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Consultants in Hydrogeology and Environmental Science

Preliminary Hydrogeological Assessment for Vavenby Groundwater Issues, Vavenby, B.C.

Prepared for:

THOMPSON-NICOLA REGIONAL DISTRICT TNRD
The Region of BC's Best

Thompson-Nicola Regional District
300 - 465 Victoria Street
Kamloops, B.C., V2C 2A9

February 2020
Project: 19-033-01

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February 27, 2020

Ron Storie - Director of Community Services
Thompson-Nicola Regional District
300 - 465 Victoria Street
Kamloops, BC, V2C 2A9

Via e-mail: rstorie@tnrd.ca

Dear Mr. Storie:

Re: Preliminary hydrogeological assessment – to address ongoing management of groundwater flow, Vavenby B.C.

Western Water Associates Ltd. (WWAL) is pleased to provide this preliminary hydrogeologic assessment addressing known groundwater Issues which have been occurring in the Vavenby area for many years.

The current study Involved interviewing affected property owners, reviewing existing groundwater well logs, developing geologic cross-sections and interpreting relevant data. Further, within the report we provide recommendations to address the ongoing and likely continuous groundwater flow conditions at the site.

We trust that the professional opinions and advice presented in this document are sufficient for your current requirements. Should you have any questions, or if we can be of further assistance in this matter, please contact the undersigned.

WESTERN WATER ASSOCIATES LTD.

PROFESSIONAL ENGINEER
PROVINCE OF BRITISH COLUMBIA
B. R. MANWELL
Feb 27/2020
19-033-01WL

Bryer Manwell, M.Sc., P.Eng.
Hydrogeological Engineer

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1. INTRODUCTION

The Thompson Nicola Regional District (TNRD) contacted Western Water Associates Ltd. (WWAL) in May 2019 and requested a proposal to assess known and persistent high groundwater issues in the Vavenby area, herein referred to as the 'site'. We understand the groundwater flow from the northwest towards the North Thompson River has created drainage challenges for the residents. This report provides a summary of WWAL's approach and findings in assessing the groundwater flow regime. Our study approach involved a desktop assessment of available reports, maps and well logs, development of geological cross-sections and interviews with residents who experience groundwater issues in the area.

1.1 Project Objectives

The potential for groundwater to cause drainage issues in an area can be due to several reasons including but not limited to: the hydrogeologic landscape, geology, aquifer type, leaks in TNRD water infrastructure, and change in the land use over-time. The objective of the current study is to assess the reasons for ongoing groundwater issues for properties on both the northwest and southeast sides of the North Thompson River at Vavenby. Further, we provide suggestions on how the community can manage the potential flooding caused by the high groundwater table during the spring freshet and the summer melt.

1.2 Scope of Current Study

The scope of the current study is preliminary in nature and relied on existing information both anecdotal and physical. The assessment included the following:

- Conducting phone interviews with property owners who experience groundwater issues in the Vavenby area;
- Reviewing maps provided by the TNRD;
- Identifying the UTM coordinates of known wells, springs and surface waters in the BC Ministry of Environment (MOE) and Ministry of Forests, Lands and Natural Resource Operations (MFLNRO) databases;
- Examining the logs for water wells in the MoE GWELLS Database (where available) and identifying those wells terminating in bedrock, till or sand and gravel;
- Reviewing geology mapped in the area;
- Reviewing available consultant's reports that provided information on the area's hydrogeology;
- Creating two geological cross-section's to visually show subsurface conditions;
- Estimating groundwater flow off the hillside, which we believe is a source of the groundwater issues at the site; and
- Comparing groundwater flow estimates through the water issue area to the volumetric flow of water provided to the community by the TNRD. This comparison will help to assess the magnitude of contribution from potentially leaking TNRD water supply infrastructure.

2. SITE SETTING

The following section provides an overview of the site setting, including the site physiography, climate, geology and hydrogeology. Based on water well logs, aquifer and bedrock mapping, a conceptual model of groundwater flow downgradient of the site is also provided.

2.1 Site Physiography

The community of Vavenby is located within the North Thompson River watershed and is situated along both the northwest and southeast flank of the North Thompson River, about 22 km west of the town of Clearwater (Appendix A TNRD Vavenby Maps). The majority of the community sits on the northwest side of the North Thompson River and consists primarily of residential properties. There are three distinct terrace deposits (locally referred to as "lifts") which have been developed on the northwest side of the North Thompson River. The Southern Yellowhead Highway (Hwy 5) runs along the upper terrace, with the community located below the highway (Figure 1). The 'water issue area' exists on the second terrace, between Galiano Road and Ball Road. The area of concentrated water issues is transected by railway tracks (Figures 1, 2, 3, 4, and 5).

Above the highway is an area of forested upper plateau, which is regarded as a recharge zone within the watershed, that reaches elevations around 1370 meters above sea level (masl). The plateau has been incised by the North Thompson River, which sits at about 440 masl at Vavenby. The majority of residential development on the northwest side of the North Thompson River is situated at about 465 masl within the discharge zone of the watershed, almost 25 m above the river.

2.2 Land Use and Community Infrastructure

2.2.1 Vavenby Land Zoning

Vavenby has a total of 140 properties (Appendix A) and is a community of approximately 252 residents (Statistics Canada 2016). The primary zoning within the Vavenby area is residential, both compact and single-family. There is some commercial property designated as general and service. Within the Vavenby northwest side of the North Thompson River is a school, a fire department, community hall and park. At the southwest boundary Vavenby is the Canfor Mill which is planned for permanent shut down as of 2019. The northeast boundary Vavenby is flanked by relatively undeveloped forested lands. As mentioned above, the North Thompson River runs through Vavenby and there is a bridge that links the northwest to the southeast areas of the community. The area showing groundwater drainage issues is designated compact residential (Figure 1 and Appendix A - Vavenby Service Area Zoning Map).

2.2.2 Vavenby Water System

Vavenby includes a community water system operated and maintained by the TNRD. Table 1 Provides a summary of residential versus nonresidential water connections within the Vavenby service area (information provided by the TNRD). All wastewater is managed on-site (private sewerage disposal systems), there is no wastewater collection and treatment infrastructure in the Vavenby service area.

TRUE Consulting completed a Community Master Water Plan for Vavenby (TRUE 2018). The TRUE report contains several appendices which detail historic hydrogeologic investigations within Vavenby. Several of these hydrogeologic investigation reports are referenced in the current report.

Currently Vavenby sources water from an intake located adjacent to the North Thompson River. The water system was constructed in 1972 by the Vavenby Improvement District. The Vavenby Improvement District operated the water system on the northwest side of the North Thompson River and a small community water system was operated by local residents on the southeast side. The transfer of the Vavenby water system to the TNRD occurred in 2004. In 2005 the distribution system was extended across the river (TRUE 2018).

The population of Vavenby is 252 and the water system currently services 140 properties. The average daily demand of Vavenby is 298 m^3/day as stated by the TNRD (TRUE 2018). The Canfor property has a potable water connection but take their process water and firefighting supply directly from an onsite well-constructed in 2012. Flows within the TNRD water system prior to 2016 included many significant leaks, which have been repaired.

The current water system has persistent turbidity issues, especially during the spring freshet. To address the turbidity water quality issues TRUE recommended the Vavenby service area could consider a second attempt at establishing a groundwater supply source (TRUE 2018).

Table 1: Summary of Residential and Non-Residential Water Consumers in Vavenby

	Non-residential water consumers	Residential water consumers	TOTALS
E (Southeast) of N. Thompson River	1	22	23
W (Northwest) of N. Thompson River	12	105	117
TOTALS	13	127	140 (total properties)

Note: Data provided from the TNRD (2019)

2.3 Climate

The site is located within the Interior Cedar-Hemlock Zone at an elevation of 465 masl. The site is located approximately 150 km north of Kamloops, BC, and the nearest climate station, with a long climatic record, is at Kamloops. The Kamloops climate station (Climate ID 1163780) is positioned at a slightly lower elevation than the elevation of Vavenby (465 masl). Although there is a slight difference in elevation between the site and Kamloops, the overall seasonal trends in climate will be similar for the site as at Kamloops. The site may see higher precipitation and slightly lower temperatures depending on elevation and aspect. Table 1 summarizes the monthly climate normals for temperature and precipitation for the Kamloops station from between 1981 and 2010. The seasonal high temperatures occur in July and August and the seasonal lows occur in December and January. Average precipitation is highest in June and July and lowest between January and April. The annual average precipitation is 278 mm and the average daily temperature is 9˚C.

Table 2: Climate Normals for Kamloops BC, from 1981 to 2010. Climate ID. 1163780

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Daily Average (°C)	-2.8	0.1	5.2	9.9	14.6	18.4	21.5	20.9	15.6	8.5	2.1	-2.7	9.3
Standard Deviation	3.4	2.7	1.6	1.1	1.4	1.4	1.6	1.2	1.5	1	2.8	3	0.9
Precipitation (mm)	21.1	12.4	12.8	14.2	27.3	37.4	31.4	23.7	29.4	19.4	23.3	25.4	277.6

2.4 Geology

2.4.1 Surficial Deposits

According to Tipper (1971), the North Thompson River valley was once a glacial meltwater channel. The river has subsequently incised glacial deposits and is presently flanked by morainal, terraced alluvial and fan deposits (Kohut 1982). Vavenby is underlain by a mixture of till, sand, gravel and boulders of glacial and alluvial origins. WWAL developed two lithological cross sections based on the available well logs in the area perpendicular and relatively parallel to the North Thompson River (Figures 2 and 3). The thickness of the unconsolidated materials in the Vavenby area is at least 215 ft thick. From these cross sections and from the BC terrain mapping the community lies above areas mapped as glaciofluvial terrace deposits, (AGt), fluvial fan deposits (Af) mixed with silty lacustrine sediments (SL).

Above the community along Highway 5, areas are mapped as fluvial fan with colluvial fan (Cf) mixed with silty lacustrine sediments. Higher elevations are mapped as colluvium blanket and veneer (Cb, Cv) with glacial till (M) and rock (R). The terrain within which most of the community is located forms a series of fluvial or glaciofluvial terraces. The terraces are comprised of brown sand with gravel. On the southeast side of the River pockets of glaciolacustrine silt were noted immediately above the upper terrace (BCGW 2018).

