HIGH ELEVATION MONITORING IN THE COLUMBIA BASIN:

PILOT YEAR SUMMARY REPORT

Living Lakes CANADA

Prepared by Heather Shaw, Living Lakes Canada

April 2023

ACKNOWLEDGEMENTS

Living Lakes Canada would like to thank all of our advisors and partners who supported the development of the High Elevation Monitoring Program in its pilot year, including Janet Fischer, Mark Olson and Ben Pelto, BC Parks, MacDonald Hydrology Consultants Ltd., and the Living Lakes Canada Advisory Board. A special thank you to the Alpine Club of Canada for supporting the program's Citizen Science project, and to the Backcountry Lodges of British Columbia Association and participating lodge owners for promoting the program among their guests. We gratefully acknowledge the financial support from individual donors and funders — the Province of British Columbia, Read Family Foundation, Alpine Club of Canada and Helicat — for making the High Elevation Monitoring Program possible.

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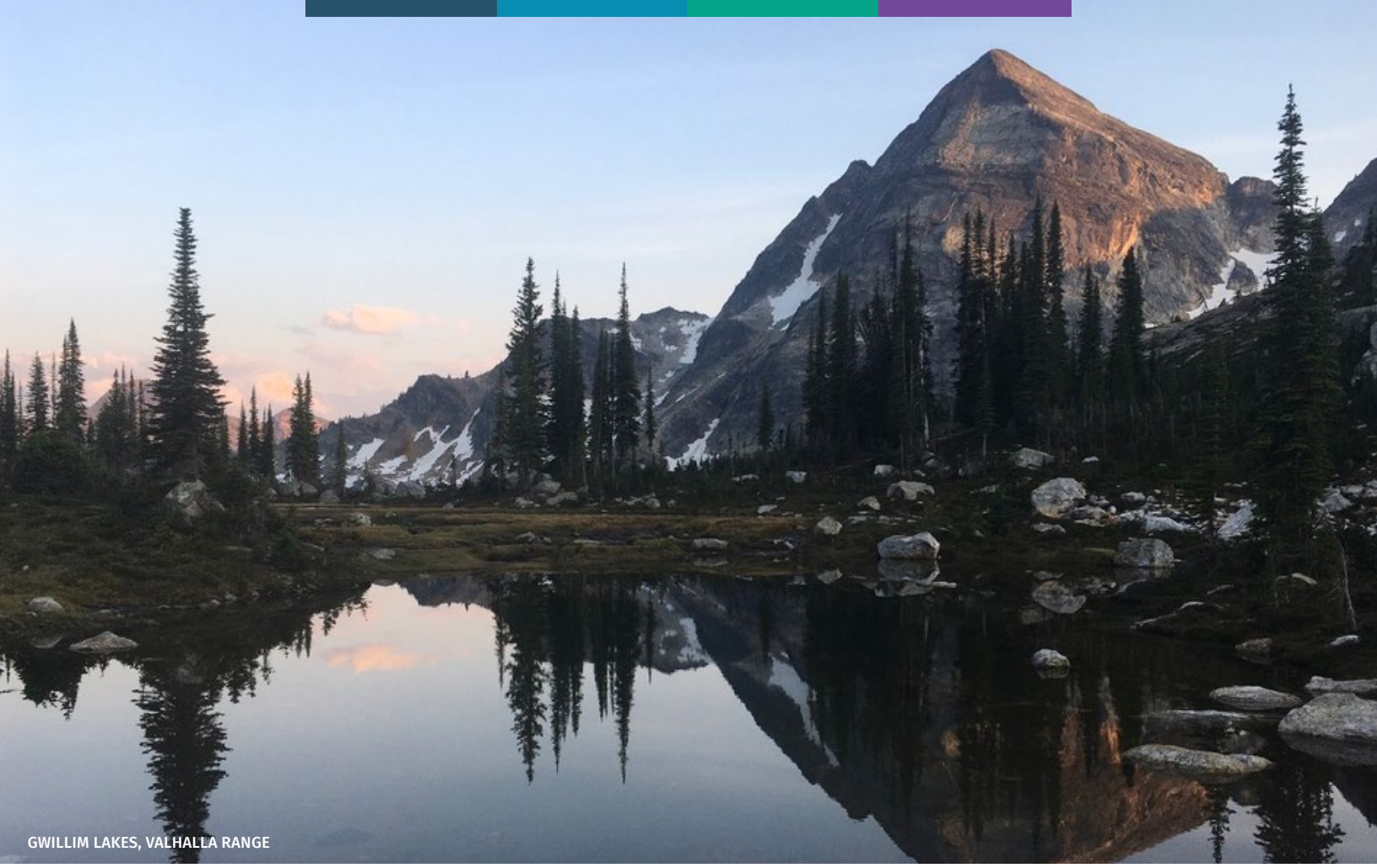
LAND ACKNOWLEDGEMENT

Living Lakes Canada acknowledges that this project is taking place in the unceded traditional territories of the Ktunaxa, Secwepemc, Sinixt and Syilx Nations who have stewarded these lands for generations. Recognizing Indigenous People as the rightful caretakers of their unceded territories, we work to complement their intergenerational work and Indigenous-led water stewardship initiatives.



GWILLIM LAKES, VALHALLA RANGE

FIRST NATIONS ENGAGEMENT

In acknowledging the rightful caretakers of the land, Living Lakes Canada is committed to engaging with the Ktunaxa, Secwepemc, Sinixt and Syilx Nations on aspects of this project that they deem appropriate.

The location of the two pilot monitoring areas were chosen based on scientific and feasibility factors, as well as to complement the implementation of the Columbia Basin Water Monitoring Framework (CBWMF). All pilot high elevation monitoring sites overlap with the 2022 pilot areas of the CBWMF. Living Lakes Canada engaged with the Ktunaxa, Secwepemc, and Sylix regarding water monitoring concerns in the CBWMF pilot areas.

Expansion of the High Elevation Monitoring Program will involve further opportunities for the inclusion of Indigenous voices in water monitoring. Specifically, high elevation content will be included in the CBWMF's community and one-on-one meetings to discuss local monitoring priorities and water concerns. The High Elevation Monitoring Program can respond to potential concerns by prioritizing locations of value to Indigenous Peoples when adding monitoring locations.

EXECUTIVE SUMMARY

Air temperatures at high-mid elevations are increasing at a faster rate than at lower elevations[1]. As a result, high elevation ecosystems in mountainous regions, often referred to as alpine ecosystems, are more vulnerable and expected to experience climate impacts more rapidly than lower elevations. There is an urgency to start collecting data as many high elevation areas have not been actively monitored.

