Bridge Seton Water Use Plan

Carpenter Reservoir Drawdown Zone Riparian Enhancement Program

Comprehensive Report

Reference: BRGWORKS-1

Carpenter Reservoir Drawdown Zone Riparian Enhancement Program

Synthesis Year 1-7, Report

Project Period: 2014-2020

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BRGWORKS -1 Carpenter Reservoir Drawdown Zone Riparian Enhancement Program

Year 8, 2022 Comprehensive Report

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Executive Summary

The vegetated areas of the Carpenter Reservoir drawdown zone vary by elevation and terrain type, and plant survival is heavily influenced by substrate conditions and annual inundation timing and peak pool. The overall objective of the BRGWORKS-1 program was to undertake a program to aid in the establishment of natural vegetation and work toward encouraging natural recolonization through riparian enhancement of the area of the Carpenter Reservoir drawdown zone between Tyaughton Lake Road Junction and the Gun Creek Fan. The program focus was to determine which native species, and what revegetation techniques were effective and whether physical treatments could improve site conditions to promote colonization of the drawdown zone by native species. Through the 7-year project, riparian enhancements were experimental and scaled up over time. Early treatments targeted species that showed potential for survival and sites with favorable planting conditions. Early treatments included planting, live staking and seeding trials. As successful species were identified, treatment areas were expanded. Later, physical treatments in the form of machine mounding were implemented and eventually, revegetation treatments were combined with physical treatments to compare effectiveness.

Over the course of the program, fifteen native species were planted in different trials. Selected native species were planted at targeted sites within the upper 12 vertical metres of the Carpenter Reservoir drawdown zone. Elevation bands were further stratified based on the inundation frequency, timing and duration. Elevation bands treated were low 639m-644m, mid 644m-646m, upper 646m-648m and buffer zone 648m-651m. Treatments were carried out on 5 terrain types: a Steep Beach, a Shallow Beach, a Steep Alluvial Fan and the Gun Creek Fan East and West sides, as well as across the Low Mud Flats. Near the end of the project, the bulk of treatments were implemented on the Low Mud Flat and the Gun Creek Fan within the low, upper and buffer zone elevations.

The coarse loose soils of the steep and shallow beaches and the coarse soils of the Steep Alluvial Fan proved very difficult to treat using planting and live staking. These steeper terrains are characterized by coarse soils that are highly vulnerable to erosion and movement when inundated. The coarse sandy soils are also low in nutrients, and surviving plants did not thrive. The drought conditions prior to inundation have made it difficult to get live stakes established. Arid spring and early summer conditions also proved stressful to young and establishing herbs. A small trial of planting rooted cuttings was carried out in 2016 on the Gun Creek Fan East, and thus far indicated this may be a technique at challenging sites.

Kellogg's sedge (*Carex kelloggii*) plugs and seed) has proven to be the most promising species in low elevation mud flat trials, with successful colonization and establishment recorded from planted plants (plugs). At one four-year-old planted patch of sedges on the Low Mud Flat, seed production from planted plants was voluminous enough to support harvesting for re sowing proving a resounding success. Common horsetail (4-inch pot), smooth scouring rush (1-gallon pots) and native annual legume meadow bird's-foot trefoil (seeded) are showing promise on the Low Mud Flat, but need another assessment period. At the mid and upper elevations, native grasses, Canada wildrye (1-gallon pots), bluejoint reedgrass (*Calamagrostis canadensis*) (plugs) and foxtail barley (*Hordeum jubatum*) (plugs) have been planted and have done well with Canada wildrye (*Elymus canadensis*) dispersal underway. Upper elevation plantings of willow (1-gallon pots and live stakes) and black cottonwood (*Populous trichocarpa ssp.*

balsamifera) (1-gallon pots), as well as Ponderosa pine (*Pinus ponderosa*) (plugs) have shown some positive results thus far, when combined with physical treatments.

Physical mounding treatments were carried out on the Low Mud Flats, as well as between the mid and buffer zone elevations of the Gun Creek East and West side. Mounding alone has not resulted in a dramatic increase in native vegetation cover, but mounding coupled with the addition of native species through seeding and planting has increased native species diversity and cover. Observations of high settling and disturbance of mounded fine silt soils treatments led to shifting. To avoid heavy losses of planted plants from wave action and settling, mounded areas were left for an inundation cycle before carrying out combined treatment. This avoids, plant extrusion or complete floatation of planted plants.

The silty Low Mud Flat (<642m elevation) is the broadest area within the targeted treatment area. Kellogg's sedge has proven the most reliable species for treatments at low elevations. The sedge has performed well in mounded polygons where it was seeded and planted on the non-mounded mud flats within and outside of areas seeded with fall rye. Treatments require one more year of monitoring to assess longer term survival and treatments.

Mounding has thus far improved survival and vigor of live stakes of willow in trials in the upper drawdown elevations on the Gun Creek Fan West (646m-648m elevation). Machine mounding of the coarse soils of the upper drawdown and buffer zone have also improved survival and growth in planted trees and shrubs versus treatments carried out in non-mounded areas. Supplemental irrigation and mulching of planted plants in upper and Buffer zone mounded polygons were included to the treatment program to improve moisture retention and microsite conditions of these arid sites. Supplemental irrigation was also provided at lower elevation treatment sites to mitigate low soil moisture prior to inundation. Live stake cuttings in the Buffer zone thus far have performed poorly due to the same arid conditions and coarse soils in which planted plants struggle. The Buffer Zone (648m -651m elevation) is inundated so infrequently that in the latter years of the program drought tolerant upland species Ponderosa pine (*Pinus ponderosa*) was planted. As of the end of this program, the Buffer zone treatments have yet to be inundated.

Treatments have not reduced dust storms but have identified key information regarding dust generation sites and direction of dust storms. Aesthetics have increased at sites where vegetation has thrived. Recreation opportunities have not been influenced much by the program. Terrestrial and aquatic habitat has been improved at sites where vegetation has survived. Most impacts are at a fine scale.

Elevation has proven a key variable in plant survival, and this is heavily dependant on reservoir operations. The timing of inundation of the lowest elevation BRGWORKS-1 treatment areas during the program 2014-2020 were 2 weeks later than the previous WUP period (2000-2014) and the pre-WUP period (1990-1999). The longer growing season may have benefited vegetation within the treatment trial elevations and could have shifted the zone of survival to the low elevation of the BRGWORKS-1 treatments 639m. Questions arise regarding whether this delayed annual hydrograph pattern will continue or can it be incorporated into management operations thereby affording a longer growing season for perennial native vegetation within the BRGWORKS-1 treatment elevations and Carpenter Reservoir as a whole.

Summary Status Table

Table 1 BRGWORKS-1 program summary results from 2014-2020.

OBJECTIVES, MANAGEMENT QUESTIONS and HYPOTHESES after 2014			
Study Objectives **Numbers relate to MQ.**	**Management Questions**	**Management Hypotheses**	**Year 2020 (Status)**
To design and implement a reservoir riparian enhancement program for the western end of Carpenter Lake (Reservoir) focusing on the area between the Tyaughton Lake Road Junction Gun Creek Fan.	MQ1: Will riparian enhancement in the drawdown area mitigate the effects of dust storms resulting from reservoir drawdowns particularly in the western end of the reservoir near the Town of Gold Bridge?	H1: Riparian enhancement in the drawdown area does not mitigate the effects of dust storms resulting from reservoir drawdowns particularly in the western end of the reservoir near the Town of Gold Bridge.	5 years of monitoring dust events indicates: - Dust originates from very localized sites within the zone of the bank-full width of the Bridge River during low pool. - The principal winds are westerlies blowing from west to east away from populated areas. - Most dust activity ceases when mud flats are inundated to 642m. - A secondary disturbance is associated with dust generation at the site, such as river erosion and vehicle disturbance. -Vegetated areas will trap sediments and reduce chances of resuspension of fines.

To focus on planting of appropriate native species of vegetation and site-specific physical terrain alterations to encourage natural colonization (this will be done using information gained in the BRGMON-2 program. A supportive argument must be made on the choice of species and physical treatment).	MQ2: Will riparian enhancement in the drawdown area increase the aesthetic quality and recreational opportunities in the western end of the reservoir?	H2: Riparian enhancement in the drawdown area does not increase the aesthetic quality and recreational opportunities in the western end of the reservoir.	Management question is somewhat subjective in essence. The barren look of the reservoir is viewed negatively, green vegetation positively, therefore where we have increased vegetation cover aesthetics has been improved at at a fine scale. If mud flats east of the Gun Creek Fan continue to develop vegetation cover, we will have assisted the expansion of the vegetated drawdown zone eastward and increased the area of the drawdown considered aesthetically pleasing. Recreational use of the area is varied. There is likely more use of the targeted riparian enhancement zone during low pool levels for all-terrain vehicles, rather than for water sport.

To conduct annual evaluations of the program to assess the degree to which the riparian enhancement program helps to establish natural re-colonization of the area from Tyaughton lake Road Junction to Gun Creek Fan and apply adaptive management strategies to increase enhancement success (evaluations will be conducted under the BRGMON-2 program).	MQ3: Will the program enhance the quality of riparian habitats to increase their potential to support wildlife populations and provide localized improvements in the quality and productivity of aquatic habitats in the reservoirs?	H3: The program in the drawdown area does not enhance the quality of riparian habitats to increase their potential to support wildlife populations and provide localized improvements in the quality and productivity of aquatic habitats in the reservoirs.	Wildlife sign and incidental observations throughout the BRGWORKS-1 project have indicated infrequent presence of wildlife at most treatment areas. Species that have been observed: spotted sandpiper have utilized patches of planted sedges for nesting; Canada geese feed on planted sedges; juvenile western toads dispersing along the Bridge River are observed among planted sedges and in mounded polygons. Juvenile Western terrestrial garter snakes have been also observed in mounded polygons and among planted sedges. Mule deer browse on planted cottonwoods in the buffer zone, and beaver have cut planted cuttings. Small increases in patches of vegetation created through the BRGWORKS-1 program have created higher value patches of habitat compared with the barren mud flats.

To conduct evaluations of the program in order to assess the degree to which the riparian enhancement program helps enhance the quality of riparian habitats, increase their potential to support wildlife populations, and provide localized improvements in the quality and productivity of aquatic habitats in the drawdown zone of the Carpenter Reservoir.			With regard to aquatic habitat, it is likely that successful establishment of vegetation in the Carpenter Reservoir drawdown zone will also result in an increase in benthic community productivity with associated benefits in productivity up the reservoir's aquatic food chain.

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1. Introduction

The BRGWORKS-1 Carpenter Reservoir Riparian Enhancement Program was conducted from 2014 through 2020. The program was part of the Bridge-Seton Water Use Plan study programs (BC Hydro, 2011). Over a seven-year period, six years of riparian enhancement treatments were implemented within the Carpenter Reservoir drawdown zone. The program objectives were to aid in the establishment of natural vegetation and to work toward encouraging natural recolonization of the Carpenter Reservoir drawdown zone. This was done through testing and identifying appropriate species, types of propagules and effective riparian enhancement treatments. Treatments were implemented and adapted based on recommendations from the associated monitoring program BRGMON-2, Carpenter Reservoir Riparian Vegetation Monitoring Program. Under the BRGMON-2 program, the BRGWORKS-1 treatments were monitored annually in each of 2015 through 2020. The BRGMON-2 study provided annual recommendations to guide and inform the BRGWORKS-1 program.

The BRGWORKS-1 program was initiated under the 2014 Terms of Reference (BC Hydro, 2014) and was originally scheduled to occur over a 5-year period in a staged and escalated approach. The program TOR was revised in 2017 (BC Hydro, 2017). The TOR was updated to ensure that the approach included physical works, hence the title change from a 'revegetation' program to a 'riparian enhancement' program. The TOR revisions and physical treatment emphasis was predicated on the idea that "physical alteration methods can be more successful at re-colonizing an area with vegetation and more cost effective than planting treatments alone" (BC Hydro, 2017). This statement would be tested through the revised program. Small scale physical treatments had been implemented in 2016, physical treatments were expanded in 2017, and combined physical treatments and revegetation efforts were carried out in 2017, 2019, and 2020. The TOR revision extended the program from a continuous 5-year, to a 7-year program, including a lag year in 2018 where there were no new treatments. The intention of the lag year was to allow for more time to assess treatments before making recommendations for the final two years of the project.

