APPENDIX B

HYDROGEOLOGICAL ASSESSMENT

CITY OF COURTENAY

INTEGRATED RAINWATER MANAGEMENT PLAN (IRMP) - SURFICIAL INFILTRATION POTENTIAL DELINEATION
CITY OF COURTENAY, BRITISH COLUMBIA

Submitted To:

CITY OF COURTENAY

City of Courtenay
830 Cliffe Avenue
Courtenay, BC
V9N 2J7

Submitted By:

Waterline Resources Inc.

Waterline Resources Inc.
Nanaimo, British Columbia
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1.0 INTRODUCTION

The City of Courtenay (the City) is preparing an integrated rainwater management plan (IRMP) to support sustainable development within the municipal boundary (Figure 1). Stage 2 data collection of the IRMP is on-going in conjunction with stakeholder engagement (Stage 1). The goal of Stage 2 is to initiate and guide the evaluation of rain management strategies (Stage 3) before the end of 2019.

On behalf of the City, Urban Systems Ltd. (USL) has retained Waterline Resources Inc. (Waterline) to provide a high-level hydrogeological interpretation of the mapped surficial geology units and an overview of the infiltration potential within the City boundary. This data will be superimposed upon aquifer vulnerability mapping to guide future subsurface stormwater disposal infrastructure design criteria with a view to promote sustainable development within the City. It is understood that, in addition to consideration of vulnerable aquifers, the IRMP will also consider other valued ecosystem components such as surface water and biological resources.

2.0 OBJECTIVES AND SCOPE OF WORK

The objective of this study is to overview surficial infiltration potential based on available surficial geology mapping, City of Courtenay land cover data and a conceptual site model. A secondary objective is to characterize the risk to groundwater quality in mapped aquifers based on the interpreted surficial infiltration potential.

Publicly available data used to complete the study was drawn from various open access sources and data layers from the City. The associated scope of work included:

- **Task 1** – Collection of Public and Courtenay-specific data sets;
- **Task 2** – Data upload into Waterline's GIS Web application tool, known as Enviro Web Services™ (EWS);
- **Task 3** – Development of a Conceptual Site Model whereby poor, marginal, and good infiltration rates were assigned based on descriptions and depositional environments of surficial geological units; and
- **Task 4** – Preparation of a technical report describing the data used and a high-level interpretation of the infiltration potential of surficial geology units and relative risk of stormwater infiltration potential to groundwater quality. The report includes some discussion on infiltration enhancement and additional work as part of management strategies.

3.0 APPROACH TO ASSESSING INFILTRATION POTENTIAL

3.1 GIS Database Development

Waterline has developed a GIS Web application tool, known as Enviro Web Services™ (EWS), which was used to focus our efforts during this desktop study. EWS fully integrates publicly available information on geology, hydrogeology, surface water, climate data and other site-specific information. Information sources include water well records, aquifer mapping where available, surficial and bedrock geology mapping, terrain mapping, real-time hydrometric data collection and numerous other data sources related directly, or peripherally, to hydrogeology and groundwater. The public data set was augmented by private data provided by the City from numerous internal environmental studies and City infrastructure projects. EWS is completely scalable and allows us to view local scale information (quadrants of the City; Courtenay West or Courtenay East), city-scale (entire City of Courtenay) and watershed-scale (Courtenay River Watershed), to conceptualize the hydrogeological regime and define surficial infiltration potential and its potential impact on groundwater quality.

3.2 Available information and Data compilation

EWS was developed to construct two- and three-dimensional hydrogeological images so that both scientific and non-scientific users could visualize and understand how surficial features and activities relate to subsurface aquifers. A significant amount of groundwater and surface water information exists within the City. Data was sourced publicly from various government databases (open access) and directly from the City's private database. Most of the data provided by the City was in digital format (Shapefiles or GIS format). However, surficial geology mapping was digitized and integrated into a consistent electronic format so that surface and subsurface information could be considered concurrently for development of the conceptual site model. In addition, hydraulic conductivity values reported from *Infrastructure Planning Division – Studies and Reports* provided by USL, from the City, were also digitized and were uploaded into EWS. This information was used to confirm interpretations of infiltration potential for the various surficial geology units across the City. A total of 27 reports were reviewed as part of this scope of work.

3.3 Conceptual Site Development

Waterline characterized the relative infiltration potential across the City by assignment of a permeability range to mapped surficial geology units based on their descriptions (gravel, sand, silt or clay) and depositional environment (alluvial, fluvial, marine, glacio-marine etc.). Assigned permeability ranges were based on the authors' experience at performing infiltration tests in various surficial geology units and the general ranges outlined in Freeze and Cherry (1979; *Table 2.2 Range of Hydraulic Conductivity and Permeability*). A copy of Table 2.2 is included in Appendix A. For quality assurance and quality control (QA/QC) purposes, these interpretations were compared with published data for calculated hydraulic conductivities values from laboratory testing of different clast sizes (from Morris, D.A. and A.I. Johnson 1967) and with hydraulic conductivity values reported from past studies for various infrastructure planning projects within the City. The relative infiltration potential and assigned permeability range is provided in Table 1.

Table 1: Relative Infiltration Potential and Assigned Permeability Range

Relative Infiltration Potential	Assigned Permeability Range (m/s)	
	Maximum	Minimum
Good	n/a	$1x10^{-4}$
Marginal	$1x10^{-4}$	$9x10^{-7}$
Poor	$9x10^{-7}$	n/a

Note: n/a means not applicable and there is no upper or lower bound assigned; m/s means metre per second

Generally, granular sediments such as sands and gravels that are well-sorted (poorly graded) mixtures, are highly transmissive and allow surface water to infiltrate freely through the unsaturated zone. These zones were generally assigned a good infiltration capacity. Conversely, cohesive sediments such as silts, clays and poorly sorted (well-graded) mixtures are less transmissive and can restrict the ability of surface water to infiltrate the unsaturated zone. These zones were generally assigned a poor infiltration capacity. A marginal infiltration capacity was assigned where both cohesive sediments and granular sediments were mapped within the same surficial geology unit, and discrete areas having good infiltration capacity and poor infiltration capacity are anticipated. A marginal infiltration capacity was also assigned when a cohesive soil was mapped underlying a granular soil.

Based on this interpretation, a separate infiltration potential layer was developed. The infiltration potential layer was superimposed upon layers representing land cover, topography, bedrock exposures that are expected to restrict infiltration potential to varying degrees. Finally, a separate layer showing the extent of mapped aquifers underlying the City was applied. Superimposition of these layers facilitated development of our conceptual site model and identification of areas where surface water (precipitation and overland flow) is likely to infiltrate the unsaturated zone and report to the underlying aquifers.

A summary of the key GIS layer references for this project is presented in Table 2.

Table 2: List of Data Provided by the City and Public Sources

Relevant Data Layers	Reference and Date (if known)
Private Data	
Cadastral Data (Land Parcels, Roadways)	City of Courtenay, 2019
Municipal Boundary	City of Courtenay, 2014
Building Footprints	City of Courtenay, 2017
OCP Land Use	City of Courtenay, 2005
Watercourses	City of Courtenay, 2017
Storm water Infrastructure (All)	City of Courtenay, 2019
2012 LiDAR (most recent available)	City of Courtenay, 2012
Land Cover Type	City of Courtenay, Unknown
Infrastructure Planning Division – Studies and Reports	City of Courtenay, Database 5225-21
Public Data	
Surficial Geology	Fyles 1960
Bedrock Geology	Massey et. al., 2005
Watershed Data	GeoBC, 2011
Water Survey of Canada (Hydrometric Stations)	Environment and Climate Change Canada, 2019
Aquifer Mapping	Government of BC Ministry of Environment, 2019
Water Wells	Government of BC Ministry of Environment, 2019
Crown Land Parcels in British Columbia	ParcelMap BC Parcel Fabric, 2016

4.0 PHYSICAL FRAMEWORK

The following subsections outline the physical framework of the City and the technical evaluation of the data used to develop the conceptual site model.

4.1 Study Area and Land Use

The City encompasses a total area of 34 square kilometres (km^2) along east coast of Vancouver Island straddling the Tsolum and Courtenay River Valley adjacent the Courtenay River discharge into the Strait of Georgia (Figure 1). It is bordered to the southwest by Cumberland; to the south by Royston; and to the east by Comox and to the north and northwest by the Comox Valley Regional District (Figure 1). The City and surrounding area are made up of various land use types as listed on Figure 2.

The City's land use distribution shows:

- 15% is unassigned, defined as roadways, ocean, and easements;
- 49% is assigned as residential, for urban, suburban, and rural settings;
- 25% is assigned as agricultural, industrial, and commercial; and
- 11% is assigned as parks, recreation, and public use.

The existing storm water infrastructure within the City has also been identified as an important data layer to the overall IRMP (Figure 3). The system has 52 storm catchment areas with various storm water network lines (gravity mains and open drains) that primarily follow the main roadways (Figure 3). The existing storm detention areas are assumed to be impermeable to subsurface exfiltration. They are connected to the storm water network lines and designed to temporarily hold stormwater prior to discharging via the storm water network to storm discharge points (Figure 3). Storm discharge points are mainly in low-lying areas adjacent surface water bodies (Figure 3).

4.2 Topography and Surface Water Features

The City is centred at the mouth of the Tsolum and Puntledge Rivers, which combine to become the Courtenay River (Figure 4). The Courtenay River discharges into the Straight of Georgia 2.3 km downstream of the confluence of Tsolum and the Puntledge Rivers. The City's municipal boundaries also transect the Millard Creek, Little River, Brooklyn Creek and Glen Urquhart Creek watersheds (Figure 4). All six watersheds are part of the larger Courtenay River basin (Figure 4), with a total combined area of 907 km^2.

Of the larger watercourses, the Tsolum and Puntledge Rivers have reported discharge rates ranging between <1 and 220 m^3/s and 6 to 200 m^3/s, respectively. This data represents a one-year cycle between July 1, 2018 to July 1, 2019 (Environment and Climate Change Canada, 2019). As expected, these changes in flow rate correspond to seasonal fluctuation of river levels between the winter months (high river level) and the summer months (low river level). Water levels ranged by 3 m in the Tsolum River and 2 m in the Puntledge River (Environment and Climate Change Canada, 2019).

Topography within the municipal boundary is variable and ranges between 0 to 95 metres above sea level (masl). The topographic high point is at the intersection of Ryan Rd and Lerwick Rd, and marks the divide between the Tsolum River, Glen Urquhart Creek, Brooklyn Creek and Little River watersheds (Figure 5). These watersheds drain the City east of the Tsolum River. The Millard Creek watershed drains the City south of the Puntledge and west of the Tsolum River (Figure 5).

Generally, topography is expected to affect subsurface infiltration such that a greater percentage of runoff is expected to infiltrate to the subsurface in flat-laying areas and a lesser percentage of runoff is expected to infiltrate the subsurface on slopes.

4.3 Geology

Landscape and landforms within the City resulted from glacial and post-glacial processes. The latest and largest glacial period was the Fraser Glaciation which deposited most of the present-day surficial sediments. These sediments have since been re-worked by modern (post glacial) fluvial and marine transport processes.

Surficial geology within the City was mapped by the Geological Survey of Canada (Fyles 1960). The surficial geology map has been digitized, geo-referenced and compiled on EWS and was considered in the development of the conceptual site model (Figure 6). A bedrock geology map prepared by the BC Geological Survey (Massey et. al., 2005) covering the City was referenced for rock type and structure (Figure 7). The bedrock geology beneath the entire City is mapped as Nanaimo Group sedimentary rocks comprised of conglomerate, sandstone, siltstone, shale, and coal.

4.3.1 Surficial Geology

Unconsolidated surficial deposits within the City are conceptualized in the following stratigraphic sequence (youngest to oldest):

1. **Salish:** Recent shore, deltaic, and fluvial deposits deposited by rivers and creeks and by wave action along coastal areas (Fyles 1963). The deposits contain gravel, sand, silt, clay, peat, and can form local aquifers along river/creeks (Bednarski 2015). The Salish sediments are designated as Unit 8 on Figure 6.
2. **Capilano:** Glacio-fluvial, deltaic, and marine veneer deposits deposited during glacial retreat and ocean regression (Fyles 1963). The deposits contain silt, clay, stony clay, with the coarser fractions forming local unconfined aquifers, whereas the finer clays and silts form aquitards (Clague 1977). The Capilano sediments are designated as Units 5 and Unit 6 on Figure 6.
3. **Vashon:** Glacio-fluvial material deposited during glaciation by surface and/or subsurface rivers and creeks formed with the retreat of ice sheets (Fyles 1963). The deposits are an extension of the Capilano sediments, containing sand, gravel, clay, and dense clay till (Fyles 1960). Like the Capilano sediments, the coarser fractions form local unconfined aquifers, whereas the finer clays and silts form aquitards (Clague 1977). The Vashon sediments are designated as 5d|3, 5e|3 and 7, 3, R on Figure 6. Units 5d|3 and 5e|3 are described has being a combination of both Vashon and Capilano sediments.
4. **Quadra:** Pro-glacial fluvial outwash materials deposited during glacial advance at the leading edge of the ice sheet (Fyles 1963). The Quadra is composed of mainly sand, with minor gravel, silt, peat, peaty soil, driftwood, forming regionally significant aquifers (Clague 1977). Where the Quadra sands are mapped within the City, they are below a veneer of Capilano sediments (unconformity) and or directly exposed at ground surface (such as at the Anderton Pit). The Quadra sediments are designated as 5d/1 and 5d/2 on Figure 6. Units 5d/1 and 5d/2 are described has being a combination of both Quadra and Capilano sediments.

4.3.2 Bedrock Geology

Bedrock (the Nanaimo group) is a regionally extensive unit (Figure 7), displaying a pattern of alternating coarse-grained (potential regional aquifers) and fine-grained (potential regional aquitards) material (Hamblin, A.O. 2012). The Nanaimo group is known locally in the City, as the Comox formation (lowermost unit of the Nanaimo group). The Comox formation is a sandstone and conglomerate deposited along a fluvial shoreline (Hamblin, A.O. 2012).

Where post-glacial processes have eroded surficial deposits, the Comox formation is now exposed at surface. These areas are designated as subset R on Figure 6. The Comox formation has the potential to be a bedrock aquifer, especially where fractures, caused by faulting exist (Figure 7; Hamblin, A.O. 2012). A significant fault is mapped sub-parallel to the Tsolum River valley, and a tributary fault transects the northwest corner of the City and cuts beneath the Puntledge River (Figure 7). Although no data has been reviewed that confirms that exposed bedrock along the Puntledge River Valley is significantly fractured, it is conceivable that some Puntledge River water may directly recharge an underlying bedrock aquifer.

4.4 Water Infiltration Considerations

Based on interpretation of the surficial geology units (Fyles 1960 & 1963), Waterline assigned an expected hydraulic conductivity or in the case of discrete variations within mapped surficial geology units, a range of hydraulic conductivities was assigned (Table 1) to each surficial geology unit. This assignment of hydraulic conductivities culminated in the designation of a relative infiltration potential to each surficial geology unit as per Table 1.

In areas where soil testing has been completed as part of past studies, the location name, coordinates, hydraulic conductivity value and the study from which the data was extracted, were compiled, and included in Table 3. Of the 27 reports reviewed only three reports had relevant data that could be compared with the range of interpreted hydraulic conductivities for surficial geology units.

Table 3: Hydraulic Conductivity Testing from Infrastructure and Planning Studies

Location Number	Location Name	UTM Coordinates (Zone 10)		Hydraulic Conductivity (m/s)	Surficial Geology Units (Fyles 1960)	Report Reference
		Easting	Northing			
1	TW17-1	360512	5509030	1.80E-04	5d|1	05 Waterline Resources Inc. Hydrogeological Assessment for Stormwater Management – Crown Isle North Development
2	OBS 17-2	360579	5508986	1.50E-04		
3	OBS 17-3	360561	5509095	2.60E-04		
4	SS2	354128	5505001	1.00E-05	5d|3	STU 78 EBA Engineering Consultants Ltd. West Courtenay LAP Stormwater Mgm Plan - Stream & Soils
5	SS4	355057	5503860	1.00E-05		
6	TP1	358082	5508964	7.00E-05		STU 90 Levelton Consultants Ltd. Little River Catchment Stormwater Mgm Study - Quail Ridge Subdivision

Notes: **m/s** means metres per second

Reported hydraulic conductivities from field-testing were within the expected range of hydraulic conductivities as presented in Table 1. The infiltration potential assigned to each surficial geology unit is presented in Table 4. The distribution of infiltration potential over the City, including the location of field-tested hydraulic conductivities compiled as part of the *Infrastructure Planning Division – Studies and Reports* review are displayed spatially on Figure 8.