Living Lakes Canada developed the High Elevation (HE) Monitoring Program to address the climate challenges unfolding in alpine areas and bridge data gaps. The aim of the HE Monitoring Program is to generate baseline data on alpine ecosystems and establish long-term monitoring to understand how these ecosystems, and the watersheds they are a part of, are responding to climate change. Water quality and quantity are variables that will be analyzed as they are important for all biological communities.

The HE Monitoring Program is a component of a larger Living Lakes Canada project, the Columbia Basin Water Monitoring Framework (CBWMF). This project is addressing the deficit of water knowledge across the Upper Columbia River Basin, expanding the existing water monitoring network to track climate impacts on freshwater sources.

In 2022, Living Lakes Canada piloted the HE Monitoring Program in Kokanee Glacier Provincial Park and Shannon Lake in B.C. A large part of the pilot year involved consulting with professional hydrologists, biologists, and the Living Lakes Canada Advisory Team to develop the High Elevation Framework (HEF). The HEF outlines the methodologies and protocols required to collect meaningful scientific data in high elevation areas.

The data collected for the HE Monitoring Program will be made publicly accessible through the Columbia Basin Water Hub database[2]. The Water Hub is a central place where decision-makers, researchers, students, professionals and the public can access a wide variety of data and information about water in the Columbia Basin.

ABBREVIATIONS

CABIN - Canadian Aquatic Biomonitoring Network

CBWMF - Columbia Basin Water Monitoring Framework

EDW - Elevation-dependant warming

ESSFwc4 Engelmann Spruce Subalpine fir - wet cold zone

FOR - Ministry of Forests

LCK - Lower-Columbia-Kootenay Hydrologic Region

MCK - Mid-Columbia-Kootenay Hydrologic Regime

HE - High Elevation Monitoring Program

HEF - High Elevation Monitoring Framework

ICHmw1 - Interior Cedar Hemlock - dry warm biogeoclimatic zone

ICHmw2 - Interior Cedar Hemlock - moist warm biogeoclimatic zone

IMH - Interior Mountain - Heather Alpine biogeoclimatic zone

HRs - Hydrologic Regions

KGP - Kokanee Glacier Provincial Park

STREAM - Sequencing The Rivers for Environmental Assessment and Monitoring

WCT - Westslope Cutthroat

LIMESTONE LAKES, HEIGHT OF THE ROCKIES PARK

INTRODUCTION

Program Goal

The goal of the HE Monitoring Program is to generate baseline data on high elevation ecosystems that are data deficient and establish sustainable long-term monitoring. Baseline data enables us to understand how high elevation ecosystems are currently functioning. Long-term monitoring will enable us to understand how these sensitive areas are responding to climate change over time. Water quality and quantity – vital for a functioning ecosystem – are the primary variables being measured and analyzed. The data will help guide science-based management decisions, and support ecosystems and communities as they adapt to a changing climate and hydrological regime.

Background

A report written by Janice Brahney and colleagues[3] suggests future warmer air temperatures will result in less precipitation as snow, an increase in evapotranspiration, and a decrease in glacial contribution to streamflow. Further, a reduction in snow accumulation and earlier peak melts may reduce streamflow in the late summer. These types of events will leave ecosystems, aquatic species and humans vulnerable to wildfire and reduced habitat. Further, these events will lead to a reduction in water supply for drinking water, agriculture and hydropower.

High elevation ecosystems are especially susceptible to the events and impacts described in Brahney's paper. A number of reports have identified the urgency to increase monitoring and research in high elevation areas within the Columbia River Basin, to better understand how climate change is altering the quality and quantity of water resources. These reports include *An Integrated Lake Monitoring Framework for British Columbia*[4], *Water Monitoring and Climate Change in the Upper Columbia Basin*[5], and *Water Quantity and Quality in the Columbia Basin Trust Region*[6].

Recognizing that there is a need for high elevation monitoring in the Columbia River Basin, Living Lakes Canada developed and implemented the HE Monitoring Program. The HE Monitoring Program supports the goal of the CBWMF, which is to improve and strengthen the monitoring configuration for tracking and understanding a broader range of climate impacts on the water supply for Basin ecosystems and its people, and support local and regional efforts to increase adaptation options and support the longer-term viability of natural ecosystems and ecosystem services.


HUSS CREEK
VALHALLA RANGE

The High Elevation Monitoring program contributes to the overarching goal of CBWMF by providing data that will support the long-term viability of alpine ecosystems and the water they supply to downstream ecosystems and communities. The health and function of high elevation ecosystems directly influence the quality and quantity of water delivered downstream, and therefore is an integral part of CBWMF.

Development of Methodology

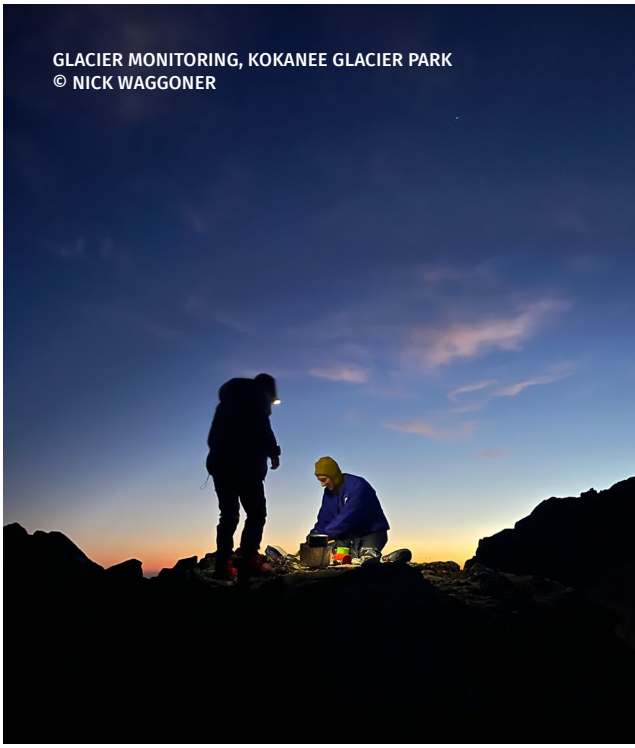
The methodologies and protocols that make up the HEF were developed in collaboration with the provincial government, professional hydrologists and biologists, and Living Lakes Canada's experienced team of advisors. The HE pilot was implemented from July to November 2022 in two areas within the Columbia Basin. Due to the supply chain for monitoring equipment, which was still recovering from COVID-19, Living Lakes Canada was not able to pilot all of the methodologies and protocols of the HEF. The complete HEF will be implemented at nine monitoring locations in 2023 (See Figure 1 for details). The following monitoring objectives will be completed at each monitoring site within the nine monitoring areas.