In both cross sections A-A' and B-B' an approximately 10 m thick silt and clay layer is present beneath the area identified as having groundwater issues (Figures 2 and 3). Above the 10 m thick silt and clay layer is sand and gravel present in the upper terrace formations. The presence of this silt and clay is significant and is likely the underlying reason for the groundwater issues experienced by some of the community in the area denoted on Figure 1.

2.4.2 Bedrock Geology

The dominant structural feature of the site is the large Vavenby thrust fault which underlies the town site. The map area covers a belt of structurally complex low-grade metamorphic rocks that lies along the western margin of the Omineca Belt. It is flanked by high-grade metamorphic rocks of the Shuswap Complex to the east and by rocks of the Intermontane Belt to the west. The area is underlain mainly by Paleozoic metasedimentary and metavolcanic rocks of the Eagle Bay Assemblage and the Fennel Formation (Schiarizzia and Church 1996). Late Devonian granitic orthogneiss locally intrudes Eagle Bay rocks.

The Paleozoic rocks are cut by mid Cretaceous granodiorite and quartz monzonite of the Raft and Baldy batholiths, and by Early Tertiary quartz feldspar porphyry, basalt and larnprophyre dykes. They are locally overlain by Eocene sedimentary and volcanic rocks of the Kamloops Group and by Miocene plateau lavas (Stantech 2005). The Paleozoic rocks occur in four structural slices separated by southwesterly-directed thrust faults. The upper three fault slices contain only Eagle Bay rocks, while the lowest slice comprises Eagle Bay strata structurally overlain by the Fennell Formation.

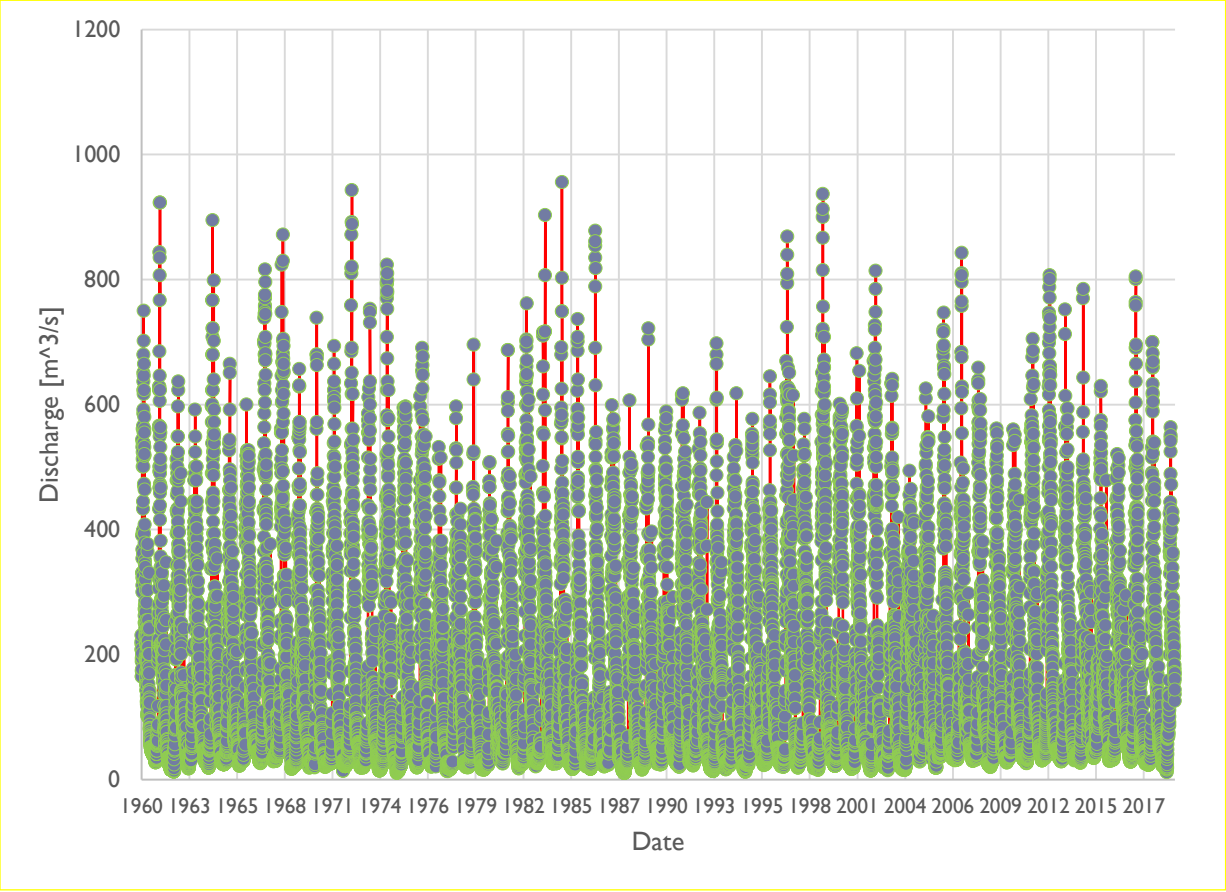
2.5 Hydrology

As mentioned earlier, the community of Vavenby flanks of the North Thompson River (River) making the River the most dominant surface water body in the vicinity of the site. The River is a high order stream draining approximately 20,750 km² (ENV 2019). Regionally and locally the River flows from the

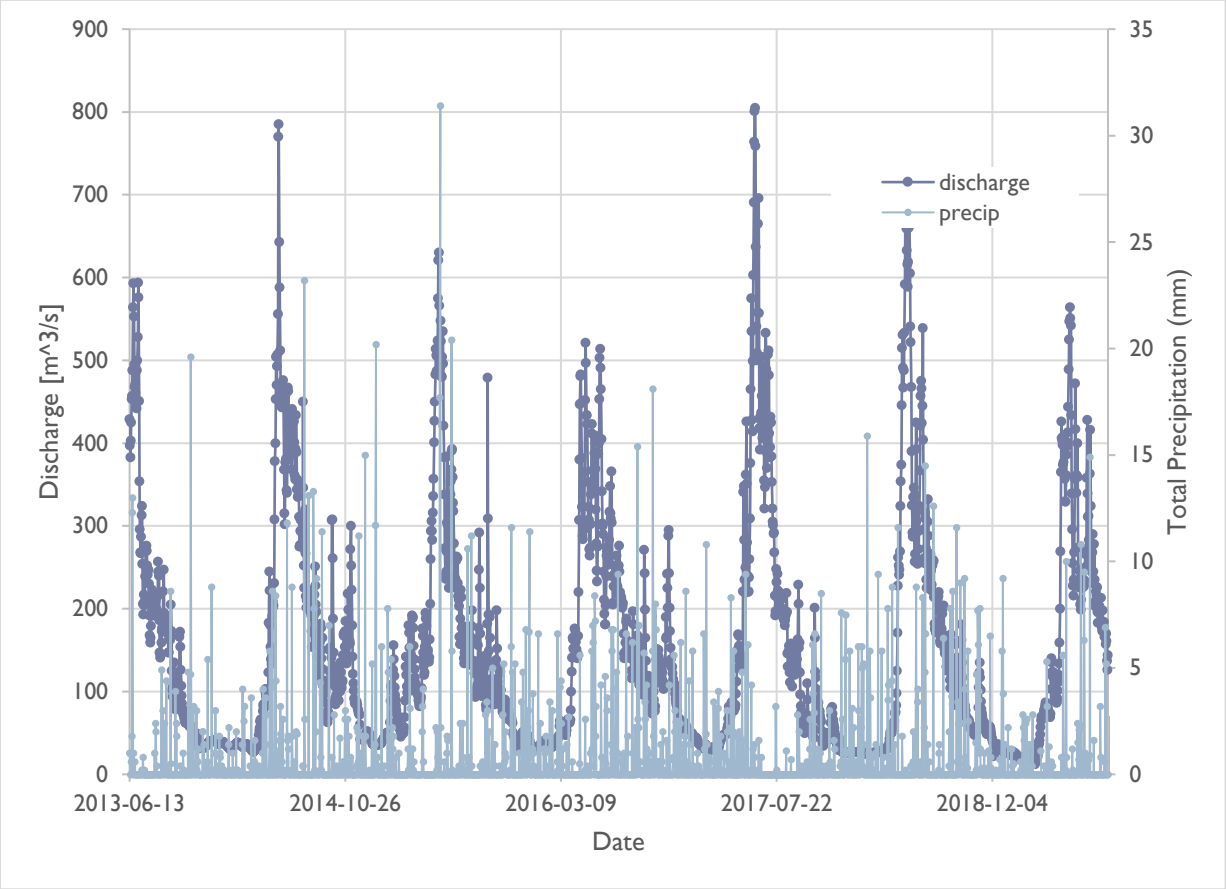
northeast to the southwest at about a 0.1% grade. There are numerous small tributes entering into the North Thompson River valley, as the valley is the major discharge zone for the upper watershed.

Plot 1 below shows discharge in the North Thompson River at Birch Island (just downgradient of Vavenby) from between 1960 and 2019 (Environment Canada 2019). Typically the annual hydrograph for the North Thompson River at Birch Island peaks in June, with the lowest discharges occurring in about January. Peak discharge in the North Thompson River can range between about 500 m³/sec and over 900 m³/sec depending on the seasonal snow melt occurring in the upper reaches of the watershed.

Plot 2 displays the mean daily discharge for the North Thompson River at Birch Island and daily total precipitation from the climate station at Kamloops for the years 2013 through 2019 (September). Although there can be a direct relationship between precipitation and increase in discharge in the River that relationship is not always observed. Likely, peak discharge the North Thompson River is driven by snow melt in the upper watershed as opposed to direct infiltration at the lower elevations.



Plot1: Mean Daily Discharge – North Thompson River at Birch Island 1960 - 2019



Plot 2: Mean Daily Discharge and Total Precipitation – North Thompson River at Birch Island 2013 - 2019

2.6 Hydrogeology

The province has mapped the North Thompson River associated alluvial aquifer system as Aquifer 807IIB (ENV 2019). The geologic formations overlying the aquifer are glacial and post-glacial sediments. Well records indicate the aquifer is partially confined by material described as clay, till or silt. The majority of well records show highly permeable post- glacial material (i.e. coarse sand, gravel, rocks, and boulders) overly the confining material. The aquifer is mapped as likely glaciofluvial deposits (ENV 2019).

