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21.0 WHITEMANS CREEK TIER 3 WATER BUDGET AND RISK ASSESSMENT

The purpose of the Whitemans Creek Tier 3 Water Budget and Water Quantity Risk Assessment (Tier 3 Study) is to determine the likelihood that future water demands for the Whitemans Creek Subwatershed can be met. This was completed by evaluating the risk of water quantity impacts to municipal drinking water supplies, namely the Bright Well Field in Oxford County, and the Bethel Well Field in the County of Brant, based on combinations of current and proposed land use, average climate, and drought conditions. The Tier 3 Study was triggered by predictions during the Tier 2 Study, of insufficient water being available at the Bright Well Field to maintain supply during drought conditions (AquaResource Inc., 2009a).

Tier 3 Studies must be completed per the Technical Rules for Assessing Risks to Sources of Drinking Water in Ontario under the *Clean Water Act, 2006*, S.O. 2006, c.22 (Technical Rules) (MECP, 2011/2017/2018). As such, each study consists of the following tasks:

- Characterize the surface water and groundwater systems;
- Estimate existing and future (allocated) water demands;
- Develop and calibrate a numerical water budget model to simulate water use;
- Delineate vulnerable areas to evaluate impacts to water quantity;
- Assign risk levels (low, moderate or significant) to each vulnerable area; and
- Identify drinking water quantity threats in each significant vulnerable area.

The Whitemans Creek Tier 3 Study was completed by Earthfx Inc. (Earthfx). Sections 1.1 to 1.4 highlight the results of the study, as documented in Earthfx (2018a/b). Section 1.5 summarizes the study findings and emphasizes the results that will affect land use and water management policies.

21.1. Surface Water and Groundwater Characterization

21.1.1 Topography, Physiography and Climate

The Study Area (**Map 21-1**) covers 1,400 km^2 including the Whitemans Creek subwatershed and surrounding areas that contribute to the subwatershed's water budget. Ground surface topography is a mix of high relief (e.g., drumlins or moraines) and low relief (e.g., modern or ancient river valleys), decreasing from 360 m above mean sea level (AMSL) in the northwest to 230 m AMSL in southeast (**Map 21-2**).

Chapman and Putnam (1984) identified six physiographic regions within the Study Area. For the purposes of this Tier 3 Study, these were grouped into three general regions:

- The **Upper Whitemans Till Plains** cover the northwest of the Study Area and correspond to Chapman and Putnam's Oxford and Stratford Till Plain regions. This region is generally flat with poorly drained clay to silty clay tills. Occasional high relief features (drumlins) and low relief features (glacial meltwater valleys) are also present.

- The **Central Whitemans Glacial Outwash** covers the centre of the Study Area and corresponds to Chapman and Putnam's Mount Elgin Ridges region. This region is bounded on its east and west by moraines consisting of clay or silty clay till. Between the moraines are low lying, poorly drained vales, comprised of glacial outwash (gravel, sand, or silt alluvium).

- The **Lower Whitemans Sand Plain** covers the southeast of the Study Area and corresponds to Chapman and Putnam's Horseshoe Moraine and Norfolk Sand Plain regions. The topography in this region is variable in the north and includes kames (irregularly shaped hills composed of sand, gravel and/or till), outwash, and terrace deposits (sand and gravel). In the south, the landform is flat and low lying, and covered by glaciolacustrine (silt to sand) deposits.

Precipitation and temperature data from 1867 onwards were reviewed for the Tier 3 Study. These data were obtained from 79 climate stations, within 15 km of the Study Area. The average annual precipitation is correlated to the ground surface topography, decreasing from 950 mm in the northwest to 850 mm in the southeast. The annual average daily temperature is inversely correlated to the ground surface topography, increasing from 7.1 C in the northwest to 7.6 C in the southeast.

21.1.2 Land Use

Land Use in the Study Area is predominantly rural. Approximately 76% of land use is agricultural, with 60% as actively cultivated fields and 16% as undifferentiated uses (e.g., orchards, fallow fields, and undeveloped pasture). The remaining land use consists of 19% natural areas (e.g., forests and treed swamps) and 5% developed areas (e.g., rural residential, transportation, industrial/commercial).

Municipal water demand may be affected by future land development, which consists of a small residential subdivision and aggregate extraction pit near to the Bright Well Field in Oxford County (**Map 21-3**); and a business park, two commercial areas, an urban residential area and an aggregate extraction pit near to the Bethel Well Field in the County of Brant (**Map 21-4**). The effect of land development on water demand is discussed further in the Risk Assessment section.

21.1.3 Geology and Hydrogeology

Hydrologic Field Program

To better understand groundwater - surface water interactions and groundwater level trends observed in the Study Area, hydrogeologic field investigations were completed. Drivepoint piezometers were installed at 19 locations throughout the Study Area to allow for groundwater and surface water level monitoring. Dataloggers were used to take continuous measurements of shallow groundwater and surface water levels from February to November of 2015. Additional dataloggers were installed at 10 private water wells to continuously monitor groundwater levels over the same period. These data were used to supplement other continuous water level data obtained from local municipalities and the province. The data informed the regional and local area characterizations for the Bright and Bethel well fields.

Regional Characterization

Regional stratigraphy is characterized by Quaternary-aged overburden overlying Paleozoic-aged bedrock. The overburden consists of regionally extensive till units (e.g., Wentworth Till, Maryhill Till, Main Catfish Creek Till) with intervening sand and gravel deposits. The main aquifers in the Study Area are formed by thick and/or laterally extensive layers of the intervening sand and gravel deposits, while the till units form the aquitards. Bedrock consists of sedimentary rocks that were deposited in an ancient marine environment. Groupings of mudstones (shale), carbonates (limestone and dolostone) and/or evaporites (anhydrite, gypsum and halite) are therefore common. The top 5 to 10 m of bedrock is often highly weathered and may yield sufficient groundwater to act as an aquifer, although water quality may be poor. The various bedrock units may act as aquifers or aquitards, depending on the hydraulic properties of the rock formation. **Figure 21-1** shows a typical east-west schematic of the regional geology, after Bajc and Dodge (2011).

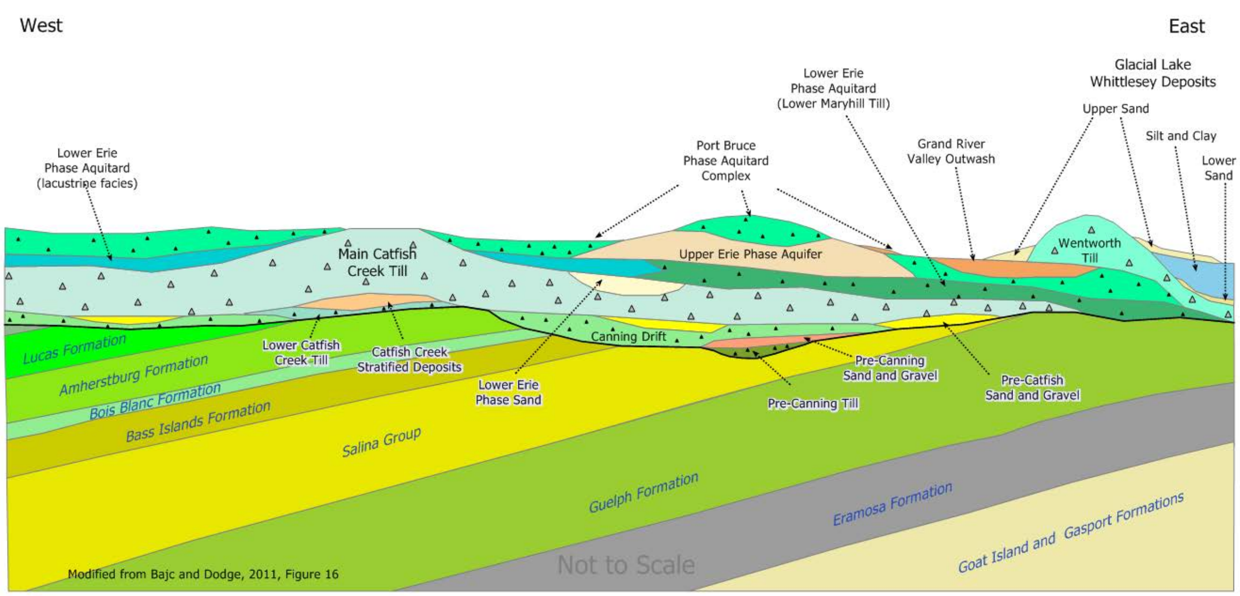


Figure 21-1: Representative Hydrostratigraphic Section

Three-dimensional hydrostratigraphic models from the Ontario Geological Survey (OGS) were extended and refined to create the hydrostratigraphic model. Data for the updates were sourced from the Ontario Ministry of the Environment, Conservation and Parks (MECP) water well information system (WWIS), municipal drilling data, and the Ontario Oil, Gas and Salt Resources Library. The hydrostratigraphic model contains 18 layers: 11 overburden aquifers and aquitards, a weathered bedrock unit representing the upper 10 m of bedrock, and 7 bedrock aquifers and aquitards (**Table 21-1**).

Table 21-1: Hydrostratigraphic Units

Unit Number	Unit Name	Hydrogeologic Role
Overburden		
1	Whittlesey Sand	Aquifer/Aquitard
2	Whittlesey Aquitard	
3	Wentworth Aquitard	Aquitard
4	Sand Plain and Outwash Aquifer	Aquifer
5	Port Stanley / Tavistock Aquitard	Aquitard
6	Waterloo Moraine Aquifer	Aquifer

7	Maryhill Till Aquitard	Aquitard
8	Post Catfish Aquifer	Aquifer
9	Catfish Creek Till Aquitard	Aquitard
10	Pre-Catfish Aquifer	Aquifer
11	Canning Till Aquitard	Aquitard
Bedrock		
12	Weathered Bedrock Contact Aquifer	Aquifer
13	Dundee-Lucas-Amherstburg Aquifer	Onadaga Limestone Aquifer
14	Bois Blanc Aquifer	
15	Bass Island Aquifer	
16	Upper Salina Port Aquifer/Aquitard	Aquifer/Aquitard
17	Lower Salina Shale Aquitard	Aquitard
18	Guelph-Eramosa Aquifer	Aquifer

The availability of groundwater resources in the Study Area varies by physiographic region.