- Water Quantity
  - Lake Level
  - Bathymetric surveying
- Water Quality
  - Multimeter measurements - temperature, turbidity, dissolved oxygen, chlorophyll A, specific conductivity, fluorescent and dissolved organic matter (FDOM)
  - Water samples- heavy metals, nitrate, ammonium, total phosphorus
- Biological parameters
  - Zooplankton
  - Phytoplankton
  - Macroinvertebrates
- Climate variables
  - Meteorological Stations - relative humidity, precipitation, air temperature, wind speed and direction, snow depth, insolation,

Monitoring areas for 2022/23 were selected based on the need to fill data gaps identified in the Integrated Lake Monitoring Framework for British Columbia[7], and the CBWMF Priority Monitoring Matrix.

HIGH ELEVATION MONITORING FRAMEWORK

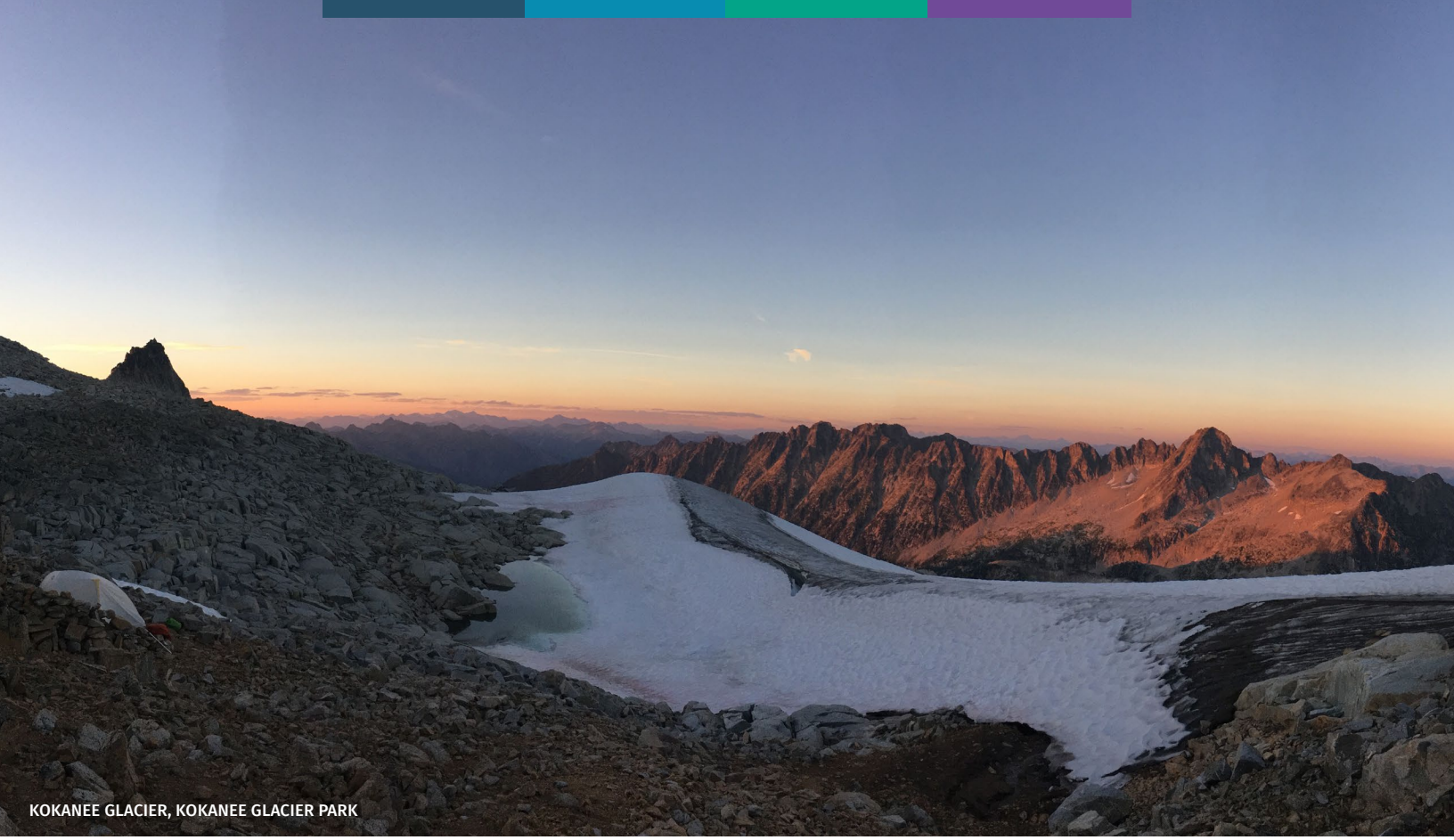
The Columbia River Basin can be divided into 10 Hydrologic Regions (HRs). Living Lakes Canada is working to implement the CBWMF program in new HRs each year. Monitoring areas for the HE Monitoring Program are selected within the same HRs where the CBWMF program is being implemented. After monitoring areas are identified, water monitoring sites within each area are selected. For example, Kokanee Glacier Provincial Park (KGP) is considered a monitoring area within the Lower and Mid Columbia-Kootenay Hydrologic Regions (LCK and MCK). Water monitoring sites are localized features within a monitoring area, such as a lake and the inflows and outflows (streams/creeks) of said lake. The surrounding vegetation and geography are integral to the function of the water monitoring sites, and data on the general characteristics of these features are collected.



GLACIER MONITORING, KOKANEE GLACIER PARK
© NICK WAGGONER

Where possible a variety of monitoring sites within an area are selected to capture variability. For example, in KGP we selected lakes that were snow-fed, glacier-fed, and differed in elevation, aspect, depth and surrounding vegetation. Collecting data from sites that differ in these ecosystem features will generate a broader understanding of climate impacts on the various types of high elevation ecosystems. At each site, biological, physical and chemical parameters are measured and analyzed. An inventory of flora and fauna present within a monitoring area is tracked through the HE Citizen Science Project, and photo plots are established to track changes on a landscape level at each site. More details about the HE Citizen Science Project can be found on the High Elevation Monitoring Program webpage[8].

