Appendix 6. 2021 Preconstruction Rare Plant Surveys

2021 Annual Report

Pre-construction Rare Plant Surveys

Site C Clean Energy Project

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1. INTRODUCTION

1.1. Background

The Environmental Assessment Certificate (EAC #E14-02) for the Site C Clean Energy Project (the Project) sets out the conditions that BC Hydro must comply with during construction and operation of the Project (BC Environmental Assessment Office 2014). Condition 9 states in part:

- *The EAC Holder must, with the use of a QEP, complete an inventory in areas not already surveyed and use rare plant location information as inputs to final design of access roads and transmission lines. These preconstruction surveys must target rare plants as defined in Section 13.2.2 of the EIS —including vascular plants, mosses, and lichens.*
- *The EAC Holder must create and maintain a spatial database of known rare plant occurrences in the vicinity of Project components that must be searched to avoid effects to rare plants during construction activities. The database must be updated as new information becomes available and any findings of new rare plant species occurrences must be submitted to Environment Canada and MOE using provincial data collection standards.*

In addition, the Federal Decision Statement (FDS) issued under the Canadian Environmental Assessment Act sets out conditions relating to rare plants (Canadian Environmental Assessment Agency 2014). Condition 16 states in part:

- *16.1 The Proponent shall ensure that potential effects of the Designated Project on species at risk, at-risk and sensitive ecological communities and rare plants are addressed and monitored.*
- *16.2. The Proponent shall develop, in consultation with Environment Canada, a plan setting out measures to address potential effects of the Designated Project on species at risk, at-risk and sensitive ecological communities and rare plants.*
- *16.3. The plan shall include:*
    - *16.3.3. measures to mitigate environmental effects on species at risk and at-risk and sensitive ecological communities and rare plants;*
    - *16.3.4. conservation measures to ensure the viability of rare plants, such as seed recovery and plant relocation;*
    - *16.3.6. an approach to monitor and evaluate the effectiveness of mitigation measures and to verify the accuracy of the predictions made during the environmental assessment on species at risk, at-risk and sensitive ecological communities and rare plants; and*

- *16.3.7. an approach for tracking updates to the status of listed species identified by the Government of British Columbia, Committee on the Status of Endangered Wildlife in Canada, and the Species at Risk Act, and implementation of additional measures, in accordance with species recovery plans, to mitigate effects of the Designated Project on the affected species should the status of a listed species change during the life of the Designated Project.*

To partially fulfill EAC condition 9 and FDS conditions 16.1, 16.2, 16.3.3, 16.3.4, 16.3.6 and 16.3.7, BC Hydro is conducting preconstruction rare plant surveys in previously unsurveyed areas of the proposed transmission line, access roads, and other construction corridors. By documenting additional occurrences of rare plants within the Project footprint, measures to mitigate effects to these occurrences—including seed recovery and translocation—can be identified.

Data collected during these pre-construction rare plant surveys are added to the Project's spatial environmental features database. These spatial data are used during detailed design and construction to identify opportunities for avoidance, areas where extra care is needed, and areas where losses will occur. The first season of pre-construction surveys was completed in the summer and fall of 2015, and the work has been proceeding every year since. This interim report documents the methods and results of the surveys completed from 2015 through the end of the 2021 field season.

1.2. Scope

The goals of the study are:

- to develop, maintain, and update a spatial database of rare plant occurrences in the vicinity of Project facilities;
- to determine the location of rare plant occurrences in previously unsurveyed areas that are proposed for ground or vegetation disturbance during construction and operation of the Project;
- to determine the location of rare plant occurrences within two mitigation parcels that will be used to compensate for project effects;
- to record detailed occurrence data in the master rare plant spatial database for all rare plant populations found, and submit these data to the B.C. Ministry of Environment and Climate Change Strategy (MOECCS) and—for taxa of federal concern—to Environment and Climate Change Canada (ECCC);
- to develop occurrence-specific mitigation measures to eliminate or reduce adverse effects to rare plant populations resulting from the Project; and
- to assist construction teams in implementing the ongoing rare plant mitigation measures.

1.3. Study Area

Pre-construction rare plant surveys are being conducted in:

- the Highway 29 realignment corridors;
- the proposed transmission line corridor;
- the proposed new or upgraded transmission line access road corridors;
- the proposed new or upgraded access road corridors into the reservoir clearing zone—excluding the reservoir footprint;
- the proposed aggregate extraction areas;
- the proposed haul road running along Ice Bridge and Septimus Roads from Area E to the Dam Site;
- the proposed Project Access Road corridor running from Jackfish Road to the Dam Site;
- the proposed access road extension at the Portage Mountain site;
- the 85th Avenue industrial site;
- the proposed conveyor corridor from the 85th Avenue industrial site to the dam site;
- the 204 hectare Rutledge mitigation parcel along Highway 29 at Dry Creek; and
- the 423 hectare Wilder Creek mitigation parcel located along the Peace River approximately six kilometres downstream from Bear Flat.

Pre-construction rare plant surveys were completed for some of these areas during the 2015 through 2020 field seasons. The 2021 work focussed on the remaining segments of Highway 29 realignment corridors on the north side of the Peace River, access roads on the south side of the Peace River, and on the Del Rio and Area E proposed aggregate extraction sites as well as the Area E proposed haul road.

2. Methods

2.1. Pre-field Review

Each year in the spring the investigation begins with a pre-field review designed to collect and analyze existing data. This information is used to create a field study plan and to identify data gaps in order to direct further research.

For the purpose of the investigation, “rare plants” are defined as the following vascular plants, mosses, and lichens:

- species listed on Schedule 1 of the Canadian Species at Risk Act (SARA) as amended (Government of Canada 2002);

- species assigned a status of Extinct, Extirpated, Endangered, Threatened, or Special Concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2021); and
- species on the B.C. MOECCS' provincial Red or Blue lists (BCCDC 2021).

Since 2005, BC Hydro has been conducting rare plant surveys in the Project's Regional Assessment Area (RAA)—as defined in the Site C Environmental Impact Statement (Hilton et al. 2013). As such, much is known about the rare flora of the area, and the pre-field review is based heavily on rare plant occurrence data collected over the last 16 years. Currently, 26 different rare plant taxa are reported to occur in the Project area. Consequently, these 19 vascular plants, four lichens, and three mosses form the basis of the target species list for the work, comprising the rare species with the highest likelihood of occurrence.

Since 2011 all rare plant data for the Project are managed in a master rare plant spatial database. This database contains occurrence information for all known rare plant sites in the RAA, as well as rare plant survey tracks, field notes, species information, and other collected data relevant to the rare plant work. Periodically, the master rare plant spatial database is queried to update the Project's spatial environmental features database (separately maintained by BC Hydro). This environmental features database is made available to Project engineers for use in mitigation planning.

In order to identify additional rare plant species that could potentially occur in the Project area, each year the dataset of all B.C. vascular plants, mosses, and lichens is downloaded from the MOECCS' Species and Ecosystem Explorer (BCCDC 2021). Queries are run on the dataset to extract a list of the rare plant species that MOECCS associates with the Peace River Regional District and the Boreal Black and White Spruce Biogeoclimatic Zone. Each species on this list is further reviewed to determine its potential for occurrence within the areas targeted for survey.

In addition, the B.C. Conservation Data Centre's (BCCDC) occurrence dataset of all species and ecosystems at risk (MOECCS 2019) is downloaded from the B.C. Data Catalogue and added to the master rare plant spatial database. The dataset is queried to investigate historic and verified extant rare plant occurrences within the Project area.

All the above information is compiled to produce a list of target rare plant species potentially occurring within the Project area. This target list includes the 26 taxa currently reported to occur in the Project area, as well as numerous other possible Peace Region species uncovered during the pre-field review of data and literature. The target list is used as a working guideline and can never be an exhaustive list of all potential rare plants for a given area. For this reason, the botanists consider all described plant taxa while conducting surveys.

Aerial imagery, contour information, and project maps are reviewed to predict the habitat types present in the survey corridors. General plant communities are determined, and the locations of possible high-suitability rare plant habitat are noted.

To refine their search images for the target taxa, the surveyors study photographs, herbarium specimens, and species descriptions in various published references (Hitchcock et al. 1955; Flora of North America Editorial Committee 1993; Goward et al. 1994; McCune et al. 1995; Douglas et al. 1998; Goward 1999;

Brodo et al. 2001; Cronquist et al. 2013; Brodo 2016) and online databases (CNALH 2021; Klinkenberg 2021; NatureServe 2021). In addition, they review similar data for species that might be confused with the target taxa. Tables of summary identification characteristics are prepared for field use. The goals are to maximize detectability of the target species and to reduce surveyor bias during the field work.

The final field plan each year is designed to guide the methods, coverage, and timing of the rare plant surveys. Seasonal timing is based on the predicted phenologies of the target species.

2.2. Field Survey

The pre-construction surveys began in June of 2015 and have taken place every year since. Over the seven field seasons, 297 surveyor-days have been spent surveying a total transect distance of 1,753.9 kilometres (Table 1 and Figure 1).

Table 1: Rare Plant Survey Effort

Year	Start Date	End Date	Surveyor-Days	Total Survey Km
2015	June 30	September 7	42	209.8
2016	June 20	August 23	41	191.8
2017	June 23	August 12	12	51.7
2018	June 13	August 29	56	409.3
2019	May 31	August 15	46	250.7
2020	June 4	October 9	56	322.3
2021	June 8	September 4	44	318.3
Totals			**297**	**1,753.9**

Table notes:

- *Surveyor-Days = days spent surveying x number of botanists*
- *Total Survey Km = total survey transect distance*

For all seven years, the surveys were performed by two senior-level rare plant botanists, both of whom have been working with the rare flora of the Project area for the past 11 years. The surveyors primarily use a habitat-directed meander search protocol to cover the areas surveyed. This survey technique is based on floristic, intuitive-controlled meander search types outlined in various rare plant survey guidelines (Whiteaker et al. 1998; ANPC 2000; ANPC 2012; Penny & Klinkenberg 2012; MOECCS Ecosystems Branch 2018). The surveyors, working together or separately, walk the length of the linear corridors, zig-zagging back and forth from one edge of the proposed disturbance area to the other. For non-linear survey areas such as the Industrial 85th Avenue or Portage Mountain sites, the surveyors conduct meander transects to cover the entire area.

When using the habitat-directed meander search protocol:

- surveyors walk variable-width transects that are spaced relatively close together (typically so that the edge of the transect just surveyed is still visible to the surveyor or their partner—this distance varies based on the habitat surveyed and the detectability of the target species);
- surveyors attempt to locate all rare plant occurrences and high-suitability rare plant habitat within a defined unit in a systematic way (e.g., by walking in a zig-zag pattern along linear features, or in a contour pattern when surveying non-linear features); and
- surveyors attempt to traverse a representative cross-section of all low-suitability rare plant habitat within the unit.

The habitat-directed meander search preferentially covers high-suitability ecosystems over the more common low-suitability habitats (MacDougall & Loo 2002). The survey method is floristic in nature, meaning that all plant taxa encountered are recorded and identified to a level necessary to determine their rarity (ANPC 2012). Furthermore, the habitat-directed meander search pattern is of variable intensity, such that when a rare plant occurrence or high-suitability rare plant habitat is located, the surveyors increase the intensity of their survey by narrowing the spacing of the transect pattern they are walking. Depending on the kind of habitat being surveyed and the detectability of the target rare species, this can require very close, hands-and-knees survey work in some areas.

For certain linear corridors that traverse habitat with a low potential for rare plant occurrence, the botanists drive slowly along the corridor in a Utility Terrain Vehicle (UTV) or truck, scanning both sides for rare plants and pockets of high-suitability rare plant habitat. This procedure is only conducted in corridors where the majority of habitat is low-probability, and at a speed of approximately 5 kilometres per hour. If high-potential rare plant habitat is encountered—such as wetlands or rock outcrops—the surveyors exit the vehicle and survey the habitat on foot. In 2015, 5.1% of the total 209.8 kilometres traversed was surveyed from UTV and the rest was walked. In 2016 only 0.9% of the total 191.8 kilometres survey distance was covered by UTV. In 2017, none of the transects were surveyed by UTV. In 2018, 14.6% of the total 409.3 kilometres was covered by UTV or truck, and in 2019, 2.3% of the total 250.7 kilometres was covered by UTV. Likewise in 2020, 2.3% of the total 322.3 transect kilometres were surveyed in this way. No corridors were surveyed by UTV in 2021.

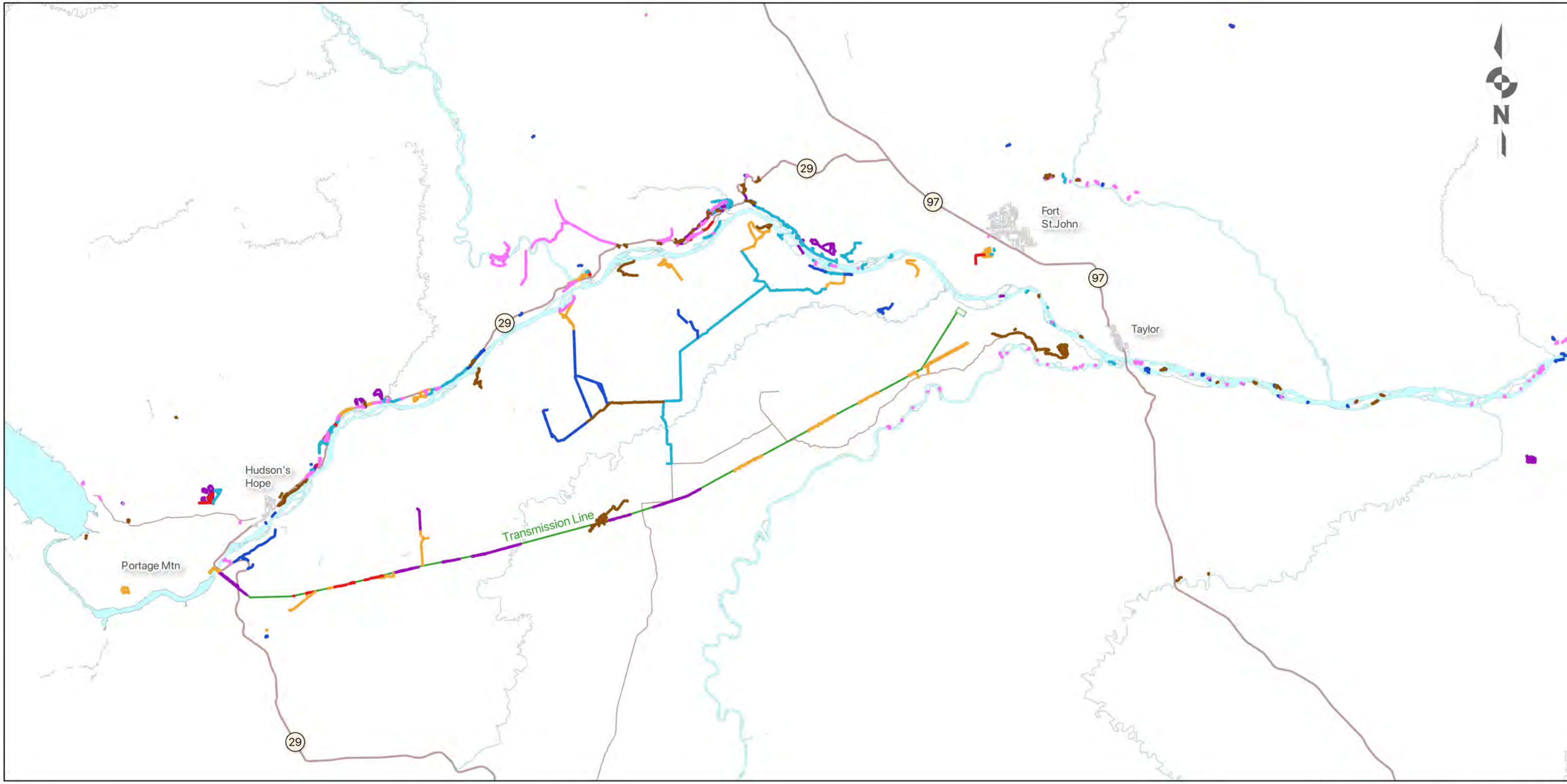
In 2016, surveys were conducted within the Rutledge and Wilder Creek mitigation parcels. These surveys were designed to provide a general overview of the rare plant populations present within the parcels, in order to inform mitigation planning. As such, these areas were surveyed at a lower intensity level, covering a smaller percentage of the suitable habitats than in the areas proposed for disturbance. Although the habitat-directed meander survey technique described above was used in the mitigation parcels, certain areas of suitable habitat were not covered.

During the fieldwork, the surveyors constantly monitor all areas traversed for changes in habitat and plant association, as well as for previously unrecorded plant species (common and rare). Lists are kept of all plants and plant communities observed; unknown species are collected for later identification in the lab; Global Positioning System (GPS) units are used to mark location points as appropriate; and notes and photographs are taken to record plants of interest, landforms and unique features, habitat quality and disturbance, and areas requiring further survey.

When target rare plants are found during the fieldwork, occurrence information is entered into custom-built digital forms or recorded on printed BCCDC rare plant survey forms (BCCDC 2012). Where paper forms are used, the information is later transcribed into digital format to facilitate analysis of the sites. Photographs are taken of both the individual plants and the surrounding habitat. Consistent with the B.C. Resource Information Standards Committee guidelines and the rare plant survey guidelines on the B.C. E-Flora website a voucher specimen is collected where permitted by the landowner, and when doing so would not compromise the viability of the population (RIC 1999; Penny & Klinkenberg 2012; MOECCS Ecosystems Branch 2018). At each vascular rare plant site, GPS units are used to record the boundary of the occurrence to facilitate mitigation planning.

Delimitation of occurrences is based on *A Habitat-Based Strategy for Delimiting Plant Element Occurrences* (NatureServe 2004). The Element Occurrence (EO) is a fundamental unit of information in the CDC system, and is defined as "an area of land and/or water in which a species or natural community is, or was present." (NatureServe 2002). Based on the NatureServe guidance, rare plants are typically grouped into a single occurrence when they are located closer than one kilometre from another individual of the same species. In some cases, occurrences are composed of two or more discrete patches—also referred to as "sites" in this report—spread out over a large area. These patches are mapped separately to facilitate mitigation planning, but are recorded as a single occurrence when the patches are closer than one kilometre to each other.

The botanists conducting the 2019, 2020, and 2021 preconstruction surveys were also working on the Site C Experimental Rare Plant Translocation program at the time, selecting and documenting potential recipient sites for translocation outplanting. When new rare plant sites were found during potential recipient site selection work, they were documented using the same methods as described above. All of the new rare plant sites found during the survey work for either program are reported here to provide a single document that contains all the new rare plant sites.



Map Notes:

1. Based on surveys completed through September 2021.
2. Map Datum: NAD83
3. Map Projection: UTM Zone 10 N
4. Water Features Base Data from BC FreshwaterAtlas.
5. Road Base Data from the BC Digital Roads Atlas project.
6. Project-specific spatial data supplied by BC Hydro.

Legend

Roads
- Highway
- Secondary Roads
- Urban

Survey Transects
- 2015
- 2016
- 2017
- 2018
- 2019
- 2020
- 2021

Map Scale 1:350000

0 10 20 30 km

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SITE C CLEAN ENERGY PROJECT

Figure 1
Rare Plant Survey Routes
2015 to 2021

Date	December 10, 2021	DWG NO	2021-12-10-001	Revision 0

2.3. Mitigation Planning and Implementation Assistance

In certain priority cases, where rare plant occurrences are situated in or near Project construction zones, the botanists work with BC Hydro planning teams and contractors to develop mitigation measures designed to reduce or eliminate impacts to the occurrences. This takes place on an as-needed basis in situations where a species is particularly difficult to identify in the field, or the layout of the occurrence is complex and difficult to map on the ground. The mitigation measures developed are focussed on avoidance or impact reduction, and include flagging occurrences in the field, coordinating with on-site construction personnel, and assisting rare plant salvage operations.

In addition, for one Red-listed species confirmed for the project area in 2018—*Selaginella rupestris* (rock selaginella)—a set of mitigation options were developed for all known occurrences in the RAA.

2.4. Analysis

As field data are collected, they are imported into the master rare plant spatial database on a daily basis. This includes rare plant occurrence information, survey transect routes, and field notes. Collected data are encrypted and secured with multi-factor authentication protocols. The information and field photos are backed up nightly to secure off-site servers.

Following the field season, the collected rare plant information is compiled and analyzed in the Project rare plant Geographic Information System (GIS). Voucher specimens are examined and sent to outside experts when additional verification is required. New rare plant locations are compared with BCCDC data to determine if the newly discovered sites can be combined as extensions of previously recorded occurrences.

Every year, once the data have been compiled, verified, and cleaned, a submission package is prepared for the BCCDC. This dataset contains all the new rare plant occurrences found during the previous field season, as well as any updates and extensions to previously reported occurrences. The data are provided in a spatial format compatible with BCCDC submission requirements. Voucher specimens are prepared based on MOECCS guidelines (MOECCS 2018) and submitted to the appropriate herbarium (typically UBC).

The following quality assurance and quality control measures are applied to promote accurate data collection and analysis:

- The master rare plant spatial database, which contains all rare plant data for the project, is a custom-built spatial database (PostgreSQL 13.1 spatially enabled with PostGIS 3.1). The database server software is regularly updated to the latest stable versions and all security patches are applied soon after issue.
- The tables in the database have been normalized to reduce data redundancy and improve integrity.

- Primary key constraints are enforced for all relational tables to improve database integrity and allow complex queries to be run.
- Fields are constrained at the database level to ensure type-consistency. Electronic input forms also constrain entered data to provide front-end validation and user guidance.
- Regular updates are pulled from the MOECCS' Ecosystem Explorer and are added to the master database to ensure that analyses are performed using the latest BCCDC rare plant statuses and nomenclature.
- The data fields *UTM northing*, *UTM easting*, *lat_long,* and *occurrence area* are calculated programmatically from the rare plant polygons, for accuracy of the derived fields. Point data are also derived programmatically from the rare plant polygons for locational consistency between the spatial fields.
- Multipolygons—a GIS feature class that allows one or more closed plane figures to be recorded for each occurrence—are used as the basic spatial descriptor for the rare plant occurrences recorded after 2008. This allows for more precise avoidance mitigation than would be possible using single polygons or points.
- Custom-built electronic forms are used by the botanists to enter rare plant data in the field while at the occurrence. Paper versions of the forms are also used in cases where there are difficulties with the electronic entry devices. In these cases, the paper forms are transcribed onto the electronic forms as soon as possible to allow for data validation.
- Every record is reviewed for typographical and transcription errors at the end of the field season.
- Associated species lists are reviewed by a second botanist to ensure identification accuracy.
- Rare plant polygons are reviewed on aerial imagery and ecosystem layers in the GIS to check boundary accuracy by the botanist(s) who recorded the occurrence.
- Voucher specimens are collected where appropriate and verified in the lab and herbarium, or are sent to species experts for further verification when taxonomic questions still exist.

3. Results

3.1. Pre-field Review

The 2021 pre-field review identified 102 rare plant taxa with potential for occurrence in the overall Project area (Appendix 1). The list comprises 38 vascular plant species, 47 bryophytes, and 17 lichens. As noted previously, this list was used for planning purposes and was not considered to be an exhaustive listing of all possible rare plant taxa in the project area. The surveyors considered all rare taxa during the surveys, whether they were on the target list or not.

It should also be noted that the BCCDC regularly reviews the statuses of the plant taxa in the province to determine if new information warrants a change in the rarity rankings. As the Site C rare plant work proceeds, the numerous new occurrences that have been found during the surveys have allowed the BCCDC to reassess many of the plant taxa in the RAA. These reassessments are typically published by the BCCDC in May of the year, allowing Project botanists to incorporate the updates into the field plan for the upcoming season.

However, in 2019 the BCCDC status update was not published until July 5, after several weeks of field work had been completed. The update removed 10 RAA plant taxa from the Red or Blue lists, meaning that they no longer meet the definition of "rare plants" for the Project (see Section 2.1). This reduced the number of rare plant sites within the RAA by more than half, from 261 occurrences before the update, to 124 after the update.

In 2021, the BCCDC status updates were published in the first half of June, allowing time to incorporate the results into the 2021 field plan. However, the 2021 status changes were more limited than in 2019, resulting in only a few modifications to the target species list, and no changes to the statuses of species that have been observed during rare plant surveys for the Project.

3.2. Field Survey

The 2015 field surveys found 34 new sites of 14 different rare plant species—11 vascular plants and three lichens. Some of these new sites were within one kilometre of other occurrences of the same species found in previous years, and so were considered to be extensions of these previously reported occurrences. Of the 14 rare species, five were on the MOECCS's Red list, with the remaining nine being on the Blue list. None of the taxa were listed on Schedule 1 of the Species at Risk Act, or were considered to be Extinct, Extirpated, Endangered, Threatened, or Special Concern by COSEWIC (Government of Canada 2002; COSEWIC 2021). Some of the rare taxa found in 2015 have since had their statuses revised and are no longer Red- or Blue-listed by MOECCS.

In 2016, 88 new sites of 13 different rare plant species were found—10 vascular plants and three lichens. As in 2015, some of the new sites were considered to be extensions of occurrences found in previous years. Of the 13 rare species found in 2016, five were on the B.C. Red list, while the remaining eight were on the Blue list. None of the 2016 taxa were listed on Schedule 1 of the Species at Risk Act, or were considered to be Extinct, Extirpated, Endangered, Threatened, or Special Concern by COSEWIC (Government of Canada 2002; COSEWIC 2021). As with the 2015 rare plant taxa, some of the 13 rare plant species found in 2016 are no longer Red- or Blue-listed by the MOECCS.

In 2017, three new sites of two different lichen species were found. One of the sites was considered to be an extension of a previously reported occurrence, and two were new occurrences. Both taxa found in 2017 were on the B.C. Blue list, however they have both since been removed. Neither was listed on Schedule 1 of the Species at Risk Act, or was considered to be Extinct, Extirpated, Endangered, Threatened, or Special Concern by COSEWIC (Government of Canada 2002; COSEWIC 2021).

For the 2018 field season, 46 rare plant sites were found. Several of these were extensions of previously known occurrences. Fourteen different rare plant taxa were found: four B.C. Red list, and 10 Blue list. None of the 14 were listed on Schedule 1 of the Species at Risk Act, or were considered to be Extinct, Extirpated, Endangered, Threatened, or Special Concern by COSEWIC (Government of Canada 2002; COSEWIC 2021). Several of the taxa documented in 2018 have since been removed from the B.C. Red/Blue lists.

In 2019, 21 occurrences of nine rare or formerly rare taxa were found or expanded. These 21 occurrences contained 47 separate patches. One of the taxa was on the B.C. Red list, six were on the Blue list, and two were on the Yellow list (*i.e.*, apparently secure) after being revised in July 2019 when the BCCDC status changes were published (BCCDC 2021). None of the nine taxa were listed on Schedule 1 of the Species at Risk Act, or was considered to be Extinct, Extirpated, Endangered, Threatened, or Special Concern by COSEWIC (Government of Canada 2002; COSEWIC 2021).

During the 2020 field season, 22 rare plant occurrences (comprising 47 separate patches) were discovered or expanded. Nine rare plant species were documented: three Red-listed taxa and six Blue-listed taxa. None of the nine species are listed on Schedule 1 of the Species at Risk Act or are considered to be Extinct, Extirpated, Endangered, Threatened, or Special Concern by COSEWIC (Government of Canada 2002; COSEWIC 2021).

The 2021 field surveys discovered or expanded 19 occurrences (comprising 43 separate patches) of eight different rare vascular plant taxa: two B.C. Red-listed taxa, and six B.C. Blue-listed taxa. None of the eight species are listed on Schedule 1 of the Species at Risk Act or are considered to be Extinct, Extirpated, Endangered, Threatened, or Special Concern by COSEWIC (Government of Canada 2002; COSEWIC 2021).

In total, 169 occurrences containing 360 patches of 29 currently or formerly listed rare plant taxa were discovered or expanded during the preconstruction surveys (Table 2 and Figure 2). Over the course of the seven survey years, the investigators recorded 697 vascular plant, bryophyte, and lichen taxa (Appendix 2).

Table 2: Rare plants found during the Site C Preconstruction surveys

Taxon	Common Name	Current BC List	Occurrences	Patches
Vascular Plants				
Artemisia herriotii	Herriot's sage	Yellow	7	24
Atriplex gardneri var. gardneri	Gardner's sagebrush	Red	2	3
Avenula hookeri	Spike-oat	Yellow	1	1
Calamagrostis montanensis	plains reedgrass	Yellow	5	14
Carex backii	Back's sedge	Yellow	4	11
Carex sprengelii	Sprengel's sedge	Blue	4	8
Carex torreyi	Torrey's sedge	Blue	6	11
Carex xerantica	dry-land sedge	Blue	13	25
Castilleja miniata var. fulva	tawny paintbrush	Yellow	1	1
Cirsium drummondii	Drummond's thistle	Yellow	4	13

Taxon	Common Name	Current BC List	Occurrences	Patches
Geum triflorum var. triflorum	old man's whiskers	Yellow	7	28
Juncus stygius var. americanus	bog rush	Yellow	1	1
Lomatium foeniculaceum var. foeniculaceum	fennel-leaved desert-parsley	Blue	1	1
Oxytropis campestris var. davisii	Davis' locoweed	Blue	20	33
Pedicularis parviflora	small-flowered lousewort	Yellow	1	2
Penstemon gracilis	slender penstemon	Blue	11	31
Piptatheropsis canadensis	Canada ricegrass	Red	5	17
Polypodium sibiricum	Siberian polypody	Yellow	1	12
Potentilla pulcherrima	pretty cinquefoil	Yellow	4	9
Ranunculus rhomboideus	prairie buttercup	Blue	7	11
Salix petiolaris	meadow willow	Blue	1	1
Selaginella rupestris	rock selaginella	Red	7	12
Silene drummondii var. drummondii	Drummond's campion	Yellow	3	3
Sphenopholis intermedia	slender wedgegrass	Yellow	7	13
Symphyotrichum puniceum var. puniceum	purple-stemmed aster	Yellow	7	7
Lichens				
Physcia biziana	frosted rosette	Yellow	16	28
Physcia stellaris	immaculate rosette	Yellow	8	11
Ramalina sinensis	threadbare ribbon	Yellow	14	25
Usnea cavernosa	pitted beard	Yellow	1	4

Table notes:

- *BC List (B.C. MOECCS): Red = Endangered, Threatened, or Extirpated; Blue = Special Concern; Yellow = Apparently Secure*
- *Occurrences: Includes newly discovered occurrences as well as occurrences expanded during the preconstruction surveys*

Many of the rare plant taxa found during the pre-construction surveys had been documented previously in other occurrences during the baseline surveys performed for the Project environmental impact assessment. Species descriptions for the eleven currently rare-listed taxa recorded during the 2015–2021 preconstruction surveys are presented in Appendix 3. Each section also contains an overview of the new sites documented in 2021, and to-date summary information on all reported occurrences for each of these taxa in the RAA.

In this report all of the rare plant taxa discussed in Appendix 3 are currently Red- or Blue-listed by the BCCDC. For clarity, rare species found in previous years that have subsequently been removed from the Red or Blue lists are not included. Although not currently of conservation concern, the occurrence data for these taxa have been retained in the master rare plant spatial database for future reference if needed.

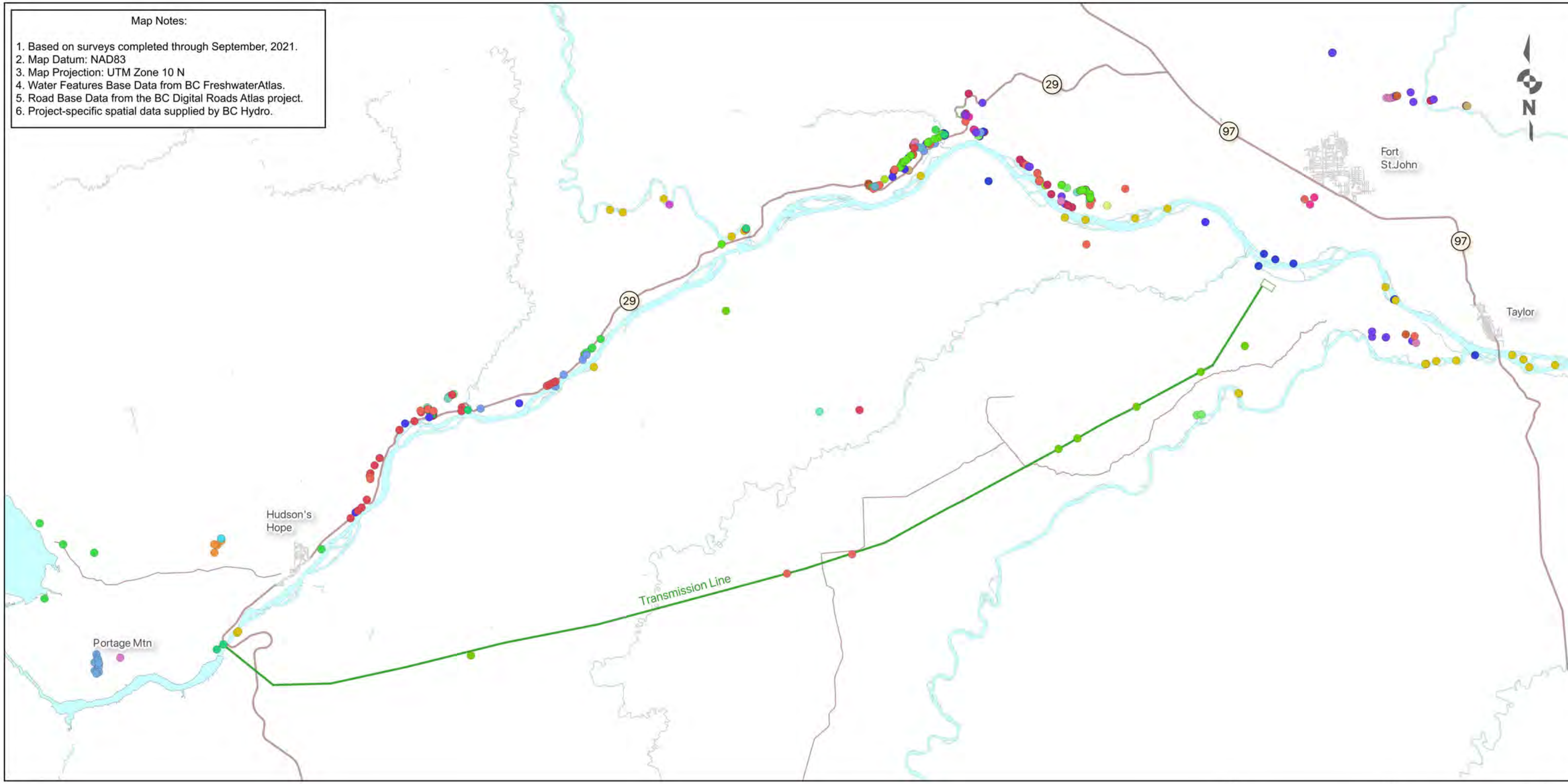
Information on additional taxa and occurrences documented in the RAA prior to 2015 can be found in the following references:

- Site C Project Environmental Impact Statement, Volume 2, Appendix R, Part 1 (Hilton et al. 2013);
- Report: Site C Clean Energy Project: Pre-disturbance Rare Plant Assessment #1: Rolling Work Plan 10 (Eagle Cap Consulting Ltd 2014);
- Report: Site C Clean Energy Project: Wildlife, Vegetation and Mapping Inventory for the Marl Fen Property (Simpson et al. 2014); and
- B.C. Ecosystem Explorer website (BCCDC 2021).

3.3. Mitigation Planning and Implementation

To-date, seven priority rare plant occurrences have required specific mitigation assistance from the pre-construction rare plant survey team. In 2018, two occurrences of Red-listed species—*Piptatheropsis canadensis* (Canada ricegrass) and *Atriplex gardneri* var. *gardneri* (Gardner's sagebrush)—adjacent to access roads in the Wilder Creek area were flagged, mapped, and photographed to assist the road crews in avoiding these occurrences. The forestry contractor responsible for the area was contacted so that crews understood how the sites were flagged and the importance of avoiding them in the field. Monitoring surveys conducted in 2019 found that both sites had been substantially avoided during the road work and the viability of the occurrences had not been threatened by the activity. The Canada ricegrass occurrence had been completely avoided, and the Gardner's sagebrush occurrence had only a few individuals impacted, leaving the majority untouched.

In 2019, a priority rare plant site in the Farrell Creek East Highway 29 realignment clearing zone was identified that required additional mitigation assistance. The site contained two priority rare plant occurrences—*Selaginella rupestris* (rock selaginella) and *Penstemon gracilis* (slender penstemon)—that could be reduced or extirpated by clearing activities. Due to access restrictions, propagule salvage operations could not occur at this site until BC Hydro acquired rights to the land. In cooperation with the BC Hydro off-dam environmental planning team, a mitigation plan was developed delaying clearing activities until 2021, allowing for propagule salvage after land acquisition. In 2021 the preconstruction botany team assisted the Experimental Rare Plant Translocation program team in salvaging some of the rock selaginella and slender penstemon individuals at this site, before the area was cleared for aggregate extraction.



- *Artemisia herriotii*
- *Atriplex gardneri var.gardneri*
- *Avenula hookeri*
- *Calamagrostis montanensis*
- *Carex backii*
- *Carex sprengelii*
- *Carex torreyi*
- *Carex xerantica*
- *Castilleja miniata var.fulva*
- *Cirsium drummondii*
- *Geum triflorum var.triflorum*
- *Juncus stygius var.americanus*
- *Lomatium foeniculaceum var.foeniculaceum*
- *Oxytropis campestris var.davisii*
- *Penstemon gracilis*
- *Physcia biziana*
- *Physcia stellaris*
- *Piptatheropsis canadensis*
- *Pohlia elongata*
- *Polypodium sibiricum*
- *Potentilla pulcherrima*
- *Ramalina sinensis*
- *Ranunculus rhomboideus*
- *Salix petiolaris*
- *Selaginella rupestris*
- *Silene drummondii var.drummondii*
- *Sphenopholis intermedia*
- *Symphyotrichum puniceum var.puniceum*
- *Usnea cavernosa*

Map Scale 1:250000

0 10 20 km

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Figure 2
Rare Plant Sites Found
in Project Vicinity (2015-2021)

Date	December 10, 2021	DWG NO	2021-12-10-0002	Revision 0

In 2020, preconstruction rare plant surveys discovered an occurrence of *Carex sprengelii* (Sprengel's sedge) in an area at Dry Creek that had been recently cleared. The overstory trees and shrubs had been cut and removed, and some ground disturbance had taken place. In the opening, four Sprengel's sedge plants were found, all of which were in late fruit. The remaining undispersed Sprengel's sedge achenes were collected and sent to NATS Nursery in Langley, B.C. to be incorporated into the Project's Experimental Rare Plant Translocation program. The four plants were left in place and will be monitored in future years. In 2021 the site was revisited and it was found that all four of the original plants were persisting. In addition, a fifth individual plant was found near one of the others.

Also in 2020, late season field work within the Cache Creek Highway Realignment construction corridor discovered another new occurrence of Canada ricegrass. Nine separate patches were found in and adjacent to the Leave to Construct (LTC) corridor. Several detailed options were developed to mitigate impacts to the patches. Because clearing in this area was scheduled for the Fall of 2020, the rare plant botanists returned to the site in early October to implement and facilitate mitigation measures for the occurrence.

One of the nine patches was in an area that had been cleared. Twelve Canada ricegrass plants were still present along the edges of the former patch—some stems were broken but the remaining base and root portions of the plants were intact. Several of the stem heads contained undispersed fruit and 27 seeds were collected. After microscope examination, nine of the seeds were found to be apparently viable, and these were sent to NATS Nursery for storage and propagation as part of the Project's Experimental Rare Plant Translocation program. The 12 plants were salvaged and directly replanted at two suitable recipient sites outside of the LTC zone. The replanting work was fully documented and these two plantings will be monitored in future years.

The remaining eight patches had not been affected by project activities. Two of these patches are well away from the LTC zone and are not expected to be affected by the Project. The other six are in areas of the LTC zone where construction activities may be able to avoid disturbing the patches. These six were clearly flagged and staked in the field to facilitate avoidance. Personnel from the construction firms were contacted so that they were aware of the rare plant sites and understood how the patches are flagged in the field. In addition, the botanists met with a representative from the Site C off-dam environmental team and visited each of the flagged patches. This occurrence will be monitored in subsequent years to determine the success of these measures and implement additional mitigation (such as salvage) if needed.

In 2021, this Canada ricegrass occurrence at Cache Creek was again revisited to determine its status. As expected, the patch that had been cleared in 2020 was extirpated under the newly built highway. One other patch straddling the edge of the right-of-way (ROW) fence had been partially cleared by highway construction, although the portion outside of the ROW appeared to be unaffected. The remaining seven patches did not appear to have been directly impacted by highway construction.

Also in 2021, another Canada ricegrass occurrence near the proposed Area E aggregate extraction site was staked and flagged to facilitate contractor avoidance. This occurrence is located approximately 60 m outside of the extraction site boundary, and is not expected to be affected by construction activities. The occurrence was flagged as a precautionary measure to reduce the chance that unintentional indirect impacts would occur within its boundaries.

4. Discussion

4.1. Coverage

Survey coverage of the areas proposed for construction disturbance—both the linear corridors and non-linear areas—was considered sufficient to locate the majority of identifiable target rare plant species. The field crew used a habitat-directed search protocol, employing a variable-intensity survey pattern that focussed time and effort on the habitats most likely to contain rare plant occurrences. Transects were spaced so that the majority of rare plant occurrences and high-suitability rare plant habitat would have been visible during the surveys. See Section 2.2 above for a complete description of the survey methods.

For the mitigation parcels—where the goal was to provide only a general overview of the rare plant populations present—the lower intensity meander surveys sampled most of the important habitats at both parcels. Although there are likely additional rare plant occurrences to be found at the mitigation parcels, the surveys provided a general picture of the rare plant resources present.

The logistics of performing rare plant surveys in the project area present certain challenges for coverage and timing. Several of the target rare plant species have extremely limited seasonal identification periods—some can only be optimally found during a four-week-long window that may change slightly from year to year depending on the weather. In addition, access is often unsafe or impossible during substantial periods of the growing season due to severe weather events, flooding, road wash-outs, and impassable wetland conditions. These physical access limitations are particularly constraining on the plateau south of the Peace River, but can also be challenging on the north side of the river. Furthermore, landowner restrictions prevent surveyors' access to certain areas until BC Hydro is able to acquire access rights to the specific survey parcels (and often the roads that lead up to them).

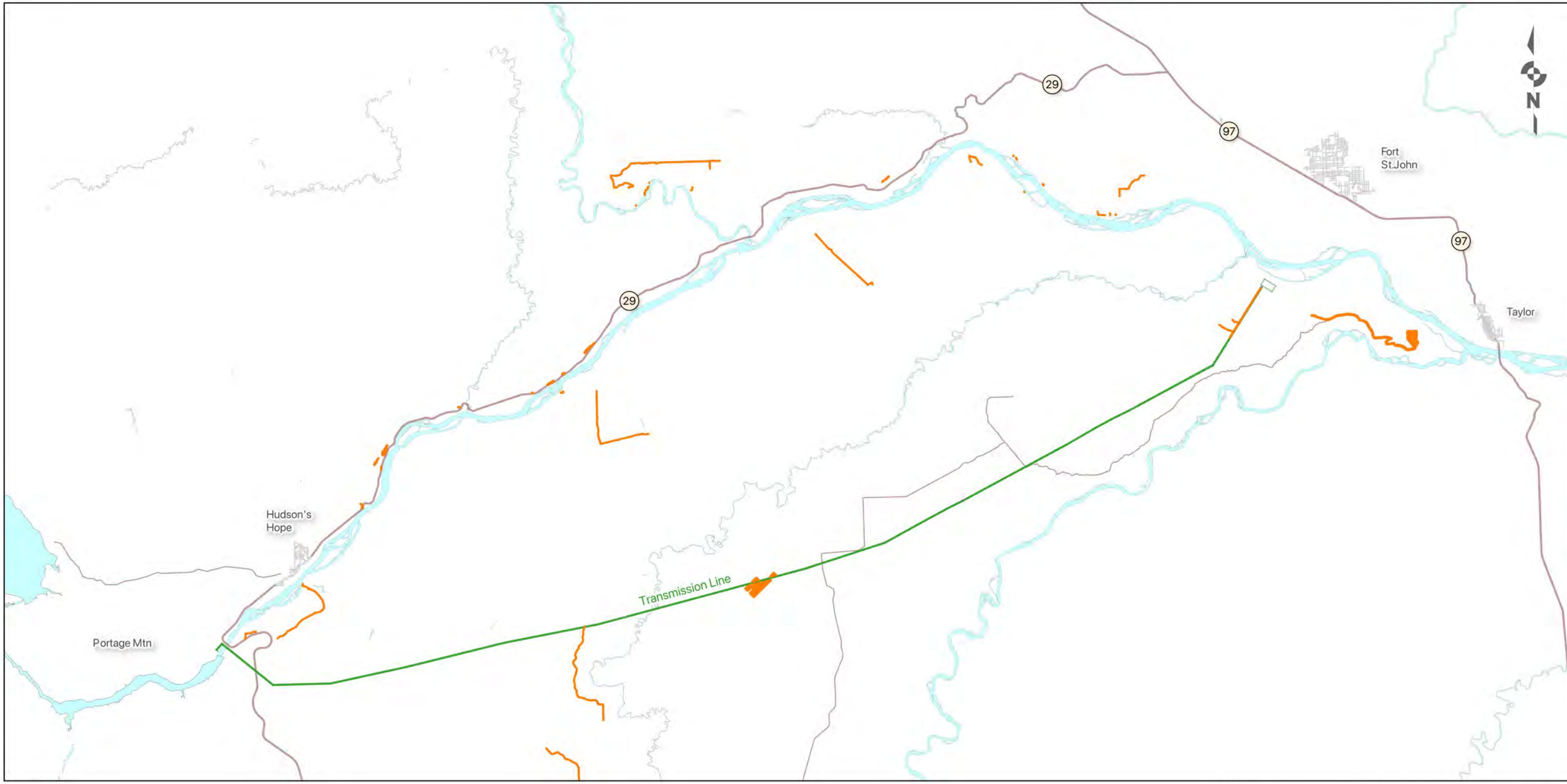
All these factors—target species identification periods, favourable weather and road conditions, legally granted access permission—must coincide for a successful survey visit. Often, repeated attempts are necessary. In a limited number of cases, it was not possible to access certain planned construction corridors at the appropriate time of year prior to clearing. Over the seven years of pre-construction surveys, an estimated 1,326 hectares of corridor have been surveyed (including the mitigation areas). Of that total, the surveyors found approximately 51.4 hectares (3.9% of the total) were cleared before they arrived. Nevertheless, these areas were surveyed using the standard methods described in Section 2.2 when rare plant habitat persisted following the clearing.

4.2. Seasonal Timing

Based on the observed phenology of the plants in the areas surveyed and data gathered during previous years' survey work, the seasonal timing of the surveys was sufficient to identify most of the target rare plants. The June and early July work typically focussed on sites north of the Peace River, where floodplain and grassland habitats make up the majority of the high-potential rare plant habitats present. Target species in these habitats often bloom early in the season, and then wither by later in the summer (although some notable exceptions have been observed, such as Canada ricegrass, which is not clearly identifiable until later in the season). The late summer and early fall surveys mainly focussed on areas south of the Peace River, where wetlands are the primary high-potential rare plant habitats. Many of these wetland-associated target rare plants bloom later in the season, and persist longer into the fall than those found in the upland areas.

4.3. Remaining Areas to Survey

At the beginning of the 2021 field season, 365.1 hectares of preconstruction corridor remained to be surveyed. Field work began on those areas in early June and progressed well. Over the course of the summer, BC Hydro provided updates to the project facilities spatial layers, increasing the amount of required survey corridor. This increase was primarily a result of continuing refinements to the proposed access routes and additional layout changes to the Highway 29 realignment routes. In addition, in late summer, a proposal was made to use the Area E aggregate extraction site and associated haul road, increasing the required survey area further. By the end of the 2021 field season, 437.9 hectares of planned corridor and extraction areas remained to be surveyed (Figure 3). This includes corridors that need to be surveyed for the first time, as well as areas that need to be revisited to complete the coverage. Rare plant surveys of these areas are scheduled to take place during the 2022 field season.



Map Location

Map Notes:

1. Based on surveys completed through September 2021.
2. Map Datum: NAD83
3. Map Projection: UTM Zone 10 N
4. Water Features Base Data from BC FreshwaterAtlas.
5. Road Base Data from the BC Digital Roads Atlas project.
6. Project-specific spatial data supplied by BC Hydro.

Legend

Roads
- *Highway*
- *Secondary A*
- *Urban*

Preconstruction Corridors
- *To Be Surveyed*

Map Scale 1:250000

0 10 20 km

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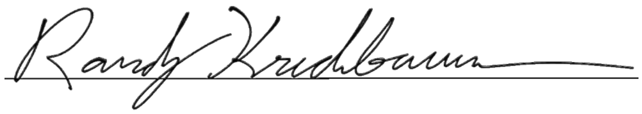
Figure 3
Remaining Preconstruction Survey Areas

Date	December 10, 2021	DWG NO	2021-12-10-0003	Revision 0

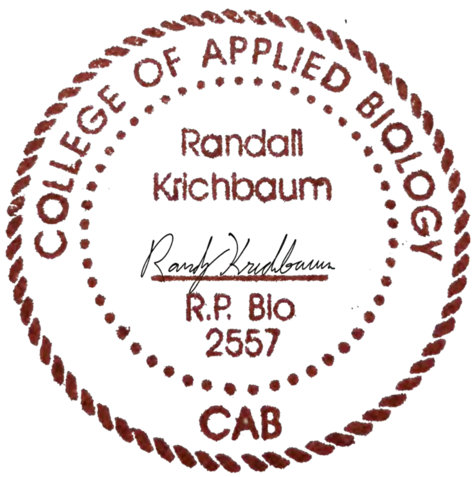
5. CLOSURE

Reviewed and approved:



Randy Krichbaum M.Sc., R.P. Bio., P. Biol.
Senior Ecologist
Eagle Cap Consulting Ltd.

<Original signed and sealed December 20, 2021 at Calgary, Alberta>



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7. APPENDICES

7.1. Appendix 1: Rare plant taxa with potential for occurrence in the Site C Project area

Scientific Name	Common Name	BC List	COSEWIC	SARA
VASCULAR PLANTS				
Acorus americanus	American sweet-flag	Blue		
Alopecurus magellanicus	alpine meadow-foxtail	Red		
Arctophila fulva	pendantgrass	Blue		
Artemisia alaskana	Alaskan sagebrush	Blue		
Atriplex gardneri var. gardneri	Gardner's sagebrush	Red		
Botrychium montanum	mountain moonwort	Blue		
Botrychium paradoxum	two-spiked moonwort	Blue		
Carex bicolor	two-coloured sedge	Blue		
Carex lapponica	Lapland sedge	Blue		
Carex sprengelii	Sprengel's sedge	Blue		
Carex torreyi	Torrey's sedge	Blue		
Carex xerantica	dry-land sedge	Blue		
Drosera linearis	slender-leaf sundew	Blue		
Epilobium saximontanum	Rocky Mountain willowherb	Blue		
Lomatium foeniculaceum var. foeniculaceum	fennel-leaved desert-parsley	Blue		
Oxytropis campestris var. davisii	Davis' locoweed	Blue		
Packera ogotorukensis	Ogotoruk Creek butterweed	Red		
Penstemon gormanii	Gorman's penstemon	Blue		
Penstemon gracilis	slender penstemon	Blue		
Piptatheropsis canadensis	Canada ricegrass	Red		
Polemonium boreale	northern Jacob's-ladder	Blue		
Polygala senega	Seneca-snakeroot	Red		
Polygonum ramosissimum ssp. prolificum	proliferous knotweed	Red		
Potentilla furcata	forked cinquefoil	Red		
Prenanthes racemosa	purple rattlesnake-root	Red		
Ranunculus cardiophyllus	heart-leaved buttercup	Red		
Ranunculus rhomboideus	prairie buttercup	Blue		
Rosa arkansana	Arkansas rose	Blue		
Salix petiolaris	meadow willow	Blue		
Salix raupii	Raup's willow	Red		

Scientific Name	Common Name	BC List	COSEWIC	SARA
Sarracenia purpurea ssp. purpurea	common pitcher-plant	Red		
Saussurea angustifolia var. angustifolia	northern sawwort	Red		
Selaginella rupestris	rock selaginella	Red		
Silene repens	pink campion	Blue		
Symphyotrichum falcatum var. commutatum	white prairie aster	Red		
Tephroseris palustris	marsh fleabane	Blue		
Thalictrum dasycarpum	purple meadowrue	Blue		
Utricularia ochroleuca	ochroleucous bladderwort	Blue		
LICHENS				
Anaptychia crinalis	electrified millepede	Red		
Anaptychia ulotrichoides	amputated millepede	Blue		
Cladonia parasitica	fence-rail pixie	Red		
Collema bachmanianum	Caesar's tarpaper	Blue		
Collema coniophilum	crumpled tarpaper	Red	T (2010)	1-T (2017)
Fulgensia desertorum	desert sulphur	Blue		
Fulgensia subbracteata	creeping sulphur	Blue		
Heterodermia speciosa	smiling centipede	Red		
Phaeophyscia adiastola	granulating shadow	Blue		
Phaeophyscia hispidula	whiskered shadow	Red		
Physcia dimidiata	exuberant rosette	Blue		
Physcia tribacia	beaded rosette	Red		
Physciella chloantha	downside shade	Blue		
Squamarina cartilaginea	pea-green dimple	Red		
Squamarina lentigera	snow-white dimple	Red		
Thyrea confusa	candied gummybear	Blue		
Xanthoparmelia camtschadalis	rockfrog	Red		
BRYOPHYTES				
Acaulon muticum var. rufescens	[no common name]	Red		
Amblyodon dealbatus	[no common name]	Blue		
Atrichum tenellum	[no common name]	Red		
Aulacomnium acuminatum	[no common name]	Blue		
Barbula convoluta var. gallinula	[no common name]	Red		
Bartramia halleriana	Haller's apple moss	Red	T (2011)	1-T (2003)
Bryobrittonia longipes	[no common name]	Blue		
Cynodontium glaucescens	[no common name]	Blue		

Scientific Name	Common Name	BC List	COSEWIC	SARA
Dicranum majus var. orthophyllum	[no common name]	Red		
Didymodon rigidulus var. icmadophilus	[no common name]	Blue		
Didymodon subandreaeoides	[no common name]	Red		
Encalypta brevicollis	[no common name]	Blue		
Encalypta intermedia	[no common name]	Blue		
Encalypta mutica	[no common name]	Blue		
Encalypta spathulata	[no common name]	Blue		
Grimmia teretinervis	[no common name]	Red		
Haplodontium macrocarpum	Porsild's bryum	Red	T (2017)	1-T (2011)
Hygrohypnum alpestre	[no common name]	Blue		
Hygrohypnum alpinum	[no common name]	Blue		
Lescuraea saxicola	[no common name]	Blue		
Meesia longiseta	[no common name]	Blue		
Myurella sibirica	[no common name]	Red		
Orthothecium strictum	[no common name]	Blue		
Philonotis yezoana	[no common name]	Blue		
Plagiobryum demissum	[no common name]	Red		
Pohlia bulbifera	[no common name]	Blue		
Pseudocalliergon turgescens	[no common name]	Blue		
Schistidium boreale	[no common name]	Blue		
Schistidium confertum	[no common name]	Red		
Schistidium pulchrum	[no common name]	Blue		
Schistidium robustum	[no common name]	Blue		
Schistidium trichodon	[no common name]	Blue		
Seligeria subimmersa	[no common name]	Red		
Seligeria tristichoides	[no common name]	Blue		
Sphagnum balticum	[no common name]	Blue		
Sphagnum contortum	[no common name]	Blue		
Sphagnum wulfianum	[no common name]	Blue		
Splachnum vasculosum	[no common name]	Blue		
Tayloria froelichiana	[no common name]	Blue		
Tayloria splachnoides	[no common name]	Red		
Tetraplodon urceolatus	[no common name]	Red		
Timmia norvegica	[no common name]	Blue		
Timmia sibirica	[no common name]	Red		
Tortella humilis	[no common name]	Red		

Scientific Name	Common Name	BC List	COSEWIC	SARA
Trichostomum crispulum	[no common name]	Blue		
Warnstorfia pseudostraminea	[no common name]	Blue		
Weissia brachycarpa	[no common name]	Blue		

Table notes:

- *B.C. List (B.C. Ministry of Environment): Red = Endangered, Threatened, or Extirpated; Blue = Special Concern*
- *COSEWIC (Committee on the Status of Endangered Wildlife in Canada): E = Endangered; T = Threatened; SC = Special Concern; DD = Data Deficient*
- *SARA (Species at Risk Act): 1-E = Schedule 1 Endangered; 1-T = Schedule 1 Threatened; 1-SC = Schedule 1 Special Concern*

7.2. Appendix 2: Plant and lichen species recorded during the 2015–2021 surveys

Vascular Plants

Acer glabrum var. douglasii
Acer negundo
Achillea alpina
Achillea borealis
Achillea millefolium var. lanulosa
Achnatherum nelsonii ssp. dorei
Achnatherum richardsonii
Aconitum delphiniifolium
Actaea rubra
Agropyron cristatum ssp. pectinatum
Agrostis capillaris
Agrostis exarata
Agrostis gigantea
Agrostis scabra
Alisma triviale
Allium cernuum
Allium cernuum var. cernuum
Allium schoenoprasum var. sibiricum
Alnus incana ssp. tenuifolia
Alnus viridis ssp. crispa
Alnus viridis ssp. sinuata
Alopecurus aequalis
Alopecurus pratensis
Amelanchier alnifolia
Amerorchis rotundifolia
Anaphalis margaritacea
Androsace septentrionalis
Anemone cylindrica
Anemone multifida var. multifida
Anemone patens ssp. multifida
Anemone virginiana var. cylindroidea
Angelica genuflexa
Antennaria howellii ssp. canadensis
Antennaria howellii ssp. petaloidea
Antennaria microphylla
Antennaria neglecta
Antennaria parvifolia
Antennaria pulcherrima ssp. pulcherrima
Antennaria racemosa
Antennaria rosea
Anthoxanthum hirtum
Apocynum androsaemifolium
Apocynum androsaemifolium var. androsaemifolium
Aquilegia brevistyla
Aralia nudicaulis
Arctium minus
Arctium sp.
Arctostaphylos uva-ursi
Arnica chamissonis
Arnica cordifolia
Artemisia biennis
Artemisia campestris ssp. pacifica
Artemisia dracunculus
Artemisia frigida
Artemisia herriotii
Askellia elegans
Asparagus officinalis
Astragalus agrestis
Astragalus alpinus var. alpinus
Astragalus americanus
Astragalus australis
Astragalus canadensis
Astragalus cicer
Astragalus eucosmus
Astragalus laxmannii var. robustior
Astragalus tenellus
Athyrium filix-femina ssp. cyclosorum
Atriplex gardneri var. gardneri
Avena sativa
Avenula hookeri
Axyris amaranthoides
Beckmannia syzigachne
Betula neoalaskana
Betula papyrifera
Betula pumila
Betula pumila var. glandulifera
Bidens cernua
Blitum capitatum
Boechera divaricarpa
Boechera grahamii
Boechera pendulocarpa
Boechera retrofracta
Boechera stricta
Botrypus virginianus
Brassica rapa var. rapa
Bromus ciliatus
Bromus inermis
Bromus pumpellianus ssp. pumpellianus
Calamagrostis canadensis
Calamagrostis canadensis var. langsdorfii
Calamagrostis montanensis
Calamagrostis purpurascens var. purpurascens

Calamagrostis stricta ssp. inexpansa
Calla palustris
Callitriche palustris
Caltha natans
Campanula rotundifolia
Canadanthus modestus
Capsella bursa-pastoris
Caragana arborescens
Cardamine oligosperma var. oligosperma
Carex aquatilis
Carex aquatilis var. aquatilis
Carex arcta
Carex atherodes
Carex atratiformis
Carex aurea
Carex backii
Carex bebbii
Carex brunnescens
Carex brunnescens ssp. brunnescens
Carex canescens ssp. canescens
Carex capillaris
Carex chordorrhiza
Carex concinna
Carex crawfordii
Carex cusickii
Carex deweyana var. deweyana
Carex diandra
Carex disperma
Carex duriuscula
Carex eburnea
Carex filifolia
Carex foenea
Carex gynocrates
Carex inops ssp. heliophila
Carex interior
Carex lasiocarpa
Carex limosa
Carex livida var. radicaulis
Carex magellanica ssp. irrigua
Carex microptera
Carex obtusata
Carex peckii
Carex pellita
Carex praticola
Carex retrorsa
Carex richardsonii
Carex rossii
Carex sartwellii
Carex siccata
Carex sprengelii
Carex tenera
Carex tenuiflora
Carex torreyi
Carex utriculata
Carex vaginata
Carex viridula ssp. viridula
Carex xerantica
Castilleja miniata
Castilleja miniata var. fulva
Centaurea stoebe ssp. micranthos
Cerastium arvense
Cerastium fontanum
Cerastium nutans
Chamerion angustifolium
Chenopodiastrum simplex
Chenopodium album
Chenopodium album ssp. album
Chenopodium album ssp. striatum
Chenopodium desiccatum
Chenopodium pratericola
Chrysosplenium tetrandrum
Cicuta bulbifera
Cicuta douglasii
Cicuta virosa
Cinna latifolia
Circaea alpina ssp. alpina
Cirsium arvense
Cirsium drummondii
Cirsium foliosum
Cirsium vulgare
Clematis occidentalis ssp. grosseserrata
Clematis tangutica var. tangutica
Coeloglossum viride var. virescens
Collomia linearis
Comandra umbellata
Comandra umbellata var. pallida
Comarum palustre
Conyza canadensis
Corallorhiza maculata
Corallorhiza striata var. striata
Corallorhiza trifida
Cornus canadensis
Cornus stolonifera
Corydalis aurea ssp. aurea

Corylus cornuta
Crepis tectorum
Cypripedium passerinum
Cystopteris fragilis
Dactylis glomerata
Dactylorhiza viridis
Danthonia intermedia ssp. intermedia
Danthonia spicata
Dasiphora fruticosa
Delphinium glaucum
Deschampsia cespitosa ssp. cespitosa
Descurainia sophia
Diphasiastrum complanatum
Dracocephalum parviflorum
Drosera linearis
Drosera rotundifolia
Drosera rotundifolia var. rotundifolia
Dryas drummondii
Drymocallis arguta
Dryopteris carthusiana
Dryopteris expansa
Elaeagnus commutata
Eleocharis mamillata ssp. mamillata
Eleocharis palustris
Elymus albicans
Elymus canadensis
Elymus glaucus
Elymus glaucus ssp. glaucus
Elymus lanceolatus ssp. lanceolatus
Elymus repens
Elymus trachycaulus
Elymus trachycaulus ssp. subsecundus
Elymus trachycaulus ssp. trachycaulus
Epilobium angustifolium
Epilobium ciliatum
Epilobium ciliatum ssp. ciliatum
Epilobium ciliatum ssp. glandulosum
Epilobium halleanum
Epilobium hornemannii ssp. hornemannii
Epilobium palustre
Equisetum arvense
Equisetum fluviatile
Equisetum hyemale
Equisetum hyemale ssp. affine
Equisetum laevigatum
Equisetum palustre
Equisetum pratense
Equisetum scirpoides
Equisetum sylvaticum
Equisetum variegatum ssp. variegatum
Erigeron caespitosus
Erigeron glabellus var. pubescens
Erigeron philadelphicus
Erigeron philadelphicus var. philadelphicus
Eriophorum angustifolium
Eriophorum chamissonis
Eriophorum gracile
Eriophorum sp.
Eriophorum viridicarinatum
Erysimum cheiranthoides
Euphrasia nemorosa
Eurybia conspicua
Eurybia sibirica
Fallopia convolvulus
Festuca rubra ssp. rubra
Festuca saximontana
Festuca trachyphylla
Fragaria vesca var. bracteata
Fragaria virginiana
Fragaria virginiana var. platypetala
Galearis rotundifolia
Galeopsis bifida
Galium boreale
Galium labradoricum
Galium trifidum
Galium trifidum ssp. trifidum
Galium triflorum
Gentianella amarella ssp. acuta
Geocaulon lividum
Geranium bicknellii
Geum aleppicum
Geum macrophyllum
Geum macrophyllum ssp. macrophyllum
Geum macrophyllum var. perincisum
Geum triflorum
Geum triflorum var. triflorum
Glyceria borealis
Glyceria grandis var. grandis
Glyceria striata
Gnaphalium uliginosum
Goodyera repens
Grindelia squarrosa var. quasiperennis
Gymnocarpium dryopteris
Halenia deflexa ssp. deflexa

Halerpestes cymbalaria
Hedysarum alpinum
Hedysarum boreale
Helictochloa hookeri
Heracleum maximum
Hesperostipa comata ssp. comata
Hesperostipa curtiseta
Heuchera richardsonii
Hieracium aurantiacum
Hieracium canadense
Hieracium umbellatum ssp. umbellatum
Hierochloë hirta ssp. arctica
Hippuris vulgaris
Hordeum jubatum ssp. jubatum
Hypopitys monotropa
Impatiens noli-tangere
Juncus alpinoarticulatus ssp. americanus
Juncus balticus ssp. ater
Juncus bufonius
Juncus dudleyi
Juncus nodosus
Juncus stygius ssp. americanus
Juncus vaseyi
Juniperus communis
Koeleria macrantha
Lactuca serriola
Lappula occidentalis var. occidentalis
Lappula squarrosa
Larix laricina
Lathyrus ochroleucus
Lemna minor
Lepidium densiflorum
Leucanthemum vulgare
Leymus innovatus ssp. innovatus
Limosella aquatica
Linaria genistifolia ssp. dalmatica
Linaria vulgaris
Linnaea borealis
Linum lewisii ssp. lewisii
Listera borealis
Listera cordata
Lithospermum incisum
Lomatium foeniculaceum var. foeniculaceum
Lonicera dioica var. glaucescens
Lonicera involucrata
Lotus corniculatus
Lycopodium dendroideum
Madia glomerata
Maianthemum canadense
Maianthemum racemosum ssp. amplexicaule
Maianthemum stellatum
Maianthemum trifolium
Matricaria discoidea
Medicago lupulina
Medicago sativa
Medicago sativa ssp. falcata
Melampyrum lineare var. lineare
Melica smithii
Melilotus albus
Melilotus officinalis
Mentha arvensis
Menyanthes trifoliata
Mertensia paniculata var. paniculata
Mitella nuda
Moehringia lateriflora
Monarda fistulosa var. menthaefolia
Moneses uniflora
Monotropa uniflora
Muhlenbergia glomerata
Mulgedium pulchellum
Myriophyllum sibiricum
Nassella viridula
Neslia paniculata
Nuphar sp.
Oplopanax horridus
Opuntia fragilis
Orobanche fasciculata
Orthilia secunda
Orthilia secunda var. secunda
Orthocarpus luteus
Oryzopsis asperifolia
Osmorhiza berteroi
Osmorhiza sp.
Oxybasis glauca
Oxytropis campestris var. davisii
Oxytropis deflexa
Oxytropis sericea var. speciosa
Oxytropis splendens
Packera paupercula
Packera plattensis
Packera streptanthifolia
Parnassia palustris
Pascopyrum smithii
Pedicularis groenlandica