- In the **Upper Whitemans Till Plains**, groundwater resources are mainly found in the thin, intermittent, sand and gravel deposits of the overburden. These discontinuous deposits receive limited amounts of groundwater recharge, have low storage capacities, and are not a significant groundwater resource.
- In the **Central Whitemans Glacial Outwash**, groundwater resources are typically found in outwash deposits, which can be thick and laterally extensive enough to yield supply and groundwater storage for municipal needs. The numerous wetlands in this region also provide additional groundwater storage.
- In the **Lower Whitemans Sand Plain**, the thick sand and gravel deposits of the Whittlesey Sand and Sand Plain and Outwash Aquifer provide significant groundwater resources. They are potentially sensitive to water quality threats because they are unconfined.

Where present, regardless of physiographic region, regional aquifers such as the Waterloo Moraine units (unit 6, 8 and 10, **Table 21-1**) and the Onondaga Limestone units (units 13 to 15, **Table 21-1**) act as significant groundwater resources throughout the Study Area.

Regional groundwater levels and flow were characterized by reviewing static water level data from the MECP WWIS, and transient water level data from municipal monitoring programs, the Provincial Groundwater Monitoring Network (PGMN), and the Tier 3 hydrogeologic field program. Groundwater elevations in the overburden range from approximately 370 m AMSL in the north/northwest of the Study Area to 210 m AMSL in the southeast (**Map 21-6**). Groundwater flow follows a similar pathway, from the north/northwest to the south/southeast, however local variations are observed where groundwater discharges to the surface. Groundwater elevations in the bedrock are approximately 10 m lower than in the overburden, with a flow pattern similar to that in the overburden (**Map 21-7**).

Local Characterization – Bright and Bethel Wellfields

The Bright Well Field is located in the community of Bright in Oxford County (**Map 21-1**). The well field consists of two production wells, Production Well 4A and Production Well 5, which are completed in the overburden at depths between 25.9 to 38.4 m below ground surface (290.5 to 293.9 m AMSL), in a confined to semi-confined aquifer.

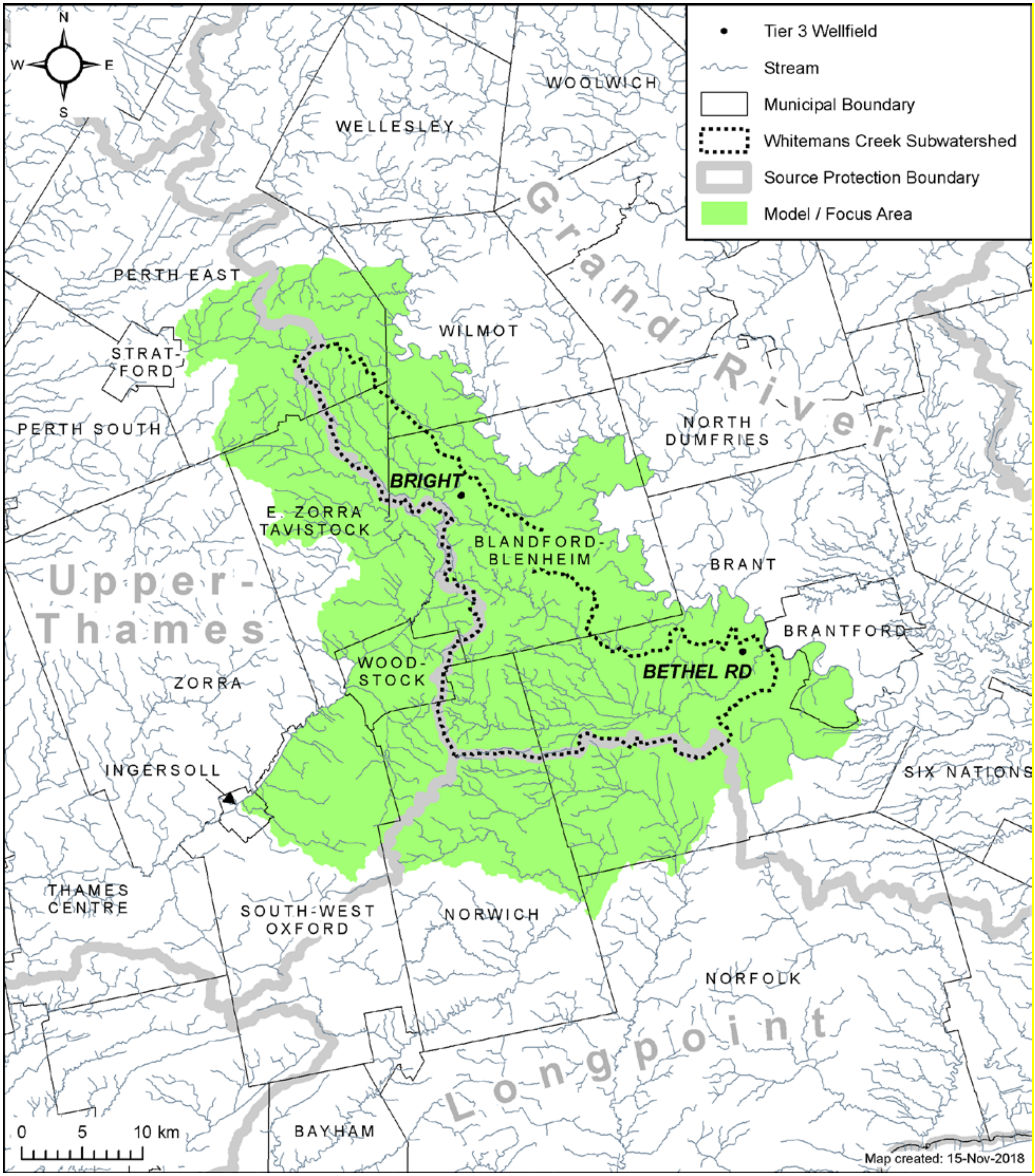
The Bethel Well Field is located near the southeast boundary of Whitemans Creek subwatershed in the County of Brant (**Map 21-1**). The well field has four production wells; TW1/05 (P52), PW1/12 (P51), PW2/12 (P53), PW4/12, which are completed in the overburden at depths ranging from 22.3 to 33.0 m below ground surface (222.5 to 227.2 m AMSL) in a confined to semi-confined aquifer.

Both the Bright and Bethel productions well are completed in the Waterloo Moraine Aquifer (unit 6, **Table 21-1**). This aquifer is overlain by up to 10 m of surficial till at the Bright Well Field, corresponding to the Port Stanley/Tavistock Aquitard (unit 5, **Table 21-1**). At the Bethel Well Field, the Waterloo Moraine Aquifer is overlain by up to 25 m of silty clay interpreted to be the Port Stanley/Tavistock Aquitard, which is itself overlain by deposits of the Sand Plain and Outwash Aquifer (unit 3, **Table 21-1**) and the occasional surficial till of the Wentworth Aquitard (unit 1, **Table 21-1**).

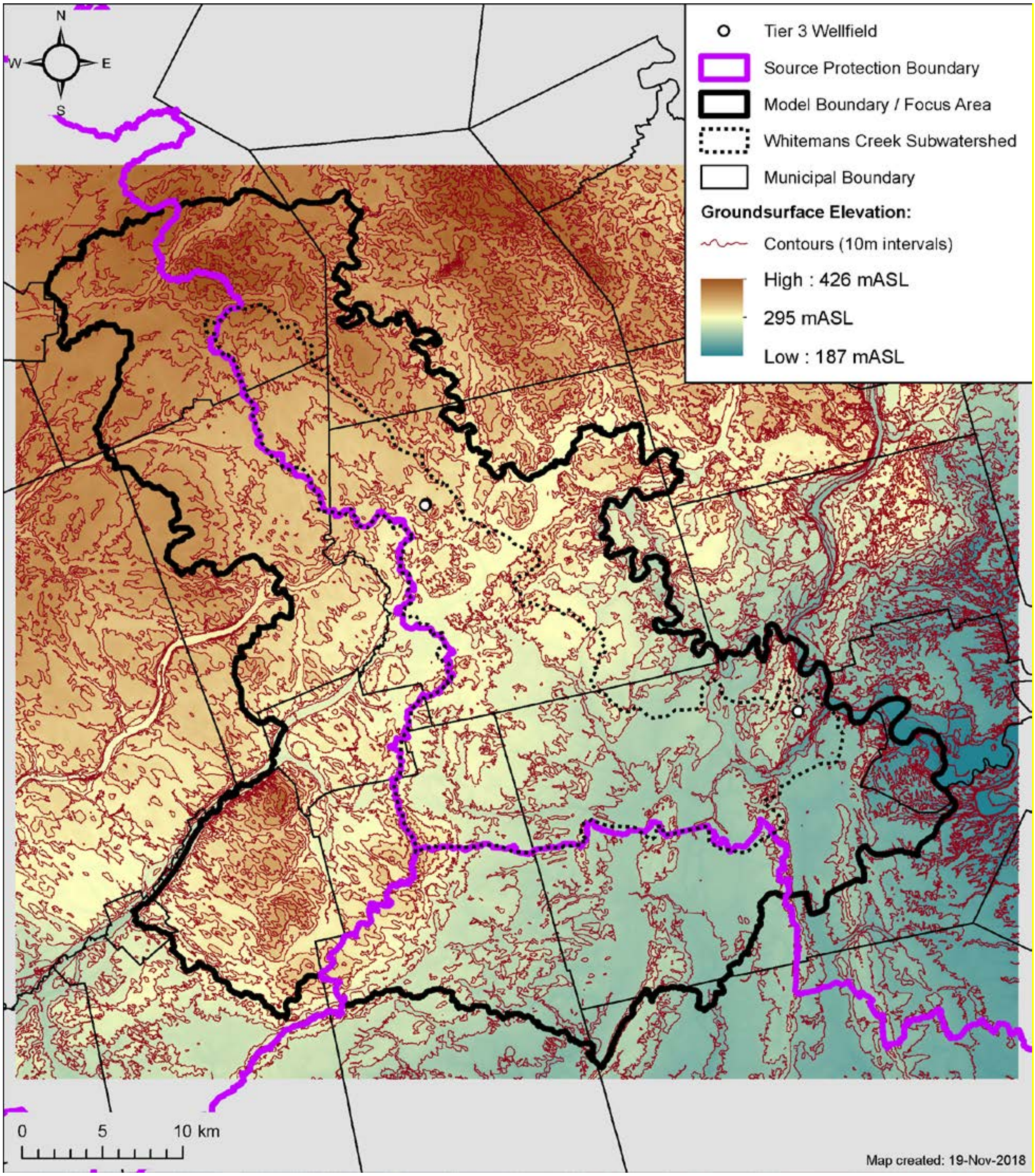
The thickness of the Port Stanley/Tavistock Aquitard varies at both well fields. At the Bright Well Field, the aquitard thins and gradually disappears to the south, where the Waterloo Moraine Aquifer becomes unconfined. At the Bethel Well Field, the Port Stanley/Tavistock aquitard is also noted to pinch out to the south, allowing the Waterloo Moraine Aquifer and Sand Plain and Outwash Aquifer to function as one continuous aquifer unit. The Waterloo Moraine Aquifer is highly heterogeneous in the vicinity of both well fields. Beneath the aquifer, is the Maryhill Till Aquitard, a regionally extensive and competent till unit.