Other parameters that are not directly measured through HE Monitoring Program, but are key components in understanding high elevation ecosystem health, are climate, streamflow, snowpack and glacier mass-balance. Climate and streamflow variables are monitored through climate and hydrometric stations installed by the CBWMF and existing climate stations operated by various ministries and organizations. Snowpack data are being collected and shared in three of the HE monitoring areas by partnering backcountry lodge operators. In B.C., glacier mass-balance is primarily monitored by collaborative efforts with the Hakai Institute. Data on multiple glaciers throughout the Columbia Basin can be found on the World Glacier Monitoring Service[9].



KOKANEE GLACIER, KOKANEE GLACIER PARK

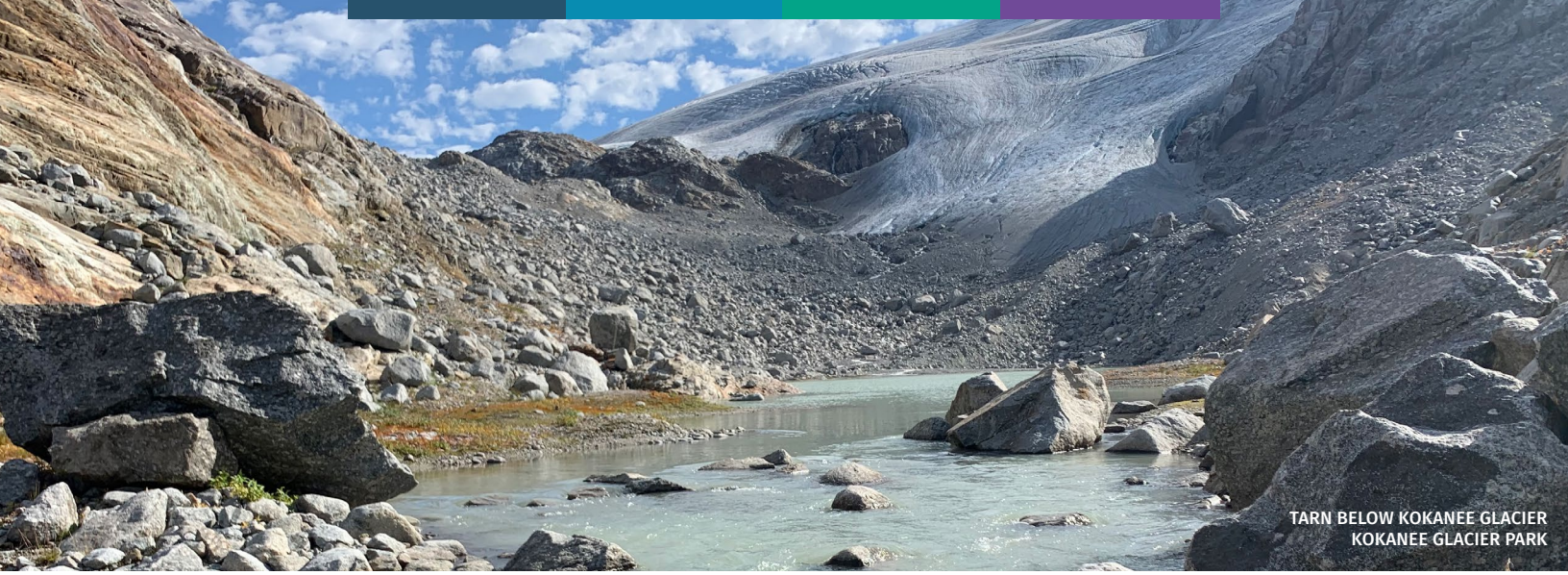
Data are collected according to the appropriate standards and recognized protocols to ensure that they can be used for analysis, research, and decision-support. The Methods section of this report expands on the methods that were implemented in the two pilot areas in 2022. The Results section focuses on the preliminary lake data collected during the pilot.

2022 Pilot Implementation

In 2022, Living Lakes Canada piloted the High Elevation Program in two areas that included four lakes and two streams.

- Kokanee Glacier Provincial Park/Slocan Valley – Lemon Creek, Sapphire, Tanal and Upper Joker Lakes
- North Valhallas - Shannon Lake, Huss Creek

Preliminary data from the pilot project will be available on the Columbia Basin Water Hub in early 2023. The data can then be used by community members, researchers, the private sector, and all levels of government to inform water management and stewardship decisions.



TARN BELOW KOKANEE GLACIER
KOKANEE GLACIER PARK

MONITORING LOCATIONS

Kokanee Glacier Provincial Park

Kokanee Glacier Provincial Park (KGP) is situated northeast of Nelson, B.C. in the LCK/MCK. Selected bodies of water in KGP were identified as a priority by the Integrated Lake Monitoring Framework for British Columbia[10]. The park holds historical and cultural significance for Indigenous Peoples and the community of Nelson, and offers endless recreation activities such as mountaineering, skiing, fishing and hiking. The popular Alpine Club of Canada Kokanee Glacier Cabin is situated within the park along the shoreline of Kaslo Lake and attracts visitors from around the world.

Due to the existing data gaps, socio-economic values, and the importance of select bodies of water, Living Lakes Canada chose to implement the pilot for the HE Monitoring Program in KGP. The park hosts a climate station that is operated by the Ministry of Forests (FOR). In the future, data from this station will be used to identify and track the relationship between climate and water quality/quantity. At the time this report was being developed, Living Lakes Canada did not have the 2022 quality assured/quality controlled climate data so it was not included in the analysis. Upper Sapphire, Tanal and Upper Joker Lakes, all within the KGP, were chosen to establish HE monitoring sites. Details about the significance of each site, as well as the monitoring methods that were implemented at each lake, are provided in the Monitoring Sites and Methodologies section of this report.

Valhalla Mountain Touring - Shannon Lake

Shannon Lake is located north of Valhalla Provincial Park in the Selkirk Mountains within the MCK. The lake falls within the Valhalla Mountain Touring Lodge (VMT) tenure, which is a popular backcountry ski and hiking lodge. The lodge hosts a climate station that is operated by the CBWMF program.

MONITORING SITES AND METHODOLOGIES

See Appendix A for a table with the monitoring objectives that were completed at each monitoring site in 2022, and the monitoring objectives that will be completed in 2023. The table includes monitoring sites that will be added to the HE Monitoring Program for 2023.

