TABLE OF CONTENTS

LIST OF MAPS

LIST OF TABLES

This page left blank intentionally.

12.0 CITY OF HAMILTON

12.1 Lynden Communal Well System

The City of Hamilton operates a groundwater water supply and distribution system located in the Lynden Rural Settlement Area. The system collects water from a single pumping well (FLD-01) located at 3630 Governors Road. In 2015, a new production well, FDL-03 was drilled 230 m to the south of FDL-01. Both wells are screened in a confined overburden aquifer between 50 and 55 metres below ground surface. The aquifer is locally confined by a thick deposit of clay and silt. Neither well meets the requirements to be considered groundwater under the direct influence of surface water (GUDI) (WSP, 2016).

The location of the existing well site and serviced area is shown on **Map 12-1**. The system currently supplies, on average, approximately 103 m^3/d of potable water to 380 residents (City of Hamilton, 2017). With the addition of FDL-03, the system will have a capacity of 518.4 m^3/day (Earthfx, 2018). The raw water passes through a two-stage treatment process to remove naturally occurring hydrogen sulphide and provide disinfection.

The system operates under Permit to Take Water (PTTW No. 0634-ASERU8). **Table 12-1** to **Table 12-2** summarize the system characteristics.

Table 12-1: Municipal Residential Drinking Water System Information for the City of Hamilton in the Grand River Source Protection Area (Lynden Communal Well System)

DWS Number	DWS Name	Operating Authority	GW or SW	System Classification[1]	Number of Users served[2]
250001830	Lynden Communal Well System	City of Hamilton	GW	Large Municipal Residential System	380

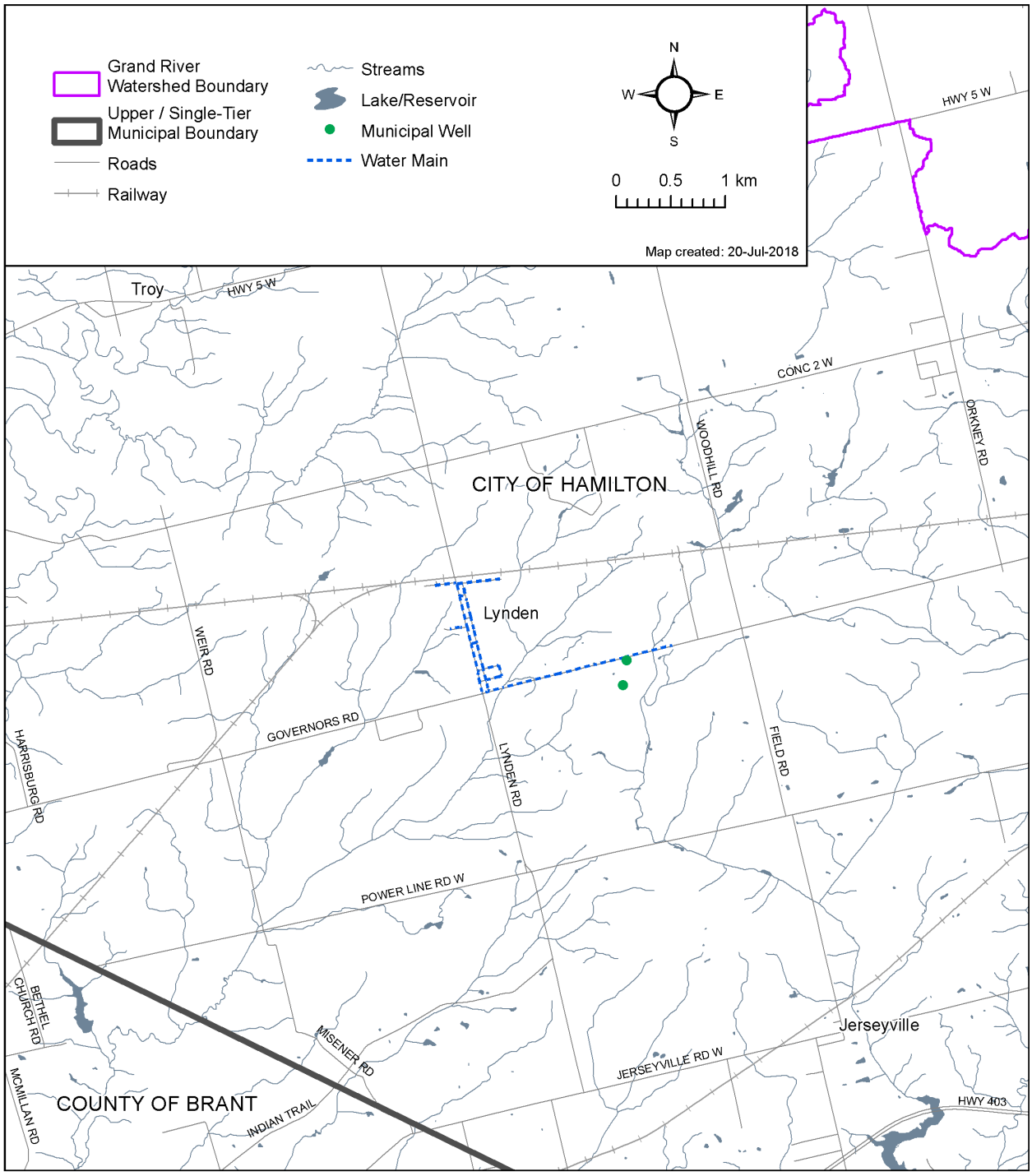
[1] as defined by O. Reg. 170/03 (Drinking Water Systems) made under the *Safe Drinking Water Act, 2002.*
[2] Drinking Water System Regulation 170/03, 2017

Table 12-2: Annual and Monthly Average Pumping Rates for the Lynden Communal Well System

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
FDL01	82.75	84	77	78	82	83	85	92	80	84	80	81	87

[1] source: City of Hamilton 2017 annual summary report

Map 12-1: Lynden Communal Well System Serviced Areas



12.1.1 Delineation of Wellhead Protection Areas for Lynden Communal System

A numerical groundwater flow model and a hydrologic model for the Fairchild Creek subwatershed were developed to delineate wellhead protection areas for the Lynden Communal Wells System (Earthfx, 2018). Five different pumping configurations were tested in order to simulate a wide range of operational conditions. The most conservative and/or most realistic WHPA was delineated based on the different capture zones generated under different pumping configurations.

