March 22, 2021

To: Interested Parties
From: Living Lakes Canada

Re: Hydrogeological Characterization of the Windermere Creek Watershed

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Please find attached a preliminary hydrogeological characterization for the area around Windermere Creek and Windermere Loop Road. Living Lakes Canada is pleased to provide this report to interested parties.

The purpose of this work was to conduct a preliminary characterization of the groundwater system in the Windermere Loop Road and Windermere area. It was completed as a case study to assess how groundwater level data collected as part of the Living Lakes Canada Upper Columbia Basin Groundwater Monitoring Program could be collated with other publicly accessible watershed data to improve our understanding of groundwater flow systems in the region and support water management strategies, restoration activities, and adaptation to climate change. The work was conducted by GW Solutions.

If you have any questions or would like to follow up on any of the work presented in this report, please contact the Living Lakes Canada Groundwater Program Manager, Carol Luttmer at carol@livinglakescanada.ca or 250 309 8325.

Sincerely,

Kat Hartwig
Executive Director

cc.
Adjacent Property Owners
Akisqnuk First Nation
Certainteed Gypsum Mine
Columbia Headwaters Aquatic Restoration Secwépemc Strategy (CHARS)
Columbia Wetland Stewardship Partners
Friends of Windermere Creek
Lake Windermere Ambassadors
MacHydro
Ministry of Forests, Lands, and Natural Resources Operations
Regional District of East Kootenay
Shadybrook Resort
Shuswap Indian Band
Windermere Creek B&B Cabins

Windermere
Preliminary Hydrogeological Characterization

Prepared for:

Living Lakes Canada

Prepared by:

GW Solutions Inc.

March 2021

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1 BACKGROUND AND OBJECTIVES

1.1 Background

This report describes our preliminary hydrogeological assessment for Windermere (the study area) using publicly available information and data collected by Living Lakes Canada (LLC) and the Lake Windermere Ambassadors (LWA).

This work was conducted as a case study in the use of water-related information to shape our understanding of local water flow systems, water management strategies, restoration activities, and adaptation to climate change. In 2018, residents along Windermere Loop Road approached Living Lakes Canada regarding concerns of some domestic water supply wells in the area going dry in recent years. In response, Living Lakes Canada installed water level monitoring equipment in two existing wells (that are not used as water supply wells) along Windermere Loop Road in October 2018. At that time, Living Lakes Canada also retained GW Solutions to develop a preliminary 3D hydrogeological model of the area to help characterize the groundwater system. The 3D model was developed using Leapfrog Works geological modelling software.

Recent changes in the flow path of Windermere Creek have been observed and over the last two years large sediment loads have been carried downstream, increasing flooding potential and other risks. In 2020, Living Lakes Canada and GW Solutions collaborated to update the 3D model and analyze existing publicly available data for the area, including the two years of groundwater level data collected by Living Lakes Canada.

We have defined the study area using watershed boundaries for surface water and mapped aquifers boundaries for groundwater. Figure 1 presents the defined study area including the Windermere watershed boundary (red polygon).

1.2 Objectives

The goal of this study is to further characterize the groundwater system within the study watershed. The specific objectives are to:

- Update the 3D hydrogeological conceptual model to better understand the aquifer/aquitard system.
- Identify surface water and groundwater interaction zones along Windermere Creek.
- Identify potential sources of aquifer recharge.
- Interpret available groundwater level data.

- Conduct a preliminary water chemistry characterization.

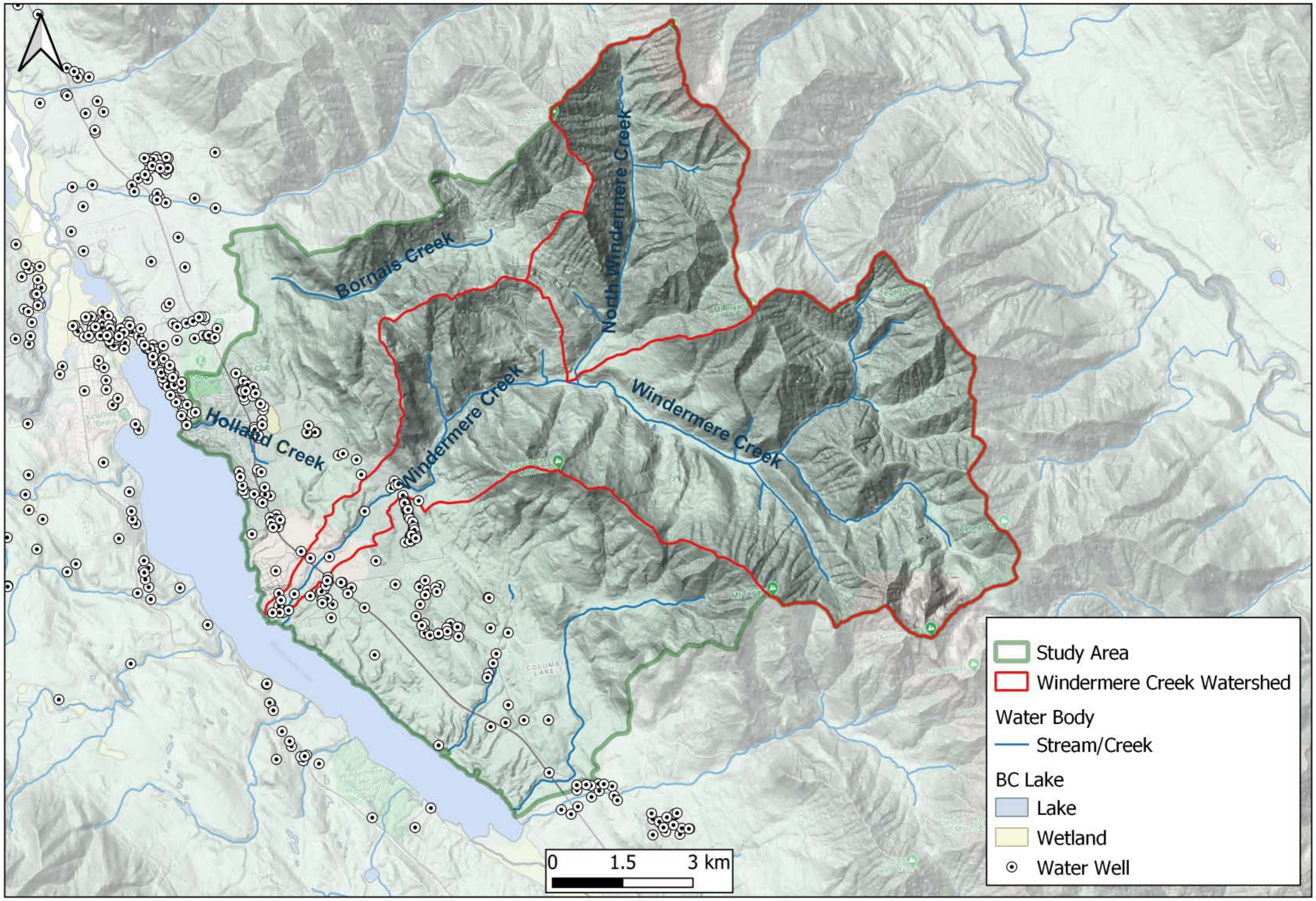

Figure 1. Study area including the Windermere Creek watershed

2 DATA COLLECTION, REVIEW, AND INTEGRATION

2.1 Data Type and Sources of Information

GW Solutions has accessed and compiled the information summarized in Table 1. The compilation has been completed in collaboration with Living Lakes Canada (LLC).

Table 1. Data types and sources of information used to characterize Windermere groundwater system

Data Type	Data Source
Aquifer and Groundwater	BC Wells Database (GWELLS) - https://catalogue.data.gov.bc.ca/dataset/groundwater-wells BC Groundwater Aquifers - https://catalogue.data.gov.bc.ca/dataset/ground-water-aquifers BC Lithology of Groundwater Wells - https://catalogue.data.gov.bc.ca/dataset/lithology-of-ground-water-wells BC Aquifer Classification System - http://www.env.gov.bc.ca/wsd/plan_protect_sustain/groundwater/aquifers/Aq_Classification/Aq_Class.html Living Lake Volunteer Observation Well (VOW) Groundwater Level Data (VOW 10 & 11) - Data available from https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-science-data/water-data-tools/real-time-water-data-reporting
Watersheds and Surface water	BC Freshwater Atlas Assessment Watersheds - https://catalogue.data.gov.bc.ca/dataset/freshwater-atlas-assessment-watersheds Lake Windermere Ambassadors - Water level data for Windermere Creek, personal communication Water Survey Canada (WSC) - https://wateroffice.ec.gc.ca/search/historical_e.html
Elevation	LiDAR data (1 m resolution) from the Province of BC(GeoBC, 2018)

Data Type	Data Source
	30 m x 30 m digital elevation model from the Province (Natural Resources Canada-NRCan)
Water Chemistry	Environmental Monitoring System (EMS) - https://www2.gov.bc.ca/gov/content/environment/research-monitoring-reporting/monitoring/environmental-monitoring-system A private well located close to LLC Volunteering observation well VOW 10 – personal communication

2.2 Water Wells and Mapped Aquifers

2.2.1 Groundwater wells (type, lithology, yield, vulnerability)

The BC Ministry of Environment and Climate Change Strategy (BC MoE) maintains a water wells database (GWELLS) that includes information on well construction/completion, initial water level, alteration, or decommissioning. Information on the geological or water-bearing materials encountered during drilling are contained in the Lithology tables. The GWELLS database comprises eight data tables: General; Screen; Casing; Development Method; Drilling Method; Production; Perforation; and Lithology. GW Solutions has cleaned and standardized the GWELLS database and extracted information relevant to aquifer delineation and use in Leapfrog Works.

Figure 2 shows the water wells from the database within the study area. Very few wells are completed in the fractured bedrock aquifer. There is one abandoned observation well (Provincial Well Tag Number 60415) in the wells database that was installed for an appeal on a water license. There are two active Volunteer Observation Wells (VOW 10 and VOW 11) in the study area which are maintained by LLC. Of these, only VOW 10 is registered in the wells database.

Of the wells registered in the wells database, approximately, 20% of the wells are completed at shallow depths (< 15 m), 40% at depths between 15 and 50 m, and 35% at depths between 50 m and 100 m. Well completion depths were not reported for the remaining 5%.

2.2.2 Mapped aquifers and physical aquifer properties

Figure: 3 shows the boundaries of the three provincially mapped aquifers within the study area: Sand and gravel aquifers 460 and 453; and bedrock aquifer 1000 (Table 2). Aquifer 453 is located at the south east portion of the study area.

Table 2: Aquifer properties based on Provincial Aquifer Classification and Mapping

Aquifer ID	Material	Mapping year	Type	Stratigraphy	Productivity	Demand	Vulnerability	Main water usage	Location
460	Sand and Gravel	2012	Unconfined	Alluvial fan	Moderate	Moderate	Moderate	Domestic	Madias Ck.; N. of Fairmont Hot springs
453	Sand and Gravel	2016	Confined	Glaciofluvial	Moderate	Low	Moderate	Multiple	Windermere; E. side of Windermere LK.
1000	Bedrock	2012	Fractured sedimentary rock	Fine Sedimentary Rocks- McKay Group	Moderate	Low	Moderate	Domestic	Eastern side of Windermere Lake

