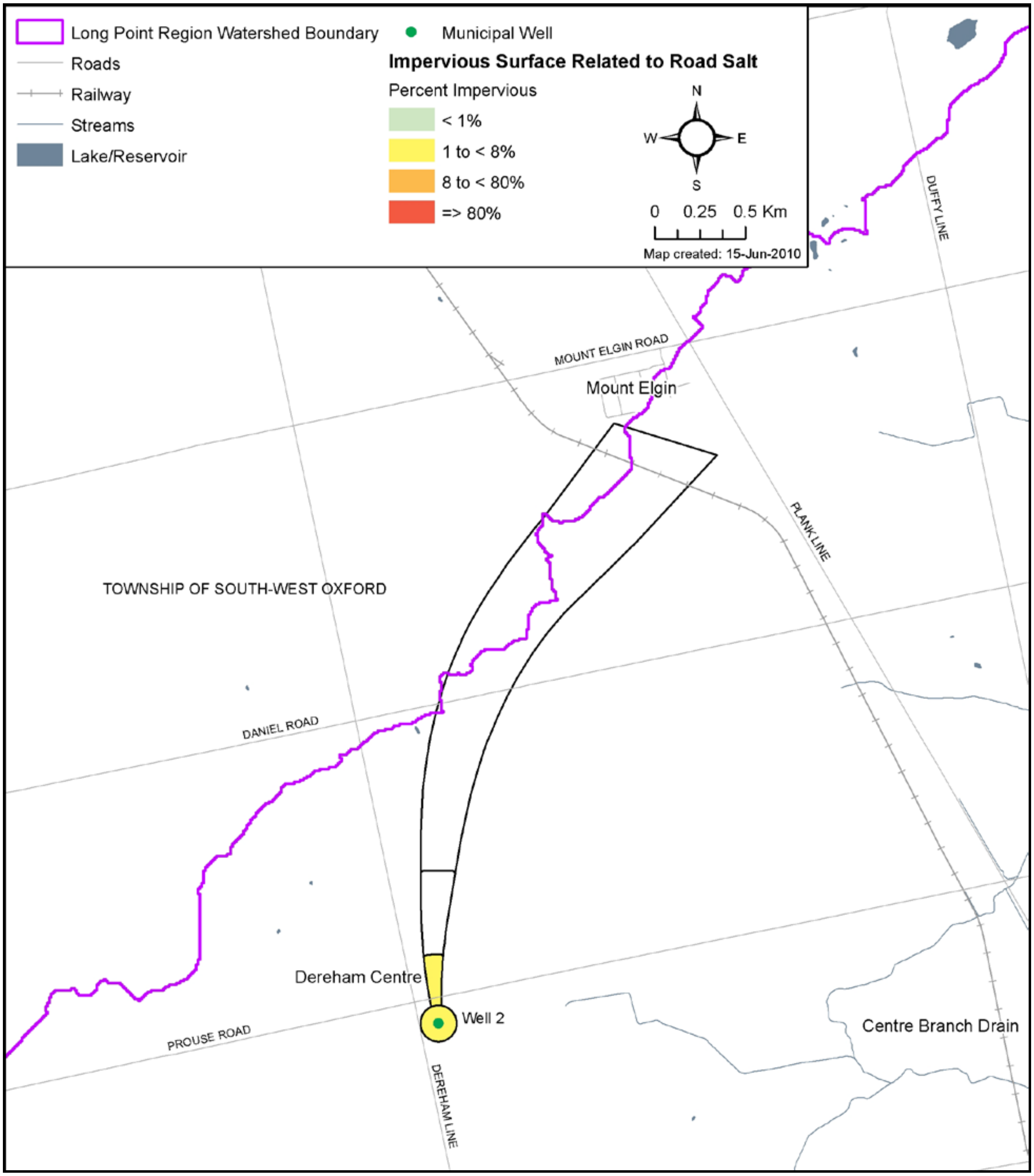
Map 4-6: Percent Managed Lands within the Dereham Wellhead Protection Area



Map 4-7: Livestock Density within the Dereham Wellhead Protection Area



Map 4-8: Percent Impervious Surfaces within the Dereham Wellhead Protection Area



4.4.3 Dereham Centre Threats Assessment

The Ontario *Clean Water Act, 2006* defines a Drinking Water Threat as “an activity or condition that adversely affects or has the potential to adversely affect the quality or quantity of any water that is or may be used as a source of drinking water, and includes an activity or condition that is prescribed by the regulation as a drinking water threat.”

Significant threats to the Dereham Centre groundwater supply were assessed through the development of a desktop land use inventory.

The identification of a land use activity as a significant, moderate, or low drinking water threat depends on its risk score, determined by considering the circumstances of the activity and the type and vulnerability score of any underlying protection zones, as set out in the Tables of Drinking Water Threats available through www.sourcewater.ca. Information on drinking water threats is also accessible through the Source Water Protection Threats Tool: http://swpip.ca. The information above can be used with the vulnerability scores shown in **Map 4-3** to help the public determine where certain activities are or would be significant, moderate and low drinking water threats.

Table 4-7 provides a summary of the threat levels possible in the Dereham Centre Well Supply for Chemical, Dense Non-Aqueous Phase Liquid (DNAPL), and Pathogens. A checkmark indicates that the threat classification level is possible for the indicated threat type under the corresponding vulnerable area / vulnerable score; a blank cell indicates that it is not. The colours shown for each vulnerability score correspond to those shown in **Map 4-3**.

Table 4-7: Identification of Drinking Water Quality Threats in the Dereham Centre Wellhead Protection Areas

Threat Type	Vulnerable Area	Vulnerability Score	Threat Classification Level		
			Significant 80+	**Moderate 60 to <80**	**Low >40 to <60**
Chemicals	WHPA-A	10	✔	✔	✔
	WHPA-B	6		✔	✔
	WHPA-C/D	2 & 4			
Handling / Storage of DNAPLs	WHPA-A/B/C	Any Score	✔		
	WHPA-D	2 & 4			
Pathogens	WHPA-A	10	✔	✔	
	WHPA-B	6			✔

Drinking Water Threats

Under the preliminary threats assessment, available desk top level land use information, air photo interpretation and local knowledge of County and municipal staff was used to determine the types of land use activity information and therefore, the threats and circumstances associated with these land uses. In most cases, professional judgment and assumptions were made when determining the presence of significant threats for each property. Consultation with property owners to verify the existence of circumstances that constitute a significant threat will be refined at a later date.

In the case of Dereham Centre, the significant threats that were enumerated occur in WHPA-A. A list of all significant threat types identified in Dereham Centre as of September 2017 and the number of times each threat occurs is shown in **Table 4-8** below.

Table 4-8: Significant Drinking Water Quality Threats in the Dereham Centre Wellhead Protection Areas

PDWT #[1]	Threat Subcategory[2]	Number of Activities	Vulnerable Area
2	Sewage System Or Sewage Works - Onsite Sewage Systems	2	WHPA-A
3	Application Of Agricultural Source Material (ASM) To Land	1	WHPA-A
8	Application Of Commercial Fertilizer To Land	3	WHPA-A
10	Application Of Pesticide To Land	1	WHPA-A
15	Handling and Storage Of Fuel	2	WHPA-A
Total Number of Properties			**3**
Total Number of Activities			**9**

1: Prescribed Drinking Water Threat Number refers to the prescribed drinking water threat listed in O. Reg 287/07 s. 1.1.(1).

2: Where applicable, waste, sewage, and livestock threat numbers are reported by sub-threat; fuel and DNAPL by Prescribed Drinking Water Threat category.

Note: Certain types of activities on residential properties that are incidental in nature and that are significant drinking water threats are not enumerated. These threats include the application of commercial fertilizer on residential properties, the storage of organic solvents (dense non-aqueous phase liquids) on residential properties, and the storage of fuel (e.g., heating fuel tanks) on residential properties in natural gas serviced areas.

Note: Storm sewer piping is not considered to be part of a storm water management facilty.

There were two types of land uses that have, or could potentially have land use activities that pose a significant threat to groundwater in Dereham Centre. These land uses are: agricultural and residential land uses. All properties referenced intersect with WHPA-A in Dereham Centre. The number of significant threat activities occurring in Dereham Centre is 9 and are as follows:

- 2 locations where septic systems are likely present;
- 1 location where the application of manure may be occurring;
- 3 locations where the application of commercial fertilizer may be occurring;
- 1 location where the application of pesticide may be occurring; and
- 2 locations where the storage of fuel may be present for heating purposes.

4.4.4 Dereham Centre Drinking Water Issues

Health Related Parameters

No health-related parameters were found to exceed their applicable ODWQS MAC. Microbiological results are consistently satisfactory and indicate no Issues. Arsenic concentrations are naturally occurring in the groundwater and do not appear to be trending upwards. Concentrations of arsenic are below the MAC of 0.025 mg/L.

Aesthetic or Operationally Significant Parameters

With the exception of hardness, iron and organic nitrogen, no operational or aesthetic parameters exceed the associated ODWQS. Hardness, which has a guideline range from 80 to 100 mg/L, is typically exceeded in groundwater systems. The Dereham Centre well's hardness concentration is 235 mg/L. The iron concentration in the system is slightly above the ODWQS of 0.30 mg/L at 0.49 mg/L. Organic nitrogen concentrations are at the aesthetic objective of 0.15 mg/L. Organic nitrogen can be associated with unpleasant taste and high levels can reduce the effectiveness of chlorine as a disinfectant.

Results

The parameters in the Dereham Centre Water Supply System that meet the screening threshold are arsenic, hardness, iron and organic nitrogen. These parameters are all naturally occurring, do not affect the treatment process, and there is no evidence of upward trending. No drinking water Issues have been identified under Technical Rule 114.

4.5 Oxford South: Norwich

The Norwich portion of the Oxford South water system (**Map 4-9**) is supplied by three secure bedrock wells. Two wells (Wells 2 and 5) are located at the Public Utilities Commission building in the centre of the town. The third well (Well 4) is located on the east edge of the town, approximately 1.4 km east of Wells 2 and 5. Wells 2 and 5 are approximately 34 and 40 mbgs, respectively. Well 4, constructed in 2003, was completed at approximately 26 mbgs.

Groundwater is treated at two locations, the Pitcher Street and Main Street facilities. The Pitcher Street facility treats groundwater from Wells 2 and 5 with filtration to remove iron and disinfection with sodium hypochlorite. The Main Street facility treats Well 4 with sodium hypochlorite for disinfection and sodium silicate to sequester iron.

The Oxford South water system, which the Norwich wells are a part of, is a Large Municipal Water system as defined by Regulation 170/03; the serviced population of Norwich is approximately 3150. Norwich operated as an independent system until November 2013, when a transmission main connecting the Norwich system to the Otterville-Springford system was commissioned, forming the Oxford South Water System

4.5.1 Norwich Wellhead Protection Areas and Vulnerability

The Norwich groundwater model developed by Golder (2001) covers an area of approximately 135 km^2, and is oriented in a northwest to southeast direction, parallel to the direction of regional groundwater flow in the bedrock aquifer. The following provides a summary of the Norwich Groundwater Flow Model based on hydrogeological information available at the time of the Golder (2001) study.

Well 1 used in the original Golder (2001) model is no longer in use and has been replaced by Well 5, which is situated at the same location as Well 1. The Wellhead Protection Areas for Wells 2 and 5 were re-assessed by Golder in 2007 using the 2001 model and the original pumping rates. The modelling showed no change to the original 2001 Wellhead Protection Areas. A forecasted pumping rate of 912 m^3/day was used to model the Wellhead Protection Areas.

Stratigraphy

The Norwich Groundwater Model was constructed using a single layer of bedrock. The limestone bedrock layer in the model contributing flow to the well was assumed to be 20 metres thick.

Groundwater Flow Boundaries

Groundwater flow in the bedrock at Norwich is inferred to occur in a southeasterly direction and the Norwich Groundwater Model was therefore oriented in this direction. To the northeast and southwest of the water supply wells the model boundaries follow inferred groundwater flowlines, and were therefore assigned as "no flow" boundaries. It is assumed that groundwater flow in the bedrock does not occur across these boundaries. To the northeast, the model boundary coincides with an inferred groundwater contour in the bedrock and was assigned as a constant head boundary at an elevation of 295 masl. Groundwater inflow to the model occurs across the northeast boundary. To the southeast, the model boundary was also assigned a constant head boundary at elevations ranging from 235.8 masl in the southwest to 255 masl in the southeast. Groundwater flow occurs out of the model at the southeast boundary.

Groundwater/Surface Water Interaction

Otter Creek flows through the town of Norwich in a south/southeasterly direction. While there is the potential for groundwater discharge from the bedrock to Otter Creek in this area, the bedrock groundwater elevation contour map does not provide any clear indication that this is occurring. It is assumed in the model that Otter Creek is not directly connected to the bedrock aquifer and that leakage to/from the creek is negligible.

Recharge

No recharge was applied to the bedrock aquifer in the Norwich Groundwater Model. Hydraulic gradients are primarily horizontal to slightly upward over much of the model area and local recharge rates are expected to be very low to negligible. The bedrock aquifer is likely recharged to the northwest of Norwich in the area of the St. Thomas and Ingersoll Moraine. This recharge is introduced into the Norwich Groundwater Model as inflow across the northwest boundary.

Hydraulic Conductivity and Porosity

The transmissivity of the bedrock aquifer was estimated from the results of the November 2000 pumping test at Norwich Well 2 (Lotowater Technical Memorandum, December 7, 2000) to be 95 m^2/day. Assuming an aquifer thickness of 10 m (the estimated open interval of the water supply well); this corresponds to an aquifer hydraulic conductivity of 1.1×10^{-4} m/s. The hydraulic conductivity in the Norwich Groundwater Model was assigned at 1.3×10^{-4} m/s, with an effective porosity of 3%.

Other Water Takings

There were no significant private water takings from the bedrock aquifer identified in the review of the MOE PTTW Database for the Norwich area. It was thus assumed that the Norwich water supply wells are the only water taking from the bedrock aquifer in this area.

Calibration of the Norwich Groundwater Model involved the adjustment of the recharge into the bedrock aquifer and the hydraulic conductivity of the bedrock until there was a reasonable match between the simulated groundwater elevations and the recorded groundwater elevations for Norwich area bedrock wells in the MOE Well Record Database. The hydraulic conductivity of the bedrock aquifer was estimated to be 1.3×10^{-4} m/s, with no recharge applied to the bedrock. The average annual pumping rate in 1999 (729 m^3/day) was used in the calibration process. **Map 4-10** illustrates the Wellhead Protection Areas for the Norwich area. A forecasted pumping rate of 912 m^3/day was used to delineate the Wellhead Protection Areas, which both extend approximately 14 km to the northwest. The Wellhead Protection Area occurs as two lobes, one from the wells located in the centre of the town and one from Well 4. The lobes merge and overlap at a distance of approximately 4 km from the wells.

Vulnerability Scoring

The intrinsic vulnerability for the Wellhead Protection Areas for the municipal wells were mapped using the SWAT method. Wellhead Protection Areas A, B, C and D are all determined to have low intrinsic vulnerability.

The vulnerability scoring was extended to fill gaps within the WHPA using professional judgment. The results show a vulnerability score of 6 in both lobes of WHPA-B. With the exception of two areas where adjustments were made to account for potential transport pathways, vulnerability scores are 2 in both Zones C and D of the WHPAs as presented on **Map 4-11**.

An adjustment of low to medium was made within the village of Burgessville located in the WHPA-D for Well 2 and Well 5 to account for transport pathways (clusters of septic systems and private wells) located in this area (see **Map 4-10**). This resulted in an increase vulnerability score from 2 to 4 in the Burgessville area in WHPA-D. Further, adjustments were made along Highway 59 located in the WHPA for Well 4 due to the high density of private wells and septic systems. This adjustment increased the vulnerability from low to moderate. The resulting vulnerability scores for these areas were increased from 2 to 4 in WHPA-D and from 2 to 6 for WHPA-C.

The adjusted vulnerability for Norwich is presented on **Map 4-13**. Although the sanitary sewer system is indicated as a transport pathway within the WHPA surrounding Well 2 and 5, an increase in vulnerability was determined not to be necessary. The overburden thickness is approximately 20 - 30 m in the Norwich area, with fine-grained (lower K) sediments making up a significant portion of the overburden (Golder, 2001). It is unlikely that the sewer system extends more than about 3 – 5 mbgs. As a result, the vulnerability was not adjusted.

The adjustments resulted in an increase in the vulnerability scores within these portions of the WHPA. The final vulnerability scores are presented on **Map 4-14.**

4.5.2 Managed Lands and Livestock Density in Norwich

The managed lands and livestock density work for Norwich was completed in WHPA-A, WHPA-B for both wells and portions of WHPA-C for Well 4 where the vulnerability was 6 or higher. As presented in **Table 4-9**, the results of the calculations showing that both WHPA-A zones and WHPA-B for Wells 2 & 5 are in the moderate category for percent managed lands while the WHPA-B and WHPA-C for Well 4 fall in the high percent managed lands category. All these zones for Norwich fall into the low livestock density category (**Map 4-15** and **Map 4-16**).

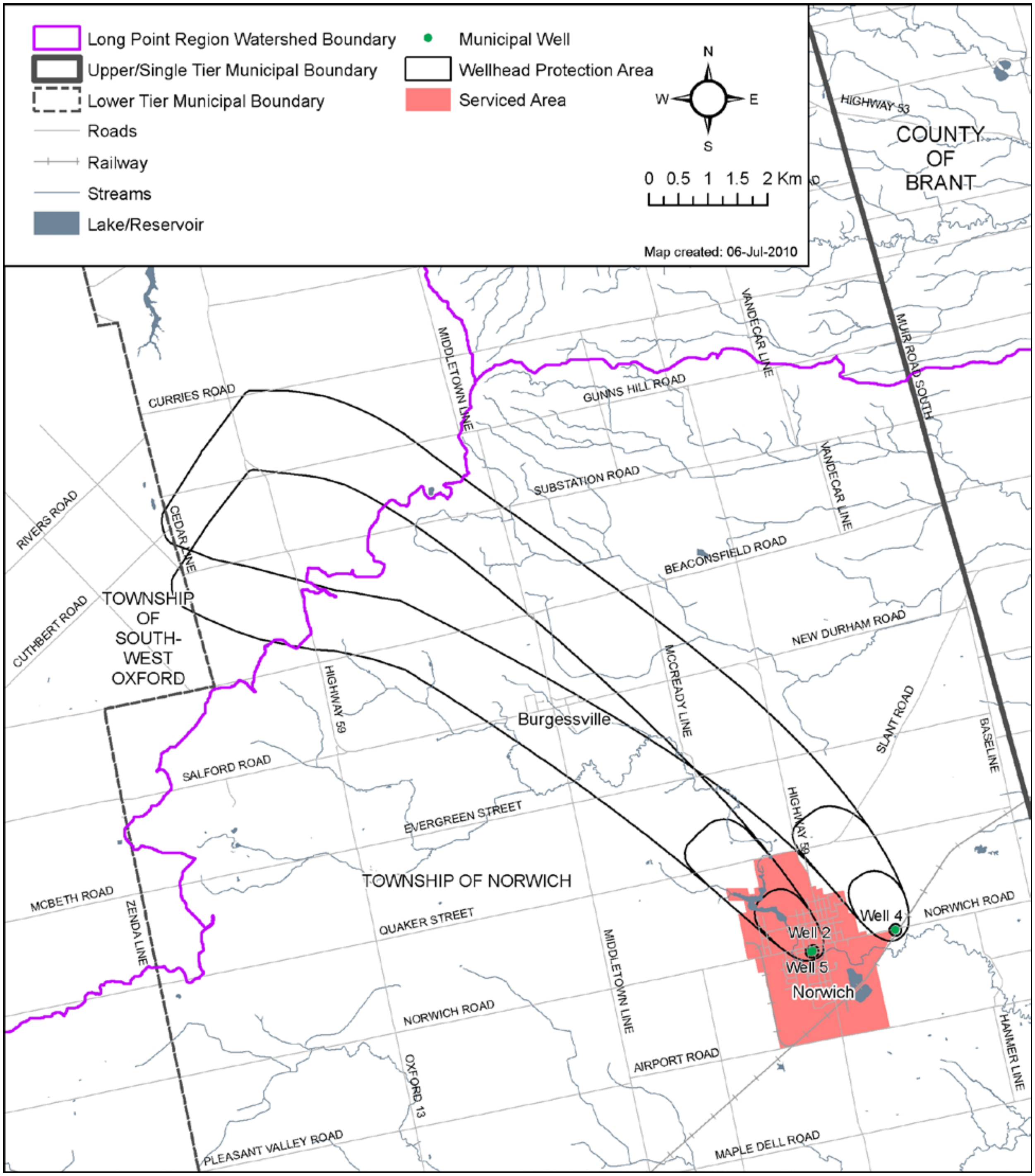
Table 4-9: Managed Lands and Livestock Density in Norwich

WHPA Zone	Percent Managed Land	Livestock Density
	%	NU/acre
Norwich Wells 2 & 5 WHPA-A	39%	0.0
Norwich Wells 2 & 5 WHPA-B	54%	0.0
Norwich Well 4 WHPA-A	76%	0.1
Norwich Well 4 WHPA-B	97%	0.2
Norwich Well 4 WHPA-C (a portion)	86%	0.0

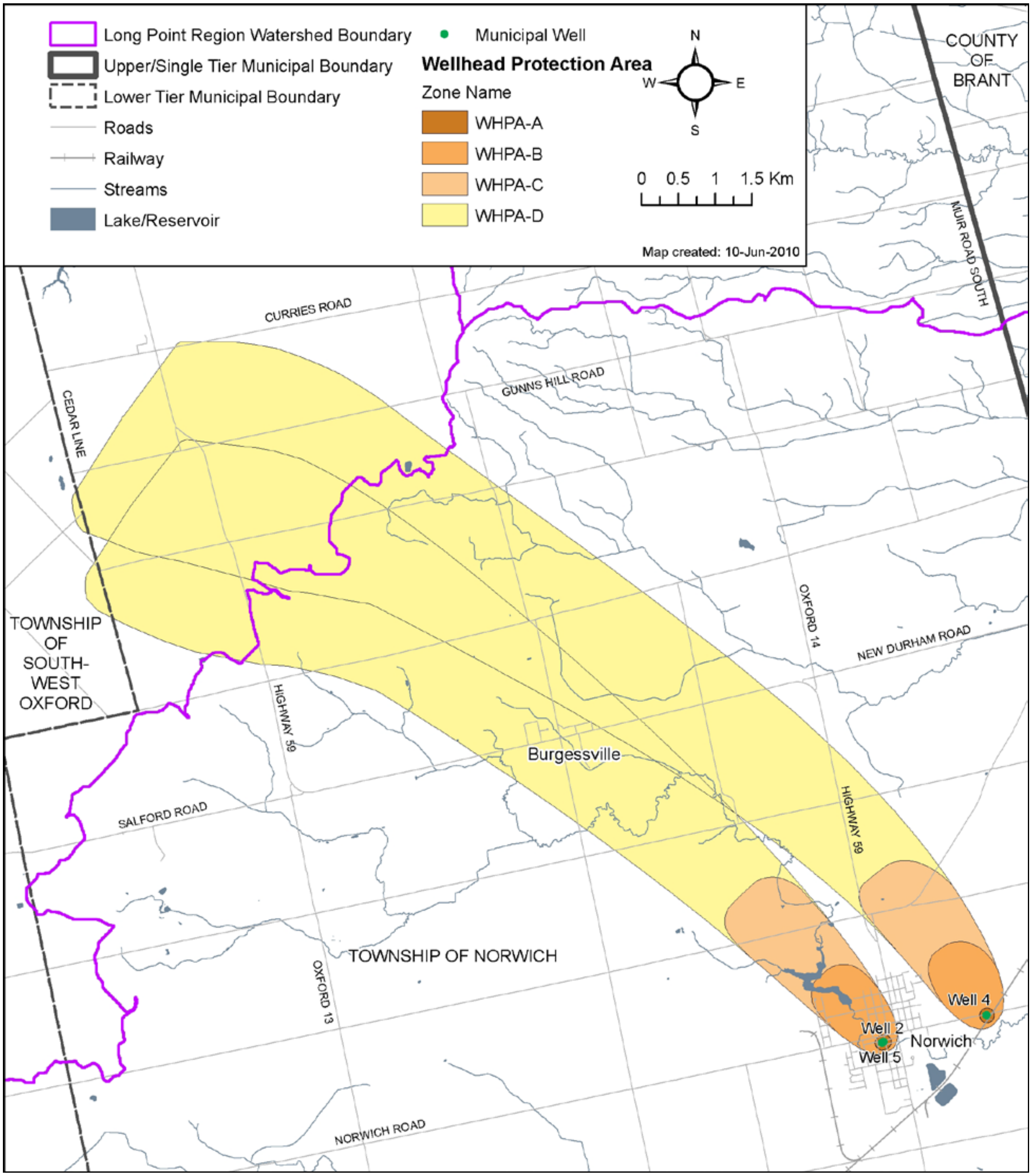
4.5.3 Impervious Surfaces in Norwich

For Norwich, impervious surfaces were mapped in WHPA-A, WHPA-B and in only a portion of WHPA-C. The results presented in **Map 4-17** show that due to the low percent impervious surfaces, the application of road salt would not be a significant threat.

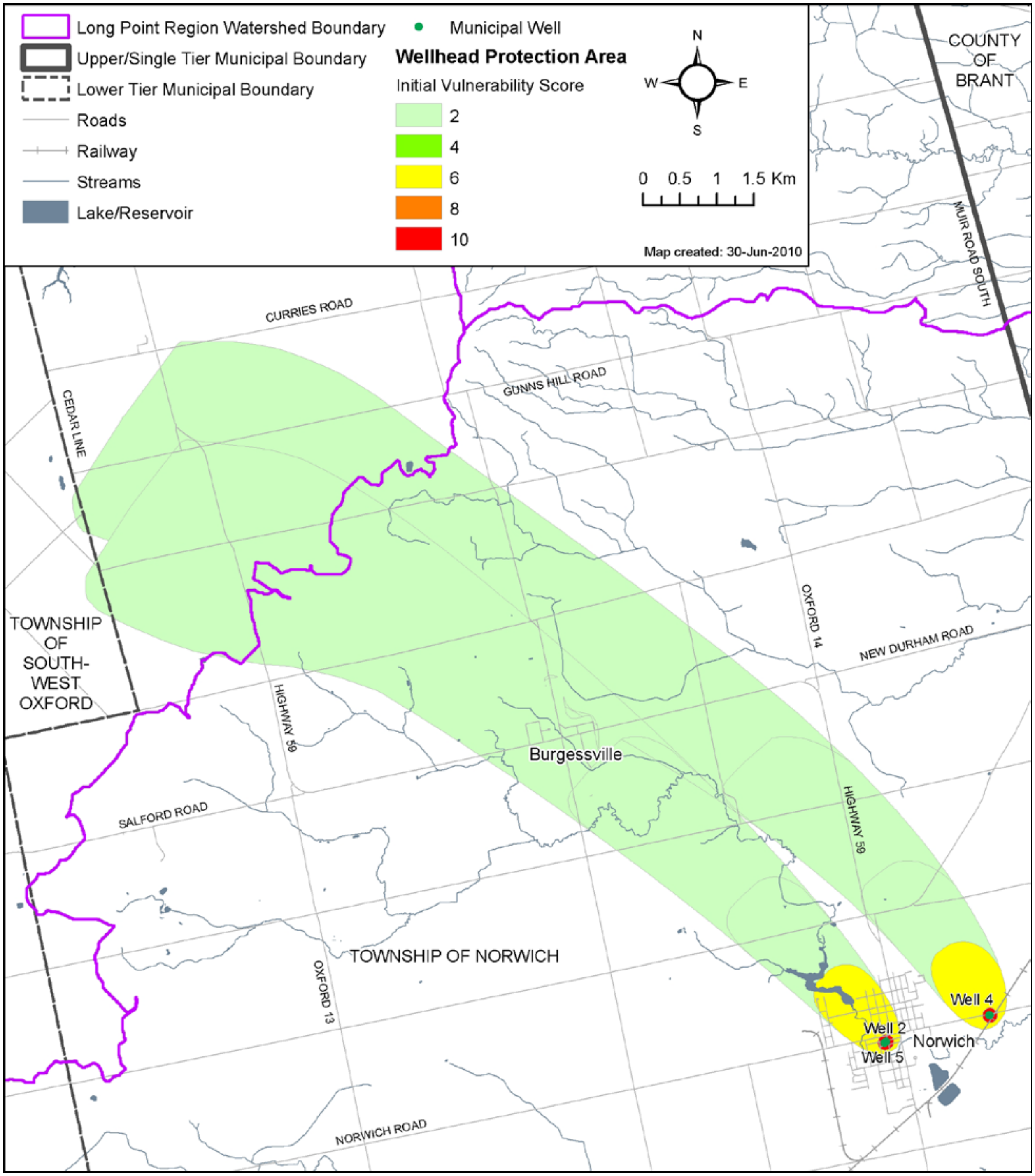
Map 4-9: Serviced Areas for Oxford South-Norwich



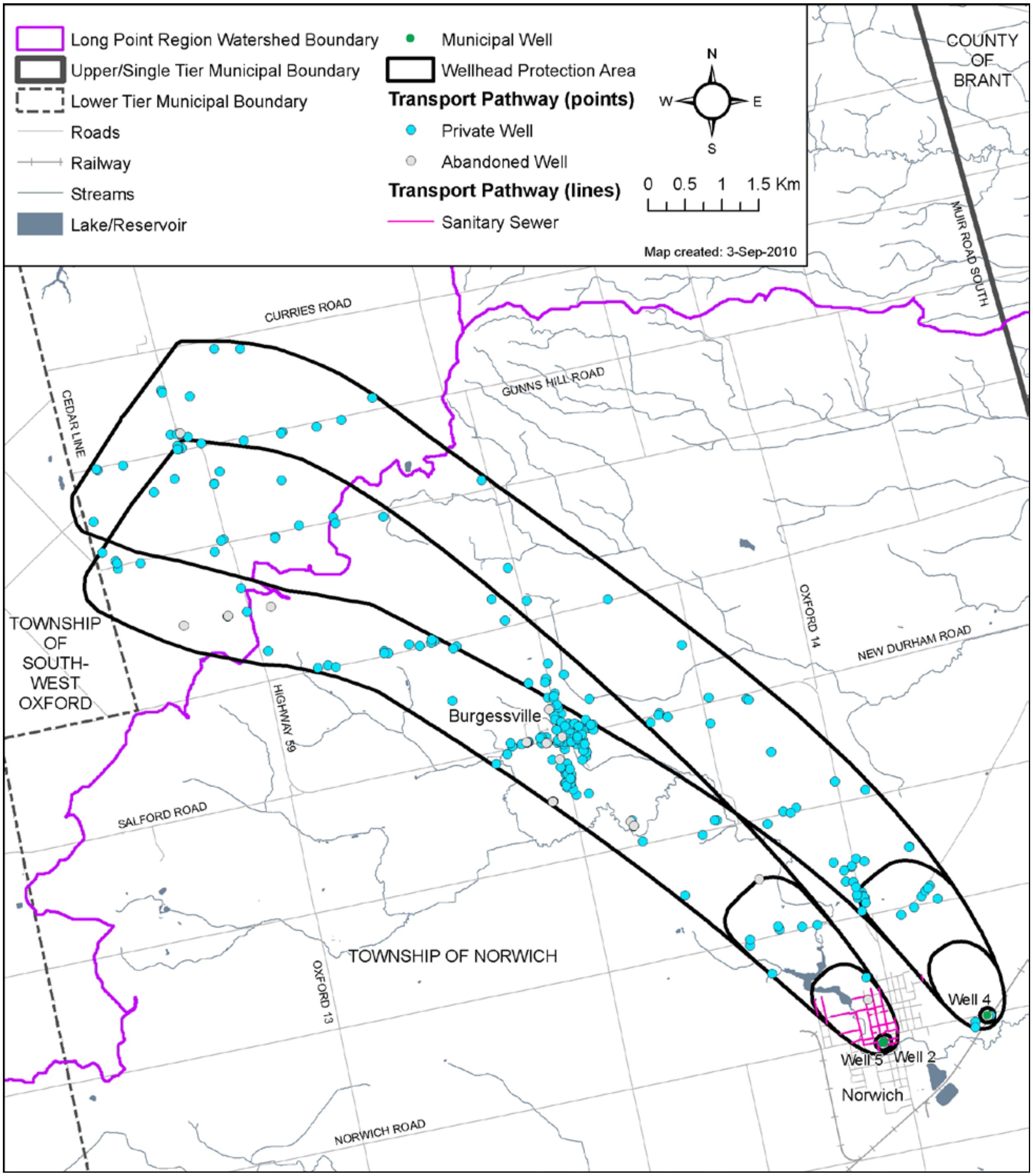
Map 4-10: Norwich Wellhead Protection Areas



