Water Resources Audit Report

Lobird Mobile Home Park

Water Resources Branch

February 2023

The opinions and recommendations expressed in this report are based on field observations and relevant scientific data, reports, interpretations and analyses that are available to Water Resources Branch (WRB). However, we strive to recognize diverse ways of knowing and being and to create space to learn from both Indigenous and scientific perspectives side-by-side.

While WRB provides support to inspectors on enforcement and compliance matters related to water licences, it is not WRB's role to determine or enforce compliance. As such, the findings of this report should not be considered as a determination of compliance with any existing permit or licence.

Executive Summary

The Lobird Mobile Home Park (Lobird) is located in the City of Whitehorse and is home to almost two hundred residents. Lobird has a Type B Municipal Water Use Licence (WUL) to operate water supply and wastewater treatment systems. The water supply system is served by up to eight active groundwater production wells supplemented by trucked water from the City of Whitehorse's municipal water supply system.

This audit involved surface water and groundwater sampling with the following objectives:

1. Identify where the discharge from the sewage lagoons likely reports to McLean Creek,
2. Evaluate potential impacts of the sewage lagoons on the water quality of McLean Creek, and
3. Characterize the water quality of the Lobird production wells to support understanding of why uranium is present in groundwater near Whitehorse and to assess the likelihood of direct influence of surface water on well water.

Groundwater sampling was conducted on September 6, 2022. A sample from Ice Lake sample was collected on September 13, 2022. Sampling of the wastewater treatment lagoons, the gravel pit area (hereafter referred to as the L-4 area) stations located topographically downgradient of the lagoons, and McLean Creek was carried out on September 29, 2022.

Discharge from the sewage lagoons likely reports to McLean Creek between audit sampling locations LB-SW-3 and LB-SW-4. This interpretation is based on increases in concentrations of chloride and artificial sweeteners, both indicators of human wastewater. The interpretation is consistent with a desktop interpretation of the groundwater flow direction downgradient of the lagoons; however, this should be confirmed via the hydrogeological assessment of the wastewater treatment facility required by the WUL to be completed by November 4, 2025.

The water quality of McLean Creek changes from upstream to downstream and WRB attributes some of these changes to the influence of the Lobird wastewater treatment facility; however, WRB does not consider the changes to be significant to aquatic life in

McLean Creek because concentrations remain below applicable guidelines. Based on the results of this study, Water Resource Branch recommends the following:

1. Update schedule 1A of the WUL to require sampling of McLean Creek at the stations identified in this report as LW-SW-3 and LB-SW-5, which are representative of water quality conditions upstream and downstream, respectively, of the influence of the Lobird wastewater lagoons.
2. Include sewage lagoon cell 3 in routine sampling as it likely represents the final stage in an alternate flow path before infiltrating to ground and daylighting in the L-4 (gravel pit) area.
3. Sample the L-4 area twice yearly as far as possible upstream in the hypothesized discharge zone of infiltrated water from the sewage lagoons, when water is present in the area.
4. Confirm infiltrated groundwater flow paths during the hydrogeological assessment, potentially by installing wells between Cell 3 and the L-4 area.
5. Collect information regarding the procedure and frequency of the flushing of the U treatment system.
6. Fully assess the risk to Lobird drinking water wells from influence of adjacent surface water bodies.

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1 Introduction

Government of Yukon's (YG) Water Resources Branch (WRB) selected the Lobird Mobile Home Park (LMHP) (Figure 1) as a subject for an audit in the summer of 2022 to support upcoming changes to LMHP's water licence and planned upgrades to the sewage treatment lagoons. The initial water licence (MS94-021) expired on March 31, 2021. The proponent requested a new water licence (MN20-047) be issued for a 25-year duration, but the Yukon Water Board (YWB) issued the licence in December 2020 for a period of 6 years to provide sufficient time to the proponent to gather further information prior to the issuance of the full requested licence period. The licence, now MN20-047-1, was assigned to a new licensee, Lobird Living Corp. (LLC), in December 2021.

Water licence MN20-047-1 permits the extraction of 110 m^3 of groundwater per day from the 8 wells in the LMHP drinking water system (DWS), with the remainder trucked in from the City of Whitehorse municipal drinking water supply. This licence also stipulates the following conditions, which should be met prior to issuance of the requested 25-year licence:

- Submission of detailed plan for the construction of an additional sewage lagoon (Cell 6), and as-built updated plans submitted within 60 days of construction completion by a licensed professional engineer,
- Completion of a hydrogeological assessment of the LMHP wastewater treatment facility by a licensed professional hydrogeologist or engineer by November 4, 2025, the results of which must inform the addition of groundwater monitoring to the current sampling program.
- Submission of an updated Adaptive Management Plan (AMP) by Nov. 1, 2025.
- Continued monitoring of all stations and parameters listed in the water licence on a twice-yearly basis.
- Other requirements as listed in Appendix A.

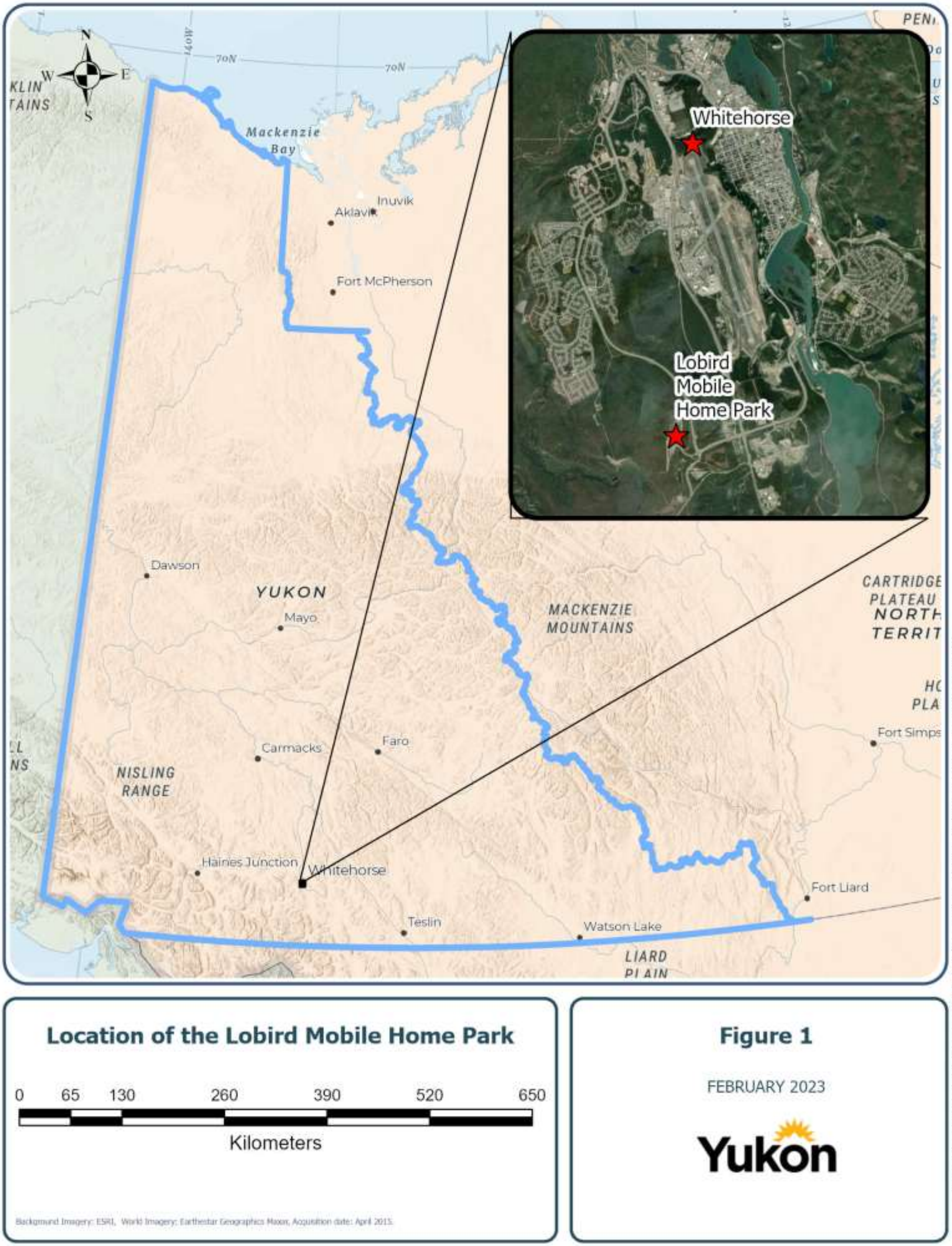


Figure 1 - Location of Lobird Mobile Home Park

The final decision document issued by the Yukon Environmental and Socioeconomic Assessment Board (YESAB) also stipulated that the proponent must develop a source water protection plan (SWPP) identifying and proactively mitigating potential sources of contamination to groundwater for the duration of the requested 25-year licence. Government of Yukon (YG) also recommended the completion of a SWPP by a professional engineer/hydrogeologist and upgrades to the water treatment facility and wellheads to meet Section 35 of Yukon's drinking water regulations (O.I.C 2007/139) (YG, 2020).

All of the wells in the LMHP water supply system have shown exceedances of CCME guidelines for uranium (U) in the past. The MHP currently has a U removal system in place in the water treatment facility accompanying the regular water treatment system, although specific details of the U removal system are not available.

2 Purpose and Objectives

The purpose of this audit is to support decision making regarding LMHP's source-to-discharge drinking water systems, specifically the following objectives:

1. Identify where the discharge from the sewage lagoons likely reports to McLean Creek to suggest monitoring locations to be included in future water licensing for the park.
2. Evaluate potential impacts of the sewage lagoons on the water quality of McLean Creek.
3. Characterize the water quality of the Lobird Park Water Supply System wells to support understanding of why uranium is present in groundwater near Whitehorse and assess likelihood of direct influence of surface water on well water.

3 Methods

3.1 Desktop review

All documentation on Waterline and the YESAB online registry pertaining to LMHP's water licence was reviewed during the planning phase of the audit. Discussions with Government of Yukon's Environmental Health Services (EHS) and Environmental Compliance and Inspections (ECI) branches were carried out to further refine audit objectives. Finally, the conditions of water licence MN20-047-1 were reviewed to ensure audit objectives aligned with water licence renewal requirements.

Water Resources Branch's EQWin database contains water licence monitoring data for certain LMHP sites as early as 2006. A review of all historical data present in this database was also conducted during this audit for the purposes of comparison with audit data.

Indicator elements (hereafter referred to as tracers), stable water isotopes, and artificial sweeteners were designated as a primary focus in the fulfillment of the audit objectives. By analyzing elements unique to each component of the LMHP water system, connectivity and water balance relationships are estimated.

