Site C Clean Energy Project Agriculture Monitoring and Follow-up Program 2020 Annual Report

Prepared in accordance with the Agricultural Monitoring and Follow-up Program (December 22, 2015)
2020 Annual Report Submission Date: July 21, 2020

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1.0 Background

The Site C Clean Energy Project (the Project) is a hydroelectric dam and generating station under construction in northeast B.C. Construction started in July 2015 and will be in service in 2024. The Project will help meet future electricity needs by providing 1,100 megawatts of dependable capacity, and producing about 5,100 gigawatt hours of energy each year — enough to power the equivalent of 450,000 homes per year. Once built, the Project will be a source of clean, reliable and cost-effective electricity in B.C. for more than 100 years.

The key components of the Project are:

- Access roads and a temporary construction bridge across the river, at the dam site.
- Worker accommodation at the dam site.
- Upgrades to 240, 269, 271 and Old Fort roads.
- The realignment of six segments of Highway 29.
- Two temporary cofferdams across the river to allow for construction of the earthfill dam.
- Two new 500 kilovolt transmission lines connecting Site C to the Peace Canyon Substation, within an existing right-of-way.
- Shoreline protection at Hudson's Hope, including upgrades to DA Thomas Road.
- An 800-metre roller-compacted-concrete buttress to enhance seismic protection.
- An earthfill dam, approximately 1,050 metres long and 60 metres high above the riverbed.
- A generating station with six 183 MW generating units.
- An 83-kilometre-long reservoir that will be, on average, two to three times the width of the current river.

2.0 Environmental Assessment Certificate Conditions

Condition 31 of the Environmental Assessment Certificate (EAC) requires the following:

> *"The Agriculture Monitoring and Follow-up Program must include at least the following:*
>
> *Monitoring for Project-induced changes in wildlife habitat utilization, and evaluation of associated crop or feed storage damage for, agricultural operations within 5 km of the reservoir, to assess if there is an increase in wildlife-related crop depredation due to Project-related habitat losses. Monitoring must include pre- and post- reservoir filling field surveys, wildlife monitoring, farm operator interviews, and analysis of relevant records related to wildlife-related crop depredation.*
>
> *Monitoring for Project-induced changes to humidity within 3 km of the reservoir, and evaluate associated effects on crop drying within this area. Monitoring must include collection and analysis of climate data, calculation of crop drying indices, and farm operator interviews.*
>
> *Monitoring for Project-induced changes to groundwater elevations within 2 km of the reservoir (the area potentially influenced by groundwater elevation changes), and evaluate*

associated effects on crop productivity. Monitoring must include field surveys and farm operator interviews.

Monitoring for climatic factors to estimate moisture deficits and to estimate irrigation water requirements in the vicinity of the reservoir to provide information for potential future irrigation projects. Data collection will be undertaken before reservoir filling, and in the 5 years after reservoir filling, and data will be reviewed as required for proposed irrigation projects.

The Agriculture Monitoring and Follow-up Program reports must be provided annually during the monitoring and follow-up period to affected agricultural land owners and tenure holders, and Ministry of Agriculture.

The results of the Agriculture Monitoring and Follow-up Program must inform the Farm Mitigation Plans.

Reporting must begin 180 days after the commencement of the monitoring and follow-up program that is to begin 180 days after commencement of construction.

The EAC Holder must provide this draft Agriculture Monitoring and Follow-up Program to the Ministry of Agriculture, Peace River Regional District and the District of Hudson's Hope for review within 90 days after the commencement of construction. The EAC Holder must file the final Agriculture Monitoring and Follow-up Program with EAO, Ministry of Agriculture, Peace River Regional District and the District of Hudson's Hope within 150 days of commencement of construction.

The EAC Holder must develop, implement and adhere to the final Agriculture Monitoring and Follow-up Program, and any amendments, to the satisfaction of EAO."

3.0 Agriculture Monitoring and Follow-up Program Overview

BC Hydro described the approach required by the above condition in the Agriculture Monitoring and Follow-up Program ("AMAFP"), submitted as final on December 22, 2015. The AMAFP was developed and has been implemented in accordance with Condition 31 of EAC #14-02, dated 14 October 2014, which was issued in respect of the Project.

Regarding the schedule presented in the AMAFP and those presented in this report (and previous Annual Reports), the discrepancy is due to the change to reservoir filling schedule that occurred in 2017. The most current project schedule dated February 2020 can be found on the Site C Project website here:

https://www.sitecproject.com/sites/default/files/construction-schedule-202002.pdf

The Project's Environmental Assessment assessed how the creation of the reservoir may result in site-specific changes that may affect agricultural operations on individual farm operations, and where Project effects on agricultural operations are not already addressed under agreements with BC Hydro. The monitoring programs, included as described in EAC Condition 31 and the AMAFP, will be used to determine if a Project-induced change has occurred as it relates to the following:

A. Effects on crops and stored feed as a results of changes in wildlife habitat utilization,
B. Effects on crop drying due to changes in humidity, and
C. Effects on crop productivity as a result in changes to groundwater elevations.

Upon completion for the above monitoring programs, the collected data will be evaluated and used to inform Individual Farm Mitigation Plans (where applicable) or on other mitigation measures.

Additional monitoring will occur for climatic factors to:

D. Estimate moisture deficits and irrigation water requirements.

The resulting estimations will be used in supporting future potential decisions regarding irrigation improvements, including support for projects that may be proposed under the Agricultural Mitigation and Compensation Plan.

The AMAFP states that monitoring, analysis and reporting will be undertaken in accordance with the following schedule:

Phase Description	**Timeline**[1]
Historical data review, baseline data collection[2], climate station siting and installation, preparation for field survey, consultation and interviews.	• January 2016 – December 2018
Data collection, field surveys, interviews, consultation, and data analysis.	• Five Years Prior to Reservoir Filling (December 2018 - December 2023) • Five Year Post Reservoir Filling (January 2024 - January 2029)
Annual and Final Reporting	• July 2016 – July 2029

[1] Updated timeline as per 2017 schedule change

[2] Baseline data refers to the continued collection of data from existing climate stations and monitoring sites. As new stations and sites are added, and additional parameters are included at existing stations, this data will be incorporated into reporting as it becomes available.

The AMAFP stated that annual reports on the implementation of the AMAFP will be submitted beginning on July 21, 2016 (360 days after commencement of construction). These reports will include a summary of monitoring plan implementation activities. The annual reports will be posted on BC Hydro's website and notifications sent to affected agricultural land owners and tenure holders, and the Ministry of Agriculture.

4.0 Annual Report Time Period and Format

The 2020 AMAFP Annual Report covers the time period from April 1, 2019 to March 31, 2020 and includes separate updates for each of the monitoring programs:

- Program A – Crop Damage Monitoring Program
- Program B – Crop Drying and Humidity Monitoring Program
- Program C – Groundwater and Crop Productivity Monitoring Program
- Program D – Irrigation Water Requirement Program

Program reporting, included in the appendices as a report or a memo, all employ a similar format:

- Introduction,
- Methods (i.e., study area and program activities),
- Results and analysis,
- Next steps, and
- References

5.0 Summary of Activities

Each of the programs are in the monitoring phase and a summary of each program for the reporting year is provided below.

5.1 Crop Damage Monitoring Program

BC Hydro's Crop Damage Monitoring Program (CDMP) contractor is Blackbird Environmental Ltd. (Blackbird), who developed and implemented activities to monitor for project-induced wildlife habitat utilization, while also evaluating the associated crop and feed storage damage.

During the reporting year, BC Hydro and the project team implemented an outreach program for local agriculture producers to introduce the monitoring program. Interested producers were invited to participate, which included field activities on their holdings beginning with the 2019 growing season and for the 10-year duration of the monitoring program. In total, 49 producers are participating in the program, representing approximately 9,200 hectares or 88% of the land currently utilized for agriculture production in the project area.

Additional activities during the reporting year included:

- Engagement with
  - Ministry of Agriculture (AGRI),
    - Regional Agrologist
    - Agriculture Wildlife Program (AWP) Manager
  - Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD) wildlife biologists, and
  - Regional agricultural producer groups.
- Historical data review of

- AGRI's AWP data,
- Ministry of Transportation and Infrastructure wildlife-vehicle collision reports, and
- FLNRORD wildlife inventory surveys.

One of the key tasks from the reporting year was to identify and select fields to be used as benchmark sites to provide spatial coverage within the Project Area. Benchmark sites have been selected from agriculture fields that are identified to be subject to higher wildlife pressures both pre- and post-inundation. In total, 34 agriculture fields were identified to have the properties required for consideration as a benchmark site.

Based on findings from the reporting year, the following additional monitoring tools are being implemented:

- Field establish benchmark sites,
- Deploy passive camera traps, and
- Deploy exclusion cages.

5.2 Crop Drying and Humidity Monitoring Program

The Crop Drying and Humidity Monitoring Program (CDHMP) scope was assessed and developed in coordination with RWDI; the BC Hydro contractor responsible for climate station operation and management. Program scope was to monitor project-induced changes to humidity and evaluate associated effects within the area.

The climate stations currently available (as of the date of this report) were determined to be appropriate and sufficient for the purposes of the program. These stations monitor climate parameters on an ongoing basis to evaluate if changes occur and how these changes may affect crop drying indices.

5.3 Crop Productivity and Groundwater Monitoring Program

BC Hydro's Crop Productivity and Groundwater Monitoring Program (CPGMP) contractor is Blackbird, who developed and implemented activities to monitor and assess groundwater levels and related change to agricultural crops.

During the reporting year, BC Hydro and the project team implemented the program to meet the monitoring requirements as described in Condition 31. It was determined that the groundwater monitoring wells in the existing BC Hydro network could be employed within the CPGMP in place of installing all new wells. Only one (1) new well was required and installed in the reporting year (October 2019) in Bear Flats; identified to be a data collection gap area.

Blackbird will monitor in-season crop development through remote sensing, supplemented with field visits to assess crop variability in relation to soil moisture factors. Field methodology is being refined based on project experience.

5.4 Irrigation Water Requirements Program

The Irrigation Water Requirements Program (IWRP) was assessed and developed in coordination with RDWI.

The climate stations currently available (as of the date of this report) were determined to be appropriate and sufficient for the purposes of the program. These stations monitor climate parameters on an ongoing basis which will be available, when required, to support future proposed irrigation projects.

Appendix A – Crop Damage Monitoring Program Report

2020 Annual Report
Site C Clean Energy Project
Crop Damage Monitoring Program

BC Hydro and Power Authority

Blackbird Environmental Ltd.

July 20, 2020

Final Report – Rev. 0

Blackbird File No.: 19002

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Table of Revisions

Revision No.	Date	Reason/Type of Revision
R0	July 20, 2020	Original report issued

1 Introduction

1.1 Project Background

The Site C Clean Energy Project (the Project) is a hydroelectric dam and generating station under construction in northeast British Columbia (BC). Construction started in July 2015 and the project is anticipated to be in service in 2024 (BC Hydro 2020).

1.2 Regulatory Context

During the joint federal-provincial environmental assessment process, the Project's Environmental Impact Statement (EIS; BC Hydro 2013) noted a potential for increased wildlife crop damage.

EIS Section 20.7.2.1 (page 20-53, lines 12 to 14) states: "*The loss of wildlife habitat in the reservoir may lead to an increase in wildlife in agricultural areas near the reservoir, which could lead to wildlife damage to crops and stored livestock feed for farm operations*."

EAC Condition No. 31 states: "*the Agriculture Monitoring and Follow-up Program must include monitoring for Project-induced changes in wildlife habitat utilization, and evaluation of associated crop or feed storage damage for, agricultural operations within 5 km of the reservoir, to assess if there is an increase in wildlife related crop depredation due to Project-related habitat losses. Monitoring must include pre- and post-reservoir filling field surveys, wildlife monitoring, farm operator interview, and analysis of relevant records related to wildlife-related crop depredation*."

As a result, the Environmental Assessment Certificate for the Project (EAC # E14-02, issued Oct. 14, 2014) contains a condition to develop an Agricultural Monitoring and Follow-Up Plan (AMAFP), which requires BC Hydro to monitor and assess wildlife habitat use and related damage to agricultural crops for a 10-year period including five years prior to reservoir filling and the first five years of operation.

1.3 Scope

BC Hydro and Power Authority (BC Hydro) has retained Blackbird Environmental Ltd. (Blackbird) in 2019 to implement the Crop Damage Monitoring Program (CDMP) component of the AMAFP for the Project. Blackbird's scope includes the development and implementation of field methodologies to monitor for Project-induced changes in wildlife habitat utilization and the evaluation of associated crop and feed storage damage.

As part of BC Hydro's annual reporting requirements, this report outlines Project activities completed in relation to the CDMP component between **April 1, 2019** and **March 31, 2020**.

As per the requirements of EAC Condition No. 31, the CDMP focuses on parcels with agricultural production within a five-kilometre buffer around the future Project reservoir (project area).

2 Methods

2.1 Stakeholder Consultation & Producer Engagement

Blackbird's CDMP team developed and implemented a comprehensive agricultural producer outreach and engagement program throughout the 2019 growing season. As part of the outreach and engagement program, Blackbird identified agricultural producers and associated parcels within the CDMP area through an analysis of high-resolution aerial imagery as well as an existing Project landowner contact database provided by BC Hydro. Blackbird project staff subsequently contacted identified producers through phone calls and emails to introduce the CDMP, outline benefits of participation, and provide an opportunity to ask project-related questions.

For all producers that expressed interest in the CDMP, these initial phone or email conversations were followed up on with an in-person interview to gather current project-relevant background information, including farm/ranch operational and production information, historic wildlife damage patterns on temporal and spatial scales, as well as wildlife-related crop damage mitigation measures employed.

Producers participating in the CDMP were updated on project activities on their holdings throughout the growing season, and a post-season interview program was implemented to gather information on observations and perceptions with regards to the 2019 growing season and wildlife-related crop damage in the 2019 crop.

BC Hydro and Blackbird's CDMP project team invited representatives from regional producer association (i.e. Peace River Forage Association of BC, BC Grain Producers Association, Peace River Cattlemen's Association, Peace River Forage Seed Association) and provincial government representatives to participate in a CDMP agricultural forum in Fort St. John to receive updates on the work completed on the CDMP in early March 2020.

2.2 Historical Data Collection & Analysis

Blackbird's CDMP team conducted a review of relevant and available wildlife and agricultural information that could help Blackbird detect trends in wildlife movement, habitat utilization changes, and associated damage to standing and stored agricultural crops. The results of the review of historic data pertaining to the CDMP project area have been compiled in a technical report (Blackbird 2020).

2.2.1 AGRI Wildlife Program

The Agriculture Wildlife Program (AWP) is a provincially delivered, but federal-provincial cost-shared program that compensates agricultural producers for crop losses caused by eligible wildlife species.

The BC Ministry of Agriculture (AGRI) maintains all AWP information as strictly confidential and not accessible to the public, but allows registered agricultural producers to request the release of AWP information to third parties through the completion and submission of an 'Authorization to Release Information' form (Schedule H-6). During initial producer interviews, seven producers indicated past participation in the AWP, four of which authorized the release of their AWP and production insurance (PI) information to Blackbird for use in this review. Upon receipt of the requested datasets from AGRI, Blackbird's project team analysed the released information in the context of the CDMP project scope.

2.2.2 MOTI Wildlife Accident Reporting System

The BC Ministry of Transportation and Infrastructure (MOTI) released to the project team raw collision data of wildlife-vehicle collisions from 1983-2018 along the segment of Highway 29 traversing the CDMP area (i.e., from Hudson's Hope to Mile 54 north of Fort St. John) for the purpose of informing CDMP development (WARS 2019).

Blackbird staff spatialized the supplied records, removed records not overlapping the project area, and completed a geospatial analysis of the resulting wildlife-vehicle collision dataset.

2.2.3 FLNRORD Wildlife Inventory Surveys

Blackbird's project team engaged wildlife biologists with the BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD) tasked with large ungulate and bear research in the Peace Region during the initial engagement phase of the CDMP in 2019. Based on the direction provided through these engagements, Blackbird worked with the Knowledge Management Branch at the BC Ministry of Environment & Climate Change Strategy (MOECCS) to secure access to secure wildlife inventory data applicable to the project.

Upon release of the requested information, Blackbird staff digitized the raw survey data and completed a geospatial analysis of the datasets in the context of the CDMP project area. Similarly, applicable project reports were obtained, reviewed, and analyzed, and project results were discussed with the wildlife biologists responsible for the most recent surveys.

2.3 Benchmark Selection

In 2019, the project team developed a crop damage risk matrix based on a review of the available wildlife inventory information, producer engagement interviews, crop types, and spatial locations, and selected benchmark fields distributed throughout the CDMP area that will be assessed annually as part of the program.

This benchmark-based approach includes sites considered likely to be subject to higher wildlife pressures (both during the baseline survey period and following the creation of the reservoir) and sites that have experienced lower historic wildlife pressures. The benchmark approach makes efficient use of resources, while providing adequate spatial coverage of the agriculturally used private land that is part of the CDMP.

2.4 Crop Damage Monitoring & Methodology Development

Blackbird's project team implemented a work plan to develop and implement scientifically sound and defensible methodologies to assess and measure wildlife-related crop damage in a variety of crop types commonly encountered in the CDMP project area, including annual forage, perennial forage, cereals, pulses, and oilseeds. Throughout the 2019 growing season, field methodologies and techniques, including loss assessments as well as remote sensing and on-the-ground crop health evaluations, were tested, evaluated, and adapted to fit program requirements.

3 Results and Analysis

3.1 Stakeholder Consultation & Producer Engagement

In early 2019, Blackbird project staff identified approximately 10,400 ha of land under agriculture production within the CDMP project area. Based on the results of the geospatial land use analysis, a list of 57 agricultural producers and/or landowners was compiled as the basis for direct stakeholder engagement in the 2019-2020 reporting year.

54 producers within the project area were subsequently engaged through direct means to provide information about the CDMP and offer interested producers an opportunity to participate in the program. As a result of this engagement, 49 of the producers expressed an interest in participating in the CDMP.

These 49 producers operate on approximately 9,200 ha (88 %) of the land currently utilized for agricultural production within the project area. Of those 9,200 ha of agricultural land (partitioned into 203 fields and pastures), approximately 3,300 ha were used to produce an annual crop (i.e. grain, oilseed, or pulse) within the 2019 growing season with the remaining 5,900 ha used for perennial forage production.

Producers consistently stated that agricultural production within the CDMP project areas is subject to significant wildlife pressures. Primary species causing wildlife-related crop losses are perceived to be elk, mule deer, and black bears. For perennial forage crops, most quantitative and qualitative crop losses are believed to occur during the dormant season, particularly in the spring. Wildlife-related crop losses to annual crops are perceived to occur throughout the growing season, with heavier losses associated with weather-induced harvest delays and a lack of available alternative foraging habitat.

Producers, agricultural associations, producer groups, and government agencies were invited by BC Hydro to attend a meeting on March 4, 2020 in Fort St. John, BC to hear an overview of the work completed on the CDMP to date, ask questions, and provide input on future project activities.

3.2 Historical Data Collection & Analysis

The CDMP project team reviewed a total of 135 AWP field inspection forms, over 7,000 aerial wildlife inventory observation points, and 514 wildlife-vehicle collision records (Thiessen 2009, Bridger 2016, Bridger 2018, Gagne-Delorme 2018).

The reviewed data illustrated a common theme with that of the initial engagement efforts outlined above. In essence, agricultural operations in the CDMP project area are shown to operate in an environment with historically high, healthy ungulate populations, which exert significant pressures on all crop types.

Perennial forage crops appear to be subject to slightly lower crop losses during the growing season than annual crops but may experience significant suppression losses during the dormant season. The absolute levels of yield losses in annual crops appear to depend not only on the crop type, but also on the location on the landscape, annual weather patterns, and the time of year when the damage occurred.

The AWP records indicated significant in-field variation to crop losses independent of the crop type, with headlands, edges, and particularly areas in close proximity to escape and wintering habitat experiencing the highest levels of wildlife-related damage.

The review findings support using a benchmark approach for the CDMP. Benchmarking will allow objective monitoring of a subset of agricultural fields in the project area independent of wildlife-related crop losses in any given year, thus facilitating the objective of assessing long-term trends in wildlife habitat utilization in relation to agricultural land.

AGRI recommends the use of exclusion cages to enable an objective assessment of dormant-season damage in perennial forage crops. While producers in the project area have historically elected to not utilize cages, they have agreed to the implementation of an exclusion cage program at benchmark sites under the CDMP to ensure the availability of undamaged reference sites for objective and accurate assessments.

3.3 Benchmark Site Selection

The CDMP team, in consultation with participating producers and BC Hydro project management, selected a total of 34 benchmark sites within the project area based on the outcome of initial engagement efforts, the review of available historic information, and a geospatial review of factors related to wildlife occurrence in the project area (e.g. proximity of escape or wintering habitat).

During the 2019 growing season, twelve of the selected benchmark sites were used for annual crop production and 22 sites contained a perennial forage stand.

While benchmark sites are anticipated to remain in the annual assessment pool for the entire timeframe of the CDMP, the project team will use an adaptive approach to ensure that a sufficient subsample of fields and pastures are assessed every year. The project team may add supplemental assessment sites in future growing seasons, if required (e.g., to respond to a reduction in the availability of an original site through a change in ownership, etc.).

3.4 Crop Damage Monitoring & Methodology Development

The evaluated and implemented methodology varies with the target crop in the respective benchmark fields.

For benchmark sites producing annual crops in 2019, fields were scouting using remotely piloted aircraft systems (RPAS) with regular and/or multispectral payloads to delineate stand health patterns relevant to the subsequent ground assessment. Qualified environmental professionals experienced in the assessment of wildlife-related crop losses then completed a stand-level health assessment, documenting damage patterns and estimating losses. This included replicated plant, tiller, stem, head/pod, and seed counts in representative areas delineated during the remote sensing activities.

Similarly, perennial forage stands were scouted using RPAS with multispectral payloads to identify stand health patterns and yield variations. The remote sensing information was used to delineate areas of higher and lower plant vigour, which aided in the selection of assessment plots for the subsequent ground assessment. Destructive sampling (i.e. clipping) was implemented in several forage benchmark fields to evaluate crop yield correlations to multispectral information and to calibrate the assessment professionals. These forage samples were weighed, processed, and dried to approximate dry matter yields.

Yield estimates from both annual and perennial crops were compared to yield information provided by the participating producers after harvest.

4 Recommendations

In accordance with EAC Condition No. 31, field surveys and interviews will continue to be completed with the goal of continuing monitoring until five years after reservoir filling. Similarly, the CDMP team will continue to work closely with agricultural producers, agricultural associations, producer groups, and government agencies that may have data or local knowledge related to this monitoring plan.

The following recommendations are based on the findings of project activities during the 2019 growing season, including producer engagement, research on available wildlife and agricultural information, and the implementation of the field program.

1. Deploy passive camera traps at all benchmark sites to better facilitate long-term monitoring and enable objective trend detection with regards to wildlife utilization of agricultural fields in the CDMP project area. Deployment locations will be selected in consultation with landowners, with the goal of the cameras remaining in place until the end of the project.

2. Complete RPAS assessments of benchmark sites through the 2020 growing season to delineate crop health patterns, estimate forage yields, and objectively record wildlife impacts to field crops.

3. Continue destructive sampling of forage crops on benchmark fields during the growing season to reinforce yield estimates and allow for an accurate characterization of wildlife-related crop losses to growing stands.

4. Procure and deploy exclusion cages within benchmark sites containing perennial forage stands to allow for an objective evaluation of dormant season impacts to forage stand composition and yields.

5 Closure

Services provided by Blackbird for this technical report have been conducted in a manner consistent with the level of skill, care, and competence ordinarily exercised by registered members of the profession of agrology and biology currently practicing under similar conditions and like circumstances in the same jurisdiction in which the services were provided.

The conclusions of this report are based in part on information provided by others. Blackbird believes this information to be accurate but cannot guarantee or warrant its accuracy or completeness.

The information presented in this report was acquired, compiled and interpreted exclusively for BC Hydro for the purposes described in this report.

If you have questions with regards to this report, feel free to contact the lead author at your convenience by email at matthias@blackbird.ca.

6 References

Blackbird Environmental Ltd. (Blackbird). 2020. Analysis of Available Records for Wildlife-related Crop Depredation. Technical Report, Fort St. John, BC.

BC Hydro. 2020. Site C Construction Schedule February 2020. Available at: https://www.sitecproject.com/sites/default/files/construction-schedule-202002.pdf (Accessed May 13, 2020)

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Bridger, Mike. 2016. 2016 Winter Moose Survey: MU 7-34. BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development, Fort St. John, BC.

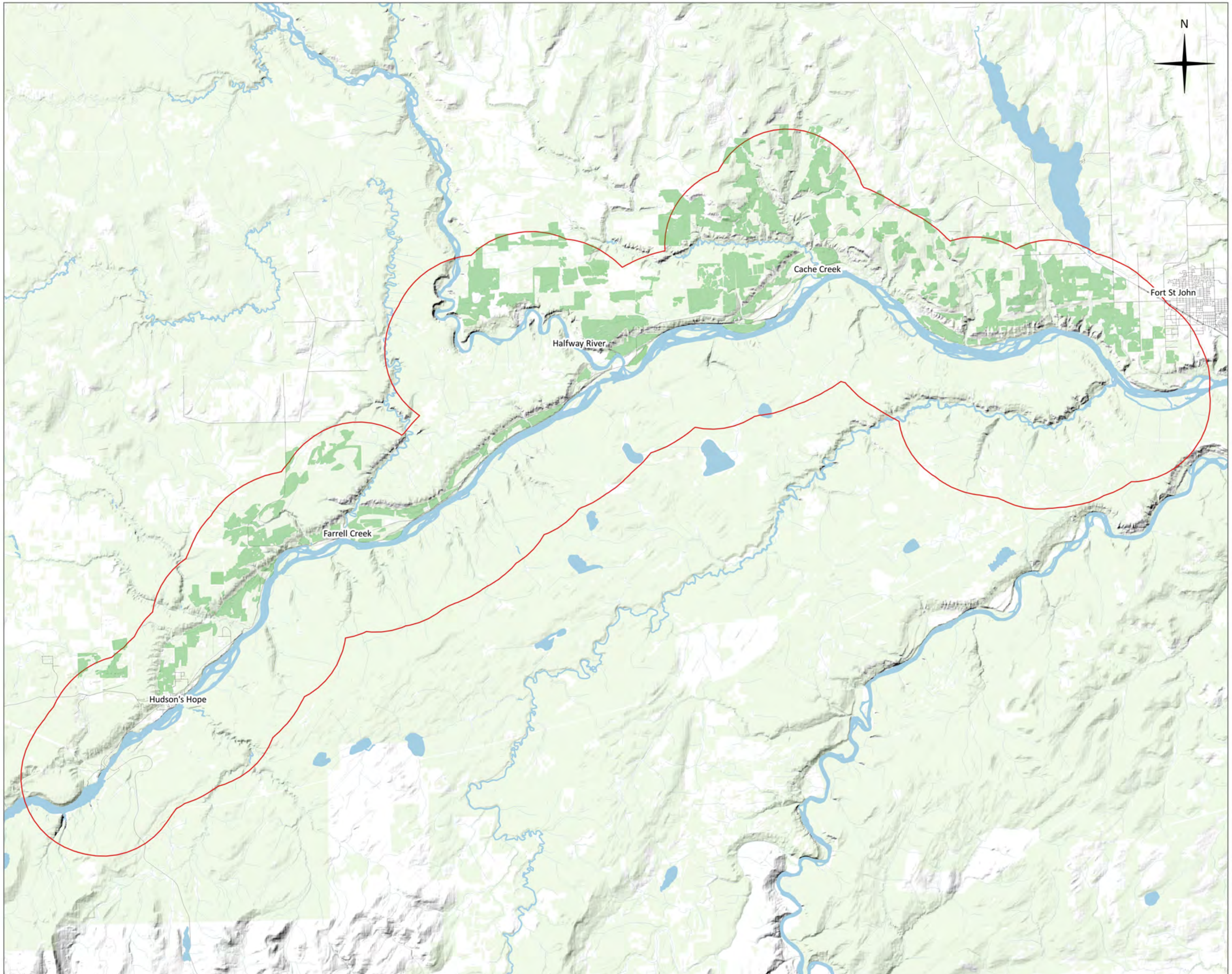
Bridger, Mike. 2018. 2018 Winter Moose Survey: MU 7-32. BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development, Fort St. John, BC.