A final monitoring effort of the BRGWORKS-1 treatments is scheduled for 2022 under year 10 of the BRGMON-2 program. Annual reports of the BRGWORKS-1 program were produced from 2014 through 2020 with the exception of 2018 (Scholz, 2015. Scholz, 2016. Scholz, 2017. Scholz, 2018. Scholz, 2020. Scholz, 2021. Scholz, 2022). Annual reports through the BRGMON 2 program were also produced from 2015 through 2020. In 2018, a mid-term comprehensive report was compiled through the BRGMON-2 program with the intension of looking at all the BRGWORKS-1 treatments to date and to recommend the most promising direction for the final two years of BRGWORKS-1 treatments. This report is a summary of the BRGWORKS-1 program's approaches and treatments over the course of the program and reviews how annual findings and recommendations under the BRGMON-2 Carpenter Reservoir Drawdown Zone were incorporated into the program from 2014 through 2020. Lessons learned and adaptations imposed are reported, and an overall summary of the programs successes and failures are central to the discussion.

1.1 Project Location

The BRGWORKS-1 revegetation project is located approximately 280 km northeast of Vancouver, British Columbia in the Coast Cascade Mountains. The treatment area in the Carpenter Reservoir drawdown zone is approximately 8 km north east of the town of Gold Bridge, BC (Figure 1). The site is located within Northern St'at'imc traditional territory. The area is in the Southern Interior Eco-province and is within the Interior Transitional Ranges ecoregion. The treatment area is classified as Interior Douglas-fir very dry cold (IDFxc) biogeoclimatic zone (BC Ministry Forests, 2012); one of the drier forested ecosystem types in British Columbia.

The primary area of treatments took place approximately 8 km east of the town of Gold Bridge, from the Gun Creek alluvial fan east to the Tyaughton Road turnoff on Rd 40 (Figure 2). Gun Creek is one of several large tributaries to the Carpenter Reservoir; the river's historic alluvial fan is central to much of the BRGWORKS-1 project target restoration area. Historically (1934-1950), this was the site of a mining town Minto which mainly occupied the east side of the fan within the Carpenter Reservoir drawdown zone. A number of underground mines were operated around the reservoir drawdown zone during the Minto days. Minto was used as a Japanese internment camp during the 1940's. Currently the forested, east side of the Gun Creek Fan is a BC Hydro-operated 13 site, public recreation campground. The west side of the fan has a dormant Ministry of Transportation and Infrastructure gravel pit.

The bulk of the BRGWORKS-1 treatment sites are accessed on the east side of the Gun Creek fan. Apart from treatment trials in 2014 and 2015, all treatments have been implemented on the north shore of the reservoir. Treatments have been implemented between 639m and 651m elevation within the drawdown zone.

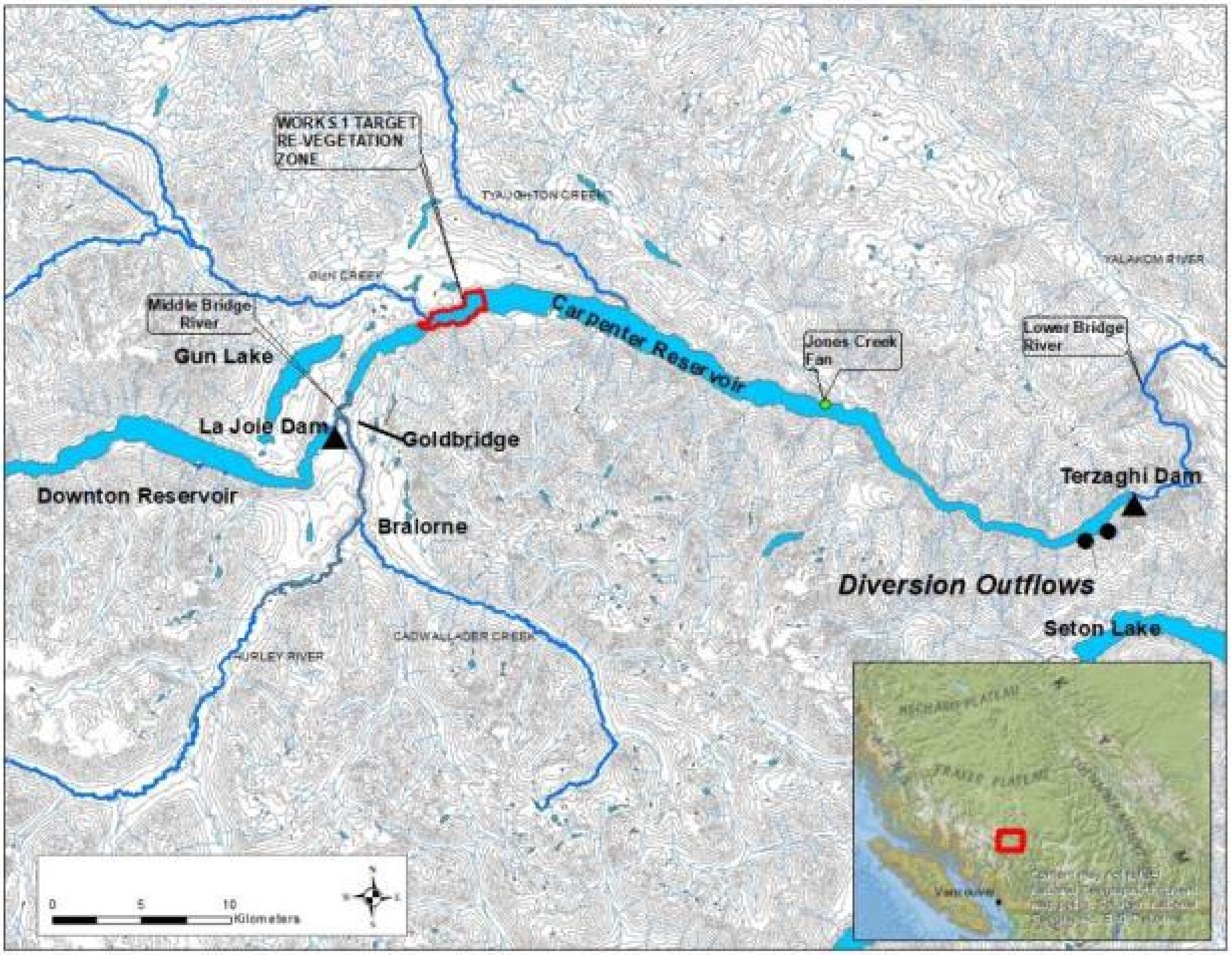

Figure 1. Geographic location of Carpenter Reservoir in British Columbia and the Approximate 292 ha targeted revegetation region of the Carpenter Reservoir BRGWORKS-1 Revegetation Program

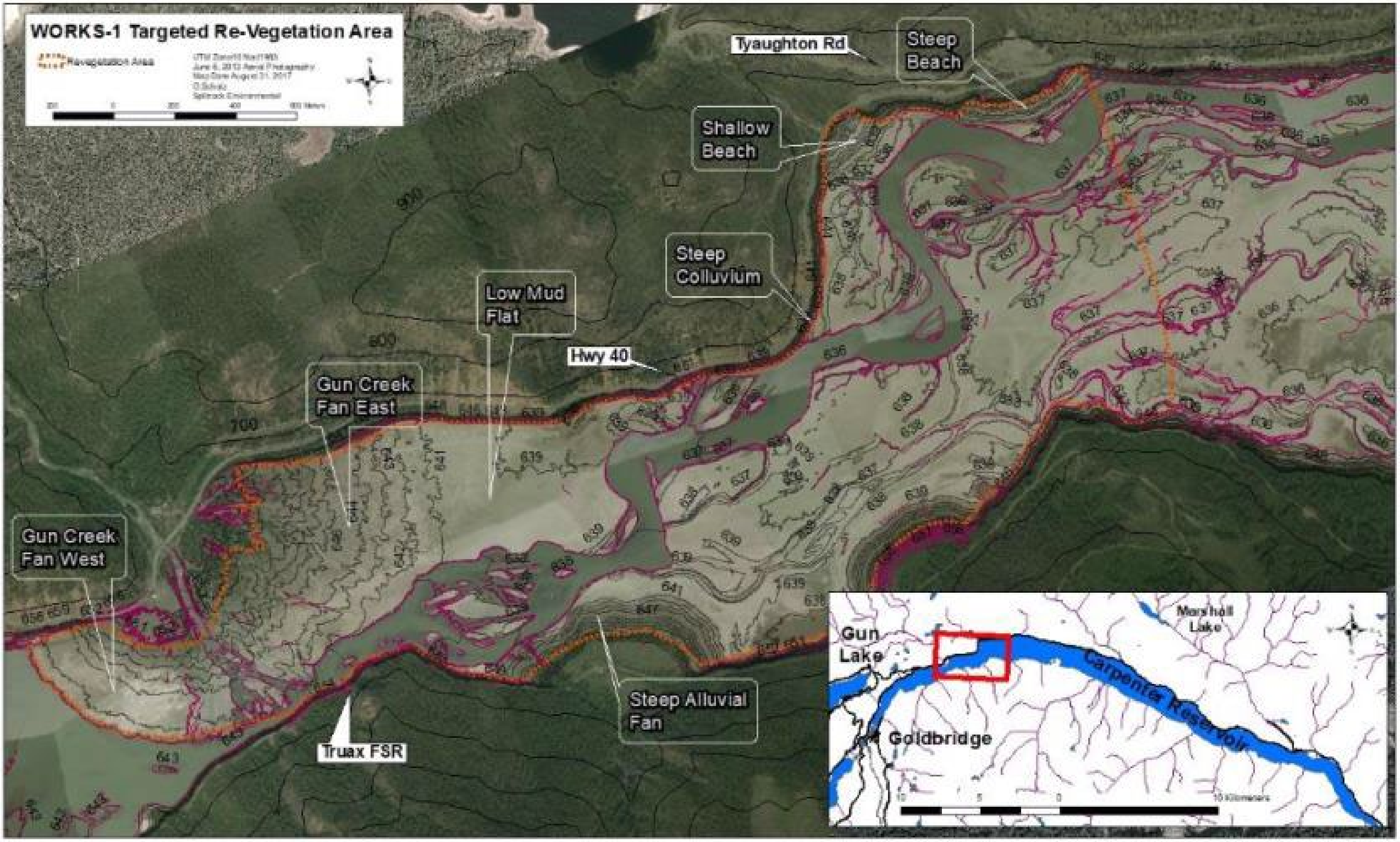

Figure 2. Target revegetation area of the Carpenter Reservoir drawdown zone. 2020 focus on Low Mud Flat and Gun Creek Fan East and West.

1.2 Reservoir Operations

Carpenter Reservoir is impounded from Terzaghi Dam in the east, backing up water over approximately 50km over the historic Bridge River Valley, to the town of Gold Bridge. Construction of Terzaghi Dam was completed and Carpenter Reservoir first filled in 1960. From 1960 through 2000, water was released through Terzaghi Dam into the Lower Bridge River only as sporadic spill events when water levels and management were above the reservoir's holding capacity. Most of the water entering Carpenter Reservoir exits the watershed through penstocks to generate power at the Bridge 1 and Bridge 2 power facilities at the west end of Seton Lake. Since 2000, in order to manage the reservoir for power generation and fish habitat and to minimize water spills to the Lower Bridge River, BC Hydro makes reasonable efforts to target a maximum water elevation in Carpenter Reservoir of 648 mASL for the end of snowmelt season in mid-August. Water levels are managed between a licensed minimum and maximum of 606.55 mASL and 651.08 mASL (BC Hydro, 2011). Annual full pool levels are achieved anywhere from as early as June to as late as November.