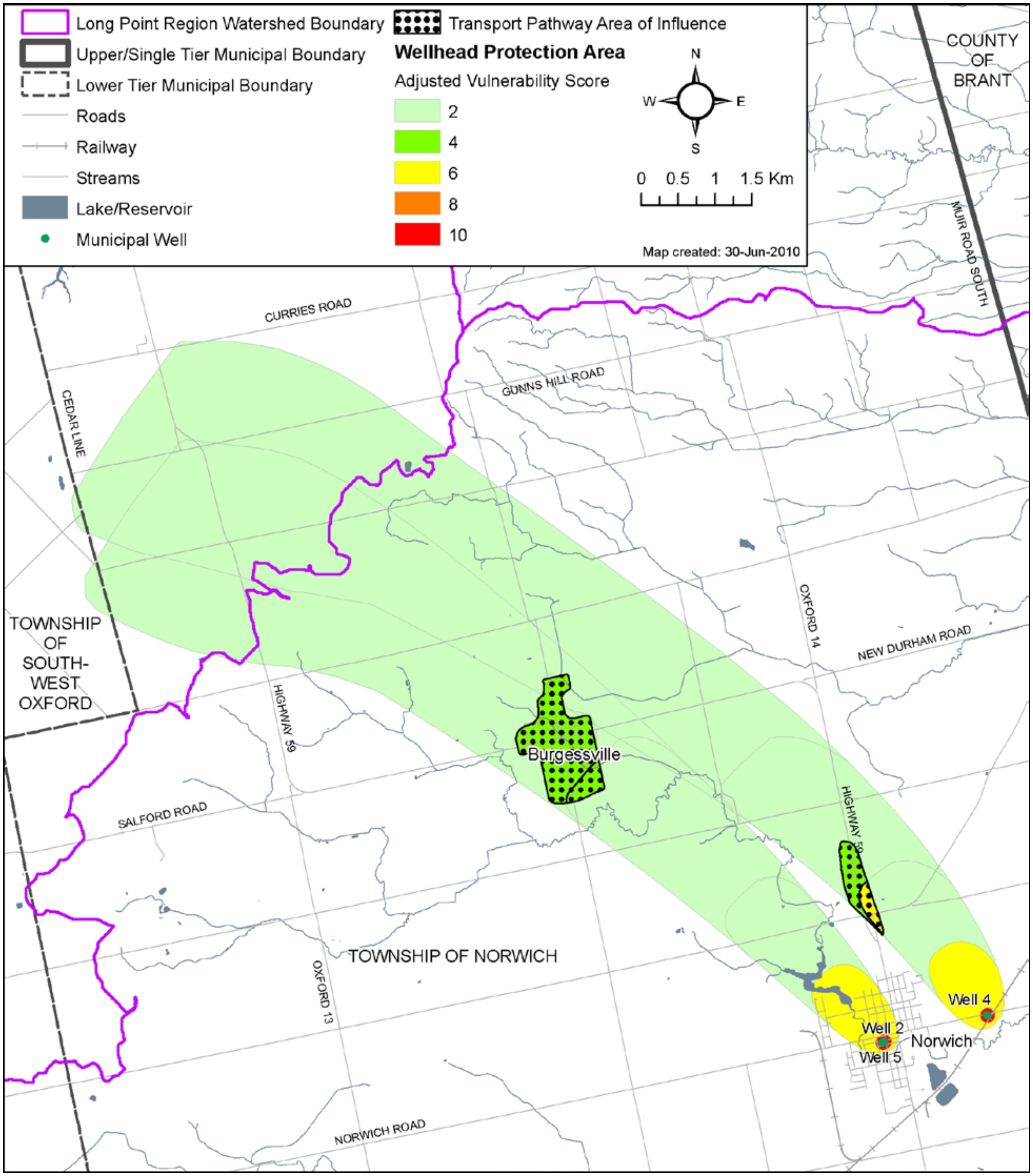
Map 4-11: Norwich Wellhead Protection Area Initial Vulnerability



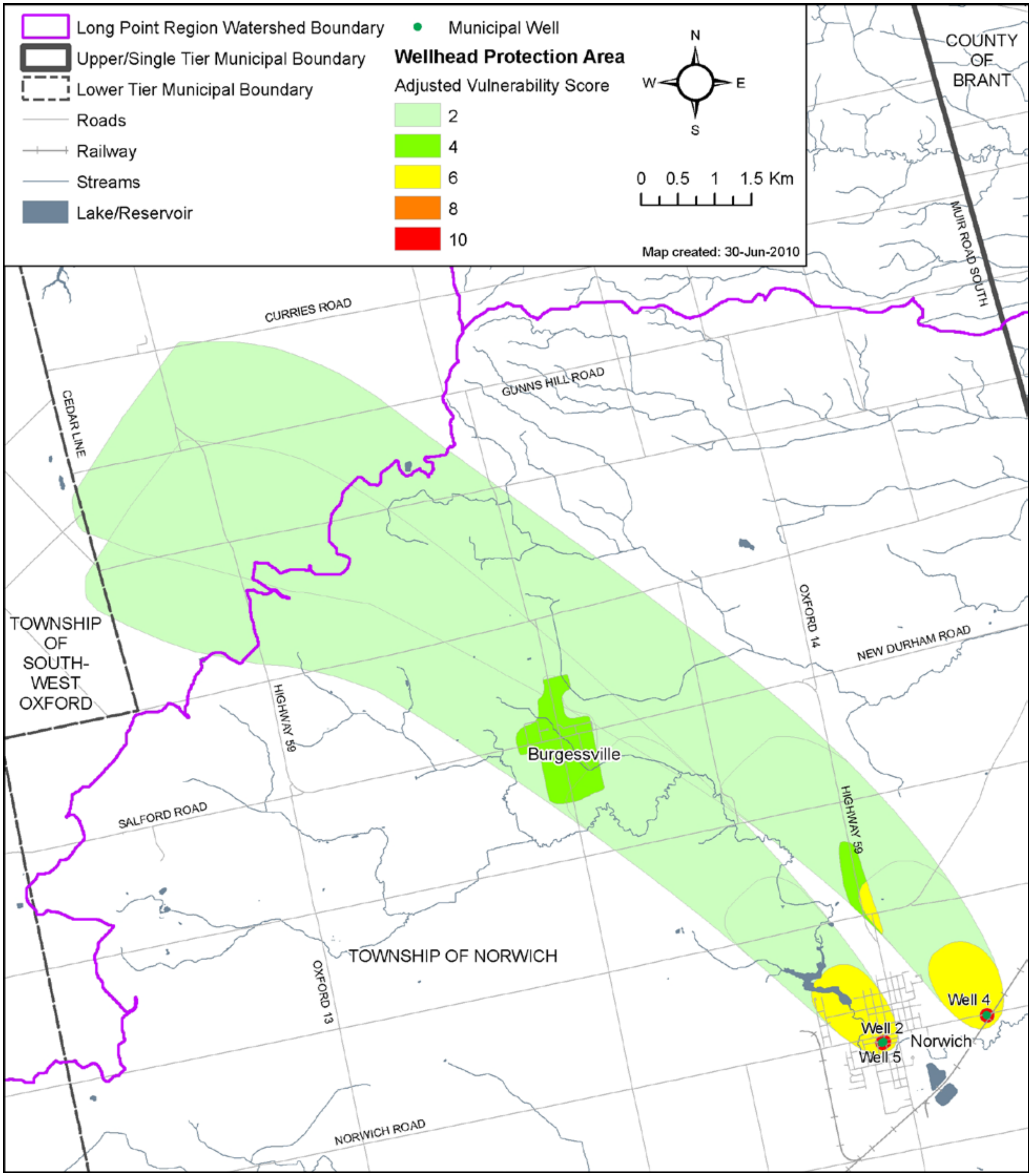
Map 4-12: Norwich Transport Pathways



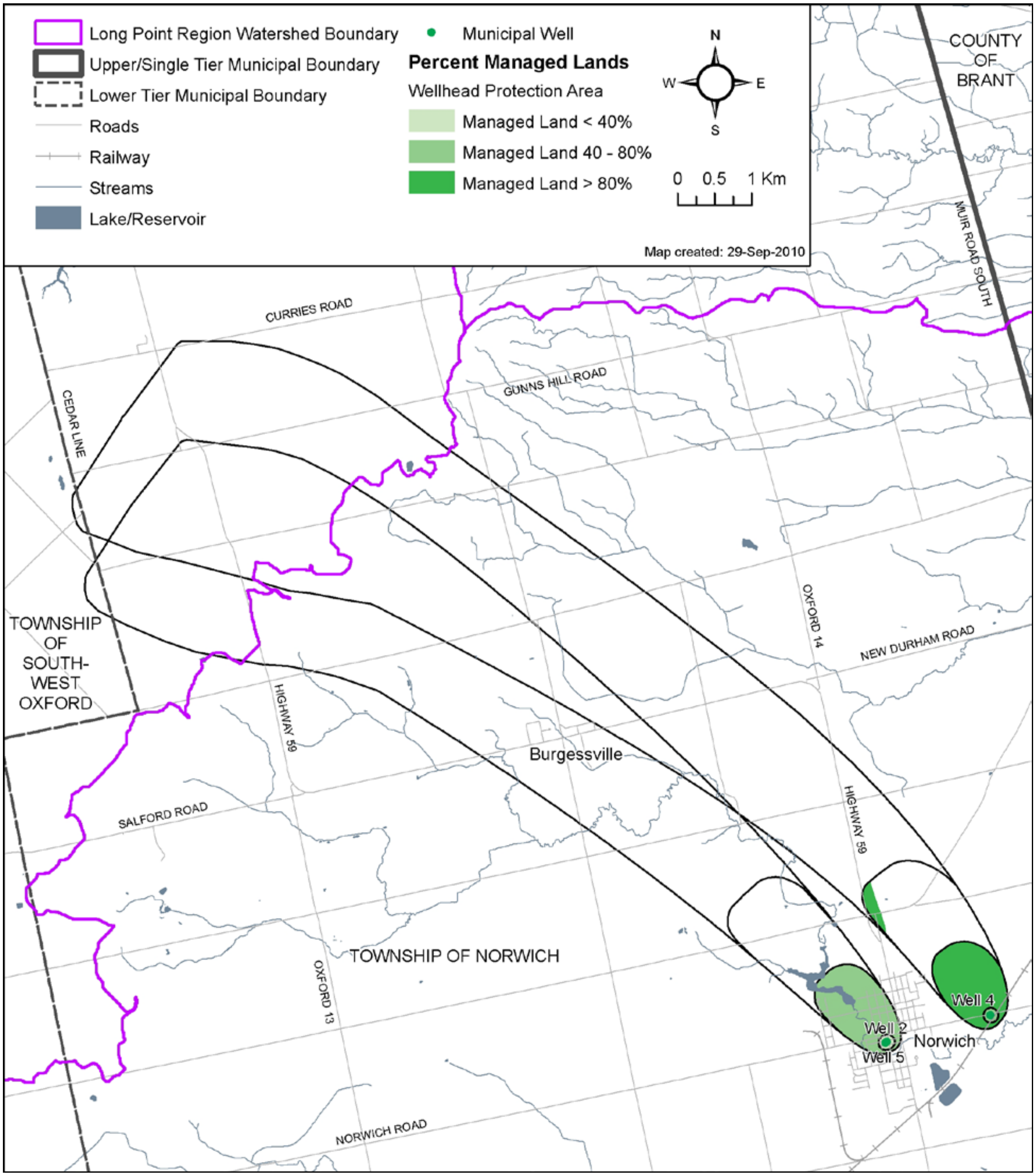
Map 4-13: Norwich Wellhead Protection Area Transport Pathways Area of Influence



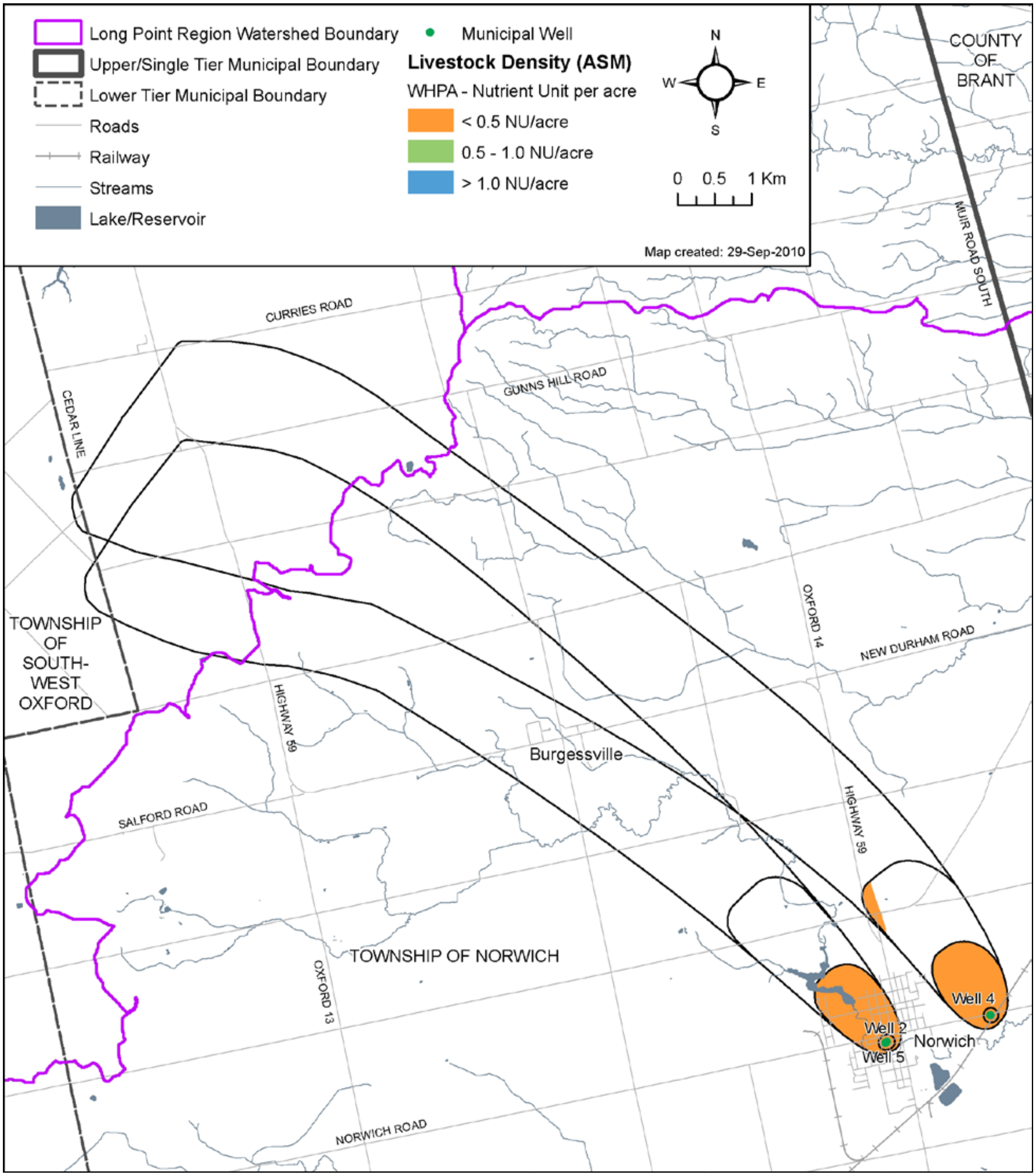
Map 4-14: Norwich Wellhead Protection Area Adjusted Vulnerability



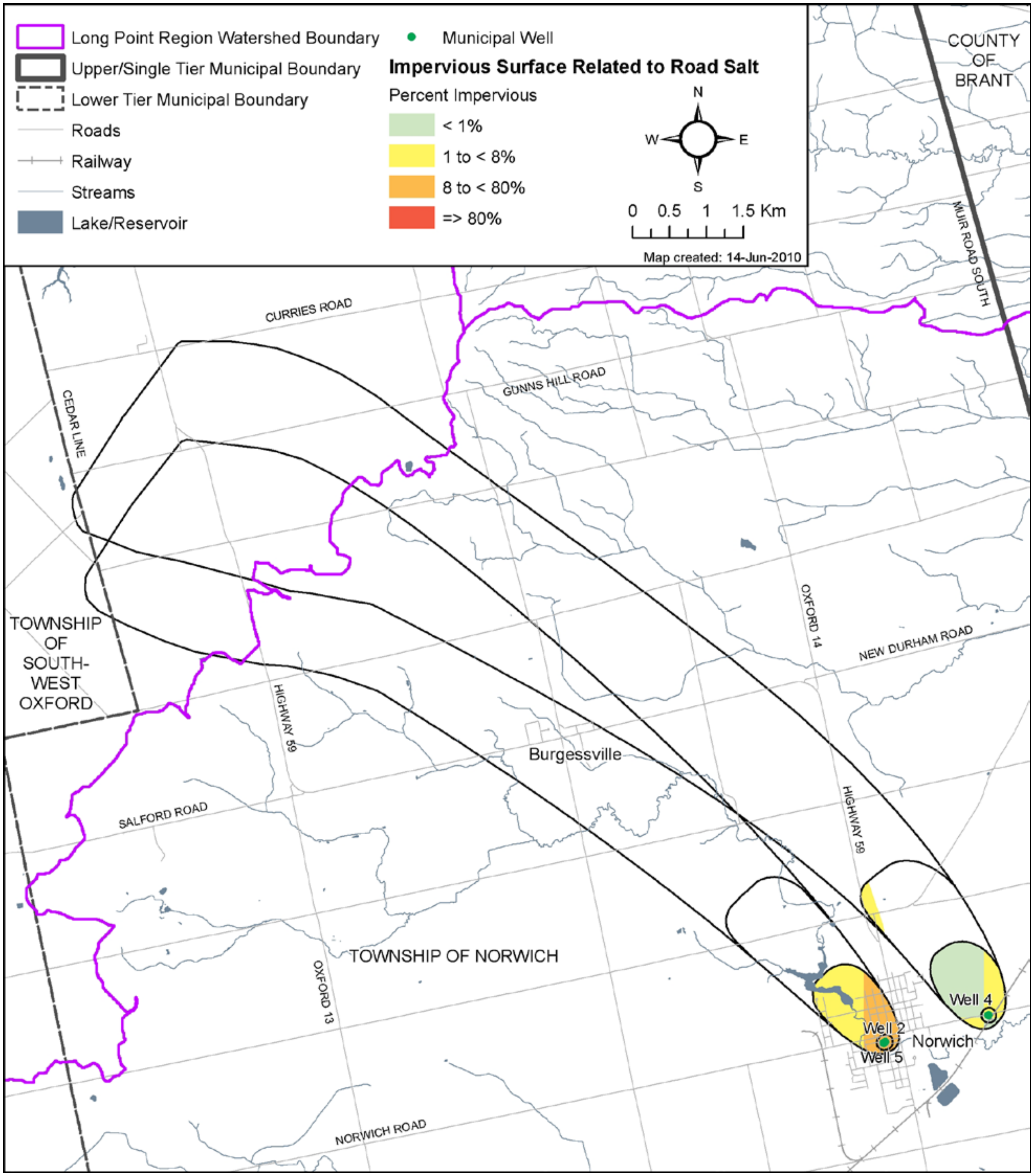
Map 4-15: Percent Managed Lands within the Norwich Wellhead Protection Area



Map 4-16: Livestock Density within the Norwich Wellhead Protection Area



Map 4-17: Percent Impervious Surfaces within the Norwich Wellhead Protection Area



4.5.4 Norwich Threats Assessment

The Ontario *Clean Water Act, 2006* defines a Drinking Water Threat as "an activity or condition that adversely affects or has the potential to adversely affect the quality or quantity of any water that is or may be used as a source of drinking water, and includes an activity or condition that is prescribed by the regulation as a drinking water threat."

The identification of a land use activity as a significant, moderate, or low drinking water threat depends on its risk score, determined by considering the circumstances of the activity and the type and vulnerability score of any underlying protection zones, as set out in the Tables of Drinking Water Threats available through www.sourcewater.ca. Information on drinking water threats is also accessible through the Source Water Protection Threats Tool: http://swpip.ca. The information above can be used with the vulnerability scores shown in **Map 4-14** to help the public determine where certain activities are or would be significant, moderate and low drinking water threats.

Table 4-10 provides a summary of the threat levels possible in the Norwich Well Supply for Chemical, Dense Non-Aqueous Phase Liquid (DNAPL), and Pathogens.A checkmark indicates that the threat classification level is possible for the indicated threat type under the corresponding vulnerable area / vulnerable score; a blank cell indicates that it is not. The colours shown for each vulnerability score correspond to those shown in **Map 4-14**.

Table 4-10: Identification of Drinking Water Quality Threats in the Norwich Wellhead Protection Areas

Threat Type	Vulnerable Area	Vulnerability Score	Threat Classification Level		
			Significant 80+	Moderate 60 to <80	Low >40 to <60
Chemicals	WHPA-A	10	✔	✔	✔
	WHPA-B/C	6		✔	✔
	WHPA-C/D	2 & 4			
Handling / Storage of DNAPLs	WHPA-A/B/C	Any Score	✔		
	WHPA-D	2 & 4			
Pathogens	WHPA-A	10	✔	✔	
	WHPA-B	6			✔

Drinking Water Threats

Under the preliminary threats assessment, a desk top land use inventory was developed to determine the types of land use activity information and therefore, the threats and circumstances associated with these land uses. In most cases, professional judgment and assumptions were made when determining the presence of significant threats for each property. Consultation with property owners to verify the existence of circumstances that constitute a significant threat is currently being conducted.

In the case of Norwich, significant threats occur in WHPA-A and WHPA-C of wells 2 and 5 and well 4. A list of all significant threat types identified in the Norwich Wellhead Protection Areas as of September 2017 and the number of times each threat occurs is presented on **Table 4-11**.

Table 4-11: Significant Drinking Water Quality Threats in the Norwich Wellhead Protection Areas

PDWT #[1]	Threat Subcategory[2]	Number of Activities	Vulnerable Area
1	Waste Disposal Site - Storage of wastes described in clauses (p), (q), (r), (s), (t) or (u) of the definition of hazardous waste	1	WHPA-A
2	Sewage System Or Sewage Works - Sanitary Sewers and related pipes	1	WHPA-A
	Sewage System Or Sewage Works - Onsite Sewage Systems	1	WHPA-A
3	Application Of Agricultural Source Material (ASM) To Land	2	WHPA-A
10	Application Of Pesticide To Land	2	WHPA-A
11	Handling and Storage Of A Pesticide	1	WHPA-A
15	Handling and Storage Of Fuel	1	WHPA-A
16	Handling and Storage Of A Dense Non Aqueous Phase Liquid (DNAPL)	5	WHPA-A WHPA-C
17	Handling and Storage Of An Organic Solvent	1	WHPA-A
Total Number of Properties			**9**
Total Number of Activities			**15**

1: Prescribed Drinking Water Threat Number refers to the prescribed drinking water threat listed in O.Reg 287/07 s. 1.1.(1).

2: Where applicable, waste, sewage, and livestock threat numbers are reported by sub-threat; fuel and DNAPL by Prescribed Drinking Water Threat category.

Note: Certain types of activities on residential properties that are incidental in nature and that are significant drinking water threats are not enumerated. These threats include the storage of organic solvents (dense non-aqueous phase liquids) on residential properties and the storage of fuel (e.g., heating fuel tanks) on residential properties in natural gas serviced areas. The threat point representing linear feature infrastructure such as sanitary sewers was not added into the total number of properties, since this feature is not attached to one specific property.

Note: Storm sewer piping is not considered to be part of a storm water management facilty.

There were four types of land uses that have, or could potentially have land use activities that pose a significant threat to groundwater in Norwich. These land uses are: agricultural, commercial, industrial and infrastructure. All properties and infrastructure referenced intersect with WHPA-A or WHPA-C in Norwich.

The number of significant threat activities occurring in Norwich is 15 as follows:

- 1 location where a septic system is likely present;
- 2 locations where the application of manure may be occurring;
- 5 locations where DNAPLS may be used or stored;
- 2 locations where pesticides may be applied to land;
- 1 location where pesticides may be stored;
- 1 location where organic solvents may be used or stored;
- 1 location where fuel may be stored;
- 1 location where waste disposal may be taking place; and
- 1 location where sewage may be collected, stored, transmitted, treated, or disposed of through a municipal system (sanitary sewer).

4.5.5 Norwich Drinking Water Issues

Issues Evaluation Results

Health Related Parameters

No health-related parameters were found to exceed their ODWQS MAC. Microbiological results at Well 4 are consistently satisfactory. There have been occasional low counts of total coliforms and E.coli in the raw water at Wells 2 and 5. There does not appear to be a regular trend to the results and does not indicate a concern.

Aesthetic or Operationally Significant Parameters

The Norwich wells have several operational or aesthetic parameters exceed the ODWQS that are detailed below.

Hardness which has a guideline range from 80 to 100 mg/L is typically exceeded in groundwater systems. The Norwich's well's hardness concentrations are typically 305 to 320 mg/L. This parameter is naturally occurring in the groundwater and does not pose a health risk, nor does it impact the treatment process.

The raw water from the Norwich wells exceed the objective of 0.3 mg/L for iron. Raw water iron concentrations are approximately 0.6 mg/L. Iron is an aesthetic parameter and does not interfere with the treatment process. No increasing trend is evident.

Sodium concentrations are occasionally marginally above the reporting level of 20 mg/L. The results are well below the objective of 200 mg/L. Chloride concentrations are quite low suggesting that the sodium is not caused by road salt application but is naturally occurring. No increasing trend is evident in the results.

The aesthetic objective for colour is 5 "True Colour Units" (TCU). Concentrations are generally below this objective with one result marginally above. There is no evidence of upwards trending and the parameter does not impact the treatment process. The one elevated result is insufficient to screen the parameter as a potential issue.

Organic nitrogen concentrations at Well 5 are above the aesthetic objective of 0.15 mg/L with average concentrations of 0.23 mg/L. Organic nitrogen can be associated with unpleasant taste and high levels can reduce the effectiveness of chlorine as a disinfectant. There is no history of objectionable taste that is sometimes associated with organic nitrogen.

Summary of Identified Issues

The parameters in the Norwich wells that meet the screening threshold are total coliforms for Wells 2 and 5, hardness, and iron. The occasional total coliforms and E.coli counts found in Wells 2 and 5 are low level and do not suggest any trending. Hardness and iron are all naturally occurring and typical to groundwater sources. They do not affect the treatment process and there is no evidence of upward trending. Organic nitrogen was detected, however there was no objectionable taste associated with the noted elevated concentrations.

4.6 Oxford South: Otterville – Springford Wells

The Otterville – Springford portion of the Oxford South Drinking Water System provides water from four secure groundwater wells.

The water is treated in both Otterville and Springford with sodium hypochlorite for disinfection. The Oxford South water system, which the Otterville and Springford wells are a part of, is a Large Municipal Water system as defined by Regulation 170/03; the serviced population of Otterville and Springford is approximately 1787.

Otterville and Springford were formerly two separate drinking water systems; in 2004 a 3.3 km long transmission main was constructed to connect these two communities into one system. In 2013, another transmission main connecting the Norwich system to the Otterville-Springford system was commissioned, forming the Oxford South Water System.

Within Otterville, as shown on **Map 4-18**, the two overburden production wells (Wells 3, 4) are located east of the village on the north side of Otterville Road. The Otterville wells are completed in a regionally extensive overburden aquifer, comprised of fine to coarse-grained sand and gravel. In the Otterville area, this aquifer extends to ground surface, creating a shallow unconfined aquifer. Most wells in the area are completed in this shallow aquifer. To the east and southeast, these sands pinch out as the Port Stanley Drift thickens and forms the core of the Tillsonburg Moraine. The Otterville municipal wells are completed with screen depth settings at approximately 13 m bgs.

The two overburden production wells near Springford (Wells 4, 5) are located in the northwest part of the village and are completed in the intermediate aquifer at a depth of 20 to 25 mbgs, respectively. These production wells were added to the water supply system as shown on Map 4-25 in about 2004 as a replacement for the original supply wells (Wells 1, 2, 3) that were located on the east side of the village.

4.6.1 Otterville Wellhead Protection Areas

The Otterville Wellfield WHPAs were delineated using the Long Point Region Tier 3 groundwater flow model. This regional-scale model was originally developed as a part of the Long Point Region Tier 3 Water Budget Study (Matrix, 2015). To ensure the Tier 3 model was suitable to predict capture zones for the Otterville municipal wells, the Otterville area within the model was locally refined and calibrated (Matrix, 2019). This process entailed local refinements to zones of hydraulic conductivity in different hydrostratigraphic units and zones of recharge to achieve a match between observed and simulated water levels.

The total pumping rate assigned to the Otterville municipal wells for the WHPA delineation was 360 m^3/day. This rate represents an approximate 16.5% increase over recent average pumping rates from 2012 to 2016. This increase in total municipal demand is consistent with planned growth for Otterville. The pumping rate of 360 m^3/day used for the capture zone delineation was split equally between the two Otterville municipal wells to provide consistency with the actual proportion of takings between the two wells from 2012 and 2016.

Capture zones were delineated by releasing virtual particles in the groundwater flow model which were tracked forward or backward in time through the subsurface for various time intervals. Particle tracking was completed for the locally refined and calibrated Tier 3 model (Base Case scenario) and a set of sensitivity scenarios. Sensitivity scenarios were designed to assess the impact of parameter uncertainty on the delineated capture zones. Composite capture zones were delineated from all of the particle pathlines from both the Base Case and sensitivity scenarios.

Four WHPAs were delineated for the two Otterville wells. WHPA-A was delineated as a 100 m fixed radius zone around each of the wells, independent of the time-of-travel capture zone. WHPA-B was delineated as the area outside the WHPA-A, within which the time-of-travel to the well is less than or equal to 2 years. WHPA-C was delineated as the area outside WHPA-B, within which the time-of-travel to the well is greater than 2 years, but less than or equal to 5 years. Lastly, WHPA-D was delineated as the area outside WHPA-C, within which the time-of-travel to the well is greater than 5 years, but less than or equal to 25 years.

4.6.2 Springford Wellhead Protection Areas

The groundwater model covers an area of approximately 11 km², and is oriented in a northwest to southeast direction, parallel to the direction of regional groundwater flow in the overburden aquifer. The following provides a summary of the Springford Groundwater Flow Model based on hydrogeological information available at the time of the Golder (2001) study.

The municipal wells in the original Golder (2001) model (Wells 1, 2 and 3) are no longer in use and were replaced in 2004 by 2 overburden wells (Wells 4 and 5). These newer production wells are located in the northwest part of the village. The original supply wells were interpreted to be part of the intermediate aquifer. The depth of the screens at Wells 4 and 5 are between 20 to 25 mbgs, indicating that they are also completed in the intermediate aquifer. The forecast pumping rate used for the Wellhead Protection Area delineation in the Phase II Groundwater Protection Study was 69 m^3/day.

Stratigraphy

The intermediate aquifer is the principal overburden aquifer in the Springford area. It is reported to occur over a depth range of 18 to 26 mbgs in the area of the Springford wells (Burnside, 1999). The shallow aquifer is present although it is generally limited to the southwest area of the village. The Springford wells are screened in the intermediate aquifer and overlain by varied sediments which may serve to semi-confine the municipal aquifer. Approximately one km to the north Springford, the Port Stanley Till predominates the surficial sediments. The bedrock surface is at a depth of about 30 to 35 mbgs.

Based on the above, the Springford Groundwater Model was constructed using three overburden layers; an upper overburden layer primarily represented by till; a second overburden layer that was varied spatially within the model area based on the distribution of the Shallow Aquifer and Port Stanley Till; and a 10 m thick intermediate aquifer layer. The base of the model was assumed to be defined by the base of the intermediate aquifer.

Groundwater Flow Boundaries

Groundwater flow in the intermediate aquifer at Springford is inferred to occur in a southeasterly direction and the Springford Groundwater Model was therefore oriented in this direction. To the northwest and southeast of Springford the model boundaries follow inferred groundwater contours and were assigned as constant head boundary conditions. To the northwest, a constant head boundary elevation of 260 masl was assigned. Groundwater will flow into the model across this boundary. To the southeast, a constant head boundary ranging in elevation from 235 masl to 250 masl was assigned. Groundwater will flow out from the model across this boundary. To the east and west of Springford the model boundaries follow inferred groundwater flowlines, and were therefore assigned as "no flow" boundaries. It is assumed that groundwater flow in the intermediate aquifer does not occur across these boundaries.

Groundwater/Surface Water Interaction

The shallow aquifer (where present) is inferred to discharge to Spittler Creek to the east/northeast of Springford as well as to the creek (Plumb Creek) that runs west to east to the south of Springford. These creeks are not deeply incised and are therefore not considered to be directly connected to the intermediate aquifer. However, groundwater discharge from the intermediate aquifer may discharge to these surface drainage features via the shallow aquifer. In the Springford Groundwater Model, these surface drainage features were assumed to be directly connected to the overburden aquifers (where present) and the surface water elevation in the drainage system (from the DEM) was assumed to be similar to the overburden groundwater elevation beneath the creek (i.e. the upper layer of overburden in the model).

Recharge

Three separate recharge zones were established for the model to reflect the variability in overburden sediments that overlie the intermediate aquifer around Springford; a recharge rate of 150 mm/yr was assigned where the shallow aquifer is present; a recharge rate of 50 mm/yr was assigned where there are surficial sands and gravels present; and a recharge rate of 20 mm/yr was assigned where the intermediate aquifer is overlain by Port Stanley Till. These values were established through the model calibration process.

Hydraulic Conductivity and Porosity

The transmissivity of the intermediate aquifer at Springford was estimated to be on the order of 30 m^2/day based on an eight hour pumping test completed in December 2000 (Lotowater, 2000b). Assuming an aquifer thickness of about 5 to 10 m, this corresponds to an aquifer hydraulic conductivity on the order of 4.4×10^{-5} to 6.9×10^{-5} m/s. Following model calibration, the hydraulic conductivity of the intermediate aquifer in the Springford Groundwater Model was assigned at 1×10^{-4} m/s, with an effective porosity of 25%. The hydraulic conductivity for the Port Stanley Till was assigned at 1×10^{-7} m/s.

Other Water Takings

Approximately 160 m to the north (upgradient) of the Springford water supply there is a private water taking permit (95-P-1051) with a permitted groundwater extraction rate of 37.7 m^3/day from the intermediate aquifer. A well at this location was included in the groundwater model, with an average annual pumping rate of 37.7 m^3/day. There was no other private water taking wells located in the intermediate aquifer in the Springford area identified in the MOE PTTW Database.

Calibration of the Springford Groundwater Model involved the adjustment of the recharge rates and hydraulic conductivity of the intermediate aquifer, until there was a reasonable match between the simulated groundwater elevations and the recorded groundwater elevations for Springford area overburden wells in the MOE Well Record Database. As defined above, the hydraulic conductivity of the intermediate aquifer was estimated to be 1×10^{-4} m/s, with recharge rates ranging from 20 mm/yr (Port Stanley Till) to 150 mm/yr (shallow aquifer). The average annual pumping rate in 1999 (of 69 m^3/day) was used in the calibration process.