Gagne-Delorme, Audrey. 2018. 2018 Elk Survey in 7-20A. BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development, Fort St. John, BC.

Thiessen, Conrad. 2009. Agriculture Zone Elk Inventory 2007/2008. Ministry of Environment, Fort St. John, BC.

Wildlife Accident and Reporting System (WARS). 2019. Highway 29: Fort St. John to Hudson’s Hope. Ministry of Transport and Infrastructure, Victoria, BC.

Appendix A: Project Area Overview



BC Hydro and Power Authority

Crop Damage Monitoring Program
Project Area Overview

Horizontal Scale 1:250,000

0 2 4 6 8 10 km

Map to scale when plotted on a page 280 mm x 432 mm (Tabloid)

Legend

- CDMP Project Area
- Agricultural Fields and Pastures
- Lakes & Rivers
- Road Network

Disclaimer

UTM Zone 10, NAD 83
Date of data acquisition: n/a
Data Credit: Blackbird Environmental Ltd., BC Geodata Warehouse
For representational purposes only, all locations are approximate.

Our File:	19002	Gov. File #:	n/a	Revision #:	0
Client File:	n/a	GIS:	ML	Date:	June 12, 2020

Blackbird Environmental

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Fort St. John, BC
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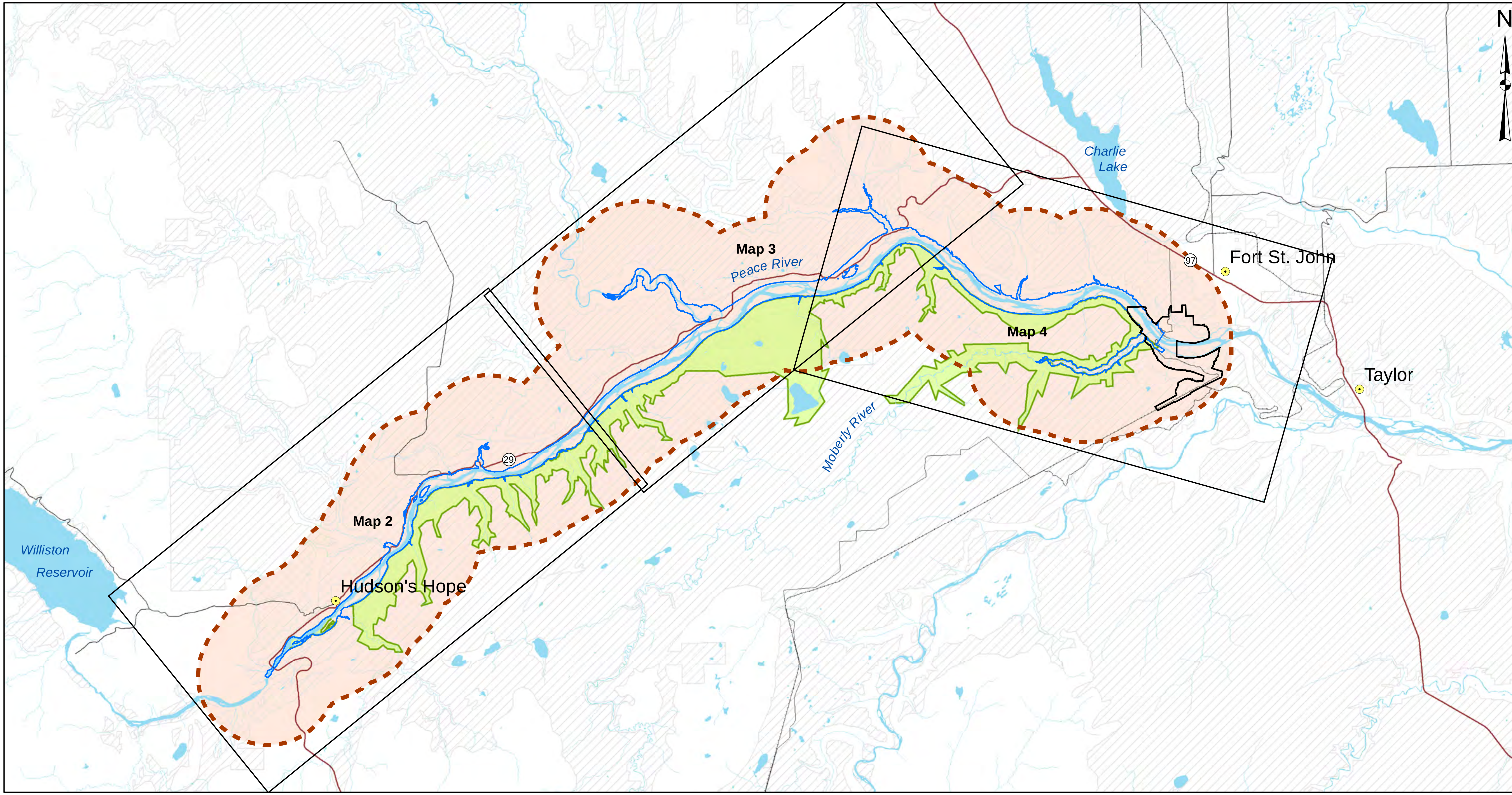
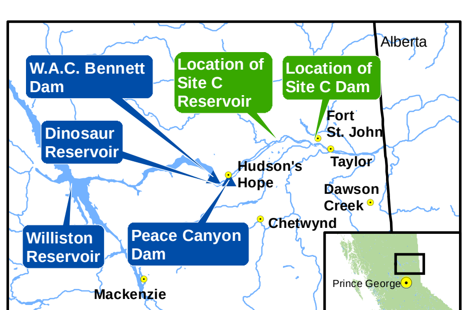
Figure 1





Map Notes:
1. Datum: NAD83
2. Projection: UTM Zone 10N
3. Base Data: Province of B.C.
4. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

Legend

- Area to be considered for wildlife habitat utilization monitoring
- Agricultural Land Reserve
- Proposed Reservoir
- Proposed Peace Boudreau Protected Area
- Dam Site Area
- Town
- Road
- Highway
- Railway

1:280,000 0 5 km

BC Hydro

Wildlife Habitat Utilization Monitoring Area Identification - Overview Map 1 of 4

Date	July 14, 2016	DWG NO	1016-C14-07343-1	R 0

Construction of the Site C Clean Energy Project is subject to required regulatory and permitting approvals.

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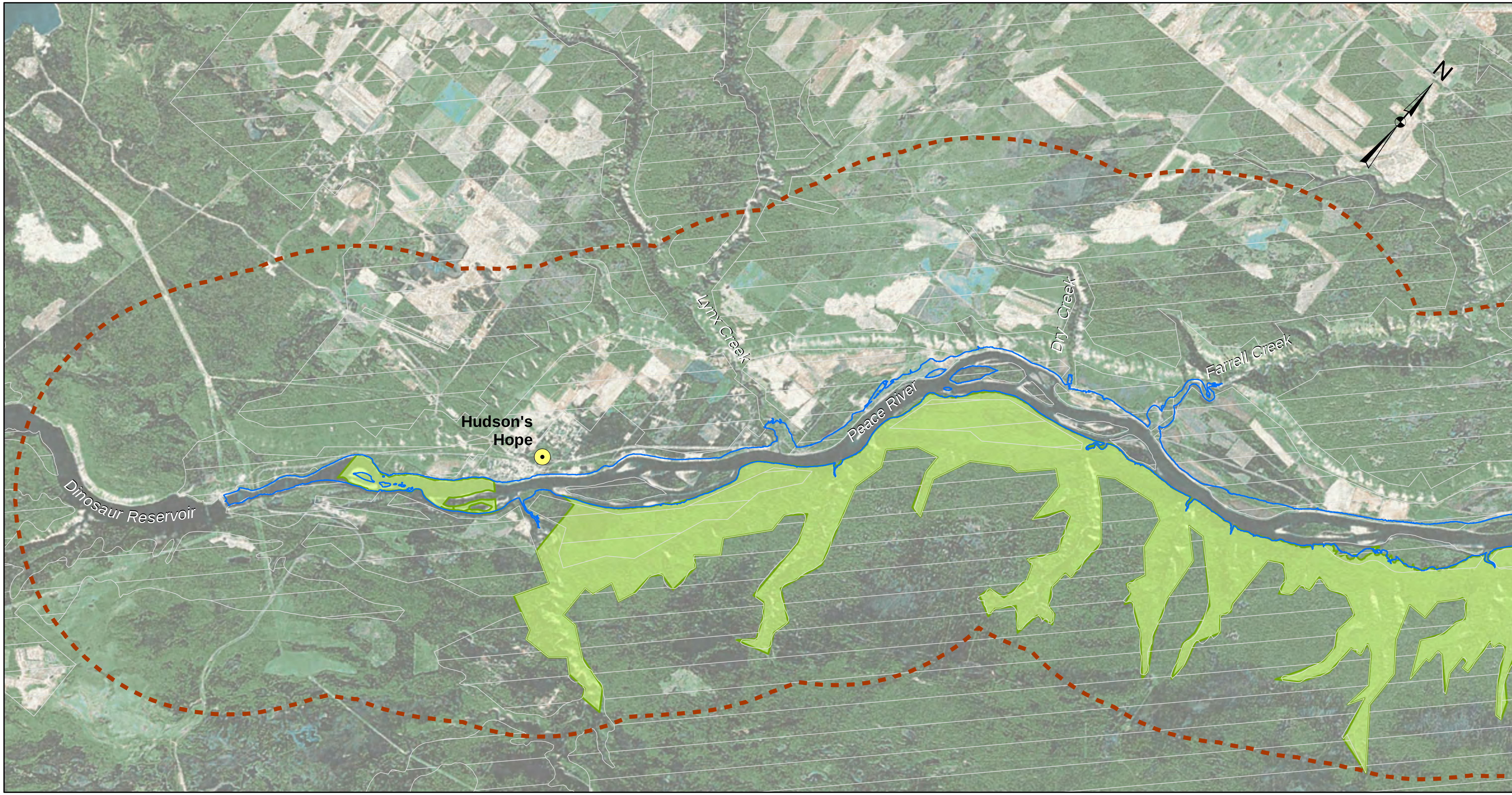

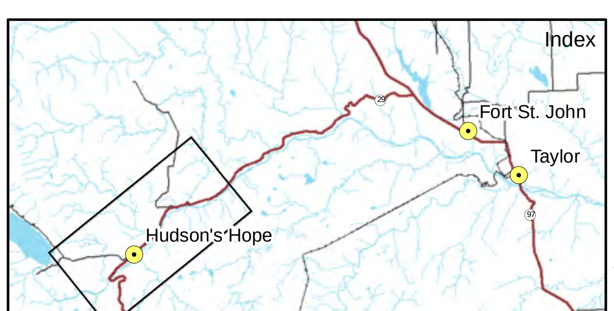

Map Notes:
1. Datum: NAD83
2. Projection: UTM Zone 10N
3. Base Data: Province of B.C.
4. Orthophotos provided by ESRI
5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

Legend

- Area to be considered for wildlife habitat utilization monitoring
- Agricultural Land Reserve
- Proposed Reservoir
- Proposed Peace Boudreau Protected Area
- Dam Site Area

1:90,000

0 2 km

BC Hydro

Wildlife Habitat Utilization Monitoring Area Identification - Map 2 of 4

Date	July 14, 2016	DWG NO	1016-C14-07342-2	R 0

Construction of the Site C Clean Energy Project is subject to required regulatory and permitting approvals.

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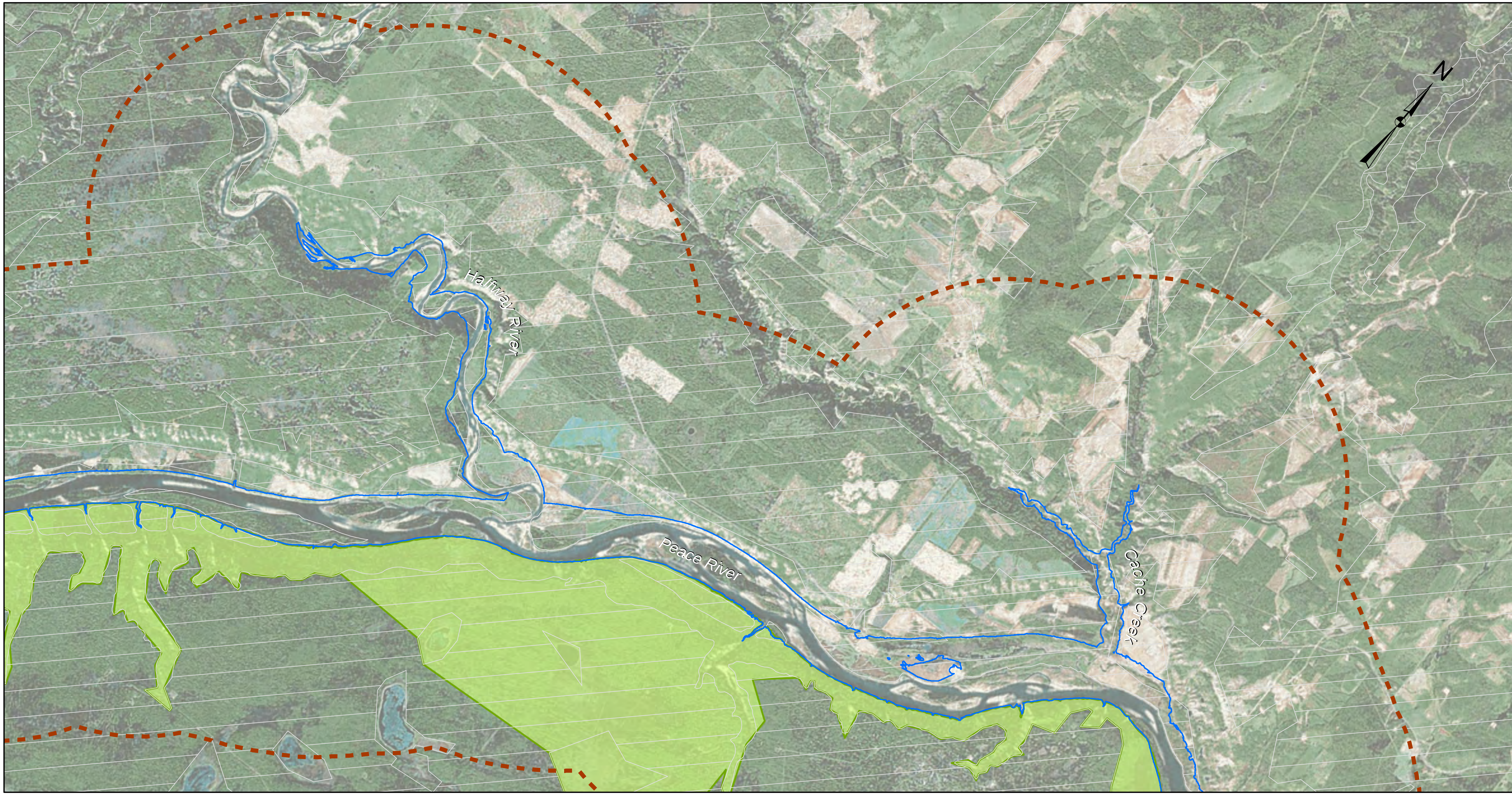

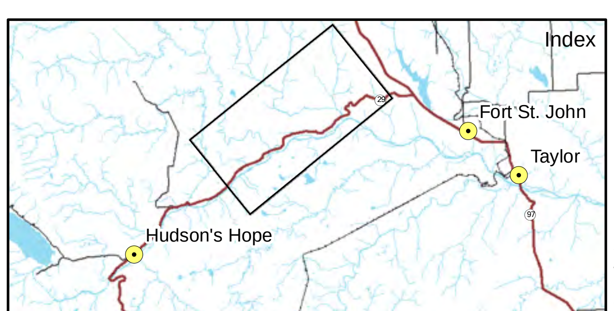

Map Notes:
1. Datum: NAD83
2. Projection: UTM Zone 10N
3. Base Data: Province of B.C.
4. Orthophotos provided by ESRI
5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

Legend

- Area to be considered for wildlife habitat utilization monitoring
- Agricultural Land Reserve
- Proposed Reservoir
- Proposed Peace Boudreau Protected Area
- Dam Site Area

1:90,000

0 2 km

BC Hydro

Wildlife Habitat Utilization Monitoring Area Identification - Map 3 of 4

Date	July 14, 2016	DWG NO	1016-C14-07342-3	R 0

Construction of the Site C Clean Energy Project is subject to required regulatory and permitting approvals.

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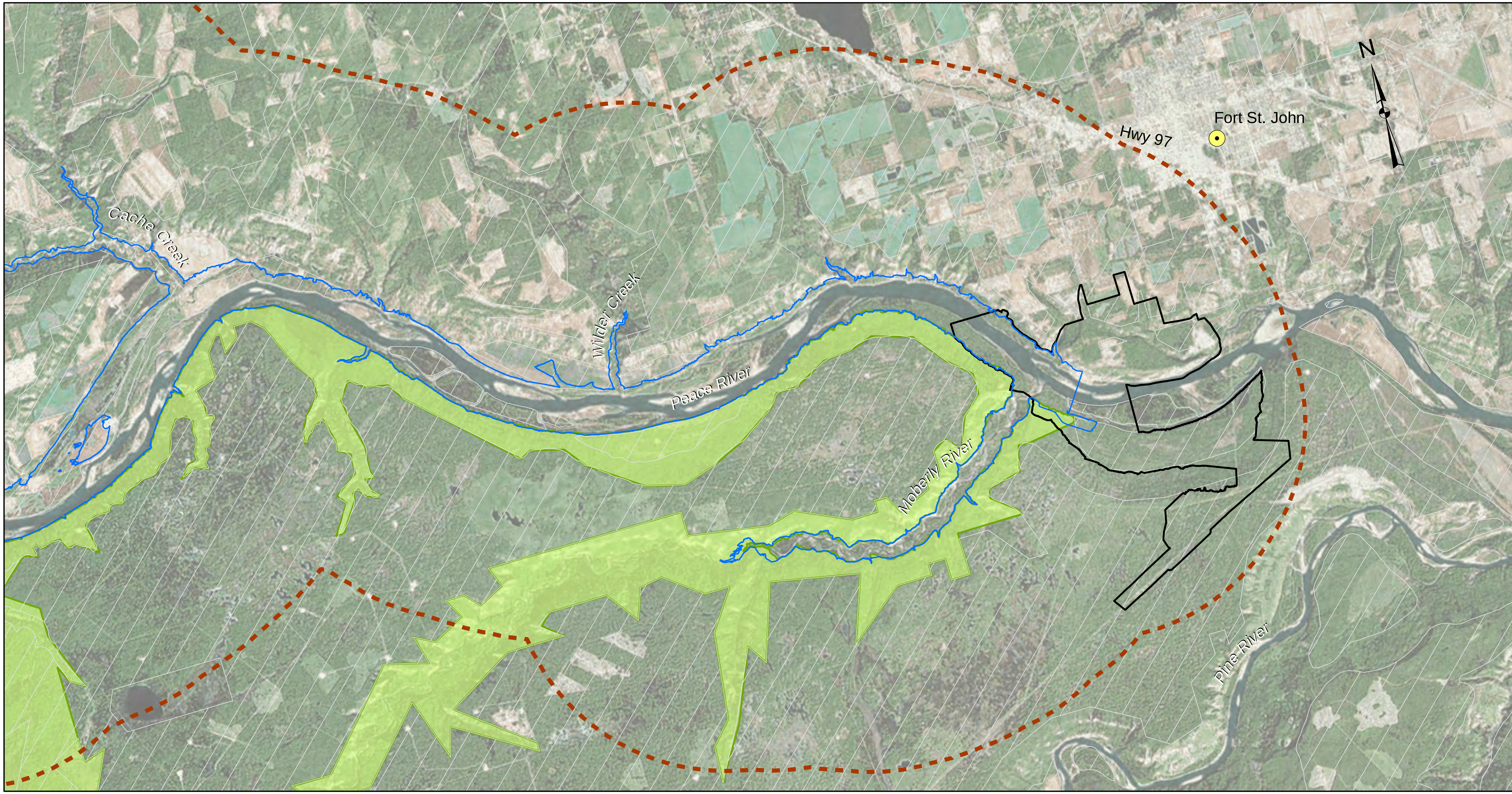

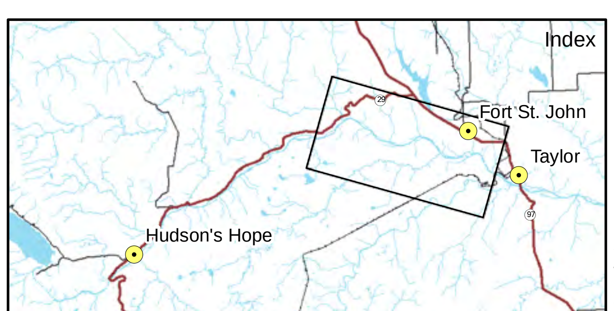

Map Notes:
1. Datum: NAD83
2. Projection: UTM Zone 10N
3. Base Data: Province of B.C.
4. Orthophotos provided by ESRI
5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

Legend

- Area to be considered for wildlife habitat utilization monitoring
- Agricultural Land Reserve
- Proposed Reservoir
- Proposed Peace Boudreau Protected Area
- Dam Site Area

1:90,000

0 2 km

BC Hydro

Wildlife Habitat Utilization Monitoring Area Identification - Map 4 of 4

Date	July 14, 2016	DWG NO	1016-C14-07342-4	R 0

Construction of the Site C Clean Energy Project is subject to required regulatory and permitting approvals.

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Appendix B – Crop Drying and Humidity Monitoring Program Report

REPORT

SITE C AGRICULTURAL CLIMATE REPORT

FORT ST. JOHN, BC

2019 ANNUAL REPORT

RWDI # 1601625

July 15, 2020

SUBMITTED TO

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EXECUTIVE SUMMARY

This report provides background information on agricultural climate stations and their distribution within the Site C monitoring area. The report summarizes the results of eddy-covariance (EC) estimates of evapotranspiration (*ET*) and output from a Climate Moisture Deficit (CMD) and a Crop Drying Model (CDM) for the 2019 growing season (GS). Where available, the EC technique provided a direct measurement of *ET* and these were used to facilitate an improved estimate of potential evapotranspiration (PET) and its use in CMD and CDM at each of the seven BC Hydro climate stations. This was done through an assessment of the energy balance closure (EBC) correction and Priestley-Taylor (PT) proportionality constant (α) at EC equipped stations.

The EC system performance for collected high frequency data was over 75% complete for both stations and the daily collection of half hour computed fluxes and climate data resulted in a 100% data representation for 2019.

Climatologically, 2019 was a wet and cool year. Differences between stations' climate are the result of differences in elevation, aspect and exposure as well as vegetation cover and soil type. Stations at higher elevations recorded higher wind speeds. Stations 1, 4 and 10 had higher monthly net radiation throughout the GS than other stations. The ground/field cover type differed at all three of these locations (and are representative of the Site C monitoring area), from wheat and grasses, Alfalfa/clover/grasses/wildflower cover crop and Alfalfa/clover/grasses forage, respectively.

The total amount of *ET* recorded at Stations 1 and 4 was 344 and 384 mm, respectively. The average monthly EBC was 0.70 and 0.84 for Stations 1 and 4, respectively. Applying the monthly corrections to each station's estimate of *ET* increased their annual cumulative values from to 423 and 473 mm, respectively. This adjustment resulted in an improvement in the accuracy of the modelled values.

The PT proportionality constant (α) was used to provide an estimate of actual *ET* from PET estimates made using the PT radiation-based approach. A common value recommended for this constant is 1.26. From measurements during the growing season, it was determined that PT *α* for Stations 1 and 4 were closer to 0.81 and 0.75, respectively. Linear regression analysis showed that while the correlation of the relationship between measured vs. modelled values did not change, using this new α reduced the slope of the relationship and further improved the accuracy of the model output. An average value of 0.78 was selected to improve the accuracy of modelled *ET* at all of the climate stations where EC measurements were not available. Testing both the PET and the actual *ET* estimates for each climate station in the network, it was possible to compute drying indices that were used as an input for the CMD and CDM for each location.

Station 10 had the highest CMD value, more than 50 mm above the average by the end of the growing season (288.6 mm). The stations in decreasing order of CMD (CDM = *ET* – Effective Precipitation) are 10, 4, 11, 1, 7, 3 and 6. For all stations ET > EP during the GS and so they all experienced moisture deficit by the end of the growing season. The largest difference in *ET* was recorded between Stations 10 and 6 with 357.9 and 276.2 mm, respectively.

Output from the CDM was used to compute the cumulative good crop drying days for each month and station. From this output, it was determined that on average the most good drying days were recorded in May with a trend towards fewer good drying days per month as the growing season progressed. In line with the CMD results, station 10 had the fastest and stations 3 and 6 had the slowest drying rates. August and September had the lowest average cumulative good drying days with 25. Stations to the west of the monitored area in general had fewer good drying days, as a result of differences in regional rainfall amounts.

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1	July 15, 2020	All	David Chadder, Hon. B.Sc., QEP Iain Hawthorne, Ph.D.

ACRONYMS

BC MECCS	British Columbia Ministry of the Environment and Climate Change Strategy
CDM	Crop Drying Model
CMD	Climate Moisture Deficit
CDI	Crop Drying Index
DM	Dry Matter (content)
DR	Drying Rate
EBC	Energy Balance Closure
EC	Eddy Covariance
EP	Effective Precipitation
ET	Evapotranspiration
FCRN	Food Climate Research Network
FHAYD	Field Hay Drying Model
GS	Growing Season
HF	High Frequency
Hz	Hertz
IRGA	Infrared Gas Analyzer (Open Path)
PET	Potential Evapotranspiration
PT	Priestley and Taylor
RWD	Rewetting through Dew Formation
RWP	Wetting Rate from Precipitation
SDM	Synchronous Device for Measurement
VWC	Volumetric Water Content (soil)

1 INTRODUCTION

BC Hydro's Site C Clean Energy Project (the Project) in British Columbia's Peace region will create a new hydroelectric dam and generating station on the Peace River in the vicinity of the City of Fort St. John. To characterize the microclimate and to provide a baseline against which to compare future changes brought on as a result of the Project, BC Hydro installed a network of climate monitoring stations in the Peace River Valley. This network has been active since 2011, through the preparation and submission of the Project's Environmental Impact Statement, and throughout Project construction to date, which began in mid-2015.

The Site C Clean Energy Environmental Impact Statement (EIS) (BC Hydro, 2013) identified reservoir induced changes to microclimate on adjacent agricultural operations as a key indicator (EIS Section 10, Table 20.3). Effect on crop drying is one reservoir-induced change which may occur. EIS Section 20.3.6 (page 20-50, lines 27 to 36) states: "Predicting the effect that the reservoir might have on crop drying is made difficult by the complexity of the effect of the reservoir on several climatic parameters that drive both drying and wetting effects. Generally, the RWDI model predicts increases in humidity up to 15% for stations located closely adjacent to the reservoir during the summer and fall months. the model predicts the effect on humidity during the summer and fall not to be statistically significant for locations not directly adjacent to the reservoir. The RWDI report predicts that effects on fog formation from the reservoir are in the order of 0.5% or less over the year. However, due to increased humidity, the reservoir could potentially have a small effect on crop drying during summer and early fall in the Peace River valley in areas adjacent to the reservoir."

As a result of these general conclusions, a commitment was made to monitor project-induced changes to humidity within 3 km of the reservoir; and evaluate associated effects on the calculated Climate Moisture Deficit (CMD) and Crop Drying Model (CDM) within the area. Monitoring will include continued collection and analysis of climate data from the BC Hydro monitoring network, calculation of the CMD and a Crop Drying Index (CDI) (Dyer and Brown, 1977), and farm operator interviews as they become available.