2.0 Methods

2.1 General Program

This report is compiled by reviewing and revisiting BRGWORKS-1 and BRGMON-2 reports from 2014 through 2020 and includes summarizing:

1. The focus of annual treatments,
2. Key treatments accomplished annually,
3. Key annual observed results as reported under the BRGMON-2 program, and
4. Program adaptations and changes made based on BRGMON-2 observations and recommendations.

2.2 Weather

As part of monitoring dust storm occurrence, a weather station was installed and operated on 5-mile ridge (3.5km NE of treatment area). The weather station collected meteorological data as well as having a camera that recorded photo data to measure and detect dust events. Temperature and precipitation data was used throughout the project to measure growing degree days (GDD) as well as infer when plants may be experiencing drought conditions.

Growing degree days (GDD) wase computed based on the BC government range readiness approach (Fraser, 2006). Accumulated Growing Degree Days (AGDD's) were tabulated based on summing the daily GDD beginning in spring after 5 days where GDD was above 0°C, and not earlier than March 15th. Growing season was measured until temperatures drop to 0°C or when elevations are inundated. Growing season is also rooted in the annual weather conditions. The Base temperature below which plant growth is impeded was conservatively presumed to be 0°C (as in range management). Daily GDD's were calculated using the following formula:

[daily Max. temp (°C) + Daily Min. temp (°C)] / 2 – base temperature 0 (°C).

Using this formula, a day with a Maximum Daily temperature of 25°C and a minimum Daily temperature of 15°C would produce 20 GDD units. In the unlikely event that a week had seven consecutive days with this same high and low temperature the AGDD would amount to 140 AGDD. For many crop species, plants do not grow any faster when temperatures are over 30°C (Rawson and Macpherson, 2000). Therefore, in order to use a conservative estimate of GDD, the mean daily temperatures were filtered to cap the high temperature days at 30°C. AGDD highlight the length and proportion of growing season experienced by vegetation at different elevations within the drawdown zone of Carpenter Reservoir since 2014.

2.3 Water Levels and Drawdown Zone Elevations

Hydrometric datacomprised of daily water levels issued by BC Hydro Power Records, has been compiled and analysed in the context of the periods of the WUP (2000-2021) and the BRGWORKS-1 program (2014-2020). Figures were generated to enable comparison of annual growing season lengths and inundation timing and duration. The mean, 10^{th} and 90^{th} percentile hydrographs for the WUP period are determined and used for analysis and discussion of impacts of inundation factor on the BRGWORKS-1 treatments. Inundation timing was combined with daily temperature data to determine annual accumulated growing degree days (AGDD) by elevation within the drawdown zone.

2.4 Permitting

Permits that were acquired throughout the BRGWORKS-1 program included:

- Section 11 BC *Water Sustainability Act* application for “Changes In and About a Stream” were submitted on behalf of BC Hydro. 2017-2019
- Short Term Water Use permits to provide irrigation for the maintenance through the Water Sustainability Branch were applied for on behalf of BC Hydro. 2019
- Short-term occupation of Crown Land. (for weather station). 2016-2021
- Two archaeology impact assessments were carried out over the project treatment area by archaeology subcontractors. (Begg, 2017), (Begg, 2019).

2.5 Riparian Enhancements

The program took an experimental, staged and adaptive approach to carrying out treatments with the intention to identify; what species would work best, what plant materials and planting and sowing techniques were effective and the conditions, sites and locations at which treatments would work. Trials included seeding by hand and with a tractor, planting container stock of various sizes, planting live stake cuttings by hand and, with machine assistance, planting rooted live stakes, physical mounding and scarification of the substrate.

A multitude of native species were used through the program, including a focus on native grasses, sedges, a rush, one forb shrubs and trees. Treatments were implemented at a variety of terrain types and substrates, including a Steep Beach, a Shallow Beach, a Steep Alluvial Fan, and, at Gun Creek, a shallow alluvial fan, as well as the Low Mud Flats. Drawdown zone elevation was a key consideration in treatment trials. Over the course of the program, treatments were carried out in combination and in isolation.

2.4.1 Seeding Trials

Native grass and herb seed was employed as a treatment in each year of the BRGWORKS-1 program years (Table 2). The initial year of the BRGWORKS-1 project was focused on trialing species in small (1X1m) plots at varied locations and elevations within the drawdown zone. Seeding was initially carried out by hand and, in later years, in combination with a tractor equipped with a seeding attachment. Testing native species to determine which species could be successfully sown in the drawdown zone was a main focus of the program. Domestic species fall rye was also sown, given its proven track record in drawdown zone revegetation establishment (Jackson et al. 1995). Fall rye was selected due to its rapid germination and relatively rapid growth and high biomass production. Native species that were included in seeding trials were:

Native Grasses:

- ticklegrass (*Agrostis scabra*),
- bluejoint reedgrass (*Calamagrostis canadensis*),
- blue wildrye (*Elymus glaucus*)
- northern wheatgrass (*Elymus lanceolatus*),
- slender wheatgrass (*Elymus trachycaulus*),
- fowl bluegrass (*Poa palustris*),
- Canada wildrye (*Elymus canadensis*),

Agronomic Grass:

- Fall rye (*Secale cereale*)

Sedge:

- Kellogg's sedge (*Carex kelloggii*),

Herb:

- meadow birds-foot trefoil (*Lotus denticulatus*, now *Acmispon denticulatus*) a

Kellogg's sedge, meadow bird's-foot trefoil and Canada wildrye seed, used throughout the program, were all collected locally. Bluejoint reedgrass, fowl bluegrass and blue wildrye seed was harvested locally for container plant production for the project only. Grass seed for some seeding trials was sourced from seed suppliers. A summary of seeding treatment trials from throughout the BRGWORKS-1 program is presented in Table 2.

Table 2 Summary of seeding treatments throughout the BRGWORKS-1 program.

Seed Treatments	Treatment	Location	Elevation	Species
2014	Hand seed 1X1m quadrats	Steep Beach, Shallow Beach, Gun Creek Fan East	642m-651m	bluejoint reedgrass (*Calamagrostis canadensis*), Canada wildrye (*Elymus canadensis*)
2015	Tractor seeding trials 20mX50m	Low Mud Flat	639m-641m	fall rye (*Cereale secale*), Kellogg's sedge (*Carex kelloggii*)
		Gun Creek Fan East	644m-648m	ticklegrass (*Agrostis scabra*), Bluejoint reedgrass, Northern wheatgrass, slender wheatgrass (*Elymus trachycaulus*), foul bluegrass (*Poa palustris*), fall rye
2016	Tractor seeding (9.5ha)	Low Mud Flat	639m-640m	Fall rye, Kellogg's sedge, Canada wildrye
2017	Hand seeding within physical mounding areas	Low Mud Flat, Gun Creek Fan East	640m-644m	Kellogg's Sedge
2019	Tractor seeding, Hand seeding raking within mounded area	Low Mud Flat	639m-640m	Fall rye, Meadow bird's foot trefoil, Kellogg's sedge
	Hand seed raking within mounded area	Gun Creek Fan East	642m	Meadow bird's-foot trefoil
2020	Tractor seeding	Low Mud Flat	639m-640m	Fall rye,
	Hand seeding raking within mounded areas	Low Mud Flat, Gun Creek Fan East	641m	Kellogg's sedge, Meadow bird's-foot trefoil

Figure 3 left 2014 watering 1m^2 quadrats sown with Canada wildrye and bluejoint reedgrass. Right; In 2015 20X50m tractor sown linear plots using fall rye, Kellogg's sedge and mechanical treatment only.

Figure 4 Left: fall rye sprouting in tractor seeded 9.5ha area in 2016. Right; Kellogg's sedge seedlings observed in 2018 growing in mounded polygon seeded and raked in 2017.

Figure 5 Hand seeding and raking Kellogg's sedge seed among mounded and planted polygons 2020.

2.4.2 Planting

Planting rooted container stock has been a key treatment throughout the BRGWORKS-1 program (Figure 6). Stock was grown in containers from 1-gallon pots, 6-inch sandwich pots and styro block plugs (415D[1]) have been utilized. The latter size was the most frequently used. The majority of plants used throughout the program were grown at a local nursery from seed harvested from local sources through the program. Key areas used as seed sources were higher elevation mudflats on Carpenter Reservoir, west of the treatment sites. The west end of Downton Reservoir was also used as a seed collection site, as were several other local region areas. Planting was done using standard tree planting shovels and bags. Larger diameter potted plants were planted with long handled shovels. After the initial years of planting, an effort was made to water some of the drier upper elevation sites by hand during the planting process and periodically after planting.

Initial planting treatments in 2014 were carried out to identify native species that could work for revegetation within a 6 vertical meters band of the upper elevations of the

[1] Cavity width 4.3cm, depth 15.2cm, cavity volume 172ml.

drawdown zone (642m through 648m). Species selections were derived from observations made through the BRGMON-2 baseline monitoring survey of the reservoir

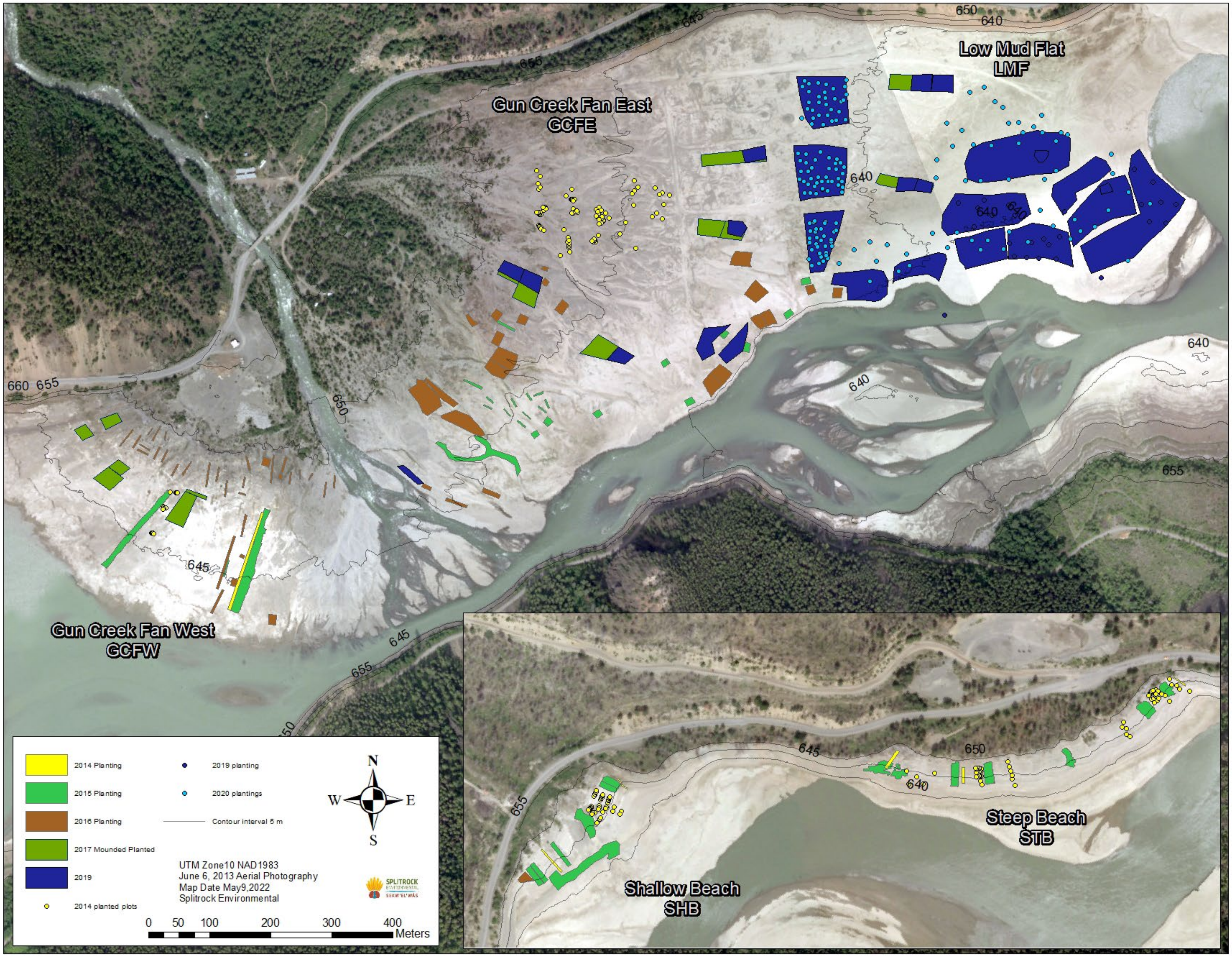

Figure 6 Planting sites treated through the BRGWORKS-1 program by year.

drawdown zone, as well as from research of revegetation work on other reservoirs (Whitlow and Harris, 1979; Carr et al. 1993; Arocena et al, 1996; Enns et al, 2009) and from input and guidance from experienced reservoir revegetation Senior Biologist, Anne Moody (Table 3).