Groundwater recharge rates for the study area were estimated using a new hydrologic model developed for this study area using the USGS PRMS hydrologic modelling code. The model was calibrated to match observed streamflow at Water Survey of Canada gauges on Fairchild and Spencer creeks. In addition, updated conceptual geologic and hydrostratigraphic models were developed as part of this study, which incorporated geologic datasets from the OGS and a previous study by Earthfx (2010).

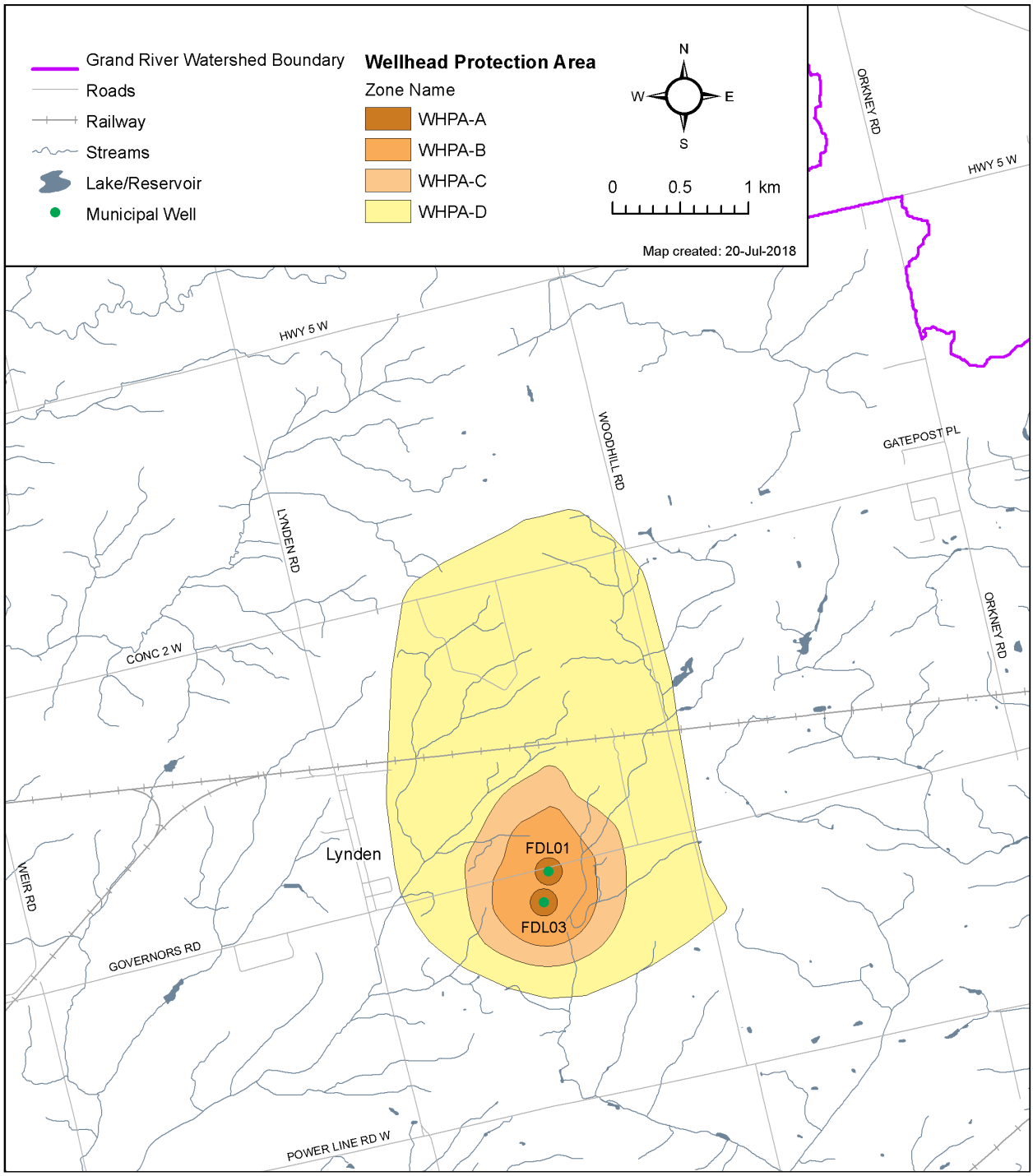
A single WHPA was delineated for the two Lynden supply wells because of their close proximity to one another and because they both draw from the same deep sand and gravel aquifer. Pumping was distributed 2:1 in favour of the new supply well (FDL-03), with a total wellfield production equal to the maximum permitted rate of 6 L/s. The WHPA is oriented in a the northern direction and does not appear to be influenced by any major hydrogeologic features. The Lynden Communal System WHPA is presented on **Map 12-2**.

Vulnerability Scoring in Wellhead Protection Areas

Aquifer vulnerability was mapped using the Surface to Well Advection Time (SWAT) method which utilizes the groundwater flow model by tracking particles forward in the model to estimate their time of travel from ground surface to the municipal wells.