4.6.3 Otterville-Springford Vulnerability, Transport Pathways and Vulnerability Adjustment

Map 4-19 and **Map 4-26** illustrate the Wellhead Protection Areas for the Otterville and Springford wells. The WHPAs for the Otterville wells extend approximately 2.5 km east of the well site. Land use is primarily rural agricultural. The Wellhead Protection Areas for the

Springford wells extend to the northwest for a distance of approximately 850 m. Land use in the WHPAs is primarily rural-agricultural. The forecast pumping rate used for the Springford Wellhead Protection Area delineation in the Phase II Groundwater Protection Study was 69 m^3/day.

Vulnerability Scoring

The vulnerability for the Otterville-Springford WHPAs was mapped using the AVI method as a part of the Golder (2001) study. The Otterville WHPAs are all mapped as highly vulnerable as the municipal aquifer is shallow and unconfined. The vulnerability of the Springfield WHPAs is low since the municipal aquifer has been mapped as being a part of an intermediate, confined system. Intrinsic vulnerability is shown in maps **Map 4-20** and **Map 4-27**.

The vulnerability mapping within Oxford County was completed using the AVI method (ARL Groundwater Resources Ltd., 2010; Golder, 2001) with score thresholds of <30, 30-80, and >80 to identify areas of high, medium and low vulnerability respectively.

The assessment of transport pathways in Springford's Wellhead Protection Areas resulted in a limited number of private wells located within the Wellhead Protection Areas. No adjustments were made to the vulnerability as a result of the assessment. A transport pathway assessment was not completed for the Otterville WHPAs as the intrinsic vulnerability is high; therefore transport pathways cannot increase the vulnerability score.

Final vulnerability scoring is shown on **Map 4-21** and **Map 4-28**. In Springford, vulnerability scores, which reflect the low vulnerability of the aquifer, range from 10 in WHPA-A, to 6 in WHPA-B, 4 in WHPA-C and 2 in WHPA-D. In Otterville, where aquifer vulnerability is high, vulnerability scores range from 10 in WHPA-A and -B, to 8 in WHPA-C, and 6 in WHPA-D. There are no anticipated changes between the current vulnerability scoring and the revised scoring for both Otterville and Springford using an AVI threshold of >30 for areas of high vulnerability.

4.6.4 Managed Lands and Livestock Density for Otterville-Springford

The managed lands and livestock density work for Otterville was completed in WHPA-A through WHPA-D and for Springford just WHPA-A and WHPA-B for both wells. **Table 4-12** presents the results of the calculations, showing that the zones fall into either the moderate or high percent managed lands category (**Map 4-22** and **Map 4-30**). Livestock density is illustrated in **Map 4-23** and **Map 4-31** for Otterville and Springford.

Table 4-12: Managed Lands and Livestock Density in Otterville and Springford

WHPA Zone	Percent Managed Land %	Livestock Density NU/acre
Otterville Wells 3 & 4 WHPA-A	78%	0.0
Otterville Wells 3 & 4 WHPA-B	70%	0.0
Otterville Wells 3 & 4 WHPA-C	75%	0.0
Otterville Wells 3 & 4 WHPA-D	87%	0.493
Springford Well 4 WHPA-A	68%	0.3
Springford Well 4 WHPA-B	86%	0.2
Springford Well 5 WHPA-A	77%	0.0
Springford Well 5 WHPA-B	97%	0.0

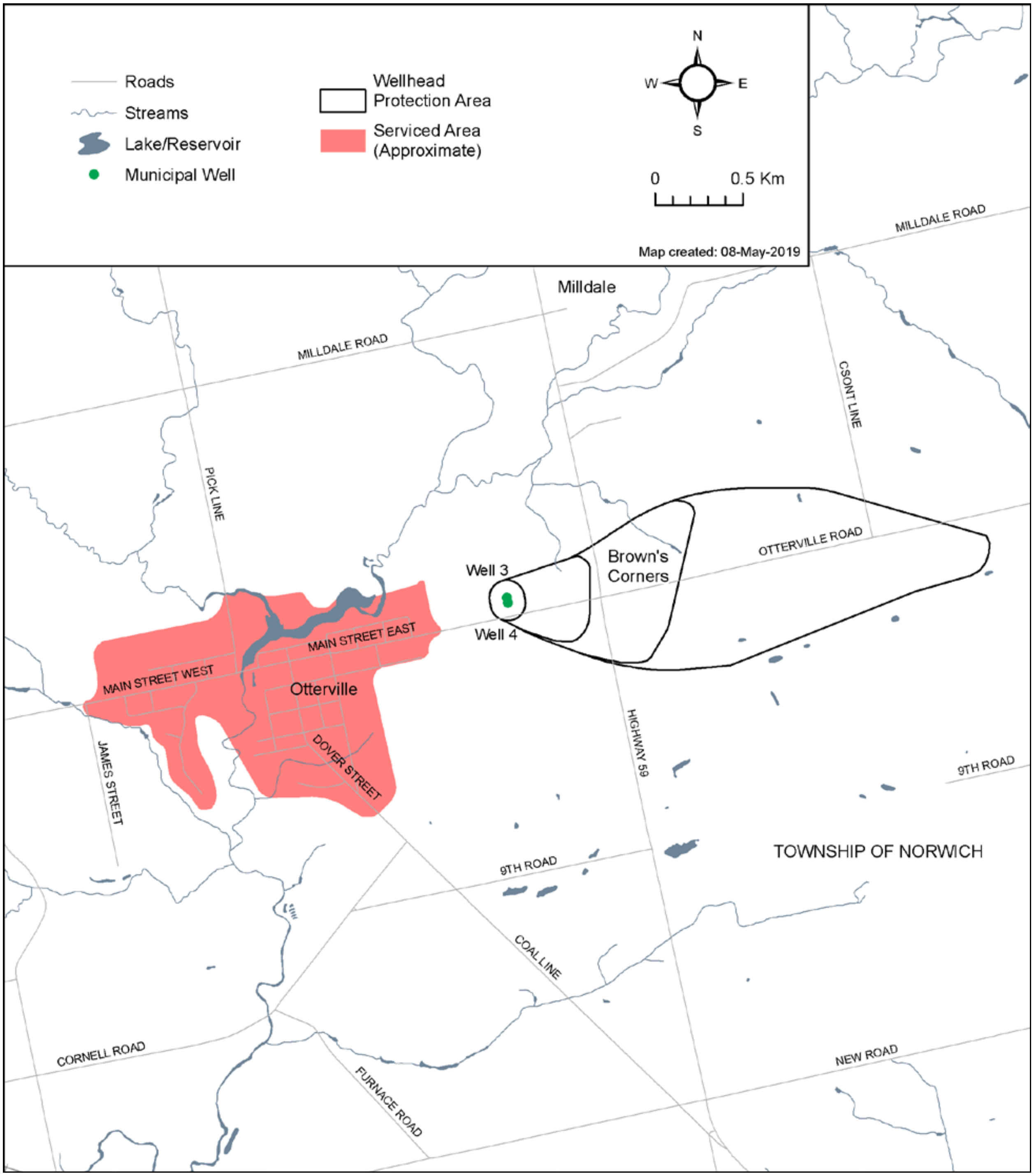
4.6.5 Percent Impervious Surface Area in Wellhead Protection Areas in Otterville-Springford

Impervious surfaces were only calculated for WHPAs where the vulnerability score is 6 or higher as presented in **Table 4-13.** For Springford, the impervious surfaces were mapped in WHPA-A and WHPA-B. In the case of Otterville, WHPA-A through WHPA-D were calculated and mapped due to the high vulnerability score of the Otterville WHPA. The results show that due to the low percent impervious surfaces, the application of road salt would not be a significant threat (**Map 4-24** and **Map 4-32**).

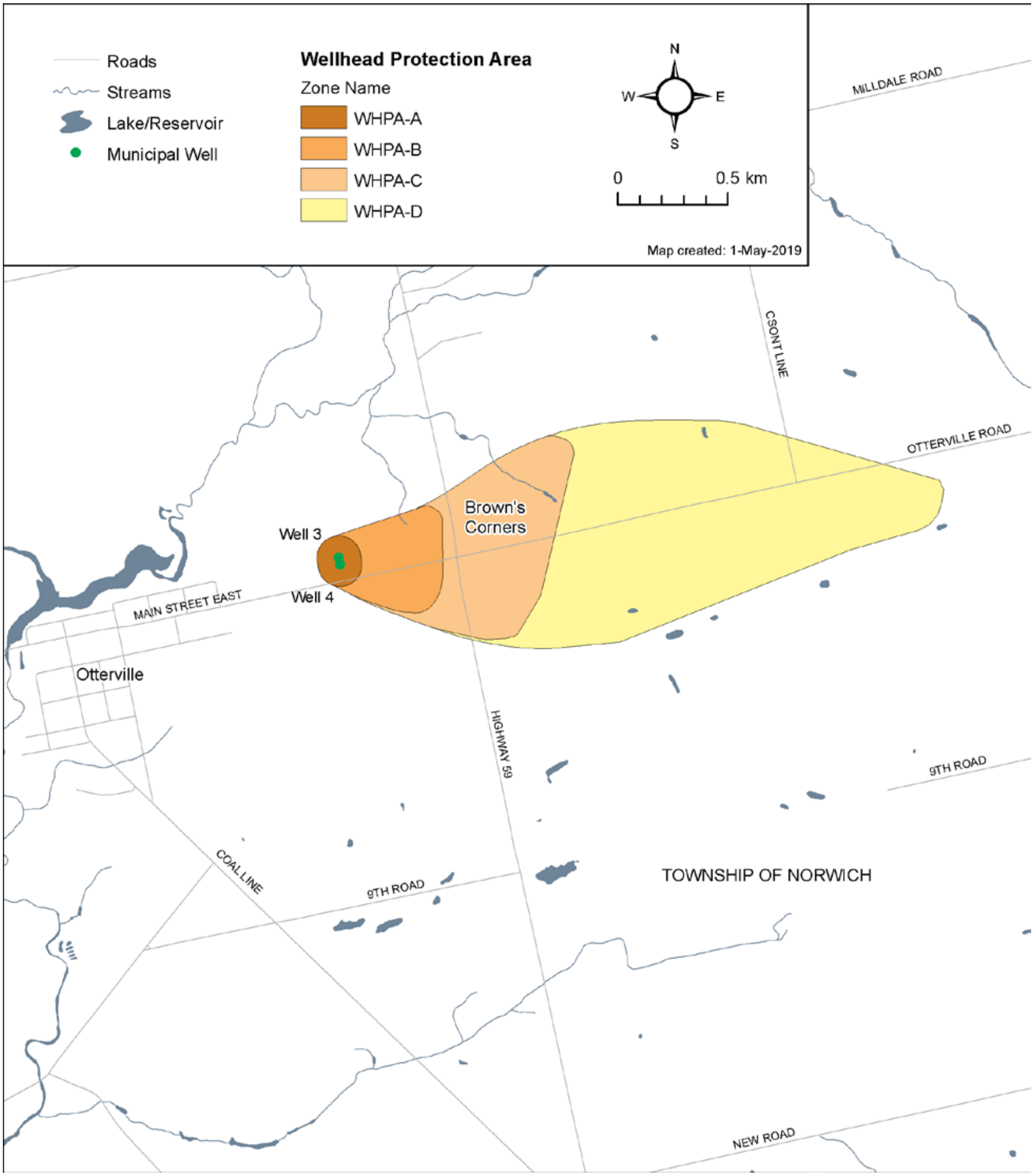
Table 4-13: Impervious Surface Percentage for Otterville/Springford

Well	Impervious Surface (%)
Otterville Wells 3 & 4	0% to 2.6%
Springford Wells 4 & 5	2%

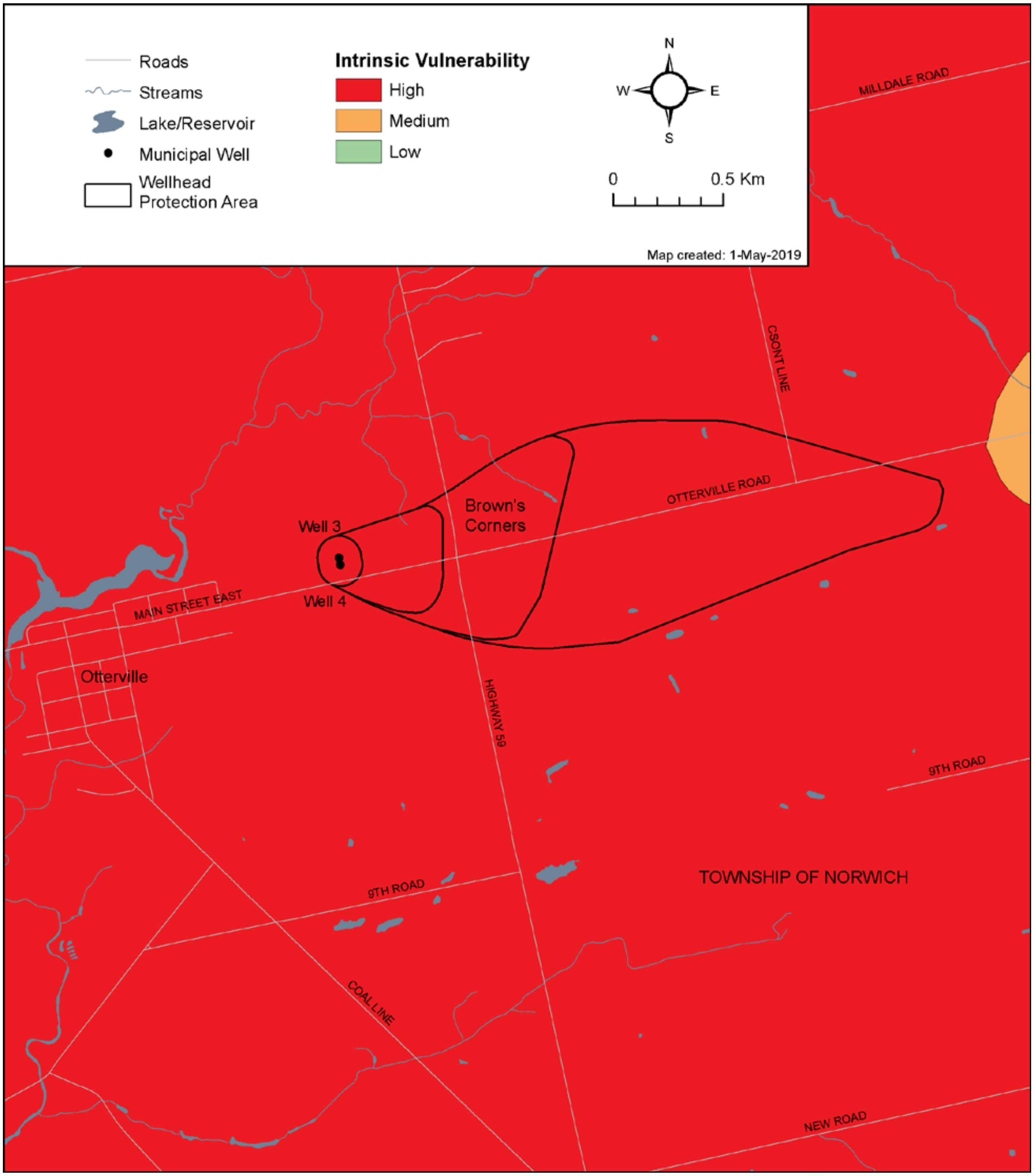
Map 4-18: Serviced Areas for Oxford South (Otterville)



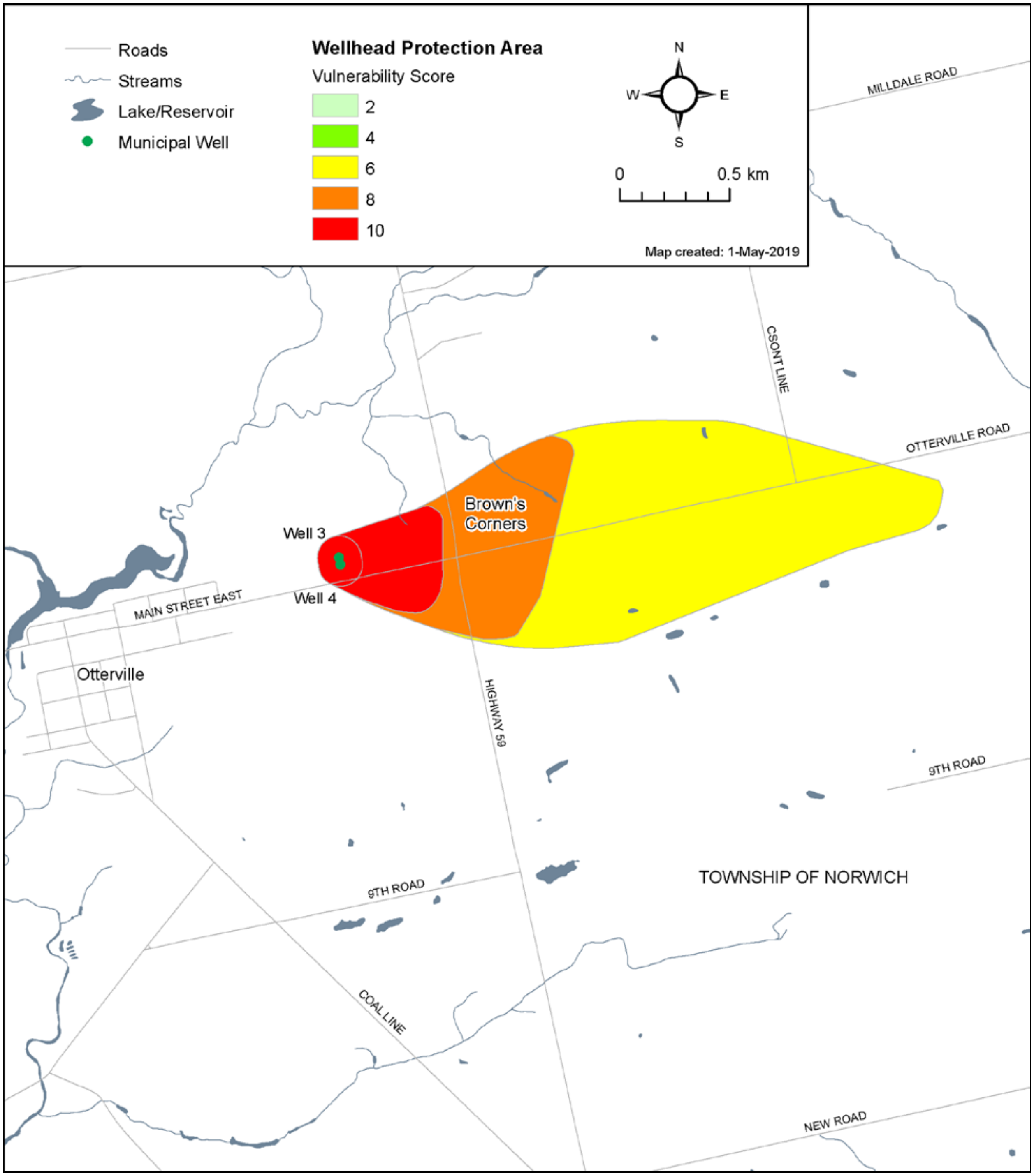
Map 4-19: Otterville Wellhead Protection Area



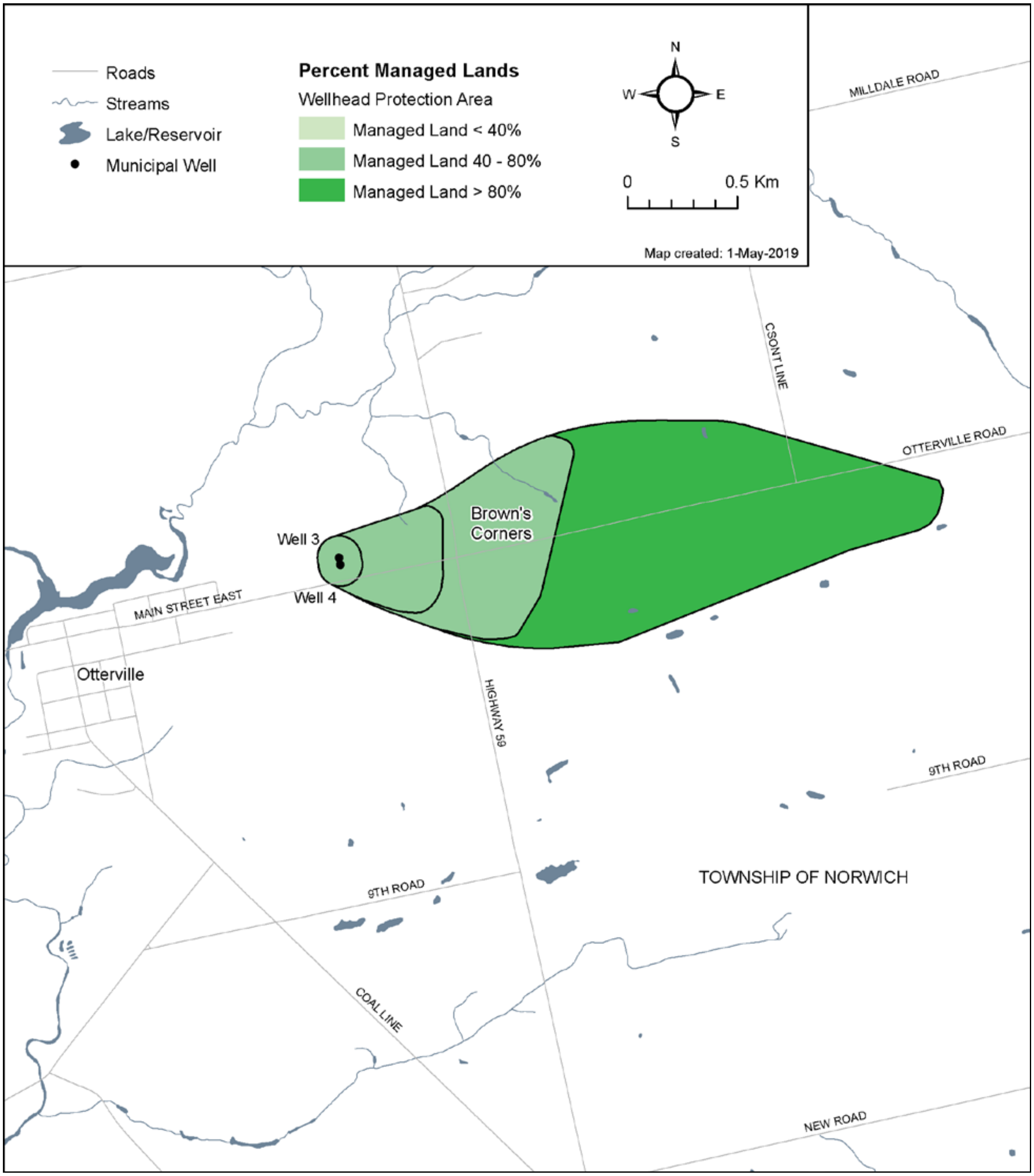
Map 4-20: Otterville Intrinsic Vulnerability



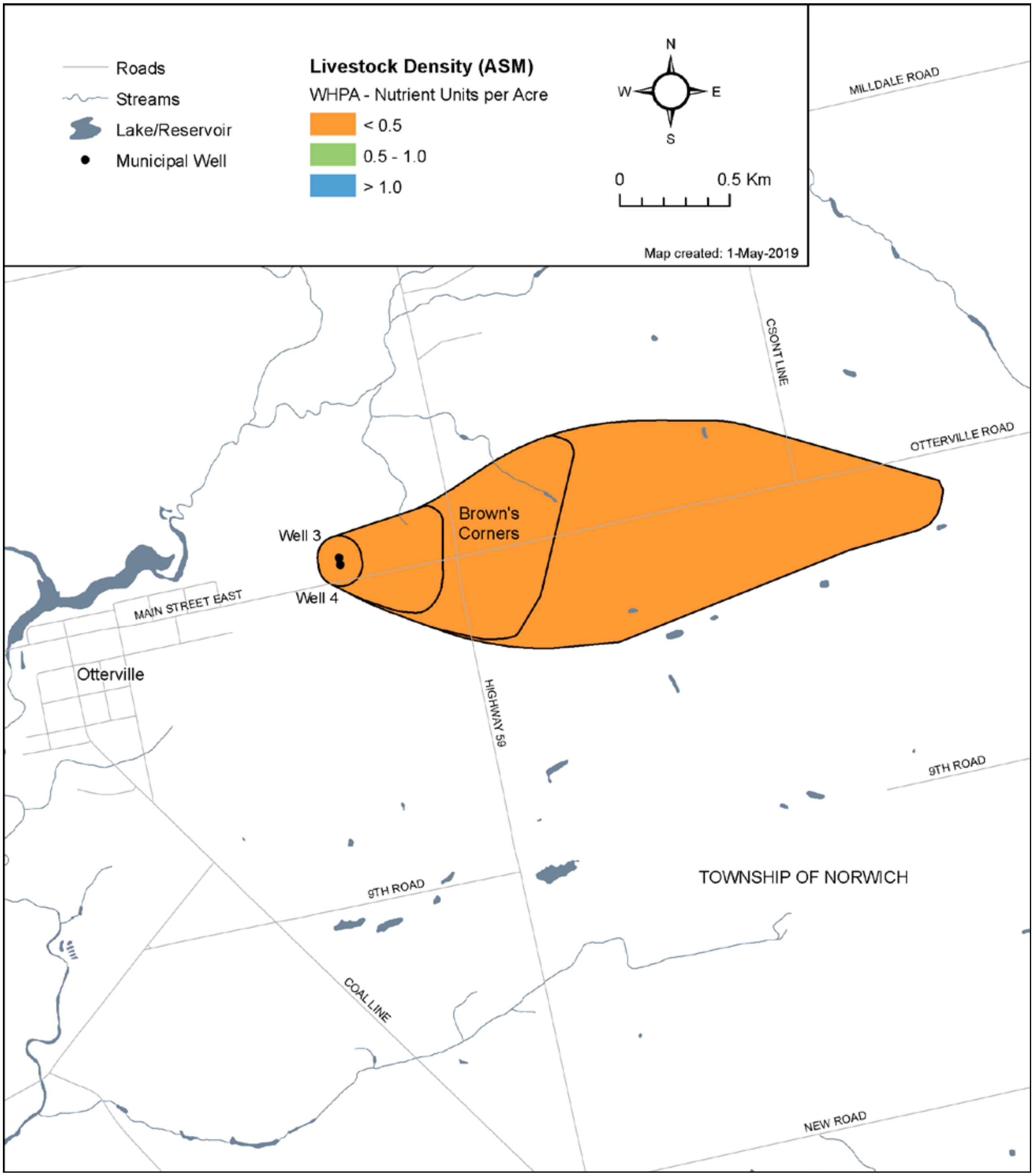
Map 4-21: Otterville Wellhead Protection Area Vulnerability



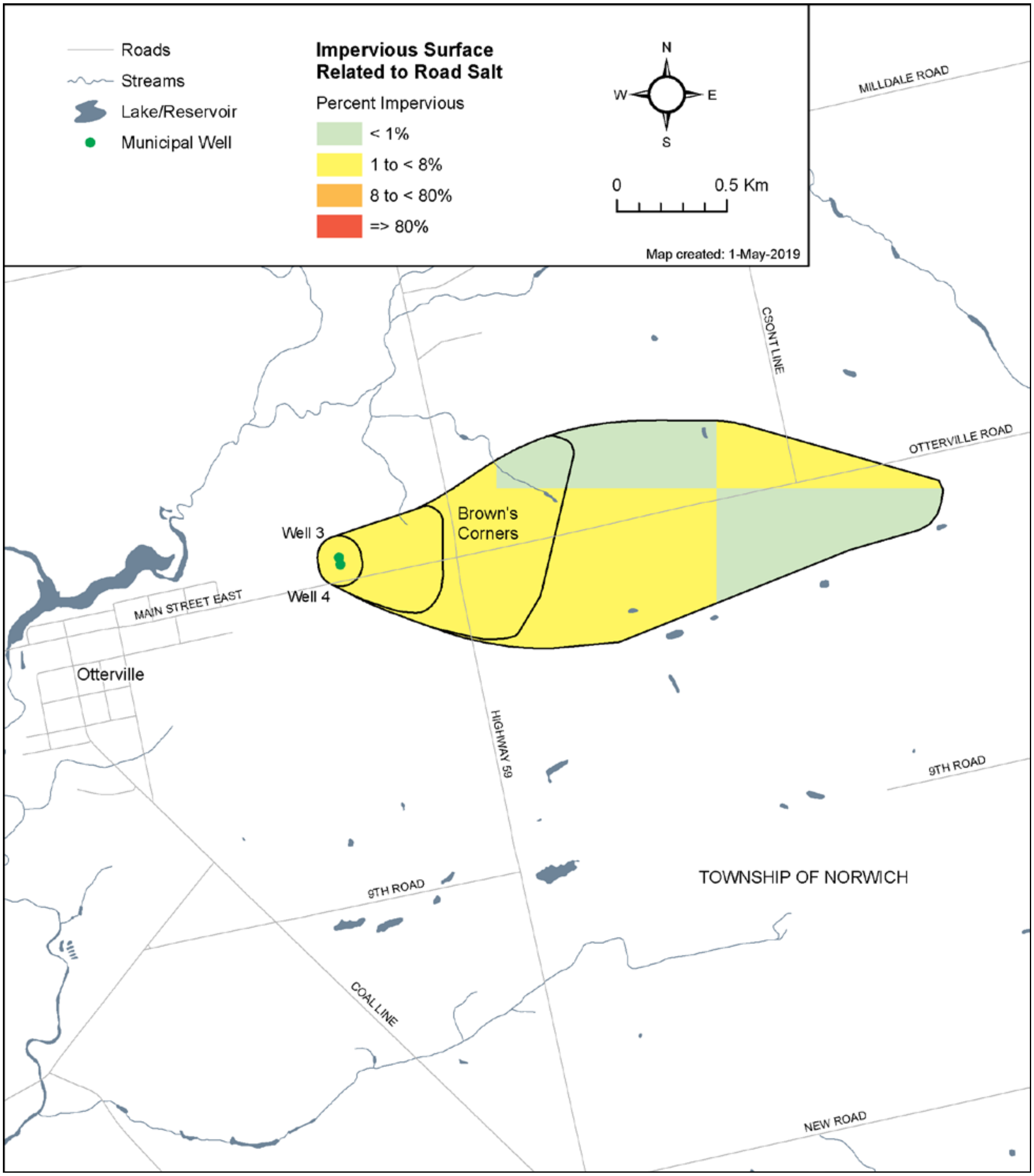
Map 4-22: Percent Managed Lands within the Otterville Wellhead Protection Area



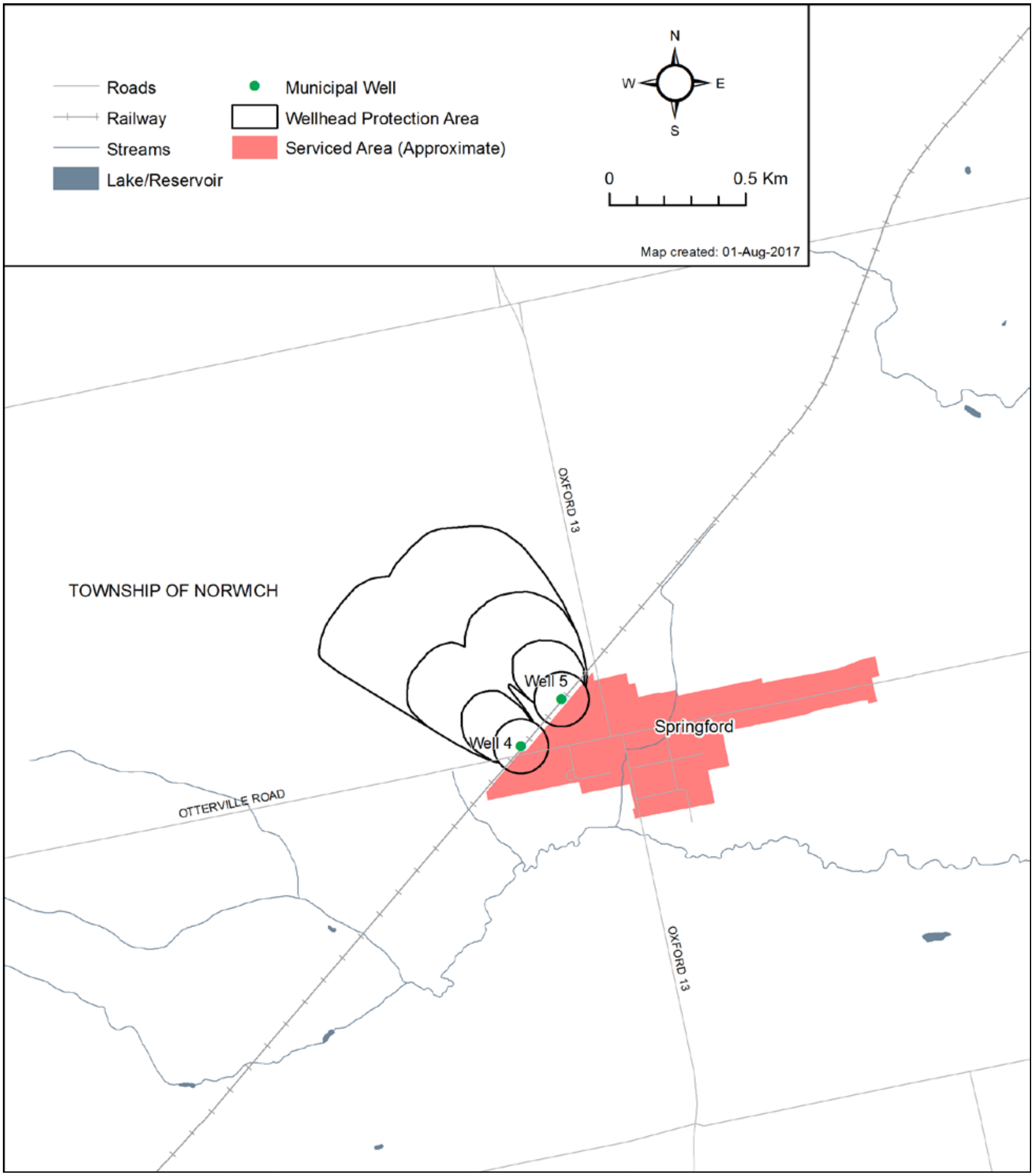
Map 4-23: Livestock Density within the Otterville Wellhead Protection Area