Based on the limited subsurface data from available well logs, it is evident that within the unconsolidated deposits, there are water-bearing sand and gravel zones, at least 18 ft thick (Kohut 1982). Based on a groundwater exploration report at the Canfor site, close to the North Thomson River, two aquifers have been identified. The upper aquifer is a total of about 57 feet thick and the lower aquifer is about 50 feet thick (BCGW 2012 – appendix in True 2018).The source of recharge to the aquifer(s) is partly from direct precipitation (rain or snow-melt), underflow from the valley sides, and the North Thompson River (BCGW).

2.6.1 Conceptual Flow of Groundwater

The predominant regional direction of groundwater flow in the area is in the downstream direction - southwest, subparallel and hydraulically connected to the North Thompson River. Locally, there is likely

groundwater flow, driven be local precipitation and snowmelt within the identified unconfined upper sand and gravel unit that sits atop till, which transition into silt and clay at the 'water issue area' of Vavenby (Figures 2 and 3). Locally, on the northwest side of the River, water moves from the upper plateau towards the River from north to south-southeast. As that water attempts to infiltrate on its flow paths towards the river it is seeing downward flow restriction due to the low permeability silt and clay wedge encountered in the vicinity of the water issue area.

Previous hydrogeological characterization was completed by WWAL near Chu Chua, a community located about 60 km downstream of Vavenby and on the southeast side of the North Thompson River. Chu Chua is situated on a lower bench of a terraced topography, similar to the Vavenby area. At both Vavenby and Chu Chua windows of sand and gravel are positioned within the silt and clay layer and they create preferential groundwater flow channels within the less permeable sediments. These windows or "channels", present within the silt and clay are the conduit which, when over saturated create high groundwater levels that presents as an issue on the northwest terrace between Galiano road and Ball Road (Figures 4 and 5).

2.6.2 Groundwater Discharge Estimate for the Water Issue Area

An estimate of groundwater discharge through the thin sand and gravel layer (which sits above the silt and clay wedge in the water issue area and can become fully saturated during the spring freshet) was completed based on Darcy's Law, outlined below. Results are summarized in Table 3 below.

$$Q = kia$$

Where: Q = groundwater discharge (length^3/time)
k = hydraulic conductivity (length/time)
i = hydraulic gradient (unitless)
a = aquifer (saturated flow) cross sectional area (length^2)

The hydraulic conductivity (k) value was estimated form Freeze and Cherry (Freeze and Cherry 1979) for sand and gravel. The cross-sectional area of the thin saturated sand a gravel overlying the silt and clay wedge was estimated from the geologic cross-section outlined on Figures 2 and 3.

Hydraulic gradient (i) was estimated from ground elevations taken from the Google Earth digital elevation model and assuming the hydraulic gradient is a subdued replica of the site topography.

From the calculation it is estimated that about 750 m^3/day of groundwater could flow through the water issue area, if the sand a gravel within and above the silt and clay layer is saturated. The values used in the analysis with the greatest uncertainty are hydraulic conductivity (k) and gradient (i).

Compared to the average daily demand for the Vavenby water system (266 m^3 per day), the potential groundwater flow through the saturated sand and gravel which lies above the silt and clay layer in the

water issue area is about triple. Although this groundwater flow estimate assumes a full 2 m of saturated thickness the saturated thickness may be thinner and is dependent on the quantity of snow melt and precipitation. The purpose of this flow comparison is to show that the 'water issue area' is not simply due to leaking TNRD water supply infrastructure and the root cause of the issue is the hydrogeological setting. We understand the TNRD will be implementing water metering to help aid monitoring potential leaking infrastructure.

Table 3: Groundwater Discharge Estimate for the Issue Area from Darcy's Flux

Parameter	Units	Info source	Length (m)	Thickness (m)	Values
A	m^2	From geological cross section of sand and gravel above till layer (saturated thickness) and length of the contour where groundwater flow issue is occurring below Galiano Road (360 m)	360	2	720
i		from surface topography			1.2%
b	m	Well lithology			2.00
k	m/sec	Estimated from Freeze and Cherry 1979 Table 2-2			0.001
k	m/day	Calculated from above value			86.4
Q	m^3/sec	Estimated from Darcy's Flux (Equation above)			0.01
	m^3/min				0.52
	m^3/day				746
	Usgpm				**137**

3. SUMMARY OF INTERVIEWS WITH AFFECTED PROPERTY OWNERS

From conversation with a local government official, contact information for several property owners who were known to have had groundwater flow issues in the past were provided to WWAL. Each property owner whose information was provided to WWAL was contacted by phone, if they were unavailable a message was left requesting they returned the call. A total of six property owners were contacted and four were interviewed. Three property owners on the northwest side of the River and one property owner on the southeast side of the River were interviewed.

Appendix B provides a summary of interviews, and the issues the property owner have been managing. Note that Emergency Management BC (EMBC) does not provide funding to local governments, in this case the TNRD, to manage groundwater flow issues The following sections provide summaries of the groundwater flow issues noted on both the northwest and southeast sides of the North Thompson River at Vavenby. The flooding from high groundwater level on the southeast side of the River appeared to be of a different nature than the issues on the northwest side. However, the issue on both sides of the River stem from the fact that the River valley bottom is a groundwater discharge zone for the North Thompson watershed.

3.1 Northwest Side of the North Thompson River

From interviews with local residents, numerous property owners have had high groundwater issues primarily during spring freshet and the summer melt in the area(s) shown on Figures 1, 4 and 5. We understand there are numerous properties that have been affected by groundwater flow issues between the area encompassing Galiano Road, Hudsbedt Road, Wood Road and McCorvie Road/Vavenby Bridge Road and along Ball Road (Figures 4 and 5 and Appendix A Vavenby Water System Map). However, we interviewed only three property owners on the northwest side of the River.

Residents spoke of long-term historic high groundwater flow through the affected area. Nuisance groundwater occurs primarily in springtime. There is mention of land-use changes upgradient to affected properties that potentially changed the drainage path of subsurface groundwater flow which then created problems for downgradient property owners during the spring freshet in summer snow melt.

Further, there was mention of how around Ball Road there are seasonal shifts in house foundations due to the presence and then recession of high groundwater level within the shallow subsurface. As mentioned in the hydrogeological section above, the area noted to have the most complaints of high groundwater issues on the northwest side of the River correspond to an area underlain by a silt and clay deposit.

Residents describe changes to subsurface flow paths as land use has changed over time. Specifically, one resident near the corner of McCorvie Road and Vavenby Bridge Road described the change in subsurface ground water flow downgradient from a property whose owner has made significant changes to their landscaping. This property owner spoke about the ongoing labour and costly maintenance that they have had to do to manage high groundwater flows issues since the reworking of the landscape upgradient to their property.

Residents spoke about potential changes to the subsurface due to ongoing heavy transportation (trucks and trains), given the potential change groundwater flow can have within the identified clay layer, transportation activity could have affected i.e. changed subsurface flow paths.

Residents also spoke of ongoing leakage from the TNRD water system. We understand the TNRD has engaged in significant leakage repair between 2016 and in 2018 the area around Wood Road and Hundsbedt Road. Residents downgradient of this area may find less groundwater flow after these leaks, with these leaks being addressed in the past year. that the TNRD is currently in the process of installing water meters on all properties connected to the TNRD owned water system. The meter installs should be completed in 2020 and this measure will help to identify leakage within private properties.

The overall opinion from interviews with residents on the northwest side of the North Thompson River at Vavenby is that a combination of influences are affecting groundwater and surface water interaction which in turn influences site drainage. The suspected influences include the following:

- the underlying silt and clay wedge that exists within the Wood Rd., Hundsbedt Road and Ball Road area (Figures 2 and 3) which acts as a barrier to downward hydraulic flow of groundwater originating in the upper plateau and migrating down the hillside and discharging to the River;
- contribution to the saturated groundwater flow from onsite wastewater system in the affected area;

- land use changes upgradient of affected property owners (landscaping, property specific drainage management that does not integrate with the downgradient properties, sustained logging truck activity in the area that has changed the subsurface flow though sand and gravel windows within the silt and clay); and
- Leaking TNRD water infrastructure.

3.2 Southeast Side of the North Thompson River

WWAL interviewed one property owner located on the southeast side of the North Thompson River who spoke about the hardship of ongoing flooding at their property due to groundwater issues typically in the spring. Just upgradient and east of the Vavenby southeast residential subdivision, which borders on the North Thompson River (depicted in Figure 7) is a creek that drains the upland hillside into the River valley bottom. Herein the creek will be referred to as the Subject Creek. The affected property owner spoke about how there has been an illegal diversion of the Subject Creek from its natural watercourse on to a property located upgradient of their own but within the residential subdivision, so as to gain access to surface water.

From review of the BC Water Resources Atlas (ENV 2019) along with review of TNRD Maps (see Appendix A) there appears to be a natural watercourse that historically directed the Subject Creek from the uplands. The apparent natural watercourse for the Subject Creek moves creek water under the Birch Island - Lost Creek Road via a culvert, through agricultural land and into the North Thompson River, north of the residential subdivision (Figures 6, 7 and 8). Figure 7 and 8 show the apparent historical natural watercourse along with what appears to be diversion infrastructure that leads the Subject Creek in to the subdivision. Figure 8 shows an existing water licence for a spring entering into the North Thompson River downgradient (northwest) of the residential subdivision; the spring is referred to in the provincial database as Firebirth Springs (ENV 2019).

A data gap exists regarding this high groundwater flooding issue on the southeast side of the River. WWAL does not fully understand what the natural watercourse for the Subject Creek is and who owns the rights to the Subject Creek which appear to be hydraulically connected to the provincially registered Firebith Springs. Is the natural watercourse as it is today, migrating through the TNRD southeast residential subdivision or is the natural watercourse of the Subject Creek to the north through a culvert under Birch Island Lost Creek Road and through the agricultural land? Was the culvert installed under Birch Island Lost Creek Road a diversion of the natural watercourse many years ago? More sleuthing with the provincial water licensing department would be required to derive the answers and this degree of investigation was not within the scope of the current study.

What is understood, is the property owners within the subdivision downgradient of the Subject Creek are affected by groundwater flooding in the spring. Allowing the Subject Creek to flow within what appears to be it's natural watercourse (though the agricultural land to the north of the subdivision) may create less property damage over-time.

4. CONCLUSIONS

From the current study, we provide the following conclusions:

C1 The Community of Vavenby sites on terraced surficial deposits within the discharge zone of the North Thompson River watershed. As the community sits in the natural discharge zone of the watershed the community is susceptible to potential flooding associated with groundwater level increases in the spring, when the upper watershed drains into the River valley bottom.