Pedicularis labradorica
Pedicularis parviflora
Penstemon gracilis
Penstemon procerus var. procerus
Persicaria amphibia
Persicaria amphibia var. emersa
Persicaria amphibia var. stipulacea
Persicaria hydropiper
Persicaria lapathifolia
Persicaria sp.
Petasites frigidus var. palmatus
Petasites frigidus var. sagittatus
Phalaris arundinacea var. arundinacea
Phleum pratense ssp. pratense
Picea glauca
Picea mariana
Pinus contorta var. latifolia
Piptatheropsis canadensis
Piptatheropsis pungens
Piptatherum pungens
Plantago major
Platanthera aquilonis
Platanthera huronensis
Platanthera obtusata ssp. obtusata
Platanthera orbiculata
Platanthera sp.
Poa alpina ssp. alpina
Poa annua
Poa compressa
Poa glauca
Poa glauca ssp. glauca
Poa nemoralis ssp. interior
Poa palustris
Poa pratensis
Poa pratensis ssp. pratensis
Poa secunda
Polygonum achoreum
Polygonum aviculare
Polygonum douglasii
Polygonum fowleri
Polygonum ramosissimum
Polypodium sibiricum
Populus balsamifera
Populus tremuloides
Potamogeton alpinus
Potamogeton gramineus
Potamogeton pusillus ssp. tenuissimus
Potentilla anserina
Potentilla gracilis var. fastigiata
Potentilla hippiana
Potentilla norvegica
Potentilla pensylvanica
Potentilla pensylvanica var. pensylvanica
Potentilla pulcherrima
Prosartes trachycarpa
Prunus pensylvanica
Prunus virginiana ssp. melanocarpa
Prunus virginiana var. demissa
Pseudoroegneria spicata
Puccinellia distans
Puccinellia nuttalliana
Pulsatilla nuttalliana
Pyrola asarifolia
Pyrola chlorantha
Pyrola minor
Ranunculus acris
Ranunculus aquatilis var. aquatilis
Ranunculus aquatilis var. diffusus
Ranunculus cymbalaria
Ranunculus gmelinii
Ranunculus macounii
Ranunculus rhomboideus
Ranunculus sceleratus
Ranunculus sceleratus var. multifidus
Rhinanthus minor
Rhododendron groenlandicum
Ribes hudsonianum var. hudsonianum
Ribes lacustre
Ribes oxyacanthoides ssp. oxyacanthoides
Rorippa palustris
Rorippa palustris ssp. palustris
Rosa acicularis ssp. sayi
Rosa woodsii ssp. woodsii
Rubus arcticus ssp. acaulis
Rubus chamaemorus
Rubus idaeus ssp. strigosus
Rubus parviflorus var. parviflorus
Rubus pedatus
Rubus pubescens
Rumex britannica
Rumex crispus
Rumex fueginus
Rumex occidentalis
Rumex triangulivalvis

Salix arbusculoides
Salix bebbiana
Salix candida
Salix discolor
Salix drummondiana
Salix interior
Salix lasiandra var. lasiandra
Salix maccalliana
Salix myrtillifolia
Salix pedicellaris
Salix petiolaris
Salix planifolia
Salix prolixa
Salix pseudomonticola
Salix pseudomyrsinites
Salix pyrifolia
Salix scouleriana
Salix serissima
Salsola tragus
Sanicula marilandica
Saxifraga tricuspidata
Schedonorus arundinaceus
Schizachne purpurascens
Schoenoplectus tabernaemontani
Scirpus microcarpus
Scutellaria galericulata
Selaginella rupestris
Senecio eremophilus var. eremophilus
Senecio vulgaris
Shepherdia canadensis
Silene drummondii var. drummondii
Silene latifolia
Sisymbrium altissimum
Sisyrinchium montanum var. montanum
Sium suave
Solidago altissima ssp. gilvocanescens
Solidago bellidifolia
Solidago glutinosa
Solidago lepida var. lepida
Solidago lepida var. salebrosa
Solidago multiradiata
Solidago simplex var. simplex
Sonchus arvensis
Sonchus arvensis ssp. uliginosus
Sorbus scopulina var. scopulina
Sparganium emersum
Sparganium natans
Sparganium sp.
Sphenopholis intermedia
Spiraea betulifolia ssp. lucida
Spiraea lucida
Spiranthes romanzoffiana
Sporobolus cryptandrus
Stachys palustris ssp. pilosa
Stellaria borealis
Stellaria borealis ssp. borealis
Stellaria longifolia
Stellaria longipes var. longipes
Stellaria media
Stuckenia pectinata
Symphoricarpos albus
Symphoricarpos occidentalis
Symphyotrichum boreale
Symphyotrichum ciliolatum
Symphyotrichum ericoides var. pansum
Symphyotrichum laeve var. geyeri
Symphyotrichum lanceolatum var. hesperium
Symphyotrichum puniceum var. puniceum
Tanacetum vulgare
Taraxacum officinale
Thalictrum venulosum
Thinopyrum intermedium
Thlaspi arvense
Tofieldia pusilla
Tragopogon dubius
Triantha glutinosa
Trifolium hybridum
Trifolium pratense
Trifolium repens
Triglochin maritima
Triglochin palustris
Tripleurospermum inodorum
Triticum aestivum
Turritis glabra
Typha latifolia
Urtica dioica ssp. gracilis
Utricularia intermedia
Vaccinium caespitosum
Vaccinium membranaceum
Vaccinium myrtilloides
Vaccinium oxycoccos
Vaccinium vitis-idaea ssp. minus
Valeriana dioica ssp. sylvatica
Verbascum thapsus

Veronica americana
Veronica beccabunga ssp. americana
Veronica peregrina var. xalapensis
Veronica scutellata
Viburnum edule
Vicia americana
Viola adunca var. adunca
Viola canadensis var. rugulosa
Woodsia scopulina
Zizia aptera

Bryophytes

Abietinella abietina
Antitrichia curtipendula
Aulacomnium palustre
Barbula convoluta var. convoluta
Brachythecium salebrosum
Brachythecium sp.
Bryum argenteum
Ceratodon purpureus
Climacium dendroides
Dicranum polysetum
Dicranum undulatum
Didymodon fallax
Didymodon ferrugineus
Distichium capillaceum
Ditrichum flexicaule
Drepanocladus aduncus
Encalypta rhaptocarpa
Funaria hygrometrica
Hamatocaulis vernicosus
Hedwigia ciliata
Hylocomium splendens
Hymenostylium recurvirostre var. recurvirostre
Leptobryum pyriforme
Marchantia polymorpha
Marchantia quadrata
Mnium thomsonii
Orthotrichum anomalum
Orthotrichum obtusifolium
Orthotrichum speciosum
Philonotis fontana var. fontana
Plagiomnium cuspidatum
Plagiomnium ellipticum
Plagiomnium sp.
Pleurozium schreberi
Pohlia nutans
Polytrichum commune
Polytrichum juniperinum
Ptilium crista-castrensis
Pylaisiella polyantha
Sanionia uncinata
Sphagnum capillifolium
Sphagnum magellanicum
Sphagnum sp.
Syntrichia norvegica
Syntrichia ruralis
Tomentypnum nitens
Tortula mucronifolia

Lichens

Bryoria capillaris
Bryoria fuscescens
Bryoria lanestris
Bryoria sp.
Buellia elegans
Caloplaca cerina
Caloplaca holocarpa
Cetraria ericetorum
Cladina rangiferina
Cladina sp.
Cladonia carneola
Cladonia pocillum
Cladonia sp.
Collema furfuraceum
Diploschistes muscorum
Enchylium tenax
Endocarpon pusillum
Evernia mesomorpha
Flavocetraria cucullata
Hypogymnia occidentalis
Hypogymnia physodes
Icmadophila ericetorum
Lathagrium undulatum var. granulosum
Lecanora impudens
Leptogium saturninum
Leptogium teretiusculum
Lobaria pulmonaria
Melanelixia subaurifera
Melanohalea exasperatula
Melanohalea septentrionalis
Melanohalea subolivacea
Nephroma resupinatum
Parmelia fraudans
Parmelia sulcata
Parmeliopsis ambigua

Parmeliopsis hyperopta
Peltigera aphthosa
Peltigera britannica
Peltigera didactyla
Peltigera elisabethae
Peltigera extenuata
Peltigera lepidophora
Peltigera leucophlebia
Peltigera malacea
Peltigera neckeri
Peltigera sp.
Phaeophyscia orbicularis
Phaeophyscia sciastra
Phaeophyscia sp.
Physcia adscendens
Physcia aipolia
Physcia alnophila
Physcia biziana
Physcia caesia
Physcia phaea
Physcia stellaris
Physcia tenella
Physconia muscigena
Physconia perisidiosa
Platismatia glauca
Ramalina dilacerata
Ramalina obtusata
Ramalina sinensis
Rinodina sp.
Stereocaulon tomentosum
Tuckermannopsis americana
Tuckermannopsis sp.
Umbilicaria americana
Usnea cavernosa
Usnea filipendula
Usnea lapponica
Usnea scabrata
Usnea sp.
Usnea substerilis
Vulpicida pinastri
Xanthomendoza fallax
Xanthoparmelia wyomingica
Xanthoria candelaria

7.3. Appendix 3: Species Accounts for Rare Plant Taxa Found During Preconstruction Surveys

7.3.1. Atriplex gardneri var. gardneri (Gardner's sagebrush)

Gardner's sagebrush (Figure 4), a small perennial sub-shrub with a woody base, is a member of the Chenopodiaceae (goosefoot family). Variety *gardneri* is found on fine-textured saline soils and dry grassy slopes in the Great Plains and Intermountain regions of central North America (Douglas et al. 1998; Welsh 2003). In B.C., Gardner's sagebrush is known only from the Peace River region (BCCDC 2021). The taxon can be found as far east in Canada as southern Manitoba, and as far south as Utah and Colorado in the United States (Welsh 2003; NatureServe 2021).

Gardner's sagebrush has a rank of S2 (Imperilled) in B.C. and is on the province's Red list (BCCDC 2021). The taxon has a global classification of G5TNR (*Atriplex gardneri* as a species is ranked globally Secure, but variety *gardneri* has not been given a global rank). Several other sub-national jurisdictions provide a rank for Gardner's sagebrush: Saskatchewan and Montana S5 (Secure), Alberta S4 (Apparently Secure), and Utah and Nebraska S1 (Critically Imperilled) (NatureServe 2021).

Figure 4: *Atriplex gardneri* var. *gardneri* (Gardner's sagebrush)

No new occurrences of Gardner's sagebrush were reported in the Site C Regional Assessment Area (RAA) in 2021.

There are a total of four known occurrences (in five patches) of Gardner's sagebrush in the RAA. Three of these occurrences (four patches) are situated north of the Peace River near the Alberta border, and, excluding the patch located in 2020, are older records without information on the number of individuals or areal coverage. The patch found in 2020 contained an estimated 50 male and female plants over an approximate area of 50 square metres. The fourth occurrence of Gardner's sagebrush, discovered in 2018 during Site C survey work, is some 60 kilometres to the west near Wilder Creek. Here, an estimated 150 male plants were found scattered over an area of 618 square metres; no female plants were observed at this site.

All four of the Gardner's sagebrush occurrences are situated on open, dry, south-facing grassland slopes. The dominant associated species include native grasses such as various wildryes (*Elymus* spp.), junegrass (*Koeleria macrantha*), and green needlegrass (*Nassella viridula*), and native forbs such as prairie sagewort (*Artemisia frigida*) and asters (*Symphyotrichum* spp.).

7.3.2. Carex sprengelii (Sprengel's sedge)

Sprengel's sedge (Figure 5) is a perennial herb belonging to the Cyperaceae (sedge family); plants have tall stems with fibrous bases and bear achenes in drooping heads. The species forms loose clumps in a variety of dry to wet habitats, including openings, slopes, and alluvial woodlands, often on calcareous substrates (Douglas et al. 1998; Ball & Reznicek 2002). Sprengel's sedge was only known from three locations in B.C. prior to the Site C rare plant survey work: two near Williams Lake, and one in the Peace River region (BCCDC 2021). The taxon ranges across North America as far east as New Brunswick, and as far south as Colorado, Missouri, and New Jersey. It is also reported from Alaska (Ball & Reznicek 2002; NatureServe 2021).

Figure 5: *Carex sprengelii* (Sprengel's sedge)

Sprengel's sedge has a rank of S3 (Vulnerable) in B.C., and is on the provincial Blue list (BCCDC 2021). Globally, the taxon is classed G5 (Secure). Across much of North America the taxon is classed as Secure (S5) or Apparently Secure (S4), but is considered rare on the western, southern, and eastern edges of its range: S3 (Vulnerable) in Québec, Pennsylvania, Illinois, Montana and Wyoming; S2 (Imperilled) in New Brunswick, Maine, Ohio, Missouri, and Colorado; S1 (Critically Imperilled) in Alaska, and SH (Possibly Extirpated) in Delaware (NatureServe 2021).

One new patch of Sprengel's sedge, consisting of one large plant in flower, was found in the study area in 2021, on the east edge of Dry Creek canyon north of Highway 29. The discovery extends a previously-known occurrence slightly, so that now five fruiting plants have been documented in four patches at this site, in an overall area of 95 square metres. The surveyors also noted that the southernmost plant at this occurrence had been partly covered by a pile of aspen logs, but was still in bloom. The habitat at this site consists of shrubby aspen woodland that has been recently cleared, and it is unknown whether further ground-disturbing work will eventually extirpate the occurrence; if the Sprengel's sedge plants are not disturbed further, they may survive if the surrounding vegetation is allowed to regrow.

In total, there are six known occurrences (in 11 patches) of Sprengel's sedge in the RAA. Four of these occurrences (eight patches)—found during survey work for the Site C project—are situated between Dry Creek and Wilder Creek, on flat to south-facing slopes north of the Peace River. An estimated 38 plants have been observed growing in a total approximate area of 17 square metres, in various shrub and woodland habitats. All of these sites are moist to mesic, and the Sprengel's sedge plants are generally found in relatively shaded microhabitats. Associated species are similar, including prairie saskatoon (*Amelanchier alnifolia*), prickly rose (*Rosa acicularis*), chokecherry (*Prunus virginiana*), aspen (*Populus tremuloides*), and native and weedy herbs such as smooth brome (*Bromus inermis*), northern bedstraw (*Galium boreale*), and American vetch (*Vicia americana*).

The remaining two sites of Sprengel's sedge in the RAA are derived from BCCDC records that lack certain population data. An occurrence of 20 plants in two patches was discovered between a hay field and a shrubby south-facing escarpment above the Pine River in 2016; areal extent, associated species, and other details of this occurrence were not documented. Additionally, a sixth occurrence of Sprengel's sedge, first observed in 2010, is reported from over 80 kilometres southwest, in moist balsam poplar (*Populus balsamifera*) woods north of the Moberly River. No clear information is available on the number of individuals or areal coverage (BCCDC 2021).

7.3.3. Carex torreyi (Torrey's sedge)

Torrey's sedge (Figure 6) is a soft-hairy perennial in the Cyperaceae (sedge family) found growing in montane meadows, shrublands, and moist woods (Douglas et al. 1998; Ball & Reznicek 2002). In B.C. the species is found only in the Peace River region (BCCDC 2021). Globally, Torrey's sedge is distributed east across Canada to Ontario, and south in the U.S. as far as Colorado and Wisconsin (NatureServe 2021).

Figure 6: *Carex torreyi* (Torrey's sedge)

Torrey's sedge is ranked S3? (Vulnerable?) in B.C. and is on the province's Blue list (BCCDC 2021). The species is ranked G4G5 (Apparently Secure or Secure) globally. Sub-national ranks vary—Torrey's sedge is classed as S4 (Apparently Secure) in Alberta and Saskatchewan, S3 (Vulnerable) in Manitoba and Montana, S2 (Imperilled) in Ontario and Wyoming, and S1 (Critically Imperilled) in Colorado and Wisconsin (NatureServe 2021).

No new sites of Torrey's sedge were documented in the study area in 2021.

There are a total of 11 occurrences (in 18 patches) of Torrey's sedge reported in the RAA. An estimated 550 plants have been observed growing in a total area of approximately 425 square metres. Ten of the occurrences are situated north of the Peace River; the 11th occurrence (not reconfirmed since the 1960 report) is located more than 45 kilometres south, near Dawson Creek, B.C. All of the occurrences were found on mesic to xeric south-facing slopes in open shrub grassland complexes. Associated species are similar at the sites and include native shrubs such as prickly rose, prairie saskatoon, and snowberry

(*Symphoricarpos* spp.); native and non-native graminoids such as smooth brome, bluegrasses (*Poa* spp.), and sedges (*Carex* spp.); and a diverse mix of native and weedy forbs.

7.3.4. Carex xerantica (dry-land sedge)

Dry-land sedge (Figure 7), a perennial herb with silvery-gold heads of the Cyperaceae (sedge family), is found in xeric steppe and montane habitats such as dry grasslands and hillsides, open forests, and rock outcrops (Douglas et al. 1998; Ball & Reznicek 2002). In B.C., dry-land sedge has been collected in the Peace River area as well as scattered locations in the central interior and central Rocky Mountains (BCCDC 2021; Klinkenberg 2021). There is some disagreement on the taxon's global range. Douglas et al. (1998) note that dry-land sedge extends east from B.C. to Manitoba, and south to Minnesota and Nebraska; Ball & Reznicek (2002) show the species occurring as far east as Ontario and also in Wyoming; and Natureserve (2021) reports the sedge from as far north as Yukon and Alaska, and as far south as Arizona and New Mexico.

Figure 7: *Carex xerantica* (dry-land sedge)

Dry-land sedge is classed as S3 (Vulnerable) in B.C., and is on the provincial Blue list (BCCDC 2021). Although globally the taxon is considered Secure (G5), most jurisdictions that provide a rank for the species indicate some degree of rarity: S1 (Critically Imperilled) in Alaska, Yukon and Wyoming; S2 (Imperilled) in Manitoba, Ontario, Nebraska, Colorado, and New Mexico; and S3 (Vulnerable) in Minnesota. Alberta and Saskatchewan rank the species S4 (Apparently Secure) (NatureServe 2021).

Eight new patches of dry-land sedge were recorded in the study area in 2021: four newly-found occurrences in 6 patches, and two occurrence extensions.

The first new occurrence (of two patches) was found on a gentle slope above Bentley Road, west of Cache Creek. A total of thirteen plants were observed over an area of two square metres in disturbed grassland and open woodland. A second new occurrence was discovered on a steep shrub-grassland slope above Highway 29 just east of Bear Flat: 21 plants were found growing in an approximate area of twelve square metres. The third new occurrence was documented 1.3 km to the northeast, on a gentle shrub-grassland hillside above Highway 29 at the Cache Hill truck pullout.

A fourth new occurrence of dry-land sedge was observed on south-facing shrubby grassland slopes along Ice Bridge Road, north of the Pine River. Here, eleven plants in two patches were found above the road, in an approximate total area of 6 square metres.

The remaining two new patches of dry-land sedge were determined to be extensions of previously-reported occurrences. The first of these was a patch of 2 plants found east of Bear Flat on a dry grassland hillside approximately 130 metres north northwest of an occurrence first documented in 2015.

The final new dry-land sedge patch consisted of the substantial expansion of a previously-known occurrence, on a grassland bench west of the confluence of the Peace and Pine Rivers (Area E). This site was first observed in 2012, when only a portion of the very large bench was surveyed; during the 2021 revisits, the estimated number of dry-land sedge plants was increased to 6,250 and the areal coverage was nearly doubled, to over 20 hectares (however, the full extent of the grassland bench remains unsurveyed). The diverse native plant community at this site is in very good condition and few non-native species were observed.

In total, there are 20 known occurrences of dry-land sedge (in 42 patches) in the RAA. An estimated 13,500 plants have been observed growing in an approximate total area of 29.8 hectares. Seventeen of the occurrences were found on south-facing slopes north of the Peace River from Bear Flat east to the Alberta border, and two occurrences were documented from a large bench and adjacent south-facing slopes on the south side of the Peace River at the Pine River. Dry-land sedge has also been collected on a slope above the Pouce Coupe River, over 25 kilometres to the south.

The dry-land sedge sites are invariably located in xeric grassland habitat, generally in the vicinity of low shrub thickets. The dominant associated species include native shrubs such as prairie saskatoon, prickly rose, and snowberry; native dryland sedges such as hay sedge (*Carex siccata*); and native grasses such as junegrass, short-awned porcupinegrass (*Hesperostipa curtiseta*), spike-oat (*Helictochloa hookeri*), wildryes, and needlegrasses (*Achnatherum* spp. and *Nassella viridula*). A diverse mix of native and non-native forbs are also present at dry-land sedge occurrences.

7.3.5. Lomatium foeniculaceum var. foeniculaceum (fennel-leaved desert-parsley)

Fennel-leaved desert-parsley (Figure 8), a low perennial herb with a long taproot, is a member of the Apiaceae (carrot family) (Douglas et al. 1998). The taxon is found on dry, open slopes across much of central North America (Hitchcock et al. 1961; NatureServe 2021). Fennel-leaved desert parsley var. *foeniculaceum* is restricted to the Peace River region in British Columbia (BCCDC 2021), but its global range extends east as far as Manitoba and Missouri, and south into Texas (NatureServe 2021).

In B.C., fennel-leaved desert-parsley var. *foeniculaceum* carries a rank of S3 (Vulnerable) and is on the province's Blue list (BCCDC 2021). The taxon's global classification is G5T5 (Secure for both the species and the variety), however of the six other jurisdictions that provide a rank for this variety, four indicate some degree of rarity: S2 (Imperilled) in Colorado and Missouri, and S3 (Vulnerable) in Alberta and Manitoba. Wyoming and Saskatchewan class fennel-leaved desert-parsley var. *foeniculaceum* as S4 (Apparently Secure) and S5 (Secure), respectively (NatureServe 2021).

Figure 8: *Lomatium foeniculaceum var. foeniculaceum (fennel-leaved desert-parsley)*

One new occurrence of fennel-leaved desert-parsley was discovered in the study area in 2021. An estimated 50 to 250 individuals were found growing over an area of approximately 50 square metres on a steep, open-soiled grassland hillcrest above Highway 29 near Bear Flat. One plant was in fruit but the remainder either had not fruited or were past the fruiting stage. Associated species included low shrubs such as prairie saskatoon and prickly rose, and herbs such as thick-spike wildrye (*Elymus lanceolatus* ssp. *lanceolatus*), junegrass, and prairie sagewort.

A total of six occurrences of fennel-leaved desert-parsley are known from the RAA. In addition to the new occurrence described above, there are two dating from 1981, near the Peace River downstream of the Beatton River, and three from Site C survey work in 2017, of which two are above the Beatton River and one is near Cache Creek. An estimated 950 plants have been documented in an approximate total area of 8,600 square metres. All fennel-leaved desert-parsley sites occur on steep, dry, south-facing grassland slopes in plant associations similar to the one described for the 2021 site.

7.3.6. Oxytropis campestris var. davisii (Davis' locoweed)

Davis' locoweed (Figure 9) is a small perennial in the Fabaceae (pea family) that grows on stream gravels and in mesic to dry meadows and forest openings in the montane zone (Elisens & Packer 1980; Welsh 1991; Douglas et al. 1998). Variety *davisii* is found in northeast B.C. where it can be locally abundant, and is also reported from Alberta (Welsh 2001; BCCDC 2021; NatureServe 2021). Davis' locoweed is classed S3? (Vulnerable?) by the BCCDC, and is on the provincial Blue list (BCCDC 2021). Globally, the variety is also ranked as Vulnerable (T3), due to its limited range. Alberta lists Davis' locoweed as S2? (Imperilled?) (NatureServe 2021).

Figure 9: *Oxytropis campestris* var. *davisii* (Davis' locoweed)

Two new sites of Davis' locoweed were documented in the study area in 2021; both were determined to be extensions of previously-reported occurrences. An estimated 100 plants were found over an area of 45 square metres in a cobble-soiled opening in mature forest on an island in the Peace River near Taylor, B.C. Associated species included white spruce (*Picea glauca*), balsam poplar, common juniper (*Juniperus communis*), kinnikinnick (*Arctostaphylos uva-ursi*), and weedy herbs such as smooth brome and chick-pea milk-vetch (*Astragalus cicer*). The main patch of this occurrence was found in 2020 approximately 635 metres to the west in open areas of the same island.

A second new patch of an estimated 50 plants in bloom was found in an approximate area of 1,795 square metres on an island in the Peace River eight kilometres downstream from Taylor, B.C. The location of this new patch merged two previously-documented occurrences into one large occurrence of four separate patches. The Davis' locoweed plants were growing in a sparsely vegetated cobble-soiled opening in early seral balsam poplar.

There are a total of 27 occurrences of Davis' locoweed (in 40 patches) reported in the RAA. An estimated 70,000 plants have been recorded in an approximate total area of 13 hectares. Nineteen of the occurrences have been documented from along the Peace River, and many of these sites contain hundreds or thousands of individuals and cover relatively large areas of ground. Four occurrences have been observed along the Halfway River, and three on the Pine River near its confluence with the Peace River. There is also one historical record of Davis' locoweed on the Pine River at Highway 97, over 50 kilometres to the south (not reconfirmed since the 1954 report).

Except for the historical record on the Pine River, all Davis' locoweed occurrences in the RAA have been mapped within 400 metres of current river shorelines, on non-active cobble bars, floodplains or river benches. Habitat at the majority of sites is similar, consisting of open, often bare cobble-silt substrates and young to medium-aged balsam poplar. Other associated species include a relatively sparse cover of native and weedy herbs such as chick-pea milk-vetch, yellow mountain-avens (*Dryas drummondii*) and sweet-clover (*Melilotus* spp.) as well as quackgrass, slender wheatgrass, Canada wildrye (*Elymus* spp.) and other species of locoweeds. The notable exceptions to this early seral habitat are one occurrence of Davis' locoweed on a forested bedrock shoreline, and three patches in mature floodplain forest.

7.3.7. Penstemon gracilis (slender penstemon)

Slender penstemon (Figure 10) is a perennial herb of the Plantaginaceae (plantain family)—formerly of the Scrophulariaceae (figwort family)—that inhabits mesic to dry plains and grasslands (Hitchcock et al. 1959; Douglas et al. 1998; Freeman & Rabeler 2016). The species is commonly found throughout much of central North America, but in B.C. is restricted to the Peace River area (Hitchcock et al. 1959; BCCDC 2021; NatureServe 2021).

Figure 10: *Penstemon gracilis* (slender penstemon)

Slender penstemon is ranked S3 (Vulnerable) in B.C., and is on the province's Blue list (BCCDC 2021). The species' global status is G5 (Secure) (NatureServe 2021). Of the remaining 17 jurisdictions where it is known to occur, only four rank slender penstemon with any degree of rarity—Manitoba and Wyoming as S3 (Vulnerable), and Iowa and Michigan as S1 (Critically Imperilled) (NatureServe 2021).

Four new sites of slender penstemon were discovered in the study area in 2021. A small occurrence was recorded on a narrow southwest-facing ridge west of Cache Creek, in a grassland and woodland mosaic. Here, 10 slender penstemon plants in early flower were found growing in an area of 5.6 square metres. This occurrence is within the right-of-way of a newly-constructed segment of Highway 29 (not yet in use). A second small occurrence was documented on a steep, south-facing hillcrest above Highway 29 east of Bear Flat. Nine senescent slender penstemon plants were observed in an area of approximately 2 square metres.

The remaining two new sites of slender penstemon were determined to be extensions of previously-reported occurrences. A patch of 18 flowering and vegetative plants over approximately 29 square metres was located on a steep grassland opening west of Watson Slough; this site is in the right-of-way of a newly-constructed segment of Highway 29 (not yet in use). Finally, a patch of four flowering plants in two clusters was found on a steep shrub-grassland hillside east of Farrell Creek. This site is within the right-of-way of a proposed new segment of Highway 29.

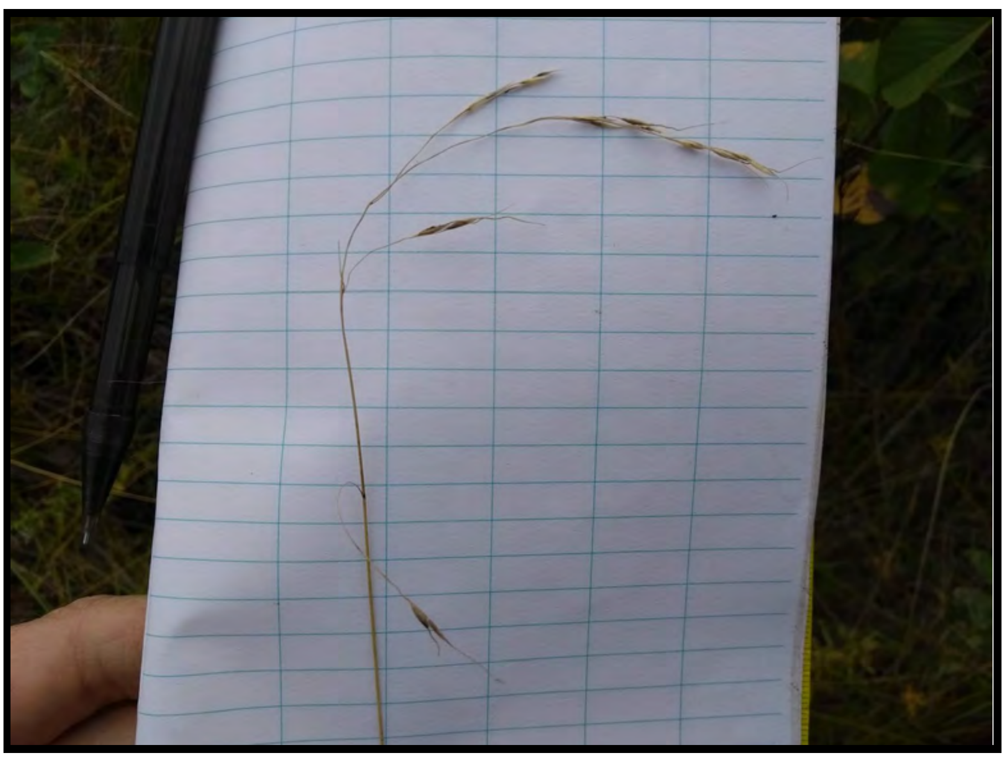
In total, there are 27 occurrences of slender penstemon (in 59 patches) reported in the RAA. All of the occurrences are situated north of the Peace River, from the Farrell Creek area east to the Alberta border.

An estimated 3,700 plants have been documented in an approximate total area of 4 hectares. All of the occurrences were found on south-facing slopes and invariably located in xeric grassland habitat, often in the vicinity of low shrub thickets. Dominant associated species include the native shrubs prairie saskatoon, kinnikinnick, and common snowberry (*Symphoricarpos albus*), native graminoids such as junegrass, wildryes, and dryland sedges, and a diverse mix of native and non-native forbs.

7.3.8. Piptatheropsis canadensis (Canada ricegrass)

Canada ricegrass (Figure 11) is a delicate perennial bunchgrass of the Poaceae (grass family). The species grows in grasslands and open woods and on hillsides and dry slopes; additionally, in eastern North American sites, the taxon is specifically reported from dry, sparsely-vegetated soils which are usually sandy or rocky, as well as moist peaty barrens. Canada ricegrass ranges from Alberta east across Canada to Newfoundland, and south into the U.S. Northeast and Great Lakes regions (Gray & Fernald 1950; Moss & Packer 1983; Lapin 2004; Barkworth 2007; BCCDC 2021). Prior to the 2018 Site C rare plant survey work, no verified extant occurrences of Canada ricegrass were known from B.C. (BCCDC 2021). Of note: the genus *Piptatheropsis* was only recently described (Romaschenko et al. 2011), therefore Canada ricegrass is still referred to by the name *Piptatherum canadense* in some important literature (Lapin 2004; Barkworth 2007; NatureServe 2021).

Figure 11: *Piptatheropsis canadensis* (Canada ricegrass)



Canada ricegrass is ranked S1 (Critically Imperilled) in B.C., and is on the province's Red list (BCCDC 2021). The taxon's global classification is G4G5 (Apparently Secure or Secure) (NatureServe 2021). However, although Canada ricegrass is widely distributed across North America, the species has few reported occurrences and most of these are small (frequently less than 100 individuals at a site) (Lapin 2004). Accordingly, Canada ricegrass is generally classed as rare sub-nationally: SH (Possibly Extirpated) in Prince Edward Island; S1 (Critically Imperilled) in Manitoba, Wisconsin, West Virginia, and New Hampshire; S2 (Imperilled) in Alberta, New Brunswick, Nova Scotia, Newfoundland, Minnesota, Michigan, New York, and Maine; S3 (Vulnerable) in Saskatchewan; and S4 (Apparently Secure) in Ontario and Québec (NatureServe 2021).

Five new sites of Canada ricegrass were documented in the study area in 2021: one newly-found occurrence with four patches, and one occurrence extension. The new occurrence was discovered on a dry shrub-grassland hillcrest above a steep draw west of Watson Slough. Here, an estimated 45 fruiting plants were observed in four patches, with a total areal coverage of 21.8 square metres. It was noted that none of the plants appeared to have set any viable seed, perhaps as a result of an extreme heat event earlier in the growing season (Preprost 2021). The fifth new Canada ricegrass patch reported in 2021 consisted of an expansion to an occurrence first reported in 2020, on a native grassland bench near the confluence of the Peace and Pine Rivers. A few new plants were found and the total area of the occurrence was expanded by approximately 115 square metres. The fruiting panicles observed at this occurrence also did not appear to contain any viable seed.

There are a total of five known occurrences of Canada ricegrass (in 17 patches) in the RAA, all found during Site C survey work. The occurrences are located from the Cache Creek area east to the Pine and Beatton Rivers. An estimated total of 285 plants have been documented in an approximate total area of 745 square metres. All of the Canada ricegrass sites occur on level to gently sloped, open, good quality native shrub-grassland or remnants of such, usually in close proximity to aspen woodlands. Soils at the sites can be moist to dry. The Canada ricegrass plants grow scattered in dense vegetation consisting of a diverse assemblage of low shrubs and herbs. Dominant associated species are native plants and include the shrubs prairie saskatoon, prickly rose, and chokecherry; graminoids such as spreading needlegrass (*Achnatherum richardsonii*), slender wheatgrass (*Elymus trachycaulus* ssp. *subsecundus*), false melic (*Schizachne purpurascens*), and hay sedge, and forbs such as northern bedstraw and anemones (*Anemone* spp.). A few non-native species are also present at the sites, particularly Kentucky bluegrass (*Poa pratensis*).

7.3.9. Ranunculus rhomboideus (prairie buttercup)

Prairie buttercup (Figure 12) is a soft-hairy perennial of the Ranunculaceae (buttercup family). The species grows in grasslands, prairies, open woods and thickets across north-central North America (Whittemore & Parfitt 1997; Douglas et al. 1998). In B.C., prairie buttercup is only known from the Peace River region (BCCDC 2021). The taxon's range extends north to Northwest Territories and southeast through the Canadian prairie provinces and the northern U.S. Great Plains into Nebraska, Iowa, Illinois, Michigan, and southern Ontario (Whittemore & Parfitt 1997; NatureServe 2021).

Figure 12: Ranunculus rhomboideus (prairie buttercup)

Prairie buttercup has a ranking of S2S3 (Imperilled and Vulnerable) in B.C., and is on the province's Blue list (BCCDC 2021). Globally, the taxon is ranked G5 (Secure). Only sporadic sub-national ranks are provided for prairie buttercup: Alberta, Saskatchewan, Manitoba, and Ontario class the species as S4 (Apparently Secure); Iowa as S3 (Vulnerable); Illinois and Michigan as S2 (Imperilled); Nebraska as S1 (Critically Imperilled); and Québec as SX (Presumed Extirpated) (NatureServe 2021).

No new occurrences of prairie buttercup were documented in the study area in 2021.

In total, 11 occurrences of prairie buttercup (in sixteen patches) have been reported in the RAA. Eight of the occurrences (thirteen patches)—discovered during the Site C rare plant survey work—are situated north of the Peace River from the Cache Creek area east to the Pine River, and contain an estimated 220 plants in an approximate total area of 416 square metres. The remaining three occurrences are historical records not recently verified and with no information available on precise location, number of individuals or areal coverage. The habitat for prairie buttercup is somewhat variable: soils can range from moist to dry, shrub cover can be dense to sparse, and occurrence microsite can be flat to sloped. Dominant associated species include a wide variety of native forbs such as northern bedstraw and American vetch as well as weedy grasses such as smooth brome and Kentucky bluegrass. Native shrub species are also present, the most commonly reported being rose (*Rosa* spp.) and prairie saskatoon.

7.3.10. Salix petiolaris (meadow willow)

Meadow willow (Fig 13), a shrub or small tree of the Salicaceae (willow family), has long, slender leaves and is found in moist to wet habitats across north-central North America (Douglas et al. 1998; Argus 2010). In B.C., the species has only been collected in the northeast part of the province (BCCDC 2021; Klinkenberg 2021). Meadow willow extends north to Northwest Territories, east across Canada to Nova Scotia, and south in the United States as far as New Jersey, Missouri, and Colorado (NatureServe 2021).

Figure 13: *Salix petiolaris* (meadow willow)

Meadow willow is ranked S3 (Vulnerable) in B.C. and is on the Blue list for the province (BCCDC 2021); the species is classed as G5 (Secure) globally. Across much of North America the taxon is classed as Secure (S5) or Apparently Secure (S4), but is considered rare on the southern edge of its range: S1 (Critically Imperilled) in Prince Edward Island and Missouri; S2 (Imperilled) in Ohio and Colorado, and S3 (Vulnerable) in Nova Scotia and Illinois (NatureServe 2021).

One new occurrence of meadow willow was discovered in the study area in 2021: two female plants were found growing approximately 10 metres apart on the southern edge of a large wetland on the plateau between the Peace and Moberly Rivers. The plants were surrounded by deep standing water and were growing in partial shade in a thicket of diverse tree and shrub species along a weedy road edge. Associated species included *Salix discolor* (pussy willow), *Salix lasiandra* var. *lasiandra* (Pacific willow), *Salix bebbiana* (Bebb's willow), balsam poplar, western snowberry, and prickly rose.

Including the new site described above, there are a total of six reported occurrences of meadow willow in the RAA, five of which have not been recently field verified. Four records date from 1967 to 1976 and provide little or no information besides a collection point: two are from east of Fort St. John, B.C., and two are located to the south near Dawson Creek, B.C. The fifth occurrence was reported in 2008 from along a forest road south of Hudson's Hope, B.C., but subsequent attempts to relocate this site have not been successful and it is presumed that either the location data or the identification are incorrect. The record states that 250–1000 individuals were observed over an area of 1,500 square metres along the edge of a logging road in mixed upland forest.

7.3.11. Selaginella rupestris (rock selaginella)

Rock selaginella (Figure 14) is a small, mat-forming evergreen perennial in the Selaginellaceae (spike-moss family). The taxon is found in a variety of open, dry, rocky or gravelly habitats in eastern and central North America (Valdespino 1993; Douglas et al. 1998). In B.C., rock selaginella is known only from the Peace River region (BCCDC 2021; Klinkenberg 2021). The taxon ranges east across Canada to Nova Scotia and southeast in the U.S. to southern Georgia (Valdespino 1993; NatureServe 2021).

Figure 14: *Selaginella rupestris* (rock selaginella)

Rock selaginella is ranked S2 (Imperilled) in B.C., and is on the Red list for the province (BCCDC 2021). The taxon is classed as G5 (Secure) globally, but sub-national rankings vary. Of the jurisdictions providing a rank, rock selaginella is listed as S5 (Secure) in Ontario, Québec, Arkansas, Georgia, and Virginia; as S4 (Apparently Secure) in Saskatchewan, Manitoba, and New York; as S3 (Vulnerable) in Alberta, Illinois, North Carolina, West Virginia, Vermont, and Massachusetts; as S2 (Imperilled) in Iowa, Alabama, and New Jersey; as S1 (Critically Imperilled) in New Brunswick, Nova Scotia, Ohio, Indiana, North Dakota, and Wyoming; and SX (Presumed Extirpated) in Delaware (NatureServe 2021).

One new patch of rock selaginella was documented in the study area in 2021; this was determined to be an extension of a previously-reported occurrence. An estimated 250–1,000 plants over an approximate area of 925 square metres were observed about 50 metres west of another large patch first discovered in 2018. The site is located on a steep shrub-grassland hillside above Highway 29 east of Farrell Creek.

In total, there are ten known occurrences of rock selaginella (in 15 patches) in the RAA. Nine of the occurrences—discovered or resurveyed as part of the Site C rare plant work—are located north of the Peace River, from Williston Reservoir east to the Alberta border, and contain an estimated 4,630 individuals in an approximate total area of 8,600 square metres.

The tenth occurrence of rock selaginella in the RAA, reported for 2020 but not part of the Site C work, consists of a collection from over 45 kilometres south of the Peace River. A few clumps were found on a dry grassland hillcrest north of Highway 97, sixteen kilometres southwest of Chetwynd, B.C.; areal extent, associated species, and other details were not documented.

The rock selaginella sites are dry and usually rocky; most of the occurrences are in open shrub-grassland habitat on south-facing hillsides or hillcrests, and slopes are often quite steep. Dominant associated species include the shrubs prairie saskatoon, kinnikinnick, and common juniper (*Juniperus communis*); graminoids such as junegrass, thickspike wildrye (*Elymus lanceolatus* ssp. *lanceolatus*), and various dryland sedge species; and forbs such as prairie sagewort, northern bedstraw, and woolly yarrow (*Achillea borealis*). The exceptions are two occurrences found in open forest near the east end of Williston Reservoir, where the rock selaginella was growing with mosses on rock in shaded, dry microsites.

Appendix 7. Portage Mountain Bat Studies: 2020 and 2021 Annual Report

Site C Wildlife Monitoring – Portage Mountain Bat Studies: 2020 and 2021 Annual Report

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EXECUTIVE SUMMARY

BC Hydro's quarry on Portage Mountain, which has been operating since 2019, supplies blast rock and fill materials for the Site C Clean Energy Project. The quarry is close to rock crevice habitat that is highly suitable for bats and is used by federally designated at-risk bat species. The Portage Mountain quarry operates under spatial and temporal constraints intended to minimize impacts on bats and bat habitat. Starting in 2016, BC Hydro undertook bat monitoring as part of its bat mitigation and monitoring plan, with the objective of collecting data to identify and characterize impacts to bats and bat habitat due to quarry construction and assess the effectiveness of mitigation. Mitigation included a 300-m spatial setback between all quarry activities and the approximate locations of crevices identified as potential hibernacula, and temporal constraints on blasting. Annual reports of monitoring results have been produced since 2016. This report contains the results of 2020-2021 monitoring, as well as statistical analyses of data collected since 2017 to assess temporal trends in bat activity and potential impacts of blasting on bat activity.

Bats have been monitored year-round between 2017 and 2021 (spring and fall monitoring occurred in 2016) using two types of data: emergence count data and data from acoustic detectors. Emergence counts were used to monitor two suspected maternity roosts. Detectors were used to provide continuous, long-term monitoring of bat activity at Portage Mountain. Noise and vibration produced by quarry activities (including blasting) were periodically monitored to assess compliance with thresholds recommended in *Best Management Practices (BMP) for Bats in British Columbia*.

The monitoring results indicate noise and vibration produced from the quarry appear to have remained below the provincial thresholds. Analysis of bat activity data from acoustic detectors and bat emergence counts is challenging due to the high variability inherent in bat activity data, which can make it difficult to confidently identify trends or causal relationships. In addition, few baseline data were collected before quarry development and operation began. While some trends and correlations were identified in this report, conclusions based on those results are presented with caution due to the nature of the data and missing data due to equipment malfunctions.

The numbers of bats counted at roost sites over the years show that bats continue to use roost sites in the cliffs adjacent to the quarry based on annual surveys, and a maternity roost discovered during baseline surveys continues to provide functional habitat. An average of 40.5 bats had been counted exiting maternity roost 9247G during early-period roost surveys in 2018. Average emergence counts in subsequent years did not reach the peak observed in early 2018 and were variable, but appear to have generally declined, particularly in 2020 and 2021. There are insufficient data to assess the statistical significance of the differences and it is unknown whether the changes in numbers are due to effects from the quarry or represent natural variation in roost use.

Based on the results of acoustic analysis, bat species composition did not change between years. The relationship between bat acoustic activity data and temperature, precipitation, and year were modelled for different bat life stages to test for declines in bat activity related to quarry use, while controlling for weather conditions. The results indicate bat activity varied between years.

Summer activity showed a statistically significant decline in 2018 relative to 2017; however, changes in activity were not significantly different from 2017 in 2019 to 2021. Fall activity showed statistically significant declines in 2018 and 2019 relative to 2017, and a statistically significant increase in 2021 relative to 2017. Bat activity showed a statistically significant negative relationship to blasting occurrence during the fall period. Swarming, based on a peak of bat activity in late summer or early fall, could not be detected in 2019 or 2020 but was detected in 2021. Data were insufficient to determine a swarming period in 2017 or 2018. Bat activity during the hibernation period showed a statistically significant decline in 2018, 2019 and 2021 relative to 2017, despite no blasting occurring during the hibernation period. Bat activity in summer showed a statistically significant positive relationship with blasting occurrence, but that result is suspected to be due to an unmeasured confounding variable. There were too few data to test for potential impacts on acoustic bat activity during the emergence period. Bats selecting tree roosts within the 300-m spatial setback distance from the quarry may be subject to higher noise levels compared to bats using the rock crevice roosts outside that buffer.

Recommendations are provided to continue data collection to increase the quality and quantity of monitoring data to support additional analysis of quarry impacts. BC Hydro has no further plans for production blasting at Portage Mountain Quarry and plans to conduct additional monitoring. Considering the statistically significant negative relationship between bat activity and blasting occurrence in fall, it is recommended that to be precautionary, the no-blasting period for future mining and quarry projects in proximity to high-suitability bat hibernating habitat should be extended to include the swarming period (i.e., starting September 1).

This work was performed in accordance with 579005 between Hemmera Envirochem Inc. (Hemmera), a wholly owned subsidiary of Ausenco Engineering Canada Inc., and BC Hydro (Client), dated 21 June 2016 (Contract). This report has been prepared by Hemmera, based on fieldwork conducted by Hemmera, for sole benefit and use by BC Hydro. In performing this work, Hemmera has relied in good faith on information provided by others and assumes that information provided is complete and accurate. This work was performed to current industry standard practice for similar environmental work, within the relevant jurisdiction. The findings presented herein should be considered within the context of the scope of work and the findings are considered valid only at the time the report was produced. The conclusions and recommendations contained in this report are based upon the applicable guidelines, regulations, and legislation existing at the time the report was produced. This Executive Summary is not intended to be a stand-alone document, but a summary of findings as described in the following Report. It is intended to be used in conjunction with the scope of services and limitations described therein.

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LIST OF ACRONYMS AND ABBREVIATIONS

Acronym / Abbreviation	Definition
AIC	Akaike's Information Criterion
BC	British Columbia
BMP	Best Management Practice(s)
CI	Confidence interval
K	Number of parameters
LL	Log-likelihood
NA	Not applicable
quarry	Portage Mountain Quarry
Project	Site C Clean Energy Project
study area	Portage Mountain Quarry and adjacent cliffs
SARA	*Species at Risk Act*

LIST OF SYMBOLS AND UNITS OF MEASURE

Symbol / Unit of Measure	Definition
%	Per cent
dB	decibel
dBA	A-weighted decibels
in	inch
kHz	kilohertz
kPa	kilopascal
km	kilometre
m	metre
mm	millimetre
n	number

1.0 INTRODUCTION

Portage Mountain, approximately 15 kilometres (km) west of Hudson's Hope in northwestern BC (**Figure 1**), is the site of a quarry developed to supply the construction of the Site C Clean Energy Project in the Peace River valley. The Portage Mountain Quarry provides riprap material used for constructing the Highway 29 realignment and protecting the shoreline along the Peace River near Hudson's Hope during the eventual filling of the reservoir.

Baseline studies for the Site C Clean Energy Project (Andrusiak 2014; Simpson et al. 2013) as well as subsequent surveys (Sarell and Alcock 2017) identified cliff faces at Portage Mountain as hibernation and roosting habitat for bats, including two at-risk bat species: little brown myotis (*Myotis lucifugus*) and northern myotis (*Myotis septentrionalis*) are listed as endangered on Schedule 1 of the *Species at Risk Act* (SARA). Disturbance of bats during winter may cause them to arouse from hibernation and repeated arousals in response to disturbance are considered detrimental to their survival (Boyles 2017; Sheffield et al. 1992; Thomas 1995).

The potential effects of development and operation of the Portage Mountain Quarry (**Figure 2.1**) on nearby bats were assessed in the Site C Environmental Impact Statement (BC Hydro 2013) and monitoring and mitigation for bats is required by the provincial Environmental Assessment Certificate, the Federal Decision Statement, and Schedule A of the Project's conditional water licences. BC Hydro has implemented mitigation (BC Hydro 2020) to minimize the potential for impacts on bats, including the following:

- spatial setback of quarry activities from roost sites;
- temporal restrictions on high-intensity noise or vibration (i.e., blasting) from 15 September to 15 May to avoid disturbing bats during winter hibernation.

The objective of monitoring bat activity at Portage Mountain is to collect data to 'help identify and characterize any impacts to bats and bat habitat due to the construction and operation of Portage Mountain Quarry', as described in the *Bat Mitigation and Monitoring Plan* (BC Hydro 2020), which allows the efficacy of mitigation and previous predictions of impacts to be tested. Bat activity monitoring at Portage Mountain used the following general approaches:

- monitoring of noise and vibration from construction activities, including blasting, to assess whether the disturbance is within best management practices (BMP) guidelines (BC Ministry of Environment 2016c) and evaluate whether there are significant relationships with bat activity patterns (**Section 4.2**).
- emergence counts (**Section 4.3.1** and **Appendix D**) at identified maternity roosts (9427G and 6287F; **Figure 2.1**).
- additional emergence counts at roosts not yet determined to be occupied by maternity colonies (**Section 4.3.1** and **Appendix D**).
- roost monitoring using remote logger devices (**Section 4.3.2**) to sample activity, temperature, and humidity at the identified maternity roosts.
- long-term, year-round passive acoustic monitoring (**Section 4.4**) using remote bat detectors at the north and south cliffs and near the quarry. Data from acoustic monitoring provide ongoing documentation of bat species presence and activity to assess seasonal and year to year changes in bat activity and potential effects of quarry operation on bat activity and species presence.

This report summarizes the results of bat monitoring at Portage Mountain from late summer 2017 to fall 2021 undertaken to meet the objectives of the Bat Mitigation and Monitoring Plan (BC Hydro 2020).

2.0 STUDY AREA

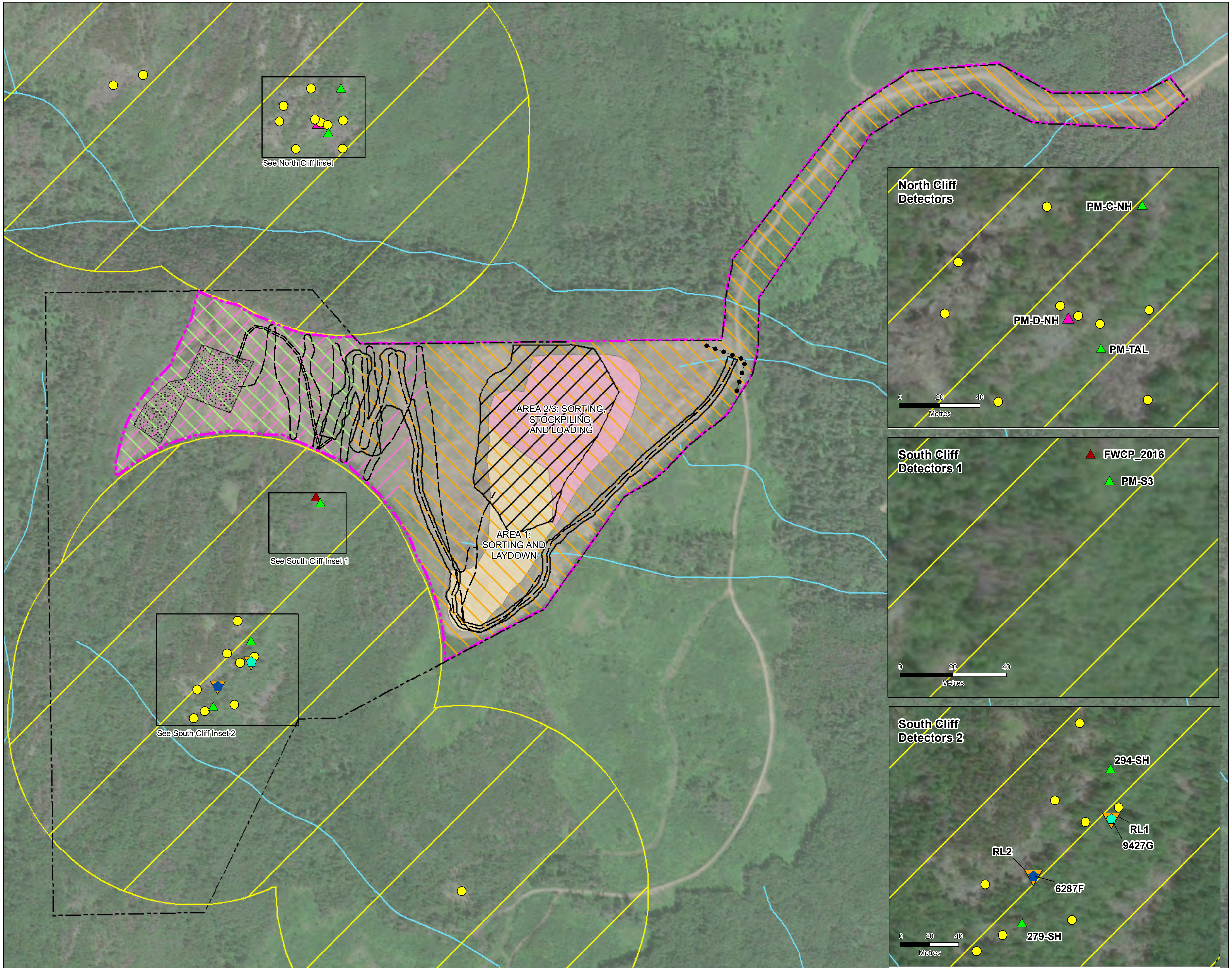
The study area has been described in Hemmera (2020) and is briefly summarized here. The bat monitoring study area (**Figure 2.1**) includes the quarry (BC Hydro 2020) and the adjacent cliffs to the north and south within approximately 750 metres (m) of the quarry. This study area has the following characteristics indicative of potential bat hibernacula (BC Ministry of Environment 2016a, 2016b; Nagorsen et al. 1993):

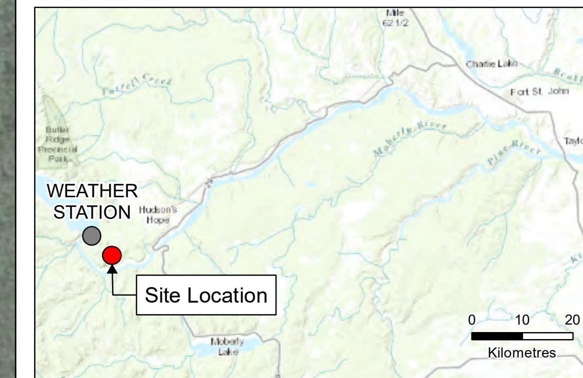
- large and exposed (i.e., sparsely vegetated) rock features that gain and maintain solar insolation and have numerous crevices; and
- deep crevices and caves (including mine adits) that provide cool and stable temperatures and high humidity for hibernating bats.

The Portage Mountain cliffs are located within boreal forest dominated by hybrid white spruce (*Picea engelmannii* x *glauca*) and trembling aspen (*Populus tremuloides*). The two main areas of cliff (north and south) are separated by an unnamed creek gully that drains into Dinosaur Reservoir. A stand of mature balsam poplar (*Populus balsamifera*) is present within the gully. Development of the Portage Mountain quarry, located on the south side of the creek gully, began in 2017 with clearing and access road construction. Production blasting and extraction of quarry rock began in the summer of 2019. Further details of quarry activities are provided in **Section 3.3**. The site is accessed by a forestry road (400 Road).

Site C Clean Energy Project
Wildlife Mitigation and Monitoring Services

Study Area and Bat Detector Locations for Portage Mountain Bat Monitoring





Legend

- Permanent Bat Detector
- Bat Detector (Historic)
- Short-Term Bat Detector
- Confirmed Maternity Roost
- Potential Hibernacula
- Potential Maternity Roost
- Roost Logger
- Weather Station
- Security Fencing
- In Quarry Access Road
- Quarry Haul Road
- Stockpile Road
- Site Boundary
- Potential Hibernacula - 300m Buffer
- Portage Mountain LOO
- Stripping/Overburden Stockpile Area
- Quarry Road
- Stockpile & Sort Area
- Quarry Development Area
- Grubbing Area by BC Hydro
- Clearing Area by BC Hydro
- Area 1: Sorting and Laydown
- Area 2/3: Sorting, Stockpiling, and Loading

Notes

1. All mapped features are approximate and should be used for discussion purposes only.
2. This map is not intended to be a "stand-alone" document, but a visual aid of the information contained within the referenced Report. It is intended to be used in conjunction with the scope of services and limitations described therein.

Sources

- Base Data: BC Hydro, 2017
- Aerial Image: ESRI World Imagery
- Inset Basemap: ESRI World Topographic Map

N

1:6,000

0 50 100 150 200 250

Metres

NAD 1983 UTM Zone 10N

Page Size: 11" x 17"

989619-10	Production Date: Feb 10, 2022	Figure 2.1

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BC hydro

3.0 BACKGROUND

Bat studies were conducted from 2012 to 2014 at Portage Mountain to support the development of the Environmental Impact Statement for the Site C Clean Energy Project. Those studies determined that some rock features in the vicinity of the proposed quarry area were highly suitable for hibernating bats (Andrusiak 2014). Two at-risk bat species are known present at Portage Mountain and very likely hibernating based on the dates of detections: little brown myotis (*Myotis lucifugus*) and northern myotis (*Myotis septentrionalis*). Both species are listed as endangered on Schedule 1 of the *Species at Risk Act* (SARA) and both have been confirmed to use rock crevices for hibernation (COSEWIC 2013; White et al. 2020). The results of the previous surveys and the characteristics of the habitat led to the determination that rock crevices used by little brown myotis and northern myotis for hibernation at Portage Mountain meet the criteria for critical habitat under SARA (COSEWIC 2013). Six other bat species have been recorded at Portage Mountain, at least four of which are likely hibernating and all of which may be using maternity roosts (trees and rock crevices) in the vicinity (**Table 3.1**).

Table 3.1 Bat Species* Previously Recorded** at Portage Mountain

English Name	Scientific Name	BC Status	SARA Schedule 1 Status	Winter Behaviour
Long-eared myotis	*Myotis evotis*	Yellow	None	Hibernate
Little brown myotis	*Myotis lucifugus*	Yellow	Schedule 1 Endangered	Hibernate
Northern myotis	*Myotis septentrionalis*	Blue	Schedule 1 Endangered	Hibernate
Long-legged myotis	*Myotis volans*	Yellow	None	Hibernate
Silver-haired bat	*Lasionycteris noctivagans*	Yellow	None	Hibernate / Migrate
Eastern red bat	*Lasiurus borealis*	Unknown	None	Migrate
Hoary bat	*Lasiurus cinereus*	Yellow	None	Migrate
Big brown bat	*Eptesicus fuscus*	Yellow	None	Hibernate

*English and scientific names are those used by the BC Conservation Data Centre (2021)

**(Andrusiak 2014; Hemmera 2018, 2020; Sarell and Alcock 2017)

The bat studies conducted since 2014 (Andrusiak 2014; Hemmera 2018, 2020; Sarell and Alcock 2017) used a combination of passive acoustic surveys and emergence surveys to build an understanding of bat activity and habitat use, and provide evidence that bats are using Portage Mountain rock crevices for the following:

- hibernacula in the winter (typically both sexes, likely in small groups);
- maternity roosts in the summer where breeding females congregate to gestate, give birth, and raise young; and,
- day roosts in the spring, summer, and fall, used by single individuals or small groups of males or of non-reproductive females.

BC Hydro prepared a bat monitoring plan in 2017, which was updated in 2020 (BC Hydro 2020) with input from the Vegetation and Wildlife Technical Committee.

The ongoing bat monitoring program at Portage Mountain (**Table 3.2**) consists of:

- year-round acoustic monitoring;
- emergence counts at maternity roosts during the summer;
- monitoring of noise and vibration produced by quarry operation; and,
- monitoring of temperature and humidity at two roost locations (initiated in 2020).

Monitoring studies (Hemmera 2018, 2020) have been designed to determine the efficacy of mitigation implemented during construction and operation of the quarry to reduce the disturbance or displacement of bats that use rock crevices as maternity roosts and/or hibernacula (**Figure 2.1; Figure 3.1; Table 3.2**).

Table 3.2 Bat Monitoring Program Components Conducted at Portage Mountain

Monitoring Activity	2017	2018	2019	2020	2021
Passive acoustic bat activity	X	X	X	X	X
Maternity roost emergence counts / roost inspection	X	X	X	X	X
Temperature and humidity	–	–	–	X	X
Noise and vibration	–	X	X	X	X

Note: X = surveys were conducted, – = surveys were not conducted.

3.1 Quarry Noise and Vibration Mitigation Thresholds

There have been very few field tests of the actual impacts of blasting noise and vibration on hibernating bats (e.g., West Virginia Department of Environmental Protection, Office of Explosives and Blasting 2006). *Best Management Practices (BMP) for Bats in British Columbia* (BC Ministry of Environment 2016c) recommends that high-intensity activities, such as blasting or use of heavy machinery, not occur between October and April within 1 km of significant roosts, which includes occupied hibernacula. The provincial BMP also recommends that noise and vibration at significant occupied bat roosts as a result of blasting activities should remain below the following thresholds (BC Ministry of Environment 2016c):

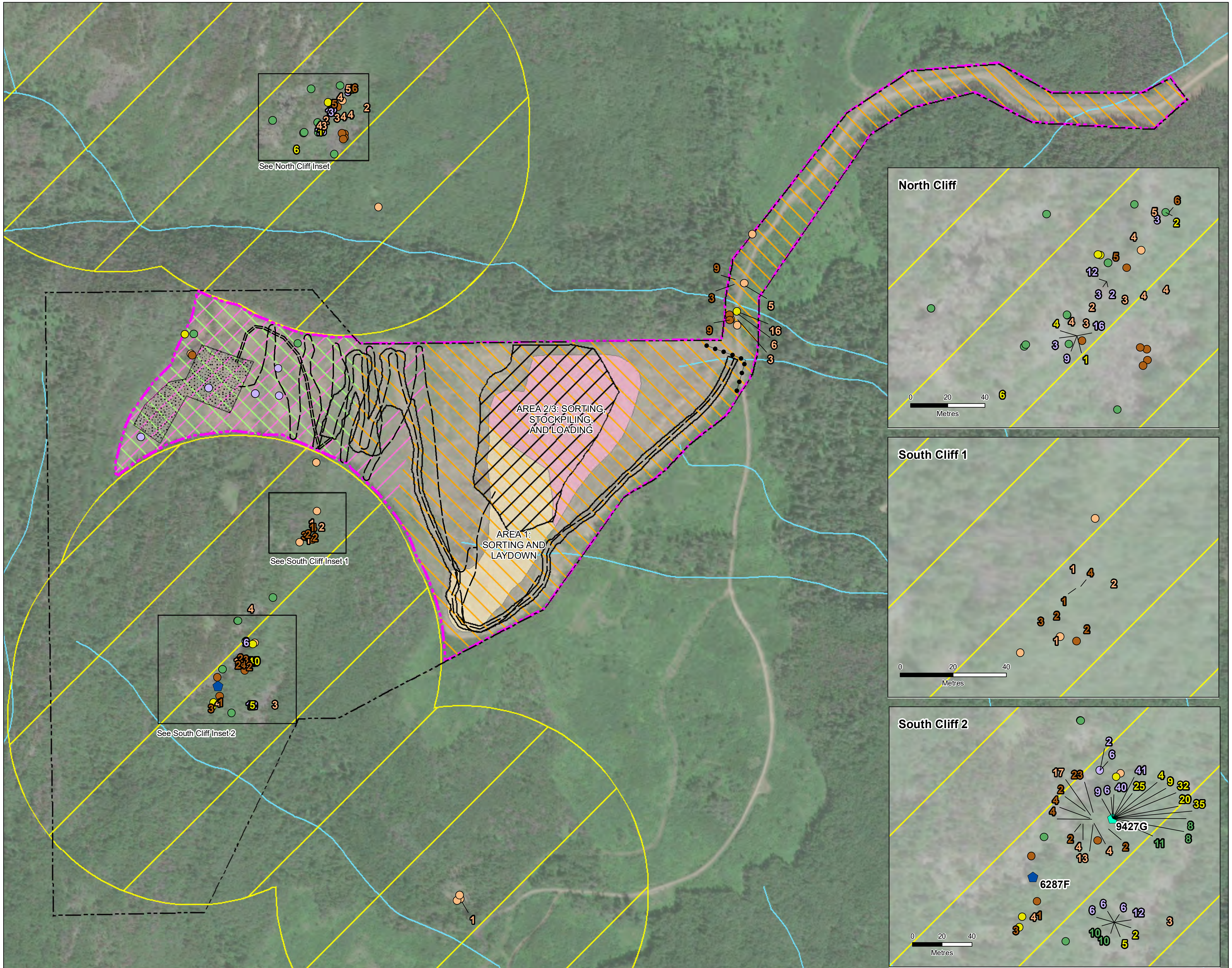
- sound concussion less than 150 decibels (dB);
- shock wave less than 15 pounds per square inch (103.4 kPa); and,
- peak particle velocity less than 15 mm/second.