Analysis of stable water isotopes, or the ratio of heavier to lighter O and H atoms in water molecules, can assist with the identification of water source. Water molecules containing greater proportions of heavier isotopes (O^{18}, H^2) precipitate more readily from atmospheric water and resist evaporation from stagnant water, meaning water bodies subject to rainfall and evaporation will become enriched in O^{18} and H^2 (upper right portion of water isotope charts). Inversely, water bodies with little exposure to atmospheric influences or fed principally by snowmelt (i.e. groundwater) tend to be more enriched in lighter isotopes O^{16} and H^1 (bottom left portion of chart). Stable water isotope results are generally plotted alongside the local meteoric water line (LMWL), representative of the typical isotope fractionation in meteoric water (precipitation, rain and snow) for a designated area. Comparison of sample data with the LMWL informs conclusions regarding the source of a given water sample.

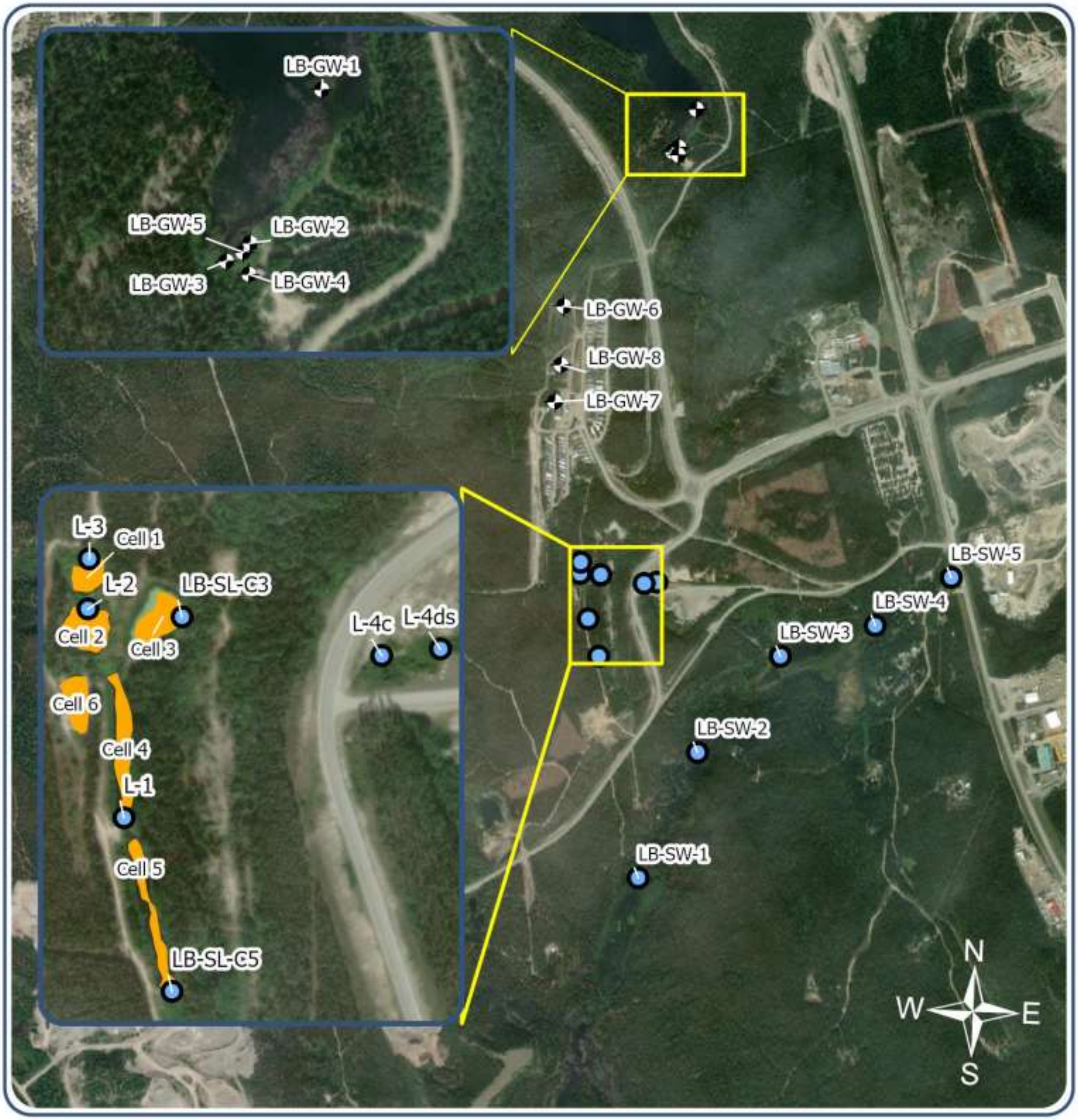
Artificial sweeteners are man-made compounds commonly used as food additives. These compounds have no natural source and are persistent in the natural environment, making them useful as tracers of human wastewater. Artificial sweeteners analyzed for this project include acesulfame, saccharin, cyclamate, and sucralose, of which acesulfame is the most persistent.

Other elements, particularly chloride (Cl), do not strongly attenuate with transport through a typical subsurface. This lack of attenuation designated Cl as a "conservative tracer", useful for the same reasons as stable water isotopes and artificial sweeteners.

Analysis of redox-sensitive components of a water sample (i.e. nitrate speciation) can also be used to estimate connectivity between water bodies, subject to interpretation with the influence of atmospheric gases.

3.2 Field methods

Audit sample collection was divided into two parts, targeted towards the surface water and groundwater components of the audit. Audit sampling locations are presented in Figure 2. Photos collected from the sampling programs are presented in Appendix B.



Lobird Mobile Home Park - Water Resources Branch 2022 Audit Sampling Locations

0 125 250 500 750 1,000 1,250 1,500 Metres

Background Imagery: ESRI, World Imagery: Earthstar Geographics Maxar, Acquisition date: April 2015.

Figure 2

FEBRUARY 2023

Yukon

Figure 2 - Water Resources Branch 2022 Audit Sampling Locations

Groundwater sampling was conducted on September 6, 2022. Sampling was directed by Cole Fischer, groundwater technologist with the WRB, with Craig Van Lankveld (EHS) and Shaun Hefferman (Lobird staff) also on site to collect coliform samples and facilitate well head access respectively. Groundwater wells 4 and 5 were sampled with an SS GeoSub pump powered by a generator, after temporarily switching off all electrical connections to the well to prevent activation during sampling. The pump head was lowered into the well to its maximum depth of 30m below top of casing (30m) and run at a speed at which static water level drawdown was minimized. Field parameters were monitored during purging using a calibrated YSI, and included water temperature (°C), pH, specific conductance (SPC, µS/cm), oxidation-reduction potential (ORP, mV), turbidity (NTU), and dissolved oxygen (DO, mg/L). Samples were collected once all field parameters stabilized (see field sheets for stabilization criteria), indicating pumped water was representative of ambient aquifer conditions. Samples were also collected after a 40 L purge volume from wells 4 and 5, to assess "stagnant" well water condition. Groundwater wells 6 and 8, which had been run semi-continuously for 24 hours according to the site operator, were sampled via inline sampling taps installed in the well head enclosures. Well pumps were activated via local control panels and field parameters were monitored during pumping. Radon gas samples were also collected from groundwater wells 4, 5, and 6, in tightly sealed glass vials with no headspace to prevent offgassing. The Ice Lake sample was collected one week after groundwater sampling on September 13, 2022 by Cole Fischer.

Surface water sampling was carried out by Cole Fischer, Devon O'Connor (water quality technologist), Brendan Mulligan (senior scientist – groundwater), and Tyler Williams (water resources scientist) from the WRB on September 29, 2022. The McLean Creek and sewage lagoon components of the audit objectives were each targeted separately by two teams of two staff. All samples were collected as grab samples, in the case of the sewage lagoons using a grab stick to facilitate sampling from the edge of the lagoons. Field parameters were measured using the same YSI instruments as the groundwater sampling program calibrated on the day of sampling. Samples were collected from all points designated in the LMHP water licence based on their description as no coordinates are yet specified in the licence. Several additional isotope samples were also collected at points decided in-field to have the potential to support audit objectives. Full sample and isotope-only surface water sample locations are presented in Figure 2.

All water samples were preserved and filtered in the field as per laboratory directions, then placed on ice within five minutes of sample collection for transport to the lab. If samples were being stored overnight at the WRB facility they were kept at less than 5°C and delivered to the lab in the morning. Water quality samples were analyzed by Canadian Association for Laboratory Accreditation (CALA)-accredited laboratory ALS, all isotope samples were analyzed by the University of Waterloo Environmental Isotopes Lab (UWEIL), and artificial sweetener samples were analyzed by Environment and Climate Change Canada (ECCC) as a part of a research collaboration. Radon samples were analyzed by Dr. Elliott Skierskan (University of Saskatchewan (USask) using university equipment at the WRB offices.

Analytical parameters for groundwater, sewage lagoon, and surface water samples are compared to the Health Canada – Drinking Water Quality guideline (HC-DWQ) as well as the Canadian Council of Ministers of the Environment – Protection of Freshwater Aquatic Life (CCME-PaL) standards. Where guidelines do not exist for dissolved constituents, guidelines for total concentrations are used in place.

3.3 QA/QC

Quality Assurance/Quality Control (QA/QC) controls were implemented into all sampling programs. These controls took the form of two duplicate samples to monitor precision, a lab blank to monitor laboratory contaminants, and a field blank to monitor ambient environment contaminants.

Analysis of the relative percent difference (RPD) of individual analytes between duplicate samples provides an indication of sample precision. Values of less than 25% are generally considered acceptable, taking into account the Practical Qualifying Limit (PQL) which accounts for how close measurements are to the reported detection limit (RDL).

Comparison between field and lab measurements provides an indication of field accuracy. An RPD of less than 10% is generally considered acceptable for field versus lab pH measurements, as this parameter is sensitive to changes in temperature and exposure to atmospheric gases. Specific conductance between field and lab measurements is considered acceptable when RPD values do not exceed 20%.

Analysis of laboratory and field blanks provide an indication of potential sources of contamination resulting from field sampling conditions and from laboratory equipment Detection of any analyte in field or lab blanks is cause for discussion.

4 Results

4.1 Desktop results

4.1.1 Flow paths in the LMHP

A desktop assessment of the expected flow paths present in the LMHP water system was conducted to inform tracer analyses. Limited information is available concerning the flow paths from the groundwater wells through the water treatment system to distribution, but data obtained from EHS indicates that the pump room sample represents the furthest downstream point in the system before distribution.