This report summarizes the results of the eddy covariance (EC) component of the baseline environmental measurement program for 2019. This technique provides a direct measurement of evapotranspiration (*ET*) that is then used to facilitate the computation of the CMD at each of seven climate stations within 1-km distance of the proposed Site C reservoir. The CMD for each station is then used as an input to a CDM to be computed for each location.

2 METHODS

The seven climate stations available for this study are listed in Table 2-1. As part of the collection of baseline environmental data for the Site C project area, EC systems continue to be operated at two meteorological stations: Station 1 (Attachie Flat Upper Terrace) and Station 4 (Bear Flat). EC systems were installed at Station 4 (Bear Flat) on December 2, 2010 and at Station 1 (Attachie Flat Upper Terrace) on January 13, 2011. Station locations are shown in Appendix A, station pictures can be found in Appendix B.

Table 2-1: Available Climate Stations

Station Name	Latitude, Longitude (decimal degrees)	Elevation (m)	Dominant Ground Cover	Distance (m)[1]
Station 1 – Attachie Flat Upper Terrace	56.23N, -121.42W	479	Wheat and other grasses	209
Station 3 – Attachie Plateau	56.23N, -121.46W	645	Wheat and other grasses	522
Station 4 – Bear Flat	56.27N, -121.21W	474	Alfalfa/clover/grasses/wildflower	73
Station 6 – Farrell Creek	56.12N, -121.70W	471	Pasture (Grasses/wildflower/small shrubs)	70
Station 7B – Site C North Camp	56.20 N, -120.90W	581	Grasses/wildflower/small shrubs	573
Station 10 – Tea Creek	56.24 N, -120.95W	653	Alfalfa/clover forage	812
Station 11 – Taylor	56.17N, -120.76W	411	Pasture (Grasses/wildflower/small shrubs)	9744

Notes: 1. Approximate distance from the reservoir high water mark.

Land use and ground cover vary between locations. Broadly, in 2019 it was observed that the abundant ground cover at Station 1 was wheat and other grasses. The wheat portion of the field was harvested in October and the grasses left alone. At Station 3, there was wheat and other grasses and like Station 1 this was harvested in October. At Station 4, there was an Alfalfa/clover/grasses/wildflower cover crop that grew undisturbed throughout the year. At Station 6, there was unmanaged pasture that had a dominant ground cover of mostly grasses/wildflower/small shrubs. The ground cover at Station 7B was mostly unmanaged and consisted of grasses/wildflower/small shrubs. At Station 10, there was Alfalfa/clover forage crop that was harvested in September. Lastly, at Station 11 there was unmanaged pasture that had a dominant ground cover of mostly grasses/wildflower/small shrubs. Efforts are being made to better characterize differences between locations with the potential for feedback during famer interviews. One of the requirements of this monitoring program is to monitor climate variables to be used in the calculation of CMD and CDM within a 3 km distance of the reservoir. Table 2-1 shows that Station 11 is the only station further than 812 m from the reservoir edge and it is significantly more than 3 km distance at 9.7 km. Station 11 will be helpful in monitoring downstream climate effects on agriculture after reservoir filling but it is not helpful in monitoring from 1-3 km, where there is a significant spatial data gap.

2.1 Eddy Covariance Measurements

The EC technique has become the standard method for measuring sensible heat flux (*H*) and latent heat flux (λ*E*) over footprints of ≤ 1 km^2 (Baldocchi, 2003). Knowledge of the partitioning of available energy (R_n – *G*, or net radiation minus soil heat flux) between sensible and latent heat fluxes is critical for understanding the interaction of the measured ecosystem with the overall water cycle, atmospheric boundary layer development, weather, and climate (Wilson et al. 2002).

Since the installation, continuous 10 Hz measurements of the three components of the wind vector and air temperature have been made using a 3-dimensional ultrasonic anemometer (model CSAT3, Campbell Scientific Inc. (CSI), Logan, Utah), while 20 Hz turbulent fluctuations of CO_2 and H_2O have been measured using an open-path infrared gas analyzer (IRGA) (model LI-7500A, LI-COR, Inc., Lincoln, Nebraska). Signals were measured with a data logger (CSI, model CR1000) with a synchronous-device-for-measurement (SDM) connection. High frequency (HF) data were stored on a compact flash card that was replaced every 2-3 weeks. Half-hourly covariances and other statistics were calculated on the data logger (to provide near-real time diagnostics), and as well from the raw HF data using in-house MATLAB processing code. Fluxes of *H* and λ*E* were calculated as the half-hourly covariances of the sonic air temperature and H_2O mixing ratio with the vertical wind velocity (*w*). Further details of the flux calculations can be found in Brown et al. (2010). The *λE* flux is calculated using Equation 1 below.

$$\lambda E = \lambda \rho_a \overline{w' s_v'} \qquad \text{Equation 1}$$

where ρ_a is the dry air density, *w* is the vertical wind velocity, s_v is the H_2O mixing ratio, λ is the latent heat of vaporization, and the primes indicate fluctuations from the half-hourly mean value and the overbar indicates the time average. The calculation is therefore a 30-minute block average with no detrending applied.

2.2 Climate Moisture Deficit Calculations

Daily potential evapotranspiration (PET) from May to September 2019 was calculated for each of the six BC Hydro climatological stations for which air temperature (T_a), net radiation (R_n) and precipitation (*P*) data were collected, using Equation 2, the PT energy balance formulation (Priestley & Taylor, 1972). This approach has been shown to accurately estimate PET (LE_0) from a forage crop in the Peace River region of British Columbia (Davis & Davies, 1981; Davis, 1978).

$$LE_0 = \alpha \frac{s}{s+\gamma}(R_n - G) \qquad \text{Equation 2}$$

where:

L = latent heat of evaporation for water (W m^{-2} day^{-1}).
LE_0 = Potential evapotranspiration (λ*E*L)* (mm day^{-1}).
s = slope of the saturation vapour pressure-temperature curve.
γ = psychrometric constant.
R_n = net radiation flux at the surface (W m^{-2} day^{-1}).
G = soil heat flux (W m^{-2} day^{-1}).

α = the PT proportionality constant (shown to have a value close to 1.26 in studies in the Peace River region (Davis & Davies, 1981) and elsewhere. By making direct measurements of *ET* using EC, the PT equation can be re-arranged to provide an accurate estimate of α.

Actual *ET* is given by providing location specific α. A growing season assessment of the PT proportionality constant (α) was performed by comparing modelled LE_0 estimates to EC measured LE_0 on occasions when incoming energy and water were not limiting to plant growth. In this way, an improved parametrization of the PT energy balance model was possible.

The slope of the saturation vapour pressure-temperature curve (s), shown below in Equation 3, was calculated following Eq. 13 in the Food and Agriculture 0rganisation Crop Evapotranspiration Guidelines (FAO, 1998) as follows:

$$s = (4098 * (0.6108 * \exp((17.27 * T_a) / (T_a + 237.3))) / (T_a + 237.3)2 \quad \text{Equation 3}$$

where: T_a = air temperature (°C) at two meters height. A value of 0.062 was used for the psychrometric constant (Table 2.2 in the FAO Guidelines lists values for different altitudes above sea level).

Site specific CMD was computed daily by subtracting the effective precipitation (*EP*) from the cumulative daily LE_0 as shown in Equation 4, for each station:

$$CMD = Cumulative\ Daily\ LE_o - ((Cumulative\ Daily\ P - 5) * 0.75) \quad \text{Equation 4}$$

The values accumulate over the course of the growing season for each station to a growing season maximum by the end of September. Statistical spatial and temporal analysis were calculated annually and interannually to determine and significant effects.

2.3 Crop Drying Model Calculations Steps

The CDM follows closely the Field Hay Drying Model (FHAYD) described by Dyer and Brown (1977), with improvements where better data is now available. The main computational steps are described here. On a daily time step, a CDI is first calculated using Equation 5:

$$CDI = Cumulative\ Daily\ LE_o - (Cumulative\ Daily\ P * 0.2) \qquad \text{Equation 5}$$

The drying rate (*DR*) and wetting rate from precipitation (*RWP*) is calculated, using empirical constants provided in Dyer and Brown (1977), as shown in Equations 6 and 7:

$$DR = CDI \times 4.3 \qquad \text{Equation 6}$$

$$RWP = 0.5 \times P \times 1.03 \qquad \text{Equation 7}$$

The last wetting rate calculation accounts for rewetting through dew formation (*RWD*) only occurring on specific nights when RH > 90% and the calculated dew point temperature was above air temperature. The total amount of moisture added to the hay was computed from the average number of hours where dew was formed (X_{ave}) and could not be larger than 10%. This was multiplied by the ratio of the dry matter content (*DM*) of the crop (90%) and the days prior moisture (M_{n-1}) content as shown in Equation 8:

$$RWD = \frac{DM}{M_{n-1}} \times \frac{0.1}{X_{ave}} \qquad \text{Equation 8}$$

It was assumed that the starting moisture content by wet weight of the crop material was 80% at the start of each month for all stations and the total number of days until dry (<20 % moisture content) was estimated. Additionally, the total number of good drying days (DR>(RWP+RWD)) within each month was calculated. Statistical spatial and temporal analysis were calculated annually and interannually to determine any significant effects.

2.4 System uptime/data loss

System uptime describes when the EC system was operating and HF data card collection was succesful. Only time periods when the IRGA/sonic anemometer are malfunctioning or there is no system in place (e.g., calibration time period for Station 4) contribute to data loss and require gapfilling through modelling. At other times (e.g., CF card failure) the 30 min fluxes that are downloaded daily can be carefully assessed for use.

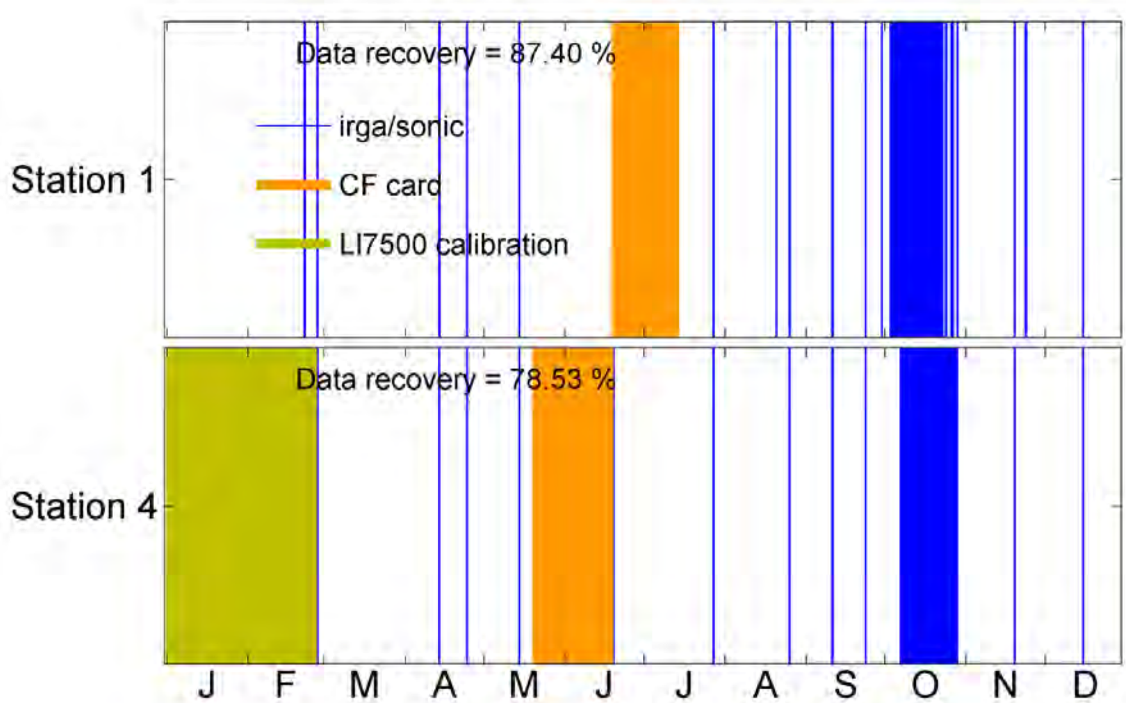

Figure 2-1: System High Frequency Performance in 2019.

The 2019 system performance was over 75% complete at both stations (Figure 2-1). Station 4 had lower data recovery due to HF data collection issues from the CSAT sonic anemometer during the time period when that stations IRGA was away for annual calibration. Both stations experienced data loss due to card errors during spring into summer, when power surges associated with industrial operations causing spikes in supply voltages and card data loss due to static discharges. An assessment of system grounding is being proposed for spring 2020 to reduce the likelihood of re-occurring, as industrial development is expected to increase in the area over the coming years. Both stations also experienced data loss due to instrument malfunctions in October, prior to annual calibration, which resolved these issues. Additionally, the utilization of a spare IRGA allowed annual calibrations starting in December to occur with no associated data loss. During all data periods where HF EC data was missing, half-hourly EC computed values had been collected daily and were used to gap-fill. Additionally, the climate systems were operating and gap-filling through modelling (described in Section 2.6) was possible for any periods without computed 30-minute fluxes. These steps resulted in a 100% data representation for the year of 2019.

2.5 Quality Assurance and Quality Control Measures

Data from the Site C climate stations and half-hour computed fluxes are remotely downloaded on a regular basis to RWDI computers using Campbell Scientific Loggernet software over cellular and satellite modem connections. In addition, HF data collected for the EC calculations is collected monthly from data cards. Stations with AC power (Station 1) have more frequent collection intervals of 1 hour whereas solar powered stations (Station 3, 6, 7, 10 and 11) have their data collected on a daily interval to preserve battery power at the stations. Station 4 is connected to AC power but also uses a satellite modem connection. Downloads from Station 4 are daily to reduce connection charges.

Data QA procedures are in line with those used by regulatory agencies such as the BC MECCS. QA is carried out at least weekly. This involves running R-script to plot the data over the past day-month (user selected) to allow for a visual inspection so the operator can detect anomalous trends or data outliers. This allows rapid detection and repair of any instrumental breakdown.

A second QA/QC operation is conducted on a monthly basis to remove or flag any anomalous data points. Corrections are also applied to the data where appropriate such as setting precipitation to 0 mm when a large value is recorded on the same hour that maintenance was performed on the precipitation gauge in question, for example.

The EC measurements are manually downloaded on site by RWDI on a monthly basis. The QA of these data includes:

- Plausibility checking for each variable from the IRGA and sonic anemometer (i.e. checking measurement from the EC equipment against plausible thresholds so that, for example, unreasonable wind speeds of 500 km/h or CO_2 concentrations of 20,000 ppm for the atmospheric background are discarded).
- Removal of spikes in the data.
- Flagging measurements using the diagnostic flags output by each instrument (for example, neither the sonic anemometer or the IRGA produces reliable data during rain and snow and the diagnostic flags from each tell us this (i.e., the IRGA starts reporting that its optical path is being obstructed due to water on the optical windows). Precipitation data from the climate stations are used to help confirm that the data from the IRGA and sonic anemometer can indeed be discarded during these periods.
- Checking the **energy balance closure (EBC)**. A CNR4 4-way radiometer and soil heat flux plates are operated at the EC sites. Conservation of energy tells us that the net radiation (R_n) as measured by the CNR4 minus the soil heat flux (G) as measured by the soil heat flux plates should ideally equal the sum of the sensible heat flux (H) and latent heat (water vapour) flux (λE) measured by the EC equipment. Any difference is checked and reported to show the degree to which the EC method is capturing all of the turbulent fluxes.
- Redundant measurements are used to check the EC instrumentation. For example, the cup anemometer, air temperature and humidity monitors at the station can be used to check the independent measurements of air temperature (obtained from the sonic anemometer) and humidity (from the IRGA).

All of the QA/QC tasks have both automated and manual components. Every EC trace is inspected after the data is collected, so as not to rely completely on automation.

In a natural forest or grassland ecosystem, filling data gaps in the λE fluxes would typically be accomplished using protocols slightly modified from those used in the Fluxnet Canada Research Network and the Canadian Carbon Program (Barr et al. 2004, Brown et al., 2010). This approach is best suited to natural ecosystems where the response of the local vegetation is largely the result of the integration of the phenological response of the individual species of plants and trees and environmental variables such as light, air temperature and soil temperature and moisture.

In the agricultural settings in which the Site C EC stations are situated, the biological response is affected by human factors, as the farmer is the one controlling the timing of sowing and planting. Gap-filling of λE was accomplished using the EBC model approach (Amiro et al., 2006) with no additional uncertainty as *H* continued to be measured throughout the IRGA calibration period.

2.6 Uncertainty Analysis

Uncertainties associated with calculating annual totals of *ET* from the half-hour EC fluxes were determined using techniques detailed extensively elsewhere (Brown et al. 2010, Krishnan et al. 2006, Morgenstern et al 2004). Random error was assessed using propagation of errors following Morgenstern et al. (2004), in which up to a 20% error is randomly assigned to each half-hourly measured flux (λE). The uncertainty due to the gap filling algorithms was estimated using Monte Carlo simulation following the procedure of Krishnan et al. (2006). Briefly, gaps were created in annual λE ranging from a half-hour to 10 days in length and a uniformly distributed random number generator was applied to day- and night-time readings separately to approximate the typical diurnal distribution of data gaps in the annual dataset for each site. For each iteration, the standard Food Climate Research Network (FCRN) gap filling approach as modified by Brown et al. (2010) was used to fill the gaps generated. This procedure was then repeated 1,000 times, and the simulated annual values of *ET* were then sorted to determine the 95% confidence intervals. For the Site C EC stations, the combined random and systemic error introduced from the gap filling procedure amounted to ~10 mm for the annual *ET*.

Finally, as is standard Fluxnet protocol, the annual totals for *ET* reported have not initially been corrected for EBC. However, analysis discussed later in this report indicated that performing this correction on λE was important prior to use in the CMD and CDM models, and so this was done to provide the most accurate estimate of *ET*.

3 RESULTS

The measured climate variables used as inputs to the CMD and CDM models are presented to characterize any differences between the stations and potential influences on *ET*. To aid a better understanding of seasonal climate impacts on model output, additional climate variables which control *ET* are also included. Reference is made to the Site C Climate & Air Quality Monitoring: 2019 Annual Report where necessary (RWDI. 2020). This is followed by a more specific presentation of EC λE measurements and EBC estimates at those stations. Next, results of the *ET* measurements are presented, followed by reporting the differences between the measured and modelled *ET* estimates and the *PT* α parameter discussed. The daily CMD components and estimate is then presented and annual budgets are provided for the growing season period (May – September). Lastly, the daily CDM components and estimates are presented monthly for the growing season (May – September).

3.1 Model Input Climate Variables

A detailed review of BCH Site C climate station data is available in the Site C Climate and Air Quality Monitoring: 2019 Annual Report (RWDI, 2020). Here the focus is on measurements made during the Growing Season (GS) that were input variables or of interest to the computation of the CMD and CDM. The Fort St. John Airport normals indicate that 2019 was a cooler and wetter year than others on record (RWDI, 2020).

In Figure 3-1, *G* is an order of magnitude lower than the other energy balance components that are measured at all stations. Stations 6 and 11 both have high *G* values early in the GS and this difference is likely due to similarities in ground cover (unmanaged pasture dominated by grasses and small shrubs) and soil types (i.e., likely fluvial soils as both stations are close to the Peace River). All stations display a normal distribution in radiation balance components that is controlled by the suns seasonal cycle. The R_n values indicate that R_n is greatest at Stations 1, 4 and 10 after spring melt and before the winter freeze (Figure 3-1). High R_n values would suggest that *ET* would be larger at those locations.

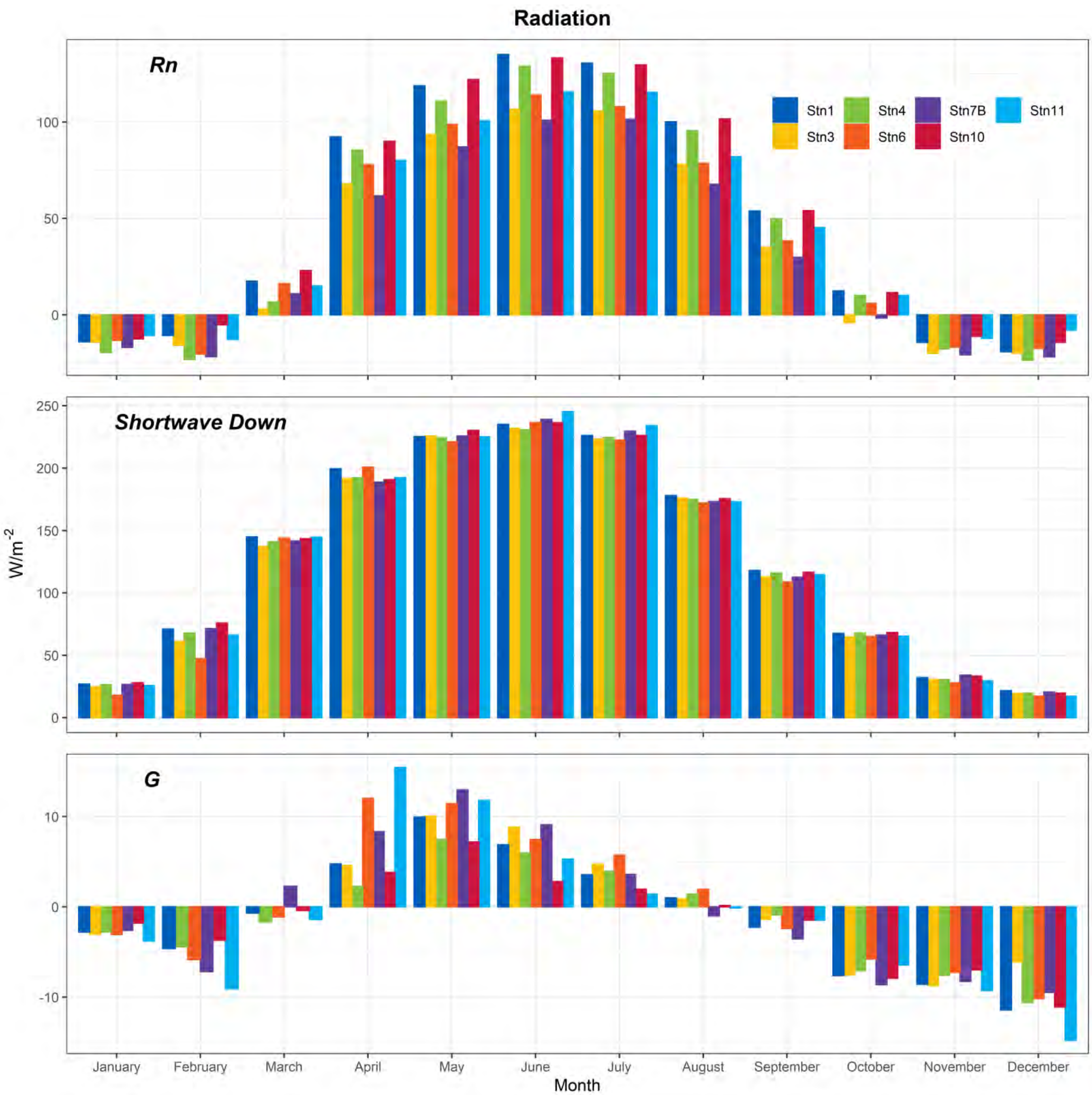

Figure 3-1: Mean monthly radiation balance components measured at all climate stations

Net-radiation components (incoming and outgoing short and longwave radiation) are only measured at Stations 1, 4, 10 and differences are small between the Stations (Figure 3-2). Incoming shortwave radiation is measured at all locations and was similar between stations (Figure 3-1). One would expect incoming longwave radiation to be similar (likely controlled by regional weather patterns for the day). Differences in R_n are likely due to differences in the surface absorption of long or shortwave radiation resulting in less of either of these outgoing components at stations where R_n is higher. Increasing absorption of these components over vegetated land surfaces that there is increasing biomass. Increasing live biomass would result in faster rates of photosynthesis and more *ET*, assuming all other things remaining the same.

Wind speeds were highest at Stations 1, 3, 7 and 10. These stations are in more exposed locations and at a higher elevation that the other stations. Higher wind speeds increase ET by moving moist air away from surfaces and increasing the moisture gradient. Mean monthly T_a was highest at Stations 7B and 11 during the GS (Figure 3-3). These two stations are at the most southeasterly edge of the monitored area and close to the urban areas of Fort St. John and Taylor (Appendix A). Relative humidity (Figure 3-3) was highest at Station 11 (lowest elevation, close to Peace River) throughout the entire year, steadily increasing at all stations from a seasonal low in April (~55 %) to a high in December (75 – 85 %). There was next to no precipitation during the time of spring melt in March, while precipitation measurements were highest during the GS in June and August. The highest precipitation (Figure 3-3) at all stations was measured in August, with Stations 1, 3 and 4 significantly exceeding Stations 7B, 10 and 11. Farmers in that area reported difficulty accessing fields for fall harvest due to wet soil conditions (Pers. comms Barry Tompkins). Station 3 recorded the highest monthly precipitation in May, June, July and August. It is clear from Figure 3-3 that the soil volumetric water content (VWC) was greatest throughout the GS at Station 3 and this is likely in part due to the higher precipitation and also the specific soil type at that location. This suggest that there would be less of a limitation to *ET* and rates should be high at this station. Earlier in the GS, Station 4 had the second highest soil VWC and this switched to Station 1 towards the end of the GS.

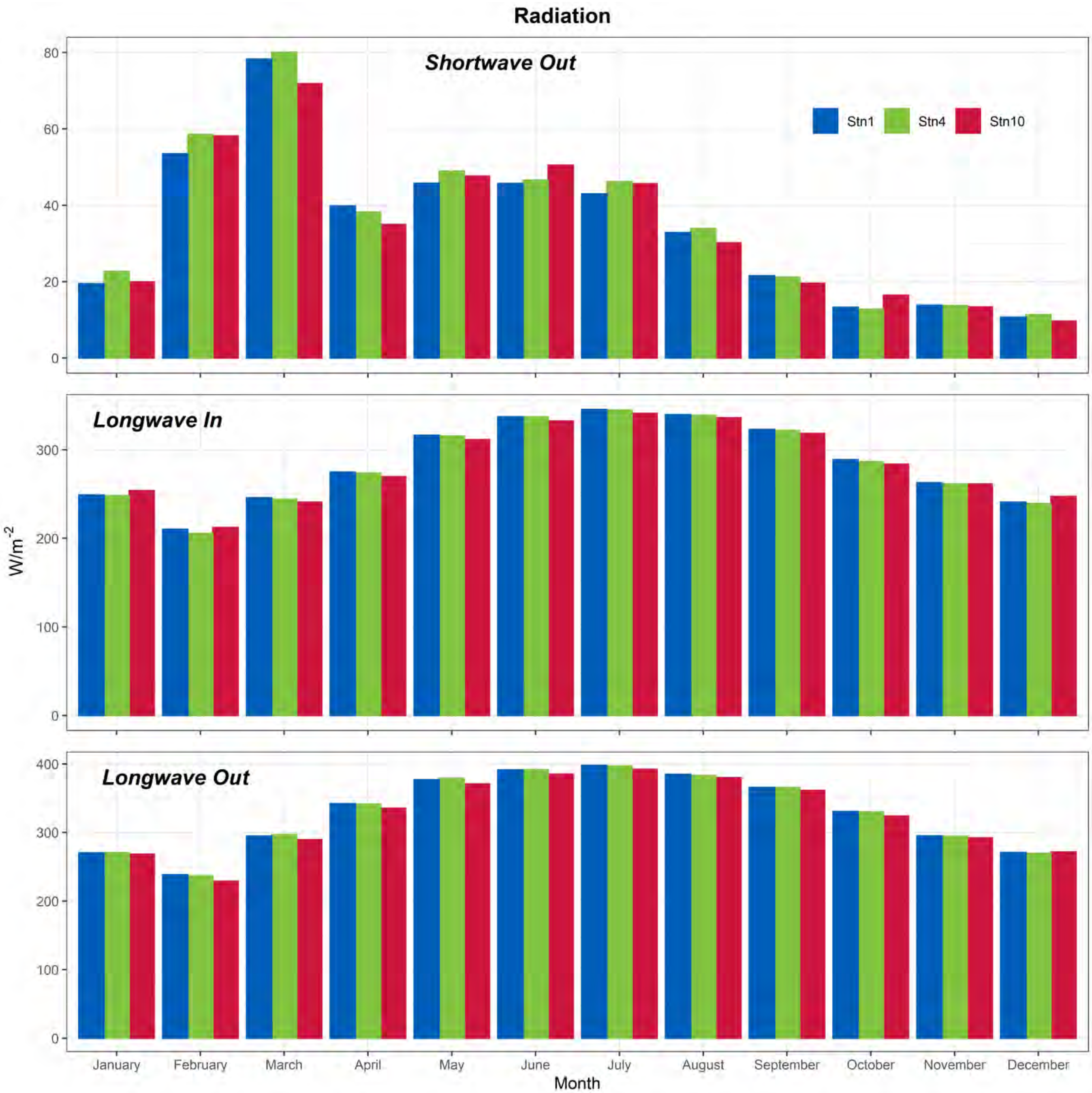

Figure 3-2: Mean monthly radiation balance components measured at EC Stations 1 and 4 and climate Station 10.