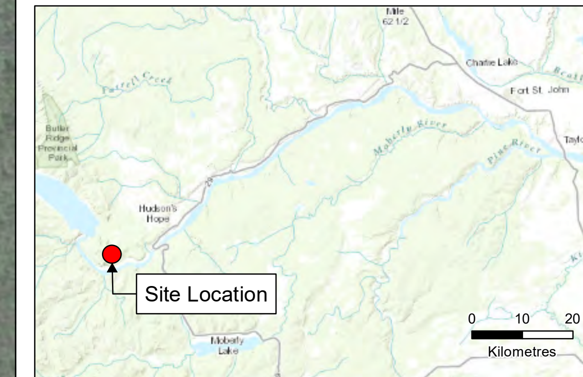
BC Hydro implemented a temporal restriction on all blasting activities between September 15 and May 15 to reduce the potential for disturbance to hibernating bats (BC Hydro 2020), as well as a 300-m setback between all quarry activities and the approximate locations of crevices identified as potential hibernacula. The 300-m setback area was used in the design of the quarry to avoid areas identified as supporting hibernating bats. The 300-m buffer used to design the quarry was based on identified potential hibernacula (Andrusiak 2014) rather than areas of suitable habitat. Modelling conducted by Horan and Frappell (2016) predicted that the noise and vibration of expected blasts at Portage Mountain would not exceed BC BMP thresholds at 150 m from the quarry development boundary, such that a 300-m buffer would be conservative.

The quarry is located approximately 350 m from the closest identified maternity roost (9427G) and approximately 130 m from the nearest rock feature (south cliff) that could provide roosting habitat. The quarry is therefore consistent with recommended BMP (BC Ministry of Environment 2016c) to avoid activities that modify habitat within 100 m of identified bat maternity and hibernation sites.

Site C Clean Energy Project
Wildlife Mitigation and Monitoring Services

Cumulative Emergence Count Locations and Results, 2017-2021





Legend

- 12 Bat Emergence Count
- No Bats Observed
- Confirmed Maternity Roost
- Potential Maternity Roost
- Security Fencing
- In Quarry Access Road
- Quarry Haul Road
- Stockpile Road
- Site Boundary
- Potential Hibernacula - 300m Buffer
- Portage Mountain LOO
- Stripping/Overburden Stockpile Area
- Quarry Road
- Stockpile & Sort Area
- Quarry Development Area
- Grubbing Area by BC Hydro
- Clearing Area by BC Hydro
- Area 1: Sorting and Laydown
- Area 2/3: Sorting, Stockpiling, and Loading

Year

- 2017
- 2018
- 2019
- 2020
- 2021

Notes

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2. This map is not intended to be a "stand-alone" document, but a visual aid of the information contained within the referenced Report. It is intended to be used in conjunction with the scope of services and limitations described therein.

Sources

- Base Data: BC Hydro, 2017
- Aerial Image: ESRI World Imagery
- Inset Basemap: ESRI World Topographic Map

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0 50 100 150 200 250
Metres

NAD 1983 UTM Zone 10N

Page Size: 11" x 17"

989619-10	Production Date: Mar 31, 2022	Figure 3.1

Hemmera An Ausenco Company
BC hydro

Path: S:\Geomatics\Projects\989619\10_portage_mtn_bats\mxd\Fig3_1_989619_10_PortageMtnBats_Emergence_220331.mxd

The BMP thresholds do not include specifications for the frequency of blasting events or of the waveform frequencies produced by blasts, which are important considerations when assessing potential impacts of blasting noise and vibration (Orica Limited Group n.d.). "Significant" roosts have been defined in the provincial BMP (BC Ministry of Environment 2016c) based on characteristics that are difficult to apply directly at Portage Mountain because access and technical challenges prevent accurate determination of the species, sex and reproductive status of each individual exiting a cliff crevice. However, for practical purposes any roost identified as likely being a maternity roost and /or a hibernaculum is considered a significant roost at Portage Mountain.

3.2 Known and Suspected Hibernacula and Maternity Roosts

Early studies identified sections of the cliffs adjacent to the quarry and the adits of an abandoned mine (King Gething mine) as potential hibernacula (Andrusiak 2014; Sarell and Alcock 2017). Hemmera (2018a, 2018b, 2020) conducted passive acoustic monitoring over multiple years to identify peaks of bat activity during the mating period in the fall (swarming), some winter bat activity, and activity in the spring when bats start emerging from hibernation, supporting the conclusion that bats were hibernating at the cliff features at Portage Mountain.

Early studies also identified use of the cliffs as day roosts (Hemmera 2018, 2020). Emergence counts conducted in 2017, 2018, and 2019 (**Table 3.3**) identified potential maternity roosts (6287F, 9247G) in the cliffs south of the quarry (**Figure 3.1**) based on multiple individuals observed exiting the cliffs during emergence counts. Other counts identified areas of the cliff where smaller numbers of bats were observed emerging. However, finding specific roost crevices in the cliffs is difficult due to the presence of multiple crevices in close proximity, the height above ground of many crevices, and the steep and hazardous terrain that prevents surveyors from closely approaching crevices. Bats may also roost in the trees on Portage Mountain.

Table 3.3 Emergence Counts Previously Conducted at Portage Mountain

Year	Dates of Emergence Counts
2017	July 31 to August 10
2018	June 17 to June 20 June 30 to August 03
2019	June 09 to June 13 June 19 July 22 to July 25

3.3 Quarry Construction and Operation Activities and Bat Mitigation

Quarry construction and operation activities within the quarry boundaries (**Figure 2.1**) between 2019 and 2021 have included the following:

- developing and upgrading road access;
- clearing vegetation in the quarry area;
- blasting, excavating, and transporting material; and,
- rock sorting (in the lower area close to 400 Road).

Construction activities for road access, vegetation clearing, and the haul road began in 2016 and were completed in fall 2019 (**Table 3.4**). In 2020, riprap loading and sorting and tree clearing continued, and nighttime activities took place from July 1 to October 9. Production blasting occurred during 2020 and 2021.

Table 3.4 Quarry Construction and Operation Activities 2017- 2021

Dates	Location *	Activity
2016	Access road and quarry site	Clearing and access road construction
August 10 to August 14, 2018	Future quarry site	Test blasting
June 6 to September 15, 2019	Quarry and along 400 Road	Tree clearing
June 6 to August 20, 2019	Quarry	Blasting for haul road construction
August 21 to September 15, 2019	Pit	Production blasting
May 16 to September 14, 2020	Pit	Production blasting
May 16 to early November, 2020	Quarry, Stockpile and Sorting Area (Area 1) to Offsite Rip Rap Stockpile Area (Area 4)	Tree clearing
May 16 to early November 2020	Area 1 to Area 4	Riprap loading and sorting
July 1 to August 18, 2020	Area 1 to Area 4	Nighttime hauling
July 22 to August 18, 2020	Pit to Area 1	Nighttime hauling with vehicle lights only
July 22 to August 18, 2020	Pit	Nighttime excavation at the pit
August 9, 2020	Area 1	Installation of lights for safety at nighttime
August 28 to October 9, 2020	Area 1 to Area 4	Nighttime hauling
May 16 to August 17, 2021	Pit	Production blasting
March to April, 2021	Area 5	Clearing, grubbing, stripping and hauling
May to August 2021	Area 1 to Area 4	Nighttime hauling in areas 1 and 4
September to December, 2021	Area 1	Processing material

*See **Figure 2.1**.

Noise and vibration monitoring was conducted for representative test blasts at Portage Mountain Quarry in 2018 (Johnston et al. 2018), and for quarry construction and operation activity in 2019, 2020 and 2021 (Dailyde and Johnston 2020; Dailyde et al. 2022) to compare the noise and vibration produced at the quarry to the BMP thresholds (**Section 3.1**). The test blasting indicated that noise and vibration 300 m or more from blasts were below the thresholds described by the provincial BMPs (BC Ministry of Environment 2016c), with ground-borne vibrations below threshold by 141 and 228 m from the blast on the north and south cliffs, respectively, and air overpressure below threshold by 34 m from the blast (Johnston et al. 2018).

In 2020 artificial lights were used for safety at the Stockpile and Sorting Area (Area 1; **Figure 2.1; Table 1.3**). Artificial light at night has the potential to affect bat behavior (Rowse et al. 2016; Straka et al. 2019; Voigt et al. 2021). BC Hydro has minimized the use of artificial lights at the quarry to mitigate the potential adverse effects of light. Additional mitigation for the use of lights was as follows:

- lights had full directional capability with shrouding;
- lights were pointed down and away from the cliff faces; and,
- lights were turned off when not needed.

BC Hydro's mitigation plan for bats also includes potential creation of bat habitat during future reclamation of the quarry, if analyses of monitoring data determine that hibernating or roosting sites for bats were affected by quarry operations (BC Hydro 2020).

4.0 METHODS

Methods implemented at Portage Mountain from 2017 through 2021 were developed in consultation with the Vegetation and Wildlife Technical Committee and local biologists (Hemmera 2018). Methods are based on standard techniques used for bat studies (Bachen et al. 2020; BC Ministry of Environment 2016b) with minor variations to account for the specific habitats, terrain, and access challenges at the monitoring sites.

4.1 Weather and Sunset Data

Two temperature loggers were installed at the south cliff in 2020 (**Section 4.3.2**), but those units did not produce a complete data record due to rodent damage and premature battery failure. No provincial weather stations were located close enough to Portage Mountain for their data to be useful. BC Hydro provided hourly weather data from their weather station at the Portage Mountain quarry (**Figure 2.1**). Data included precipitation in millimetres (mm) and air temperature in degrees Celsius (^{o}C), both reported hourly, but did not include barometric pressure. The time of sunset at Fort St. John on each day was obtained from National Research Council Canada (2021).

4.2 Noise and Vibration Monitoring

RWDI Consulting Engineers and Geoscientists (Dailyde et al. 2022) and TetraTech Canada (Nickoli et al. 2022) reported the results of noise and vibration (including blasting) monitoring and modelling at the north and south cliffs for 2020 and 2021. **Appendix A** and **Appendix B** include detailed descriptions of noise and vibration monitoring methods, which are briefly summarized here.

Baseline noise monitoring occurred in 2019 (Dailyde and Johnston 2020). Baseline measurements were completed at a representative location far enough away from the quarry that work there would not affect the noise levels measured. Quarry noise monitoring in 2020 and 2021 was carried out at both the north cliffs and the south cliffs.

No vibration monitoring occurred in 2020, as vibration data are more difficult to collect, and based on the expectation that blasts in 2020 would be similar to those in 2018 and 2019. Vibration monitoring occurred regularly at the south cliff and north cliff monitoring locations in 2021 (Dailyde et al. 2022). Blast monitoring was conducted from May through September in 2021.

Nickoli et al. (2022) used 2019 and 2021 blasting data provided by BC Hydro to develop site-specific best fit equations to calculate peak particle velocity and sound concussion for the north and south cliffs for the 2020 blasts that were not monitored. The resulting metrics for sound concussion (also known as the air overpressure or airborne vibration), shock wave, and peak particle velocity (also referred to as ground vibration) were compared against provincial BMP thresholds (**Section 3.1**) for noise and vibration due to blasting near bat habitat features (2016c). The results of the noise and vibration monitoring also provided additional environmental context to inform the analysis of bat activity over time (**Section 4.4.2.2**).

4.3 Roost Emergence Counts, Roost Inspections, and Maternity Roost Monitoring

Consistent daily emergence of bats from maternity roosts at dusk for feeding provides opportunities for roost identification and enumeration of bats via emergence counts. Roosts used by pregnant and nursing female bats have more regular patterns of emergence than roosts used by male or non-reproductive individuals (Barclay 1989; BC Ministry of Environment 2016b). The objectives of the emergence surveys were to identify maternity roosts, to assess potential changes in use of the cliffs as maternity roosts, and to examine the relationship between any changes in maternity roost use and quarry operation.

Two methods were used to collect emergence data at identified and suspected maternity roosts and non-maternity roosts:

- emergence counts and roost inspections; and,
- continual roost monitoring with remote roost loggers placed near the roost entrances to record bat calls.

4.3.1 Roost Emergence Counts and Roost Inspections

Roost emergence counts were conducted in 2020 following methods described in Loeb et al. (2015) and Vonhof (2006). The methods have been previously described in Hemmera (2019). Information on site selection criteria was provided in the 2017 to 2019 bat monitoring report (Hemmera 2020). Physical inspections for roosting bats or bat sign such as guano were conducted where potential features could be safely accessed by surveyors.

Visual emergence counts were completed twice yearly during the maternity period: once ('early period') during pre-volancy (i.e., when pups are not able to fly) between June 1 and June 21, and once ('late period') during post-volancy (i.e., when pups can fly) from July to early August. Emergence counts were conducted from 30 minutes before dusk until approximately 1 hour after dusk, when visibility became a limiting factor, or until bats started to return to the roost. Each site on the north and south cliffs was surveyed on two consecutive nights both pre- and post-volancy (4 surveys total). Surveyors were equipped with handheld acoustic detectors (Echometer Touch) that recorded bat vocalizations in the vicinity of the surveys. Sites where no bats were observed were not resurveyed in subsequent years.

A single exploratory roost emergence count with multiple observers was conducted during the 2020 post-volancy period at the access road (400 Road) to investigate bat activity at the mouth of the gully located east of the quarry (**Figure 3.1**). This survey was focused on the mouth of a gully, upstream of which is a linear patch of mature balsam poplar with potential to provide tree roosting habitat for bats. The survey stations were located along 400 Road, where multiple observers visually scanned the edge of the forest. Surveyors used handheld bat detectors (Echometer Touch) to alert them to bats emerging from the stand and to record calls for later analysis.

4.3.2 Roost Monitoring

Two of the previously-identified maternity roosts at the south cliff (9427G and 6287F; **Figure 2.1**; Hemmera 2020) were monitored with Anabat roost loggers (Titley Scientific Inc.) from March 2, 2019 to through 2021. The roost loggers recorded acoustic data continuously for 24 hours, providing bat identification information, the daily timing of emergence from the roost, and quantification of movements in and out of the roost. The effective range of the loggers was 5 m. Files recorded within 90 minutes of sunset were considered to be recorded within roost emergence time.

In October 2020, roost logger RL1 was moved closer to roost 9427G with the aim of reducing the number of recordings from foraging bats and obtaining more recordings of bats emerging from and returning to the roost. Due to the lack of activity (no bats observed on emergence counts and low numbers of bat passes) at the 6287F roost, roost logger RL2 was relocated to roost 9427G with the intent of recording bats approaching that roost.

Temperature / humidity loggers (Onset HOBO model MX2302A) were installed in 2020 at the top of the south cliff and next to roost 9427G to assess relationships between bat activity and changes in the temperature and humidity. The loggers were attached to trees where they would remain in the shade to record ambient air temperature. The south cliff temperature logger was rendered non-functional by rodent damage in summer 2020 and was not replaced, leaving a single working unit at 9427G.

4.3.3 Data Analysis

Precipitation at the time of sunset was obtained from the BC Hydro weather station at the Portage Mountain quarry. Daily relative humidity data at sunset on each survey date were obtained from the temperature logger at 9427G and consisted of the value recorded closest to the sunset time on the date being assessed.

The numbers of bats observed exiting the cliff at each roost emergence count location on each date were totalled. Observations of bats foraging or flying by the observer were not included in the total unless the surveyor had observed the bats emerging from the cliff.

Acoustic data recorded by the Echometer Touch hand-held units during emergence counts were analysed using same process used for all of the other acoustic data analyses in this project (**Section 4.4**). Acoustic data were correlated with the visual observations made by the surveyors wherever possible, based on the location and time of the observations and of the recordings made by the hand-held units as well as the comments noted by the surveyors.

The bat mitigation and monitoring plan (BC Hydro 2020) and previous monitoring reports for Portage Mountain (Hemmera 2020) use a threshold of 10 bats emerging at a given site to define a 'maternity roost', although some of the provincial BMP definitions for a 'significant' roost (see **Section 3.1**) specify fewer individuals than the threshold of 10 bats used for this project. Hemmera is not aware of any literature that provides a minimum number of bats that constitute a maternity roost.

The following criteria were used to determine likely maternity roost occupancy:

- at least 10 bats emerging from a single feature during at least one emergence count during the maternity period (assumed to occur from mid-May to mid-August [Paterson, B., pers. comm., July 2019]);
- emergence timing at or near sunset (indicative of lactating females with dependent pups);
- observations of bats returning to the roost (i.e., to feed dependent pups) during the emergence survey; and,
- a marked increase in count numbers occurring at a single site over the pre-volant to volant period for young-of-year bats, in consideration of other influencing factors such as weather.

Daily emergence at or near sunset may indicate lactating female bats. Lactating bats leave their roosts at or near sunset because the energetic burdens of pregnancy and nursing require them to start foraging early to maximize foraging duration (Henry et al. 2002; Lemen et al. 2016). The daily emergence times of males and non-breeding females are more flexible because they have lower energy demands than lactating females and can use daily torpor to further decrease their metabolic requirements (Kurta et al. 1989; reviewed in Sedgeley 2001). Lactating females must also return to the roost during the night to nurse dependent pups.

The presence of juveniles also provides strong evidence of a maternity roost, at least up to the late summer period. The presence of juveniles in the roost can be inferred by a sudden increase in the number of bats counted during emergence counts late in the summer, when young-of-the-year can fly, compared to the number of bats counted during emergence surveys early in the summer.

4.3.4 Assumptions and Data Limitations

The assumptions in the emergence count data include:

- observers are able to accurately distinguish between a bat emerging from the cliff and a bat foraging along the cliff; and,
- vocalizations recorded on the observer’s handheld detector at the time as a visual observation of an emerging bat are those of the bat observed.

The accuracy of emergence counts was limited by physical and weather conditions at the sites monitored. Surveyors had to choose vantage points that were safe for them to access, which often meant that they could not get the best view of emerging bats. Some bats emerged from crevices high on the cliffs and it was difficult for observers at the bottom of the cliffs to see them. Rain and fog impeded visibility on some counts as described in **Section 5.2**. The assumptions related to acoustic data recorded during emergence counts are similar to those described for long-term acoustic monitoring (**Section 4.4**).

4.4 Long-term Passive Acoustic Monitoring

Bioacoustic technology is an efficient, non-invasive tool for examining bat activity patterns and species diversity over long durations and provides a metric of bat activity based on the number of bat calls recorded within approximately 50 m of the detectors (Fraser et al. 2020; Lausen 2016). Year-round acoustic monitoring is used to assess ongoing bat activity and compare that activity between years and annual bat life stages. Acoustic data can confirm the presence of individual species and document any changes in bat species diversity between years. Acoustic data can also provide information to infer the use of hibernacula. Evidence of hibernation occurring in proximity to the detector includes:

- relatively high bat activity recorded during the fall mating and swarming periods;
- limited and localized winter activity; and,
- surges of activity during spring emergence.

4.4.1 Detector Locations

The rationale behind selection of locations for long-term bat detectors on the north and south cliffs (**Figure 2.1**) was described in Hemmera (2019). A single Songmeter detector was installed at each of 4 locations in November 2017 (**Figure 2.1**) and those locations have been monitored continuously to date, although some data gaps have occurred due to equipment issues. The SM2 detectors installed in 2017 at the beginning of the study period were replaced by new SM4BATZC units equipped with SMM-U1 or SMM-U2 microphones in summer 2019. One detector (PM-C-NH) was deployed at the north cliff, two (279-SH and 294-SH) on the south cliff, and one (PM-S3) between the south cliff and the quarry (**Table 4.1**). Those four locations have monitored year-round from 2017 through 2021. A fifth detector (PM-TAL) was installed on June 26, 2020, upslope from a talus field at the north cliff (**Figure 4.1**) and has been operating continuously since its installation.

Table 4.1 Long-term Passive Acoustic Monitoring Sites, 2017 to 2021

Name	General location	Distance (m) from closest quarry boundary	Comment
PM-D-NH	North cliff	320	
PM-C-NH	North cliff	402	
PM-TAL	North cliff talus	330	Installed 2020
279-SH	South cliff	401	Suspected maternity roost 6287F
294-SH	South cliff	334	Suspected maternity roost 9427G
PM-S3	Quarry	81	

Detector settings have been described in Hemmera (2019). Microphones were calibrated twice in summer 2020 (June 22 and July 15) and again in July 2021 to confirm sensitivity within the manufacturer's specified range and ensure consistency in data collection. The detectors were visited every other month to download data and verify detector operation.

The detectors were prepared for winter with protected microphones and cables, a water- and snow-resistant housing, and a combination battery/solar power supply. Each detector was outfitted with a 12-volt battery (7 amp-hours) powered by a Renogy 100-watt solar panel, and a Morningstar SS 20L-12V SunSaver 20-amp solar charge controller.

Equipment issues and cable damage by rodents has led to data loss. Additional gaps in recording have resulted from snowfall covering the solar panels.

Figure 4.1 Location of Detector TAL (arrow) at the Small Talus Field Downslope of the North Cliff

4.4.2 Data Analysis

Acoustic analysis methods used in 2020 and 2021 were identical to those of previous years although some classification categories were merged. The acoustic analysis followed a conservative approach as recommended for the analysis of acoustic data by Lausen (2016); only files with two or more echolocation pulses (Vonhof 2006) separated by at least one second (termed a bat 'pass', 'call' or 'file') were included in the analysis and were considered for classification to species level or species group. A series of bat passes could be made by the same bat flying multiple times in front of the microphone or by multiple individuals (Adams et al. 2015); therefore, the results provide a relative index of bat activity (files per detector-night) but do not represent an estimate of bat populations in the study area.

Bat files were classified based on acoustic parameters for the targeted bat species (summarized in **Appendix A**) using two automated species classifications: Kaleidoscope Pro (V3.1.6 Wildlife Acoustics Inc.) and species-specific filters developed for AnalookW V4.5 (Titley Electronics, Ballina, New South Wales, Australia). Noise files, such as ambient background sounds, were excluded from the dataset using a filter in AnalookW. The automated classification results were then manually verified based on professional judgement. Bat calls were either classified according to species or grouped into categories based on their acoustic parameters (**Appendix A**). Files with multiple species or individuals were assigned each of the relevant categories, i.e., were counted once for each species and individual. Social calls were identified through manual inspection.

The acoustic parameters used for the identification of each call were derived from accepted characteristics based on scientific studies and acoustic libraries (Lausen 2016). Updated provincial bat protocols for acoustic monitoring are not yet available; therefore, after consultation between Hemmera and a bat specialist with the BC Ministry of Forest, Lands, Natural Resource Operations and Rural Development (Hansen, I.J., pers. comm., September 2018), the methods used for 2017 to 2019 studies (Hemmera 2018, 2020) were repeated for the 2020 and 2021 analysis with minor improvements (summarized in **Appendix A**).

Bat echolocation calls, especially those from the *Myotis* genus, can be difficult to identify to species due to high variability within species (Obrist et al. 2004) and overlap in call characteristics among some species. Where Myotis calls could not be definitively identified to species, they were assigned to the Myotis category that includes little brown myotis, long-eared myotis, northern myotis, and long-legged myotis because of overlap in call characteristics (**Appendix A**). The Myotis category (**Appendix A**) was assumed to indicate the potential presence of the endangered little brown myotis or northern myotis. Similarly, silver-haired and big brown bat are often grouped together, as are eastern red bat and little brown myotis. Files known to be or potentially Myotis species (including all files identified as any of the Myotis species, the Myotis category, and the 35K eastern red bat/little brown myotis category) were merged into a broader Myotis group for analysis. The 'big brown bat' broad species group used for some summaries included files categorized as big brown bat and as big brown bat / silver-haired bat.

A night of monitoring by a single detector was termed a 'detector-night', assigned to the date on which the night began even though the file itself may have been recorded in the early morning of the next day. Each file was assigned to the detector-night on which it was recorded, and further assigned to an hour bin (0-23) that corresponded to the time at which the file was recorded. The numbers of bat passes recorded per detector-night were compared between detectors and over time to examine patterns in bat activity.

An R script was created to identify dates when no bat or noise files were recorded by each detector. Detector log files were not available for 2018 or 2019, so a subjective number of consecutive days without data was chosen to assess whether a detector was functioning correctly: if no bat calls or noise files were recorded for a period of 5 nights or more in summer or 20 or more nights in winter, fall, or spring, the detector was considered inactive. Each bat file was linked to the time of sunset on the night the file was recorded, and the quarry weather station temperature recorded closest to the file's time (**Section 4.1**).

4.4.2.1 Bat Life Stages

Bat annual life stages include hibernation, emergence, maternity (summer), and swarming. Bat activity levels vary considerably through the year, driven by seasonal weather patterns and life stages. The beginnings and ends of these stages are gradual rather than sharply defined by a single date (BC Ministry of Environment 2016b). However, to aid with the seasonal examination of bat data, dates corresponding to annual life stages were defined using yearly bat acoustic data. The species detected at Portage Mountain are a mixture of migratory and hibernating bats (**Table 3.1**), and the onset and duration of annual life stages will vary between species (Whitaker Jr and Rissler 1992; van Schaik et al. 2015) and by overwintering strategy. Ideally, life stage dates would have been defined for each species, but *Myotis* sp. made up the majority of bat calls in the Portage Mountain dataset, with too few calls of other acoustic classes to complete a quantitative analysis of life stages. Therefore, life stage dates were only based on data classified as being *Myotis* sp. files. For the bat life stage analysis, the Myotis group consisted of the following identification categories: all Myotis species, the red bat / little brown myotis groups (assumes there are few to no red bats in the group), and high-frequency bats. Data from all detectors on Portage Mountain were combined as it was assumed that any seasonal effects would apply to all detectors.

The method described by Meyer et al. (2016) was used to define the start and end of emergence and hibernation, which is based on the cumulative number of calls within defined periods. Hibernation start was defined as the date by which 95% of the cumulative sum of files had occurred between September 22 - November 15 and end was defined as the date by which 5% of the cumulative sum of files occurred between March 20 and June 1 (Meyer et al. 2016). Emergence start was defined as the date on which 5% of the cumulative sum of files occurred between March 20 and June 1 (i.e., hibernation end) and emergence end was the date on which 50% of the cumulative sum of files occurred between March 20 and June 1.

Bat activity increases just prior to hibernation at sites where they hibernate (Van Schaik et al. 2015). This increase in activity is termed 'swarming' and is believed to be associated with mating and the search for hibernacula (Parsons et al. 2003, Van Schaik et al. 2015). There is limited published work that uses a statistical approach to identify the swarming period with acoustic data. Part of the challenge in identifying a swarming period is the high variability in activity levels between nights due to factors such as temperature and precipitation (Parsons et al. 2003). However, by fitting a non-linear curve to the nightly count of bat files, it is possible to smooth out the nightly fluctuation and identify periods with a peak in activity that corresponds to swarming (Parsons et al. 2003). Another advantage of this method is that it provides an objective method to identify the swarming period as compared to visually looking for peaks in bat acoustic data.

Adopting the method of Parsons et al. (2003), non-linear equations were fitted for the total number of Myotis files per active detector-night between the period of July 15 and September 30 for the years that had sufficient data for this period: 2019, 2020, and 2021. This period was used to ensure that a peak was detected, despite July and early August being outside the typical swarming period (i.e., late August to late September). Following Parsons et al. (2003), SigmaPlot was used to fit non-linear curves to the data and the best-fitting curve was selected based on the R^2 value from the set of equations available in SigmaPlot. Equations tested were those available in the peak category: 3-parameter Gaussian, 4-parameter Gaussian, 4-parameter modified Gaussian, 5-parameter modified Gaussian, 3-parameter Lorentzian, 4-parameter Lorentzian, 4-parameter Pseudo-Voigt, 5-parameter Pseudo-Voigt, 3-parameter Log Normal, 4-parameter Log Normal, 4-Parameter Weibull, and 5-Parameter Weibull.

Once the best fitting curve was identified, the start and end dates of swarming were selected based on predicted values from the best-fitting equation. The date on which the increase in the slope of curve (i.e., predicted files) was ≥5 files from one night to the next and the decrease in file numbers was ≤5 files per night, respectively, were selected to identify the start and end dates of swarming. In other words, start of swarming was occurred when the slope of the curve of predicted bat activity started to increase and swarming ended when the slope the curve started to level out.

4.4.2.2 Trends in Bat Activity

There are two primary questions regarding the impacts of the Portage Mountain Quarry on bats:

1. Has seasonal bat activity decreased since 2017?
2. Does blasting associated with the quarry affect bat activity?

A null model, a base model and two *a-priori* models were used to examine effects of the quarry while accounting for the potentially confounding effect of weather conditions on seasonal bat activity:

1. Null model: Total bat calls per night ~ 1
2. Base model: Total bat calls per night ~ mean temperature + precipitation
3. Year model: Total bat calls per night ~ year + mean temperature + precipitation
4. Blast model: Total bat calls per night ~ blast + mean temperature + precipitation

As a response variable, calls from all acoustic groups were combined to provide the largest dataset possible. A null model was used to test the relative model fits of the Year and Blast models. Bat growing season activity and winter arousal is known to be correlated with weather, including temperature, barometric pressure, wind speed and precipitation (Ciechanowski et al. 2007; Erickson and West 2002; Gorman et al.

2021; Hayes 1997; Meyer et al. 2016; Paige 1995; Patriquin et al. 2016; Whitaker Jr et al. 1997; Wolbert et al. 2014; Voigt et al. 2011). Of these variables, nightly measurement of temperature and precipitation data were available (**Section 4.1**). As such, temperature and precipitation were included as base variables in the *a-priori* models and as a base model because these are known to have a large influence on bat activity, therefore interpreting the effects of year and blasting require holding weather effects constant. A base model was included for the same reasons as the null model, to test relative model fitness.

The Year model will test for a change in yearly bat activity. If there is a decrease in activity since 2017, the coefficient of years post 2017 will be negative and significantly different from zero. The Blast model will test for an effect of blasting (occurred/ did not occur) on bat activity during the night. If there is a negative relationship between blasting and bat activity, the blast coefficient will be negative and significantly different from zero.

To evaluate model fit, the Akaike's Information Criterion (AIC) scores of the Year and Blast models were compared to the null and base models. The model with the AIC weight closest to 1 was selected as the most parsimonious model that best explained the data from the set of models. We could not compare the Year and Blast models using AIC scores because they were generated using different datasets (i.e., year 2017 was dropped for the Blast model because no blasting occurred in that year). For model selection, we ran the null model and the base model on the same dataset as either the Year or Blast model.

Due to the influence of life stages on bat activity, each of the above models was evaluated during the following four bat life stages: emergence, summer (including maternity), swarming, and hibernation, which were calculated as described in **Section 4.4.2.1**. However, because we were only able to identify a swarming period in 2021 and there was no identifiable swarming period in 2019 and 2020 (**Section 5.3.2.2**), we defined a fall period instead of swarming. For the purposes of assessing bat activity, the fall period was defined as occurring from September 1 to the start of hibernation, the latter of which was defined on a yearly basis (**Table 5.10**).

We also considered investigating distance to quarry as predictor variable, to test if bat activity would be lower closer to the quarry. However, there was a natural effect of distance to quarry based on placement of the detectors, such that bats were most active at detectors furthest from the quarry before most construction activity at the quarry began (2017).

Decibel and peak particle velocity were also considered as model variables; however, these measurements were only available for 2021 and there were several gaps in the 2021 data. Therefore, to investigate the effects of the blasting we included blast by date only, as having occurred (yes, no) during the day as a model variable. There were two blast records that did not have a date (assumed to have occurred in 2019) and therefore were not included in the model. Blasting did not occur in 2017 and therefore this year was dropped from the Blast model. Because blasting only occurred during the summer and fall bat life stages, we only ran the Blast model during these periods. Dropping the year 2017 reduced the number of detectors used in the model to five detectors since PM-D-NH, which was located at the north cliff, only recorded in 2017.

A generalized linear mixed effects model with a negative binomial distribution was used for the above models. Due to the nature of bat acoustic data (e.g., spatial autocorrelation, temporal autocorrelation, and unequal sampling), generalized linear mixed effects models are regularly used to test bat acoustic data (Perks and Goodenough 2020; Jameson and Willis 2014; Muthersbaugh et al. 2019a). A negative binomial distribution was used because overdispersion was an issue when a Poisson distribution was used.

The variance of the data was much larger than the mean, further supporting the use of a negative binomial distribution. All models were tested for overdispersion using the ratio of the Pearson x^2 to the model degrees of freedom, and a threshold value of 5 was used (Payne et al. 2018).

The identity of the detector nested within the area was used as a random effect for each model. Using random effects accounts for the spatial and temporal autocorrelation (i.e. repeat sampling at one detector) of the study design and the difference in sampling effort between detectors (Gillies et al. 2006). Detectors were distributed across four main areas: south cliff, north cliff, quarry, and gully. Data from the acoustic detectors within an area are spatially autocorrelated due to the relatively small size of the area being studied. The detectors are all well within the foraging range of a single bat; 90 m separates the PMC-NH and TAL detectors and 120 m separates 279-SH and 294-SH. As such, individual bats recorded on one detector may also be recorded on other detectors depending on the bat's flight path. Data recorded by the detector at the gully were removed from the dataset because the detector was considered to have operated too infrequently, leaving six detectors in total (**Table 4.1**).

Year was included as a categorical variable with the lowest year (i.e., 2017) as the reference level to which the other years were compared. Mean temperature was the mean hourly temperature (˚C) between sunset and sunrise. Precipitation was the total precipitation (mm) between sunset and sunrise.

All continuous variables were standardized so that the mean was equal to zero and standard deviation was equal to one. Standardizing data improves model convergence, makes the standard deviation the unit of measurement, and therefore allows direct comparison of standardized model coefficients in terms of their influence on the response variable (Zuur et al. 2009). Variables were standardized using this formula:

$$\frac{x - mean(x)}{standard\ deviation(x)}$$

Due to the pseudo-replicated nature of acoustic data from detectors, the unit of sampling is not the number of nights the detector was active, but the number of detectors deployed. If the spatial autocorrelation is accounted for, the sample size is further reduced to 3 (i.e., north cliff, south cliff, and quarry). If the spatial autocorrelation is disregarded, the sample size is only 6 detectors (or 5 in the case of the Blast model). Data from five to six detectors at 3 areas is a relatively small sample size for the complexity of the models and this resulted in several challenges that required adjusting the model structure. For some seasonal models, the random effects structure of detectors nested in area was too complex for the data, resulting in a singular fit of the model. While the random effects structure was justified given the study design, there were likely too few data to support the more complex model. Singular fits can result in a lower power to detect significant trends (Matuschek et al. 2017). When models had a singular fit, area was removed as a random effect, the model AIC score was compared with the maximal model and the more parsimonious model was selected (Matuschek et al. 2017).

4.4.3 Assumptions and Data Limitations

Studies using bat activity as a metric have several assumptions (Gannon et al. 2003; Hayes 1997, 2000):

- recorded bat calls reflect the use of a site by bats.
- the probability of detecting an individual bat is the same for each detector and for each bat species.
- bats are randomly distributed in three-dimensional space.

The modelling approach described above includes several assumptions that should be noted:

- All bat species respond to yearly effects of the quarry and blasting effects in the same manner.
- Life stage dates based on Myotis activity are reflective of general activity patterns for other bat genera present at Portage Mountain.
- When models had to be simplified by removing area as a random effect, spatial autocorrelation was assumed to not affect model coefficients and their significance.
- Using date of blasting as a predictive model variable assumes that all blasts have an equal effect on bats and the blasts have an equal effect on bats at all areas.
- Any effect of year on bat activity is associated with quarry activity and is not related to natural causes.

There is a high level of natural variability in nightly bat activity, which can be influenced by insect phenology, time of day, and the gender and reproductive condition of individuals (Fischer et al. 2009; Gorman et al. 2021; Fraser et al. 2020; Hayes 1997; Sherwin et al. 2000; Talerico 2008), as well as weather and life stage as described earlier. This natural variability can make it challenging to detect trends due to change in the habitat (e.g., noise levels). Considering the amount of natural variability and the small sample size, models may be limited in power to detect trends.

5.0 RESULTS

5.1 Blasting, Noise and Vibration Monitoring

Blasting, noise and vibration monitoring began in 2019 and the results for 2019 are available in Hemmera (2020). Results of the blasting, noise, and vibration monitoring for 2020 and 2021 are briefly summarized below from Nickoli et al. (2022) and Dailyde et al. (2022), presented in **Appendices B** and **C**, respectively.

5.1.1 2020

One hundred one blasts took place at the Portage Mountain Quarry in 2020 between May 16 and September 14 (**Table 5.1**). Information on the daily timing of blasts was incomplete.

Table 5.1 Number of Blasts by Month at the Portage Mountain Quarry in 2020

Month	Number of Blasts
May	12
June	26
July	28
August	30
September	5
2020 Total	**101**

Vibration monitoring was not conducted in 2020. The best-fit equations calculated from the 2021 monitoring data were used with the 2020 blast data to estimate peak particle velocity for 2020. Based on this analysis, it was determined to be unlikely that any of the 2020 blasts exceeded the recommended thresholds (**Section 3.1**).

Monthly noise monitoring occurred during 2020 quarry operations between May and September at the north and south cliffs as well as the background location. Measured noise levels at the south cliff in 2020 ranged from 41-51 A-weighted decibels (dBA) during the day, and 32-43 dBA at night, levels at the north cliff ranged from 52-57 dBA during the day and 38-55 dBA at night, and background noise levels measured 5 km northeast from the quarry (daytime measurements only) ranged from 33-58 dBA (see Table 2 in **Appendix C**).

High-frequency noise (6,300 - 20,000 Hz) measured by a monitoring unit on the south cliff was examined to determine the differences in high-frequency noise levels during working hours between days when quarry construction was ongoing versus days without construction (Dailyde and Johnston 2020). Differences were very small (up to 0.07 dB), which the authors attributed to the speed at which high-frequency noise is attenuated. A similar analysis in 2021 (**Appendix C**) found slightly increased noise levels at the 6,300 Hz and 8,000 Hz frequency bands but lower noise levels in the higher-frequency bands.

5.1.2 2021

Sixty-one blasts took place at the quarry in 2021 between May 16 and August 17 (**Table 5.2**), almost all of which occurred between the hours of 1500 and 1800.

Table 5.2 Number of Blasts by Month at the Portage Mountain Quarry in 2021

Month	Number of Blasts
May	14
June	14
July	22
August	11
September	0
2021 Total	**61**

Noise monitoring was carried out at the south and north cliffs on May 31, 2021, for a duration of 64.7 hours at the south cliff and 85.5 hours at the north cliff (Dailyde et al. 2022). The results of the noise monitoring are presented in **Table 5.3**. Sound levels at the north cliffs were higher than those at the south, and levels of noise in general, and of high-frequency noise were similar to those measured in 2019. The levels of higher-frequency sound in the 6,300-8,000 Hz range were higher than pre-construction levels, but the levels of sound in the 10,000 to 20,000 Hz range were lower than pre-construction levels

Table 5.3 Average Sound Levels (dBA) Recorded at the Portage Mountain Cliffs in May 2021 (from Table 2 in Appendix C)

South Cliffs		North Cliffs	
Day	Night	Day	Night
45	40	53	42

Blast monitoring was conducted from May through September in 2021 (Dailyde et al. 2022). The maximum peak particle velocity recorded at either the south or north cliffs was 9 mm/second, the maximum sound concussion was 130 dB, and the maximum shock wave was 0.0095 psi – all measurements under the thresholds specified in BC Ministry of Environment (2016c). All of the blasts in 2021 were below (most of them well below) the threshold values for all three variables.

5.2 Maternity Roost Emergence Counts

5.2.1 2020 and 2021 Roost Emergence Counts and Roost Monitoring

The results of the 2020 and 2021 roost emergence counts and roost monitoring are detailed in **Appendix D** and only key results are summarized here. Thirty-nine emergence counts were conducted during June and July 2020 (**Figure 3.1**).

Most of the counts recorded one to four bats emerging, although 16 bats were counted exiting the gully during early period counts, and 17 bats were counted exiting the suspected maternity roost 9247G on the south cliff during the late period counts. The first bats that left 9247G during the two late period counts in 2020 exited the roost before sunset, and bats were observed returning to that roost during one of the late period counts. A maximum of four bats was observed during emergence counts at the other suspected maternity roost, 6287F, indicating that this site was less likely to be used as a maternity roost in 2020. One emergence count was conducted within the quarry on June 27 but no bats were observed exiting rock faces at that location.

Both roost loggers suffered from water damage in early 2020 and did not record data between May and late August. Although the loggers did not function as planned for much of the bat active period, activity at roost 9427G in 2020 was confirmed by the roost logger RL1. In total, 1,418 files were recorded in 2020, of which 1,390 were assigned to the Myotis category. Myotis activity was first recorded at 9247G in April and was increasing in early May when the loggers were compromised. Details are provided in **Appendix D**.

Thirty-two emergence counts were conducted during June and July 2021 (**Figure 3.1**). No bats were observed emerging on 13 of the counts. One to four bats were observed emerging on most of the remaining counts, although 23 bats were counted on June 19 at 9427G, the suspected maternity roost. The first bats were observed leaving 9247G 19 to 52 minutes after sunset during the early period and 33 to 35 minutes after sunset during the late period in 2021, and one bat was observed returning to the roost during one of the late surveys. A maximum of three bats was observed during emergence counts at the other suspected maternity roost, 6287F, indicating that this site was less likely to have been used as a maternity roost in 2021 according to the criteria in the bat mitigation and monitoring plan (BC Hydro 2020). One emergence count was carried out within the quarry on June 19 but no bats were observed.

RL1 recorded minimal activity at roost 9247G in 2021, and no activity after July. Only 45 files, almost entirely Myotis and 30K species groups, were recorded. The lack of data is likely due to a technical issue with the roost logger. The function of RL2 at roost 9247G was also compromised based on the lack of data recorded in July and August. RL2 began recording activity in April with a substantial increase in activity in May but stopped recording June 6. RL2 recorded eight files in August, and its last file on September 21. Details are provided in **Appendix D**.

5.2.2 Cumulative Roost Emergence and Roost Monitoring

Thirty-five maternity roost emergence counts have been conducted at the two suspected maternity roosts since 2017 (**Table 5.4**; **Figure 3.1**). No rain was recorded by the Portage weather station during the 2017 or 2018 emergence surveys. Rain occurred only on July 22 during the 2018 surveys, on June 24 and July 20 during the 2020 surveys, and on July 20 in 2021. The time that the first bat was detected was recorded irregularly during the 2017-2019 emergence counts.

Using the criterion of 10 bats and long-term activity to define a maternity roost, the 9247G site has continued to be used as a maternity roost from 2017 through 2021. The numbers of bats counted emerging from that roost have fluctuated both between years and between the early and late counts, with the highest number of emerging bats counted in 2018 early-period surveys (**Table 5.4**). Relatively few bats have been counted at 6827F since the peak number (10) was observed in 2017. No observations were recorded of bats returning to the 6827F roost.

Table 5.4 Emergence Count Surveys Completed, and Average* Number of Bats by Survey Night, at Two Suspected Maternity Roost Sites on Portage Mountain, 2017-2021

Maternity Roost ID	Session	Average bats counted (number of counts) 2017	Average bats counted (number of counts) 2018	Average bats counted (number of counts) 2019	Average bats counted (number of counts) 2020	Average bats counted (number of counts) 2021
9427G	Early	-	40.5 (2)	15 (3)	4 (2)	13.5 (2)
	Late	9 (3)	7.5 (2)	26.3 (3)	15 (2)	2.5 (4)
6287F	Early	-	6 (2)	4 (2)	3.5 (2)	0 (1)
	Late	10 (2)	9 (1)	0	-	2 (2)

*as sample sizes are small, no measure of variance has been calculated

In total, 152 emergence counts (including the maternity roost counts described above) have been completed between 2017 and 2021 (**Figure 3.1**). Two (NHEC2, NHEC3b) additional potential maternity sites were located in 2018 (**Table 5.5**), using the criterion of a minimum of 10 bats counted to define a maternity roost. Those sites had fewer than 10 bats counted in all subsequent years. There were multiple locations at which 3-9 bats were observed emerging between 2018 and 2021 (**Table 5.5**). Those locations are potentially maternity roosts used by fewer than 10 females.

Table 5.5 Emergence Counts Where 3-9 Bats Were Observed, 2018-2021

Location	Date of count	Survey period	Identifier	Lat	Long	Emerging bats counted
South	2018-06-17	Early	SHEC294	55.97412	-122.119	6
North	2018-06-19	Early	NHEC3b	55.98152	-122.117	3
North	2018-06-19	Early	NHEC1	55.98208	-122.116	3
North	2018-08-01	Late	NHEC3b	55.98152	-122.117	9
North	2018-08-02	Late	NHEC2	55.98178	-122.117	3
North	2019-06-09	Early	NHEC3b	55.98152	-122.117	4
North	2019-06-12	Early	north cliff	55.98124	-122.118	6
South	2020-06-22	Early	EC-DW1-062220	55.97324	-122.12	4
South	2020-06-22	Early	EC-JF1-062220	55.9746	-122.119	4
North	2020-06-24	Early	EC-JF3-062420	55.98199	-122.116	4
North	2020-06-24	Early	EC-FMN-200624	55.98169	-122.117	3
North	2020-06-25	Early	EC-DW4-062520	55.98174	-122.116	4
North	2020-06-25	Early	EC-JF4 062520	55.98171	-122.116	4
South	2020-06-27	Early	EC-DW6-062720	55.97321	-122.118	3
North	2020-07-17	Late	EC_JF04_071720_North Cliff	55.98211	-122.116	5
North	2020-07-17	Late	EC_FMN-NH	55.98158	-122.117	3
North	2020-07-18	Late	200728EC_FMN_NH	55.98159	-122.117	4
South	2021-06-18	Early	DW061821	55.97565	-122.117	3
South	2021-07-15	Late	DW071521	55.97316	-122.12	3
North	2021-07-18	Late	DW071821-NH	55.9819	-122.117	5
North	2021-07-18	Late	7/18/2021_BM_NH	55.98211	-122.116	6
South	2021-07-19	Late	7/19/2021_BM_sH	55.97577	-122.117	4

5.3 Long-term Passive Acoustic Monitoring

The results of the long-term passive acoustic monitoring for the years of 2020 and 2021 are presented in **Appendix D**. The cumulative results for 2017 to 2021 are provided below.

5.3.1 Cumulative Survey Effort and Results

The remote detectors on Portage Mountain have varied in number and dates of deployment. Equipment issues have also resulted in data gaps. A summary of cumulative survey effort (8 detectors) between 2017 and 2021 is presented in **Table 5.6**. The number of active detector nights per season and year is also available in **Appendix F**. The five permanent detectors recorded acoustic data on 5,447 detector-nights between August 21, 2017 and November 3, 2021 (**Table 5.6**).

Table 5.6 Remote Detector Survey Effort (Nights When Detectors Were Operating), 2017-2021

Detector	2017	2018	2019	2020	2021	Total Detector-nights
279-SH*	133	210	99	366	307	1,115
294-SH*	133	232	365	339	307	1,411
PM-C-NH*	85	223	249	342	307	1,264
PM-D-NH	126	-	-	-	-	126
PM-GULLY	-	-	-	11	-	11
PM-S3*	2	163	172	274	307	1,245
PM-TAL*	-	-	-	190	307	497
Total Detector-nights	**503**	**1,056**	**961**	**1,622**	**1,535**	**5,677**

*permanent detector

The timing of data gaps due to detector damage from rodents, power failures or other technical issues could affect the results of the analyses, especially if the gaps occurred during periods when high bat activity would have been expected. A summary of the data gaps by date is presented in **Table 5.7**, and a graphical representation of the gaps is presented in **Figure 5.1**.

Table 5.7 Timing of Data Gaps by Detector, 2017-2021

Detector	Data Gap	Gap Length (nights)
279-SH	Jul. 30, 2018 - Jul. 25, 2019	361
	Aug. 23, 2019 – Oct. 21, 2019	60
294-SH	Feb. 3, 2018 – Apr. 8, 2018	65
	Jul. 30, 2018 – Oct. 5, 2018	68
	Jun. 22, 2020 – Jul. 18, 2020	27
PMC-NH	Nov. 14, 2017 – Jan. 18, 2018	66
	Feb. 8, 2018 – Apr. 6, 2018	58
	Aug. 1, 2018 – Oct. 5, 2018	66
	Apr. 16, 2019 – Jun. 10, 2019	56
	Aug. 23, 2019 – Oct. 21, 2019	60
	Jun. 24, 2020 – Jul. 17, 2020	24
PM-GULLY	Jul. 1, 2020 – Jul. 8, 2020	8

Detector	Data Gap	Gap Length (nights)
PM-S3	Dec. 7, 2017 – Dec. 30, 2017	24
	Jan. 1, 2018 – Feb. 1, 2018	32
	Feb. 3, 2018 – Feb. 22, 2018	20
	Feb. 24, 2018 – Mar. 21, 2018	26
	Mar. 23, 2018 – Apr.13, 2018	22
	Apr. 15, 2018 – May 23, 2018	39
	Sep. 8, 2018 – Oct. 5, 2018	28
	Nov. 26, 2018 – Dec. 17, 2018	22
	Dec. 19, 2018 – Jan. 14, 2019	27
	Jan. 16, 2019 – Mar. 18, 2019	62
	Apr. 15, 2019 – Jun. 9, 2019	56
	Aug. 23, 2019 – Oct. 22, 2019	61
	Jan. 4, 2020 – Jan. 25, 2020	22
	Jan. 27, 2020 – Apr. 5, 2020	70

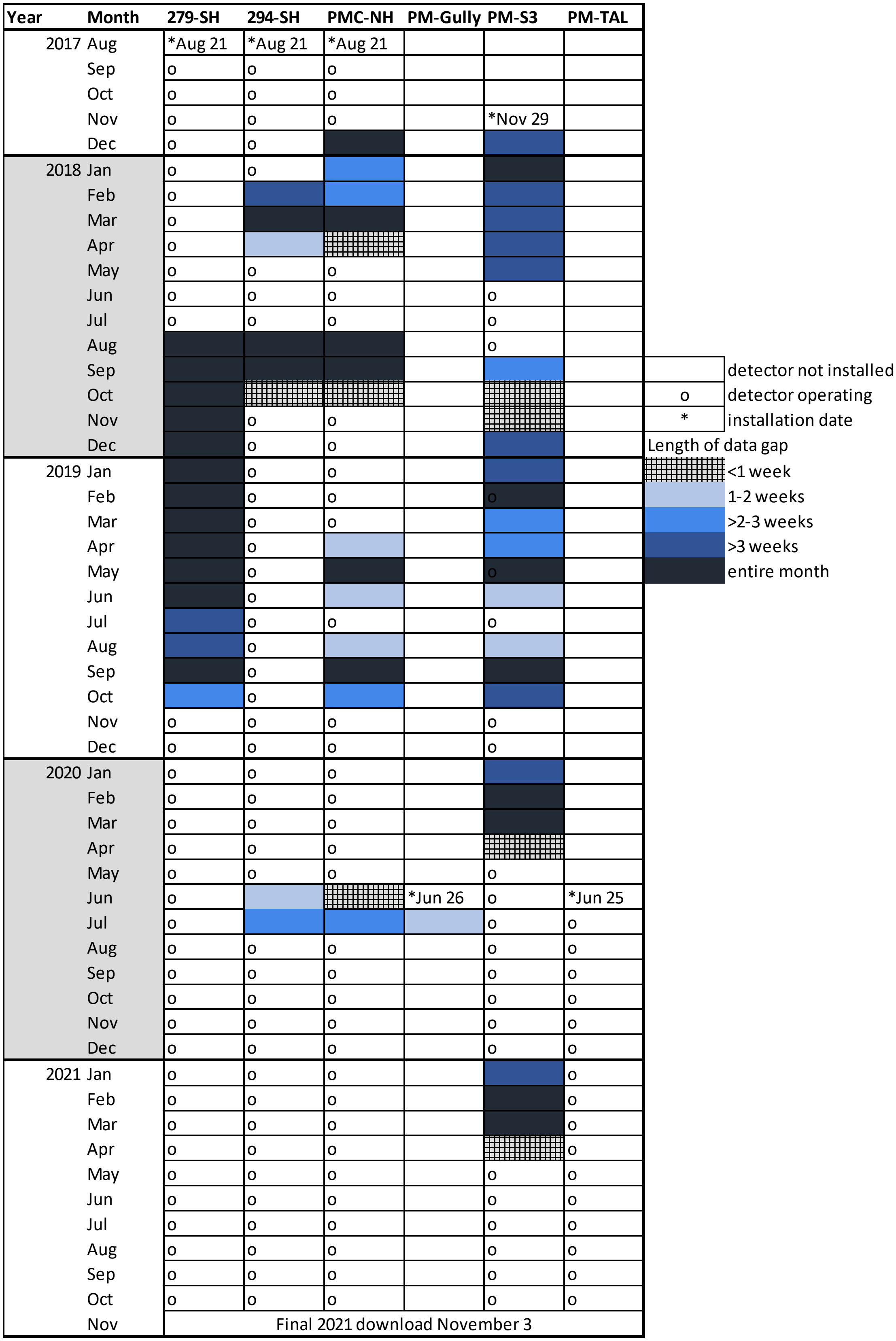

Figure 5.1 Graphical Representation of Detector Data Gaps

In total, over 300,000 bat calls were identified from the detector recordings between late summer 2017 and fall 2021 (**Table 5.8**). **Table 5.9** presents the number of files per detector-night for each identification category between 2017 and 2021. No measure of variation has been calculated because many of the categories overlap, depending on the quality of the file. All of the species expected, with the exception of long-legged myotis, have been detected every year.

Table 5.8 Numbers of Bat Files by Detector (Excluding Social Calls), 2017-2021

Year	279-SH	294-SH	PM-C-NH	PM-D-NH	PM-E-NH	PM-GULLY	PM-S3	PM-TAL	Grand Total
2017	17,464	4,786	-	2,631	13,276	-	3	-	38,160
2018	10,043	3,658	10,899	-	-	-	2,378	-	26,978
2019	11,557	6,232	12,945	-	-	-	2,118	-	32,852
2020	51,210	14,141	22,104	-	-	123	9,049	5,055	101,682
2021	48,765	26,294	31,927	-	-	-	21,295	10,901	139,182
Total	**139,039**	**55,111**	**77,875**	**2,631**	**13,276**	**123**	**34,843**	**15,956**	**338,854**

Table 5.9 Files per Detector-Night by Identification Category (Excluding Social Calls), 2017-2021

Identification category	2017	2018	2019	2020	2021
Low-frequency bat	2.392	2.250	2.020	0.700	6.466
High-frequency bat	0.000	0.003	0.185	0.000	0.001
Hoary bat	0.700	0.097	0.068	0.080	0.329
Big brown bat	2.903	2.005	1.165	2.184	2.318
Big brown bat / silver-haired bat	8.624	4.054	4.462	12.711	13.734
Silver-haired bat	0.398	0.009	0.360	0.224	0.550
Eastern red bat	0.034	0.035	0.106	0.066	0.128
Red bat / little brown myotis	0.014	0.020	0.776	0.361	0.262
Little brown myotis	0.177	0.292	0.764	0.699	0.460
Long-eared myotis	0.082	0.350	0.893	5.462	4.960
Long-legged myotis	0	0	0	0	0
Northern myotis	0.056	0.102	0.157	0.205	0.218
Myotis	60.487	16.332	23.228	40.938	62.870

5.3.2 Bat Life Stages

Based on the number of calls in spring and autumn, the date at which bat emergence started and ended varied from 2018 to 2021 but hibernation consistently started September 22 for most years, except in 2018 when it started two weeks later on October 6 (**Table 5.10**).

Table 5.10 Yearly Bat Life Stages for *Myotis* sp. Bats at Portage Mountain

Year	Emergence start*	Summer start*	Swarming start*	Swarming end*	Hibernation start
2017	NA	NA	NA	NA	22/09/2017
2018	16/04/2018	19/04/2018	NA	NA	06/10/2018
2019	11/04/2019	18/04/2019	None	None	22/09/2019
2020	11/04/2020	19/04/2020	None	None	22/09/2020
2021	09/04/2021	13/04/2021	02/09/2021	21/09/2021	22/09/2021

*NA indicates insufficient data to calculate a period. None indicates that there was no increase in activity to identify a swarming period.

Insufficient detector data were available in 2017 and 2018 during the months of August and September to estimate a swarming period for those years. Using data from July 15 - September 30 in 2019, 2020, 2021 we fit a non-linear curve to the number of Myotis calls per active detector-night to estimate swarming life stage in each year. In 2019, the best fit curve was a Weibull 5-parameter equation, however the model fit was moderate (R^2= 0.54, **Figure 5.2**). Using this equation, a peak in activity was estimated to have occurred in 2019 from July 20 to August 22, which likely coincides with the juvenile flight period and is too early to be considered a swarming period. There was no later peak in activity that occurred in 2019 and thus swarming was not detected in 2019. In 2020, there was no peak in activity to suggest that swarming occurred at either the south or north cliffs of the study area (**Figure 5.3**). A modified Gaussian 5 parameter equation was the best fit of the equations tested, but the fit (R^2=0.35) was poor. In 2021 a peak in activity occurred (**Figure 5.4**, **Table 5.10**), suggesting a swarming period may have occurred in the study area in that year. A modified Gaussian 5-parameter equation was the best fit (R^2=0.51) of the non-linear equations tested on the 2021 data, although the fit was only moderate. Based on predicted values from the best fit equation, the swarming period in 2021 is estimated to have started September 2 and ended September 21 (**Table 5.10)**.

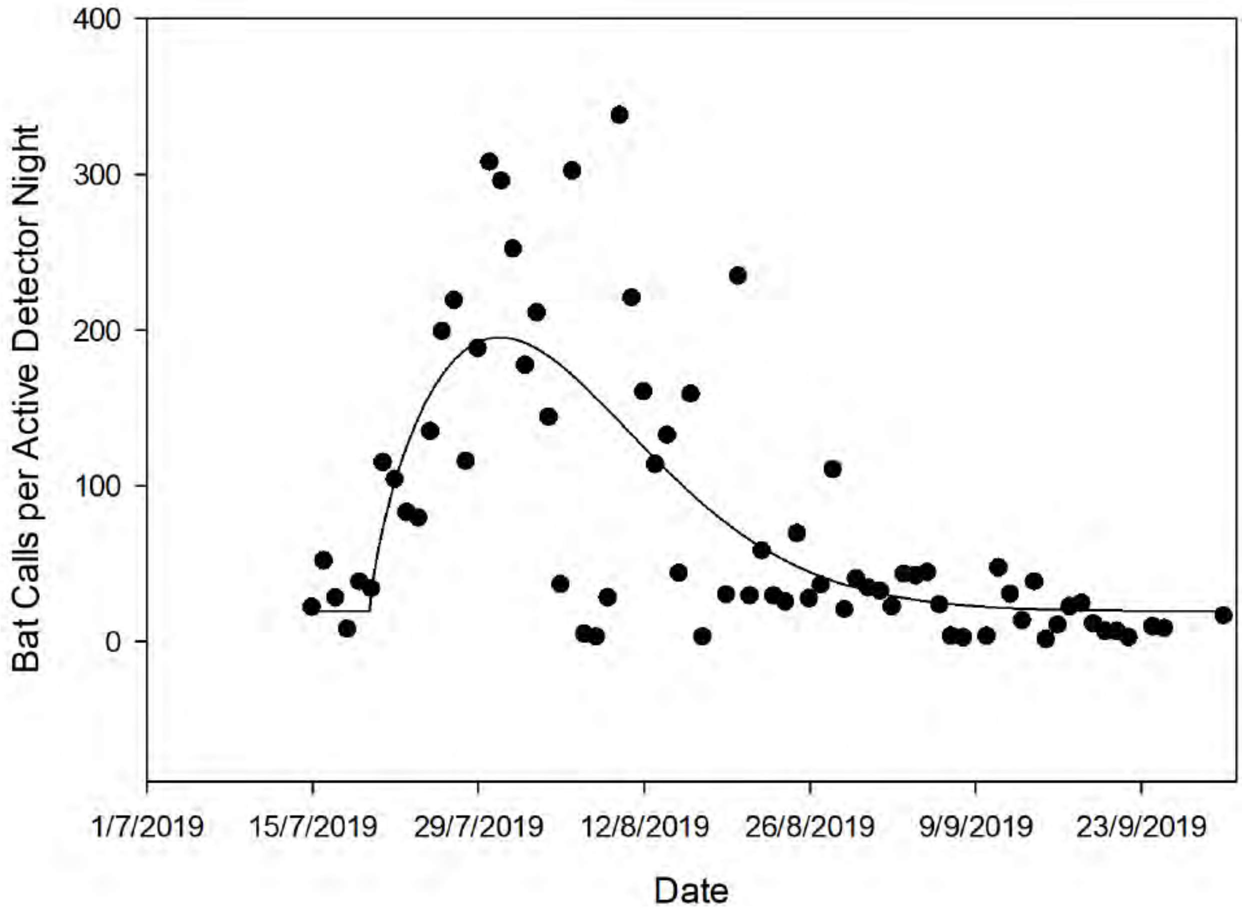

Figure 5.2 Myotis Calls from July 15 to September 30, 2019 with a Modified Gaussian 4-Parameter Bell Curve to Predict a Peak In Calls During the Swarming Period

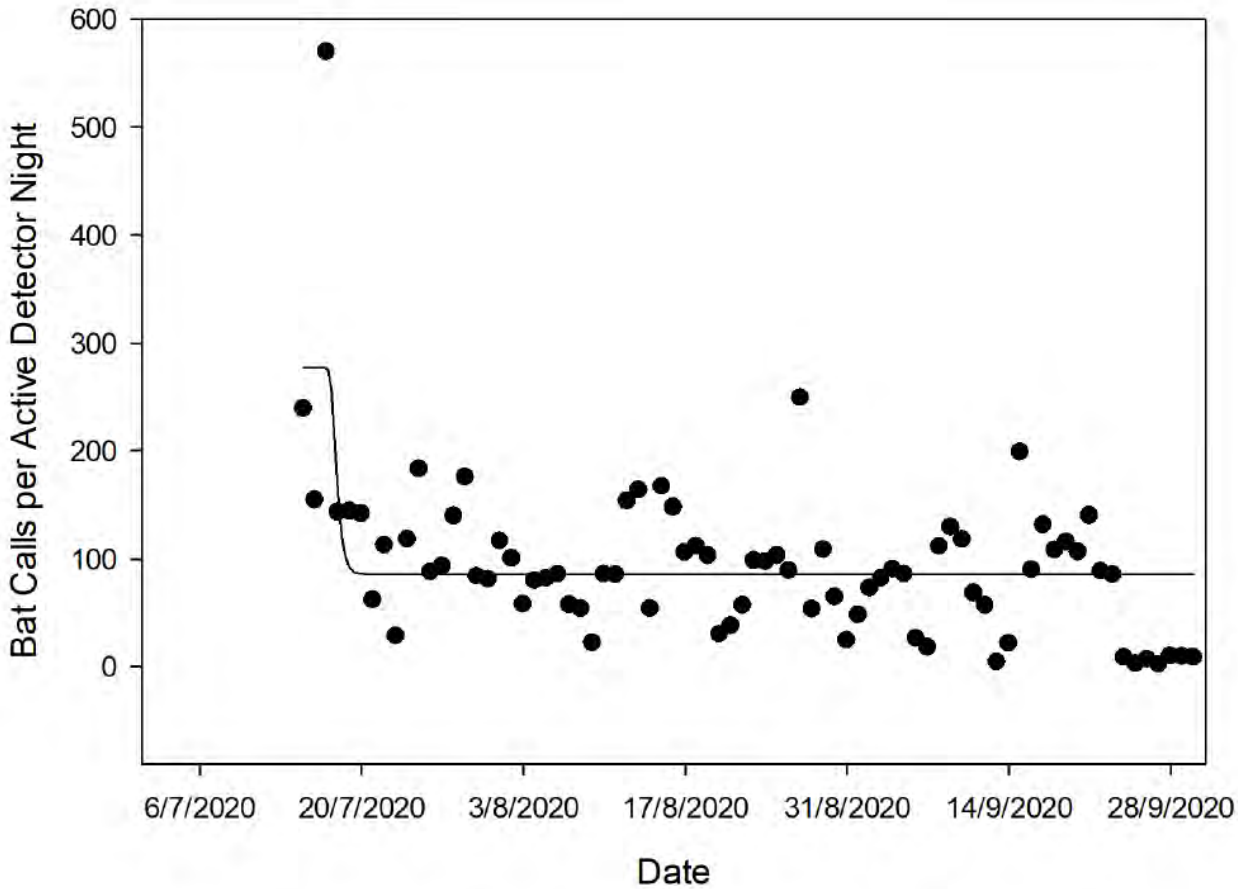

Figure 5.3 Myotis Calls from July 15 to September 30, 2020 with a Modified Gaussian 5-Parameter Bell Curve to Predict a Peak in Calls During the Swarming Period

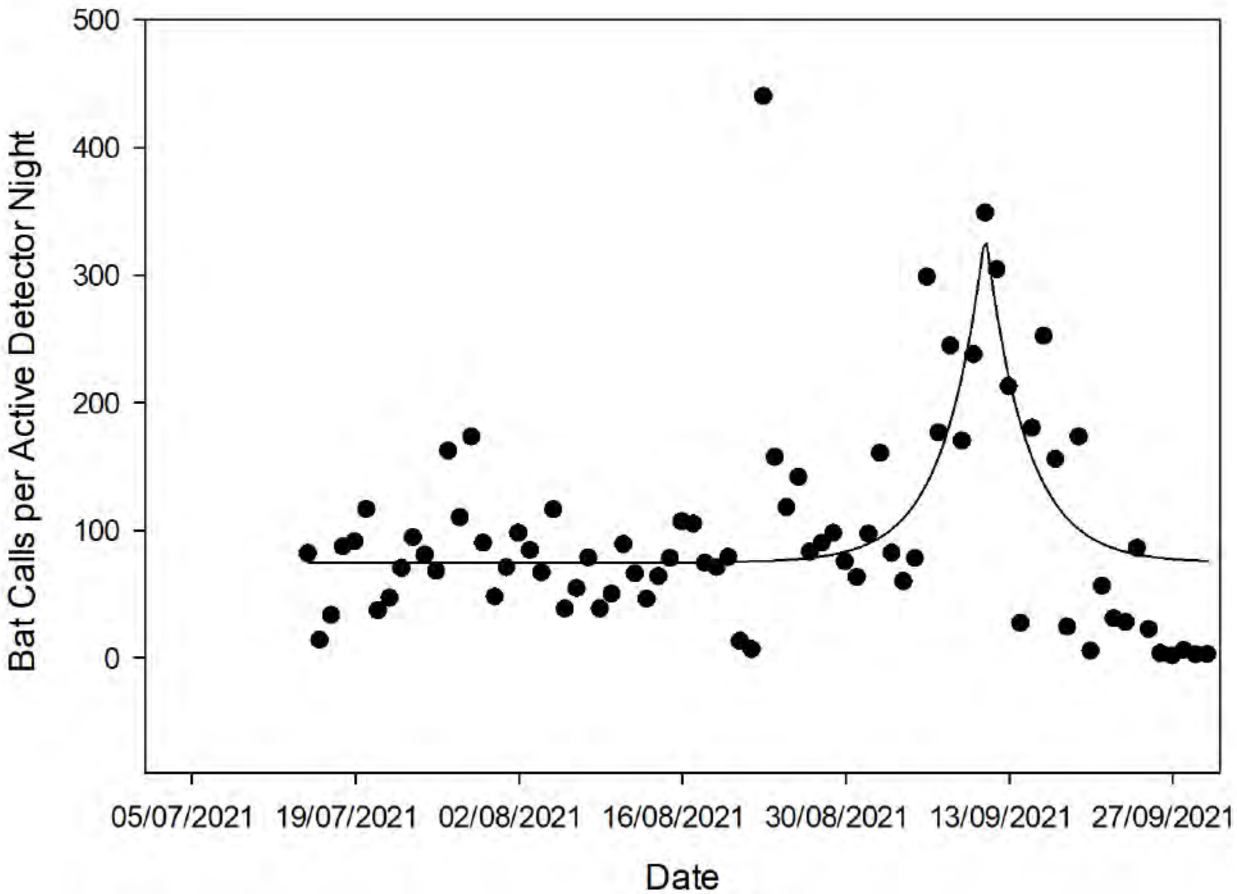

Figure 5.4 Myotis Calls from July 15 to September 30, 2021 with a Modified Gaussian 5-Parameter Bell Curve to Predict a Peak in Calls During the Swarming Period

A summary of bat activity by life stage and detector over all years is presented in **Table 5.11**. Standard deviations have not been provided as that measure of variation is based on the normal distribution and the data are not normally distributed.