Table 4: Surficial Geology Descriptions and the Assigned Infiltration Potential

Surficial Geology Units (Fyles 1960)	Category/ Subcategory	Descriptions	Infiltration Potential
5a	Capilano - Marine Deposits (Including Glacio-Marine)	Silt, clay, stony clay	***Poor***
5a, 5b	Capilano - Marine Deposits (Including Glacio-Marine)	Silt, clay, stony clay & sand, pebbly sand, sandy gravel; generally underlain by clay.	***Poor***
5b	Capilano - Marine Deposits (Including Glacio-Marine)	Sand, pebbly sand, sandy gravel; generally underlain by clay	***Marginal***
5c	Capilano - Marine Deposits (Including Glacio-Marine)	Gravel and sand	***Good***
5d	Capilano - Marine Deposits (Including Glacio-Marine)	Varied stony, gravelly, and sandy	***Good***
5d/1*	Capilano - Marine Deposits (Including Glacio-Marine) and Quadra	TOP: Varied stony, gravelly, and sandy. BELOW: Sand; minor gravel, silt, peat, peaty soil, driftwood	***Good***
5d/2	Capilano - Marine Deposits (Including Glacio-Marine) and Quadra	TOP: Varied stony, gravelly, and sandy marine-veneer deposits. BELOW: Gravel, sand, silt, clay, till	***Good***
5d/3*	Capilano - Marine Deposits (Including Glacio-Marine) and Vashon Drift - Ground Moraine Deposits	TOP: Varied stony, gravelly, and sandy marine-veneer deposits. BELOW: Till; lenses of gravel, sand, and silt	***Marginal***
5d/R	Nanaimo Group and Capilano - Marine Deposits (Including Glacio-Marine)	Areas of bedrock outcrop interspersed with patches of thin overburden. Varied stony, gravelly, and sandy marine-veneer deposits.	***Poor***
5e/3	Capilano - Marine Deposits (Including Glacio-Marine) and Vashon Drift - Ground Moraine Deposits	TOP: Varied stony, sandy, loamy, and clayey marine-veneer deposits. BELOW: Till; lenses of gravel, sand, and silt	***Marginal***
5e/R	Nanaimo Group and Capilano - Marine Deposits (Including Glacio-Marine)	Areas of bedrock outcrop intersected with patches of thin overburden. Varied stony, sandy, loamy, and clayey marine-veneer deposits.	***Poor***
6a	Capilano Sediments - Terraced Fluvial Deposits	Gravel and sand commonly underlain by silt and clay	***Marginal***
6b	Capilano Sediments - Terraced Fluvial Deposits	Gravel, sand, minor silt	***Good***
7, 3, R	Nanaimo Group and Vashon Drift - Ground Moraine Deposits	Areas of bedrock outcrop interspersed with patches of thin overburden. till; lenses of gravel, sand, and silt	***Poor***
8	Salish Sediments - Shore, Deltaic, and Fluvial Deposits	Gravel, sand silt, clay, peat	***Marginal***

Notes: * denotes surficial geology units where assigned hydraulic conductivities have been compared against quantitative data from studies and reports provided by the City of Courtenay

4.5 Hydrogeology and Groundwater Resources

The City overlies three mapped aquifers; two comprised of surficial sediments (Aquifer #951, #408; Figure 9) and the other comprised of bedrock (Aquifer #413; Figure 9). A summary of each aquifer in order of stratigraphic sequence is summarized in Table 5. All data was obtained from the Ministry of Environment Groundwater Wells and Aquifer database (GWELLS; 2019). Separate fact sheets for each aquifer are included in Appendix B as reference.

Table 5: Description of Aquifers within the City of Courtenay

Aquifer Information	Surficial Sediments		Bedrock
Aquifer Name	Capilano Aquifer (Aquifer #951)	Quadra sand (Aquifer #408)	Bedrock (Aquifer #413)
Aquifer Type	Unconfined	Confined, small portions of the aquifer are exposed at grade	Partially Confined
Aquifer Material and Environment	Glacio-fluvial Sand and gravel	Glacio-fluvial Sand and gravel underlying till.	Comox Formation (sandstone, conglomerate).
Aquifer Area (km^2)	12.7	147.7	35.2
Productivity	Moderate	Moderate	Low
Mean Depth to Groundwater (mbgl)	2.2	6.5*	3.2
Mean Well Completion Depth (mbgl)	3.9	22.7	5.4**
Aquifer Vulnerability	High	Low	Moderate
Aquifer Use	Domestic and Unknown (Figure 10)	Domestic, Unknown, Waterworks, Commercial & Industrial and Irrigation (Figure 11)	Commercial & Industrial (Figure 12)
Comments	Contamination from surface activities is high due to the shallow unconfined nature of the aquifer. There are no well licenses issued within the City boundary	Generally, a confining layer exists above the aquifer (mean thickness is 25.1m). There are no well licenses issued within the City boundary	Bedrock exposures have been observed within City. The mean thickness of the confining layer is 5.9m. There are no well licenses issued within the City boundary

Notes: mean is the Geometric mean value; mbgl is meters below ground level; * means flowing artesian conditions have been observed in low-lying areas of the City; ** indicates mean depth to top of bedrock

4.5.1 Groundwater Flow Patterns and Surface Water Interaction

Based on the mapped surficial sediments, Aquifers #951 and #413 could potentially interact with surface water or be influenced by changes to surface water flow patterns. The median depth to groundwater at both Aquifers #951 and #413s is 2.2 and 3.2 metre below ground level (mbgl) respectively. A breakdown of the potential groundwater - surface water interaction is as follows:

- **Aquifer #951** – The aquifer south boundary is a groundwater divide from where the groundwater flow direction is head-controlled. The east and west boundaries of the aquifer are mapped based on borehole stratigraphy and reported well yields. The northern boundary of this aquifer is the Puntledge River into which the aquifer discharges. Groundwater in this aquifer is expected to flow from southwest to northeast generally following the topographic gradient of the slope. (Figure 10). Since this aquifer is unconfined, recharge to Aquifer #951 is expected to be directly from precipitation and to a lesser extent infiltration from creeks and rivers that transect the aquifer footprint.

- **Aquifer #408** - Groundwater is generally expected to flow from areas of high elevation to low elevation (Figure 11). This assertion is based on the mapped artesian wells at the toe of the north-facing Little River valley wall and along the toe of the west-facing Tsolum River valley wall (Appendix B; Figure B2). In these areas the static water level exceeds ground level suggesting groundwater flow does not mimic surface topography but is controlled by pressure gradients. Where glacio-fluvial processes have eroded the sediments above the Quadra sand or where post - fluvial processes have incised the Quadra sand, the aquifer is potentially in direct contact with surface water (potential recharge). Areas where this could be happening are along Tsolum River (Figure 11), the Glen Urquhart Creek and Little River, where the Quadra sand is mapped at surface (Figure 6; surficial geology Units 5d|1 &5d|2; Table 4).

- **Aquifer #413** - Groundwater flow within the bedrock is thought to be controlled by regional pressure gradients that depend on the frequency and continuity of fractures. Recharge to the aquifer is expected to be mainly from precipitation at higher elevations in the watershed (west of the City; Figure 12) where these fractures are exposed to surface. Within the City, local recharge from precipitation is possible where bedrock is exposed at surface. Depending on the extent and continuity of bedrock fractures exposed to the river channel, the Puntledge River may at times recharge the bedrock aquifer, while at other times at the lower reaches of the Puntledge, the bedrock aquifer may discharge groundwater into the Puntledge (Figure 6; surficial geology Units 7, 3, R; Table 4).

4.6 Land Cover Type

Land cover type can affect the overall infiltration potential of any surficial sediment (fine clay, silt, or coarse sand and gravel, or fractured bedrock) by modifying the amount of surface water that can infiltrate into the subsurface and how much water in the subsurface can be taken up and vaporized as evapotranspiration. Surface water can infiltrate directly into the subsurface at bare lands or vegetated areas. However, infiltration in vegetated areas can also be removed through evapotranspiration via trees (deciduous/coniferous) and vegetation (grass). At impermeable surfaces (roads, buildings) runoff, can be directed to the storm collection system or re-directed to neighbouring vegetated areas.

Within the municipal boundaries, land cover type was interpreted based on LiDAR Satellite imagery collected by the City in 2012. The City's landcover distribution has been grouped into three categories (bare land and surface water areas, vegetated and impermeable area), with the following distribution:

- 7% can have direct infiltration, defined by bare lands with no vegetation or impermeable surfaces and natural surface water bodies (creeks and rivers; Figure 13);
- 72% is vegetated, defined by grass, coniferous trees, deciduous trees (leaf on or off) and shadows (assumed the result of tree cover; Figure 13); and
- 21% is impermeable, defined by paved areas and buildings (Figure 13). In fact, asphalt-paved roads have a low permeability. However, for purposes of this project, asphalt-paved roads are considered impermeable.

For the development of a conceptual site model, each land cover type is weighted based on the knowledge that a vegetated land will have a lower infiltration potential than direct infiltration through bare land. Impermeable surfaces and surface water bodies have no infiltration potential and will re-direct all water towards lower lying areas.

5.0 CONCEPTUAL SITE MODEL

Precipitation and runoff are expected to be the primary sources of recharge to aquifers #951 and #413. Sources of recharge to Aquifer #408 are uncertain. Generally, groundwater flows from recharge zones at higher elevations to discharge zones at lower elevations.

5.1 Unconfined Aquifer #951

Aquifer #951 is a highly vulnerable unconfined glacio-marine aquifer. Its high vulnerability level is based on the following:

- The water table is within a mean of 2.2 mbgl; and
- There are few discontinuous cohesive soil units overlying it to protect it from surficial sources of contamination.

The glacio-marine depositional environment of the Capilano sediments that constitute this aquifer, suggests that lenses of clay and silt, and well-grade silty sands and gravels may occur within the mapped extent of the aquifer, but these units are not considered to be laterally extensive (GWELLS, 2019; Figure 9).

5.1.1 Areas of Good Infiltration over Aquifer #951

In superimposing the infiltration potential, the surficial geology and storm water infrastructure layers upon the mapped aquifer layer, a single area of good Infiltration potential is suggested overlying Aquifer #951 (Figure 14). This area is bounded by a bluff that can be seen approximately 60 m northwest of 5th Street, 50 m west of Quinn Avenue, 110 m west of Pidcock Avenue, sub-parallel to Robert Lang Drive, between 20 and 240 m east of Malcolm Place and 100 m north northwest of Lake Trail Road. Roy Morrison Park is developed in this area. The surficial geology (Unit 6b) in this area is described as a Capilano terraced fluvial channel deposit comprised of gravel, sand, and minor silt averaging 1.5 m or more in thickness (Fyles, 1960). The river terrace is transected by both Morrison and Arden Creeks. Each of these creeks may contribute some component of recharge to the underlying Aquifer #951.

Subsurface disposal of stormwater in this area (Unit 6b) without consideration of stormwater contaminant attenuation could present some risk to the underlying groundwater quality. Since the aquifer is expected to discharge to the Puntledge River, any impacts to groundwater quality are likely to affect the Puntledge River, where some dilution is expected to occur.

Landcover overlying Aquifer #951 in the area (Unit 6b) is primarily composed of vegetative cover (71%) with lesser areal coverage of impermeable areas (27%) and or area of direct infiltration (2%). The vegetative cover is expected to intercept a small component of infiltration from precipitation and stormwater discharged in the subsurface and release it as evapotranspiration.

5.1.2 Areas of Marginal Infiltration over Aquifer #951

Some marginal areas of infiltration potential overlying Aquifer #951 are expected (Figure 14). These areas are described as having sand and gravel overlying clay. Assuming Aquifer #951 exists below this clay, the clay is expected to provide some protection for the underlying aquifer. However, since it is conceivable that the clay layer underlies both the surficial geology deposit and Aquifer #951, further investigation is required to determine the depth of the clay relative to the depth of the aquifer and better the impact of stormwater infiltration potential upon the underlying aquifer. The marginal infiltration potential areas overlying Aquifer #951 are variable due to the wide range of surficial sediments. From higher to lower infiltration potential are:

1. Unit 6a – Terrace Fluvial Delta Deposits of the Capilano sediments comprised of sand and gravel overlying clay and silt;
2. Unit 5b – Marine and glacio-marine Capilano Sediments comprised of sand and sandy gravel, generally underlain by clay;

3. Unit 5d|3 and 5e|3 - Ground moraine Capilano sediments and Vashon Drift comprised of a stoney, sandy, loamy, and clayey veneer above till deposits with silt and gravel lenses.

5.1.3 Areas of Poor Infiltration over Aquifer #951

Areas of Poor infiltration potential overlying Aquifer #951 cover the Puntledge River valley and are described as patches of Vashon drift ground moraine till overlying Nanaimo Group sedimentary rocks (Unit 7, 3, R; Figure 14). Furthermore, this area is within the groundwater discharge zone of Aquifer #951 and any stormwater infiltrated into this area is likely to report to the Puntledge River, with little capacity for contaminant attenuation. Other areas of poor infiltration overlying Aquifer #951 included clay and silts deposits (Capilano sediments) that are mapped at surface (Unit 5a; Figure 14).

5.2 Confined Quadra Sand Aquifer #408

The Quadra sand Aquifer #408 is a regionally extensive confined glacio-fluvial sand aquifer that extends from Comox Harbour, beyond the City's north boundary and is bounded on the east by the Straight of Georgia and the west by the Tsolum River (Figure 9).

Generally, Aquifer #408 is confined by the Vashon Till and/or the Capilano Sediments. Where valleys have been incised deep enough by rivers and creeks (namely Little River, Tsolum River and Glen Urquhart Creek), the Quadra sand Aquifer #408 is exposed at grade and discharges as springs at the toe of valley walls. Since most of the Quadra sand Aquifer #408 is confined and is thought to discharge to the Tsolum River valley, the Straight of Georgia, and Comox Harbour, the source of recharge to this aquifer is unknown. If the aquifer is situated at a regional discharge zone, it is conceivable that the aquifer is recharged from the underlying bedrock. However, to date, there is no data available to support this. Aquifer #408 is considered to have low vulnerability based on the following:

- The geometric mean thickness of the confining layer is 25.1 m; and
- The aquifer is confined (pressurized) and where exposed, groundwater discharges from the aquifer.

5.2.1 Areas of Good Infiltration over Aquifer #408

Several areas of good infiltration capacity are noted overlying the Quadra sand Aquifer #408 which include:

- A southern elongate zone 1200 m x 300 m that extends from the Valleyview Greenway Trail to the City south boundary at Back Road and includes Hawk Glen Park (Figure 15); and
- A northern triangular-shaped zone transected by the bend in the Veterans Memorial Parkway that extends from the 81 m contour across the north City boundary to Meadowbrook Court and Gail Crescent in the Comox Valley Regional District (Figure 15).

These areas are Capilano marine and glacio-marine sands and gravels (Unit 5c and 5d), with depths ranging from 1.5 to 9.0 mbgl. They are ideal for subsurface stormwater disposal since the risk of affecting the groundwater quality in the confined Aquifer #408 is expected to be low; the northern zone is more suitable than the southern zone based on a greater anticipated thickness of the sands and gravels.

Landcover in the southern and northern zones are primarily vegetative cover (80 to 96% respectively) with lesser areal coverage of impermeable surfaces (17 to 3% respectively) and areas of direct infiltration (3 to 1% respectively). The extensive vegetative cover at both the north and south zones suggests that some component of infiltration from precipitation and stormwater discharged in the subsurface will be intercepted and released as evapotranspiration.

Other areas of good infiltration potential were noted adjacent the intersection of Ryan Road and Anderton Road (Unit 5d|1; known locally as the Anderton Pit) and sub-parallel to Back Road (Unit 5d|2; Figure 15). In these areas, exposures of the Quadra sand Aquifer #408 have been mapped where springs discharge from the toe of the Little River and Glen Urquhart Creek valley walls, respectfully. Since these are Aquifer #408 groundwater discharge zones stormwater discharged subsurface in these areas are expected to have a brief subsurface travel time before discharging to surface. Consequently, these zones offer little contaminant attenuation potential prior to discharge to grade.