The primary flow path of a given volume of water through the sewage lagoons is expected to be roughly L-3 → L-2 → L-1 → LB-SL-C5 (Figure 2), after which sufficient infiltration is expected to have taken place to reduce water volumes. An alternative flow path may occur through the diversion cell LB-SL-C3, progressing through L4c → L-4ds → receiving environment. Lagoon cell 6 was prior to issuance of the 202 water license, and may act as an extra step between cell 2 (L-2) and cell 4 (L-1).

McLean Creek samples are identified with LB-SW-1 as the furthest upstream site, and LB-SW-5 as the furthest downstream site closest to the highway (Figure 2). In Water Licence MN20-047-1, monitoring location L-5 represents the closest point in McLean Creek to Cell 4, roughly analogous to LB-SW-2, while location L-6 is analogous to LB-SW-1 and L-7 corresponds to locations downstream of LB-SW-2. No coordinates are given in the water licence for L-5, L-6, or L-7, but will be assigned prior to water licence renewal.

4.1.2 Review of historical data

All Lobird data available in the WRB EQWin database, as well as specific data requested from EHS, was reviewed during the desktop study portion of the audit. The principal focus was identification of water quality parameters with a history of guideline exceedances, specifically those relevant to the completion of the audit objectives.

Groundwater samples show consistent exceedance of the CCME-PAL guidelines for fluoride (F), selenium (Se) and U, with U concentrations also consistently exceeding the HC-DWQ guideline. Infrequent CCME-PAL exceedances of Cd, Cu, Fe, Mn, and Zn were also observed in the historical groundwater record. These observations represent raw groundwater prior to any kind of filtration and should not be taken as instances of non-compliance. In addition, no information is available regarding sampling methodology or sampling location for groundwater samples collected prior to the WRB audit. It is the WRB's understanding that licence GW samples are collected via taps in the water treatment room, by which point the raw groundwater has already travelled through a preliminary distribution system and may not be representative of ambient aquifer conditions.

The historical record of the sampling location in the pump room, indicated by EHS staff as the furthest downstream point before distribution to residences, does not show any exceedances of any guideline.

All sewage lagoon sampling locations have a history of guideline exceedances for many parameters. The parameters most often exceeding guidelines are Cl, fecal coliforms, NH_4, and U. Since these locations are downstream of any current or planned water use, and do not discharge via surface conduction into the receiving environment, discussion of these exceedances is limited.

Sample sites L-5, L-6, and L-7 in McLean Creek, implemented in water licence MN20-047-1, show consistent exceedances of the HC-DWQ for total coliforms in their relatively short period of record.

4.1.3 Uranium in groundwater

Uranium is a common geogenic contaminant that occurs naturally in granitic bedrock in the Yukon. Uranium has no known biological function and is toxic to humans via chemical effects with radiological effects generally being much lesser (Goulet et. Al., 2011). Uranium frequently occurs alongside elevated concentrations of arsenic (As) and dissolved radon (Rn), the latter of which volatilizes quickly upon exposure to atmospheric temperatures and pressures. Numerous studies have been conducted on U and As in the

Whitehorse area and greater Yukon, with a particular focus on anthropologically unimpacted areas of the Dawson range. Raw water from the LMHP wells frequently exceed guidelines for U which is removed via a filtration system in the water treatment plant. No exceedances of total U are observed in the historical record for the sewage lagoons or licence surface water sampling sites.

4.2 Site Visit Results

Sampling results of the current project are compared with previously collected water licence samples and relevant guidelines where available. Audit results are presented roughly in the order of the flow path relevant to the current project:

1. Water extraction from groundwater wells, treatment, and dilution with trucked water from City of Whitehorse aquifers.
2. Wastewater effluent along the sewage lagoon flow paths.
3. Receiving environment, namely the gravel pit across McLean Lake Road and McLean Creek.

4.2.1 General geochemistry

The three sample types collected during this audit (groundwater, sewage lagoons, and surface water) cluster in distinct groups based on geochemical water type. The general

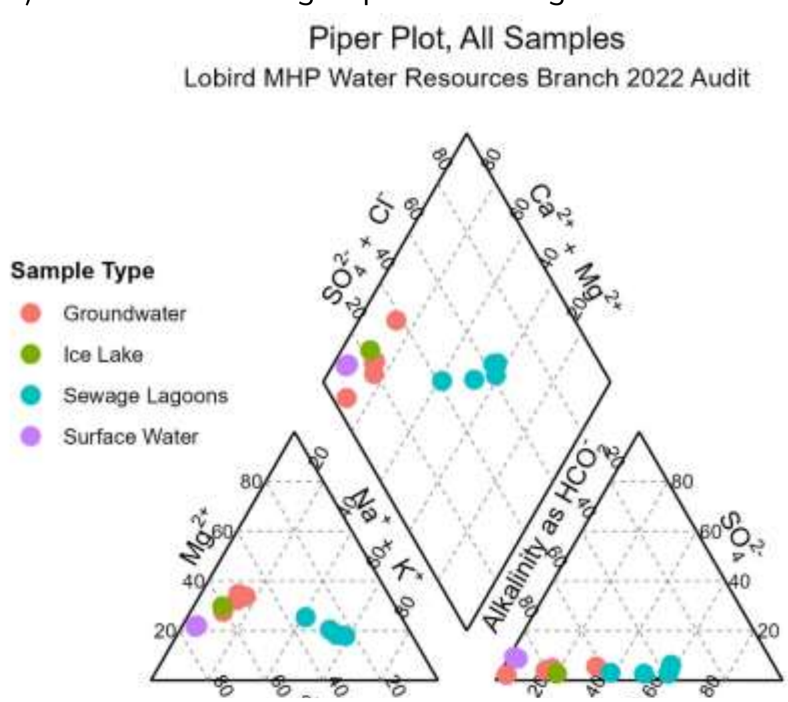


Figure 3 - Piper plot showing general geochemistry of LMHP water samples

geochemistry of all water samples is presented via Piper diagram in Figure 3. Piper diagrams show the dominant major cations and anions of a water sample, expressed in terms of contribution to the overall charge balance. Piper plots do not represent the specific concentrations of cations and anions, rather the contribution of each species to the ionic charge balance. This contribution is referred to as the "dominance" of a constituent.

Groundwater samples and the Ice Lake sample are Ca/Mg/HCO_3^- type waters, a common composition for groundwater in carbonate-rich bedrock areas. Sewage lagoon samples are Na/Ca/Cl^-/HCO_3^- type waters, indicative of the generally high-salt nature of human waste products and distinct from all other samples collected over the course of this audit. All the samples collected from McLean Creek cluster closely on the plot with Ca/HCO_3^- water types. Samples from the Lobird groundwater wells, Ice Lake, and McLean Creek appear to form distinct groups with some degree of overlap. The Ice Lake sample plots near the middle of the groundwater well grouping, indicating these sample groups may share a common source or influence.

4.2.2 Groundwater sampling results

Groundwater samples show temperature values from 3.1 to 4.6°C, circumneutral to slightly basic pH (7.19 to 7.57), conductivity within expected ranges for groundwater (510 to 681 μS/cm), ORP values between 224 and 226 mV, and total alkalinity values from 276 to 335 mg/L present nearly exclusively as HCO_3^-. No DO was measured in wells 4 and 5 but was higher than expected in wells 6 and 8 (10.21 and 8.27 mg/L respectively). Field parameter measurement results for groundwater are presented in Figure 4.

The two field measurement readings taken from GW-4 represent where a sample was taken at a 40L purge volume to assess the stagnant water column.

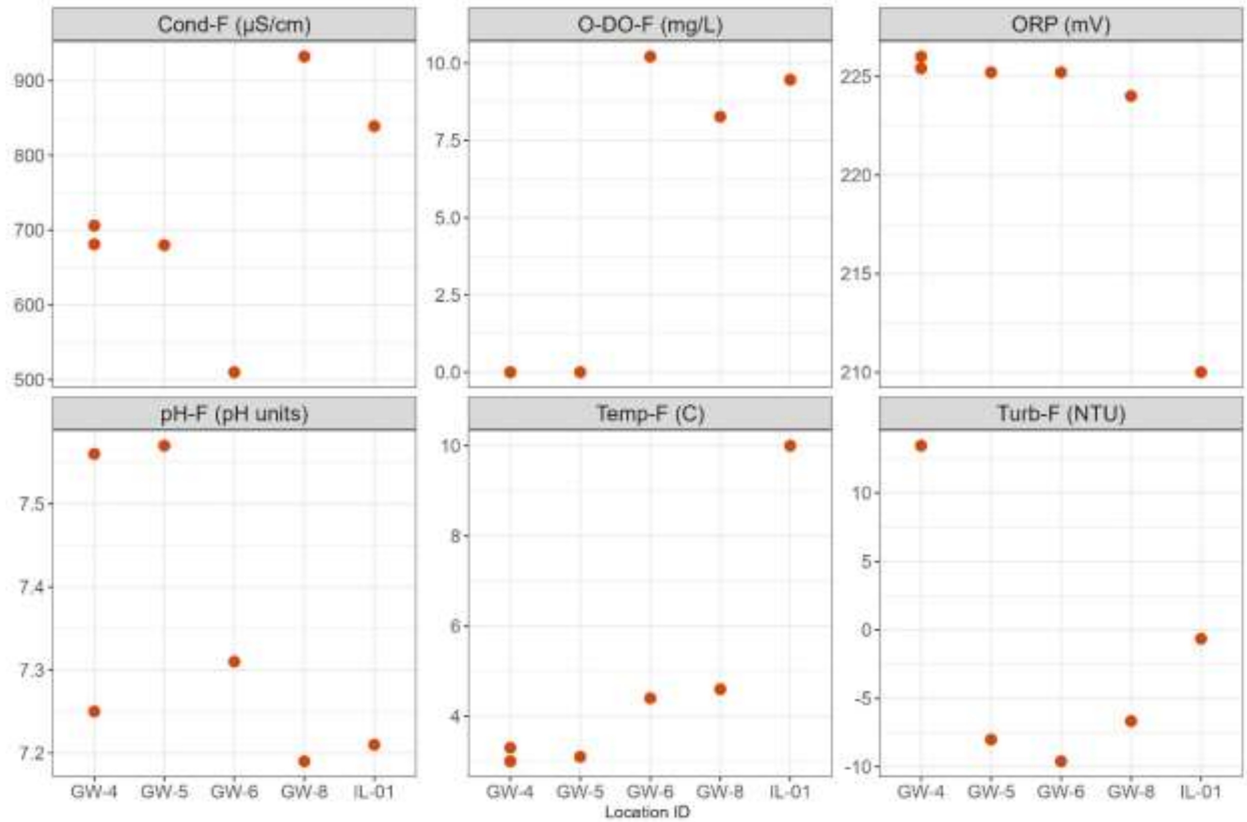


Figure 4 - Field parameter measurement results collected from LMHP GW wells and Ice Lake

The sample collected from Ice Lake shows some geochemical similarities and some differences from those collected from groundwater wells. The SPC of Ice Lake lies within, but in the upper range of, the range in SPC values measured in the groundwater wells. Measured pH values show the opposite with the Ice Lake sample having a pH closer to the bottom of the range observed in groundwater samples. Dissolved oxygen shows similar concentrations to groundwater wells 4 and 5, and the ORP of the Ice Lake sample appears to be lower than the rest of the groundwater samples. Temperature values align with the expected trend of being warmer in the surface water body (IL-01) than in the groundwater wells.

