Pilot Collaborative Water Monitoring Program, Northeastern British Columbia (NTS 094A and Parts of 093O, P, 094B, G, H): Year Two Update

R.L. Rolick, British Columbia Oil and Gas Commission, Fort St. John, British Columbia, ryan.rolick@bcogc.ca

S.L. Lapp, Climaterra Consulting Ltd., Fort St. John, British Columbia

E.G. Johnson, British Columbia Ministry of Energy, Mines and Low Carbon Innovation, Victoria, British Columbia

D.L. Cottrell, Shell Canada Ltd., Calgary, Alberta

W.T. Van Dijk, Matrix Solutions Inc., Edmonton, Alberta

B. Shepherd, Matrix Solutions Inc., Grande Prairie, Alberta

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Program Background

The Pilot Collaborative Water Monitoring Program was initiated in 2020 to address needs identified during projects such as British Columbia's (BC) Provincial Regional Strategic Environmental Assessment and Northeast Water Strategy, and findings in the *Scientific Review of Hydraulic Fracturing in British Columbia* (Scientific Hydraulic Fracturing Review Panel, 2019). The collaboration involves three Geoscience BC water projects aimed at further understanding the hydrological, hydrogeological and climatic interactions in northeastern BC, and incorporating Traditional Knowledge into this understanding.

1) Northeast B.C. Hydrometric Monitoring Project (Project 2019-016): installation of five hydrometric stations to measure surface water quantity.
2) Co-ordinated Groundwater, Surface Water and Climate Monitoring Program, Northeast B.C. (Project 2019-023): co-location of supplemental monitoring to greatly expand collected knowledge at the monitoring sites, increase the opportunity for research and understanding into watershed processes, and increase the capacity and participation of local First Nations as a partner in water monitoring. Supplemental monitoring includes the installation of groundwater monitoring wells for water quantity and quality where it is anticipated there will be groundwater–surface water interaction; surface water quality monitoring, including benthic invertebrate sampling; installation or improvement of local climate stations to monitor factors that affect surface and groundwater, such as rainfall, snowfall, humidity, wind and solar radiation; and training of local First Nations to capture data and maintain equipment.
3) Traditional Knowledge Project (Project 2019-018): an innovative venture to bridge communication barriers and gain understanding through the gathering of Traditional Knowledge at each monitoring site at specific seasonal times, with the goal to braid Traditional Knowledge with Western-style scientific observations.

By co-locating groundwater monitoring stations near hydrometric stations, particularly at sites identified as regional data gaps, not only are project costs reduced, but the research will hopefully answer several key questions with the datasets produced (groundwater quantity and quality, surface water quantity and quality, and climate data). This approach will maximize the return on 'foundational science' through a more complete baseline monitoring program, which will augment the existing approved Surface Water Quantity Monitoring and Traditional Knowledge programs. The baseline data will allow for advanced analysis to support assessment of groundwater–surface water interaction, watershed water balance calculations and meteorological data, to support a variety of assessments.

Project Updates

This program was initiated with a virtual kick-off workshop on December 2, 2020, with the six Treaty 8 First Nations (FN) located within the study area boundary in attendance, along with program partners from the BC Oil and Gas Commission, the BC Ministry of Energy, Mines and Low Carbon Innovation, Shell Canada Ltd., Matrix Solutions Inc. (Matrix) and Geoscience BC. The six First Nation communities included Blueberry River First Nations (BRFN), Doig River First Nation (DRFN), Halfway River First Nation (HRFN), McLeod Lake Indian Band (MLIB),

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Saulteau First Nations (SFN) and West Moberly First Nations (WMFN). All First Nations expressed interest in participating in the research and monitoring partnership, and in joining program staff during field site visits. Participation in field site visits decreased in 2022 to five First Nations, with WMFN not participating.

With most of the monitoring infrastructure installed by the fall of 2021, a fair amount of data were collected in 2022, with site visits to each station scheduled and co-ordinated directly with each respective First Nation. Hydrometric monitoring was conducted monthly between April and October. Four groundwater monitoring wells were drilled and installed in March 2022, and groundwater monitoring was conducted in the spring and fall of 2022. Surface water quality samples were collected in June of 2022 to add summer sampling data to the fall and early winter samples collected in 2021. A spring sample will be collected in early 2023 to ensure sampling is carried out during all four seasons at each monitoring location.

Climate data were collected from two new stations installed in late 2021, at Stewart Creek and Alexander Creek, and two additional stations were partially installed at the Blueberry River and Doig River (upgrades to the BC Wildfire Service's [BCWS] Osborn wildfire climate station) sites in late 2022. Due to supply-chain manufacturing delays for some of the sensors, the Blueberry River and Doig River station installations will not be completed until 2023.