Sapphire Lake-Lemon Creek

Upper Sapphire Lake is located in the southwest regions of KGP at an elevation of 2,263 metres above sea level. As the name suggests, the lake is a deep blue sapphire colour and lies within the Interior Mountain-Heather Alpine (IMA) biogeoclimatic zone[11]. The lake is predominantly fed by snowmelt and marks the headwaters of Lemon Creek, a large fish-bearing tributary of Slocan Lake.

SAPPHIRE LAKE

In mid-August, a level logger was installed off the lake's east shore, bathymetric map surveying began, and site locations were identified to complete the stream monitoring component of the HEF for 2023. The level logger continuously tracked changes in lake level and temperature at 15-minute intervals from August 15th - October 7th, 2022. Bathymetric surveying was used to create a contoured map of the lake bottom, and locate the deepest part of the lake. Locating the deepest part of the lake is important because this marks the location where a line of light and temperature sensors will be installed, and depth profiles will be completed in 2023. The method of locating the deepest part of the lake and using this location for depth profiles and light/temperature sensors applies to all of the lakes monitored through the HE Monitoring Program.

Lemon Creek

Lemon Creek is a fish-bearing stream and provides fresh water for 13 licence holders along the lower portion of the creek. These include four agriculture, seven municipalities and two Ministry of Transportation licences. The headwaters of the creek (Sapphire lake) is situated in the IMA, and the lower portion of the creek is situated in the Engelmann Spruce Subalpine fir-wet cold zone (ESSFwc4)/Interior cedar Hemlock-moist warm zone (ICHmw2) [12]. There is an existing hydrometric station installed and operated by Water Survey Canada, however, it is currently compromised because the cableway is out of service. Subsequent to the cableway being repaired, data will be collected from the station and used to inform the HE Monitoring Program.

In October 2022 biomonitoring on the lower portion of the creek was completed using nationally recognized and standardized Canadian Aquatic Biomonitoring Network (CABIN), and Sequencing the Rivers for Environmental Assessment and Monitoring (STREAM) protocols. Biomonitoring for

the upper portion of the creek (i.e., the outflow of Sapphire Lakes) is scheduled to begin in 2023. Biomonitoring of the upper and lower portion of the creek enables us to track and compare trends in the lower and higher elevation macroinvertebrate communities. This applies to all of the stream/creek monitoring sites for the HE Monitoring Program.

Tanal Lake

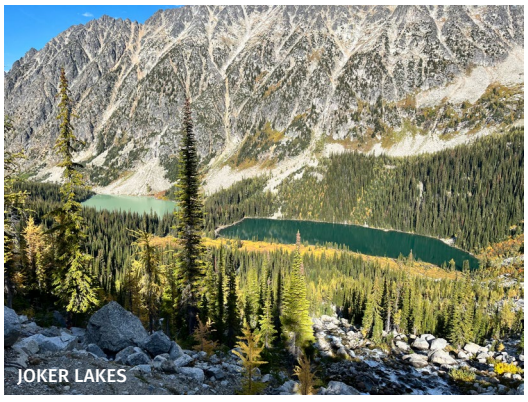
Tanal Lake sits approximately 500 metres below Upper Sapphire Lake at 1,797 metres. The dominant surrounding area is characterized by the Engelmann Spruce Subalpine Fir-wet cold (ESSFwc4) biogeoclimatic zone[13]. The lake is predominantly fed by snowmelt and marks the headwaters of Enterprise Creek, another large tributary to Slocan Lake. Tanal was stocked with Westslope (Yellowstone) Cutthroat Trout (WCT) beginning in the mid-1970s, and the last public record of fish observations provided by the Ministry of Environment is from 1995[14]. In August 2022, fish presence (not species) was confirmed in the lake.


TANAL LAKE

The monitoring activities carried out at Tanal Lake for the 2022 monitoring season were consistent with the monitoring activities at Upper Sapphire Lake. This included bathymetric mapping, the installation of a level logger on the southeast shoreline, and the identification of stream monitoring sites for the 2023 monitoring season. Biomonitoring for the lower and upper reaches of Enterprise Creek will be established in 2023. The upper portion of Enterprise creek lies within the same biogeoclimatic zone as Tanal Lake, and the lower portion lies within the ICHmw2[15].

Upper Joker Lake

Joker Lakes are the only two lakes in KGP that are fed by Kokanee Glacier. Upper Joker Lakes is a darker emerald colour, which is a stark contrast to the bright turquoise colour of Lower Joker Lake only 50 metres away. The colour difference is due to the fact that the glacial stream from Kokanee Glacier feeds mainly into Lower Joker, and only a small portion of the melt enters Upper Joker. Glacial streams carry loads of glacial flour which can be characterized as a fine white powder. The white particles reflect blue-green wavelengths and create the bright turquoise colour seen by the naked eye[16].


JOKER LAKES

Upper Joker Lakes was stocked with WCT from 1970 until 1983. The last public record of fish observations provided by the Ministry of Environment is from 1989[17]. In August 2022, Living Lakes Canada staff observed many fish jumping in the lake. Fish species are yet to be determined through this study.

In August 2022, a lake level on the east side of Upper Joker Lakes was installed, as well as a string of temperature and light sensors spaced in one-metre intervals from the lake surface to the lake bottom. The sensors continuously tracked changes in light and temperature from August 11th-September 27th. Due to the technical nature of accessing Upper Joker Lakes, monitoring sites will be moved to a more accessible area with two lakes that share similar characteristics to Upper and Lower Joker Lakes. These lakes are represented by the "Talus Lodge Lakes" in Figure 1.

Shannon Lake - Huss Creek

Shannon Lake is a deep alpine lake fed predominantly by snowmelt. It was stocked with WCT from 1968-1974. The last public monitoring record provided by the Ministry of Environment was in 1981[18]. The dominant vegetation around the lake is characterized by the Engelmann Spruce Subalpine Fir-wet cold (ESSFwc4) biogeoclimatic zone, however, less than one kilometre from the south end of the lake is characterized by the Mountain-heather Alpine (IMA) biogeoclimatic zone[19].


SHANNON LAKE

In 2022, bathymetric map surveying commenced on Shannon Lake, with 25% of the survey completed. In comparison to the other lakes in KGP, Shannon Lakes is much larger and deeper (Table 1). Bathymetric mapping is planned to be completed in 2023, as well as monitoring of the biological, physical and chemical components of the lake.

Huss Creek

Huss Creek is a steep mountain creek and the largest tributary flowing into Shannon Lake. The upper portion of the creek is situated in the ICH, and the lower portion of the creek is situated in the ICHmw1[20]. In late September of 2022, a CABIN/STREAM site was established with biomonitoring completed on a representative portion of the creek. In 2023, a lower elevation site will also be established.