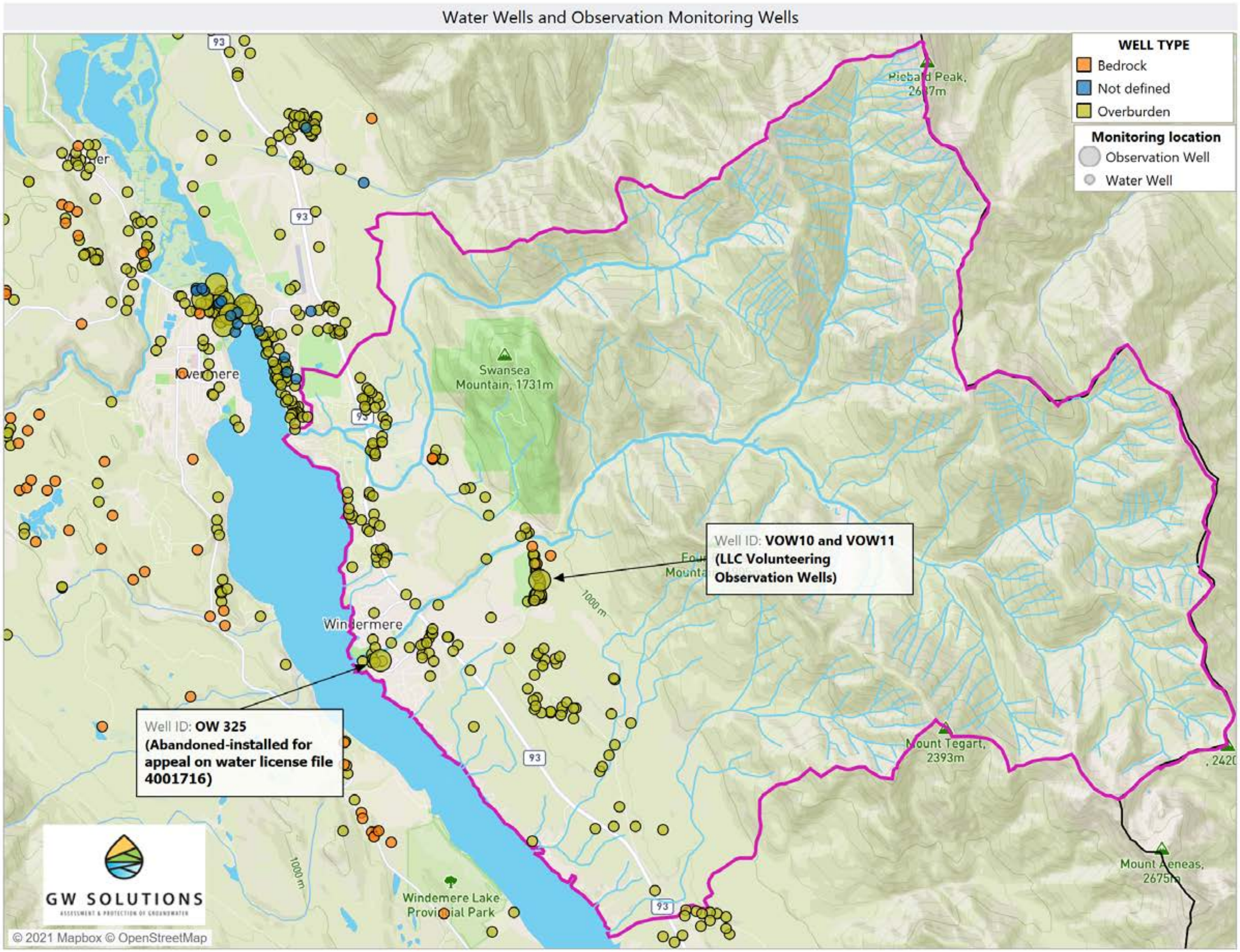

Figure 2: Water wells within the study area

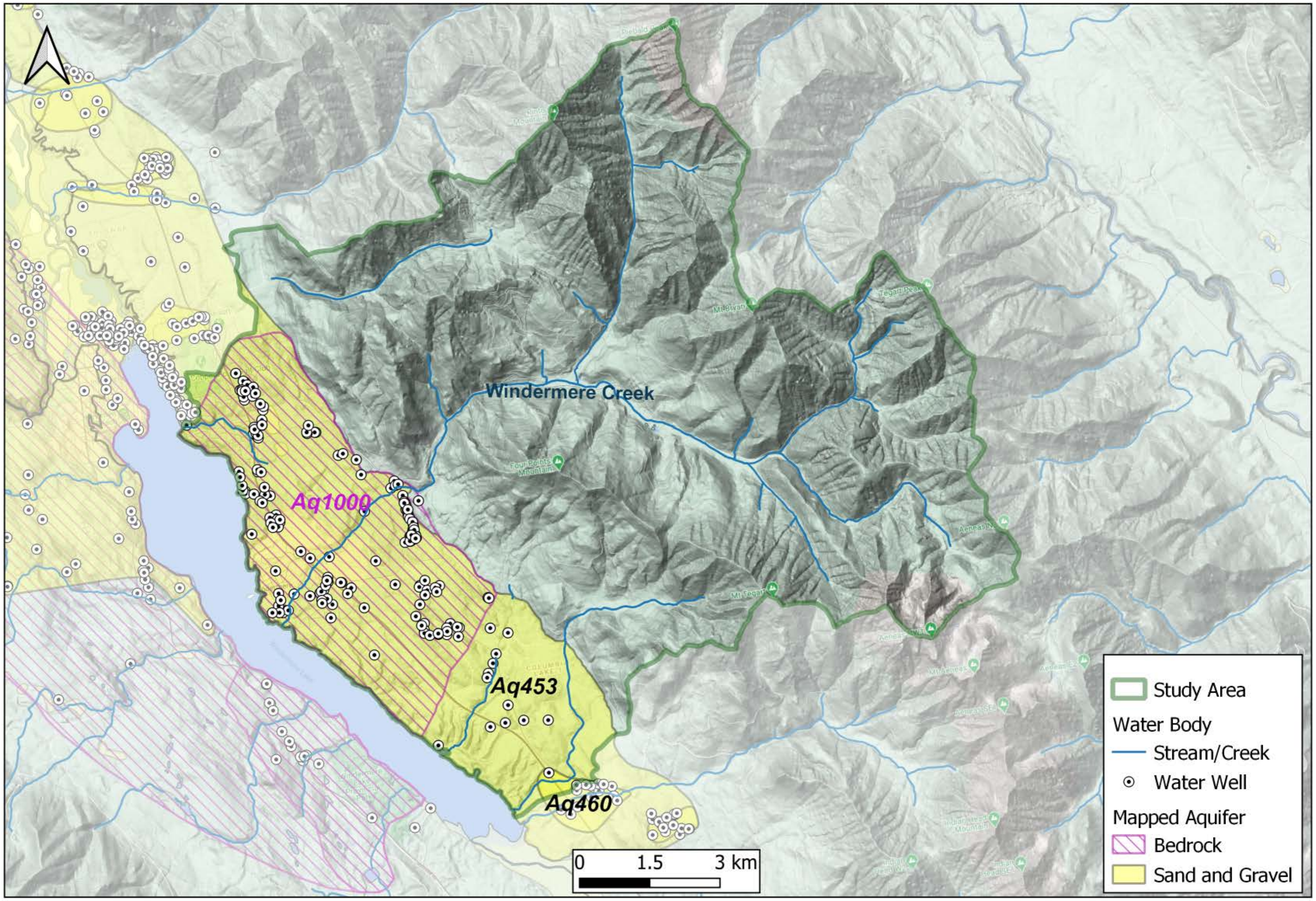

Figure: 3. BC mapped aquifers within the study area

3 3D HYDROGEOLOGICAL CONCEPTUAL MODEL

3.1 Background and Model Settings

GW Solutions updated the August 2018 3D hydrogeological conceptual model in Leapfrog Works (Seequent Limited, 2020) that covered the Windermere Loop Road area. The updated model extends to include more of the Windermere Creek watershed, thereby incorporating more well log and water level information. Newly available, high-resolution LiDAR topography resulted in a higher resolution model and better definition of the Windermere Creek floodplain and fan.

Creating a conceptual model in Leapfrog Works involves generating contact surfaces that correspond to the boundaries between lithological units, refining these surfaces, and arranging them in chronological order. Modelling aquifer/aquitard units involves further grouping lithological units according to texture, permeability, and likelihood of bearing water.

Two broad categories of aquifers were considered: Bedrock and Overburden. In bedrock aquifers, groundwater flows through fractures, voids and bedding planes. Bedrock can also as an aquitard (or aquiclude) where permeability is absent and groundwater movement is impeded. In the standardized GWELLS lithologies, all bedrock intervals are grouped together to define the fractured bedrock aquifer/aquitard system.

In overburden aquifers (also known as surficial or unconsolidated aquifers), groundwater flows in the pore spaces between grains of sand, gravel, or other fine material. Overburden materials in well logs are classified in terms of relative permeability: 1) permeable; 2) low-permeability; and 3) ambiguous – i.e., units that could be permeable or of low permeability.

The well data were imported to Leapfrog as collar, interval, screen and downhole point data (in the case of static water levels). Aquifer and aquitard materials are grouped in the 3D model based on relative permeability, screen location, reported water level, drilling comments (e.g. “water bearing”) and correlations with surrounding wells. Figure 4 illustrates the updated model domain.

3.2 3D Conceptual Hydrogeological Model

The resulting 3D hydrogeological conceptual model is presented in Figure 4. Figure 5 shows the locations of hydrogeological cross-sections created along and crossing the Windermere Creek, and Figure 6 to Figure 8 present these cross sections.

Based on the hydrogeological cross sections, the water wells within the study area are completed in three water bearing zones:

1- Upper Aquifer (unconsolidated and unconfined). This aquifer is the most widespread across the study area and likely consists of glaciofluvial and alluvial fan sediments shed from the mountain front.

2- Middle Aquifer (unconsolidated and confined). This aquifer consists of a sand and gravel lenses within low permeability material (primarily clay, silt aquitard). The aquifer is noted in twenty-five wells and it appears discontinuous across the study area. Wells penetrating this aquifer are clustered in the north (near Holland Creek) and south of Windermere Creek near Kootenay No.3 Road.

3- Lower Aquifer (unconsolidated and confined). This aquifer consists of thin sand and gravel lenses within low permeability material (primarily clay, silt aquitard). The aquifer is noted in only four wells and it appears discontinuous across the study area.

4- Bedrock Aquifer (mostly confined).

Based on the available data, the hydrogeological river profile (Figure 6) shows the potential for a connection between the Upper Aquifer and Windermere Creek. In the headwaters, where bedrock is exposed along the Creek, the fractured bedrock likely has a role in recharging the creek. Downstream of the mountain front, the middle reach of Windermere Creek is potentially losing water to the aquifer. Multiple springs present along the cut banks of lower Windermere Creek (below the Highway 93 bridge) indicate groundwater is daylighting in this area. The lower creek reaches are therefore likely gaining water from the Upper Aquifer.

Figure 7 shows how the Upper Aquifer potentially interacts with lower Windermere Creek. In addition, it shows the limited extent of the lenses that comprise the Lower Aquifer. Well Tag Number 14309 is shown completed in the Lower Aquifer. This well is reported to yield approximately 30 gallons per minute and static water level is reported at 161 ft.

Finally, Figure 8 shows the variability in aquifer thickness upgradient of mapped Aquifer 453. Additionally, this hydrogeological cross section shows wells completed in the fractured Bedrock Aquifer. The aquitard layer is discontinuous at this location where the Upper Aquifer is in contact with the Bedrock Aquifer.

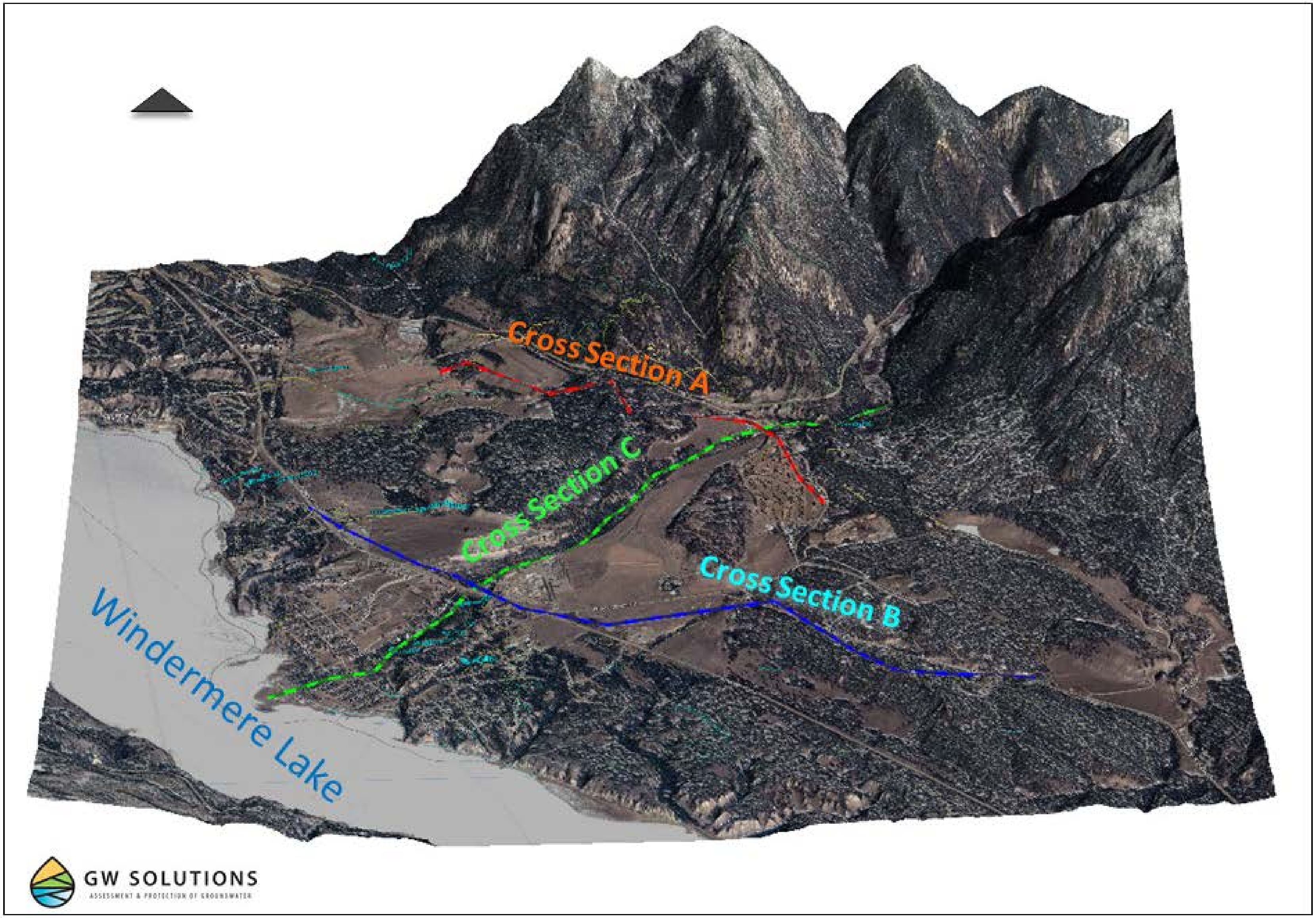

Figure 4. The domain covering the updated 3D hydrogeological conceptual model with the cross-section lines (A, B and C)