C2 Over-time there have been changes in the groundwater drainage off the terrace deposits which flank the northwest side of the North Thompson River at Vavenby.

C3 Settlement and development of the North Thompson River valley at Vavenby which has occurred over the past 100 years has created much disruption in the natural flow of both groundwater and surface waters in the area.

C4 From assessment of lithologic cross-sections created from water well logs in the area, there is a silt and clay deposit located beneath the properties on the northwest side of the river that experience the most groundwater issues. This silt/clay is a barrier to infiltration, and results seasonally in a perched aquifer that rises to the surface.

C5 Phone interviews were conducted with property owners that have been negatively affected by flooding due to high groundwater levels in the area between Gallagher Road and Ball Road.

C6 The hydrogeologic setting creates a situation where high groundwater levels during the spring melt are inevitable.

C7 The estimated groundwater discharge through the water issue area is triple the average daily demand for the community of Vavenby. This estimate is likely higher than actual discharge; however, the comparison is meant to show that the 'water issue area' is not simple caused by leaking TNRD water system, though leaks may have contributed to the problem.

C8 The TNRD has engaged in significant leakage repair between 2016 and in 2018 the area around Wood Road and Hundsbedt Road. Property owners downgradient of this area may find less groundwater flow after these leaks, with these leaks being addressed in the past year.

5. RECOMMENDATIONS

From the current study, we provide the following recommendations:

R1 Consider creating an Integrated Community Drainage Plan. When property owners are looking to change site drainage patters as assessment of the predicated downgradient effects should be assessed by a Qualified Professional and the work should not contradict the Drainage Plan.

R2 Consider using instruments to monitor the groundwater levels at the water issue area' over the next few years to see if the issue persists or if fixing the water system leaks will have had measurable effect.

R3 Present the findings of this study to the community and gather more anecdotal information from property owners not yet interviewed.

R4 At the same time WWAL staff attends the Vavenby Community meeting, inspection of the area around the historic culvert that drains the Subject Creek on the southeast side of the North Thompson River (see Figure 6).

REFERENCES

BC Groundwater Consulting Services Ltd. (BCGW). 2018. Vavenby Community Water System: Geological Overview. Prepared for the TNRD Community Water Master Planning (TRUE Project No. 379-491) on April 17, 2018.

British Columbia Ministry of Environment and Climate Change Strategy (ENV). 2018. On-line Water Resources Atlas. Accessed online: http://maps.gov.bc.ca/ess/hm/wrbc/

Environment Canada. 2019. Discharge data set provided to WWAL from Environment Canada for all historic discharge at the Birch Island hydrometric station.

Freeze, R.A., and Cherry, J.A.. 1979. Groundwater. Englewood Cliffs. NJ, Prentice-Hall, 604 p.

Kohut A. 1982. Vavenby Improvement District -Groundwater Investigation prepared for B.C. Ministry of Environment. Memorandum File No. 82M/12. Prepared April 2, 1982.

Schiarizza P. and B. N. Church. 1996. The Geology of the Thompson-Okanagan Mineral Potential Assessment Region (East Part), OF 1996-20, BCGS. Accessed online: https://www.mindat.org/loc-27397.html

Stantech Consulting Ltd. (Stantech). 2005. Phase 1 – Groundwater Potential evaluation (GPE) report of findings for Thompson Nicola regional District, Vavenby BC. Report No. 804627. Prepared for the TNRD on August 5, 2005.

Statistics Canada. 2019. Accessed online: https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/index-eng.cfm

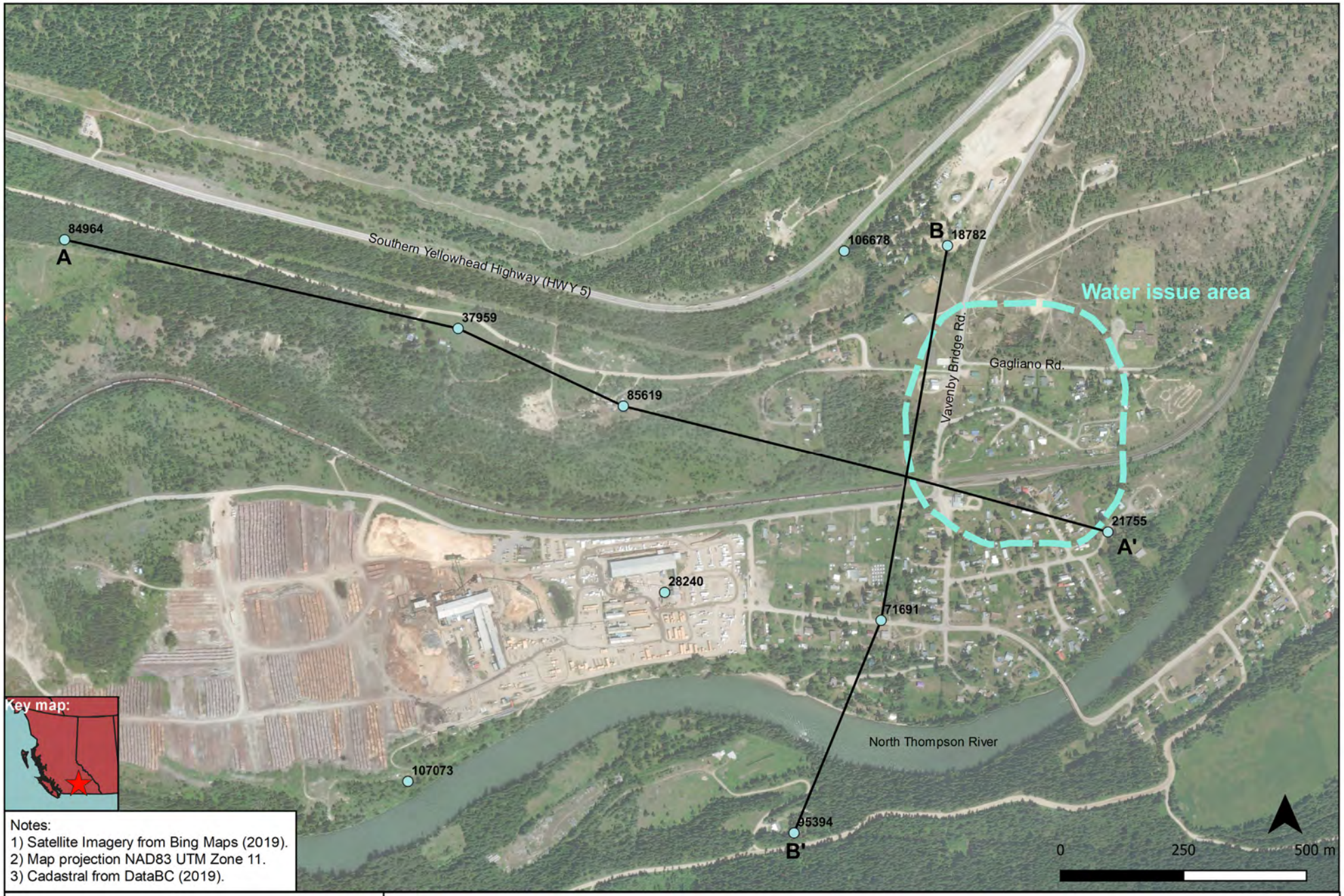
Tipper, H W. 1971. Geological Survey of Canada, Bulletin no. 196, 1971, 103 pages (8 sheets), https://doi.org/10.4095/102344 (Open Access). Published by Geological Survey of Canada.

True Consulting. 2018. Vavenby Master Water Plan. Project No. 379-491 prepared for the Thompson Nicola Regional District May 2010.

Figures

19-033-01VR

Preliminary Groundwater
Assessment for Vavenby, BC



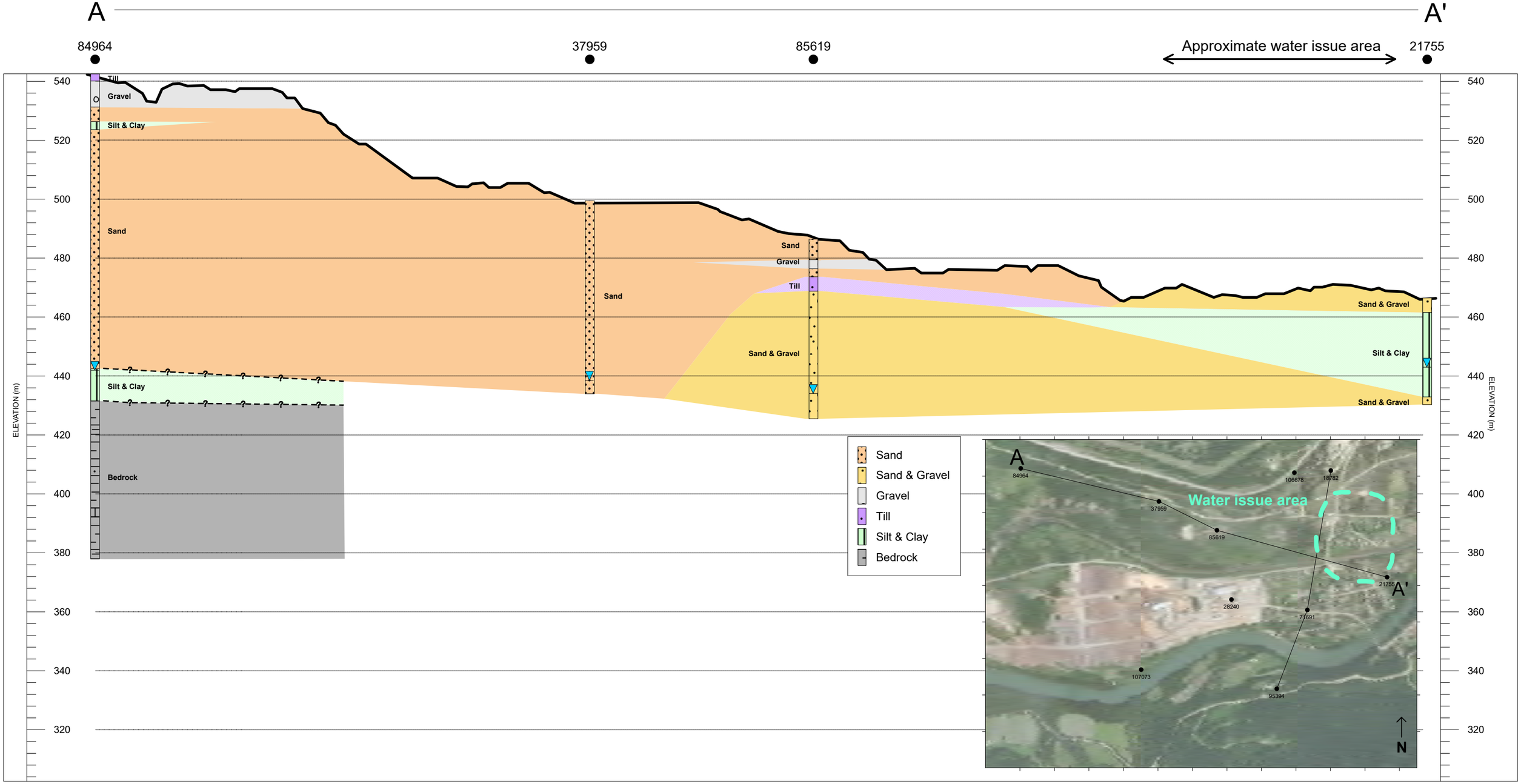
Preliminary Groundwater Assessment for Vavenby