Vulnerability scores were calculated by combining the WHPAs with the vulnerability indices (High, Medium, and Low) from the SWAT analysis. The Lynden supply wells are screened beneath a thick deposit of clay till and simulated water levels indicate relatively little connection with the shallow groundwater system. Accordingly, the intrinsic vulnerability scores are low. The intrinsic vulnerability of the Lyden Communal Well System is shown on **Map 12-3.**

Map 12-2: Lynden Communal Well System Wellhead Protection Areas



Identification of Transport Pathways and Vulnerability Adjustment

Adjustments to the vulnerability scores are needed to account for the presence of transport pathways (i.e., constructed preferential pathways) that might bypass the natural protective geologic layers. Unsaturated zone travel times were not considered in the analysis of SWAT times. Therefore, constructed pathways that could possibly reduce unsaturated zone travel times, such as stormwater ponds and pipeline bedding, would not result in an increase in the vulnerability scores already assigned. The focus, therefore, was to identify constructed pathways that could reduce travel times in the saturated zone. This included a review of:

- Wells that may leak or have been improperly abandoned;
- Pits and quarries that breech the upper confining unit;
- Lakes in connection with the municipal aquifer system;
- Landfills located in former pits or quarries that may breach the upper confining unit; or
- Other deep excavations.

Transport Pathways in the Lynden Wellhead Protection Areas

The discharge of contaminants to deep wells could provide a pathway to the underlying confined aquifer. As an initial screening, all wells that penetrated the bedrock aquifers were identified. Of these, the wells that were installed after 1990, when Ontario Regulation 903 (Wells) under the *Ontario Water Resources Act*), set out minimum standards for the construction and proper decommissioning of all types of wells, were assumed to be less likely to have failures of the casing or annular seals.

A total of 68 wells were identified within the delineated WHPA-A through WHPA-D areas for the Lynden supply wells. Of these, 13 wells were considered high risk by potentially not meeting the current MECP well standards and are in connection with the aquifer used for municipal supply.

Adjusted Vulnerability Scoring for the Lynden Wellhead Protection Areas

No adjustments due to transport pathways were made to the vulnerability scores for the Lynden WHPAs.

The vulnerability scoring is presented in **Map 12-4.** The Lynden supply wells are completed beneath a thick deposit of clay till and simulated water levels indicate relatively little connection with the shallow groundwater system. Accordingly, the vulnerability scores are low for the WHPA-C and D, medium vulnerability for WHPA-B and high vulnerabilty for WHPA-A (Earthfx, 2018).

Limitations and Uncertainty in the Wellhead Protection Area Delineation and Vulnerability Scoring for the Lynden Communal Well System

Uncertainty associated with WHPAs must be identified as either High or Low. There are uncertainties and limitations related to both the WHPA modeling, the aquifer vulnerability assessment and the mapping of transport pathways. Results of the final uncertainty factors for the WHPA delineation and vulnerability scoring are summarized in **Table 12-3**.

Table 12-3: Summary of Uncertainty Analysis

Uncertainty Element	Uncertainty for WHPA Delineation	Uncertainty for Vulnerability Scoring
Distribution, variability, quality and relevance of data	Low	Low
Ability of the methods and models used to accurately reflect the flow processes in the hydrogeological system	High	High
Quality assurance and quality control procedures applied	Low	Low
Extent and level of calibration and validation achieved for models used or calculation or general assessments completed.	Low	Low
Accuracy to which the groundwater vulnerability categories effectively assess the relative vulnerability of the underlying hydrogeological features.	Not applicable	High
Overall	**High**	**High**

While a good overall calibration was achieved, we recognize that the Fairchild Creek model may be overpredicting drawdown and underpredicting water levels. For that reason, the model uncertainty is considered to be high.

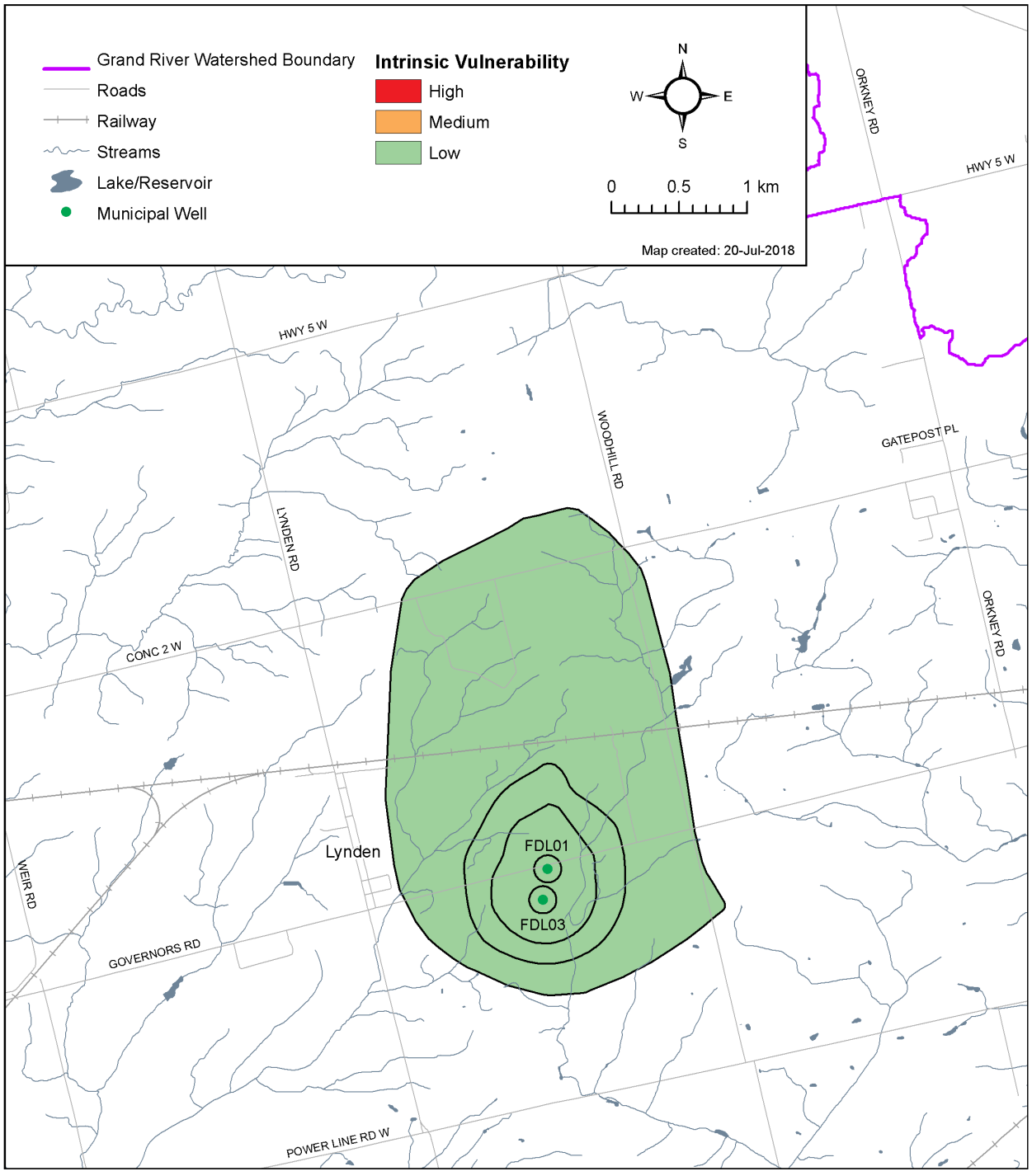
Average groundwater recharge, a common source of uncertainty in groundwater models, was estimated by developing and calibrating a separate hydrologic model (PRMS). The uncertainty and limitations associated with PRMS include the absence of field measured values for groundwater recharge, limited ability to represent groundwater feedback using an uncoupled surface model, and uncertainty in the input and calibration target data.