The highest numbers of files recorded during all life stages were recorded at 279-SH, the detector located furthest from the quarry (**Figure 2.1**). Due to a lack of detectible swarming in 2019 and 2020 and insufficient data in 2017 and 2018, the fall period was defined as September 1 to the start of hibernation (**Table 5.10**) and this was applied to all years.

Table 5.11 Comparison of Bat Activity by Life Stage and Detector between Late Summer 2017 and Fall 2021

Detector	Bat life stage*	Total files	Active detector-nights	Files per detector-night
279-SH (south cliff)	emergence	628	15	41.87
	summer	102,008	417	244.62
	fall	32,933	84	392.06
	hibernation	3,698	599	6.17
294-SH (south cliff)	emergence	156	23	6.78
	summer	39,017	497	78.51
	fall	14,065	112	125.58
	hibernation	2,221	744	2.99
PM-C-NH (quarry)	emergence	58	20	2.90
	summer	58,487	440	132.93
	fall	30,242	84	360.02
	hibernation	2,429	662	3.67
PM-D-NH (north cliff)	summer	1,096	11	99.64
	fall	1,326	28	47.36
	hibernation	212	87	2.44
PM-GULLY	summer	123	11	11.18
PM-S3 (north cliff)	emergence	31	16	1.94
	summer	21,965	450	48.81
	fall	12,354	63	196.10
	hibernation	686	389	1.76
PM-TAL (north cliff)	emergence	4	4	1.00
	summer	13,065	209	62.51
	fall	2,317	56	41.38
	hibernation	706	228	3.10

*Bat life stage dates were based on Myotis activity but files are from all bat species detected.

5.3.2.1 Emergence from Hibernation

Emergence began consistently in the first or second week of April between 2018 and 2021 (**Table 5.10**), although data were limited by detector failures during April of 2018 and 2018 (**Figure 5.1**). The highest numbers of files per detector-night during the emergence period were recorded at the south cliff detectors 279-SH (**Table 5.11**) and 294-SH, with relatively little activity at the quarry detector (PM-C-NH) and north cliff detector (PM-S3 and PM-TAL).

The summer period also began consistently in mid-April (**Table 5.10**) within a few days of the start of emergence, indicating a swift increase in bat activity immediately after emergence. Summer activity was highest at 279-SH at the south cliff, followed by the quarry detector PM-C-NH and the other south cliff detector 294-SH.

5.3.2.2 Fall

Swarming was only detected in 2021 (**Table 5.10**). There was insufficient fall data in 2017 and 2018 due to detector failures (**Figure 5.1**) to assess for a peak in activity. In 2019 and 2020 no peak in activity was detected (**Figure 5.2 and Figure 5.3**). However, it's possible that detector failures (**Figure 5.1**) in 2019 contributed to a lack in our ability to detect swarming at Portage Mountain in that year as only one detector (294-SH) was active for the months of August and September and it's possible that bats did not swarm near this detector. Swarming in 2021 began September 2 and lasted just under two weeks. The highest cumulative levels of activity during fall were recorded at 279-SH on the south cliff and PMC-NH on the north cliff.

Social calls have been recorded by the Portage Mountain detectors as early as July, but most of the social calls recorded between 2017 and 2021 were from mid-August to late September, with the latest social call recorded in early October. Most of these social calls are probably emitted by big brown bat or silver-haired bat based on the call parameters (minimum frequency 23 to 27 kHz) and several characteristic search-phase big brown bat/ silver-haired bat calls recorded within seconds of when social calls were recorded. Social calls have been recorded every year between late summer 2017 and fall 2021.

5.3.2.3 Hibernation

September data were limited by detector failures in 2018 and 2019 (**Figure 5.1**). Hibernation began consistently on September 22 during 2017, 2019, 2020 and 2021, but in 2018 began two weeks later on October 6 (**Table 5.10**). Detector 279-SH recorded the highest cumulative activity during hibernation (6.17 files per detector-night (**Table 5.11**), nearly twice the number of files per detector-night recorded during hibernation than the detector with the next greatest number of files (PM-C-NH).

Some bat activity was recorded during the coldest months of the year (December, January, and February). Files identified as big brown bat or silver-haired bat were recorded during those months during all years but Myotis activity was not recorded during those periods (**Table 5.12**).

Table 5.12 Number of Files Recorded per Detector-night during December, January and February 2017 to 2021

Year	30K	Big brown bat	Big brown bat / silver-haired bat	Low-frequency bat	Myotis	Grand total
2017-2018	0	0.0571	0.3429	0.1143	0.000	0.5143
2018-2019	0	0.0000	0.5000	0.0000	0.0000	0.5000
2019-2020	0.0333	0.0167	0.3083	0.1667	0.0000	0.5250
2020-2021	0.0020	0.0143	0.3449	0.1388	0.0000	0.5000
Grand Total	**0.0073**	**0.0190**	**0.3397**	**0.1399**	**0.0000**	**0.5109**

5.3.3 Cumulative Trends in Bat Activity

5.3.3.1 Yearly Activity

There were only 78 active detector-nights in the emergence period between 2018 and 2021, which was insufficient to model yearly bat activity in the emergence period and as a result, the Year model failed to converge due to insufficient data (**Table 5.13**).

The Year model converged during the summer, fall, and hibernation periods (**Table 5.14,Table 5.15,Table 5.16**) and all models had sufficiently low overdispersion ratios to produce reliable results: the ratio of the Pearson x^2 to the model degrees of freedom was <3 (Payne et al. 2018) for all models. During summer, fall, and hibernation, the Year model was the top model based on AIC score and weight (**Table 5.14,Table 5.15,Table 5.16**). The Year model therefore explains more of the data than the base and null models.

Summer activity showed a statistically significant decline in 2018 relative to 2017, as well as an apparent decline in 2019 and 2020 and an increase in 2021 that were not statistically significant relative to 2017 (**Table 5.17, Figure 5.5**). Note that **Figure 5.5** does not account for differences in weather between years, but modelling results do. Fall activity showed statistically significant declines in 2018 and 2019 relative to 2017, and a statistically significant increase in 2021 relative to 2017 (**Table 5.18, Figure 5.5**). During hibernation, bat activity showed a statistically significant decline in 2018, 2019 and 2021 relative to 2017 and an apparent decline in 2020 that was not statistically significant (**Table 5.19, Figure 5.5**). Bat activity in all life stages increased with the average nightly temperature, and in summer and fall, bat activity decreased with the total amount of precipitation. During hibernation, bat activity increased with precipitation, but this is because the amount of precipitation does not include snow and therefore any rainfall would have been related to warmer temperatures (**Table 5.19**).

Table 5.13 Model Selection Results for Emergence Bat Activity Models at Portage Mountain with Number of Parameters (K), Log-Likelihood (LL), and Akaike's Information Criterion (AIC) Score and Weight for each Model

Emergence models	K	LL	AIC	AIC weight
Null: total bat calls per night ~ 1 + 1| Area/ Detector ID	4	-206.45	420.91	0.00
Base: total bat calls per night ~ mean temperature + precipitation + 1| Detector ID	5	-197.67	405.33	1.00
Year: total bat calls per night ~ year + mean temperature + precipitation + 1| Detector ID	8	-	-	-

Table 5.14 Model Selection Results for Summer Bat Activity Models at Portage Mountain with Number of Parameters (K), Log-Likelihood (LL), and Akaike Information Criterion (AIC) Score and Weight for each Model

Summer models	K	LL	AIC	AIC weight
Null: total bat calls per night ~ 1 + 1|Detector ID	3	-11,089.37	22,184.74	0.00
Base: total bat calls per night ~ mean temperature + precipitation + 1| Detector ID	5	-10,947.61	21,905.22	0.00
Year: total bat calls per night ~ year + mean temperature + precipitation + 1| Detector ID	9	-10,840.55	21,699.10	1.00

Table 5.15 Model Selection Results for Fall Bat Activity Models at Portage Mountain with Number of Parameters (K), Log-Likelihood (LL), and Akaike Information Criterion (AIC) Score and Weight for each Model

Fall models	K	LL	AIC	AIC weight
Null: total bat calls per night ~ 1 + 1|Detector ID	4	-2,623.36	5,254.73	0.00
Base: total bat calls per night ~ mean temperature + precipitation + 1| Detector ID	5	-2,595.79	5,201.58	0.00
Year: total bat calls per night ~ year + mean temperature + precipitation + 1| Detector ID	9	-2,560.93	5,139.87	1.00

Table 5.16 Model Selection Results for Hibernation Bat Activity Models at Portage Mountain with Number of Parameters (K), Log-Likelihood (LL), and Akaike Information Criterion (AIC) Score and Weight for each Model

Hibernation models	K	LL	AIC	AIC weight
Null: total bat calls per night ~ 1 + 1|Detector ID	3	-5216.80	10439.60	0.00
Base: total bat calls per night ~ mean temperature + precipitation + 1| Area/Detector ID	6	-4829.45	9670.90	0.00
Year: total bat calls per night ~ year + mean temperature + precipitation + 1| Detector ID	10	-4783.96	9587.91	1.00

Table 5.17 Model* of Yearly Bat Activity during the Summer Period at Portage Mountain

Variable	Coefficient estimate	Standard error	z value	Lower 95% C.I.	Upper 95% C.I.
Intercept	**3.66**	0.31	11.62	3.04	4.27
Year 2018	**-1.01**	0.21	-4.83	-1.42	-0.60
Year 2019	-0.39	0.21	-1.83	-0.80	0.03
Year 2020	-0.02	0.21	-0.10	-0.43	0.39
Year 2021	0.23	0.21	1.10	-0.18	0.63
Mean temperature	**1.01**	0.07	14.78	0.87	1.14
Total precipitation	**-0.42**	0.03	-15.67	-0.48	-0.37

* Model based on data from 6 detectors at 3 areas. The reference year was 2017. Coefficients in bold are statistically significant.

Table 5.18 Model* of Yearly Bat Activity during the Fall Period at Portage Mountain

Variable	Coefficient estimate	Standard error	z value	Lower 95% C.I.	Upper 95% C.I.
Intercept	**4.30**	0.39	11.08	3.54	5.06
Year 2018	**-1.09**	0.55	-1.99	-2.16	-0.01
Year 2019	**-1.88**	0.24	-7.69	-2.35	-1.40
Year 2020	-0.06	0.15	-0.43	-0.35	0.22
Year 2021	**0.37**	0.15	2.47	0.08	0.66
Mean temperature	**0.73**	0.17	4.21	0.39	1.07
Total precipitation	**-0.30**	0.05	-6.38	-0.39	-0.21

*Model based on data from 6 detectors at 3 areas. The reference year was 2017. Coefficients in bold are statistically significant.

Table 5.19 Model of Yearly Bat Activity during the Hibernation Period at Portage Mountain

Variable	Coefficient estimate	Standard error	z value	Lower 95% C.I.	Upper 95% C.I.
Intercept	**1.78**	0.21	8.58	1.37	2.18
Year 2018	**-0.58**	0.15	-3.86	-0.87	-0.29
Year 2019	**-1.10**	0.15	-7.47	-1.38	-0.81
Year 2020	-0.14	0.13	-1.07	-0.40	0.12
Year 2021	**-0.65**	0.14	-4.56	-0.93	-0.37
Mean temperature	**1.24**	0.05	27.49	1.15	1.33
Total precipitation	**0.18**	0.03	5.97	0.12	0.24

*Model based on data from 6 detectors at 3 areas. The reference year was 2017. Coefficients in bold are statistically significant.

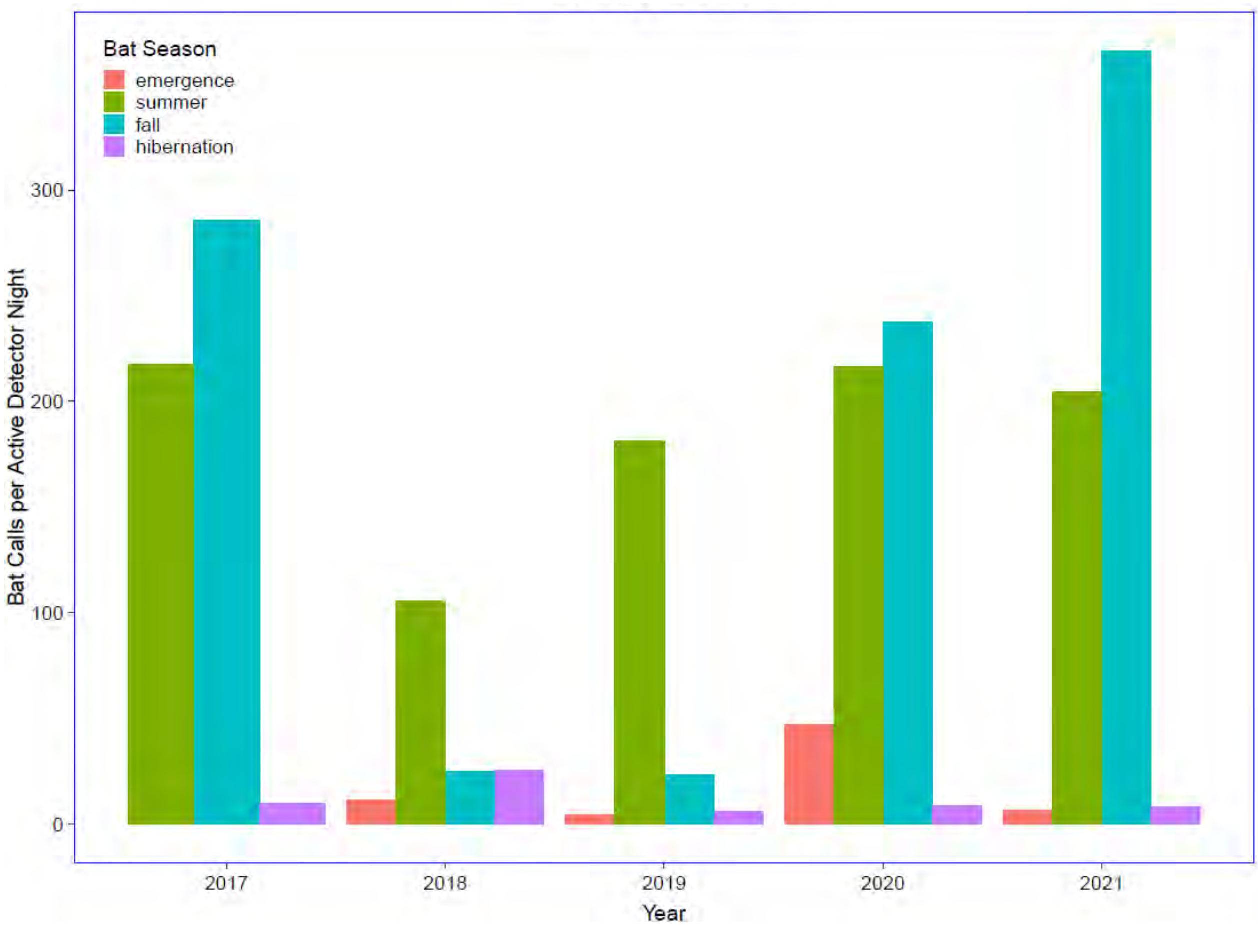

Figure 5.5 Yearly Bat Activity by Bat Life Stage at Portage Mountain

During summer and fall, the Blast model was the top AIC model as compared to the null and base models (**Table 5.20-Table 5.21**). In summer, bat acoustic activity showed a statistically significant positive relationship with blasting occurrence (**Table 5.22**). However, this effect disappears if the year 2018, which only included 5 blasts, is dropped from the data: blast becomes a non-significant model variable and the base model is the top AIC model (**Appendix G**). Bat activity showed a statistically significant negative relationship to blasting occurrence during the fall period (**Table 5.23**).

Graphs of bat calls per active detector-night plotted with blasting dates and temperature for years 2018-2021 are available in **Figure 5.6, Figure 5.7, Figure 5.8,** and **Figure 5.9**. Trends relative to blast dates are difficult to discern due to natural variability in the data but there does appear to be an associated decline in fall bat activity in 2019 and potentially in July of 2019 (**Figure 5.7**). In contrast, during summer and fall of 2020 blasting occurred on a near daily basis and a trend in bat activity is not easily observed (**Figure 5.8**). In 2021, the numbers of bat calls appear to be relatively low when blasting occurred compared to time intervals when there was no blasting (April to early May and mid-August to October) (**Figure 5.9**). Compared to 2019 and 2020, when blasting took place in early September, 2021 was the only year where blasting did not occur during the month of September and was also the only year in which a swarming period was identified.

Table 5.20 Model Selection Results for Summer Bat Activity Models at Portage Mountain with Number of Parameters (K), Log-Likelihood (LL), and Akaike Information Criterion (AIC) Score and Weight for each Model.

Summer models	K	LL	AIC	AIC weight
Null: total bat calls per night ~ 1 + 1|Detector ID	3	-10,805.56	21,617.11	0.00
Base: total bat calls per night ~ mean temperature + precipitation + 1| Detector ID	5	-10,666.08	21,342.15	0.00
Blast: total bat calls per night ~ blast + mean temperature + precipitation + 1| Detector ID	6	-10,654.42	21,320.85	1.00

Table 5.21 Model Selection Results for Fall Bat Activity Models at Portage Mountain with Number of Parameters (K), Log-Likelihood (LL), and Akaike Information Criterion (AIC) Score and Weight for each Model.

Fall Models	K	LL	AIC	AIC weight
Null: total bat calls per night ~ 1 + 1|Detector ID	4	-1921.68	3,851.35	0.00
Base: total bat calls per night ~ mean temperature + precipitation + 1| Detector ID	5	-1901.38	3,812.76	0.08
Blast: total bat calls per night ~ blast + mean temperature + precipitation + 1| Detector ID	6	-1897.88	3,807.75	0.92

Table 5.22 Model of Bat Activity in Response to Blasting During the Summer Period at Portage Mountain, Based on Data from 5 Detectors at 3 Areas

Variable	Coefficient estimate	Standard error	z value	Lower 95% C.I.	Upper 95% C.I.
Intercept	**3.68**	0.27	13.80	3.16	4.21
Blast	**0.29**	0.06	4.80	0.17	0.40
Mean temperature	**0.75**	0.07	11.02	0.62	0.88
Total precipitation	**-0.43**	0.03	-16.13	-0.48	-0.37

Table 5.23 Model of Bat Activity in Response to Blasting During the Fall Period at Portage Mountain, Based on Data from 5 Detectors at 3 Areas

Variable	Coefficient estimate	Standard error	z value	Lower 95% C.I.	Upper 95% C.I.
Intercept	**4.49**	0.39	11.56	3.73	5.25
Blast	**-0.58**	0.21	-2.81	-0.98	-0.18
Mean temperature	**0.97**	0.26	3.74	0.46	1.48
Total precipitation	**-0.35**	0.04	-8.29	-0.44	-0.27

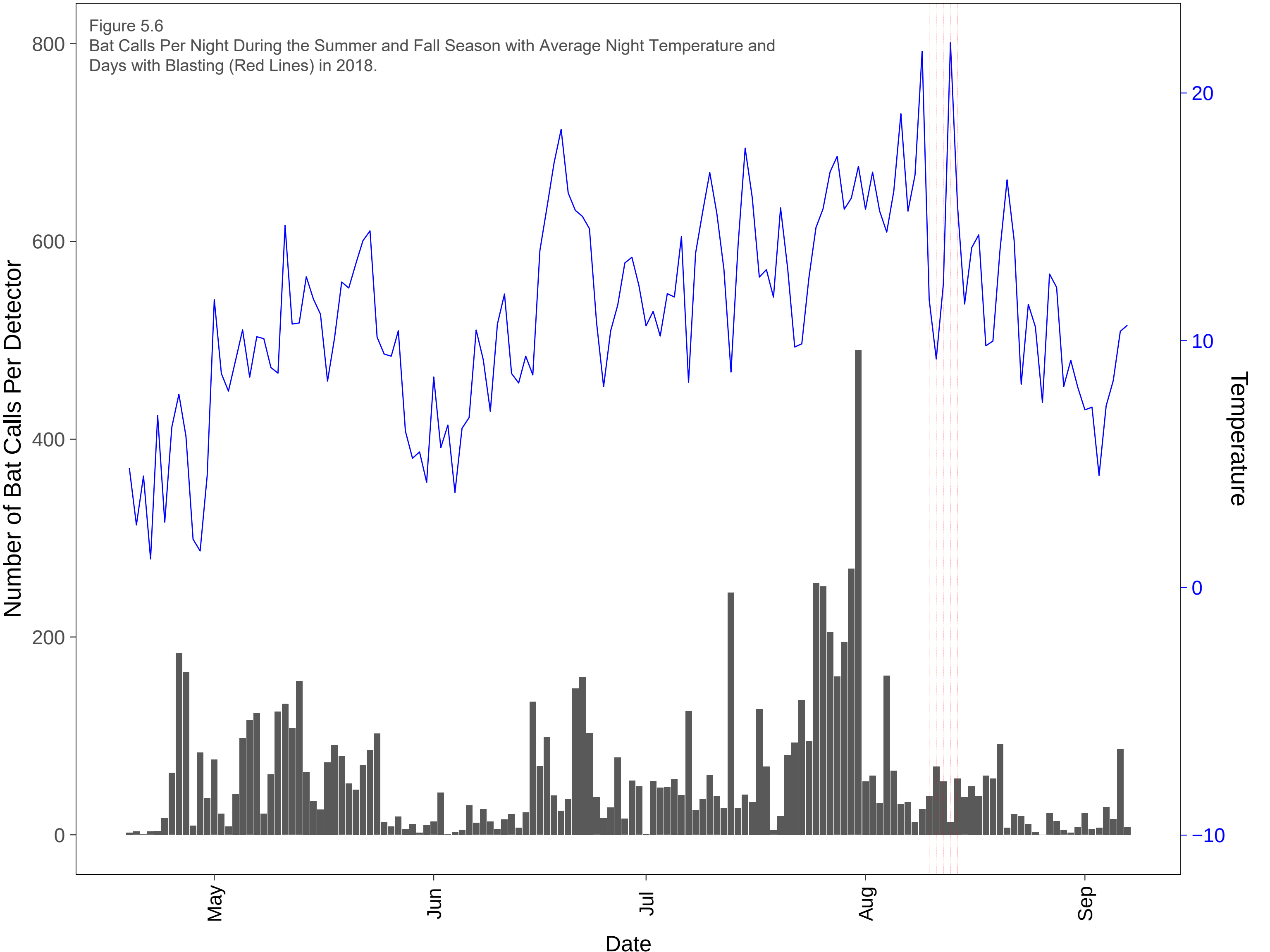
Figure 5.6
Bat Calls Per Night During the Summer and Fall Season with Average Night Temperature and
Days with Blasting (Red Lines) in 2018.
Number of Bat Calls Per Detector
800
600
400
200
0
Temperature
20
10
0
−10
May
Jun
Jul
Aug
Sep
Date

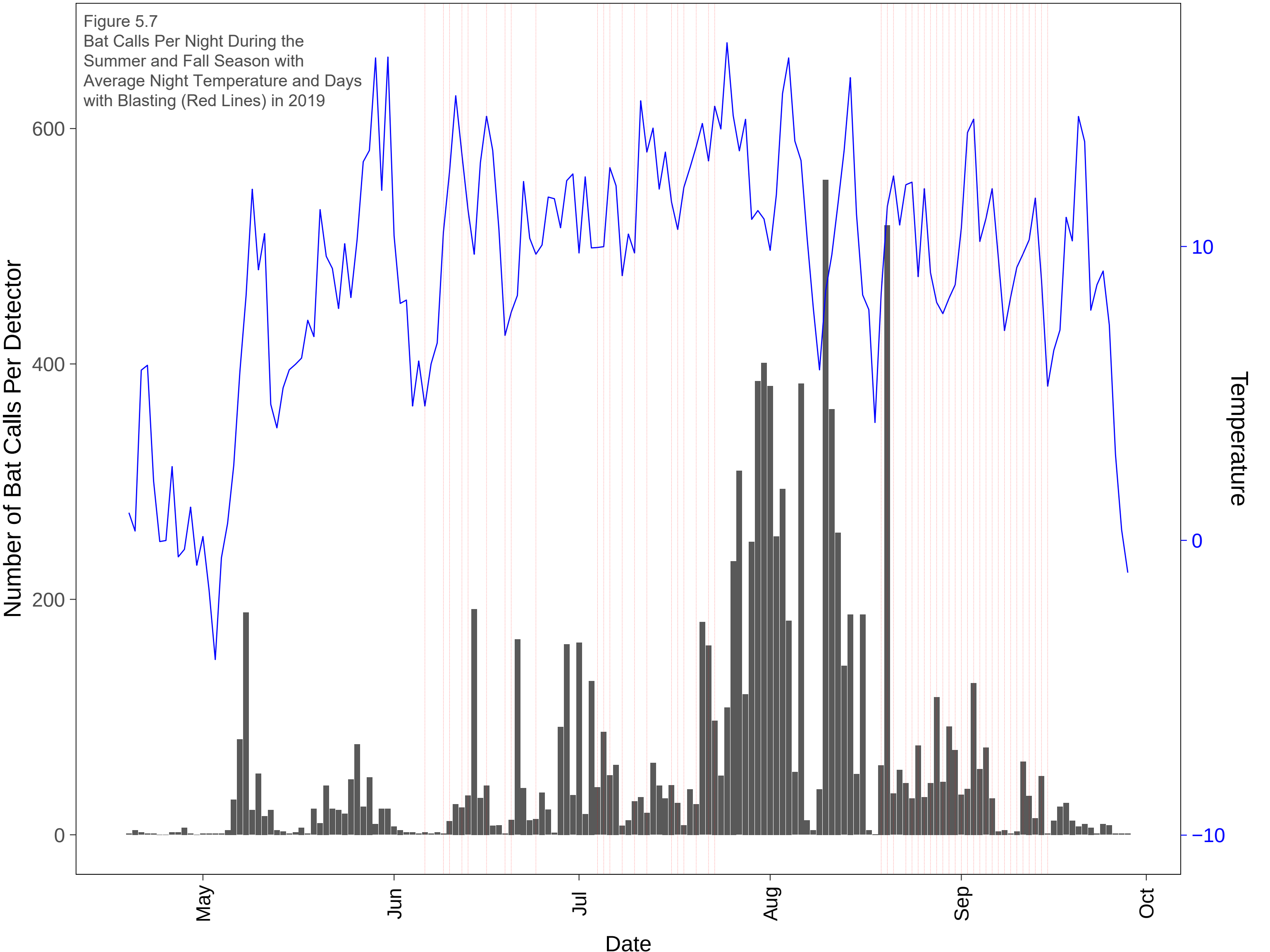
Figure 5.7
Bat Calls Per Night During the
Summer and Fall Season with
Average Night Temperature and Days
with Blasting (Red Lines) in 2019
Number of Bat Calls Per Detector
600
400
200
0
Temperature
10
0
−10
May
Jun
Jul
Aug
Sep
Oct
Date

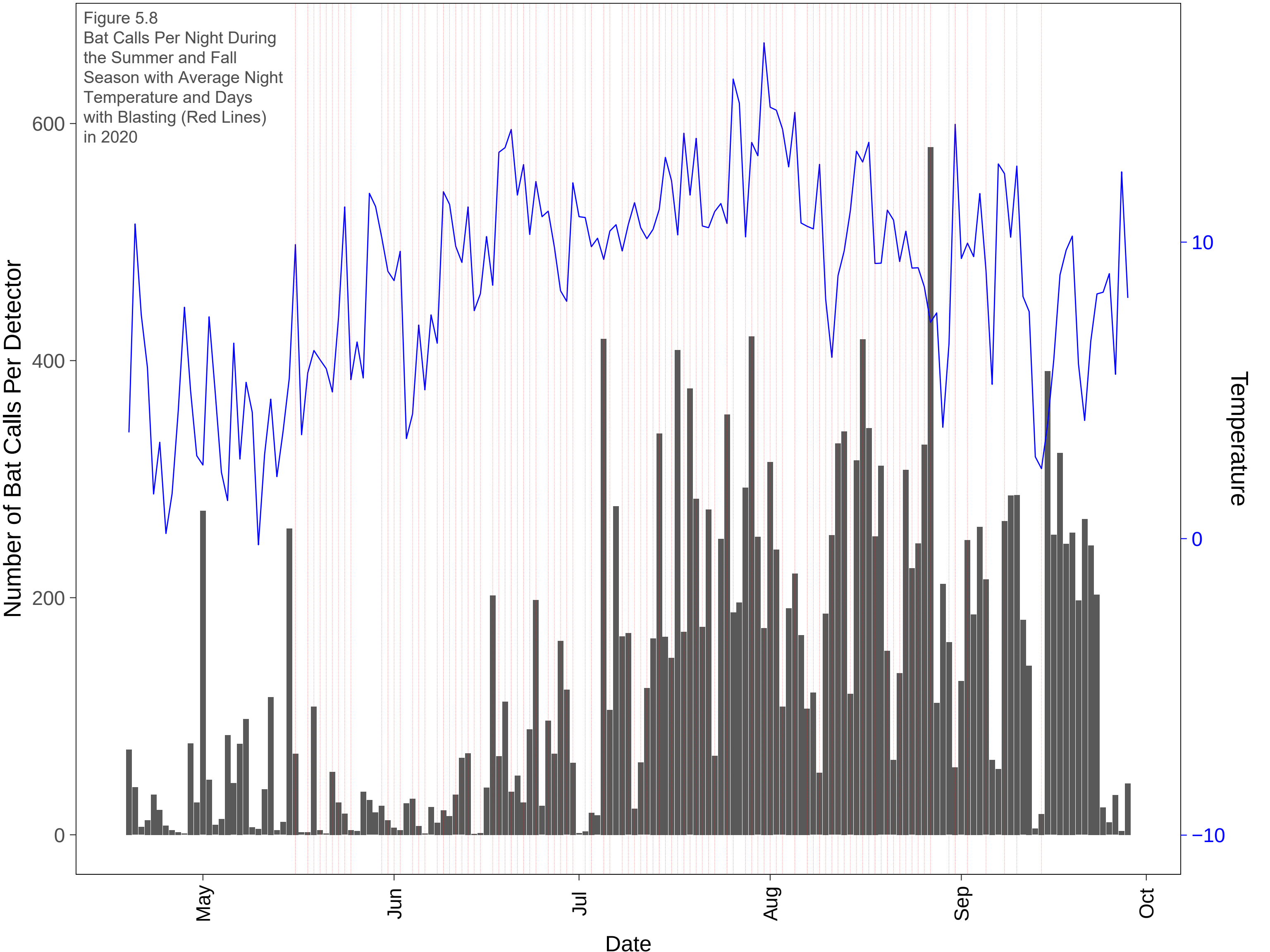
Figure 5.8
Bat Calls Per Night During the Summer and Fall Season with Average Night Temperature and Days with Blasting (Red Lines) in 2020
Number of Bat Calls Per Detector
0
200
400
600
Temperature
10
0
−10
May
Jun
Jul
Aug
Sep
Oct
Date

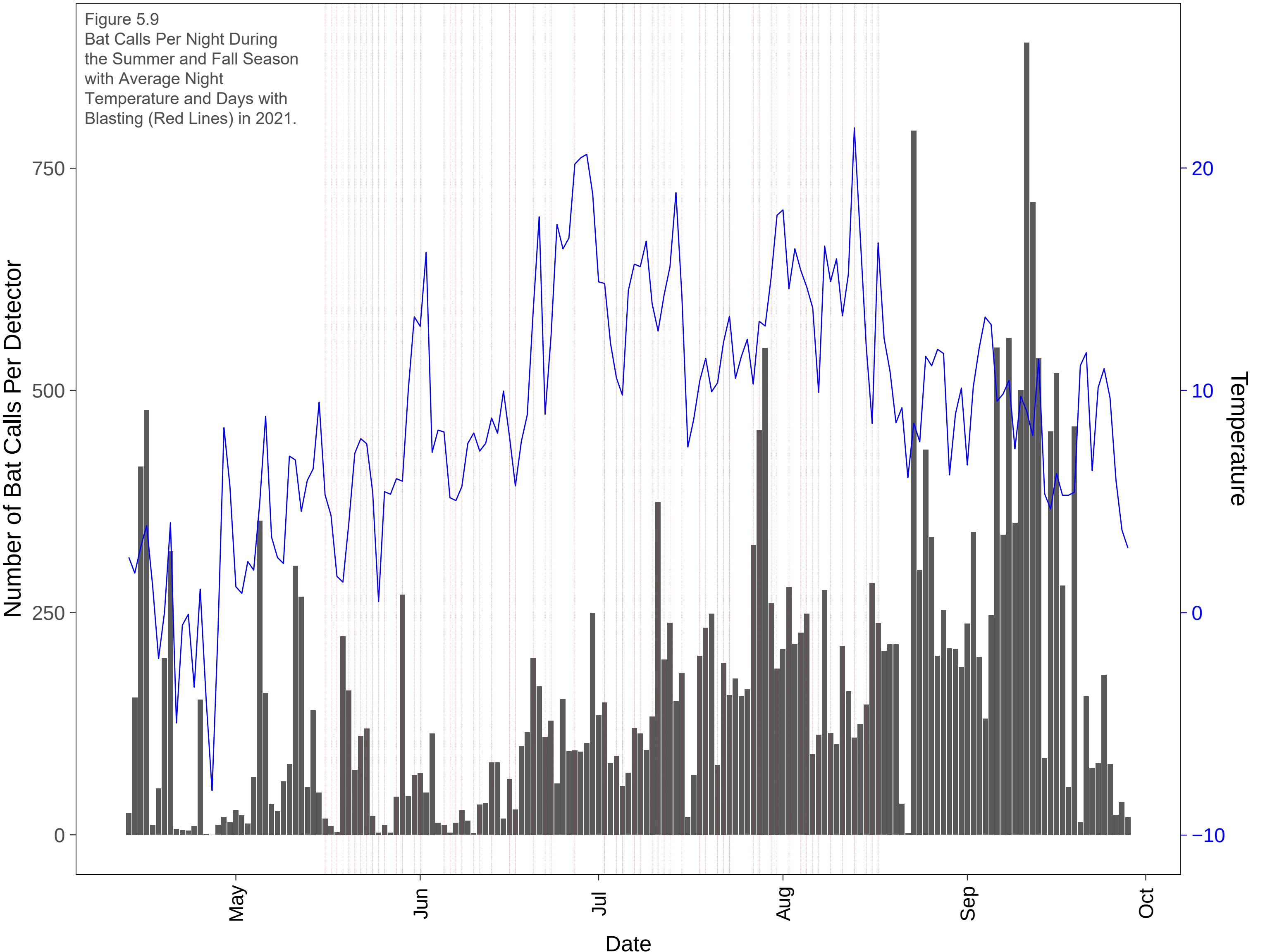

Figure 5.9
Bat Calls Per Night During the Summer and Fall Season with Average Night Temperature and Days with Blasting (Red Lines) in 2021.

6.0 DISCUSSION

6.1 Maternity Roost Monitoring

Maternity roost monitoring was conducted during the period when bats generally give birth; between June and July (BC Ministry of Environment 2016b). Bats were observed exiting the previously identified roost 9427G (Hemmera 2020) on the south cliff during emergence count surveys in 2020 and 2021 (**Section 5.2.1; Appendix D**). Early emergence from roosts is likely associated with nursing female bats needing to forage early in the night to meet the energy demands of nursing their pups (Barclay 1989; Kurta et al. 1989; Lee and McCracken 2001). Some bats at 9247G were observed leaving the roost before sunset during late period surveys in 2020 and returning to that roost during the late-season emergence counts in 2020 and 2021 (**Section 5.2.1**), behaviours consistent with females leaving early to forage and returning to nurse dependent pups. Female little brown myotis in Watson Lake, Yukon, emerged from their maternity roost significantly earlier relative to sunset during the lactation/volant young period than during the pregnancy period (Talerico 2008). Radio-tagged female little brown myotis in Quebec rarely returned to their maternity roost during the night during pregnancy but lactating females returned once or twice a night (Henry et al. 2002).

At site 9427G during the maternity roosting period, the consistent activity, the number of bats observed (e.g., 17 bats in July 2020 and 23 bats in June 2021) emerging, and observations of bats leaving the roost before sunset and returning to the roost during emergence surveys all provide evidence that this site was most likely still being used for maternity roosting in 2020 and 2021 (**Appendix D**).

The number of bats observed fluctuated between 2017 and 2021 at 9427G. An average of 40.5 bats had been counted exiting during early-period roost surveys in 2018 (**Table 5.4)**. Average emergence counts in subsequent years did not reach the peak observed in early 2018 and were variable, but appear to have generally declined, particularly in 2020 and 2021. The reason for the differences is unknown and there are insufficient data to assess the statistical significance of the differences in the context of natural variability. High variability between roost counts between years and seasons is not uncommon (Burles 2000; Kellner 2020). Schorr and Siemers (2021) captured adult female little brown myotis leaving a roost in Colorado each June over multiple years. Annual numbers of bats at that roost ranged from 30 to 162.

The variation in roost count numbers at Portage Mountain could be due to a number of factors, such as the following:

- roost switching by some individuals between years (**Section 5.2**), as roost-switching by female little brown myotis has been documented to occur frequently in the Yukon (Slough and Jung 2020) and in the lower mainland of BC (Rensel 2021);
- variation in weather during emergence counts resulting in some bats leaving the roost later;
- observer error in accurately counting distant, fast-moving bats in low-light conditions;
- quarry activity affecting the patterns of maternity roost use.

Previously suspected maternity roosts such as 6287F on the south cliff, and NHEC3b at the north cliff (Hemmera 2020), had low numbers of bats emerging during the 2017 to 2019 surveys compared with roost 9427G, and no bats were observed there in 2020 or 2021. As described above, roost-switching, observer error or quarry activity could be the cause of the observed cessation of use. Changes in the suitability of the roost itself (e.g., incursion of woodrats, parasite infestation, vegetation growth shading the roost) could also cause roost abandonment or roost-switching. The trees, cliffs and talus within the study area – and in other forest stands and rock faces on Portage Mountain outside of the study area – offer multiple crevices that appear suitable for bat roosting and it is unlikely that bats at Portage Mountain are limited to specific features. There were multiple other sites in the north and south cliffs where bats were observed emerging (**Section 5.2**) that could also be maternity roosts, but were used by fewer bats than the threshold of 10 individuals used for determining likely maternity roosts (BC Hydro 2020).

No new roosts were identified during the 2020 and 2021 emergence counts, but continuous bat activity was observed visually and recorded on handheld detectors across the entire south and north cliffs at dusk during emergence counts. Continued observations of bats early in the evening at emergence time suggests that bats continue to use rock features in the cliffs as roosting sites despite quarrying activity. Bats may move between crevices at the north and south cliffs as well as between tree roosts, making the identification of specific roosts and ongoing monitoring of maternity colonies challenging. Ongoing technical issues have limited the utility of data from the roost loggers in assessing bat roosting activity. Although emergence counts of bats at sunset and inspection of rock features with roosting potential are the best and least invasive methods to monitor bat activity at specific rock roosting locations, these techniques are limited by the difficulties of safely accessing the rock faces and getting close enough to the features under study to conduct an accurate count.

Consistent with previous reports, there is still no evidence of roosting bat activity at the small rock outcrops at the top of the quarry and the small bluff previously surveyed by Hansen et al. (2016) where the detector PM-S3 is deployed. Those areas are close to quarry development and operation activities, including forest harvest and road-building beginning in 2016. Emergence counts conducted from 2017 to 2021 did not result in observations of bats emerging from those two locations. These results continue to suggest that the larger cliff bands (south and north cliffs) with their large, and more exposed complex roosting habitats provide more suitable habitat for bats than the rock outcrops at the top of the quarry and the small bluff next to the quarry.

There are other habitat types in the study area that are expected to be used by roosting bats, at least outside of the hibernation period. Individuals using tree roosts in the study area will also be recorded on the bat detectors and may switch between tree roosts and rock crevice roosts. All of the bat species present in northeastern BC may use trees as roosts (BC Ministry of Environment 2016b; Lausen et al. 2022b), of which there are many nearby. Bats have previously been observed moving back and forth between a mature stand of balsam poplars at the bottom of the gully between the north and south cliffs and larger forest polygons east of 400 Road (M. Sarell, pers. comm. 2018).

6.2 Bat Species Presence and Seasonal Bat Activity from Passive Acoustic Monitoring

6.2.1 Species Presence

Species diversity remains unchanged at Portage Mountain from 2017 through 2021. Seven of the eight bat species that have been identified from acoustic data previously in the study area between 2017 and 2019 continued to be detected in 2020 and 2021, including the at-risk little brown and northern myotis. Long-legged myotis was not detected during passive acoustic monitoring in 2020 and 2021. This species is difficult to distinguish acoustically from some other Myotis species (especially little brown myotis) so it may be present but not detected. Big brown bat and long-eared myotis were the most common bats in 2018 through 2021, while in 2017 more hoary bat, silver-haired bat and little brown myotis files were identified than long-eared myotis files. The 2017 monitoring did not begin until August 21, which may have resulted in relatively more migratory species being detected.

The bat species detected are discussed below, along with their presence through the seasons. Bat activity data confirm that the periods of hibernation and emergence for bats at Portage Mountain are within the no-blasting temporal exclusion period (September 15 – May 15), suggesting that the timing of this mitigation was appropriate to avoid impacts on those behaviours. Activity consistent with regular life stages of bats was recorded in 2021 after three years of quarry operation (i.e., emergence from hibernation, maternity roosting, swarming), and even detections during the coldest months of winter, which collectively is evidence that the habitat and conditions at Portage Mountain remain suitable for bats. The calls recorded during the winter and early spring suggest that bats are hibernating near the Portage Mountain detectors.

Hoary bat

Hoary bats were detected almost exclusively (96% of the files identified as hoary bat) in July through September from 2017 through 2021, suggesting that this species passes through the Portage Mountain area primarily while on fall migration and consistent with the results of other studies (Nagorsen et al. 2014). Spring migration may follow an alternate route. Migration routes of hoary bats are poorly known (Baerwald et al. 2014; Wieringa et al. 2021) and may exhibit a high degree of individual variation (Weller et al. 2016).

Eastern red bat

The eastern red bat is believed to be undergoing a range expansion in western Canada (Lausen et al. 2022a; Solick et al. 2020) and makes up just 0.1% of the calls recorded in 2020 and 2021. Eastern red bat was detected in all years, with the earliest detections recorded April 21 in 2020 and April 14 in 2021, and latest detections recorded on October 13 in 2018 and October 3 in 2020. This species was identified in June, July, and August in all years from 2018 through 2021 with peak numbers of detections in July and August.

Silver-haired/Big brown bat

Acoustic characteristics of silver-haired bat and big brown bat calls may overlap (Lausen et al. 2022a) and many files were assigned to the group that included both species (Appendix A). Files identified specifically as silver-haired bat first appeared in April. Only big brown bats were detected during winter studies along the Peace Reach of Williston Reservoir, and it has been hypothesized that silver-haired bats migrate to and from the Peace region seasonally (Paterson et al. 2017). Big brown bat files were recorded in all seasons and this species likely hibernates in the vicinity of Portage Mountain. The big brown bat is known to be particularly cold-tolerant (Baerwald 2017), and individuals hibernating in rock crevices in Alberta have been recorded arousing an average of 17 times per winter (Lausen et al. 2022a). Studies of hibernating big brown bats on the Canadian prairies revealed that winter flight was common, but individuals rarely switched hibernacula during mid-winter (Klüg-Baerwald et al. 2017).

Few bat calls were recorded at Portage Mountain during the coldest months (i.e., December, January, and February; **Table 5.12**). All were identified as big brown bat, big brown bat/silver-haired bat, or low-frequency bat. Of the 171 bat files recorded in January and February of 2021, 102 were recorded at detector 279-SH, the southernmost detector. All detectors except PM-S3 were functioning during those months (**Figure 5.1**). Bats active during these months may hibernate closer to detector 279-SH than to the other detectors, or the primary flight path of bats leaving and re-entering hibernacula during the winter is south over 279-SH, rather than north over the other detectors. The 279-SH detector is also one of the detectors furthest from quarry activity, although blasting and heavy construction have not occurred during the winter. The 279-SH detector also had a high average number of files recorded during the fall and during emergence (**Table 5.11**), further evidence that it is close to a hibernaculum.

Bats were recorded at Portage Mountain during temperatures as low as -7.4°C in April of 2021 (**Appendix D**). Bat activity during winter has been documented on many occasions in several bat species, including long-eared myotis and big brown bat at southern locations on the Canadian prairies (Lausen and Barclay 2006) and northern myotis and big brown bat in Nebraska (Lemen et al. 2016). However, few studies have focused on winter activity in northern climates (Reimer et al. 2014). Bat emergence during the hibernation period is still not well understood. Some studies and observations in the prairies have suggested that bats will arouse during winter to drink near or inside the hibernacula or move between winter roosts, and there have been records of mating activity (BC Ministry of Environment 2016b; Lausen and Barclay 2006; Lemen et al. 2016; Lowe 2012). Winter bat activity has been detected at -10.4°C in Alberta (Klüg-Baerwald et al. 2016).

Myotis

The Myotis species group includes the two species classified as endangered on Schedule 1 of SARA, little brown myotis and northern myotis. Hibernacula of these species have been identified as critical habitat features (Government of Canada 2018). Myotis species typically are inactive during the winter while in deep hibernation so late fall detections followed by early spring detections can be used to infer the nearby presence of hibernacula.

Paterson et al. (2017) reported no winter Myotis detections along the Peace Reach of Williston Reservoir (including 5 detectors within 15 km of the Portage Mountain Quarry) and noted that a general lack of winter Myotis activity seemed common to other studies within the Peace Region, even at locations where they were detected in late fall and early spring. Paterson et al. (2017) also reported Myotis emerging from hibernation in early to mid-April, consistent with the findings of this study. Lausen and Barclay (2006) reported Myotis detections on the Canadian prairies when temperatures at emergence were above -5.8°C.

Northern myotis had an 89% probability of detection during the winter in Nebraska at temperatures >5°C (Lemen et al. 2016). Northern myotis has been known to move between hibernacula during winter in southern regions (Whitaker Jr and Rissler 1992; Lemen et al. 2016), although no winter detections have been recorded in most of their range, including the Peace Region. This species tends to hibernate in smaller numbers and is not as active during the winter as other bats such as big brown bat and silver-haired bat (Caceres and Barclay 2000; Boyles et al. 2006), which could explain its absence from Portage Mountain winter records.

6.2.2 Seasonal activity

The bat activity patterns observed at Portage Mountain and the associated inferences drawn are consistent with those of other published studies (e.g., Barclay 1989; BC Ministry of Environment 2016b; Kurta et al. 1989). A summary of activity in each season is provided below.

Winter

Bats are not known to venture far from hibernacula during the low temperatures of winter due to the need for energy conservation (Holroyd et al. 2016), so it is likely that hibernation by big brown bats and Myotis species is occurring in or near Portage Mountain. The winter observations from acoustic monitoring suggest that hibernating big brown bats are occasionally active during the winter and are most likely using the rock crevices in the study area as hibernacula. It also suggests that Myotis species are virtually inactive during the winter, based on the lack of calls, but are very likely hibernating in the area based on calls recorded during late fall and very early in the spring.

The winter temporal restriction on blasting at the quarry between September 15 and May 15 eliminates disturbance from blasting during the hibernation period for Myotis (**Table 5.10**). Most non-migratory BC bat species form mating swarms in areas where they will hibernate during the winter, similar to other bat species in temperate areas (van Schaik et al. 2015).

Spring

Simpson et al. (2013) reported that Myotis activity was first detected in spring at potential hibernacula at the Alwin Holland cliffs on the Peace River on April 6 of 2011, five days after detector installation, and at Tea Creek on April 3, three days after detector installation, while the larger bat species were first recorded slightly earlier (the first or second day after detector installation). No detectors were deployed during the winter in that study. Bats in that study were first recorded at foraging sites (waterbodies) in mid to late April. Acoustic data indicate that Myotis bats begin emerging from hibernation on Portage Mountain in mid-April, and migratory bats start using the area at the end of April (**Appendix B; Table 5.10**). Big brown bats are active frequently through the winter so it is more difficult to define the date of the first spring activity The spring temporal restriction on blasting at the quarry to after May 15 eliminates disturbance from blasting during the emergence period and the beginning of the summer period for Myotis (**Table 5.10**).

Summer and fall

Summer bat activity recorded by the long-term detectors in 2020 and 2021 (**Appendix D**) showed increasing levels of activity in June and July, consistent with increased activity by reproducing females and the general pattern of bat activity increasing in response to warmer temperatures and greater availability of insects. Further increases in Myotis activity in mid-August into September are likely due to a combination of additional bats returning from their summer roosts, feeding activity as young of the year become volant, and fall swarming. Hibernating species begin fattening for winter by increasing their foraging activity, using torpor more frequently during the day and between foraging bouts, choosing cooler roosts to conserve energy and returning from their summer sites to the hibernating area in preparation for mating (MOE 2016a; Kerth et al. 2001; Lausen and Barclay 2003; Rintoul and Brigham 2014). Social calls are often an indication of mating behaviours (Pfalzer and Kusch 2003; van Schaik et al. 2015). The detection of social calls during the fall together with a peak of activity consistent with swarming in fall in 2021 (**Section 5.3.2.2**), provide additional evidence that bats are continuing to use the cliffs within the study area as hibernacula.

6.3 Bat Response to Quarry Activity

The noise and vibration from quarry activities appear to have remained below the thresholds specified in the bat mitigation and monitoring plan (BC Hydro 2020) despite the variation in year to year quarry activities (**Table 3.4**). Trend analysis of bat activity in response to quarry blasting has produced results (**Section 5.3.3**) that show variable interactions between bats and quarry activity. These results, which varied by year and by bat life stages, show that in some years and for some bats there are interactions that suggest a positive or negative trend as a result of quarry activity.

Emergence and Summer

The emergence period was too brief (3 to 8 days, depending on year) for there to be enough data to assess for temporal trends during the emergence period. The difference in bat activity during summer 2019 to 2021 compared to 2017 was not statistically significant, but this may be due to only 11 active detector-nights during which data were recorded in the 2017 summer period, (**Appendix F**), increasing the chance of a type II statistical error.

Blasting does not appear to have had a negative impact on bats during summer (**Table 5.22** and **Appendix G**).

Swarming

Pre-hibernation swarming activity in BC and in the Peace region typically occurs in fall. For example, high bat activity (up to 3,000 files - mostly Myotis - in a single night) recorded at the end of September 2011 at the Bear Flats cliffs on the Peace River was suggestive of swarming (Simpson et al. 2013). At Tea Creek, another suspected cliff hibernaculum on the Peace River, bat activity peaked between August 31 and September 10. Andrusiak (2014) conducted reconnaissance acoustic sampling at Portage Mountain in 2013 between August 29 and September 5, and the highest amount of activity was recorded September 2 to 3. At Portage Mountain in 2021 Myotis activity peaked somewhat later, in mid-September (**Appendix D**). This was the only year that a peak in bat activity at Portage Mountain could be detected within the usual fall swarming period (**Section 5.3.2.2**), however, detector failures during late August and September 2017 - 2019 (**Figure 5.1**) have limited the amount of data available for those months.

Blasting may have had an impact on swarming activity at Portage Mountain. Fall activity showed statistically significant declines in 2018 and 2019 relative to 2017, but a statistically significant increase in 2021 relative to 2017. Bat activity also showed a statistically significant negative relationship with blasting occurrence during the fall period (**Table 5.23**). Furthermore, in 2021 blasting ceased on August 17, which was earlier than other years and well before the 2021 swarming period (September 2 to September 21; **Table 5.2**) and 2021 was the only year during which a peak in bat activity at Portage Mountain was detected during the swarming period. Blasting in 2019 and 2020 continued until mid-September (**Table 3.4**), which overlaps with the typical swarming period in other parts of the Peace region. The earlier cessation of blasting in 2021 may have had less impact on swarming behaviours. Bats are very likely to have been using tree roosts as well as rock roosts during the swarming period, including tree roosts within the buffer zone and much closer to the quarry than the rock roosts that were monitored. An alternative explanation for the lack of detectible swarming is that the tree-roosting bats closer to the quarry may have been subject to higher levels of quarry noise and vibration disturbance from blasting, potentially altering swarming activity.

Swarming behaviour has been relatively little studied, and the purposes of swarming are still under investigation (Burns and Broders 2015; Neubaum and Siemers 2021). Most studies of swarming have been undertaken at large, point-location hibernacula such as caves or mines (Burns and Broders 2015; Lowe 2012; Muthersbaugh et al. 2019b; van Schaik et al. 2015), and the form of the behaviour at smaller, more dispersed rock crevice hibernacula, including its annual variability in space and time, is unclear. It is possible that swarming at Portage Mountain occurs during some years at other locations outside our study area, out of range of the detectors. Crevices potentially providing suitable hibernacula are broadly distributed across the north and south cliffs of the study area and beyond. The landscape at Bear Flats and Tea Creek on the Peace River where swarming was recorded in the fall (Simpson et al. 2013) differs from the study area in that these are prominent sites with extensive areas of concentrated vertical rock habitat and considerable clear airspace to facilitate recording bats.

Hibernation

During the hibernation period, bat activity showed a statistically significant decline in 2018, 2019 and 2021 relative to 2017 (**Table 5.19, Figure 5.5**). This suggests a potential influence from quarrying activity, although there was reduced quarry activity and no blasting during the hibernation period (**Section 3.1**).

There is minimal information in the literature regarding responses of hibernating bats to industrial activity. The arousal responses of four species of hibernating bats in an active mine to underground mining blasts in Wisconsin were studied by Summers (2017). Bat arousals increased significantly after underground blasts, although the study could not distinguish between multiple individuals arousing and multiple detections of the same individual (Summers 2017). Luo et al. (2014) studied the responses of torpid greater mouse-eared bats (*Myotis myotis*) to noise disturbance, finding that bats responded most strongly to colony (conspecific) and vegetation (wind in trees) noise while responses to anthropogenic (traffic) noise were relatively weak. There was evidence of rapid habituation to repeated and prolonged exposure to noise, with habituation to traffic noise being more pronounced than to bird, colony or vegetation noise (Luo et al. 2014).

Bat Responses to Noise

Bats' perception of noise is different from the way people perceive noise (Caltrans 2016, Page and Bernal 2020) and for this reason assessments of quarry effects should consider the sensitivity of bats to noise frequencies. There is little information available on the noise levels that result in disturbances to roosting bats, causing Caltrans (2016) to suggest as a conservative response to these unknowns that the minimum noise criterion for assessing potential adverse effects on bats is the distance at which project noise attenuates to background noise levels. Caltrans (2016) also noted that measured noise levels are likely overestimates of the actual noise that is within the spectral range of bat hearing. Background daytime noise levels measured near Portage Mountain in 2020 ranged from 33 dBA to 55 dBA and averaged 44.4 dBA (Dailyde and Johnston 2020; **Section 5.1** and **Appendix C**). Quarrying noise from all sources (i.e., blasting and other quarry operating activities) averaged within the range of background noise level but sometimes exceeded it: south cliff nighttime averaged 41 dBA (maximum 52.7 dBA) and during the day averaged 45-47 dBA (maximum 53.1 dBA), and at the north cliff averaged 48 dBA at nighttime (maximum 55 dBA) and 55 dBA (maximum 57 dBA) during the day. Again, bats roosting in trees within the Portage Mountain Quarry disturbance buffer may have been subject to increased noise disturbance compared to those roosting in the cliffs and trees outside the buffer.

Bats are rarely sensitive to noise frequencies below 12 kHz (Page and Bernal 2020) and as a result the sound spectra of construction and traffic noise 'do not appreciably overlap with most bat echolocation calls or their hearing of them' (Caltrans 2016). The audiometric range of the big brown bat spans 10 kHz to 100 kHz (Simmons et al. 2016) and its hearing is most sensitive at 20 kHz (Koay et al. 1997). The lower hearing limit of the little brown myotis has been reported as 10 kHz, with peaks in sensitivity at 20 and 60 kHz (Dalland 1965 as reproduced in Department of Psychology 2021). Blasts at Portage Mountain Quarry were typically in and around 15 Hz (Dailyde and Johnston 2020).

There was little difference in the amount of high-frequency (6,300-20,000 Hz) noise measured at the south cliff during days with construction versus days without construction (**Section 5.1**; Dailyde and Johnston 2020). The greatest difference was 0.07 dB, which the authors attributed to the speed at which high-frequency noise is attenuated. Ultrasound frequencies over 20 kHz may be more disturbing to bats than lower-frequency noises such as those from instruments like surveying equipment. However, ultrasound attenuates swiftly as it travels through air, meaning that an ultrasound source would need to be very close to a bat for the noise to be audible. Arnett (2013) noted that a 65 dB level of noise can only be achieved by ultrasound noise sources within 5-20 m, depending on the portion of the ultrasound spectrum. The rapid attenuation of ultrasound through air (Drew et al. 2016) combined with the additional shielding effects of the rock within which the bats are roosting, over 130 m away, make it very unlikely that bats in the identified rock roost locations at Portage Mountain would detect any ultrasound produced at the quarry. Bats were likely to have been roosting in trees within the 300-m spatial buffer, closer to the quarry, and may have been subject to high-frequency noise produced at the quarry.

Unmeasured Parameters

Some of the variation in interactions between bat and quarry activity across bat life stages may be due to uncontrollable variables. Bat activity is known to be influenced by wind speed but no local source of wind data was available so that variable could not be included in models. Bat responses to blasting disturbance could also be affected by the number of blasts per day, though it was rare that there was more than one blast in a day at Portage Mountain. In particular, the results of the Blast model during summer (**Table 5.22**) are likely due to confounding factors because a positive response of bat activity to blasting is unlikely.

The level of noise and how far noise travels is dependent on many variables, including distance to blast, vegetation, weather, and geography. For example, quarry noise levels at the north cliff are higher than at the south cliff because there is a clear line of sight from the quarry (Dailyde et al. 2020). Based on **Figure 5.7**, **Figure 5.8**, and **Figure 5.9,** bats do not appear to be responding to singular blast events, but during periods of concentrated blasting, activity might be depressed lower that what would be expected for the temperature and time of year. For example, in 2019, the highest concentration of blasting occurred in mid-August to mid-September when a peak in activity would have been expected due to swarming, but instead bat activity was relatively low. Bats may have a threshold response to disturbance (Bennett and Zurcher 2013), where no change is evident in bat activity until a particular level of disturbance is reached. That threshold may vary by species, life stage and sex, which could also affect the variation in the results of the trend analysis.

7.0 CONCLUSIONS AND RECOMMENDATIONS

Acoustic monitoring conducted at the north and south cliffs confirm that the quarry blasting cessation period (September 15 to May 15) avoided the periods of hibernation and emergence but blasting did overlap the swarming period in early September. The data also confirm the maternity roost occupation period (June 1 to August 15). These results support the need for spatial (buffer zones) and temporal (no-blasting period) mitigation described in the *Bat Mitigation and Monitoring Program* (BC Hydro 2020).

Results of the monitoring data analysis suggest that quarry mitigation has been generally effective:

- Noise and vibration monitoring during 2018 through 2021 (Appendix C) confirmed that work activity within the quarry appears not to have exceeded the noise and vibration thresholds in the bat mitigation and monitoring plan (BC Hydro 2020).
- Nearly all bat species previously observed in the study area starting in 2013 continue to be present based on acoustic data, including little brown myotis and northern myotis. Long-legged myotis has not been confirmed in recent years but acoustic recordings of this common and widely-distributed species are extremely difficult to discern from those of other 40 kHz Myotis species (Lausen et al. 2022a).
- Data consistent with normal annual life stages of bats continue to be recorded in 2021 after three years of quarry operation, such as:
  - emergence from hibernation;
  - maternity roosting;
  - fall activity (swarming; albeit variable); and
  - production of social calls prior to winter hibernation.
- Ongoing detections of big brown bat during the coldest months of winter are consistent with continued hibernation by this species nearby.

While these results suggest that quarry mitigation has generally been effective, some results suggest potential adverse effects and / or improvements to mitigation that could increase effectiveness.

For example, the maternity roost 9427G continues to be used, although in general, fewer bats have been counted emerging there since the peak number observed in 2018. It is unclear if the change in numbers represents a real decline or natural variability in roost use (Kellner 2020; Schorr and Siemers 2021).

Additionally, the trend analysis of bat responses to quarry disturbance produced results that vary by year and by bat life stage. In general, there was a decline in bat activity in 2018 and 2019 relative to 2017 when the quarry started (**Table 5.17,Table 5.18,Table 5.19**), but in the 2021 fall period, bat activity increased, so the decline was not consistent. The decline was, however, fairly consistent during the hibernation period - bat activity at Portage Mountain decreased in all years relative to that recorded in 2017 although the decrease in 2020 was not statistically significant.

The modelling results indicate that bat activity declined in the fall period during blasting at the quarry (**Table 5.23**). Since bats tend to swarm where they hibernate (van Schaik et al. 2015) it's possible that quarry activities, such as blasting, are causing bats to swarm elsewhere and possibly hibernate elsewhere where overwintering conditions could be different and potentially less suitable.

Recommendations are described below. Implementation of these recommendations would increase the quantity of the monitoring data to support future analysis of the effects of the quarry. BC Hydro plans to continue monitoring bats at Portage Mountain. As rock extraction at the Portage Mountain Quarry by BC Hydro has now been completed, no recommendations have been developed for modification of the mitigation for Portage Mountain quarry operations specifically.

1. The 2020 bat mitigation plan specifies a threshold of 10 bats emerging to define a maternity roost (BC Hydro 2020). This threshold may be high as maternity roosts may have fewer than 10 bats (M. Sarell, pers. comm. 2019). Specifying a lower number of individuals to be used as the threshold in future roost monitoring would also be more consistent with the 'significant roost' definitions provided in the provincial BMP (BC Ministry of Environment 2016c), which include thresholds of 6 and 4 individuals for some species/sex criteria.
2. Monitoring of the maternity roost 9427G should be continued to confirm if the changing numbers of bats recorded emerging from this roost represent a persistent decline or a change that reverses due to a combination of natural variation and the decline in quarry activity.
3. Acoustic data collection should continue as reclamation activities begin at the quarry, with the objective of comparing 2022 data with previous years to assess whether bat activity levels increase once rock extraction at the quarry has been terminated.
4. Expanding the no-blasting period to include the swarming period, e.g., September 1 to May 15, should be considered for mitigation of future mining and quarrying operations in proximity to bat hibernacula, to avoid potential impacts of blasting during this period.

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APPENDIX A

Acoustic Characteristics Used to Analyze Bat Species in the Study Area

Text description of call characteristics of bat species in the study area, modified from Lausen, C. 2017. Bat data analysis cheatsheet. Unpubl.

Common name	Scientific name (species code)	Description*
Big brown bat / silver-haired bat	*Eptesicus fuscus / Lasionycteris noctivagans* (EPFU/LANO)	Calls are very similar. Diagnostic features include: LANO produces flat calls at 25 kHz, which EPFU does not; EPFU tends towards higher frequencies in clutter seen as an Fmax that can start above 60 kHz, whereas even with higher clutter calls (call duration < 6 ms), LANO tends towards Fmax values <50 kHz. The presence of second harmonic can aid in making differentiation because an Fmax <50 kHz can be attributed to species differences rather than distance of bat from microphone.
Eastern red bat	*Lasiurus borealis* (LABO)	Can have a low Sc <45 in open environments. Fmin ranges from 35 – 45 kHz and calls often have a characteristic "upturn" to the toe. MYLU in open environments can produce calls with very low Sc values also, so in an uncluttered situation, differentiating LABO and MYLU should be done using more than just call parameters. MYLU will generally have a more pronounced "elbow" or bend to its call (like a hockey stick shape) that you do not see in LABO (which instead is a smoothly curving call) Also, LABO, being a lasiurine, will tend to an undulating up/down call pattern
Hoary bat	*Lasiurus cinereus* (LACI)	Long passes containing numerous pulses will be needed to differentiate this species from other low-frequency bats unless the calls are obviously <20 kHz with long duration (>10 ms) and TBC* (>400 ms). When call Fmin is > 20 kHz, the duration and TBC is substantially less, but there will generally be an "up and down Fmin pattern" which characterizes this species
Long-eared myotis	*Myotis evotis* (MYEV)	Calls are generally steep (Sc>250+ but as low as 150 in some cases), with Fmin varying from 30 kHz up to 40. Can overlap with northern myotis at its highest Fmin (~39 - 42 kHz). At higher frequencies where MYEV and MYSE can overlap, these passes should be placed into a general “long-eared” category. EPFU/ LANO can produce calls around 25 kHz that are steep, so there is possibility of overlapping with this species group, however, their Sc+ values are usually <150, whereas long-eared calls are steeper than this
Northern myotis	*Myotis septentrionalis* (MYSE)	Calls are generally steep, but unlike some of the other long-eareds, their call body slopes are more often low (as low as 150 OPS). Individual calls are generally Fmin 38-48 kHz. Below 43 kHz, MYSE overlaps with MYEV and would thus be grouped within the “Long-eared” category.
Little brown myotis	*Myotis lucifugus* (MYLU)	Often included in a more general “Myotis” or “High-frequency” category as MYLU calls resemble those of other Myotis species. Generally, this species echolocates with Fmin 32-45 kHz with a highly variable slope (Sc can be as low as 20 OPS in extremely uncluttered situations, but higher than 400 OPS in a cluttered situation such as interacting with another bat or encountering vegetation). In low clutter, the low slope of MYLU generally allows it to be discerned from other myotis; a pronounced bend (elbow) in the pulse may be seen in low clutter, and this feature is typically not present in other 40 kHz myotis. This species is widespread across Canada and is versatile in its echolocation, such that variation is immense.
Long-legged myotis	*Myotis volans* (MYVO)	Similar call to MYLU. Include in a more general “Myotis” or “High-frequency” category.