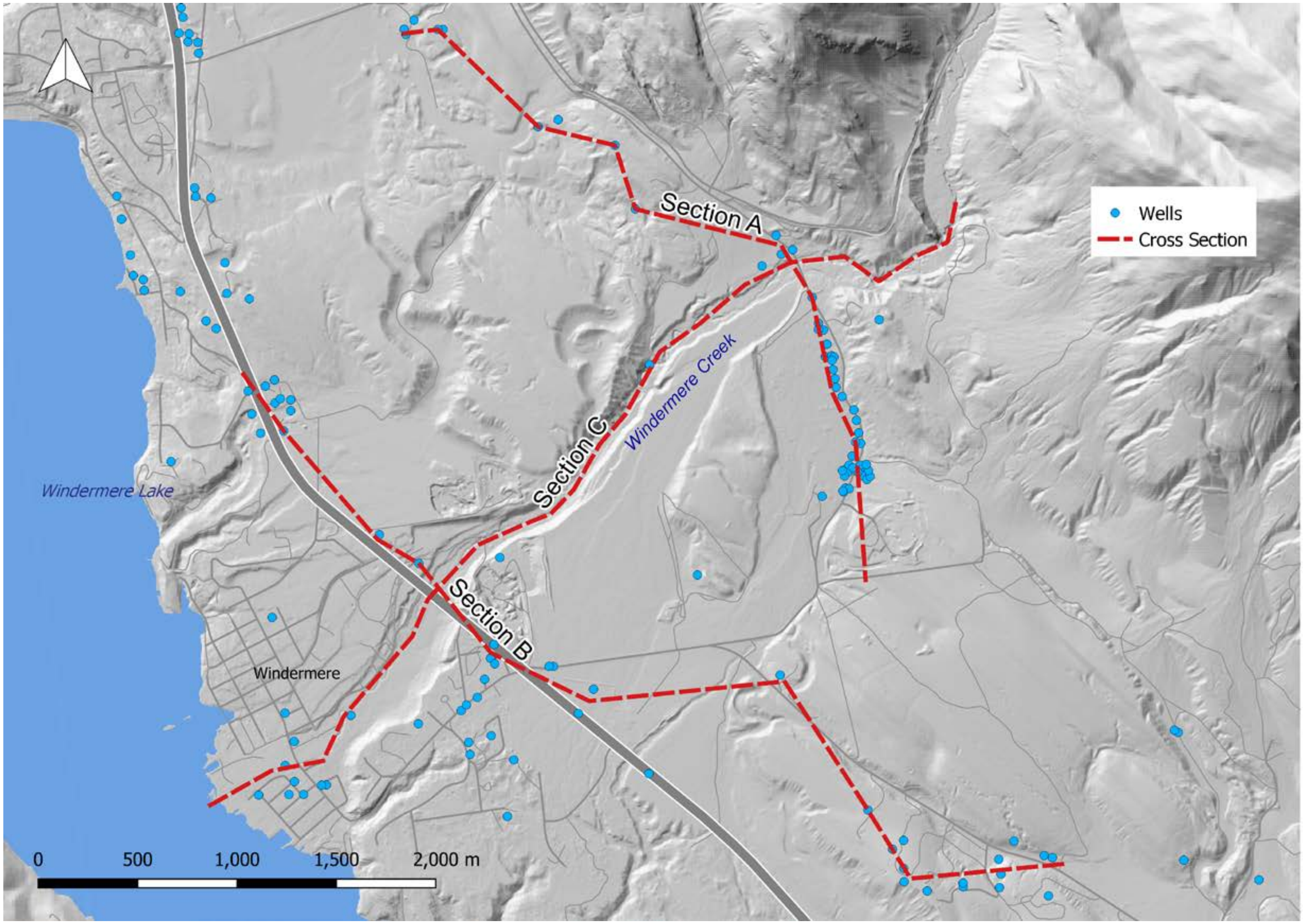

Figure 5. Location of the hydrogeological cross-sections on LiDAR topographic layer

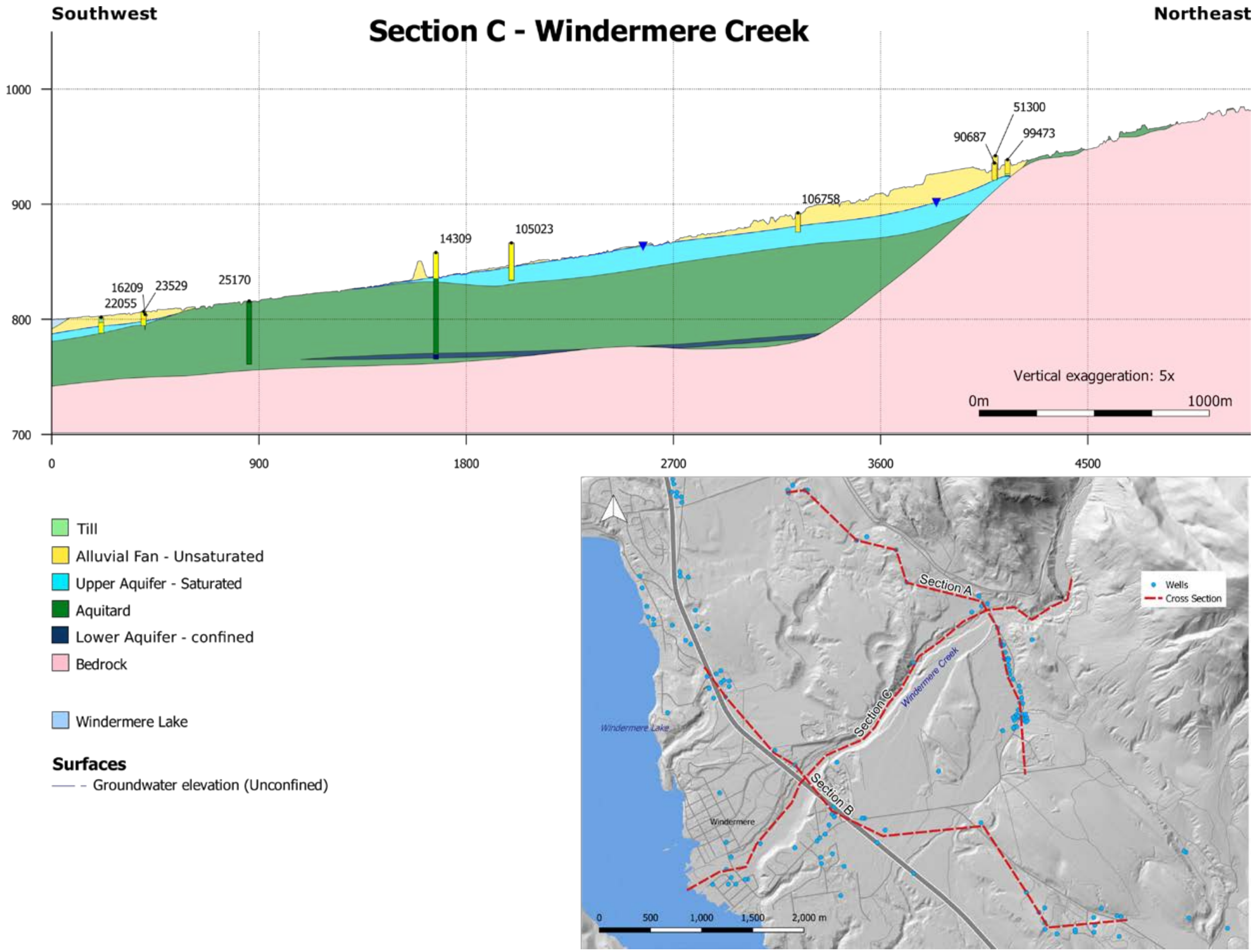

Figure 6. Hydrogeological creek base profile along the Windermere Creek (cross section C)