5.2.2 Areas of Marginal Infiltration over Aquifer #408

Areas of marginal infiltration capacity overlying Aquifer #408 are described as follows:

- Capilano marine and glacio-marine sands and gravels a few centimetres to 9.0 m thick and generally underlain by clay (Unit 5b). Of the zones identified as marginal, this zone could be good if the depth to the underlying clay can be proven to be thick enough for the design stormwater flows. This zone is within the Little River valley (Figure 15).
- Capilano marine and glacio-marine sediments and Vashon drift ground moraine till comprised of sands and gravels with lenses of silt (Unit 5d|3). This surficial geology unit is reported to be generally less than 1.5 m thick and could be suitable for subsurface stormwater disposal if discharged over broad areas (Figure 15).
- Capilano marine and glacio-marine sediments and Vashon drift ground moraine till comprised of sandy, loamy, and clayey deposits generally less than 1.5 m thick with lenses of gravel, sand, and silt (Unit 5e|3). While these deposits are expected to offer contaminant attenuation potential, they are expected to have a low infiltration rate (Figure 15).

5.2.3 Areas of Poor Infiltration over Aquifer #408

Zones of poor infiltration capacity were identified at two locations overlying Aquifer #408 (Figure 15). These areas consist of Capilano clays, silts, sands, and gravels having thicknesses between a few centimetres up to 9.0 m (Unit 5a and 5a, 5b).

5.3 Bedrock Aquifer #413

Aquifer #413 is a partially confined bedrock aquifer. The bedrock aquifer extends between 200 and 300 m west from Courtenay's western boundary and underlies the unconfined Aquifer #951 (Figure 9). The aquifer extends between its southern boundary at Royston and its northern boundary approximately 100 m north of Piercy Road (in the Comox Valley Regional District) and beneath the City's northern extent at the Puntledge River (Figure 9). The eastern and northern extents of Aquifer #413 are mapped based on borehole stratigraphy and groundwater occurrence (Figure 12). Since very few wells have been drilled into bedrock east of the Courtenay and Tsolum Rivers, it is conceivable that the bedrock aquifer extends east of these rivers. Saltwater intrusion has been reported at one well location northwest of Royston (GWELLS; 2019). It is unknown if this well is within the City limits or how deep the well was completed. Aquifer #413 is moderately vulnerable based on the following:

- The aquifer is confined at 68% of the wells by glacio-marine clay and till of the Capilano sediments having an average thickness of 5.9 m;
- The average depth to groundwater is reported to be 3.2 mbgl; and
- Based on the average reported well yield (0.13 L/s), the extent and continuity of bedrock fractures is inferred to be limited.

5.3.1 Areas of Good Infiltration over Aquifer #413

Good infiltration capacity, such as at the Capilano glacio-fluvial river terrace adjacent the Puntledge River (Unit 6b) in proximity to known bedrock exposures along the Puntledge River valley (Unit 7,3, R), was noted overlying bedrock Aquifer #413 (Figure 16). Subsurface disposal of stormwater in this area without consideration of stormwater contaminant attenuation could present some risk to the underlying groundwater quality in Aquifer #413.

5.3.2 Areas of Poor Infiltration over Aquifer #413

Based on the low average groundwater discharge rate (0.13 L/s) from wells completed in the bedrock, and an average clay or till layer thickness of 5.4 m at 68% of the wells installed in the bedrock aquifer, subsurface stormwater disposal in areas having a poor infiltration potential (Unit 5d|R and 5e|R) are unlikely to present significant risk to the underlying bedrock aquifer (Figure 16).

5.4 Courtenay River Watershed

The valleys of the Courtenay River watershed are blanketed with modern Salish sediments comprised of shore, deltaic and fluvial sands and gravels, silt, clay, and peat (Unit 8; Fyles, 1960). This zone has been assigned a marginal infiltration capacity based on the following rationale:

- The extent of silt clay and peat is unknown;
- The Tsolum and Courtenay Rivers are local groundwater discharge zones. As such, if stormwater is discharged subsurface within these valleys, the travel-time before discharge into the river is expected to be short.

- Where sufficient infiltration capacity can be proven in the Tsolum and Courtenay River valleys, the *in-situ* contaminant attenuation potential is expected to be limited and there is a risk of contaminant discharge into the rivers. In these areas, some enhanced contaminant attenuation potential could be warranted.
- Conversely, where there is adequate *in-situ* contaminant attenuation potential, there is unlikely to be adequate infiltration capacity.

5.5 Areas Where Infiltration can be Enhanced

Generally, identification of areas where infiltration can be effectively enhanced requires some understanding of how the existing storm water system currently operates. Additionally, best practices for the protection of groundwater resources under the *Underground Stormwater Infiltration Document* (MOE 2014) would be consulted to determine that potential risks from redevelopment are mitigated. Since Waterline has only a general understanding of how the stormwater system currently operates, the following bullet list is considered a general list of suggestions (that may already be incorporated into the City storm water disposal system or management plan) for the City to explore further:

- Many of the City storm detention ponds are in areas of marginal and good infiltration potential;
- It is assumed that these storm detention ponds are designed to be impermeable and do not allow exfiltration to the subsurface;
- Designing storm water detention ponds in areas of marginal or good infiltration potential to allow exfiltration to the subsurface could allow *in-situ* subsurface contaminant attenuation to occur prior to discharge at surface water bodies;
- Allowing exfiltration at detention ponds will also reduce the storm water flows discharged at storm discharge points adjacent surface water bodies, thereby reducing the potential for contaminant loading at the surface water bodies;
- At stormwater collection points enhanced contaminant attenuation can be explored by having stormwater discharge into bioswale that can remove low-level hydrocarbon, pesticides, salts, trace metals and organics concentrations from the stormwater prior to discharge into surface water bodies;
- In areas where high levels of hydrocarbons have been detected in storm water, consider installation of an oil-water separator; and
- Installation of head-controlled sediment traps upstream of storm discharge points will allow suspended sediment to fall out of the storm water prior to discharge to a fish-bearing stream. These sediment traps would require periodic removal of sediment collected in the trap.

6.0 CONCLUSION AND RECOMMENDATIONS

Surficial and bedrock geology as published by the Geological Survey of Canada and the BC Geological Survey, respectively, has been reviewed and interpreted for infiltration potential. Areas of good, marginal, and poor infiltration potential have been interpreted and superimposed upon the government of BC, Ministry of Environment aquifer mapping within the City using Waterline's Enviro-Web Services GIS geospatial data platform.

Areas for subsurface stormwater infiltration having low risk of affecting aquifer groundwater quality are listed (in order of decreasing feasibility and increasing risk) in Table 6. Perceived constraints to subsurface stormwater disposal and additional work expected to be necessary to prove feasibility and reduce the risk of environmental impact to both underlying aquifers and proximal surface water bodies are also included on Table 6.

Table 6: Prioritized List of Areas for Stormwater Infiltration Potential

Priority	Overlying Aquifer #	Surficial Geology Unit Fyles (1960)	Location	Infiltration Potential	Perceived Constraints	Additional Work
1	408	5c	The north zone transected by the Veterans Memorial Parkway	Good	Granular sediment thickness may be limited.	A site investigation will be required to prove the granular sediment thickness is enough to meet design stormwater discharge rate
2	408	5d and 5c	The south zone at Hawk Glen Park	Good	Granular sediment thickness may be limited.	A site investigation will be required to prove the granular sediment thickness is enough to meet design stormwater discharge rate
					Glen Urquhart Creek flows through Hawk Glen park.	The site investigation will need to show that stormwater discharged subsurface will not discharge into the creek
3	408	5b	The Little River Valley	Marginal	Granular sediment thickness may be limited	A site investigation will be required to prove the granular sediment thickness is sufficient to meet design stormwater discharge rate
					Granular sediment is reported to be underlain by clay	Depending on the design stormwater discharge rate and granular sediment thickness, the site investigation may need to outline the surface of the top of the clay to determine stormwater flow direction following discharge
					Several canals transect the Little river valley	The site investigation will need to show that stormwater discharged subsurface will not discharge into the canals
4	408	5dl1	Little River South Valley Wall	Good	Groundwater discharge zone of Quadra sand Aquifer #408	The site investigation will need to show that stormwater discharged subsurface will have adequate travel time before discharge at lower springs or enhanced treatment will be required prior to subsurface discharge
5	951	5b	West side of Roy Morrison Park and adjacent Lake Trail School	Marginal	Granular sediment thickness may be limited.	A site investigation will be required to prove the granular sediment thickness is sufficient to meet design stormwater discharge rate
					Granular sediment is reported to be underlain by clay	Depending on the design stormwater discharge rate and granular sediment thickness, the site investigation may need to outline the surface of the top of the clay to determine stormwater flow direction following discharge
					The deposit is transected by both Morrison and Arden Creeks	The site investigation will need to show that stormwater discharged subsurface will not discharge into Morrison and Arden Creeks
6	951	6a	North area bounded by Anderton Avenue, 8th Street, Johnston Avenue and Puntledge River Valley	Marginal	Granular Sediment Thickness may be limited	A site investigation will be required to prove the granular sediment thickness is sufficient to meet design stormwater discharge rate
					Granular sediment is reported to be underlain by clay	Depending on the design stormwater discharge rate and granular sediment thickness, the site investigation may need to outline the surface of the top and continuity of the clay to determine stormwater flow direction following discharge and to be certain protect the underlying unconfined aquifer
					The deposit is near the confluence of the Puntledge and Courtenay Rivers	The site investigation will need to show that stormwater discharged subsurface will have adequate travel time before discharge into either the Puntledge or Courtenay Rivers
7	408	5dl2	Courtenay River Northeast Valley Wall	Good	Granular sediment thickness may be limited.	A site investigation will be required to prove the granular sediment thickness is sufficient to meet design stormwater discharge rate
					Groundwater discharge zone of Quadra sand Aquifer #408	The site investigation will need to show that stormwater discharged subsurface will have adequate travel time before discharge at lower springs or enhanced treatment will be required prior to subsurface discharge
8	951	6b	East side of Roy Morrison Park and adjacent Puntledge Park Elementary	Good	The deposit overlies the unconfined, highly vulnerable Aquifer #951	To protect the aquifer from stormwater contaminants, A lower confining layer needs to be proven underlying the granular deposits or enhanced treatment of the stormwater must occur prior to subsurface discharge
					The deposit is near the Puntledge River, and is transected by Morrison and Arden Creeks	A site investigation will need to show that stormwater discharged subsurface will have adequate travel time before discharge into either the Puntledge River and does not discharge into Morrison and Arden Creeks
9	none	8	Tsolum and Courtenay River Valleys	Marginal	Granular sediments are expected to have lenses of silt, clay and peat	A site investigation is required to prove a sufficient thickness of unsaturated granular material
					Unsaturated thickness of granular sediment is expected to be thin	The site investigation will need to prove the distance from the infiltrative surface to the seasonal high-water table is adequate for the flow discharged subsurface and the area available for discharge
					Discharged Stormwater is expected to eventually discharge into the Rivers.	Adequate travel time in the subsurface prior to discharge in the River must be proven in the site investigation

7.0 CERTIFICATION

We trust the information provided meets the current requirements of Urban Systems Ltd. If you have any questions or concerns, please do not hesitate to contact the undersigned at your convenience.

Respectfully submitted,

Waterline Resources Inc.

PROFESSIONAL
PROVINCE OF
S. T. Y. WING
42572
BRITISH COLUMBIA
GEOSCIENTIST

19/11/2020

Scott Green, P.Eng.
Senior Hydrogeologist

Simon Wing, P.Geo.
Intermediate Hydrogeologist

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9.0 LIMITATIONS AND USE

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FIGURES

Appendix A

Range of Hydraulic Conductivity and Permeability (Freeze and Cherry 1979)

Table 2.2 Range of Values of Hydraulic Conductivity and Permeability

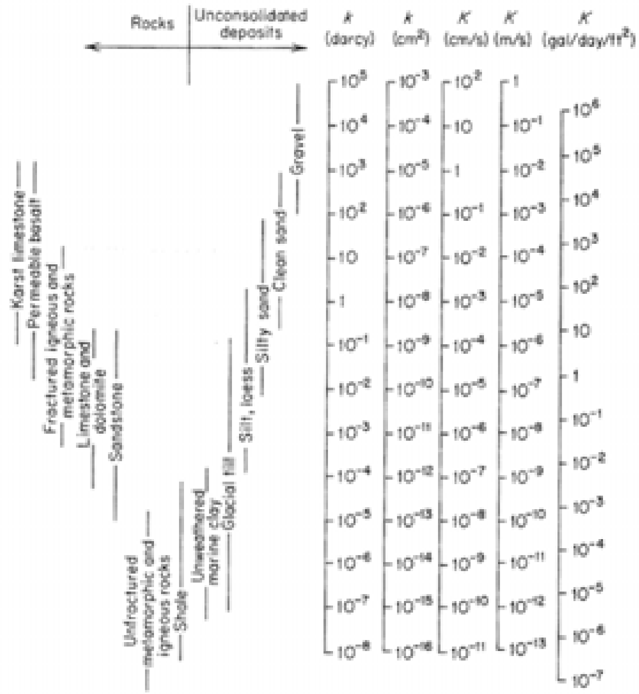


Table 2.3 Conversion Factors for Permeability and Hydraulic Conductivity Units

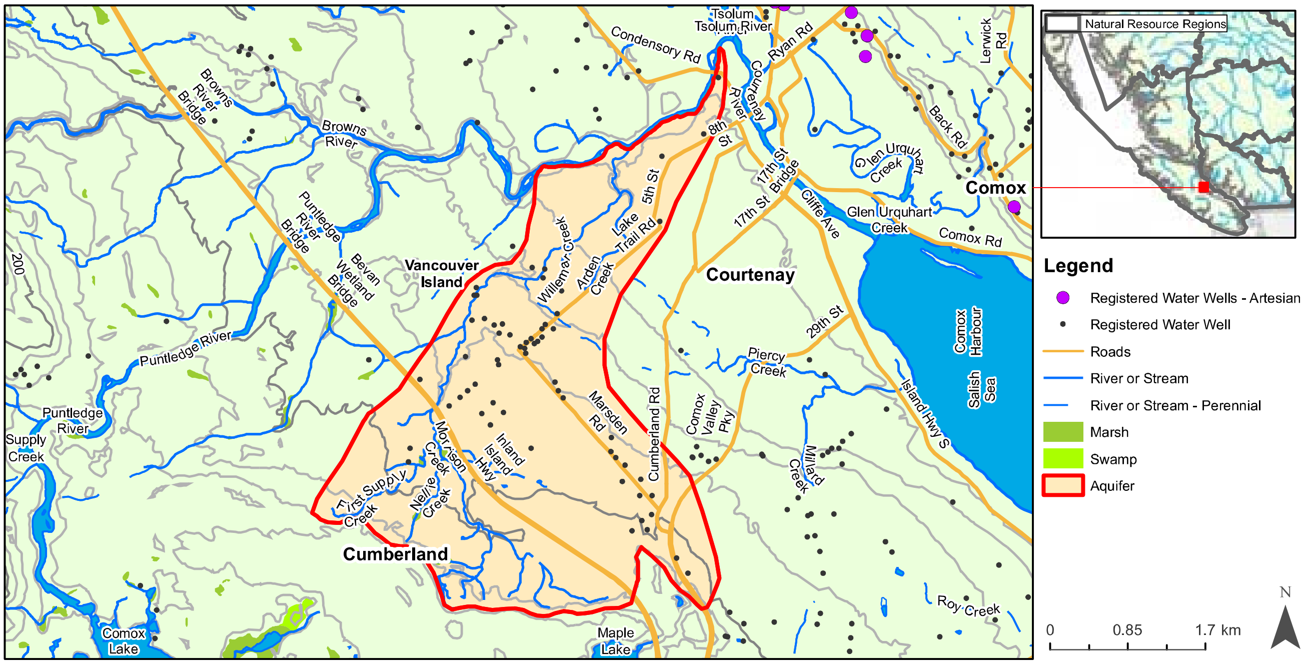
	Permeability, k*			Hydraulic conductivity, K		
	cm²	ft²	darcy	m/s	ft/s	gal/day/ft²
cm²	1	1.08×10^{-3}	1.01×10^{8}	9.80×10^{2}	3.22×10^{3}	1.85×10^{9}
ft²	9.29×10^{2}	1	9.42×10^{10}	9.11×10^{5}	2.99×10^{6}	1.71×10^{12}
darcy	9.87×10^{-9}	1.06×10^{-11}	1	9.66×10^{-6}	3.17×10^{-5}	1.82×10^{1}
m/s	1.02×10^{-3}	1.10×10^{-6}	1.04×10^{5}	1	3.28	2.12×10^{6}
ft/s	3.11×10^{-4}	3.35×10^{-7}	3.15×10^{4}	3.05×10^{-1}	1	5.74×10^{5}
gal/day/ft²	5.42×10^{-10}	5.83×10^{-13}	5.49×10^{-2}	4.72×10^{-7}	1.74×10^{-6}	1

*To obtain k in ft², multiply k in cm² by 1.08×10^{-3}.