* Fmin = minimum frequency, OPS = octaves per second, Sc = Slope of the call, TBC = Time between calls

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Acoustic Characteristics of Bat Species in the Study Area (modified from Lausen 2016 with input from Hansen, I-J (pers. comm. 2018)

Species Group*						Common Name	Acoustic Parameters									
Little Brown Myotis / Eastern Red Bat	Myotis Species	Big Brown / Silver-haired Bat	High-frequency Bat	Bats with Minimum Frequency 30 kHz	Low-frequency Bat	Species	Duration (milliseconds)		Maximum Frequency (kHz)		Minimum Frequency (kHz)		Characteristic Frequency (kHz)		Slope of Call Body (Octaves per second)	
							Avg**.	Range of Averages	Avg.	Range of Averages	Avg.	Range of Averages	Avg.	Range of Averages	Avg.	Range of Averages
					■	Hoary bat	9.5	7.2–3.5	34	24–42	21	18 - 23	22	20 - 24	29	13 - 57.5
		■		■	■	Silver-haired bat	7.3	4.9–12.1	37	28–49	25.5	23–27	27	25–28	36.5	11–73.5
		■		■	■	Big brown bat	7	3.3–13.3	41	26–62	25.5	21–31	27	21–32	48	12–135
	■		■	■		Long-eared myotis	4.1	1.4–2.4	64	49–88	34	29–41	42.8	34.5–66.6	343	158–855
	■		■			Long-legged myotis	3.2	1.7–6.3	68	56–85	41	36–45	47	39–63	202	64–503
■			■			Eastern red bat	6.5	5–8	53	49–59	41	37–45	41	37–45	29	23–41
■	■		■			Little brown myotis	3.5	1.6–6.7	76.5	49–91	42	32–47	48	38–57	175	63–464
	■		■			Northern myotis	1.9	1.0–2.7	71.5	51–81	42	38.5–44	51	45–57	354	211–484

*Grey cell = Bat categories are assigned to groups of bats based on the frequency (kHz) of their calls
**Avg. = average

APPENDIX B

Portage Mountain Riprap Quarry –
Blasting Vibration and Sound Levels Memo

TETRA TECH

TECHNICAL MEMO

ISSUED FOR USE

To:	Brock Simons, MSc, RP Bio Terrestrial Biodiversity Specialist Site C Clean Energy Project	**Date:**	March 28, 2022
c:		**Memo No.:**	01
From:	Aaron Nickoli, P.Eng., Ben Howden, P.Eng.	**File:**	704-ENG.KGEO03574-01 Task 003
Subject:	Portage Mountain Riprap Quarry – Blasting Vibration and Sound Levels Memo		

1.0 INTRODUCTION

Tetra Tech Canada Inc. was retained by BC Hydro to complete an assessment of blast monitoring data from the riprap quarry at Portage Mountain, Hudson's Hope, BC. This report details the review of the available monitoring data from the 2019 and 2021 construction seasons and provides estimates for the sound concussion, shockwave and ground vibration produced from blasting at the Portage Mountain riprap quarry during the 2020 construction season. The estimated values were compared to the thresholds stated in the *Best Management Practices Guidelines for Bats in British Columbia, Chapter 2 (Holroyd and Craig, 2016).* These thresholds include the following with respect to blasting:

- Sound concussion of less than 150 decibels (dB);
- Shockwave of less than 15 p.s.i. (104 kPa); and
- Ground vibration of peak particle velocity (PPV) of less than 15 mm/s.

In 2019, the blasting at Portage Mountain Quarry (PMQ) was monitored to produce a baseline for the expected sound concussion, shockwave, and ground vibrations from blasting operations. The 2020 blasting program was planned to use similar blast layouts as in 2019 and therefore the blasts were not monitored. However, during the 2020 blasting program, the blast layouts changed without additional monitoring being undertaken. The purpose of this memo is to estimate the sound concussion, shockwave, and ground vibrations resulting from the 2020 blasts using the site-specific data collected from monitoring the 2019 and 2021 blasting programs.

Since the degree to which blasting sound and vibrations propagate is atmospheric and site dependent, site specific blasting parameters were developed based on the field reports supplied by BC Hydro. Tetra Tech's derivation of these site-specific parameters relied entirely on the field data available.

2.0 NOISE AND VIBRATION MONITORING DETAILS

Bat hibernacula are located to the north and south of the quarry. Monitoring locations were set up as part of the 2019 baseline data collection program near the hibernacula. These locations have been used for each subsequent annual blasting program. The coordinates for the monitoring locations are presented in Table 2.0-1 below.

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Table 2.0-1: Monitoring Location Coordinates

Monitoring Location	UTM (10U)
North Bluff	555132E, 6204447N
South Bluff	554963E, 6203616N

Baseline noise and blast vibration monitoring was conducted in 2019 by RWDI and the results provided in *Site C Portage Mountain Quarry Hibernacula Noise & Vibration Study 2019 Report*.

Spot noise monitoring was undertaken during the 2020 blasting season. No vibration monitoring was undertaken in 2020.

In 2021, noise and blast vibration monitoring was routinely undertaken at the north and south monitoring locations.

2.1 Blast Design Reports

The blast design reports and summary tables were provided for most blasts during the 2019, 2020, and 2021 blasting programs. When reviewing the blast design reports versus the summary blast information tables, some discrepancies and errors were found. Tetra Tech revised the summary blast information assuming the blast design and diagram information best represented the blasting undertaken.

3.0 BLAST VIBRATION ANALYSIS

3.1 Blast Vibration Data

The Instantel seismographs used to monitor blasting vibration measure the vibrations caused by the blast in three directions: longitudinal, transverse, and vertical. The peak particle velocity (PPV) for a blast is the highest of those three values recorded. The *Best Management Practices Guidelines for Bats in British Columbia* provide a ground vibration limit of less than 15 mm/s for the PPV.

The vibration monitoring data for the 2019 program was provided as peak vector sum (PVS) values. The PVS is the 3D sum of the three axes (3D Pythagoras). As a result, the PVS is always larger than the PPV and if used to develop a site-specific equation for a site, can result in a 10% to 25% over estimation of the PPV value. For this reason, the 2019 data was excluded from the data set used to develop a site-specific equation for the Portage Mountain Quarry site. However, even with the potential PVS overestimation of the PPV, all 2019 monitored blasts were under the 15 mm/s PPV limit.

The Instantel blast reports for both the north and south monitoring locations were provided for the 2021 blast monitoring, which gives the PPV for the longitudinal, transverse, and vertical directions. These data were used in the development of site-specific equations for PPV estimation.

3.2 Scaled Distance

Scaled Distance (SD) reduces two controllable blast variables, distance from the blast and, charge weight of explosives, to a single variable. In blasting, the charge weight of explosives is defined as the weight of explosive detonated within an 8-millisecond delay. This means that when using appropriate delays in a blast, a very large blast acts as a series of smaller blasts. Therefore, increasing the number of holes in a blast does not necessarily correspond to an increase in peak vibrations, air overpressures, or noise expected with an increase in the total weight of explosive used.

The Scaled Distance is defined as:

$$SD = \left(\frac{D}{\sqrt{W}}\right)$$

Where: D = Distance from the blast, in metres
W = charge weight of explosives, in kg

To estimate the Peak Particle Velocity (PPV) the following equation is used:

$$PPV = k\left(\frac{D}{\sqrt{W}}\right)^{\beta}$$

Where k and β are site specific constants developed through a SD plot. These constants allow for the capture of site-specific conditions such as, but not limited to, explosive type, rock strength, rock mass conditions such as joints and faults and topography.

3.3 Scaled Distance Plots

A SD plot is a log-log scale plot of SD versus measured PPV. The trendline (best fit) of the plotted data provides the k and β in the equation of the trendline.

Typically for forecasting PPV for a blast, a 95% regression analysis is used. This equation can then be used to estimate the maximum charge weight per delay a blast could contain while providing a high degree of confidence that a blast designed using the 95% regression equation should not exceed site PPV limits. However, when back analyzing blasts to predict PPV, the charge weight per delay is a known parameter, and a 95% regression for back analysis would result in the same overestimation of PPV from a given blast. Therefore, when reviewing the 2020 blasts for compliance with the regulatory PPV limit, the best fit equation was used to produce more realistic or likely estimates of PPV generated from the blasts, with known charge weights per delay. An equation was also developed one standard deviation above the best fit line to increase confidence that PPV estimates would not have been exceeded.

The vibration monitoring data for each bluff was analyzed separately to account for variations in the rock mass between the two monitoring locations.

3.3.1 North Bluff Best Fit Analysis

Table 3.3.1-1 below, summarizes the available blast data at the North Bluff for the 2021 monitoring program. A few outlier blasts were removed from the data set with completion of the best fit analysis as they were skewing the resulting trendline plots outside of the expected range of values of k and β. The removed blasts either plotted much higher or much lower than would be expected given the SD for the blast. Review of the blast plans provided could not resolve the discrepancies and therefore the blasts were removed from the data set for purposes of developing the best fit equation.

Table 3.3.1-1: 2021 North Bluff Monitoring Data Summary

Data	Number
Total 2021 Blasts	60
Blasts Measured at North Bluff	42
Blasts with sufficient information for scaled distance calculation	39
Blasts used in best fit model	33
Average distance to blast	502 m

The resulting best fit equation for the North Bluff was estimated to be:

$$PPV = 831.26(SD)^{-1.622}$$

Table 3.3.1-2 presents a summary of the 2020 blasts monitored at the North Bluff.

Table 3.3.1-2: 2020 North Bluff PPV Estimate Summary

Data	Number
Total 2020 Blasts	100
Blasts with sufficient information for PPV estimation	97
Number of blasts with estimated PPV above limit using best fit equation	0
Number of blasts with estimated PPV above limit using one standard deviation equation	0

3.3.2 South Bluff Best Fit Analysis

Table 3.3.2-1 below, summarizes the available blast data at the South Bluff for the 2021 monitoring program. A few outlier blasts were removed from the data set when completing the best fit analysis as they were skewing the resulting trendline plots outside of the expected range of values of k and β. The removed blasts either plotted much higher or much lower than would be expected given the SD for the blast. Review of the blast plans provided could not resolve the discrepancies and therefore the blasts were removed from the data set for purposes of developing the best fit equation.

Table 3.3.2-1: 2021 South Bluff Monitoring Data Summary

Data	Number
Total 2021 Blasts	60
Blasts Measured at South Bluff	52
Blasts with sufficient information for scaled distance calculation	47
Blasts used in best fit model	41
Average distance to the blast	364 m

The resulting best fit equation for the South Bluff was found to be:

$$PPV = 789.83(SD)^{-1.602}$$

Table 3.3.2-2 presents a summary of the 2020 blasts monitored at the South Bluff.

Table 3.3.2-2: 2020 South Bluff PPV Estimate Summary

Data	Number
Total 2020 Blast	100
Blasts with sufficient information for PPV estimation	97
Number of blasts with estimated PPV above limit using best fit equation	0
Number of blasts with estimated PPV above limit using one standard deviation equation	0

Initial review of one blast on July 17, 2020 indicated a potential exceedance in PPV. However, upon more detailed analysis of its blast geometry, it was found that the blast was unlikely to have exceeded the 15 mm/sec limit. This is discussed further in Section 5.0 – Discussion of Results and Recommendations.

4.0 AIR OVERPRESSURE ANALYSIS

In the International Society of Explosive Engineers (ISEE) Blaster's Handbook it provides the following factors which influence air overpressures resulting from a blast:

- Charge weight
- Depth of burial
- Volume of displaced rock
- Delay time intervals
- Type of explosive
- Atmospheric conditions, including but not limited to temperature, wind, temperature inversions, weather condition
- Topography

This indicates that two identical blasts, initiated at two different times could have different air overpressure readings due to changes in atmospheric conditions, at the same location.

4.1 Noise and Air Overpressure Data

During the 2021 monitoring program, data were collected from both the north and south bluffs and provide a larger data set than previous years. As such, the 2021 data were used in the noise and air overpressure analysis.

4.2 Scaled Distance

Estimation of air overpressure also relies on scaled distance in the development of the equation. The scaled distance for air overpressure utilizes the same parameters as used in the PPV calculations, except the cube root of the charge weight is used instead of the square root.

The scaled distance is defined as:

$$SD = (D/(W^{\frac{1}{3}})$$

Where: D = Distance from the blast, in metres
W = charge weight of explosives, in kg

The best fit line to calculate the air overpressure from scaled distance is defined as:

$$P = A * (SD)^{-B}$$

Where: P = Air Overpressure (pascals)
SD = Air Overpressure scaled Distance (cube roots charge weight of explosives)
B = Slope of the line (slope is negative)

Sound pressure level (SPL) in decibels (dB) is then calculated using the equation below:

$$SPL = 20\log(P) + 154$$

4.3 Scaled Distance Plots

A scaled distance plot is a log-log scale plot of scaled distance versus measure peak air overpressure. The trendline of the plotted data provides the A and B in the equation of the trendline. The 2021 monitoring air overpressure data and trendlines were plotted separately for the North and South Bluffs. Efforts to reduce the randomness of the data by filtering by weather condition and further filtering by wind direction did not improve the fit of the trendline or the randomness of the data. This was likely due to the limited atmospheric data collected, such as wind speed and atmospheric pressure.

This resulted in it not being possible to create a site-specific Air Overpressure equation for the site.

4.4 Air Overpressure Prediction Equations

Tetra Tech compiled a list of air overpressure equations from a literature review. These equations are presented in Table 4.4-1 below. For each equation, the PMQ data were utilized to predict the air overpressures generated. A review of the actual measured air overpressure versus predicted values was completed.

Table 4.4-1: Air Overpressure Prediction Equations

Blasting	Equation	Units	Source
Quarry Face	$P = 1.32 * SD_3^{-0.97}$	psi	USBM RI 8485
Behind Free Face	$P = 0.056 * SD_3^{-0.515}$	psi	USBM RI 8485
Buried (total confinement)	$P = 0.061 * SD_3^{-0.96}$	psi	USBM RI 8485
Construction Blasting – Best Fit (mean)	$P = 0.14 * SD_3^{-0.89}$	psi	Konya (2021)
Construction Blasting (95% confidence)	$P = 0.95 * SD_3^{-0.89}$	psi	Konya (2021)
Surface Coal Mine	$P = 6.31 * e^{-b} * SD_3^{-1.16}$	kPa	Linehan and Wiss (1980)

The parameters for the equations in Table 4.4-1 are as follows:

P is peak overpressure measured in the units listed

SD_3 is the cube root scaled distance

e is the base natural logarithm (e = 2.7183) – used in the Surface Coal Mine equation

b is the scaled depth of burial ($C/W^{1/3}$), $m/kg^{1/3}$ – used in the Surface Coal Mine equation

C is the depth to center of gravity of charge in metres

W is charge weight per delay in kg

4.5 Air Overpressure Equation Analysis – 2021 Data

Utilizing the equations from Section 4.4, the air overpressures for the 2021 blasts were estimated. These estimations were then compared to the measured values obtained from the monitoring program.

Table 4.5-1: 2021 North Bluff – Estimated versus Measured Air Overpressures

Item Reviewed	Quarry Face	Behind Free Face	Buried (total confinement)	Construction Blasting – Best Fit (mean)	Construction Blasting (95% confidence)	Surface Coal Mine
Number of blasts with usable monitoring data	39	39	39	39	39	39
Number of estimates higher than measured	34	20	0	0	35	24
Percentage of estimates which overestimated the air overpressure value	87%	51%	0%	0%	90%	62%

The Quarry Face and the Construction Blasting (95% Confidence) equations provided the most conservative estimates for the air overpressure experienced at the North Bluff from blasting operations.

Table 4.5-2: 2021 South Bluff – Estimated versus Measured Air Overpressures

Item Reviewed	Quarry Face	Behind Free Face	Buried (total confinement)	Construction Blasting (mean)	Construction Blasting (95% confidence)	Surface Coal Mine
Number of blasts with usable monitoring data	47	47	47	47	47	47
Number of estimates higher than measured	47	44	0	15	47	47
Percentage of estimates which overestimated the air overpressure value	100%	94%	0%	32%	100%	100%

The Quarry Face, Construction Blasting (95% Confidence) and Surface Coal Mine equations all over-predicted the air overpressures at the South Bluff, with the Behind Free Face equation over-predicting the air overpressure 90% of the time.

The air overpressures indicated are all under the threshold limits for the 2020 data, even using the most conservative predictions.

5.0 DISCUSSION OF RESULTS AND RECOMMENDATIONS

The 2021 monitoring data and blast records provided the most complete set of records and were therefore used for development of site-specific equations for PPV estimation. The 2021 data were also used for the air overpressure analysis and review of published air overpressure estimation equations.

Engineering judgement was used when doing quality control and compilation of the blast data, particularly when blast records were incomplete or missing information. Blasts with incomplete or missing information were either excluded from the analysis or conservative assumptions were used to fill in minor gaps in the available information.

It should be noted that the distance from the monitoring location to the blast was calculated based off the coordinates provided on the blast plans. The methodology for determining the coordinate of the blast was not provided but was assumed to be the geometric center of the blast.

With regards to the estimated PPV of the 2020 blasting, the North Bluff, which is located further from the blasting, experienced lower estimated PPV values. None of the blasts were estimated by the best fit equation to be above the best practice 15 mm/s limit at the North Bluff.

The South Bluff is located closer to the location of the 2020 blasting, and as a result it was expected to have experienced higher PPV than would be recorded at the North Bluff for the same blast. None of the blasts were estimated by the best fit equation to be above the best practice 15 mm/s limit at the South Bluff.

The initial review of the 2020 blast data suggested the July 17, 2020 blast may have exceeded the *Best Management Practices Guidelines for Bats in British Columbia* for ground vibration which is 15 mm/s. This conclusion was reached based on the Scaled Distance calculation which looks at the distance from the blast and the maximum weight of explosives per 8 millisecond delay (instantaneous charge). The blast records showed that the July 17, 2020 blast was not delayed and this was confirmed through email communication with the Blasting Contractor. Therefore, the total weight of explosives was applied as the maximum instantaneous charge of the blast. Using this full weight, the estimated PPV from the blast exceeded the 15 mm/s limit.

However, upon further analysis it was found that the July 17, 2020 blast was unique in that the blast pattern was a single row of 47 holes without a delay. From analysis of the blast geometry, spacing of the holes, length of the blast, and the velocity of detonation of the detonating cord, it was estimated that the entire blast would take 17 milliseconds to detonate. This equates to more than double the 8 millisecond delay time of the instantaneous charge criterion.

(2.5 m spacing x 47 holes = 115 m)/6,700 m/sec = 17.1 milliseconds

The maximum charge per 8 millisecond delay is 347.3 kg (23 holes) which would produce a resultant PPV of 9.2 mm/s.

Therefore, under more detailed scrutiny, we believe it is unlikely that the July 17, 2020 blast would have generated a PPV in exceedance of the 15 mm/s limit in the Best management Practices Guidelines.

For estimating the air overpressures resulting from the 2020 blasts, all 6 of the equations presented in Section 4.4 were applied to the 2020 blast data. For both the North and South Bluffs, all blasts were estimated to be under the *Best Management Practices Guidelines for Bats in British Columbia* threshold values of:

- Sound concussion of less than 150 decibels (dB)
- Shockwave of less than 15 p.s.i. (104 kPa)

Based on the percentage of 2021 blasts where the air overpressure was overestimated by the Quarry Face and Construction Blasting (95% Confidence) equations, it is unlikely that any of the 2020 blasts exceeded the sound concussion and shockwave thresholds.

With the difficulty in back analysis air overpressure values for blasts, it would be recommended that any future blasts be monitored to ensure compliance with the best practice guidelines.

6.0 LIMITATIONS OF REPORT

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7.0 CLOSURE

We trust this technical memo meets your present requirements. If you have any questions or comments, please contact the undersigned.

Respectfully submitted,
Tetra Tech Canada Inc.

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APPENDIX A

TETRA TECH'S LIMITATIONS ON THE USE OF THIS DOCUMENT

LIMITATIONS ON USE OF THIS DOCUMENT

GEOTECHNICAL

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If any error or omission is detected by the Client or an Authorized Party, the error or omission must be immediately brought to the attention of TETRA TECH.

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The Client acknowledges that it has fully cooperated with TETRA TECH with respect to the provision of all available information on the past, present, and proposed conditions on the site, including historical information respecting the use of the site. The Client further acknowledges that in order for TETRA TECH to properly provide the services contracted for in the Contract, TETRA TECH has relied upon the Client with respect to both the full disclosure and accuracy of any such information.

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During the performance of the work and the preparation of this Professional Document, TETRA TECH may have relied on information provided by third parties other than the Client.

While TETRA TECH endeavours to verify the accuracy of such information, TETRA TECH accepts no responsibility for the accuracy or the reliability of such information even where inaccurate or unreliable information impacts any recommendations, design or other deliverables and causes the Client or an Authorized Party loss or damage.

1.6 GENERAL LIMITATIONS OF DOCUMENT

This Professional Document is based solely on the conditions presented and the data available to TETRA TECH at the time the data were collected in the field or gathered from available databases.

The Client, and any Authorized Party, acknowledges that the Professional Document is based on limited data and that the conclusions, opinions, and recommendations contained in the Professional Document are the result of the application of professional judgment to such limited data.

The Professional Document is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation from the site conditions present, or variation in assumed conditions which might form the basis of design or recommendations as outlined in this document, at or on the development proposed as of the date of the Professional Document requires a supplementary exploration, investigation, and assessment.

TETRA TECH is neither qualified to, nor is it making, any recommendations with respect to the purchase, sale, investment or development of the property, the decisions on which are the sole responsibility of the Client.

1.7 ENVIRONMENTAL AND REGULATORY ISSUES

Unless stipulated in the report, TETRA TECH has not been retained to explore, address or consider and has not explored, addressed or considered any environmental or regulatory issues associated with development on the subject site.

1.8 NATURE AND EXACTNESS OF SOIL AND ROCK DESCRIPTIONS

Classification and identification of soils and rocks are based upon commonly accepted systems, methods and standards employed in professional geotechnical practice. This report contains descriptions of the systems and methods used. Where deviations from the system or method prevail, they are specifically mentioned.

Classification and identification of geological units are judgmental in nature as to both type and condition. TETRA TECH does not warrant conditions represented herein as exact, but infers accuracy only to the extent that is common in practice.

Where subsurface conditions encountered during development are different from those described in this report, qualified geotechnical personnel should revisit the site and review recommendations in light of the actual conditions encountered.

1.9 LOGS OF TESTHOLES

The testhole logs are a compilation of conditions and classification of soils and rocks as obtained from field observations and laboratory testing of selected samples. Soil and rock zones have been interpreted. Change from one geological zone to the other, indicated on the logs as a distinct line, can be, in fact, transitional. The extent of transition is interpretive. Any circumstance which requires precise definition of soil or rock zone transition elevations may require further investigation and review.

1.10 STRATIGRAPHIC AND GEOLOGICAL INFORMATION

The stratigraphic and geological information indicated on drawings contained in this report are inferred from logs of test holes and/or soil/rock exposures. Stratigraphy is known only at the locations of the test hole or exposure. Actual geology and stratigraphy between test holes and/or exposures may vary from that shown on these drawings. Natural variations in geological conditions are inherent and are a function of the historical environment. TETRA TECH does not represent the conditions illustrated as exact but recognizes that variations will exist. Where knowledge of more precise locations of geological units is necessary, additional exploration and review may be necessary.

1.11 PROTECTION OF EXPOSED GROUND

Excavation and construction operations expose geological materials to climatic elements (freeze/thaw, wet/dry) and/or mechanical disturbance which can cause severe deterioration. Unless otherwise specifically indicated in this report, the walls and floors of excavations must be protected from the elements, particularly moisture, desiccation, frost action and construction traffic.

1.12 SUPPORT OF ADJACENT GROUND AND STRUCTURES

Unless otherwise specifically advised, support of ground and structures adjacent to the anticipated construction and preservation of adjacent ground and structures from the adverse impact of construction activity is required.

1.13 INFLUENCE OF CONSTRUCTION ACTIVITY

Construction activity can impact structural performance of adjacent buildings and other installations. The influence of all anticipated construction activities should be considered by the contractor, owner, architect and prime engineer in consultation with a geotechnical engineer when the final design and construction techniques, and construction sequence are known.

1.14 OBSERVATIONS DURING CONSTRUCTION

Because of the nature of geological deposits, the judgmental nature of geotechnical engineering, and the potential of adverse circumstances arising from construction activity, observations during site preparation, excavation and construction should be carried out by a geotechnical engineer. These observations may then serve as the basis for confirmation and/or alteration of geotechnical recommendations or design guidelines presented herein.

1.15 DRAINAGE SYSTEMS

Unless otherwise specified, it is a condition of this report that effective temporary and permanent drainage systems are required and that they must be considered in relation to project purpose and function. Where temporary or permanent drainage systems are installed within or around a structure, these systems must protect the structure from loss of ground due to mechanisms such as internal erosion and must be designed so as to assure continued satisfactory performance of the drains. Specific design details regarding the geotechnical aspects of such systems (e.g. bedding material, surrounding soil, soil cover, geotextile type) should be reviewed by the geotechnical engineer to confirm the performance of the system is consistent with the conditions used in the geotechnical design.

1.16 DESIGN PARAMETERS

Bearing capacities for Limit States or Allowable Stress Design, strength/stiffness properties and similar geotechnical design parameters quoted in this report relate to a specific soil or rock type and condition. Construction activity and environmental circumstances can materially change the condition of soil or rock. The elevation at which a soil or rock type occurs is variable. It is a requirement of this report that structural elements be founded in and/or upon geological materials of the type and in the condition used in this report. Sufficient observations should be made by qualified geotechnical personnel during construction to assure that the soil and/or rock conditions considered in this report in fact exist at the site.

1.17 SAMPLES

TETRA TECH will retain all soil and rock samples for 30 days after this report is issued. Further storage or transfer of samples can be made at the Client’s expense upon written request, otherwise samples will be discarded.

1.18 APPLICABLE CODES, STANDARDS, GUIDELINES & BEST PRACTICE

This document has been prepared based on the applicable codes, standards, guidelines or best practice as identified in the report. Some mandated codes, standards and guidelines (such as ASTM, AASHTO Bridge Design/Construction Codes, Canadian Highway Bridge Design Code, National/Provincial Building Codes) are routinely updated and corrections made. TETRA TECH cannot predict nor be held liable for any such future changes, amendments, errors or omissions in these documents that may have a bearing on the assessment, design or analyses included in this report.

APPENDIX C

Site C Portage Mountain Quarry Hibernacula Noise and Vibration Study

REPORT

SITE C PORTAGE MOUNTAIN QUARRY HIBERNACULA NOISE & VIBRATION STUDY

HUDSON'S HOPE, BC.

2020 – 2021 MEASUREMENT SUMMARY

RWDI # 2002354

January 14, 2022

SUBMITTED TO

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DRAFT	December 14, 2021	All	Matthew Johnston, P.Eng. Daniel Kremer, EIT, M.Sc.
DRAFT	January 14, 2022	All	Matthew Johnston, P.Eng. Daniel Kremer, EIT, M.Sc.

1 INTRODUCTION

RWDI was retained by BC Hydro (BCH) to analyze noise and vibration data collected by BCH from the Portage Mountain Quarry (PMQ) operations over the years of 2020 and 2021. Monitoring was conducted at representative locations for nearby bat roosts (hibernacula). The monitoring programs were completed in the 2020 and 2021 summer months and covered the following:

1. Monthly noise measurements at the north bluff, south bluff, and background locations; and
2. Long-term sound concussion and vibration blast monitoring at the north bluff and south bluff.

We acknowledge this work is being conducted on the traditional territory of Treaty 8 First Nations of Dunne Zaa, Cree and Tse'khene cultural descent.

This report summarizes the findings from the monitoring. Where measurements captured blasting, the measured levels were compared to the specified criteria limits taken from the Best Management Practices (BMP) Guidelines for Bats in British Columbia (BC MOE 2016). The BMP suggests best practice limits for noise and vibration due to blasting with respect to levels experienced at hibernacula.

1.1 Site and Measurement Overview

The PMQ is located approximately 13 km southwest of the town of Hudson's Hope, BC. The quarry provides aggregate materials for the construction of the Site C hydroelectric dam. Bat hibernacula were identified on the north bluff and the south bluff overlooking the working area. Monitoring of noise and vibration was focused near the identified hibernacula. Background noise measurements were taken approximately 5 km northeast from the quarry.

Figure 1 shows the overview of the considered area highlighting the north and south bluff hibernacula areas, the PMQ footprint, and the locations of the monitoring. Both the monthly noise monitoring and the 2021 blast monitoring were conducted in the general areas marked for the north and south bluffs.

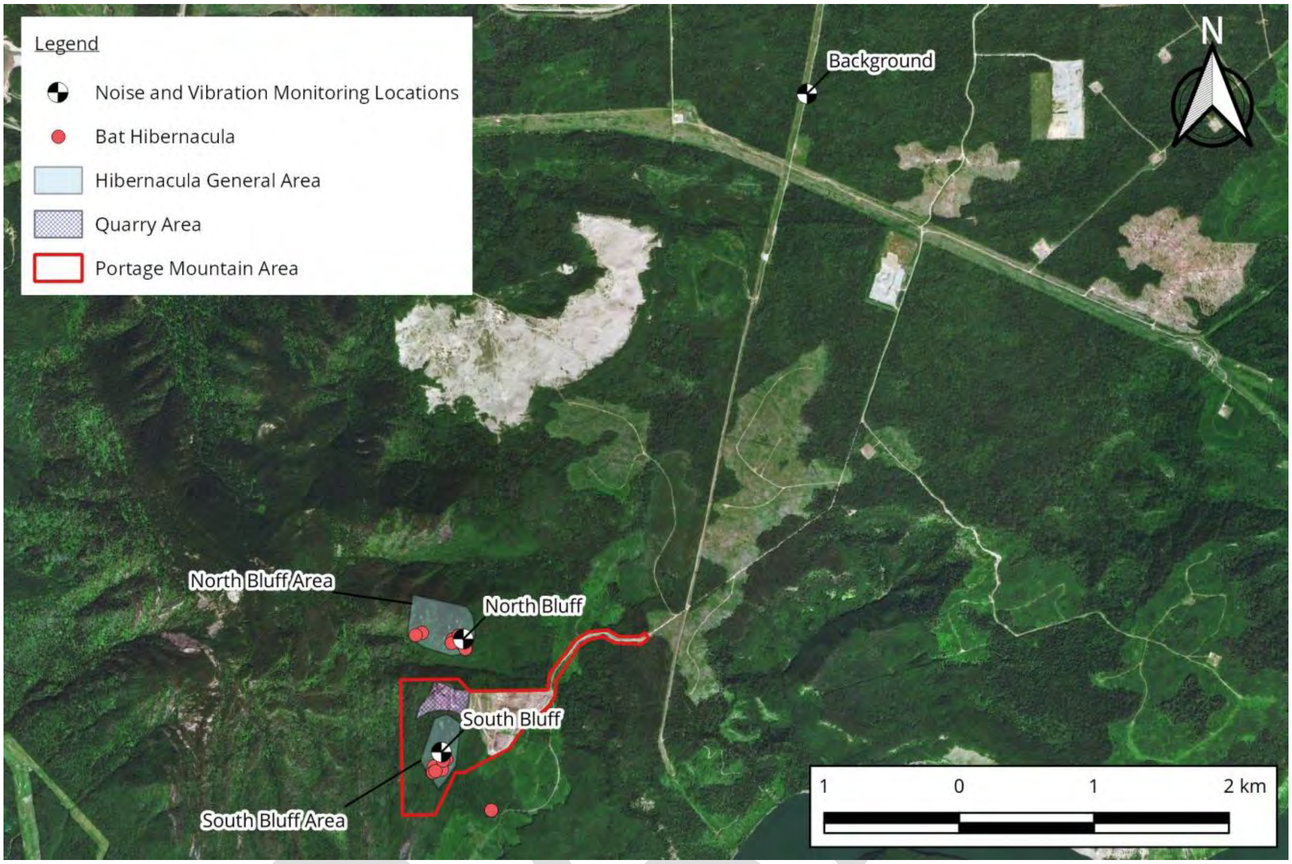


Figure 1: Location of the noise and vibration monitoring locations, bat hibernacula, and Portage Mountain Quarry.

1.2 Hibernacula Criteria

The guideline criteria specified in the Best Management Practices Guidelines for Bats in British Columbia (BC MOE 2016) for blasting states criteria of:

- sound concussion less than 150 dBL; and
- shockwave less than 15 psi (equivalent to 194 dB, using a reference pressure of 20 μPa)
- peak particle vibration level threshold of 15 mm/s.

Overall daytime and nighttime sound level limits do not have any specific criteria limits for the hibernacula. Overall levels are computed and presented for comparison to historic measured levels.

2 MEASUREMENT SUMMARY

2.1 Monthly Noise Monitoring: 2020 and 2021

Monthly noise monitoring was conducted by BCH staff during 2020 and 2021. In general, three measurements at different locations were taken during monthly monitoring. The first being at the south bluff, the second at the north bluff, and the third taken at a representative background noise location. The background noise measurements were taken at a distance such that the PMQ activities would not influence the sound levels.

Monitoring was conducted using a Bruel and Kjaer 2250 class 1 sound level meter. The sound level meter was deployed on a tripod approximately 1.5 m above the ground. The sound level meter was set to record continuous time weighted sound levels (Leq). The length of the measurement was at the discretion of BCH staff.

Table 1 lists the summary of the monthly monitoring data obtained from BCH. Figures of the measurement levels can be found in Appendix A.

Table 1: Summary of the Monthly Noise Monitoring

South Bluff		North Bluff		Background	
Deploy Date	Length of Measurement (Hours)	Deploy Date	Length of Measurement (Hours)	Deploy Date	Length of Measurement (Hours)
5/23/2020	23.7	5/24/2020	0.7	5/24/2020	0.9
6/26/2020	25.4	6/26/2020	0.8	6/25/2020	0.8
7/20/2020	23.7	7/21/2020	22.8	7/23/2020	0.5
8/15/2020	23.8	8/15/2020	8.2	8/17/2020	0.6
9/25/2020	23.8	9/27/2020	24.4	9/28/2020	1.0
5/31/2021	64.7	5/17/2021	85.5	-	-

Note: - indicates no measurement was conducted

2.2 Long-term Blast Monitoring

Long-term blast monitoring was conducted by BCH with support from Explotech and RWDI from May through September, 2021. The monitoring used the MiniMate Plus blast monitoring device, and measured overpressure and peak particle velocity (PPV). Both the north and south bluffs had one MiniMate monitor each. The system used a threshold trigger in both overpressure and PPV to log events, and was connected to a cellular modem for remote data collection.

In total, over 3,000 triggered events were recorded by the MiniMates at the two locations combined. RWDI received a log of the PMQ blasts for the 2021 year from BCH. The blast log was used to filter for blasting events recorded by the MiniMate by specifying exact times and dates.

3 RESULTS

3.1 Monthly Noise Monitoring: 2020 and 2021

The daytime and nighttime A-weighted average equivalent sound level (LA_{EQ}) per month has been calculated and are presented in Table 2. The average daytime and nighttime LA_{EQ} for the entire monitoring period of 47 dBA and 41 dBA respectively for the south bluff, and 55 dBA and 48 dBA respectively for the north bluff.

Table 2: Monthly and Overall Average Sound Levels for North Bluff, South Bluff, and Background

Month	Overall Sound Levels (dBA)					
	South Bluff		North Bluff		Background	
	Day[1]	Night[2]	Day[1]	Night[2]	Day[1]	Night[2]
May-20	41	32	55	-	55	-
Jun-20	48	43	57	-	49	-
Jul-20	51	41	52	38	33	-
Aug-20	49	43	52	43	38	-
Sep-20	47	42	55	55[3]	58	-
May-21	45	40	53	42	-	-
Overall	**47**	**41**	**55**	**48**	**-**	**-**
2019 Overall	45	41	ND			

Notes: [1] Daytime hours are from 07:00 to 22:00
[2] Nighttime hours are from 22:00 to 07:00
[3] Construction throughout the nighttime audible
- indicates no measurement conducted
ND indicates not determined in the 2020 report.

The table also compares the overall LA_{EQ} for the south bluff as measured during the 2019 south bluff monitoring program (RWDI, 2020), having average daytime and nighttime levels of 45 dBA and 41 dBA respectively. The overall sound levels demonstrate that levels have remained consistent for the three years during the monitoring months.

Of particular interest are the sound levels at the north bluff. The daytime levels may be explained by the vantage the north bluff has to the quarry: an almost unobstructed view, which would result in potential louder daytime levels.

The nighttime sound levels at the north bluff for September 2020 are equal to the daytime levels, and can be attributed to nighttime work. The audio for that period indicates that construction occurred continuously throughout the night.

The background measurements 5 km northeast from the quarry show how much the sound levels can change in a wooded environment. Daytime levels were measured as low as 33 dBA (similar to the nighttime levels on the south bluff), to as much as 58 dBA in the area.

For each hour of the day, an LA_{EQ} was computed for the entire monitoring period. Figure 2 shows the LA_{EQ} sound levels at the north and south bluffs, for each hour of the day. South bluff hourly data match the 2019 results with good agreement.

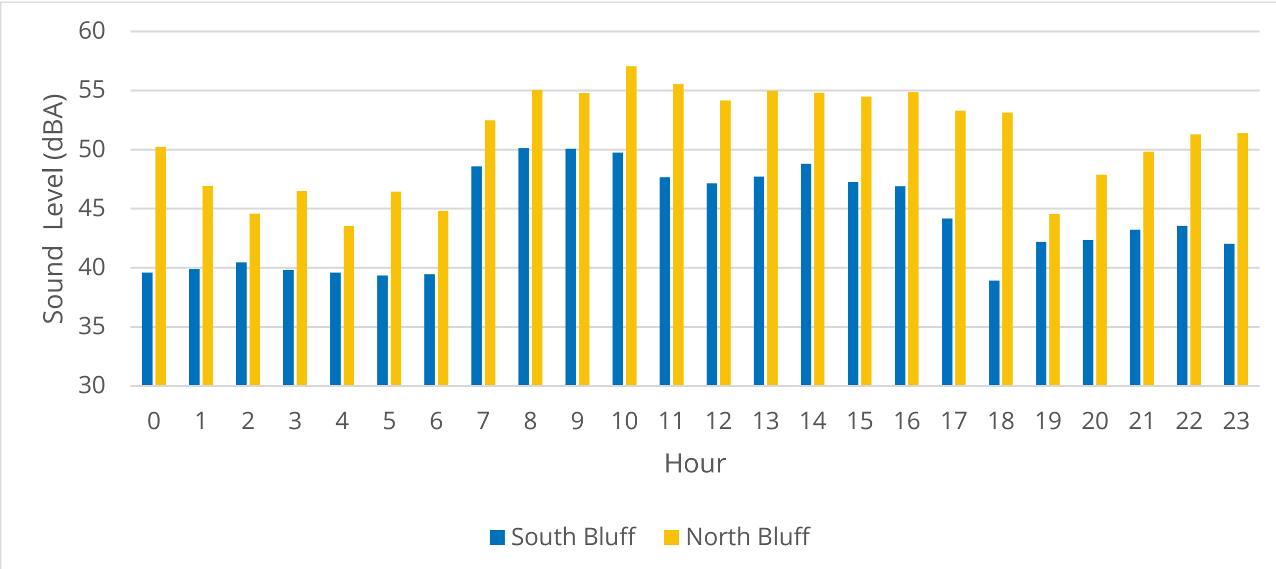


Figure 2: Average Overall Hourly LA_{EQ} for the South and North Bluffs (2020 and 2021 monitoring)

3.1.1 High Frequency Noise

As bats use high frequency acoustics for echolocation and communication, a review of the measured levels in the upper frequency ranges of the noise data unit was completed. There are no established criteria with which to compare high frequency noise, to determine if the levels are acceptable.

In the 2019 south bluff report, the high frequency noise components from 6300 Hz to 20000 Hz were reported using the 99th percentile values for daytime hours when construction was active and not active. The conclusion was that there was negligible difference between the construction and non-construction.

The same high frequency components were calculated for the south bluff using the same parameters for the daytime construction hours of 06:00 – 17:00 for the 2020/2021 program.

Figure 3 shows the computed the 99th percentile high frequency levels during construction (blue), and compares the data to the 2019 no construction levels (red). The figure shows that the levels are slightly different for the south bluff between the two monitoring programs (2019 and the 2020/2021 programs). The frequency bands of 6300 Hz and 8000 Hz show slightly increased levels at the south bluff, but that levels are lower in the higher frequency bands.

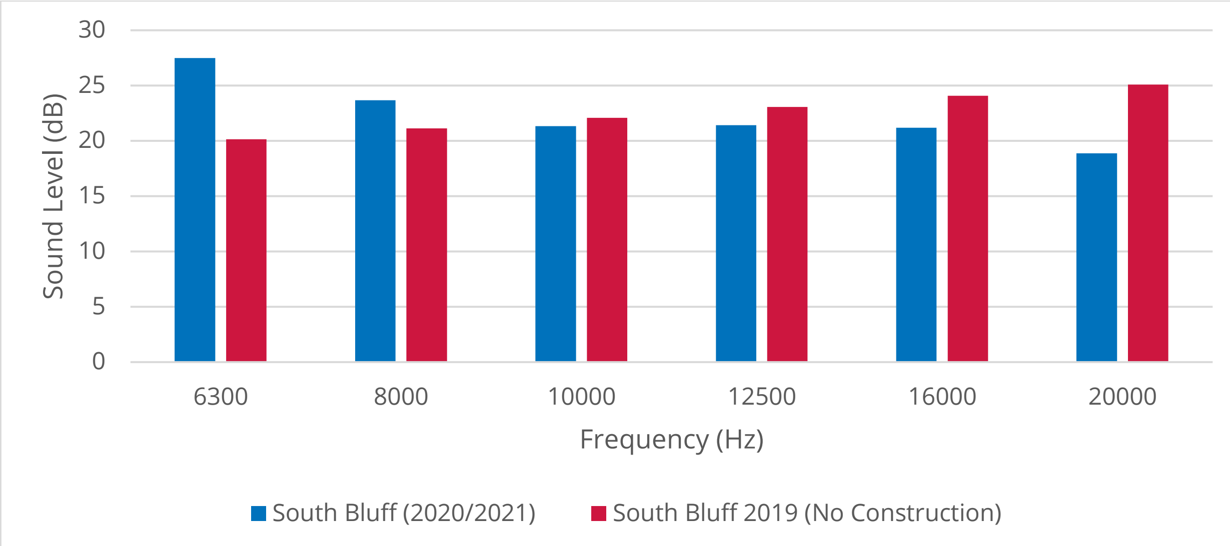


Figure 3: Comparison of High Frequency Sound Levels During 2020/2021 Construction to the 2019 Off Hours on the South Bluff

3.2 Long-Term Blast Monitoring

The MiniMate records sound concussion pressure in Pa, which has been converted to dBL using a reference pressure of 20 μPa. The MiniMate records ground-vibration as Peak Particle Velocity (PPV) in mm/s for the X, Y, and Z components of ground movement. The maximum PPV signal in the X, Y and Z components have been summed to provide the Peak Vector Sum (PVS) for comparison to criteria.

Table 3 shows the maximum recorded values at either south or north bluff, and their corresponding criteria limits.

Table 3: Maximum Measured Metrics Compared to Blasting Criteria

Metric	Measured	BC MOE 2016 Limit
Max PVS (mm/s)	9	15
Max Sound Concussion (dBL)	130	150
Max Shock Wave (psi)	0.0095	15

As shown in Table 3, the maximum measured metrics are all below the applicable criteria and therefore, all measured blasts are below the applicable criteria.

A full listing of the all the recorded blasts is provided in Appendix B. Figure 4 below shows the sound concussion for recorded blasts at the south and north bluffs in dBL. Figure 5 shows the PVS for recorded blasts at the south and north bluffs in mm/s.

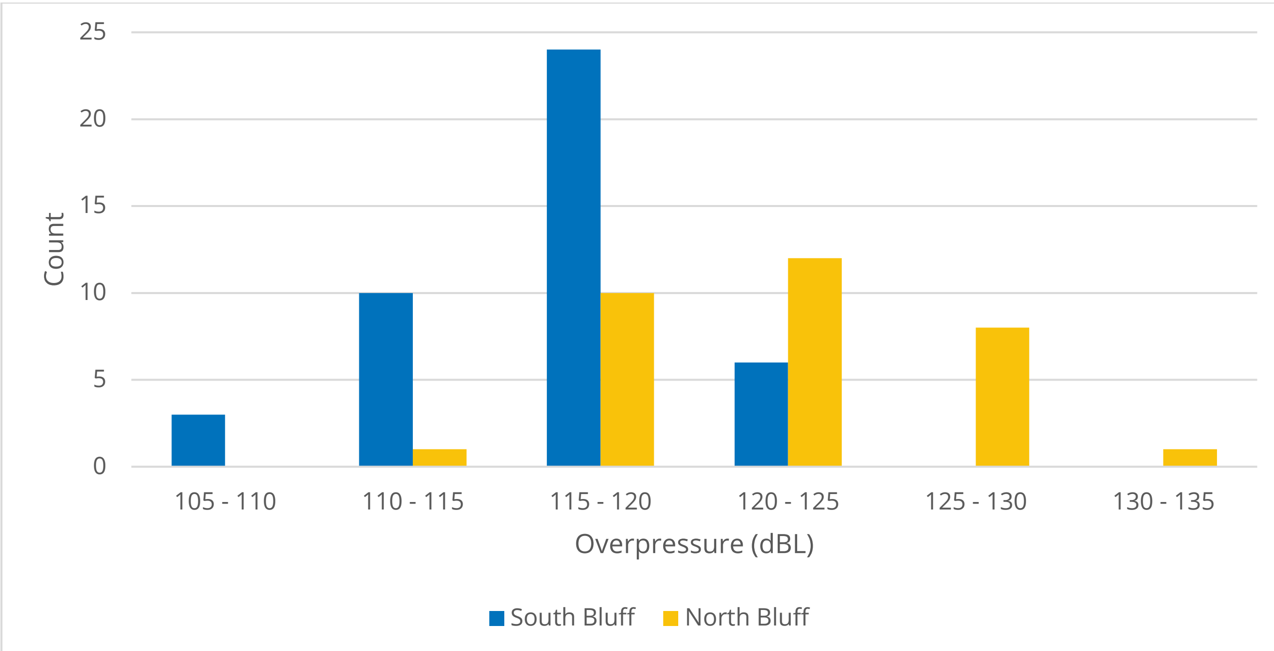


Figure 4: Count of Blasts Binned by Recorded Sound Concussion (dBL)

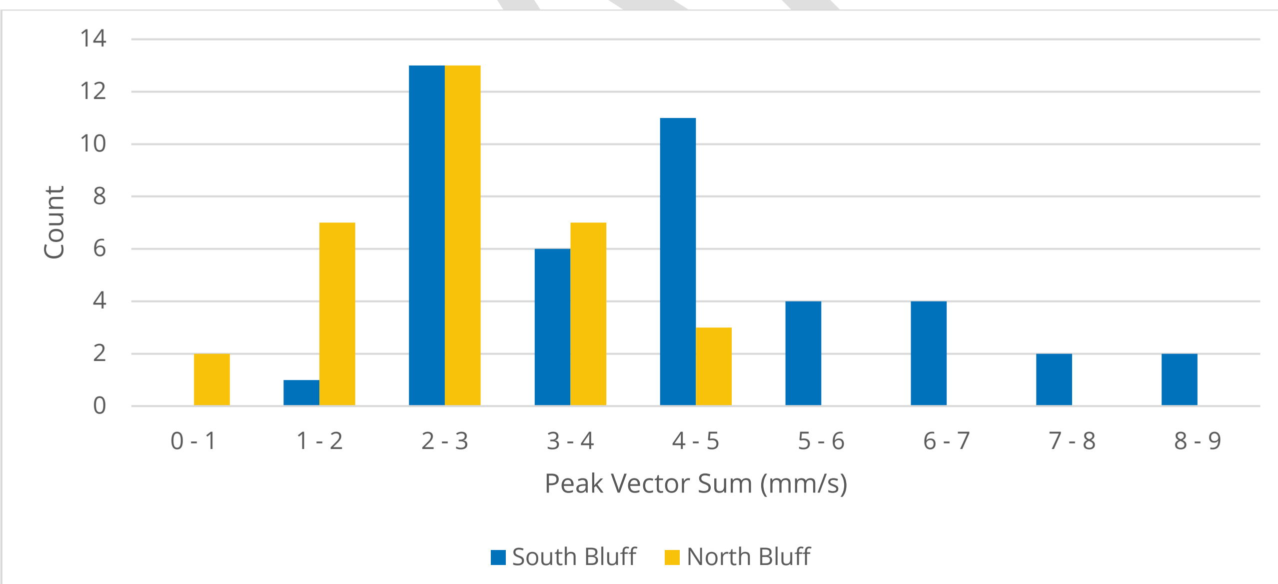


Figure 5: Count of Blasts Binned by Recorded Peak Vector Sum (mm/s)

3.2.1 Comparison on LZpeak and Overpressure / Sound Concussion (dBL)

In the 2019 PMQ measurements, a standard scientific IEPE microphone was used to obtain noise measurements. The LZpeak measurement level from this standard class 1 microphone was used to compare with BMP overpressure blast criteria.

The May 2021 noise measurements at the North Bluff captured LZpeak with the Bruel and Kjaer sound level meter, which uses a standard class 1 microphone. At the same time the MiniMate captured events using the overpressure microphone. Two blasts were captured on both devices at approximately the same distance from the blasts on the north face. These blasts are shown in Appendix A, Figure A17.

Table 1 shows the comparison of the two measurements from the two devices. The levels agree well with each other indicating that at these distances from a blast, a standard microphone reporting LZpeak is representative of overpressure.

Table 4: Comparison of Measured Blast Levels using the MiniMate Overpressure Microphone and a Standard Microphone reporting LZ Peak

Date	Time	MiniMate Overpressure (dBL)	Bruel and Kjaer LZ Peak (dB)
5/19/2021	6:02:50 PM	130	132
5/20/2021	5:59:31 PM	122	122

4 CONCLUSIONS

RWDI obtained and analyzed the blasting data for the two bluffs and compared the results to Best Management Practices (BMP) Guidelines for Bats in British Columbia (BC MOE 2016) criteria limits. The record showed that for the north and south bluffs all blasts were less than the specified criteria from the BMP.

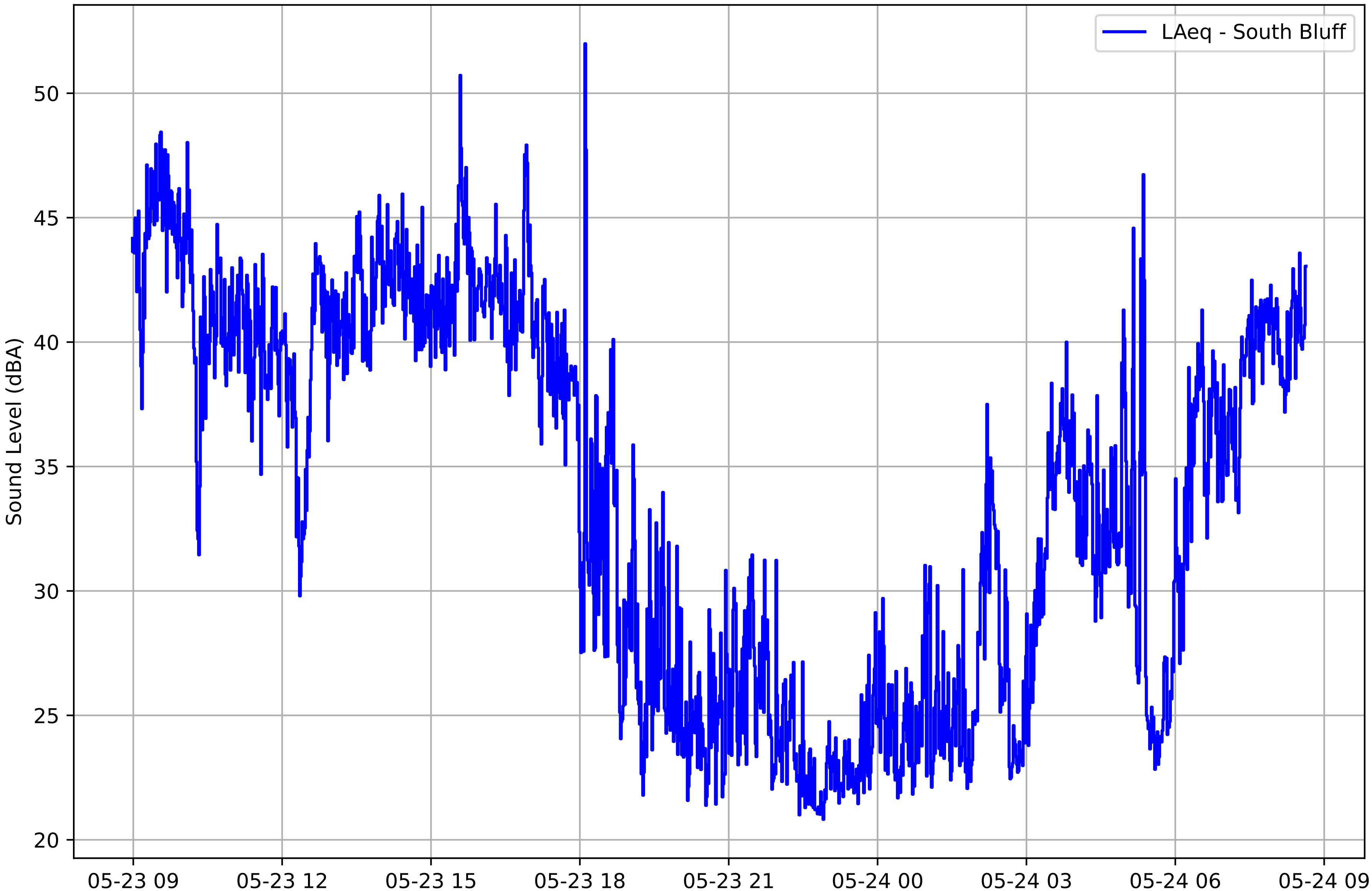
Six months of monthly noise data were obtained for general construction noise at the two bluffs and key metrics were analyzed. Although there are no applicable noise limits for construction, the levels at the south bluff in 2020 and 2021 are similar (+2 dB for daytime hours) to previous measurements conducted in 2019. This indicates that sound levels from construction activities have remained relatively constant. High frequency noise has also remained objectively consistent, with octave bands in the 6300 Hz and 8000 Hz frequencies being greater and all remaining higher frequencies in 2020 and 2021 being less than previously measured in 2019.

5 REFERENCES

BC MOE (British Columbia Ministry of Environment), 2016. Best Management Practices Guidelines for Bats in British Columbia, Chapter 2: Mine Developments and Inactive Mine Habitats, British Columbia.

RWDI, 2020. Site C Portage Mountain Quarry Hibernacula Noise & Vibration study, Hudson's Hope BC. April 9, 2020.RWDI # 1601625. Vancouver, British Columbia.

APPENDIX A



BC Hydro Site C

Monthly Noise Monitoring

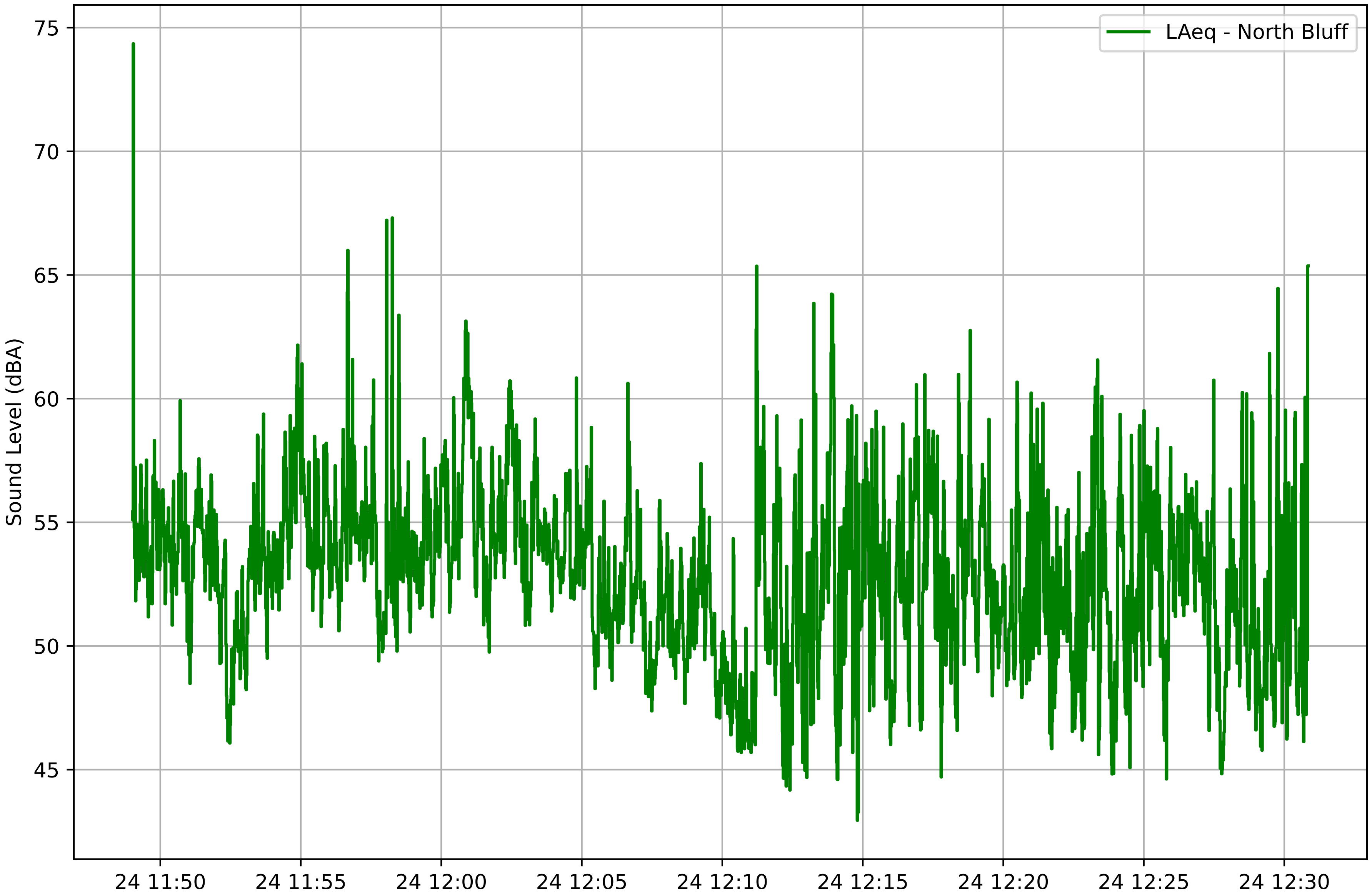
May 2020 - South Bluff

Portage Quarry, British Colombia

Project #: 2002352

Figure No. A1

Date Revised: 2021-12-14



BC Hydro Site C

Monthly Noise Monitoring

May 2020 - North Bluff

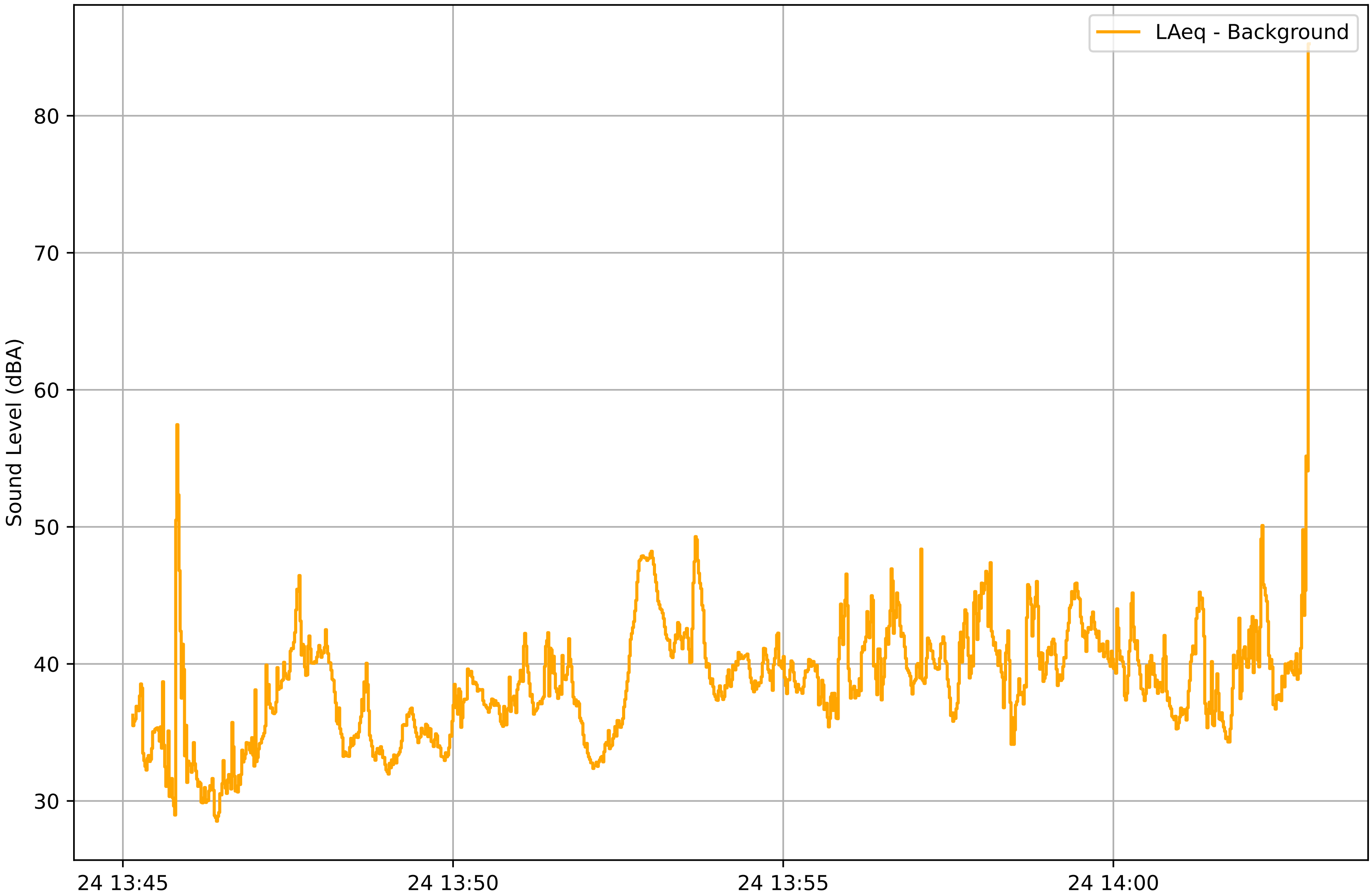
Portage Quarry, British Colombia

Project #: 2002352

Figure No. A2

Date Revised: 2021-12-14

RWDI



BC Hydro Site C

Monthly Noise Monitoring

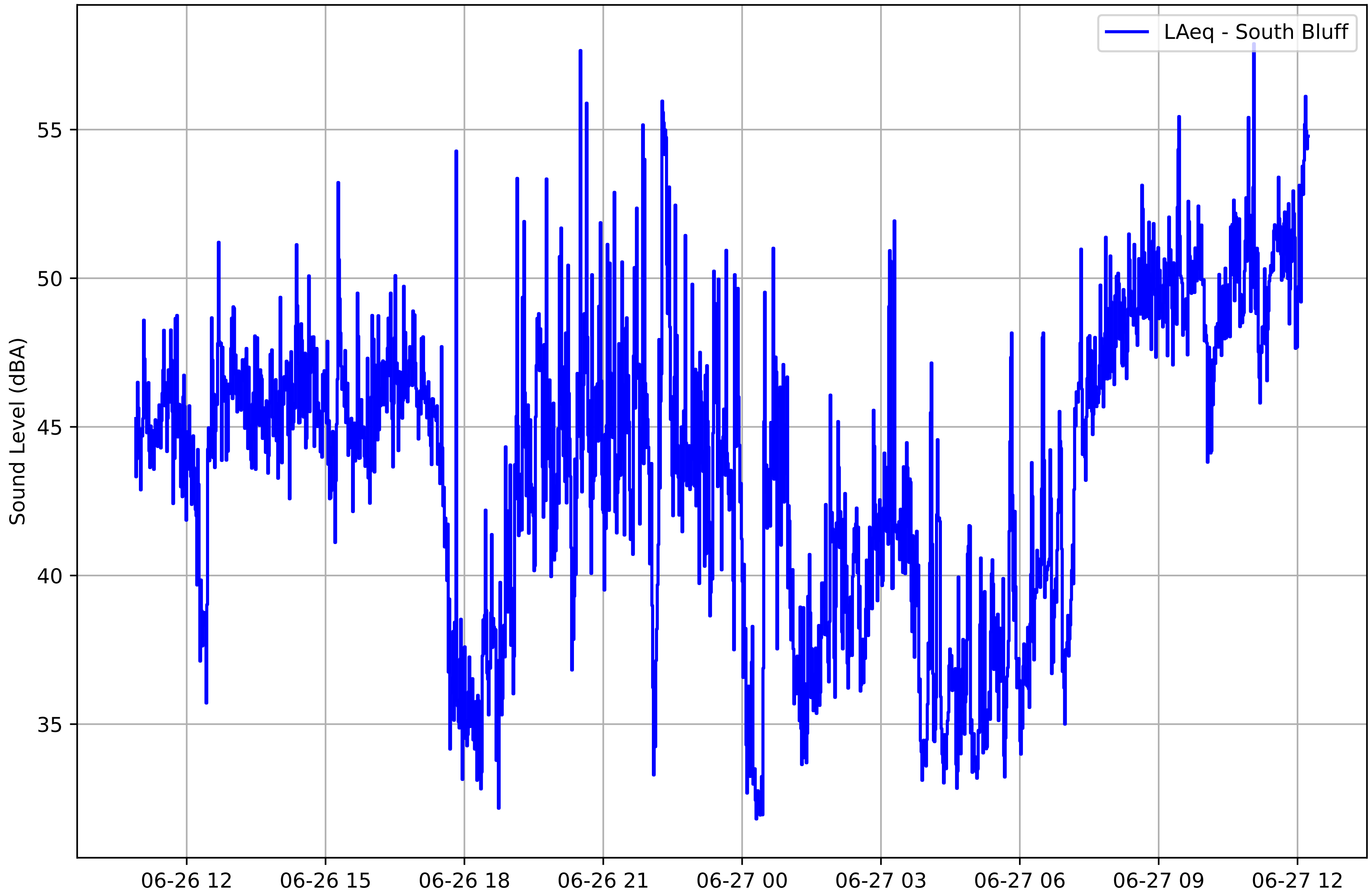
May 2020 - Background

Portage Quarry, British Colombia

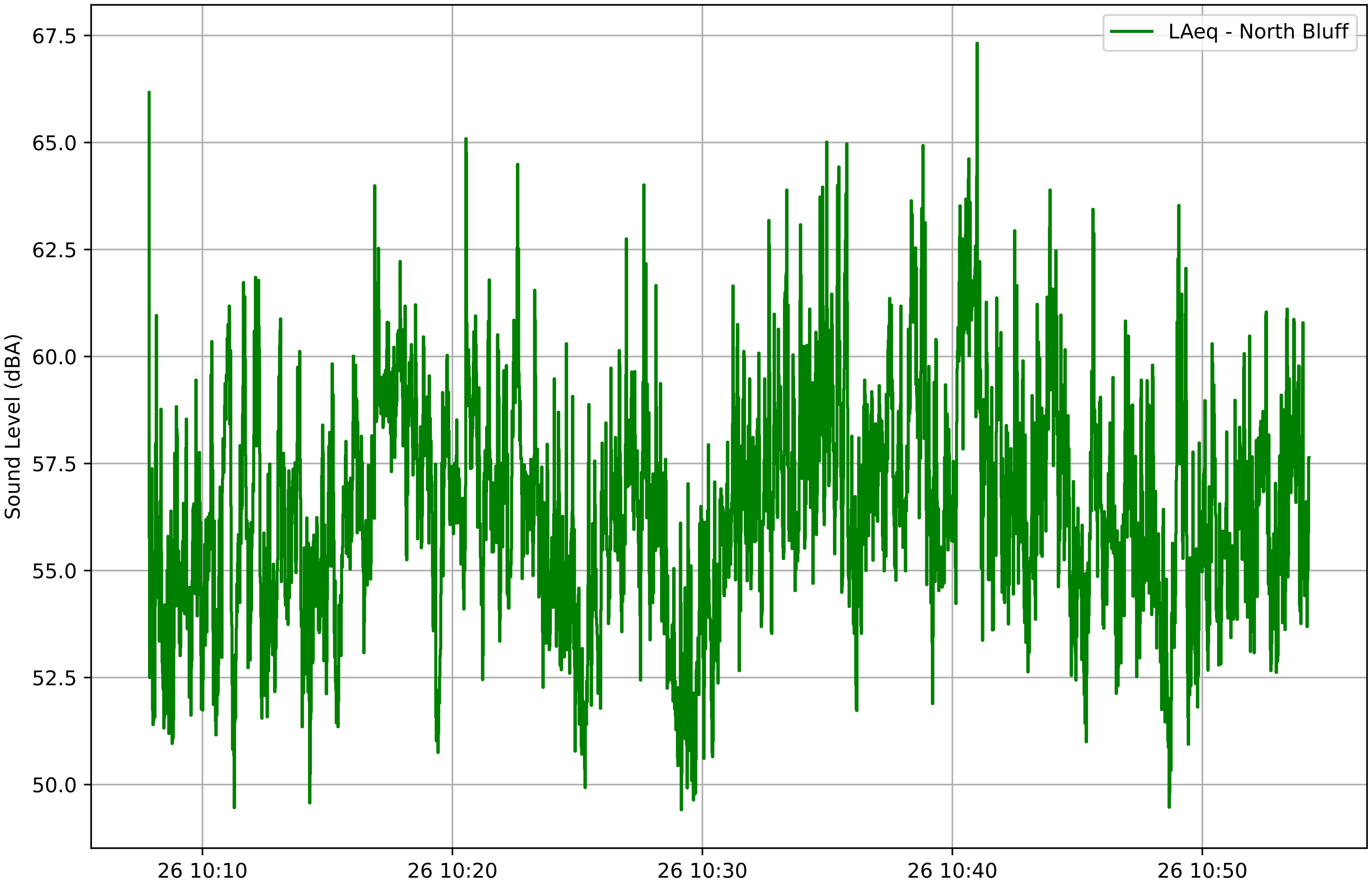
Project #: 2002352

Figure No. A3

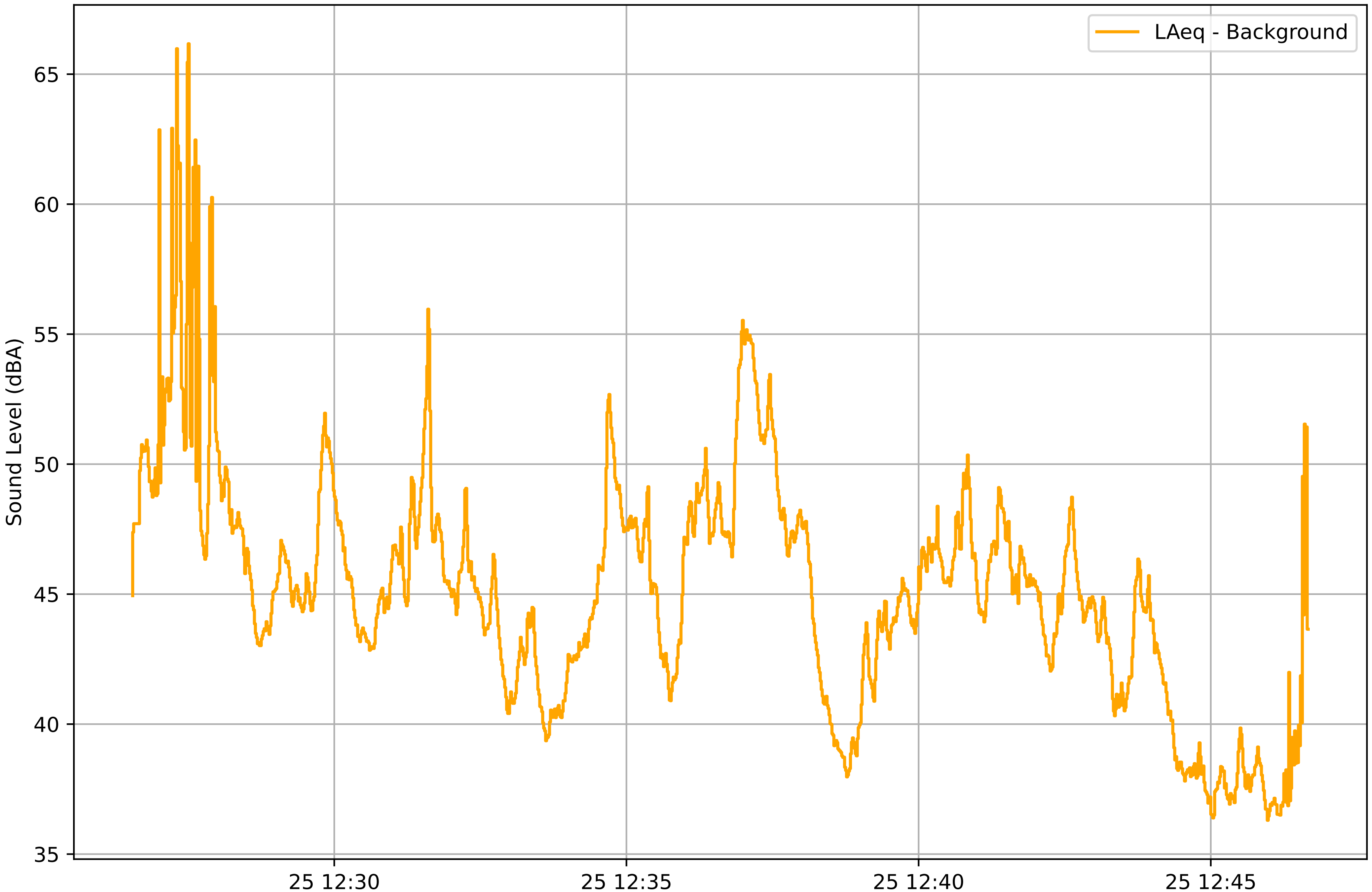
Date Revised: 2021-12-14



BC Hydro Site C **Monthly Noise Monitoring** **June 2020 - South Bluff** Portage Quarry, British Colombia Project #: 2002352	Figure No. A4 Date Revised: 2021-12-14	RWDI