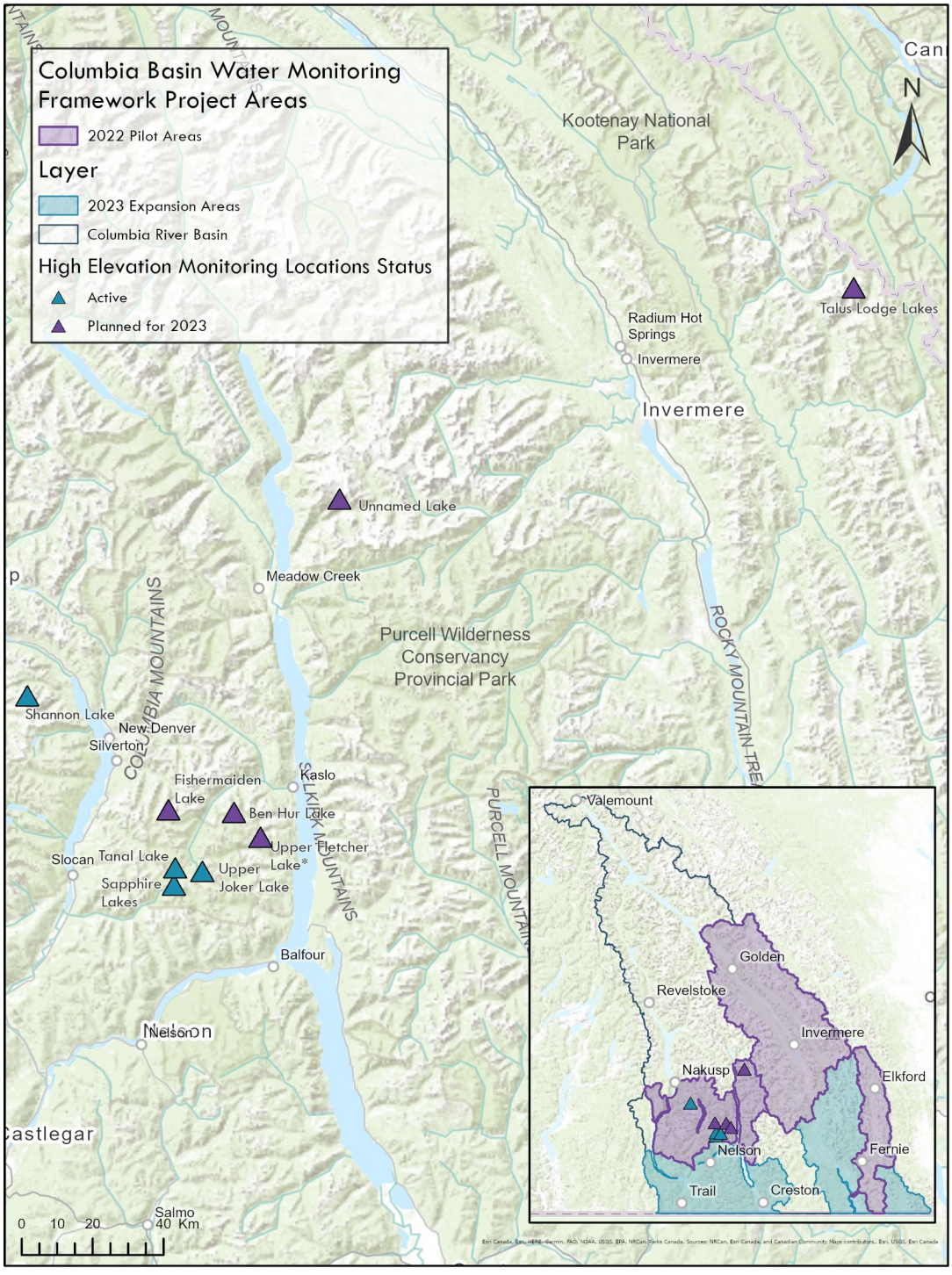
Silverton Creek

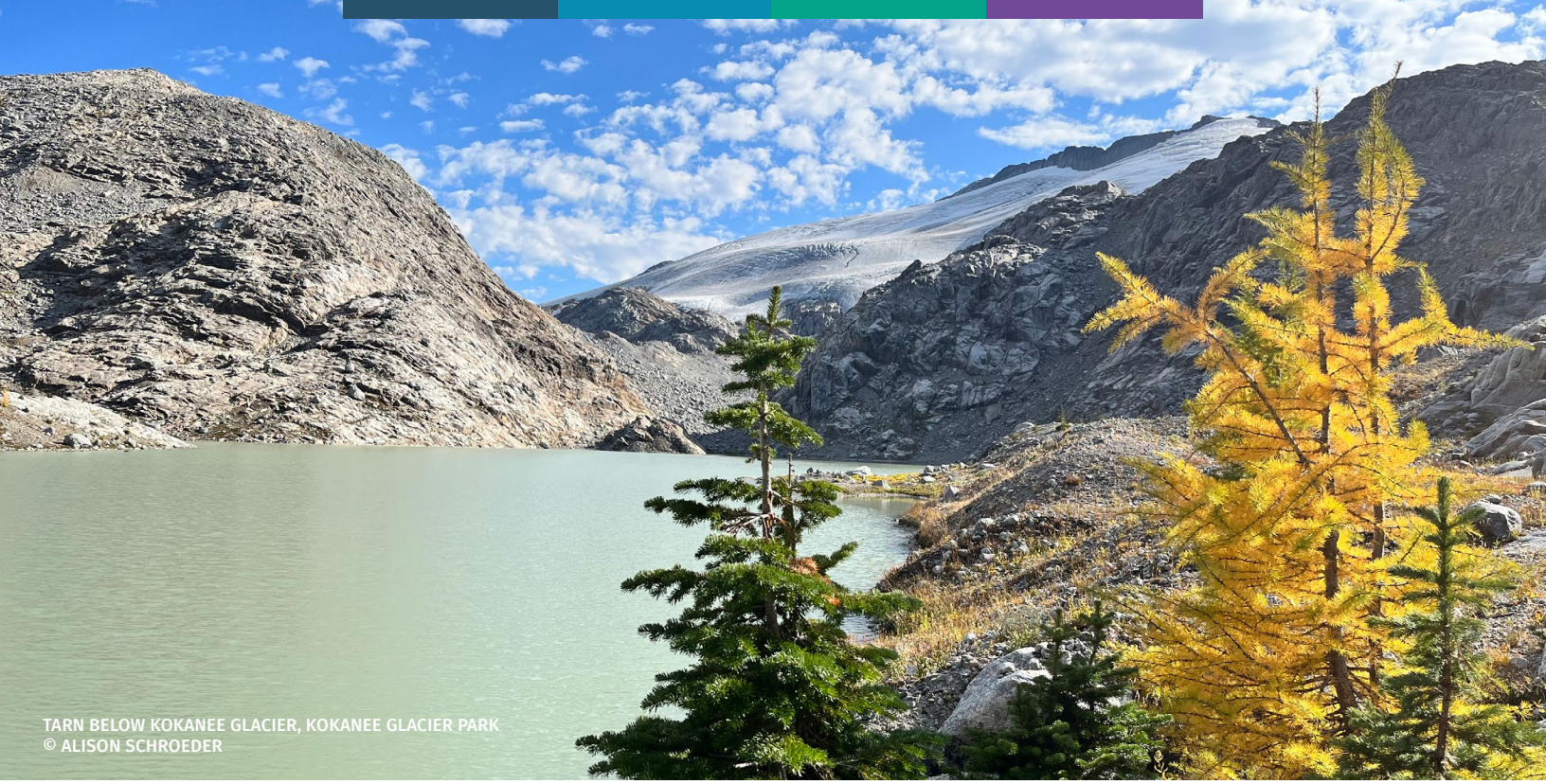
The headwaters for Silverton Creek begin in KGP at Nanatak Lake. Silverton Creek flows out of Nanatak into Fishermaiden and downstream of Fishermaiden until it reaches Slocan Lake. Silverton Creek is fish-bearing and flows through the small community of Silverton. The creek was identified as a priority by local community groups.