Appendix B

Aquifer Mapping Fact Sheets

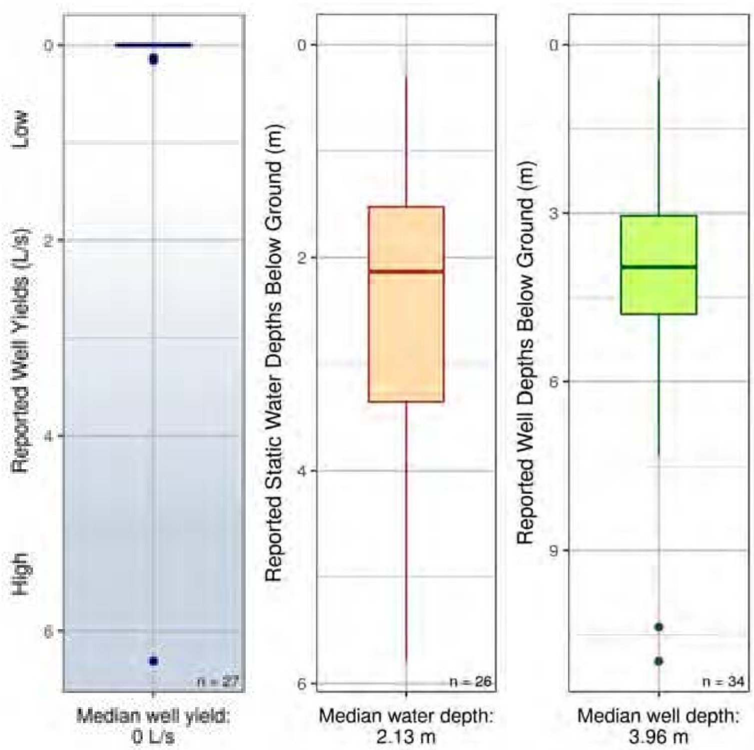
Aquifer #951



Aquifer Description (Mapping Report): Unconfined glacio-fluvial outwash or ice contact sand and gravel aquifers generally formed near or at the end of the last period of glaciation (subtype = 4a).

Aquifer Details	
Region	West Coast
Water District	Nanaimo
Aquifer Area	12.7 km^2
No. Wells Correlated to Aquifer	34
Vulnerability to Contamination	High
Productivity	Moderate
Aquifer Classification	IIA
Hydraulic Connectivity[1]	Likely
Aquifer Stress Index	Less stressed
No. Water Licences Issued to Wells	0
Observation Wells (**Active**, Inactive)	None

[1] Based on broad regional assessment

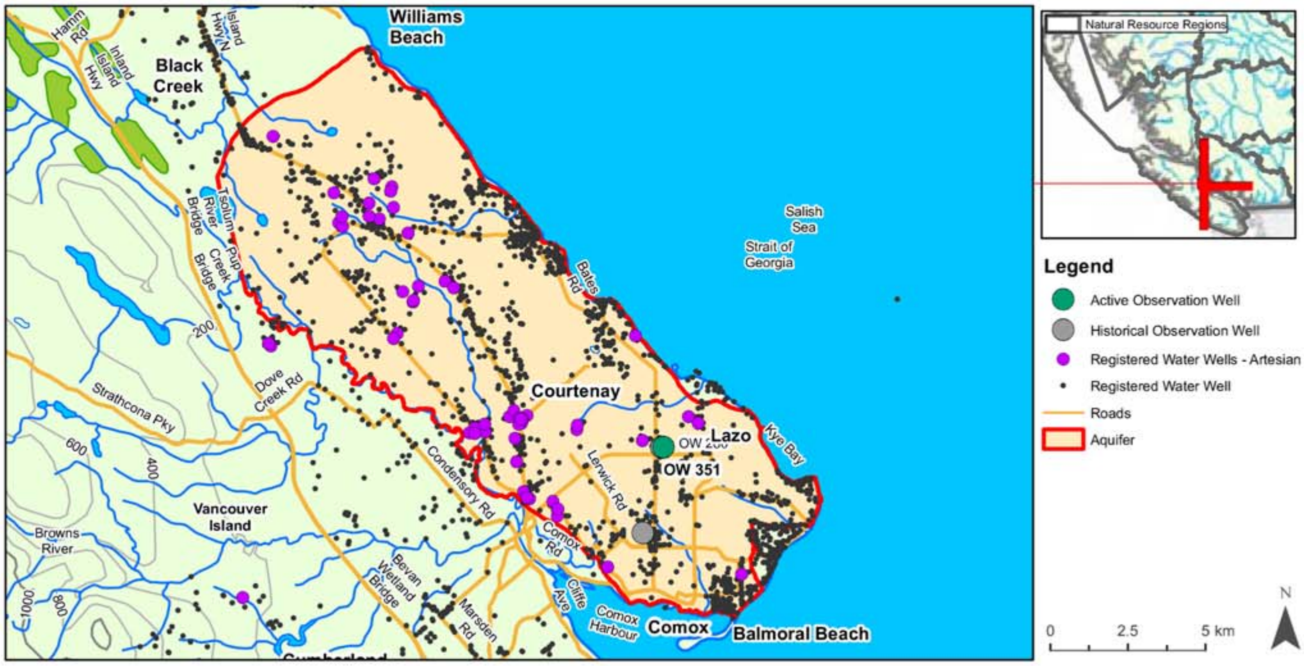


Disclaimer:

Detailed methods for all figures are described in the companion document (Aquifer Factsheet - Companion Document.pdf).

Factsheet generated: 2019-03-06. Available from: https://s3.ca-central-1.amazonaws.com/aquifer-docs/00000/00951_Aquifer_Factsheet.pdf.

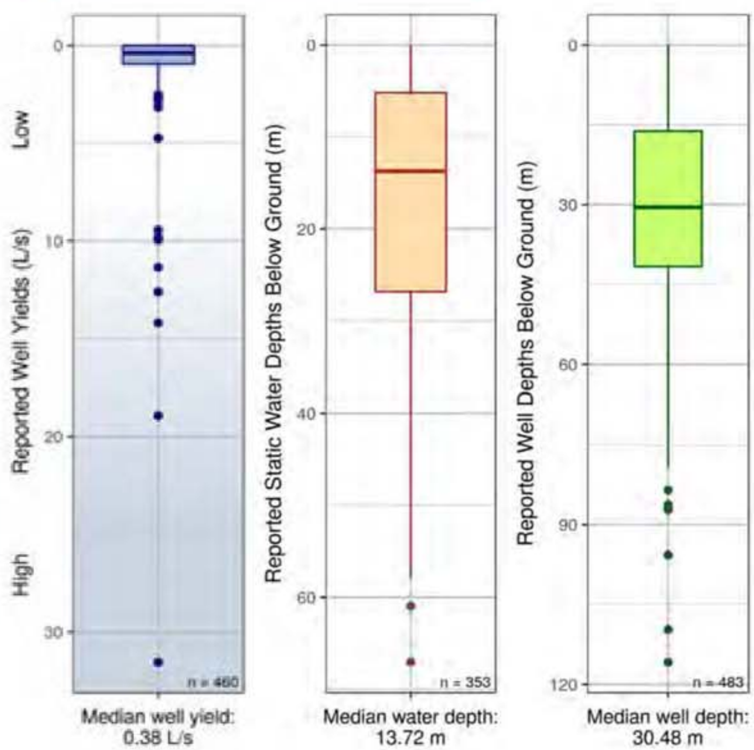
Aquifer #408



Aquifer Description (Mapping Report): Confined Glacio-fluvial sand and gravel aquifers underneath till, in between till layers, or underlying glacio-lacustrine deposits (subtype = 4b).

Aquifer Details	
Region	West Coast
Water District	Nanaimo
Aquifer Area	147.7 km^2
No. Wells Correlated to Aquifer	484
Vulnerability to Contamination	Low
Productivity	Moderate
Aquifer Classification	IIC
Hydraulic Connectivity[1]	Not Likely
Aquifer Stress Index	Method not applicable - confined aquifer
No. Water Licences Issued to Wells	3
Observation Wells (**Active**, Inactive)	280, 285

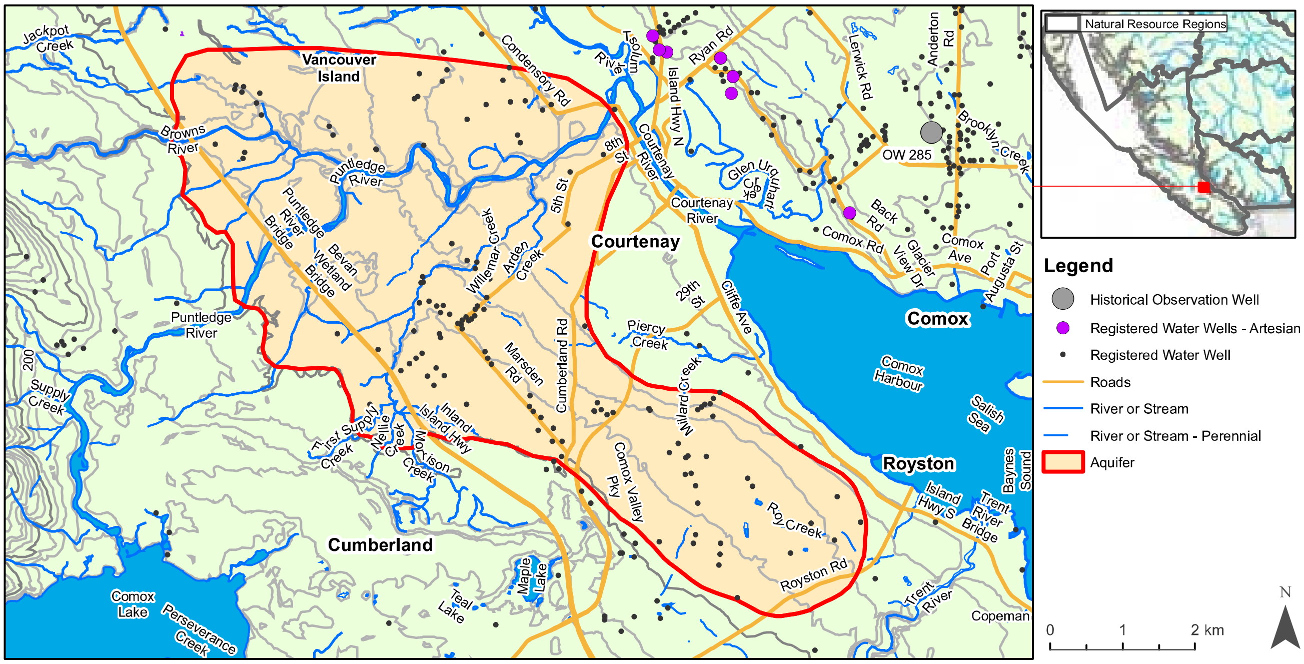
[1] Based on broad regional assessment



Detailed methods for all figures are described in the companion document (Aquifer Factsheet - Companion Document.pdf).

Factsheet generated: 2019-03-06. Available from: https://s3.ca-central-1.amazonaws.com/aquifer-docs/00000/00408_Aquifer_Factsheet.pdf.

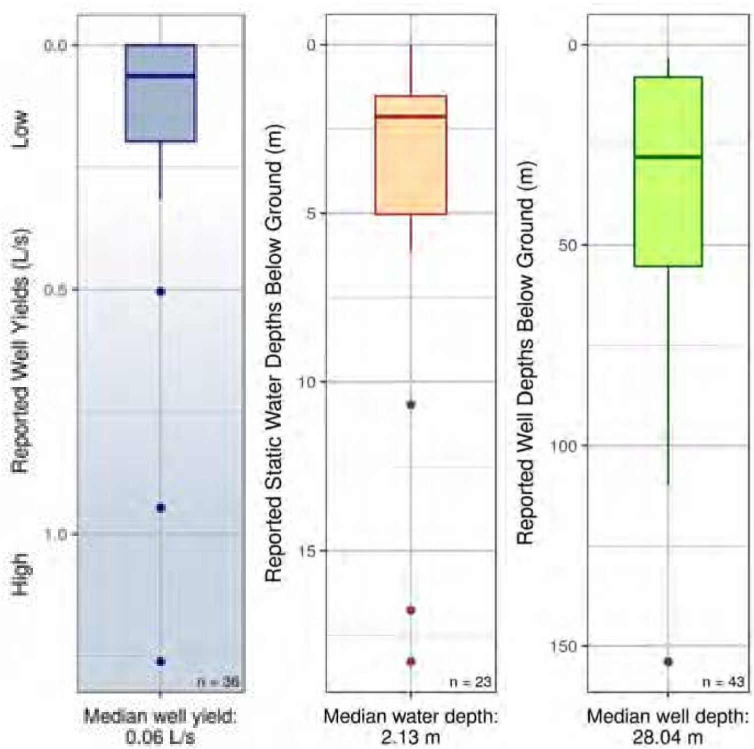
Aquifer #413



Aquifer Description (Mapping Report):
Fractured sedimentary rock aquifers primarily found in association with old sedimentary basins (subtype = 5a).

Aquifer Details	
Region	West Coast
Water District	Nanaimo
Aquifer Area	35.2 km^2
No. Wells Correlated to Aquifer	47
Vulnerability to Contamination	Moderate
Productivity	Low
Aquifer Classification	IIB
Hydraulic Connectivity[1]	Not Likely
Aquifer Stress Index	Method not applicable - confined aquifer
No. Water Licences Issued to Wells	0
Observation Wells (**Active**, Inactive)	None

[1] Based on broad regional assessment



Disclaimer:

Detailed methods for all figures are described in the companion document (Aquifer Factsheet - Companion Document.pdf).