TITLE **Figure 1:** Location Plan

Wells — Cross-section Line

western water ASSOCIATES LTD

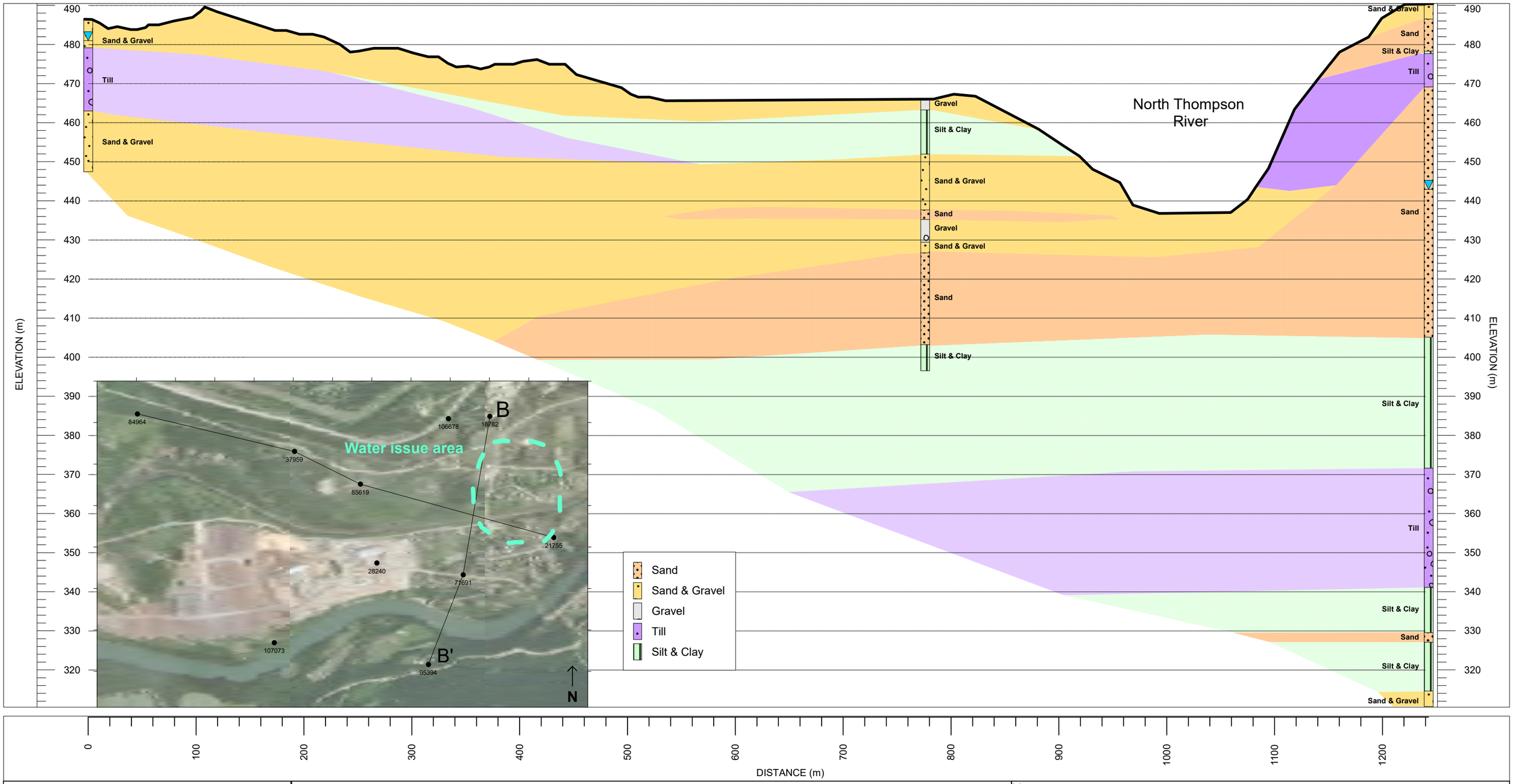
DRAWN	Tim Sivak	DATE	September 10, 2019	PROJECT NO.	19-033-01VR
CHECKED		SCALE	See bar scale	DWG	
REVIEWED		FILE		FIGURE VERSION	



Preliminary Groundwater Assessment for Vavenby	**Figure 2.** Cross-section A-A'		**Notes:** Map Projection: NAD83 UTM Zone 11 Vertical Exhaggeration: 4.9x
western water ASSOCIATES LTD	**Drawn:** T. Sivak	**Client:** TNRD	
	Reviewed:	**Project Number:** 19-033-01VR	
	Revision:	**Date:** September 10, 2019	

B — Approximate water issue area — B'

18782 — 71691 — 95394



Preliminary Groundwater Assessment for Vavenby

Figure 3. Cross-section B-B'

Drawn:	T. Sivak	**Client:**	TNRD
Reviewed:		**Project Number:**	19-033-01VR
Revision:		**Date:**	September 4, 2019