In addition to using a variety of native species, different terrain types were planted with similar test plots, including two beach sites, and two alluvial fans. One of the alluvial fans was the Gun Creek Fan, where trials were carried out on the east and west sides. The Gun Creek fan is the largest alluvial fan in the reservoir (Scholz, 2014). No treatments of any kind were carried out on the Low Mud Flat in 2014, as water levels were too high at the time that the program was ready to go.

In 2014, planting was carried out methodically laying out planting sites within 1m² quadrats at set elevations (See details in Scholz, 2015). Plots were planted with 6 grasses, Kellogg's sedge and Baltic Rush. Linear strips of Kellogg's sedge were also planted at the 5 different terrains within the drawdown.

In 2015 and 2016, plantings were carried out in various-sized patches at 5 sites, including the Low Mud Flat (Table 4, Figure 5). In 2017, plantings were carried out within mounded polygons on 3 terrain sites. Planting in 2019 and 2020 were focused within mounded polygons and in patches across the Low Mud Flat.

In addition to planting of plugs and container plants, a couple of smaller trials were conducted;

1. In 2015 a test was conducted planting fertilizer in the form of 'tea bags' alongside grasses planted in a patch on the Shallow Beach.
2. In an attempt to provide more of an anchor to planted plugs in 2017, thin wooden skewers (approx. 30cm long) were pressed through the roots of plugs planted and into the surrounding substrate, in mounded polygons on the Low Mud Flat.
3. A small trial of planting rooted cuttings was done in 2016 on the Gun Creek Fan East (GCFE), adjacent to Gun Creek. Cuttings had been rooted in tall containers (60cm long), cuttings were planted 1m deep with machine assistance in 2016.

Table 3 List of Native species planted through the BRGWORKS1 program

Ref#	Native Grass Species (Planted)
1	blue wildrye (*Elymus glaucus*)
2	bluejoint wheatgrass (*Calamagrostis canadensis)*
3	Canada wildrye (Elymus canadensis)
4	fowl bluegrass (*Poa palustris)*
5	foxtail barley (*Hordeum jubatum*)
6	slender wheatgrass (*Elymus trachycaulus*)
	Native Rush
7	Baltic rush (*Juncus balticus*)
	Horsetails
8	common horsetail (*Equisetum arvense*)
9	scouring rush (*Equisetum hymale*)
	Native Sedge
10	Kellogg's sedge (*Carex Kelloggii*)
	Native Shrub
11	willow sp. (*Salix sp.*)
12	sandbar willow (*Salix exigua*)
13	mountain alder (*Alnus incana*)
14	red osier dogwood (*Cornus stolonifera*)
	Native Trees
15	black cottonwood (*Populus trichocarpa ssp. balsamifera*)
16	ponderosa pine (*Pinus ponderosa*)
17	trembling aspen (*Populus tremuloides*)

Table 4 Summary of annual planting treatments carried out through the BRGWORKS-1 program.

Treatment Year	Treatment Type	Location	Elevation	Species planted (see ref# in Table 3.)
2014	Planting 1X1m plots,	STB, SHB, GCFE, GCFW,	644m-648m	blue wildrye, bluejoint wheatgrass, Canada wildrye fowl bluegrass, foxtail barley, slender wheatgrass, Baltic rush, Kellogg's sedge
	Planting linear strips	STB, SHB, GCFE, GCFW, SAF	644m-648m	Kellogg's sedge
2015	Planting in patches	LMF	639m-644m	Kellogg's sedge
		STB, SHB, GCFE, GCFW	644m-649m	bluejoint wheatgrass, Canada wildrye, fowl bluegrass, foxtail barley
2016	Planting in patches	LMF	640m-642m	Kellogg's sedge
		GCFE	644m-649m	bluejoint wheatgrass, foxtail barley, black cottonwood
		GCFW	644m-650m	bluejoint wheatgrass, black cottonwood, trembling aspen
2017	Planting polygons within mounded terrain,	LMF	639m-640m	bluejoint wheatgrass, Kellogg's sedge
		GCFE	642m-649m	bluejoint wheatgrass, Canada wildrye, fowl bluegrass, foxtail barley, Kellogg's sedge, black cottonwood
		GCFW	646m-649m	bluejoint wheatgrass, Canada wildrye, fowl bluegrass, foxtail barley, black cottonwood
2019	Planting within mounded areas and in patches	LMF	639m-642m	common horsetail, Kellogg's sedge
		GCFE	642m-649m	bluejoint wheatgrass, willow sp., sandbar willow mountain, alder, black cottonwood, Ponderosa pine
2020	Planting in patches	LMF	639m-642m	bluejoint wheatgrass, common horsetail, scouring rush, Kellogg's sedge, willow sp.
		GCFE	642m-649m	bluejoint wheatgrass, common horsetail, scouring rush, Kellogg's sedge, willow sp., black cottonwood
		GCFW	648m-650m	bluejoint wheatgrass, willow sp., black cottonwood, Ponderosa pine

2.4.3 Live Stake Cuttings

Live stake cuttings are recommended for use in many riparian restoration situations (Johnson and Stypula eds, 1993., Donat, 1995., Province of British Columbia, 1997). Through the BRGWORKS-1 program, live staking was tested as a riparian enhancement technique in 2014-2015. Three live staking approaches were used:

1. Hand planting, using modified steel bars for creating planting holes. (2014, 2015).
2. Machine-assisted planting, using trenching and hand planting with steel bars and shovels to back fill (2014, 2015).
3. Machine assisted planting, watering within areas also treated by mounding (2017).

Species used were black cottonwood and willow. Cuttings were harvested from the local area. Willows were harvested from the west end of Carpenter Reservoir drawdown zone. Cottonwood was harvested from sites located under BC Hydro powerlines near Lillooet. In 2015, large diameter cottonwoods were harvested from a gravel pit on the west side of the Jones Creek Fan located along Carpenter Reservoir. Cuttings were soaked for at least 24hrs prior to planting. Cuttings were harvested late winter or early spring.

Early live stake trials were established with the intention of testing the success at a range of elevations at different sites. A summary of cuttings and plantings is summarized in Table 5 and Figure 7. Cuttings were left long in 2014 and 2015 trials, some over 2m in height above ground. The intention was that cuttings could remain above water longer if left long. In the 2016 and 2017 after-planting, cuttings were cut down to < 30cm tall. Cuttings were watered in with each planting either by hand or, in 2016, a water truck was employed to soak the trenches prior to backfilling.

Table 5 Summary table of live stake cuttings treatments by location over the course of the program.

Year	Treatment	Location	Elevations	No. of stakes Planted
2014	Hand planting	Steep Beach	644m-649m	153
		Shallow Beach	644m-646m	79
		Steep Alluvial fan	644m-650m	175
	Machine assisted planting	Gun Creek Fan East	644m–649m	775
		Gun Creek Fan West	644m-649m	272
2015	Hand planting	Gun Creek Fan East	645m–649m	180
		Gun Creek Fan West	645m-648m	206
		Steep Alluvial Fan	644m-648m	533
		Shallow Beach	644m-647m	116
		Steep Beach	643m-646m	586
	Machine assisted planting	Gun Creek Fan East	647m-650m	499
		Gun Creek Fan West		427
2016	Cuttings Bar	Shallow Beach	646m-648m	136
	Machine assisted planting	Gun Creek Fan West	648m-650m	960
2017	Machine mounding and assisted planting	Gun Creek Fan West	647m-649m	246

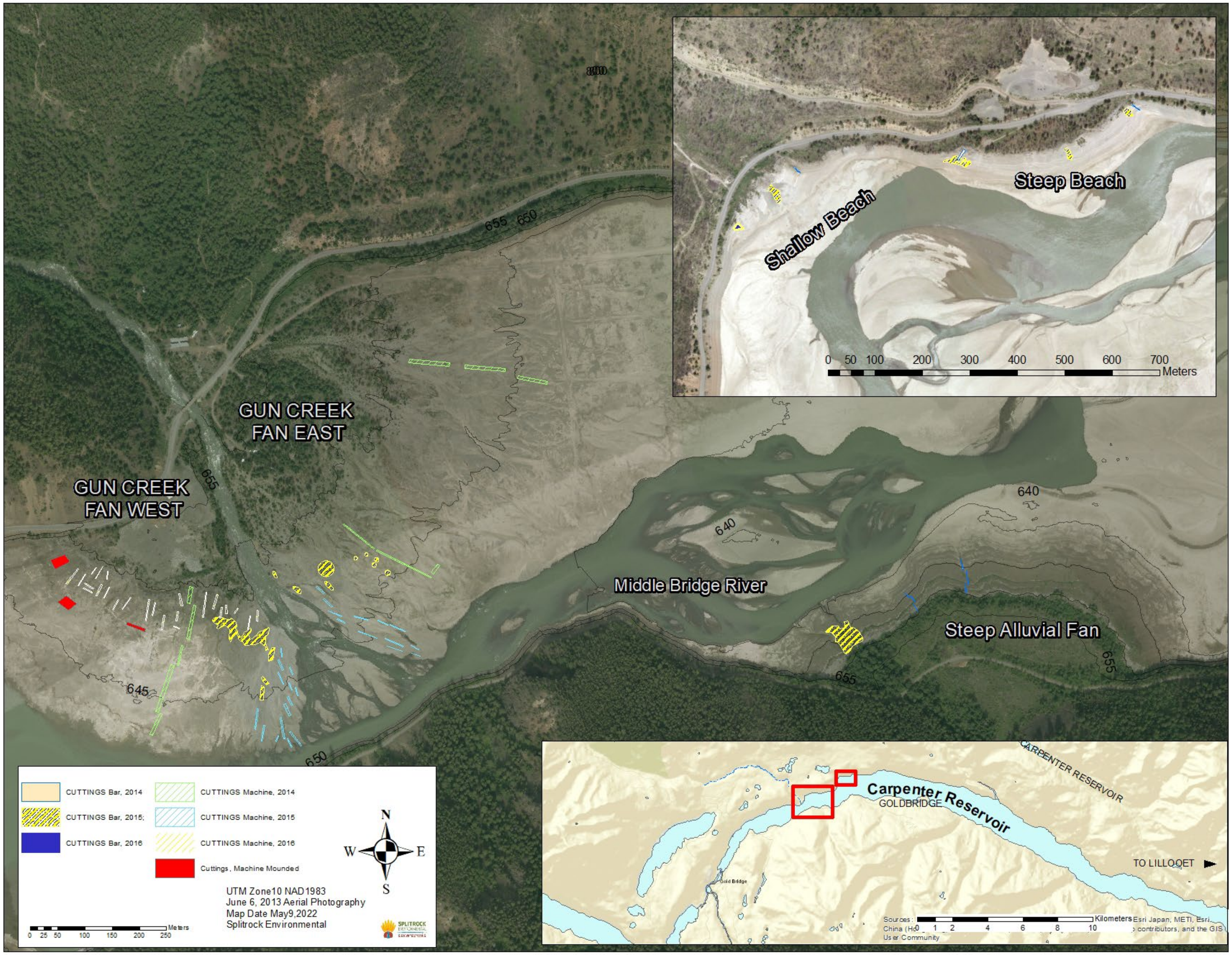

Figure 7 Locations of live stake cuttings treatments carried out through the BRGWORKS-1 program.