The Tier 3 hydrostratigraphic model was improved in the area of the Bright Well Field by refining the extent and thickness of the Port Stanley/Tavistock aquitard, and removing an aquifer to the north of Bright, which was previously interpreted to be between the Pre-Catfish Aquifer and the Canning Till Aquitard (units 10 and 11, **Table 21-1**). At the Bethel Well Field, the occurrence of the surficial Wentworth Aquitard was refined and its thickness increased. Additionally, the Port Stanley/Tavistock aquitard was incorporated to separate the Waterloo Moraine and Sand Plain and Outwash aquifers, and the bedrock topography refined.

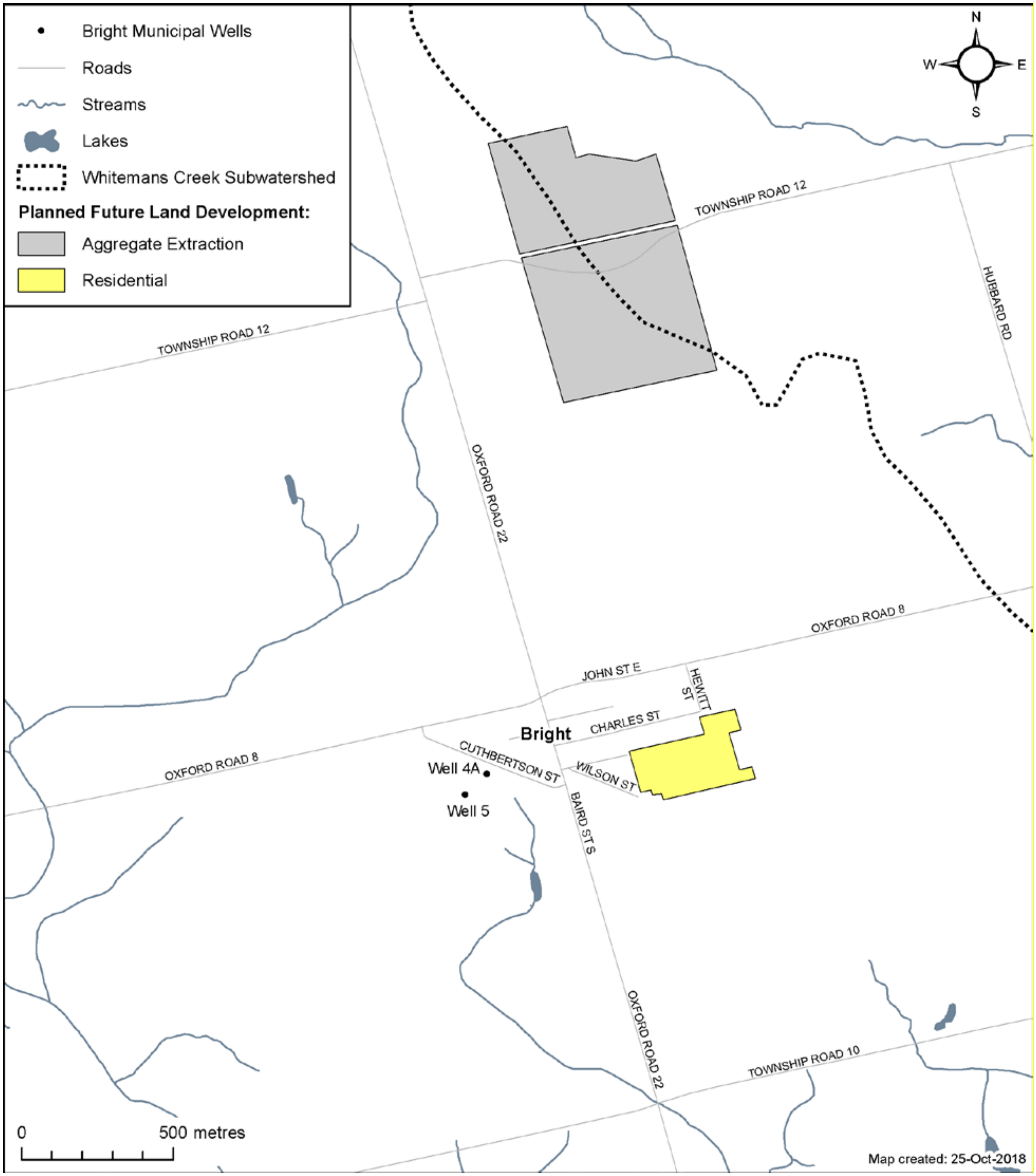
Map 21-1: Tier 3 Study and Focus Area



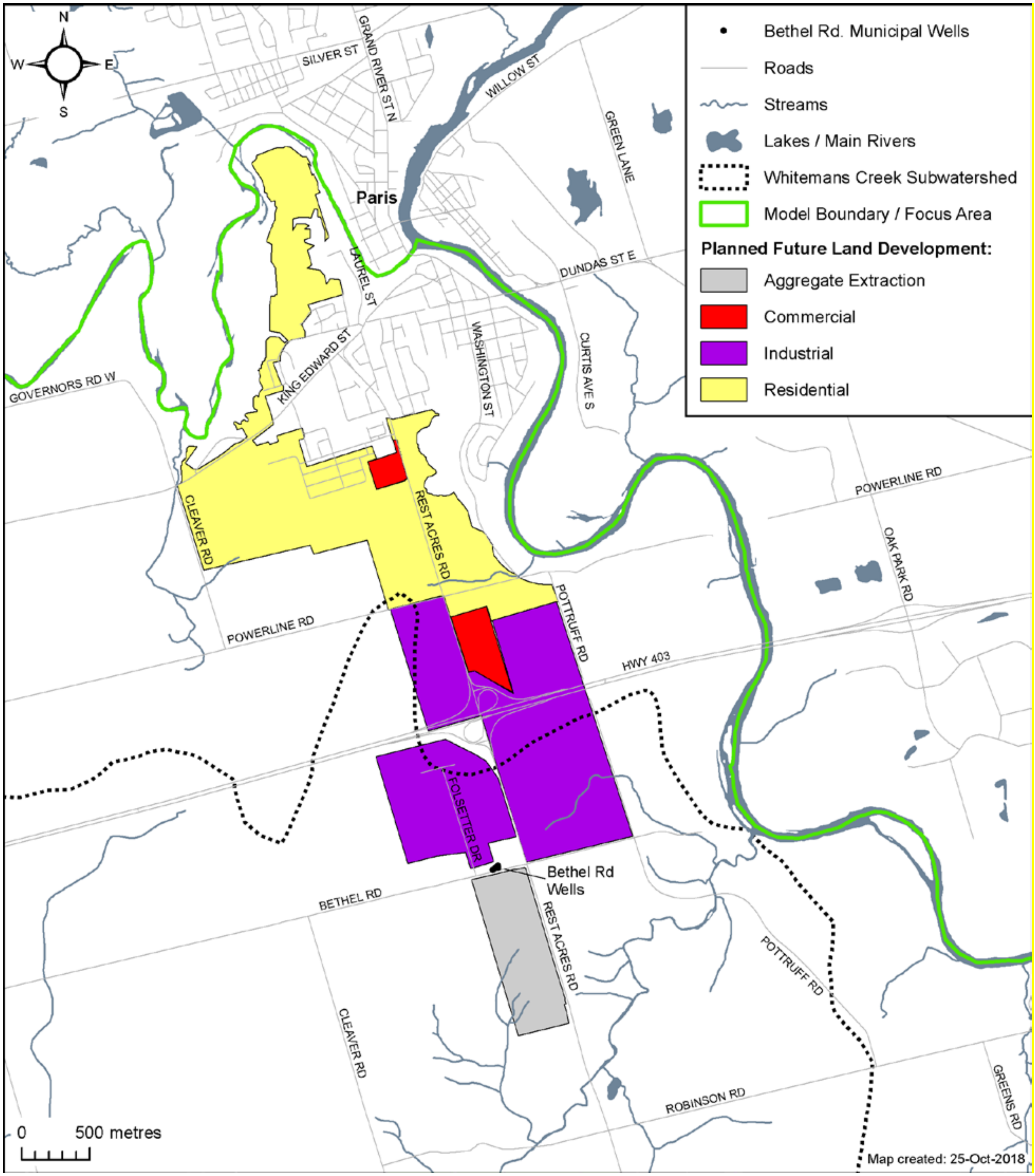
Map 21-2: Tier 3 Study and Focus Area Topography