While the application of a calibrated numerical groundwater model to delineate the WHPAs is considered to be the most robust and precise of the options available for determining the time of travel to a well, sources of uncertainty are introduced from both the groundwater flow model and the time of travel analysis itself. Subtle variations in the flow directions near the wells caused by local variation in aquitard or aquifer thickness, aquifer and aquitard hydraulic conductivity values, and/or recharge rates can lead to significant changes in the flow paths of the particles. For this study, the uncertainty in the groundwater flow patterns was relatively low due to the uniformity of the municipal aquifer system.

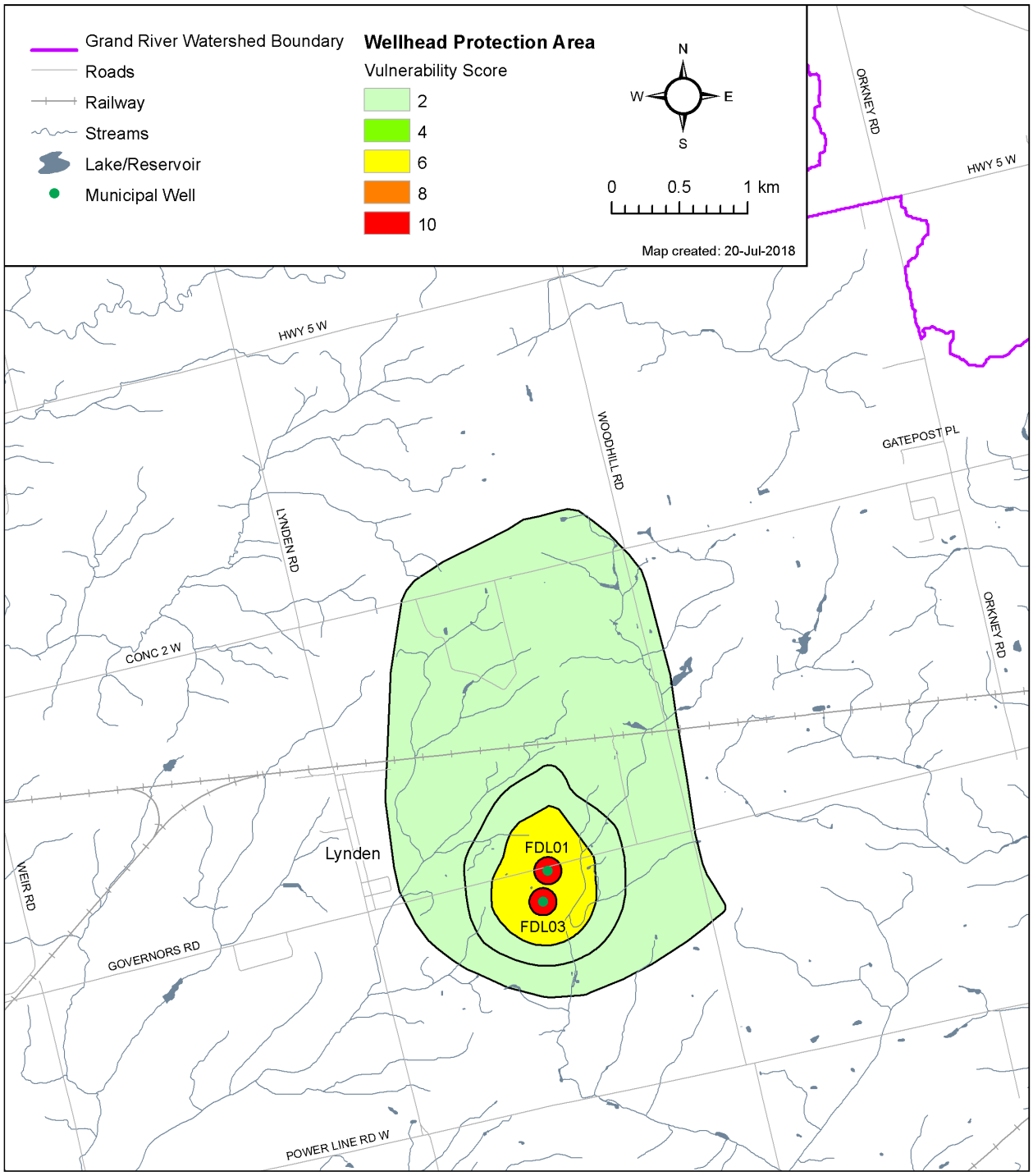
The overall uncertainty of the vulnerability score has been assessed and is considered to be high, consistent with the low level of uncertainty associated with the groundwater flow component of the study.