2.4.3 Physical Works

Some physical manipulations of large substrates (rocks) were carried out by hand in the 2015 revegetation efforts. At several sites, cobbles and small boulders were moved into piles and rows. The intention of creating these rock features was to create microsites by cutting wind and providing shade to promote fines capture and sediment under inundation.

In 2017, with input from BC Hydro Vegetation Subject Matter Experts (SME), the project actions were shifted to take a more intensive approach to implement physical works. In 2017, a 200 series Hitachi excavator and operator worked with the BRGWORKS-1 field lead to create a series of substrate alteration treatment trials at the Low Mud Flat, Gun Creek Fan East and Gun Creek Fan West terrain sites (Scholz, 2018). Treatments were conducted at these relatively level sites; polygons roughly 1800m² in area were treated with mounding.

Mounding was carried out by a 200 series excavator. The treatment followed the rough and loose approach to substrate modification as described by Polster (2013). At the two lowest elevation sites (639m-640m) the technique was varied by using the larger volume clean-up bucked to more efficiently construct larger and taller mounds. Soils at these sites were relatively homogenous lacustrine silts with some fine sands (Figure 8). In one polygon a very large mound was created (5m high) in an attempt to create higher elevation microsites within the treatment polygons. The rough and loose technique created a series of mounds and pits across what was initially a relatively flat surface. Mounding resulted in loosening of the soils, mixing of substrate layers and creation of microsites. The intent was to foster seed and propagule capture, hold precipitation, improve growing conditions. Adjacent to these mounded polygons, areas of similar size were designated as non treatment control areas to be monitored for comparison under the BRGMON-2 program.

Figure 8 Mounding in 2017 outer mounds created with clean up bucket and inner with smaller digging bucket.

Further stratification of mounded polygons was incorporated into trials where half of the polygon was maintained with no further treatments (mounding only - M), and half was planted with native species (mounded planted - MP), the four lowest elevation polygons had Kellogg's sedge seeding treatments set up within them (mounded seeded (MS) discussed above in 2.4.1 Seeding Trials). These three treatments were monitored along with the adjacent control area to monitor and compare vegetation community composition over time. Mounding treatments were carried out in 2017, 2019 and 2020 on the Gun Creek Fan East and West and the Low Mud Flat were mounded in 2019 and 2020 (Figure 9).

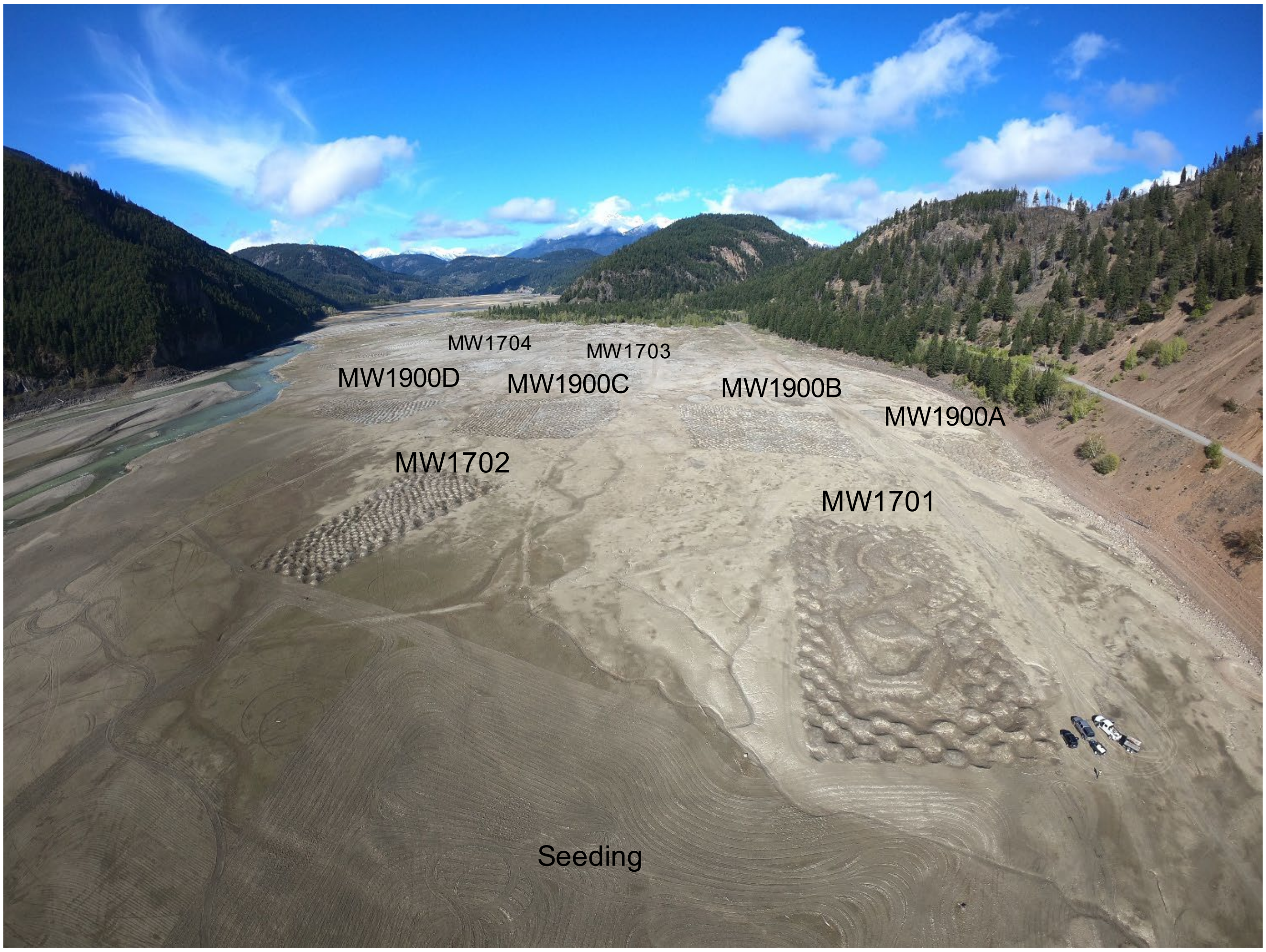

Figure 9 Drone photo looking west over Low Mud Flats and the Gun Creek Fan East side, several mounding polygons (MW). 05 May 2020 (A.Ned).

2.6 Dust Storms

Dust generation within the BRGWORKS-1 treatment area was monitored from a weather station equipped with a camera and data logging system assembled and installed in 2016 on 5-mile ridge east of the treatment areas (Figure 10). Photos and weather data have been collected through to fall 2021. Still images were collected every 15 minutes during daylight period throughout the year. Images were visually analysed for dust storm occurrences, origin of events, storm frequency, duration and size, and were entered into an Excel worksheet.

The weather station was dismantled in October 2021.

Figure 10. Map showing location of the dust storm monitoring weather station with camera trained South West overlooking the project area. Example of station photo inset.

2.7 Wildlife Use

The presence of wildlife species at the treatment area was gathered by incidental and structured methods throughout the BRGWORKS-1 and BRGMON-2 programs. Incidental observations of wildlife and wildlife sign were recorded whenever BRGWORKS-1 field operations were taking place. The location, species observed, type of evidence (i.e., direct observation, tracks, scat, feather, bone) date and observed activity were recorded. Songbird point counts using the BC Resource Inventory Committee's Inventory Methods for Forest and Grassland Songbirds (RIC, 1999) and Monitoring Bird Populations by point counts (Ralph et al., 1995). Monitoring survey sites were chosen to include a selection of BRGWORKS-1 treatment areas, control sites and nearby reference areas. Songbird surveys were conducted by a wildlife biologist in 2016 (Heinrich, 2016) and 2018 (Heinrich, 2019). In 2018, auditory survey techniques for amphibians were used to survey both treatment and control areas. The amphibian auditory survey (Heinrich, 2019) was conducted using methods in 'Pond Breeding Amphibians and Painted Turtle' (RIC, 1998). Amphibian surveys were carried out at the same locations as the bird point count stations in 2018. In 2020, a targeted area constrained search for amphibians was conducted at selected BRGWORKS 1 treatment and control areas on the Low Mud Flat (Scholz, 2021). The targeted area-based survey was done as a controlled effort following up on incidental records of amphibians and reptile occurrences that were recorded in previous treatment years (Scholz, 2020).

Anecdotal information was provided by locals who provided general wildlife observations for the reservoir area in general, as a component of the public survey conducted in 2014-2015, and the results were reported in the 2014 annual report (Scholz, 2015).

2.8 Aesthetics and Recreation

Management question 2 requires assessing the effect of the BRGWORKS-1 on aesthetics and recreation values in the Carpenter Reservoir Drawdown zone. During the first year of the program, a survey was compiled and solicited to residents and visitors to the area at local public events. An online version of the survey was created and promoted among locals and regionally. Details of the survey are reported in the initial year of the program (Scholz, 2015). Incidental observations of recreational use of the site were noted during works program field operations.

3. Results

3.1 Weather

The length of the growing season at the site of the BRGWORKS-1 treatments varies from year to year (Figure 11). Monitoring from the 5-mile weather station indicates growing season typically began late March to early April, after ice melt. In most years a layer of ice from the surface of the reservoir was deposited onto the mud flats as the reservoir was drawn down. This process had a notable mechanical impact on cuttings planted in 2014 and 2015, as water levels dropped over the winter, ice lowered and crushed and broke stems (Figure 12). When water levels have dropped to low levels in late winter the ice sheet remains with snow accumulated through the winter. This sheet melts as conditions warm. During the 6 years that the 5-mile ridge weather station was operated between 2016 through 2021, the ice and snow was observed to be completely melted from the Western Gun Creek fan mud flats between March 31 and April 16th. Meltwater flowed across the surface of the mud flats, sometimes in small channels, back into the river. The mud flat soils remain saturated by the melt water. Between snow melt and inundation, vegetation is dependant on this winter moisture in the soils and then any spring early summer precipitation for growth.

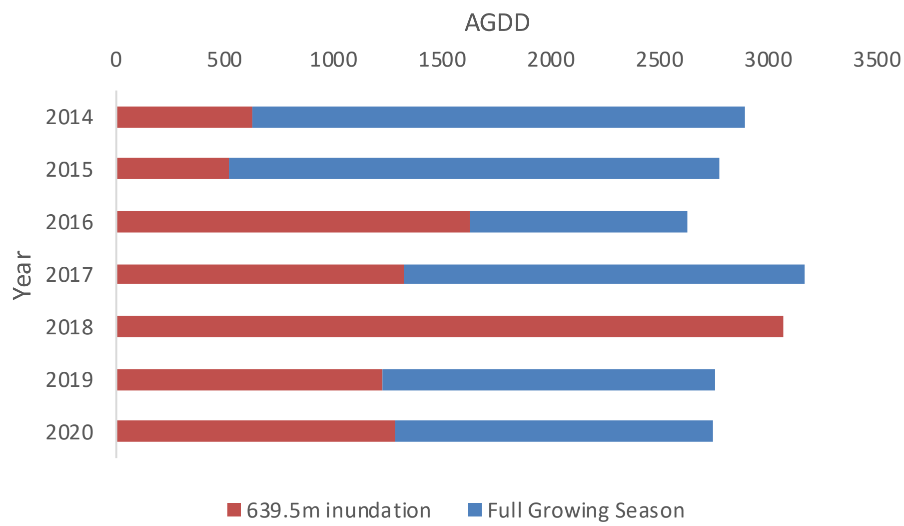

Figure 11 Annual Accumulated Growing Degree Days for BRGWORKS-1 years. 2014-2020. Red is the AGDD experienced by the lowest elevations of BRGWORKS-1 treatments due to inundation.