Groundwater samples and the Ice Lake sample are Ca/Mg/HCO_3^- type waters. Concentrations of dissolved U exceed CCME PAL and the HC-DWQ guidelines at GW-4, -5, and -8, while the sample collected from Ice Lake exceeds only the HC-DWQ guideline. Groundwater wells 4, 5, and the Ice Lake sample exceed the HC-DWQ for Fe as well. Isolated exceedances of Mn and Se were also observed. Select analytical results are presented in Figure 5, with full results in Appendix D.

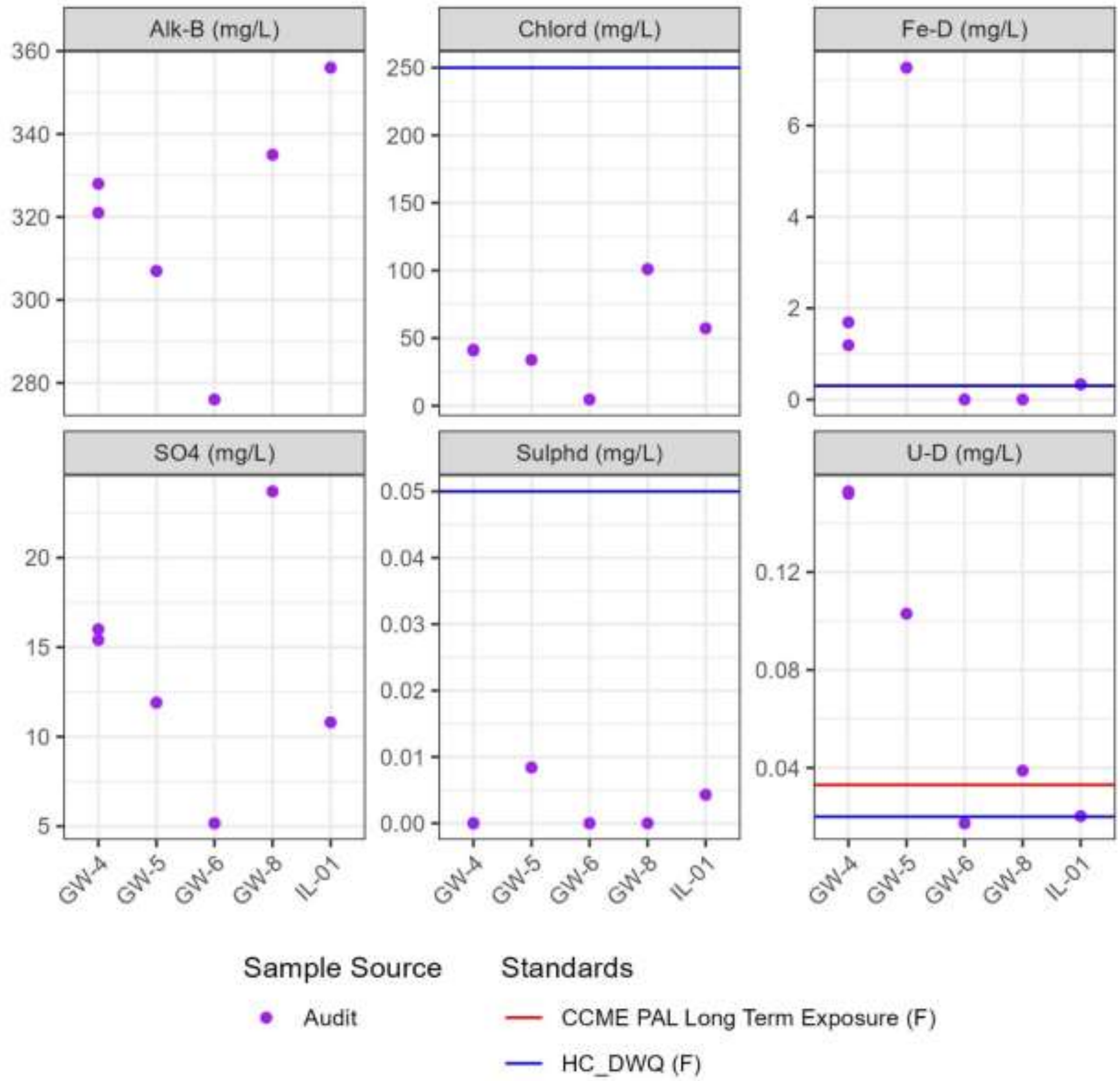


Figure 5 - Select analytical results for LMHP groundwater samples, collected during the 2022 WRB Audit

Groundwater well samples GW-4, GW-5, and GW-6 were analyzed for dissolved radon gas by the University of Saskatchewan in the WRB office building. No radon was observed in wells 4 and 5, whereas a radon measurement of 63.0 Bql/L was observed at well 6. No guideline exists for dissolved radon I water, as it offgases immediately upon exposure to atmospheric pressure. Guidelines governing Rn concentrations in air are provided by various authorities but are outside the scope of this report.

No fecal coliforms were observed in any of the samples collected by EHS during the groundwater sampling event.

4.2.3 Sewage lagoon sampling results

Sewage lagoon samples show temperature values from 5.4 to 8.1°C, circumneutral pH (6.62 to 8.11), high conductivity (expected for wastewater samples)(630 to 1751 µS/cm), and total alkalinity values from 276 to 335 mg/L HCO_3^-. Dissolved oxygen measurements align with expected values for surface water bodies exposed to the atmosphere (0.49 to 10.87 mg/L). Field parameter measurement results for the sewage lagoon sampling program are presented in Figure 6.

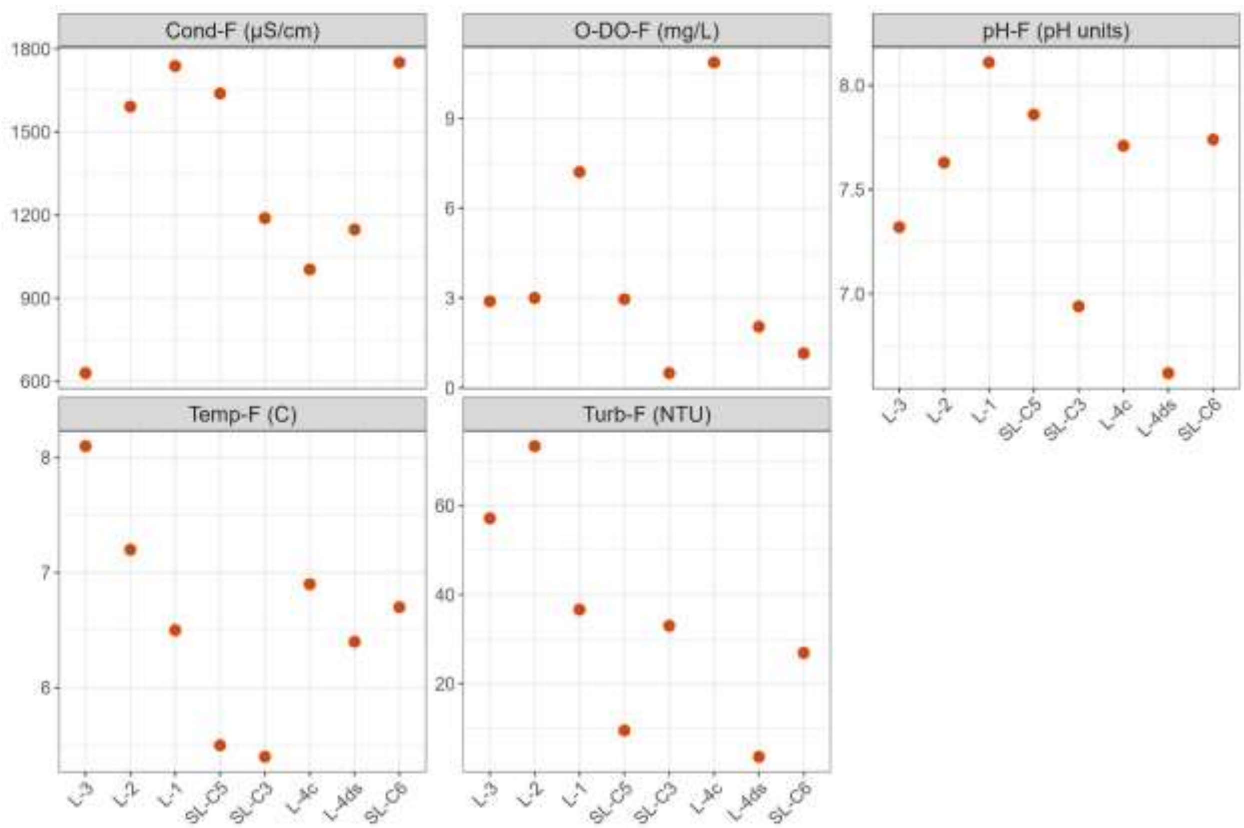


Figure 6 - Field parameter measurement results collected from the LMHP sewage lagoons

Temperature decreases steadily through the primary flow path (L-3 to SL-C5 and L-4c to L-4). A large discrepancy was observed between the specific conductance values measured by WRB and ALS at L-3 (Cell 1). Laboratory values provide a value closer to those observed in the other cells, suggesting an error in field data collection.

Sewage lagoon samples are Na^{+}/Cl^{-} type waters, distinct from all other samples collected over the course of this audit. Several samples exceed the HC-DWQ guideline for Cl, sulphide, Fe, and U. Of these exceedances, one sample (U, SL-C5) exceeds the CCME-PAL guideline. Select analytical results for the sewage lagoons are presented in Figure 7, with full analytical results in Appendix D.

Note that sewage lagoon stations L-4c and L-4ds were only sampled for stable water isotopes and artificial sweeteners and are not included in these results.