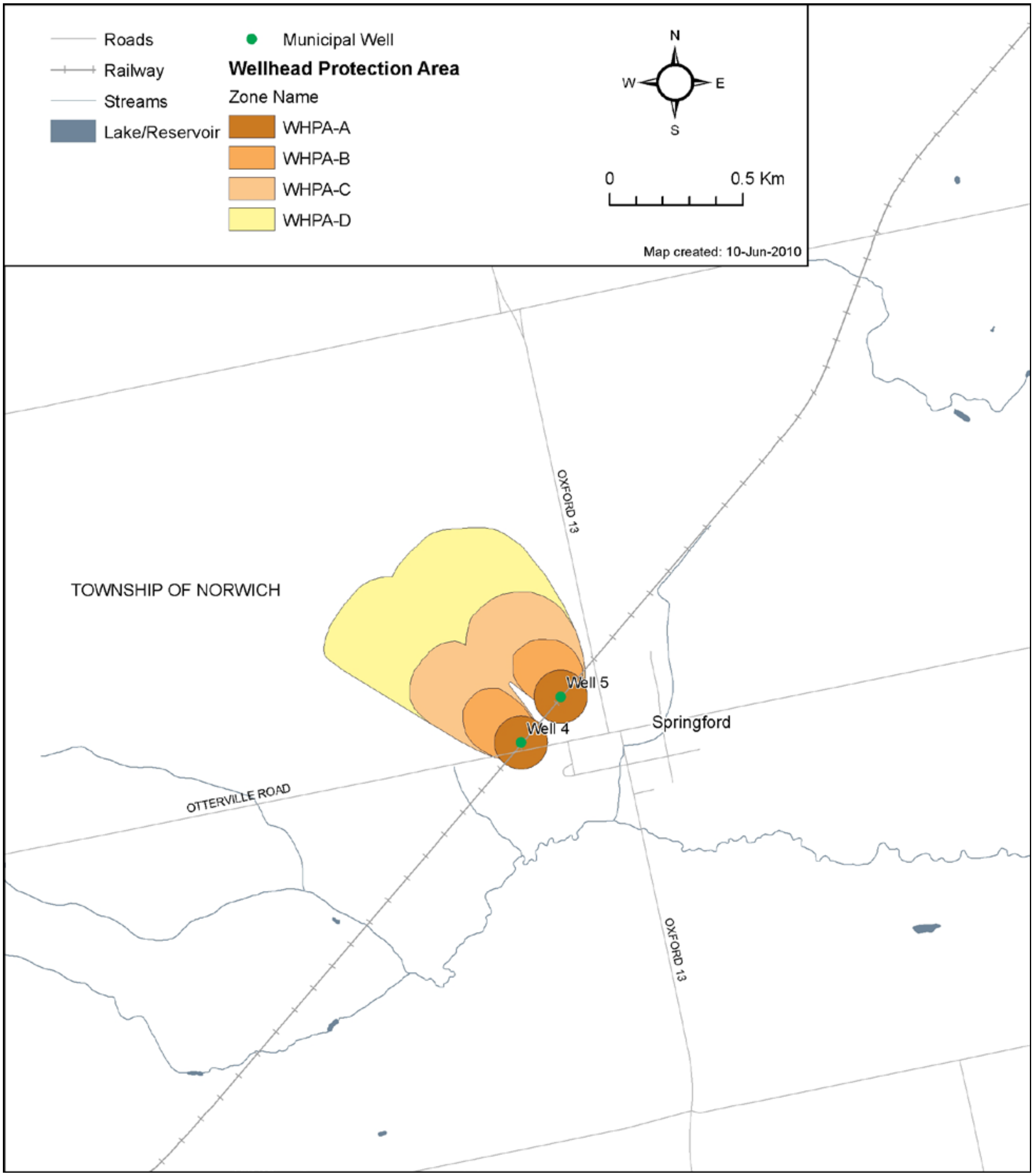
Map 4-24: Percent Impervious Surfaces within the Otterville Wellhead Protection Area



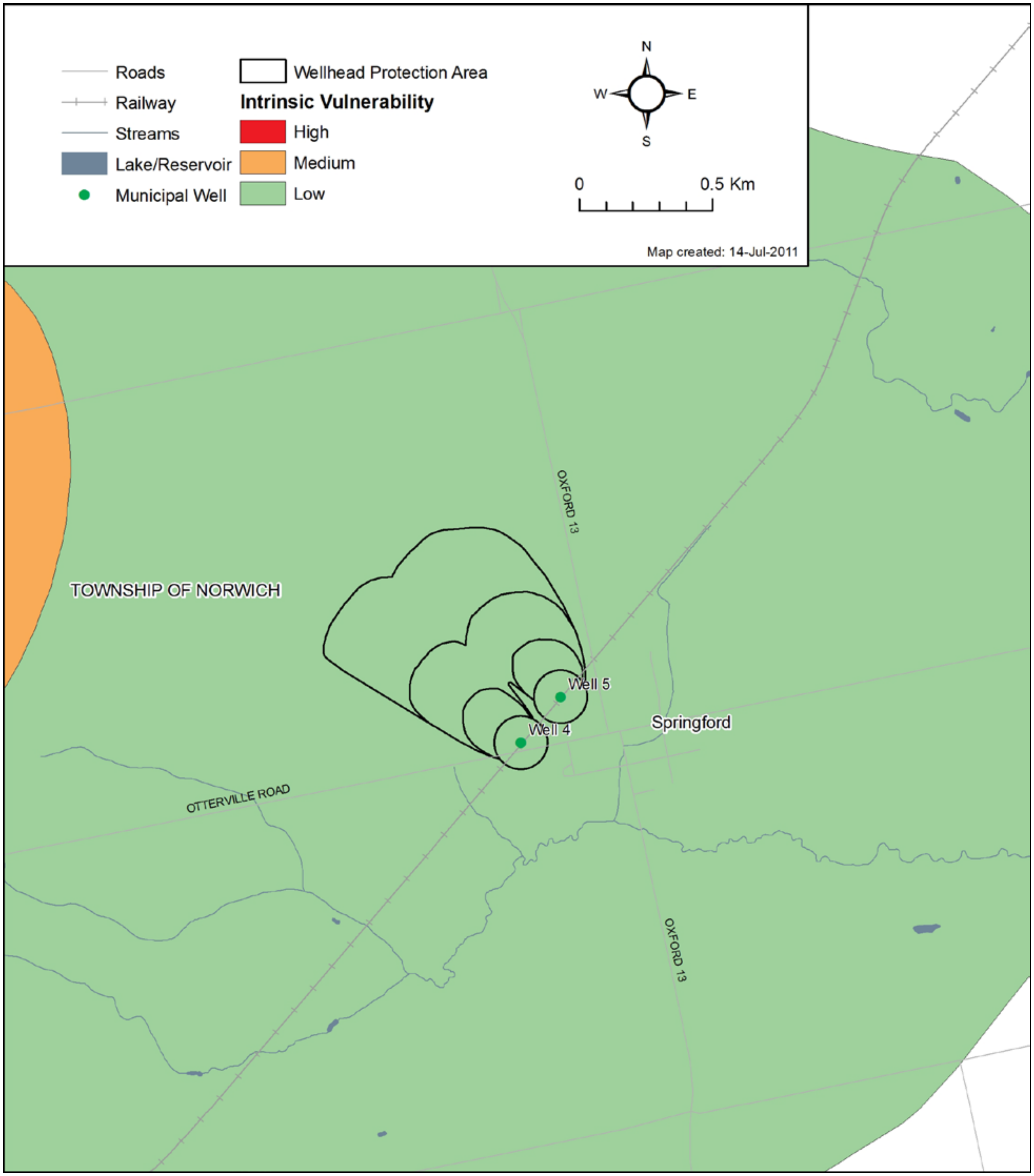
Map 4-25: Serviced Areas for Oxford South (Springford)



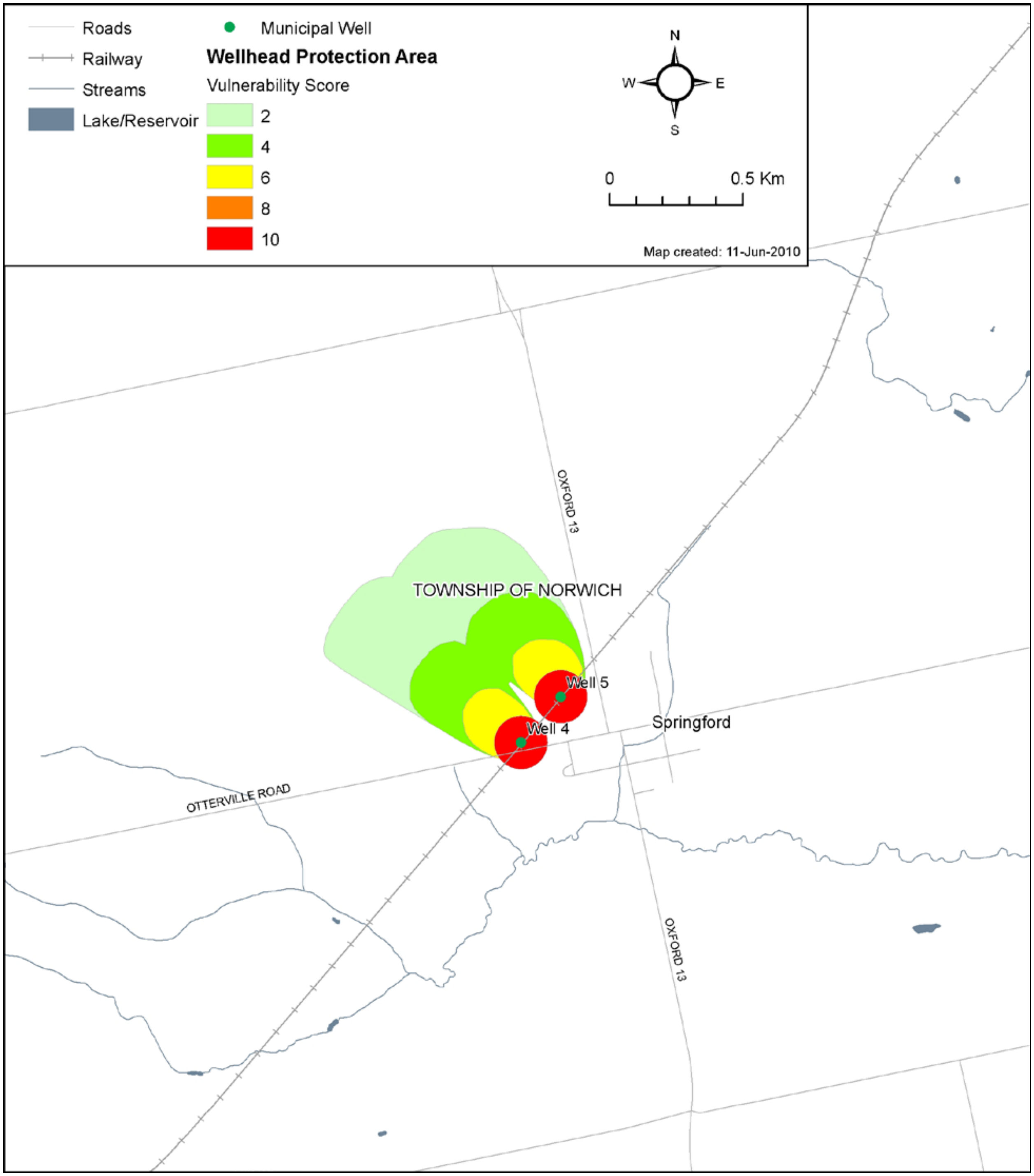
Map 4-26: Springford Wellhead Protection Area



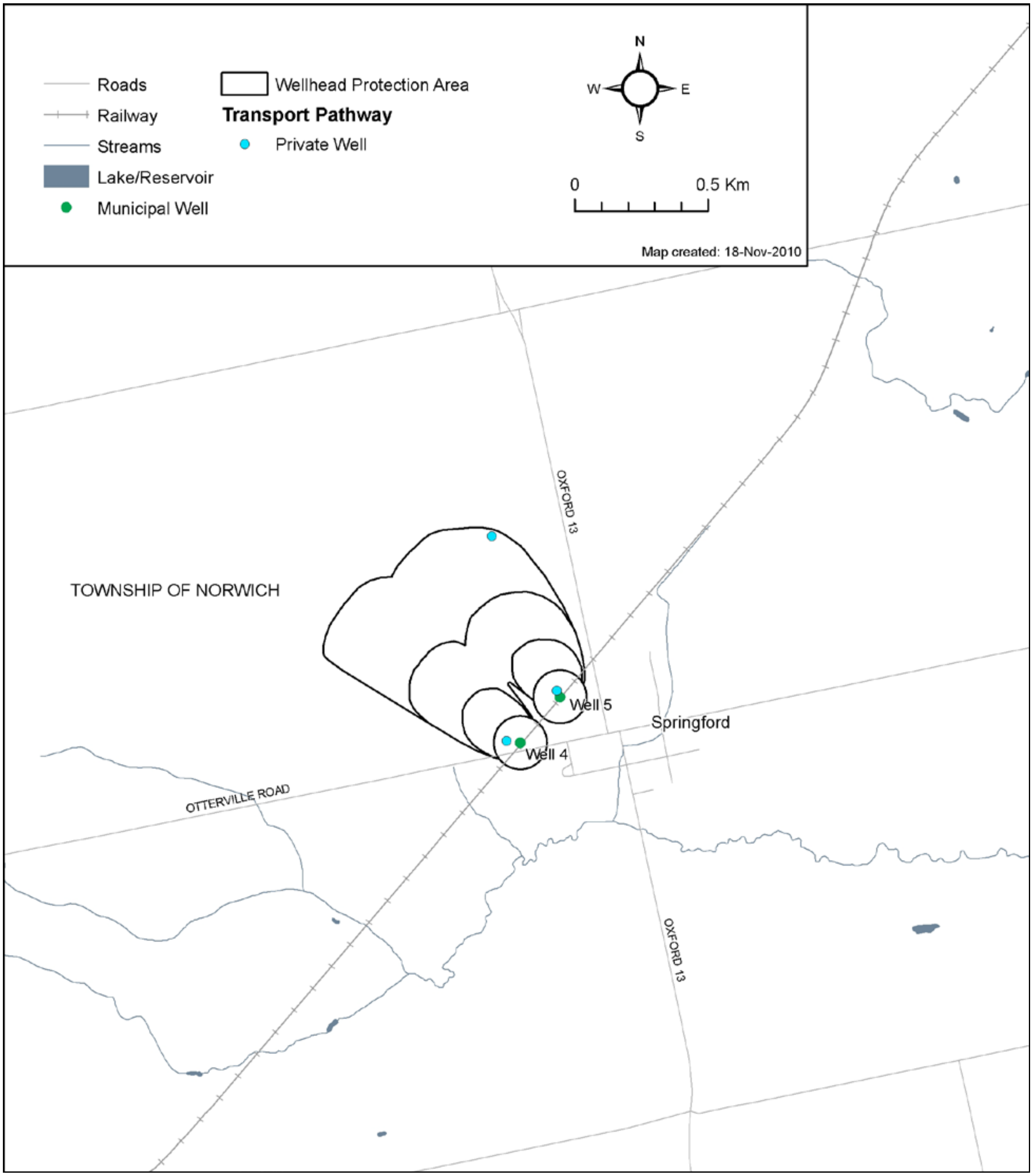
Map 4-27: Springford Intrinsic Vulnerability



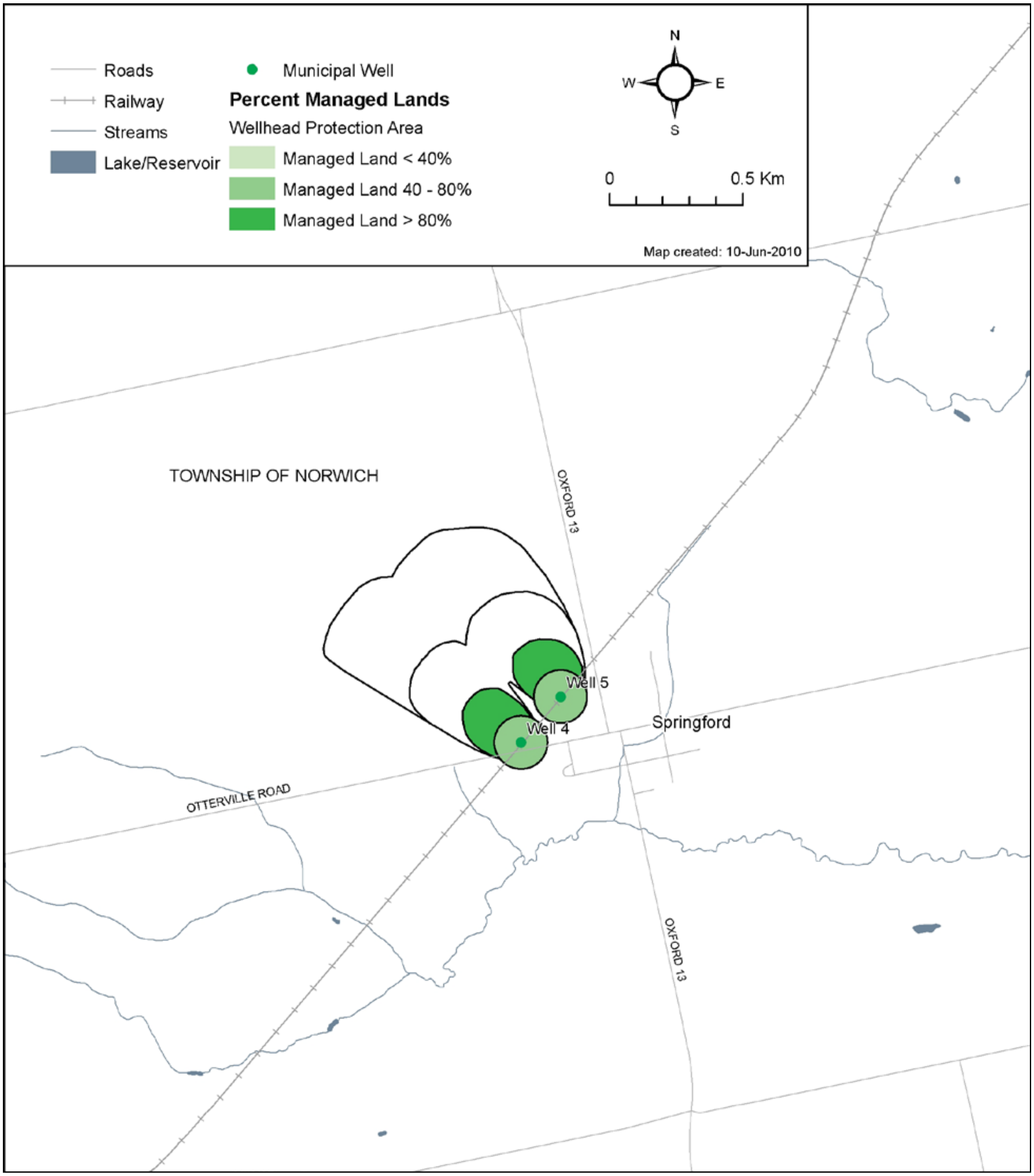
Map 4-28: Springford Wellhead Protection Area Vulnerability



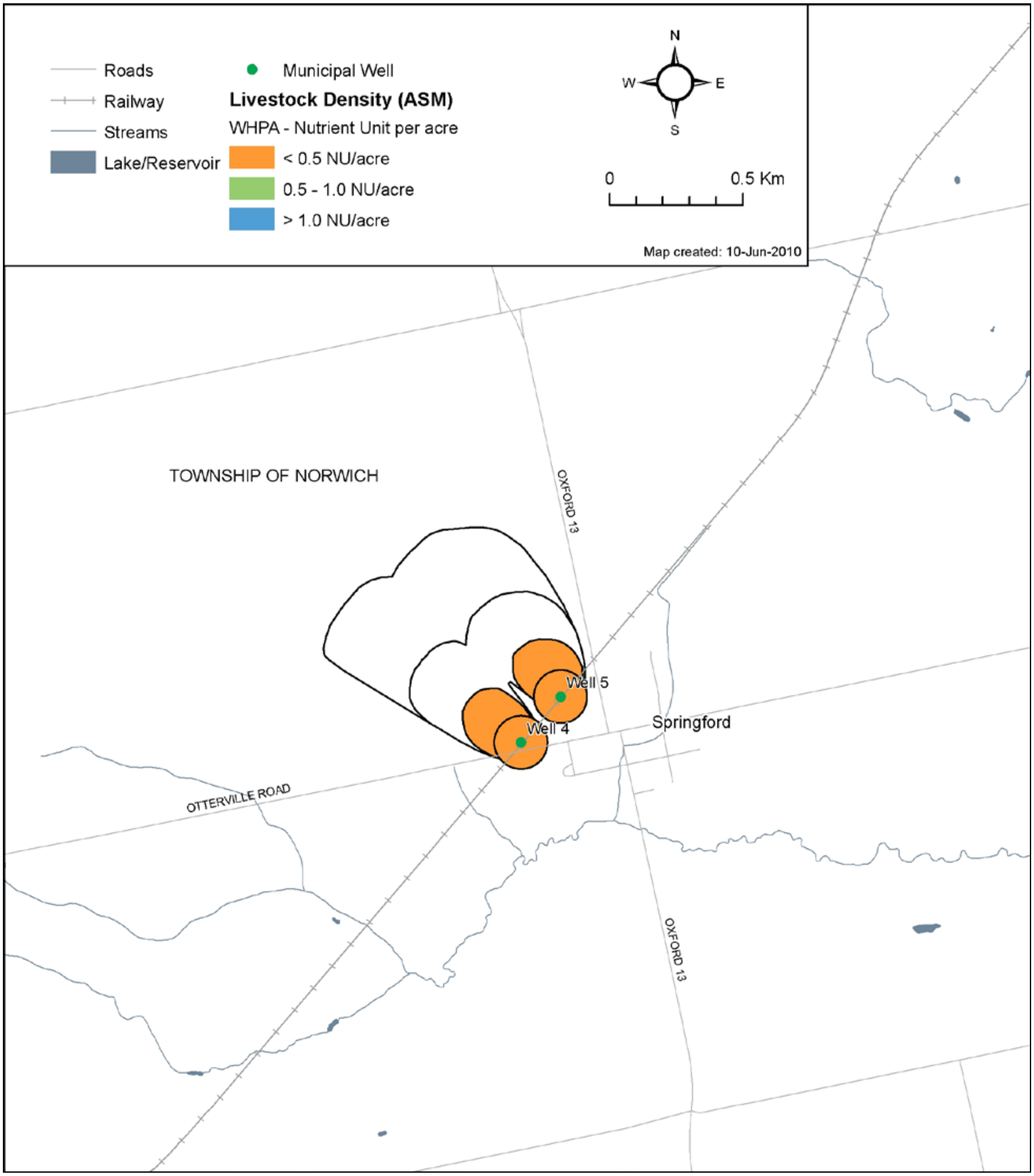
Map 4-29: Springford Transport Pathways



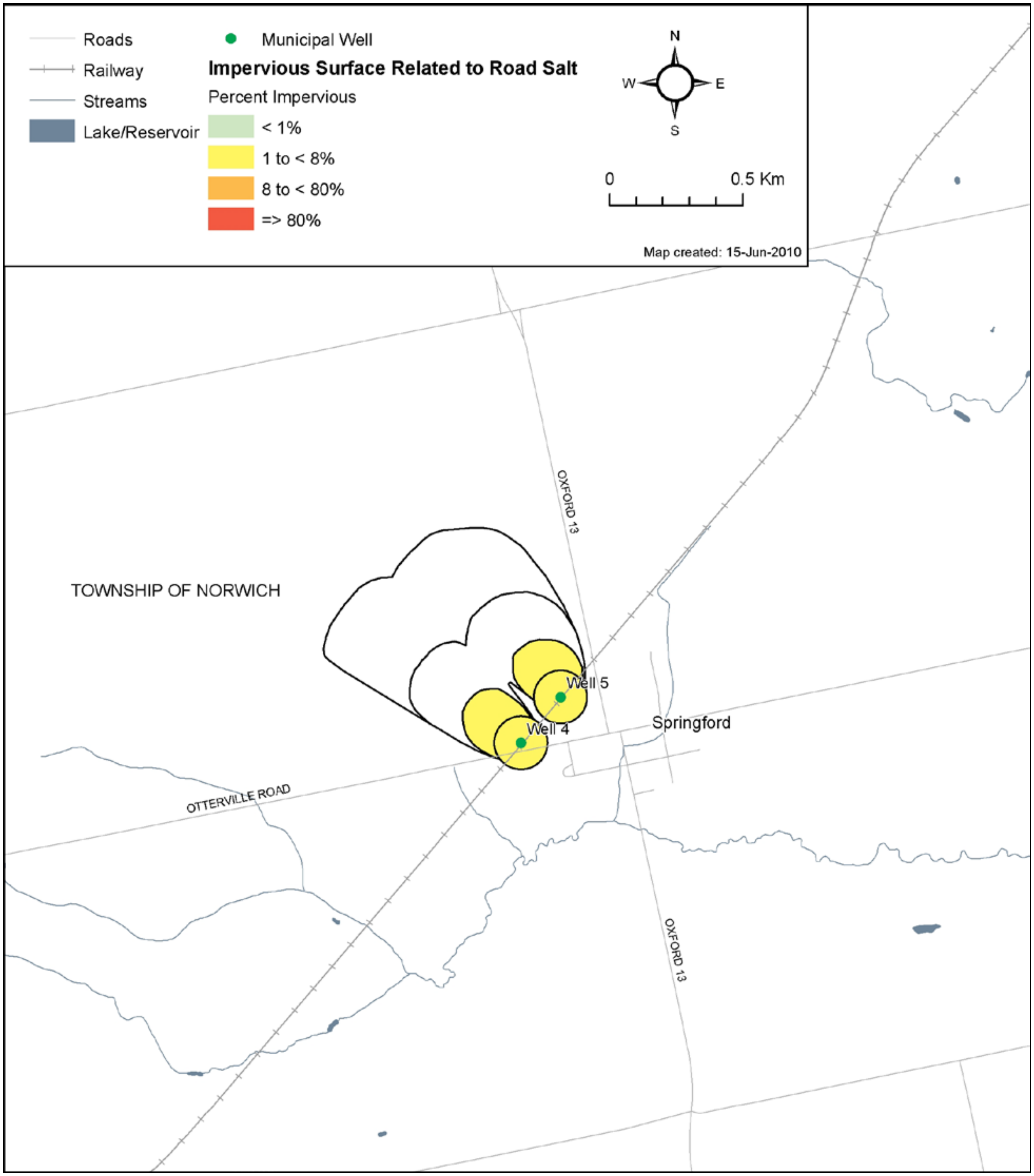
Map 4-30: Percent Managed Lands within the Springford Wellhead Protection Area



Map 4-31: Livestock Density within the Springford Wellhead Protection Area



Map 4-32: Percent Impervious Surfaces within the Springford Wellhead Protection Area



4.6.6 Otterville-Springford Threats Assessment

The Ontario *Clean Water Act, 2006* defines a Drinking Water Threat as "an activity or condition that adversely affects or has the potential to adversely affect the quality or quantity of any water that is or may be used as a source of drinking water, and includes an activity or condition that is prescribed by the regulation as a drinking water threat."

The identification of a land use activity as a significant, moderate, or low drinking water threat depends on its risk score, determined by considering the circumstances of the activity and the type and vulnerability score of any underlying protection zones, as set out in the Tables of Drinking Water Threats available through www.sourcewater.ca. Information on drinking water threats is also accessible through the Source Water Protection Threats Tool: http://swpip.ca. The information above can be used with the vulnerability scores shown in **Map 4-21** and **Map 4-28** to help the public determine where certain activities are or would be significant, moderate and low drinking water threats.

Table 4-14 provides a summary of the threat levels possible in the Otterville-Springford Well Supply for Chemical, Dense Non-Aqueous Phase Liquid (DNAPL), and Pathogens. A checkmark indicates that the threat classification level is possible for the indicated threat type under the corresponding vulnerable area / vulnerable score; a blank cell indicates that it is not. The colours shown for each vulnerability score correspond to those shown in **Map 4-21** and **Map 4-28**.

Table 4-14: Identification of Drinking Water Quality Threats in the Otterville-Springford Wellhead Protection Areas

Threat Type	Vulnerable Area		Vulnerability Score	Threat Classification Level Significant 80+	Threat Classification Level Moderate 60 to <80	Threat Classification Level Low >40 to <60
Chemicals	Otterville	WHPA-A/B	10	✔	✔	✔
		WHPA-C	8	✔	✔	✔
		WHPA-D	6		✔	✔
	Springford	WHPA-A	10	✔	✔	✔
		WHPA-B	6		✔	✔
		WHPA-C/D	2 & 4			
Handling / Storage of DNAPLs	Otterville	WHPA-A/B/C	Any Score	✔		
		WHPA-D	6		✔	✔
	Springford	WHPA-A/B/C	Any Score	✔		
		WHPA-D	2 & 4			
Pathogens	Otterville	WHPA-A/B	10	✔	✔	
Pathogens	Springford	WHPA-A	10	✔	✔	
		WHPA-B	6			✔

Drinking Water Threats

Under the preliminary threats assessment, a desktop land use inventory was used to determine the types of land use activity information and therefore, the threats and circumstances associated with these land uses. In most cases, professional judgment and assumptions were made when determining the presence of significant threats for each property. Consultation with property owners to verify the existence of circumstances that constitute a significant threat is currently being conducted.

In the case of Otterville, significant threats occur in WHPA-A, WHPA-B, WHPA-C, and the ICA. A list of all significant threat types identified in the Otterville Wellhead Protection Area as of March 2019 and the number of times each threat occurs can be seen in **Table 4-15**.

Table 4-15: Significant Drinking Water Quality Threats in the Otterville Wellhead Protection Areas (current to March 2019)

PDWT #[1]	Threat Subcategory[2]	Number of Activities	Vulnerable Area
2	Sewage System Or Sewage Works - Onsite Sewage Systems	22	WHPA-A WHPA-B ICA
3	Application Of Agricultural Source Material To Land	18	WHPA-A WHPA- B ICA
4	Storage of Agricultural Source Material	9	WHPA-A WHPA- B ICA
8	Application Of Commercial Fertilizer To Land	18	ICA
9	Storage of Commercial Fertilizer	9	WHPA-A WHPA- B ICA
10	Application Of Pesticide To Land	4	WHPA-A WHPA-B
11	Handling and Storage Of A Pesticide	2	WHPA-A WHPA- B
15	Handling and Storage Of Fuel	3	WHPA-A WHPA-B
16	Handling and Storage Of DNAPL	1	WHPA-B
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard	2	ICA
Total Number of Properties			**25**
Total Number of Activities			**88**

1: Prescribed Drinking Water Quality Threat Number refers to the prescribed drinking water threat listed in O. Reg 287/07 s.1.1.(1).

2: Where applicable, waste, sewage, and livestock threat numbers are reported by sub-threat; fuel and DNAPL by Prescribed Drinking Water Threat category.

Note: Certain types of activities on residential properties that are incidental in nature and that are significant drinking water threats are not enumerated. These threats include the application of commercial fertilizer on residential properties, the storage of organic solvents (dense non-aqueous phase liquids) on residential properties, and the storage of fuel (e.g., heating fuel tanks) on residential properties in natural gas serviced areas.

Note: Storm sewer piping is not considered to be part of a storm water management facilty.

There were four types of land uses that have, or could potentially have land use activities that pose a significant threat to groundwater in Otterville. These land uses are: agricultural, commercial, industrial and infrastructure. All properties referenced intersect with either WHPA-A, WHPA-B, WHPA-C or the ICA in Otterville.

Springford Land Use Inventory and Drinking Water Threats

In the case of Springford, significant threats occur in WHPA-A. A list of all significant threat types identified in the Springford Wellhead Protection Area as of September 2017 and the number of times each threat occurs can be seen in **Table 4-16**.

Table 4-16: Significant Drinking Water Quality Threats in the Springford Wellhead Protection Areas

PDWT #[1]	Threat Subcategory[2]	Number of Activities	Vulnerable Area
2	Sewage System Or Sewage Works - Onsite Sewage Systems	5	WHPA-A
3	Application Of Agricultural Source Material (ASM) To Land	1	WHPA-A
10	Application Of Pesticide To Land	1	WHPA-A
Total Number of Properties			**6**
Total Number of Activities			**7**

1: Prescribed Drinking Water Threat Number refers to the prescribed drinking water threat listed in O. Reg 287/07 s.1.1.(1).

2: Where applicable, waste, sewage, and livestock threat numbers are reported by sub-threat; fuel and DNAPL by Prescribed Drinking Water Threat category.

Note: Certain types of activities on residential properties that are incidental in nature and that are significant drinking water threats are not enumerated. These threats include the application of commercial fertilizer on residential properties, the storage of organic solvents (dense non-aqueous phase liquids) on residential properties, and the storage of fuel (e.g., heating fuel tanks) on residential properties in natural gas serviced areas.