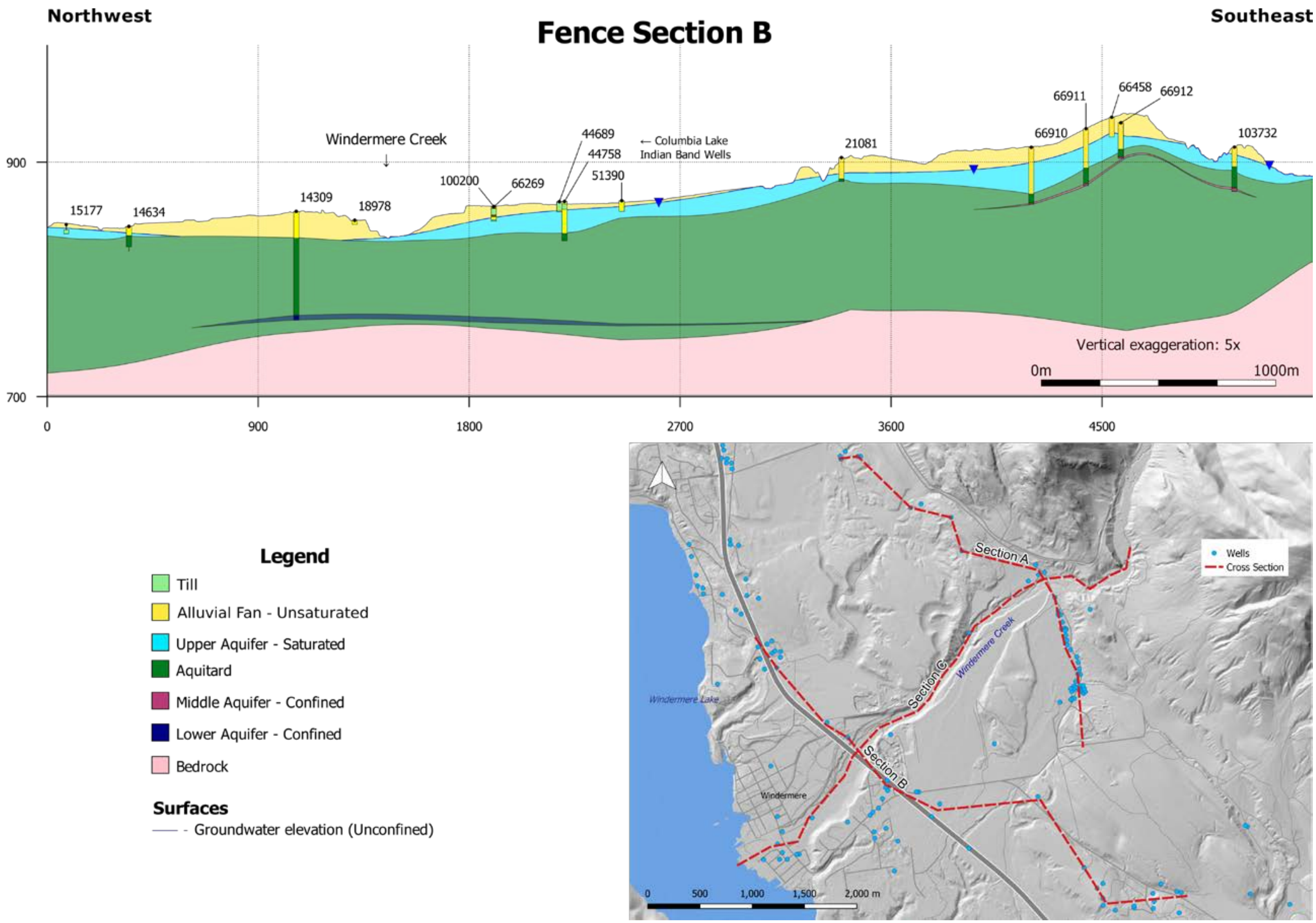

Figure 7. Hydrogeological cross section B

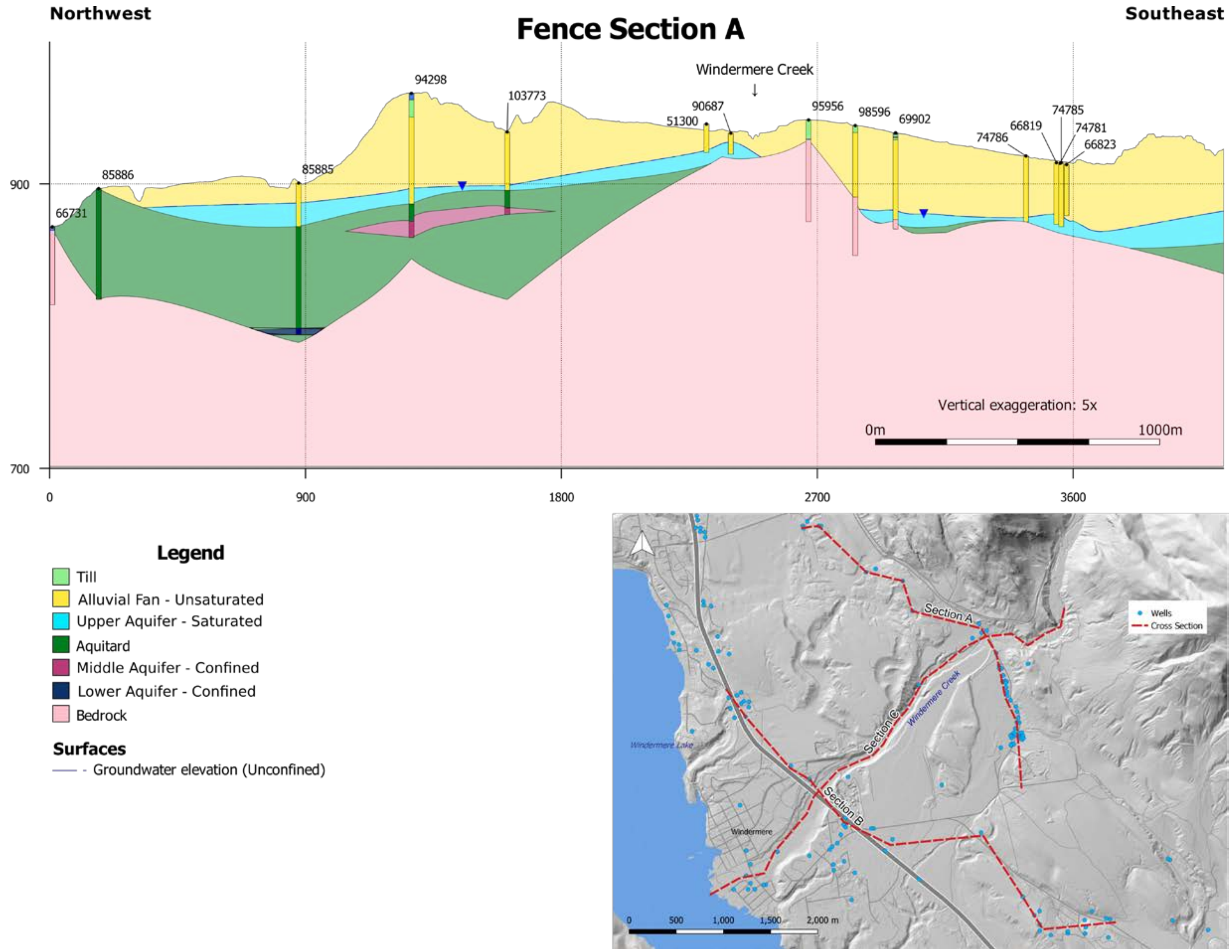

Figure 8: Hydrogeological cross section A

4 SURFACE WATER AND GROUNDWATER INTERACTION

4.1 Groundwater level

Living Lake Canada (LLC) has been monitoring water level in two water wells in the Windermere area: Volunteer Observation Wells (VOW) 10 and 11. This was prompted by the absence of long-term records of groundwater levels within the study area. VOW 10 is located on the east side of Windermere Loop Road and VOW 11 is on the west (Figure 2). Both wells are 6" steel cased, lack screens, and are unused for water supply.

Based on the conceptual hydrogeological model and the available well information, VOW 10 (Provincial Well Tag Number (WTN) 66814) is completed in the Upper Aquifer. There is no well log available for VOW 11 (VOW 11 is not registered in the Provincial GWELLS database). However, given their similar elevations, total depths and water levels, it is likely that both wells are analogous and completed in the Upper Aquifer.

Hourly groundwater levels for VOW 10 and VOW 11 since October 2018 are shown in Figure 9 and Figure 10, respectively. Data are missing for VOW 11 from December 2019 to April 2020, when the data logger was removed. The water table fluctuated by approximately 0.7 m in both wells, with the minimum level occurring in June and maximum occurring in October-November.

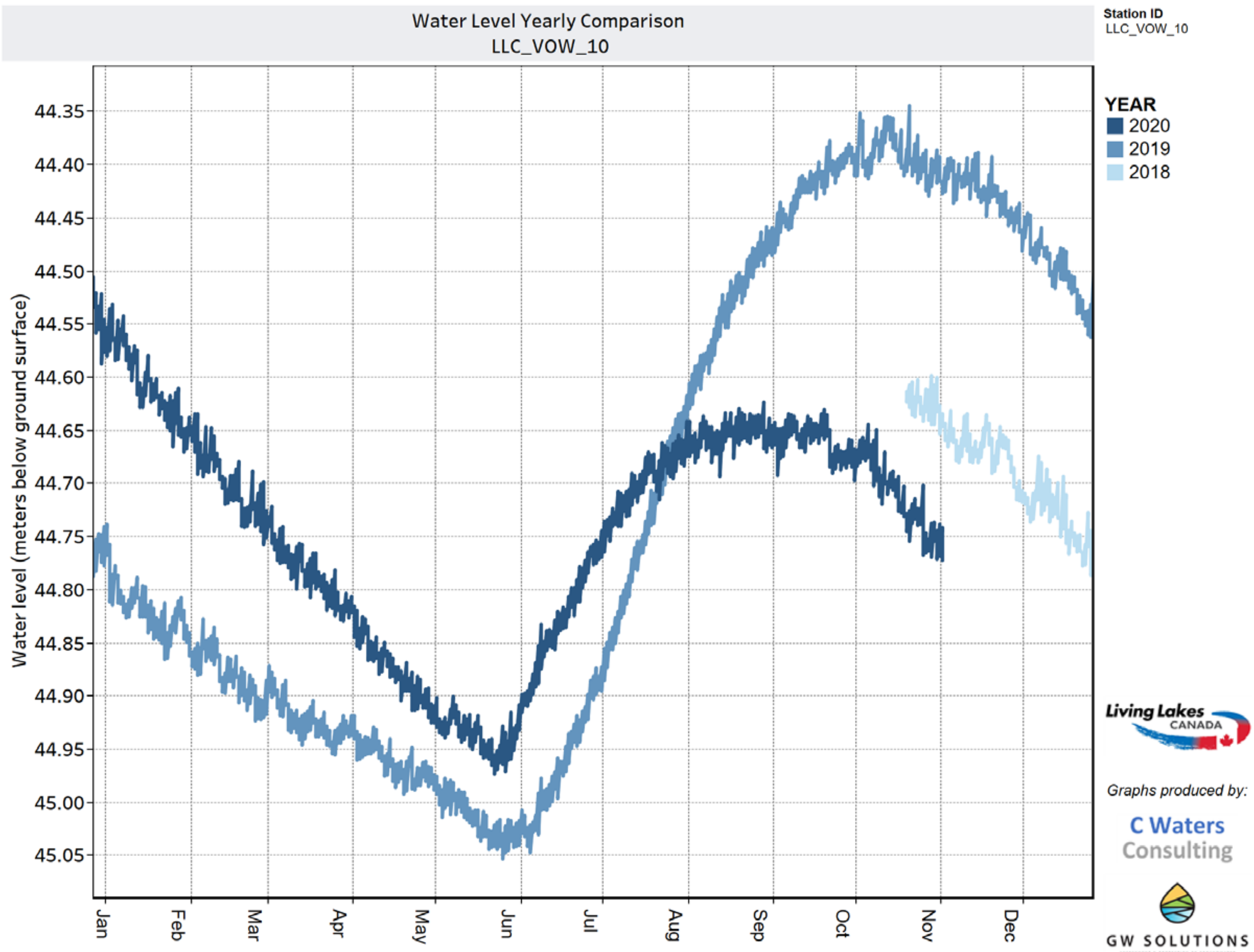

Figure 9. Hourly groundwater levels in VOW 10

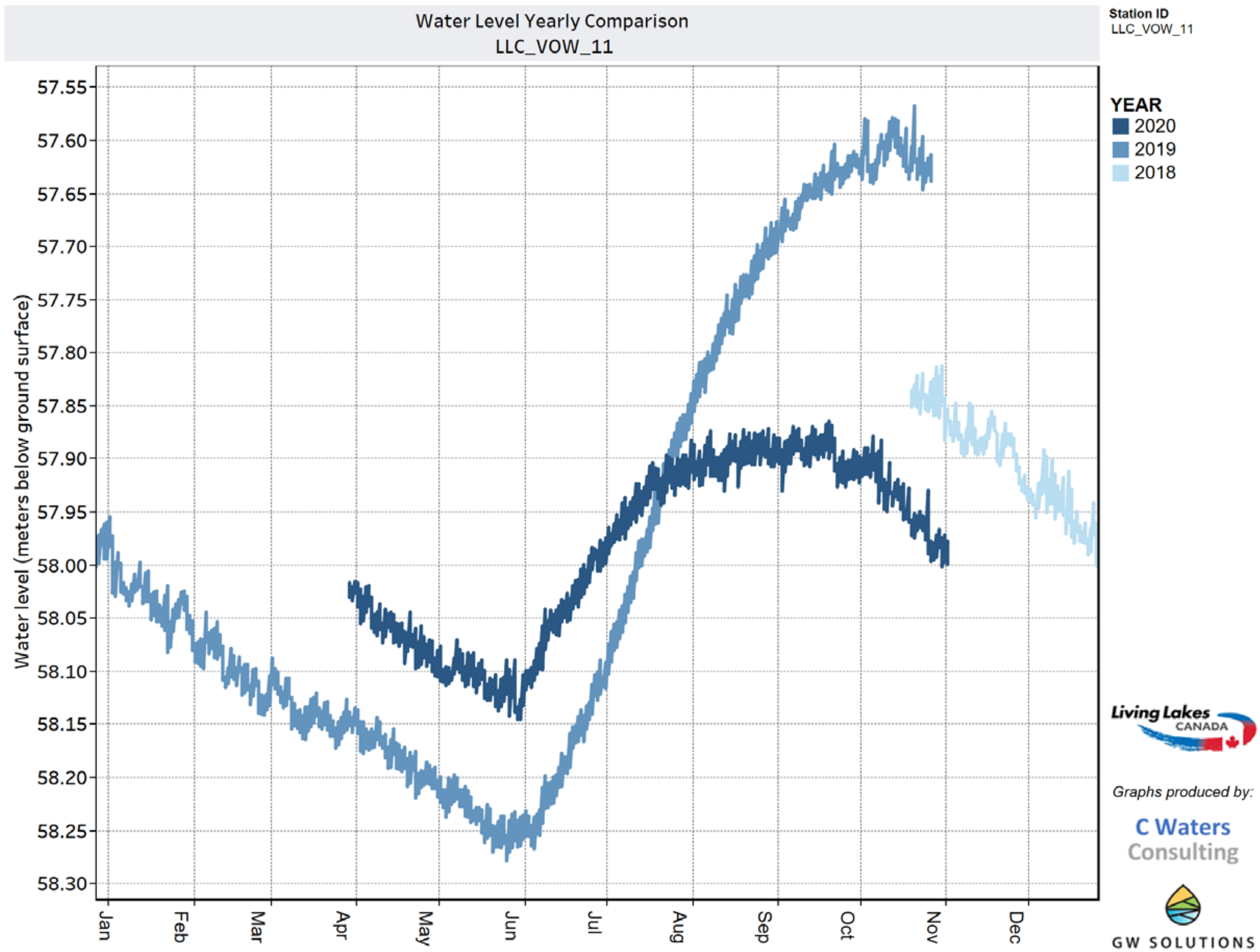

Figure 10. Hourly groundwater levels in VOW 11 Surface water levels

4.2 Surface water levels

Streamflow data is limited to one hydrometric station (ID: LWA Windermere Creek), located at the mouth of Windermere Creek. The station is operated by the Lake Windermere Ambassadors (LWA) and measures water level with a data logger. Data are available from March 2018 to April 2020 when the station was washed out by spring meltwater. One inactive hydrometric station (08NA024) was maintained by the Water Survey Canada in the headwaters of Windermere Creek with flow information available from 1915 to 1980. The available streamflow and level data are presented in Figure 11.