Between 2013 and 2021, it has been observed that April is one of the driest months May and June are also typically dry (25-26mm on average). These are the main growing months for the BRGWORKS-1 lower treatment elevations of the drawdown zone. The July rainfall volumes were quite variable within the small sample window (Figure 13). Average daily temperatures rose throughout the growing season, peaking in July and August. Drier months of May and June coincide with rising daily mean temperatures. Spring weather and inundation timing has combined to vary the AGDD experienced by vegetation growing at 639.5m by up to 2545 units. This elevation is lowest level of BRGWORKS-1 treatments, and the maximum variability in AGDD is a total equivalent to an entire growing season (Figure 14, Figure 15).

Figure 12 March 29 2016, cuttings planted the previous year on the Steep Beach Site showing mechanical ice damage.

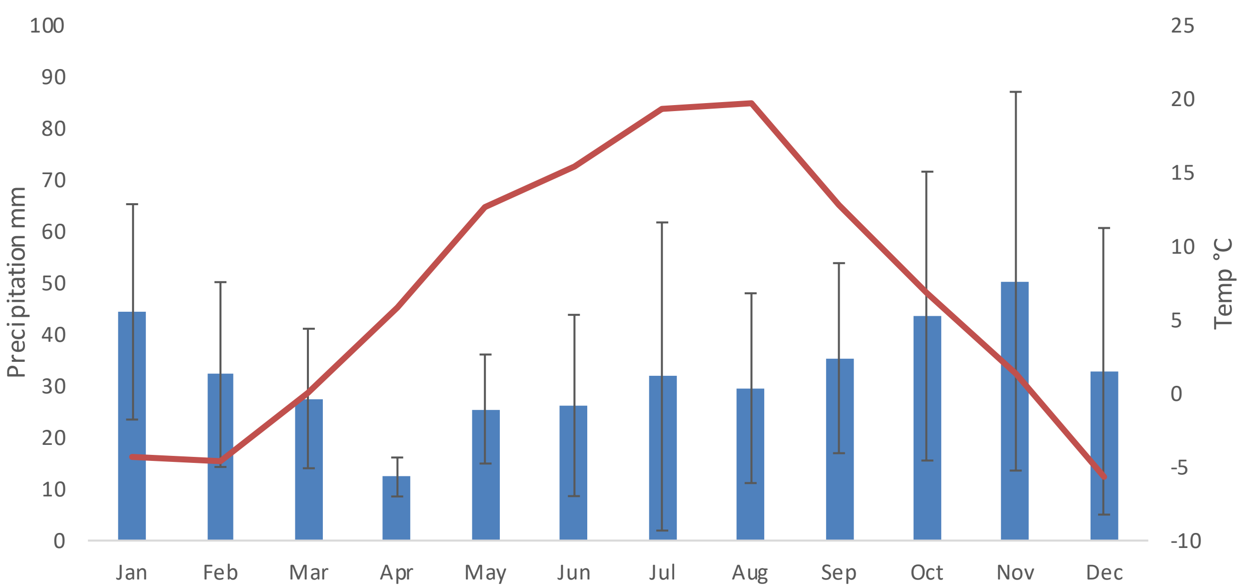

Figure 13 Average annual precipitation from the 5-mile weather station, data from 2013 through 2021. Error bars are standard deviation. Average monthly temperature data from 5-mile ridge weather station 2014-2021.

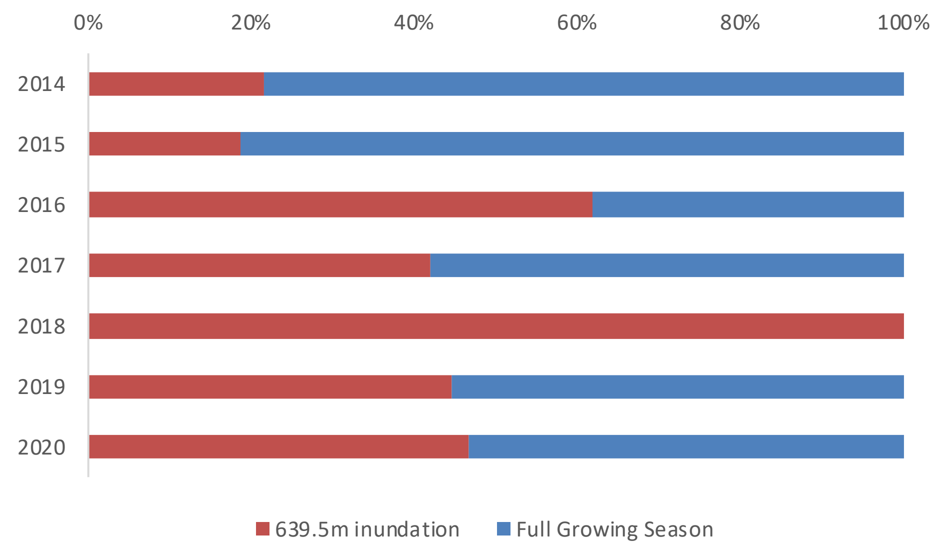

Figure 14 Percent of the Accumulated growing degree days experienced by lowest elevations of BRGWORKS-1 treatments through the BRGWORKS-1 period.

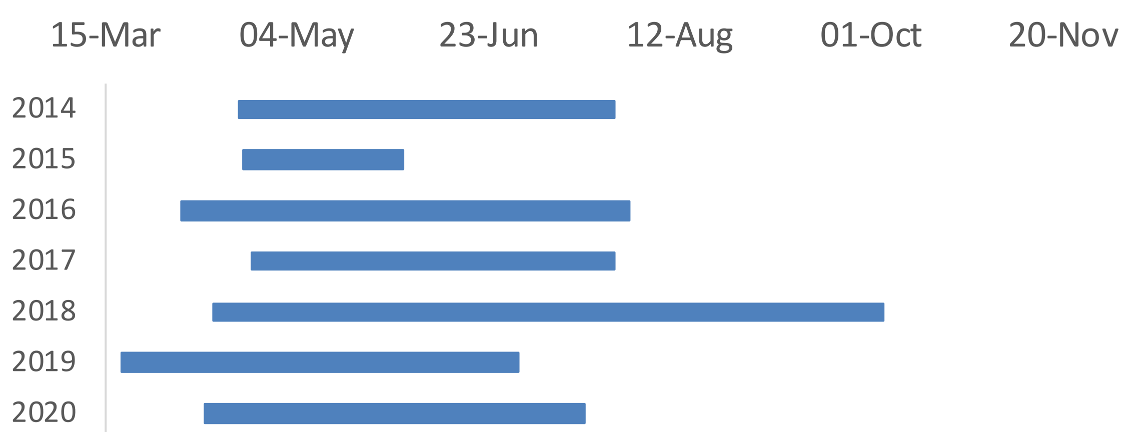

Figure 15 Length of growing season depicted for each year of the BRGWORKS-1 program for vegetation growing at the 639.5m elevation (lowest elevation of BRGWORKS-1 treatments).

3.2 Reservoir Water Levels

Based on observed inundation patterns and considering elevation, inundation, duration and length of growing season, BRGWORKS-1 treatments were implemented at elevations between 639 mASL and 651 mASL in the Carpenter Reservoir drawdown zone. The timing of inundation of the treatment elevations varied from year to year throughout the 7 years of the BRGWORKS-1 treatments (Figure 16, Table 6). The rate and timing of Reservoir filling varied annually within the seven-years of the

BRGWORKS-1 Program. The time of year that the lowest treatments at (639m-640m) were inundated varied by up to 4 months (126-days). The 640m elevation was flooded as early a June 2nd (2015) and as late as Oct 10th (2018). During the program, treatment elevations were inundated to a depth as little as 1.15 m (10% of vertical zone of treatment elevations 639m-650m) (2014) and inundated as high as 8.84 m (80% of the vertical zone treatment) (2015) (Figure 17). The timing of inundation of the BRGWORKS-1 treatment elevations was relatively early in both 2014 and 2015, with short to little growing in the month of June for low elevations. In 2014, the rapid early inundation affected treatment layout and limited treatments to above 642m. In 2015, Low Mud Flat elevations were inundated very early on limiting germination and establishment times. In 2016, 2017, 2018 and 2020 inundation came mid-July or later, which allowed for a moderate to long growing season even for the Low Mud Flat treatments (Table 7). In 2018, inundation was early July, which had a moderate effect on treatment elevations.

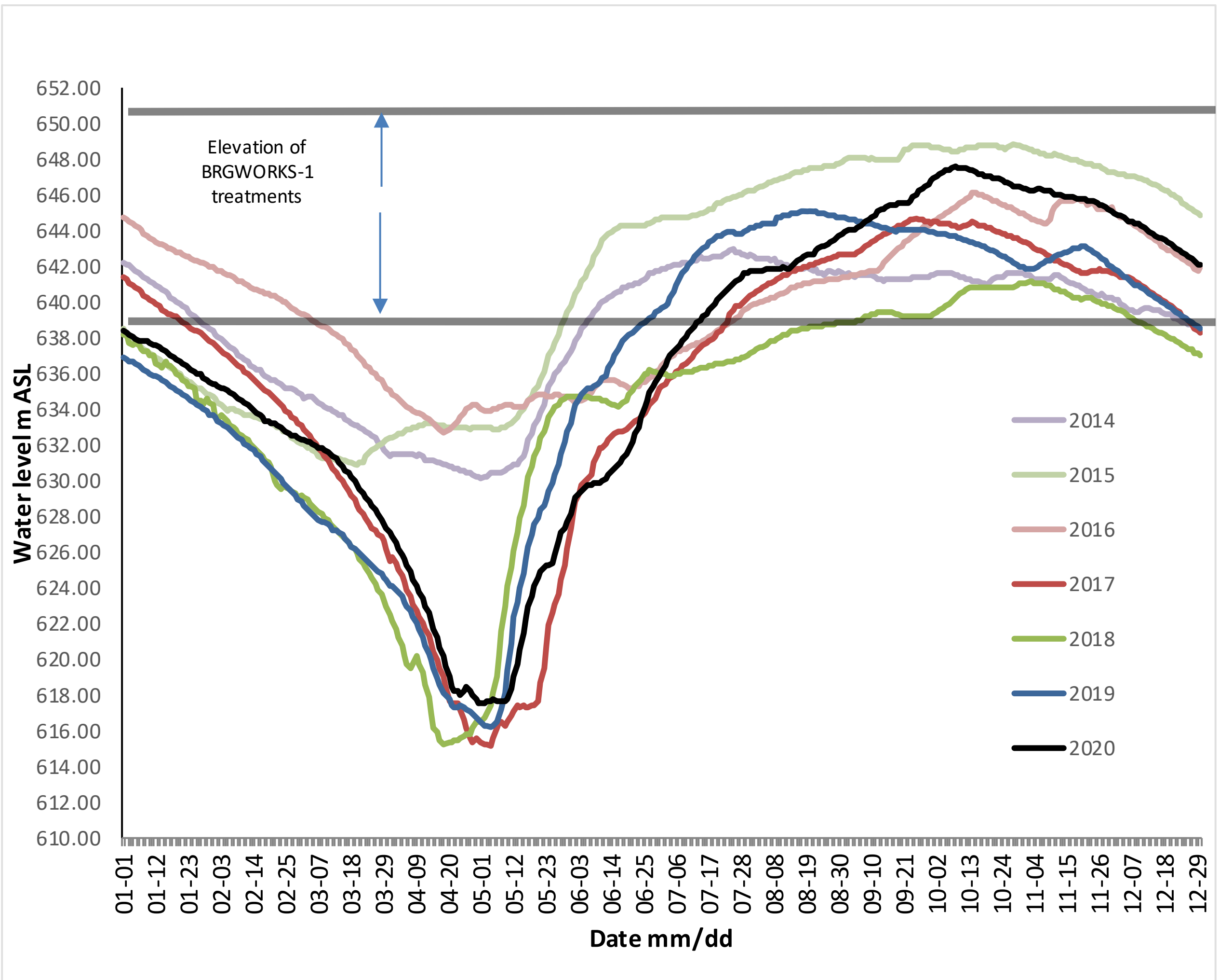

Figure 16 Hydrograph depicting the reservoir fluctuation for each year of the BRGWORKS-1 program.