In October 2022, biomonitoring on the lower portion of the creek, which is situated in the ESSFwc4 [21], was completed using the standardized CABIN/STREAM protocols. Biomonitoring for the upper portion of the creek is scheduled to begin in 2023. The upper portion of the creek is situated in the ICHmw1/Interior Cedar Hemlock-dry warm (CHmw2) biogeoclimatic zone [22].

MAP OF MONITORING LOCATIONS

2022 High Elevation Monitoring Locations and Proposed 2023 Monitoring Locations





TARN BELOW KOKANEE GLACIER, KOKANEE GLACIER PARK
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DATA ANALYSIS

The results of the preliminary lake data analysis for the HE pilot are discussed in this section. Stream data, as well as the temperature/light data from Upper Joker Lake, have not yet been reviewed. General lake characteristics are provided in Table 1 and express the variation among monitoring sites.

METHODS

Lake level and temperature data for Sapphire, Tanal, and Upper Joker were collected. These were compared with air temperature and precipitation data extracted from the Redfish Creek climate station[23]; the nearest climate station to all of the named lakes. Lake level was measured in meters above sea level and represents the depth of water above the level logger. The level logger continuously tracked water level (m) and temperature (˚C) at 15-minute intervals and was compensated with the nearest barometric logger to account for atmospheric pressure.

The FOR Redfish Creek climate station is located in Ross-White Lady Lake Recreation site just south of the KGP boundary at 2,104 metres. Hourly temperature (˚C), and past 24-hr precipitation (mm) were measured. These data were used to infer how air temperature and precipitation events impact lake level and water temperature.

RESULTS

This section outlines the results of the preliminary lake data for the HE pilot collected from Sapphire, Tanal, Upper Joker, and Shannon Lake. Not featured are the results from the temperature and light loggers from Upper Joker; this data are currently being reviewed. Table 1 summarizes the general characteristics of each lake, followed by graphs that indicate lake level and water temperature values from August - October 2022, correlated with past 24-hr precipitation and temperature data from Redfish Creek.

TABLE 1. GENERAL LAKE CHARACTERISTICS OF 4 LAKES IN THE COLUMBIA BASIN 2022

Lake Name	Elevation (m)	Aspect	Dominant Surrounding Vegetation	Max Depth (m)	Trophic Status	Glacier/ Snow Fed
Sapphire Lake	2,263	West	Alpine Tundra (IMA)	12	*Oligotrophic	Snow fed
Tanal Lake	1,767	North West	Forest (ESSFwc4)	3.5	*Oligotrophic	Snow fed
Upper Joker Lake	2,013	North West	Forest (ESSFwc4)	8.7	*Oligotrophic	Glacier & Snow
Shannon Lake	1,866	North	Forest (ESSFwc4)	70	*Oligotrophic	Snow fed

**Likely Oligotrophic, 2023 nutrient analysis and depth profiles will confirm trophic status.*

Of the three lakes shown in Figure 2, Sapphire Lakes expressed the lowest water temperatures ranging from approximately 7-11 ˚C. The highest water temperatures for all lakes occurred in August with the lowest temperatures observed in late September to early October.

The largest fluctuations in lake level are correlated with a decrease in water temperature, air temperature, and a precipitation event (Figure 2). The change in water level recorded by the level logger from August to September/October was approximately 10 centimetres at Sapphire Lake, 12 centimetres at Tanal Lake and 20 centimetres at Upper Joker Lake (Figure 2). These changes in water level are consistent within 2.5 centimetres of the field measurements taken from a fixed point-water surface at each monitoring site.

FIGURE 2. VALUES IN LAKE LEVEL AND WATER TEMPERATURE (T WATER) FOR THREE HIGH ELEVATION LAKES WITHIN THE COLUMBIA BASIN, CORRELATED WITH AIR TEMPERATURE (T AIR), AND PAST 24-HR PRECIPITATION DATA FROM THE REDFISH CREEK, B.C. CLIMATE STATION FROM AUGUST-OCTOBER 2022.

LOWER SAPHIRE LAKE, KOKANEE GLACIER PARK

DISCUSSION

The headwaters of most watersheds within the Columbia River Basin are situated in high elevation areas. These sensitive areas are experiencing climate impacts at an accelerated rate compared to lower elevations. High elevation ecosystems and the species that inhabit them have adapted to cool air and water temperatures. Climate change and EDW, both factors that are contributing to warming air and water temperatures, are putting the health and function of these sensitive ecosystems at risk. The quality and quantity characteristics of water throughout the Columbia Basin are directly influenced by the health and function of headwaters. The High Elevation Monitoring program aims to provide data to develop an understanding of how these vulnerable spaces will change in response to climate impacts.