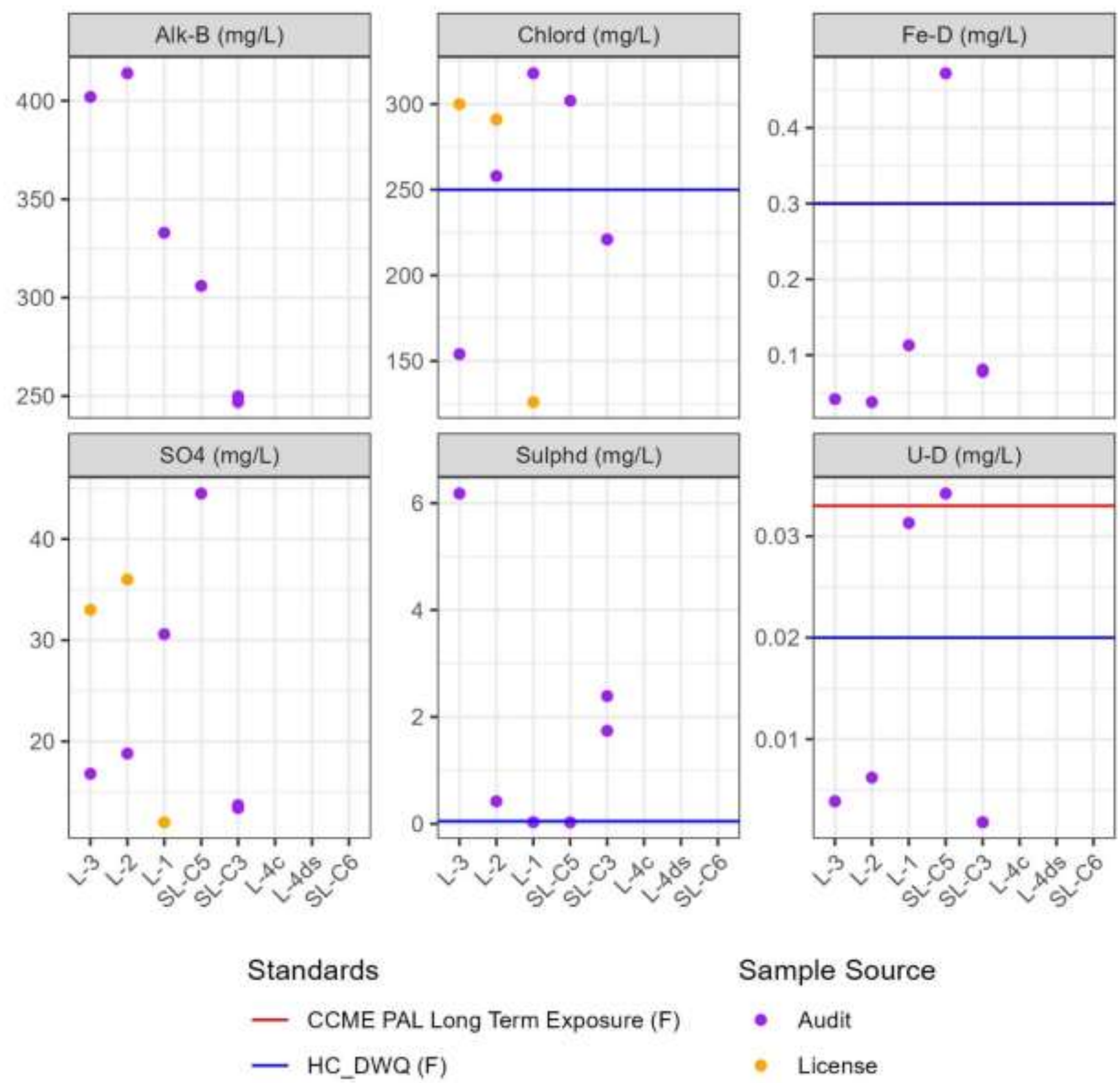


Figure 7 - Select analytical results for LMHP sewage lagoon samples and data identified in the historical record

4.2.4 Surface water sampling results

Sewage lagoon samples show temperature values from 6.3 to 6.7°C, circumneutral pH (7.56 to 7.92), specific conductance between 274 to 313 µS/cm, and total alkalinity values from 147 to 153 mg/L, with approximately 5% present as CO_3^{2-} and the rest as HCO_3^-. Dissolved oxygen /*-measurements align with expected values for surface water bodies exposed to the atmosphere (8.31 to 10.67 mg/L). Field parameter measurement results for the surface water sampling program are presented in Figure 8.

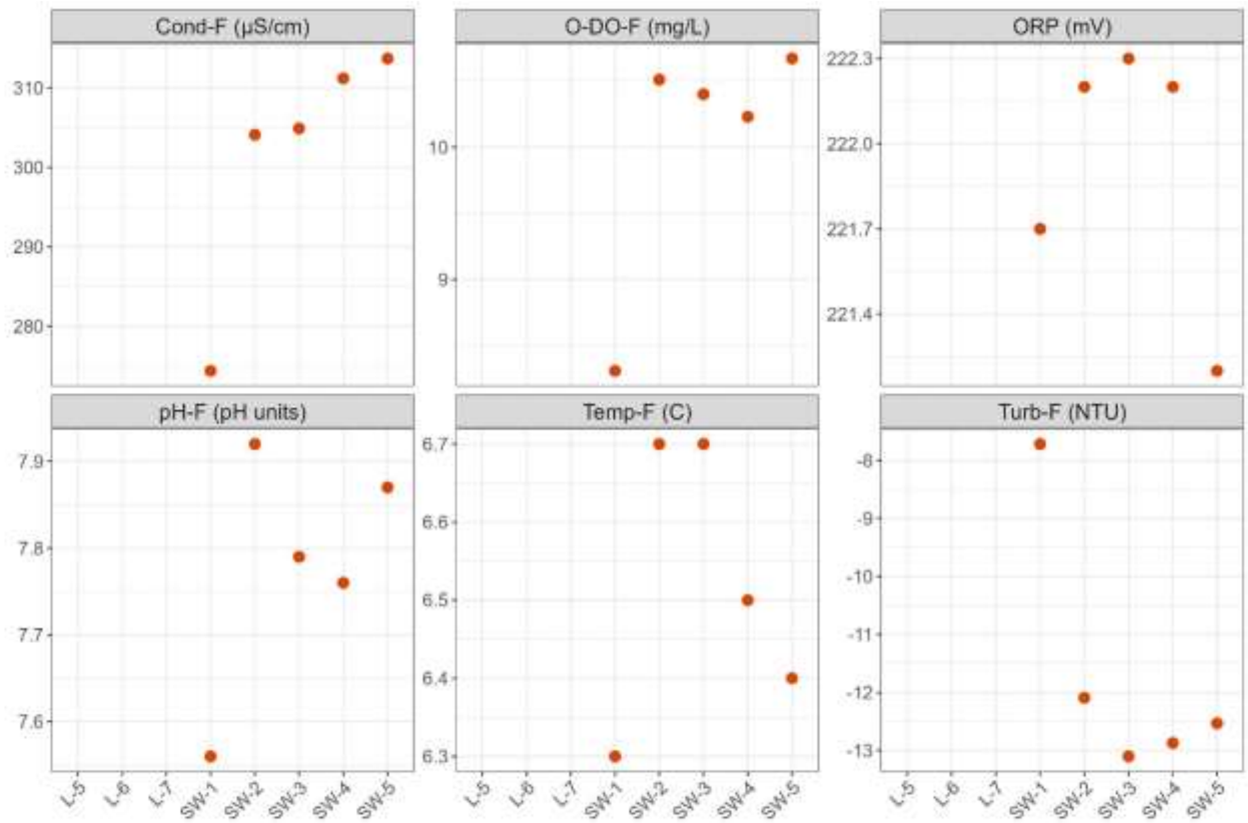


Figure 8 - Field parameter measurement results collected from McLean Creek

Field parameter measurements remain consistent throughout McLean Creek, from, SW-1 to SW-5 (upstream to downstream), expected given the relatively singular flow path with minimal surficial inputs. However, a slight increase is observed in nearly all parameters between SW-I\1 and SW-2, coinciding with the creek leaving the upper marshland and travelling alongside several residences that border the creek.

All surface water samples are Ca/HCO_3^- type waters, typical of most surface water bodies. No clear change in water types is observed through the McLean Creek flow path, evidenced by the tight grouping of samples on the piper plot (Figure 3). Except for fecal coliforms, no other parameter exceeded guidelines in the surface water samples. To facilitate visual assessment of parameter change along the flow path, standards are not included in the plots as samples were well below guidelines for parameters presented in Figure 9. Select analytical parameters for the surface water sampling program are presented in Figure 9, with full analytical results in Appendix D.