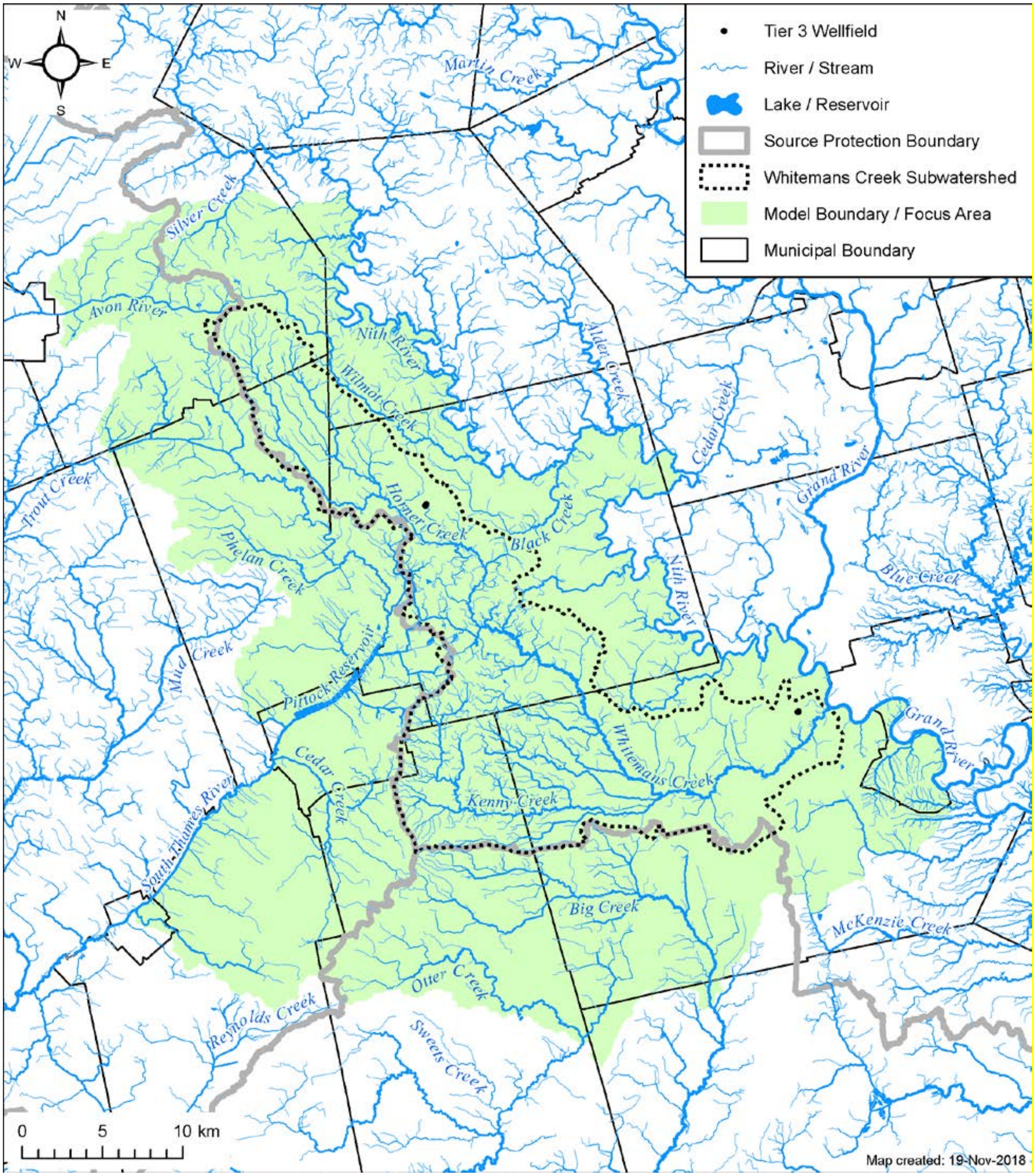
Map 21-3: Land Use Change – Bright Well Field



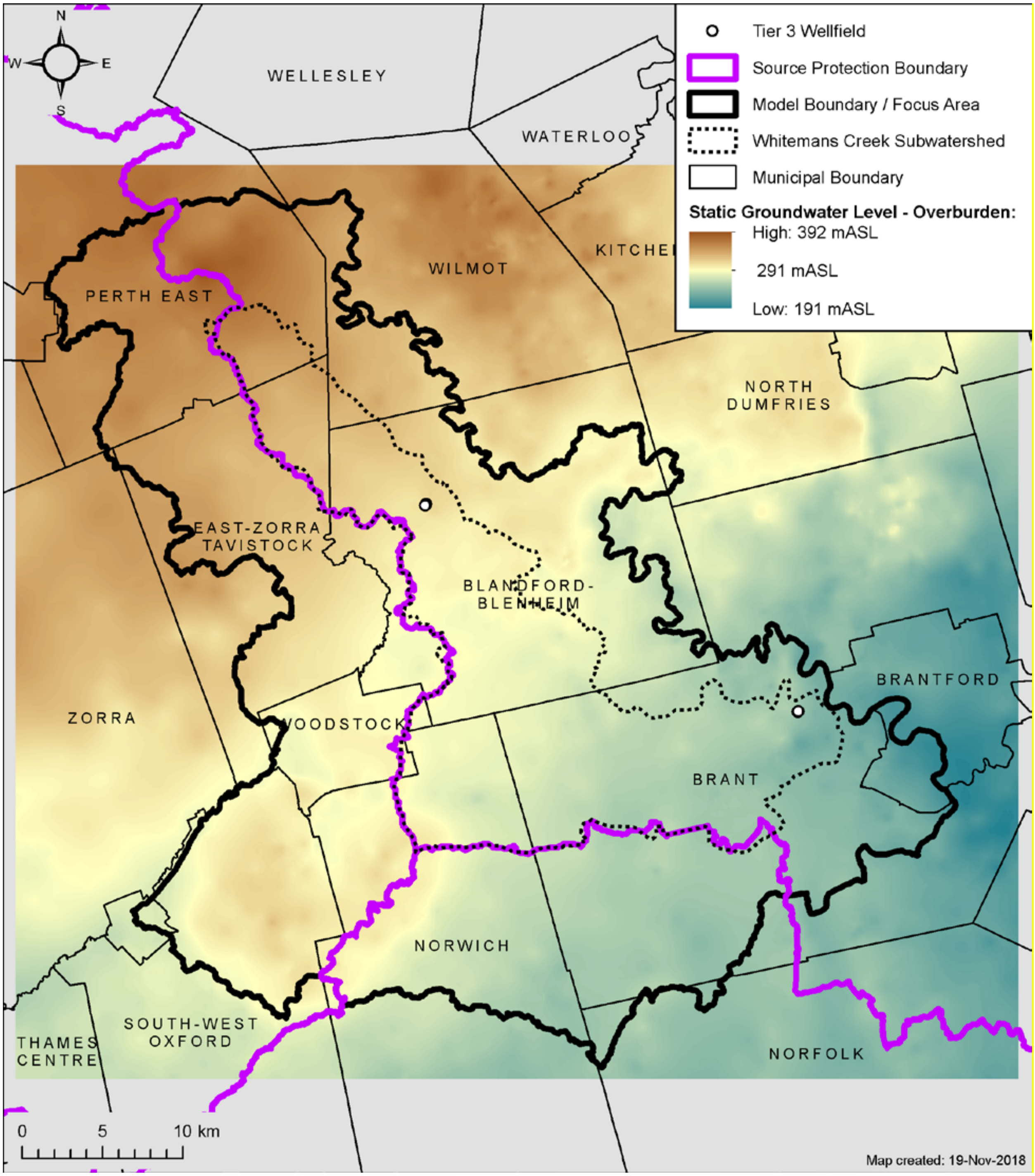
Map 21-4: Land Use Change – Bethel Well Field