The preliminary data from the 2022 pilot implementation is the beginning of a greater understanding of high elevation ecosystem health and function, and how it relates to the future of water quality and quantity in the Columbia Basin. Preliminary data expresses the relationship between lake level, water temperature, air temperature and precipitation. While too early to identify a baseline condition for these lakes, the study can deduce that due to the strong relationship between the mentioned variables, lake level (quantity) and water temperature (quality) will be impacted by climate change.

The High Elevation Program in conjunction with the CBWMF program will address these vulnerabilities by providing long-term monitoring and data that will be used to identify and develop strategies for climate change adaptation.

LOOKING AHEAD

After a successful pilot implementation, Living Lakes Canada looks forward to expanding the HE Monitoring Program throughout the Canadian Columbia Basin. In 2023, the HE Monitoring Program will see the addition of three monitoring areas, and will be adopting two monitoring areas that were recently part of Living Lakes Canada's Kootenay Watershed Science program. Living Lakes Canada is excited to continue our collaboration with members of the Backcountry Lodge of British Columbia Association (BLBCA) to carry out monitoring efforts. In 2022/23, three lodges are contributing snowpack data to the Columbia Basin Water Hub and six lodges offered their support by educating and guiding guests to the HE donation page[24] Multiple lodges have agreed to offer their support in 2023 after their busy 2022 winter season is completed, and Talus lodge will begin lake monitoring in spring 2023.

We are also looking forward to continuing our partnership with the Alpine Club of Canada. There members were involved in the HE Citizen Science project in 2022, and we look forward to seeing an increase in participants in 2023.

DATA SHARING AND ANALYSIS

Once processed and graded, data will be made available through the Columbia Basin Water Hub database, managed by Living Lakes Canada. The data can then be used by community members, researchers, the private sector, and all levels of government to inform water management and stewardship decisions, in addition to supporting the broader goal of developing a water balance for the Columbia Basin. The data gathered through this project will inform climate adaptation activities throughout the Basin as decision makers gain a comprehensive understanding of the state of water supply and water quality in their jurisdictions.

LEARNINGS AND RECOMMENDATIONS

The successful pilot implementation yielded many learnings to be carried forward into future implementations of this project.

• Living Lakes Canada would like to engage more citizen scientists for the HE Monitoring Program. The project was announced on CBC's Daybreak South with Chris Walker, multiple local radio stations and newspapers, and the Alpine Club of Canada shared the project in their newsletter. Despite these announcements, the HE Monitoring Program did not receive the engagement anticipated. Before the 2023 monitoring season begins, Living Lakes Canada will develop methodology to achieve broader participation.

• The accessibility of Upper Joker Lakes when accounting for all of the monitoring equipment needed to implement the HE Monitoring Program was overlooked. Nevertheless, it was a great learning opportunity, and it shone a light on what is and isn't possible in terms of monitoring site locations.

• Living Lakes Canada would like to see the HE Monitoring Program engaging with youth and students. The nature of the HE Monitoring Program offers exciting opportunities for youth and students to engage in science in the outdoors, particularly in backcountry and alpine spaces. The HE Monitoring Program is currently exploring ways to make this happen in 2023.

Living Lakes Canada intends to continue to expand this program to include additional areas over the coming years, continuing to adapt and refine the methodology.

The HE Monitoring Program, in conjunction with CBWMF, provides a proven example for other watersheds to support local and regional efforts to increase adaptation options and support the long-term viability of natural ecosystems and ecosystem services. The watershed security and adaptation work being facilitated by Living Lakes Canada in the Canadian Columbia Basin can serve as a paradigm-changing template for other regions.

APPENDIX A

Monitoring objectives completed at monitoring sites in 2022 and monitoring objectives for 2023

Lake Name	Monitoring objectives completed in 2022	Monitoring objectives that will be completed in 2023
Sapphire Lake/ Lemon Creek	· 80% Bathymetric mapping · Level logger/ barometric logger · Biomonitoring on lower Lemon Creek	· Complete bathymetric mapping · Level logger/barometric logger · Stringed temp/light sensors · 3x Depth profiles · Lake water sampling (chemical/biological) · 3x Spot sampling on upper/ lower Lemon Creek · Biomonitoring on upper/ lower Lemon Creek
Tanal Lake/ Enterprise Creek	· 80% Bathymetric mapping · Level logger/ barometric logger	· Complete bathymetric mapping · Level logger/barometric logger · Stringed temp/light sensors · 3x Depth profiles · Lake water sampling (chemical/biological) · 3x Spot sampling on upper/ lower Lemon Creek · Biomonitoring on upper/ lower Enterprise Creek
Upper Joker Lake	· 90% Bathymetric mapping · Level logger/barometric logger data · Temperature/Light logger string installed (1-meter intervals)	Monitoring will not be repeated on Upper Joker Lakes in 2023
Shannon Lake/ Huss Creek	· 25% Bathymetric mapping · Biomonitoring on upper Huss Creek	· Complete bathymetric mapping · Level logger/barometric logger · Stringed temp/light sensors · 3x Depth profiles · Lake water sampling (chemical/biological) · 3x Spot sampling on upper/ lower Huss Creek · Biomonitoring on upper/ lower Huss Creek

Lake Name	Monitoring objectives completed in 2022	Monitoring objectives that will be completed in 2023
Upper Fletcher	· Temperature/Light logger string installed (1-meter intervals)	· Temperature/Light logger string installed (1-meter intervals) · 3x depth profiles · Additional monitoring will be subject to budget
Ben Hur	· Temperature/Light logger string installed (1-meter intervals)	· Temperature/Light logger string installed (1-meter intervals) · 3x depth profiles · Additional monitoring will be subject to budget
Unnamed Lake	Monitoring to being 2023	· Complete bathymetric mapping · Level logger/barometric logger · Stringed temp/light sensors · 3x Depth profiles · Lake water sampling (chemical/biological) · 3x Spot sampling on upper/lower Glacier Creek · Biomonitoring on upper/lower Glacier Creek
Talus Lodge Lakes	Monitoring to begin 2023	· Temperature/Light logger string installed (1-meter intervals) · Additional monitoring will be subject to budget
Fishermaiden Lake/ Silverton Creek	· Lake Monitoring to begin 2023 · Biomonitoring on lower Silverton Creek	· Complete bathymetric mapping · Level logger/barometric logger · Stringed temp/light sensors · 3x Depth profiles · Lake water sampling (chemical/biological) · 3x Spot sampling on upper/lower Silverton Creek · Biomonitoring on upper/lower Silverton Creek

ENDNOTES

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