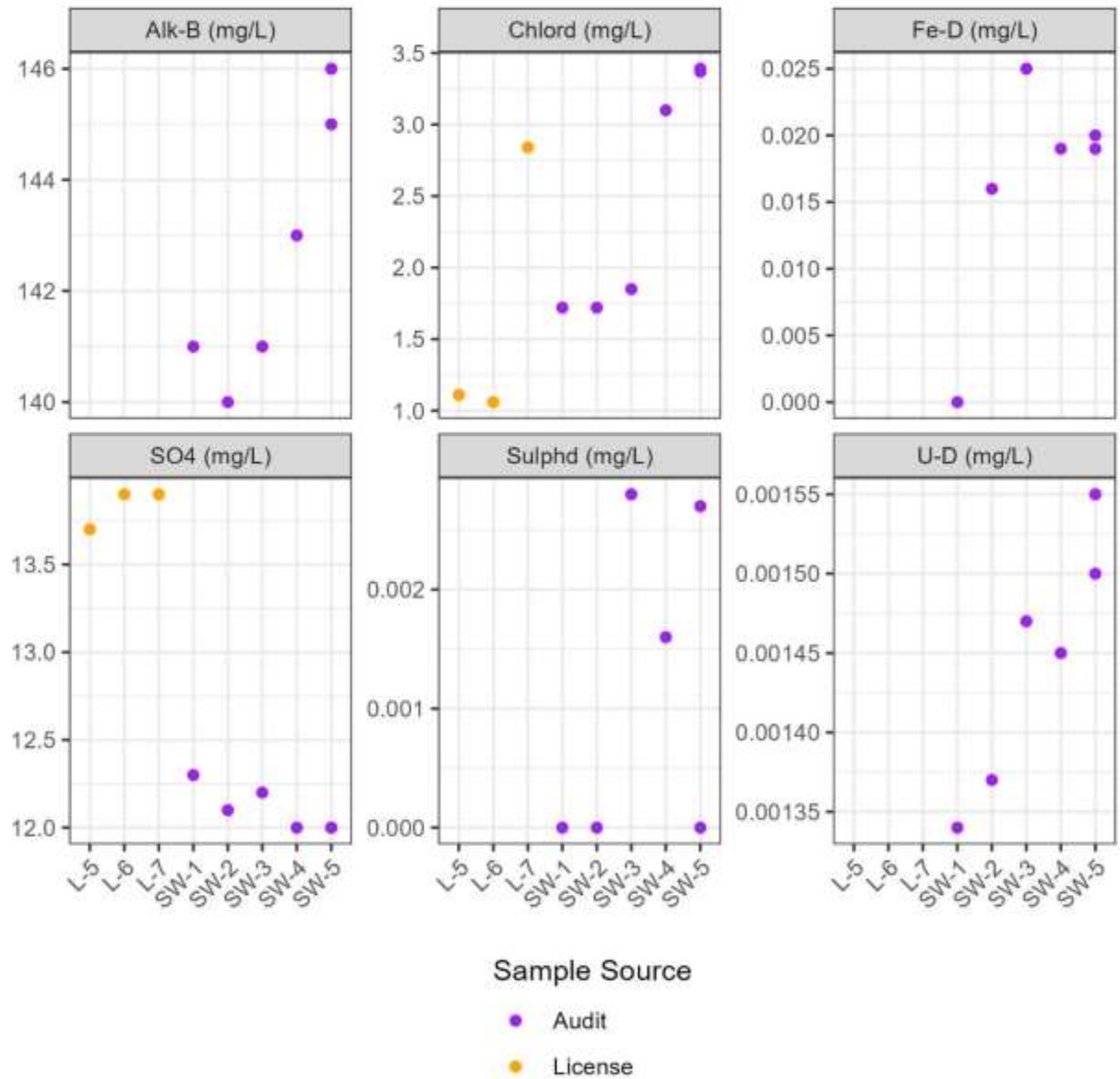


Figure 9 - Select analytical results for McLean Creek samples and data identified in the historical record

Chloride and U increase slightly along the flow path, remaining below guideline values. Concentrations of SO_4^{2-} appear to decrease and concentrations of Fe generally increase downstream of the first sampling location.

Observances of fecal coliforms progressively increase downstream of LB-SW-2. Fecal coliform results are presented in Table 1 below.

Table 1 - Total coliform measurements collected from McLean Creek

Sample	mL of original sample	CFU	Comments
LB-SW-1	100	0	
LB-SW-2	100	0	
LB-SW-3	100	1	One brown colony
LB-SW-4	100	2	Eleven brown colonies
LB-SW-5	100	9	

4.2.5 Stable water isotope sampling results

Stable water isotope samples were collected at all stations analyzed for this audit. Similar to geochemical water types, isotope samples appear to cluster in visually distinct groups based on sample source. Samples collected from the groundwater wells, Ice Lake, the gravel pit containing the L-4 samples, and the McLean Creek samples show smaller $\delta^{18}O$ ratios, meaning the samples contain relatively less O^{18} compared to the samples from the sewage lagoon. All samples except for those collected from the lagoon appear to follow with the local meteoric water line (LMWL), while the lagoon samples appear to follow a modified line subject to significant evaporation identified as the Local Evaporation Line (LEL). Stable water isotope results are presented in Figure 10.

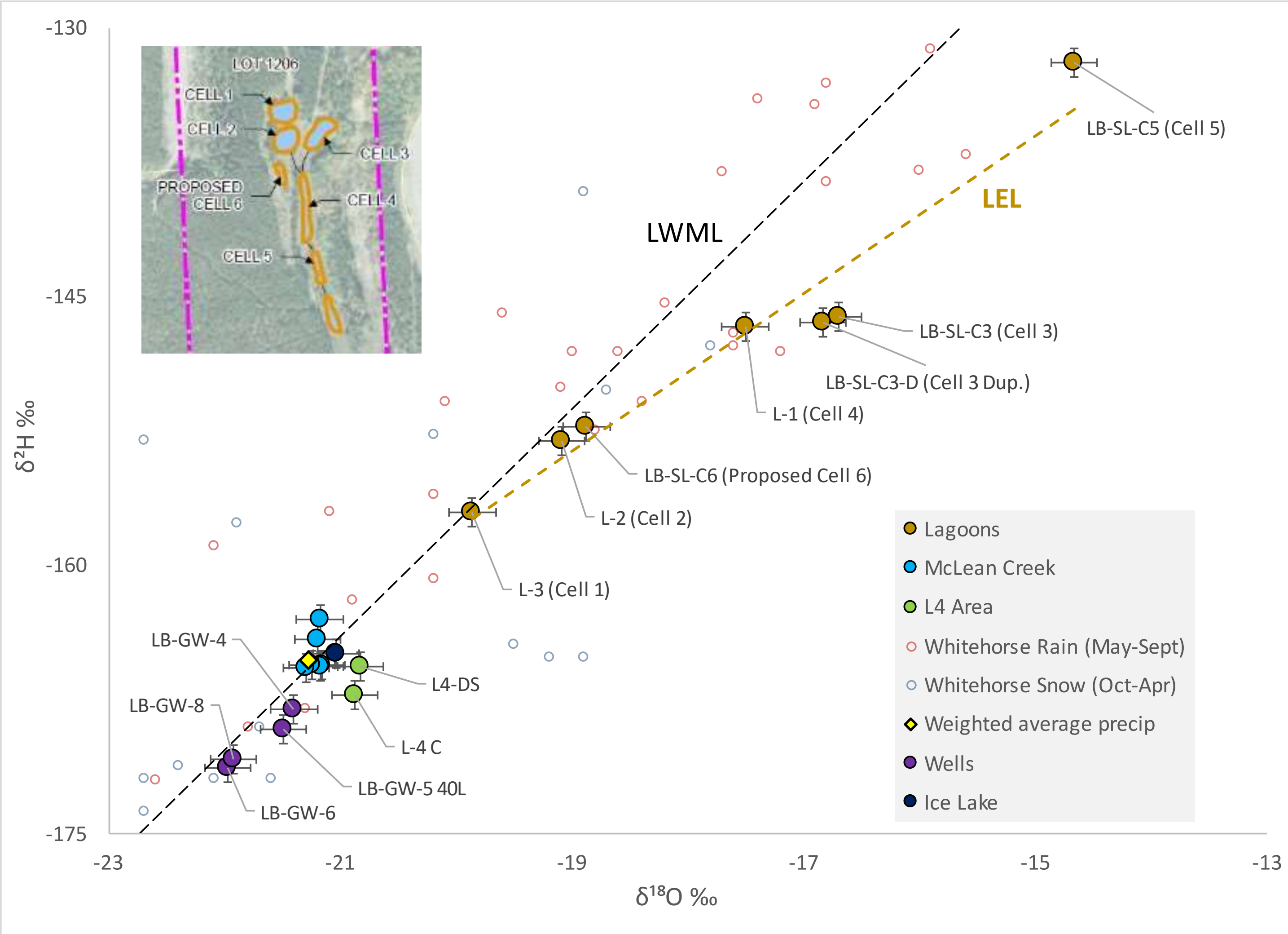


Figure 10 - Stable Water Isotopes presented alongside the Whitehorse LMWL

4.2.6 Artificial sweetener sampling results

Varying proportions of the four analyzed artificial sweeteners were observed at all sampled sites except for the three surface water sites furthest upstream, LB-SW-1, LB-SW-2, and LB-SW-3. Artificial sweetener results are presented in Figure 11. Artificial sweetener concentrations in the L-4 (gravel pit) area, although appearing small in the left chart, remain over two orders of magnitude above those observed in McLean Creek.

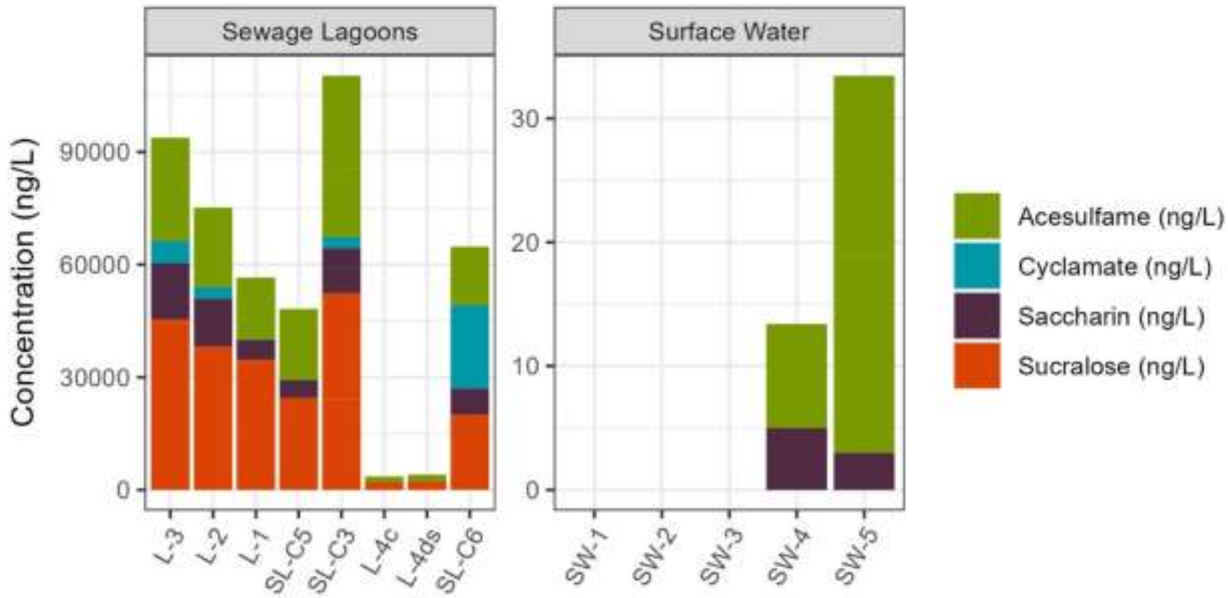


Figure 11 - Artificial sweetener sampling results

The highest total concentration of sweeteners is observed in cell 3, followed by a progressive decrease along the principal sewage lagoon flow path to SL-C5. A slight increase is observed between L-4c and L-4ds (the sites in the gravel pit across McLean Lake Road from the sewage lagoons). In McLean Creek, no sweeteners are observed upstream of SW-4 after which concentrations appear to increase at least until McLean Creek passes under the Alaska Highway. No obvious relationship is apparent between the ratios of the different artificial sweeteners and the sampling locations, although sucralose appears to be the dominant component of most sewage lagoon samples. Most sweeteners observed in McLean Creek are acesulfame, know as the most persistent of the artificial sweeteners.