Note: Storm sewer piping is not considered to be part of a storm water management facilty.

There were two types of land uses that have, or could potentially have land use activities that pose a significant threat to groundwater in Springford. These land uses are: agricultural and residential. All properties referenced intersect with WHPA-A in Springford.

The number of activities occurring in Springford is 7 as follows:

- 5 locations where septic systems are likely present;
- 1 location where there may be the application of manure; and
- 1 location where pesticides may be applied to land.

4.6.7 Otterville Issues Evaluation Results

Ontario regulation 170/03 requires regular testing of microbiological and chemical parameters, with increased testing frequency for certain parameters depending on the results of regular analysis. The County takes regular samples of both the effluent from the Otterville Water Treatment Facility (WTF) and raw water in Otterville Wells 3 and 4.

Microbiological Parameters

Summaries of weekly samples analyzed for Escherichia coli (E. coli) and total coliforms were available from 2009 to 2014 and weekly sample data was available from 2016 to 2018. Microbiological results are typically good however occasional low level positive results for Total Coliforms have been found when one of the wells is operated in standby mode. In 2007, there was a six month period where Total Coliforms counts were higher than usual and there were occasional low level E.coli positive results as well. Following rehabilitation of the well in January 2008, the levels returned to normal. Between 2016 and 2018, there were no detections of *E. coli* in either well and only one detection of total coliforms in Otterville Well 3.

Due to the infrequency of detections, no microbiological parameters were identified as Issues. Additionally, the current treatment (disinfection by sodium hypochlorite) at the Otterville WTF is considered sufficient for this level of microbiological contamination.

Health Related Chemical Parameters

In the previous Issues evaluation (County of Oxford, 2009), no health-related parameters were identified as Issues. However, a review of new analytical data (2010-2018) revealed that quarterly analytical nitrate results from effluent at the Otterville WTF began to exceed 5 mg/L (50% of the MAC for nitrate) in 2012. Since 2012, concentrations of nitrate in the treated effluent have consistently remained above 5 mg/L, but below 10 mg/L (the MAC for nitrate). Regular sampling of nitrate the in the raw water from Otterville Wells 3 and 4 began in late 2016. With some limited exceptions at Otterville Well 3, analytical results from these samples have consistently shown concentrations of nitrate between 5 and 10 mg/L. Analysis of four consecutive weekly samples of raw water from Otterville Well 4 showed concentrations of nitrate exceeding the MAC. Due to these results nitrate is identified as an Issue at the Otterville Wellfield. No other health-related chemical parameters were found to exceed 50% of their respective ODWQS MAC.

Aesthetic or Operationally Significant Parameters

The Otterville wells have several operational or aesthetic parameters exceed the associated objectives or guidelines as detailed below.

Hardness, which has a guideline range from 80 to 100 mg/L, is typically exceeded in groundwater systems. The Otterville's hardness concentrations (2010 to 2016) are between 277 and 304 mg/L. Previous to 2010, hardness concentrations ranged from 247 to 366 mg/L. This parameter is naturally occurring in the groundwater and does not pose a health risk nor does it impact the treatment process.

Between 2010 and 2016, analytical results showed concentrations of sodium in the raw water from Otterville Wells 3 and 4 ranging from 21.1 to 31.0 mg/L. Previous to 2010, sodium is raw water ranged from 28 to 44 mg/L. While these concentrations are well below the aesthetic objective for sodium (200 mg/L), they are above the recommended threshold for reporting (MOE 2006b). Chloride concentrations were also reported well below their respective aesthetic objective. Low concentrations of these parameters suggest that the parameters are naturally occurring in groundwater and not related to road salting. No trend was observed in the results between 2010 and 2016.

Between 2010 and 2016, analytical results showed concentrations of organic nitrogen in the raw water from Otterville Wells 3 and 4 ranging from below the method detection limit (MDL) to 0.83

mg/L. Analytical results from the three sampling events (2010, 2014, and 2016) showed concentrations exceeding the operational guideline once in Otterville Well 3 (2016) and twice in Otterville Well 4 (2010, 2014). Previous to 2010, organic nitrogen concentrations were 0.29 mg/L. Organic nitrogen can be associated with unpleasant taste and high levels can reduce the effectiveness of chlorine as a disinfectant. There is no history of objectionable taste that is sometimes associated with organic nitrogen.

4.6.8 Springford Issues Evaluation Results

Health Related Parameters

No health-related parameters were found to exceed their respective MAC. Microbiological results are typically good however occasional low level positive results for Total Coliforms have been found when one of the wells is operated in standby mode.

Fluoride concentrations are typically 1.65 mg/L which is above half of the MAC of 2.4 mg/L. The fluoride is naturally occurring in the groundwater, there is no evidence of upwards trending and does not impact the treatment process.

Aesthetic or Operationally Significant Parameters

The Springford wells have several operational or aesthetic parameters exceed the associated objectives or guidelines.

Sodium concentrations at the well field range from 44 to 47 mg/L which is above the reporting level of 20 mg/L but well below the objective of 200 mg/L. Chloride concentrations are quite low suggesting that the sodium is not caused by road salt application but rather is naturally occurring. No increasing trend is evident in the results.

The aesthetic objective for colour is 5 TCU. The source has a value of 8 TCU. There is insufficient evidence to comment on any trending. The parameter does not impact the treatment process.

4.6.9 Summary of Identified Issues

As a result of elevated nitrate concentrations in Otterville Wells 3 and 4, nitrate has been identified as an Issue under Technical Rule 114.

The parameters in the Springford Wellfield that meet the screening threshold are total coliforms, fluoride and colour. The total coliforms results are likely due to infrequent operation of the well when it is in standby mode. The remaining parameters are all naturally occurring and typical to groundwater sources. They do not affect the treatment process and there is no evidence of upward trending.

Issue Contributing Area for Otterville Wells 3 and 4

With the identification of nitrate as an Issue for Otterville Wells 3 and 4, an ICA was delineated for these wells. The area was delineated using the refined Long Point Tier 3 model, same that was done for the WHPA delineation, except that existing (i.e., average of 2012 to 2016 rates) pumping rates were used to assess the nitrate ICA. The total existing demands (i.e.,310 m^3/day) were modeled as a 50/50 split (i.e., 155 m^3/day each) between the two municipal wells, which is consistent with the relative proportion of takings between 2012 and 2016.

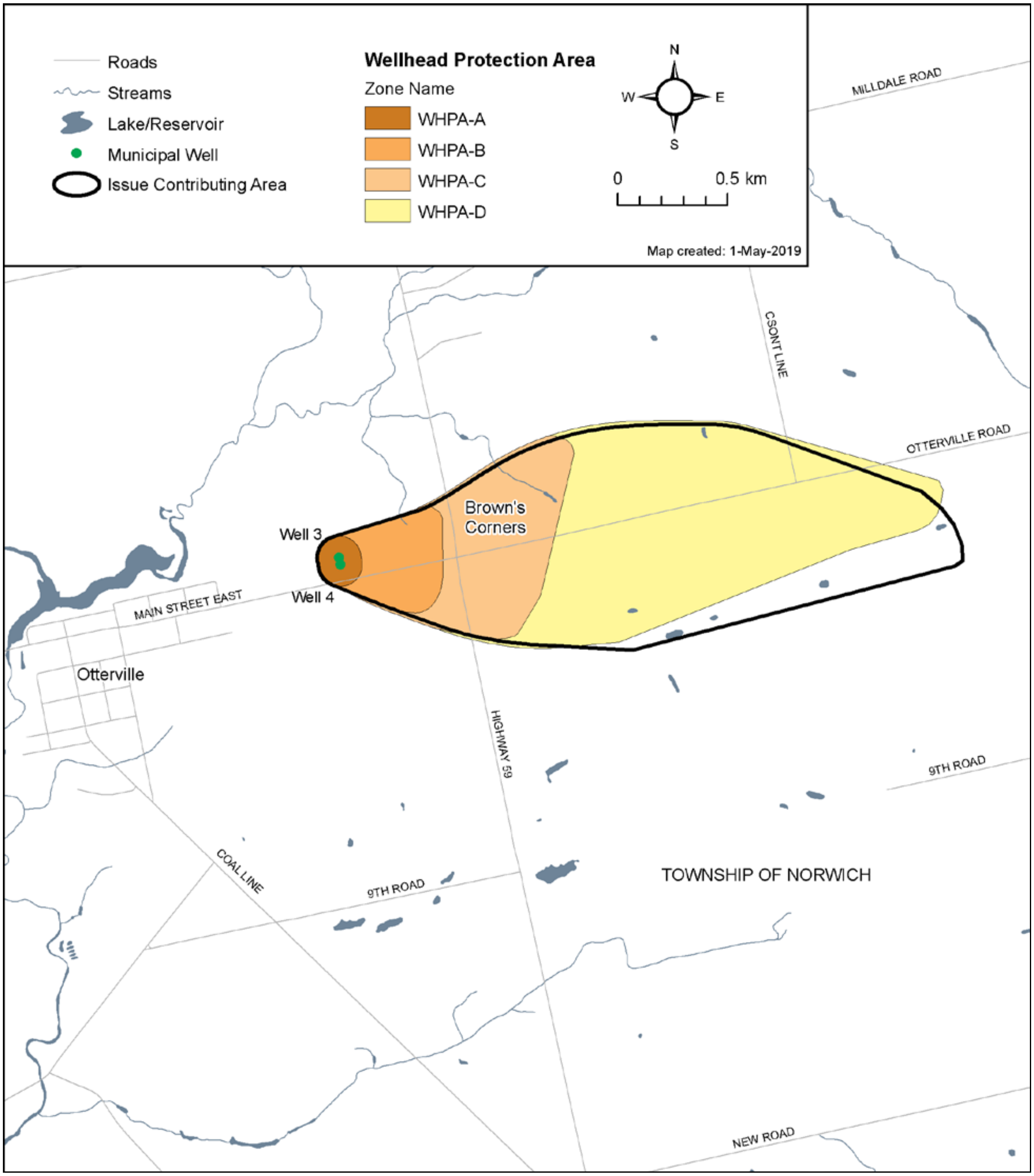
Composite capture zones were delineated for Wells 3 and 4 using a 100 m buffer surrounding the municipal wells, and time-of-travel capture zones using backward and forward particle pathlines simulated using the Base Case model and sensitivity scenarios. This included 2-, 5-, 10-, 25-, and 60-year time-of-travel zones. This maximum time-of-travel was consistent with the estimate that significant nitrate application from fertilizer began approximately 60 years ago. The shape and extent of the nitrate ICA is slightly different than the WHPA-A to WHPA-D area as the ICA reflects the Otterville wells pumping at current average rates rather than future rates. Further, the ICA reflects groundwater flow within a maximum of 60 years rather than 25 years, which was used for WHPA-D delineation.

The nitrate Issue Contributing Area for Otterville Wells 3 and 4 is illustrated on **Map 4-33**.

4.6.10 Otterville Uncertainty Assessment

Uncertainty in the delineation of the WHPAs was addressed through the simulation of multiple scenarios. The scenarios for WHPA delineation produced similarly shaped capture zones, which were all encompassed in the final WHPA delineation. Additionally, the reliability of the delineated WHPAs is supported by the reasonability of the calibrated model. The groundwater flow model is calibrated using model parameters that reflect hydraulic field tests and have values that are within expected ranges for the various hydrogeological units. This results in a low uncertainty for the capture zone delineation. The vulnerability category is high throughout the Study Area, and this designation has low uncertainty due to the shallow, coarse soils and a high water table. Therefore, the uncertainty with respect to the vulnerability score is also considered low.

Map 4-33: Issue Contributing Area (Nitrate) for Otterville Wellfield



4.7 Tillsonburg Water Supply

There are 10 active production wells supplying the Tillsonburg water system (**Map 4-34**) and 1 planned well (well 3). The southeast group of wells includes Well 1A, 2, 9, 10, 11 and 12. The north group of wells includes Well 3, 4, 5, 6A and 7A. Note that Well 7 was replaced by nearby Well 7A in 2009, in the same aquifer at a similar depth. As described below, some data, analysis and discussion were based on Well 7.

The approved Long Point Region Source Protection Area Terms of Reference (July 13, 2009) refers to a planned drinking water system in Tillsonburg (No. 220000683). It is important to note that the planned addition to the drinking water supply for Tillsonburg is not a planned system, but instead it is a planned well within the existing Drinking Water System (No. 220000683).

The Tillsonburg Drinking Water System is a Large Municipal Water system as defined by Regulation 170/03 and serves a population of approximately 16,340 people. Wells 1A, 2, 4, 5, 7A, 9 and 10 are GUDI wells with effective in-situ filtration. Wells 3, 6A, 11 and 12 are secure groundwater wells.

All of the Tillsonburg production wells are completed in the overburden aquifer system. The southeast group of wells is located in the Norfolk Sand Plain and is screened over depth intervals of approximately 20 – 25 mbgs. In the north group, Wells 3, 4, 5 and 7 (now 7A) are screened over depth intervals of approximately 18 – 23 mbgs; the screen setting in Well 6A is deeper (29 – 35 m) (County of Oxford, 2009a; MOECC, 2015).

The Phase II Groundwater Protection Study (Golder, 2001) indicates that the Tillsonburg Groundwater Model was constructed using two overburden layers. The upper layer was characterized to represent the surficial sediments present in the Tillsonburg area, varying from sand deposits (typical of the Norfolk Sand Plain) in the southeast to till deposits (silty clay to sandy silt typical of the Port Stanley Till) in the north. The lower overburden layer was characterized as an aquifer. In the model, the north group of production wells (3, 4, 5, 6A, and 7) is completed in the lower aquifer layer. The south group of production wells (1A, 2, 9, 10, 11, and 12) is completed in the upper aquifer layer.

The Phase II Groundwater Protection Study (2001) updated in 2007 indicates that the Tillsonburg Wellhead Protection Areas were based on the following forecasted pumping rates as provided in **Table 4-17.**

Table 4-17: Tillsonburg Production Wells Forecasted Pumping Rates

Well	Pumping Rate
1A	1,669 m^3/day (19.3 L/s)
2	711 m^3/day (8.2 L/s)
3	N/A*
4	1,637 m^3/day (18.9 L/s)
5	1,168 m^3/day (13.5 L/s)
6A	122 m^3/day (1.4 L/s)
7	180 m^3/day (2.1 L/s)
9	1,309 m^3/day (15.2 L/s)
10	688 m^3/day (8 L/s)
11	375 m^3/day (4.3 L/s)
12	1,309 m^3/day (15.2 L/s)

* The flow rate used in the model to generate the Wellhead Protection Area for Well 3 is 8 L/s. The maximum capacity of the well is 16.7 L/s.

Wellhead Protection Areas for the Tillsonburg Northern wellfield were remodelled in 2014 (Matrix, 2014) following the completion of the Long Point Region Tier Three groundwater flow model (Matrix, 2013). Updated pumping rates, which accounted for growth projections to 2026, were used to generate the Tillsonburg Northern wellfield Wellhead Protection Areas. These pumping rates are provided below in **Table 4-18**.

Table 4-18: Tillsonburg Northern Production Wells Forecasted Pumping Rates used in 2014 Re-modelling

Well	Pumping Rate
3	161 m^3/day
4	731 m^3/day
5	540 m^3/day
6A	161 m^3/day
7A	401 m^3/day

4.7.1 Tillsonburg Wellhead Protection Areas and Vulnerability Scoring

The Tillsonburg groundwater model covers an area of approximately 150 km^2, and is aligned in a northwest to southeast direction, approximately parallel to Big Otter Creek. The following provides a summary of the Tillsonburg Groundwater Flow Model based on hydrogeological information available at the time of the Golder (2001) study.

Stratigraphy

The Tillsonburg area is generally separated into two distinct hydrogeological areas by Big Otter Creek. To the north of Big Otter Creek the surface is primarily defined by silty clay to sandy silt sediments (Port Stanley Till) which confine the deeper aquifers beneath. To the south of Big Otter Creek, glaciolacustrine shallow water deposits (fine to medium sand, minor silt) predominate and form what is known as the Norfolk Sand Plain.

The overburden aquifers in this area are typically unconfined. The shallow, intermediate and deep aquifers in Tillsonburg are underlain by till at depth, which is in turn underlain by limestone bedrock. The Tillsonburg Groundwater Model was constructed using two overburden layers. The upper layer varies spatially across the model area as determined from the distribution of the surficial soil deposits (i.e., the Norfolk Sand Plain versus the Port Stanley Till). The second overburden layer is entirely comprised of aquifer material. The base of the model is defined as the top of the deeper till.

Groundwater Flow Boundaries

North of Tillsonburg, groundwater flow in the overburden aquifers occur in a southerly direction towards Stony and Big Otter Creek. The northwestern boundary in the groundwater model was assigned a constant head boundary condition based on inferred groundwater contours in the overburden (260 masl) aquifer. Groundwater inflow to the model occurs across this boundary. The western and eastern model boundaries follow inferred groundwater flowlines and were therefore assigned as "no flow" boundaries in the model. The southern model boundary follows Little Otter Creek which was assigned as a river boundary condition. The elevations specified in the river boundary are consistent with the topography (surface water elevation) along the creek.

Groundwater discharge from the model will occur to Little Otter Creek. In addition to the model perimeter, Big Otter Creek, which runs through the town of Tillsonburg and the central area of the model, and Stony Creek (a tributary of Big Otter Creek) were defined as river boundary conditions. As described further below, Big Otter Creek provides the principal location for overburden aquifer groundwater discharge in the Tillsonburg area.

Groundwater/Surface Water Interaction

Big Otter Creek is incised through the shallow and intermediate aquifers and provides the main location for groundwater discharge from the overburden aquifers in the Tillsonburg area. Little Otter Creek, while not as deeply incised, is inferred to provide a location for additional groundwater discharge from the Norfolk Sand Plain. In the Tillsonburg Groundwater Model, Big Otter Creek, Stony Creek and Little Otter Creek were assumed to be connected to the overburden aquifers (where present).

Recharge

Two separate recharge zones were established for the model to reflect the variability in surficial sediments in the Tillsonburg area. Where the glaciolacustrine sands are at surface, recharge would be relatively high, and was assigned a rate of 250 mm/yr. This is consistent with previous recharge rate estimates of 30 to 40% of precipitation (295 to 394 mm/yr) for this area (IWS, 1993). In areas where the shallow overburden materials are finer grained and therefore of lower permeability (i.e. Port Stanley Till), a recharge rate of 20 mm/yr was applied. Again, this is comparable with previous recharge rate estimates of less than 5 per cent of precipitation (<49 mm/yr) for the till to the north of Big Otter Creek (IWS, 1993). The final recharge rate values were estimated through the model calibration process.

Hydraulic Conductivity and Porosity

The transmissivity of the sand deposits in the Norfolk Sand Plain have been estimated to range from 100 m^2/day to 745 m^2/day, with an average of 150 m^2/day (IWS, 1993). In the area of Wells 4 and 5 (to the north of Big Otter Creek), the transmissivity was estimated to range from 45 m^2/day to 1860 m^2/day, again with a regional average of 150 m^2/day. From these estimates, IWS (1993) estimate the following range in hydraulic conductivity for the overburden aquifer: $1x10^{-4}$ m/s to $6x10^{-4}$ m/s. They also note that the hydraulic conductivity of the aquifer near the location of the wells may be greater than that estimated on a more regional scale. The hydraulic conductivity of the overburden aquifers in the Tillsonburg Groundwater Model were in general assigned at $2x10^{-4}$ m/s, with an effective porosity of 25%. However, local to the area of the supply wells to the south of Tillsonburg, a higher hydraulic conductivity was required for model calibration. In this area, a hydraulic conductivity of $1x10^{-3}$ m/s was assigned. The finer grained lower permeability till deposits at surface to the north of Big Otter Creek were assigned a hydraulic conductivity of $2x10^{-5}$ m/s.

Other Water Takings

There were two private water takings identified in the review of the MOE PTTW Database for the Tillsonburg area: Permit No. 79-P-1152 which lies approximately 1.5 km downgradient of Wells 9, 10 and 11 in the town of Tillsonburg just south of Big Otter Creek; and Permit No. 78-P-1072 which lies to the northwest of Wells 1A and 2. However, detailed information on the location and current status of the water takings are unknown and they were not included in the groundwater model. Additional permits were identified to the east of the town, although these were found at distances of more than 4 km to the east (and not upgradient) of Well 1A and Well

2. The Tillsonburg water supply wells were the only wells included in the Tillsonburg Groundwater Model.

Tillsonburg Northern Wellfield Wellhead Protection Area Update

The wellhead protection areas for wells located in the Tillsonburg Northern wellfield were updated in 2014 (Matrix) using the calibrated Tier Three steady state groundwater model which was developed as part of the Long Point Region Tier Three study, and used refined local instrinsic vulnerability information. Details regarding the development of this model are included in the report Tier Three Water Budget and Local Area Risk Assessment, Long Point Region, Model Development and Calibration Report (Matrix, 2013).

Wellhead Protection Areas and Vulnerability Scoring

Map 4-35 and **Map 4-47** illustrate the Wellhead Protection Areas for the Tillsonburg Water System which supplies water from wells in both Oxford and Norfolk counties. **Map 4-36** and **Map 4-48** illustrate the initial vulnerability mapping for the wells. The transport pathways for both wellfields are presented on **Map 4-37** and **Map 4-49**. The transport pathway area of influence is shown on **Map 4-38**. The final vulnerability scores are presented on **Map 4-39** and **Map 4-48** for both wellfields respectively, and includes any of the adjustments identified below. Vulnerability mapping for the Tillsonburg Wellhead Protection Areas was completed using the SWAT method (Golder, 2005).

The Wellhead Protection Area for Well 1A and Well 2 (Mall Road) extends approximately 4.5 km to the east and has a width of approximately 1250 m. Potential transport pathways are limited to test wells and a few domestic wells within the 100 m radius and 2-year Wellhead Protection Area. No adjustments were made to the vulnerability mapping to account for these pathways. Some adjustments were made to the vulnerability mapping within the 2 year and 5 year time of travel zones based on professional judgment. These adjustments included some smoothing of the contacts between areas with different scores, and increases to the scoring in some areas to remove anomalies to provide more consistent mapping.

The Wellhead Protection Areas for Wells 9, 10, 11 and 12 overlap each other and extend approximately 6.2 km to the east. The Wellhead Protection Areas also overlap the south part of the Wellhead Protection Areas for Wells 1A and 2. No adjustments were made to the scoring to account for potential transport pathways. Some adjustments were made using professional judgment to remove anomalies and to smooth the contact lines between areas with different scores within the Zone B.

The Wellhead Protection Areas for Wells 4 and 5 (North Street) extends approximately 4 km to the northwest. Some smoothing and minor adjustments to the vulnerability mapping were performed based on professional judgment. No adjustments were made to account for the sanitary sewer as the wells are screened greater than 20 mbgs and it is unlikely that the sewer system extends more than about 3 - 5 mbgs. As a result, the vulnerability was not adjusted. These results appear to reflect the occurrence of a contact between surficial sand deposits in the south-southeast part of the Wellhead Protection Area (relatively close to the location of Wells 4 and 5) and glacial till (Port Stanley Till) deposits over the larger area in the north part of the Wellhead Protection Area.

The Wellhead Protection Areas for Wells 3, 6A and 7A overlap each other and extend approximately 6.2 km to the northwest from the southernmost of these wells (7A). An adjustment to the vulnerability mapping along a portion of Plank Line within these Wellhead

Protection Areas was made to account for a concentration of private wells in that area as potential transport pathways as presented on **Map 4-37**. Some infilling and smoothing of contours on the scoring map was performed based on professional judgment. No adjustments were made to account for the sanitary sewer due to the depth these wells are screened at and it is unlikely that the sewer system extends more than about 3 - 5 mbgs.

WHPA-E for Wells Under the Direct Influence of Surface Water (GUDI)

Delineation of additional WHPAs may be required for each well or wellfield that has been identified as groundwater under the direct influence of surface water under subsection 2(2) of O. Reg. 170/03 (referred to as GUDI wells). A WHPA-E is required for GUDI wells where the interaction between surface and groundwater decreases the travel time of water to the well. A WHPA-F may also be delineated for GUDI wells where a drinking water issue has been identified and is believed to originate from a source outside of any other wellhead protection area.

The Tillsonburg Drinking Water System consists of eleven (11) wells, seven (7) of which have been designated as GUDI under O.Reg. 170/03. Of these seven (7), WHPA-Es have been delineated for three (3) of the wells. The remaining four (4) wells have not had WHPA-Es delineated as section 49(3) of the technical rules does not apply. This interpretation is consistent with the clarification issued by the MOE in the Technical Bulletin: Groundwater Vulnerability in June 2010. The GUDI designation for wells 1A, 2, 9 and 10 is based on the source being an unconfined aquifer allowing more rapid infiltration. There is no surface water body to circumvent the path of flow to the wells and therefore no WHPA-E is required. **Table 4-19** below shows the GUDI and WHPA-E status for each of the Tillsonburg wells.

Table 4-19: GUDI and WHPA-E status for each of the Tillsonburg wells

Well Number	Groundwater / GUDI	WHPA-E Delineation
1A	GUDI	No
2	GUDI	No
3	Groundwater	N/A
4	GUDI	Yes
5	GUDI	Yes
6A	Groundwater	N/A
7A	GUDI	Yes
9	GUDI	No
10	GUDI	No
11	Groundwater	N/A
12	Groundwater	N/A

It was also determined that WHPAs-E/F were not required for the following GUDI wells.

- WHPA-F was **not** required for Tillsonburg Wells 4, 5 & 7A.
- WHPA-E was **not** required for Tillsonburg Wells 1A and 2.
- WHPA-E was **not** required for Tillsonburg Wells 9 and 10.

Tillsonburg wells 4 and 5 are screened in a sand and gravel aquifer and well 4 is located adjacent to a small creek, which is a tributary to Stoney Creek. The GUDI study for these wells concluded that they had no influence on the shallow overburden/surface water features. Given the wells' close proximity to the creek (approximately 2m), delineation of a WHPA-E was deemed necessary. **Map 4-43** shows the location of wells 4 and 5.

Tillsonburg well 7A is screened in a sand and gravel aquifer that is overlain by clay and gravel. The nearest surface water feature is a tributary of Stoney Creek within 100m of the well house. A previous GUDI study confirmed the hydraulic connection between well 7A and the tributary of Stoney Creek. **Map 4-43** shows the location of the GUDI well relative to the tributary of Stoney Creek.

Delineation of the WHPA-Es for wells 4, 5 and 7A are based on the locations of the nearest surface water bodies to the pumping wells and consist of the area within the Stoney Creek tributaries that may contribute water within a two hour time of travel under high flow conditions, the necessary setbacks on land, and the area that contributes to the WHPA-E through transport pathways as per the technical rules.

The two hour time of travel distance was based on hydrologic and hydraulic analysis of 2-year flow conditions (bankfull discharge). Empirical equations (Moin Index Flood Method and Primary Multiple Regression Method) and field visits were used to determine the 2-year flow. A velocity of 0.56-0.57m/s was used in the time of travel analysis. The WHPA-E was extended to include all Tillsonburg stormwatersheds with outfalls upstream of well 7A. Tile drains and roadside ditches that can contribute water to the WHPA-E within a 2-hour travel time were also incorporated into the WHPA-E delineation where applicable. One tile drain which meets the 120m buffer in the north-west was included in the WHPA-E delineation. A combination of the instream 2-hour travel time, the 120m buffer and the transport pathways constitute the final WHPA-E. It should be noted that the local watershed boundaries take priority over the extent of the 120m buffer, Regulation Limits or tile drainages. The WHPA-E only includes areas that can contribute overland flow to the well. **Map 4-43** shows the extent of the Tillsonburg WHPA-E.

WHPA-E Vulnerability Scoring

The vulnerability analysis of a WHPA-E (Dillon, 2011) considers both the area and the source as described in the Technical Rules. The area vulnerability factor for a WHPA-E is prescribed to be the same as IPZ 2, i.e., between 7 and 9. The source vulnerability factors for GUDI wells in the Tillsonburg Northern well filed have been assessed on the basis of Type C intake (i.e., wellfields are hydraulically connected to in-land creeks) and therefore were assumed to be in the range of 0.9 to 1.0.

The WHPA-E for well 7A was assigned an area vulnerability factor of 8 given the high percentage of urban area, the existence of transport pathways (stormwatersheds and tile drainages), flat topography and high percentage of land. The WHPA-E for wells 4 and 5 were assigned an area vulnerability factor of 7 given the predominately rural land cover, moderate to high permeability soils and flat land.

According to the Technical Rules the source vulnerability factor for a surface water intake takes into consideration the depth of the intake from the top of the water surface, the distance of the intake from the land and historical water concerns. Factors included in the analysis of the Tillsonburg Northern well field considered that wells 4 and 5 are located within 2 meters of a tributary of Stoney Creek, both wells are approximately 21m deep and no water quality issues have been identified at these wells. Well 7A is located about 100 metres from Paget Drain and is about 27 meters deep. No water quality issues (analysis based on Well 7 data) were identified at well 7A. Overall the major source of water to the wells is attributed to groundwater, however a small and unknown portion of water may potentially originate from a surface water source. A source vulnerability factor of 0.9 was assigned to the WHPA-E for both well 4 and 5 and well 7A.

Combining the area and source vulnerability scores, the overall WHPA-E vulnerability score for wells 4 and 5 is 6.3. The WHPA-E for well 7A has a vulnerability score of 7.2. **Table 4-20** summarizes the source vulnerability factors and scores assigned to the Tillsonburg northern wellfield systems.

Map 4-44, **Map 4-45**, and **Map 4-46** show the percent managed land, livestock density and percent impervious surface for the Tillsonburg WHPA-E, and is discussed further below.

Table 4-20: Vulnerability Score Summary for the Tillsonburg WHPA-E Zones.

Location	Intake Protection Zone	Area Vulnerability Factor	Source Vulnerability Factor	Vulnerability Score
Well 4 and 5	WHPA-E	7	0.9	6.3
Well 7A	WHPA-E	8	0.9	7.2

Limitations of Data and Methods Used in the WHPA-E Vulnerability Assessment

No critical data gaps were identified during the study; however, should the vulnerability assessment be updated in the future, it would be beneficial to improve the accuracy of the following information: land use data, OMAFRA soil maps of higher resolution and a digital elevation model of higher resolution to improve watershed delineation and slope estimates.

Known and reliable empirical equations were used to determine the 2-year flow estimation and hydraulic calculations for the Paget Drain. The area vulnerability factor for both wells was assigned to WHPA-E based on known land use data, soil types, permeability, slopes, hydrological and hydraulic conditions of the area. All data was available in sufficient detail and have low uncertainty. Therefore, the degree of uncertainty related to the vulnerability factor for WHPA-E is low. The source vulnerability factor for WHPA-E is based on known well design characteristics (depth of the well, and distance to the surface water feature). Sufficient information is available to assign the source vulnerability factor. The degree of uncertainty related to the source vulnerability factor for WHPA-E is low.

Peer Review for the WHPA-E Vulnerability Assessment

The vulnerability assessment of GUDI wells in the Tillsonburg Water System was carried out by Dillon Consulting (Dillon, 2011) on behalf of Oxford County. Technical and peer review for the surface water vulnerability assessment was completed, iteratively, throughout the development of the final reports by GRCA and Oxford County staff. External peer review was provided by Stuart Seabrook, Stan Denhoed, and Rob Schincariol in 2011.

4.7.2 Managed Lands and Livestock Density

The managed lands and livestock density work for Tillsonburg was completed in WHPA-A and WHPA-B for all wells and portions of some WHPA-C where the vulnerability was 6 or higher, and part of the WHPA-D for wells 3 and 7. The summary of findings for percent managed lands in Tillsonburg have 5 zones in the high category, 16 in the moderate and one in the low category (**Map 4-40** and **Map 4-50**). For livestock density, zones are in the lowest category, as presented in **Map 4-41**, **Map 4-45**, and **Map 4-51**.

Table 4-21: Managed Lands and Livestock Density in Tillsonburg

WHPA Zone		Percent Managed Land	Livestock Density
		%	NU/acre
Tillsonburg Well 3	WHPA-A	64%	0.0
	WHPA-B	54%	0.0
Tillsonburg Well 4 & 5	WHPA-A	66%	0.0
	WHPA-B	91%	0.0
	WHPA-C (partial)	43%	0.0
Tillsonburg Well 6A	WHPA-A	85%	0.0
	WHPA-B	88%	0.0
	WHPA-C (partial)	85%	0.0
Tillsonburg Well 7A	WHPA-A	56%	0.0
	WHPA-B	30%	0.0
Tillsonburg Well 3 & 7A	WHPA-C (partial)	53%	0.0
Tillsonburg Well 3 & 7A	WHPA-D (partial)	71%	0.0
Tillsonburg Well 1A & 2	WHPA-A	67%	0.0
	WHPA-B	85%	0.0
	WHPA-C	74%	0.0
Tillsonburg Well 9, & 10	WHPA-A	65%	0.0
Tillsonburg Well 11	WHPA-A	50%	0.0
Tillsonburg Well 9, 10 & 11	WHPA-B	76%	0.02
	WHPA-C	59%	0.0
Tillsonburg Well 12	WHPA-A	46%	0.2
	WHPA-B	70%	0.1
	WHPA-C	57%	0.02

4.7.3 Percent Impervious Surfaces Area in Wellhead Protection Areas

To determine whether the application of road salt poses a threat in the Tillsonburg North wells, the percentage of impervious surface where road salt can be applied per square kilometre was calculated as per the Technical Rules 16(11) and 17.

To calculate percentage of impervious surface, guidance from the rules mentioned above were used to create a 1km by 1km grid over the vulnerable area. In the most recent amendment (November 16, 2009) of the technical rules, rule 17 from Part II changed to state that the 1 kilometer by 1 kilometer grid be centred over the “source protection area” as opposed to the original “vulnerable area”.

The application of road salt can only be a threat in areas with a vulnerability score of 6 or greater; therefore the percent impervious calculation was only completed in areas with a score of 6 or greater.