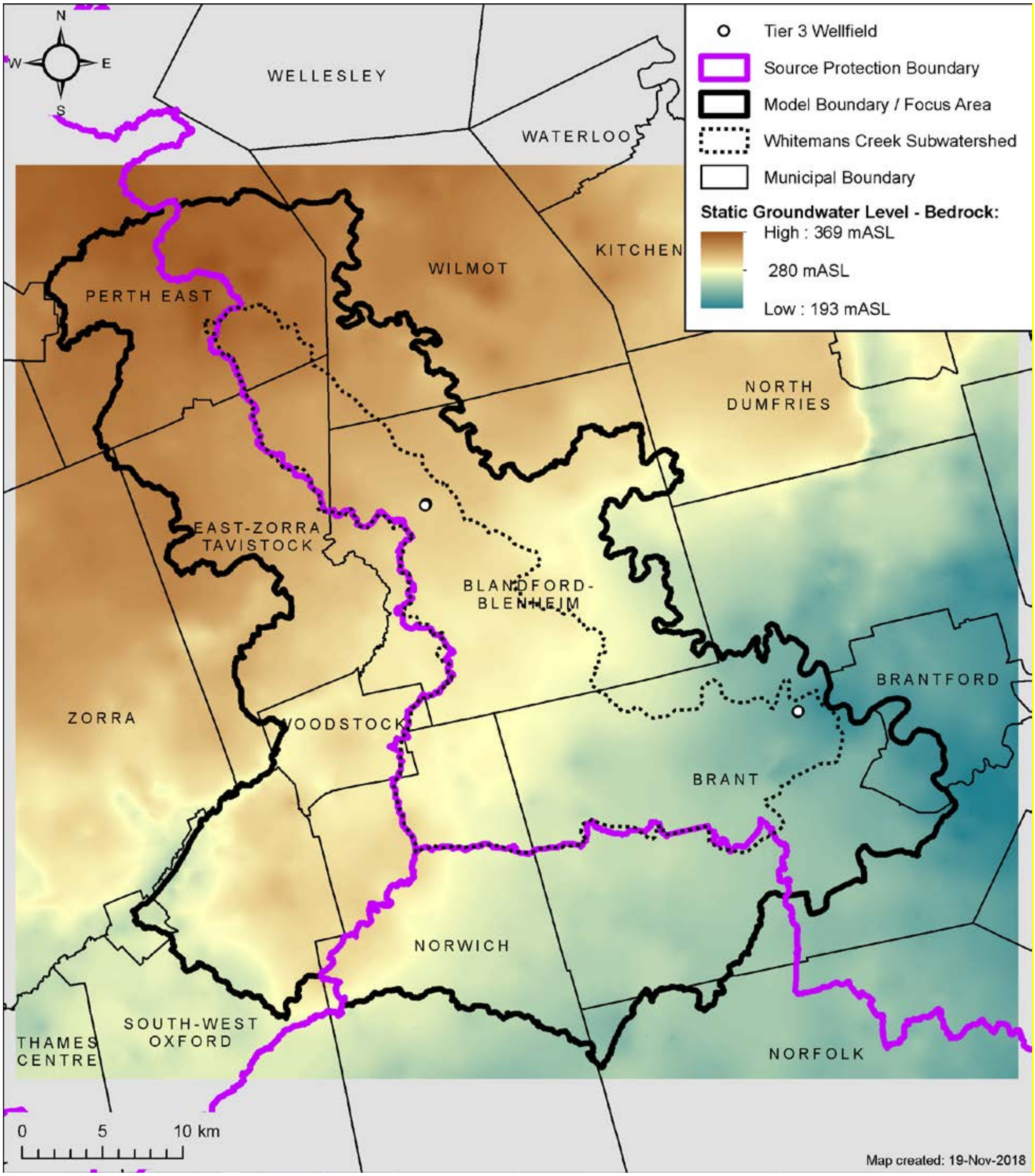
Map 21-5: Tier 3 Study Area Surface Water Features



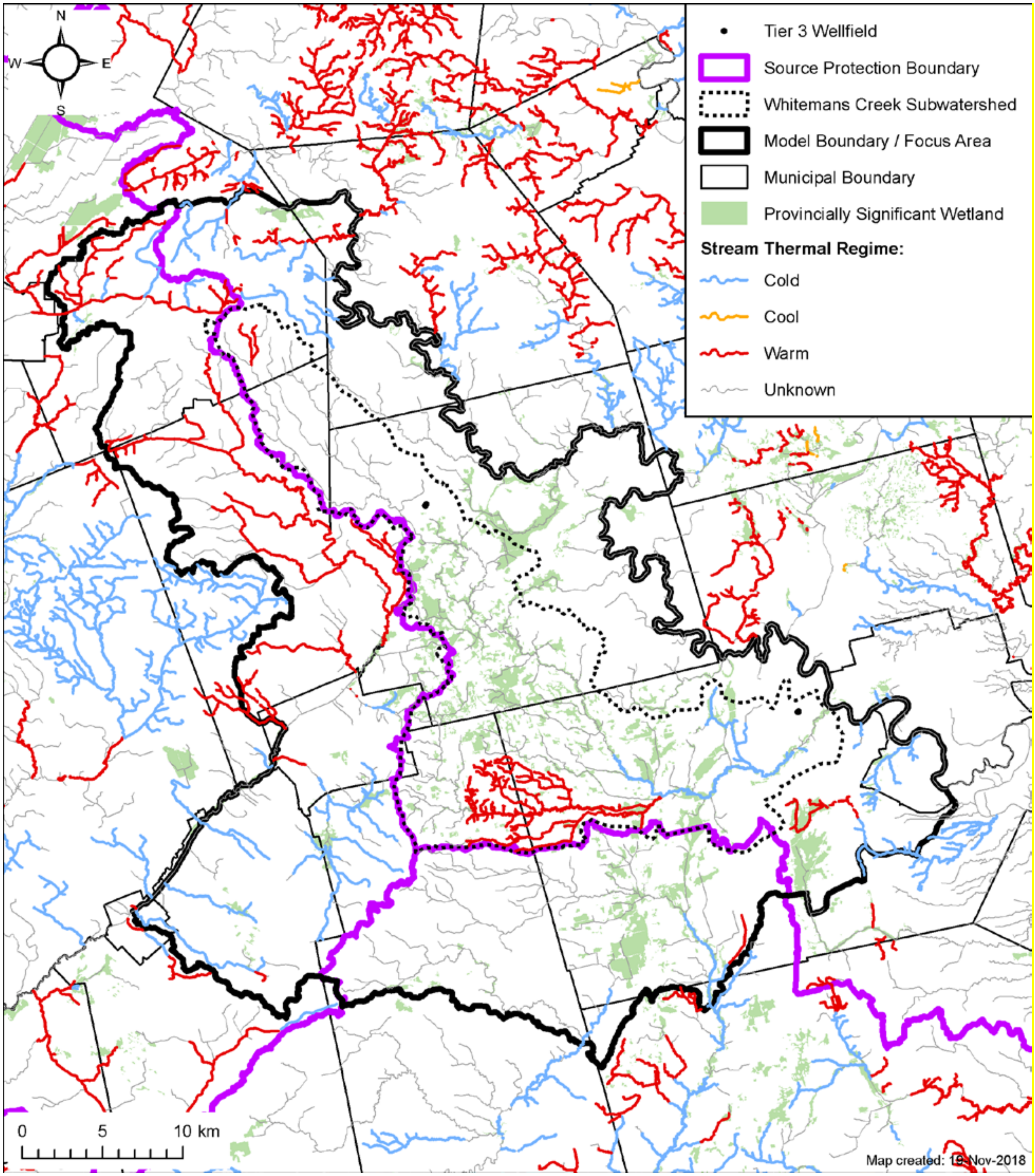
Map 21-6: Static Groundwater Levels in the Overburden



Map 21-7: Static Groundwater Levels in the Bedrock



Map 21-8: Provincially Significant Wetlands and Coldwater Streams



21.2 Water Demand

21.2.1 Municipal Water Supply

The existing demand for each water supply system is the average of the reported pumping during a specified time period. For the Bethel Well Field, the average is based on data from late 2015 and all of 2016, while the Bright Well Field average is based on data from 2012 to 2014.

The committed demand is the increase in supply required if the serviced area were developed according to the local Official Plan. For a municipal water supply, the committed demand must be less than the permitted rate, as per the Permit to Take Water (PTTW). For the Bright Well Field, the committed demand considers the addition of 18 future homes, assuming a population density of 2.89 people per household. For the Bethel Well Field, the committed demand was back-calculated from the allocated demand, as described below.

The planned demand is the amount of water required to meet growth associated within a Master Plan or Class Environmental Assessment, which is not linked to growth within an Official Plan. There are no plans to expand either well field beyond their existing capacity; therefore, no planned demand is associated with either the Bright or Bethel well fields.

Collectively, the existing, committed, and planned demands are referred to as the allocated demand. The allocated demand for the Bright Well Field was calculated by adding the existing and committed demand. The allocated demand for the Bethel Well Field is assumed to be approximately half the allocated water demand for Zone 3 of the Paris water distribution system, or 1,373.8 m3/day. This assumption is made because the Bethel Well Field is a backup source of water for Zone 3 of the Paris water distribution system, which receives its primary water supply from the Sharpe Reservoir.

Table 21-2 lists the existing, committed, and allocated water demand for each well field, as obtained from Earthfx (2018a). For both well fields, the allocated demand is below the currently permitted rate.

Table 21-2: Municipal Water Demand

Well Name	Permitted Rate (m^3/day)	Existing Demand (m^3/day)	Committed Demand (m^3/day)	Allocated Demand (m^3/day)
Bright Municipal Drinking Water System				
Well 4A	327	88.8	12.4	101.2
Well 5		6.7	0.9	7.6
Total		***95.5***	***13.3***	***108.8***
Bethel Municipal Drinking Water System				
TW1/05	3,240	53.7	376.9	430.6
P1/12		80.4	234.0	314.4
P2/12		89.9	224.5	314.4
P4/12		90.1	224.3	314.4
Total		***314.1***	***1,059.7***	***1,373.8***

Consumptive demand is the amount of water taken from a water source that is not returned to the same source within a reasonable amount of time. Municipal takings from both the Bright and Bethel well fields are conservatively assumed to be 100% consumptive. For example, water extracted from the Bethel municipal drinking water system is sent to the town of Paris, where it is used then subsequently treated and discharged to the Grand River. Since it does not return to the same source, it therefore contributes to the consumptive demand of the system. As discussed further in the Risk Assessment Section, the consumptive demand of a water taking affects how it is assessed as part of the risk assessment.

21.2.2 Agricultural Irrigation Demand

Non-municipal water demands were assessed by examining the MECP PTTW database, which contains information pertaining to other water takers in the area. The MECP Water Taking Reporting System (WTRS) database was also consulted for the periods 2009 to 2014. Data prior to 2009 were considered incomplete and therefore were not considered. Finally, the MECP WWIS was consulted to identify wells used as a non-municipal water supply.

The largest category of permitted water takers in the area is agricultural. The Study Area includes 369 permitted groundwater users and 90 surface water users for agricultural purposes. The majority are in the Norfolk Sand Plain region, in the southeastern portion of the Study Area: the well-drained soils in this region require crops to be irrigated more regularly. In the Whitemans Creek subwatershed, agricultural water users account for 98% of the non-municipal permits.

The volume and timing of agricultural water use was estimated with a custom irrigation demand module within the water budget numerical model that considered factors such as farm size, crop type, crop needs, equipment limitations, and soil properties. This level of detail, for estimating irrigation demand, was considered necessary based on the large number of agricultural users in the Study Area.