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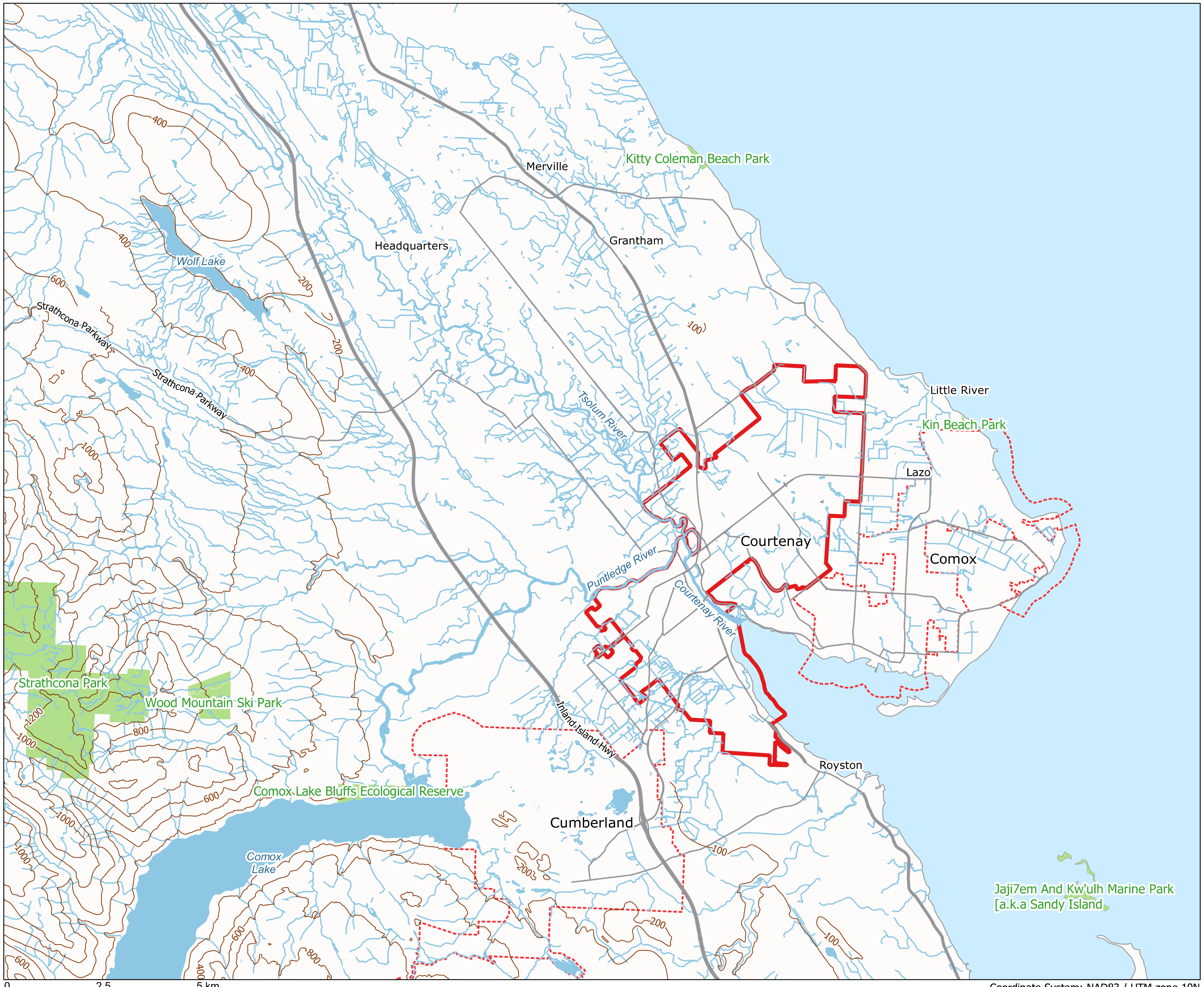


Courtenay Municipal Boundary
Elevation Index Contour (masl)
Road - Expressway / Highway
Road - Arterial / Collector
Watercourse
Lake
Municipality
Protected Park

N

References:

Urban Systems Ltd
Government of Canada; Natural Resources Canada
Government of BC Ministry of Forests, Lands and Natural Resource Operations, 2016

City Of Courtenay Surficial Geology And Infiltration Potential Delineation

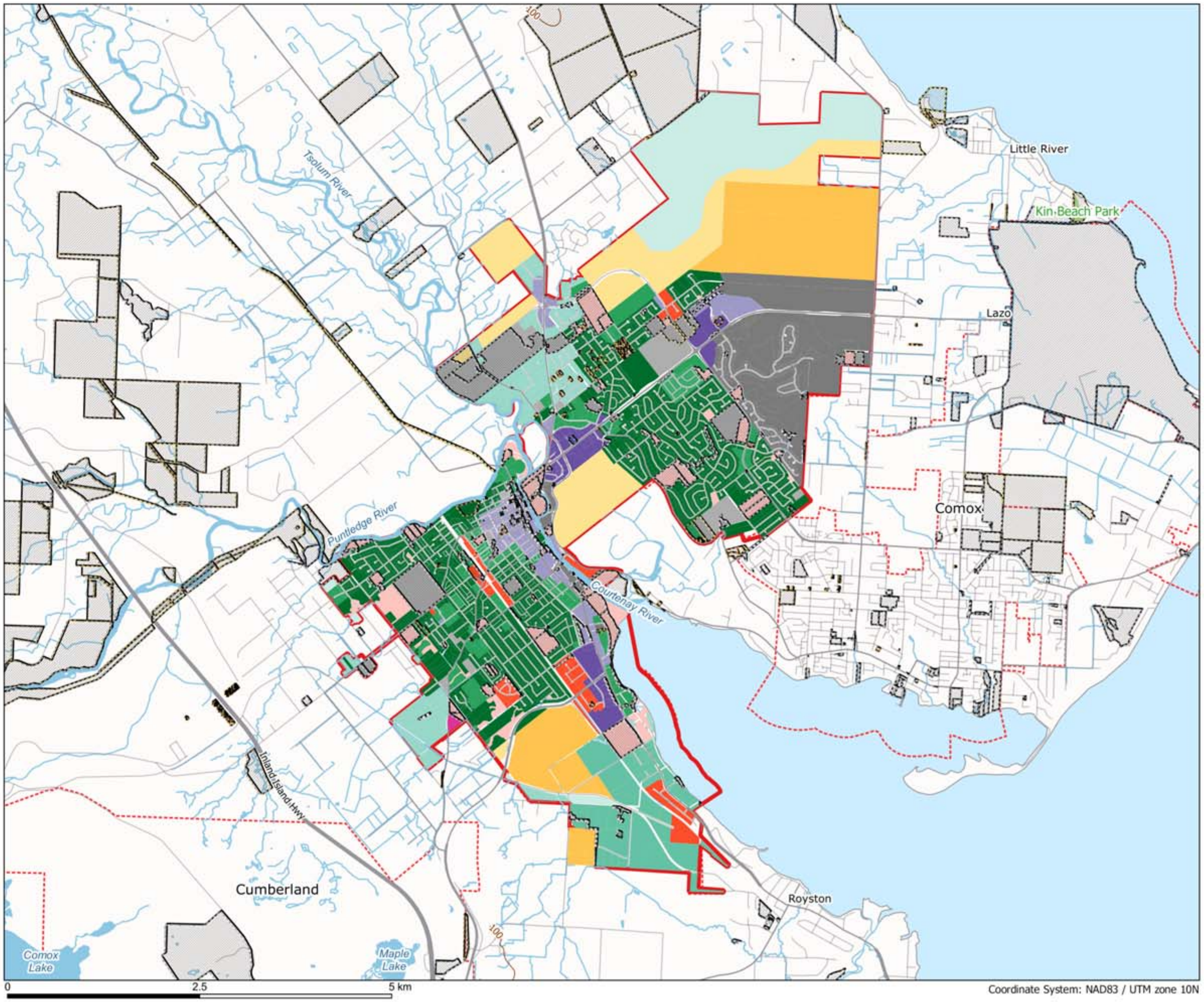
LOCATION PLAN

Waterline

Prepared By: Waterline Resources Inc.
Project Number: 3164-19-001
Compiled By: isamson
Date Issued: 2019-Jul-26
Date Revised: --

FIGURE 1

P:\2019 PROJECTS\3164-19-BC Urban City of Courtenay Infiltration Study\001 City of Courtenay Surficial Geology and Infiltration Potential Delineation\Data\Drafting\3164_figs\3164_figs2.qgs



References:

Urban Systems Ltd
Government of Canada; Natural Resources Canada
Government of BC Ministry of Forests, Lands and Natural Resource Operations, 2016

City Of Courtenay Surficial Geology And Infiltration Potential Delineation

CITY OF COURTENAY MUNICIPAL BOUNDARY AND LAND USE

Waterline

FIGURE 2

P:\2019 PROJECTS\3164-19-BC Urban City of Courtenay Infiltration Study\001 City of Courtenay Surficial Geology and Infiltration Potential Delineation\Data\Drafting\3164_figs\3164_figs2.qgs

- Storm Discharge Point
- Storm Gravity Main
- Storm Open Drain
- Storm Catchment Area
- Storm Detention Area
- River
- Courtenay Municipal Boundary

References:

Urban Systems Ltd
Government of Canada; Natural Resources Canada
Government of BC Ministry of Forests, Lands and Natural Resource Operations, 2016

City Of Courtenay Surficial Geology And Infiltration Potential Delineation

STORM WATER INFRASTRUCTURE FOR THE CITY OF COURTENAY

Waterline

Prepared By: Waterline Resources Inc.	**FIGURE 3**
Project Number: 3164-19-001	
Compiled By: isamson	
Date Issued: 2019-Jul-26	
Date Revised: --	

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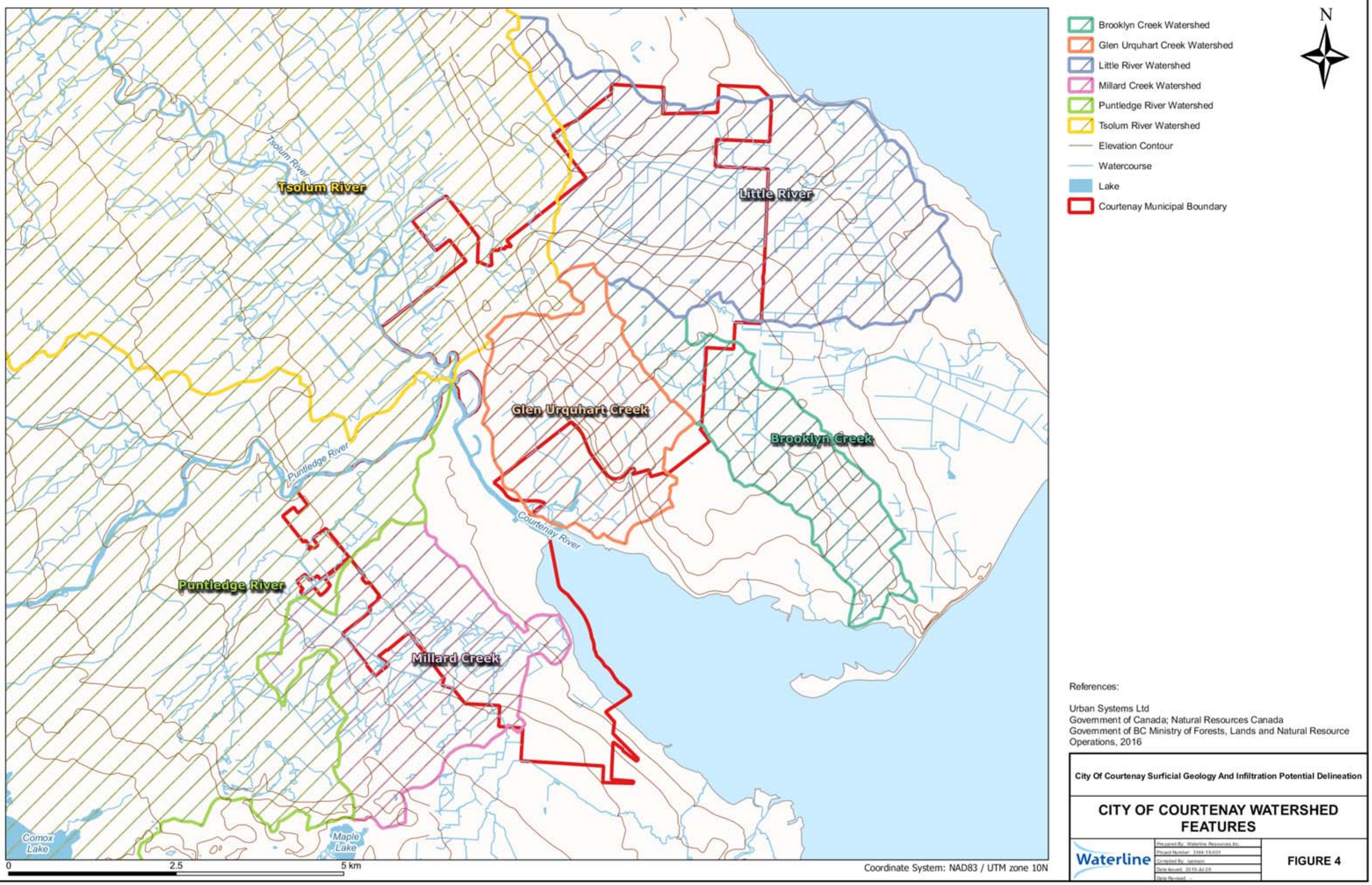


References:

Urban Systems Ltd
Government of Canada; Natural Resources Canada
Government of BC Ministry of Forests, Lands and Natural Resource Operations, 2016

City Of Courtenay Surficial Geology And Infiltration Potential Delineation

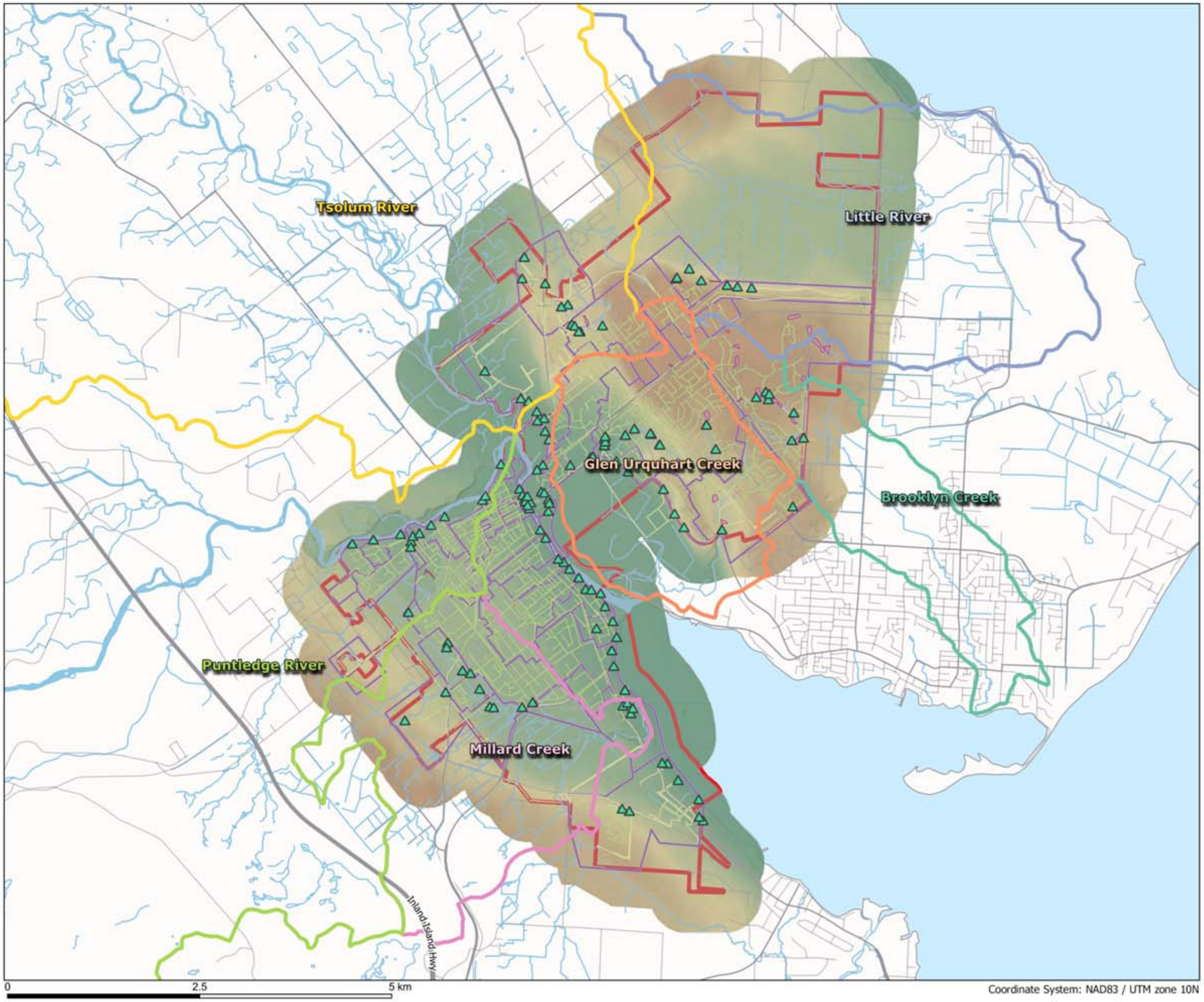
CITY OF COURTENAY WATERSHED FEATURES

Waterline

Prepared By: Waterline Resources Inc.
Project Number: 3164-19-001
Compiled By: [illegible]
Date Issued: 2019-Jul-29
Date Revised: --

FIGURE 4

P:\2019 PROJECTS\3164-19-BC Urban City of Courtenay Infiltration Study\001 City of Courtenay Surficial Geology and Infiltration Potential Delineation\Data\Drafting\3164_figs\3164_figs2.qgs