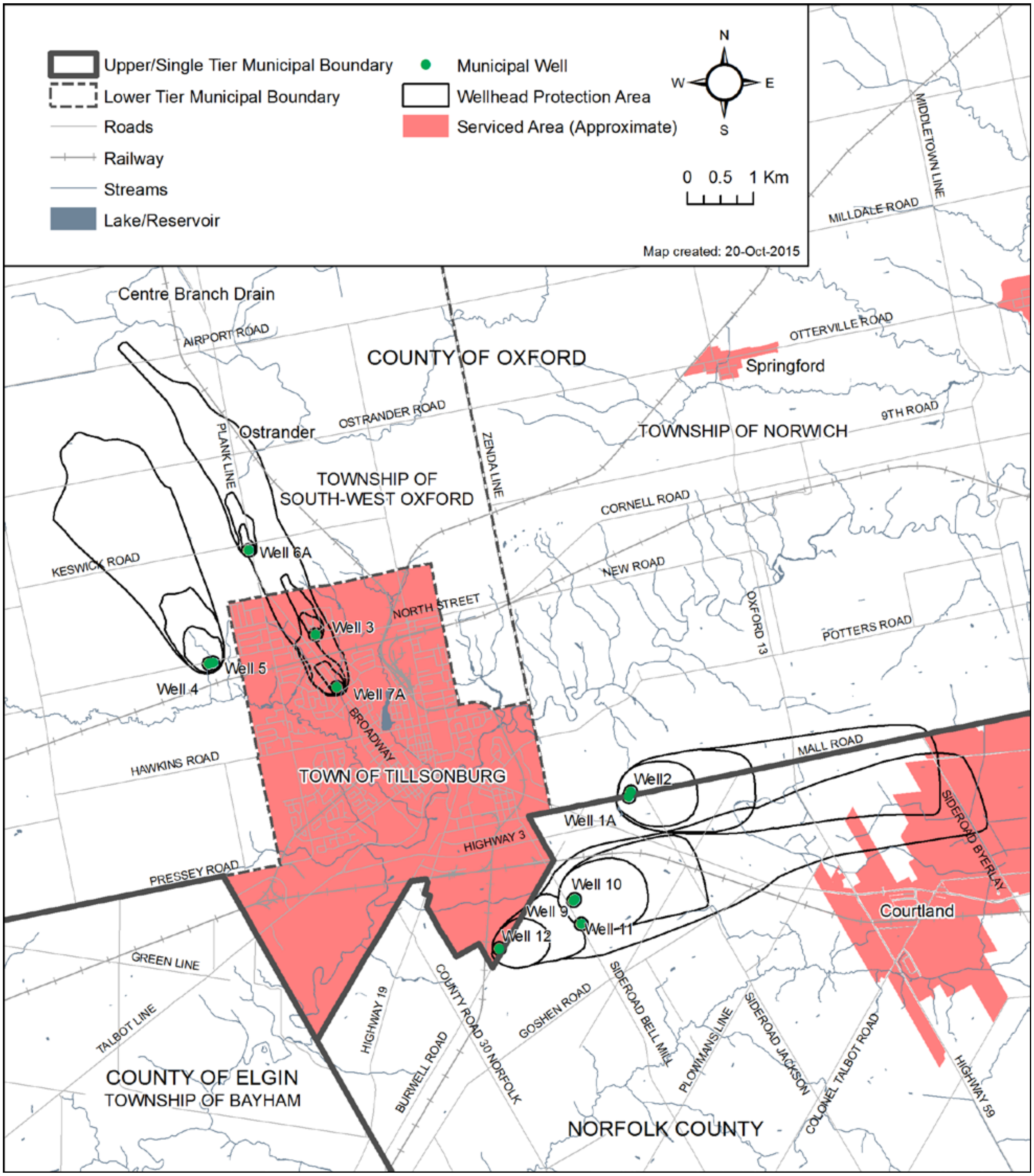
Roadways, sidewalks, driveways and parking lots were digitized on screen using ArcMap and 30cm resolution SWOOP orthoimagery from 2006 displayed at a scale of 1:500, to represent impervious surfaces. The impervious surface data layer was created in two sections. The Lower Thames Valley Conservation Area (LTVCA) GIS team digitized all impervious surfaces in the portion of the County within the Thames Sydenham and Region Source Protection Region, and Oxford County Staff digitized all impervious surfaces in the portion of the County within the Lake Erie Source Protection Region. Grids centred over each source protection area were provided by the LTVCA and the GRCA.

The impervious surface percentage in each grid cell was calculated by dividing the total impervious surface area in each grid cell by the total vulnerable area (with vulnerability scoring equal to or greater than 6) in that same grid cell. It should be noted that where a grid cell contains a portion of a Wellhead Protection Area with vulnerability score less than 6, this portion of the Wellhead Protection Area was not used in the calculation of impervious surfaces. For road salt to be considered a significant threat, the percent of impervious surface must be greater than 80%.

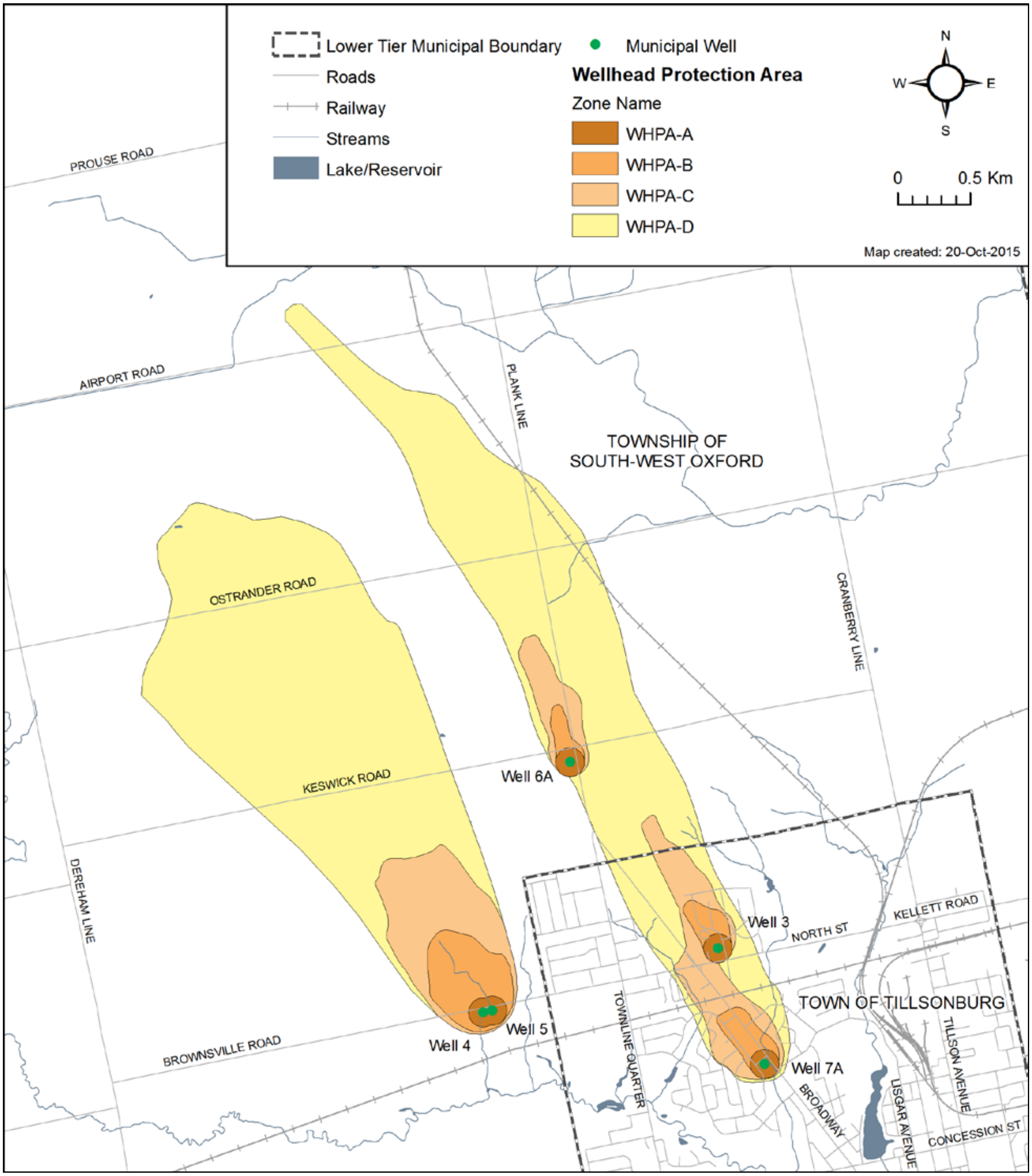
The results of the impervious surface calculations indicate that there are low percentages in the Tillsonburg North wells **(Map 4-42)** and that the application of road salt would not be a significant threat.

For the Tillsonburg South wells (wells 1A and 2, 9, 10 and 11 and 12), impervious surfaces were calculated and mapped in WHPA-A, WHPA-B and WHPA-C for all wells (**Map 4-52**). The results show that due to the low percent impervious surfaces, the application of road salt would not be a significant threat.

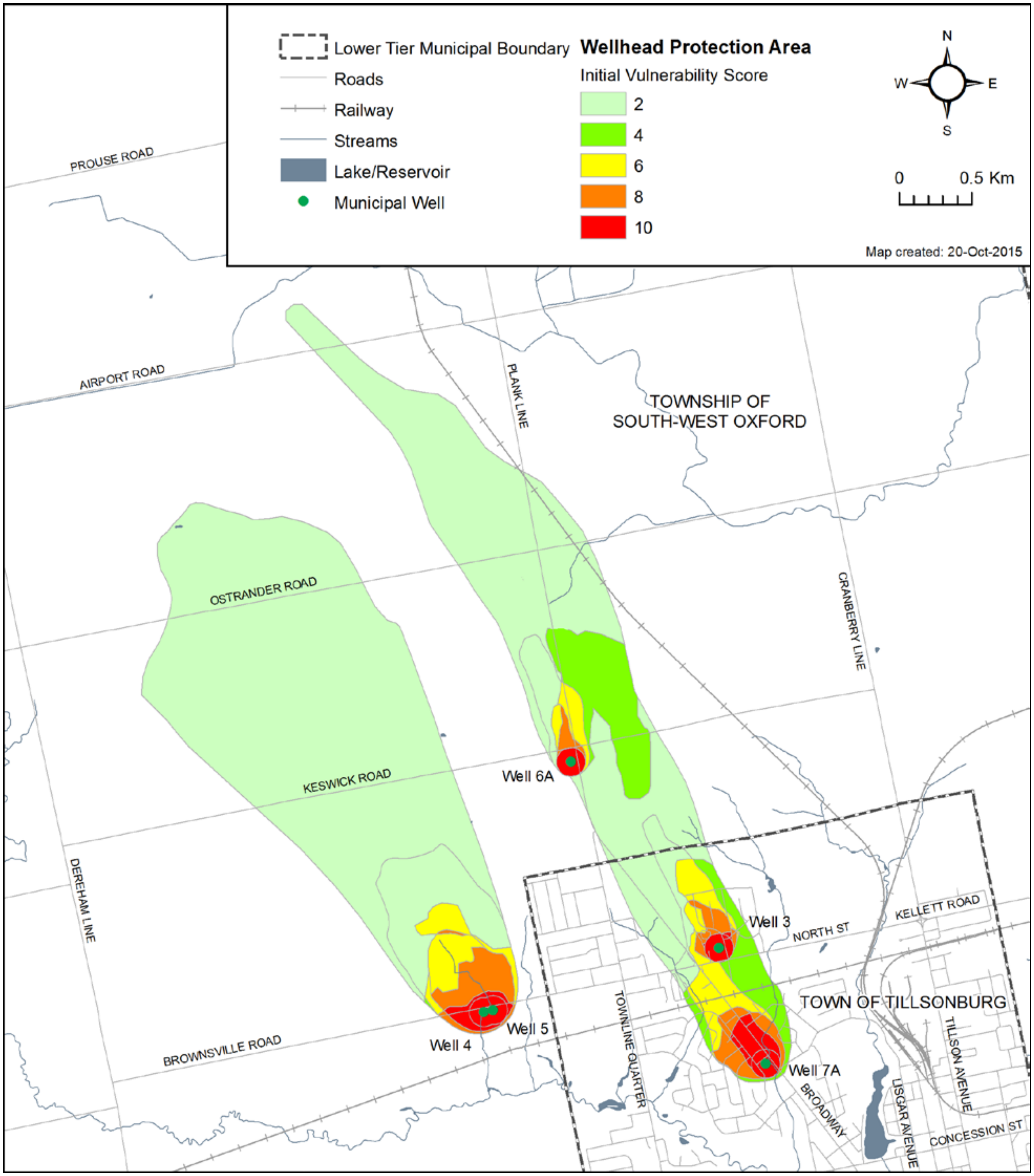
Map 4-34: Serviced Areas for the Tillsonburg Water Supply



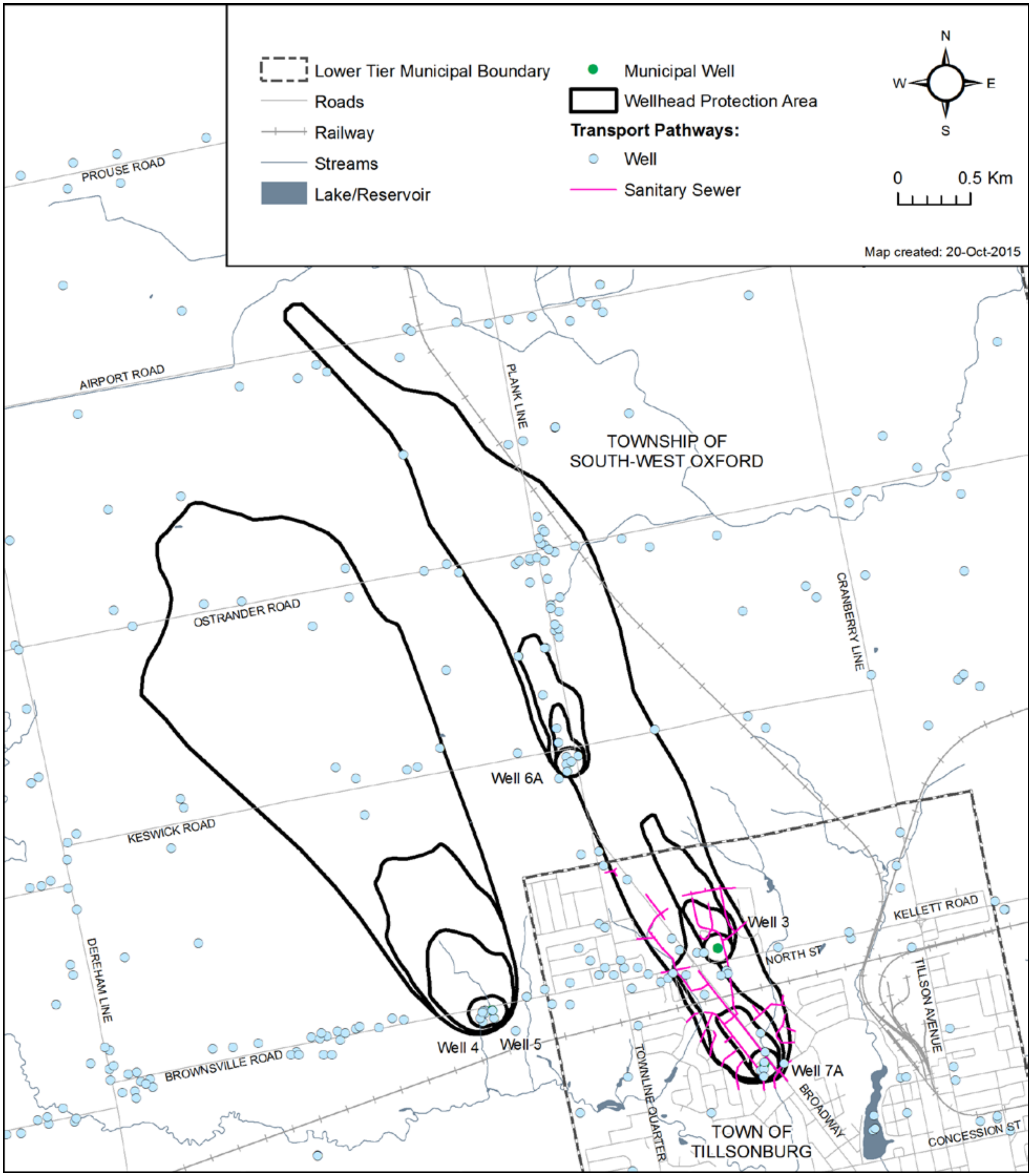
Map 4-35: Tillsonburg Wellhead Protection Areas (Wells 3, 4, 5, 6A and 7A)



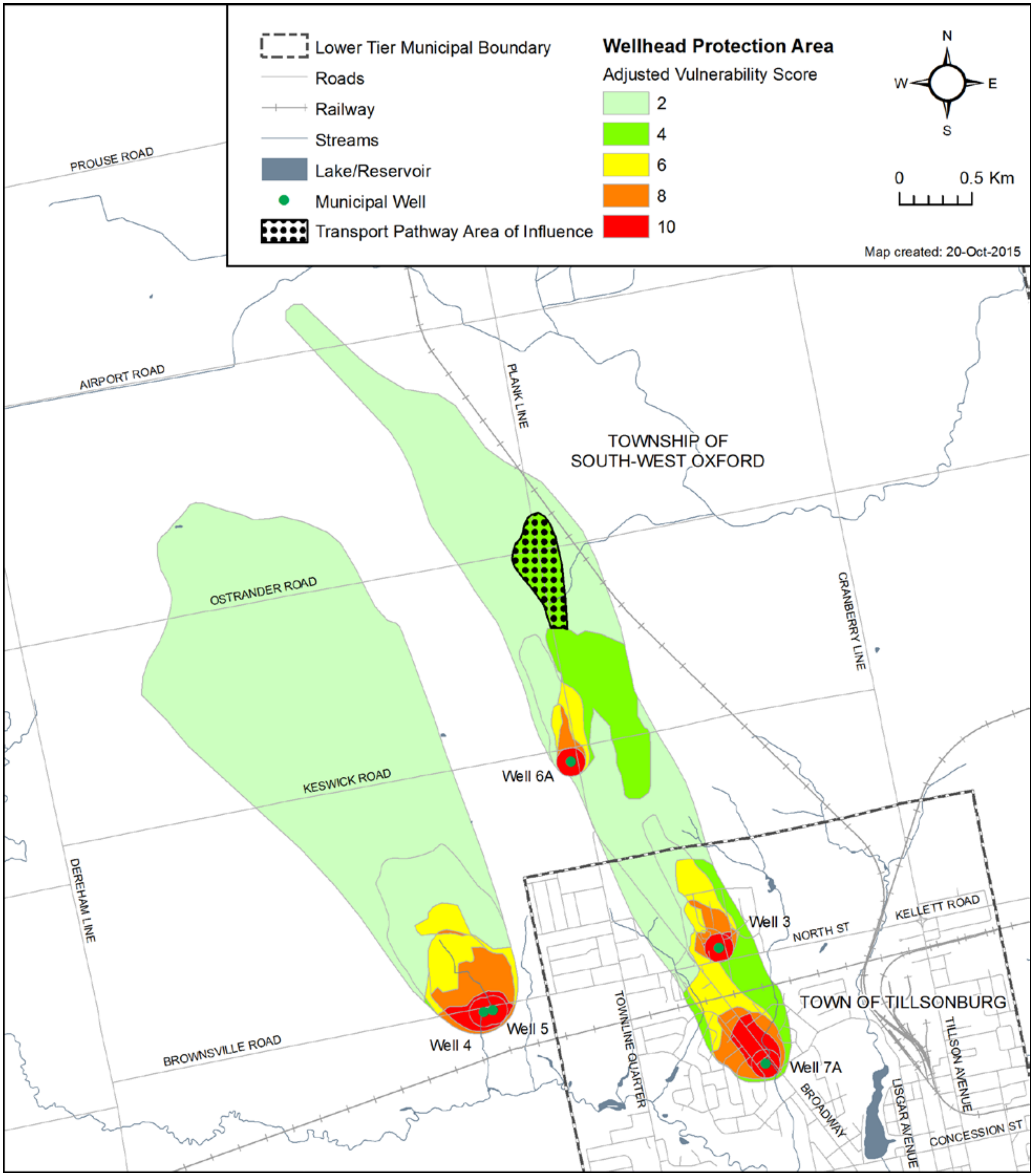
Map 4-36: Tillsonburg Wellhead Protection Area Initial Vulnerability Scoring (Wells 3, 4, 5, 6A, 7A)



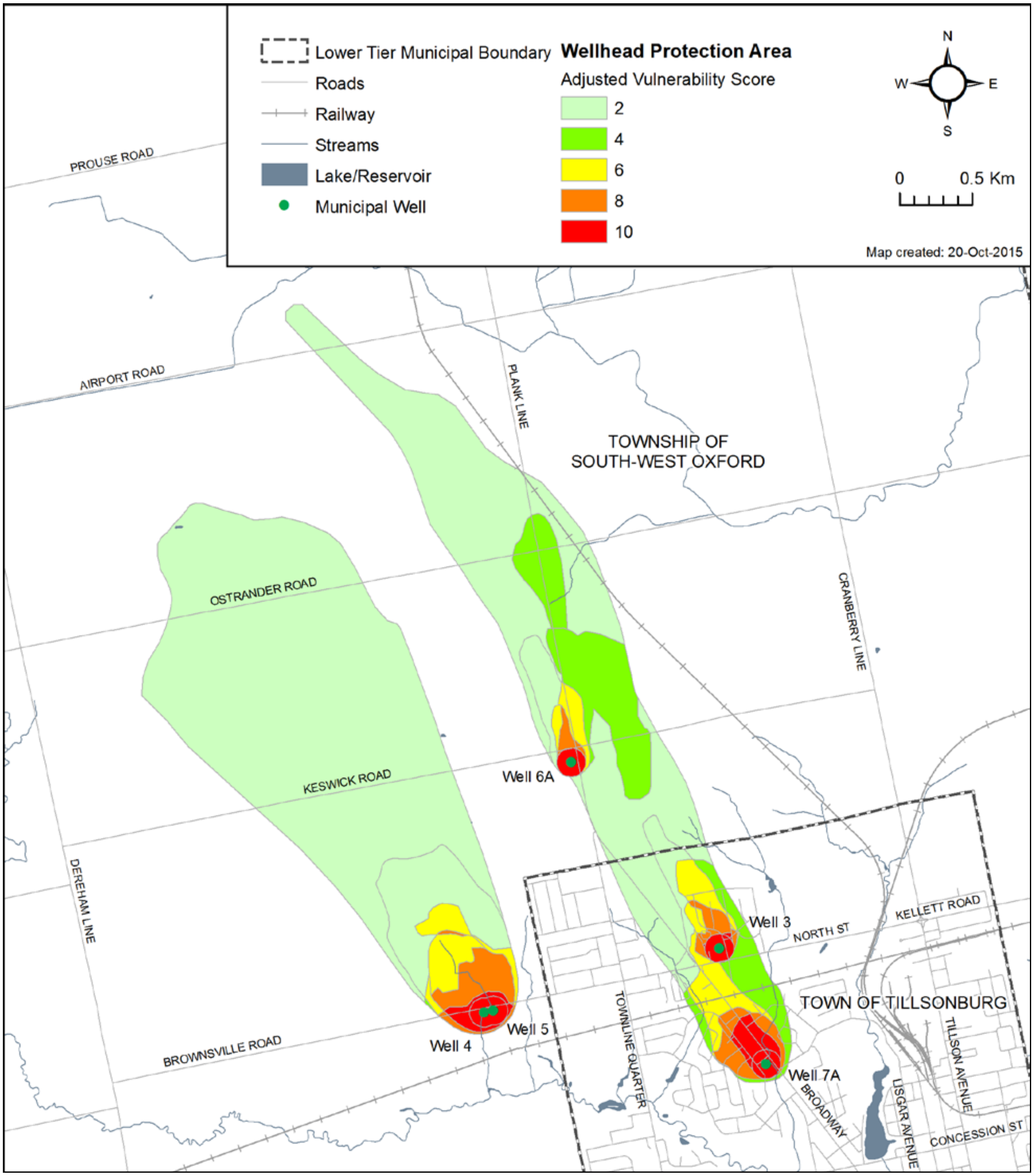
Map 4-37: Tillsonburg Transport Pathways (Wells 3, 4, 5, 6A, 7A)



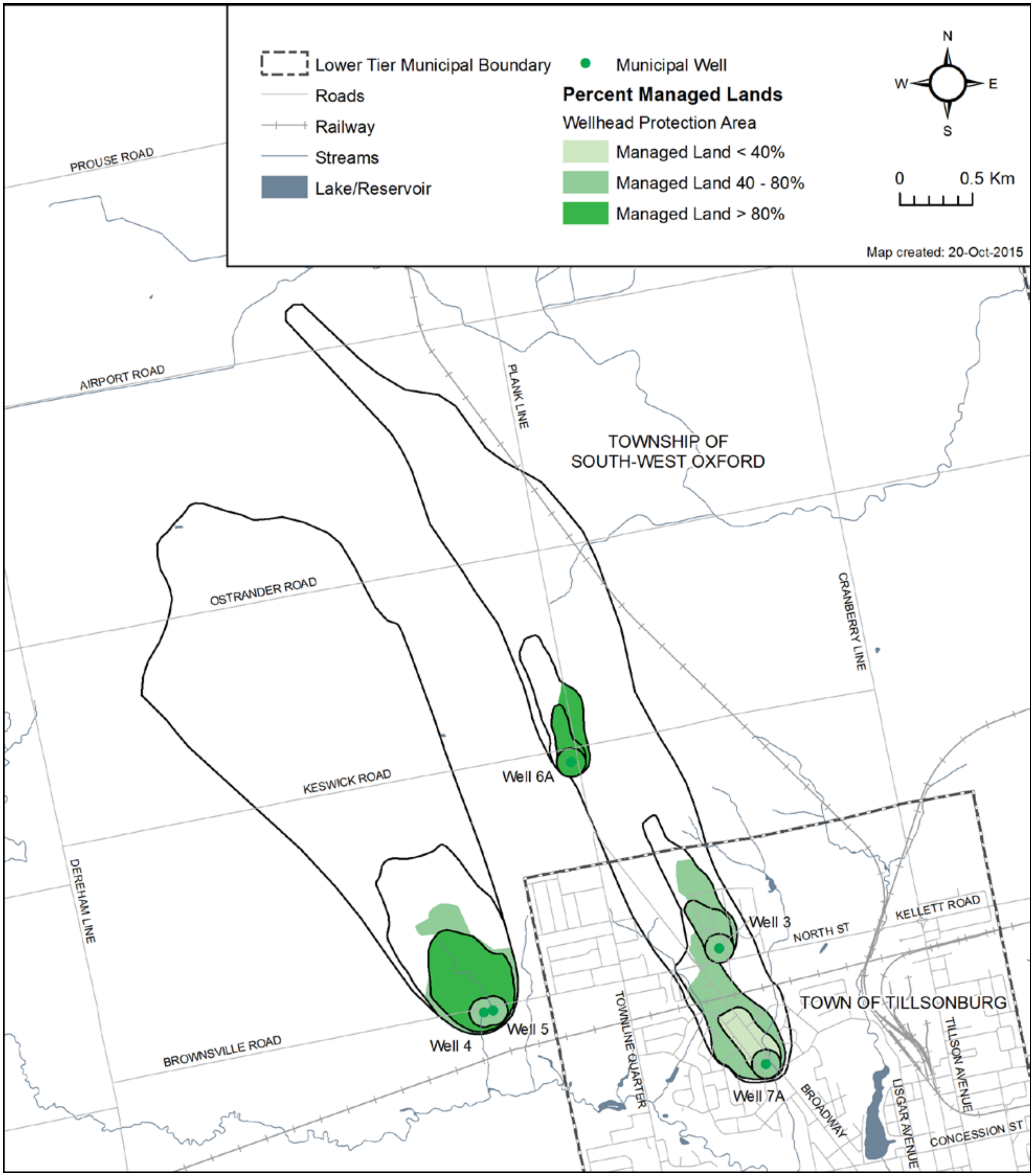
Map 4-38: Tillsonburg Transport Pathways Area of Influence (Wells 3, 4, 5, 6A, 7A)



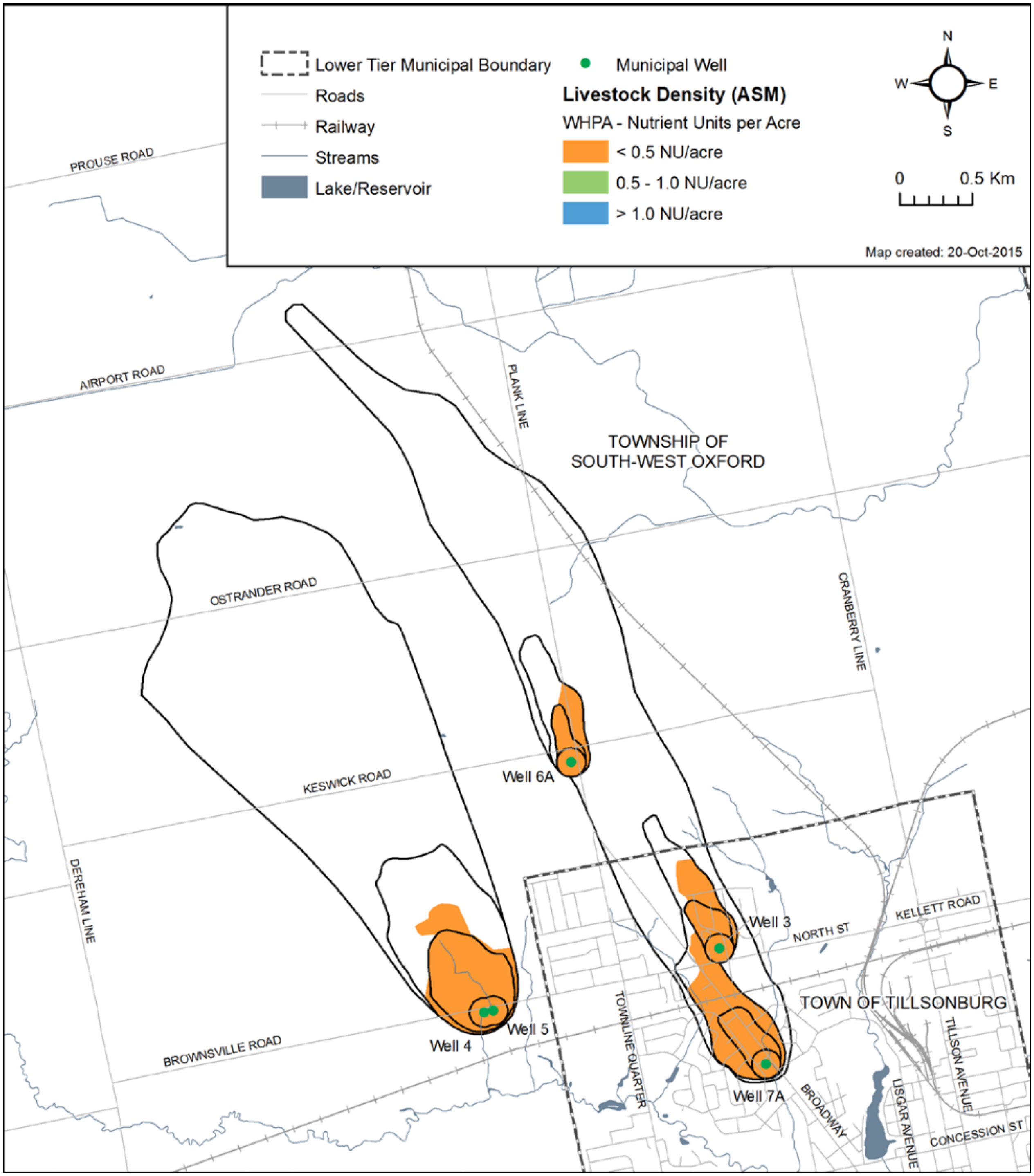
Map 4-39: Tillsonburg Wellhead Protection Area Adjusted Vulnerability (Wells 3, 4, 5, 6A, 7A)