21.2.3 Other Non-Municipal Water Demands

Other non-municipal permitted water users were also identified and takings analyzed. These included water supply for commercial (aquaculture and golf courses), construction, industrial, and other water supply well uses. These non-municipal, permitted, water uses are distributed fairly evenly across the Study Area and assumed be 100 % consumptive. Water takings reported to the WTRS for non-municipal, permitted, water uses were between 2,180 m^3/day and 5,576 m^3/day for 2012 to 2014. However, these numbers are likely underreported, since municipal takings are permitted at 5,251 m^3/day, with actual takings between 111 m^3/day and 166 m^3/day for same period. The total estimated water taking from non-municipal, permitted, water uses (groundwater and surface water) at approximately 76,940 m^3/day for the Whitemans Creek subwatershed.

Non-municipal, non-permitted, water users in the Study Area include domestic supply wells and livestock watering. A total of 1,258 wells were identified as domestic water supply within the Whitemans Creek subwatershed, based on a review of the MECP WWIS. The consumptive demand of private domestic supply wells was not considered in the Water Budget Model because their water taking rates are relatively low, compared to other takings. Additionally, since they are widely dispersed across the Study Area, the effect of the water taking is equally distributed in all areas. For the Water Budget Model, the livestock water demand was estimated based on the type and quantity of livestock animals for each farm. The total simulated livestock demand was estimated at 1,445 m^3/day for the Whitemans Creek subwatershed. Livestock water takings are not as well distributed across the Study Area as domestic water takings, and were therefore considered as part of the modelling.

21.2.4 Coldwater Streams and Provincially Significant Wetlands

Water demand assessments must consider an area's ability to meet allocated municipal water demand while maintaining requirements for other users who rely on groundwater resources to sustain their habitat, such as coldwater streams and provincially significant wetlands.

The coldwater reaches considered in the Water Budget Model include the lower part of Horner Creek, Whitemans Creek, and Landon's Creek, which is a small tributary to Whitemans Creek. The Whitemans Creek subwatershed also contains many provincially significant wetlands. A wetland complex flanks the majority of Whitemans Creek and its main tributaries, Kenny Creek and Horner Creek. These features are shown on **Map 21-8**. The risk assessment evaluated the impacts of allocated demand to water levels in these sensitive features.

21.3 Water Budget Model

21.3.1 Model Development

A fully-integrated surface and groundwater modelling approach was used to address the significant interaction between the groundwater and surface water systems in the Whitemans Creek watershed. The United States Geological Survey's GSFLOW code (Markstrom et al., 2008) was used to develop the Water Budget Model. GSFLOW is an integrated surface water/groundwater code based on two submodels: the Precipitation Runoff Modelling System (PRMS) (Leavesley et al., 1986), which simulates surface water flow processes, and MODFLOW-NWT (Niswonger et al., 2001), which simulates groundwater flow processes. Earthfx (2018a) added a third submodel to GSFLOW, the Irrigation Demand Submodel, to estimate irrigation water demands and simulate the fate of applied irrigation water.

The surface water and groundwater characterization formed the framework for the numerical model. Modelling the surface water system required inputs of climate, topography, land use, and surficial geology. For the groundwater system, only flow in the overburden, Weathered Bedrock Contact aquifer, and Onandaga Limestone aquifer was simulated, since groundwater flow in the lower bedrock does not contribute to the water supply of the Bright and Bethel well fields. Additionally, stresses on groundwater flow such as water takings, were incorporated based on water demand estimates including inputs into the irrigation demand model..

21.3.2 Model Calibration

The PRMS and MODFLOW-NWT submodels were pre-calibrated using stream flow data from the Water Survey of Canada, and static water level data from the WWIS, as calibration targets. Submodel parameters were modified until a reasonable match was obtained between the observed and simulated targets. The submodels were thencombined into the integrated GSFLOW model.

The GSFLOW model was transiently calibrated to conditions observed from 2006 to 2015. Calibration targets included shallow subsurface water level data collected in 2015 for the Tier 3 field program; continuous groundwater levels from the PGMN between 2006 and 2015; and continuous groundwater levels from municipal monitoring and production wells, between 2006 and 2015 at the Bright Well Field and between 2012 and 2015 at the Bethel Well Field. Surface water calibration targets were continuous stream flow data collected by the Water Survey of Canada between 2006 and 2015.

GSFLOW model calibration was more comprehensive than submodel pre-calibration as it required modifying a wider range of parameters to improve the match between the observed and simulated calibration targets. Earthfx (2018a) concluded that the GSFLOW model provides "a solid foundation for undertaking the Tier 3 Risk Assessment", based on their evaluation of calibration results. The following arguments were offered in support of this conclusion:

- In general, the GSFLOW model can replicate streamflow conditions, with a tendency to underpredict observed flows particularly during high flow conditions (e.g., the spring freshet).
- In general, the GSFLOW model can replicate seasonal (in the shallow subsurface) and long-term (on a regional scale) groundwater level responses.

Locally, at the Bethel and Bright well fields, the GSFLOW model provides a good match to the timing and magnitude of groundwater level fluctuations in response to changes in recharge and pumping. However, there is a discrepancy in the match to actual groundwater elevations. This limitation will not impact use of the GSFLOW model for the risk assessment, because the risk assessment evaluates the magnitude of groundwater level change, which the GSFLOW model can adequately replicate.

There is limited calibration data available for the Bethel Well Field, since the four production wells have only been in operation since summer 2015. The limited data creates some uncertainty in model results, which will affect the confidence in risk assessment results for this well field.

21.4 Risk Assessment

Eight risk assessment scenarios were simulated with the Tier 3 Model to determine the likelihood that the Bright and Bethel well fields would be able to meet future water demands. The scenarios simulated existing conditions as well as future land use and/or allocated water demand under average climate conditions and a 10-year drought. The period from 1975 to 2010 was used for average climate conditions. Precipitation input for the 10-year drought were taken from the 1957 to 1962 drought, which had an average of 829 mm/yr of precipitation; this is 126 mm/yr lower than the typical annual average (1967 to 2016), or 955 mm/yr.

21.4.1 Vulnerable Areas

WHPA-Q

A WHPA-Q1 was defined for each well field, using the results of existing conditions and the allocated water demand-average climate scenario, with a drawdown threshold of 1.0 m for the Bright Well Field and 0.5 m for the Bethel Well Field. Drawdown thresholds were selected based on a review of seasonal groundwater level fluctuations at each well field.

The simulated drawdown did not exceed the 1.0 m drawdown threshold at the Bright Well Field. The WHPA-Q1 was therefore delineated as a circle with a radius of 100 m around each production well (**Map 21-9**). The WHPA-Q1 for the Bethel Well Field is a 6 km^2 gum-drop shaped area that extends approximately 250 m to the north and south, 300 m to the west, and 400 m to the east (**Map 21-10**).

A WHPA-Q2 is defined as the WHPA-Q1 plus any area where future reductions in recharge from proposed development would have a measureable impact on water levels at the municipal wells. Model simulations were run with recharge rates adjusted for proposed developments.

These simulations did not result in a measureable impact. Therefore the WHPA-Q2 was determined to equal the WHPA-Q1 at both Bethel and Bright and will be referred to as the WHPA-Q.

Significant Groundwater Recharge Areas

The method under the Technical Rules used to delineate Significant Groundwater Recharge Areas (SGRAs) was an SGRA is the area that annually recharges water to the underlying aquifer at a rate that is greater than 1.15 or more of the annual rate of recharge across the Study Area.

The average annual rate of recharge across the Tier 3 Study Area is 295 mm/yr. Therefore, with the Water Budget Model, any model cell with an average annual recharge greater than 340 mm/yr was tagged as SGRA. Smoothing/infilling was then completed to remove holes within large groupings of tagged cells, or to remove isolated tagged cells that were considered anomalies. The smoothing/infilling procedure was completed to make it easier to use SGRAs for land use and water management planning.

Higher groundwater recharge is associated with the Lower Whitemans Sand Plain in the south of the Study Area and the Central Whitemans Glacial Outwash in the centre of the Study Area, where sand and gravel is found at surface. **Map 21-11** shows the SGRAs mapped as part of this Study, which are largely associated with these higher areas of groundwater recharge.

WHPA-Q Risk Levels

Risk levels were assigned to each WHPA-Q by assessing the change in simulated water level at each production well compared to the safe available drawdown. Per the Technical Rules, risk levels do not need to be assigned to SGRAs.

The safe available drawdown is the difference between the average pumped water level in a production well and the lowest water level at which the production well can be safely operated. The available drawdown at the Bright Well Field is estimated at 7 m for Production Well 4A and 12.5 m for Production Well 5. At the Bethel Well Field, available drawdown estimates are 14.7 m, 9.4 m, 9.5 m, and 8.9 m for Production Well TW1/05 (P52), PW1/12 (P51), PW2/12 (P53), and PW4/12 (P54), respectively.

Bright Wellfield

Production Well 4A and Well 5 met existing and allocated water demand, under future land use, average climate and drought conditions, without exceeding safe available drawdown. No impacts were predicted to other groundwater users, aquatic habitat, or wetlands with future land use, allocated water demand and the 10-year drought, which is the worst-case for potential impacts. These results are consistent with the prediction of minimal drawdown, less than 0.5 m, near the production wells between existing conditions and the allocated water demand-average climate scenario.

Based on the above, the WHPA-Q for the Bright Well Field was assigned a risk level of “low”. There is a high level of confidence in the GSFLOW model results for the Bright Well Field, as the model can accurately simulate the timing and magnitude change in groundwater levels for a reasonable length of time (seven years). The level of uncertainty in the Bright risk level assignment is therefore considered to be low.

Bethel Wellfield

Production Wells TW1/05, PW1/2, PW2/12, and PW4/12 all met existing water demands, under future land use, average climate and drought conditions, without exceeding safe available drawdown. The same was true for allocated water demand, under future land use and average climate. However, under drought conditions, the production wells could not meet the allocated water demand, because drawdown exceeded the available drawdown, and water level impacts were predicted for some nearby shallow wells. These results suggest that the Bethel Well Field can meet water demands under drought conditions with future land use changes, assuming water taking rates remain at current levels.