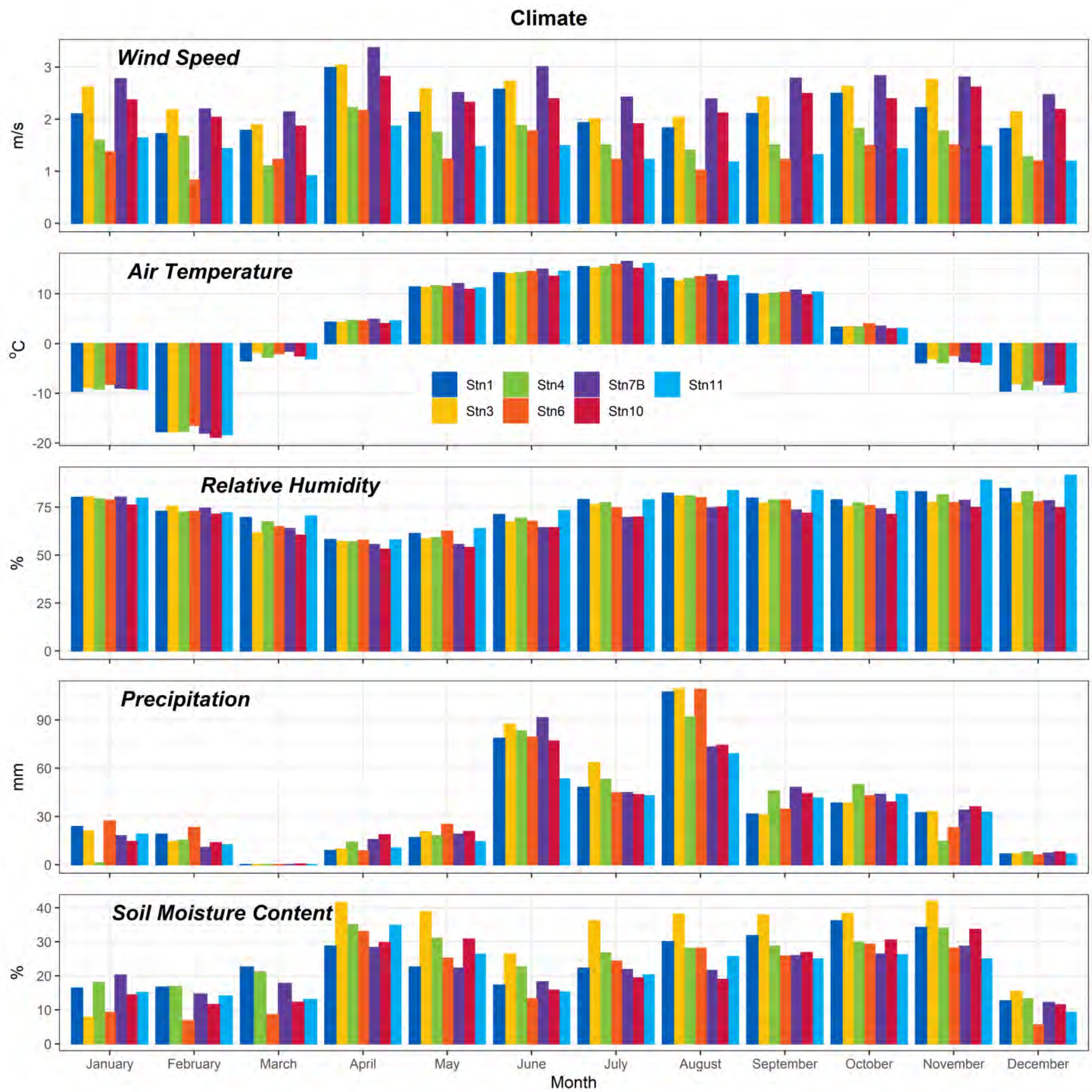

Figure 3-3: Mean monthly air temperature and relative humidity, and, cumulative monthly precipitation measured at all stations in 2019

3.2 Energy Balance Measurements and Evapotranspiration

Energy balance components at both EC stations followed similar trends throughout 2019 (Figure 3-4). The sensible heat flux (*H)* and soil heat flux (*G*) increased in April after the snow melted through March, while *LE* and R_n followed a similar normal distribution throughout the year. Net-radiation (R_n) was on average greater at Station 1 than 4 and measured *LE* was generally higher at Station 4 (Figure 3-5). These differences are likely due to differences in such things as vegetation cover and soil type. It can be seen clearly in the monthly cumulative values (Figure 3-4 and from the annual cumulative (Figure 3-5) values that Station 4 maintains a more pronounced difference in *LE* towards the end of the growing season when wheat and grasses at Station 1 were starting to flower. The cumulative *ET* was greatest at Station 4, reaching 384 mm compared to 344 mm at Station 1 with a difference of 40 mm, prior to EBC. It was possible to calculate the monthly EBC for each station. The average monthly EBC values were 0.70 and 0.84 for Stations 1 and 4, respectively. Applying the monthly corrections to the estimates of *ET* would increase their values to 423 and 473 mm, respectively. This increases the difference in annual cumulative *ET* for 2019 to 50 mm. Figure 3-5, indicates that this has little impact on the seasonal trends and monthly differences.

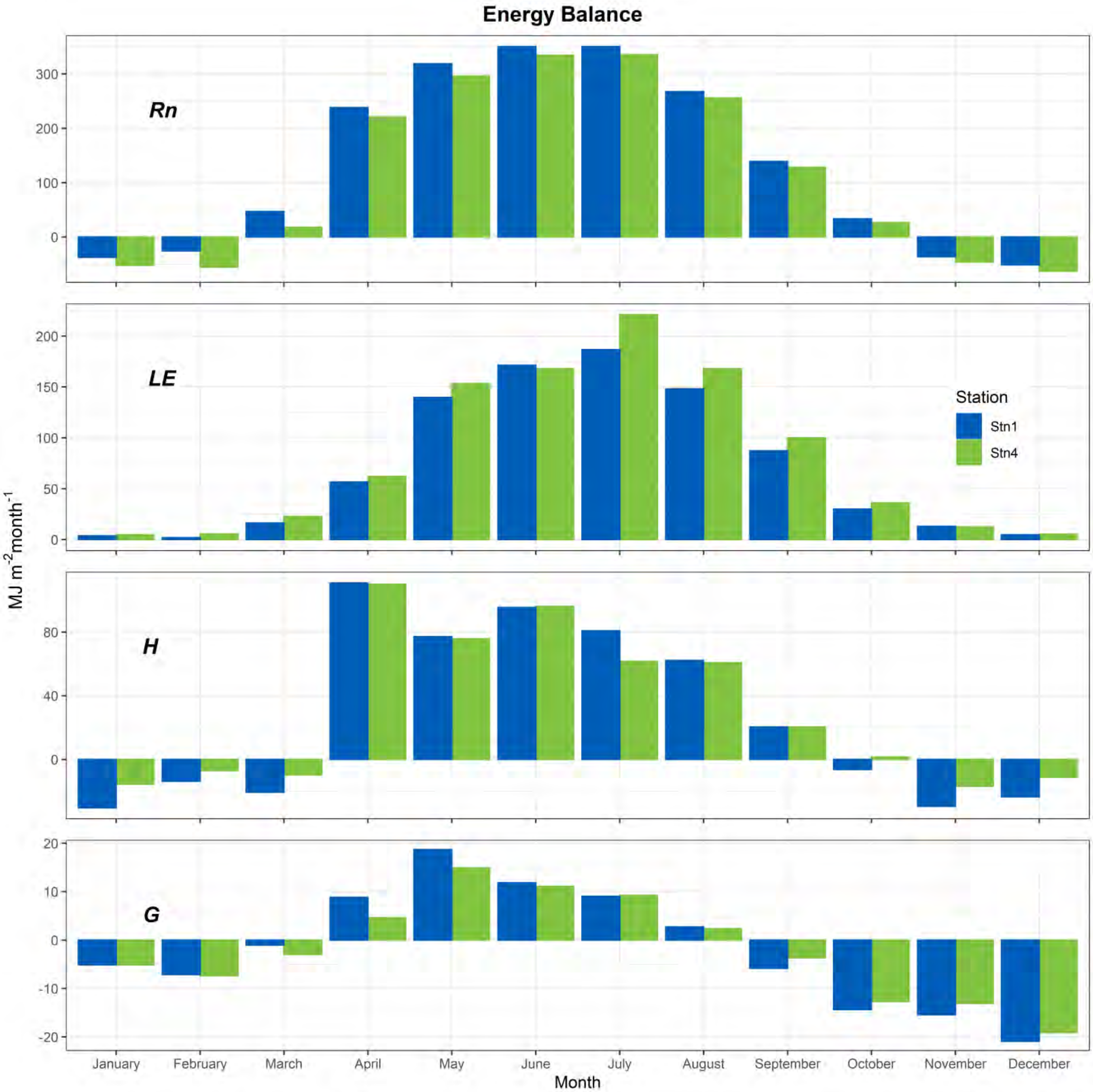

Figure 3-4: Cumulative monthly energy balance components measured at EC Stations 1 and 4.

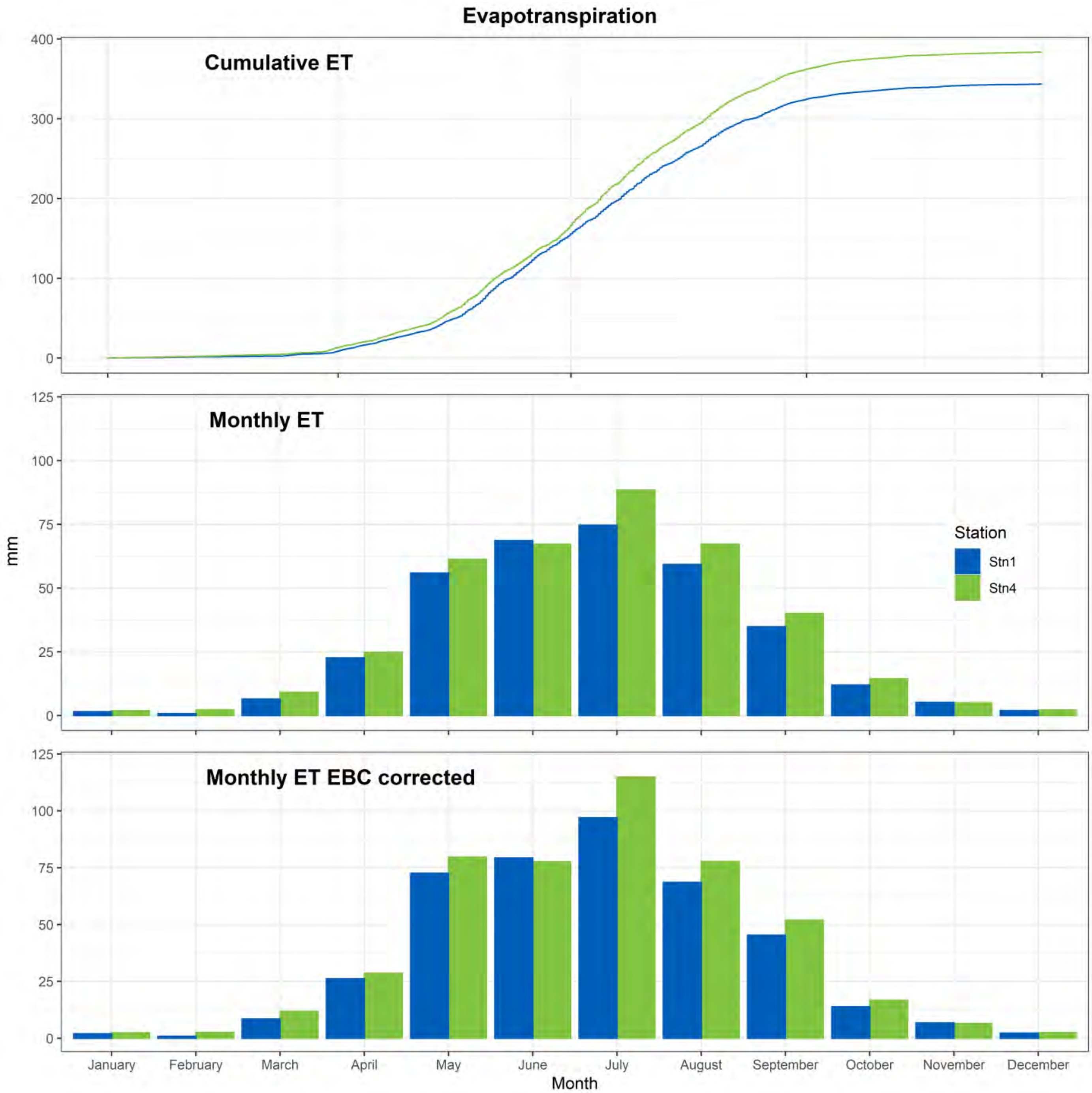

Figure 3-5: Cumulative annual and monthly ET from EC measurements available at Stations 1 and°4.

3.3 Modelled Evapotranspiration

The linear relationship between modelled and measured λE is illustrated in Figure 3-6 for Stations 1 and 4, where direct measurements of λE were available. The larger λE at Station 4 discussed above is apparent in the steeper slope of that the linear regression. The PT modelled estimates of λE were on average 174 W/m^2 greater than measured values at Station 1 and 168 W/m^2 without EBC applied. After the EBC correction was applied, this difference becomes smaller, down to 142 and 148 W/m^2 for Stations 1 and 4, respectively.

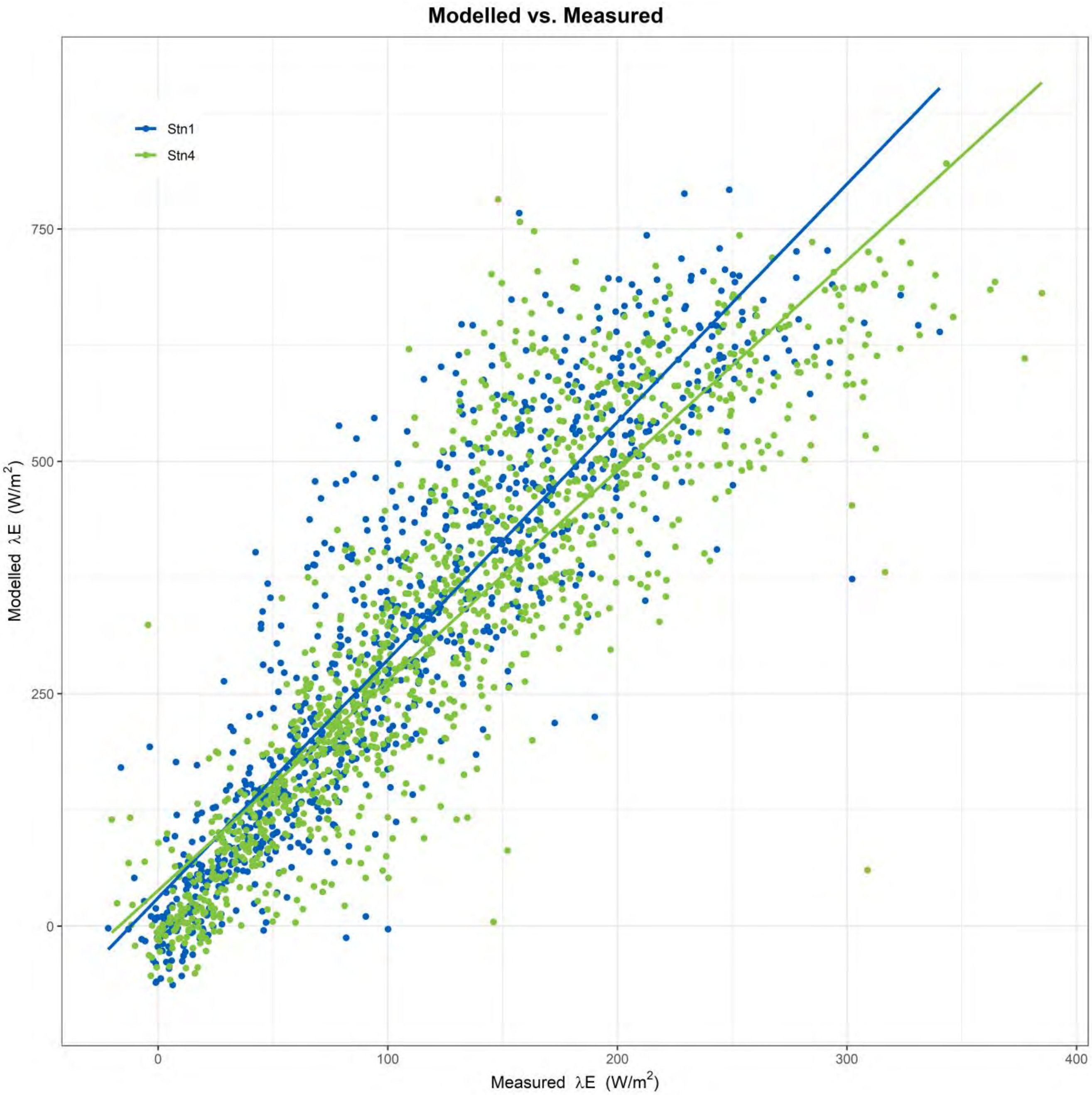

Figure 3-6: Hourly measured λE vs. PT modelled λE. No EBC correction has been applied and PT α value of 1.26 was used.

Table 3-1 illustrates the differences in the two stations linear regression equations when comparing measured vs. modelled. The correlation coefficient remains the same regardless of EBC, while the slope is shown to be reduced with the correction applied. Prior to any corrections, the difference between modelled and measured estimated values of *ET* were 0.35 and 0.37 for Stations 1 and 4, respectively. After the EBC correction was applied, this difference was reduced to 0.33 and 0.36 mm at Stations 1 and 4, respectively. This reflects an improvement in the accuracy of the modelled estimate.

PET calculated here is converted to actual *ET* using the PT α obtained from the EC systems. For this report, the measured LE_o, during periods when soil moisture was above field capacity and when incoming energy was not limiting for plant growth, were used to investigate the PT α parameter. From measurements during the growing season, it was determined that PT α for Stations 1 and 4 were likely close to 0.81 and 0.75, respectively. These are both very different from the previously provided value in the literature of 1.26 (Davis & Davies, 1981). Using these new values further reduces the difference in the estimate of *ET* for each station to a growing season mean difference of 0.18 mm/h and 0.17 mm/h. This change can be seen to also reduce the slope and the intercept of the linear regression equations (Table 3-1) reflecting a further improvement in the accuracy of the modelled estimate. For the purpose of this report, the mean α value of 0.78 was used to model *ET* for all climate stations.

Adjustments to the PT α parameter remain to be investigated further as more data is accumulated in future years of monitoring. Furthermore, efforts are underway to provide a moving average computation of this parameter to better represent the phenological changes in the vegetation cover across the growing season. This is complicated by the need for soil moisture to be above field capacity and collecting more data, year on year with the same vegetation cover, within this soil moisture range. Currently, there is insufficient data available for this to be attempted.

Table 3-1: Modelled vs. measured *λE* linear regression output.

Station	α	*γ*	EBC	Intercept	Slope	R^2	DF	*P*
1	1.26	0.062	1	30.669	2.559	0.81	934	<2.2e-16
4	1.26	0.062	1	38.631	2.258	0.78	1234	<2.2e-16
1	1.26	0.062	1.3	30.669	1.969	0.81	934	<2.2e-16
4	1.26	0.062	1.16	38.631	1.946	0.78	1234	<2.2e-16
1	0.81	0.062	1.3	19.71	1.266	0.81	934	<2.2e-16
4	0.75	0.062	1.16	22.995	1.159	0.78	1234	<2.2e-16

3.4 Climate Moisture Deficit

The hourly cumulative estimates of components and resulting CMD are presented in Figure 3-7. There is a noticeable difference between the end of year group maximum and minimum values of *EP*, *ET* and the resulting CMD (Table 3-2). Station 10 had the highest CMD, more than 50 mm above the average by the end of the growing season (288.6 mm). The stations in decreasing order of CMD are 10, 4, 11, 1, 7, 3 and 6. The largest difference in *ET* was between Stations 10 and 6 with 357.9 and 276.2 mm, respectively. Station 6 had the highest EP while Station 11 had the lowest (Table 3-2). The low EP at station 10 (69.3 mm) and high *ET* are the reason why at the end of the growing season that station had the largest CMD. At all stations, the *ET* values were larger than the *EP* values reported, and as such, there was a moisture deficit throughout the growing season. The periodic influence of *EP* on CMD can be seen by the saw-toothed increase, whereas *ET* had a diminishing rate through the growing season (Figure 3-7). A wet month of August can be seen to temper the extent of the CMD in 2019. The importance of accurate estimates of *ET* encourages continued investigation of the EBC of raw measurements and adjustments to the PT model parameters as more data becomes available.

Table 3-2: Cumulative growing season CMD and climate controls and mean air temperature.

PT α	Station	Percentage Data Cover	*Rn*	*Ta*	*EP*	*ET*	CMD	Dominant Land Cover
	1	99.8	107.8	12.8	81.6	340.4	**258.8**	Grasses and wheat
	3	100.0	90.5	12.6	90.5	278.5	**188.0**	Grasses and wheat
	4	99.9	102.2	12.9	79.0	346.7	**267.7**	Alfalfa/clover cover crop
0.78	6	100.0	89.6	13.1	93.4	276.2	**182.8**	Grasses/wildflower/pasture
	7	100.0	91.8	13.6	78.6	282.0	**203.4**	Grasses/wildflower
	10	99.8	108.2	12.4	69.3	357.9	**288.6**	Alfalfa/clover hay
	11	100	91.9	13.1	51.4	310.8	**259.3**	Grasses/wildflower/pasture
	Averages	**99.9**	**97.4**	**12.9**	**77.7**	**313.2**	**235.5**	

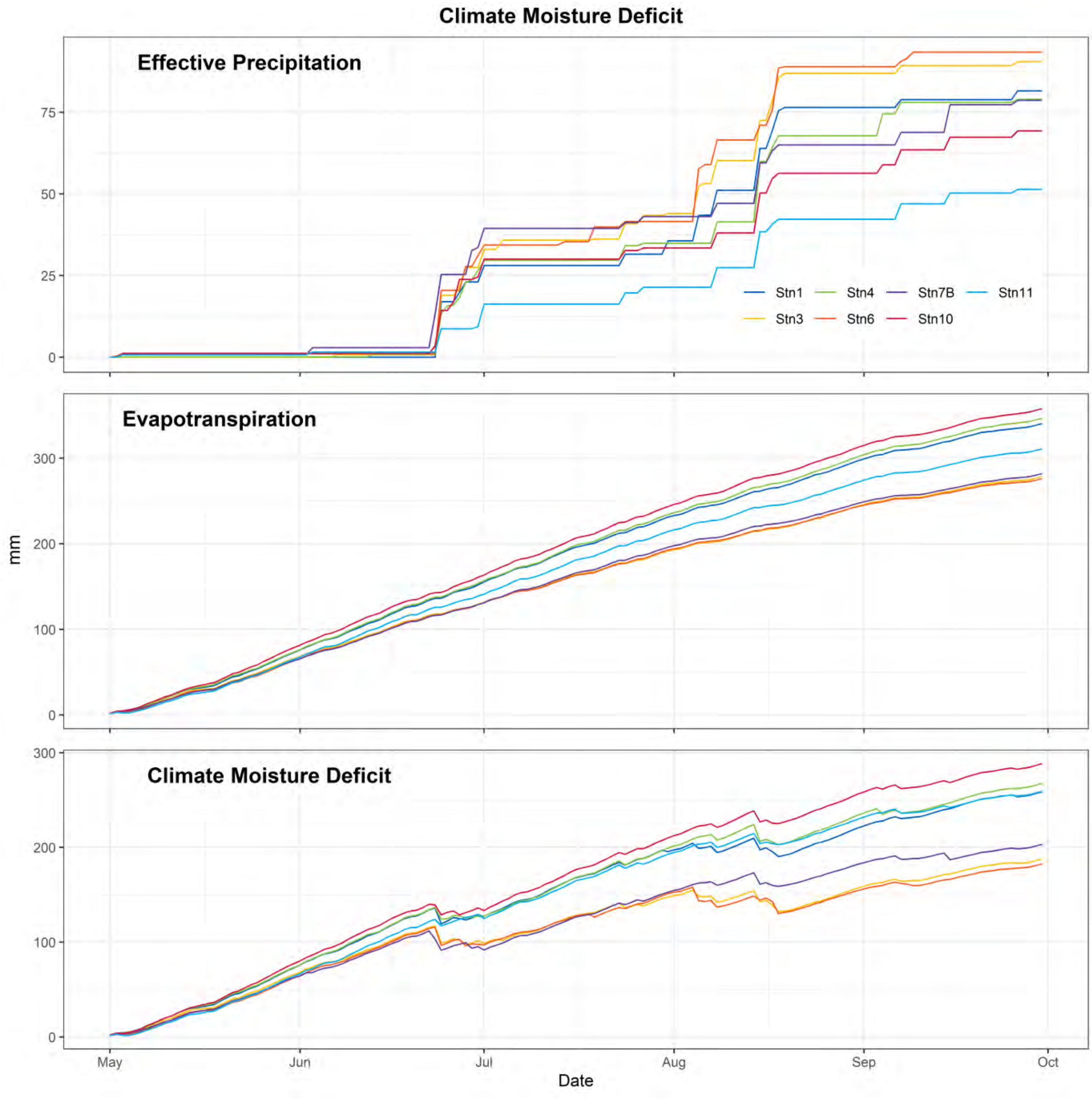

Figure 3-7: Modelled daily EP, ET and the CMD for all climate stations.

During the growing season, the CMD can be calculated monthly or on request to inform interested parties on potential water deficit and the need for irrigation in the region. As more data becomes available, statistical analysis of the different controlling variables and PT model parameters (α) on CMD will be possible. A retro-active analysis of previous years of data already collected is an option.

3.5 Crop Drying Model

The CDM was run for each month of the GS and the total number of good drying days (drying rate > wetting rate) was calculated (Table 3-3) for each station. Figure 3-8 through Figure 3-12 show the computed inputs and CDM output for each month. On average, most of the good drying days were recorded in May with a trend towards fewer good drying days per month as the GS progressed. August and September had the lowest average cumulative good drying days with 25 each. The order of stations with increasing cumulative annual good drying days is 3, 6, 1, 7B, 11, 10, and 4, with Station 4 having more than a full week (11-days) of additional good drying days (11 days) than Station 3.

Table 3-3: Growing season good drying days

Station	May	Jun	July	Aug	Sep	GS Total
1	29	25	28	24	24	**130**
3	28	25	26	23	24	**126**
4	30	27	27	26	27	**137**
6	26	27	28	23	25	**129**
7B	29	26	26	26	24	**131**
10	29	27	27	27	26	**136**
11	28	29	27	27	24	**135**
Averages	**28**	**27**	**27**	**25**	**25**	**132**

The first month of the growing season (May) had the highest average good drying days with 28. Station 4 had the most good drying days in May, while Station 10 maintained the fastest drying rate and was the first station where crop moisture content was reduced below 20% (Figure 3-8). Stations 1, 4, 7B and 10 all had above average drying days, while Stations 3 and 11 were average. Station 6 was below average with just 26 good drying days. Station 6 experienced more intense rainfall throughout May than other stations and the lowest drying rate (Station 8). Station 6 was the last station where crop moisture content was reduced below 20%.