Based on the discussion above, the uncertainty associated with the vulnerability assessment is deemed “High”, as defined by the Technical Rules.

Map 12-3 Lynden Communal Well System Wellhead Protection Area Intrinsic Vulnerability



Map 12-4: Lynden Communal Well System Wellhead Protection Area Vulnerability



Managed Lands within the Lynden Wellhead Protection Area

The Percent Managed Land Area analysis identifies lands to which nutrients are applied. The analysis categorizes managed lands into two groups: agricultural managed lands and non-agricultural managed lands. Agricultural managed lands include areas of cropland, fallow, and improved pasture that may receive nutrients. Non-agricultural managed lands include golf courses, sports fields, lawns and other built-up areas that may have received nutrients such as commercial fertilizers. The assessment of managed lands is only necessary for areas within a WHPA that have a vulnerability score of 6 or greater.

The percentage of managed lands in the Lynden WHPA is high given the rural location of the wellfield. Managed lands were completed using the methodology outlined in Chapter 3, with results of the managed lands calculations presented in **Table 12-4Error! Reference source not found.** and **Map 12-5.**

Table 12-4: Percent Managed Lands in the Lynden Wellhead Protection Areas

Wellhead Protection Area	Lynden FDL01	Lynden FDL03
A	76%	100%
B	91%	
C	94%	
D	76%	

Livestock Density within the Lynden Wellhead Protection Area

The Livestock Density analysis determines the intensity of livestock animals and is a surrogate measure of the potential for gathering, storing and applying agricultural source materials (ASM) as a nutrient source within vulnerable areas.

After a review of the air photos and *Street Views,* eight properties with potential livestock were identified in the Lynden WHPA. Livestock densities were calculated for each of the applicable WHPA zones and are presented in **Table 12-5** and **Map 12-6**. All vulnerable areas were calculated as having less than 0.5 NU/Acres. Note that while the livestock density was calculated for the WHPA-D of the Lynden WHPA, it was not evaluated as a potential threat since the vulnerability score was below 6 (Earthfx, 2018).

Confirmation of the actual situations would require site visits and interviews with property owners.

Table 12-5: Livestock Density (NU/Acre) in the Lynden WHPA

Wellhead Protection Area	Livestock Density (NU/Acre)	
	FDL01	FDL03
WHPA-A	0.2	0.0
WHPA-B	0.25	
WHPA-C	0.33	
WHPA-D	0.11	

Percentage of Impervious Surface Area within the Lynden Wellhead Protection Areas

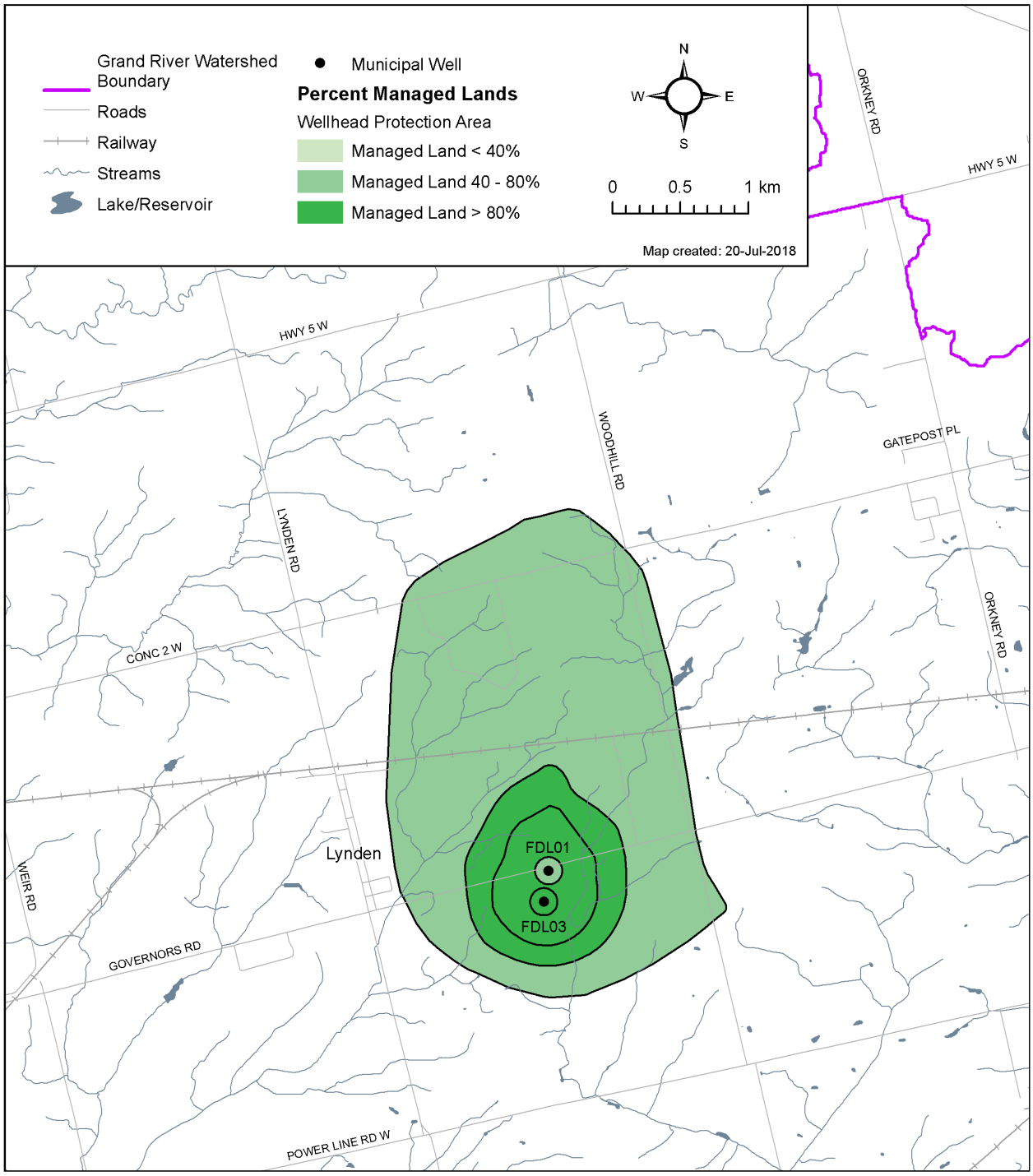
The Technical Rules 16(11) and 17 require the calculation and mapping of the percentage of total impervious surface area where road salt can be applied per square kilometre in each of the vulnerable areas. The resulting impervious surface area maps are used in the water quality risk