Table 6 Carpenter Reservoir inundation dates relevant to the BRGWORKS-1 treatments. Low elevation treatments at 640m, Highest elevation of Treatments 651m. Relative affect ranking based on how much treatments were stressed by a shortened growing season due to inundation. i.e. Early inundation= shorter growing season= High affect.

WORKS Implementation	Year	640m inundated	Max elevation flooded	Date of Max inundation	Reservoir Operations relative effect on Treatments
Early	2014	June 13th	642.97m	July 26	**High**
Early	2015	June 2nd	648.84m	Oct 24	**High**
Late	2016	August 4th	646.13m	Oct 15	**Low**
Late	2017	July 30th	644.57m	Sept 26	**Low**
Late	2018	October 8th	641.15m	Nov 3	**Low**
Mod	2019	July 5th	645.08	Aug 20	**Medium**
Mod	2020	July 21st	647.60	Oct 9	**Low**
Mod	2021	July 10th	647.82	Oct 8	**Medium**

The median date of inundation of the lower BRGWORKS-1 treatment elevation (640m) during the WUP period from 2000-2020 was June 29th (Figure 18). The median inundation of the same elevation for the 10 years pre WUP (1990-1999) was June 28th. The median date of inundation of 640m elevation during the BRGWORKS-1 program from 2014-2020 was two weeks later on July 15th. The two additional weeks in July could add up to an additional to 250 AGDD[2].

[2] Based on average AGDD for the first two weeks in July calculated from 2016-2019, base 0°.

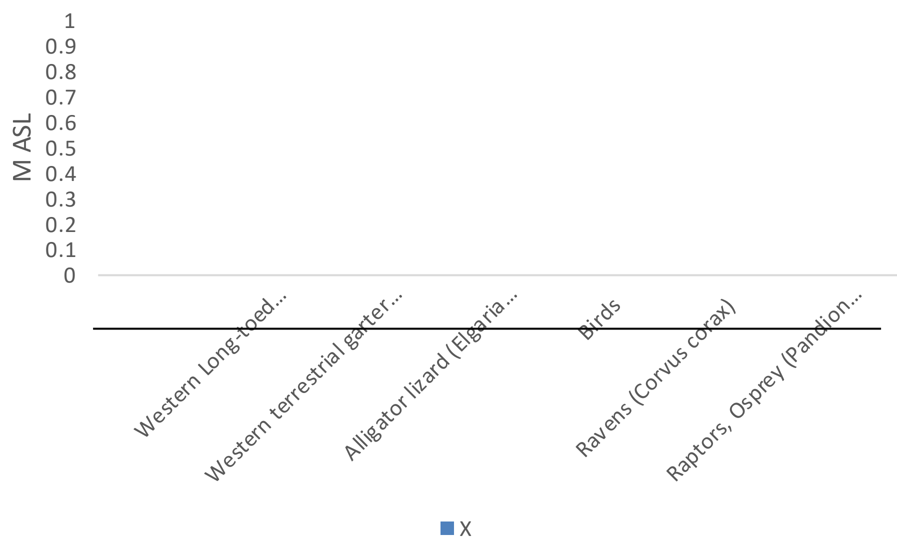

Figure 17 Peak pool elevations by year, Black line indicates 639.5 lowest elevation of BRGWORKS-1 treatments. Treatments were implemented between 639.5 and 651 m.

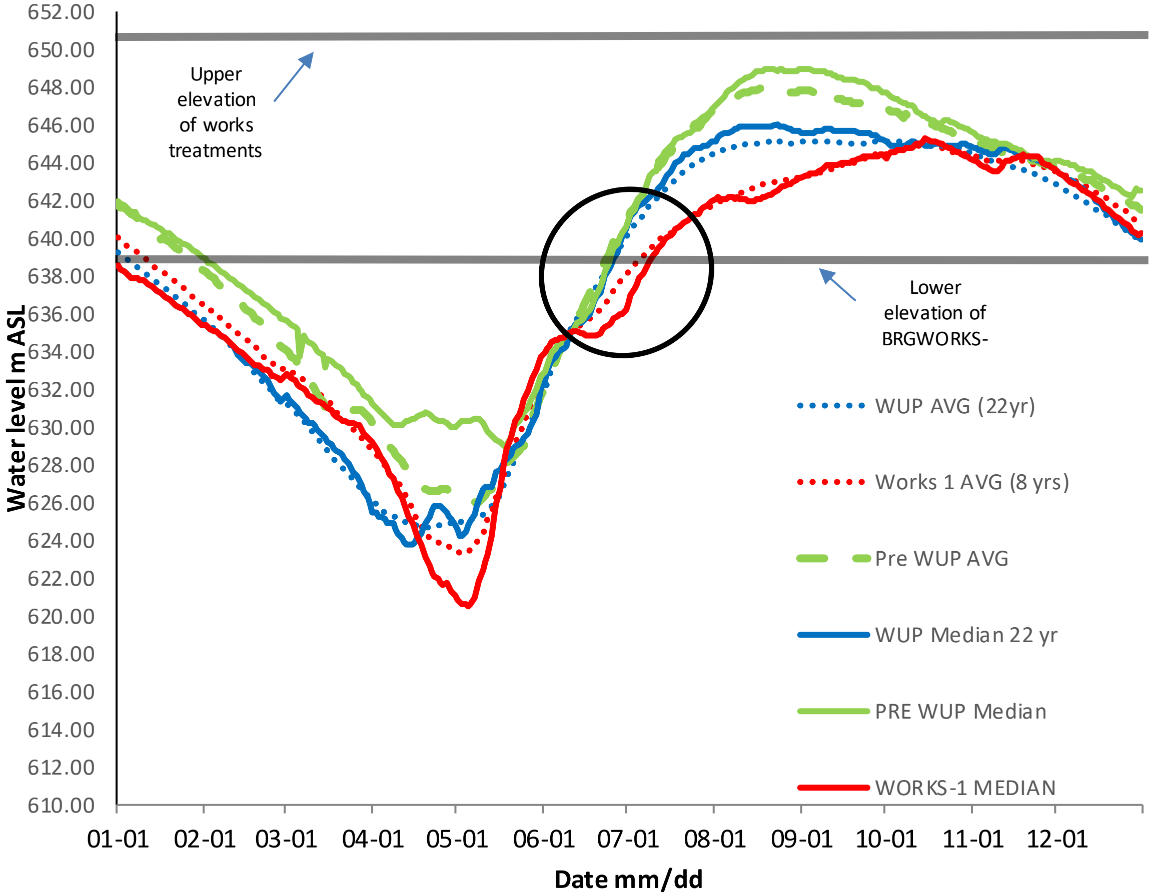

Figure 18 Average and median hydrographs through the BRGWORKS-1 treatment period (2014-2021), the Whole WUP period (2000-2021) and the pre WUP period (1990-1999). Emphasis on the variation in the historic timing of inundation of the lowest elevations of the BRGWORKS-1 treatments.

Table 7 Summary of annual inundation and percent of month available to plants growing at elevations where BRGWORKS-1 Treatments have been carried out. Zero percent is full inundation.

MONTH		Low (LMF)					Mid Drawdown		Upper Drawdown		Buffer		
		639	640	641	642	643	644	645	646	647	648	649	650
April	2014	100	100	100	100	100	100	100	100	100	100	100	100
	2015	100	100	100	100	100	100	100	100	100	100	100	100
	2016	100	100	100	100	100	100	100	100	100	100	100	100
	2017	100	100	100	100	100	100	100	100	100	100	100	100
	2018	100	100	100	100	100	100	100	100	100	100	100	100
	2019	100	100	100	100	100	100	100	100	100	100	100	100
	2020	100	100	100	100	100	100	100	100	100	100	100	100
	2021	100	100	100	100	100	100	100	100	100	100	100	100
May	2014	100	100	100	100	100	100	100	100	100	100	100	100
	2015	93.5	100	100	100	100	100	100	100	100	100	100	100
	2016	100	100	100	100	100	100	100	100	100	100	100	100
	2017	100	100	100	100	100	100	100	100	100	100	100	100
	2018	100	100	100	100	100	100	100	100	100	100	100	100
	2019	100	100	100	100	100	100	100	100	100	100	100	100
	2020	100	100	100	100	100	100	100	100	100	100	100	100
	2021	100	100	100	100	100	100	100	100	100	100	100	100
June	2014	23.3	40	73	100	100	100	100	100	100	100	100	100
	2015	0	3	13	23.3	33	50	100	100	100	100	100	100
	2016	100	100	100	100	100	100	100	100	100	100	100	100
	2017	100	100	100	100	100	100	100	100	100	100	100	100
	2018	100	100	100	100	100	100	100	100	100	100	100	100
	2019	90	100	100	100	100	100	100	100	100	100	100	100
	2020	100	100	100	100	100	100	100	100	100	100	100	100
	2021	100	100	100	100	100	100	100	100	100	100	100	100
July	2014	0	0	0	13	100	100	100	100	100	100	100	100
	2015	0	0	0	0	0	0	52	90	100	100	100	100
	2016	84	100	100	100	100	100	100	100	100	100	100	100
	2017	77	94	100	100	100	100	100	100	100	100	100	100
	2018	100	100	100	100	100	100	100	100	100	100	100	100
	2019	0	13	22.5	32	52	97	100	100	100	100	100	100
	2020	45	65	81	100	100	100	100	100	100	100	100	100
	2021	19	32	48	93	100	100	100	100	100	100	100	100
Aug	2014	0	0	0	55	100	100	100	100	100	100	100	100
	2015	0	0	0	0	0	0	0	0	39	100	100	100
	2016	0	10	58	100	100	100	100	100	100	100	100	100
	2017	0	0	19	65	100	100	100	100	100	100	100	100
	2018	100	100	100	100	100	100	100	100	100	100	100	100
	2019	0	0	0	0	0	0	71	100	100	100	100	100
	2020	0	0	0	45	74	100	100	100	100	100	100	100
	2021	0	0	0	0	16	38	90	100	100	100	100	100
Sept	2014	0	0	0	100	100	100	100	100	100	100	100	100
	2015	0	0	0	0	0	0	0	0	0	3	100	100
	2016	0	0	0	43	63	90	100	100	100	100	100	100
	2017	0	0	0	0	27	57	100	100	100	100	100	100
	2018	20	100	100	100	100	100	100	100	100	100	100	100
	2019	0	0	0	0	0	13	100	100	100	100	100	100
	2020	0	0	0	0	0	6	40	83	100	100	100	100
	2021	0	0	0	0	0	0	0	27	83	100	100	100
Oct	2014	0	0	0	100	100	100	100	100	100	100	100	100
	2015	0	0	0	0	0	0	0	0	0	0	100	100
	2016	0	0	0	0	0	0	19	100	100	100	100	100
	2017	0	0	0	0	0	29	100	100	100	100	100	100
	2018	0	22.5	97	100	100	100	100	100	100	100	100	100
	2019	0	0	0	0	35	100	100	100	100	100	100	100
	2020	0	0	0	0	0	0	0	0	39	100	100	100
	2021	0	0	0	0	0	0	0	0	6	100	100	100