Site Criteria

Sites identified and with all necessary instrumentation installed in 2021 were monitored throughout the 2022 open-water season. No additional sites are anticipated to be added to the network at this time. Please refer to Lapp et al. (2022) for an explanation of the criteria for site selection. Table 1 summarizes details of the hydrometric monitoring stations and Figure 1 shows their location.

Ongoing Monitoring

Hydrometric Stations

A total of five hydrometric stations were installed in the late summer and early fall of 2021. In April 2022, the stations were set to record the spring freshet and were then visited monthly to collect manual discharge measurements. First Nation community members were invited to participate in the equipment installation and ongoing monitoring of the station associated with their community. Water Officers from BC's Ministry of Forests (MOF), based in Fort St. John, also participated in the installation of the stations and monitoring of water quantity at these locations. At each hydrometric station, the equipment consists of OTT HydroMet GmbH's OTT PLS sensors with Sutron XLink 100 loggers. A final field visit to each of the stations was conducted in October 2022, to winterize them. The photos in Figure 2 show a variety of the hydrometric monitoring activities at each station.

Groundwater Wells

Groundwater monitoring wells were installed at four locations (Blueberry River, Alexander Creek, Stewart Creek and Hulcross Creek) in March 2022, immediately following the issuance of permits from MOF. The wells were drilled and installed using an air rotary drilling rig supplied by Anderson Water Services Ltd. of Fort St John, under the supervision of Matrix field staff (Figure 3). Each well was constructed to meet the requirements of the Provincial Groundwater Observation Well Network, including 3-inch-diameter PVC well casing. A dedicated pressure transducer was deployed in each monitoring well to collect continuous groundwater level data. The transducer data were calibrated to a reference point by measuring the depth of the water level during groundwater monitoring events.

Groundwater quality samples were collected from the wells twice in 2022 (June and October). Prior to sample collection, each well was purged of stagnant water using a submersible pump or bailer to allow the inflow of formation water, a process referred to as 'well development' in the sections below.

The hydraulic conductivity of the screened formation was assessed in 2022 by conducting a slug test or pumping test at each well.

The purpose of water wells is to monitor the groundwater level in the shallow subsurface (unconfined aquifer), monitor water quality in shallow groundwater, and ultimately, in co-ordination with the surface water and climate monitoring, provide information about surface water–groundwater

Table 1. Summary of the site locations and associated First Nation communities. All co-ordinates are in UTM Zone 10N, NAD83. Abbreviations: BRFN, Blueberry River First Nations; DRFN, Doig River First Nation; HRFN, Halfway River First Nation; MLIB, McLeod Lake Indian Band; SFN, Saulteau First Nations; WMFN, West Moberly First Nations.

Location	First Nation	Easting	Northing
Blueberry River on Mile 98 Road	BRFN	578627	6290276
Doig River at Doig River First Nation	DRFN	653587	6273135
Alexander Creek on Mile 95 Road	HRFN	574248	6271384
Stewart Creek at Stewart Lake Road	MLIB	620969	6201392
Hulcross Creek on Moberly Forest Service Road	SFN/WMFN	563289	6181243