western water ASSOCIATES LTD

Notes:
Map Projection: NAD83 UTM Zone 11
Vertical Exhaggeration: 3.6x

Map Source: Goggle Earth, 2019

Preliminary Groundwater Assessment for Vavenby, BC

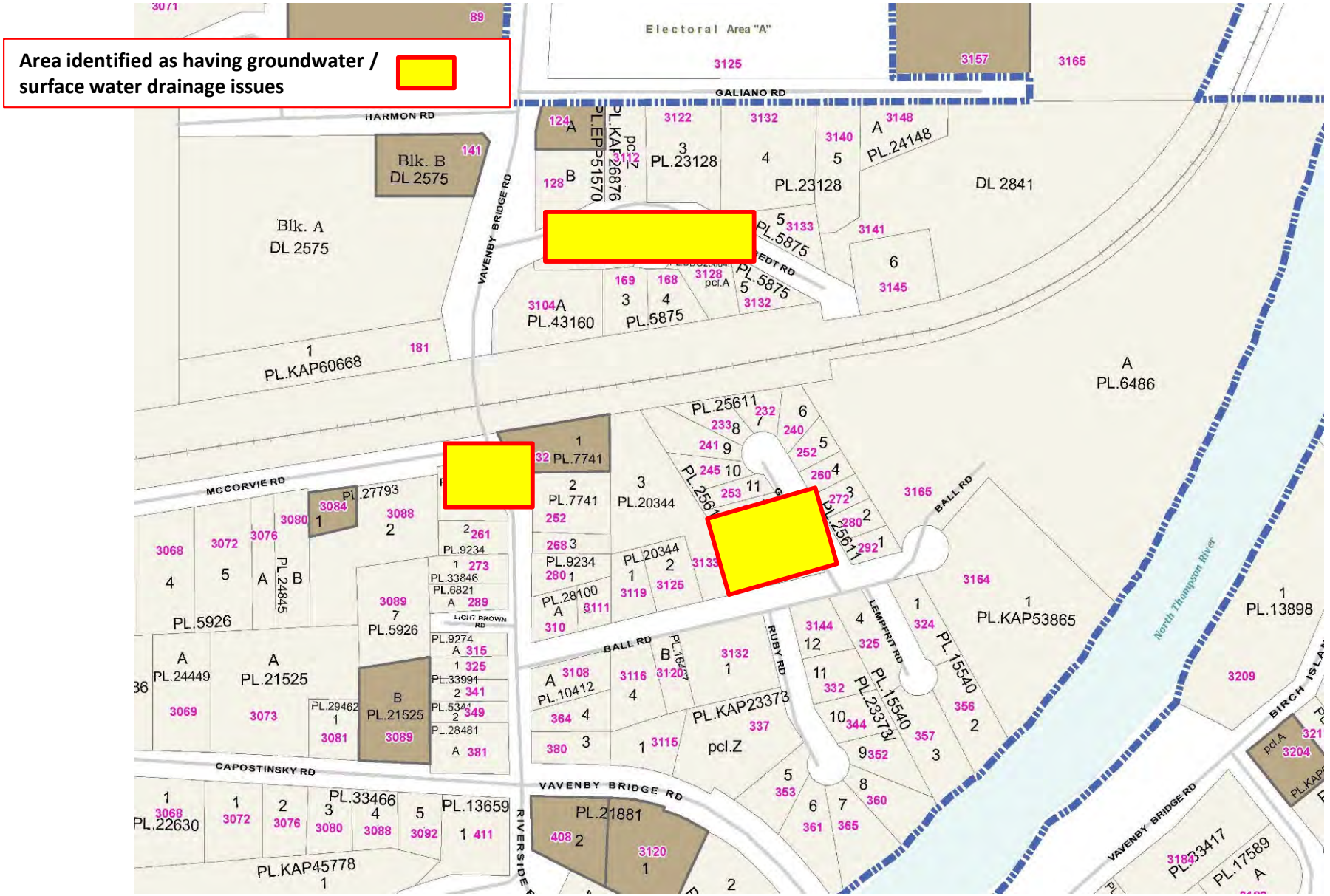
TITLE

Figure 4: Vavenby Orthophoto – Showing Northwest Side of the N. Thompson River

western water ASSOCIATES LTD

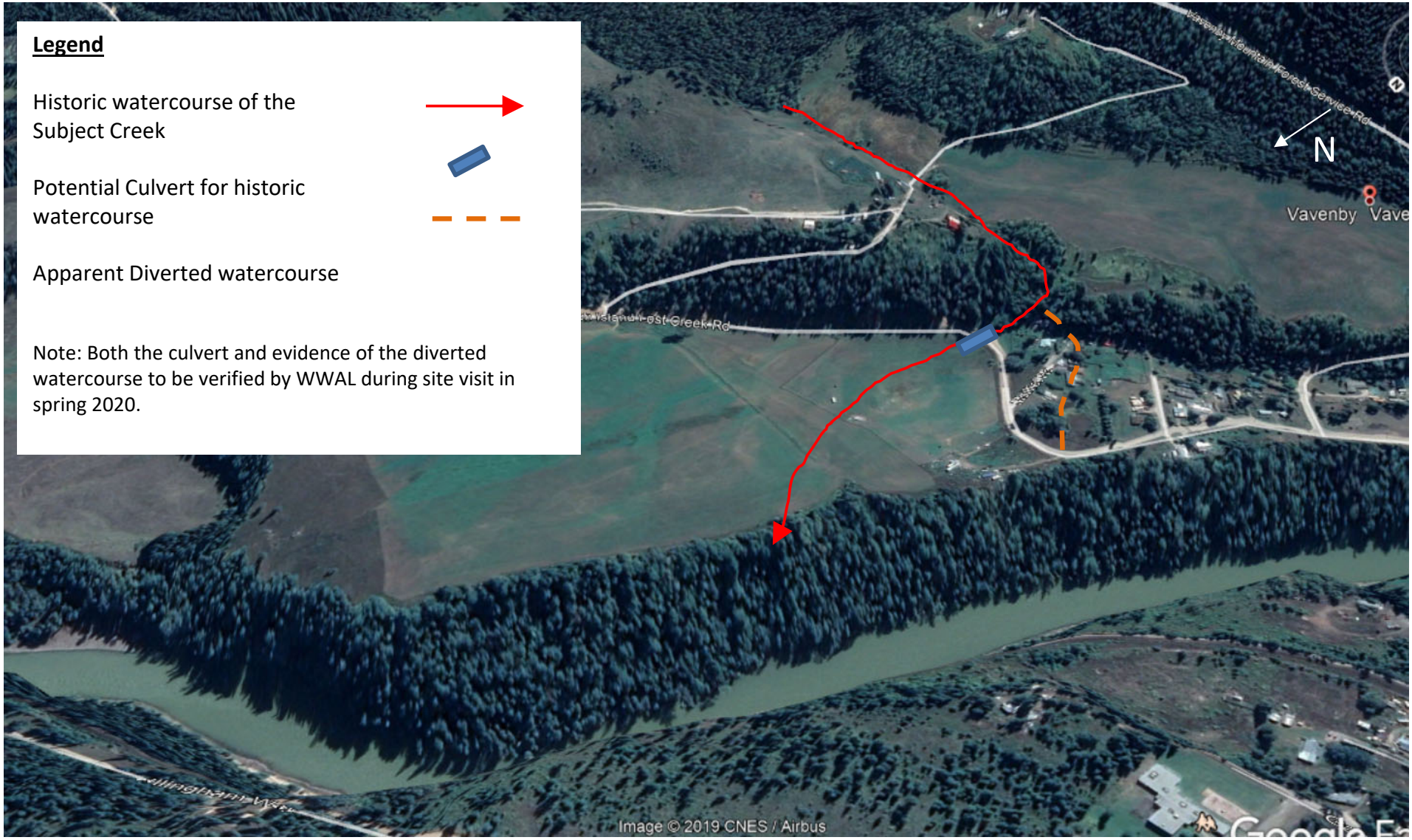
Thompson-Nicola Regional District

DRAWN	NA	DATE	September 2019	PROJECT NO.	19-033-01VR
CHECKED	brm	SCALE	Not to scale	DWG. NO.	na
REVIEWED	DG	FILE NO.		FIGURE REVISION NO.	0



Map Source: TNRD, 2019

Preliminary Groundwater Assessment for Vavenby, BC	TITLE **Figure 5: Vavenby Property Map – Showing Northwest Side of the N. Thompson River**				
western water ASSOCIATES LTD	**Thompson-Nicola Regional District**	DRAWN NA	DATE September 2019	PROJECT NO. 19-033-01VR	
		CHECKED brm	SCALE NA	DWG. NO. na	
		REVIEWED DG	FILE NO.	FIGURE REVISION NO. 0	



Map Source: Goggle Earth, 2019 with 3 X vertical exaggeration

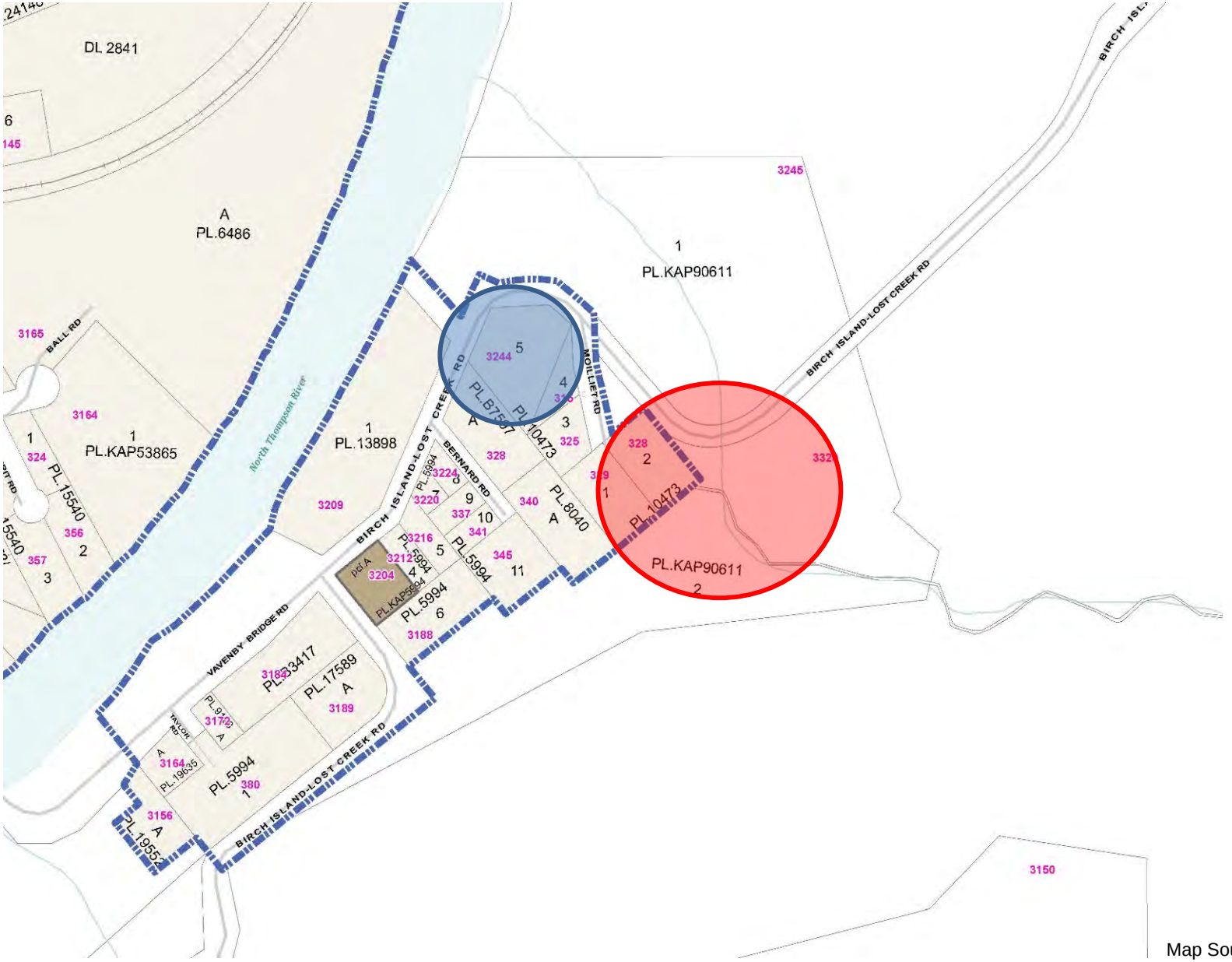
Preliminary Groundwater Assessment for Vavenby, BC

TITLE **Figure 6: Vavenby Orthophoto - Showing Southeast Side of the N. Thompson River**
Note, the markup on this drawing is based on dialog with the concerned property owner. The natural watercourse has yet to be assessed.

western water ASSOCIATES LTD

Thompson-Nicola Regional District

DRAWN	NA	DATE	September 2019	PROJECT NO.	19-033-01VR
CHECKED	brm	SCALE	Not to scale	DWG. NO.	na
REVIEWED	DG	FILE NO.		FIGURE REVISION NO.	0



Preliminary Groundwater Assessment for Vavenby, BC

TITLE **Figure 7: Vavenby Property Map - Showing Southeast Side of the N. Thompson River**

Red circle denotes the area of contention with respect to where the natural watercourse should be flowing. Blue area indicates property affected by the creek diversion.