No aquatic habitat near the Bethel Well Field experienced a flow reduction of 10% or greater under the worst-case scenario for potential impacts. The overall risk of impact to aquatic habitat is considered to be low. Five unevaluated wetlands lie within the WHPA-Q for the Bethel Well Field, indicating that drawdowns greater than 0.5 m are expected at these features. These wetlands should be evaluated to better assess the potential risk of impact.

The WHPA-Q for the Bethel Well Field was assigned a risk level of “significant” because it could not meet the allocated demand under drought conditions. However, less than one year of data were available for model calibration because combined pumping at the well field only began in summer 2015. Having such scarce data reduces the confidence in the model results and creates a high level of uncertainty in the Bethel Well Field WHPA-Q risk level assignment. Depending on the significance of risk assessment results to land use and water management policies in the County of Brant, the Tier 3 Model may need to be revisited as additional calibration data become available for the Bethel Well Field.

21.4.2 Significant Water Quantity Threats

A significant water quantity threat can only exist in a WHPA-Q where a moderate or significant risk level has been assigned. Water quantity threats apply to existing or proposed consumptive water uses or activities that reduce groundwater recharge.

The WHPA-Q for the Bright Well Field was assigned a low risk level; significant water quantity threats therefore cannot exist for this municipal water supply. The WHPA-Q for the Bethel Well Field was assigned a significant risk level; significant water quantity threats can therefore exist for this municipal supply.

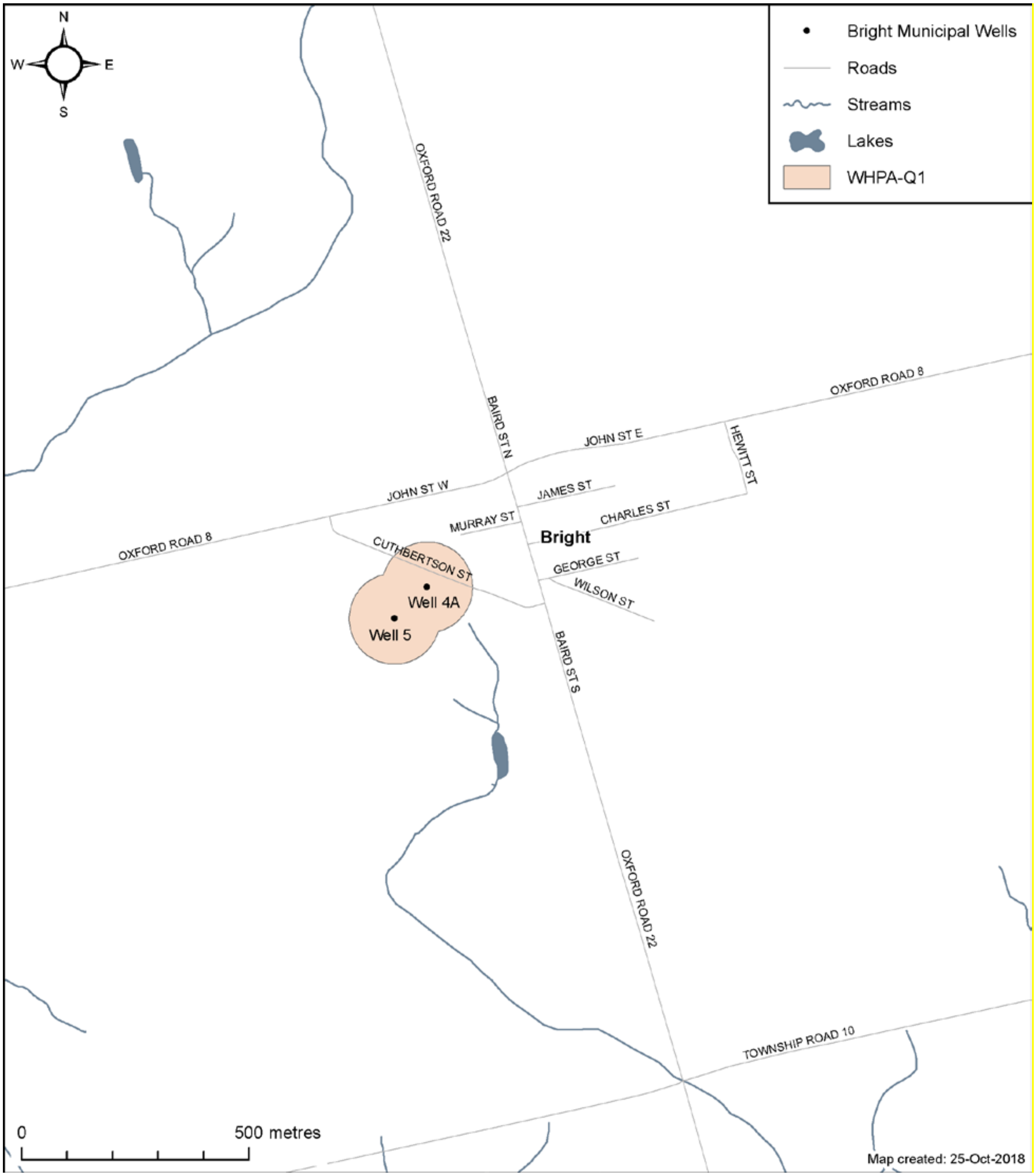
A total of 19 consumptive water uses were identified in the Bethel WHPA-Q: 14 non-municipal, non-permitted uses (e.g., private domestic and livestock water supply wells); four municipal permitted uses (e.g., the Bethel Production Wells); and one non-municipal, permitted water use (e.g., water supply for an aggregate operation). Each of these consumptive water uses is considered a significant water quantity threat to the Bethel municipal water supply. A total of 243 ha of existing and future land development were also identified as a significant water quantity threat: this development will increase the total area of impervious surfaces (e.g., paved roads) and therefore has the potential to reduce groundwater recharge within the WHPA-Q. The significant water quantity threats to the Bethel municipal water supply are illustrated on **Map 21-12** and detailed in **Table 21-3**.

Table 21-3: Summary of Significant Water Quantity Threats – Bethel Well field

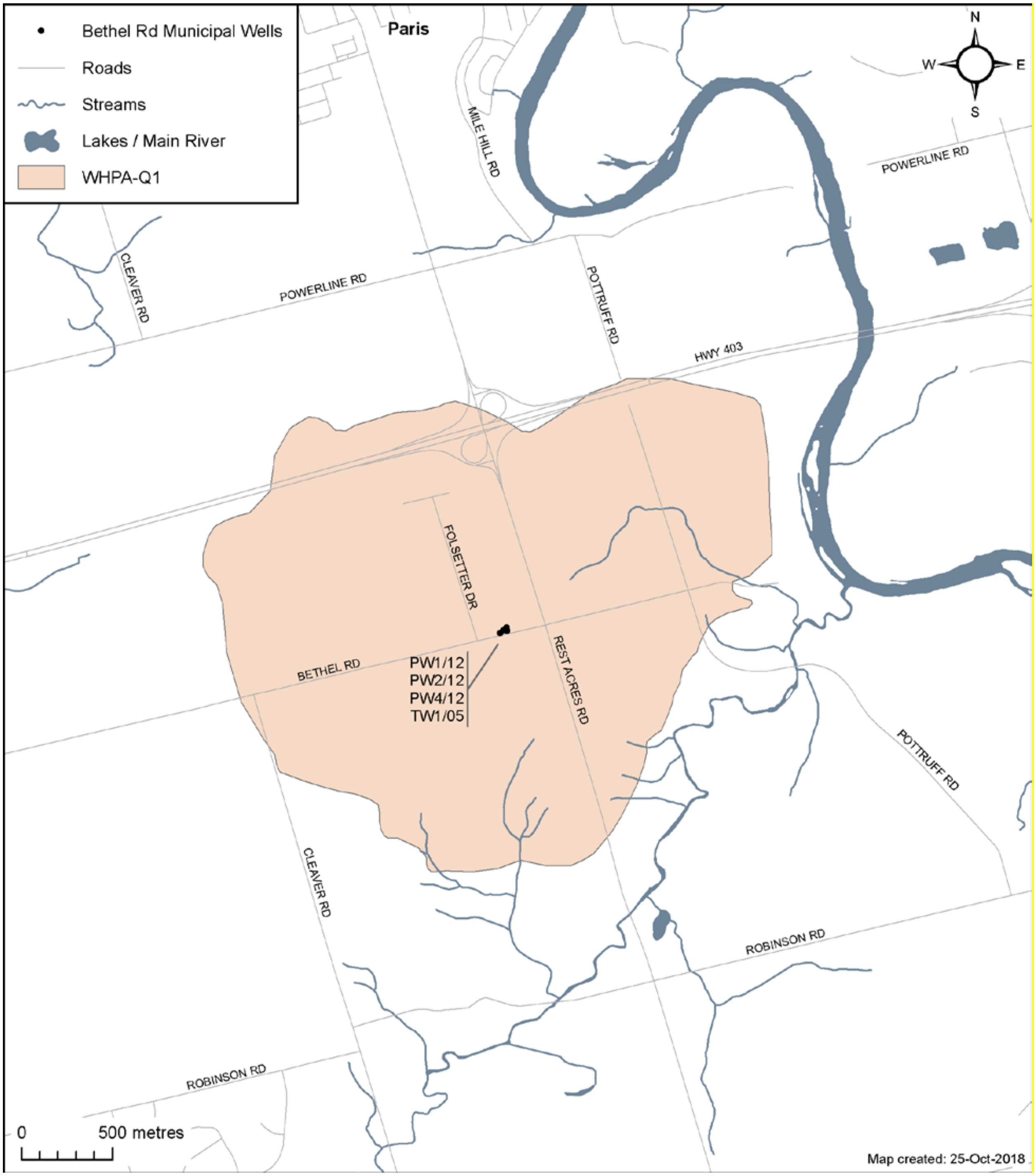
Threat Group	Vulnerable Area
	WHPA-Q1
Municipal	4
Non-municipal Permitted	1
Non-municipal, Non-permitted[1]	14
Total	19
Recharge Reduction[2]	2.43 km^2