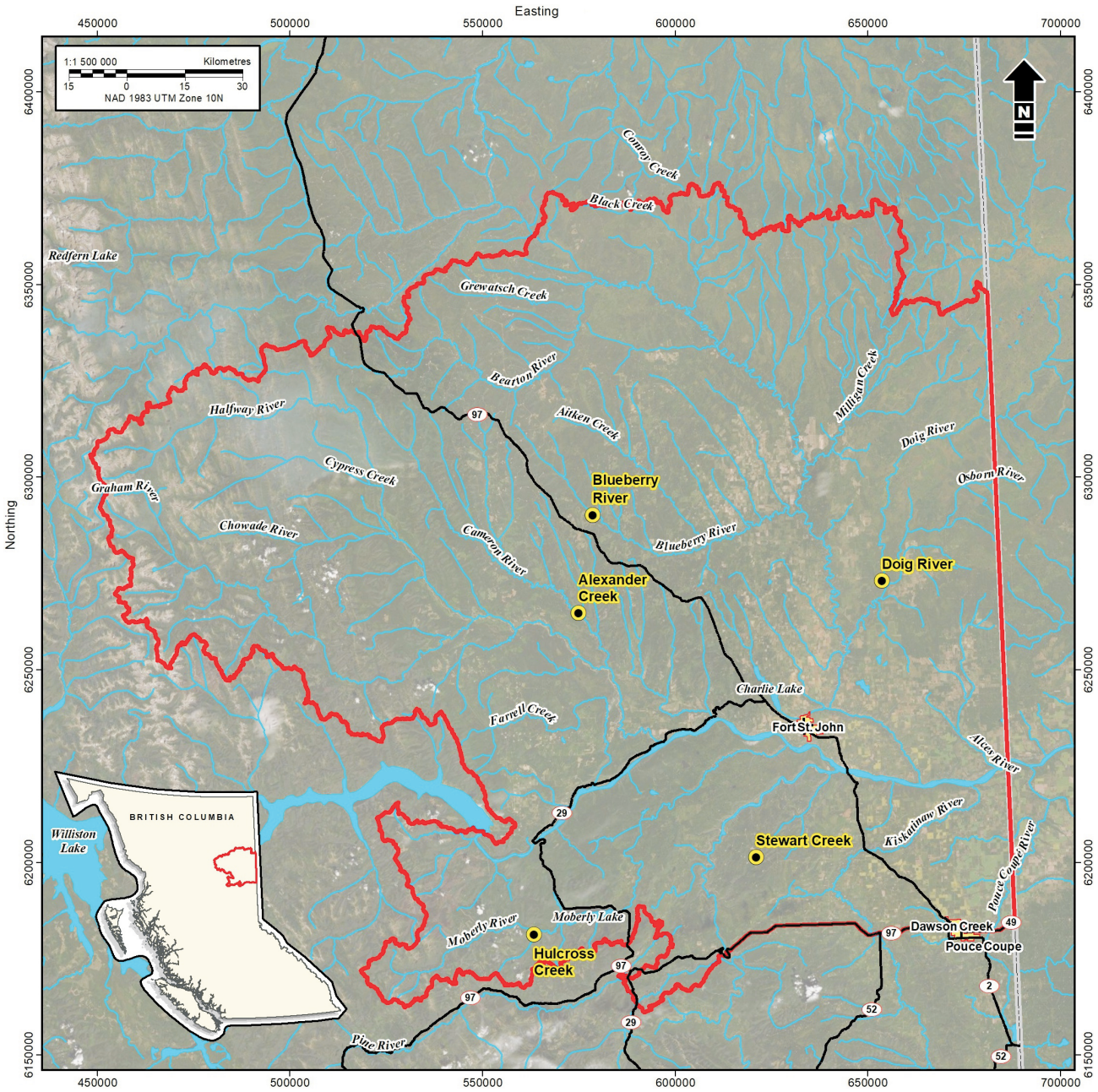

Figure 1. Location of the study area (outlined in red) and water monitoring sites (highlighted in yellow).

interaction. As such, wells were sited proximal to hydrometric stations. Some locations provided the added opportunity for testing the possible existence of a paleovalley at a slightly deeper horizon. Paleovalley research in this region has been supported by Geoscience BC with mapping, airborne geophysics, ground-based geophysics and drilling. Where possible, water wells were drilled to sufficient depths to confirm the presence of predicted paleovalleys.

Water Quality

There is general consensus that insufficient water quality monitoring data exist in northeastern BC (Northeast Water Strategy, 2017, 2018). Sampling water quality in conjunction with stream volume helps identify any linked parameters, such as dissolved solids and dissolved oxygen. The original program proposed water quality sampling at monitoring sites through four time frames during the open-water season (one in spring, two in summer, and one in fall). Surface water quality monitoring in 2021 was planned for all five monitoring locations during the four time frames; however, due to the time required to select and establish the monitoring sites and receive program consensus earlier in the year, sampling was only completed twice (August and October) at all but the Stewart Creek location (October only). For that reason, further sampling was required in