References:

Urban Systems Ltd
Government of Canada; Natural Resources Canada
Government of BC Ministry of Forests, Lands and Natural Resource Operations, 2016

City Of Courtenay Surficial Geology And Infiltration Potential Delineation

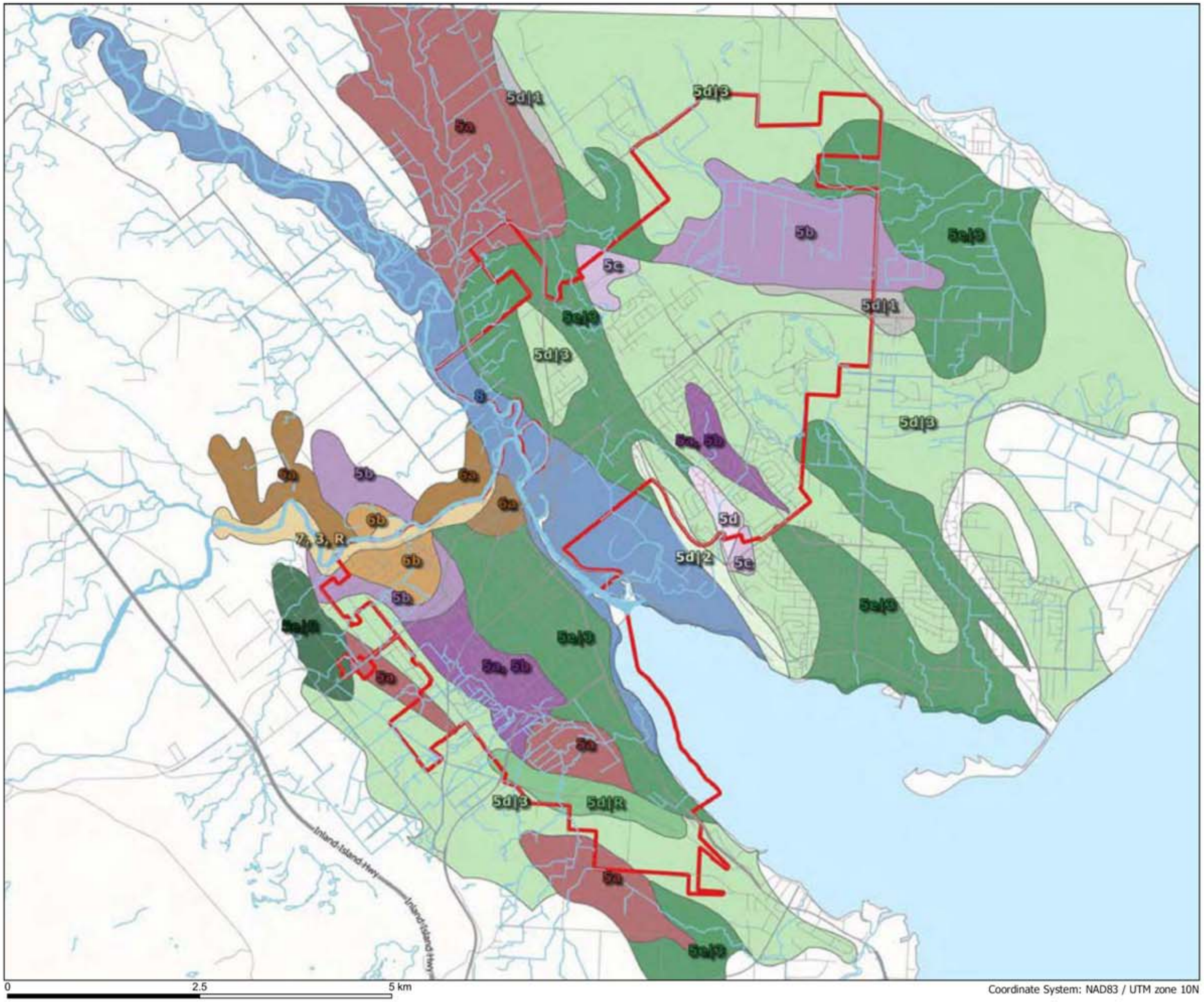
GROUND ELEVATION FOR THE CITY OF COURTENAY

Waterline

Prepared By: Waterline Resources Inc.
Project Number: 3164-19-001
Compiled By: [illegible]
Date Issued: 2019-Jul-29
Date Revised: --

FIGURE 5

P:\2019 PROJECTS\3164-19-BC Urban City of Courtenay Infiltration Study\001 City of Courtenay Surficial Geology and Infiltration Potential Delineation\Data\Drafting\3164_figs\3164_figs2.qgs



References:

Urban Systems Ltd
Government of Canada; Natural Resources Canada
Government of BC Ministry of Forests, Lands and Natural Resource Operations, 2016

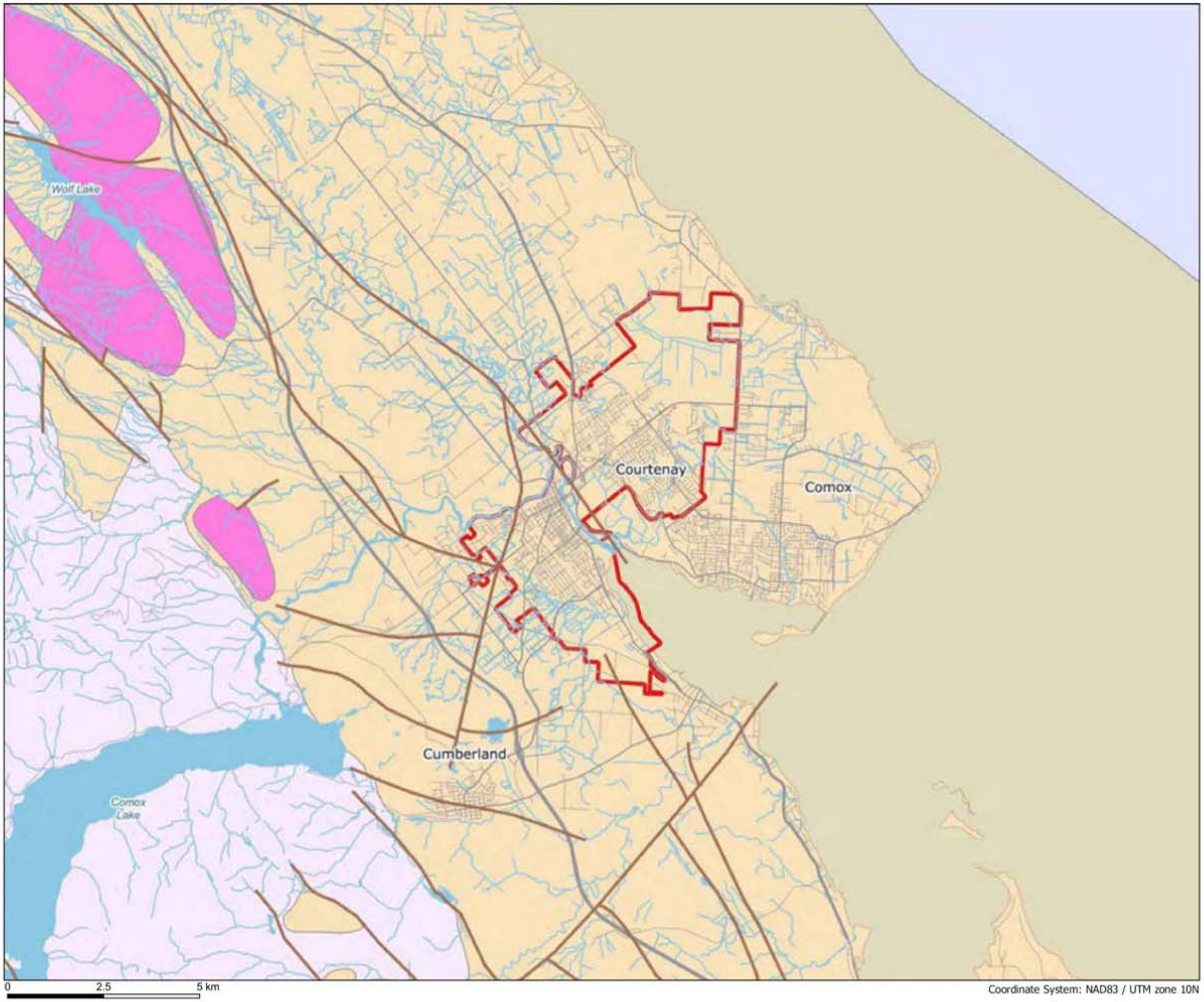
City Of Courtenay Surficial Geology And Infiltration Potential Delineation

SURFICIAL GEOLOGY MAP

Waterline

FIGURE 6

P:\2019 PROJECTS\3164-19-BC Urban City of Courtenay Infiltration Study\001 City of Courtenay Surficial Geology and Infiltration Potential Delineation\Data\Drafting\3164_figs\3164_figs2.qgs



References:

Urban Systems Ltd
Government of Canada; Natural Resources Canada
Government of BC Ministry of Forests, Lands and Natural Resource Operations, 2016

City Of Courtenay Surficial Geology And Infiltration Potential Delineation

BEDROCK GEOLOGY MAP

Waterline

FIGURE 7

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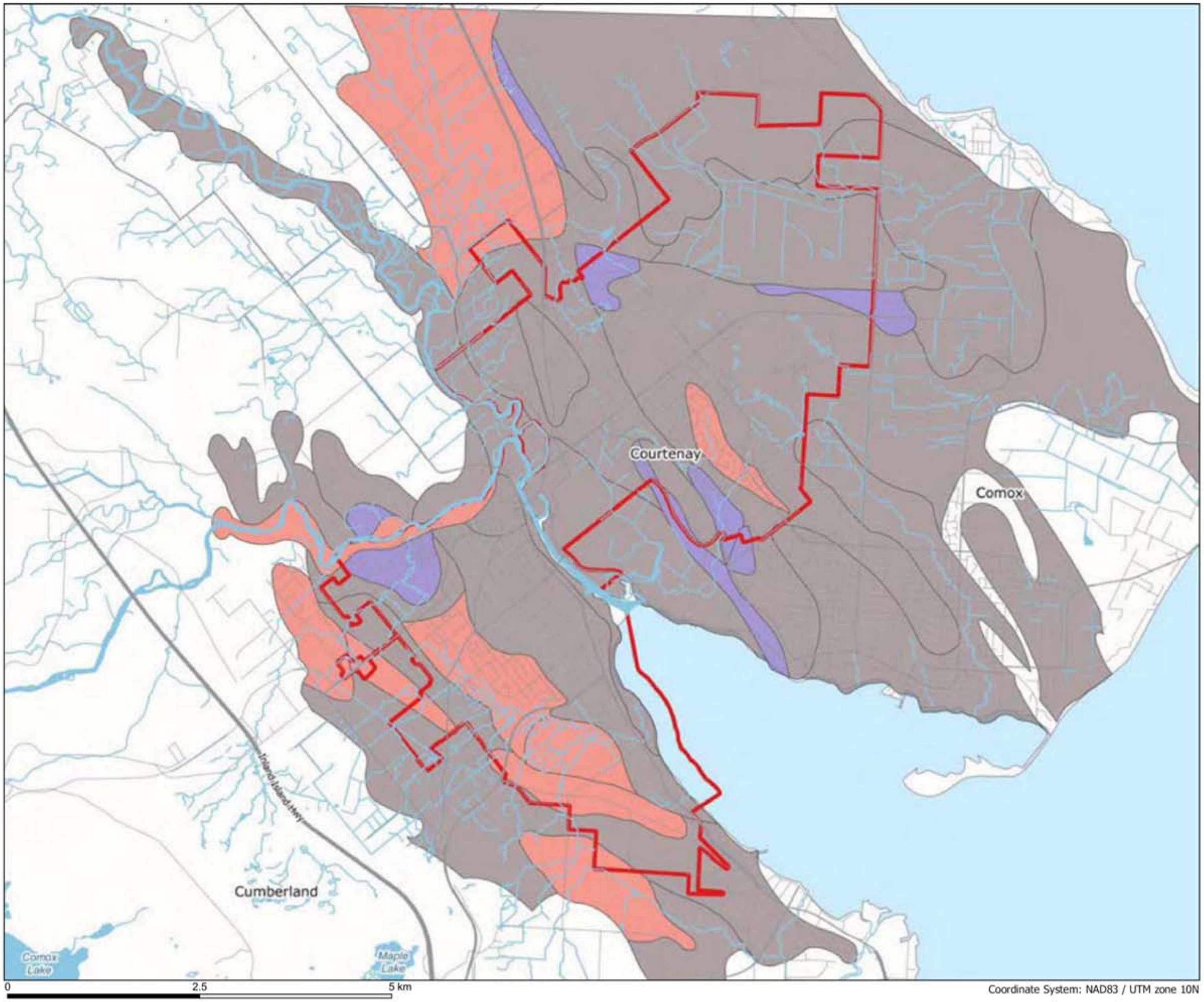


References:

Urban Systems Ltd
Government of Canada; Natural Resources Canada
Government of BC Ministry of Forests, Lands and Natural Resource Operations, 2016

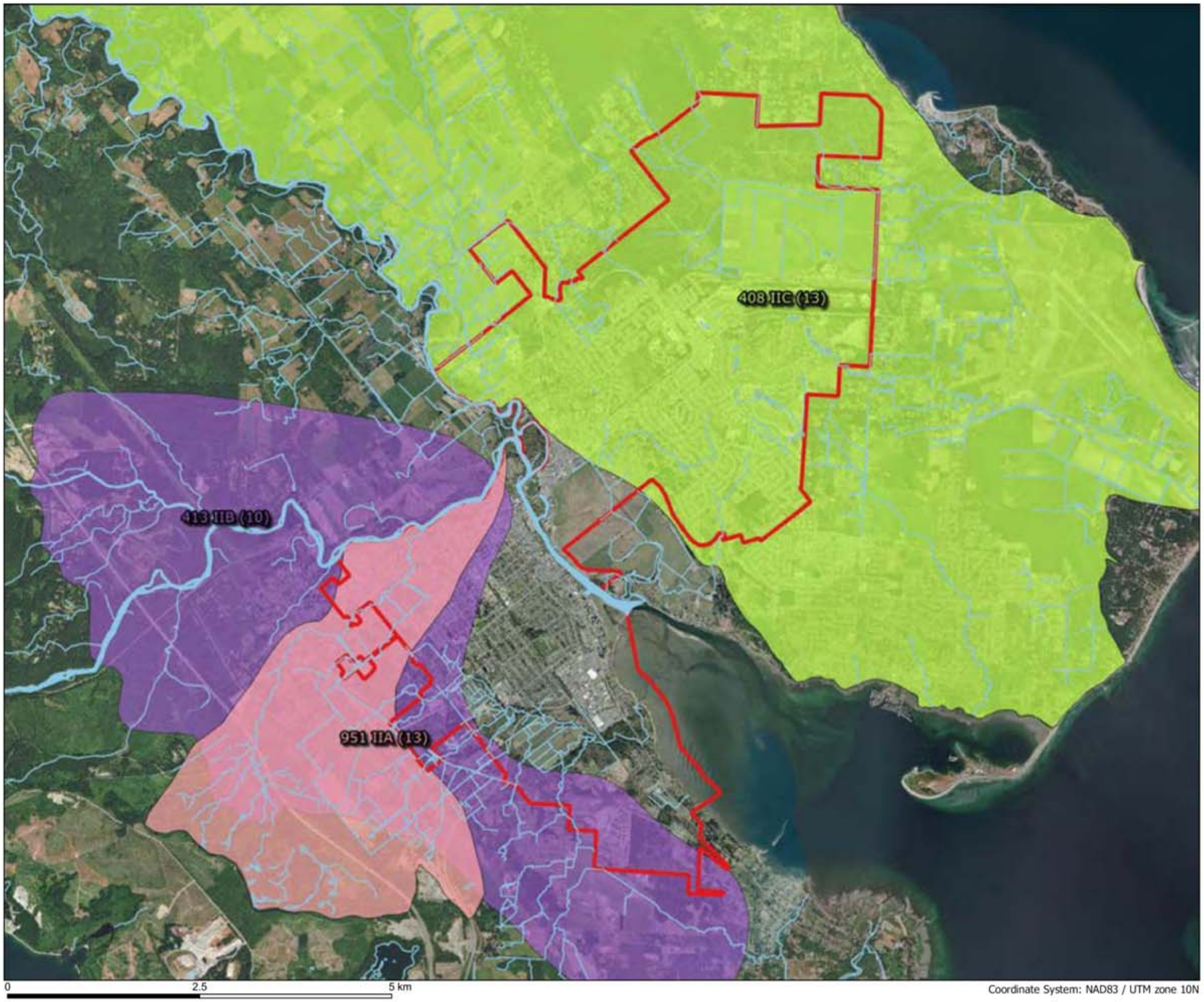
City Of Courtenay Surficial Geology And Infiltration Potential Delineation