Notes:
[1]Only domestic water wells recorded in the Water Well Information System database (MOE 2012) are included. These are exempt from permitting if they are taking less than 379,000 L/day.
[2]Recharge reduction threats are summarized by identifying the total area represented by Recharge Reduction Polygons and as a percentage of the total area of interest

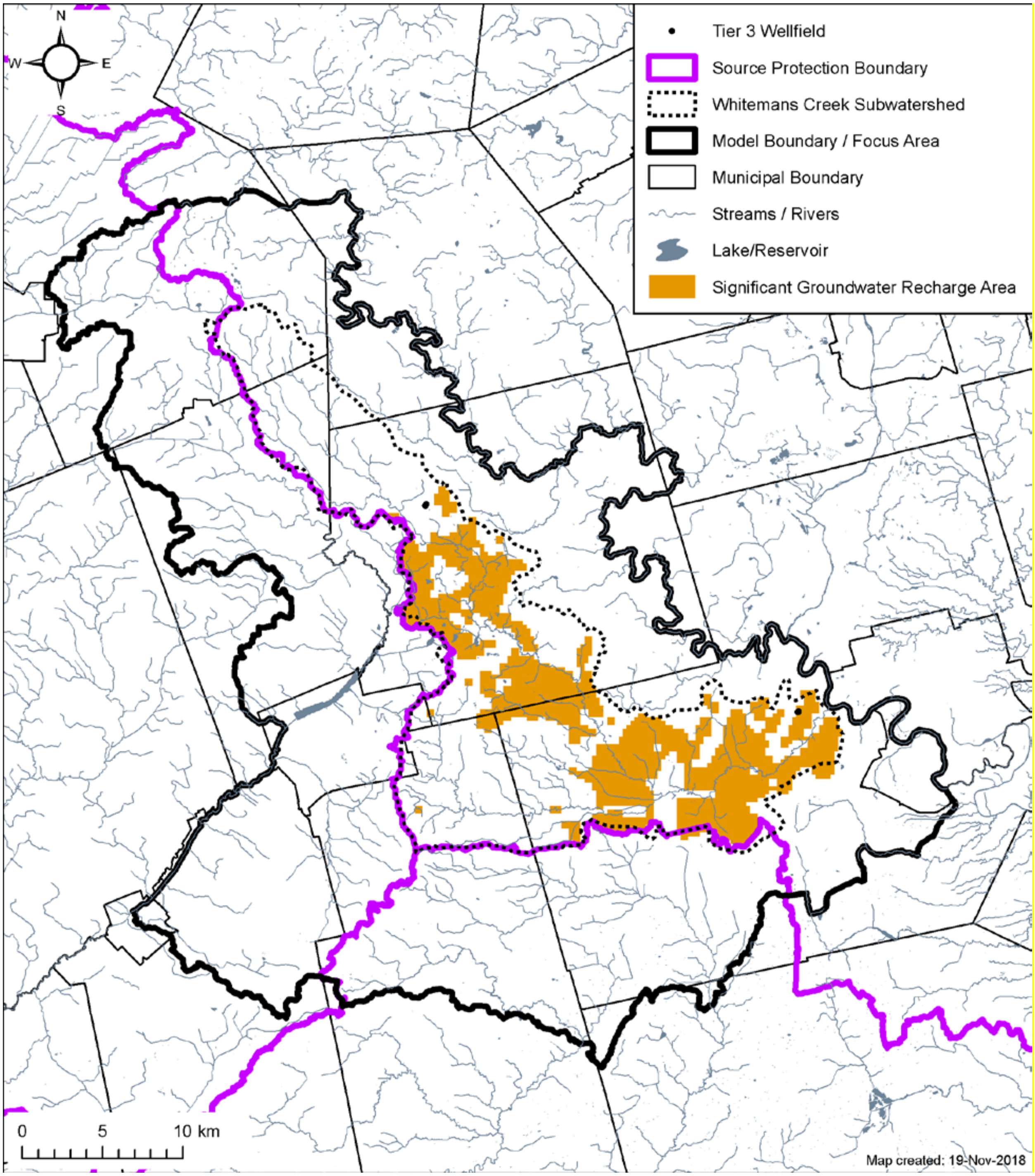
Map 21-9: Wellhead Protection Area for Quantity (WHPA-Q1) – Bright Well Field



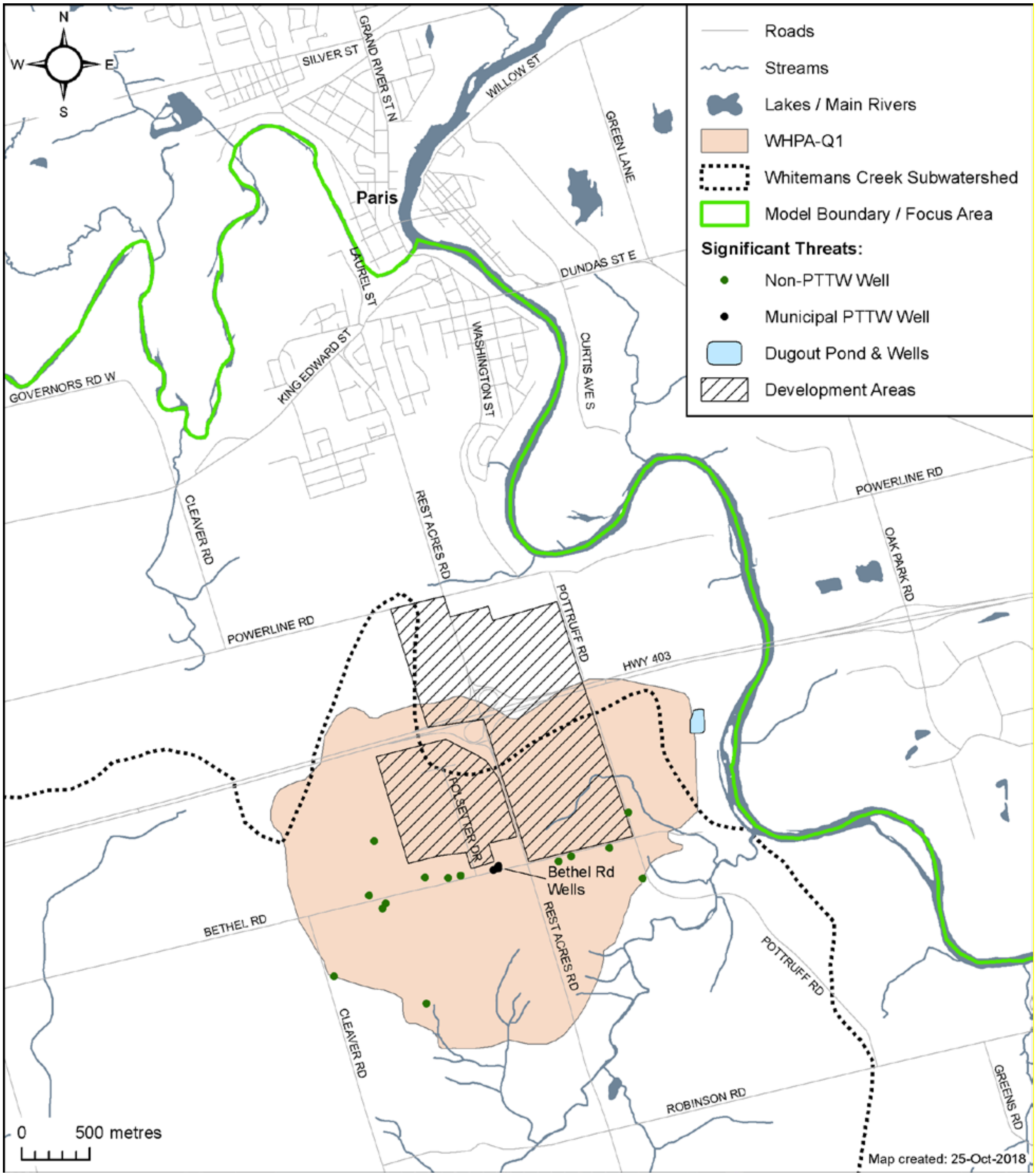
Map 21-10: Wellhead Protection Area for Quantity (WHPA-Q1) – Bethel Well Field



Map 21-11: Significant Groundwater Recharge Areas



Map 21-12: Significant Water Quantity Threats – Bethel Municipal Water Supply



21.5 Summary

The Whitemans Creek Tier 3 Study evaluated the risk of water quantity impacts to the Bright Well Field in Oxford County and to the Bethel Well Field in the County of Brant, given planned growth (future land use and allocated water demand) and variable climate (average and drought conditions).

A refined characterization of the groundwater and surface water regimes was completed and a numerical water budget model was developed using GSFLOW. The water budget model was used to simulate water use across the Whitemans Creek subwatershed and surrounding areas contributing to the watershed's water balance.

Results of the Risk Assessment indicate that the WHPA-Q for the Bright Well Field is a circle of 100 m radius around each production well, with a "low" risk level for water quantity impacts. This finding was based on the production well's ability to meet existing and allocated water demand, under future land use, average climate and drought condition, without exceeding available drawdown; and a prediction of no impacts to other groundwater users, aquatic habitat or wetland under the worst-case conditions for water-quantity impacts.

The WHPA-Q for the Bethel Well Field is a 6 km^2 area with a "significant" risk level for water quantity impacts. This finding was based on the production well's inability to meet allocated demand under drought conditions; and the potential for impacts to neighbouring shallow private wells and wetlands under worst-case conditions for water quantity impacts. There is a high level of uncertainty in the risk assessment results for the Bethel Well Field due to the scarcity of well field calibration data.

21.6 References

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