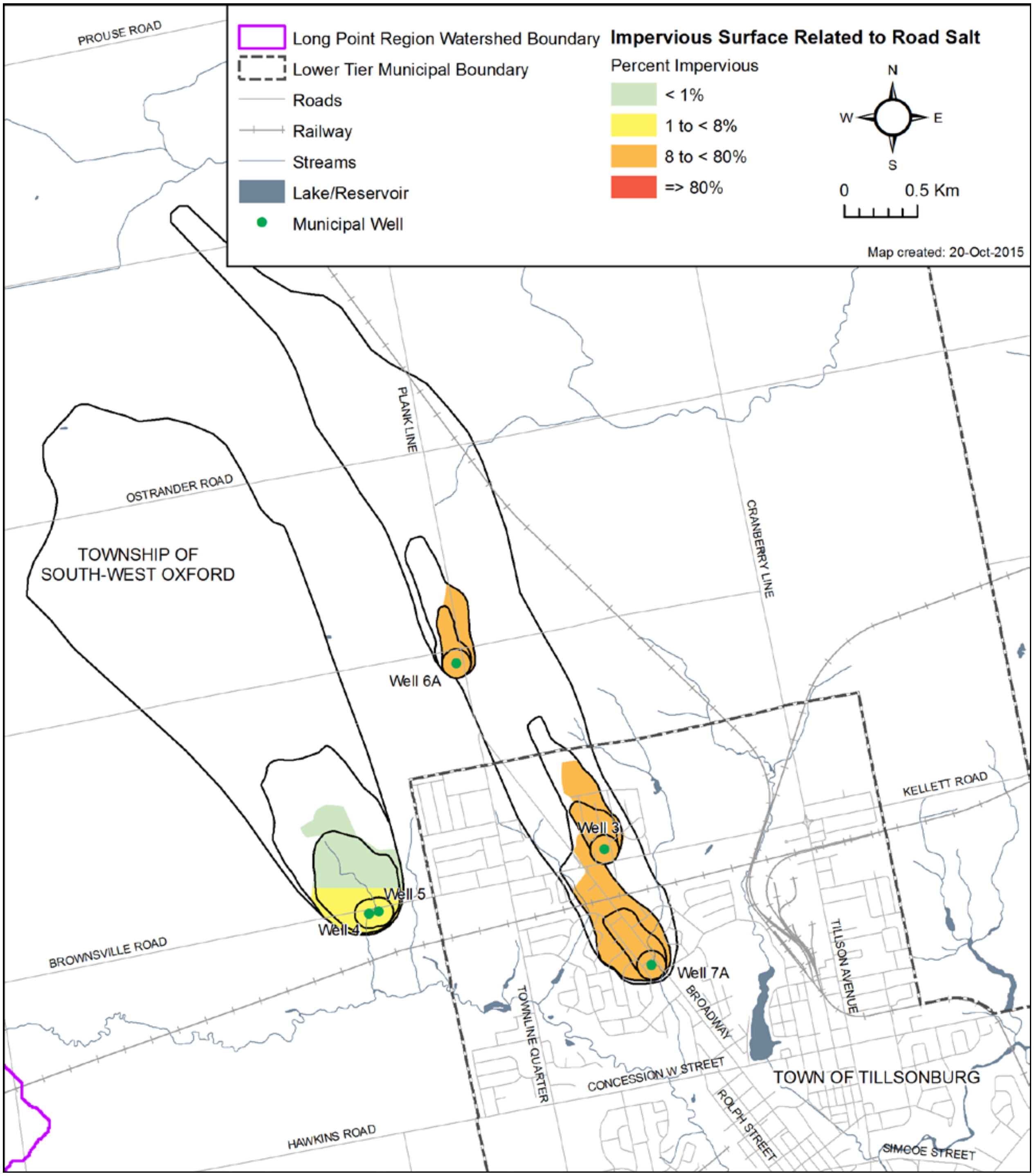
Map 4-40: Percent Managed Lands within the Tillsonburg Wellhead Protection Area (Wells 3, 4, 5, 6A and 7A)



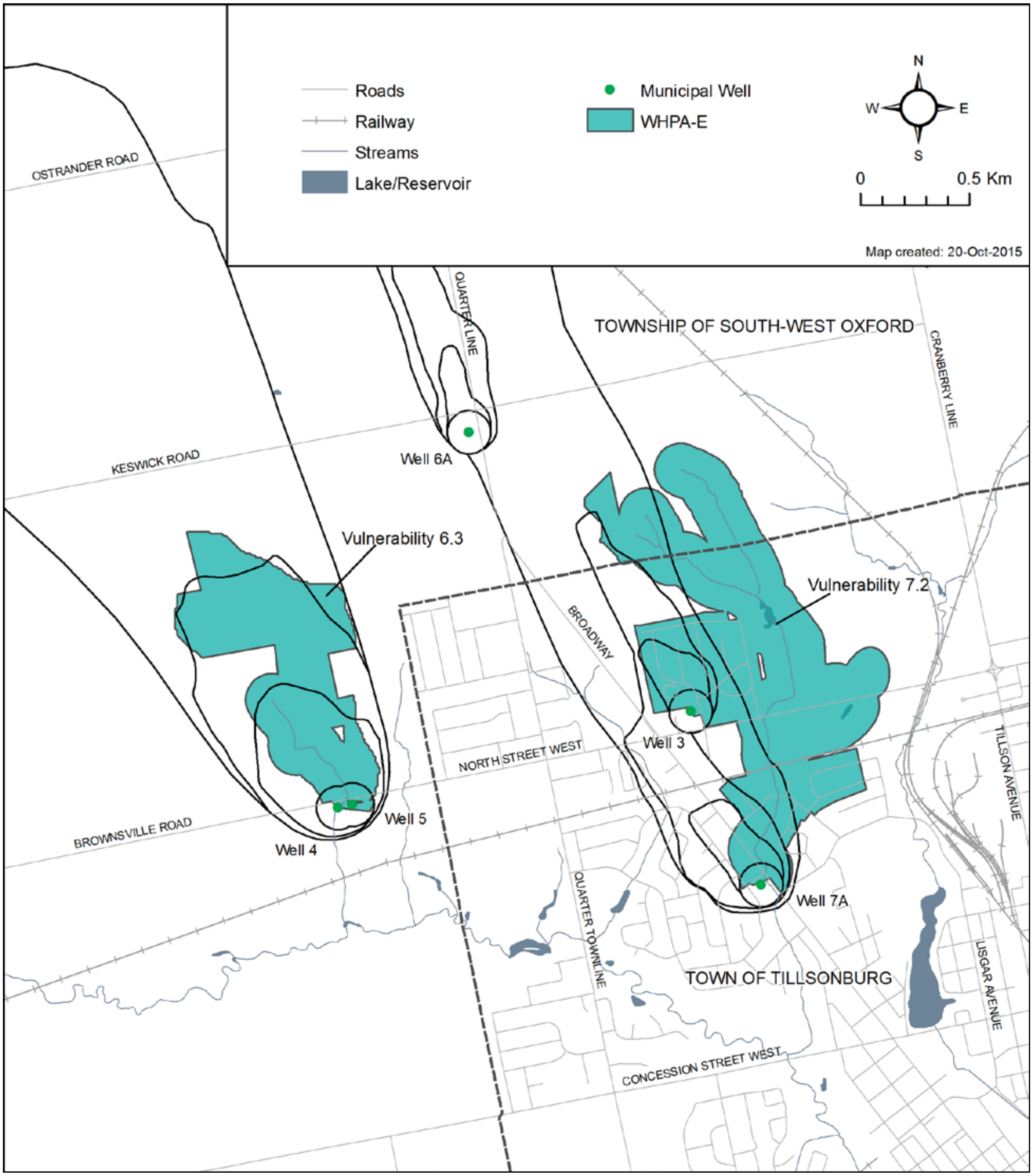
Map 4-41: Livestock Density within the Tillsonburg Wellhead Protection Area (Wells 3, 4, 5, 6A and 7A)



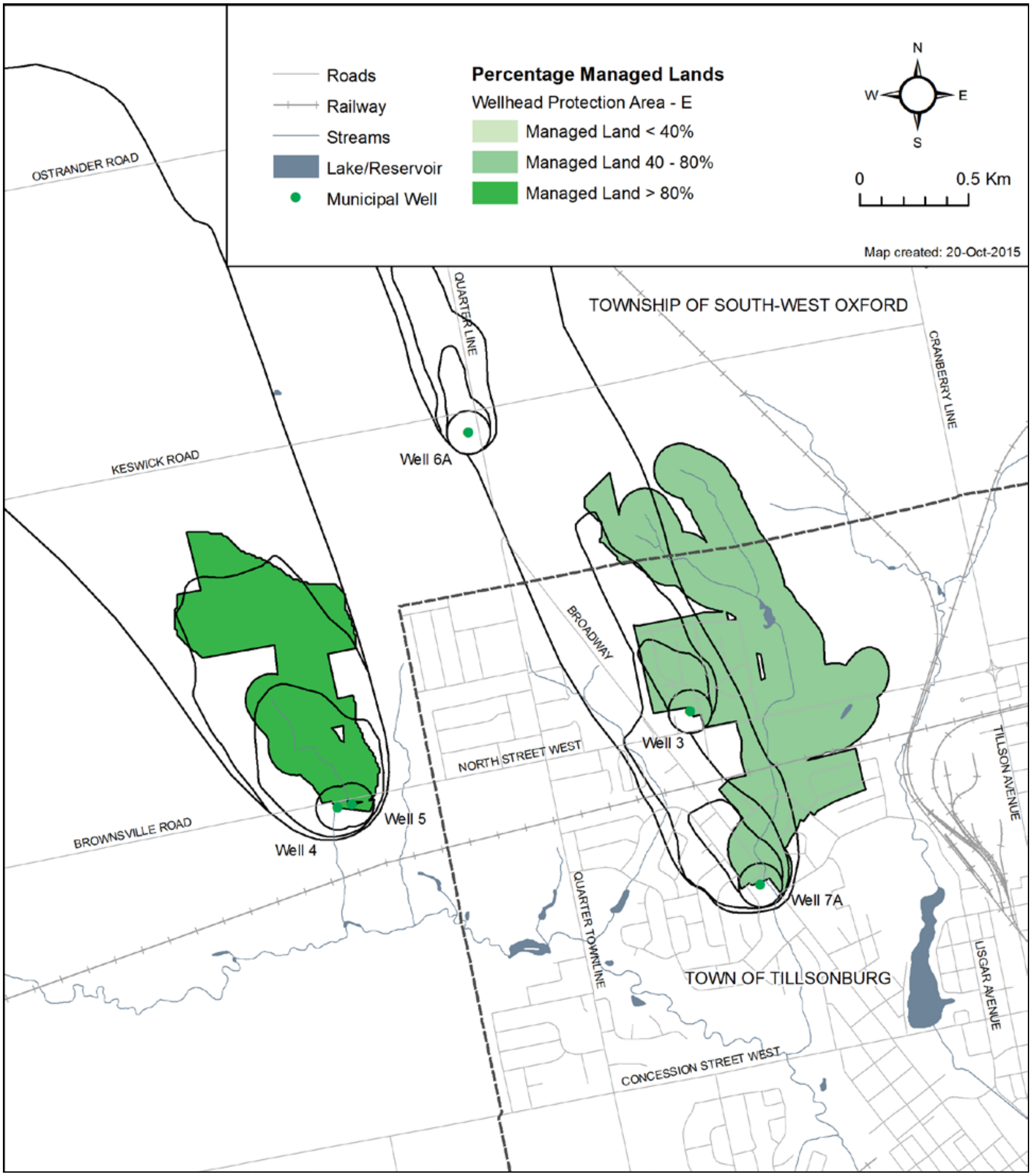
Map 4-42: Percent Impervious Surfaces within the Tillsonburg Wellhead Protection Area (Wells 3, 4, 5, 6A and 7A)



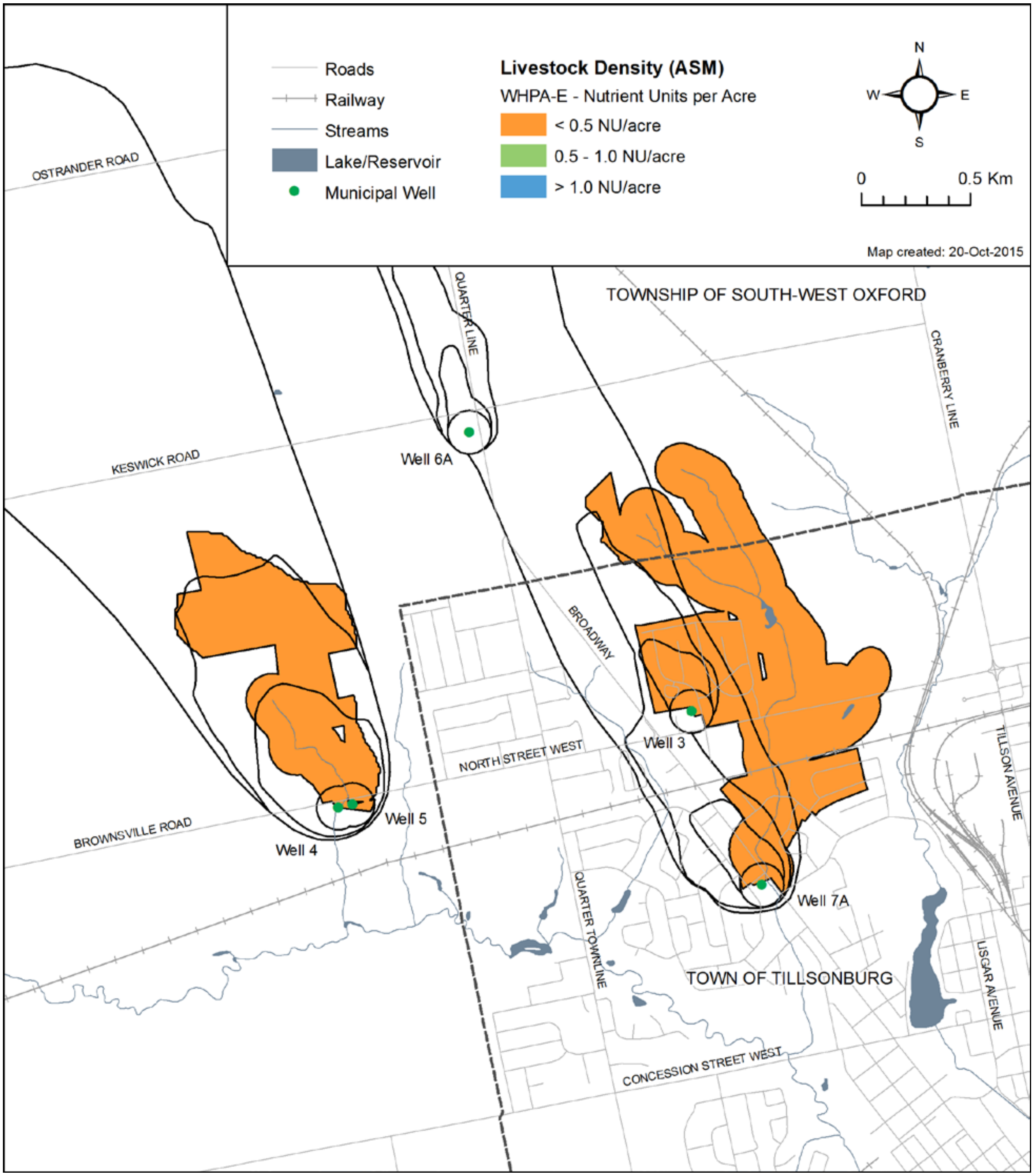
Map 4-43: Tillsonburg Northern Wellfield Wellhead Protection Area E



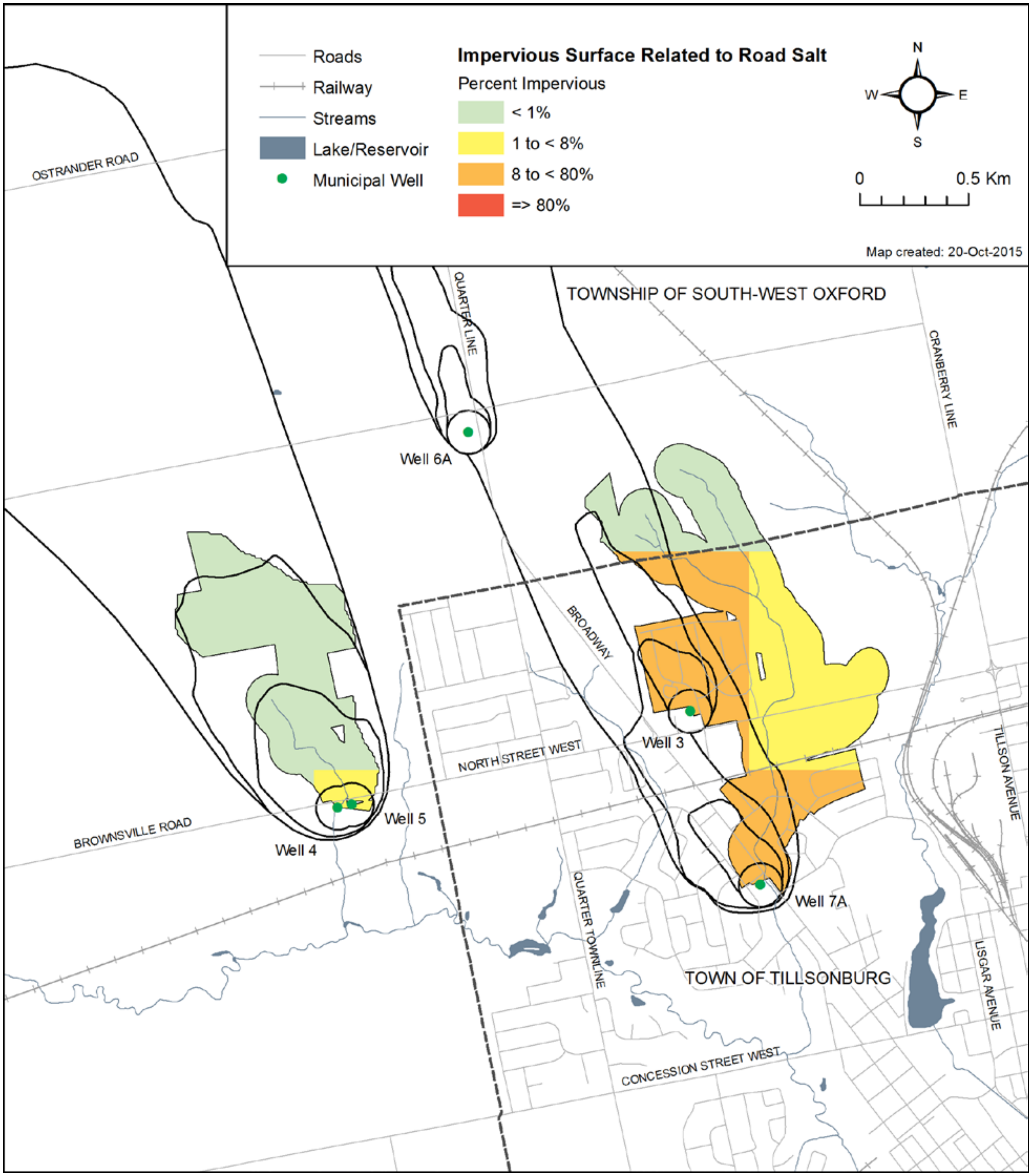
Map 4-44: Percent Managed Land within the Tillsonburg Northern Wellfield Wellhead Protection Area E



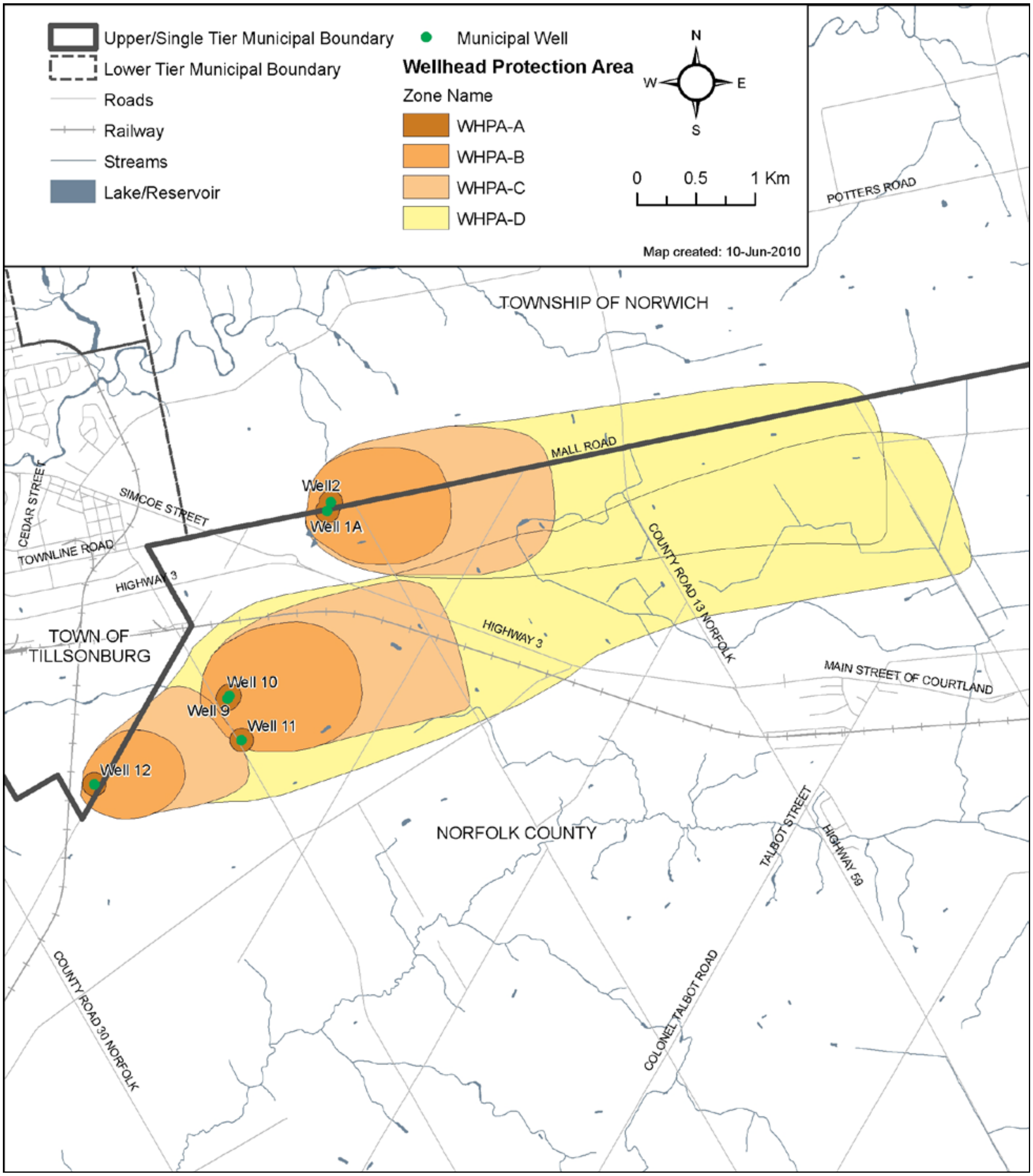
Map 4-45: Livestock Density within the Tillsonburg Northern Wellfield Wellhead Protection Area E



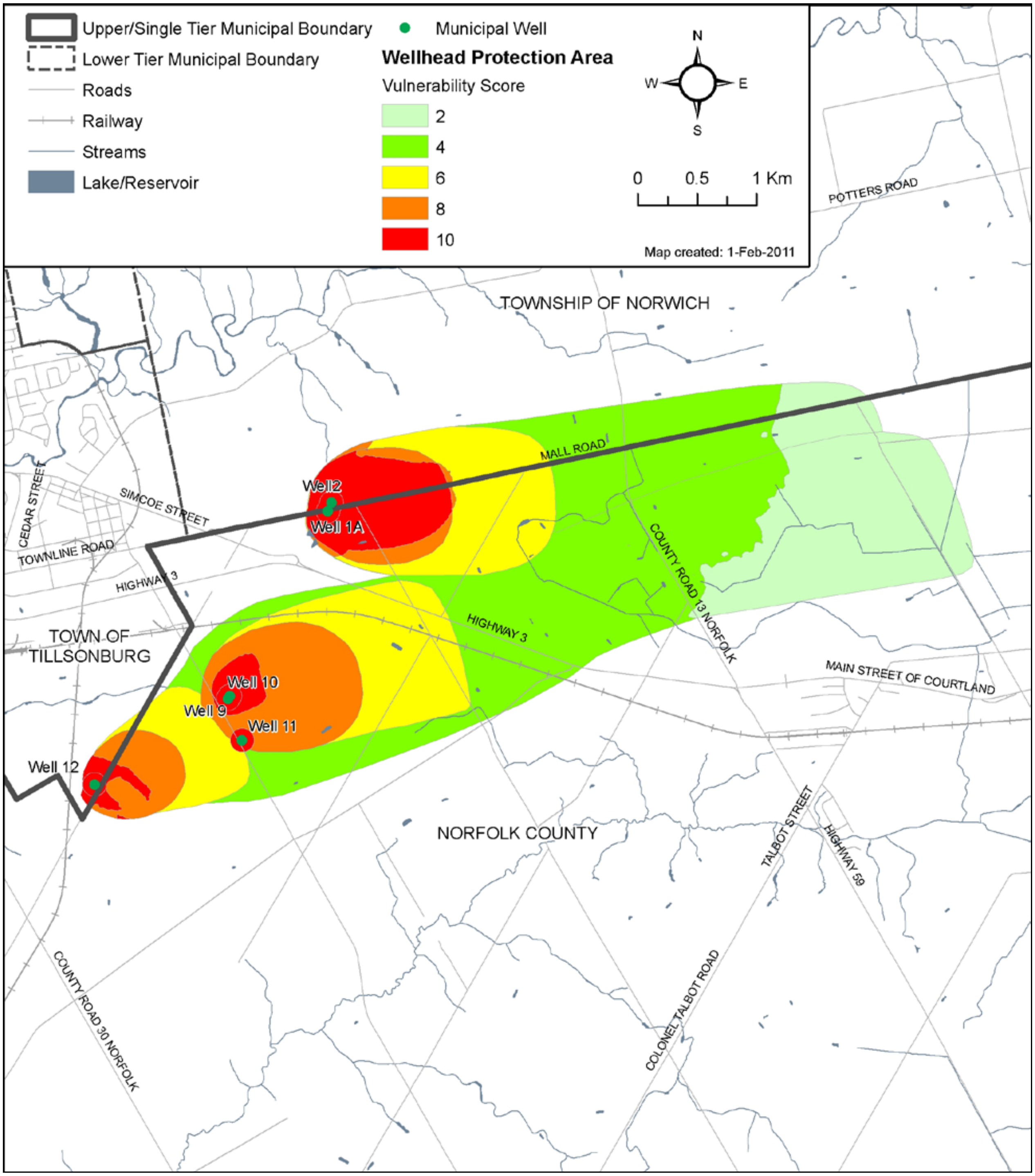
Map 4-46: Percent Impervious Surface within Tillsonburg Northern Wellfield Wellhead Protection Area E



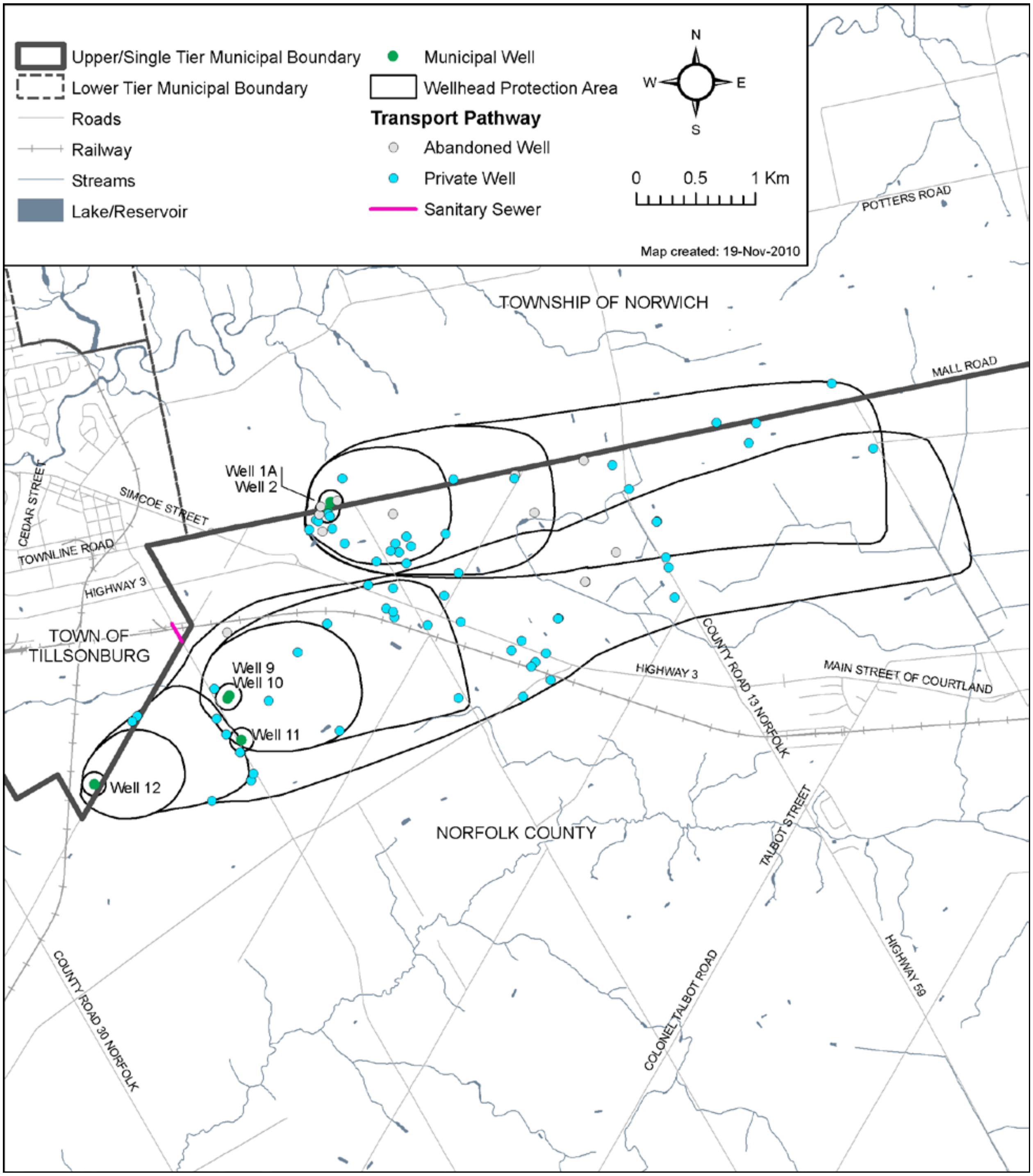
Map 4-47: Tillsonburg Wellhead Protection Areas (Wells 1A, 2, 9, 10, 11, 12)



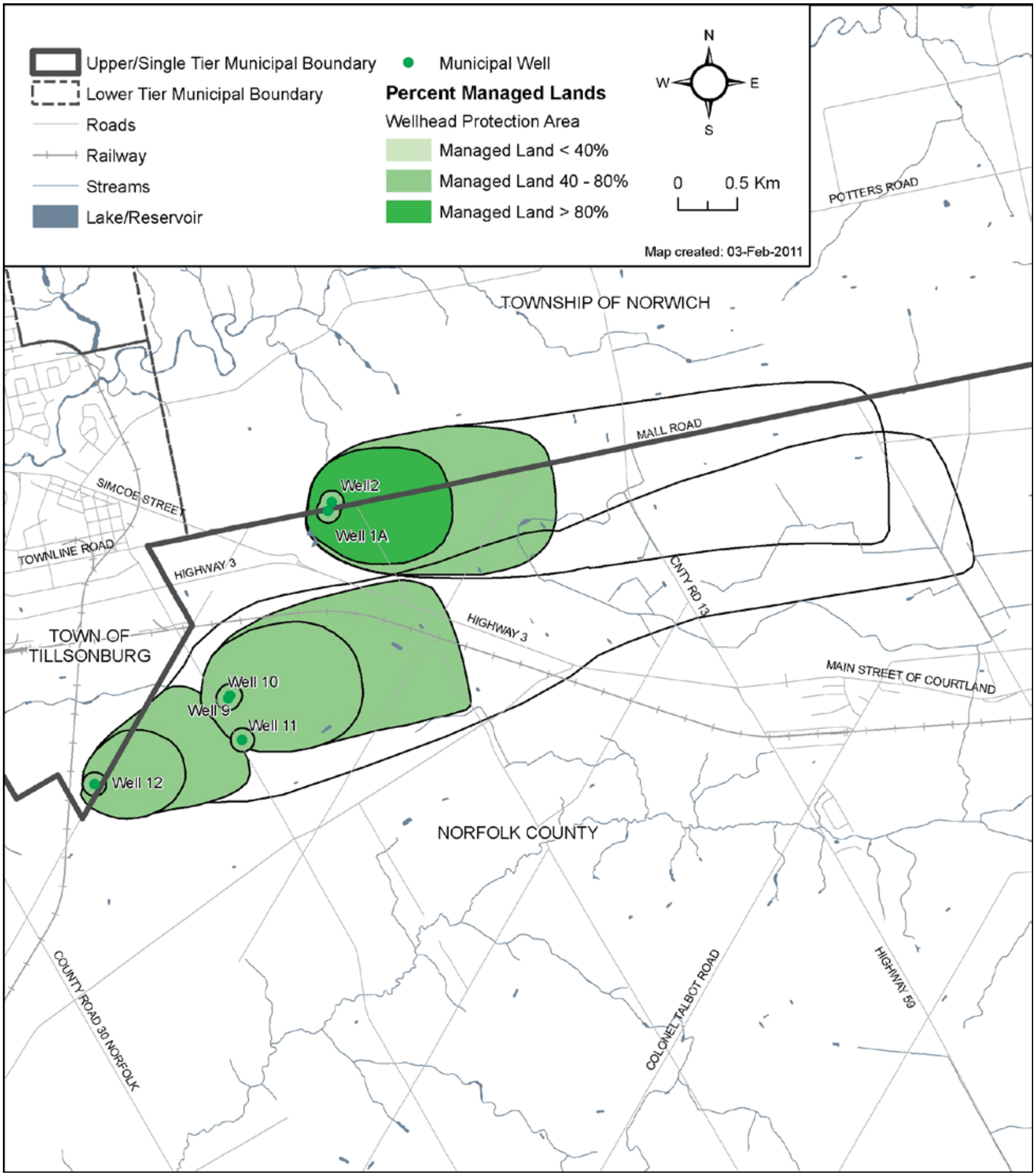
Map 4-48: Tillsonburg Wellhead Protection Areas Vulnerability (Wells 1A, 2, 9, 10, 11, 12)