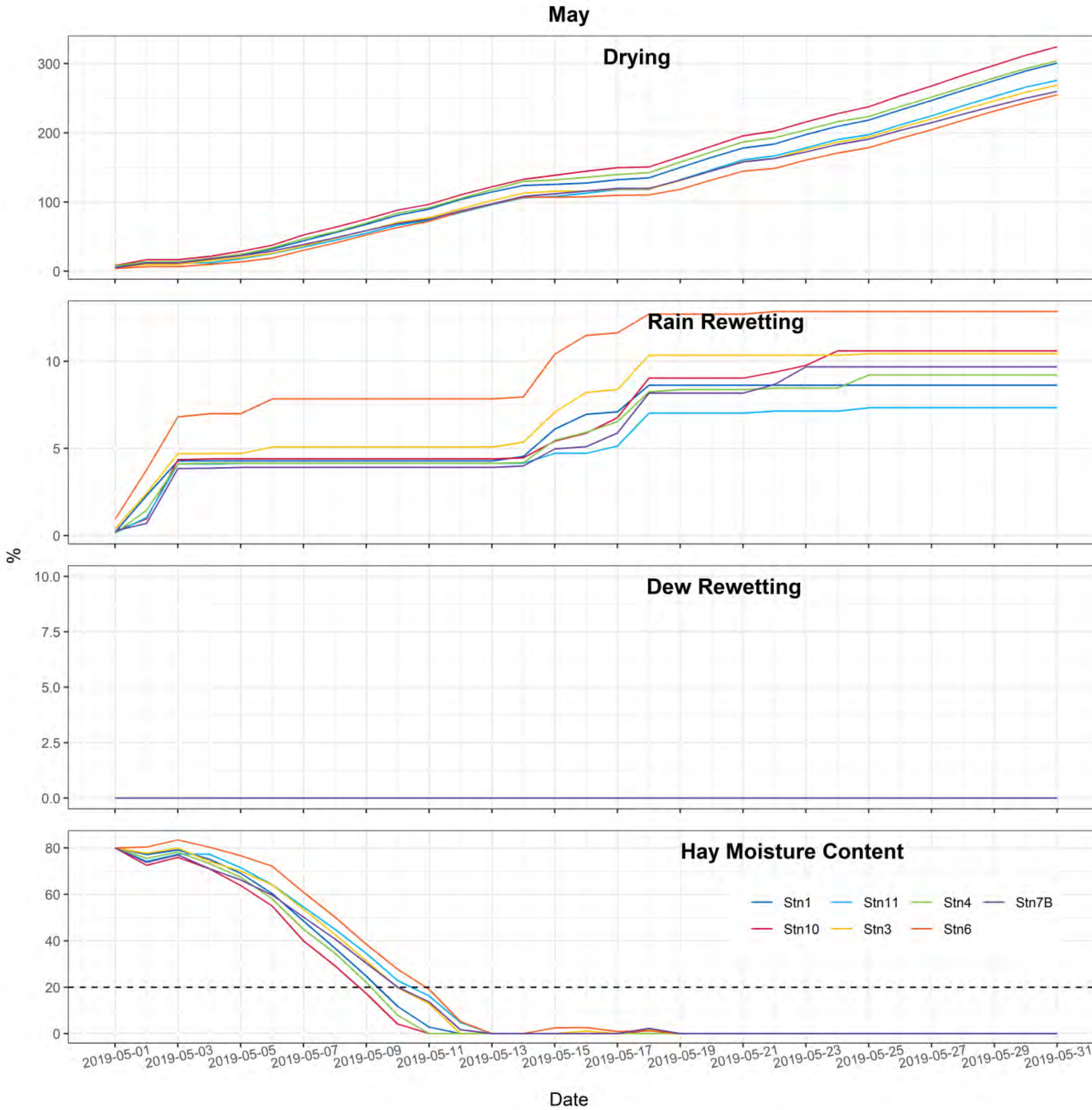

Figure 3-8: CDM components for May 2019.

The month of June had on average of 27 good drying days. Station 11 had the most good drying days with 29, while Station 10 again maintained the fastest drying rate and was the first station where crop moisture content was reduced below 20% (Figure 3-9). Stations 4, 6 and 10 all had the average number of good drying days, while Stations 1, 3 and 7B were below average. Station 3 was the last station where crop moisture content was reduced to below 20%.

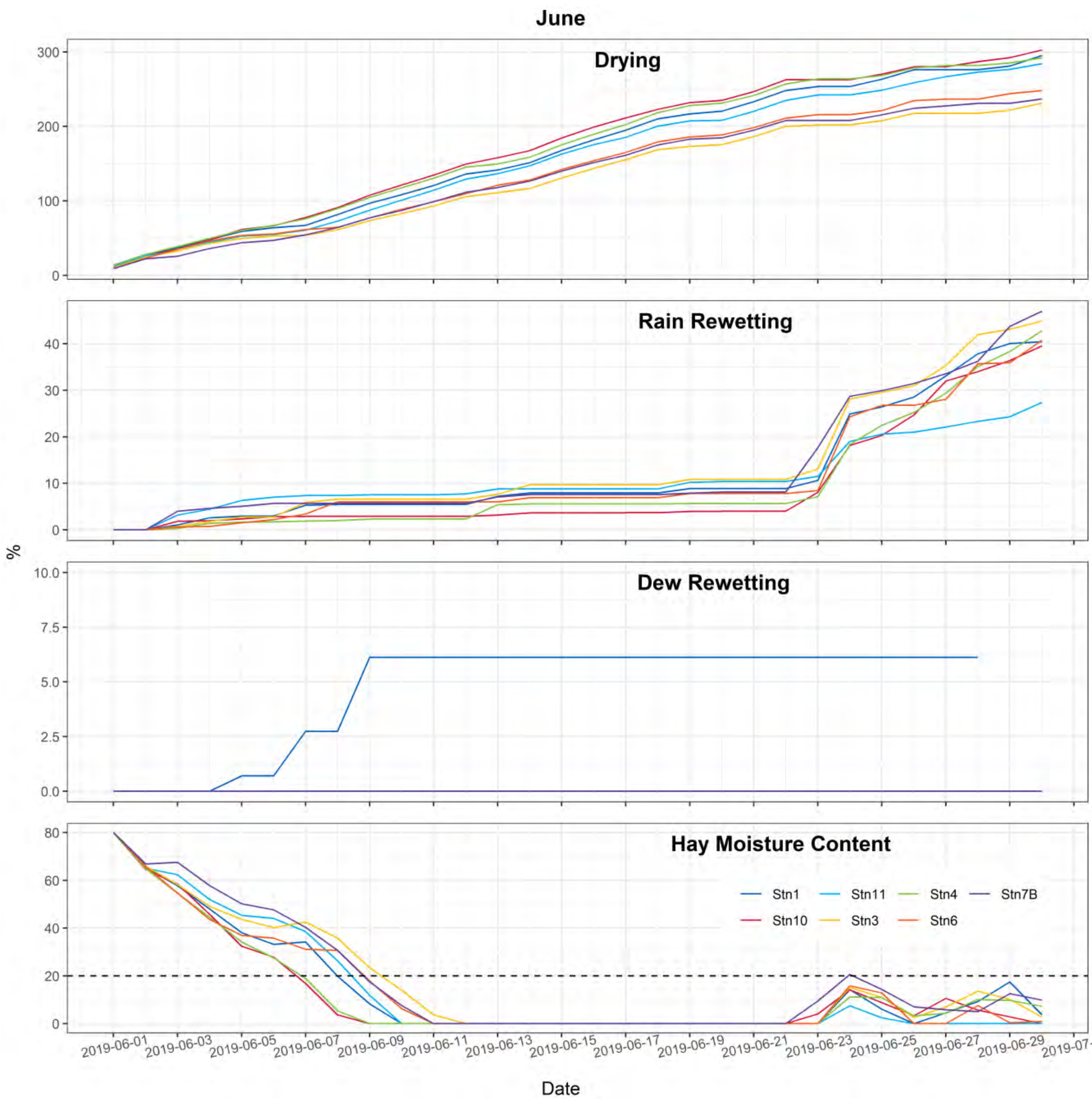

Figure 3-9: CDM components for June.

Like June, the month of July had on average 27 good drying days. Stations 1 and 6 had the most good drying days with 28 each, while Station 10 again maintained the fastest drying rate and was the first station where crop moisture content was reduced below 20% (Figure 3-10). Stations 4, 10 and 11 all had the average number of good drying days, while Stations 3 and 7B were below average. Station 3 recorded the lowest drying rate and greatest wetting rate. Station 3 was the last station where crop moisture content was reduced to below 20%.

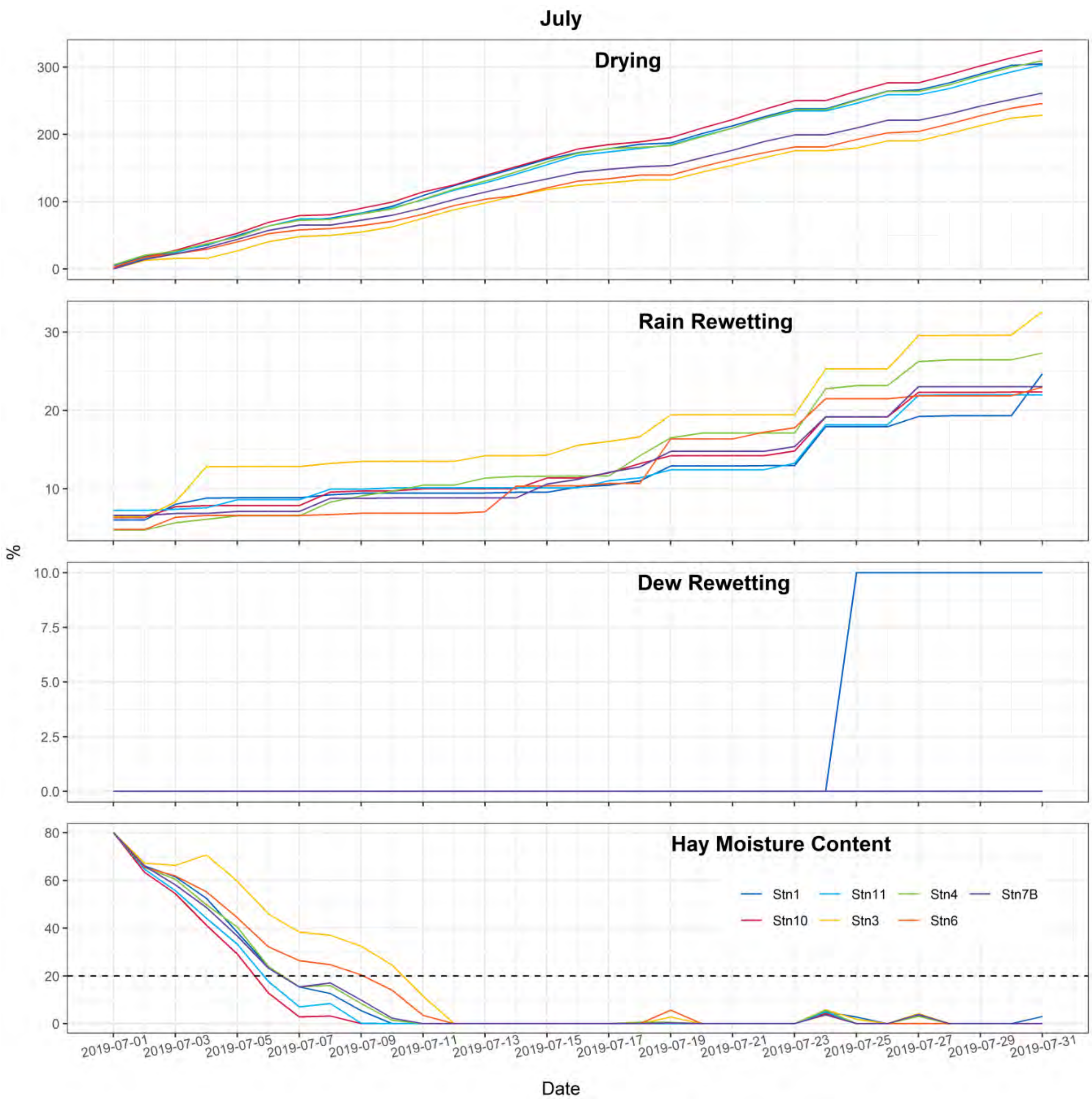

Figure 3-10: CDM components for July.

The month of August had on average 25 good drying days. During August Stations 1, 3, 4 and 6 recorded the most precipitation of all growing season months with a wetting rate >45% (Figure 3-11). Stations 10 and 11 had the most good drying days with 27 each and Station 10 again maintained the fastest drying rate and was the first station where crop moisture content was reduced below 20% (Figure 3-11). Stations 4, 10 and 11 all had the average number of good drying days, while Stations 3 and 7B were below average. Station 3 was the last station where crop moisture content was reduced to below 20%.

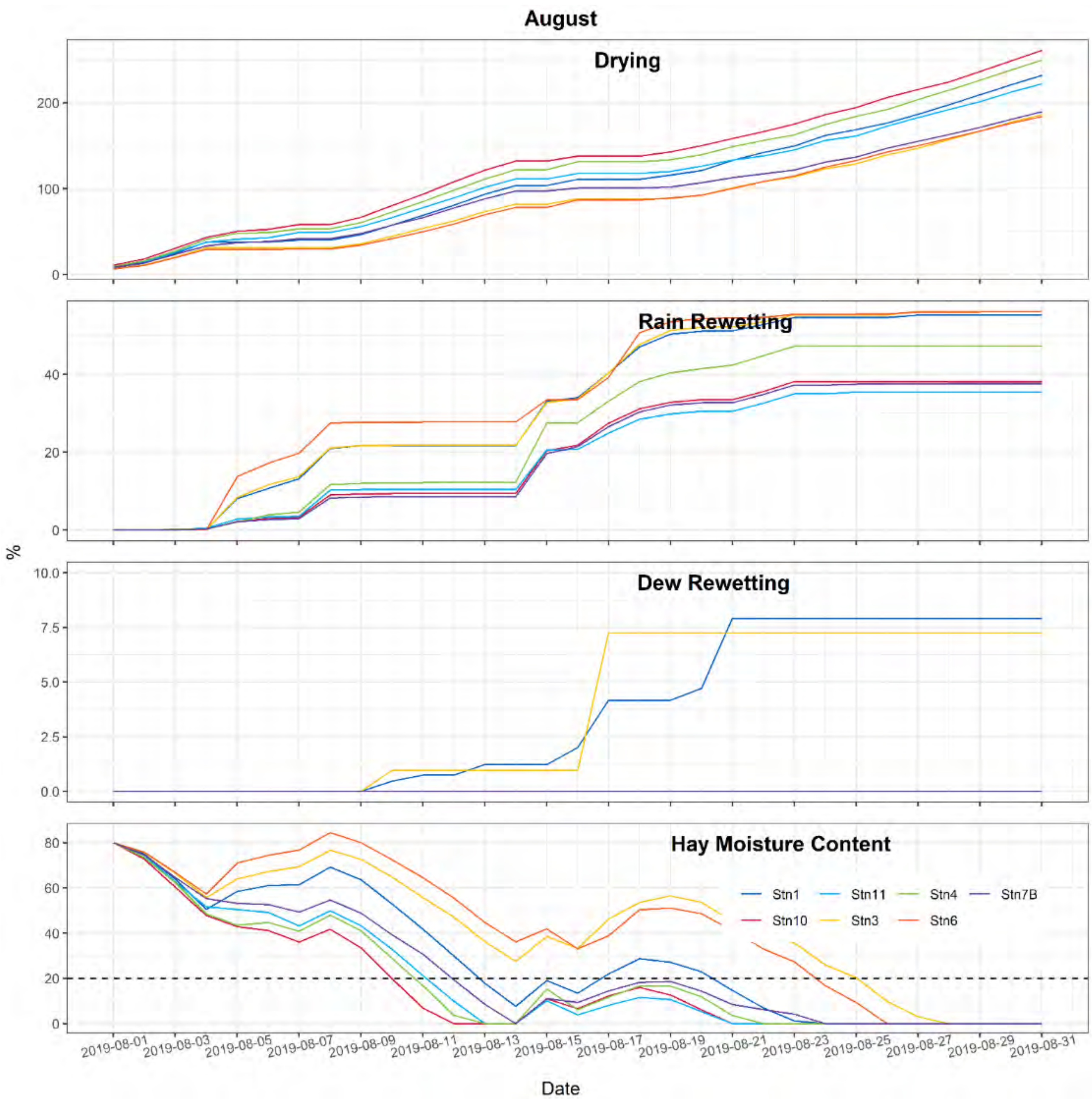

Figure 3-11: CDM components for August.

Like August, the month of September had on average 25 good drying. Station 4 had the most good drying days with 27. Again Station 10 had above average good drying days, maintained the fastest drying rate and was the first station where crop moisture content was reduced to below 20% (Figure 3-12). Station 6 had the average number of good drying days. Stations 1, 3, 7B and 11 had below average good drying days. Unlike other months, where Station 3 was last, in September Station 7B was the last station where crop moisture content was reduced to below 20% due to a rain rewetting event that occurred on the 14th and was only recorded at Stations 7B, 10 and 11, the most easterly stations in the monitoring network.

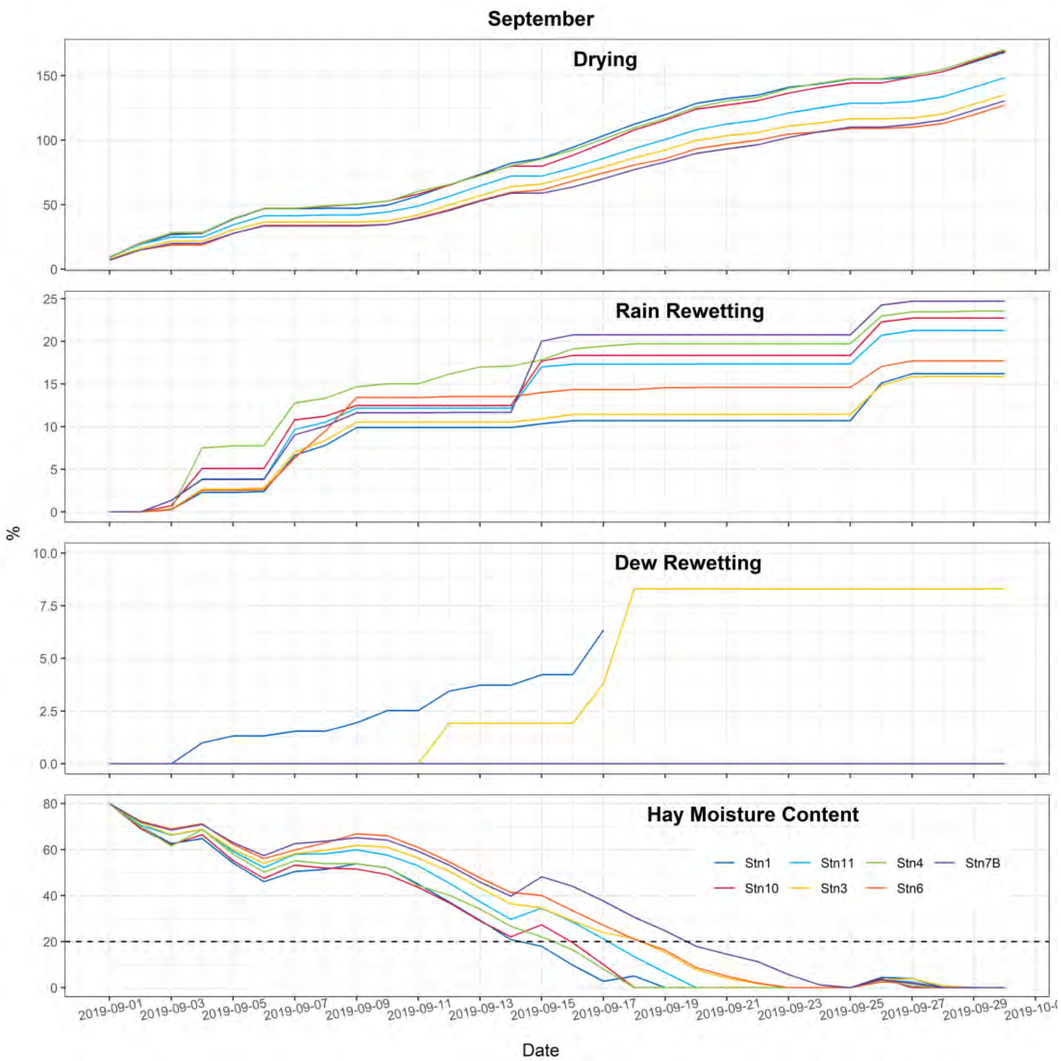

Figure 3-12: CDM components for September.

Month over month and similar to the CMD results, Station 10 can be seen to have the highest drying rate and in all cases, except September, was the first station to record crop moisture below 20% moisture content. A large rain event in September was measured at Stations 7B, 10 and 11, and not at Station 1, which was the first to record crop moisture below 20 % moisture content for that month. Of note is that the three stations recording the lowest good drying days (Stations 3, 6 and 1) are the most westerly stations being monitored and that these stations had the highest *EP* (Figure 3-7).

The monthly plots shown above are helpful in illustrating the drying trends within that month and can be provided monthly after data QA/QC has been completed. With harvest timing input from farmers along with an estimate of the starting wet weight moisture content of the crop, drying computations can be created and used to provide input on crop drying conditions in the region. A retro-active analysis of previous years of data already collected is also an option.

4 SUMMARY OF RESULTS

The EC system performance for collected high frequency data was over 75% for both stations and the daily collection of half hour computed fluxes and climate data resulted in a 100% data representation for 2019.

Climatologically 2019 was a wet and cool year. Differences between stations climate are the result of differences in elevation, aspect and exposure as well as vegetation cover and soil type. Stations at higher elevations recorded higher wind speeds. Stations 1, 4 and 10 had higher monthly net radiation throughout the GS than other stations. The ground/field cover type differed at all three of these locations (and are representative of the Site C monitoring area), from wheat and grasses, Alfalfa/clover/grasses/wildflower cover crop and Alfalfa/clover/grasses forage cover crop, respectively.

The total amount of *ET* recorded at Stations 1 and 4 was 344 and 384 mm, respectively. The average monthly EBC was 0.70 and 0.84 for Stations 1 and 4, respectively. Applying the monthly corrections to these estimates of *ET* increased their annual cumulative values from to 423 and 473 mm, respectively. This adjustment resulted in an improvement in the accuracy of the modelled values.

The PT proportionality constant (α) was used to provide an estimate of actual *ET* from PET estimates made using the PT radiation-based approach. A common value recommended for this constant is 1.26. From measurements during the growing season, it was determined that PT *α* for Stations 1 and 4 were closer to 0.81 and 0.75, respectively. Linear regression analysis showed that while the correlation of the relationship between measured vs. modelled values did not change, using this new α reduced the slope of the relationship and further improved the accuracy of the model output. An average value of 0.78 was selected to improve the accuracy of modelled *ET* at all of the climate stations where EC measurements were not available. Testing both the PET and the actual *ET* estimates for each climate station in the network, it was possible to compute drying indices that were used as an input for the CMD and CDM for each location.

A spatial summary of CMD results in presented along with the station location map in Appendix A. Station 10 had the highest CMD, more than 50 mm above the average by the end of the growing season (288.6 mm). The stations in decreasing order of CMD (CDM = *ET* – EP) are 10, 4, 11, 1, 7, 3 and 6. For all stations ET > EP during the GS and so they all experience moisture deficit by the end of the growing season. The largest difference in *ET* was recorded between Stations 10 and 6 with 357.9 and 276.2 mm, respectively.

Output from the CDM was used to compute the cumulative good crop drying days for each month and station. From this output, it was determined that on average the most good drying days were recorded in May with a trend towards fewer good drying days per month as the growing season progressed. In line with the CMD results, station 10 had the fastest and stations 3 and 6 had the slowest drying rates. August and September had the lowest average cumulative good drying days with 25. Stations to the west of the monitored area in general had fewer good drying days, as a result of differences in regional rainfall amounts.

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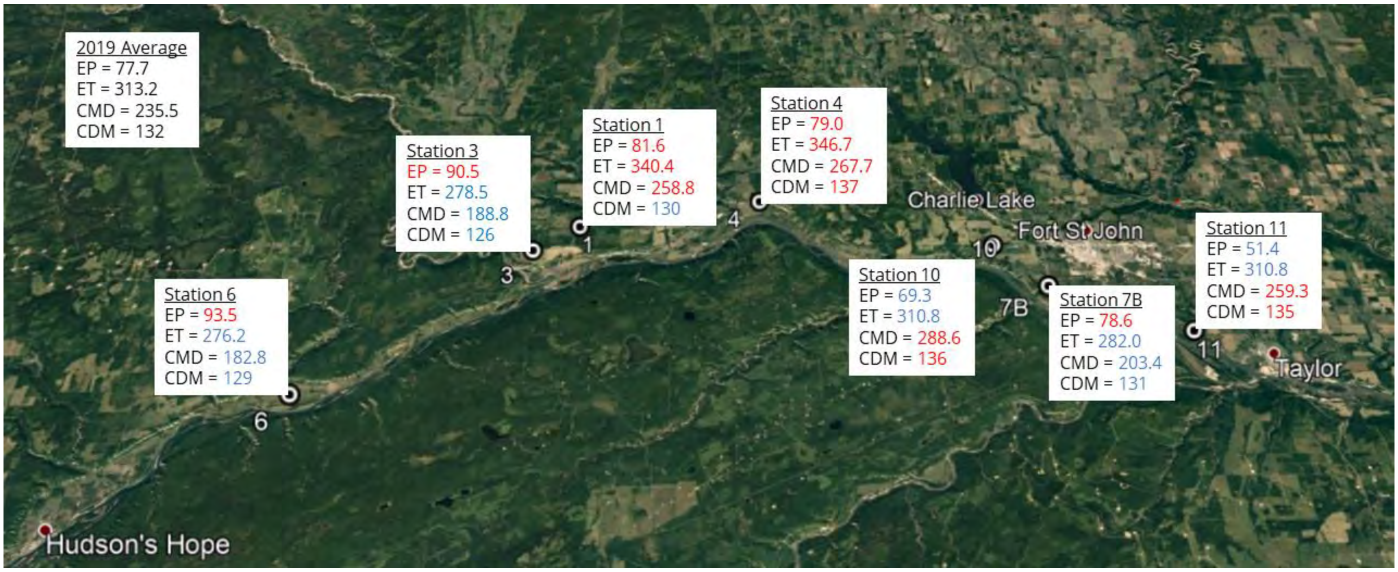
APPENDIX A

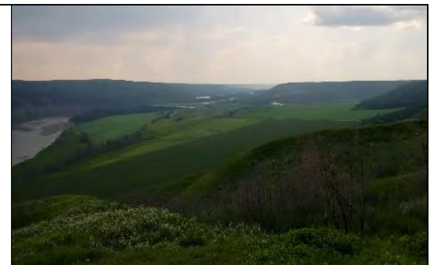
APPENDIX A: STATION LOCATION MAP WITH ANNUAL CMD & CDM RESULTS



The CMD and CDM results are presented in the figure above. The results are highlighted beside the station location and can be compared to the 2019 regional average computed using all stations (top right corner). Red indicates values that were greater than the 2019 regional average and blue indicates values that were below the annual average.