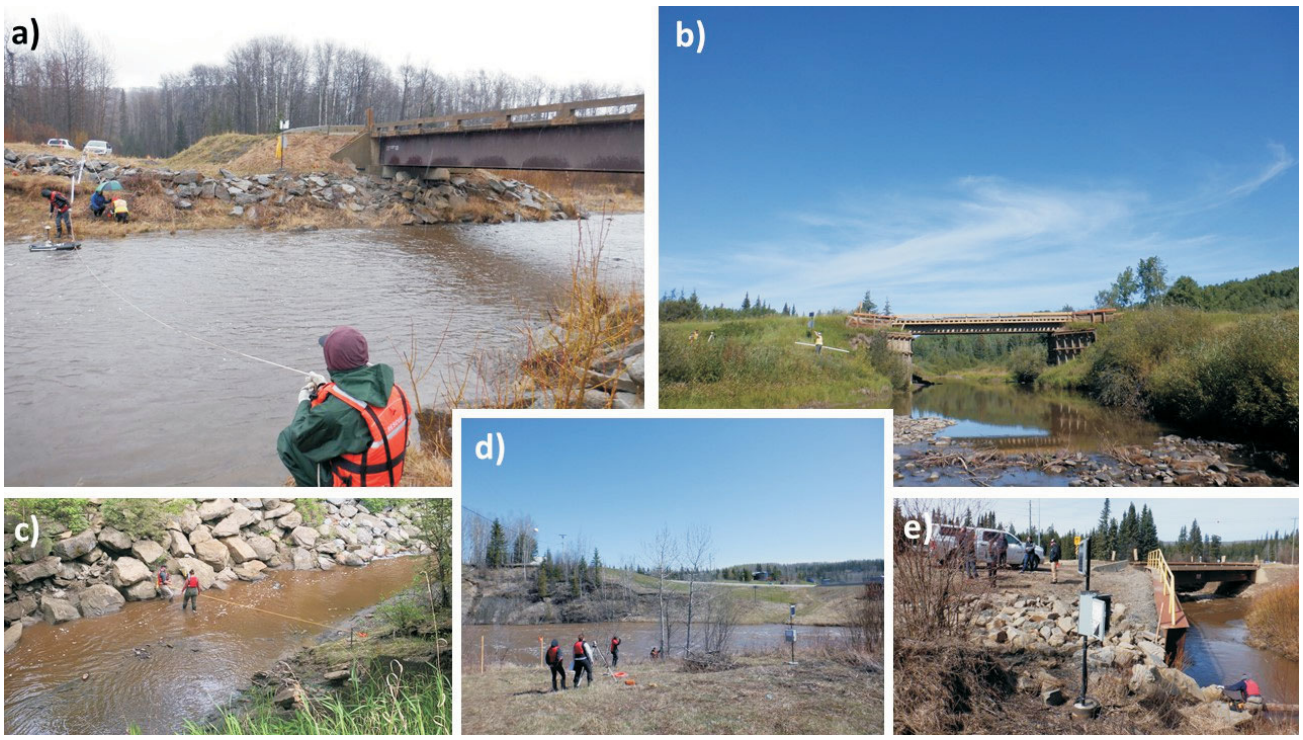

Figure 2. Hydrometric station equipment and monitoring activity at **a)** Hulcross Creek, **b)** Blueberry River, **c)** Alexander Creek, **d)** Doig River and **e)** Stewart Creek.

2022; however, it was decided that collecting a sample during each of the four major seasons (spring, summer, fall and winter) would provide a better understanding of seasonality in surface water chemistry at each monitoring location. Information about the sampling completed is detailed in the sections below. Surface water quality monitoring for the program includes sampling both field and laboratory parameters. Routine field parameters sampled include dissolved oxygen, temperature, pH and electrical conductivity; laboratory parameters sampled include the same routine field parameters in addition to turbidity, major ions, total and dissolved metals, total organic carbon, coliforms and total plate count, biochemical and chemical oxygen demand, and hydrocarbons.

In order to collect further information on aquatic ecosystem health at each monitoring location, in addition to water quality sampling, benthic invertebrate sampling was proposed at the start of the program for two monitoring sites, following the Canadian Aquatic Biomonitoring Network (CABIN) protocol. It was determined in 2021 that Matrix would investigate site suitability and benthic community diversity at all monitoring locations using CABIN methods. Information on benthic invertebrates was collected in 2021 at or near four of the monitoring sites. The results will be entered into the national CABIN database, and compared to other sites and models (including provincial datasets) to determine their overall suitability for further monitoring and evaluation of relative stream health. The CABIN program assesses the aquatic health of streams through the collection of benthic invertebrate samples. Benthic invertebrate sampling at the selected sites was completed by a CABIN-certified Matrix staff member.

Due to program delays and associated cost implications, and considering the sampling already completed in 2021, it was determined that no further CABIN sampling would be completed in 2022. Determination of future assessments will be made based on results of the 2021 assessments.