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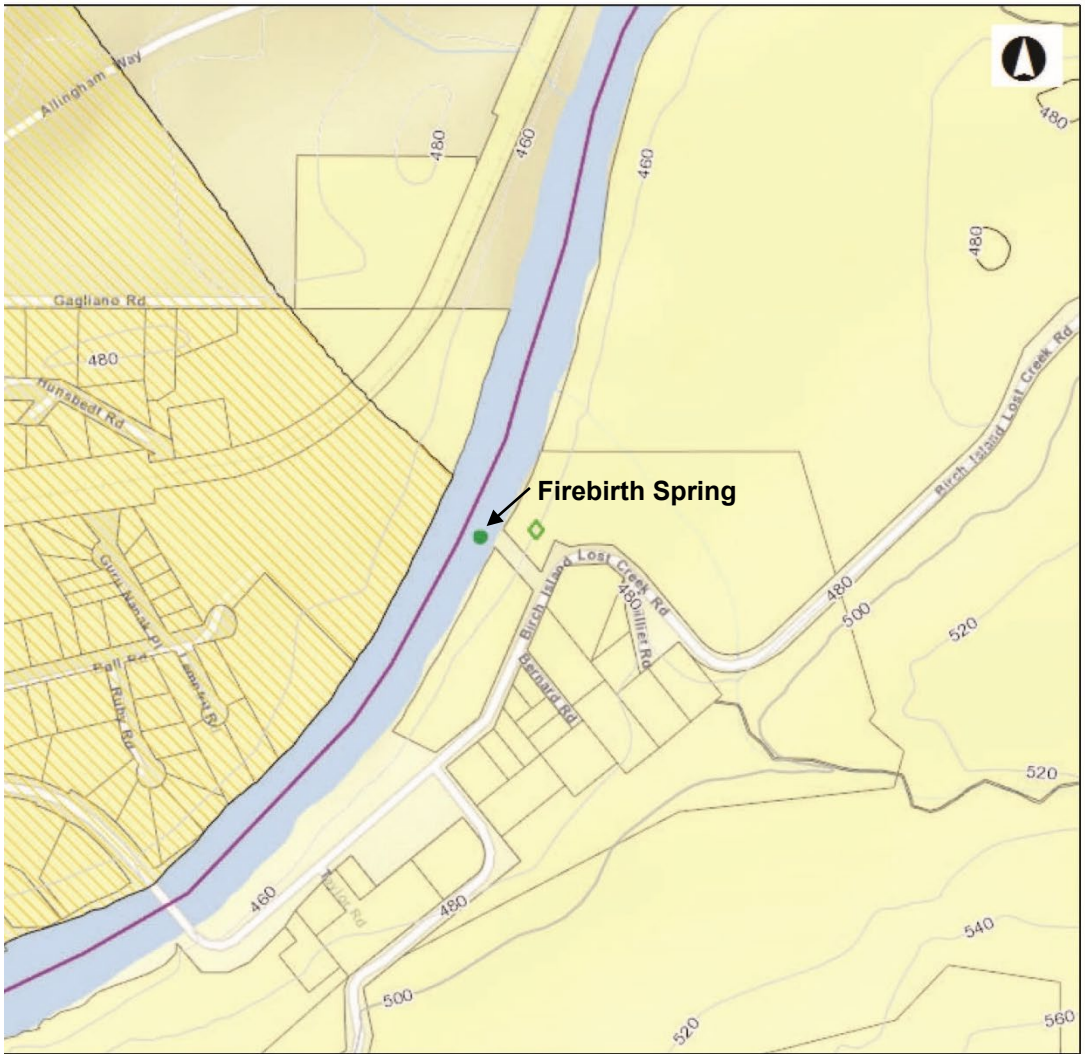
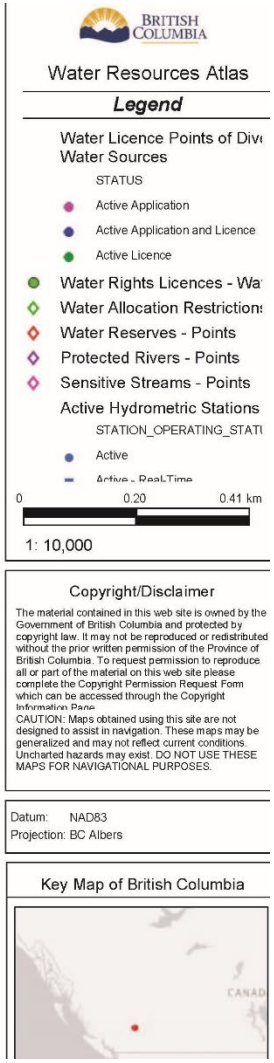
DRAWN	NA	DATE	September 2019	PROJECT NO.	19-033-01VR
CHECKED	brm	SCALE	NA	DWG. NO.	na
REVIEWED	DG	FILE NO.		FIGURE REVISION NO.	0





Map Source: WRA, ENV, 2019

Preliminary Groundwater Assessment for Vavenby, BC

TITLE

Figure 8: Firebirth Spring - Mapped along the Southeast Side of the N. Thompson River

western water ASSOCIATES LTD

Thompson-Nicola Regional District

DRAWN	NA	DATE	September 2019	PROJECT NO.	19-033-01VR
CHECKED	brm	SCALE	NA	DWG. NO.	na
REVIEWED	DG	FILE NO.		FIGURE REVISION NO.	0

Appendix A

TNRD Maps

Vavenby Water System

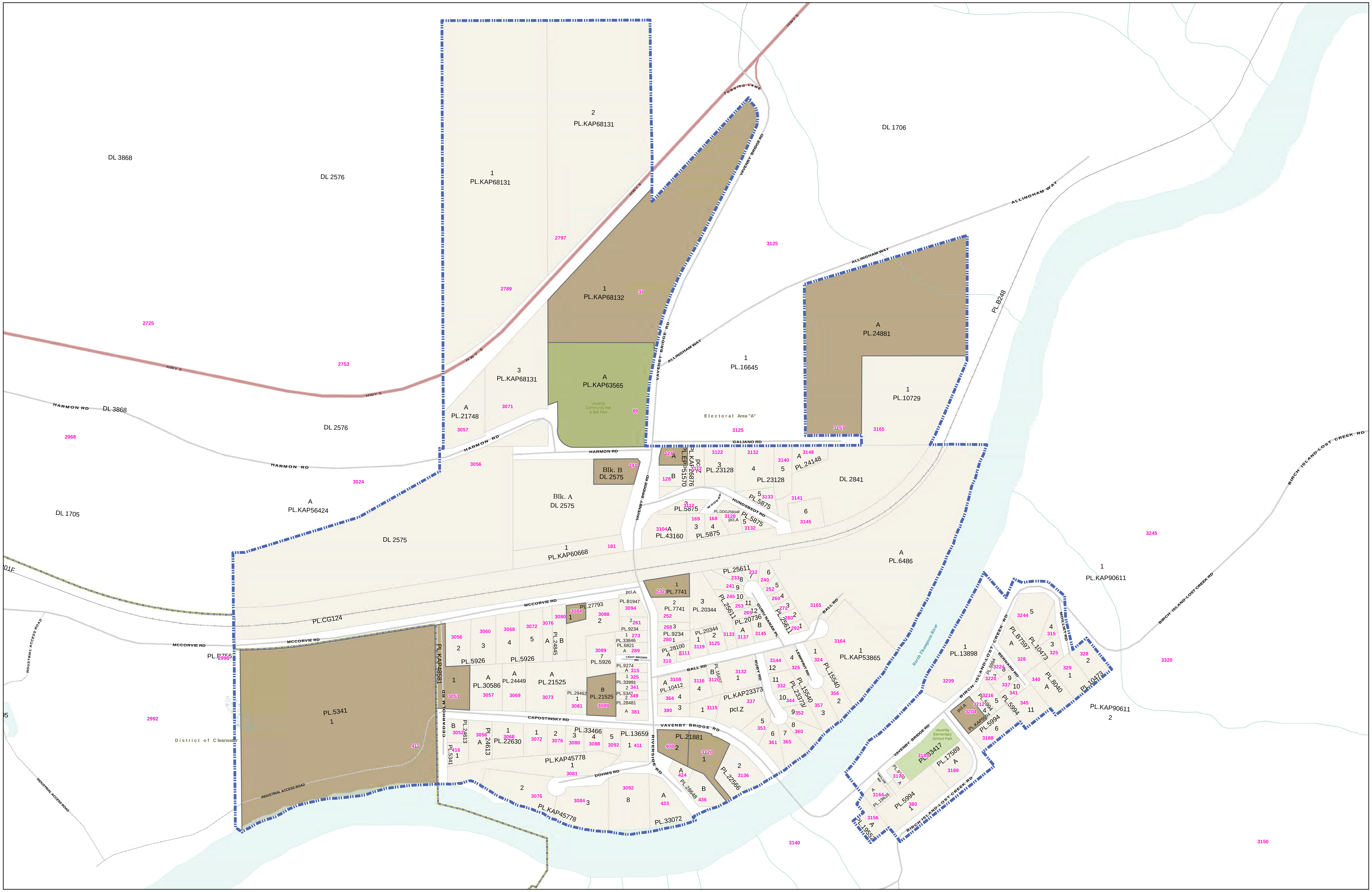
Vavenby Water System and Zoning

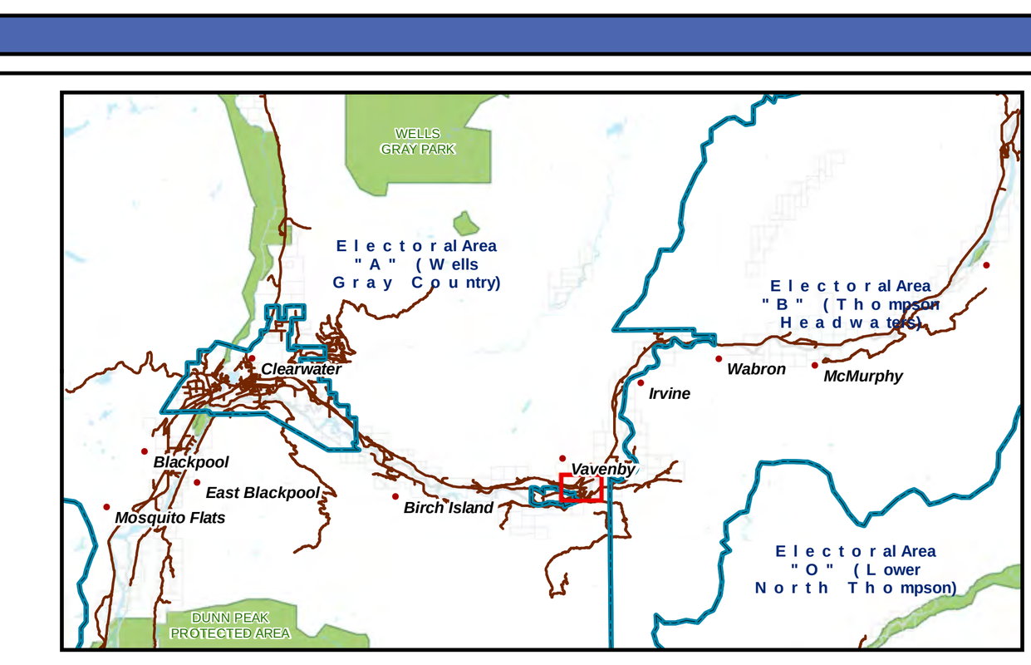
19-033-01VR

Preliminary Groundwater Assessment for Vavenby, BC

VAVENBY WATER SYSTEM

Non-Residential
Water Customers





Legend

- Vavenby Community Water System
- Non-Resident Water Customers
- Vavenby Water Residential Customers