APPENDIX B

APPENDIX B: SITE PICTURES

 May	 June	 July
No access to viewpoint in August. Road works.	 September	

Station 1 site pictures

 May	No access allowed to Station 3 in June (wet field)	No access allowed to Station in July (wet field)
No access allowed to Station in August (wet field)	No access allowed to Station in September (wet field)	

Station 3 site pictures

 May	 June	 July
No picture available for August	 September	

Station 4 site pictures

 May	No station visits in June	 July
No station visits in August	No station visits in September	 October

Station 6 site pictures

 May	 June	 July
No picture available for August	No picture available for September	 October

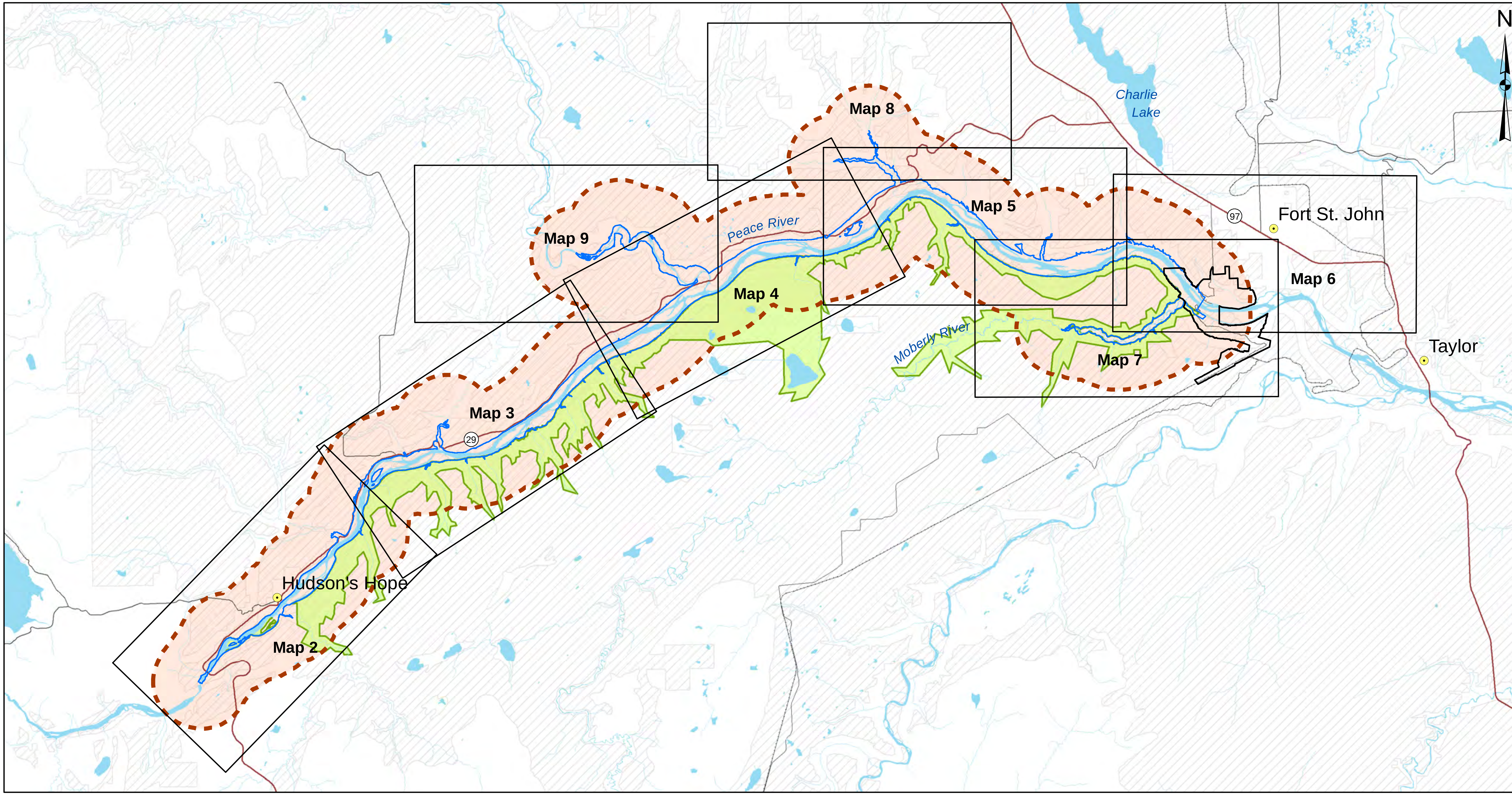
Station 7 site pictures

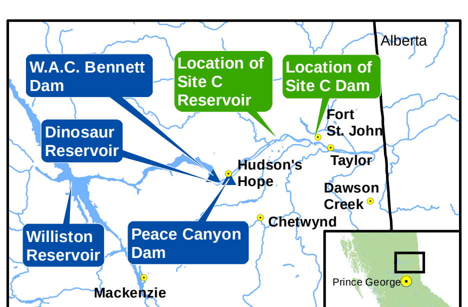
 May	No station visits in June	 July
No station visits in August	No station visits in September	 October

Station 10 site pictures

 May	No station visits in June	 July
No station visits in August	No station visits in September	 October

Station 11 site pictures





Map Notes:
1. Datum: NAD83
2. Projection: UTM Zone 10N
3. Base Data: Province of B.C.
4. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

Path: X:\ArcGISProjects\Environment\Agriculture\Ag_3kmReservoirBoundary_Overview_1016_C14_07342-1.mxd

Legend

- Area to be considered for crop drying monitoring
- Agricultural Land Reserve
- Proposed Reservoir
- Proposed Peace Boudreau Protected Area
- Dam Site Area
- Town
- Road
- Highway
- Railway

1:250,000

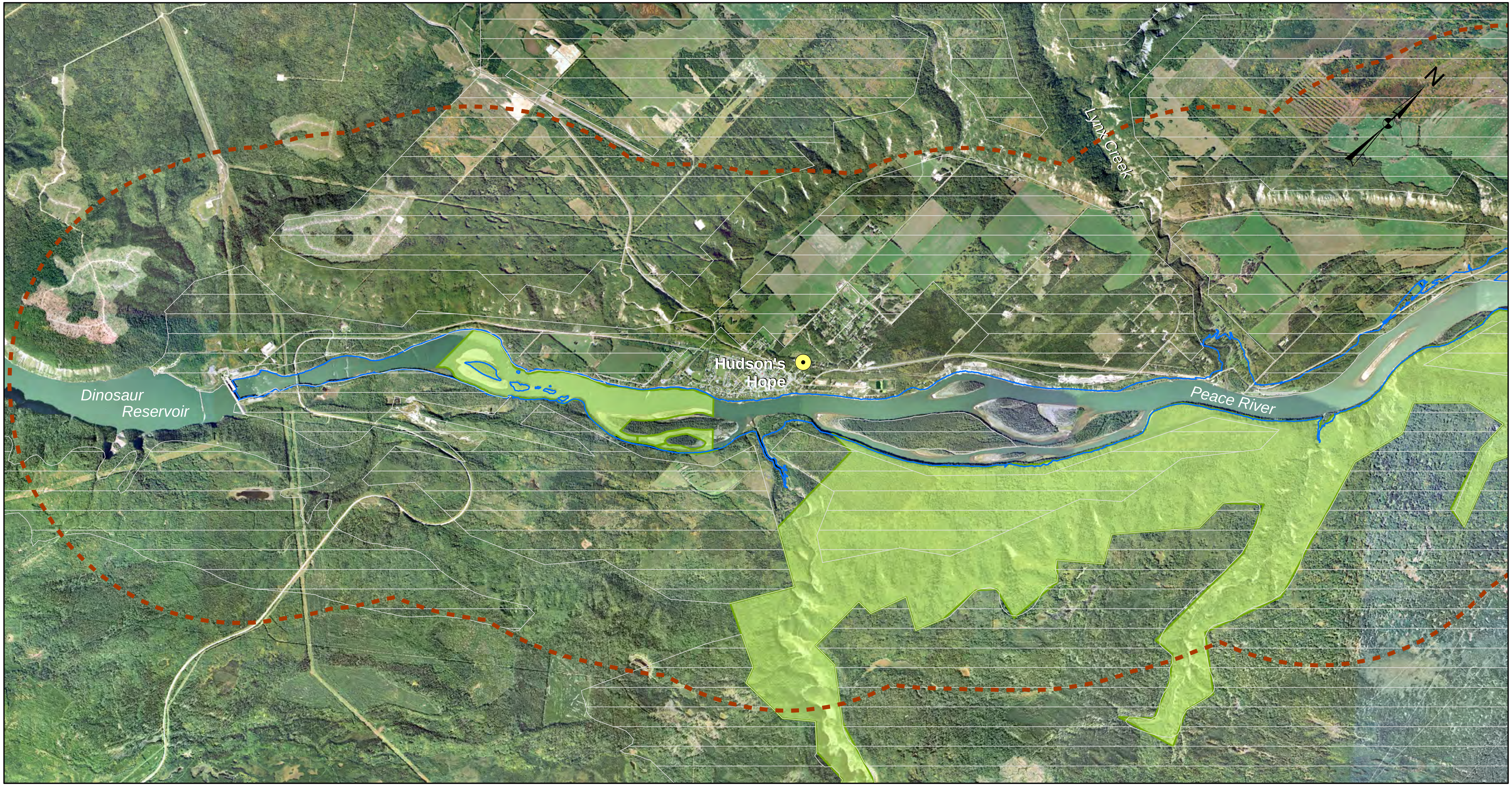
0 5 km

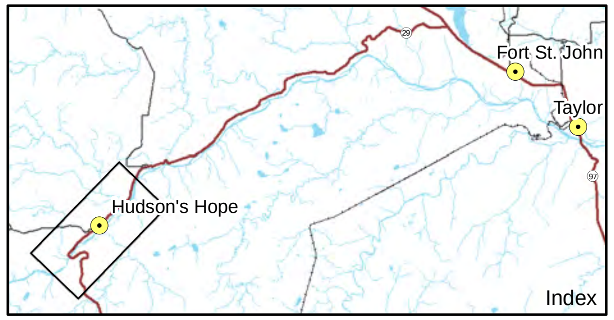
BC Hydro

Crop Drying Monitoring Area Identification - Overview Map 1 of 9

Date	July 14, 2016	DWG NO	1016-C14-07342-1	R 0

Construction of the Site C Clean Energy Project is subject to required regulatory and permitting approvals.





Map Notes:
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2. Projection: UTM Zone 10N
3. Base Data: Province of B.C.
4. Orthophotos created from 1:40,000 photos taken Sept. 10th 2007, TRIM.
5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

Legend

- Area to be considered for crop drying monitoring
- Agricultural Land Reserve
- Proposed Reservoir
- Proposed Peace Boudreau Protected Area
- Dam Site Area

1:50,000

0 2 km

BC Hydro

Crop Drying Monitoring - Area Identification Map 2 of 9

Date	July 14, 2016	DWG NO	1016-C14-07342-2	R 0

Construction of the Site C Clean Energy Project is subject to required regulatory and permitting approvals.

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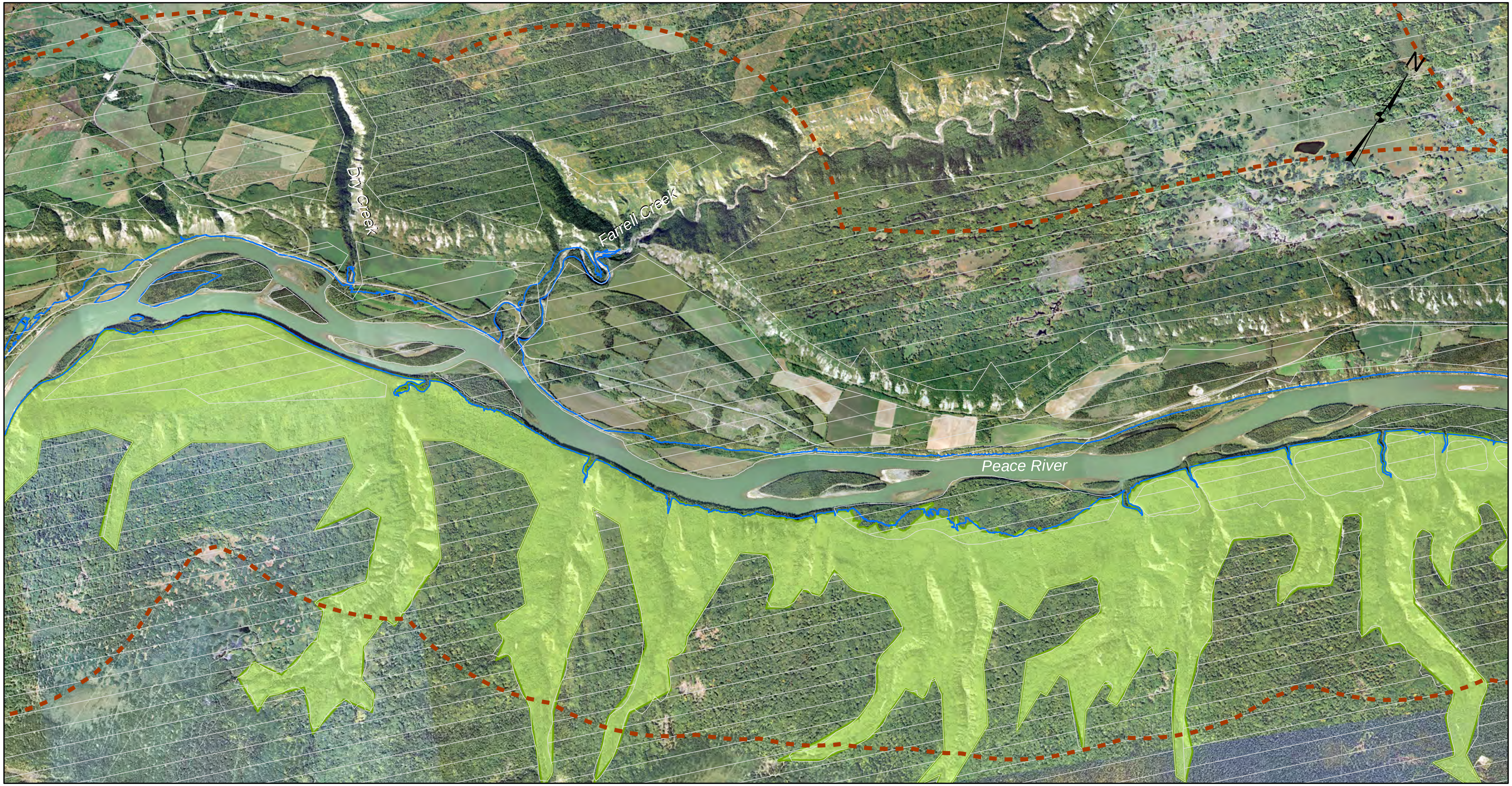

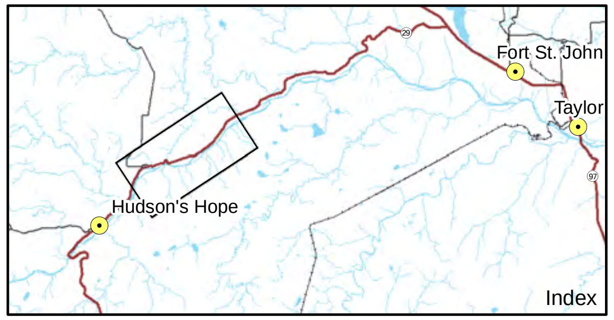

Map Notes:
1. Datum: NAD83
2. Projection: UTM Zone 10N
3. Base Data: Province of B.C.
4. Orthophotos created from 1:40,000 photos taken Sept. 10th 2007, TRIM.
5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

Legend

- Area to be considered for crop drying monitoring
- Agricultural Land Reserve
- Proposed Reservoir
- Proposed Peace Boudreau Protected Area
- Dam Site Area

1:50,000   0   2 km

BC Hydro

Crop Drying Monitoring - Area Identification Map 3 of 9

Date	July 14, 2016	DWG NO	1016-C14-07342-3	R 0

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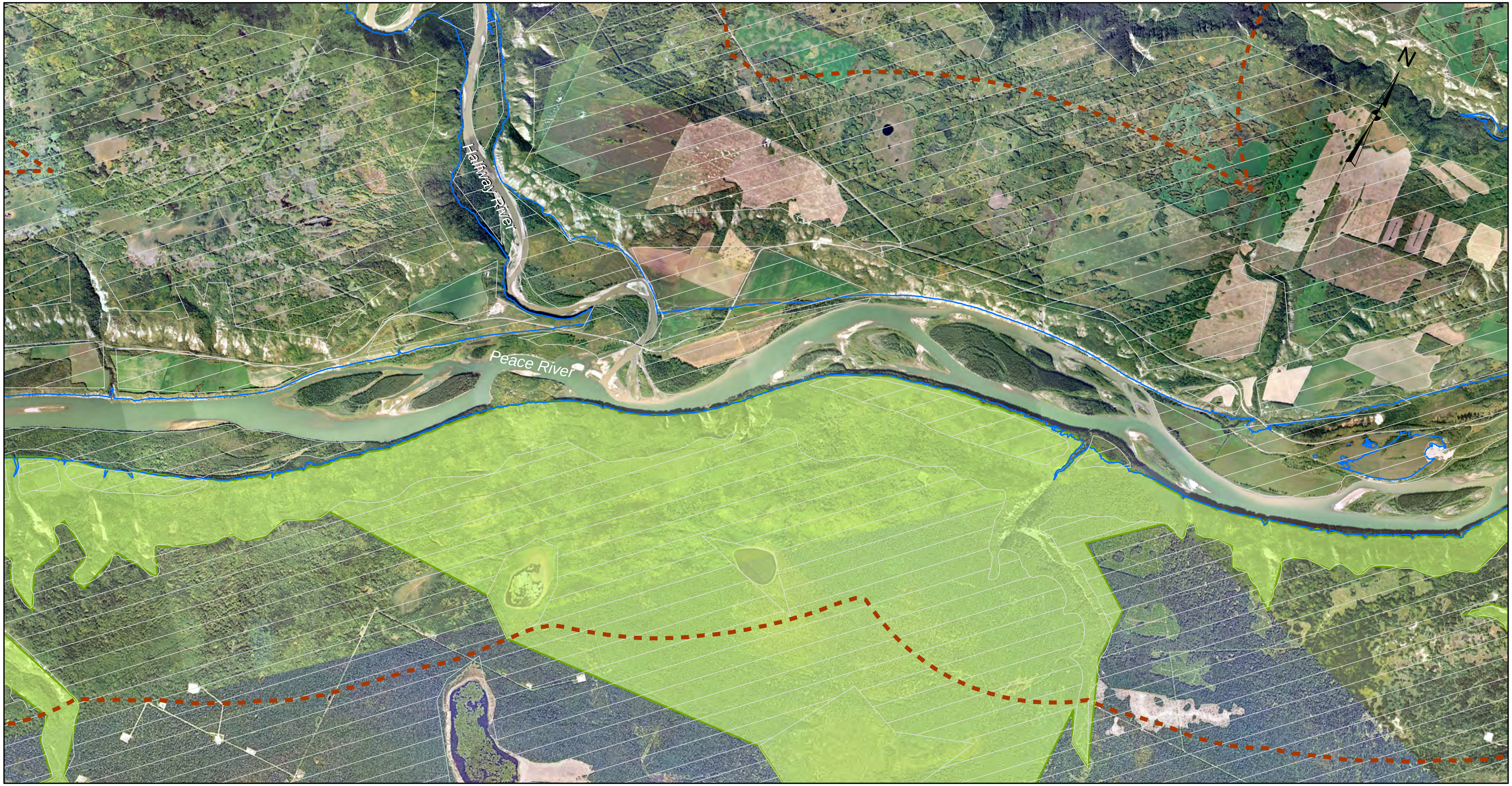
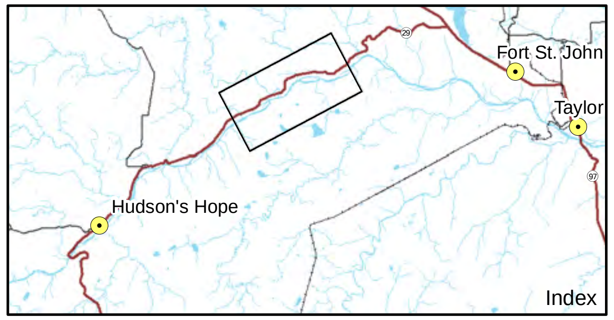




Map Notes:
1. Datum: NAD83
2. Projection: UTM Zone 10N
3. Base Data: Province of B.C.
4. Orthophotos created from 1:40,000 photos taken Sept. 10th 2007, TRIM.
5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

Legend

- Area to be considered for crop drying monitoring
- Agricultural Land Reserve
- Proposed Reservoir
- Proposed Peace Boudreau Protected Area
- Dam Site Area

1:50,000

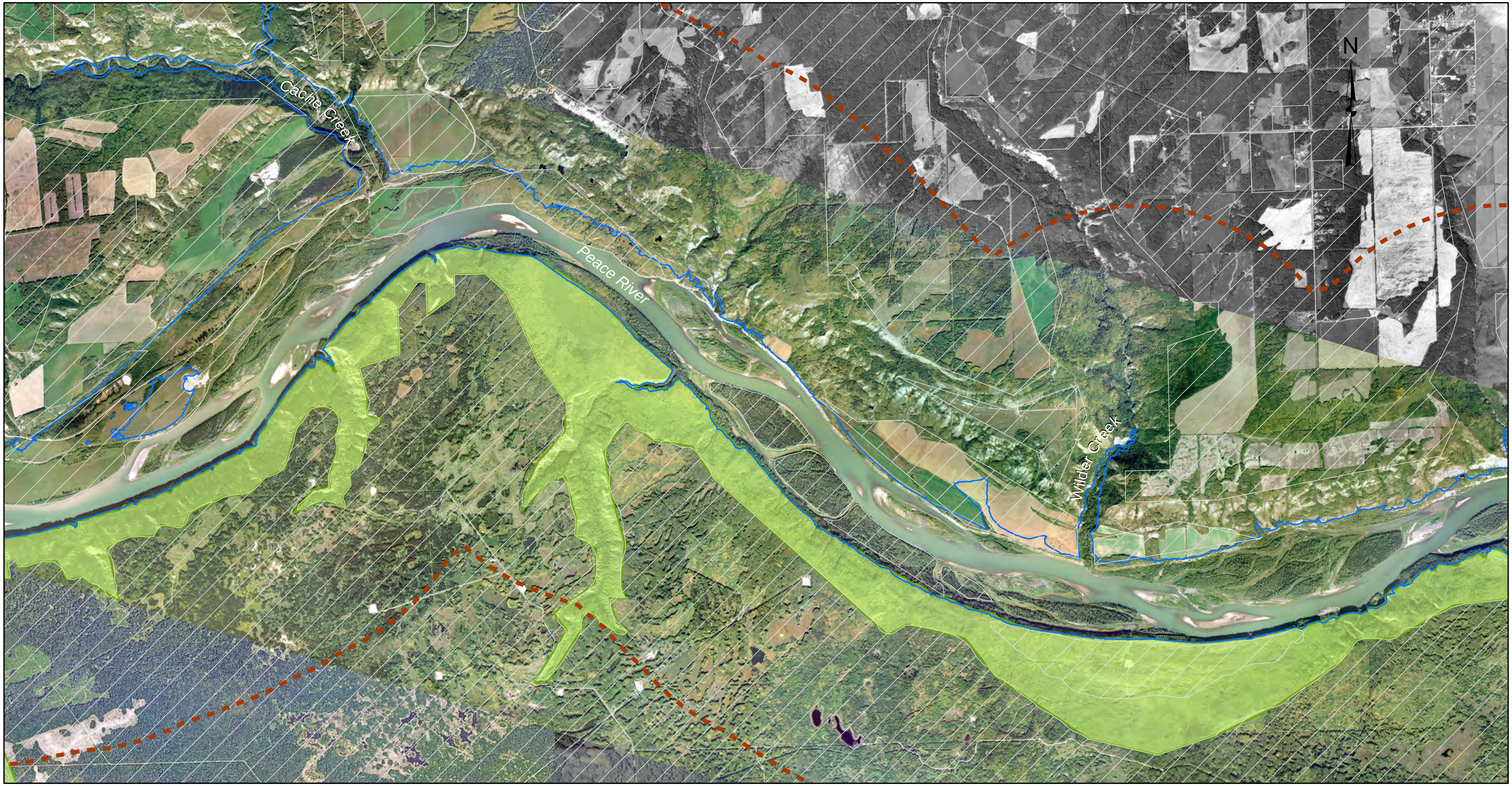
0 2 km

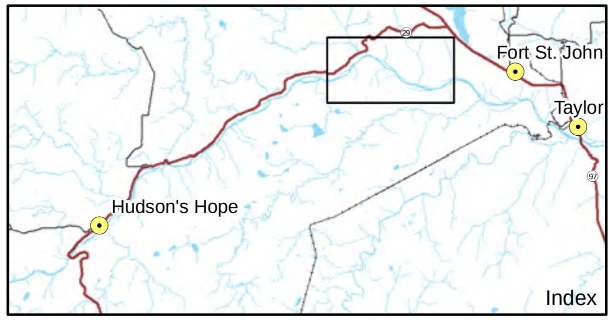
BC Hydro

Crop Drying Monitoring - Area Identification Map 4 of 9

Date	July 14, 2016	DWG NO	1016-C14-07342-4	R 0

Construction of the Site C Clean Energy Project is subject to required regulatory and permitting approvals.





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3. Base Data: Province of B.C.
4. Orthophotos created from 1:40,000 photos taken Sept. 10th 2007, TRIM.
5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

Legend

- Area to be considered for crop drying monitoring
- Agricultural Land Reserve
- Proposed Reservoir
- Proposed Peace Boudreau Protected Area
- Dam Site Area

1:50,000

0 2 km

BC Hydro

Crop Drying Monitoring - Area Identification Map 5 of 9

Date	July 14, 2016	DWG NO	1016-C14-07342-5	R 0

Construction of the Site C Clean Energy Project is subject to required regulatory and permitting approvals.

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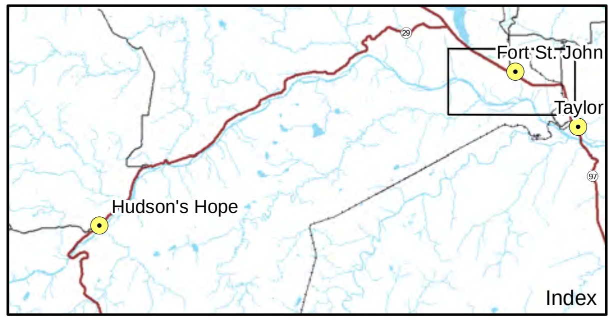

Map Notes:
1. Datum: NAD83
2. Projection: UTM Zone 10N
3. Base Data: Province of B.C.
4. Orthophotos created from 1:40,000 photos taken Sept. 10th 2007, TRIM.
5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

Legend

- Area to be considered for crop drying monitoring
- Agricultural Land Reserve
- Proposed Reservoir
- Proposed Peace Boudreau Protected Area
- Dam Site Area

1:50,000

0 2 km

BC Hydro

Crop Drying Monitoring - Area Identification Map 6 of 9

Date	July 14, 2016	DWG NO	1016-C14-07342-6	R 0

Construction of the Site C Clean Energy Project is subject to required regulatory and permitting approvals.