Climate Stations

Climate data will be used to support assessment of the water balance at each of the monitoring sites. Climate data parameters include precipitation and snow, air temperature, wind speed and direction, barometric pressure, and relative humidity. Climate stations do not need to be situated at the exact location as the hydrometric sites and monitoring wells because of the regional nature of weather systems; climate measurements in the vicinity of a monitoring site are sufficient for research needs. Additionally, climate monitoring results are superior when the station is located away from road activity, in a sheltered spot where it is not unduly influenced by wind; the hydrometric and groundwater sites are located near active roadways. Equipment to allow remote data collection at the stations has not been installed at this time, so data are manually collected, at minimum every three months, or more often as time/budget permits. Climate stations were installed using a combination of

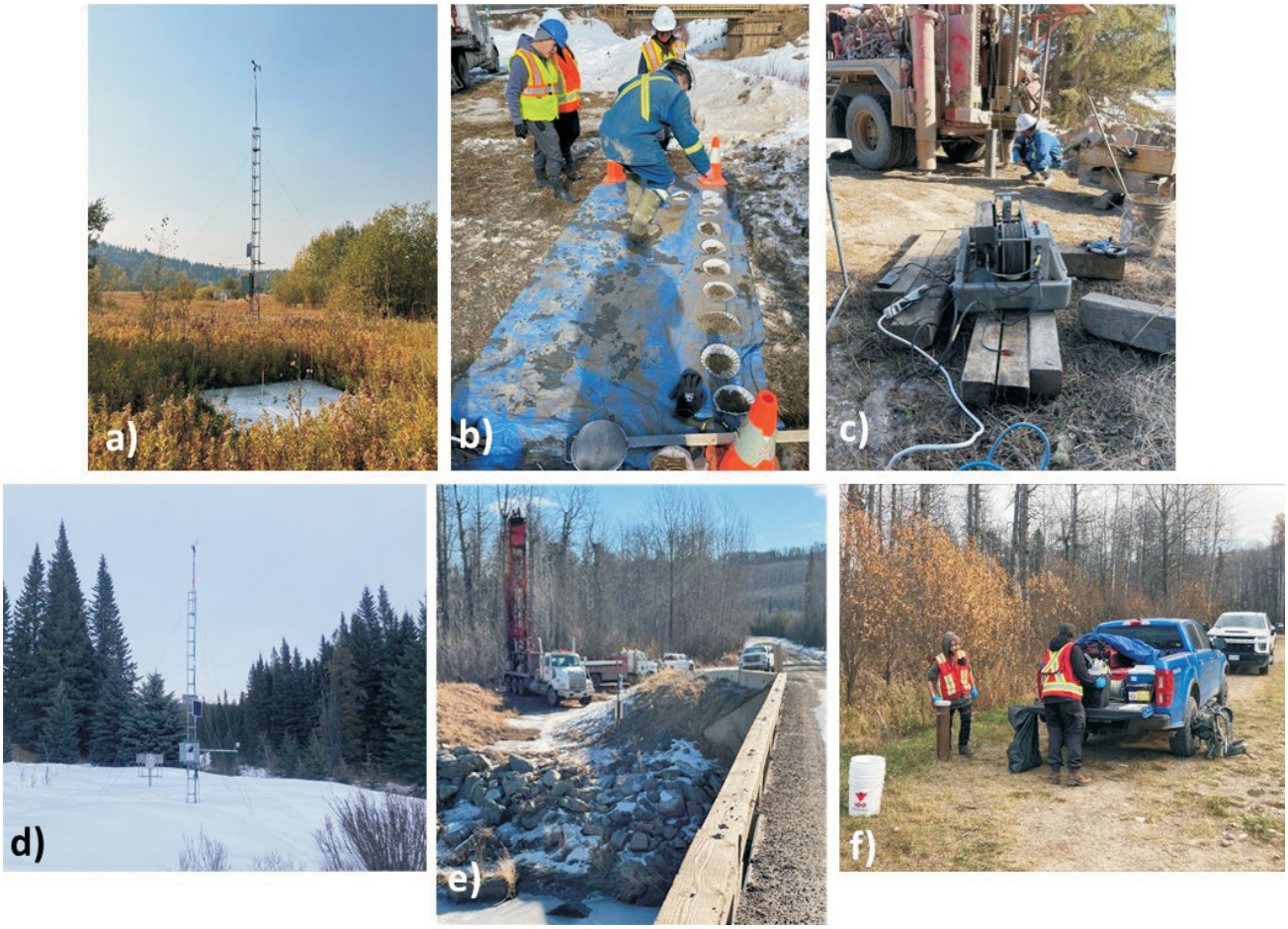

Figure 3. Examples of monitoring sites and Matrix Solutions Inc.'s well installation and monitoring: **a)** Alexander Creek climate station; September 15, 2022; **b)** examining drill cuttings during installation of the Blueberry River groundwater well; March 15, 2022; **c)** Stewart Creek groundwater well installation; March 18, 2022; **d)** Stewart Creek climate station; March 11, 2022; **e)** Hulcross Creek groundwater well installation; March 20, 2022; **f)** Hulcross Creek groundwater sampling; October 18, 2022.

provincial and federal government criteria for siting sensors.