BC Hydro Site C **Monthly Noise Monitoring** **June 2020 - North Bluff** Portage Quarry, British Colombia — Project #: 2002352	Figure No. A5 Date Revised: 2021-12-14



BC Hydro Site C

Monthly Noise Monitoring

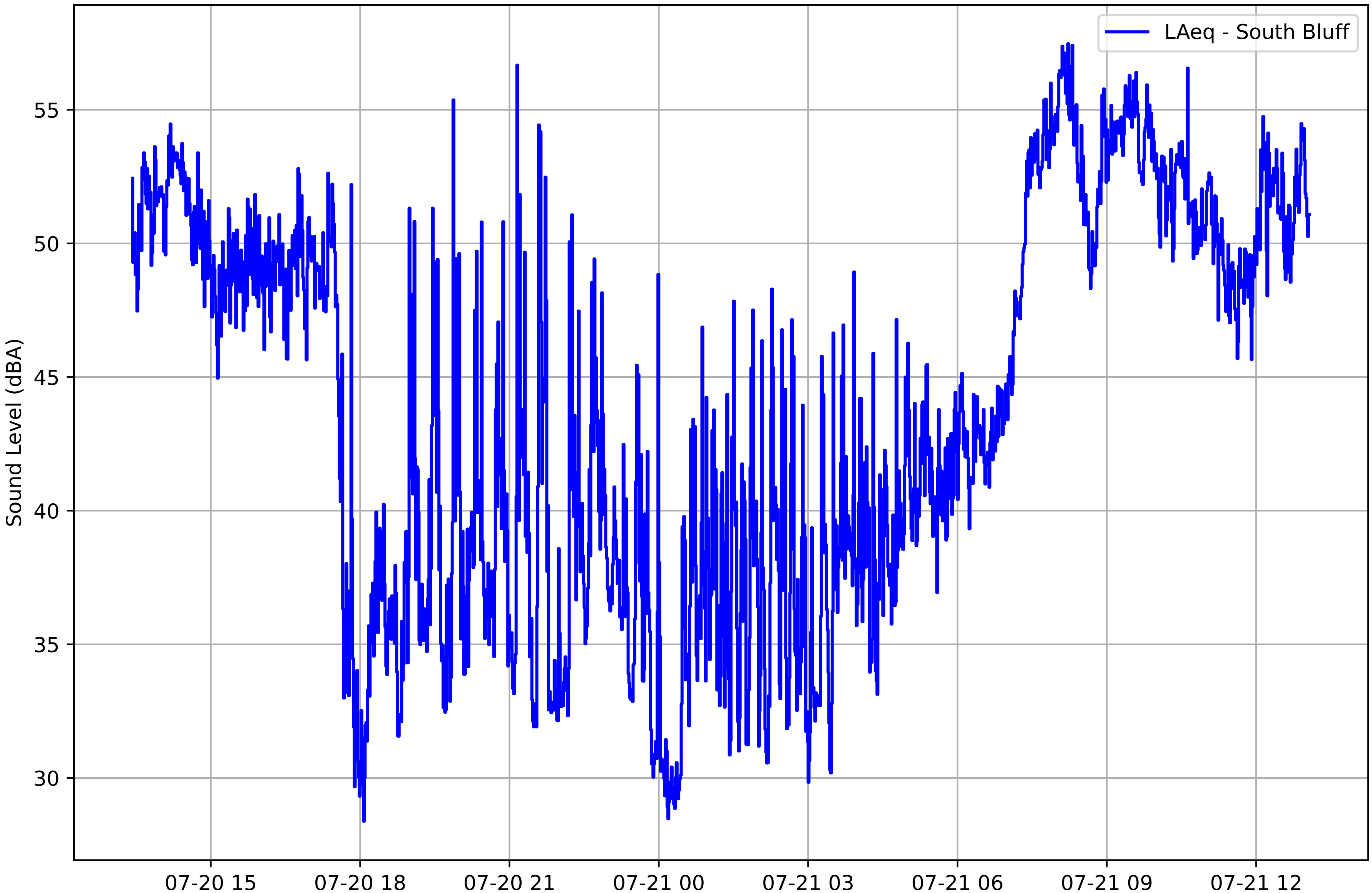
June 2020 - Background

Portage Quarry, British Colombia

Project #: 2002352

Figure No. A6

Date Revised: 2021-12-14



BC Hydro Site C

Monthly Noise Monitoring

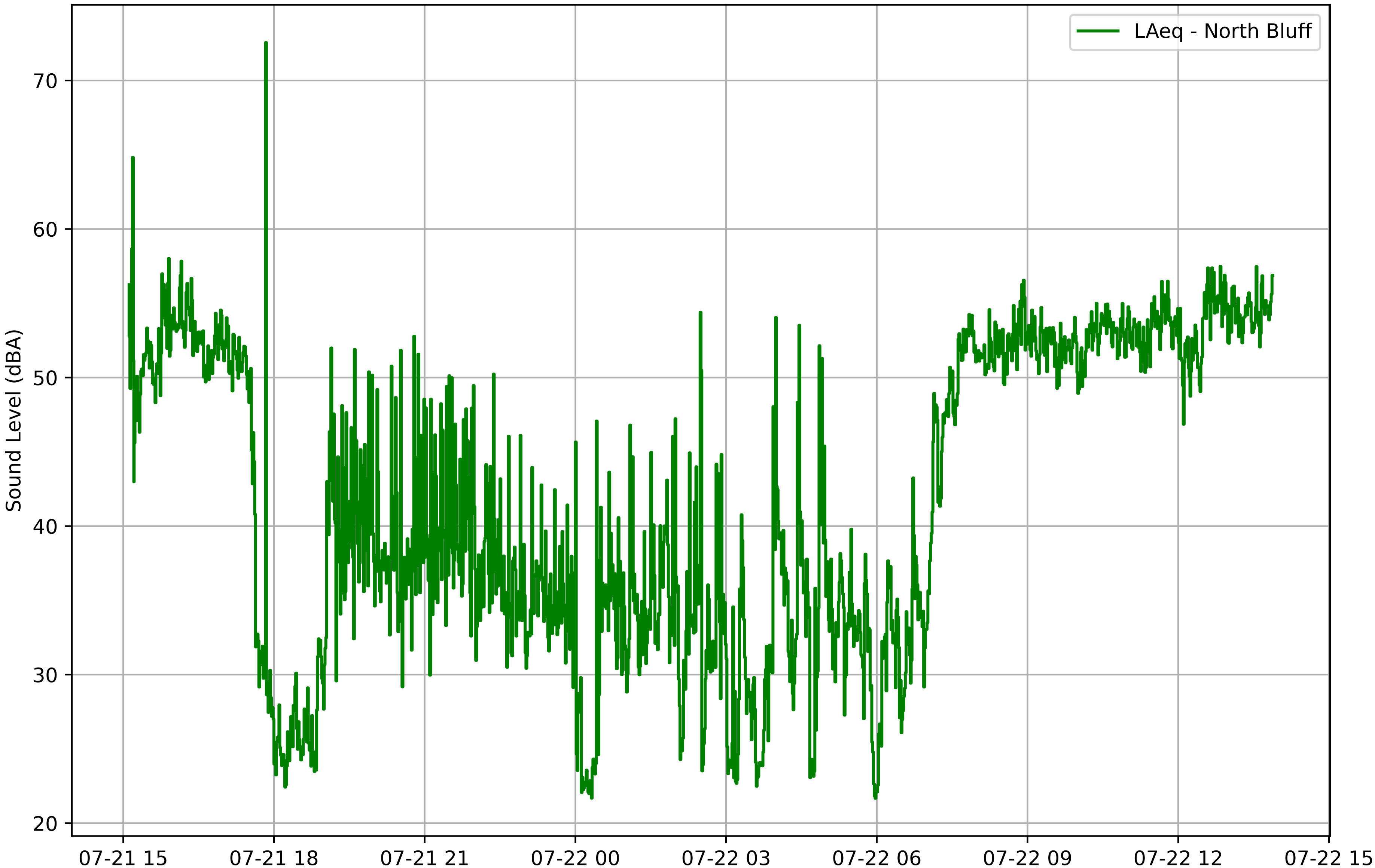
July 2020 - South Bluff

Portage Quarry, British Colombia

Project #: 2002352

Figure No. A7

Date Revised: 2021-12-14



BC Hydro Site C

Monthly Noise Monitoring

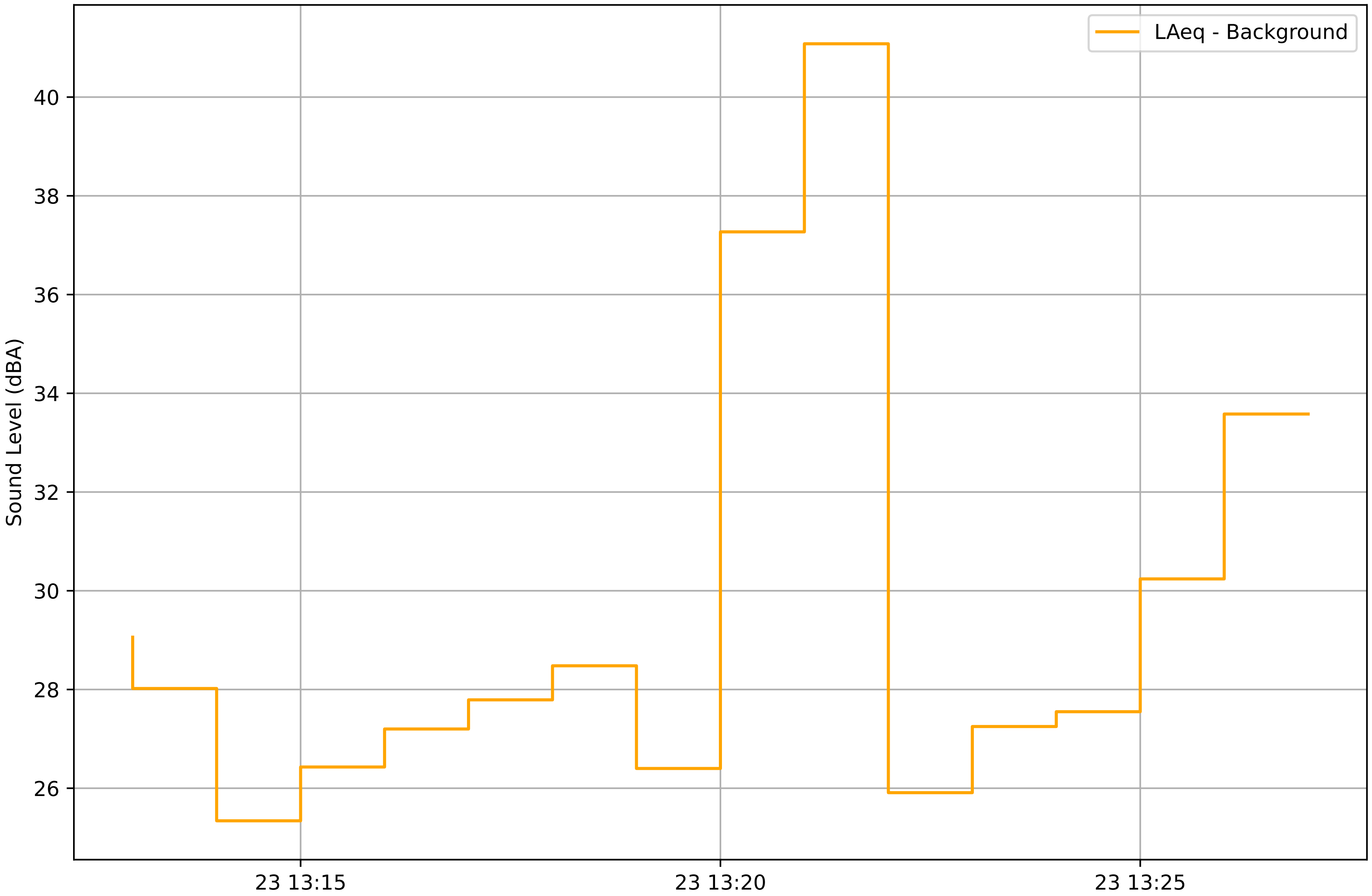
July 2020 - North Bluff

Portage Quarry, British Colombia

Project #: 2002352

Figure No. A8

Date Revised: 2021-12-14



BC Hydro Site C

Monthly Noise Monitoring

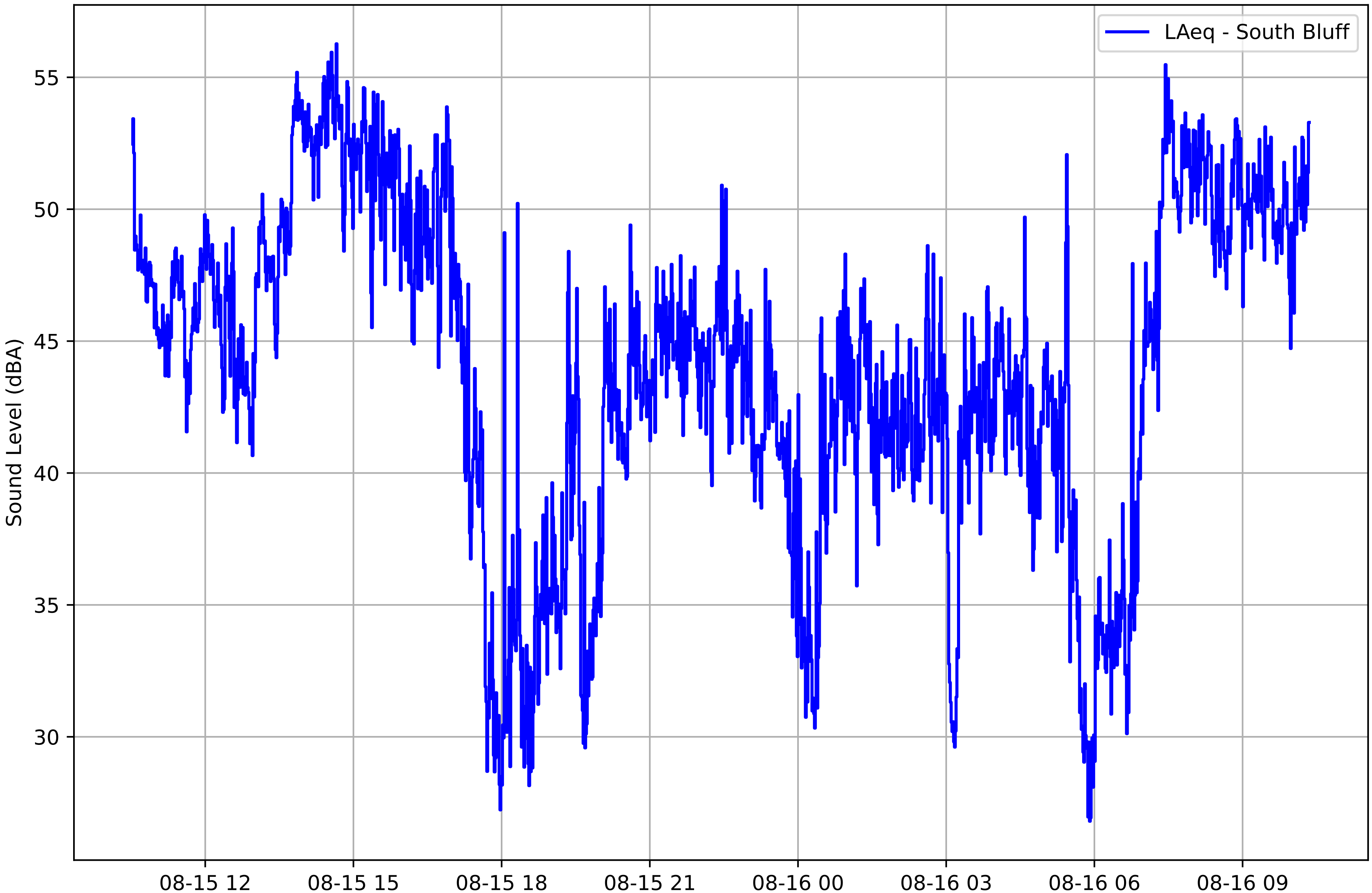
July 2020 - Background

Portage Quarry, British Colombia

Project #: 2002352

Figure No. A9

Date Revised: 2021-12-14



BC Hydro Site C

Monthly Noise Monitoring

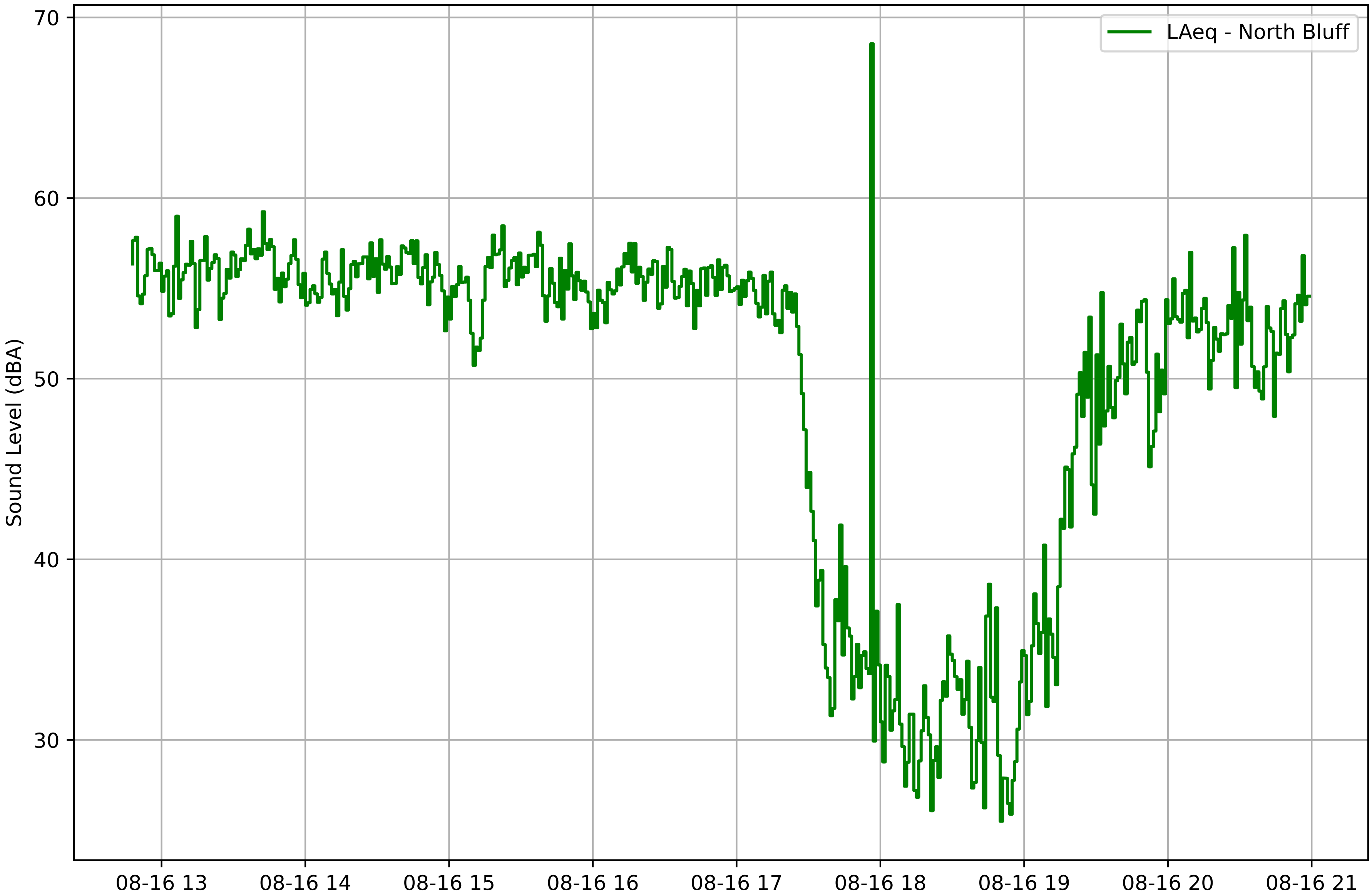
August 2020 - South Bluff

Portage Quarry, British Colombia

Project #: 2002352

Figure No. A10

Date Revised: 2021-12-14



BC Hydro Site C

Monthly Noise Monitoring

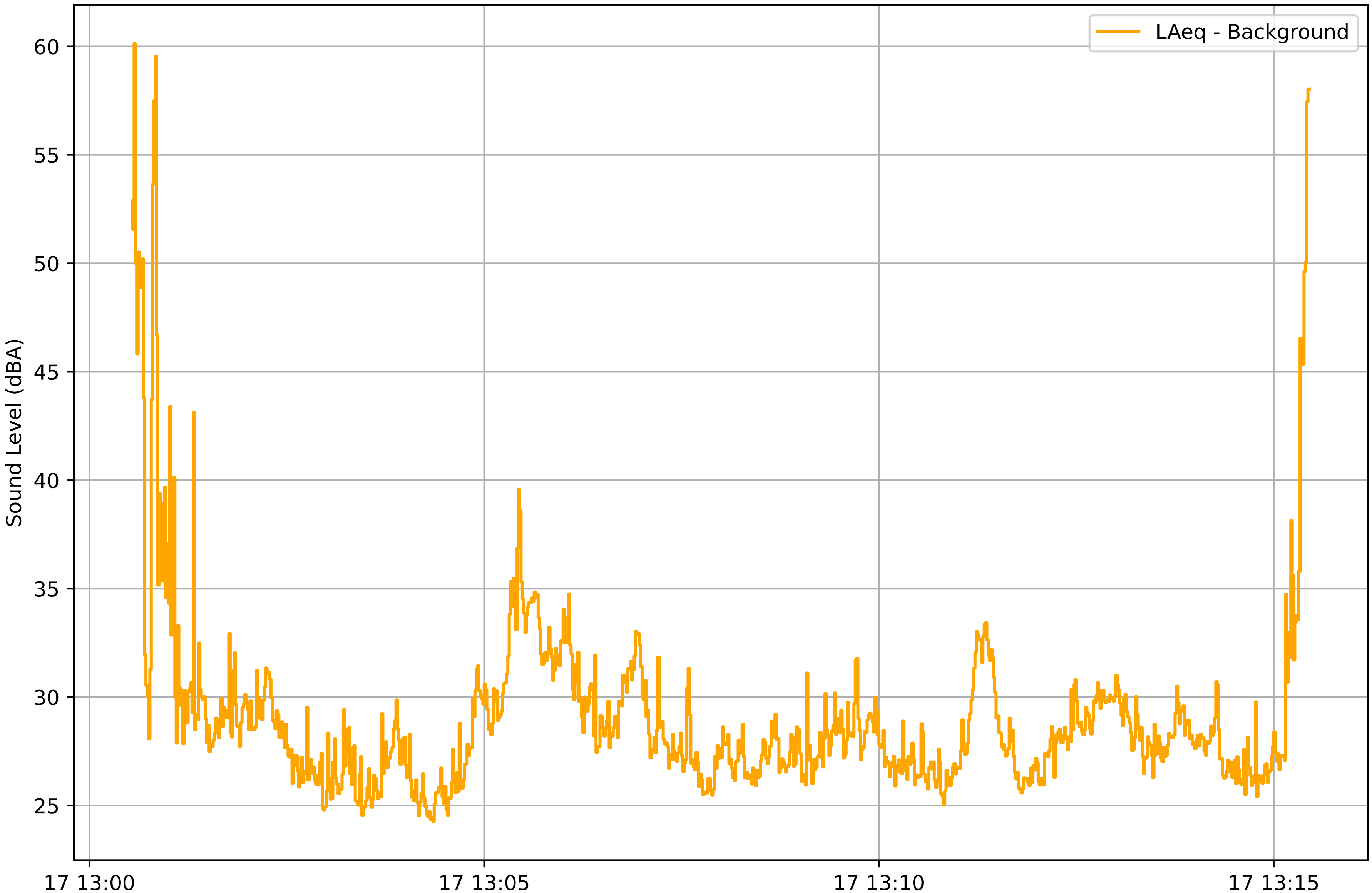
August 2020 - North Bluff

Portage Quarry, British Colombia

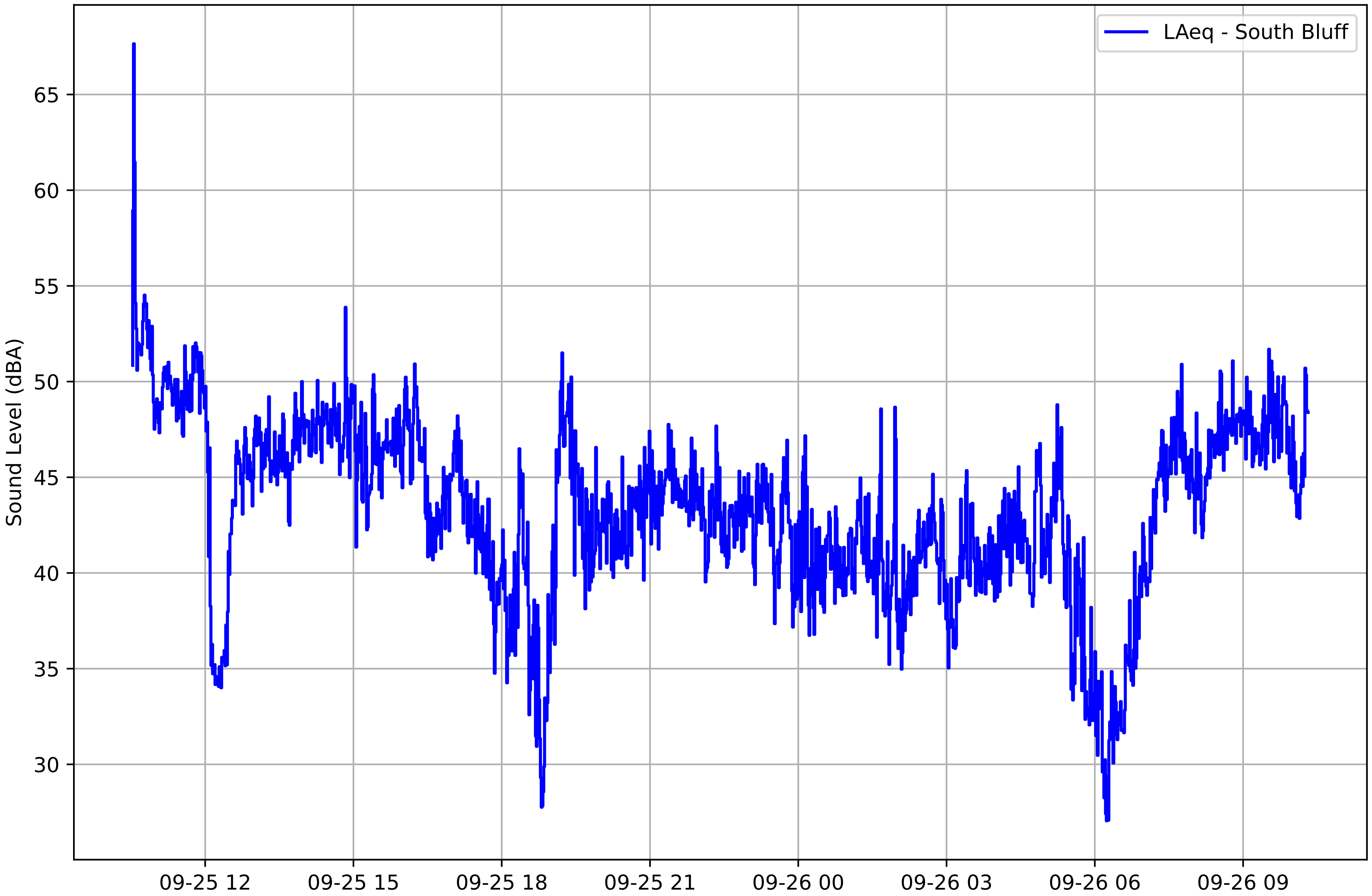
Project #: 2002352

Figure No. A11

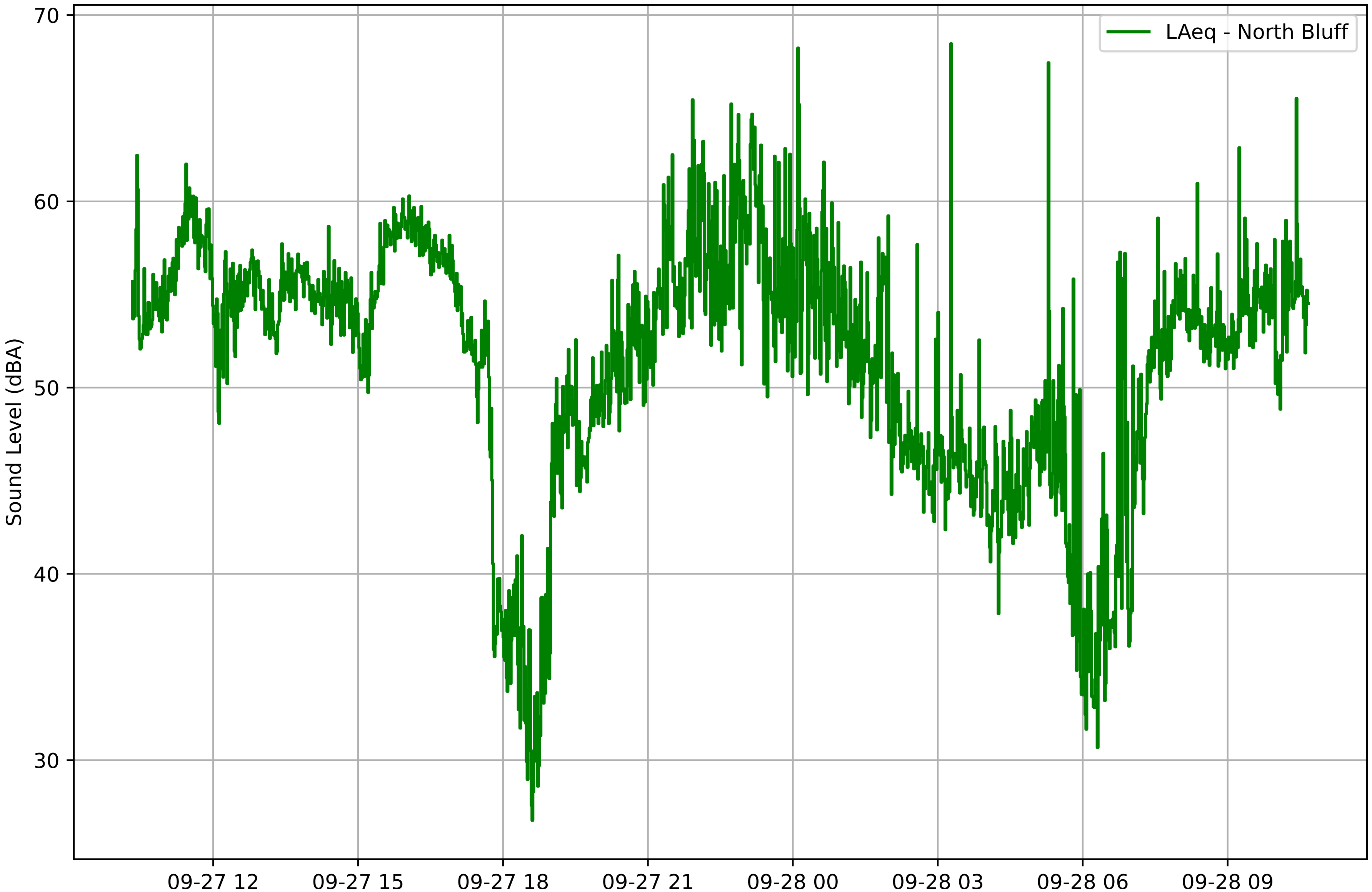
Date Revised: 2021-12-14



BC Hydro Site C **Monthly Noise Monitoring** **August 2020 - Background** Portage Quarry, British Colombia Project #: 2002352	Figure No. A12 Date Revised: 2021-12-14	RWDI



BC Hydro Site C **Monthly Noise Monitoring** **September 2020 - South Bluff** Portage Quarry, British Colombia — Project #: 2002352	Figure No. A13 Date Revised: 2021-12-14	



BC Hydro Site C

Monthly Noise Monitoring

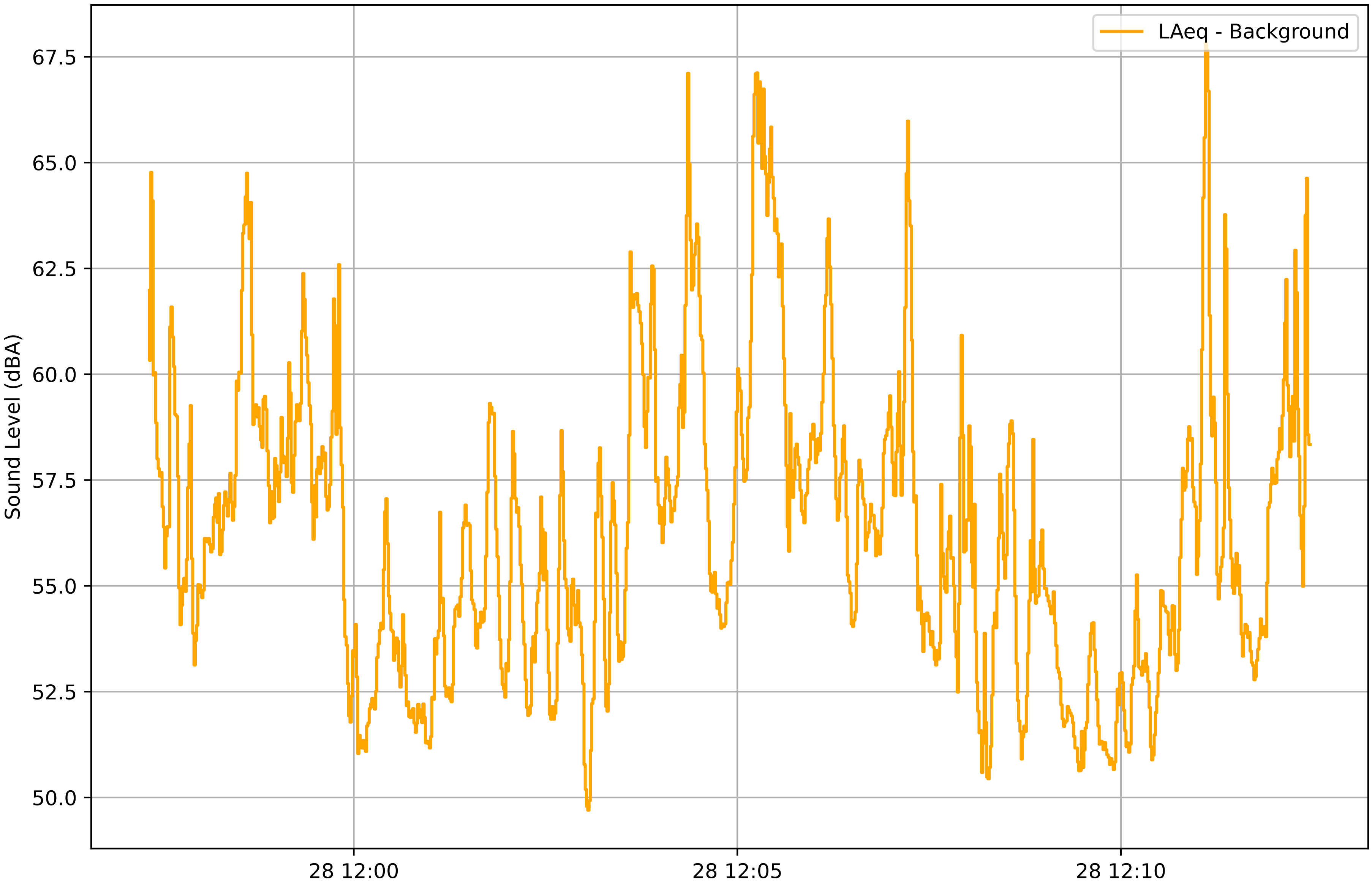
September 2020 - North Bluff

Portage Quarry, British Colombia

Project #: 2002352

Figure No. A14

Date Revised: 2021-12-14



BC Hydro Site C

Monthly Noise Monitoring

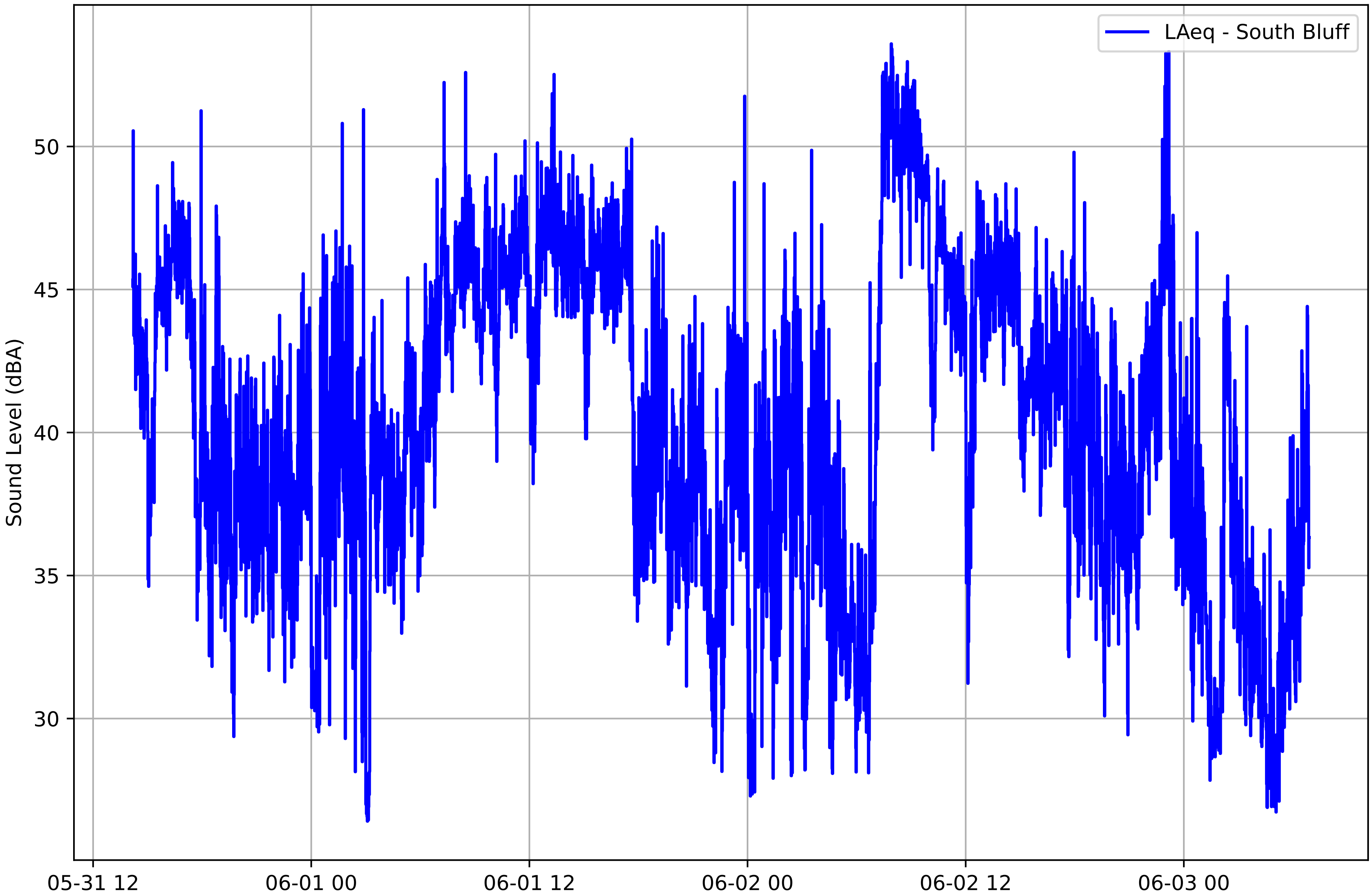
September 2020 - Background

Portage Quarry, British Colombia

Project #: 2002352

Figure No. A15

Date Revised: 2021-12-14



BC Hydro Site C

Monthly Noise Monitoring

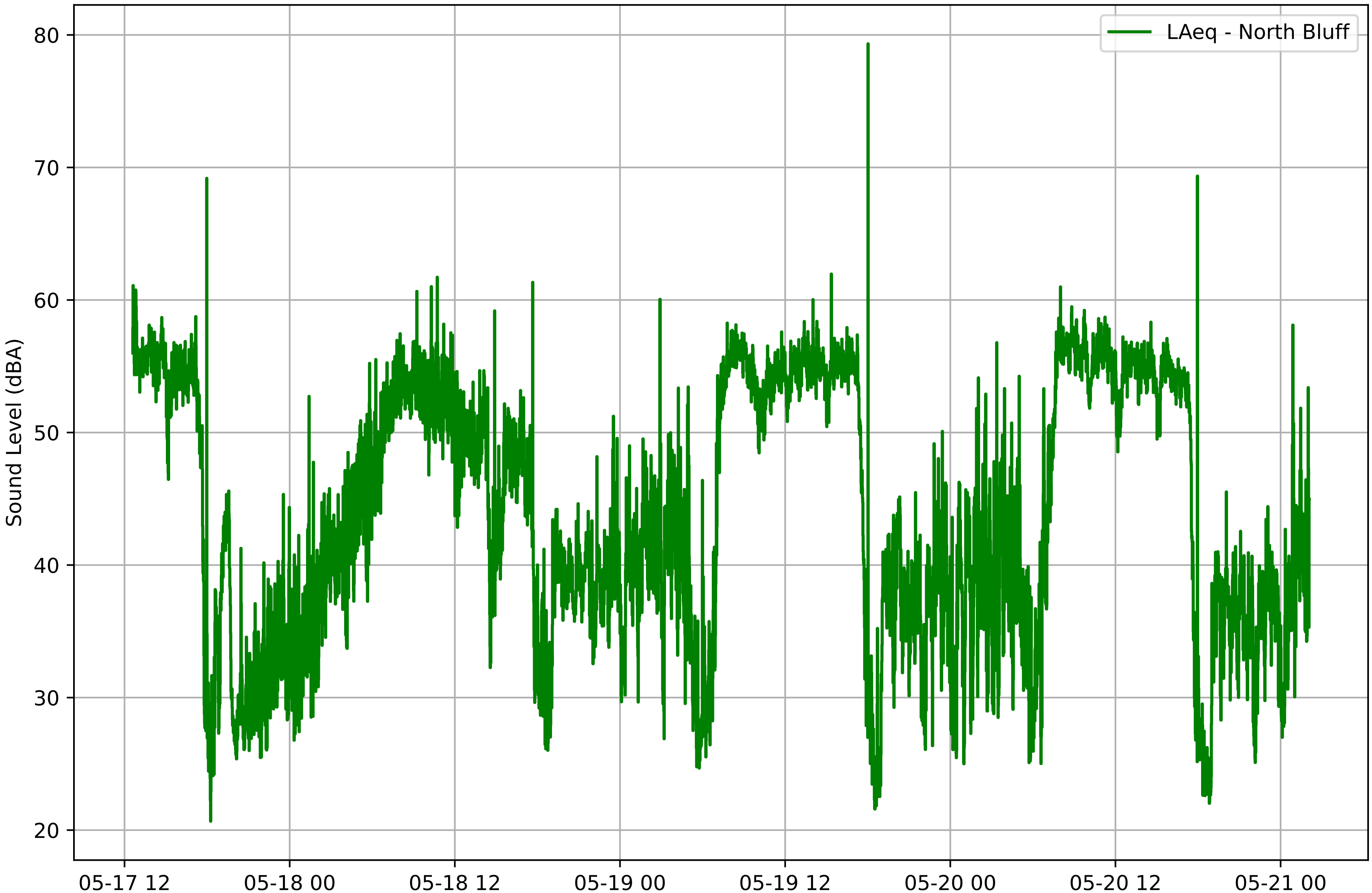
May 2021 - South Bluff

Portage Quarry, British Colombia

Project #: 2002352

Figure No. A16

Date Revised: 2021-12-14



BC Hydro Site C

Monthly Noise Monitoring

May 2021 - North Bluff

Portage Quarry, British Colombia

Project #: 2002352

Figure No. A17

Date Revised: 2021-12-14

APPENDIX B

Appendix B – Blast Record

Date	BC Hydro Blast Record	Charge Weight (kg)	South Bluff MiniMate Unit BE11251				North Bluff MiniMate Unit BE20183			
			Time Recorded	PVS (mm/s)	Sound Concussion (dBL)	Shock Wave (psi)	Time Recorded	PVS (mm/s)	Sound Concussion (dBL)	Shock Wave (psi)
				Limits per Guidelines for Bats in British Columbia (BC MOE 2016)				Limits per Guidelines for Bats in British Columbia (BC MOE 2016)		
				15	150	15		15	150	15
5/19/2021	990-210519	1132	6:02:29 PM	8.72	122	0.0038	6:02:50 PM	1.3	130	0.0095
5/20/2021	990-R-210521	755	5:59:38 PM	4.59	119	0.0027	5:59:31 PM	0.5	122	0.0035
5/21/2021	980-P-210521	101	5:56:28 PM	2.06	110	0.0009	5:56:22 PM	3.2	118	0.0023
5/22/2021	1000-T-210522	298	5:56:02 PM	2.62	112	0.0012	-	-	-	-
5/23/2021	980-P-210523	1272	6:05:22 PM	2.51	118	0.0022	6:05:19 PM	2.9	120	0.0029
5/24/2021	1000-T-210524	359	6:07:24 PM	2.85	119	0.0026	-	-	-	-
5/25/2021	980-P-210525	1033	6:11:39 PM	2.17	122	0.0037	6:11:39 PM	2.4	124	0.0045
5/26/2021	1000-T-210527	1224	-	-	-	-	-	-	-	-
5/28/2021	980-P-210528	1181	5:55:42 PM	3.38	118	0.0024	5:55:48 PM	2.9	126	0.0055
5/29/2021	980-P-210529	1013	5:57:21 PM	3.4	119	0.0026	5:57:28 PM	1.9	129	0.0086
5/31/2021	980-P-2105231	2321	5:57:14 PM	4	118	0.0022	-	-	-	-

Date	BC Hydro Blast Record	Charge Weight (kg)	South Bluff MiniMate Unit BE11251				North Bluff MiniMate Unit BE20183			
			Time Recorded	PVS (mm/s)	Sound Concussion (dBL)	Shock Wave (psi)	Time Recorded	PVS (mm/s)	Sound Concussion (dBL)	Shock Wave (psi)
				Limits per Guidelines for Bats in British Columbia (BC MOE 2016)				Limits per Guidelines for Bats in British Columbia (BC MOE 2016)		
				15	150	15		15	150	15
6/1/2021	980-P-210602	2475	-	-	-	-	-	-	-	-
6/5/2021	980-P-210605	1582	5:56:45 PM	3.81	121	0.0033	5:57:04 PM	2.1	127	0.0066
6/6/2021	980-P-210606	1392	5:45:53 PM	4.09	125	0.0050	5:46:13 PM	2.5	124	0.0046
6/7/2021	980-P-210607	2215	5:57:26 PM	5.77	118	0.0023	5:57:49 PM	4.4	128	0.0074
6/8/2021	1000-T-210608	569	5:56:09 PM	4.15	117	0.0021	5:56:33 PM	2.9	127	0.0067
6/10/2021	980-P-210610	2395	-	-	-	-	5:44:19 PM	1.9	123	0.0043
6/11/2021	980-P-210611	592	-	-	-	-	5:57:49 PM	3.0	120	0.0029
6/13/2021	980-P-210613	1904	-	-	-	-	5:49:26 PM	3.1	121	0.0032
6/16/2021	980-P-210616	3483	6:02:45 PM	7.19	119	0.0025	6:02:46 PM	1.8	120	0.0029
6/17/2021	980-P-210617	1734	5:55:54 PM	5.17	119	0.0027	5:55:57 PM	3.0	125	0.0052
6/20/2021	980-P-210620	2143	5:55:15 PM	6.12	112	0.0012	5:55:22 PM	1.9	120	0.0029
6/22/2021	980-P-210622	1055	6:03:07 PM	6.39	122	0.0038	6:03:17 PM	2.4	119	0.0027
6/23/2021	980-P-210623	3270	5:57:48 PM	6.91	123	0.0041	5:58:00 PM	2.0	125	0.0054

Date	BC Hydro Blast Record	Charge Weight (kg)	South Bluff MiniMate Unit BE11251				North Bluff MiniMate Unit BE20183			
			Time Recorded	PVS (mm/s)	Sound Concussion (dBL)	Shock Wave (psi)	Time Recorded	PVS (mm/s)	Sound Concussion (dBL)	Shock Wave (psi)
				Limits per Guidelines for Bats in British Columbia (BC MOE 2016)				Limits per Guidelines for Bats in British Columbia (BC MOE 2016)		
				15	150	15		15	150	15
6/27/2021	980-P-210627	2250	-	-	-	-	-	-	-	-
7/2/2021	980-P-210702	1160	5:00:14 PM	8.38	118	0.0022	-	-	-	-
7/4/2021	980-P-210704	738	5:50:14 PM	2.65	117	0.0021	-	-	-	-
7/5/2021	980-P-210705	453	5:59:45 PM	2.44	119	0.0027	-	-	-	-
7/7/2021	980-P-210707	705	5:39:05 PM	1.72	111	0.0010	-	-	-	-
7/8/2021	980-P-210708	1255	5:56:08 PM	2.25	117	0.0021	-	-	-	-
7/10/2021	980-P-210710	1110	-	-	-	-	-	-	-	-
7/11/2021	980-P-210711	1775	5:36:57 PM	2.22	114	0.0015	5:37:36 PM	2.5	120	0.0030
7/12/2021	980-P-210712	1050	5:50:49 PM	3.8	119	0.0027	5:51:30 PM	3.2	114	0.0014
7/13/2021	980-P-210714	1600	-	-	-	-	-	-	-	-
7/15/2021	980-P-210715	4740	5:57:18 PM	5.76	116	0.0019	5:58:04 PM	3.9	120	0.0028
7/18/2021	980-P-210718	1050	-	-	-	-	5:33:22 PM	3.0	124	0.0049
7/19/2021	980-P-210719	1675	5:52:32 PM	2.26	119	0.0026	5:53:25 PM	2.8	118	0.0022

Date	BC Hydro Blast Record	Charge Weight (kg)	South Bluff MiniMate Unit BE11251				North Bluff MiniMate Unit BE20183			
			Time Recorded	PVS (mm/s)	Sound Concussion (dBL)	Shock Wave (psi)	Time Recorded	PVS (mm/s)	Sound Concussion (dBL)	Shock Wave (psi)
				Limits per Guidelines for Bats in British Columbia (BC MOE 2016)				Limits per Guidelines for Bats in British Columbia (BC MOE 2016)		
				15	150	15		15	150	15
7/21/2021	980-P-210721	1700	-	-	-	-	-	-	-	-
7/22/2021	980-P-210722	1475	6:01:10 PM	4.33	114	0.0014	6:02:09 PM	4.5	118	0.0024
7/23/2021	980-P-210723	84	5:34:04 PM	3.14	111	0.0010	-	-	-	-
7/27/2021	970-P-210727	3138	-	-	-	-	-	-	-	-
7/28/2021	970-P-210728	2929	5:53:42 PM	3.88	119	0.0025	5:53:49 PM	4.1	117	0.0020
7/30/2021	970-P-210730	1121	-	-	-	-	-	-	-	-
8/2/2021	970-P-210802	2230	-	-	-	-	-	-	-	-
8/4/2021	970-P-210804	1967	5:00:29 PM	6.99	118	0.0024	5:00:46 PM	3.2	118	0.0024
8/5/2021	970-P-210805	1039	5:14:23 PM	2.82	109	0.0008	5:14:42 PM	2.3	121	0.0033
8/6/2021	970-P-210806	958	5:39:03 PM	2.6	108	0.0007	5:39:23 PM	2.3	126	0.0058
8/7/2021	970-P-210807	1540	5:36:48 PM	5.88	119	0.0026	5:37:12 PM	0.5	121	0.0032
8/9/2021	970-P-210809	2289	-	-	-	-	-	-	-	-
8/11/2021	1002-P-210811	1440	5:56:01 PM	7.53	118	0.0024	-	-	-	-

Date	BC Hydro Blast Record	Charge Weight (kg)	South Bluff MiniMate Unit BE11251				North Bluff MiniMate Unit BE20183			
			Time Recorded	PVS (mm/s)	Sound Concussion (dBL)	Shock Wave (psi)	Time Recorded	PVS (mm/s)	Sound Concussion (dBL)	Shock Wave (psi)
				Limits per Guidelines for Bats in British Columbia (BC MOE 2016)				Limits per Guidelines for Bats in British Columbia (BC MOE 2016)		
				15	150	15		15	150	15
8/13/2021	1002-P-210813	930	5:52:42 PM	4.66	112	0.0012	-	-	-	-
8/15/2021	1002-P-210815	1300	-	-	-	-	-	-	-	-
8/16/2021	1002-P-210816	1414	5:52:59 PM	4.72	114	0.0015	-	-	-	-
8/17/2021	1002-P-210817	1230	5:53:29 PM	4.24	119	0.0027	-	-	-	-

Notes: - indicates that either the triggered thresholds of the device were not met and a event was not recorded, or the unit was without power.

APPENDIX D

Results of 2020 and 2021 Emergence Counts, Roost Monitoring, and Long-term Acoustic Monitoring

2020 and 2021 Emergence Counts

Results of the emergence counts conducted in 2020 and 2021 are described below.

2020 Emergence Counts

Thirty-nine emergence counts were conducted during June and July 2020 (**Table D.1; Figure 3.1**). Counts were completed within the general areas of:

- south cliff including the top of the quarry;
- north cliff;
- gully; and,
- the abandoned King Gething mine (outside the study area but briefly investigated to confirm lack of bat activity).

Emergence counts generally lasted about 1.5 hours, though surveyors ended counts early if there was moderate to heavy rain. Conditions were less than ideal for many emergence counts, with rain recorded on seven of the 12 nights surveyed, and 16 of the 39 emergence counts. Temperatures ranged from 10 ^{o}C to 16^{o}C (**Appendix E**). Counts averaged 75 minutes in duration.

Table D.1 Survey Effort During the 2020 and 2021 Emergence Counts

Location	Session	Survey dates	Number of counts	Total of emerging bats counted	Average number of bats observed per count*
2020					
South cliff	Early	June 22, 23, 26, 27	10	23	2.3
	Late	July 14, 19, 20	8	32	4
North cliff	Early	June 24, 25	5	17	3.4
	Late	July 17, 18	4	12	3
Gully	Early	June 28	4	21	5.3
	Late	July 15, 16	4	9	2.3
King Gething mine	Early	Not surveyed	0	-	-
	Late	July 15, 16	4	1	.25
		Total	**39**	**36**	
2021					
South cliff including quarry	Early	June 14, 16, 18, 19	8	30	3.75
	Late	July 14, 15, 16, 19, 20	10	23	2.3
North cliff and talus	Early	June 15, 16, 17, 18	4	0	0
	Late	July 17, 18, 20	5	12	2.4
Gully	Early	June 14, 19, 20	3	18	9
	Late	July 13, 14	2	3	1.5
		Total	**32**	**86**	

*Averages provided as a rough index of use. As sample sizes are small, no variance has been calculated

At least one bat was seen emerging at 14 of 19 (74%) early counts and 10 of 20 (50%) late counts (**Table D.2**). One to four bats were observed emerging at most counts, although 16 bats (at the gully) and 17 bats (at the suspected maternity roost 9247G on the south cliff) were counted exiting during the early and late counts, respectively. Note that no particular roost tree was identified at the gully and bats counted there could potentially have exited from multiple roost trees farther west in the gully, so counts in this area represent an unknown number of roosts. Activity at the King Gething mine was minimal. One emergence count was conducted within the quarry on June 27, but no bats were observed exiting rock faces at that location. More bats were counted emerging from the south cliffs, although the numbers of non-zero counts were equivalent between the south and north cliffs.

Fourteen counts were done at 'new' sites, defined as sites more than 15 m away from locations of counts in previous years. One bat was observed emerging at each of two of those new sites. No new rock maternity roosts were detected based on the results from the early (June 22 to 28) and late (July 14 to 20) emergence counts in 2020 (i.e., no new sites where more than 10 bats were counted).