4.3 QA/QC results

Most measurements of most analytes passed WRB's QA/QC analysis protocols. However, several discrepancies were observed, including:

- Eight individual parameter exceedances of the 20% RPD guideline across all duplicate samples
- Discrepancy between field and lab pH of more than 10% RPD for four samples
- Discrepancy between field and lab conductivity above 20% RPD for one sample

- Strong detection of artificial sweeteners and Na in the field blank

The presence of Na and artificial sweeteners in the field blank suggest a source of contamination was present while creating the blank, but higher concentrations in the blank than other measurements collected on the same day indicate the sample contamination may have been an isolated event. Full QA/QC results are presented in Appendix E.

4.4 Summary of results

Water types progress from Ca/Mg/HCO^- types as raw groundwater, a signal shared by Ice Lake, through Na/Cl type waters in the sewage lagoons, back to Ca/Mg/HCO^- type waters in McLean Creek.

Three out of four groundwater samples exceed the HC-DWQ guideline for U, as well as the sample from Ice Lake. Other parameters with exceedances observed are Fe, Mn, and Se. No fecal coliforms were observed in any of the groundwater samples, and well 6 contained expected levels of Rn based on other measurements collected from similar regions in the Whitehorse area.

Multiple guideline exceedances are observed in most sewage lagoon samples and are to be expected given the nature of the lagoons as a wastewater system. Concentrations of artificial sweeteners are high in all lagoon samples, and were detected in sites L-4c and L-4ds downgradient of the lagoon cells. Stable water isotope samples from the lagoon appear to follow an LEL due to gradually increasing evaporation as water moves through the system.

No exceedances of any parameter are observed in McLean Creek in the present study. Artificial sweeteners are present in increasing concentrations at LB-SW-4 and LB-SW-5, in increasing concentrations with distance downstream.

Groundwater samples and the sample collected from Ice Lake have similar pH and specific conductance value, whereas temperature, DO, and ORP show a higher discrepancy. Concentrations of dissolved U exceed both guidelines for most groundwater stations and Ice Lake. The isotopic compositions of the groundwater wells are similar, with an increased ^{16}O ratio compared to other samples. Ice Lake plots closely to the groundwater samples but contains a higher percentage of ^{18}O.

5 Discussion

5.1 Objective 1

Identify where the discharge from the sewage lagoons likely reports to McLean Creek to suggest monitoring locations to be included in future water licensing for the park.

Based on the results of this study, the impacts of the sewage lagoons on McLean Creek are likely observed between LB-SW-3 and LB-SW-4 coinciding with the outflow of McLean Creek from a wetland area. This discharge area is characterized by increases in conductivity (305 to 311 µs/cm), Cl concentrations (1.85 to 3.10 mg/L), and artificial sweetener concentrations (non-detect to 13.4 ng/L), all common impactors of surface water quality characteristic of human wastewater. A steady decrease in artificial sweetener concentrations along the sewage lagoon flow path indicates large volumes of water infiltrate to the local groundwater table, which may be resurfacing near the outflow of the wetland in McLean Creek. A potential alterative source for these tracers is the secondary flow path through the L-4 (gravel pit) area subject to upwelling of lagoon-affected shallow groundwater, which is then channeled along a surface flow path to the wetland area of McLean Creek.

Several cabins exist along both sides of McLean Creek with dedicated outhouses on the properties, which may contribute concentrations of all three primary tracers to the creek. However, the flow rate of McLean Creek (visually estimated at approximately 0.750 cubic metres per second (cfm)) would likely be sufficient to dilute sweetener concentrations to negligible levels with an outhouse as a sole source. With an acesulfame concentration of ~20 ng/L in the creek and a visually estimated flow rate of 375 L/s, the total acesulfame load would be approximately 324 mg/day. This value is much higher than typical consumption rate of artificial sweeteners, estimated by one study to be around 15 mg/day (Debras et. Al., 2022). The high loading value is the approximate equivalent of the daily loading of 21 individuals with no attenuation, unlikely to be a representative case of the dwellings in proximity to McLean Creek. Therefore, the artificial sweetener loading in McLean Creek likely results from the influence of a high-load point source (sewage lagoons) subject to attenuation and dilution prior to entry into McLean Creek.

Progressively increasing fecal coliform observances downstream of LB-SW-2 are likely the result of animal coliforms, as microbial communities would not be expected to travel the large distance from the lagoons to the creek catchment.

Based on these results, surface water monitoring locations LB-SW-2 and LB-SW-5 would be ideally placed to assess water chemistry before and after the expected influence of the sewage lagoons respectively. Further investigation of subterranean flow paths between Cell 3 and the L-4 area would inform conclusions regarding type and quantity of components transported out of the sewage lagoons via infiltration.

5.2 Objective 2

Evaluate potential impacts of the sewage lagoons on the water quality of McLean Creek.

The principle influences of the sewage lagoons on McLean Creek appear to be the same conservative tracers used as a part of this study, as they tend to be the most environmentally persistent and more likely to travel through various pathways into the receiving environment. Steadily increasing specific conductance and concentrations of U in McLean Creek may be associated with the above-guideline U found in the sewage lagoons, or may be the influence of a mix of shallow and deep groundwater in the drainage area.

A mixing model of the L-4 area assuming conservative tracer behaviour indicates the L4ds sample is isotopically similar to a mix of 88% groundwater (based on LB-GW-04) and 12% waste water (based on LB-SL-3). A mixing model of artificial sweeteners indicates a similar (within 10%) range in concentrations based on the same ratio, providing strong evidence towards waste water daylighting in the L-4 area. Wastewater in this area would be expected to drain via surface flow into McLean Creek between SW-3 and SW-4, contributing concentrations of these tracers.

Several other parameters, including U, increase steadily in McLean Creek along the flow path. Whether this is due to further influence of the sewage lagoons or the result of local shallow and deep groundwater flow cannot be determined based on the results of this study. Concentrations of artificial sweeteners and Cl in the surface water sites sampled as a part of the audit are presented in Figure 12 and Figure 13 respectively. These figures illustrate the increasing sweetener and Cl concentrations as of LB-SW-4.