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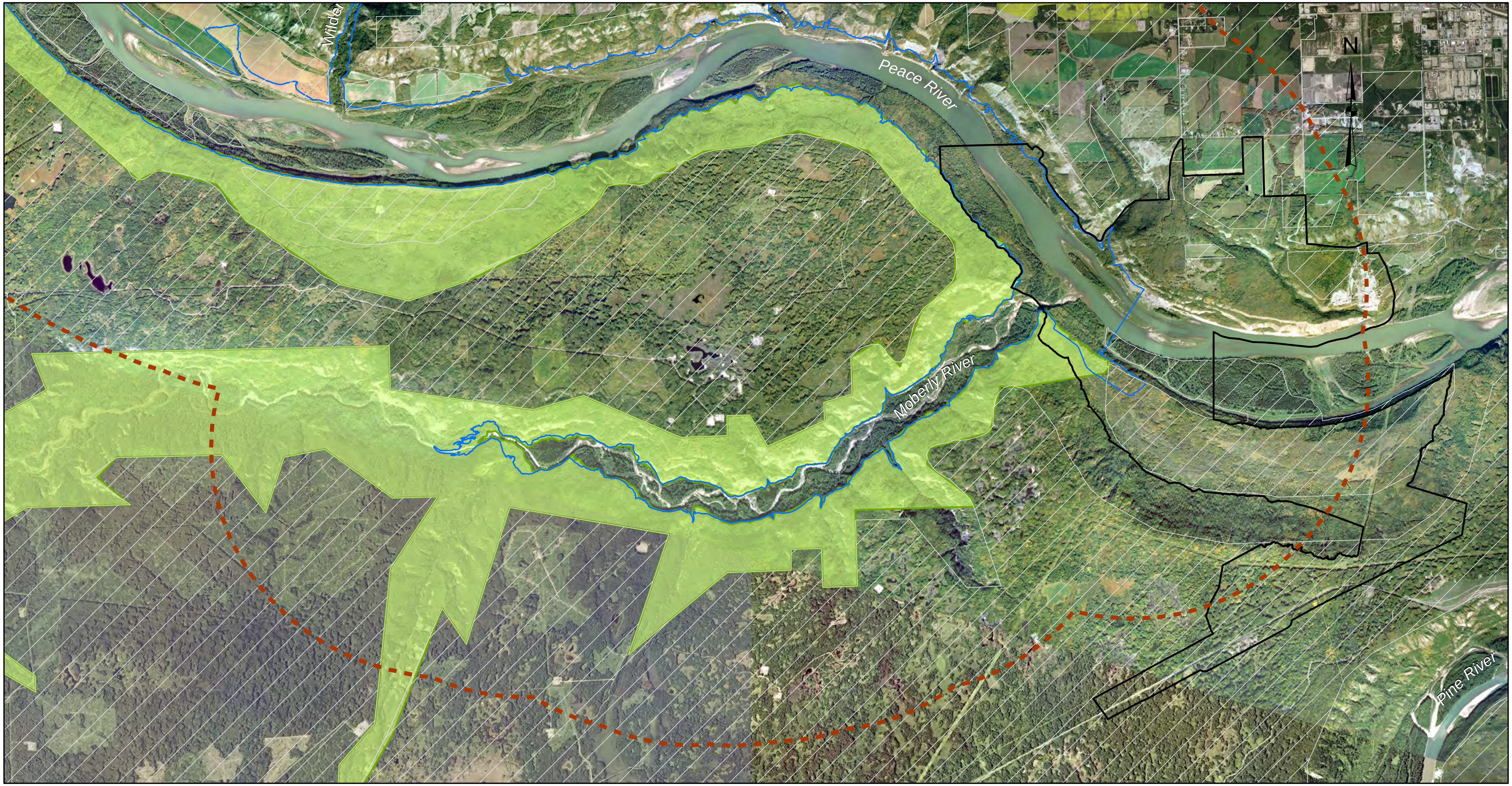

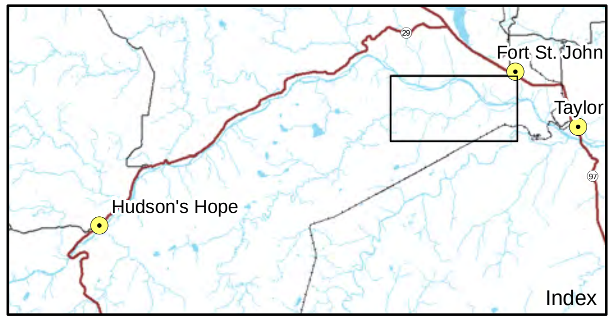

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3. Base Data: Province of B.C.
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5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

Legend

- Area to be considered for crop drying monitoring
- Agricultural Land Reserve
- Proposed Reservoir
- Proposed Peace Boudreau Protected Area
- Dam Site Area

1:50,000

0 2 km

BC Hydro

Crop Drying Monitoring - Area Identification Map 7 of 9

Date	July 14, 2016	DWG NO	1016-C14-07342-7	R 0

Construction of the Site C Clean Energy Project is subject to required regulatory and permitting approvals.

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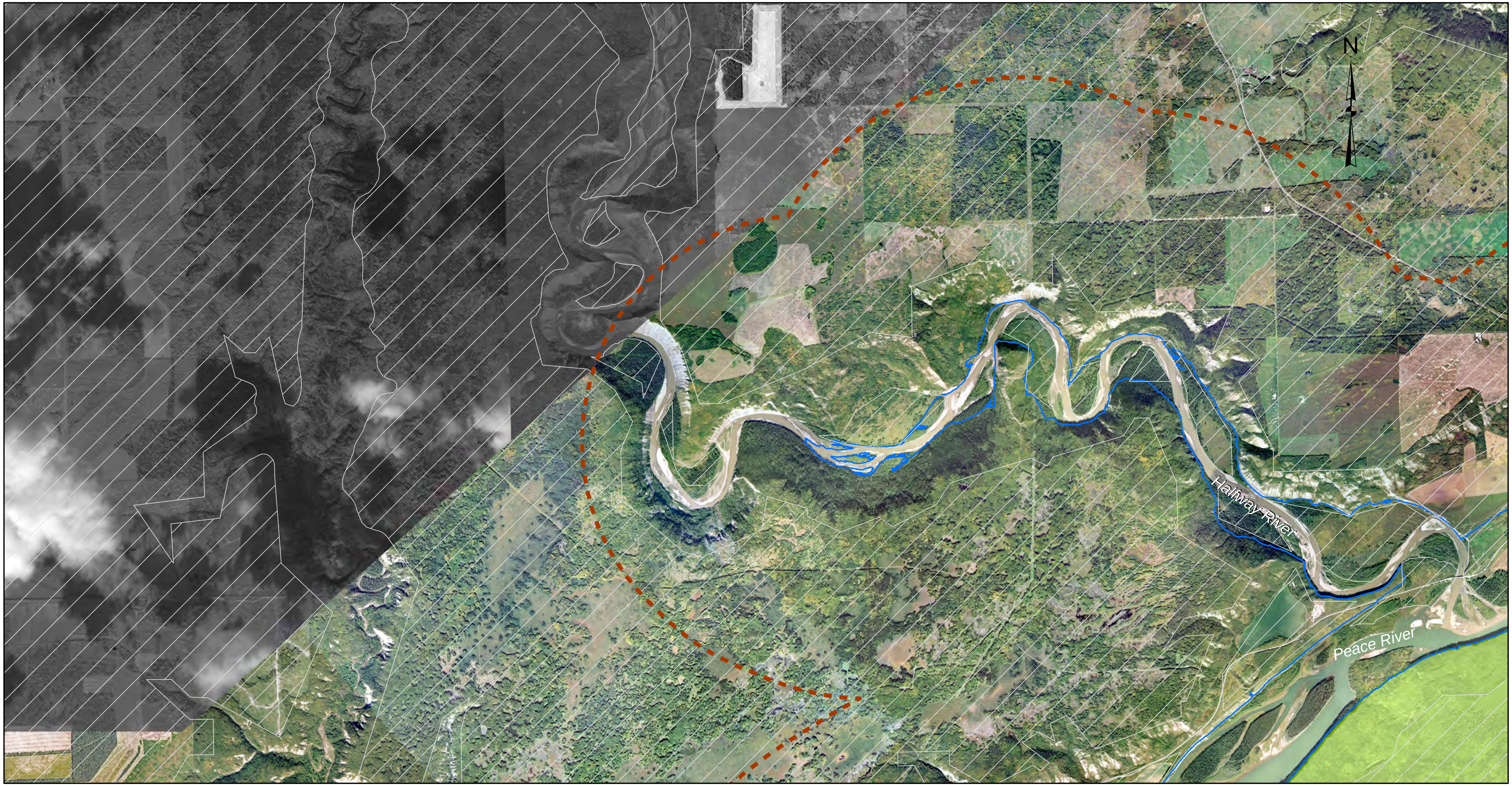

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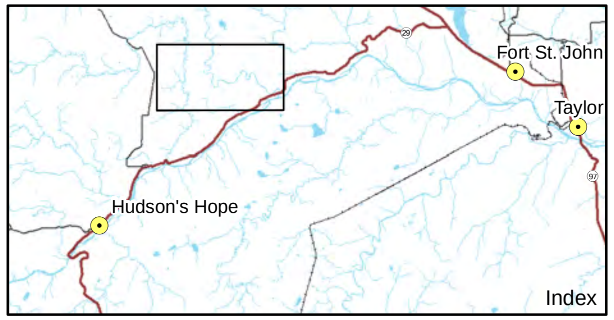
0 2 km



Map Notes:
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3. Base Data: Province of B.C.
4. Orthophotos created from 1:40,000 photos taken Sept. 10th 2007, TRIM.
5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

Legend

- Area to be considered for crop drying monitoring
- Agricultural Land Reserve
- Proposed Reservoir
- Proposed Peace Boudreau Protected Area
- Dam Site Area

BC Hydro

Crop Drying Monitoring - Area Identification Map 8 of 9

Date	July 14, 2016	DWG NO	1016-C14-07342-8	R 0

Construction of the Site C Clean Energy Project is subject to required regulatory and permitting approvals.

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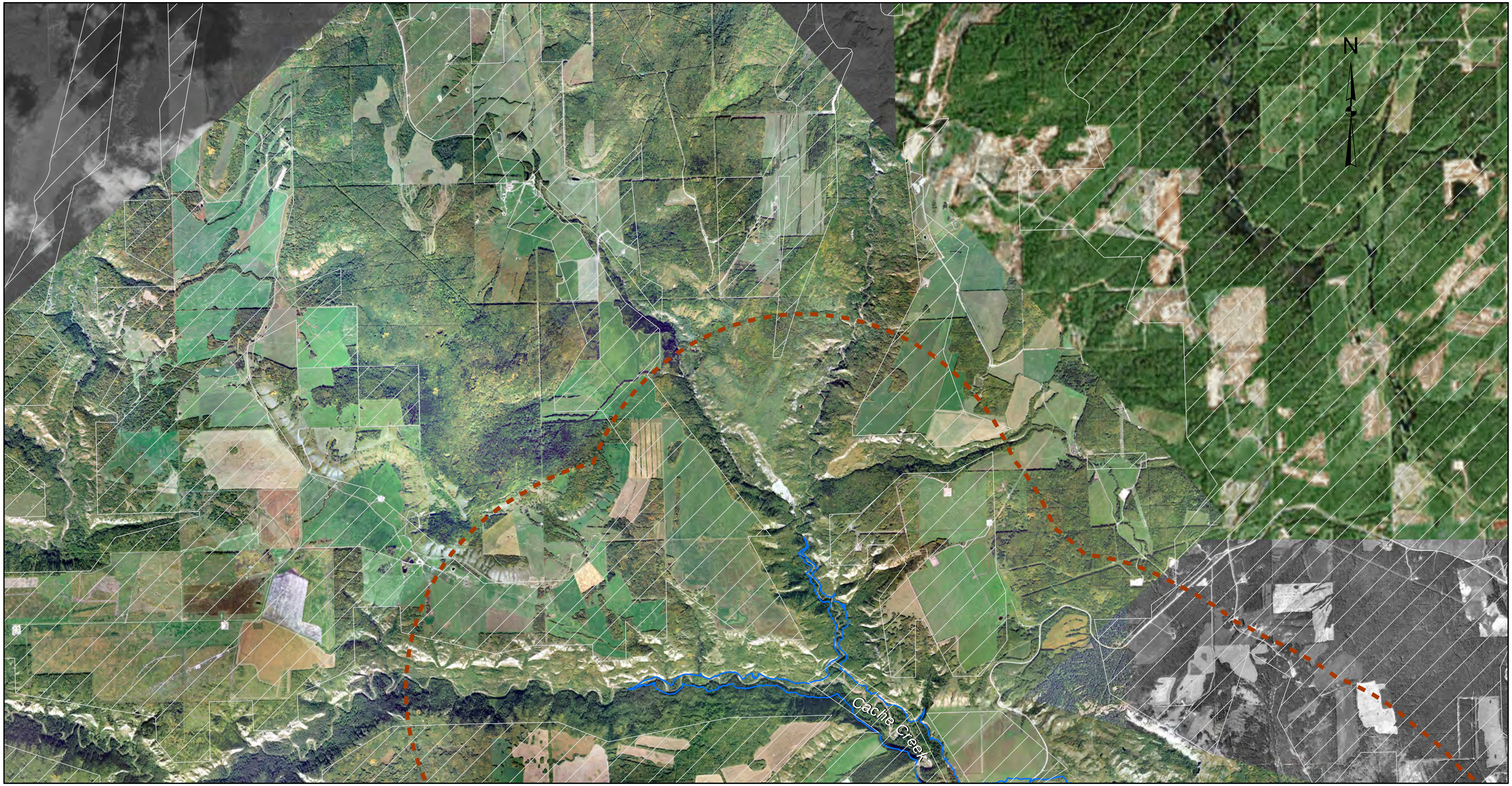

Map Notes:
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2. Projection: UTM Zone 10N
3. Base Data: Province of B.C.
4. Orthophotos created from 1:40,000 photos taken Sept. 10th 2007, TRIM.
5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

Legend

- Area to be considered for crop drying monitoring
- Agricultural Land Reserve
- Proposed Reservoir
- Proposed Peace Boudreau Protected Area
- Dam Site Area

1:50,000

0 2 km

BC Hydro

Crop Drying Monitoring - Area Identification Map 9 of 9

Date	July 14, 2016	DWG NO	1016-C14-07342-9	R 0

Construction of the Site C Clean Energy Project is subject to required regulatory and permitting approvals.

Path: X:\ArcGISProjects\Environment\Agriculture\Ag_3kmReservoirBoundary_1016_C14_07342-2-9.mxd

Appendix C – Crop Productivity and Groundwater Monitoring Program Report

BC Hydro and Power Authority
333 Dunsmuir Street
Vancouver, BC V6B 5R3

Blackbird File: 19042
June 15, 2020

**RE: Crop Productivity and Groundwater Monitoring Program
Site C Clean Energy Project
2020 Annual Report**

1. Project Background and Scope

The Site C Clean Energy Project (the Project) is a hydroelectric dam and generating station under construction in northeast BC. Construction started in July 2015 and the project is planned to be in service in 2024 (BC Hydro 2020).

During the joint federal-provincial environmental assessment process, the Project's Environmental Impact Statement (EIS; BC Hydro. 2013) noted a potential for the elevation of groundwater to rise in the vicinity of the reservoir and identified changes to local hydrology and groundwater as a key indicator (Table 20.3).

EIS Section 20.3.2.2 (page 20-34, lines 7 to 9) states: *"The reservoir would result in rises in the groundwater elevation in areas near the reservoir and may affect agricultural land where the water table is anticipated to rise within 1 m of surface. Yields or the range of suitable crops may be affected on agricultural properties located on low terraces and banks near the proposed reservoir. However, since the majority of the cultivated lands within the local assessment area are located topographically above the proposed reservoir levels by greater than 1 meter and in most cases by greater than 10 m, only limited effects related to water table rise are anticipated*."

EAC Condition No. 31 states: *"The Agriculture Monitoring and Follow-up Program must include monitoring for Project-induced changes to groundwater elevations within 2 km of the reservoir (the area potentially influenced by groundwater elevation changes), and evaluate associated effects on crop productivity. Monitoring must include field surveys and farm operator interviews."*

As a result, the Environmental Assessment Certificate for the Project (EAC # E14-02, issued Oct. 14, 2014) contains a condition to develop an Agricultural Monitoring and Follow-Up Plan (AMAFP), which requires BC Hydro to monitor and assess groundwater level and related damage to agricultural crops for a 10 year period which includes the five years prior to reservoir filling and the first five years of operation.

In September 2019, BC Hydro and Power Authority (BC Hydro) retained Blackbird Environmental Ltd. ("Blackbird") to implement the Crop Productivity and Groundwater Monitoring Program (CPGMP) component of the AMAFP. Blackbird's scope includes the development and implementation of a desktop and field program to monitor for project-related changes in groundwater and soil moisture levels specifically focused on areas used for agricultural production within a two-kilometre buffer around the future Project reservoir.

As part of BC Hydro's annual reporting requirements, this report outlines Project activities completed in relation to the CPGMP component of the AMAFP between **April 1, 2019** and **March 31, 2020**.

2. Project Activities

Groundwater monitoring under this program will be conducted through a variety of methods and technologies, including the deployment and maintenance of a network of soil moisture sensors, crop health and development monitoring, as well as cooperation with BC Hydro's hydrology specialists to access data derived from the existing well network in the project area.

Blackbird's CPGMP team engaged agricultural producers utilizing the land overlapping previously identified monitoring locations through phone and in-person interviews in the fall of 2019. Where applicable, producers were updated on project activities throughout late 2019 and early 2020.

The AMAFP identifies several sites for groundwater monitoring and potential crop impacts within 2 km of the reservoir, which defined the focus of the CPGMP. At these locations, Blackbird deployed soil probes at depths of 10, 30, and 100 cm to log moisture, temperature, and electric conductivity data at one-hour intervals throughout the year. Soil moisture monitoring benchmarks are located on land currently owned by BC Hydro in landscape/field positions that reduce the potential of an impact on agricultural operations to a minimum.

BC Hydro's existing groundwater monitoring network within the Peace River valley will be utilized to monitor actual groundwater levels in the immediate vicinity of the identified monitoring sites. Blackbird's project team reviewed the current groundwater monitoring infrastructure in relation to the previously identified focus areas and determined a requirement for additional shallow groundwater monitoring infrastructure. One of the wells was installed in Bear Flat in late 2019, while the initial installation efforts for another well in the Wilder Creek area failed due to substrate characteristics.

The CPGMP team will monitor in-season crop development through remote-sensing techniques to minimize the disturbance caused by field inspections whenever feasible. Field inspections will be completed at the monitoring locations in early spring and in mid- to late July to assess crop variability in relation to soil moisture factors. Field methodology development for this aspect of the project is ongoing.

3. Recommendations

In accordance with EAC Condition No. 31, field surveys and interviews will continue to be completed with the goal of continuing monitoring until five years after reservoir filling. Similarly, Blackbird's CPGMP team will continue to work closely with agricultural producers, agricultural associations, producer groups, and government agencies that may have data or local knowledge related to this monitoring plan.

The following recommendations are based on the findings of project activities during the 2019 growing season, including producer engagement, research on available hydrological information, and the installation of monitoring instrumentation.

1. Monitor crop development at the monitoring sites through remote sensing technologies and field surveys throughout the growing season. Standardized field forms will be developed or adopted for data collection during the 2020 growing season.

4. Closure

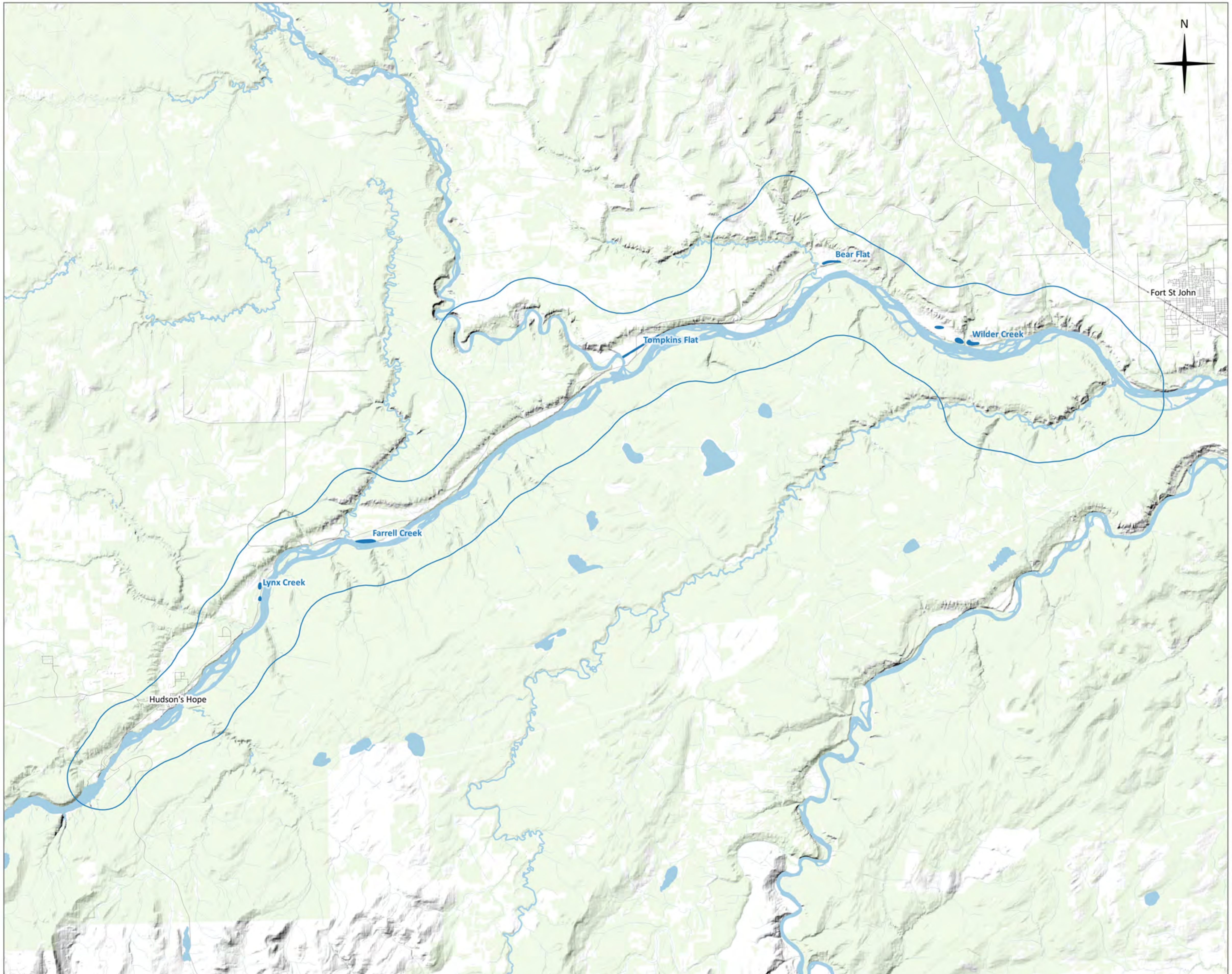
Services provided by Blackbird for this memorandum have been conducted in a manner consistent with the level of skill, care, and competence ordinarily exercised by registered members of the profession of agrology and biology currently practicing under similar conditions and like circumstances in the same jurisdiction in which the services were provided.

The conclusions of this memorandum are based in part on information provided by others. Blackbird believes this information to be accurate but cannot guarantee or warrant its accuracy or completeness.

The information presented in this memorandum was acquired, compiled and interpreted exclusively for BC Hydro for the purposes described in this report.

If you have questions with regards to this memorandum, feel free to contact the lead author at your convenience by email at matthias@blackbird.ca.

Attachments: Figure 1 – CPGMP Project Area Overview



BC Hydro and Power Authority

Crop Productivity and Groundwater Monitoring Program
Project Area Overview

Horizontal Scale 1:250,000

0 2 4 6 8 10 km

Map to scale when plotted on a page 280 mm x 432 mm (Tabloid)

Legend

- CPGMP Project Area
- Lakes & Rivers
- Crop Productivity and Groundwater Monitoring Areas
- Road Network

Disclaimer

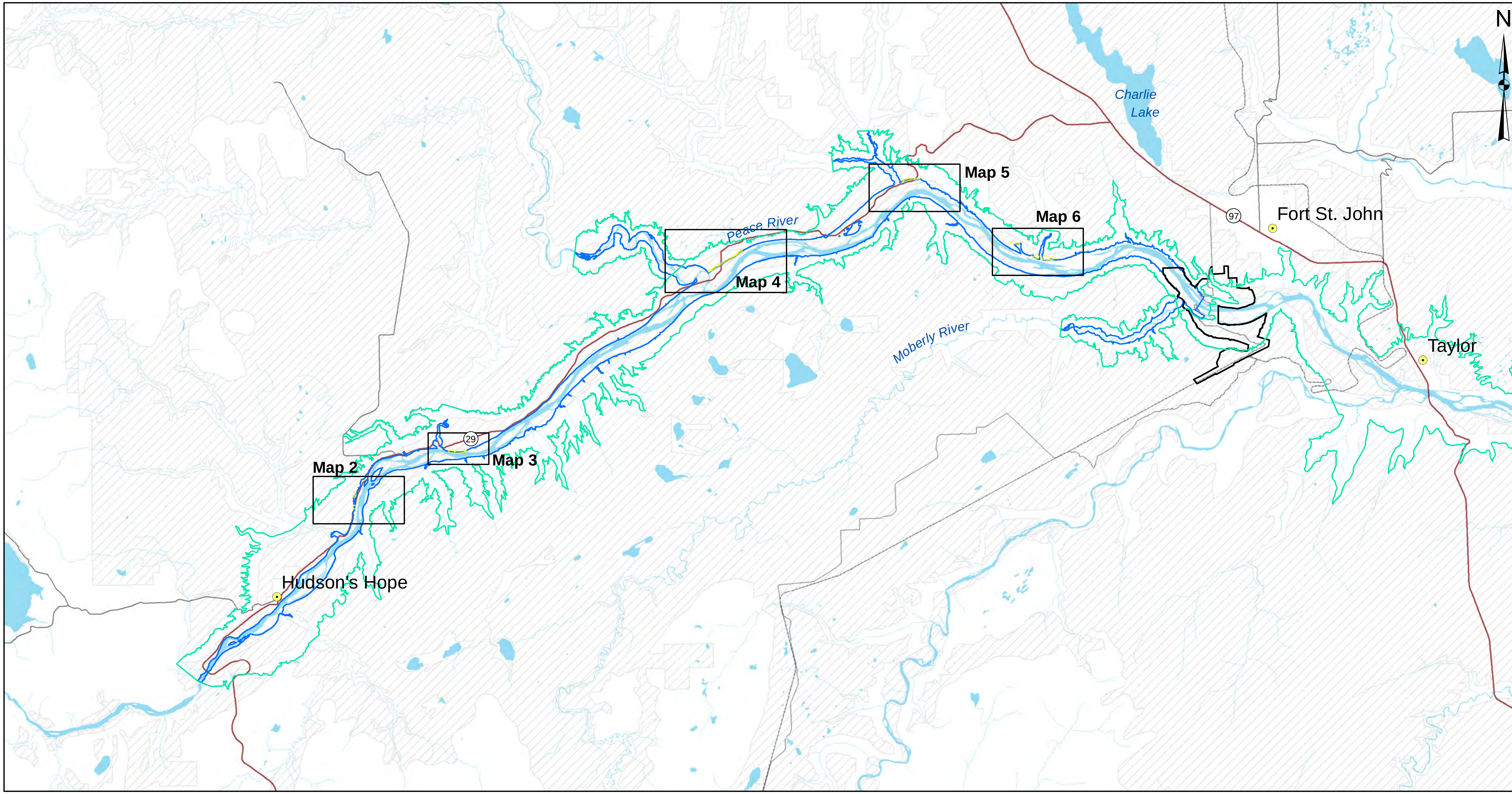
UTM Zone 10, NAD 83
Date of data acquisition: n/a
Data Credit: Blackbird Environmental Ltd., BC Geodata Warehouse
For representational purposes only, all locations are approximate.

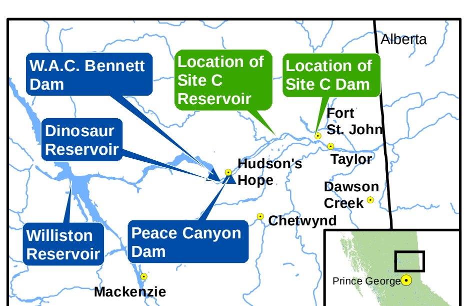
Our File:	19042	Gov. File #:	n/a	Revision #:	1
Client File:	n/a	GIS:	ML	Date:	June 15, 2020

Blackbird Environmental

blackbird.ca
Fort St. John, BC
250.793.7262

Figure 1





Map Notes:
1. Datum: NAD83
2. Projection: UTM Zone 10N
3. Base Data: Province of B.C.
4. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

Legend

- Groundwater Monitoring Area
- Peace River and Tributary Valleys Definition
- Proposed Reservoir
- Dam Site Area
- Agricultural Land Reserve
- Town
- Road
- Highway
- Railway

1:250,000

0 5 km

BC Hydro

Groundwater Monitoring Areas Overview Map 1 of 6

Date	July 14, 2016	DWG NO	1016-C14-07345-1	R 0

Construction of the Site C Clean Energy Project is subject to required regulatory and permitting approvals.