scoring and the assessment of threat circumstances relating to road salt application. Total impervious surface area is defined in the Technical Rules as the surface area of all highways and other impervious land surfaces used for vehicular traffic and parking, and all pedestrian paths. The method used to calculate impervious surfaces for the Lynden WHPAs is the 1x1 km grid and detailed in Chapter 3 of the Assessment Report.

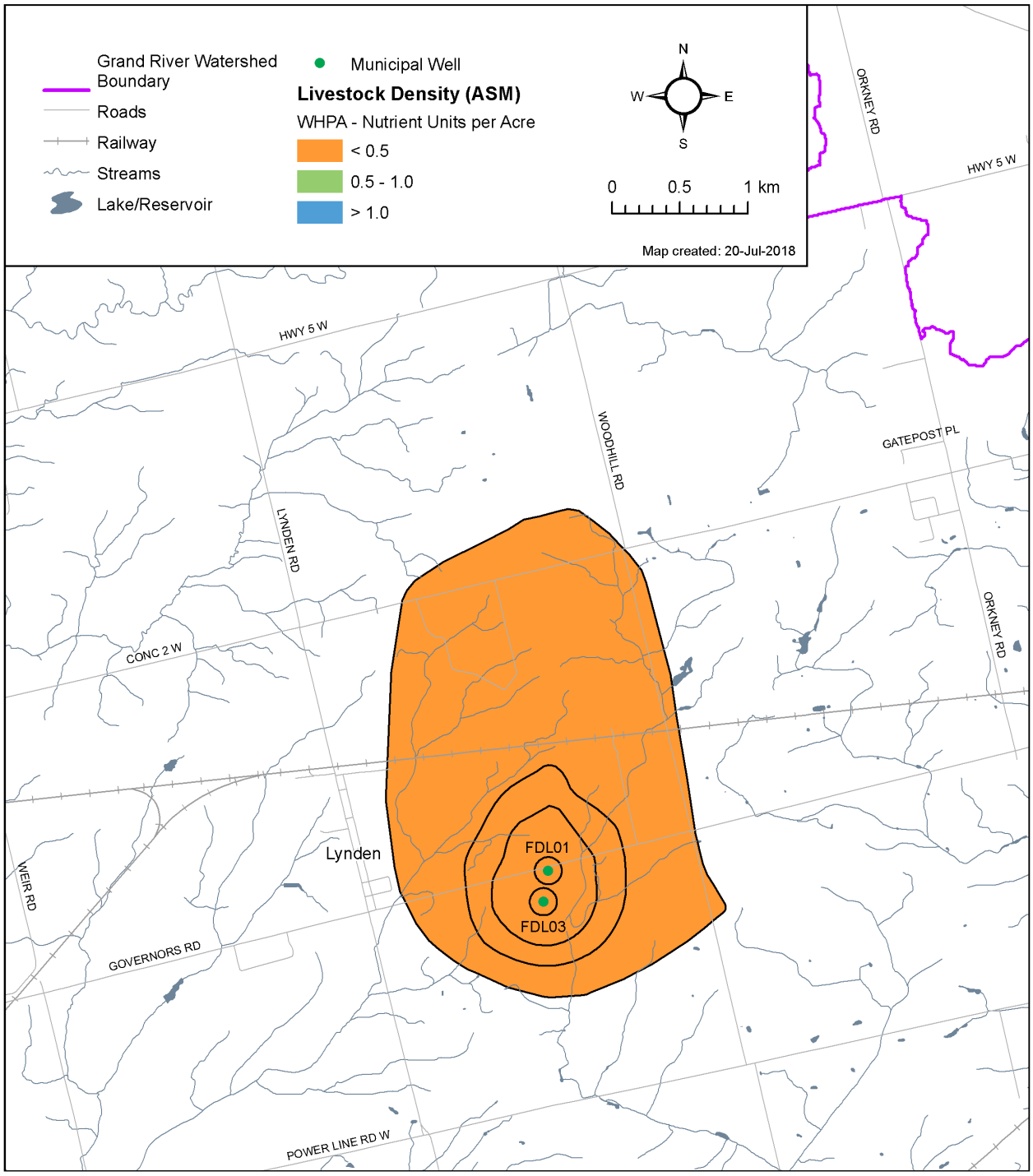
The results of the assessment are presented on **Map 12-7.** The percent impervious surface area is a combination of the '<1%' and '1% to <8%' classification categories within the WHPAs. A thin area on the outer western edge of the WHPA-D is classified as '8% to <80%' percent impervious surface.