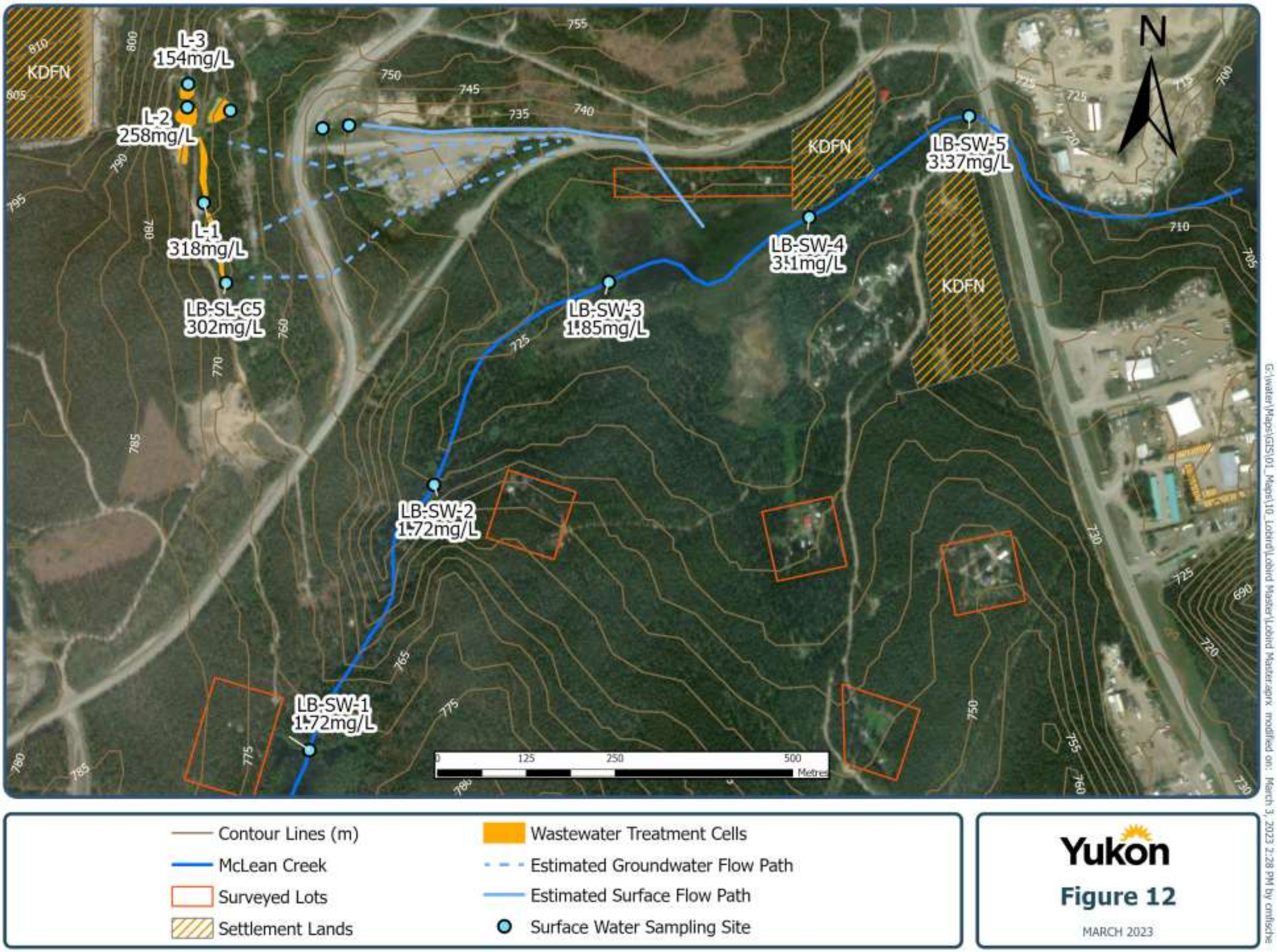


Figure 12 - Cl concentrations in surface water sampling sites

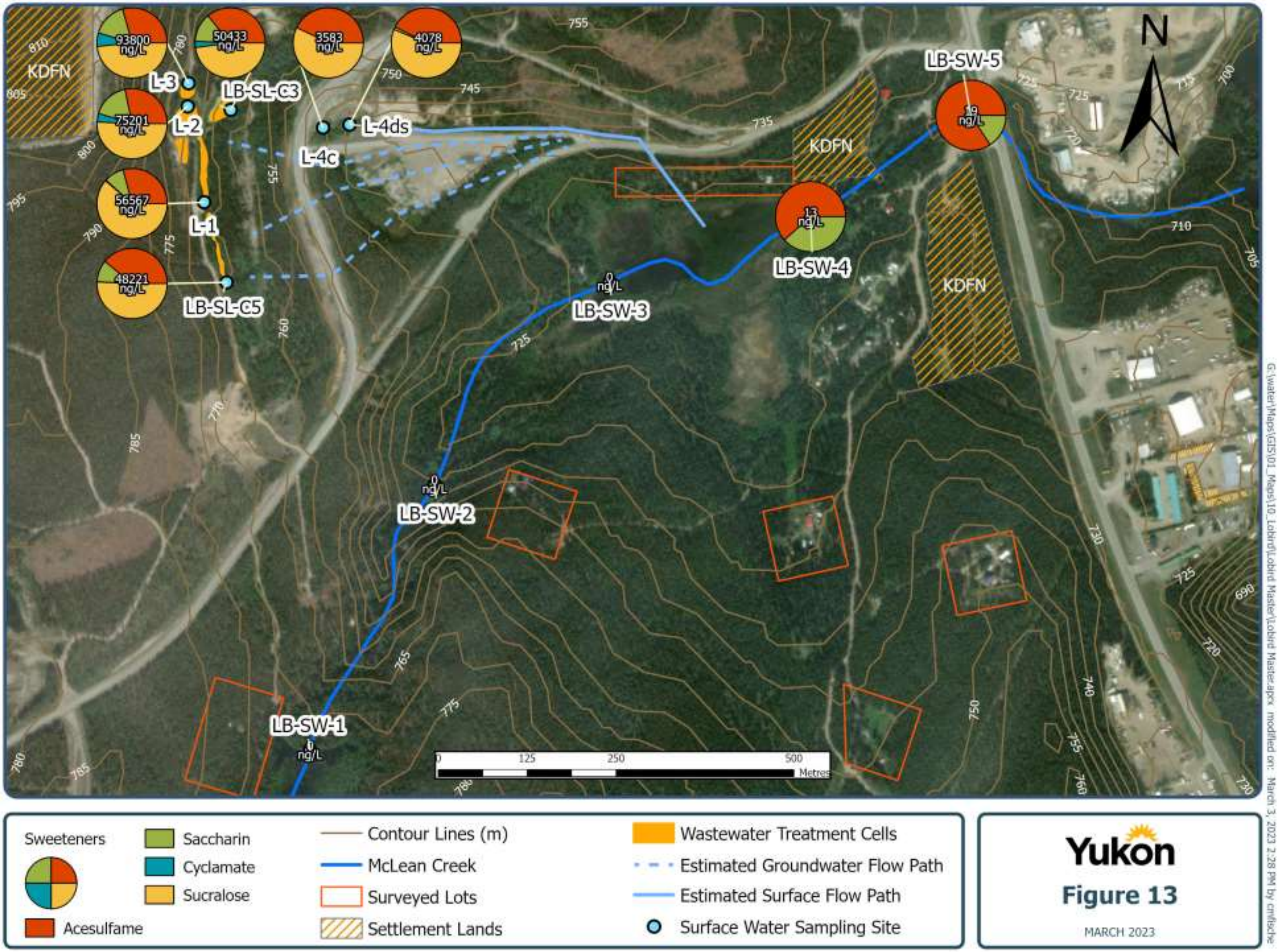


Figure 13 - Sweetener concentrations in surface water sampling sites

It is important to note that the analytes measured in the present study remain below guidelines in McLean Creek, suggesting a lack of significant adverse effects on local water quality.

5.3 Objective 3

Characterize the water quality of the Lobird Park Water Supply System wells to support understanding of why uranium is present in groundwater near Whitehorse and assess likelihood of direct influence of surface water on well water.

Three out of four sampled groundwater wells, as well as the Ice Lake sample, exceed the HC-DWQG and CCME guideline for U, but As remains under both guidelines for all samples. Unexpectedly low radon measurements were observed in two out of the three assessed wells whereas GW-6 contained close to the expected value for Rn based on other water sources expected to draw from similar bedrock types in the Whitehorse area. The high U and Rn observed in the groundwater wells is typical of granitic bedrock aquifers in the Whitehorse area and has been the subject of numerous studies.

Discrepancies in pH and SPC between Ice Lake and the groundwater samples may be due to exposure to atmosphere, which generally results in decreasing pH from CO_2 acidification, and increase in SPC via consistent evaporative concentration of dissolved constituents.

Above-guideline U concentrations were measured in sewage lagoon cells 3 and 5, as well as all groundwater wells. Given the sewage lagoons should be only receiving water below guidelines as they represent the discharge of a large public drinking water system, these exceedances are potential cause for concern. When compared to Cl as a conservative tracer, the increase in U to above guideline values cannot be attributed to evaporative concentration, as illustrated in the following table:

	Cell 1	Cell 5	% Change
[U]	154 mg/L	302 mg/L	51%
[Cl]	0.00544 mg/L	0.0370 mg/L	14%

The discrepancy between the % change of the concentrations of these two assumed conservative tracers indicates that evaporative concentration alone is not responsible for the above-guideline U in cell 5. However, water quality data from the pump room (the furthest downstream point in the water treatment system before distribution) indicates that U guidelines have not been exceeded at any point in the record, making it unlikely that the above-guideline U results from high concentrations in normal effluent as it enters the wastewater treatment system. Ruling out these two potential influences, the likely cause of the above-guideline U concentrations in the sewage lagoons likely results from periodic flushing of the ion exchange system responsible for removing U from the raw groundwater, a practice confirmed by EHS staff. Flushing this treatment system would result in a "pulse" of high-U water, which would then be presumably discharged into the water treatment system and carried into the downstream cells. Analysis of system flushing frequency would confirm this hypothesis, as flush dates are currently not recorded.

Samples collected from the groundwater wells and the sample from Ice Lake are of similar water types and show similarities both in field and analytical data. Similar ranges of pH, conductivity, and isotopic ratios indicate the groundwater wells and Ice Lake share groundwater as a common source. Greater proportions of ^{18}O in the Ice Lake sample compared to the groundwater samples indicates an influence of precipitation on Ice Lake, an influence less obvious in the groundwater wells. Although no fecal coliforms were observed in the groundwater wells during sampling, it cannot be stated with certainty that these wells are not under the direct influence of surface water (GUDI) as they are pumped consistently enough that any potential influence of surface water may be diluted by incoming groundwater. Although it cannot be stated with certainty that the wells are GUDI, the wells are likely at risk based on the Government of British Columbia Ministry of Health (BCMoH)'s GARP assessment document (BC MoH, 2017)

6 Conclusions and Recommendations

The Lobird Mobile Home Park's 5-year water licence MN20-047-1 was issued as a temporary measure to allow time for the proponent to address several key issues identified by YG, YESAB, and other third parties. The objectives of this study, formulated to address concerns identified in the water licence renewal process, were to:

1. Identify where the discharge from the sewage lagoons likely reports to McLean Creek to suggest monitoring locations to be included in future water licensing for the park.
2. Evaluate potential impacts of the sewage lagoons on the water quality of McLean Creek.
3. Characterize the water quality of the Lobird Park Water Supply System wells to support understanding of why uranium is present in groundwater near Whitehorse and assess likelihood of direct influence of surface water on well water.

The influence of the LMHP sewage lagoons on McLean Creek is likely observed between audit sampling locations LB-SW-3 and LB-SW-4. The influence of the lagoons is evidenced by increases in SPC and concentrations of Cl and artificial sweeteners, all of which are known indicators of human wastewater effluent. The potential influence pathways are likely infiltration into groundwater along the sewage lagoon flow path and resurfacing in the catchment of McLean Creek, or via infiltration through cell 3 and rapid resurfacing in the L-4 (gravel pit) area, followed by surface conduction into McLean Creek. Monitoring locations upstream and downstream of the expected zone of influence, such as LB-SW-3 and LB-SW-5, would be well placed to monitor the potential influences of the sewage lagoon on the receiving environment.

The potential impacts of the lagoons on the water quality of McLean Creek are likely similar to the elements used as tracers in the present study, namely Cl and artificial sweeteners. Although coliforms were observed in McLean Creek, they are expected to be the result of animal wastes, as the travel time from the lagoons to the creek would be sufficient to eliminate most types of coliforms. Increasing U concentrations along McLean

Creek are likely the result of a mix of deep and shallow U-rich groundwater, with potential for increased concentrations from high-U waste in the LMHP sewage lagoons resulting from periodic U filtration system flushing. Confirmation of the frequency and magnitude of these system flushes would further confirm or refute the lagoon's contribution of U to McLean Creek.

All groundwater wells in the LMHP drinking water system show consistent exceedances of guidelines for U, a common occurrence for wells in the granitic bedrock of the Whitehorse area. Concentrations of U remain below guideline in the pump room, the point furthest downstream in the drinking water treatment systems prior to distribution. High Rn measured in one of the groundwater samples confirms the radiological element-rich nature of the bedrock in which the wells are screened. Based on the results of the present study, the direction of influence between Ice Lake and the groundwater wells cannot be confirmed. These two sample types share attributes indicative of a common source or influence, namely a mix of deep and shallow groundwater which is expected to feed both the wells and Ice Lake. The lack of fecal coliform measurements in the wells supports that the wells may not be under the direct influence of surface water, but as the wells are pumped constantly any influence of surface water may be pumped out or diluted in inflowing groundwater in the pump interval.

Based on the results of this study, WRB recommends the following:

1. Update schedule 1A of the WUL to require sampling of McLean Creek at the stations identified in this report as LW-SW-3 and LB-SW-5, which are representative of water quality conditions upstream and downstream, respectively, of the influence of the Lobird wastewater lagoons.
2. Include sewage lagoon cell 3 in routine sampling as it likely represents the final stage in an alternate flow path before infiltrating to ground and daylighting in the L-4 (gravel pit) area.
3. Sample the L-4 area twice yearly as far as possible upstream in the hypothesized discharge zone of infiltrated water from the sewage lagoons, when water is present in the area.
4. Confirm infiltrated groundwater flow paths during the hydrogeological assessment, potentially by installing wells between Cell 3 and the L-4 area.
5. Collect information regarding the procedure and frequency of the flushing of the U treatment system.

6. Fully assess the risk to Lobird drinking water wells from influence of adjacent surface water bodies.

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9 Appendices

Appendix A: Lobird Mobile Home Park Water Licence MN20-047-1

Appendix B: Photo Log

Appendix C: Field Sheets

Appendix D: Laboratory Certificates of Analysis

Appendix E: Full QA/QC Results

Appendix A: Lobird Mobile Home Park Water Licence MN20-047-1

Appendix B: Photo Log

Appendix C: Field Sheets

Appendix D: Laboratory Certificates of Analysis

Appendix E: Full QA/QC Results