Table 2 shows a summary of the monitoring completed in 2022 at each site, as discussed above.

Site Status

Blueberry River at Mile 98 Road

This site is within 10 km of the community of Wonowon, which marks the site of Mile 101 on the historic Alaska Highway (Highway 97 on Figure 1). The contributing watershed area is 312 km^2. The hydrometric station was set to start recording on April 6, 2022, and subsequent streamflow measurements were conducted on May 18, June 22, August 4 and 17, September 22 and October 6, 2022. The station was decommissioned for winter during the October 6 visit and will be restarted in April 2023 to capture spring freshet.

Matrix completed surface water quality and CABIN sampling on August 17, 2021 with two members from BRFN. At that time, Matrix learned BRFN had already established a CABIN monitoring site at this same location in 2019, and members of the BRFN intend to continue their CABIN sampling program at this site with staff who have been trained by CABIN. For the purpose of the co-ordinated program, Matrix also collected CABIN samples at this site, and have shared the initial results with BRFN.

Surface water quality was sampled a second time on October 20, 2021, and again on June 22, 2022. Water quality sampling will be completed a final time in spring of 2023.

Climate data for the Blueberry River site were sourced from regional climate monitoring stations for the years 2020, 2021 and 2022. Matrix began installation of a new climate station at the Blueberry River monitoring site in fall 2022, but will not be able to complete the installation of all monitoring equipment until early 2023 due to manufacturer supply-chain delays.

A groundwater monitoring well was installed at the Blueberry River location on March 15–16, 2022. The well

Table 2. Summary of monitoring being carried out at each location. An 'X' in a cell indicates that type of monitoring is being carried out at that site. Abbreviations: BRFN, Blueberry River First Nations; CABIN, Canadian Aquatic Biomonitoring Network; DRFN, Doig River First Nation; HRFN, Halfway River First Nation; MLIB, McLeod Lake Indian Band; SFN, Saulteau First Nations; WMFN, West Moberly First Nations.

Location	First Nation	Hydrometric station	Groundwater well	Water quality	CABIN[1]	Climate station
Blueberry River on Mile 98 Road	BRFN	X	X	X	X	Regional[2]
Doig River at Doig River First Nation	DRFN	X		X	X	Regional[3]
Alexander Creek on Mile 95 Road	HRFN	X	X	X	X	X
Stewart Creek at Stewart Lake Road	MLIB	X	X	X	X	X
Hulcross Creek on Moberly Forest Service Road	SFN/WMFN	X	X	X	X	Regional

[1]Each site is being assessed for CABIN suitability.

[2]Climate station installation began in late 2022 and will be finished in spring 2023.

[3]Matrix Solutions Inc. will add additional sensors to the BC Ministry of Forests' Osborn wildfire station for this program. Upgrades began in late 2022 and will be finished in spring 2023.

screen was installed at a depth of 33.5 to 36.5 m below ground level (BGL), within bedrock of the Dunvegan Formation. Well development was conducted by airlifting with Anderson Water Services on April 11, 2022. A pressure-logging instrument (Solinst Levelogger) was deployed to collect continuous water level data. Groundwater was monitored twice in 2022: 1) on June 22 an electrical submersible pump was used to collect groundwater samples, and a pumping test was conducted to estimate the hydraulic conductivity of the aquifer; 2) collection of water level data and groundwater sampling using a submersible pump were carried out on October 17.

Doig River at Doig River First Nation

The site is located within the Doig River First Nation community, approximately 200 m from the band office. The contributing watershed area is 416 km^2. The station was set to start recording on April 8, 2022, and subsequent streamflow measurements were conducted on May 20, June 23, July 20, August 11, September 23 and October 7, 2022. The station was decommissioned for winter during the October 7 visit and will be restarted in April 2023 to capture spring freshet.

Matrix completed surface water quality and CABIN sampling at Doig River on August 18, 2021, which coincided with the hydrometric station installation. Water quality was sampled a second time on October 20, 2021, and again on June 23, 2022. Surface water quality will be sampled a final time in spring of 2023.

Climate data for the Doig River site were sourced from regional climate monitoring stations for the years 2020, 2021 and 2022. When this report was being written, Matrix had a tentative agreement with the managers of BCWS climate monitoring division to add sensors to their Osborn climate station, located approximately 7.5 km southeast of this program's monitoring site. Providing the agreement is fully executed, Matrix will begin installing additional sensors at the Osborn station in the fall of 2022 and complete the upgrades in early 2023, once all sensors are received from the manufacturer.