Overall, the error associated with the analysis is deemed low since the lands are predominantly agricultural in use with few impervious surface features.

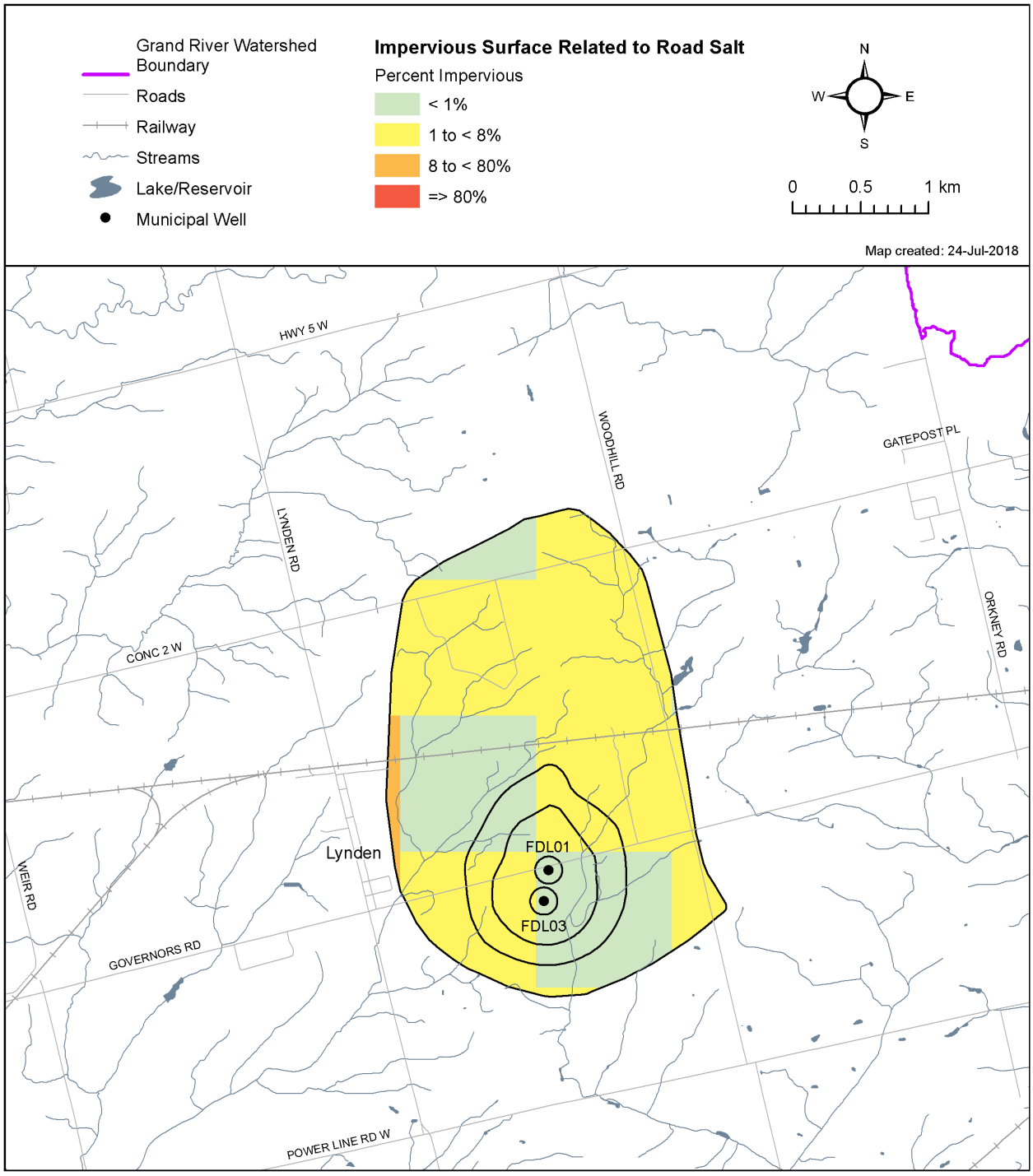
Map 12-5: Lynden Communal Well System Percent Managed Lands



Map 12-6: Lynden Communal Well System Livestock Density



Map 12-7: Lynden Communal Well System Percent Impervious Surfaces



12.1.2 Lynden Drinking Water Quality 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." A Prescribed Drinking Water Threats table in Chapter 3 lists all possible drinking water threats.

Identification of Significant, Moderate and Low Drinking Water Quality Threats for the Lynden Communal Well System

Table 12-6 provides a summary of the threat levels possible in the Lynden WHPAs for Chemicals, Dense Non-Aqueous Phase Liquids (DNAPLs) and Pathogens. A checkmark indicates possible the threat classification level 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 12-4.**

Table 12-6: Identification of Drinking Water Quality Threats in the Lynden 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			
Handling / Storage of DNAPLs	WHPA-A/B/C	Any Score	✔		
	WHPA-D	2			
Pathogens	WHPA-A	10	✔	✔	
	WHPA-B	6			✔

Enumeration of Significant Drinking Water Quality Threats for the Lynden Communal Well System

The number of significant Prescribed Drinking Water Threats identified by EarthFX (2018) are tabulated in **Error! Reference source not found.**. A total of 26 significant threats, 5 moderate and 33 low level threats were identified within the Lynden WHPA. Significant threats were primarily associated with agricultural activities in the area, the use of septic systems and handling, and storage of fuel associated with residential dwellings.