Measured stream level at the LWA Windermere Creek station and monitored groundwater level in well VOW 10 are shown in Figure 12. The monitored groundwater level mimics the stream level at the mouth of Windermere Creek suggesting that both the Creek and groundwater levels are responding to snowmelt and precipitation events.

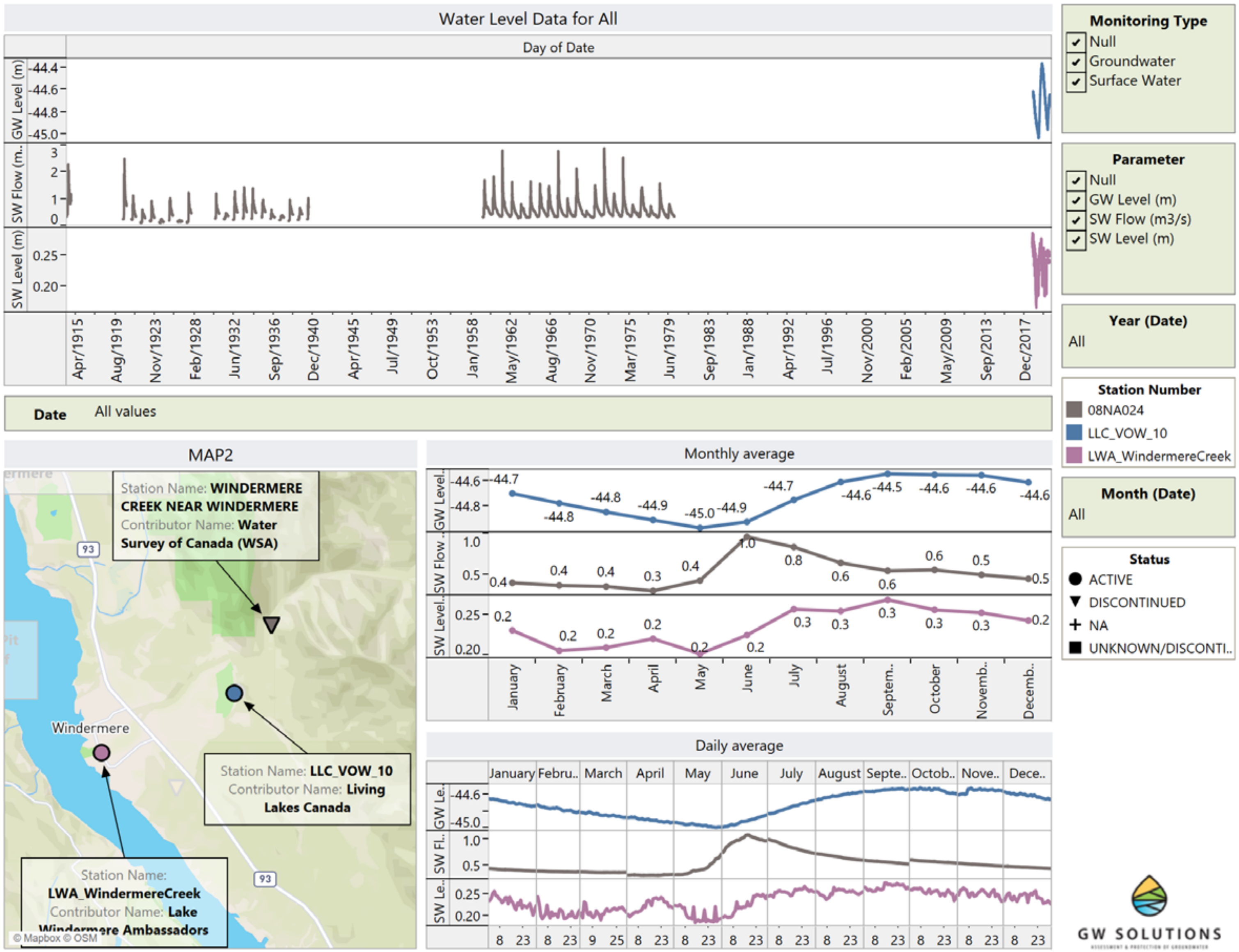

Figure 11. Stream flow (WSC Station 08NA024), stream level (LWA station), and groundwater level (VOW 10)

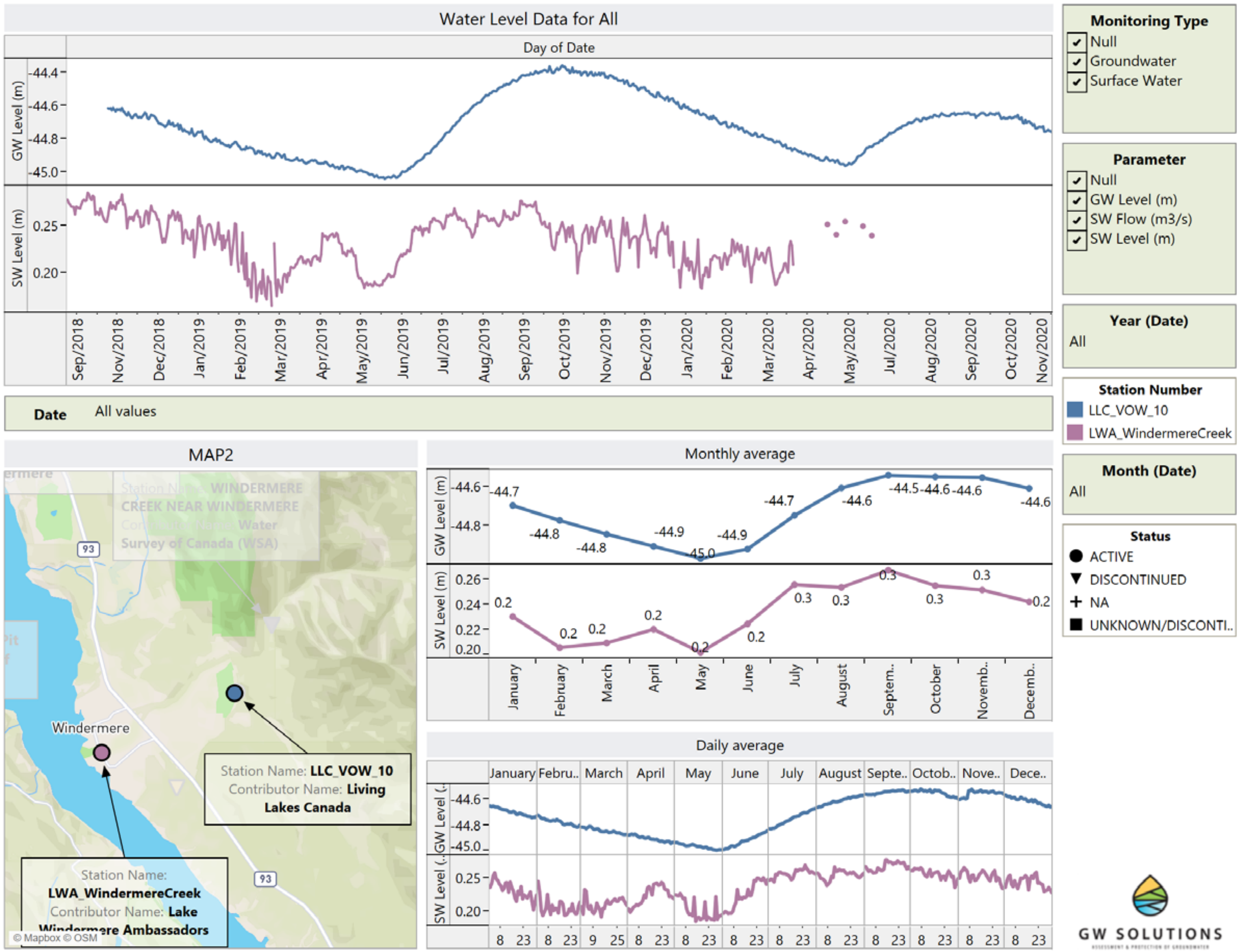

Figure 12. Stream level in Windermere Creek (LWA Station) and groundwater level in VOW 10

5 GROUNDWATER QUALITY CHARACTERIZATION

5.1 Water Chemistry

5.1.1 Data Management and Analysis

GW Solutions has developed a water chemistry data management, visualization and analysis tool using Tableau software. The available water chemistry data from different sources has been compiled, cleaned, and standardized units (e.g., µg/l converted to mg/l).

5.1.2 Sources of Information

The main source of water chemistry data for this study is the BC Environmental Monitoring System (EMS). The EMS database is a water quality repository created and maintained by the government of British Columbia. It includes chemical analyses of air, water, and soil samples collected by Ministry staff and site operators.

For this study, we integrated one water sample provided by Living Lakes Canada from a private water well located close to observation well VOW 10 (completed in the Upper Aquifer).

Data from the EMS is publicly available through the EMS Web Reporting portal (EMS WR) with no login required[1]. In addition, monitoring locations can be accessed through the Surface Water Monitoring Sites Interactive Map[2]. Table 3 summarizes the number of samples and tests including the date range and location type.

Water chemistry data has been grouped into three categories based on the location type: groundwater, surface water, and “other” (including Irrigation Spray/Sludge, In Plant and Seepage or Seepage Pools).

Results from 1, 605 samples collected from 59 stations were compiled (Figure 13), representing 35,545 analyses (Figure 14). Approximately 70% of samples were collected from surface water, 30% from groundwater, and less than 1% from “other”. Figure 15 illustrates the sampling locations and types.

[1] https://a100.gov.bc.ca/pub/ems/mainmenu.do?userAction=mainmenu

[2] https://governmentofbc.maps.arcgis.com/apps/webappviewer/index.html?id=0ecd608e27ec45cd923bdcfeefba00a7

Table 3: Water quality data based on source of information

Sources of information	Location Type Group	Tested Parameters	Number of Stations	Number of Samples	No of Tests	Sampling Date From	Sampling Date To	Timeframe
BC Environmental Monitoring System (EMS)	Groundwater	145	18	481	18,882	7/31/1984	7/3/2019	1984-2019
	Other	7	2	3	13	6/14/2016	8/17/2017	2016-2017
	Surface water	171	38	1,120	16,613	6/22/1971	8/17/2020	1971-2020
Living Lakes Canada (personal communication)	Groundwater	37	1	1	37	6/21/2016	6/21/2016	2016-2016
	Total		**59**	**1,605**	**35,545**			