Alexander Creek at Mile 95 Road

The site is within 15 km of the Halfway River First Nation. The contributing watershed area is 134 km^2. The station was set to start recording on April 13, 2022, with subsequent streamflow measurements conducted on May 16, June 16, July 25, August 18 and September 15, 2022, with the last visit and winter decommission planned for October 19, 2022. The station will be restarted in April 2023 to capture spring freshet.

Matrix completed surface water quality and CABIN sampling on August 17, 2021, which coincided with the hydrometric station installation. Three representatives from HRFN were present at the time of the site visit. Surface water quality was sampled a second time on October 20, 2021, and again on June 16, 2022. Water quality will be sampled a final time in spring of 2023.

A new climate station was installed in early November 2021, approximately 1.5 km west of the Alexander Creek monitoring site. The climate station is equipped with sensors to record air temperature, year-round precipitation, snow-water equivalent, wind, relative humidity and barometric pressure. Regional climate data will be used to supplement and compare to data collected at the program's climate station.

A groundwater monitoring well was installed at the Alexander Creek location on March 17, 2022. The well screen was installed at a depth of 3.0 to 6.1 m BGL, within a unit of sand and gravel. Well development was conducted by bailing the well, and a pressure-logging instrument (Solinst Levelogger) was deployed in the well on March 23, 2022. Groundwater monitoring was conducted on June 16, 2022; the well was purged and sampled using a bailer, and a slug test was conducted to estimate the hydraulic conductivity of the aquifer. Groundwater was monitored a second time

on October 17, 2022, and included collection of water level data and groundwater sampling using a bailer.

Stewart Creek at Stewart Lake Road

The station is located within the MLIB summer area and south of Stewart Lake. The contributing watershed area is 24 km^2. The hydrometric station was set to start recording on April 14, 2022, with subsequent streamflow measurements conducted on May 17, June 17, July 26, August 19 and September 16, 2022, with the last visit and winter decommission planned for October 20, 2022. The station will be restarted in April 2023 to capture spring freshet.

Water quality was sampled on October 21, 2021 and June 17, 2022. Water quality at this site will be sampled again in late fall 2022 and spring 2023.

A new climate station was installed approximately 0.5 km west of the Stewart Creek monitoring site in early November 2021. The climate station is equipped with sensors to record air temperature, year-round precipitation, snow-water equivalent, wind, relative humidity and barometric pressure.

A groundwater monitoring well was installed at the Stewart Creek location on March 18, 2022. The well screen was installed at a depth of 18.3 to 19.8 m BGL, within glacial till. Well development was conducted by purging with a submersible pump on April 5, 2022. A pressure-logging instrument (Solinst Levelogger) was deployed to collect continuous water level data. Groundwater was monitored twice in 2022: 1) on June 17 the well was purged and sampled using an electric submersible pump, and a slug test was conducted to estimate the hydraulic conductivity of the aquifer; 2) water level data were collected and groundwater sampling using a purge pump and bailer was carried out on October 18.

Hulcross Creek at Moberly Forest Service Road

The Hulcross Creek site is located west of the West Moberly and Saulteau First Nations, within the Moberly Lake watershed. The contributing watershed area is 132 km^2. The hydrometric station was set to start recording on April 5, 2022, with subsequent streamflow measurements conducted on May 19, June 27, July 27, August 29, September 20 and October 5, 2022. As the stream was open and flowing during the April 5 visit, an additional flow measurement was conducted at that time. The station was decommissioned for winter during the October 5 visit and will be restarted in April 2023 to capture spring freshet.

Matrix completed surface water quality sampling at Hulcross Creek on August 25 and October 21, 2021, and July 18, 2022. Final sampling will be completed in spring of 2023.

Benthic invertebrate sampling to collect CABIN data was conducted by Matrix on August 17, 2021; however, due to a location error, the work was completed at Dixie Creek, located east of Hulcross Creek. Despite the location error, the CABIN results will be shared with SFN and WMFN, as it may be of value for other watershed studies.

Regional climate data for the Hulcross Creek monitoring site for 2020, 2021 and 2022 will be sourced from Environment and Climate Change Canada's climate monitoring station at the Chetwynd airport, approximately 25 km to the southeast.