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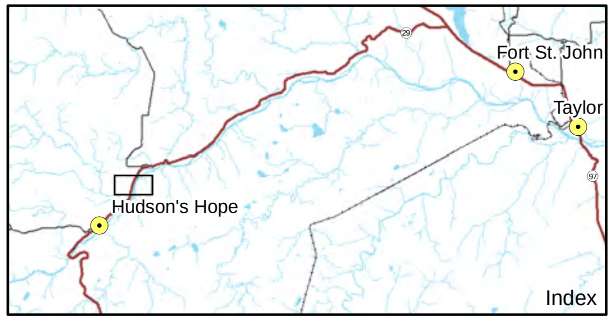

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3. Base Data: Province of B.C.
4. Orthophotos created from 1:40,000 photos taken Sept. 10th 2007, TRIM.
5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

Legend

- Groundwater Monitoring Area
- Peace River and Tributary Valleys Definition
- Proposed Reservoir
- Dam Site Area
- Agricultural Land Reserve

1:15,000 0 0.5 km

BC Hydro

Groundwater Monitoring Areas
Map 2 of 6

Date	July 14, 2016	DWG NO	1016-C14-07345-2	R 0

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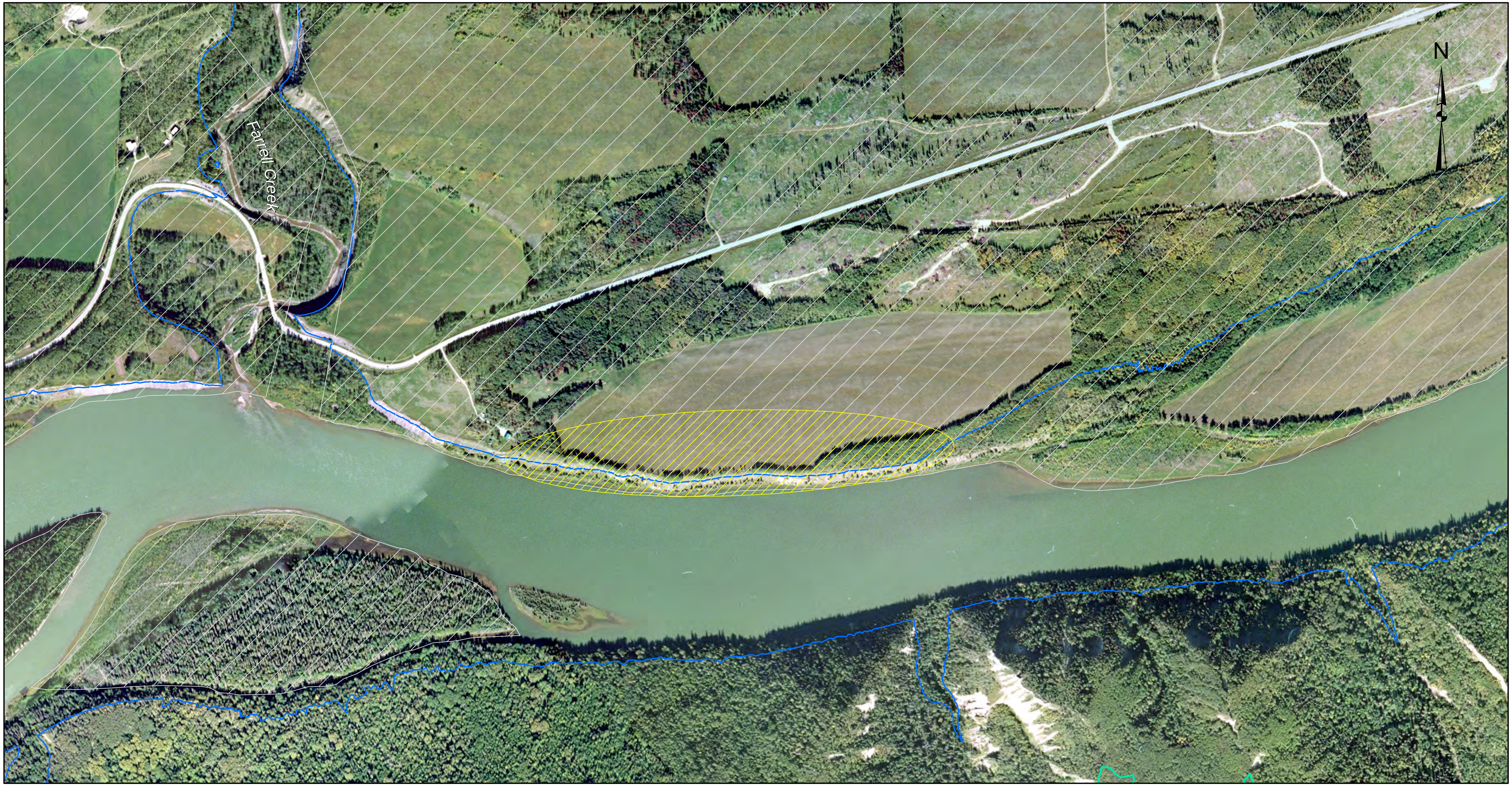

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5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

Legend

- Groundwater Monitoring Area
- Peace River and Tributary Valleys Definition
- Proposed Reservoir
- Dam Site Area
- Agricultural Land Reserve

1:10,000 0 0.5 km

BC Hydro

Groundwater Monitoring Areas
Map 3 of 6

Date	July 14, 2016	DWG NO	1016-C14-07345-3	R 0

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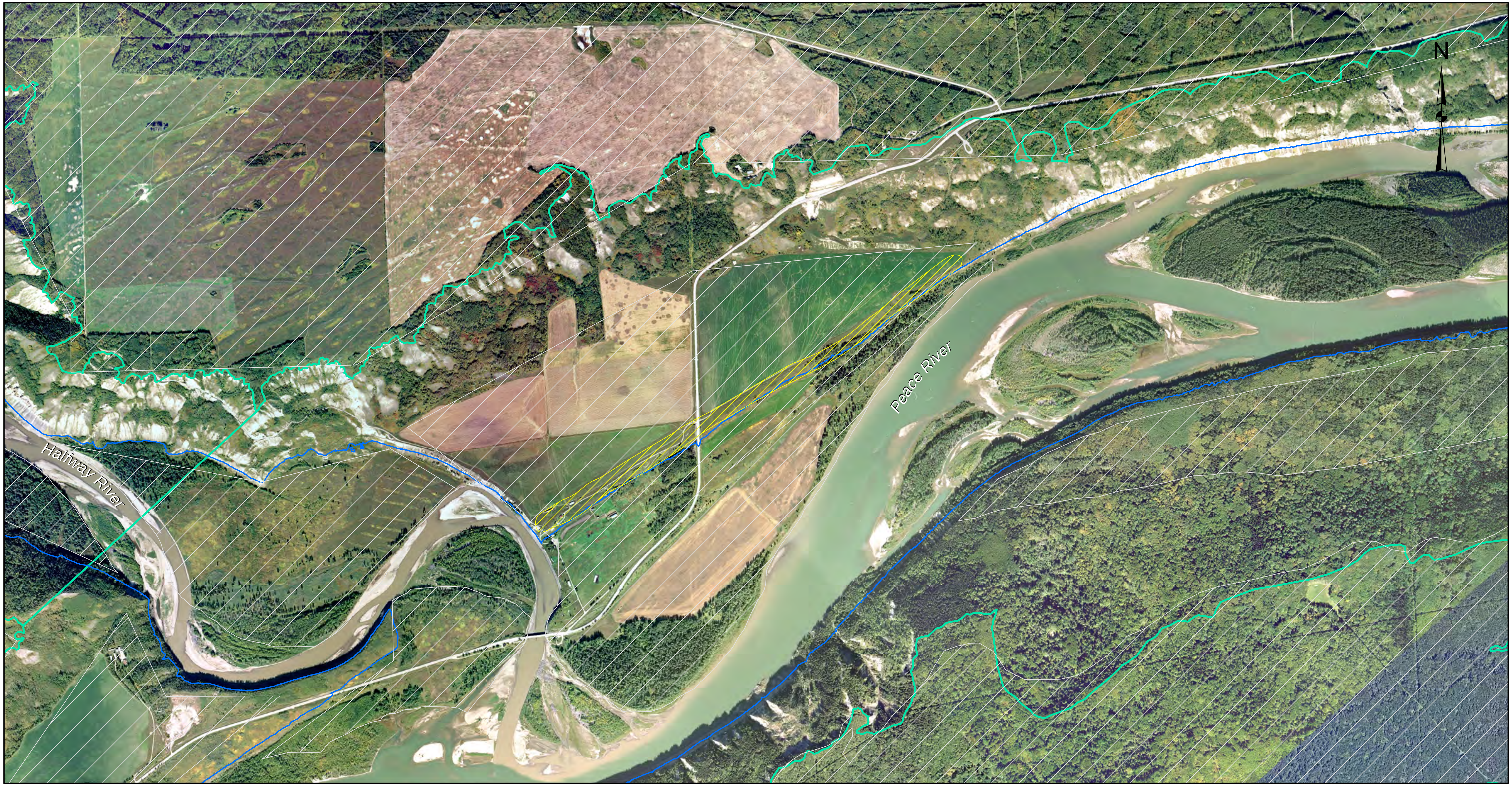

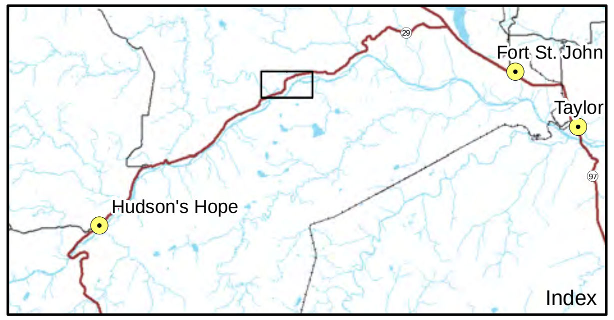

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3. Base Data: Province of B.C.
4. Orthophotos created from 1:40,000 photos taken Sept. 10th 2007, TRIM.
5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

Legend

- Groundwater Monitoring Area
- Peace River and Tributary Valleys Definition
- Proposed Reservoir
- Dam Site Area
- Agricultural Land Reserve

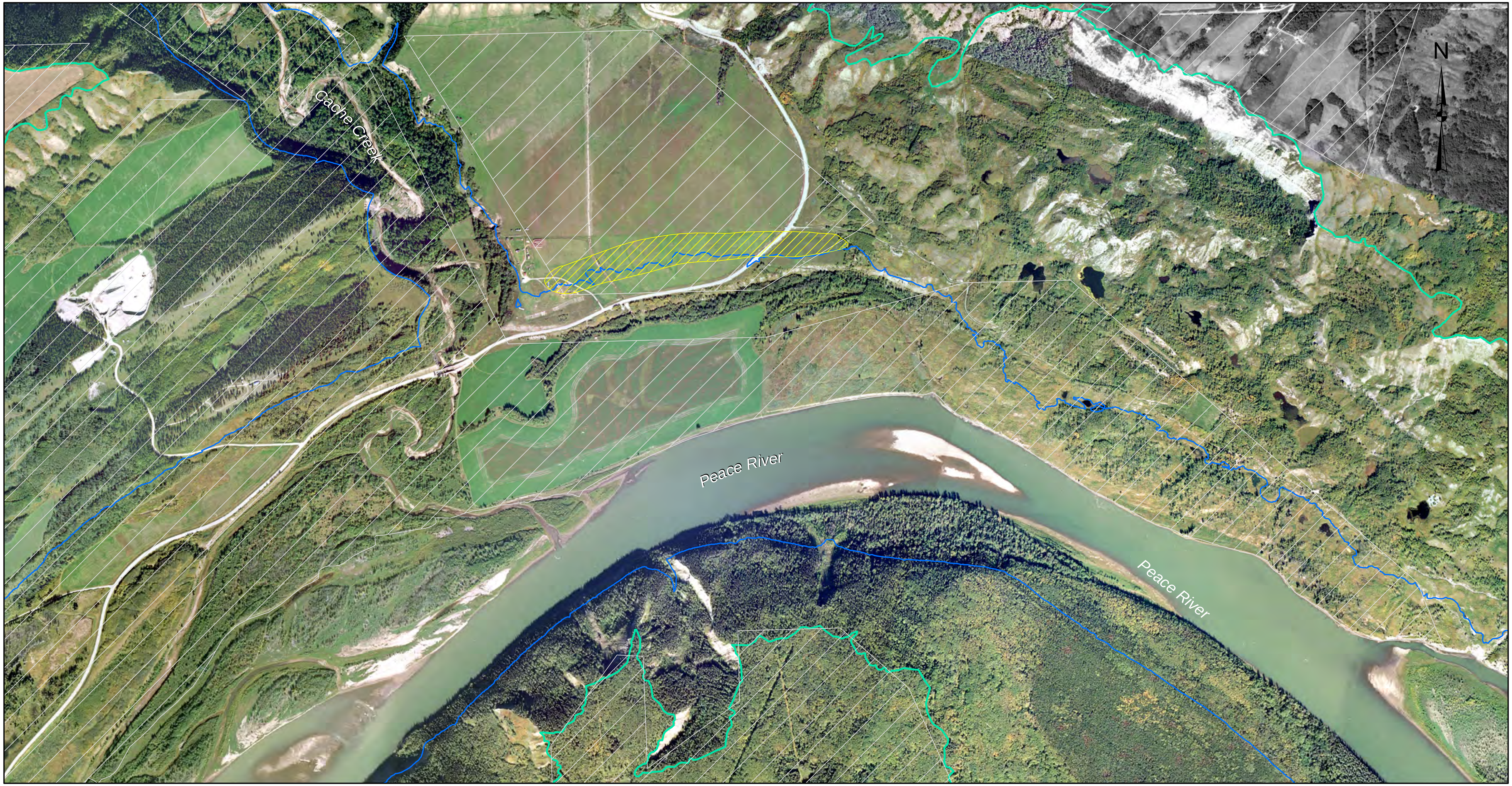
1:20,000 0 0.5 km

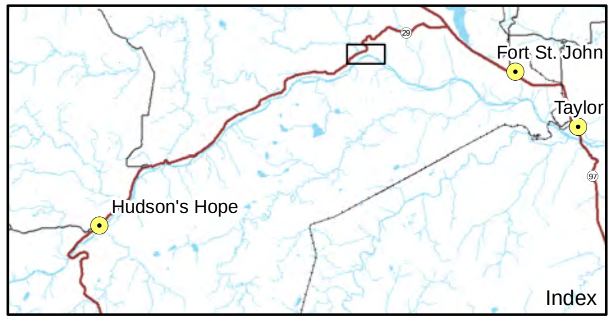
BC Hydro

Groundwater Monitoring Areas
Map 4 of 6

Date	July 14, 2016	DWG NO	1016-C14-07345-4	R 0

Construction of the Site C Clean Energy Project is subject to required regulatory and permitting approvals.





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2. Projection: UTM Zone 10N
3. Base Data: Province of B.C.
4. Orthophotos created from 1:40,000 photos taken Sept. 10th 2007, TRIM.
5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

Legend

- Groundwater Monitoring Area
- Peace River and Tributary Valleys Definition
- Proposed Reservoir
- Dam Site Area
- Agricultural Land Reserve

1:15,000 0 0.5 km

BC Hydro

Groundwater Monitoring Areas
Map 5 of 6

Date	July 14, 2016	DWG NO	1016-C14-07345-5	R 0

Construction of the Site C Clean Energy Project is subject to required regulatory and permitting approvals.

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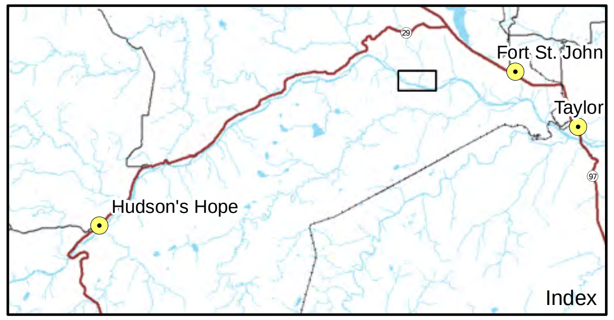

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2. Projection: UTM Zone 10N
3. Base Data: Province of B.C.
4. Orthophotos created from 1:40,000 photos taken Sept. 10th 2007, TRIM.
5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

Legend

- Groundwater Monitoring Area
- Peace River and Tributary Valleys Definition
- Proposed Reservoir
- Dam Site Area
- Agricultural Land Reserve

1:15,000 0 0.5 km

BC Hydro

Groundwater Monitoring Areas
Map 6 of 6

Date	July 14, 2016	DWG NO	1016-C14-07345-6	R 0

Construction of the Site C Clean Energy Project is subject to required regulatory and permitting approvals.

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Appendix D – Irrigation Water Requirements Program Report

Introduction

The Site C Clean Energy Project's Environmental Impact Statement (BC Hydro. 2013) ("EIS") Section 20.3.4.1.2 identifies irrigation improvements as a potential mitigation measure for the permanent loss of agricultural land. Lines 25 to 27, page 20-42, of this section state: "Irrigation research, demonstration projects, and funding assistance for irrigation water supply infrastructure will be considered within the proposed agricultural compensation fund."

EAC Condition 31 states: "The Agriculture Monitoring and Follow-up Program must include monitoring for climatic factors to estimate moisture deficits and to estimate irrigation water requirements in the vicinity of the reservoir to provide information for potential future irrigation projects. Data collection will be undertaken before reservoir filling, and in the 5 years after reservoir filling, and data will be reviewed as required for proposed irrigation projects."

In accordance with EAC Condition 31, this study will monitor climate data and estimate irrigation water requirements. The objective of this monitoring program is to collect and analyze climate data to generate estimates of irrigation water requirements.

Methods

Study Location: The study areas are agricultural operations within 3 km of the reservoir. The plan relies on climate station installation, maintenance, and data collection tasks carried out in the Appendix B: Monitoring Potential Effects on Crop Drying Plan.

Activities: Activities have included coordination of data needs with Appendix B: Monitoring Potential Effects on Crop Drying Plan, mapping, baseline data collection, climate station siting, and consideration of consultation input.

Maps supporting this program are included in Appendix B: Monitoring Potential Effects on Crop Drying Plan.

To ensure that all parameters required for the successful completion of this program, coordination with the Crop Drying and Humidity Monitoring Program is required for future climate station siting and any necessary network upgrades.

Irrigation was discussed during the consultation process and included numerous submissions by regional agricultural producers and associations for the Framework of the Agricultural Mitigation and Compensation Plan. Content relevant to irrigation was considered and will be retained for future use in this program.

Results and Analysis

During the program establishment phase there are limited results or analysis required. The climate stations are collecting information that will provide baseline information to support future analysis.

Next Steps

In the five years pre- and post-reservoir filling, complete summaries of the collected data from the new and existing BC Hydro climate stations will be analyzed annually to estimate irrigation water demand (as required). It should be noted that:

- The existing climate station network was upgraded and expanded between January 2016 and December 2017 and that data collected will be the baseline for any future irrigation project.
- Efforts will be made to collaborate with associations, producer groups and government agencies that may have data or local knowledge related to this monitoring program. Examples may include the BC Grain Producers Association which has funded the following study; *Evaluation of Irrigation Potential in the BC Peace Region*.

References

BC Grain Producers Association (2015) "Peace – Evaluation of Irrigation Potential in the BC Peace Region" Available at: http://www.bcgrain.com/Current_Projects.html. Accessed: December 2015.

FAO. (1998). Crop Evapotranspiration – Guidelines for Computing Crop Water Requirements. Rome: Food and Agriculture Organization of the United Nations – Paper 56.

BC Hydro. 2013. Site C Clean Energy Project Environmental Impact Statement. Dated January 25, 2013; Amended August 2, 2013.

Appendix E – Climate Stations Information

The following tables show information specific to the BC Hydro's existing climate station network.

Table 1 - Periods of Operation for Climate Stations Supporting the AMAFP

Monitoring Station	Period of Operation
Attachie Flat Upper Terrace	2011 - Present
Attachie Flat Lower Terrace[1]	2010 - 2017
Attachie Plateau	2010 - Present
Bear Flat	2010 - Present
Farrell Creek	2009 - Present
Site C Dam[2]	2010 - 2016
Site C North Camp[3]	2016 - Present
Old Fort	2011 - Present
85th Avenue	2013 - Present
Tea Creek	2017 – Present
Taylor	2017 – Present
Fort St. John Airport[4]	1942 – Present

[1] Attachie Flat Lower Terrace was closed in 2017 due to the location being inside the Site C reservoir

[2] Site C Dam Station was relocated in 2016 to an area adjacent to the camp and offices. It is now the Site C North Camp Station

[3] Site C North Camp Climate Station has instruments in two areas located near the Site C offices

[4] Fort St. John Airport is operated by Environment Canada

Table 2 - Locations & Elevations of Current Climate Stations Supporting the AMAFP

Monitoring Station	UTM NAD 83 (m)	Latitude and Longitude (decimal degrees)	Elevation (m)
Attachie Flat Upper Terrace	597983 E, 6232938 N	56.23N, -121.41W	479
Attachie Plateau	595065 E, 6233032 N	56.23N, -121.46W	645
Bear Flat	610669 E,6238135 N	56.27N, -121.21W	474
Farrell Creek	580779 E, 6220238 N	56.12N, -121.70W	471
Site C North Camp[1]	630127 E, 6230625 N	56.20N, -120.90W	581
Old Fort	634,890 E, 6,230,532 N	56.20N, -120.83W	421

85th Avenue	633,033 E, 6,233,949 N	56.23N, -120.85W	686
Tea Creek	626812 E, 6234340 N	56.24N, -120.95W	653
Taylor	639212 E, 6226929 N	56.17N, -120.76W	411
Fort St. John Airport	640053 E, 6234872 N	56.24N, -120.74W	695

[1] The "Site C Dam" meteorological station was decommissioned from its original location on April 13, 2016 due to excavation at that location. It was relocated to a new location, "Site C North Camp", on July 7, 2016.

Full reports including tabular summaries of the agricultural monitoring parameters are included in the 2014, 2015, 2016, 2017, 2018, and 2019 *Site Climate and Air Quality Monitoring Annual Reports*. These parameters include:

- air temperature,
- humidity,
- precipitation,
- solar radiation,
- wind speed,
- wind direction,
- barometric pressure,
- net radiation,
- soil temperature,
- soil heat flux,
- soil water content, and
- relative humidity.

References:

RWDI Inc. (2015), Site C Climate & Air Quality Monitoring Annual Report 2014, Final. August 26, 2015.

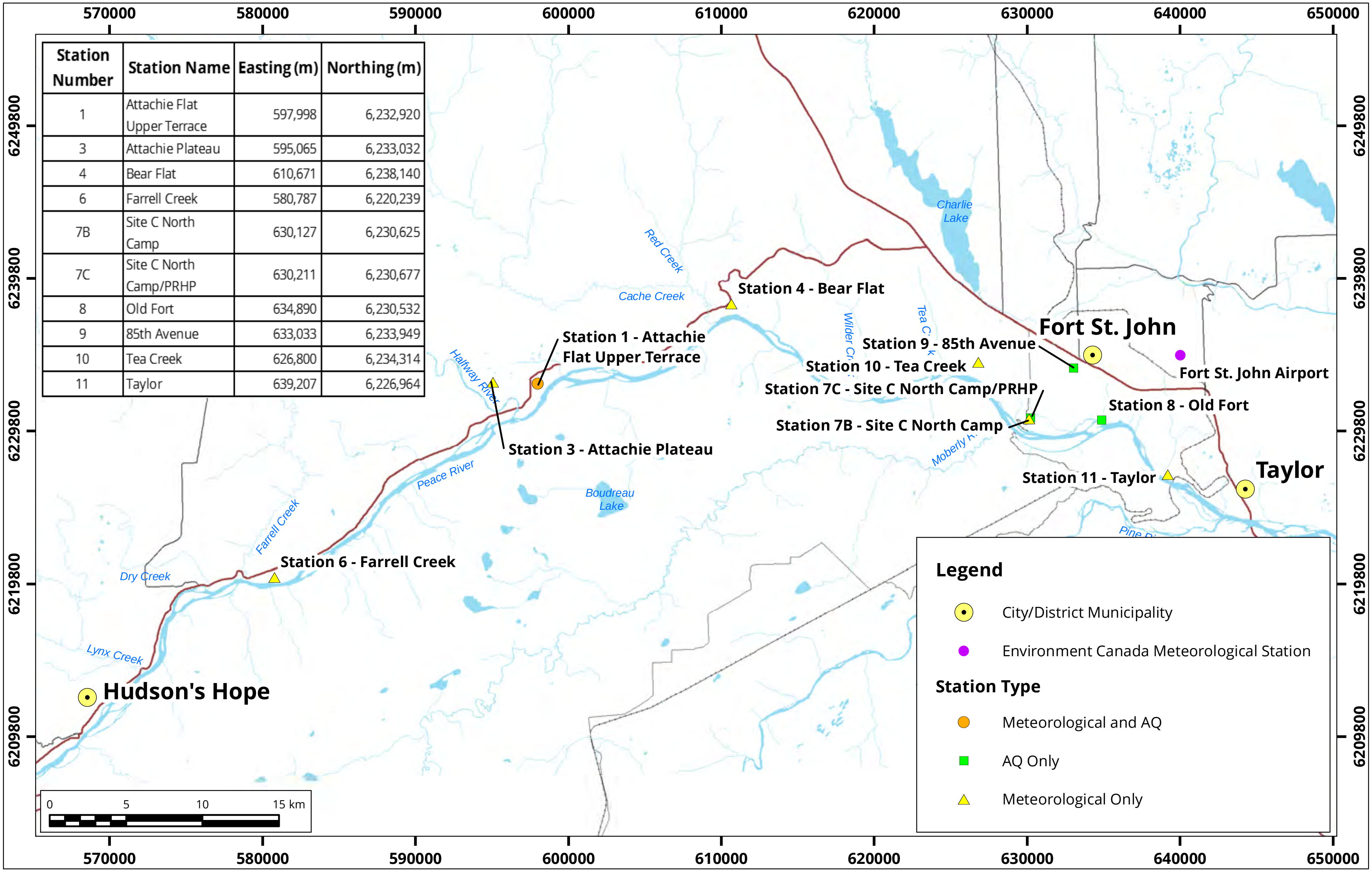
RWDI Inc. (2016), Site C Climate & Air Quality Monitoring Annual Report 2015, Final. June 9, 2016.

RWDI Inc. (2017), Site C Climate & Air Quality Monitoring Annual Report 2016, Rev. 1. June 14, 2017.

RWDI Inc. (2018), Site C Climate & Air Quality Monitoring Annual Report 2017, Final. March 12, 2018.

RWDI Inc. (2019), Site C Climate & Air Quality Monitoring Annual Report 2018, Final. February 22, 2019.

RWDI Inc. (2020), Site C Climate & Air Quality Monitoring Annual Report 2019, Final. March 31, 2020.



Station Number	Station Name	Easting (m)	Northing (m)
1	Attachie Flat Upper Terrace	597,998	6,232,920
3	Attachie Plateau	595,065	6,233,032
4	Bear Flat	610,671	6,238,140
6	Farrell Creek	580,787	6,220,239
7B	Site C North Camp	630,127	6,230,625
7C	Site C North Camp/PRHP	630,211	6,230,677
8	Old Fort	634,890	6,230,532
9	85th Avenue	633,033	6,233,949
10	Tea Creek	626,800	6,234,314
11	Taylor	639,207	6,226,964

BC Hydro - Site C Meteorological and Air Quality Stations

Map Projection: NAD 1983 UTM Zone 10N

True North

Project #: 1601625

Drawn by: DJH	Figure: 2-1
Approx. Scale:	1:350,000
Date Revised:	Sep 18, 2017

Map Document: C:\Users\djh\Desktop\GIS Temp\1601625\1601625 - Confidential BC Hydro Climate_Monitoring Locations_Figure_2-1_Sep2017.mxd