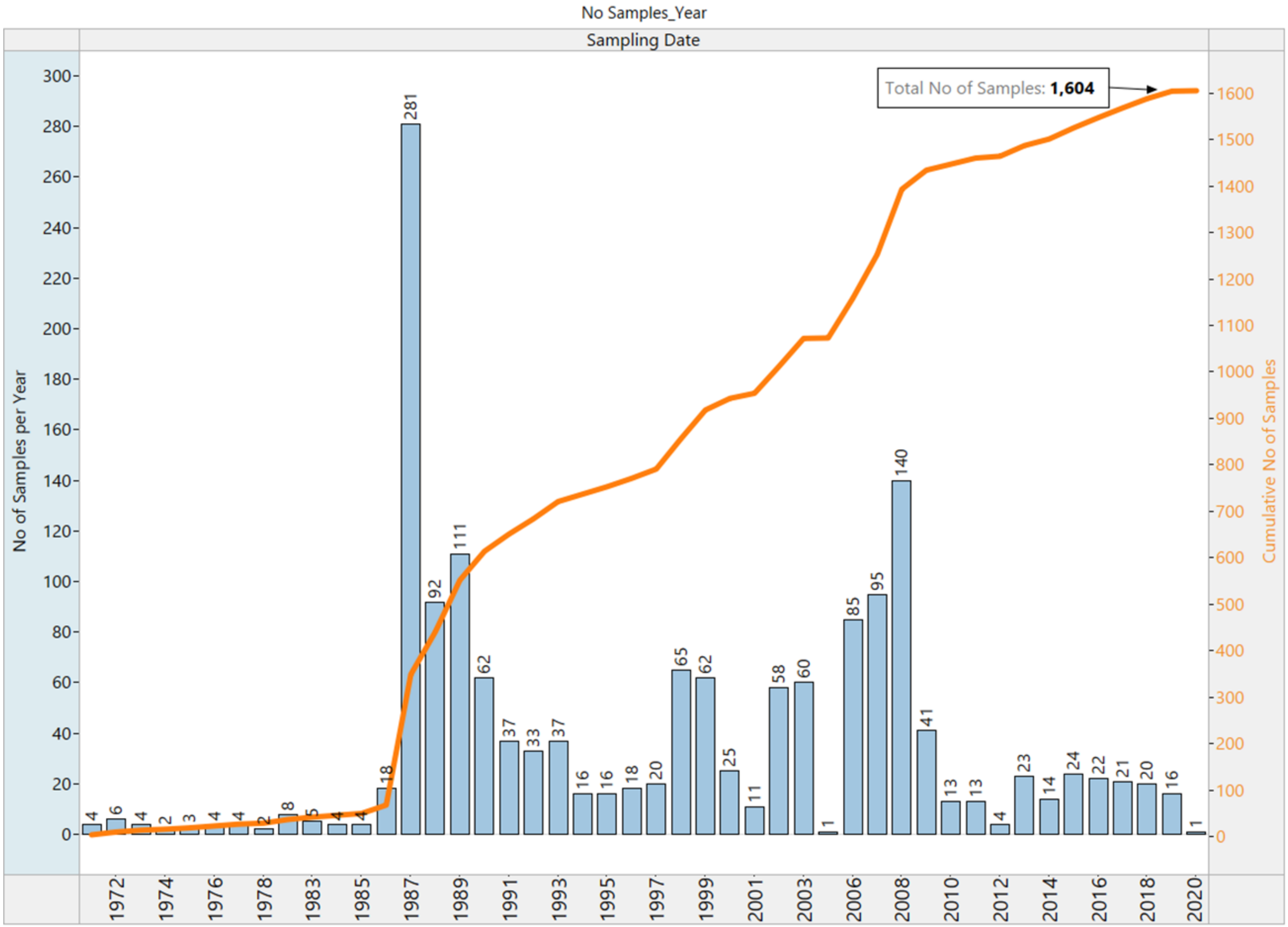

Figure 13. Number of samples per year

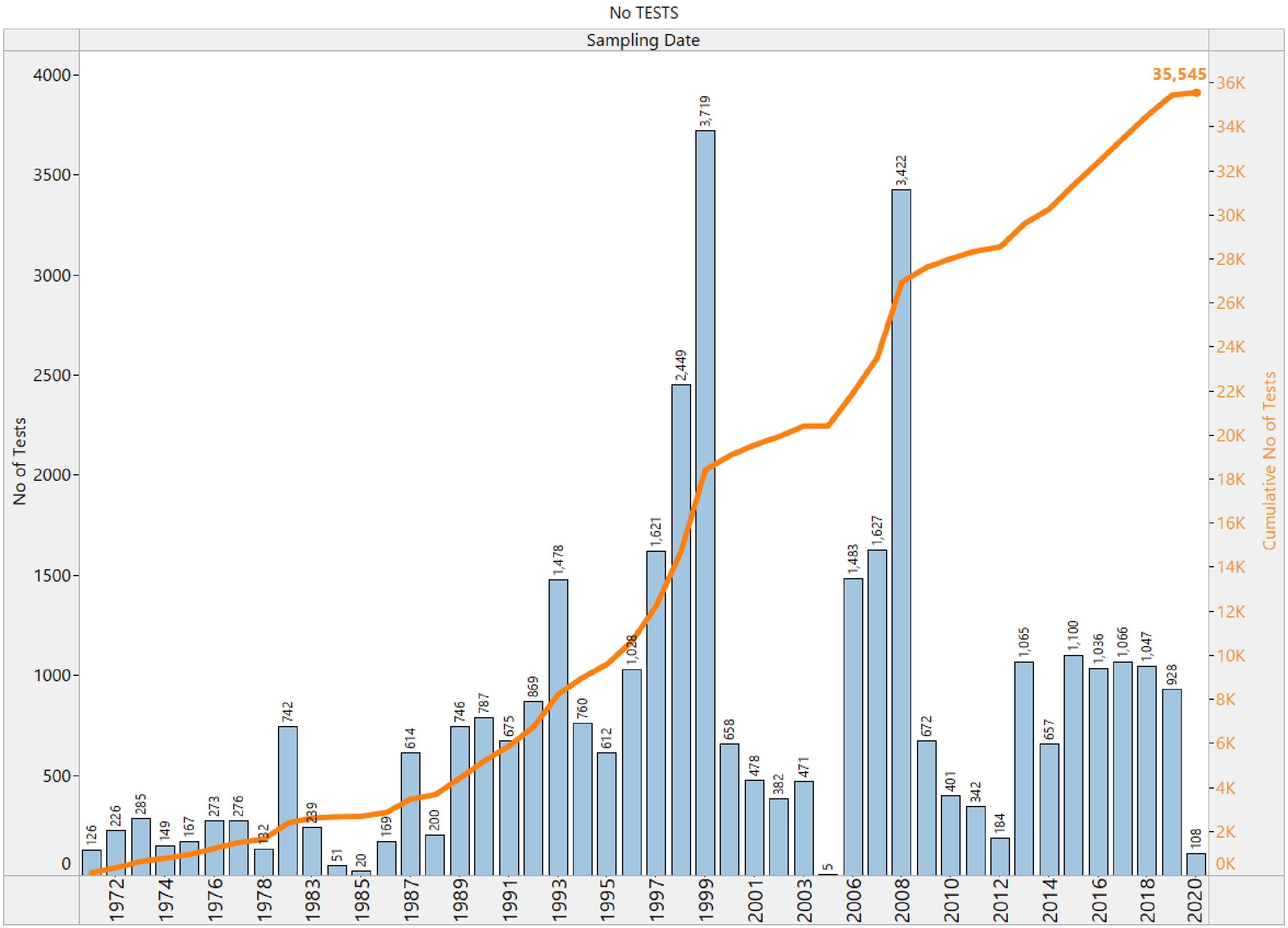

Figure 14. Number of tests per year

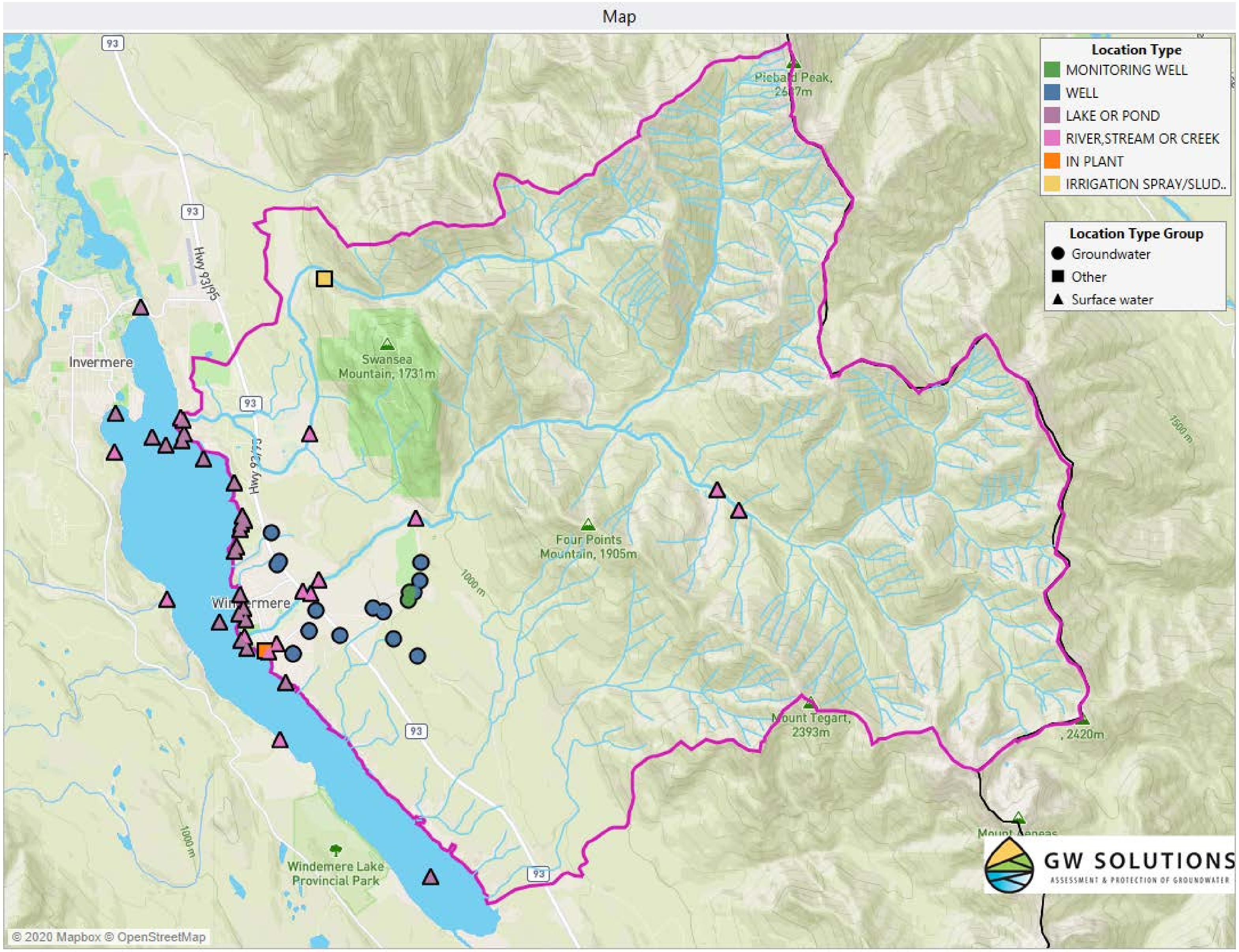

Figure 15. Water quality monitoring stations with available data within the study area

5.1.3 Water chemistry analysis

5.1.3.1 *Methodology*

Piper diagrams[3] and scatter plots were used to assess the differences in water chemistry across the study area for surface water and groundwater samples. The lower triangles in Piper diagrams are used to plot the relative concentrations of anions and cations and these are projected onto the upper diamond which is used to classify water types. The upper diamond (highlighted in Figure 16) has four quadrants, each representing a different water type: calcium-sulfate waters (upper quadrant); calcium bicarbonate waters (left quadrant); sodium chloride waters (right quadrant); and sodium bicarbonate waters (bottom quadrant). Calcium bicarbonate waters are typical of shallow, “young” groundwater. When groundwater has been in contact with bedrock for long periods of time the water type typically shifts from bicarbonate to sulfate type.

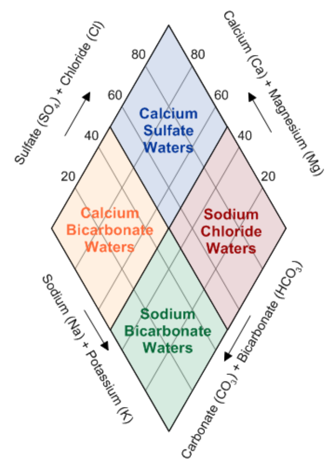

Figure 16: Interpretation of the diamond plot from a Piper diagram to categorize water type[4]

[3] Piper diagrams are commonly used to represent and visualize the key ions present in water, to compare water samples, and to illustrate changes in water chemistry. The main anions and cations present in the water are used to determine the water type, or hydrochemical facies. The major ions in water are usually calcium (Ca), potassium (K), sodium (Na), and magnesium (Mg) for the cations, and sulfate (SO_4), chloride (Cl), bicarbonate (HCO_3), carbonate (CO_3) and nitrate (NO_3) for the anions.

[4] Image from: https://support.goldensoftware.com/hc/en-us/articles/115003101648-What-is-a-piper-plot-trilinear-diagram-

5.1.3.2 *Groundwater*

The Piper diagram in Figure 17 shows the spatial variability of groundwater chemistry for the samples taken from groundwater sources in the study area. The sampled well located near VOW 10 shows bicarbonate calcium water type, suggesting younger groundwater.

5.1.3.3 *Surface Water*

The Piper diagram in Figure 18 shows the spatial variability of surface water chemistry for the samples taken near the outlets of Windermere Creek and Holland Creek. The water type for both creeks is classified as sulfate calcium, indicating that water in these creeks has been in contact with subsurface material for some time. This indicates that groundwater is contributing to the flow in these creeks.