Table 12-7: Significant Drinking Water Quality Threats for the Lynden Communal Well System (current to May 2018)

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	6	WHPA-A
9	Storage Of Commercial Fertilizer	2	WHPA-A
10	Application Of Pesticide To Land	6	WHPA-A

15	Handling and Storage Of Fuel	6	WHPA-A
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area or farm –animal yard. O. Reg.385/08, s. 3.	1	WHPA-A
Total Number of Activities		**26**	
Total Number of Properties		**7**	

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

Conditions Evaluation for the Lynden Communal Well Supply

After review of several databases and a discussion with municipal staff, there is no evidence of a Condition for the Lynden Communal Well Supply. It is possible that condition-related drinking water threats do exist; however, no data is available to either confirm or refute this possibility.

Limitations and Uncertainty of the Enumeration of Significant Drinking Water Quality Threats for the Lynden Communal Well System

No significant data gaps were encountered during the identification of significant drinking water threats. 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 amounts of chemicals stored/used/applied at the agricultural operations within the wellhead protection areas is unknown. In the absence of site-specific information, a conservative approach was taken, namely the assumption that all chemicals/materials that are commonly used in a given land use type are present.

The level of uncertainty associated with the threats assessment was classified as high (Earthfx, 2018). The level of uncertainty could be reduced by contacting the owners of the properties within the WHPA to confirm storage and application quantities and to identify any mitigation or containment measures that may be in place to reduce potential impacts to drinking water quality.

Water Quality Issues Evaluation for the Lynden Communal Well Supply

The Issues evaluation focused on the water quality parameter groupings outlined in the Ontario Drinking Water Quality Standards (ODWQS). These include: a) Pathogens, b) Schedule 1 parameters, c) Schedule 2 and 3 parameters and, d) Table 4 parameters. In addition to these parameters, the Source Protection Committee may identify other parameters that are to be evaluated; however, to date, no additional parameters have been selected.

Drinking water issues were evaluated for the Lynden Communal Well System by reviewing the available water quality data (EarthFX, 2018). No known pathogens were detected based on available test results for the Lynden Communal Well System. No Schedule 2 or 3 parameters were identified as potential or actual Issues based on a review of the available raw water quality information.

It should be noted that the City of Hamilton has reported the detection of lead a number of times within the Lynden distribution system. The operator reported that "*Turbidity is caused by colloidal sulphur, a byproduct of the reaction between hydrogen sulfide and chlorine. The colloidal sulfur*

acts as a scavenger and concentrates very low levels (close to non-detect) of lead in the raw water. The sulphur precipitate therefore contains significant levels of lead. So long as the precipitate stays at the bottom of the tank it does not cause problem in the distribution system." Since the concentration of lead is a by-product of the treatment and not a parameter of the raw water, lead has not been identified as an Issue under Technical Rule 114.

Between the period of 2003 and 2017, there were 756 reported raw water samples collected and analyzed for *E.coli*, total coliforms, and background colonies. There were no instances of *E.coli* and or total coliforms in any of the reported raw water samples.

Since 2005, there have been multiple reported water samples with sodium concentrations greater than the 20 mg/L Medical Officer of Health notification level. None of these samples exceeded the 200 mg/L ODWQS aesthetic objective. Concentrations reported at greater than 20 mg/L occurred in in 2005 and again between 2007 and 2017. Maximum reported sodium concentrations of 67 mg/L occurred in 2005 and again in 2007. Data between the years of 2007 and 2017 is only available as a range. Both the upper and lower bounds of the sodium concentration range exceeded 20 mg/L. Sodium is deemed to be naturally occurring in the groundwater and is not classified as an Issue under Technical Rule 114.

Based on historical data dating from 2005 to 2008, raw water turbidity for the Lynden system ranges between 0.26 and 3.77 NTU. More recent raw water turbidity for the Lynden system ranges between 0.07 to 0.66 NTU, with one maximum value in 2015 of 2.30 NTU. The maximum reported values for the ranges reported between 2003 and 2017 never exceeded the aesthetic objective of 5 NTU (as measured at point of consumption). The higher reported values prior to 2006 may be related to reporting protocol at the time that required reporting of all turbidity spikes including those noted during well startup. This parameter should continue to be monitored, as there is no filtration incorporated in this water system, and increasing turbidity can possibly hinder the disinfection process.

Summary of Water Quality Issues Evaluation of the Lynden Communal Well System

There are no identified Issues for the Lynden Communal Well Supply.

Sodium concentrations regularly exceeded the local Medical Officer of Health notification level of 20 mg/L but have not been reported to be above 50% of the ODWQS MAC. The sodium present in the Lynden Communal Well System is deemed to be naturally occurring in the groundwater and is not identified as an Issue.

Turbidity has been noted as a concern for continued monitoring. Similar to sodium, turbidity is classified as likely having a natural source.

The City of Hamilton has reported the presence of lead within the distribution system, which is a by-product of the treatment process where lead-containing sulphur precipitate has become mobilized. It was reported that as long as the precipitate remains at the bottom of the treatment tank, there is no problem in the distribution system. Since the presence of lead is a by-product of the water treatment process, rather than within the raw water, it is not identified as an Issue under Technical Rule 114. Furthermore there are plans for a new treatment and pumping station to be built in order to replace the existing one and to service the two wells (FDL-01 and FDL-03) (WSP, 2017).

Limitations and Uncertainty of the Water Quality Issues Evaluation

The results of this assessment are based on the review of data available at the time of the assessment (EarthFX, 2018). This was generally limited to water system annual reports. Overall, the number of tested parameters for raw water quality is limited. Since sampling and analysis is not part of this review, the analysis and conclusions drawn herein can only be based on previous data obtained by others. This analysis can also not comment on the method by which these samples were obtained or as to the laboratories used in the analysis. Any errors in data reporting or analysis associated with the referenced reports will be unknowingly carried forward through this analysis.

Data for the years between 2003 and 2017 were reviewed. Therfore the analysis of any trends in the data was limited to this time span. Nevertheless, the reviewed data was deemed adequate for the purpose of this assessment, and no significant data gaps were identified.