A groundwater monitoring well was installed at the Hulcross Creek location on March 18–19, 2022. A borehole was drilled to a depth of 47.8 m without encountering bedrock. After encountering borehole stability issues, the first borehole was plugged and an adjacent borehole was drilled for the installation of a monitoring well. The well was screened at a depth of 3.0 to 4.5 m BGL, within a unit of sand and gravel. Well development was conducted by bailing the well, and a pressure-logging instrument (Solinst Levelogger) was deployed in the well on April 8, 2022. Groundwater was monitored twice in 2022: 1) on July 18 the well was sampled using a bailer, and a slug test was conducted to estimate the hydraulic conductivity of the aquifer; 2) water level data were collected and the groundwater was sampled using a bailer on October 17.

Traditional Knowledge

This project seeks to include a holistic understanding of First Nation values, and their relationship with water. The McLeod Lake Indian Band and the Halfway River First Nations agreed to participate in the Traditional Knowledge–gathering project. On May 17, 2022, a field visit to the Stewart Creek hydrometric station was conducted with two members of the MLIB. The discussions included the historical use and importance of the area to the MLIB, and the traditional practices conducted in the area. A lot of conversation focused on the impact to water quality and quantity from development and land-use changes. Due to travel restrictions related to COVID-19, MLIB members who live on reserve were unable to attend the field visit, so a follow-up community meeting was held later that same day, with the project team brought in virtually, to hear the community's stories and view of water.

A separate meeting was also held with the HRFN, on May 16, 2022. The morning session included First Nation staff and a couple of elders sharing stories about and uses of water. There was also a discussion around environmental indicators of drought and changes in water quality. The afternoon was spent at the Alexander Creek hydrometric station, which included additional elders, with the focus on historical uses of water and changes to water associated with development.

At both the Stewart Creek and Alexander Creek field days, the First Nation members were able to watch and learn how streamflow measurements are taken. Follow-up meetings will be planned during the winter of 2022–23, with an optional field trip in the summer of 2023 to collect additional Traditional Knowledge with both communities. A final report will be prepared as part of the end of the project, scheduled for December 2023.

Summary and Next Steps

The program moved successfully forward in 2022, with a full season of monitoring for hydrometrics, and partial data collection for water quality and groundwater. Climate stations were installed and data were collected at the Alexander Creek and Stewart Creek sites, while installation of climate stations at the Blueberry River monitoring site and southeast of the Doig River monitoring site will commence in late fall 2022. The project team was able to successfully engage with five of the six First Nation communities within the study area for participation in monitoring activities at the five locations.

Hydrometric

Hydrometric data for the open-water season of 2022 (April to October) were collected at all five stations. During the winter of 2022–23 the data will be processed in accordance with the standards of BC's Resources Information Standards Committee (Resources Information Standards Committee, 2018), and posted for the public to access through the BC Water Portal (www.waterportal.geoweb.bcogc.ca) and the provincial database Aquarius (https://aqrt.nrs.gov.bc.ca). With funding expected to be extended to December 2023, the hydrometric stations will be reinstated in the spring to capture a full open-water season of data, including freshet.

Water Quality

Over the winter of 2022–23, Matrix will begin to tabulate and compare sampling results at all five monitoring locations. With funding extended to December 2023, additional sampling will be completed in the spring and summer of 2023. Full results will be tabulated, analyzed for trends, and summarized in the final report at the end of 2023.

Climate

As mentioned above, installation of the two remaining climate stations—at Blueberry River and Doig River—will begin in late 2022 and continue into 2023. Over the winter of 2022–23, Matrix will begin to summarize and compare climate data from all five monitoring locations, supplemented with regional climate data. Full results will be analyzed for trends and summarized or compared in the final report at the end of 2023.

Groundwater

In spring 2023, groundwater sampling will be completed at each site a final time. The groundwater data, including borehole logs, groundwater quality, hydraulic conductivity testing and groundwater levels, will be compiled and compared against climate and hydrometric data.

First Nations Training

Training of First Nations community members was delivered in 2022 to develop skills and facilitate ongoing participation in the program. Matrix conducted a training webinar covering climate, groundwater and water quality sampling on April 7, 2022. A training day for hydrometric monitoring was delivered on September 21, 2022, with assistance from staff from the BC Ministry of Environment and Climate Change Strategy. This consisted of a classroom-based training session, followed by field-based training, and covered all aspects of hydrometric monitoring.

The program team has requested and received an extension to the project completion date from Geoscience BC to December 2023, to ensure another full season of monitoring can be completed in 2023. The team is also exploring future funding options, to ensure the monitoring continues past the expiration of the Geoscience BC funding.

All project findings will be published in a final report, scheduled for December 2023.

Acknowledgments

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