5.1.3.4 *Surface Water and Groundwater*

A Piper diagram has been created to compare the chemistry of groundwater in the study area to that of Windermere Creek (see Figure 19). Groundwater samples have a bicarbonate calcium type, which is typical of young, shallow groundwater and/or recharge areas. Water samples taken at the mouth of Windermere Creek are sulfate calcium type. This water type is associated with deeper, bedrock-sourced, or older groundwater. These preliminary results suggest that this type of groundwater is likely discharging to the Creek.

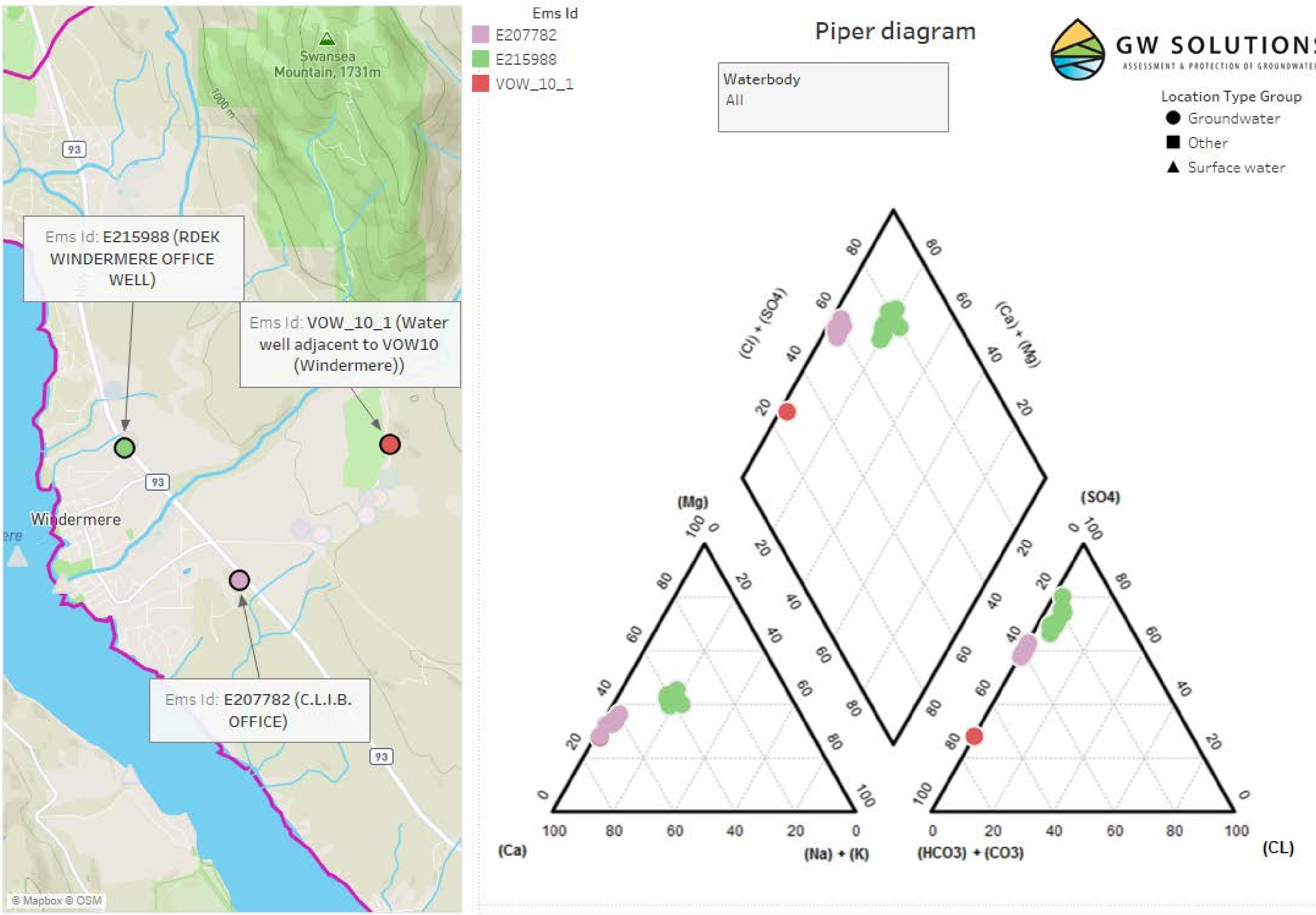

Figure 17. Piper plot diagram for water type - groundwater

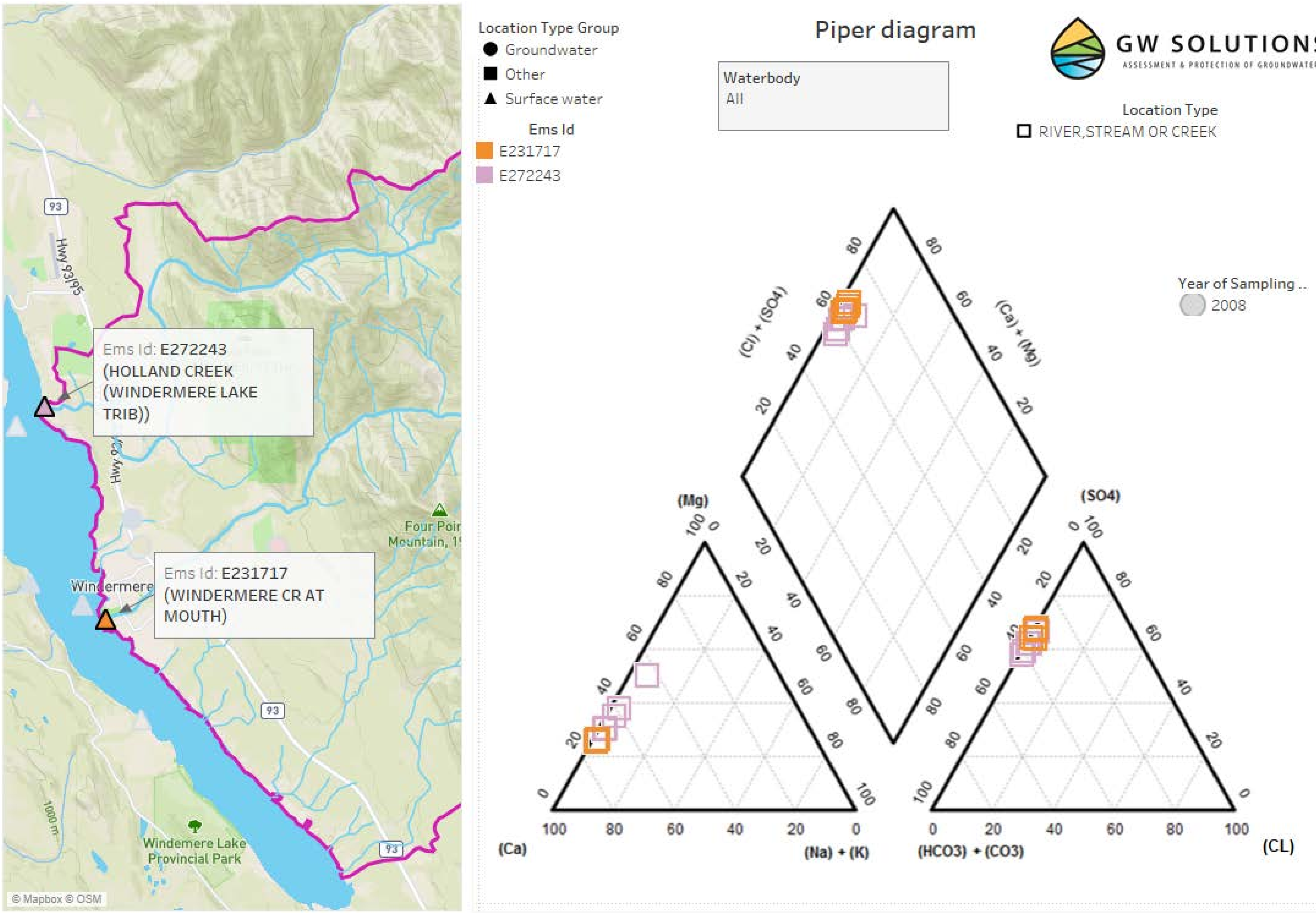

Figure 18. Piper plot diagram for water type - surface water

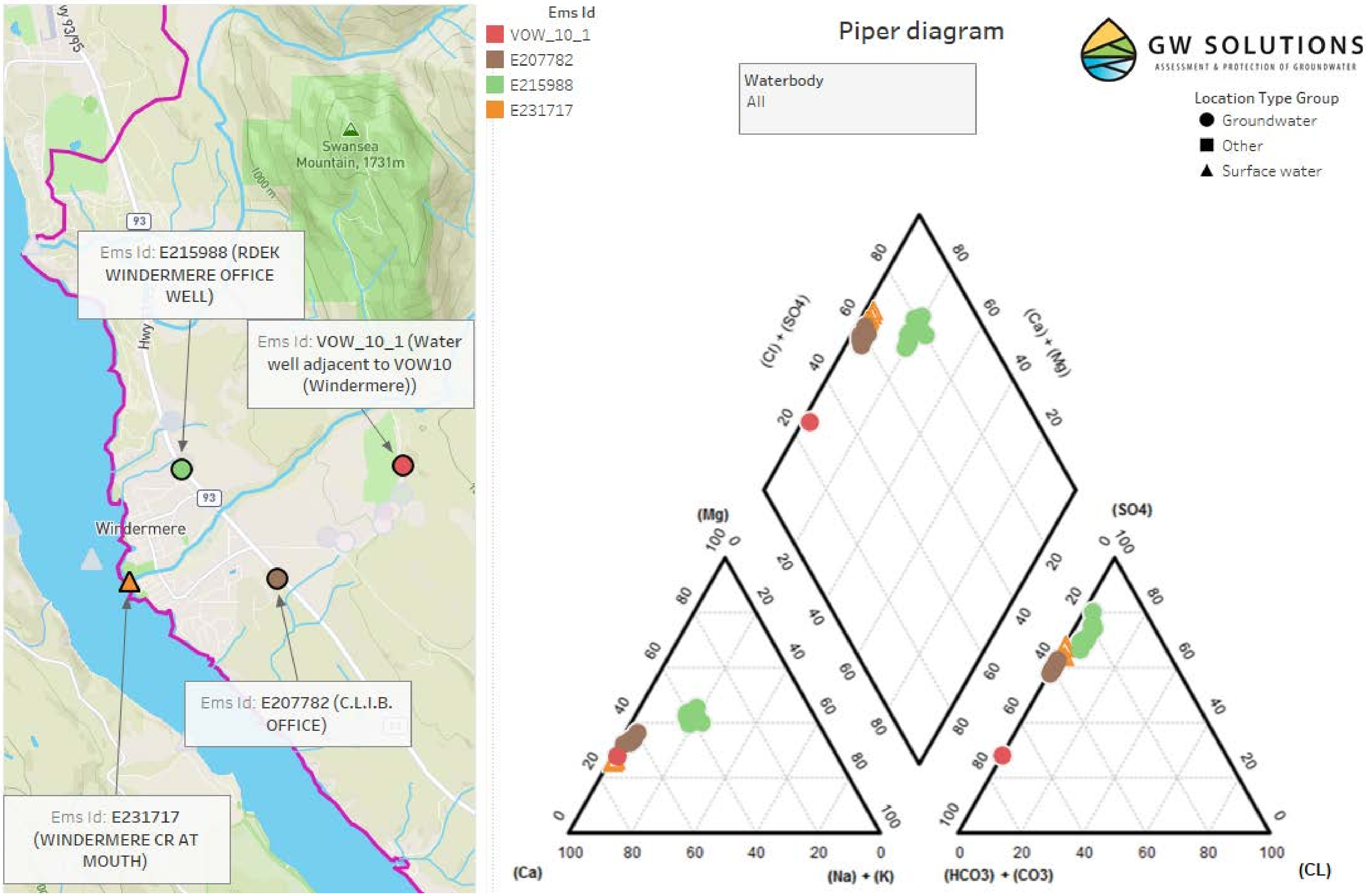

Figure 19. Piper plot diagram for water samples from Windermere Creek and select groundwater samples

6 CONCLUSIONS

Based on the completed work, GW Solutions draws the following conclusions:

1. Most water wells in the study area do not have well screen information either because the information was not reported or because screens were not installed in the wells. Overburden wells lacking screens will drastically underperform. Therefore, well yield estimates reported in GWELLS may not accurately reflect true aquifer yield in the area.

2. The aquifers currently mapped by the BC Ministry of Environment are an oversimplification of the actual architecture of the aquifer system of the Windermere area.