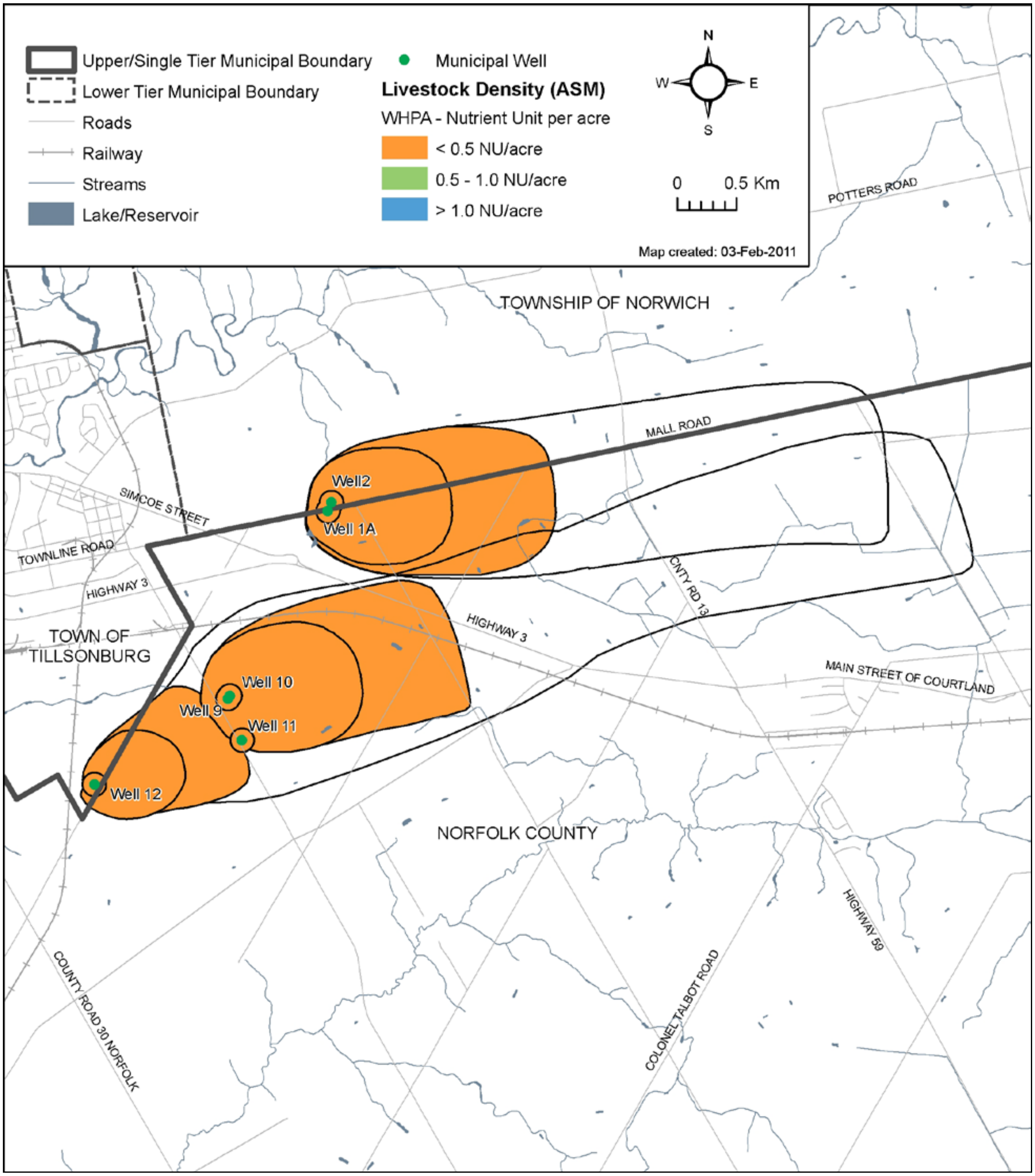
Map 4-49: Tillsonburg (Wells 1A, 2, 9, 10, 11, 12) Transport Pathways



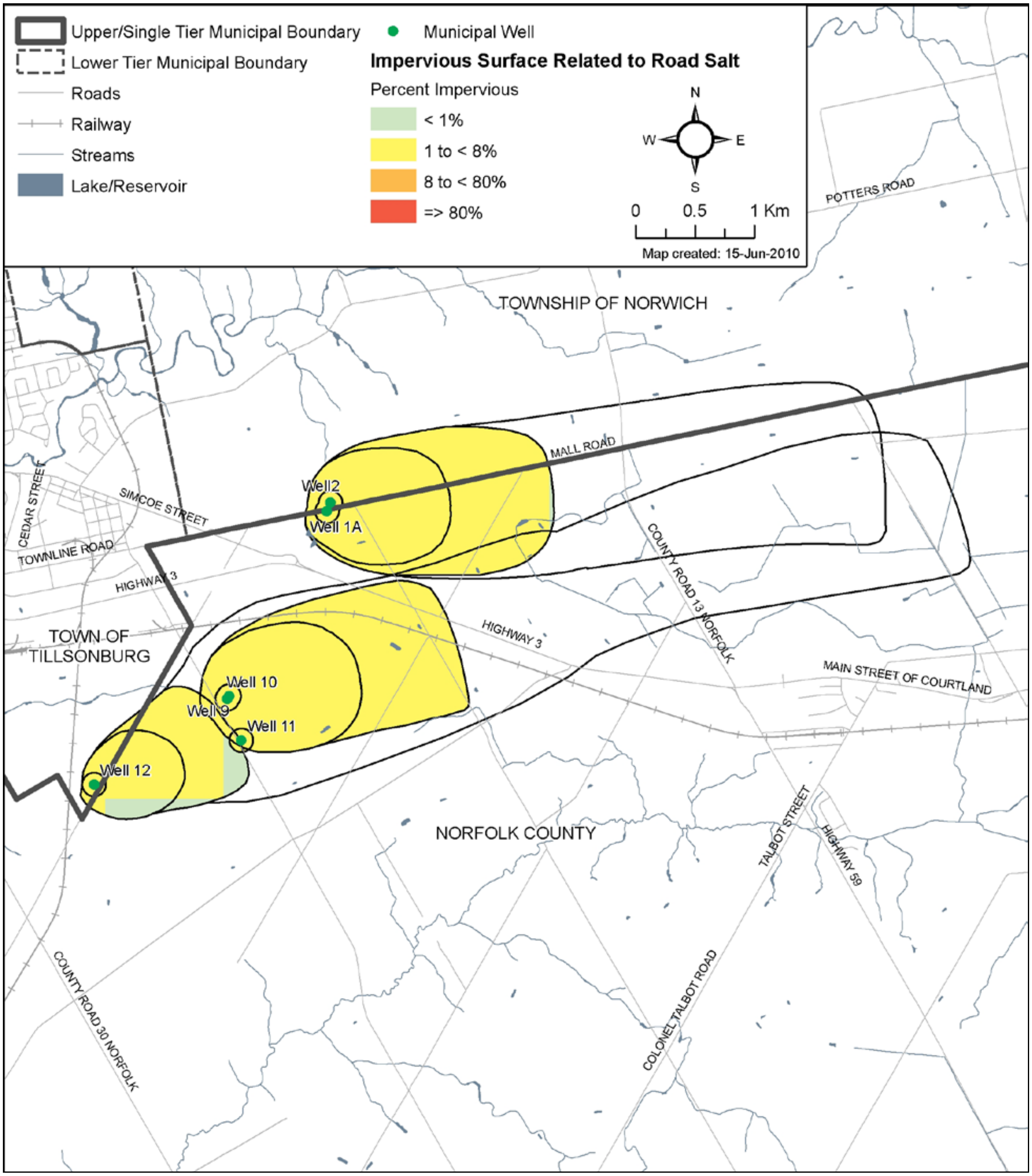
Map 4-50: Percent Managed Lands within the Tillsonburg Wellhead Protection Area (Wells 1A, 2, 9, 10, 11, 12)



Map 4-51: Livestock Density within the Tillsonburg Wellhead Protection Area (Wells 1A, 2, 9, 10, 11, 12)



Map 4-52: Percent Impervious Surfaces within the Tillsonburg Wellhead Protection Area (Wells 1A, 2, 9, 10, 11, 12)



4.7.4 Tillsonburg Threats Assessment

The Ontario *Clean Water Act, 2006* defines a Drinking Water Threat as "an activity or condition that adversely affects or has the potential to adversely affect the quality or quantity of any water that is or may be used as a source of drinking water, and includes an activity or condition that is prescribed by the regulation as a drinking water threat."

The identification of a land use activity as a significant, moderate, or low drinking water threat depends on its risk score, determined by considering the circumstances of the activity and the type and vulnerability score of any underlying protection zones, as set out in the Tables of Drinking Water Threats available through www.sourcewater.ca. Information on drinking water threats is also accessible through the Source Water Protection Threats Tool: http://swpip.ca. The information above can be used with the vulnerability scores shown in **Map 4-39** and **Map 4-48** to help the public determine where certain activities are or would be significant, moderate and low drinking water threats.

Table 4-22 provides a summary of the threat levels possible in the Tillsonburg Well Supply for Chemical, Dense Non-Aqueous Phase Liquid (DNAPL), and Pathogens. A checkmark indicates that the threat classification level is possible for the indicated threat type under the corresponding vulnerable area / vulnerable score; a blank cell indicates that it is not. The colours shown for each vulnerability score correspond to those shown in **Map 4-39** and **Map 4-48**.

Table 4-22: Identification of Drinking Water Quality Threats in the Tillsonburg Wellhead Protection Areas

Threat Type	Vulnerable Area	Vulnerability Score	Threat Classification Level: Significant 80+	Threat Classification Level: Moderate 60 to <80	Threat Classification Level: Low >40 to <60
Chemicals	WHPA-A/B	10	✔	✔	✔
	WHPA-B/C	8	✔	✔	✔
	WHPA-B/C	6		✔	✔
	WHPA-C/D	2 & 4			
	WHPA-E	7.2		✔	✔
	WHPA-E	6.3		✔	✔
Handling / Storage of DNAPLs	WHPA-A/B/C	Any Score	✔		
	WHPA-D	2 & 4			
	WHPA-E	7.2		✔	✔
	WHPA-E	6.3			✔
Pathogens	WHPA-A/B	10	✔	✔	
	WHPA-B	8		✔	✔
	WHPA-B	6			✔
Pathogens	WHPA-E	7.2		✔	✔
	WHPA-E	6.3		✔	✔

Drinking Water Threats

Under the preliminary threats assessment, available desk top level land use information, air photo interpretation and local knowledge of County and municipal staff was used to determine the types of land use activity information and therefore, the threats and circumstances associated with these land uses. In most cases, professional judgment and assumptions were made when determining the presence of significant threats for each property. Consultation with property owners to verify the existence of circumstances that constitute a significant threat is currently being conducted.

In the case of Tillsonburg, significant threats inventoried occur in WHPA-A, WHPA-B, WHPA-C and WHPA-D. The Wellhead Protection Area for the Southern Tillsonburg wells is located almost entirely within Norfolk County. Small portions of the Wellhead Protection Areas for wells 1A and 2 and well 12 are located within Oxford County. For this reason, the enumeration of significant threats located in Oxford County was reported separately from the significant threats located in Norfolk County.

A list of all significant threat types identified in the Tillsonburg Wellhead Protection Areas in Oxford County as of September 2017 are presented in **Table 4-23,** while the enumeration of significant threats in Norfolk County is presented in **Table 4-24**.The tables also indicate the number of times each threat occurs in the Tillsonburg well system.

Table 4-23: Significant Drinking Water Quality Threats in Tillsonburg (Oxford County) Wellhead Protection Areas

PDWT #[1]	Threat Subcategory[2]	Number of Activities	Vulnerable Area
2	Sewage System or Sewage Works – Onsite Sewage Systems	8	WHPA-A WHPA-B ICA
2	Sewage System or Sewage Works – Onsite Sewage Systems Holding Tank	1	WHPA-B
2	Sewage System or Sewage Works – Sanitary Sewers and related pipes	2	WHPA-A
3	Application Of Agricultural Source Material To Land	27	WHPA-A WHPA-B ICA
8	Application Of Commercial Fertilizer To Land	28	WHPA-A WHPA-B ICA
9	Handling and Storage Of Commercial Fertilizer	1	ICA
10	Application Of Pesticide To Land	10	WHPA-A WHPA-B
11	Handling and Storage Of Pesticides	1	WHPA-A
15	Handling and Storage Of Fuel	5	WHPA-A WHPA-B
16	Handling and Storage of a Dense Non-Aqueous Phase Liquid (DNAPL)	6	WHPA-B WHPA-C
Total Number of Properties			**38**
Total Number of Activities			**89**

PDWT #[1]	Threat Subcategory[2]	Number of Activities	Vulnerable Area

Table 4-23: Significant Drinking Water Quality Threats in Tillsonburg (Oxford County) Wellhead Protection Areas

1: Prescribed Drinking Water Threat Number refers to the prescribed drinking water threats listed in O. Reg 287/07 s.1.1.(1).

2: Where applicable, waste, sewage, and livestock threat numbers are reported by sub-threat; fuel and DNAPL by Prescribed Drinking Water Threat category.

Note: Certain types of activities on residential properties that are incidental in nature and that are significant drinking water threats are not enumerated. These threats include the storage of organic solvents (dense non-aqueous phase liquids) on residential properties and the storage of fuel (e.g., heating fuel tanks) on residential properties in natural gas serviced areas. The threat point representing linear feature infrastructure such as sanitary sewers was not added into the total number of properties, since this feature is not attached to one specific property.

Note: Storm sewer piping is not considered to be part of a storm water management facilty.

There were five types of land uses that have, or could potentially have land use activities that pose a significant threat to groundwater in the Tillsonburg Wellhead Protection Areas in Oxford County. These land uses are: agricultural, residential, commercial, industrial and infrastructure. All properties referenced intersect with WHPA-A, WHPA-B, WHPA-C and /or WHPA-D in Tillsonburg.

The number of significant threat activities occurring in the Tillsonburg WHPAs within Oxford County is 89 as follows:

- 8 locations where septic systems are likely present;
- 1 location where a holding tank is present
- 2 location of a sanitary sewer;
- 27 locations where there may be the application of manure;
- 10 locations where pesticides may be applied to land;
- 1 locations where pesticides may be stored;
- 6 locations where DNAPLs may be used or stored;
- 5 locations where fuel may be handled or stored;
- 28 locations where commercial fertilizer may be applied to land; and
- 1 location where commercial fertilizer may be stored.

Table 4-24: Significant Drinking Water Quality Threats in Tillsonburg (Norfolk County) Wellhead Protection Areas

PDWT #[1]	Threat Subcategory[2]	Number of Activities	Vulnerable Area
2	Sewage System Or Sewage Works - Onsite Sewage Systems	7	WHPA-A WHPA-B
3	Application Of Agricultural Source Material (ASM) To Land	11	WHPA-A WHPA-B
8	Application Of Commercial Fertilizer To Land	3	WHPA-A WHPA-B
10	Application Of Pesticide To Land	8	WHPA-A WHPA-B

Table 4-24: Significant Drinking Water Quality Threats in Tillsonburg (Norfolk County) Wellhead Protection Areas

PDWT #[1]	Threat Subcategory[2]	Number of Activities	Vulnerable Area
15	Handling and Storage Of Fuel	1	WHPA-B
16	Handling and Storage Of A Dense Non Aqueous Phase Liquid (DNAPL)	2	WHPA-C
Total Number of Properties			**20**
Total Number of Activities			**32**

1: Prescribed Drinking Water Threat Number refers to the prescribed drinking water threats listed in O.Reg 287/07 s.1.1.(1).

2: Where applicable, waste, sewage, and livestock threat numbers are reported by sub-threat; fuel and DNAPL by Prescribed Drinking Water Threat category.

Note: Certain types of activities on residential properties that are incidental in nature and that are significant drinking water threats are not enumerated. These threats include the storage of organic solvents (dense non-aqueous phase liquids) on residential properties and the storage of fuel (e.g., heating fuel tanks) on residential properties in natural gas serviced areas.

Note: Storm sewer piping iss not considered to be part of a storm water management facilty.

There were four types of land uses that have, or could potentially have land use activities that pose a significant threat to groundwater in the Tillsonburg Wellhead Protection Areas in Norfolk County. These land uses are: agricultural, residential, commercial and industrial. All properties referenced intersect with WHPA-A, WHPA-B and/or WHPA-C in Tillsonburg.

The number of significant threat activities occurring in the Tillsonburg Wellhead Protection Areas within Norfolk County is 32 as follows:

- 7 locations where septic systems are likely present;
- 11 locations where there may be the application of manure;
- 8 locations where pesticides may be applied to land;
- 2 locations where DNAPLs may be used or stored;
- 1 locations where there may be storage of fuel; and
- 3 locations where commercial fertilizer may be applied to land

4.7.5 Tillsonburg Drinking Water Issues

Both raw and treated analytical results have been reviewed because the treatment process does not substantially alter the water quality. For the purposes of water quality characteristics the wells can be grouped into six different wellfields; Mall Road (Wells 1A & 2), North Street (Wells 4 and 5), Well 6A, Well 7A, Bell Mill Side road (Wells 9, 10 and 11) and Well 12. Note that Well 7A replaced Well 7 in 2009; it is located nearby in the same aquifer and screened depth; however as 7A has not been operated since installation, the issues analysis below is based on Well 7 data.

Methodology for Identifying Drinking Water Quality Issues

As part of the issues evaluation (County of Oxford, 2009b), available water quality data was reviewed to assess whether any contaminants are impacting or have the potential to impact or interfere with the Town of Tillsonburg drinking water sources. This included the following steps:

- Collection of water quality data;
- Comparison of water quality data to the ODWQS to see if any parameters were in exceedance; and
- Concentrations of parameters of consideration over time were plotted to evaluate if there were any increasing trends.

Health Related Parameters

There were no Issues with the microbiological water chemistry reviewed. The health-related parameters to exceed the half ODWQS MAC screening threshold are nitrates, fluoride and arsenic as described below.

Nitrate concentrations in Wells 4, 5 and 12 are above half of the MAC of 10 mg/L.

Well 12 was initially identified in the “issue screening” as nitrate concentrations were periodically at the half MAC threshold ranging from 4.9 to 5.9 mg/L without an increasing trend. The nitrate concentrations at the North Street well field are typically higher and monitored regularly. In January 2005, two results were received above the MAC at 10.0 and 10.2 mg/L. In 2008, nitrate concentrations ranged from 6.18 to 9.24 mg/L. In 2009 Oxford County undertook an Issue Identification Study of all of its municipal supply wells. Further review of the data indicated that nitrate levels at Well 12 are relatively stable and range between 4.0 and 6.0 mg/L. The study concluded that there is no indication of increasing trends towards the MAC and therefore Well 12 does not need to be identified as an “Issue” under the *Clean Water Act, 2006*. Nitrate is not typically a naturally occurring parameter in groundwater at levels around the MAC and may be from nutrient application, septic systems or sewage effluent. Any future increase of nitrate at this location could compromise the supply.

At Well 7, a solitary arsenic concentration was detected above half of the MAC of 0.025 mg/L. Concentrations typically range from 0.003 to 0.017 mg/L. There does not appear to be an increasing trend in the results.

Fluoride concentrations at Well 6A were typically 1.5 mg/L, which is above half of the MAC of 2.4 mg/L. Fluoride is naturally occurring in groundwater and there is no evidence of upwards trending. The presence of fluoride does not affect the treatment process.

Aesthetic or Operationally Significant Parameters

The system has several operational or aesthetic parameters exceed the associated ODWQS objectives or guidelines as detailed below.

Hardness, which has a guideline range from 80 to 100 mg/L, is typically exceeded in groundwater systems. The system’s hardness concentration is typically around 262 to 320 mg/L. Only Well 6A does not exceed the guideline. This parameter is naturally occurring in the groundwater and is not a health risk nor does it impact the treatment process.

Sodium concentrations at the North Street Wellfield and Wells 6A and 7 are above the reporting level of 20 mg/L. North Street sodium concentrations range from 15 to 16 mg/L, Well 6A ranges from 41 to 46 mg/L, and Well 7 ranges from 81 to 89 mg/L. These levels are well below the objective of 200 mg/L. Chloride concentrations in the system are also low suggesting that the sodium is not caused by road salt application but rather is naturally occurring. No increasing trend is evident in the results.

The raw water at the Mall Road wellfield marginally exceeds the objective of 0.05 mg/L for manganese with concentrations ranging from 0.06 to 0.08 mg/L. Concentrations in the Bell Mill wellfield are slightly higher and exceed the objective, with concentrations ranging from 0.10 to 0.16 mg/L. Manganese is an aesthetic parameter and no increasing trend is evident. The treatment facility removes manganese through an oxidation and filtration process. Failure of this process could potentially result in decreased clarity of the water which would impact the effectiveness of the UV disinfection.

The raw water at the Mall Road and Bell Mill wellfields, and Well 7, exceed the objective of 0.3 mg/L for iron. The concentrations range from 0.8 to 1.2 mg/L. Iron is an aesthetic parameter and no increasing trend is evident. The treatment facilities remove iron through an oxidation and filtration process. Failure of this process could potentially result in decreased clarity of the water which in turn could impact the effectiveness of the UV disinfection.

Organic nitrogen concentrations in the system are above the aesthetic objective of 0.15 mg/L at Wells 2, 4, 6, 7, and 11. Concentrations range from 0.18 to 0.42 mg/L. Organic nitrogen can be associated with unpleasant taste and high levels can reduce the effectiveness of chlorine as a disinfectant. There is no history of objectionable taste that is sometimes associated with organic nitrogen.

Summary of Drinking Water Quality Issues Evaluation for the Tillsonburg Water Supply

As a result of elevated nitrate concentrations in Wells 4 and 5, nitrate has been identified as an Issue under Technical Rule 114.

Issue Contributing Area for Tillsonburg Wells 4 and 5

As part of the on-going Tier Three Water Quantity Risk Assessment studies, refinements to the conceptual and numerical modelling tools included the development of a new FEFLOW numerical model (Matrix, 2013). This model represents the most up-to-date representation of the hydrogeological controls over groundwater flow near the Tillsonburg wells. These updated models were used to delineate and map the saturated and unsaturated time of travel capture zones (Matrix, 2014). Using the models, the relative contribution of nitrate from each area based on total time of travel capture zones was estimated to map the nitrate contributing area (Matrix, 2013b) for the wells within the WHPAs. The WHPAs defined for Well 4 and Well 5 overlap and have therefore been delineated as a single WHPA. The nitrate Issue Contributing Area for wells 4 and 5, as illustrated on **Map 4-53**, includes areas with the following characteristics: the land area contributes 100% of recharge to the well field, the land use is primarily agricultural, and has a total travel time (combined total in the unsaturated and saturated zone) of less than 60 years. The areas contributing recharge to the well, but not considered to have significantly contributed to the measured nitrate at the well include non-agricultural land use areas and areas with total time of travel greater than 60 years.

Table 4-25 lists all activities based on the provincial Tables of Drinking Water Threats that are associated with nitrate and that would be identified as a significant drinking water threat if they exist within the Issue Contributing Area.

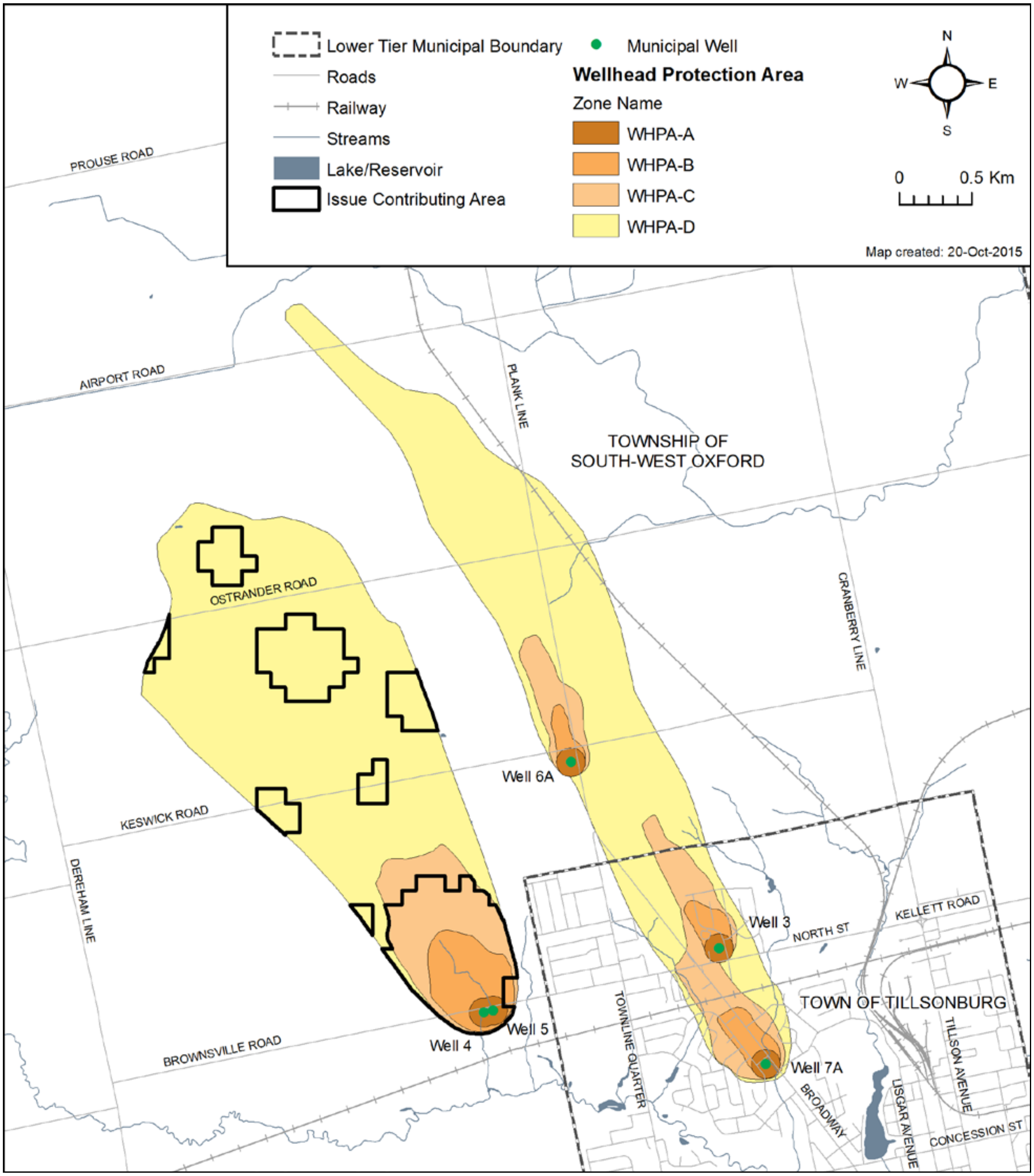
Table 4-25: Activities that Contribute to Nitrate Issues within an Issue Contributing Area

Prescribed Drinking Water Threat	Threat Subcategory	Chemical of Concern
The application of agricultural source material to land.	Application Of Agricultural Source Material (ASM) To Land	Nitrogen
The application of commercial fertilizer to land.	Application Of Commercial Fertilizer To Land	Nitrogen
The application of non-agricultural source material to land.	Application Of Non-Agricultural Source Material (NASM) To Land (Including Treated Septage)	Nitrogen
The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the Environmental Protection Act.	Application Of Untreated Septage To Land	Nitrogen
The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard.	Management Or Handling Of Agricultural Source Material - Agricultural Source Material (ASM) Generation (Grazing and pasturing)	Nitrogen
	Management Or Handling Of Agricultural Source Material - Agricultural Source Material (ASM) Generation (Yards or confinement)	Nitrogen
The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.	Sewage System Or Sewage Works - Combined Sewer discharge from a stormwater outlet to surface water	Nitrogen
	Sewage System Or Sewage Works - Discharge Of Untreated Stormwater From A Stormwater Retention Pond	Nitrogen
	Sewage System Or Sewage Works - Industrial Effluent Discharges	Nitrogen
	Sewage System Or Sewage Works - Sanitary Sewers and related pipes	Nitrogen
	Sewage System Or Sewage Works - Septic System	Nitrogen
	Sewage System Or Sewage Works - Septic System Holding Tank	Nitrogen
	Sewage System Or Sewage Works - Sewage treatment plant bypass discharge to surface water	Nitrogen
	Sewage System Or Sewage Works - Sewage Treatment Plant Effluent Discharges (Includes Lagoons)	Nitrogen
	Sewage System Or Sewage Works - Storage Of Sewage (E.G. Treatment Plant Tanks)	Nitrogen
The storage of agricultural source material.	Storage Of Agricultural Source Material (ASM)	Nitrogen
The handling and storage of commercial fertilizer.	Storage Of Commercial Fertilizer	Nitrogen
The handling and storage of non-agricultural source material.	Storage of Non-Agricultural Source Material (NASM)	Nitrogen
The storage of snow.	Storage Of Snow	Nitrogen

Table 4-25: Activities that Contribute to Nitrate Issues within an Issue Contributing Area

Prescribed Drinking Water Threat	Threat Subcategory	Chemical of Concern
The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the Environmental Protection Act.	Storage, Treatment And Discharge Of Tailings From Mines	Nitrogen
	Waste Disposal Site - Landfilling (Municipal Waste)	Nitrogen
	Waste Disposal Site - Landfilling (Solid Non Hazardous Industrial or Commercial)	Nitrogen

Map 4-53: Issue Contributing Area for the Town of Tillsonburg Water Supply



4.8 Oxford County Limitations of Data and Methods

4.8.1 Delineation of Wellhead Protection Areas

Sources of uncertainty associated with the capture zones were recognized and addressed as part of the Phase II Groundwater Protection Study (Golder, 2001). One example was the effect of uncertainty in the hydraulic conductivity. It was noted that a lower hydraulic conductivity can result in a wider, but shorter capture zone, whereas a higher hydraulic conductivity can result in a narrower, but longer capture zone. A second example was the effect of uncertainty in the direction of regional groundwater flow, which was based on interpretation of MOE water well record data. It was noted that a difference of 5 degrees in the direction of groundwater flow may be insignificant near the production wells but would be much more significant further upgradient of the wells (Golder, 2001). To address these uncertainties, the shape of the capture zone was adjusted using two shape factors. The first shape factor was a 20% increase in the overall shape of the capture zone (20% increase in width at the centerline, and a 20% increase in length upgradient and downgradient of the production well). The second shape factor was the addition of a 5 degree angle added to the centerline of the capture zone, in effect increasing the width at increasing distances from the pumping well. The objective of applying the second shape factor was to compensate for uncertainty in the regional groundwater flow direction. Golder (2001) noted that for capture zones intersecting groundwater flow divides and recharge boundaries (i.e. river boundaries), those boundaries were still used to limit the extent of the capture zone, notwithstanding the adjustments made in applying the shape factors.

Wellhead Protection Areas for the Tillsonburg Northern wellfield (wells 3, 4, 5, 6A and 7A) were remodelled (Matrix, 2014) in 2014 using the Long Point Region Tier Three groundwater model (Matrix, 2013), which has the latest modelling and understanding of groundwater flow in the area. Updated pumping rates, which accounted for growth projections to 2026, were used to generate the Tillsonburg Northern wellfield Wellhead Protection Areas.

Wellhead Protection Areas for the Otterville wellfield (wells 4 and 5) were remodelled (Matrix, 2019) in 2019 using the Long Point Region Tier 3 groundwater model (Matrix, 2013), which has the latest modelling and understanding of groundwater flow in the area. Updated pumping rates, which accounted for growth projections to 2026, were used to generate the Otterville wellfield Wellhead Protection Areas.

4.8.2 Threats and Conditions

Under the preliminary threats assessment, available desk top level land use information, air photo interpretation and local knowledge of County and municipal staff was used to determine the types of land use activity information and therefore, the threats and circumstances associated with these land uses. In most cases, professional judgment and assumptions were made when determining the presence of significant threats for each property. Consultation with property owners to verify the existence of circumstances that constitute a significant threat will be refined through a more refined threats assessment at a later date.

There was a general lack of information on the presence/absence of contamination associated with historical land uses. As a result, no condition-related drinking water threats (if present) were identified. In addition, the type and amount of chemicals stored at the commercial and industrial operations within the wellhead protection areas is unknown. Further, for other land use types, the types and amounts of potential contaminants often had to be assumed based on the land use practice. Where assumptions had to be made, often a worst case scenario approach was taken and circumstance values were assigned based on that assumption so significant threats would be noted for follow-up.

In terms of data limitations, the most problematic dataset was septic systems. The records maintained by the County Board of Health lack accurate locational information. This dataset was based in a property/structure inventory using both the County's LRIS and site inspections where aerial photography was not available (parts of Perth and Norfolk). The sanitary sewer infrastructure layer was used to determine which properties were serviced by municipal services. Using this method, there remained instances where service connection was questionable. At present, County Public Works has not yet digitized the sanitary sewer infrastructure in the County.

For the impervious surface dataset, digitizing was completed by both Oxford County and the Lower Thames River Conservation Authority (LTRCA). Heads-up digitizing from two different sources could introduce error when identifying impervious surfaces. Also, each organization may have access to different supplementary data sets to complete the analysis. Since the County has access to more current roads data, road centre lines were buffered to average road widths to create the initial impervious surface layer. Edits were then made to ensure the roadways were accurately represented and to add in sidewalks and parking lots. Human error may have occurred while digitizing the impervious surfaces.

Since there is no agricultural census information available to the County at a property scale, reasonable assumptions about the type of livestock housed in a farm structure were based on the best available information. This information ranged from local knowledge of County and municipal staff to land use information recorded in various County records. Where this information was unavailable air photo interpretation was used to determine barn type, and therefore, livestock type. Air photo interpretation and the use of GIS for area calculations could be considered limitations to the work, since the resulting shapefiles are representations and not 100 percent accurate. This limitation also applies to the layer extraction step when delineating managed lands. Certain structures, in particular residential dwellings, do not necessarily reflect the actual foot prints of the structure. However, manual edits to the shapefile were completed for larger layers if deemed necessary through air photo interpretation.

In summary, the inventory conducted was a desktop exercise and therefore subject to certain limitations. GIS datasets are representations of features on the earth and therefore are rarely 100 percent accurate. Human error can be introduced at any step in the process due to the fact that assumptions were made regarding the presence of significant threats.