Projection: Albers Equal Conic
Datum: NAD83
Data Sources:
Property - TNRD
Waterbody - TNRD
Roads - TNRD
TRIM - Integrated Cadastral Initiative Society (ICIS)

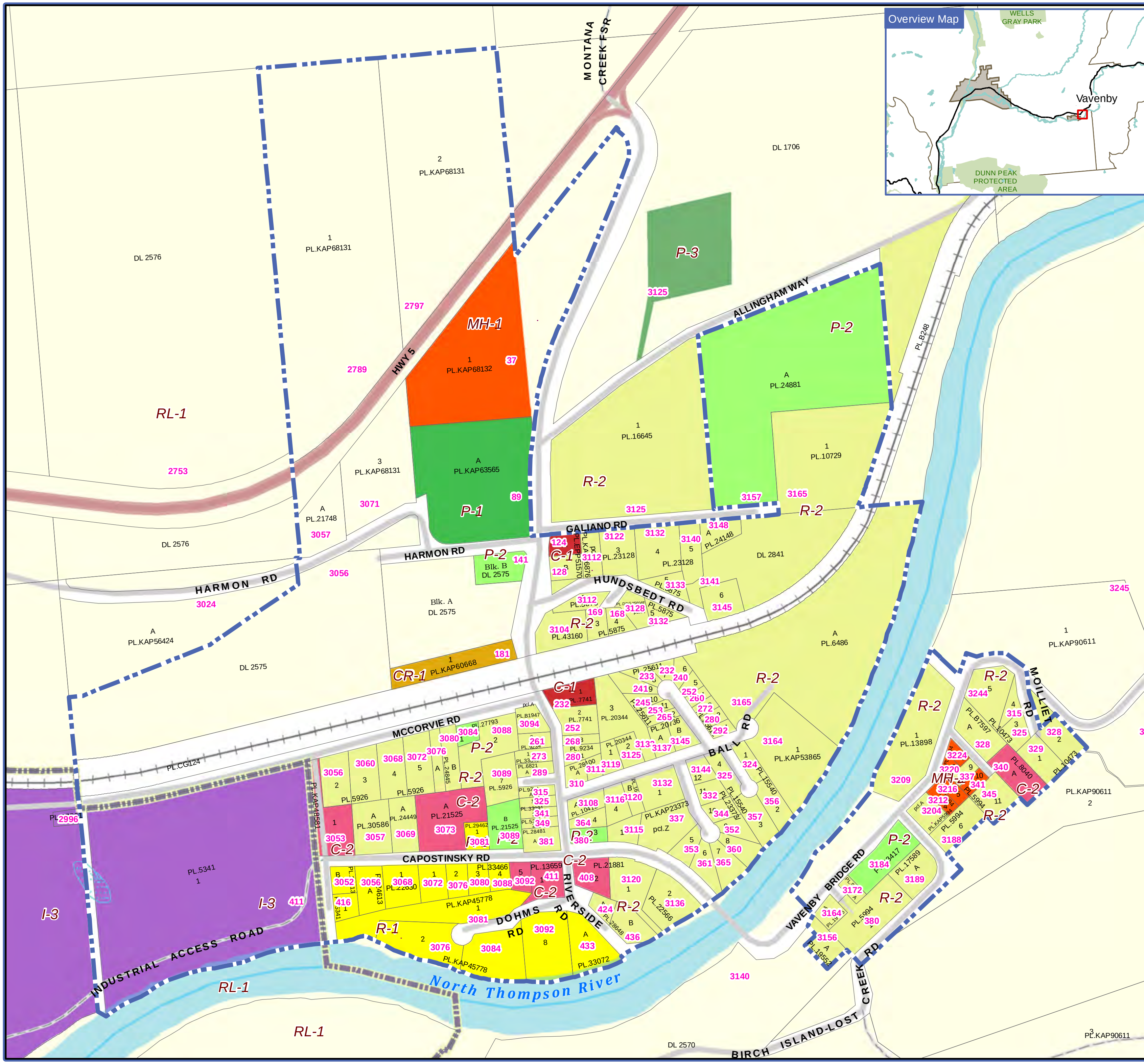
THOMPSON-NICOLA REGIONAL DISTRICT

1:2,500

0 40 80 160 240
Metres

September 05, 2019

VAVENBY WATER SYSTEM SERVICE AREA AND ZONING



Legend

C-1	General Commercial
C-2	Service Commercial
C-3	Neighbourhood Commercial
C-4	Recreational Commercial
CR-1	Country Residential
I-1	Vehicle Wrecking
I-2	Light Industrial
I-3	Heavy Industrial
LUC	Land Use Contract
MH-1	Manufactured Home Park
MX-1	Riverside Centre Mixed Use
P-1	Parks and Recreation
P-2	Institutional
P-3	Civic
R-1	Single Family/Duplex Residential
R-2	Compact Residential
R-3	Multi-Family Residential
RL-1	Rural
SH-1	Small Holding

Scale: 1:8,500

0 40 80 160 Metres

Projection: Albers Equal Area Conic

Datum: UTM NAD 83

Date: 2019-09-05

N

THOMPSON-NICOLA TNRD REGIONAL DISTRICT

Appendix B

Interview Summary Table Vavenby Preliminary Groundwater Assessment

19-033-01VR

Preliminary Groundwater
Assessment for Vavenby, BC

Site #	Address	Description of Water Issues
1	3112 Wood Rd.	The property owner described encountering bedrock 20 feet to 40 feet west along the north property boundary. The property was purchased in 1981. The property owner's describe having to manage flooding issues in the late 80s(potentially) 1989 where over 279,000 gallons of water had to be managed from the site. The owners describe three natural springs that have been managed with four-inch perforated pipe, which helps drain the springs off-site. Apparently at the property next door, a basement which had existed was filled in and that changed the groundwater flow, creating more flooding issues for the property owner's. There was an old dug well on the site, estimated depth of the well 30 feet with the water table 45 feet below ground surface, during flood years water table has been observed to be at surface. Properly owners have directed the groundwater springs on-site into the dug well. The property owner's mentioned that neighbours along Hundsbedt Rd., dealt with water system pipe leakage for over six months before the leaks were fixed. The property owners describe the use of heavy-duty trucks, driving within the gravel pit quarry located up gradient to the property. They describe seeing the subsurface having sunk on the order of 3 feet from where the trucks drove.
2	3094 McCorvie Road	The property owner's have been living at the property for 15 years (since 2004). About 4 or 5 years ago ditching efforts were made and the property owner spoke to how this ditching effort changed groundwater flow paths and created serious drainage issues at the site. The property owner mentioned they had no issues with groundwater up until the ditching that occurred off-site and up gradient of their property. To manage the immense water, which is now flowing through their property, the property owners have created three dewatering stations within their basement the dewatering stations pump water into three channels which drain into collection pipe from the drainage pipe the

		water seeps off site. The cost to set up the dewatering system was over $20,000 Typically dewatering via pumping occurs for about three months. In the spring during the runoff. The property owner's mentioned that they had a dug well on site which used to provide irrigation water but after the drainage ditch works which train changed the groundwater flow paths at their site there well is now dry.
3	3145 Ball Rd. and 3137 Ball Rd.	The property owner has lived on Ball Road since 1973. For 23 years the property owner has experienced no groundwater discharge issues, it wasn't until 2017 that they first experienced groundwater seepage issues. The downstairs rooms have flooded, and the flooding could not be managed with the sump pump. During flooding the property owners were tasked with vacuuming floodwater for days on end. The landowners believe that heavy truck use in the area could have changed the hydrogeologic setting due to compression of the clay formation in and around the problem area. It is understood that the TNRD has worked to fix known pipe breaks in the problem area during the 2019 summer season.
4	328 Bernard Rd (east side of Vavenby)	Groundwater issues experienced at 328 Bernard Rd. appear to be related to surface water diversion which has occurred upgradient of the property. WWAL has assessed the water maps and found that the surface water (believed to be known as Chuck Creek) appears to naturally migrate out of the hillside just above Birch Island - Lost Creek Road, through a culvert under the road and then northwest through Agricultural Land Reserve lands. See Figures 6 and 7 of the report. From discussion with the property owner, we understand the creek was diverted by another property owner located upgradient of their property. After this illegal diversion the property owner has experienced flooding. The flooding has been occurring since at least the late 1990s but has become worse since the year 2000. There have been at least four times that her basement has flooded in the spring; two years that were particularly bad were 2003, and 2012. The flooding has disrupted the property owner's life considerably, where she has had to remain in Vavenby during the flooding season to manage these successive flooding events.

		The property owner at 328 Bernard Rd. stated that she had pursued having the illegal diversion of the creek issue dealt with at the regional district level (TNRD) and provincial level (Ministry of Environment) to no avail. Note, when Bryer Manwell goes to Vavenby to present the findings of the current report she will investigate the claimed illegal surface water diversion. By showing the existence of a culvert under Birch Island lost Creek Road and photographing diversion works which occurred upgradient we feel we could try to substantiate her claim that the creek was unnaturally diverted.
5		Left message on phone, did not receive a call back.
6		Left message on phone, did receive two calls back but was not available to take calls. Property owner left a message saying that we had talked to his neighbour and so we had the story about his area.
7		Mentioned to WWAL but no contact info.

Western Water Associates Ltd.
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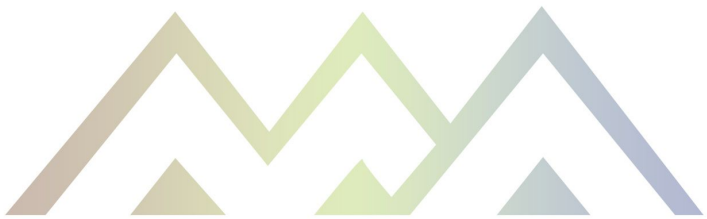

Groundwater Supply Development and Management

Source Water Assessment and Protection

Well Monitoring & Maintenance

Environmental & Water Quality Monitoring

Storm & Wastewater Disposal to Ground

Groundwater Modeling

Aquifer Test Design and Analysis

Geothermal / Geoexchange Systems

Policy and Guideline Development

Applied Research

Rural Subdivision Services

Environmental Assessment & Permitting

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