Table D.2 Results of the 2020 and 2021 Emergence Counts

Survey Period	Month-day	Location	Maternity Roost	Count ID	Number of Bats Observed
2020					
early	June 22	South	6287F	EC-DW1-062220	4
	June 22	South	-	EC-JF1-062220	4
	June 22	South	9427G	9427G	4
	June 23	South	-	EC-JF02-062320	0
	June 23	South	-	EC-DW2-062320	2
	June 23	South	-	EC_FM_200623	0
	June 24	North	-	EC-JF3-062420	4
	June 24	North	-	EC-FMN-200624	3
	June 24	South	-	EC- DW3-062420	2
	June 25	North	-	EC-JF4 062520	4
	June 25	Gully	-	EC-DW5-062620	0
	June 25	North	-	EC-DW4-062520	4
	June 25	North	-	EC_FMN_200625	2
	June 26	Gully	-	EC-FMN-200626	0
	June 27	South	9427G	9427G	4
	June 27	South	-	EC_FMN_200627	0
	June 27	South	6827F	EC-DW6-062720	3
	June 28	Gully	-	EC-FMN-200628	16
	June 28	Gully	-	EC-DW7-062820	5

Survey Period	Month-day	Location	Maternity Roost	Count ID	Number of Bats Observed
late	July 14	mine	-	EC-9415F	0
	July 14	South	-	EC_JF01_071420_South Cliff	0
	July 14	mine	-	EC-9415F	0
	July 15	Gully	-	EC_JB01_071520_ Gully	0
	July 15	Gully	-	EC_JF02_071520_Gully	3
	July 16	Gully	-	EC_FMN_Gully	6
	July 16	Gully	-	EC-gully	0
	July 16	mine	-	EC_JF03_071620_Old Mines	1
	July 16	mine	-	EC_JB02_071620_Old mine below gully	0
	July 17	North	-	EC_FMN-NH	3
	July 17	North	-	EC_JF04_071720_North Cliff	5
	July 17	North	-	EC_ST_NH	0
	July 18	South	-	EC_ST_NH	0
	July 18	North	-	200728EC_FMN_NH	4
	July 19	South	-	EC_JF06_South Cliff bear quarry	1
	July 19	South	-	EC_JB03_south cliff near quarry	0
	July 19	South	9427G	9427G	17
	July 20	South	9427G	9427G	13
	July 20	South	-	EC_JF07_South Cliff near quarry	0
	July 20	South	-	EC_JB03_south cliff near quarry	1
				Total	*115*

Survey Period	Month-day	Location	Maternity Roost	Count ID	Number of Bats Observed
2021					
early	June 14	South	9427G	9427G	4
	June 14	South	-	DW061421	0
	June 15	South	6827F	210615_EC_Bure	0
	June 15	South	-	210615_EC_FMN	0
	June 15	South	-	DW061521	0
	June 16	North	-	210616_FMN	0
	June 16	North	-	DW061621	0
	June 17	North	-	DW061721	0
	June 17	Talus	-	210617_Talus	0
	June 18	South	-	DW061821	3
	June 19	South	-	210619_EC_quarry_FMN	0
	June 19	South	9427G	9427G	23
	June 19	Gully	-	DW061921	0
	June 20	Gully	-	210620_EC_gully_FMN	9
	June 20	Gully	-	DW062021	9
late	July 13	Gully	-	210713_Gully_FMN	0
	July 13	Gully	-	DW071321	3
	July 14	South	9427G	210714_9427G_FMN	4
	July 14	South	6827F	DW071421	1
	July 15	South	9427G	210715_9427G_FMN	2
	July 15	South	6827F	DW071521	3
	July 16	Talus	-	210716_talus	0
	July 17	North	-	DW071721	1
	July 18	North	-	7/18/2021_BM_NH	6
	July 18	North	-	DW071821-NH	5
	July 18	Talus	-	210718_FMN_Talus	0
	July 19	South	9427G	210719_9427G_FMN	2
	July 19	South	-	7/19/2021_BM_sH	4
	July 19	South	-	DW071921-SH	2
	July 20	South	9427G	210720_9427G_FMN	2
	July 20	South	-	7/20/2021_BM_SH	1
	July 20	South	-	DW072021-SH	2
				Total	*86*

Emergence counts during 2020 confirmed the presence of bats at 9427G, a previously identified maternity roost (**Table D.2, Figure 3.1**). Four long-eared myotis (species identification from handheld detectors and manually verified) were observed exiting the roost at 9427G on both days of the early survey period, June 22 and 26. Seventeen bats (species undetermined) were observed exiting 9427G during the first count of the late survey period on July 19, and bats were observed to begin re-entering the roost at 2230 (64 minutes after sunset). Thirteen bats were seen exiting the roost on July 20, and three bats returned to the roost that night at 2146 (15 minutes after sunset). The first bats leaving the roost on the two late-period surveys exited before sunset. Bats leaving a roost early, foraging for a short time and then returning to the roost is behaviour consistent with females returning to nurse young pups. Observations of more than 10 bats are consistent with this location continuing to be used as a maternity roost.

On average, bats were observed emerging from the cliffs 33 minutes after sunset (range 8 minutes to 56 minutes). A maximum of 4 bats was observed emerging at 6287F, indicating that this site was less likely to be used as a maternity roost in 2020.

Calls from three Myotis species were recorded on handheld detectors during emergence counts in 2020 (**Table D.3**). Long-eared myotis, little brown myotis, northern myotis and unspecified Myotis were identified but it was often impossible to verify that the individuals exiting the roosts had produced the calls that were recorded. Precise emergence locations could not be determined for almost all sites, but a video recording was made of a bat emerging from behind a rock flake at 9427G (**Figure D.1).** Long-eared myotis, little brown myotis, and big brown bat were recorded on detectors as they were observed flying out from the gully next to the road but no specific roosting trees could be identified.

Table D.3 Bat species recorded on handheld detectors in 2020 at sites where emergence was observed

Date	Sample period	Location	Site	Emerging bats	Identification category
June 22	Early	South	9427G	4	Myotis
June 22	Early	South	EC-DW1-062220	4	Northern Myotis Myotis
June 23	Early	South	EC-DW2-062320	2	Long-eared Myotis Little Brown Myotis
June 24	Early	South	EC- DW3-062420	2	Myotis Northern Myotis
June 25	Early	North	EC-DW4-062520	4	Myotis Northern Myotis Little Brown Myotis
June 27	Early	South	EC-DW6-062720	3	Myotis Little Brown Myotis Long-eared Myotis
June 27	Early	South	9427G	4	Myotis Long-eared Myotis Little Brown Myotis
June 28	Early	Gully	EC-DW7-062820	5	Little Brown Myotis
June 28	Early	Gully	EC-FMN-200628	16	Little Brown Myotis Myotis
July 16	Late	Gully	EC_FMN_Gully	6	Long-eared Myotis Big Brown Bat
July 17	Late	North	EC_FMN-NH	3	Long--eared Myotis
July 18	Late	North	200728EC_FMN_N H	4	Long-eared Myotis Big Brown Bat

Calls of silver-haired bats and hoary bats were also recorded incidentally on acoustic detectors during early and late emergence surveys. Big brown bats and silver-haired bats were actively foraging (feeding buzzes and observations of foraging behaviour) at emergence time, together with long-eared myotis and little brown myotis.

Figure D.1 A Bat (White Circle) Emerges from Under a Slab of Rock (Arrow) at 9427G.

2020 Roost Monitoring

Both roost loggers suffered from water damage in early 2020 and did not record data between May and late August. The gap in bat activity and lower numbers of bat passes recorded in 2020 was caused by humidity and water entering both roost loggers early in the year. The roost loggers were operational, but the microphone sensors were compromised between April and August and required off-site repair. The roost loggers were dried and desiccant beads were added to absorb humidity during the July site visit. The roost loggers became operational just after August 30. Possibly residual humidity inside the loggers prevented them from operating normally until that date.

Although the loggers did not function as planned for much of the bat active period, activity at roost 9427G in 2020 was confirmed by the roost logger RL1. In total, 1,418 files were recorded in 2020, of which 1,390 were assigned to the Myotis category. Myotis bat activity was first recorded at 9247G in April and was increasing in early May when the logger was compromised. The last Myotis file was recorded on October 2 (**Table D.4**).

Roost logger RL2 deployed at potential maternity roost 6287F also recorded almost entirely Myotis files but only 104 files in total (**Table D.4**). RL2 was moved to 9247G in October (see 2021 results).

Table D.4 Bat Species Recorded by Roost Loggers in 2020

Identification category	Month							Grand total
	Apr	May	Jun	Jul	Aug	Sep	Oct	
RL1 total	**4**	**68**	**-**	**-**	**102**	**1,173**	**71**	**1,418**
30K	-	14	-	-	-	2	1	**17**
35K	-	8	-	-	-	-	-	**8**
Big brown bat / silver-haired bat	-	-	-	-	-	2	-	**2**
Long-eared myotis	-	-	-	-	-	1	-	**1**
Myotis	4	46	-	-	102	1,168	70	**1,390**
RL2 total	**-**	**-**	**-**	**-**	**1**	**72**	**31**	**104**
Myotis	-	-	-	-	1	72	31	**104**

2021 Emergence Counts

Thirty-two emergence counts were conducted during June and July 2021 (**Table D.1; Figure 3.1**). Counts were completed at:

- South cliffs, including the rock outcrop near the quarry; and,
- North cliff, including the talus slope below the cliff;
- Gully near 400 Rd (mature balsam poplar grove).

Rain was recorded on three nights during four of the 32 emergence counts. Temperatures at sunset during emergence counts as recorded by the Portage Mountain weather station ranged from 8 °C to 18 °C during the June counts and from 7°C to 21°C during the July counts (**Appendix E**). Counts averaged 83 minutes in duration.

No bats were observed emerging on 13 of the counts (**Table D.2**). One to four bats were observed emerging on most of the remaining counts, although 23 bats were counted on June 19 at 9427G, the suspected maternity roost. That observation confirms continued use of 9427 as a maternity roost based on the criterion of more than 10 bats emerging. A maximum of 3 bats was counted at 6827F, indicating that this site was unlikely to be used as a maternity roost in 2021.

Bats were observed emerging at 4 of the 15 early counts (27%) and 19 of 32 late counts (59%). The increase in numbers in the late counts was due to more bats observed emerging during counts at the south cliffs.

Five emergence counts in 2021 were located more than 15 m from counts conducted on previous years and are considered ‘new’ sites. One emergence count was carried out within the quarry on June 19 but no bats were observed. Unspecified Myotis, northern myotis and big brown bat were recorded on handheld detectors at sites where bats were observed emerging (**Table D.5**).

Table D.5 Bat species Recorded by Handheld Detectors in 2021 at Sites where Emergence was Observed

Date	Sample period	Location	Site	Emerging bats	Identification category
2021-06-18	early	South	DW061821	3	Big Brown Bat Myotis
2021-06-20	early	Gully	DW062021	9	Myotis Northern Myotis Little brown Myotis
2021-07-13	late	Gully	DW071321	3	Big brown Bat Northern Myotis
2021-07-14	late	South	DW071421	1	Myotis Big brown Bat
2021-07-15	late	South	DW071521	3	Myotis Big brown Bat
2021-07-17	late	North	DW071721	1	Myotis Big brown Bat
2021-07-18	late	North	DW071821-NH	5	Myotis
2021-07-19	late	South	DW071921-SH	2	Myotis Big Brown Bat
2021-07-20	late	South	DW072021-SH	2	Myotis

2021 Roost Monitoring

RL1 recorded minimal activity at roost 9247G in 2021, and no activity after July (**Table D.6**). Only 45 files, almost entirely Myotis and 30K species groups, were recorded. The lack of data is likely due to a technical issue with the roost logger.

The function of RL2 at roost 9247 G was also compromised based on the lack of data recorded in July and August (**Table D.6**). RL2 began recording activity in April with a substantial increase in activity in May but stopped recording June 6. RL2 recorded 8 files in August, and its last file on September 21.

Table D.6 Bat species Recorded by Roost Loggers in 2021

Identification category	Month								
	Jan	Mar	Apr	May	Jun	Jul	Aug	Sep	Grand Total
Roost logger 1 Total	**-**	**5**	**6**	**18**	**9**	**7**	**-**	**-**	**45**
30K	-	4	-	4	5	2	-	-	15
Big brown bat / silver-haired bat	-	1	-	-	-	-	-	-	1
Long-eared myotis	-	-	-	-	1	1	-	-	2
Myotis	-	-	6	13	3	4	-	-	26
Red bat / little brown myotis	-	-	-	1	-	-	-	-	1
Roost logger 2 Total	**1**	**-**	**200**	**1,892**	**153**	**-**	**8**	**176**	**2,430**
30K	-	-	30	14	2	-	-		46

Identification category	Month								
	Jan	Mar	Apr	May	Jun	Jul	Aug	Sep	Grand Total
Big brown bat / silver-haired bat	-	-	21	41	-	-	-	2	64
Eastern red bat	-	-	-	8	-	-	-		8
Long-eared myotis	-	-	1	1	2	-	-	5	9
Low frequency bat	-	-	2	6	-	-	-	7	15
Myotis	1	-	146	1,816	147	-	8	162	2,280
Red bat / little brown myotis	-	-	-	6	2	-	-	-	8

2020 and 2021 Long-term Acoustic Monitoring Results

Results of acoustic monitoring in 2020 and 2021 are described below.

2020 and 2021 Survey Effort

The 294-SH detector suffered damage from rodents chewing the cables with resulting loss of data for 27 days between June 22 and July 18 in 2020. The PM-C-NH detector also suffered rodent damage in 2020 and was not functional between June 24 and July 17. The new TAL detector recorded for 121 detector-nights from its installation on June 26, 2020 until December 31, 2020. Total survey effort in 2020 was 1,622 detector-nights over six detectors.

In 2021 5 detectors recorded from January 1, 2021, until the last download on November 3, 2021, totalling 307 nights for all five detectors, for a total survey effort of 1,535 detector-nights.

2020 and 2021 Activity

The first bat files recorded in January 2020 were categorized as big brown bat/silver-haired bat (23 files) and low-frequency bat (13 files), with the earliest file on the night of January 1 at detector PMC-NH.

The first Myotis group (all Myotis species, 35K and red bat/little brown myotis categories) file in 2020 was recorded the night of April 8, 2020 (at detector PMC-NH; **Table D.7**). The first file identified as little brown myotis in 2020 was recorded on May 15 (PMC-NH), and the first northern myotis file on April 4 (279-SH; **Table D.8**). Most (77%) of the Myotis group files recorded in April were recorded at 279-SH (**Table D.7**).

Table D.7 Numbers of Myotis Group Files Recorded n April and In Late Summer/Fall 2020

Detector	April	August	September	October	November	Total
279-SH	524	13,010	6,934	54	31	**20,553**
294-SH	40	4,438	1,965	16	23	**6,482**
PM-C-NH	104	4,235	6,545	36	77	**10,997**
PM-S3	9	3,583	1,646	66	9	**5,313**
PM-TAL	0	922	685	2	0	**1,609**
Total	**677**	**26,188**	**17,775**	**174**	**140**	**44,954**

Table D.8 Numbers of Bat Files in 2020 (Excluding Roost Logger Files and Social Calls) By Month

Identification Category	Month												Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
30K	3	0	1	28	414	8	16	0	0	0	0	1	471
35K	0	0	0	64	739	1,493	1,696	6	3	0	0	0	4,001
Low-frequency bat	13	3	5	119	207	14	34	106	56	22	32	34	641
Hoary bat	0	0	0	0	0	0	57	57	14	1	0	0	129
Big brown bat	0	0	1	127	95	32	764	1,493	957	56	10	7	3,542
Big brown bat / silver-haired bat	23	6	25	1,049	726	149	3,193	6,880	6,332	1,719	424	96	20,643
Silver-haired bat	0	0	0	3	49	3	23	133	24	126	2	0	363
Eastern red bat	0	0	0	1	10	28	46	13	8	1	0	0	107
Red bat / little brown myotis	0	0	0	7	148	232	129	59	10	0	0	0	585
Myotis	0	0	0	215	1,800	3,255	16,499	23,225	15,647	158	121	0	60,930
Little brown myotis	0	0	0	0	10	133	683	168	124	1	16	0	1,135
Long-eared myotis	0	0	0	390	1,736	286	1,892	2,559	1,977	15	3	0	8,858
Northern myotis	0	0	0	1	25	46	75	171	14	0	0	0	332
Grand Total	**39**	**9**	**32**	**2,004**	**5,959**	**5,679**	**25,107**	**34,870**	**25,166**	**2,099**	**608**	**138**	**101,710**

Figure D.2 depicts the number of bat files per detector-night over time in 2020. The first substantial numbers of bat files in 2020 – mostly big brown bat - were recorded on serial week 16 in 2020, which corresponded to April 12-18. Myotis bat files began outnumbering big brown bat files two weeks later. Activity of both big brown bats and Myotis declined to a low on week 23 (May 31-June 6), presumably as emerging bats dispersed. Activity then showed a general increasing trend with file numbers peaking at week 34 (August 16-22) for big brown bats and week 35 (August 23-29) for Myotis. No fall peak consistent with swarming activity was apparent for either species group. Activity for both the big brown bat and Myotis group dropped off sharply in week 41 (October 4-10). Of the 43,963 Myotis files recorded in August through September in 2020, 19,944 (45%) were recorded at the 279-SH detector (**Table D.7**).

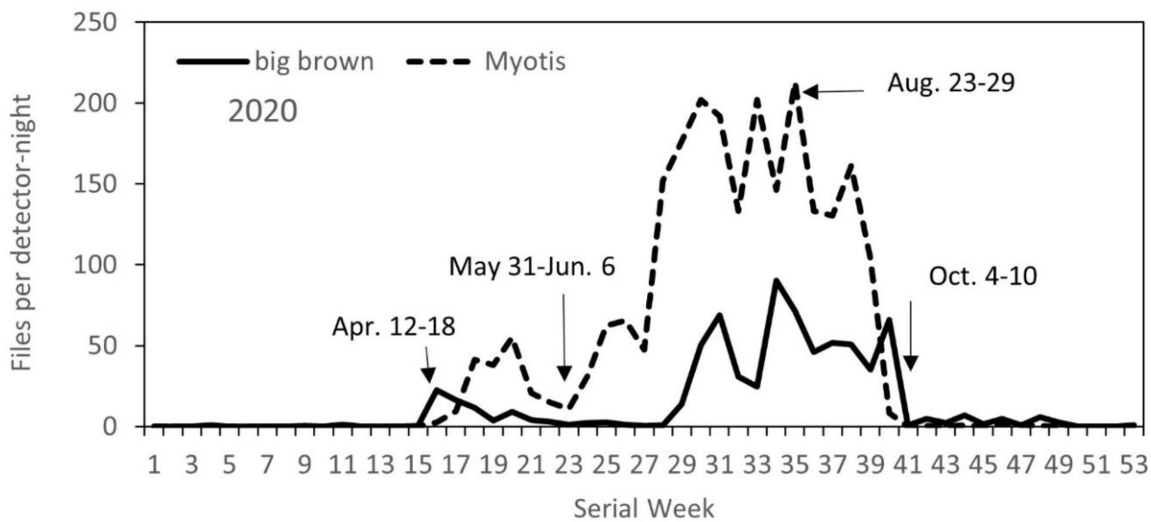


Figure D.2 Big Brown Bat and Myotis Activity Recorded Over Time During 2020, Excluding Roost Logger Data and Social Calls

The latest 2020 files (big brown bat/silver-haired bat) were recorded the night of December 30 at the PM-TAL detector. One hundred thirty-eight files were recorded during December and were assigned to the big brown bat (seven files), big brown bat/silver-haired bat (96 files), 30K bat (1 file) and low-frequency bat (34 files) species groups. The latest Myotis file was recorded November 26 (279-SH). Little brown myotis files were identified as late as November 15 (at PMC-NH), and the latest northern myotis files on the night of September 23 (at 279-SH).

Of the 140 Myotis group files recorded in November 2020, 77 were recorded at the PM-C-NH detector (**Table D.7**). There were no known detector issues during the months of August through December 2020 so all detectors had a similar number of operating nights. The detector with the greatest amount of activity between November 2020 through March 2021 for all species was 279-SH, the southernmost detector and the detector furthest from the quarry. Almost half (638) of the 1,318 files recorded during this period were recorded at that detector.

The earliest that bats were detected in 2021 was the night of January 7 when two calls identified as big brown bat/silver-haired bat were recorded at the PM-Talus detector. In total, 119 bat files were recorded in January 2021 (**Table D.9**) and were categorized as big brown bat/silver-haired bat, low-frequency bat, big brown bat, and 30K. Most (99) of the January files were recorded by the 279-SH detector on the south cliff, and 85 of those were recorded over a three-night interval on January 10, 11 and 12 during relatively mild temperatures of -1.3 to 3.6°C. Of the 136 bat files recorded in January and February of 2021, 100 were recorded at detector 279-SH, the southernmost detector.

The first Myotis group (all Myotis species, 35K and red bat/little brown myotis categories) file was recorded the night of April 6, 2021 (at detector 294-SH), the first file identified as little brown myotis on April 16 (279-SH), and the first northern myotis file on April 15 (279-SH). Of the 2,361 Myotis group files recorded in April, 1,259 (53%) were recorded at 279-SH (**Table D.10**), the same detector where the largest percentage of the April Myotis files were recorded in 2020. There were no known detector issues in 2021.

Table D.9 Locations and Numbers of Myotis Group Files Recorded in April, August, September and October

Detector	April	August	September	October	Total
279-SH	1,259	10,959	8,970	23	21,212
294-SH	191	4,372	6,401	16	10,980
PM-C-NH	439	5,273	11,974	111	17,797
PM-S3	62	4,069	10,017	28	14,176
PM-TAL	410	1,285	737	5	2,437
Total	2,361	25,958	38,099	183	66,602

The first peak of spring activity for Myotis species occurred during week 16 in 2021, which corresponds to April 11-17 (**Figure D.3**) and is consistent with 2020 (**Figure D.2**). There was a second peak around week 20 (also consistent with 2020), after which activity generally declined for both species groups to week 24, then increased again. The greatest peak of Myotis activity was recorded in weeks 37 and 38, which correspond to September 5-18, consistent with swarming. There was a dramatic drop-off in Myotis group passes after the end of week 39 on September 25, presumably indicating the onset of hibernation and consistent in timing with 2020 (**Figure D.2**). Of the 64,057 Myotis group files recorded in August and September of 2021 (**Table D.9**), 31% were recorded by the 279-SH detector. There was no peak of fall activity evident for big brown bats, only a gradual decline of activity (**Figure D.3**). The detectors were last downloaded on November 3, so the dates of the latest winter activity in 2021 are not yet known.

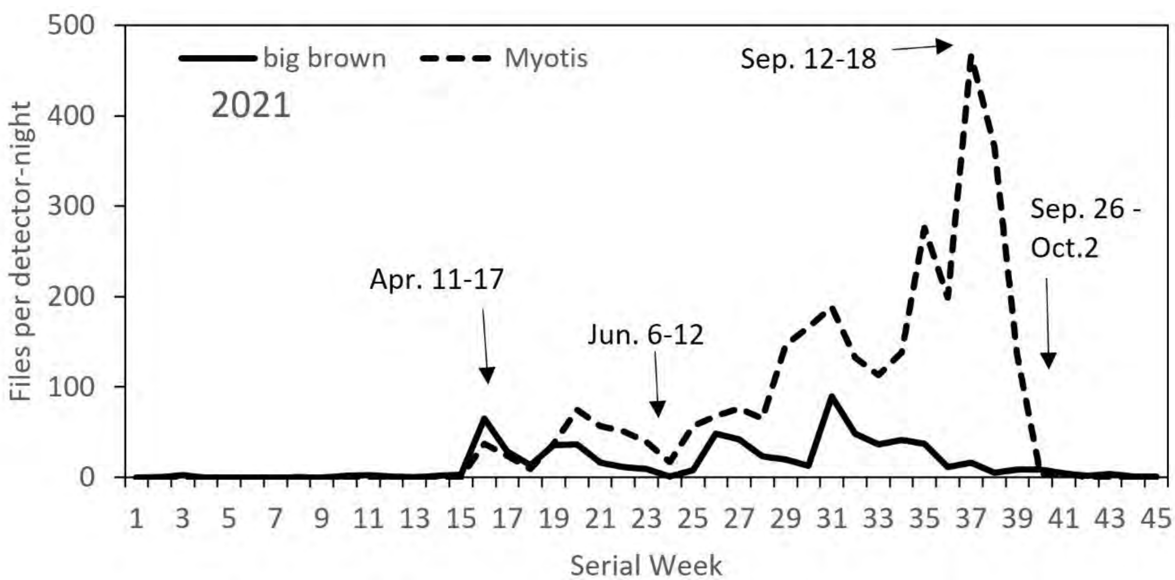


Figure D.3 Big Brown Bat and Myotis Activity Recorded During 2021, Excluding Roost Logger and Social Calls

Table D.10 Numbers of bat files identified in 2021 (excluding roost logger and social calls) by month

Identification category	Month											Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	
30K	1	0	6	387	403	99	156	69	32	1	0	**1,150**
Low-frequency bat	25	13	157	2,865	1,577	764	1,271	1,310	608	88	4	**8,682**
Hoary bat	0	0	0	1	2	2	159	239	101	1	0	**505**
Big brown bat	1	0	23	565	583	829	871	413	250	23	0	**3,558**
Big brown bat / silver-haired bat	91	0	211	3,322	3,096	2,264	4,786	5,410	1,431	380	26	**21,017**
Silver-haired bat	0	0	0	90	335	46	67	283	23	1	0	**845**
Eastern red bat	0	0	0	12	15	24	73	28	36	0	0	**188**
Red bat / little brown myotis	0	0	0	8	66	129	139	22	29	0	0	**393**
High- frequency bat	0	0	0	0	0	1	1	0	0	0	0	**2**
Myotis	0	4	7	1,248	5,999	6,849	18,819	23,696	37,406	169	1	**94,198**
Little brown myotis	0	0	0	2	11	82	383	135	93	0	0	**706**
Long-eared myotis	0	0	0	1,101	2,076	510	1,390	1,977	535	14	0	**7,603**
Northern myotis	0	0	0	2	2	19	147	128	36	0	0	**334**
Grand Total	**118**	**17**	**400**	**9,603**	**14,165**	**11,618**	**28,263**	**33,710**	**40,580**	**677**	**31**	**139,182**

Big brown bat, eastern red bat and silver-haired bat passes were well-distributed across the bat active period, although big brown bat activity began earlier and continued later in the year. Hoary bats were detected primarily in summer and fall (**Table D.10**). All of the Myotis species were first confirmed in April. Long-eared myotis had a bimodal activity pattern with peaks in April-May and in July-August. The highest numbers of northern and little brown myotis were recorded in July.

2020 and 2021 Species Presence

In total, 101,737 bat files (excluding roost logger files and social calls) were recorded in 2020, including 87,271 files assigned to species groups of two or more species and 14,466 files identified to a single species. The most commonly recorded bats were those from the *Myotis* group (almost 60% of calls) and the big brown bat / silver-haired bat group (20% of calls). Long-eared myotis and big brown bat were the species most often recorded of the files that could be identified to a single species (**Table D.11**). Seven of the eight bat species previously recorded within the study area (Keystone 2014; Hansen et al. 2016; Sarell and Alcock 2017) were identified in 2020, including the endangered little brown myotis and northern myotis. Long-legged myotis was not confirmed in 2020 although it was identified once in 2019 and twice in 2017.

Table D.11 Identification of Files Recorded In 2020 (Excluding Roost Logger and Social Calls)

Identification category	Per cent of total files recorded in 2020
30K	0.5
35K	3.9
Low-frequency bat	0.6
Hoary bat	0.1
Big brown bat	3.5
Big brown bat / silver-haired bat	20.3
Silver-haired bat	0.4
Eastern red bat	0.1
Red bat / little brown myotis	0.6
Myotis	59.9
Little brown myotis	1.1
Long-eared myotis	8.7
Northern myotis	0.3
Grand Total	**100.0**

In 2021, 139,255 bat files (excluding roost loggers and social calls) were recorded. The Myotis species group made up 68% of the total files recorded, and the big brown bat/silver-haired bat species group made up another 15% (**Table D.12**). Seven of the eight bat species previously recorded within the study area (Keystone 2014; Hansen et al. 2016; Sarell and Alcock 2017) were identified in 2021 (**Table D.12**). The endangered little brown myotis and northern myotis were both confirmed. As was the case for 2020, long-legged myotis was not identified in 2021 although it was recorded once in 2019 and twice in 2017. As in 2020, long-eared myotis and big brown bat were the species most commonly recorded. Note that comparison of **Table D.11** and **Table D.12** must consider the different survey effort (number of detector-nights) during the two years.

Table D.12 Identification of Files Recorded in 2021 (Excluding Roost Logger and Social Calls)

Identification category	Per cent of total files recorded in 2021
30K	0.8
35K	0.0
Low frequency bat	6.2
Hoary bat	0.4
Big brown bat	2.6
Big brown bat / silver-haired bat	15.1
Silver-haired bat	0.6
Eastern red bat	0.1
Red bat / little brown myotis	0.3
High frequency bat	0.0
Myotis	68.0
Little brown myotis	0.5
Long-eared myotis	5.5
Northern myotis	0.2
Grand Total	**100.0**

APPENDIX E

Weather Conditions During 2020 and 2021 Emergence Surveys

Survey Date	Sunset time	Sunset temperature[1] (°C)	Relative humidity[2] (%)	Wind speed[3] (km/hr)	Rain during survey period?[4]	Other comments
June 23, 2020	21:56	14.4	44.04	Not available	None	
June 24, 2020	21:56	13.3	37.05	Not available	None	
June 25, 2020	21:56	12.3	55.14	Not available	None	
June 26, 2020	21:56	12.1	43.28	Not available	None	
June 27, 2020	21:56	9.5	87.29	Not available	Yes	
June 28, 2020	21:55	10.4	71.88	Not available	Yes	
July 15, 2020	21:40	13.4	79.04	Not available	Yes	
July 17, 2020	21:37	11.7	72.77	Not available	Yes	
July 18, 2020	21:36	16.2	63.06	Not available	Yes	
July 19, 2020	21:34	14.5	48.49	Not available	None	
July 20, 2020	21:33	15.5	71.72	Not available	Yes	
July 21, 2020	21:31	13.5	75.87	Not available	Yes	
June 14, 2021	21:53	11.0		1	None	
June 15, 2021	21:54	12.1		1	None	
June 16, 2021	21:54	9.3		1	Yes	
June 17, 2021	21:55	7.8		1	None	
June 18, 2021	21:55	9.5		1	None	
June 19, 2021	21:55	10.1		1	None	
June 20, 2021	21:56	18.4		1	None	
July 13, 2021	21:43	18.5		1	None	
July 14, 2021	21:42	21.3		3	None	
July 15, 2021	21:41	18.6		9	None	
July 16, 2021	21:39	7.3		0	None	
July 17, 2021	21:38	9.0		4	Yes	Foggy
July 18, 2021	21:36	10.7		1	None	Foggy
July 19, 2021	21:35	12.4		1	None	
July 20, 2021	21:33	11.3		1	Yes	

1 From Portage Mountain quarry weather station
2 From 9147G data logger
3 From Hudson's Hope weather station; data not available before October 2020
4 From surveyor observations

APPENDIX F

Number of Nights Detectors were Active by Season

Table F.1 Number of Nights Detectors were Active and Number of Nights a Detectors was Inactive by Season and Year.

Year	Bat Life Stage	Number of Active Detector Nights	Number of Inactive Detector Nights
2017	fall	28	0
2017	hibernation	94	48
2017	summer	11	0
2018	emergence	3	3
2018	fall	7	35
2018	hibernation	192	190
2018	summer	135	68
2019	emergence	8	8
2019	fall	28	28
2019	hibernation	194	124
2019	summer	135	107
2020	emergence	8	0
2020	fall	28	0
2020	hibernation	195	92
2020	summer	135	27
2021	emergence	4	0
2021	fall	28	0
2021	hibernation	134	0
2021	summer	141	0

APPENDIX G
Blast Model Results for Summers 2019 to 2021

Below are the model selection results (**Table G.1**) and model coefficients (**Table G.2**) for the blast model using only data from 2019-2021, which excludes 2018 when only five blasts occurred. When the 2018 data is excluded the blast model is no longer the top AIC model and blast is not a significant model variable.

Table G.1 Models 1 and 3 of Summer Bat Activity at Portage Mountain Years 2019 - 2021, Number of Parameters (K) for the Generalized Linear Mixed Effects Models used to Predict the Number of Bat Calls Per Night, and the Model's Log-Likelihood (LL) and Akaike's Information Criterion (AIC) Score

Summer models	K	LL	AIC	AIC weight
Null: total bat calls per night ~ 1 + 1|Detector ID	3	-8,761.13	17,528.26	0.00
1: total bat calls per night ~ mean temperature + precipitation + 1| Detector ID	5	-8,634.51	17,279.01	0.69
3: total bat calls per night ~ blast + mean temperature + precipitation + 1| Detector ID	6	-8,634.33	17,280.65	0.31

Table G.2 Coefficient from Model of Bat Activity with Occurrence of Blasting During the Summer Period Years 2019 - 2021 at Portage Mountain, Based on Data from 5 Detectors at 3 Areas

Variable	Coefficient estimate	Standard error	z value	Lower 95% C.I.	Upper 95% C.I.
Intercept	**3.82**	0.28	13.77	3.27	4.36
Blast	0.04	0.07	0.60	-0.09	0.17
Mean temperature	**0.86**	0.08	11.29	0.71	1.01
Total precipitation	**-0.45**	0.03	-14.59	-0.51	-0.39

Appendix 8. Experimental Rare Plant Translocation Program 2021 Annual Report

Experimental Rare Plant Translocation Program
2021 Annual Report

Date: December 16, 2021

PRESENTED TO:

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ERRATA

In the Experimental Rare Plant Translocation Program's 2020 Annual Report, page 11, Section 3.2, Table 3.2-1: *Ex-Situ* Propagation Results from the 2019 Seed Collection Efforts, there was an error in the germination percentages reported for Davis' locoweed (*Oxytropis campestris* var. *davisii*); prairie buttercup (*Ranunculus rhomboideus*); and Sprengel's sedge (*Carex sprengelii*). The germination rates should have read, "19%; 2%; and 33%", respectively. The correct 2020 germination rates are provided in this document in Section 3.2, Phase 2 *Ex-Situ* Propagation.

ACRONYMS & ABBREVIATIONS

Term	Definition
B.C. CDC	B.C. Conservation Data Centre
EIL	Erosion Impact Line
ERPT	Experimental Rare Plant Translocation
ENSCONET	European Native Seed Conservation Network
PAZ	Potential Activity Zone
PRS	Potential Recipient Site
QA/QC	Quality Assurance and Quality Control
spp.	The abbreviation "spp." (plural) indicates "several species".
sp.	The abbreviation "sp." Refers to a single species.

1. INTRODUCTION

As part of the federal and provincial regulatory approvals of the Site C project, BC Hydro committed to the creation of an Experimental Rare Plant Translocation program (ERPT) to support the viability of target rare plant species affected by the project.

The ERPT program is designed to establish new populations of target rare plant species in areas that are secure, contain analogous habitat to the source populations, and are within the Peace Region. This program uses an experimental approach to identify critical factors affecting germination, establishment, growth, and survival of the target species, the results of which inform the scope of the design such that informed variations on salvage, propagation, and transplant methods can be employed. The ERPT program is updated on an ongoing basis to incorporate relevant information related to target rare plant species and translocation methods as it emerges.

The program is founded on positive working relationships with First Nation-owned, local businesses, and other consultants, and benefits from the shared knowledge and experience. The knowledge acquired and lessons learned can be employed to maximize the success of the program and can be shared among these partners to increase the overall understanding of these systems within the community of contributors.

This report summarizes the measures and activities undertaken in 2021. Included are a summary of the plant species of conservation concern included in the program and the general methods and activities completed for the four phases of the program: Phase 1 - propagule collection; Phase 2 - *ex-situ* propagation; Phase 3 - translocation implementation; and Phase 4 - post-translocation care, maintenance, and monitoring.

1.1 Plant Species included in the Program and their Conservation Ranks

The B.C. Conservation Data Centre (B.C. CDC) annually assesses the provincial conservation ranks of vascular plants and bryophytes in the province. This annual assessment incorporates new information about the abundance and distribution of the province’s flora, as well as newly recognized threats (or lack thereof) to known populations. The ranking update published by the B.C. CDC in 2021 (B.C. CDC 2021) changed the conservation status rank of 37 species in the province relative to their status in 2020. No changes to the conservation status rank of species included in the ERPT program were made in 2021 (Table 1.1-1).

Table 1.1-1. Species included in the Experimental Rare Plant Translocation Program

Scientific Name	Common Name	B.C. CDC Provincial Rank	NatureServe Provincial Status	NatureServe Global Status
Canada mountain-ricegrass	*Piptatheropsis canadensis*	Red	S1 (2019)	G4G5 (2016)
Davis' locoweed	*Oxytropis campestris* var. *davisii*	Blue	S3? (2019)	G5T3 (2015)
Dryland sedge	*Carex xerantica*	Blue	S3 (2019)	G5 (2016)
Prairie buttercup	*Ranunculus rhomboideus*	Blue	S2S3 (2019)	G5 (2016)
Rocky Mountain willowherb	*Epilobium saximontanum*	Blue	S3 (2019)	G5 (1984)
Rock selaginella	*Selaginella rupestris*	Red	S2 (2019)	G5 (2016)
Slender penstemon	*Penstemon gracilis*	Blue	S3 (2019	G5 (2016)
Sprengel's sedge	*Carex sprengelii*	Blue	S3 (2019)	G5 (2016)
Torrey's sedge	*Carex torreyi*	Blue	S3? (2019)	G4G5 (2016)

2. GENERAL METHODS

2.1 Phase 1. Propagule Collection

The standards for collecting and storing propagules for *ex-situ* conservation (e.g., timing, sampling, labelling, cleaning, processing, stratification, sowing, provenance) incorporate guidance outlined in Maslovat (2009) and by the European Native Seed Conservation Network (ENSCONET 2009).

The 2021 propagule collection phase included a combination of the following collection strategies:

- collection of seed from existing populations and sowing of seeds at a nursery, with the resulting seedlings targeted for out-planting at recipient sites;
- collection of mature plants, seedlings, and cuttings from existing populations, followed by *ex-situ* propagation at a nursery and eventual out-planting of propagated material at recipient sites; and
- collection of mature plants or seedlings from existing populations.

2.1.1 *In-situ* Seed Collection

The 2021 *in-situ* propagule collection efforts focused predominantly on augmenting existing seedbank resources for future propagation and for insurance against stochastic events (e.g., floods), human disturbance, and year-to-year climatic variability. Additional collection efforts focused on salvaging plants from within the project footprint and directly replanting them to areas outside of the footprint or sending them to the native plant nurseries for care and future propagation.

2.1.2 *Ex-situ* Seed Collection

Nursery staff collected seeds from the nursery stock derived from the 2017/2018 seed collection efforts. Nursery staff sorted the seeds to remove non-viable seeds (i.e., empty, or poorly developed), and the remaining seeds were cleaned and dried (where necessary) to maximize viability. Cleaning included the removal of waste material from around the seed capsule, and the use of sieves, hand separation, and air separation. Seeds were then placed in cold storage at the nursery to maintain seed quality and longevity. The provenance, seed collection procedures, and quantity collected were recorded.

2.2 Phase 2. *Ex-situ* Propagation

Ex-situ propagation involved stratification and propagation for each individual target species in a nursery environment. Curation protocols and recommendations (ENSCONET 2009) and professional horticultural experience were used to inform the methods for this aspect of the program.

Through the pre-treatment process, seeds were treated to simulate the natural conditions for breaking seed dormancy and initiating germination. Seeds were scarified and/or stratified as relevant. Scarification treatments included a short hot-water bath or sandpaper, while stratification included immersing the seeds into cold temperatures with moisture to simulate natural germination conditions. Seeds that were not intended for planting in the subsequent year were not treated and are being stored as insurance for potential future use.

Propagation methods were developed based on the ecological conditions observed at the source populations, and included several measures and considerations (Vallee et al. 2004; Maslovat 2009) such as:

- examination of the ecological and, if available, translocation literature to determine experimental trials, including optimum founder size (i.e., number of individuals and composition of life stages), reproductive status relevant to propagation for each rare plant species, and out-planting requirements;
- review of common garden experiments as a potential source of horticultural information for a specific target species;
- exploration and implementation of a range of techniques (e.g., varying soil substrate) to determine the most effective propagation options for each target species;
- multiple germination trials to determine viability; and
- holding back source propagules in an *ex-situ* collection as material for future propagation.

All utilized *ex-situ* propagation methods have been documented, including the following:

- provenance (i.e., origin of material collected);
- type of material collected (e.g., seed, live plant);
- location and date of collection; and
- growing conditions such as potting media, temperature of propagation area, watering, and treatment of seeds.

2.3 Phase 3. Translocation

Translocation implementation included four components: (i) recipient site selection; (ii) transport and plant preparation; (iii) selection of planting locations with the habitat matrix; and (iv) translocation at recipient sites.

2.3.1 Recipient Site Selection

Selection of suitable recipient sites, based on the species-specific preferred habitat characteristics, was informed by the extensive existing information collected for Site C along with the expert knowledge of qualified botanists and ecologists who performed the field verification work (see Appendix A). Selected sites contained habitat analogous to that at the source populations and were situated in areas that are unlikely to be developed in the foreseeable future. All sites selected are located within the Peace Region.

The stated goal of recipient site selection in 2021 was to locate suitable recipient sites for four target rare plant species: Davis' locoweed, slender penstemon, Canada mountain-ricegrass, and rock selaginella. Before verifying and selecting recipient sites in the field, a desktop review was conducted to identify potential locations. The desktop review included literature reviews for each priority species to evaluate current and relevant species information such as habitat and translocation requirements, with a particular focus on reviewing new information that had been published since 2020. The updated B.C. CDC database was reviewed to ensure that all existing occurrences known were incorporated into the analysis, and queries were run on the project rare plant database to extract any habitat information that had been recorded during earlier years of the ERPT program.

The habitat requirements of the four target species were grouped into four main types that represent the ideal habitats for translocation, with the following characteristics:

1. river or large stream with level, open, non-active cobble bars; shading open to partial; sparsely vegetated; sandy, well-drained soil;
2. dry, steep, open, south-facing hillside; relatively sparse low shrubs; xeric grassland vegetation with tan-coloured appearance on aerial imagery;
3. mesic to dry, open, south-facing hillcrest or gentle slope; relatively dense low shrubs; grassland vegetation with a green appearance on aerial imagery; or
4. dry, steep, open, south-facing hillcrest/hillside; relatively sparse, low shrubs; xeric grassland vegetation with a tan-coloured appearance on aerial imagery.

Aerial imagery and GIS attributes were visually evaluated to identify locations with ideal ecological and logistical characteristics that would maximize opportunities for successful translocation. GIS layers that were assessed for this included: (i) aerial imagery of the Peace River region; (ii) property ownership (provided by BC Hydro); (iii) known element occurrences of the target species; (iv) potential recipient sites identified during earlier years of the project; (v) the Site C Project Activity Zone (PAZ); and (vi) the Site C preliminary Erosion Impact Line (EIL). This analysis resulted in the following criteria that were identified as indicative of suitable recipient sites:

1. accessible by road or boat during the entire growing season;
2. outside of the Site C PAZ;
3. not located below the reservoir preliminary Erosion Impact Line (i.e., a precautionary estimate of the amount of erosion that could occur over a 100-year period);
4. located on Crown land or BC Hydro land near the Peace River;
5. within range of cell service;
6. not requiring access through a locked gate or other landowner permission;
7. contains appropriate habitat for the priority species;
8. contains low density of non-native plants;

9. has low levels of anthropogenic disturbance;
10. greater than one kilometre from known sites of the same taxon;
11. not already occupied by other rare plant species; and
12. located close to a water source.

It is recognized that the list of desirable recipient site qualities describes a hypothetical ideal site. For example, field botanists attempted to avoid occupied sites when reviewing potential planting locations; however, this was only partially successful because suitable planting sites were often found to host target rare plant species. As a result, no site is likely to fulfill all the listed criteria, and trade-offs will always be necessary to ensure that the project can proceed.

Potential Recipient Sites (PRSs) were selected partially based on distance to other planting sites, with the aim of distributing them over a wide geographical extent. In some instances, a site was found to contain suitable habitat for several ERPT target species in close proximity, and so separate PRS plots were completed for each target species. While this does provide the option to plant multiple species at the same site, with the consequent increased risk of a single disturbance event impacting multiple species, the limited number of suitable sites available for some of the target species necessitated using one site for several species in some cases. In addition, several of the target species occur together in wild populations, and thus their co-occurrence is consistent with natural conditions.

Thirty-four PRSs were identified during this desktop exercise in 2021, of which 12 received field verification and were ranked for suitability using weighted desirable site characteristics. The 22 PRSs not field-verified were either too difficult to access, have been visited during earlier field surveys of PRSs, or are under consideration as future PRSs (see Appendix A). Of the sites that were checked, two PRSs were considered to be worth investigating further, and three PRS plots were completed between these two sites. At each PRS plot, vegetation composition and cover data were recorded for the overall site, as well as for three one-metre-square plots placed in representative locations. Despite challenges with avoiding sites in the vicinity of other rare plant populations and finding areas with water sources, the two best PRSs met the majority of the stated requirements. One of the PRS areas contains a variety of habitats and is suitable for multiple species translocation (see Appendix A); the remaining PRS was specifically selected for a single taxon (Davis' locoweed) due to its distinct habitat requirements. Supplemental planting areas (i.e., specific microsites) were marked within suitable habitat to provide increased planting options.

2.3.2 Transport and Plant Preparation

Nursery seedlings (i.e., small plants in 50P or 75P size plugs) and adult plants (i.e., medium to large plants in 1-gallon pots) were shipped from NATS nursery on May 31 and September 1, 2021. Plants arrived at Dunvegan Gardens (Dunvegan) in Fort St. John on June 2 and September 2, 2021, respectively. The plants were housed at the garden centre and moved to a private residence in Fort St. John until transplant at recipient sites in the following days. Plants were stored outside in June as temperatures were above freezing and in the Dunvegan greenhouses in September to be naturally hardened-off until planting was initiated on September 9, 2021.

2.3.3 Selection of Planting Locations within the Habitat Matrix

Planting locations within the larger habitat matrix at a recipient site were identified as those that were relatively easy to access, corresponded with known ecological conditions that support the species, supported plant diversity that is similar to the source populations, were on stable substrates that are not expected to undergo erosion or deposition, and were not accessible to cattle or used intensely by native herbivores. There was limited variability in the planting patterns within species, thereby minimizing constraints on comparability across sites within species. Within species, the planting plans sought to:

- establish plant groupings such that there were similar conditions in terms of microsite conditions (e.g., soils, slope, aspect);
- create plant groupings to encourage pollinator visitation; and
- space individuals to minimize potential trampling during planting and monitoring and to minimize interspecific competition for resources (e.g., minimize density-dependent effects on survival).

2.3.4 Translocation at Recipient Sites

The specific timing windows for planting were determined based on past years' experience regarding the average first and last frost-free days for Fort St. John, as well as plant phenology, the development stage of the propagated plants, the local weather, and soil moisture conditions. The timing for planting of two species also took into consideration the need to salvage plants prior to clearing activities occurring at one location.

The initial out-planting occurred from June 9 to 15, 2021, and a subsequent out-planting occurred from September 9 to 16, 2021. Some plant stock was withheld from planting as insurance against inclement conditions that could negatively affect the initial out-planting stock. Implementation of the translocation planting included the following:

- placement of plants into optimal microhabitats at the recipient sites, and in a spatial pattern suitable to the rare plant's biology as observed at the source populations or otherwise known;
- installation of durable, long-lasting tags to label individual plants and flagging tape to label plant groupings;
- code systems to differentiate various experimental trials as needed to retain as much information as possible on the pathway of a given plant (e.g., from seed collection to planting) to facilitate annual assessments of success;
- marked boundaries for plants, plant groupings, and translocation site boundaries using GPS points and imported into the project GIS system;
- care and maintenance at the time of planting, such as watering and creation of microhabitat as necessary;
- documentation of each translocation effort (including time spent on each phase), which included the methods used to prepare and transport the material from the nursery to the recipient site,

pre-translocation site preparation, environmental conditions, method of re-introduction, care and maintenance activities, planting density, and spatial pattern; and

- post-translocation follow-up to assess the health and status of a sample and to check for other possible problems, such as desiccation, pest insects, trampling, herbivory, or vandalism at a translocation site.

2.4 Phase 4. Monitoring

Two levels of monitoring were conducted in 2021: interim monitoring and year-end monitoring. Interim monitoring efforts included general health assessments of the translocated plants as well as identification of threats and subsequent application of mitigation measures. Year-end monitoring included an assessment of: (i) **Survivorship** - to determine if individuals are surviving beyond the initial transplant year; (ii) **Maturity** - to determine if individuals are maturing to the flowering and fruiting stages; and (iii) **Reproduction** - to determine if individuals are successfully producing seeds. The following population traits were assessed during the monitoring program:

- plant presence (summarized as number of live/dead/absent individuals);
- vegetative growth (width or height) and/or health (qualitative assessment)[1];
- percent of individuals flowering/fruiting;
- seed production per individual; and
- spatial extent of the population.

Monitoring activities also re-evaluated sites for the one or more of the following to identify successes and failures to improve the survival of future plantings:

- invasive species presence, especially in close proximity to the translocated plants, and/or any species that may have inadvertently been introduced to the site during the translocation;
- herbivory or other possible problems (e.g., pest insects, trampling, ungulate grazing);
- human disturbance; and
- microsite habitat preferences.

Information gained from monitoring implementation of the various experimental translocation approaches used will help to identify which approaches are effective and to isolate inadequacies in specific methods, all within an adaptive management framework.

[1] This information was collected in 2021 but has yet to be analyzed.

2.5 Quality Assurance and Control

Quality assurance and quality control (QA/QC) measures were used for capturing data within the field program so that methods were consistently replicated across all trials and years, and so that pertinent variables or any variations in methodology were recorded. The data form was designed to accommodate data capture at the transect, plot, or individual plant level across years (Appendix B). The data form included the following fields:

1. site details (i.e., Site ID, geographical location, slope, aspect, and elevation);
2. species information (i.e., species name, nursery of origin, seedlot, key metrics for survivorship, maturity, and reproduction);
3. potential threats (i.e., herbivory, drought, others); and
4. map outlining the relative location of each individual plant and plant grouping.

Photos were taken using the Solocator App (Civi Corp Pty Limited 2021), which were date- and time-stamped and included the UTM location of the site.

3. RESULTS

3.1 Phase 1. Propagule Collection

The 2021 *in-situ* collection efforts focused on acquiring additional propagules for six species: Sprengel's sedge, Torrey's sedge, prairie buttercup, Canada mountain-ricegrass, slender penstemon, and rock selaginella (Table 3.1-1). No *in-situ* collections were made for Davis's locoweed and dry-land sedge as previous collection efforts have resulted in sufficient quantity for the translocation efforts. Additionally, no collections were made for Rocky Mountain willowherb; there have been a number of attempts in recent years to locate this species in and around the reported location, but no individuals or suitable habitat have been observed (Eagle Cap 2020). *Ex-situ* seed collections were made opportunistically for Davis' locoweed in August from NATS nursery stock, and the seeds were processed according to the methods outlined in Section 2.1.2.

Seeds were collected from existing *ex-situ* populations for two species: Sprengel's sedge and Torrey's sedge (from Dry Creek and Fish Creek, respectively, Figure 3.1-1; Eagle Cap 2021). These species were targeted for further collection to augment the existing seedbank housed at NATS nursery. The nursery will sow these seeds with the intent of generating future plant stock for transplant at recipient sites.

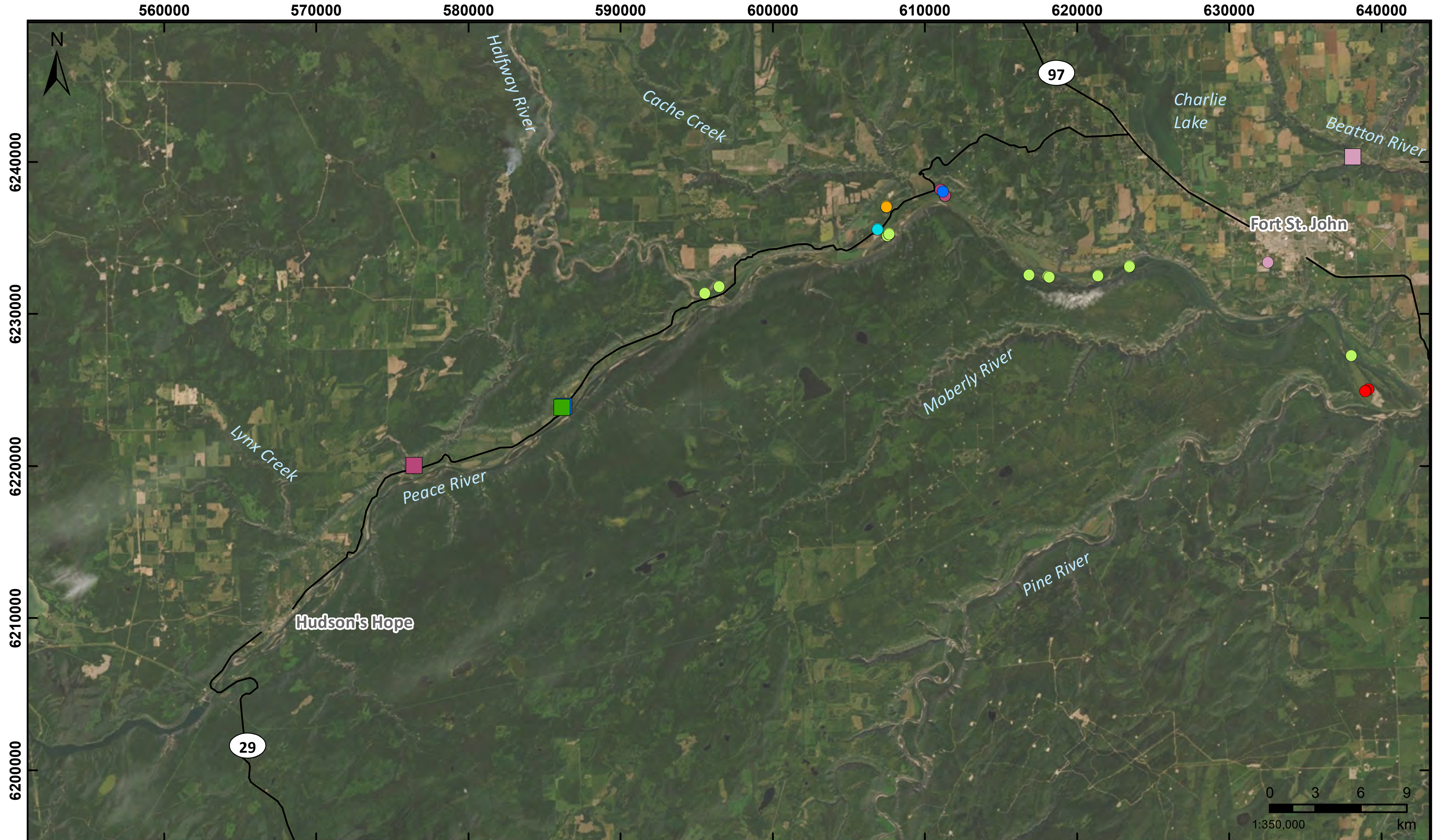
Mature plants (and/or seedlings) were collected from existing populations for two additional species: slender penstemon and rock selaginella. A substantial effort was invested in salvaging plants from Farrell Creek East in response to changes to the Hwy 29 realignment, which have resulted in the partial loss of this species occurrence. Penstemon plants along with rock selaginella sod blocks (approximately 30 cm x 25 cm) were salvaged in a manner that retained the top growth, roots, and potential seed bank intact.

Seed collections were also attempted for Canada mountain-ricegrass and prairie buttercup; however, no viable seeds were detected. Climatological conditions in 2021, particularly extreme heat during the early growing season (June), are likely the cause of poor detectability of Canada mountain-ricegrass.

Table 3.1-1. Summary of Successful 2020/ 2021 Propagule Collection Efforts

Common Name	Species Name	Propagule Amount and Type	Collection Timing	Collection Type	Collection Location
Davis' locoweed	*O. campestris* var. *davisii*	16,000 seeds*	August 17, 2021	*ex-situ*	NATS nursery
Rock selaginella	*S. rupestris*	~144 sod blocks	June 13, 2021	*in-situ*	Farrell Creek East
Slender penstemon	*P. gracilis*	~156 plants	June 13, 2021	*in-situ*	Farrell Creek East
Sprengel's sedge	*C. sprengelii*	25 seeds	August 5, 2021	*in-situ*	Dry Creek
Torrey's sedge	*C. torreyi*	100 seeds	August 03, 2021	*in-situ*	Fish Creek

* Quantity provided from the nursery is an estimate based on seed weight.



Site C Project

Experimental Rare Plant Translocation
Propagule Collection Locations
Figure 3.1-1

Date: 12/8/2021
Map Number: BCH-052
Coordinate System: NAD 1983 UTM Zone 10N
Projection: Transverse Mercator
Datum: North American 1983

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2017-2020	2021	Target Species
●	■	Sprengel's sedge (*Carex sprengelli*)
●	■	Torrey's sedge (*Carex torreyi*)
●		Dryland sedge (*Carex xerantica*)
●		Davis' locoweed (*Oxytropis campestris var. davisii*)
●	■	Slender penstemon (*Penstemon gracilis*)
●		Canada mountain-ricegrass (*Piptatheropsis canadensis*)
●		Prairie buttercup (*Ranunculus rhomboideus*)
	■	Rock selaginella (*Selaginella rupestris*)

3.2 Phase 2. *Ex-situ* Propagation

Propagation efforts in 2021 focused on seven species: Canada mountain-ricegrass, Davis' locoweed, prairie buttercup, slender penstemon, Sprengel's sedge, Torrey's sedge, and rock selaginella (Table 3.2-1). Nursery staff primarily focused on trialing methods for the two species added to the program in 2020: Canada mountain-ricegrass and rock selaginella. These trials focused on determining stratification methods for Canada mountain-ricegrass and on determining suitable growing media for rock selaginella cuttings. Additional efforts were invested in refining the stratification methods for Davis' locoweed and Torrey's sedge, both of which had low germination rates in 2020. The stratification measures were not altered for the remaining species, which included prairie buttercup, slender penstemon, and Sprengel's sedge.

In total, 2,959 rare plants were propagated from seed along with two blocks (60 cm x 30 cm) of rock selaginella, which were grown from cuttings. The overwhelming majority of the plants propagated were Davis' locoweed (2,800 seedlings: Plate 3.2-1). Notably, the germination rate was increased to over 35% from 19% due to refinement of the stratification measures. The debut trial for Canada mountain-ricegrass resulted in a 47% germination rate yielding nine seedlings (Plate 3.2-2). Additionally, the germination rate for Torrey's sedge was increased to 19% from 2% and resulted in 50 seedlings. The germination results for Sprengel's sedge increased to 37% from 33% and resulted in 50 seedlings. The germination rate for prairie buttercup increased substantially from 2% in 2020 to 29% in 2021 (Plate 3.2-3), likely as a result of refined stratification methods for this species. Rock selaginella was grown from two clumps (10 x cm by 10 cm) submitted last year (Plate 3.2-4). This species was grown in various substrate types and resulted in two large trays, both measuring 30 cm by 60 cm (Plate 3.2-5). Sufficient stock for the 2021 translocation efforts was generated for all species.

Plate 3.2-1. Canada mountain-ricegrass adult plants (1 Gallon) produced in 2021.

Plate 3.2-2. Davis' locoweed seedlings (50P) grown in 2020.

Plate 3.2-3. Prairie buttercup adults (1G) produced in 2020/2021.

Table 3.2-1. Summary of *Ex- situ* Propagation Results from the Propagule Collection Efforts

Species Name	Nursery of Origin	Seedlot	Weight and No. of Seeds Stratified	Germination Percent		Quantity and Size Produced in 2020/2021
				2020	2021	
Canada mountain-ricegrass (*P. canadensis*)	NATS	EL-180-20 EL-109-20	< 0.1 g (19 seeds)	na	47	9 seedlings
Davis' locoweed (*O. campestris* var. *davisii*)	NATS	EL-127-19 EL-183-17 EL-128-19 EL-130-19 EL-115-17 EL-206-18 NN-33-20	8 g (~ 8,000 seeds)	~ 19	~ 35%	2,800 seedlings
Prairie buttercup (*R. rhomboideus*)	NATS	EL-173-19 EL-182-18	0.45 g (360 seeds)	~ 2	29	20 1 G and 30 seedlings
Sprengel's sedge (*C. sprengelii*)	NATS	EL-181-18 EL-176-19	< 0.5 g (135 seeds)	33	37	50 seedlings
Torrey's sedge (*C. torreyi*)	NATS	EL-87-20	0.3 g (258 seeds)	2	19	50 seedlings
Rock selaginella (*S. rupestris)*	NATS	P7525FS P50LR50	na	na	na	2 sod blocks (60 cm x 30 cm)
Total						**2,961**

Plate 3.2-4. Example of rock selaginella cuttings (Source: Eagle Cap Consulting Ltd.).

Plate 3.2-5. Rock selaginella grown from cuttings in 2020/2021.

3.3 Phase 3. Translocation Implementation

Translocation implementation focused on planting trials at recipient sites that have greater long-term security than the locations of the source material. The recipient sites are within the known distribution range for the target plant within the Peace Region and have similar habitat to the location of the source material.

Translocation trials were completed in June and September 2021 with more than 760 individuals planted at eight recipient sites (Figures 3.3-1 to 3.3-3; Table 3.3-1). Two priority species, rock selaginella and Torrey's sedge, were translocated for the first time in this program.

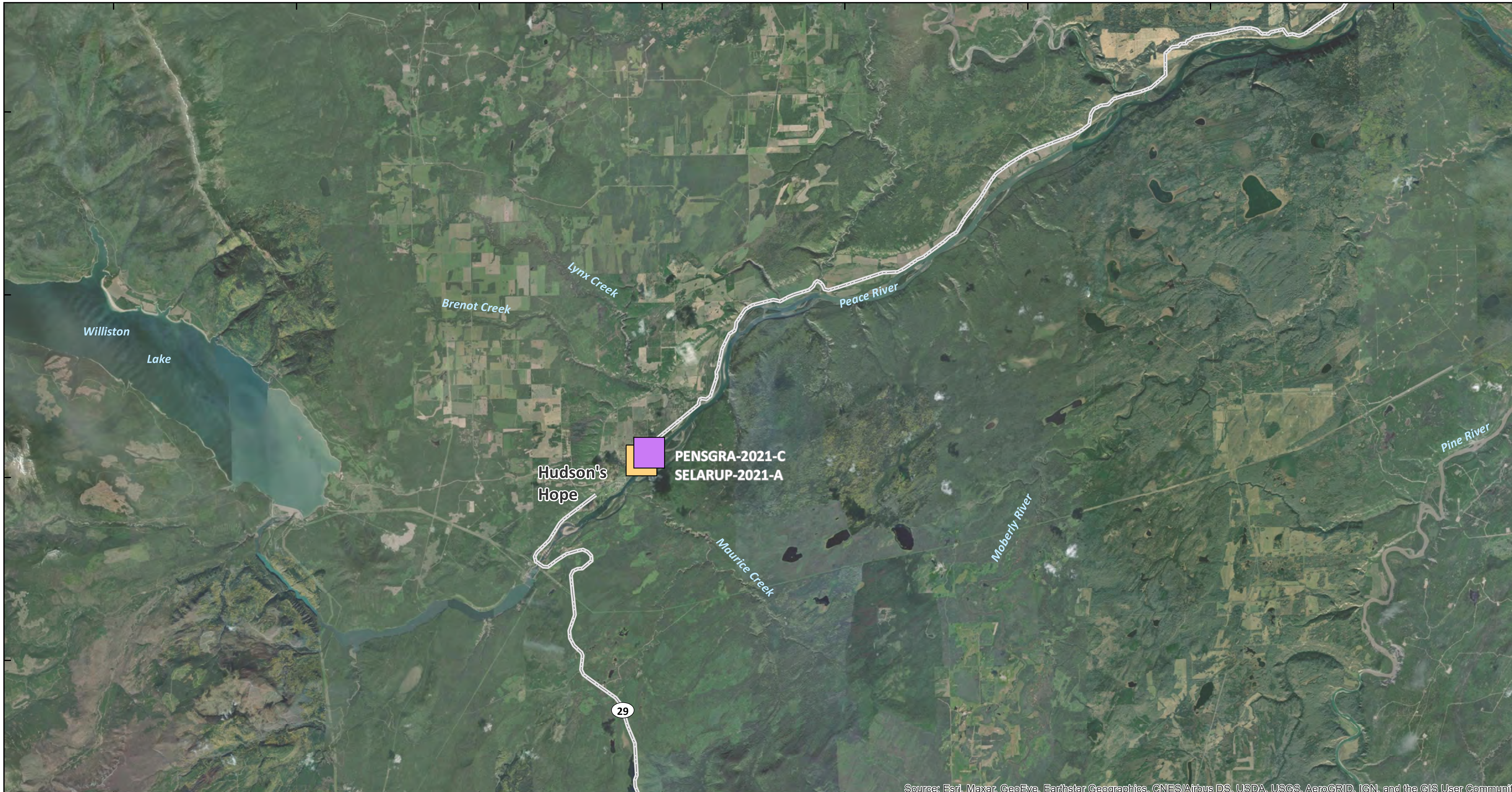
Table 3.3-1. Summary of Individuals Translocated by Species and Site ID in 2021

Species	Site ID	Translocation Date	No. of Seedlings*	No. of Adults **	Total
Davis' locoweed	OXYTCAM3-2020-C	11-Jun	298	47	345
		11-Sep	30	28	58
		16-Sep	7	41	48
Total			**335**	**116**	**451**
Prairie buttercup	RANURHO-2021-A	9-Jun	10	3	13
		13-Sep	15	2	17
	RANURHO-2021-B	8-Jun	10	4	14
Total			**35**	**9**	**44**
Slender penstemon	PENSGRA-2020-B	9-Jun	15	1	16
	PENSGRA-2021-C (salvage)	13-Jun	-	-	~104
	PENSGRA-2021-C	16-Sep	10	10	20
Total			**25**	**11**	**140**

Species	Site ID	Translocation Date	No. of Seedlings*	No. of Adults **	Total
Sprengel's sedge	CARESPR-2020-1A and 1B	15-Jun	6	2	8
	CARESPR-2021-C	15-Jun	0	1	1
Total			**6**	**3**	**9**
Torrey's sedge	CARETOR-2021-A	16-Sep	5	0	5
Total			**5**	**0**	**5**
Rock selaginella	SELARUP-2021-A (salvage)	13-Jun	-	~109	~109
	SELARUP-2021-A	16-Sep	-	2	2
Total					**111**
Grand Total					**760**

* Seedlings are provided in 50P plug size containers which are 5" deep by 2" wide.