3. The updated Windermere 3D hydrogeological conceptual model suggests there are at least three different groundwater systems within the study area: a) an unconfined, sand and gravel “Upper Aquifer”, b) a confined, sand & gravel “Lower Aquifer” (lenses of high water-bearing sand and gravel within an Aquitard) and c) a fractured Bedrock Aquifer.

4. The hydrogeological conceptual model indicates a likely connection between Windermere Creek and the Unconfined Aquifer. In the headwaters, where bedrock is exposed along the Creek, the fractured bedrock likely has a role in recharging the creek. Downstream of the mountain front, the middle reach or Windermere Creek is potentially losing water to the aquifer. The creek is likely gaining water from the Upper Aquifer along the lower reach.

5. The groundwater level fluctuation in the Upper Aquifer shows an amplitude of approximately 0.7 m with the minimum level occurring in June and maximum in October-November. This type of groundwater level pattern is typical of snow-melt dominated (nival) regimes.

6. Comparing measured stream level at the LWA Windermere Creek station and monitored groundwater level in well VOW 10 shows a similar behaviour suggesting that both surface and groundwater show a delayed response to snow melt and precipitation. Early spring snow melt in March-April creates an initial uptick in creek flows, yet a groundwater response is not evident until the main melt starts in May-June. This is likely due to nighttime freezing preventing widespread groundwater recharge in March and April.

7. In Windermere Loop Road area, groundwater is likely recharged by diffuse mechanisms (i.e. precipitation and snow melt).

8. Water chemistry data from the Provincial EMS database and Living Lakes Canada indicate that groundwater is either of the bicarbonate calcium type (in the Upper Aquifer) or sulfate calcium-magnesium type for deeper-sourced, older groundwater.

9. Surface water at the estuary of Holland Creek and Windermere Creek is classified as sulfate calcium suggesting that deeper, bedrock-sourced, or older groundwater has contributed to the flow in these creeks.

7 RECOMMENDATIONS

Based on the completed work, GW Solutions makes the following recommendations:

1. VOW 10 and VOW 11 are monitoring the same aquifer. Only one well need be retained to monitor seasonal and long-term changes in water levels in the Upper Aquifer at this location.
2. Install data loggers in wells that are representative of the other aquifers present in the study area. This will help characterize groundwater conditions in the different aquifer types and improve our understanding of recharge and discharge dynamics.
3. Protection of recharge areas is important for maintaining flows in creeks and water supply in the aquifers. Collection and analysis of water samples from the Volunteer Observation Wells or other wells in the vicinity of Windermere Loop Road would help characterize the water types present and identify primary sources of recharge (e.g., precipitation, surface water, mountain block/bedrock). Analysis of isotopes may help identifying these recharge mechanisms.
4. Install/maintain a reliable surface water gauge to measure level and flow of Windermere Creek. Consider at least three locations: Upstream where there is an inactive hydrometric station, at the discharge where the current station exists, and midway between these two points. This will further help characterize surface water and groundwater interaction.
5. Conduct a manual water quality sampling event at several locations along Windermere creek to generate a profile of temperature, pH, electrical conductivity, TDS. This will help in characterizing surface water and groundwater interaction.
6. Screens should be installed in any new wells drilled in unconsolidated sediments to improve production and longevity of the wells. Residents with wells lacking screens may also benefit from having their wells retrofitted.
7. The 3D conceptual model is primarily based on interpolation of information from GWELLS, however, many well location errors are likely to exist. Field verification of wells and additional analyses would verify the conclusions.

8 STUDY LIMITATIONS

This document was prepared for the exclusive use of the Living Lake Canada (the client) and its partners. The inferences concerning the data, site and receiving environment conditions contained in this document are based on information obtained during investigations conducted at the site by GW Solutions and others and are based solely on the condition of the site at the time of the site studies. Soil, surface water and groundwater conditions may vary with location, depth, time, sampling methodology, analytical techniques and other factors.

In evaluating the subject study area and water data, GW Solutions has relied in good faith on information provided. The factual data, interpretations and recommendations pertain to a specific project as described in this document, based on the information obtained during the assessment by GW Solutions on the dates cited in the document, and are not applicable to any other project or site location. GW Solutions accepts no responsibility for any deficiency or inaccuracy contained in this document as a result of reliance on the aforementioned information.

The findings and conclusions documented in this document have been prepared for the specific application to this project, and have been developed in a manner consistent with that level of care normally exercised by hydrogeologists currently practicing under similar conditions in the jurisdiction.

GW Solutions makes no other warranty, expressed or implied and assumes no liability with respect to the use of the information contained in this document at the subject site, or any other site, for other than its intended purpose. Any use which a third party makes of this document, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. GW Solutions accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or action based on this document. All third parties relying on this document do so at their own risk. Electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore no party can rely upon the electronic media versions of GW Solutions' document or other work product. GW Solutions is not responsible for any unauthorized use or modifications of this document.

GW Solutions makes no other representation whatsoever, including those concerning the legal significance of its findings, or as to other legal matters touched on in this document, including, but not limited to, ownership of any property, or the application of any law to the facts set forth herein.

If new information is discovered during future work, including excavations, sampling, soil boring, water sampling and monitoring, predictive geochemistry or other investigations, GW Solutions should be requested to re-evaluate the conclusions of this document and to provide amendments, as required, prior to any reliance upon the information presented herein. The validity of this document is affected by any change of site conditions, purpose, development plans or significant delay from the date of this document in initiating or completing the project.

The produced graphs, images, and maps have been generated to visualize results and assist in presenting information in a spatial and temporal context. The conclusions and recommendations presented in this document are based on the review of information available at the time the work was completed, and within the time and budget limitations of the scope of work.

Third parties may rely on the information contained in this report subject to the above limitations.

9 CLOSURE

Conclusions and recommendations presented herein are based on available information at the time of the study. The work has been carried out in accordance with generally accepted engineering practice. No other warranty is made, either expressed or implied. Engineering judgement has been applied in producing this letter-report.

This letter report was prepared by personnel with professional experience in the fields covered. Reference should be made to the General Conditions and Limitations attached in Appendix 1.

GW Solutions is pleased to produce this document. Thank you to Carol Luttmer for review and contributions to this report. If you have any questions, please contact us.

Yours truly,

GW Solutions Inc.

Prepared by:	Antonio Barroso, MSc., P.Eng. Project Hydrogeologist	Shiva Farjadian, M.Sc. M.Sc. in Hydrogeology	Gilles Wendling, Ph.D., P.Eng. Hydrogeologist - Senior reviewer

APPENDIX 1

GW SOLUTIONS INC. GENERAL CONDITIONS AND LIMITATIONS

This report incorporates and is subject to these "General Conditions and Limitations".

1.0 USE OF REPORT

This report pertains to a specific area, a specific site, a specific development, and a specific scope of work. It is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation from the site or proposed development would necessitate a supplementary investigation and assessment. This report and the assessments and recommendations contained in it are intended for the sole use of GW SOLUTIONS's client. GW SOLUTIONS does not accept any responsibility for the accuracy of any of the data, the analysis or the recommendations contained or referenced in the report when the report is used or relied upon by any party other than GW SOLUTIONS's client unless otherwise authorized in writing by GW SOLUTIONS. Any unauthorized use of the report is at the sole risk of the user. This report is subject to copyright and shall not be reproduced either wholly or in part without the prior, written permission of GW SOLUTIONS. Additional copies of the report, if required, may be obtained upon request.

2.0 LIMITATIONS OF REPORT

This report is based solely on the conditions which existed within the study area or on site at the time of GW SOLUTIONS's investigation. The client, and any other parties using this report with the express written consent of the client and GW SOLUTIONS, acknowledge that conditions affecting the environmental assessment of the site can vary with time and that the conclusions and recommendations set out in this report are time sensitive. The client, and any other party using this report with the express written consent of the client and GW SOLUTIONS, also acknowledge that the conclusions and recommendations set out in this report are based on limited observations and testing on the area or subject site and that conditions may vary across the site which, in turn, could affect the conclusions and recommendations made. The client acknowledges that GW SOLUTIONS is neither qualified to, nor is it making, any recommendations with respect to the purchase, sale, investment or development of the property, the decisions on which are the sole responsibility of the client.

2.1 INFORMATION PROVIDED TO GW SOLUTIONS BY OTHERS

During the performance of the work and the preparation of this report, GW SOLUTIONS may have relied on information provided by persons other than the client. While GW SOLUTIONS endeavours to verify the accuracy of such information when instructed to do so by the client, GW SOLUTIONS accepts no responsibility for the accuracy or the reliability of such information which may affect the report.

3.0 LIMITATION OF LIABILITY

The client recognizes that property containing contaminants and hazardous wastes creates a high risk of claims brought by third parties arising out of the presence of those materials. In consideration of these risks, and in consideration of GW SOLUTIONS providing the services requested, the client agrees that GW SOLUTIONS's liability to the client, with respect to any issues relating to contaminants or other hazardous wastes located on the subject site shall be limited as follows:

(1) With respect to any claims brought against GW SOLUTIONS by the client arising out of the provision or failure to provide services hereunder shall be limited to $10,000, whether the action is based on breach of contract or tort;

(2) With respect to claims brought by third parties arising out of the presence of contaminants or hazardous wastes on the subject site, the client agrees to indemnify, defend and hold harmless GW SOLUTIONS from and against any and all claim or claims, action or actions, demands, damages, penalties, fines, losses, costs and expenses of every nature and kind whatsoever, including solicitor-client costs, arising or alleged to arise either in whole or part out of services provided by GW SOLUTIONS, whether the claim be brought against GW SOLUTIONS for breach of contract or tort.

4.0 JOB SITE SAFETY

GW SOLUTIONS is only responsible for the activities of its employees on the job site and is not responsible for the supervision of any other persons whatsoever. The presence of GW SOLUTIONS personnel on site shall not be construed in any way to relieve the client or any other persons on site from their responsibility for job site safety.

5.0 DISCLOSURE OF INFORMATION BY CLIENT

The client agrees to fully cooperate with GW SOLUTIONS with respect to the provision of all available information on the past, present, and proposed conditions on the site, including historical information respecting the use of the site. The client acknowledges that in order for GW SOLUTIONS to properly provide the service, GW SOLUTIONS is relying upon the full disclosure and accuracy of any such information.

6.0 STANDARD OF CARE

Services performed by GW SOLUTIONS for this report have been conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions in the jurisdiction in which the services are provided. Engineering judgement has been applied in developing the conclusions and/or recommendations provided in this report. No warranty or guarantee, express or implied, is made concerning the test results, comments, recommendations, or any other portion of this report.

7.0 EMERGENCY PROCEDURES

The client undertakes to inform GW SOLUTIONS of all hazardous conditions, or possible hazardous conditions which are known to it. The client recognizes that the activities of GW SOLUTIONS may uncover previously unknown hazardous materials or conditions and that such discovery may result in the necessity to undertake emergency procedures to protect GW SOLUTIONS employees, other persons and the environment. These procedures may involve additional costs outside of any budgets previously agreed upon. The client agrees to pay GW SOLUTIONS for any expenses incurred as a result of such discoveries and to compensate GW SOLUTIONS through payment of additional fees and expenses for time spent by GW SOLUTIONS to deal with the consequences of such discoveries.

8.0 NOTIFICATION OF AUTHORITIES

The client acknowledges that in certain instances the discovery of hazardous substances or conditions and materials may require that regulatory agencies and other persons be informed and the client agrees that notification to such bodies or persons as required may be done by GW SOLUTIONS in its reasonably exercised discretion.

9.0 OWNERSHIP OF INSTRUMENTS OF SERVICE

The client acknowledges that all reports, plans, and data generated by GW SOLUTIONS during the performance of the work and other documents prepared by GW SOLUTIONS are considered its professional work product and shall remain the copyright property of GW SOLUTIONS.

10.0 ALTERNATE REPORT FORMAT

Where GW SOLUTIONS submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed GW SOLUTIONS's instruments of professional service), the Client agrees that only the signed and sealed hard copy versions shall be considered final and legally binding. The hard copy versions submitted by GW SOLUTIONS shall be the original documents for record and working purposes, and, in the event of a dispute or discrepancies, the hard copy versions shall govern over the electronic versions. Furthermore, the Client agrees and waives all future right of dispute that the original hard copy signed version archived by GW SOLUTIONS shall be deemed to be the overall original for the Project. The Client agrees that both electronic file and hard copy versions of GW SOLUTIONS's instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except GW SOLUTIONS. The Client warrants that GW SOLUTIONS's instruments of professional service will be used only and exactly as submitted by GW SOLUTIONS. The Client recognizes and agrees that electronic files submitted by GW SOLUTIONS have been prepared and submitted using specific software and hardware systems. GW SOLUTIONS makes no representation about the compatibility of these files with the Client's current or future software and hardware systems.