SPATIAL DISTRIBUTION OF INFILTRATION POTENTIAL

Waterline

FIGURE 8

P:\2019 PROJECTS\3164-19-BC Urban City of Courtenay Infiltration Study\001 City of Courtenay Surficial Geology and Infiltration Potential Delineation\Data\Drafting\3164_figs\3164_figs2.qgs



References:

Urban Systems Ltd
Government of Canada; Natural Resources Canada
Government of BC Ministry of Forests, Lands and Natural Resource Operations, 2016

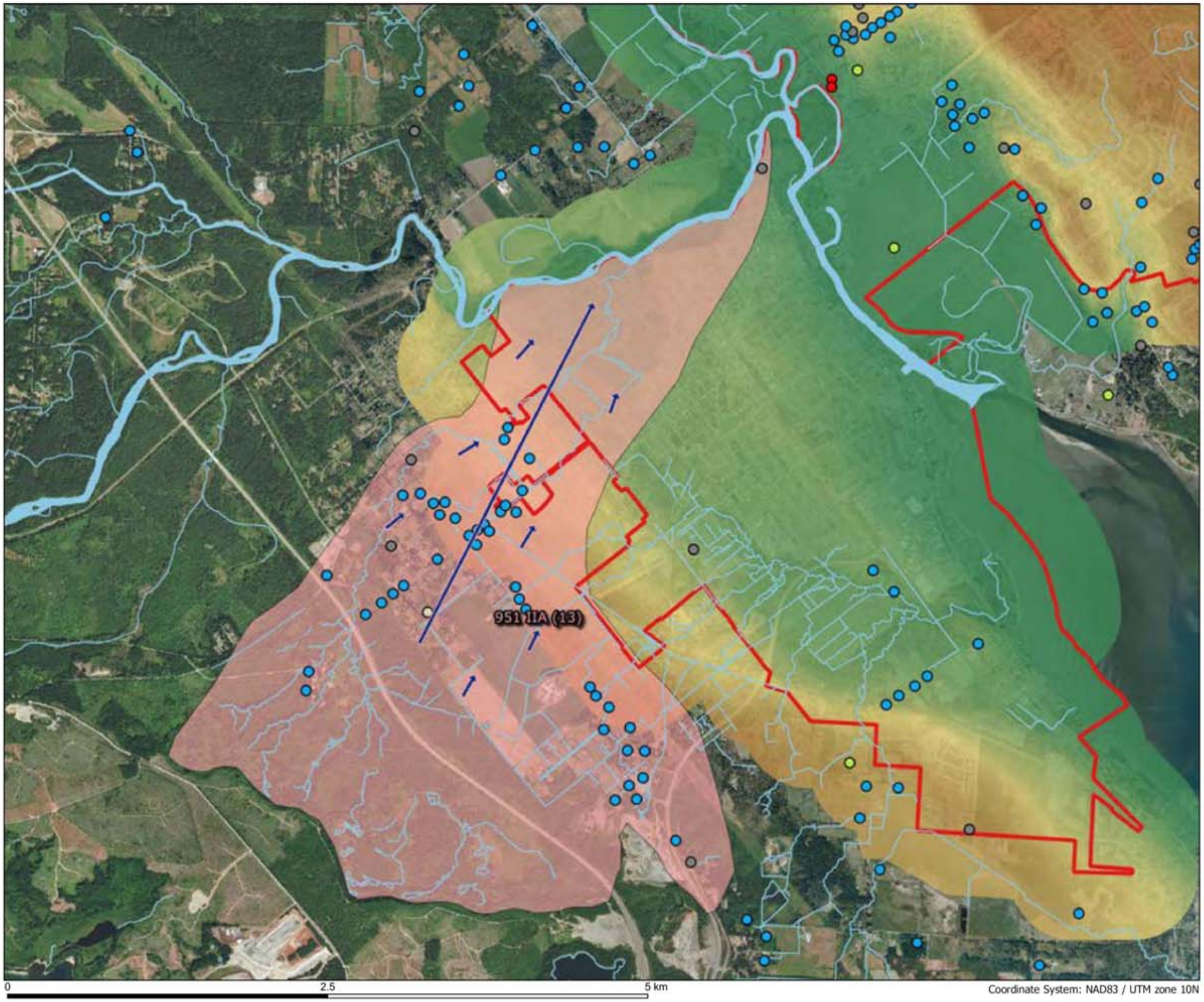
City Of Courtenay Surficial Geology And Infiltration Potential Delineation

MAPPED AQUIFERS WITHIN THE CITY OF COURTENAY MUNICIPAL BOUNDARY

Waterline

FIGURE 9

P:\2019 PROJECTS\3164-19-BC Urban City of Courtenay Infiltration Study\001 City of Courtenay Surficial Geology and Infiltration Potential Delineation\Data\Drafting\3164_figs\3164_figs2.qgs



Water Wells
- Domestic
- Water Works
- Water Supply System
- Irrigation
- Dry
- Unknown
- Watercourse

Aquifers In Overburden
- IIA
- Courtenay Municipal Boundary

Elevation (m)
- 5.7
- 20.7
- 35.6
- 50.6
- 65.5
- 80.5
- 95.5

Groundwater flow direction
Flows from southwest to northwest generally following the topographic gradient of the slope

References:

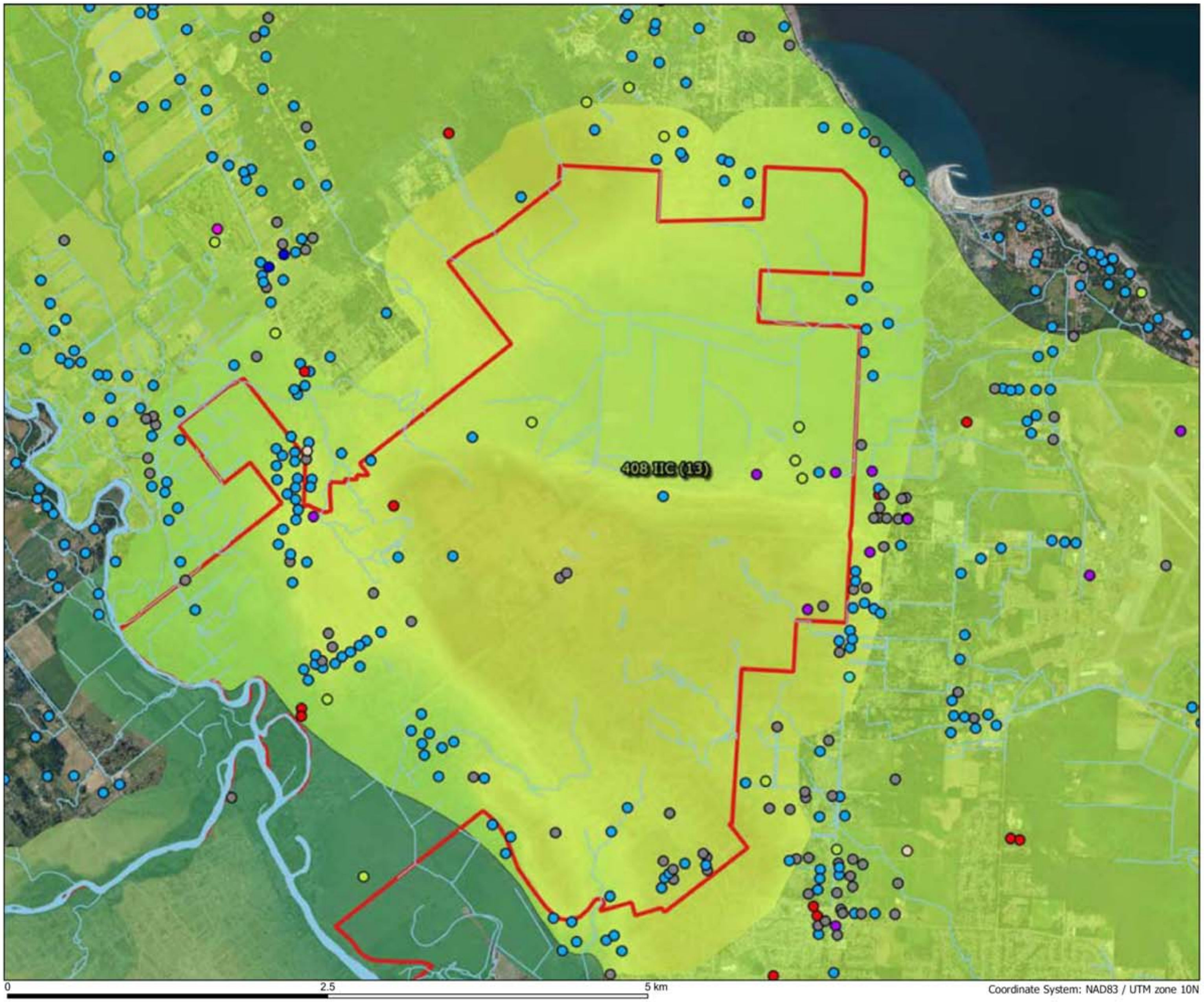
Urban Systems Ltd
Government of Canada; Natural Resources Canada
Government of BC Ministry of Forests, Lands and Natural Resource Operations, 2016

City Of Courtenay Surficial Geology And Infiltration Potential Delineation

CAPILANO AQUIFER (#951) MAP AND REGISTERED WATER WELLS

Waterline

FIGURE 10



Coordinate System: NAD83 / UTM zone 10N

References:

Urban Systems Ltd
Government of Canada; Natural Resources Canada
Government of BC Ministry of Forests, Lands and Natural Resource Operations, 2016

City Of Courtenay Surficial Geology And Infiltration Potential Delineation

QUADRA SAND AQUIFER (#408) MAP AND REGISTERED WATER WELLS

Waterline

FIGURE 11

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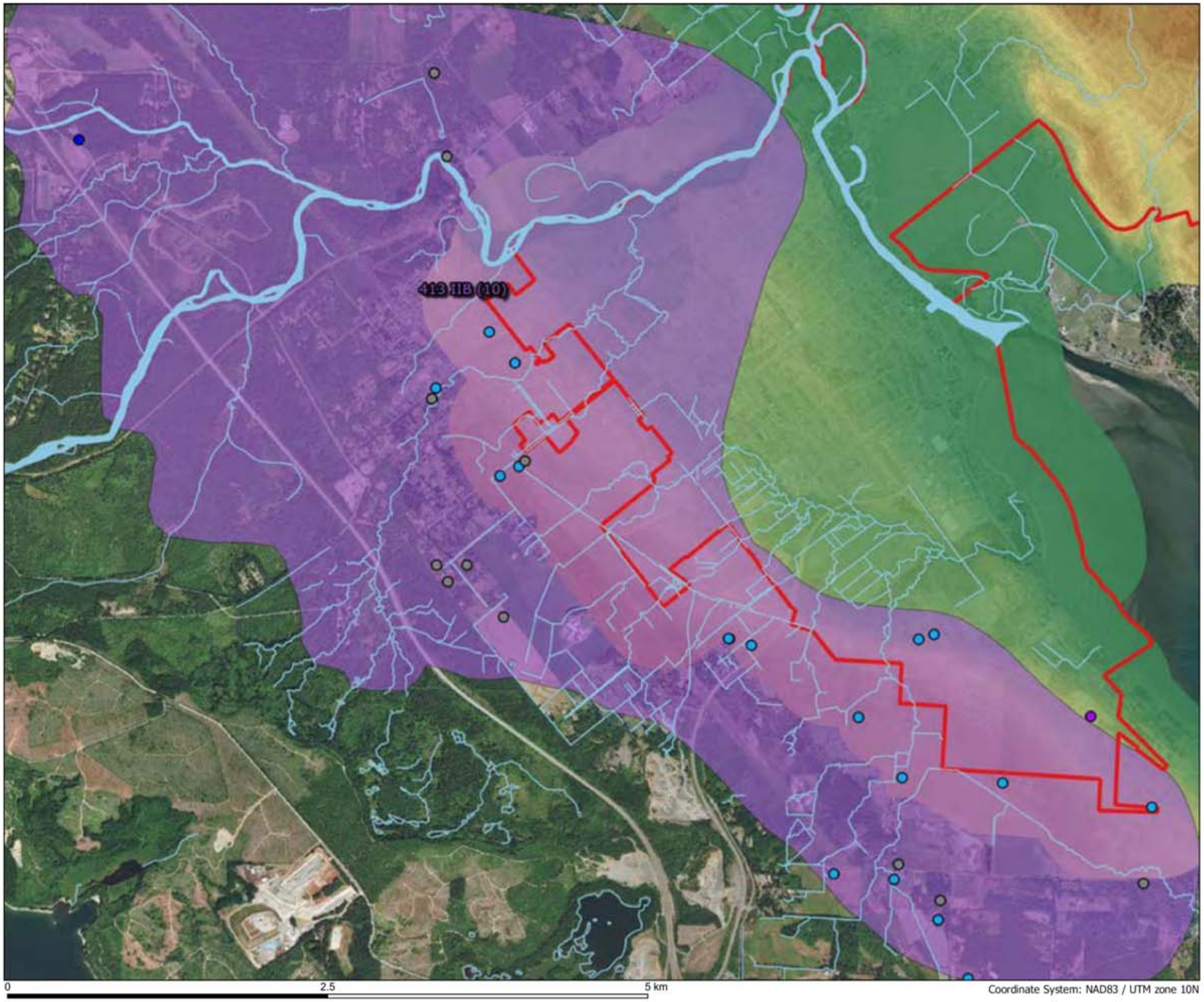


Water Wells
- Domestic
- Water Supply System
- Commercial & Industrial
- Unknown
- Watercourse

Aquifers In Bedrock
- IIB
- Courtenay Municipal Boundary

Elevation (m)
- 5.7
- 20.7
- 35.6
- 50.6
- 65.5
- 80.5
- 95.5

References:

Urban Systems Ltd
Government of Canada; Natural Resources Canada
Government of BC Ministry of Forests, Lands and Natural Resource Operations, 2016