**Adults are provided in 1-gallon pots; rock selaginella cuttings grown in trays were included in this category.



Site C Project

Experimental Rare Plant Translocation Recipient Site Locations

Figure 3.3-1

Date: 12/8/2021

Map Number: BCH-057a

Coordinate System: NAD 1983 UTM Zone 10N

Projection: Transverse Mercator

Datum: North American 1983

ECOLOGIC environmental consulting

Legend

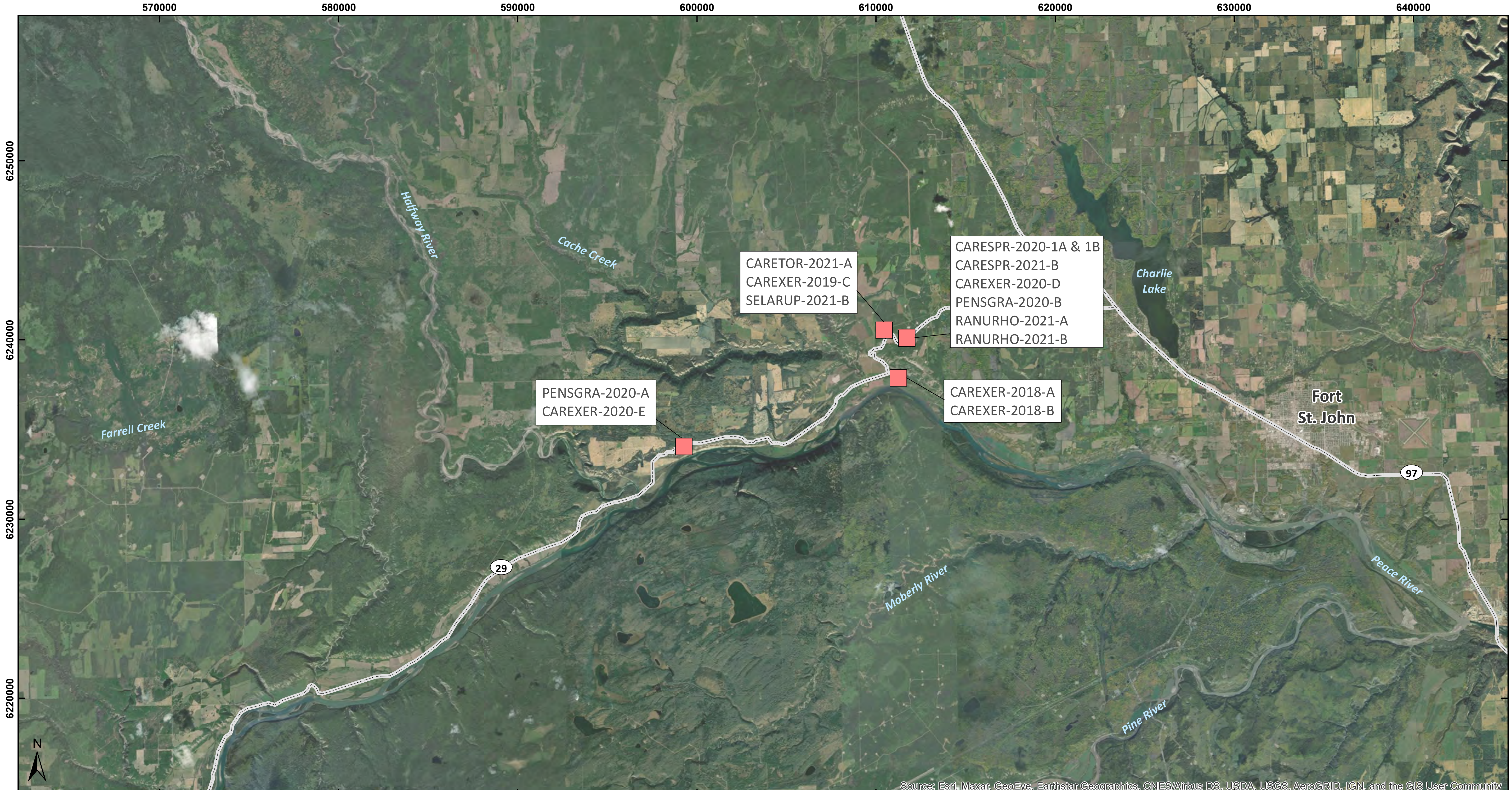
2021 Recipient Sites

- Slender penstemon (*Penstemon gracilis*)
- Rock selaginella (*Selaginella rupestris*)
- Highway

0 2 4 6 km

1:200,000

N



Site C Project

Experimental Rare Plant Translocation
Recipient Site Locations
Figure 3.3-2

Date: 12/8/2021
Map Number: BCH-057b
Coordinate System: NAD 1983 UTM Zone 10N
Projection: Transverse Mercator
Datum: North American 1983

ECOLOGIC environmental consulting

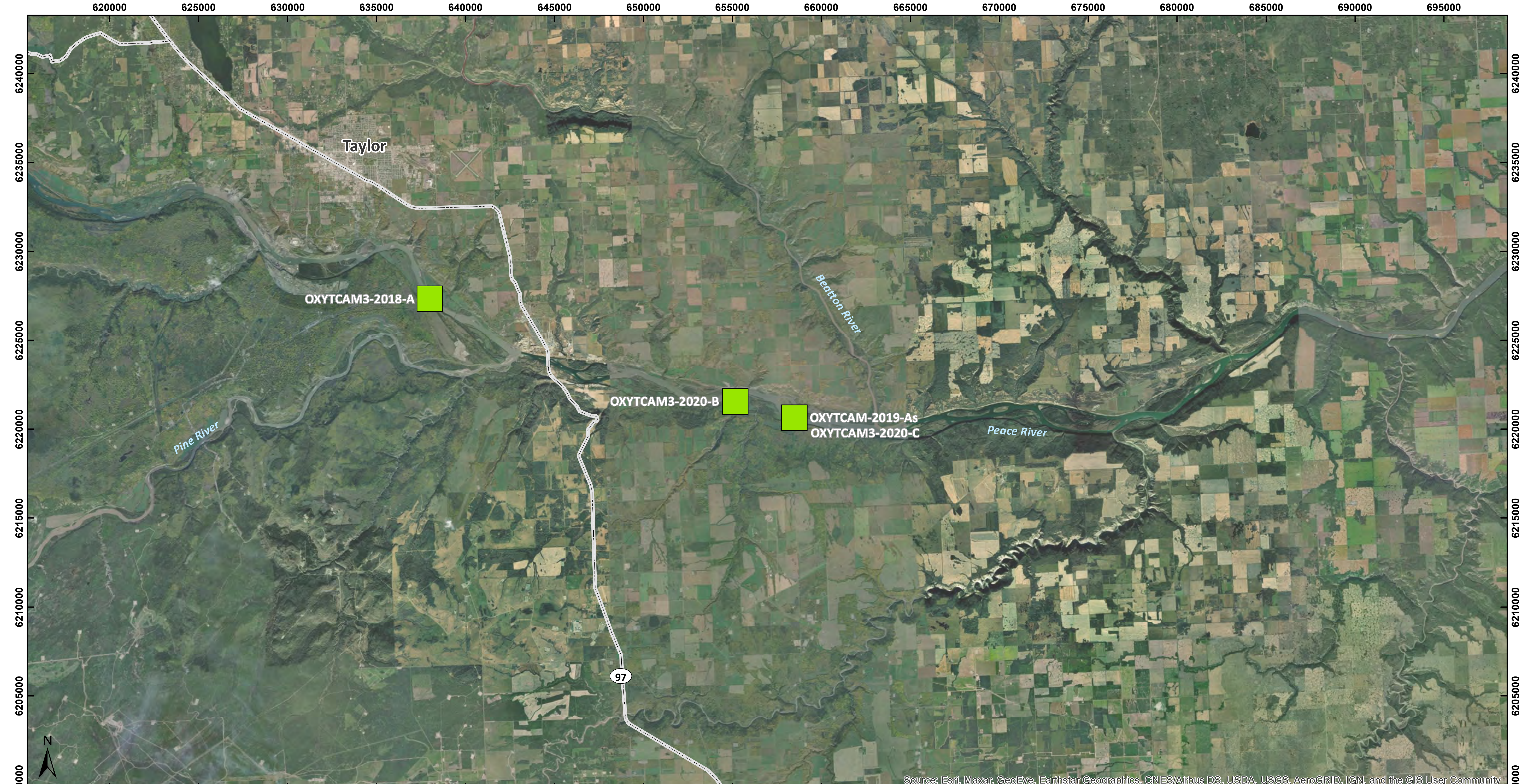
Legend

- 2018-2021 Recipient Sites[1]
- Highway

0 2 4 6 km
1:200,000

[1]Site names correspond to the following species:
- CAREXER - Dryland sedge (*Carex xerantica*)
- CARETOR - Torrey's sedge (*Carex torreyi*)
- PENSGRA - Slender penstemon (*Penstemon gracilis*)
- RANURHO - Prairie buttercup (*Ranunculus rhomboideus*)
- SELARUP - Rock selaginella (*Selaginella rupestris*)

Sources: Esri, USGS, NOAA



Site C Project

Experimental Rare Plant Translocation
Recipient Site Locations
Figure 3.3-3

Date: 12/8/2021
Map Number: BCH-057c
Coordinate System: NAD 1983 UTM Zone 10N
Projection: Transverse Mercator
Datum: North American 1983

ECOLOGIC environmental consulting

Legend

2018-2021 Recipient Sites

Davis' locoweed (*Oxytropis campestris var. davisii*)

Highway

0 2 4 6
1:200,000
km

3.3.1 Sprengel's Sedge (*Carex sprengelii*)

On June 15, 2021, existing populations of Sprengel's sedge (Site ID: CARESPR-2020-B-1A and 1B) were augmented with six seedlings at site CARESPR-2020-B-1A and two adult plants at site CARESPR-2020-B-1B (Figure 3.3-4; Plates 3.3-1 to 3.3-4). These sites were established on June 11, 2020, on the north side of Highway 29 above Bear Flat in a moist open willow thicket. One adult was also planted at site CARESPR-2021-C (Figure 3.3-4) in proximity to the trail towards site CAREXER-2020-D on June 15, 2021. The roots of each plant were gently loosened before placing each individual into excavated holes. Each hole was backfilled with the existing excavated soil and watered. Each plant was systematically tagged with a numbered yellow plastic tag fixed to the ground using 6-inch ground staples.

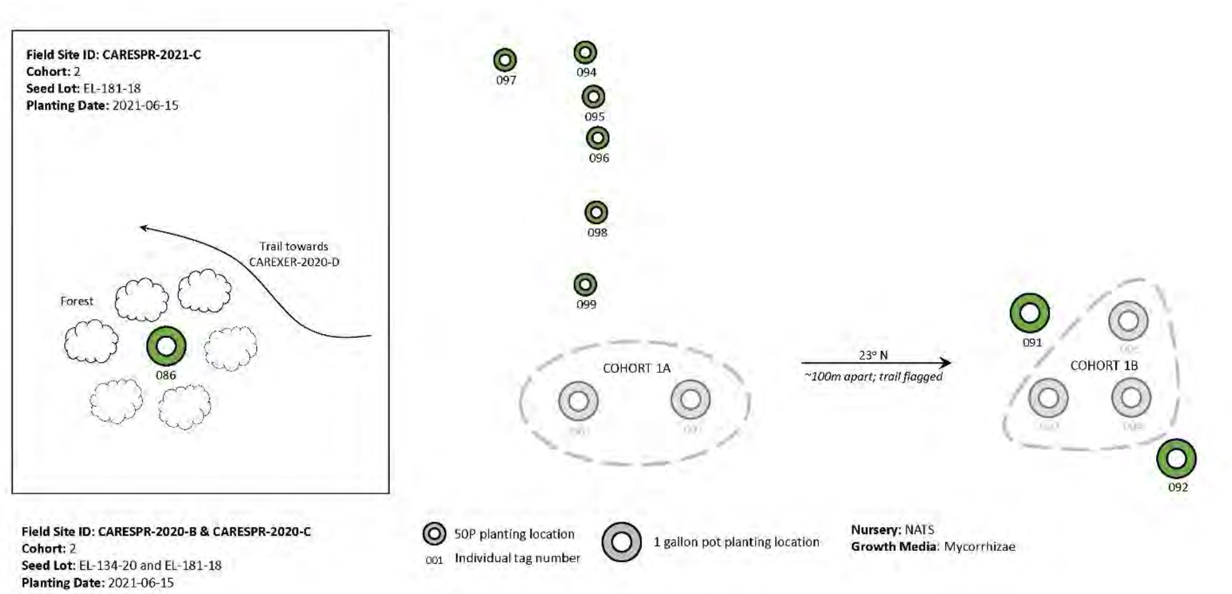


Figure 3.3-4. Planting Grid for Sprengel's Sedge at Site Id: CARESPR-2020-B 1A & 1B and CARESPR-2021-C

Plate 3.3-1. Planting site for Sprengel's sedge – CARESPR-2020-1A.

Plate 3.3-2 Planting site for Sprengel's sedge – CARESPR-2020-1B.

Plate 3.3-3. Installed Sprengel's sedge and identification tag 091– CARESPR-2020-1B.

Plate 3.3-4. Installed Sprengel's sedge and identification tag 086- CARESPR-2021-C.

3.3.2 Torrey's sedge (*Carex torreyi*)

On September 16, 2021, five seedlings were translocated in an open area with grasses and forbs adjacent to aspen forest (Site ID: CARETOR-2021-A). The planting site is close to a trail leading to site CAREXER-2019-C (Figure 3.3-5; Plates 3.3-5 and 3.3-6). The 2021 season represented the first attempt at out-planting Torrey's sedge.

Plate 3.3-5. Planting site for Torrey's sedge – CARETOR-2021-A.

Plate 3.3-6. Installed Torrey's sedge seedling (50P) and identification tag 092.

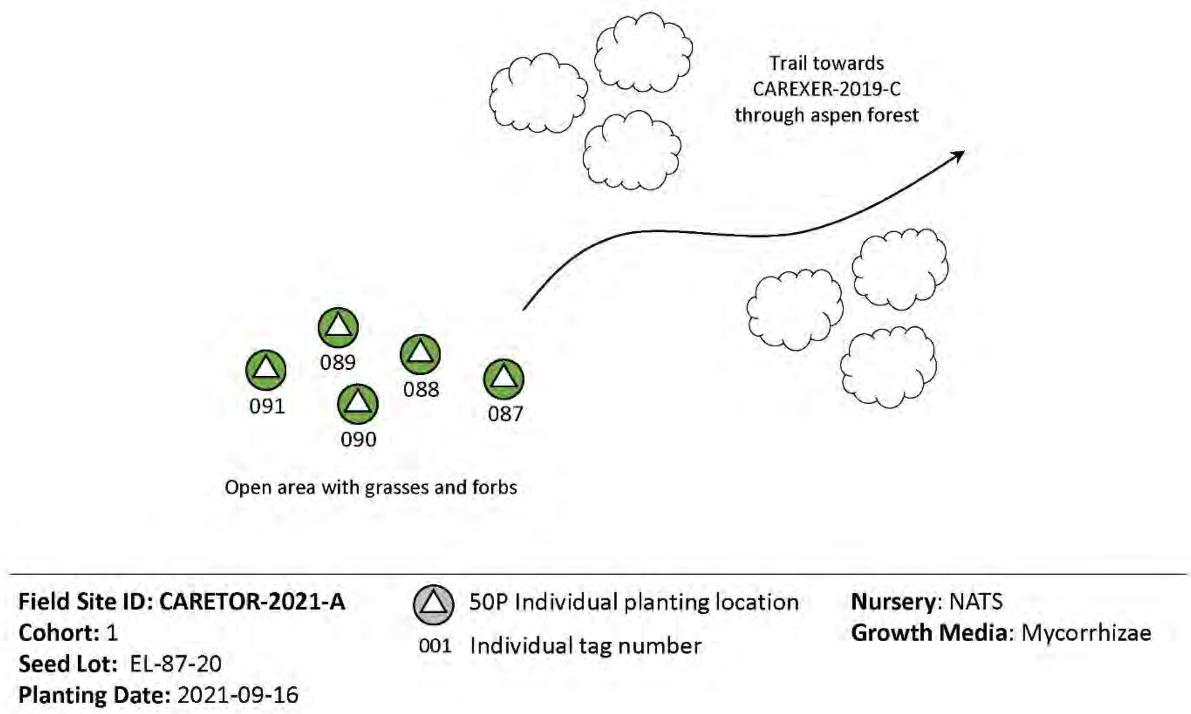


Figure 3.3-5. Planting Grid for Torrey's Sedge at Site Id: CARETOR-2021-A

3.3.3 Davis' locoweed *(Oxytropis campestris* var. *davisii)*

Existing populations of Davis' locoweed (Site ID: OXYTCAM3-2020-C) were augmented with a total of 451 individuals (116 adults and 335 seedlings; Figure 3.3-6, Plates 3.3-7 and 3.3-8). Forty-seven adults and 298 seedlings (Cohort 2) were planted on June 11, 2021; 28 adult and 30 seedlings (Cohort 3) were planted on September 11, 2021; and 41 adults and 7 seedlings (Cohort 3) were planted on September 14, 2021.

Davis' locoweed were planted in clusters and arranged in relatively close proximity to each other (see arrangement of individual plots in Figure 3.3-6). This planting arrangement was intended to encourage pollinator visitation, to minimize potential trampling during planting and monitoring, and to minimize inter-individual resources (i.e., minimize density-dependent effects on survival; Plate 3.3-8).

The planting method was similar to past years in the challenging cobbly substrate, where excavated sandy soil was separated from the cobble and mixed with wetted nursery soil to be used as back-fill (Plate 3.3-9). The cobble was then used to fill in gaps and was placed around each plant to be consistent with the existing grade. Any mosses that existed in the designated planting areas were carefully removed before excavation and replaced after planting. A water backpack was used to carry water from the river to provide additional moisture to recent plantings.

Mesh fencing was applied around plot 3 and a portion of plot 1B to deter herbivory by ungulates (Plate 3.3-10). Signs of elk were evident near the site and herbivory was observed on established transplants from the previous year.

Plate 3.3-7. Example of seedling (50P) Davis' locoweed transplanted (Plot 22).

Plate 3.3-8. Example of transplanted clusters of Davis' locoweed adult plants (1G).

Plate 3.3-9. Pre-planting trench for Davis' locoweed seedlings.

Plate 3.3-10. Mesh fencing installed around plot 3 and a portion of plot 1B.

Figure 3.3-6. Planting Grid for Davis' Locoweed at Site ID: OXYTCAM3-2020

3.3.4 Slender penstemon *(Penstemon gracilis)*

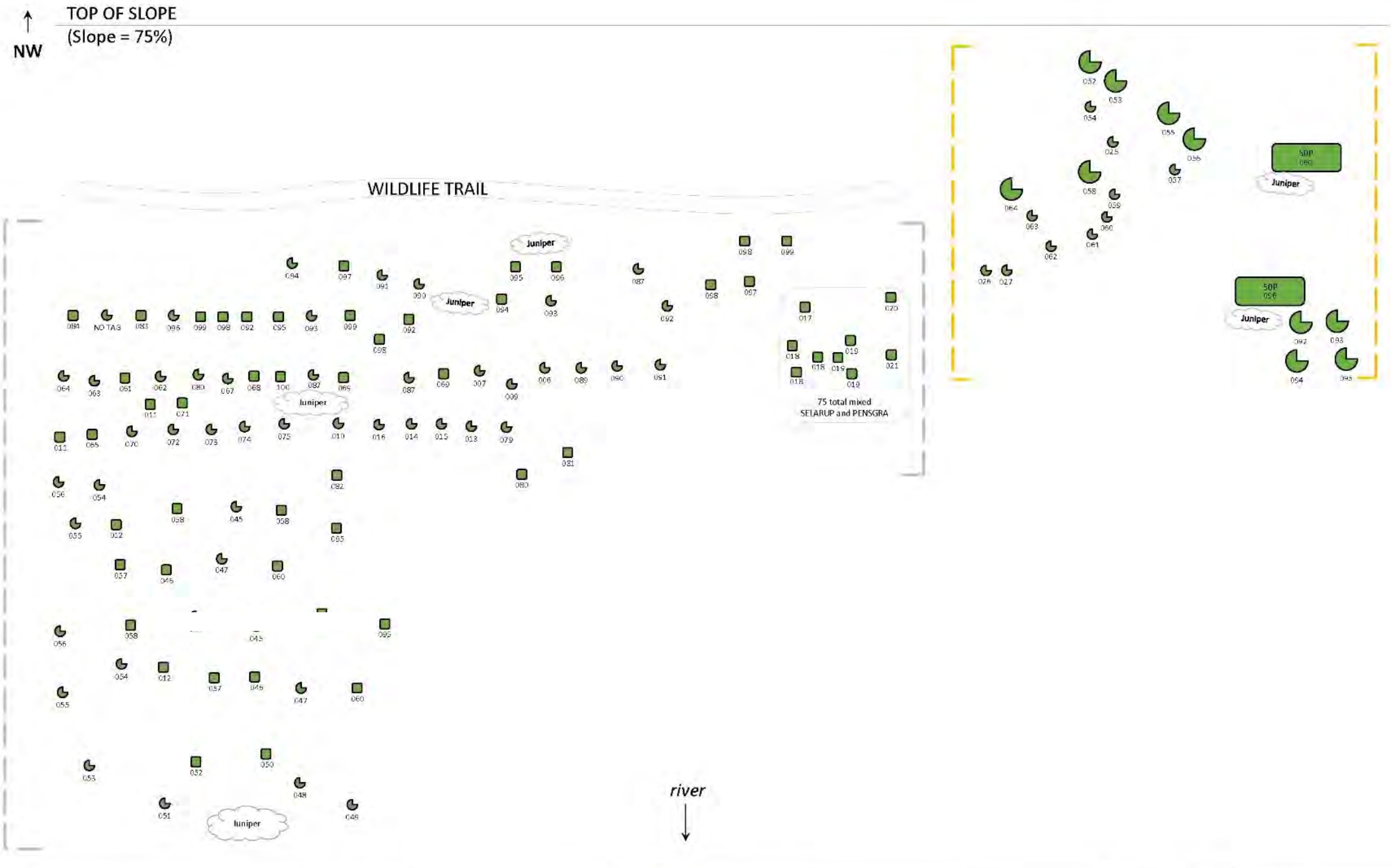
Slender penstemon at various life stages (i.e., young rosettes, flowering, seeding) were salvaged along with rock selaginella at the Farrell Creek East on June 13, 2021 (Plate 3.3-11), and transported to a new translocation site (PENSGRA-2021-C), a south-facing hill overlooking the Peace River (Figure 3.3-7; Plate 3.3-12). An additional 52 individuals were transported to NATS nursery as insurance against stochastic events.

Plate 3.3-11. Salvaged slender penstemon that were transported to Site ID: PENSGRA-2021-C.

Plate 3.3-12. Shaded site at PENSGRA-2021-A where nursery-grown plants were transplanted on September 16, 2021.

Plate 3.3-13. Examples of translocated nursery-grown slender penstemon at PENSGRA-2021-C on September 16, 2021.

Plate 3.3-14. Example of translocated nursery-grown slender penstemon at PENSGRA-2020-B on June 09, 2021.



Field Site ID: SELARUP-2021-A & PENSGRA-2021-C
Cohort: 1 and 2
Seed Lot: salvaged from Farrell Creek (COHORT 1)
7525FS and P50LR5 (COHORT 2 SELARUP)
EL-117-19 (COHORT 2 PENSGRA)
Planting Date: 2021-06-13 and 2021-09-16

COHORT 1 — COHORT 2
SELARUP planting location
001 Individual tag number
50P tray PENSGRA planting location
50P PENSGRA planting location

Nursery: NATS
Growth Media: Mycorrhizae

Figure 3.3-7. Planting Grid for Slender Penstemon Mixed Planting with Rock Selaginella at Site ID: PENSGRA-2021-C

At site PENSGRA-2021-C, slender penstemon were interplanted with rock selaginella (Figure 3.3-8). An estimated eight individuals were planted. Due to dry conditions, lack of a water source, and plant stress attributed to handling and transportation, many of the transplants in this initial cohort 1 were wilted at the time of planting despite having been stored in the shade. Follow-up watering was not completed as rainfall occurred directly after planting. At the same site but in a different location, 10 plugs (50P) and 10 1-gallon individuals (cohort 2) were planted to the east of the salvaged transplants on September 16, 2021 and labelled with orange tags (Figure 3.3-7; Plate 3.3-13). The second cohort was translocated to a shady upper portion of the slope which also contained stone-free soils of aeolian (wind-derived) origin. At site PENSGRA-2020-B-50P, 15 plugs (75P) were planted in a row above translocated individuals from the previous year (cohort 1); one additional adult was planted near cohort 1 as well (Figure 3.3-8; Plate 3.3-14).

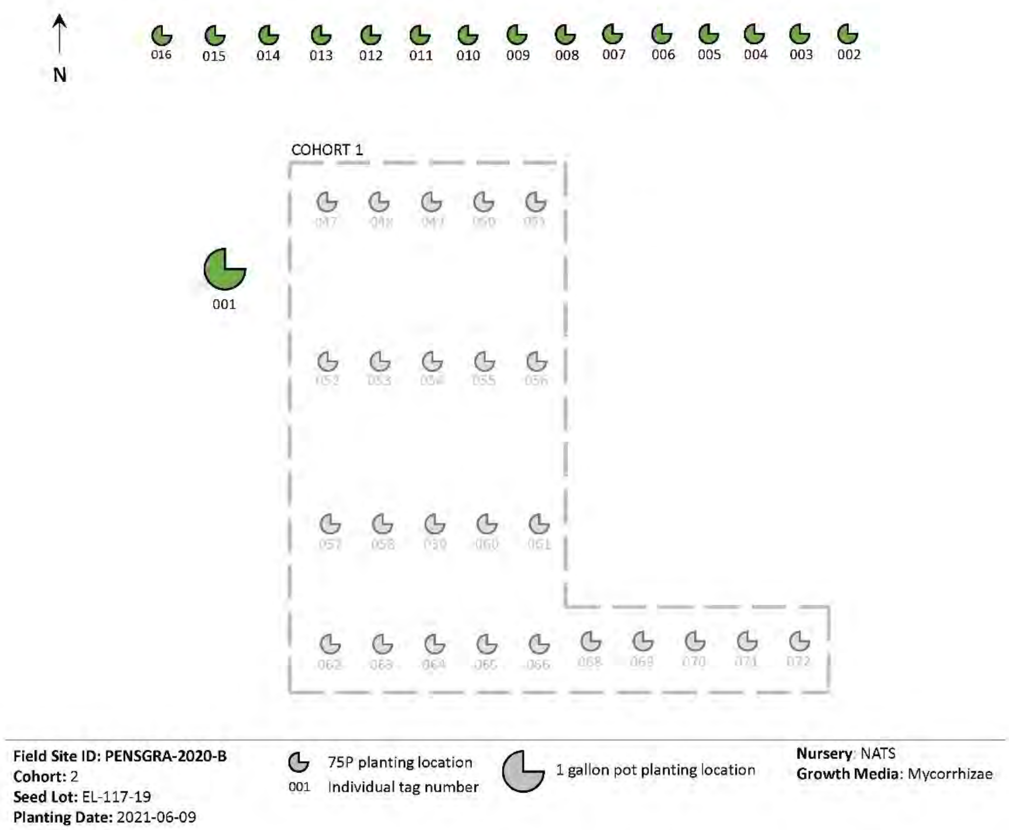


Figure 3.3-8. Planting Grid for Slender Penstemon at Site ID: PENSGRA-2020-B-50P

3.3.5 Prairie buttercup *(Ranunculus rhomboideus)*

Ten seedlings and three adult plants were planted at Site ID: RANURHO-2021-A on June 9, 2021 (cohort 1), within a saskatoon berry shrub and grass matrix (Figure 3.3-9). A second planting of 15 seedlings and 2 adult plants were also translocated at Site ID: RANURHO-2021-A on June 13, 2021 (cohort 2; Figure 3.3-10, Plates 3.3-15 and 3.3-16). The June 13 plantings were situated amongst rose, saskatoon berry, and snowberry shrubs, and wired cages and cones were established around these plantings to deter herbivory (Plate 3.3-15). On June 8, 2021, 10 seedlings (75P) and 4 (1G) adults were planted at site RANURHO-2021-B (Figure 3.3-11; Plates 3.3-17 and 3.3-18). The 2021 season represented the first attempts at out-planting this species for the ERPT program.

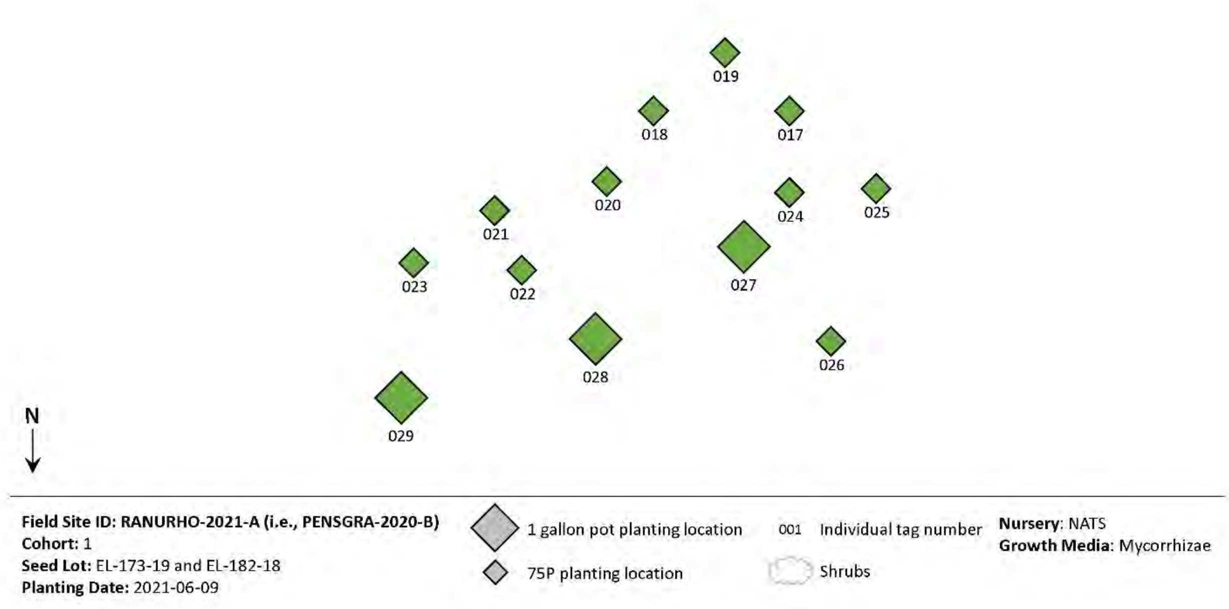


Figure 3.3-9. Planting Grid for Prairie Buttercup at Site Id: RANURHO-2021-A Cohort 1

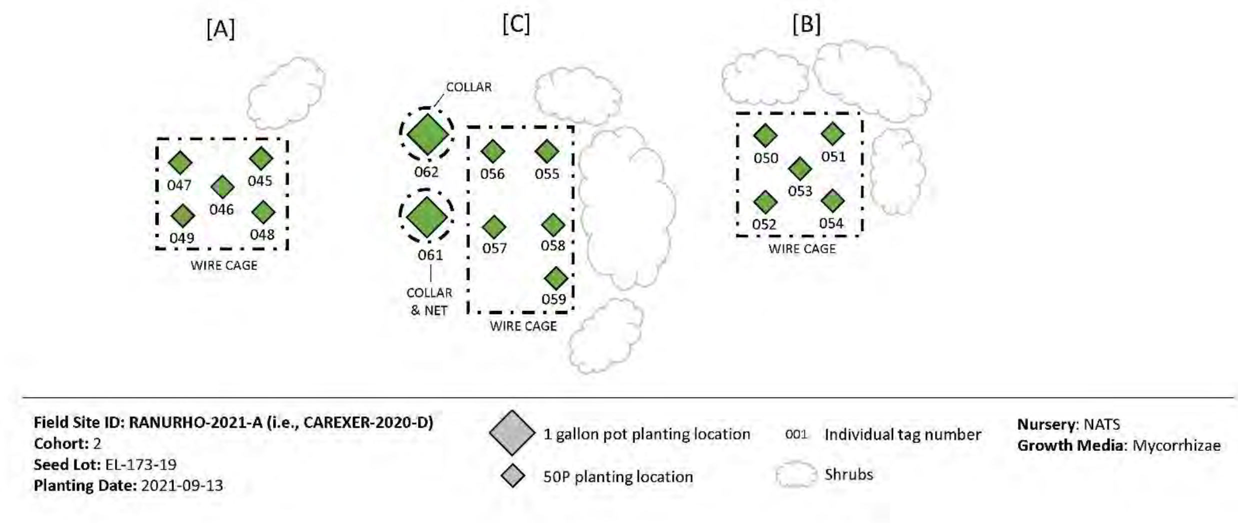


Figure 3.3-10. Planting Grid for Prairie Buttercup at Site Id: RANURHO-2021-A Cohort 2

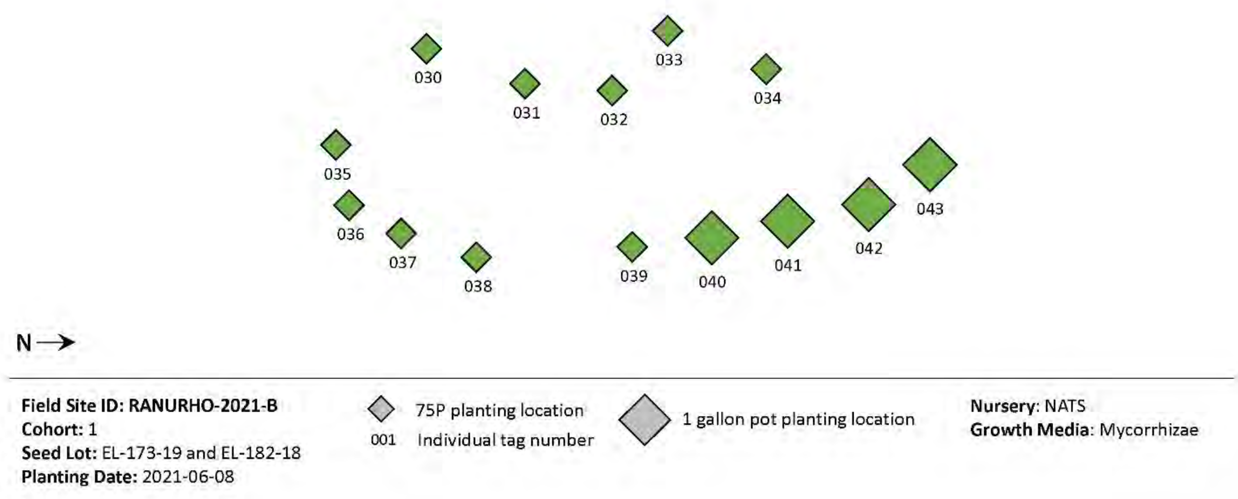


Figure 3.3-11. Planting Grid for Prairie Buttercup at Site Id: RANURHO-2021-B

Plate 3.3-15. Example of caged prairie buttercup seedlings translocated on September 13, 2021 – RANURHO-2021-A (plot A).

Plate 3.3-16. Example of prairie buttercup seedling (75P) with identification tag 051 translocated on September 13, 2021 – RANURHO-2021-A.

Plate 3.3-17. Prairie buttercup translocation site– RANURHO-2021-B.

Plate 3.3-18. Example of prairie buttercup with identification tag translocated on June 8, 2021 – RANURHO-2021-B.

3.3.6 Rock selaginella *(Selaginella rupestris)*

Approximately 136 rock selaginella blocks were salvaged along with slender penstemon at the Farrell Creek site on June 13, 2021. Individuals were mostly dormant at the time of salvage and were transported to a new translocation site (SELARUP-2021-A; Plate 3.3-19), a south-facing hill overlooking the Peace River, where they were interplanted with the slender penstemon (Figure 3.3-7). Thirty-five salvaged individuals were also transported to NATS nursery. At the same site but at a different location, two trays of nursery-grown rock selaginella were planted to the east of the salvaged transplants and watered (Figure 3.3-7; Plate 3.3-20). Eight clusters of salvaged rock selaginella were also planted at site SELARUP-2021-B adjacent to site CAREXER-2019-C (Figure 3.3-12). An additional 35 blocks of selaginella were transported to NATS nursery as insurance against stochastic events. The 2021 season represented the first attempts at out-planting this species for the ERPT program.

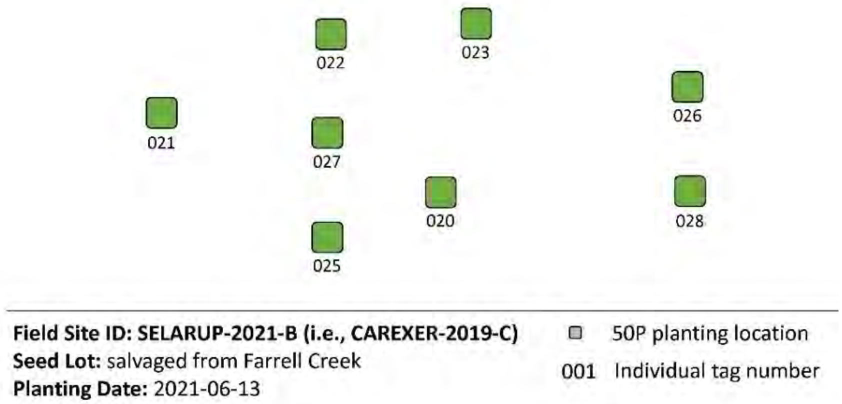


Figure 3.3-12. Planting Grid for Slender Penstemon at Site ID: SELARUP-2021-B

Plate 3.3-19. Example of salvaged rock selaginella translocated on June 13, 2021 – SELARUP-2021-A.

Plate 3.3-20. Example of nursery-grown rock selaginella translocated on September 16, 2021 – SELARUP-2021-A.

3.4 MONITORING

Translocated individuals were monitored two to three times in 2021 to correspond with seasonal changes in the phenology of each species. An early spring visit determined overwintering survival, a visit during the summer (targeted to correspond with the potential flowering period) assessed vigour and reproduction, and a visit during the fall assessed survival after transplant for those species planted in the preceding year. Monitoring frequency was increased following any interventions to address population or health declines.

3.4.1 Interim Monitoring

The translocated populations are being monitored at a frequency that permits the timely identification of threats such as vandalism, desiccation, or herbivory, and to allow for subsequent mitigation measures to address these issues. Issues identified during the interim monitoring along with follow-up measures identified in 2021 are summarized in Table 3.4-1.

Several sites were not monitored this year and are now considered inactive as they have low value for further translocation. For example, two dryland sedge sites (CAREXER-2018-A and CAREXER-2018-B) were designated as having low value for further translocation due to high herbivory and disturbance associated with cattle and deer at the site. In other instances, monitoring has been deferred to 2022 due to unforeseen logistical challenges in 2021. The remaining sites will remain active in 2022 and will be monitored. The monitoring dates as well as any follow-up actions are summarized by site in Table 3.4-1.

Table 3.4-1. Summary of Recipient Sites and Current Status

Species	Site Name	Status	Survey Date(s) 2021	Monitoring 2022	Follow-up Measures
Dryland Sedge (*C. xerantica*)	CAREXER-2018-A	Inactive	Not applicable	N	na
	CAREXER-2018-B	Inactive	Not applicable	N	na
	CAREXER-2019-C	Active	Not applicable	Y	Not determined
	CAREXER-2020-D	Active	June 8, August 2, September 13	Y	Initiate invasive plant removal and continue watering.
	CAREXER-2020-E	Active	July 9 and August 2	Y	Restrict site visits to 2 per year to minimize erosion of fine textured soils.
Canada mountain-ricegrass (*P. canadensis*)		Active	June 8, July 7, September 13	Y	None identified.
Davis' locoweed (*O. campestris* var. *davisii*)	OXYTCAM3-2018-A	Active	Not applicable	Y	Reassess site to determine if further monitoring of the plant trials is warranted. Site currently contains an existing occurrence of *O. campestris* and may serve as a future reference site.
	OXYTCAM3-2018-As	Active	Not applicable	Y	Monitor a selection of seed trials in 2022.
	OXYTCAM3-2020-B	Active	June 12	Y	Assess if fencing is required to address herbivory.
	OXYTCAM3-2020-C	Active	June 12 and September 12	Y	Evaluate the efficacy of trial fencing to address herbivory. Consider re-establishing phenocamera to track herbivory.
Prairie buttercup (*R. rhomboideus*)	RANURHO-2021-A	Active	June 8, July 7, September 10	Y	Bear encounter and signs of disturbance to plants in 2019.
	RANURHO-2021-B	Active	June 8, July 7, September 10	Y	Establish fencing to address herbivory.

Species	Site Name	Status	Survey Date(s) 2021	Monitoring 2022	Follow-up Measures
Rock selaginella (*Selaginella rupestris*)	SELARUP-2021-A	Active	July 7 and September 16	Y	None identified.
	SELARUP-2021-B	Active	July 7 and September 10	Y	None identified.
Slender penstemon *(P. gracilis*)	PENSGRA-2020-A	Active	June 08, August 25	Y	Continued watering.
	PENSGRA-2020-B	Active	June 08, August 25	Y	Continued watering.
	PENSGRA-2020-C	Active	July 7 and September 16	Y	Initiate watering in drought conditions, if needed.
Sprengel's sedge (*C. sprengelii*)	CARESPR-2020-1A	Active	June 15, July 7 and September 10	Y	Initiate watering in drought conditions, if needed.
	CARESPR-2020-1B	Active	June 15, July 7 and September 10	Y	Determine if fencing is needed to prevent animals from laying on the plants.
	CARESPR-2020-C	Active	September 10	Y	Initiate watering in drought conditions, if needed.

3.4.2 Year-end Monitoring

Year-end monitoring involved an evaluation of survivorship, maturity, and reproduction (Table 3.4-2). These metrics are being used to evaluate population viability at recipient sites and to track establishment of the translocated plants and resulting recruitment. The year-end monitoring is critical to ensure that issues with viability or establishment can be identified and addressed as they arise.

Table 3.4-2. Summary of Year-end Monitoring Results for 2021

		Survivorship		Maturity		Reproduction	
Species	Site Name	Survival in Relation to Total	Percent Flowering	Flowering in Relation to Total	Percent Flowering	Seed Production in Relation to Total	Percent Flowering
Canada mountain-ricegrass	PIPTCAN-2020-A	4/7	57%	2/7	29%	2/7	29%

Species	Site Name	Survivorship		Maturity		Reproduction	
		Survival in Relation to Total	Percent Flowering	Flowering in Relation to Total	Percent Flowering	Seed Production in Relation to Total	Percent Flowering
Davis' locoweed	OXTYCAM3-2020-B	78/89	88%	45	51%	_	_
	OXTYCAM3-2020-C	89/101	88%	51/101	50%	48/101	47%
Dryland sedge	CAREXER-2020-D	87/88	99%	_	_	62/88	70%
	CAREXER-2020-E	49/50	98%	_	_	49/50	98%
Slender penstemon	PENSGRA-2020-A	25/25	100%	25/25	100%	25/25	100%
	PENSGRA-2020-B	17/25	68%	16/25	64%	10/25	40%
Sprengel's sedge	CARESPR-2020-A	2/2	100%	1/2	50%	1/2	50%
	CARESPR-2020-B	3/3	100%	3/3	100%	3/3	100%

3.4.3 Canada mountain-ricegrass (*Piptatheropsis canadensis*)

Canada mountain-ricegrass at PIPTCAN-2020-A were monitored on June 8, July 7, and September 13, 2021 (Table 3.4-2). Of the 7 individuals planted in 2020, 2 individuals survived (29 %) and 0 individuals produced seeds (0 %; Plates 3.4-1 and 3.4-2). Lower-than-expected survivorship and reproduction in 2021 is possibly linked to the extreme climatic conditions (i.e., drought, 'heat dome') that occurred during the early growing season (June), which may have affected the establishment and growth of this species at the recipient sites. Reproduction and vigour at natural sites were found to have decreased substantially between 2020 and 2021 (see Appendix A), which supports the notion that this was the result of regional conditions rather than site-specific challenges.

Plate 3.4-1. Canada mountain-ricegrass inflorescence during July 7, 2021 monitoring – PIPTCAN-2020-A.

Plate 3.4-2. Canada mountain-ricegrass (tag 084) during
September 13, 2021, monitoring – PIPTCAN-2020-A.

3.4.4 Davis' locoweed (*Oxytropis campestris* var. *davisii*)

Davis' locoweed at OXYTCAM3-2020-B and OXYTCAM3-2020-C were monitored on June 12. OXYTCAM3-2020-C was also monitored on September 12, 2021 (Table 3.4-2). Of the 101 individuals planted at OXTYCAM3-2020-B in 2020, 99 were assessed. Of these, 78 individuals survived (88%) and 45 individuals produced flowers (51%; Plate 3.4-3). During monitoring, all of the 101 individuals planted at OXTYCAM3-2020-C in 2020 were assessed. Of these, 89 individuals survived (88%), of which 48 produced seeds (47%; Plate 3.4-4). It was noted during monitoring that 10 of the translocated plants at OXYTCAM3-2020-B and 17 of the of the translocated plants at OXYTCAM3-2020-C are showy locoweed (*O. splendens*; Plate 3.4-5), which have not been included in the summary totals. These species are similar in appearance and commonly co-occur at the same sites. Thus, some showy locoweed seeds were accidentally mixed with the Davis' locoweed seeds collected in 2017 and/or 2018.

Plate 3.4-3. Davis' locoweed adult plant flowering – OXTYCAM3-2020-C on June 12, 2021.

Plate 3.4-4. Davis' locoweed seedling plants flowering – OXTYCAM3-2020-B on June 12, 2021.

Plate 3.4-5. Showy locoweed adult plant flowering on June 12, 2021; this individual originated from seeds collected in 2017/2018 and represents accidental contamination during seed collection for Davis' locoweed – OXTYCAM3-2020-C.

3.4.5 Dryland sedge (*Carex xerantica*)

Dryland sedge at CAREXER-2020-D and CAREXER-2020-E were monitored on August 2, 2021. Of the 99 individuals planted at CAREXER-2020-D in 2020, 88 were assessed. Of these, 87 individuals survived (98%) and 62 individuals produced seeds (70%; Plate 3.4-6). All of the 50 individuals planted at CAREXER-2020-E in 2020 were assessed; of these, 49 individuals survived (98%) and all 49 produced seeds (98%; Plate 3.4-7). Due to the timing of this assessment, inflorescences contained immature/sub-mature perigynia that had not yet reached the stage of dispersal; these were interpreted as being indicative of successful seed production during the 2021 year.

Plate 3.4-6. Vigorous dry-land sedge transplant during August 2, 2021, monitoring – CAREXER-2020-D.

Plate 3.4-7. Dry-land sedge inflorescence during June 8, 2021, monitoring – CAREXER-2020-E.

3.4.6 Slender penstemon (*Penstemon gracilis*)

Slender penstemon at PENSGRA-2020-A and PENSGRA-2020-B were monitored on August 25, 2021 (Table 3.4-2). All the 25 individuals planted at PENSGRA-2020-A in 2020 were assessed; of these, all 25 individuals survived (100%) and produced flower and seeds (100%; Plate 3.4-8). Of the 25 individuals planted at PENSGRA-2020-B, 17 survived (70%), 16 produced flowers, and 10 produced seeds (42%; Plate 3.4-9).

Plate 3.4-8. Slender penstemon seed heads on July 7, 2021– PENSGRA-2020-A.

Plate 3.4-9. Slender penstemon seeds on July 7, 2021 – PENSGRA-2020-B.

3.4.7 Sprengel's sedge (*Carex sprengelii*)

Sprengel's sedge at CARESPR-2020-A and CARESPR-2020-B were monitored on June 15, July 7, and September 10 (Table 3.4-2). Both individuals planted at CARESPR-2020-A survived (100%) and produced seeds (100%; Plate 3.4-10). All three of the individuals planted at CARESPR-2020-B also survived and produced seeds (100%; Plate 3.4-11).

Plate 3.4-10. *Carex sprengelii* seed development in July 7, 2021– CARESPR-2020-1B 2021.

Plate 3.4-11. *Carex sprengelii* seed development in September 10, 2021– CARESPR-2020-1A.

3.5 PLAN FORWARD

Information gained from the 2021 program will inform improvements to project methods and management in 2022. The propagation protocols continue to be developed for species that were new to the program in 2020 (i.e., Canada mountain-ricegrass, rock selaginella) and are being refined for species with lower germination rates (i.e., Davis’ locoweed, Torrey’s sedge). Additional propagule collection and/or recipient site selection for Canada mountain-ricegrass and rock selaginella will be a primary focus of the 2022 program, as will the augmentation of existing recipient sites for Davis' locoweed, Torrey’s sedge, Sprengel's sedge, and prairie buttercup.

Future efforts will also focus on distributing sites as widely as possible to disperse the translocated plants across a larger number of recipient sites. This will build resilience into the program and help alleviate the impacts of stochastic events (e.g., floods, fires, landslides) on the overall program objectives. Although some sites will still receive multi-species plantings due to their accessibility, available planting area, available resources, and habitat conditions, additional single-species sites will be established where suitable habitats exist. New recipient sites will be evaluated with a stronger focus on the accessibility of resources, particularly water, as earlier translocation efforts have demonstrated that water availability can be a limiting factor at many sites.

In conjunction with enhancing existing populations, future efforts will be dedicated to understanding population dynamics of each species using ongoing monitoring data, including an assessment of recruitment (i.e., germination of the second and subsequent generations). However, at this early stage of program implementation, it is difficult to predict which analytical approaches will be appropriate to address questions related to population dynamics. For example, constraints imposed by small sample sizes or cohort sizes will limit analytical options for many target species. For species with larger potential sample sizes both within and across occupied sites (e.g., Davis’ locoweed), standard vital rate regression-based analyses based on counts of individuals are planned for 2022. In addition, the program will evaluate whether analysis-based population-level data (e.g., percent cover), which are simpler to apply over broader spatial areas, may have value as a rapid assessment tool (e.g., Tredennick et al. 2017).

Future efforts will also focus on improving the detectability of species using alternate markings that are more visible throughout the entire growing season. Other mitigative measures, including protective fencing or cages to prevent damage from herbivory and the control of invasive plants, will be implemented in 2022. As all phases of the program work concurrently, opportunities for improvement will be identified within an adaptive management framework throughout the remaining lifespan of the program.

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APPENDIX A. SITE C EXPERIMENTAL TRANSLOCATION PROJECT: POTENTIAL RECIPIENT SITE SELECTION METHODS & RESULTS MEMO

Date: December 8, 2021

To: Natasha Bush (EcoLogic)

From: Randy Krichbaum (Eagle Cap), Margaret Krichbaum (Eagle Cap)

Subject: Site C Experimental Translocation Project: Potential Recipient Site Selection Methods & Results

Introduction

An important component of the Site C Experimental Rare Plant Translocation (ERPT) program is the selection of suitable recipient sites for planting of propagules collected from the project activity zone. Program planning in the spring of 2021 identified a need for five recipient sites to accommodate the propagules collected (or planned for collection). This memo outlines the methods and results of the recipient site selection work performed in 2021.

The goal of this work was to locate and document suitable recipient sites for planting of rare plant propagules (seeds, achenes, spores, and started plants). The sites needed to meet a number of criteria regarding habitat (both biotic and abiotic components), accessibility, and geographic location.

Methods

Prefield Review

A prefield review was conducted to identify and delineate possible recipient areas for later verification in the field. The review followed a structured workflow designed to locate the optimal planting locations based on the desired site characteristics.

A team of two qualified botanists completed the majority of the prefield and field portions of this work, in consultation with the ERPT project manager. The botanists have performed extensive rare plant work in the BC Peace River area, and as such are familiar with both the habitat requirements of rare species and the logistics of working in the Peace Region.

Four of the nine taxa currently in the ERPT program were selected by the program manager as 2021 target species in need of additional recipient sites for translocation:

- *Oxytropis campestris* var. *davisii* (Davis' locoweed)
- *Penstemon gracilis* (slender penstemon)
- *Piptatheropsis canadensis* (Canada mountain-ricegrass)
- *Selaginella rupestris* (rock selaginella)

The project botanical team met in May 2021 to review the target species list and define desired recipient site characteristics. Each desired site characteristic was also assigned a weighting to reflect its relative importance to successful propagule establishment. This allowed for the potential recipient sites to be ranked for suitability following the field visits.

The prefield review identified thirteen desirable characteristics of the potential recipient sites. While no potential recipient site can meet all of the listed criteria, the intent of the work was to locate the best possible sites given the limitations present. An ideal site would have the following characteristics:

- contain suitable good-quality habitat for the specific rare plant taxon
- be located in the Peace River region of BC
- be located on land owned by BC Hydro or on Crown land
- not be located on lands requiring access through a locked gate or other owner permission
- not be located in the Site C Project Activity Zone (PAZ)
- not be located below the reservoir preliminary Erosion Impact Line (EIL - a precautionary estimate of the amount of erosion that could occur over a 100 year period)
- be accessible by road or boat during the entire growing season
- have a low likelihood of future disturbance
- have a low percentage of non-native plants
- have good cell service
- be more than one kilometre from known occurrences of the same taxon
- not contain known occurrences of other rare plant taxa
- be close to a source of water

A literature review was conducted for each of the nine species currently in the ERPT program to evaluate any new information relevant to the translocation work. This included checks of recent BC Conservation Data Centre (BCCDC) information to uncover any new element occurrences or changes to rare status, and a Google Scholar search for literature on the nine species published since 2020. The review supplemented literature searches conducted in previous years for the translocation project. Queries were also run on the project rare plant database to uncover apparent habitat associations for the four 2021 target species based on updated field data.

The habitat needs for the four target taxa were then reviewed and grouped into four types, in order to aid in the visual evaluation of aerial imagery:

1. river or large stream, with level, open, non-active cobble bar; shading open to partial; sparsely vegetated; sandy, well drained soil

2. dry, steep, open south-facing hillside; relatively sparse low shrub, xeric grassland vegetation with a tan-coloured appearance

3. mesic to dry, open, south-facing hillcrest or gentle slope; relatively dense low-shrub grassland vegetation with a green-coloured appearance

4. dry, steep, open south-facing hillcrest/hillside in close proximity to a gravel pit; relatively sparse low shrub, xeric grassland vegetation with a tan-coloured appearance

Using the list of desired site characteristics, the four habitat grouping types, and other collected information, Geographic Information System (GIS) layers were visually examined and potential recipient sites were selected. Primary GIS layers used for this phase of the prefield review were:

- aerial imagery of the BC Peace River region;
- property ownership provided by BC Hydro;
- known element occurrences of the priority taxa;
- potential recipient sites documented in previous years;
- the Site C Project Activity Zone; and
- the preliminary Erosion Impact Line.

Field Verification

Once recipient areas had been marked in the GIS, selected sites were inventoried in the field to determine suitability. Suitable Potential Recipient Sites (PRS) were evaluated and documented, with the data entered into a digital form for later analysis. Data elements collected included all those typically required by the BCCDC to document rare vascular plant element occurrences, as well as ratings for each of the thirteen desired site characteristics.

In addition to the vegetation composition and cover data recorded for the overall site, in certain cases three supplemental one-metre-square vegetation plots were placed in representative locations. Species codes, with their associated percent covers, were recorded on a paper form for later analysis.

Potential Recipient Sites were selected partially based on distance to other planting sites, with the aim of distributing them over a wide geographical extent. In some instances, a site was found to contain suitable habitat for several ERPT program species in close proximity, and so separate PRS plots were completed for each program species. While this does provide the option to plant multiple species at the same site, with the consequent increased risk of a single disturbance event impacting multiple species, the limited number of suitable sites available for some of the program species necessitated using one site for several species in some cases. In addition, several of the program species occur together in wild populations.

Results

Prefield Review

The literature search uncovered four recent references containing information potentially relevant to the translocation of the ERPT program species.

- *An Illustrated Key to the Onagraceae of Alberta* (Kershaw & Allen 2020)
- *Legumes of the great plains: an illustrated guide* (Stubbendieck et al. 2021)
- *Functional trait similarity predicts survival in rare plant reintroductions* (Ames et al. 2020)

- *Are large census-sized populations always the best sources for plant translocations?* (Van Rossum et al. 2021)

The queries run on the Site C rare plant database to identify habitat associations for the four 2021 target species returned three helpful correlations that may have not been otherwise noted. These refine the correlations uncovered during previous years' prefield reviews and are:

- For *Oxytropis campestris* var. *davisii*: 0-5° slope for all occurrences, except one, where slope was recorded (26 occurrences)
- For *Penstemon gracilis*: most occurrences (16 of 20) are on steeper slopes (15–30°) that are south facing (all aspects are S, SW, or SE where aspect is recorded)
- For *Selaginella rupestris*: all occurrences are on steep slopes (20–45°) where slope is recorded (6 of 10 occurrences); aspect is recorded as south facing and crown closure is listed as "open" or "partial" for all occurrences where those fields were recorded (8 of 10 occurrences)

A total of 34 planting areas that appeared to have a high likelihood of meeting the requirements for recipient sites were selected from the examination of the GIS layers (essentially these consisted of planting areas selected in the 2019 and 2020 prefield reviews that were still under consideration). The most weight was given to the *appropriate habitat types* and *ease of legal access* criteria. Some planting areas appeared to contain habitat specific to only one rare taxon, and other areas were thought to contain habitat for multiple rare taxa. Not all potential planting areas in the BC Peace Region were considered; rather the review focussed on areas that appeared to be easily accessible by road from Fort St. John, and on areas that were thought to be easily accessible by boat on the Peace River. Therefore, if additional potential recipient sites are required in the future, the as-yet unreviewed portions of the BC Peace region remain for consideration.

A unique PRS point was then generated for each planting area microsite thought to have suitable habitat for translocation of one of the four 2021 target species. These points were intended to speed the field verification work by directing the surveyors' effort on the ground towards microsites of the best quality habitat. There was no expectation that every PRS point would be field checked, and the exact location for each actual PRS plot was to be decided in the field after a cursory area survey.

The majority of the PRS points used for the 2021 recipient site evaluation work had been generated previously, in the prefield reviews completed in 2019 and 2020 for the project. Therefore few new PRS points were required for the four 2021 target taxa: 12 new points were generated for *Oxytropis campestris* var. *davisii* and one new point for *Penstemon gracilis.* No new PRS points were needed for *Piptatheropsis canadensis* or *Selaginella rupestris*.

Field Verification

The team of two botanists performed the field verification work between June 9 and 15, and on August 4 & 5, 2021. In preparation, the 34 selected planting areas were grouped according to the general access route to allow for efficient survey days. Of the 34 planting areas delineated, 12 received either complete or partial field checks (Table 1). Eleven areas were reached by road from Fort St. John, with the closest area located approximately nine kilometres away, and the farthest area approximately 105 km from the town. The 12th area consisted of boat access sites along an approximately 35 km stretch of the Peace River below Fort St. John, BC.

The 22 planting areas not field checked in 2021 consist of 11 that are still considered to be of possible use if additional potential recipient sites are required in the future, and 11 that were field checked previously and have already had plots completed or have been set aside for future consideration.

Table 1: ERPT Potential Planting Areas Considered in 2021

Planting Area ID	Field Checked?	Field Check Date(s)	Details
4	yes	2020-06-07, 2021-06-13	Plots Completed in 2020
14	yes	2020-06-05	Set Aside for Future Consideration
15	yes	2019-06-02	Set Aside for Future Consideration
16	no		Possible for Future Evaluation
17	yes	2020-07-30	Set Aside for Future Consideration
22	yes	2020-06-12, 2021-06-15	Plots Completed in 2020 & 2021
23	yes	2020-08-06	Set Aside for Future Consideration
28	yes	2020-06-05, 2021-08-05	Plots Completed in 2020
29	yes	2021-06-10	Set Aside for Future Consideration
30	yes	2021-06-11	Set Aside for Future Consideration
31	yes	2019-06-07	Set Aside for Future Consideration
32	yes	2021-06-10, 11 & 2021-08-05	Set Aside for Future Consideration
34	yes	2020-06-09, 2021-06-11	Plots Completed in 2020 & 2021
35	no		Possible for Future Evaluation
36	no		Possible for Future Evaluation
37	no		Possible for Future Evaluation
38	no		Possible for Future Evaluation
39	yes	2020-06-07	Set Aside for Future Consideration
40	yes	2020-06-07, 2021-06-13	Plots Completed in 2020
41	no		Possible for Future Evaluation
42	no		Possible for Future Evaluation
43	yes	2020-08-03	Set Aside for Future Consideration
44	yes	2020-06-07	Plots Completed in 2020
45	yes	2020-06-08	Set Aside for Future Consideration
48	yes	2020-06-04	Set Aside for Future Consideration
49	yes	2020-06-09, 2021-06-13	Plots Completed in 2020
50	no		Possible for Future Evaluation

Planting Area ID	Field Checked?	Field Check Date(s)	Details
51	yes	2021-06-09	No Habitat for Target Species
52	yes	2020-08-02	Set Aside for Future Consideration
53	no		Possible for Future Evaluation
54	no		Possible for Future Evaluation
55	no		Possible for Future Evaluation
56	yes	2021-06-10	No Habitat for Target Species
57	yes	2020-10-08, 2021-08-03	Plots Completed in 2020

The 12 field checks produced the following results:

- two planting areas did not contain appropriate habitat for the target species;
- eight planting areas were set aside for future consideration; and
- two planting areas were considered to be worth investigating further.

A survey of each of the two "best choice" planting areas was performed, and a total of three PRS plots were completed (Table 2). Supplemental planting locations were also marked in suitable habitat near the PRS plots, where appropriate, to provide options for the planting crew.

It should be noted that during the course of the field verification surveys, eight new rare plant sites were discovered: five patches of *Carex xerantica*, and one patch each of *Lomatium foeniculaceum* var*. foeniculaceum* (fennel-leaved desert-parsley)*, Oxytropis campestris* var. *davisii,* and *Penstemon gracilis.*

The late-season *Piptatheropsis canadensis* PRS survey work was curtailed due to the greatly decreased detectability of the species in the 2021 growing season, possibly due to an extreme heat event in late June (Preprost 2021). One *Piptatheropsis canadensis* PRS point was field checked and set aside for future consideration, and two PRS points were marked for field evaluation in 2022.

Table 2: Potential Recipient Site Plots 2021

PRS Site ID	*Taxon*	Habitat	Survey Date	Area (sq m)
PRS-OXYTCAM3-019	*Oxytropis campestris var. davisii*	POPUBAL regrowth on cobble bar	2021-06-15	2,500
PRS-PENSGRA-019	*Penstemon gracilis*	Dry grassland shrub slope	2021-06-11	200
PRS-RANURHO-014	*Ranunculus rhomboideus*	Mesic shrubby meadow	2021-06-11	750

Discussion

The goal of the work was to locate one or two suitable recipient sites for the current year's target taxa based on the 13 criteria listed in the Methods section above. During the course of the field verification, it became clear that the first 10 criteria were relatively easy to meet (that is, accessible planting areas outside of the Site C PAZ and EIL, on Crown land near the Peace River, which contain appropriate rare plant habitat, low levels of both non-native plants and disturbance, and that have good cellular coverage).

However, the final three criteria proved much more challenging (i.e., planting areas greater than one kilometre from known sites of the same taxon, not already occupied by other rare plant species, and close to a source of water). While the prefield review specifically avoided known rare plant sites in choosing potential planting areas to evaluate, it was anticipated that new rare plant occurrences would be discovered since the goal was to target high-quality rare plant habitats. Thus, eight new rare plant sites were documented by the survey team during the field verification process. The surveyors attempted to avoid these new sites when placing PRS plots and marking supplemental planting locations, but this was not always successful: at both recommended planting sites, PRS plots had to be placed in the vicinity of other rare plant populations (natural or translocated). In addition, one of the new rare plant patches discovered in 2021 was located less than one kilometre from a 2019 recommended recipient site for the same species, consequently lowering the desirability of that particular site. However these compromises were accepted as reasonable considering that naturally-occurring multi-species rare plant sites are frequently found in the BC Peace region.

The final compromise for PRS plot placement, as anticipated, was that only the *Oxytropis campestris* var. *davisii* plots along the Peace River could be said to have a source of water. The remaining three priority taxa require mesic to xeric habitats generally found on dry slopes well above the river, and only rarely near year-round streams or springs.

Therefore, given the above caveats, the two planting areas where PRS plots were completed in 2021 do meet the majority of the requirements of an ideal recipient site. One of the planting areas contains a variety of habitats and is suitable for multiple species translocation. The remaining planting area was specifically selected for a single taxon.

The area chosen for multiple species translocation is a Crown parcel above Bear Flat on the north side of Highway 29. Two PRS plots were completed, for *Penstemon gracilis* and *Ranunculus rhomboideus.*

For *Oxytropis campestris* var. *davisii*, which requires a specific type of riparian habitat, one PRS plot was completed on an island in the Peace River, downstream of Taylor, BC, approximately 5 km above the confluence of the Beatton River.

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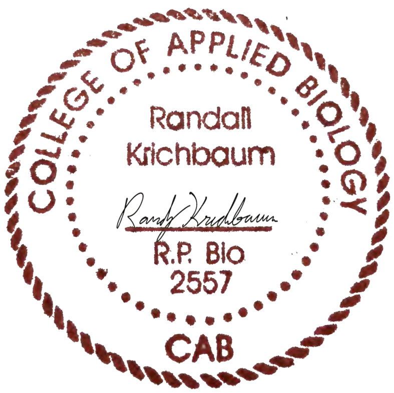
Closure

Reviewed and approved:

Randy Krichbaum M.Sc., R.P. Bio., P. Biol.
Senior Ecologist
Eagle Cap Consulting Ltd.

<Original signed and sealed December 8, 2021 at Calgary, Alberta>



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APPENDIX B. DATA CAPTURE FORM – TRANSLOCATION

Experimental Rare Plant Translocation Program

ECOLOGIC environmental consulting	**TRANSECT / PLOT / INDIVIDUAL** Data Capture Form	SITE + T/P	[S-__________] +
		Data Sheet Tracking Number	
Data Recorder:		*Team:*	

TRANSECT / PLOT Level Information		**TRANSECT or PLOT**	*specify*	**ID:**		
Species Name	**Recipient Site Name**	**UTMZone**	**Easting**	**Northing**	**Elev. (m)**	**Plot Solocator Photos**
dd	dd					

Outplanting Conditions			**Nursery**	dd	
Date(yymmdd)	**Weather Cond**	**Ambient Temp (*C)**	**Date Removed**	**Plug Size (mm)**	**Growth Media**

TRANSECT or PLOT		**MAP**	Y/ N	**subPLOT Information**	
Dimensions (m x m)	**Shape & Orientation**	**Loc. of Map**	**subPlot ID**	**Dimensions (m x m)**	**subPL Photos**
		dd	dd		

General Comments

PLANT OBVS	*Example*																											
TAG NUMBER	94																											
Plant Presence	bsent																											
Plant Condition	dead																											
Inflorescences (#)	4																											
Seeds (#heads /pods)	1																											
Implem / Monitor	mon																											
Photos	meth																											
Height (cm)	3																											
Surf.Area cm2	200																											
%CV of Surf. Area	40																											
Soil Mositure	ories																											
Soil Temperature	deg C																											
Mulch Type	osses																											
Mulch Depth	2																											
MicroCatch Created	s / no																											
Damage1 Type	down																											
Damage1 Extent	down																											
Damage2 Type	down																											
Damage2 Extent	down																											
Damage3Type	down																											
Damage3 Extent	down																											
Planter (name)	Bush																											

Species	**Recip. Site**	**Nursery**	**Loc. of Map**	**subPlotID**	**Plant Presence**	**Plant Cond.**	**Inflorescences (#)**	**Seeds (#heads /pods)**
list	list	list	list	instructions	list	list	instructions	instructions

Experimental Rare Plant Translocation Program

Surf.Area cm2	%CV of Surf. Area	Mulch Type	Damage Type	Damage Extent
instructions	instructions	list	list	list

ECOLOGIC

MAP / SITE DIAGRAM

SITE + T/P	[S-__________] +
Data Sheet Tracking Number	

Map Recorder:		*Team:*	

TRANSECT / PLOT Level Information	**TRANSECT or PLOT**	*specify T or P*	**ID:**

Species Name	**Recipient Site Name**	**Slope (deg)**	**Aspect (T)**
dd	dd		

General Comments	**Draw Slope Direct.**	**North Arrow**

Draw site diagram here. Clearly illustrate locations of specific tag numbers.