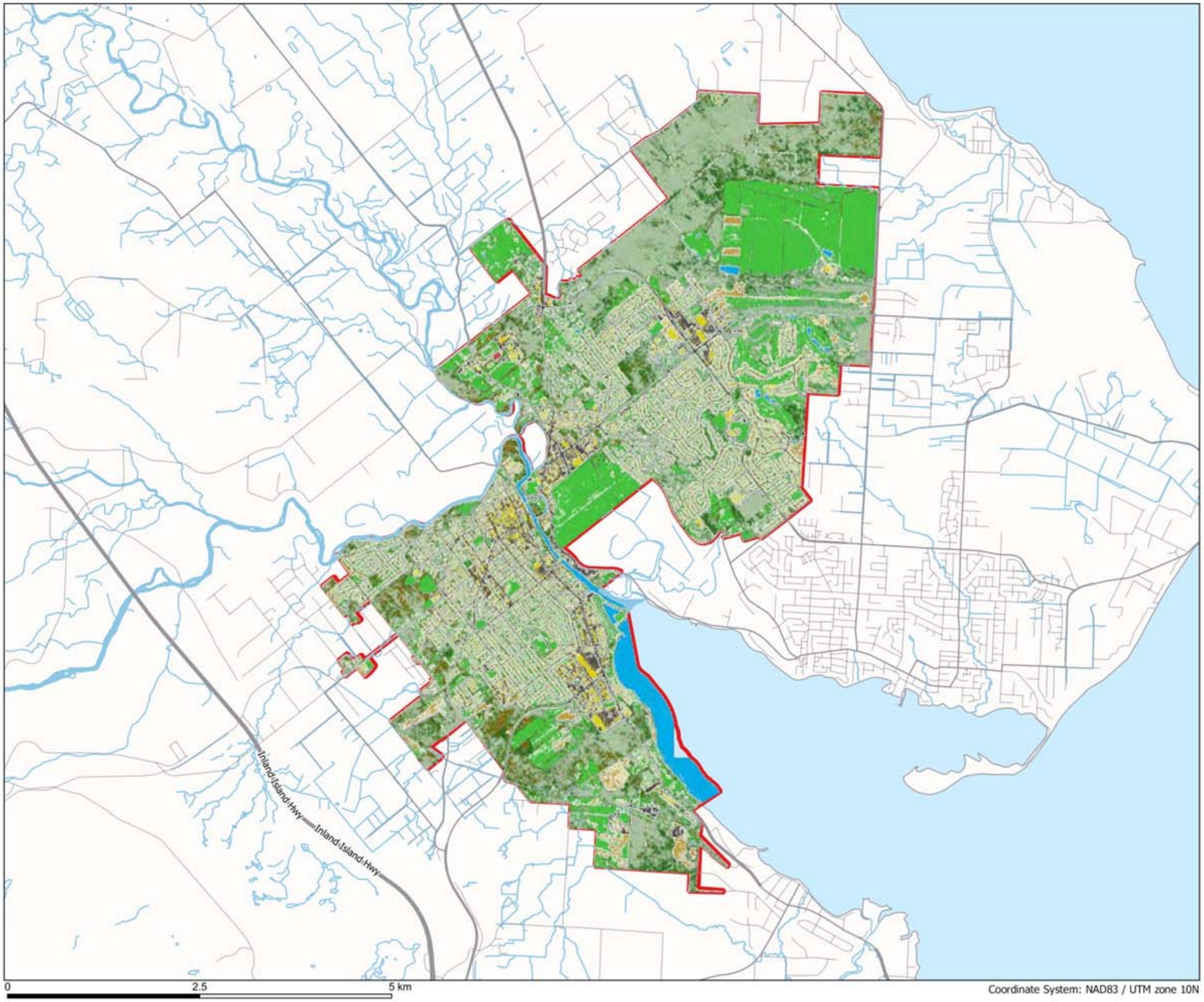
City Of Courtenay Surficial Geology And Infiltration Potential Delineation

BEDROCK AQUIFER (#413) MAP AND REGISTERED WATER WELLS

Waterline

FIGURE 12

P:\2019 PROJECTS\3164-19-BC Urban City of Courtenay Infiltration Study\001 City of Courtenay Surficial Geology and Infiltration Potential Delineation\Data\Drafting\3164_figs\3164_figs2.qgs



- Watercourse
- Road - Expressway / Highway
- Road - Arterial / Collector
- Road
- Courtenay Municipal Boundary

Direct Infiltration Landcover Types
- Bare
- Water

Vegetated Landcover Types
- Coniferous
- Dedic Leaf On
- Dedic Leaf Off
- Grass
- Shadow

Impermeable Landcover Types
- Building
- Paved
- Other Built

References:

Urban Systems Ltd
Government of Canada; Natural Resources Canada
Government of BC Ministry of Forests, Lands and Natural Resource Operations, 2016

City Of Courtenay Surficial Geology And Infiltration Potential Delineation

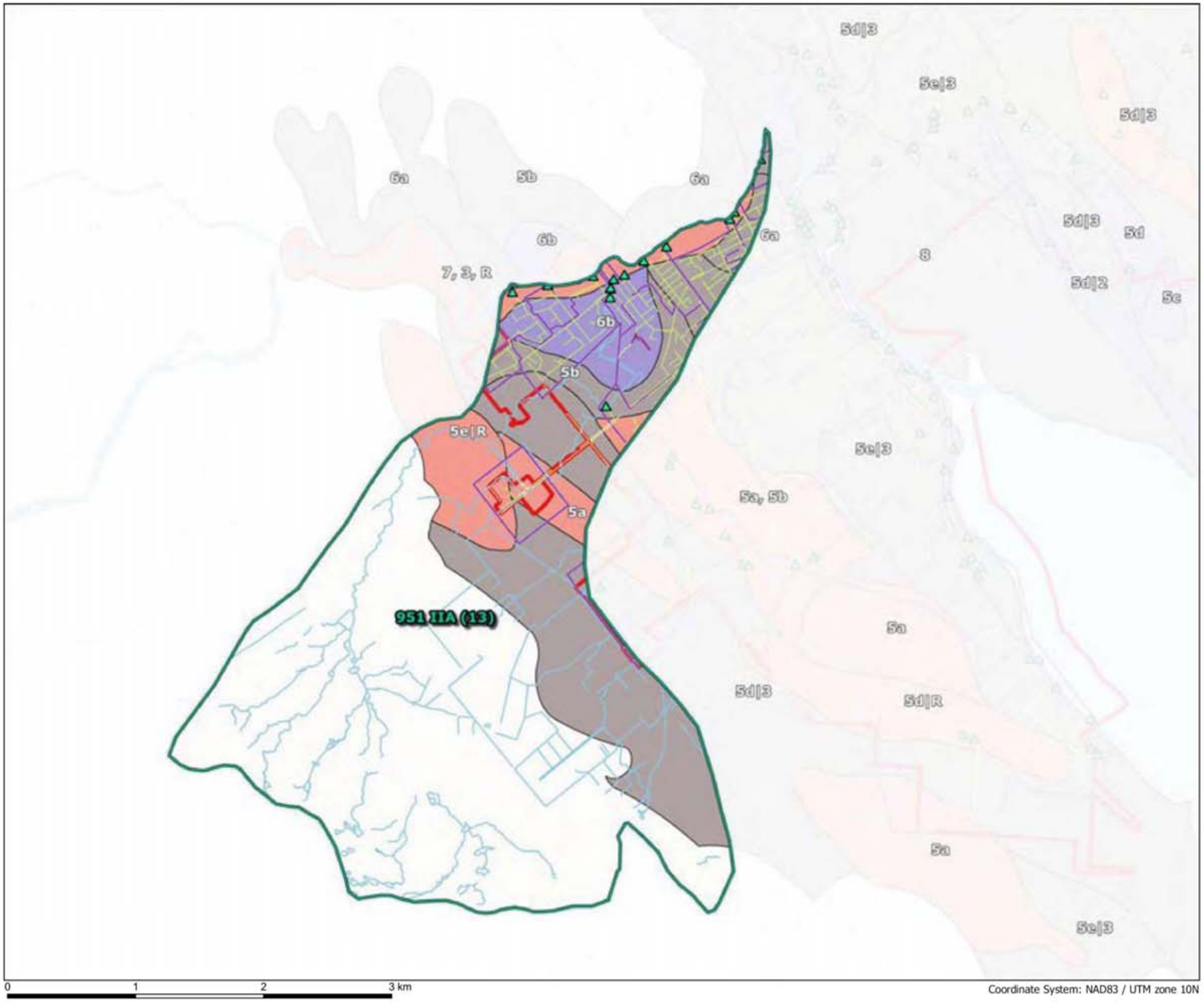
DISTRIBUTION OF LAND COVER TYPES WITHIN THE CITY OF COURTENAY MUNICIPAL BOUNDARY

Waterline

Prepared By: Waterline Resources Inc.
Project Number: 3164-19-001
Compiled By: Ijamison
Date Issued: 2019-Jul-29
Date Revised: --

FIGURE 13

P:\2019 PROJECTS\3164-19-BC Urban City of Courtenay Infiltration Study\001 City of Courtenay Surficial Geology and Infiltration Potential Delineation\Data\Drafting\3164_figs\3164_figs2.qgs



- Storm Discharge Point
- Storm Gravity Main
- Storm Open Drain
- Storm Catchment Area
- Storm Detention Area
- Watercourse
- Aquifer
- Courtenay Municipal Boundary

Infiltration Potentials

- Good
- Marginal
- Poor
- Surficial Geology Boundary

References:

Urban Systems Ltd
Government of Canada; Natural Resources Canada
Government of BC Ministry of Forests, Lands and Natural Resource Operations, 2016

City Of Courtenay Surficial Geology And Infiltration Potential Delineation

INFILTRATION POTENTIALS AND VULNERABILITY FOR AQUIFER #951

Waterline

FIGURE 14

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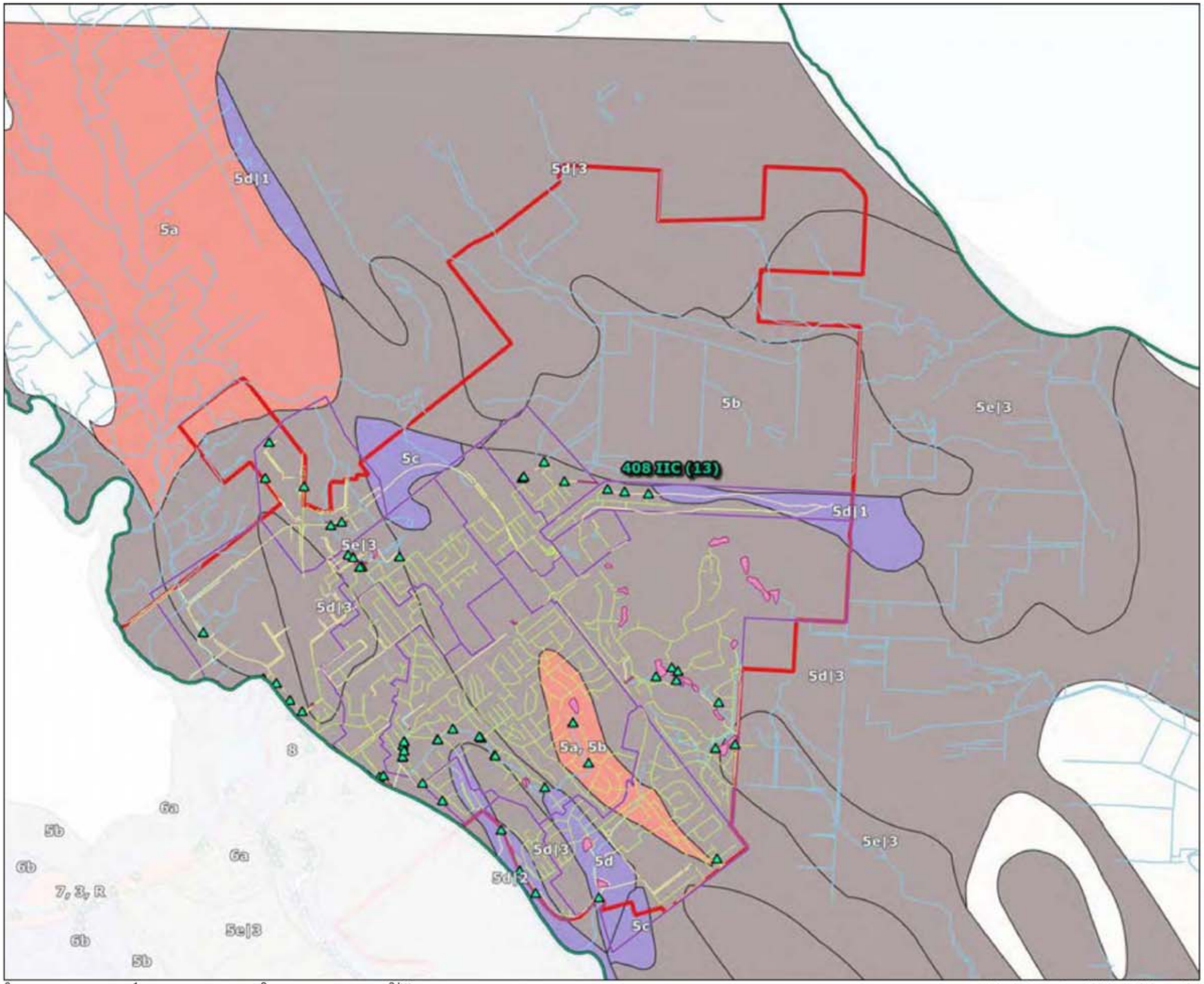

References:

Urban Systems Ltd
Government of Canada; Natural Resources Canada
Government of BC Ministry of Forests, Lands and Natural Resource Operations, 2016

City Of Courtenay Surficial Geology And Infiltration Potential Delineation

INFILTRATION POTENTIALS AND VULNERABILITY FOR AQUIFER #408

Waterline

FIGURE 15

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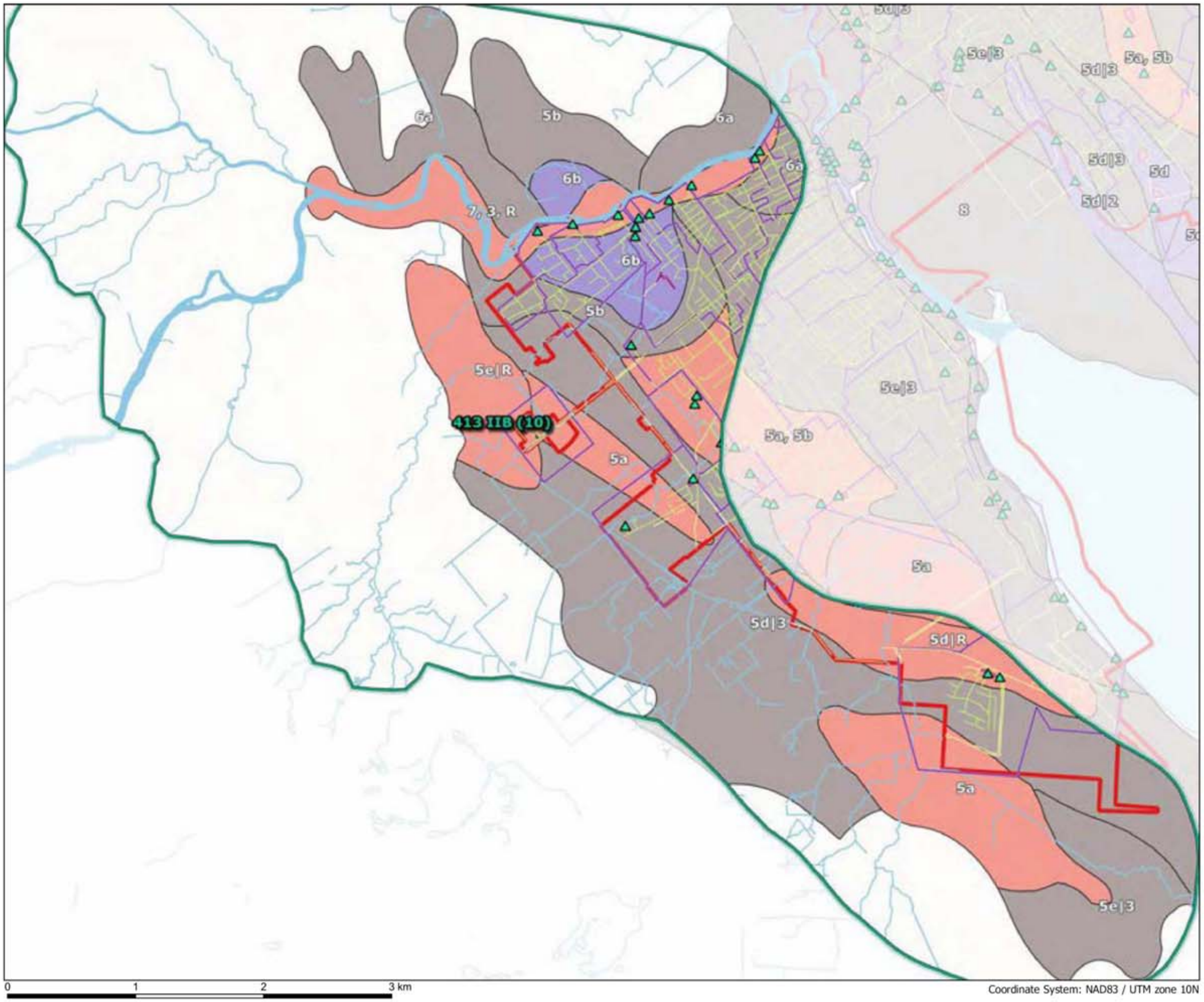

References:

Urban Systems Ltd
Government of Canada; Natural Resources Canada
Government of BC Ministry of Forests, Lands and Natural Resource Operations, 2016

City Of Courtenay Surficial Geology And Infiltration Potential Delineation

INFILTRATION POTENTIALS AND VULNERABILITY FOR AQUIFER #413

Waterline

FIGURE 16

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