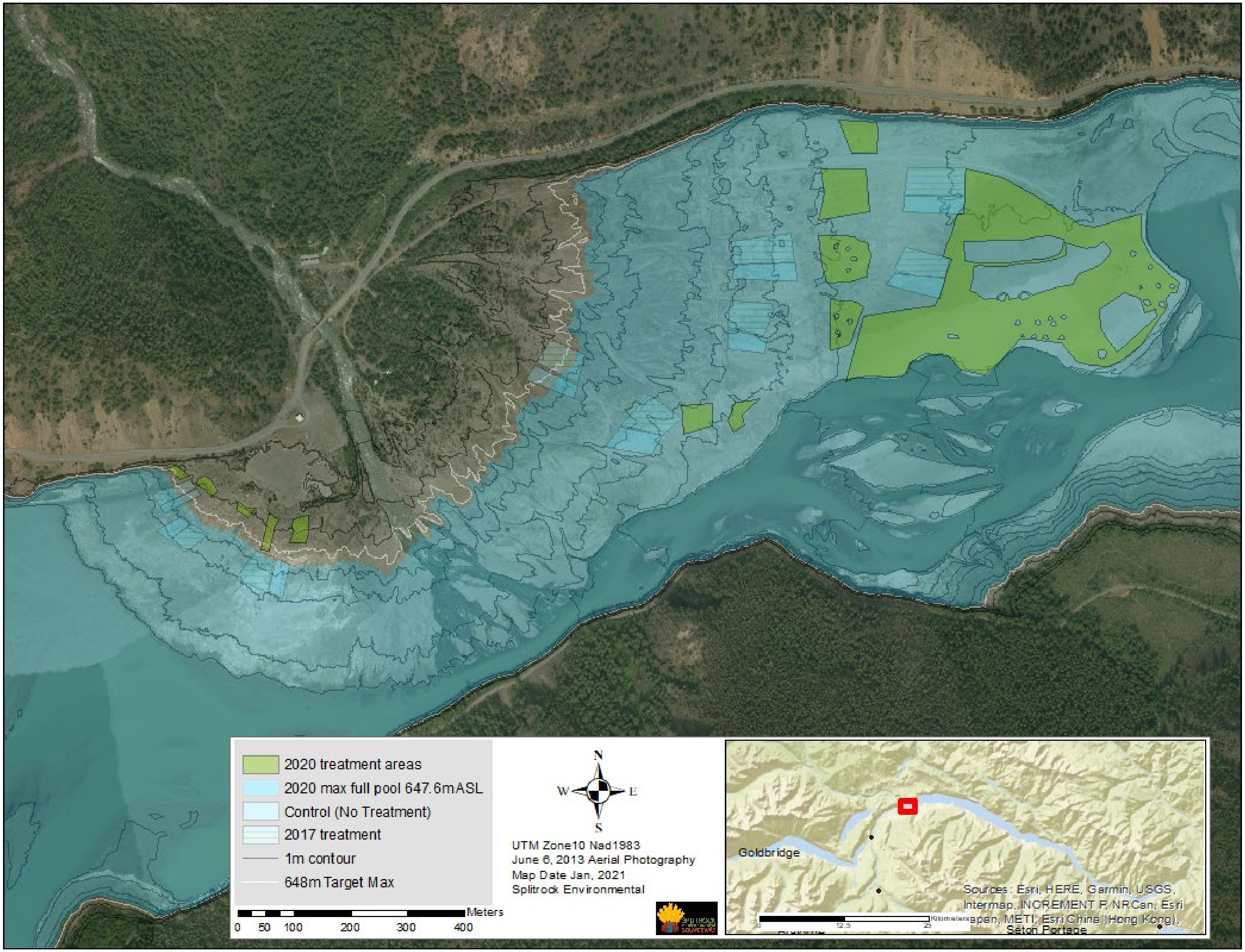

Figure 19 Treatment area around Gun Creek Fan depicting 2020 water level at full pool on August 22.

3.3 Permitting

Archaeology impact assessments conducted by Wood and Associates in 2017 resulted in a minor modification of planned treatments on the West side of the Gun Creek Fan. The 2019 assessment did not raise any concerns with planned works. Part of the reason for the limited number of finds lies in the fact that much of the substrate of the Low Mud Flat area, a key area of treatment focus, consists of deep layers of recently deposited silts. Many of the accumulated fines have been deposited from 70 years of inundation. While a few archaeological artifacts were observed through the program, much more recent detritus and debris from the Minto town site were observed. While not of heritage significance from an archaeological perspective, the site was recognized as a heritage site for its historical use as an interment camp for Japanese Canadians during World War II. During the BRGWORKS-1 project, signage was installed at the Gun Creek Campground entrance acknowledging this role in the history of the area. Local community members made expressed concern regarding disturbance of the historic town site. While some physical works had been carried out on the town site, it was decided after the 2018 lag year to keep all further treatments to areas outside of the official historic site. Most of the debris uncovered consisted of bottles, rusting metal and occasionally pottery.

A Section 11 *Water Sustainability Act* Application "Changes In and About a Stream"-was authorized by Ministry of Forests, Lands and Natural Resource Operations and Rural Development with adherence to terms and conditions in a letter dated March 20, 2013. With each year of operations Carpenter Reservoir water levels were well below the treatment zone elevations at the time of treatments, eliminating any direct impact on aquatic systems. Machine operator contractors were made aware of cultural and environmental concerns through review of site-specific safety plans.

Short Term Use of Water Approval from the Ministry for Forests Lands and Natural Resource Operations and Rural Development Assistant Water Manager was applied for to permit water extraction to irrigate plantings. Use approval enabled drawing water from Gun Creek and Carpenter Reservoir directly to water planting sites. Supplemental water was brought to site when permits were not in place.

3.4 Riparian Enhancements

From the beginning of the project, it was assumed that the revegetation effort would focus on three techniques: seeding, planting container plants and planting live stake cuttings. As the program evolved, physical treatments of the substrate were added to the experimental program. The emphasis was on identifying native species that could be used in revegetation treatments.

3.4.1 Seeding Treatments

The results of seeding as an approach to riparian enhancement is addressed by species.

Canada wildrye (*Elymus canadensis*).
Canada wildrye is a robust perennial native grass species.

- Canada wildrye was harvested near Lillooet BC and sown into test plots in 2014. Early trials showed successful germination in 1X1m plots at all site trial locations, as well as growth one year post sowing in 2015 (Scholz and Gibeau, 2018a). Grass seedlings were observed to sprout at all treatment plots on Steep Beach (fine gravel coarse sand), Shallow Beach (sand), and at Gun Creek Fan East (sand gravel). All sites were coarse substrates, some loose unconsolidated. The 2014 seeding trials were only monitored in 2015 so long-term survival of plants from initial test plots is unknown. ***Successful germination and initial growth, establishment success from these trials is unknown.***

- Canada wildrye was sown across a wide section of the mud flats in 2016. Seed was sown by a tractor and tilled in to test the potential for growth in low elevation (640m) finer substrates (Scholz, 2016). Given the unpredictable timing of inundation, the trial was conducted to determine if seedlings could germinate and produce enough initial biomass to either provide ecological functions and/or survive through to the following year. No seedlings were observed from sampling carried out in 2017 (Scholz and Gibeau, 2018b). ***No observed survival at 640m elevation even with moderate length of growing season, silt substrate.***

Bluejoint reedgrass (*Calamagrostis canadensis*)
Bluejoint reedgrass seed was sown into 1X1m quadrats at Steep Beach, Shallow Beach and Gun Creek Fan East terrain sites in 2014 (Scholz, 2014). Monitoring in 2015 revealed minimal indication of seed germination (Scholz and Gibeau, 2016a). *Calamagrostis canadensis* was part of a native grass seed mix sown by tractor in 2015 into plots on the Gun Creek Fan East side lower and upper drawdown elevations (Scholz, 2015). Monitoring of these polygons has not been conducted at the time of this report and may be worth including in the scope of the final monitoring conducted under the BRGMON-2 program in 2022.

Ticklegrass (*Agrostis scabra*), Northern wheatgrass (Elymus lanceolatus), slender wheatgrass (*Elymus trachycaulus*), foul bluegrass (*Poa palustris*),
The native grass seed mix was planted in 2015 on the Gun Creek Fan East side (Scholz, 2016). These seeded plots have not been monitored since they were sown, and it is unknown if there has been any establishment of grasses from this trial.

Meadow bird's-foot trefoil (*Acmispon denticulatus*)
Meadow bird's-foot trefoil is a naturally occurring, annual native, species in the legume family. The species has been observed growing naturally in both Carpenter and Downton Reservoir drawdown zones (Scholz and Gibeau, 2014). During the 2013 BRGMON-2 baseline survey the species was observed growing in dense stands on one steep beach site at the east end of Carpenter Reservoir (Figure 20) (Scholz and Gibeau, 2014). Trefoil seed was gathered from this site and used in riparian enhancement trials.

Bird's-foot trefoil was sown as part of riparian enhancement trials in 2019 (Scholz, 2020) and 2020 (Scholz, 2021). Monitoring of 2019 seeded areas in 2020 indicated successful though sparse take and subsequent cover by meadow bird's foot trefoil. Seeding trials were scaled up in terms of area sown (0.24ha) and density of seed sown (25kg/ha) in the final year of the BRGWORKS-1 program. In 2020, seed was sown across mounded polygon (MW1900F) situated at the transition between the Gun Creek Fan East and the Low Mud Flat (Scholz, 2020). To be successful as a riparian enhancement species and treatment method, the sown trefoil will have to self-seed on site. ***The 2020 treatment has not been monitored, but is recommended for the final BRGMON-2 survey in 2022***. ***Caveat: The lotus seed may have a prolonged dormancy. If seedlings are observed in 2022 surveys, these may be the result of seed dormancy and not necessarily an indication of self-seeding.***

Figure 20 Left photo of Steep Beach site surveyed in 2013, with meadow bird's foot trefoil (*Lotus denticulatus*) providing dominant cover. Right photo from 2019 on the Low Mud Flat, a natural patch of trefoil adjacent to seeding trials.

Fall rye (*Secale cereale*)

Fall rye is a fast-growing domestic annual grass species and was one of the original recommended approaches to revegetating the Carpenter drawdown zone to "provide protection and encourage natural revegetation", found in the TOR (BC Hydro, 2014). Fall rye is often used as a cover crop in many agricultural applications. The seed is usually sown in the fall and then killed prior to sowing crops in the following spring. The resulting biomass provides values as a green mulch and subsequently adds organic matter to the soil. Fall rye use in reservoirs in BC has occurred since the 1970's where it has been shown to not invade local, native plant communities, as inundation prevents the crop from reaching maturity (Jackson et al. 1995). Trials under the BRGWORKS-1 program were carried out in 2015, 2016, 2019 and 2020. In 2015, inundation of the mud flats occurred in early June. Fall rye plants remained very small, with only 140 AGDD between time of sowing and inundation (Scholz and Gibeau, 2018b). While no significant biomass was produced from the 2015 trials, the observed germination and growth of seed spurred larger area seeding in 2016 (Scholz 2016) (Figure 21). In 2016, inundation timing for Low Mud Flats was much later in the year (August) than in 2015, and the prolonged growing season allowed seeded rye to reach near maturity before inundation. In 2017, monitoring of 2016 seeding trials conducted under BRGMON-2 found a higher incidence of Kellogg's sedge seedlings had colonized in areas sown with fall rye versus areas either mechanically treated only, sown with Canada wildrye or sown with Kellogg's sedge seed (Scholz and Gibeau, 2019a). Two observations from fall rye seeding trials influenced the 2019 and 2020 treatments. In 2017, Kellogg's sedge seedling colonization within the 2016 fall rye seeded area and the observed 100% survival (502 plants) and marked growth in sedge plugs planted within the same fall rye seeded area, led to continued use of fall rye seeding as a riparian enhancement technique in both 2019 and 2020 (Scholz, 2020).

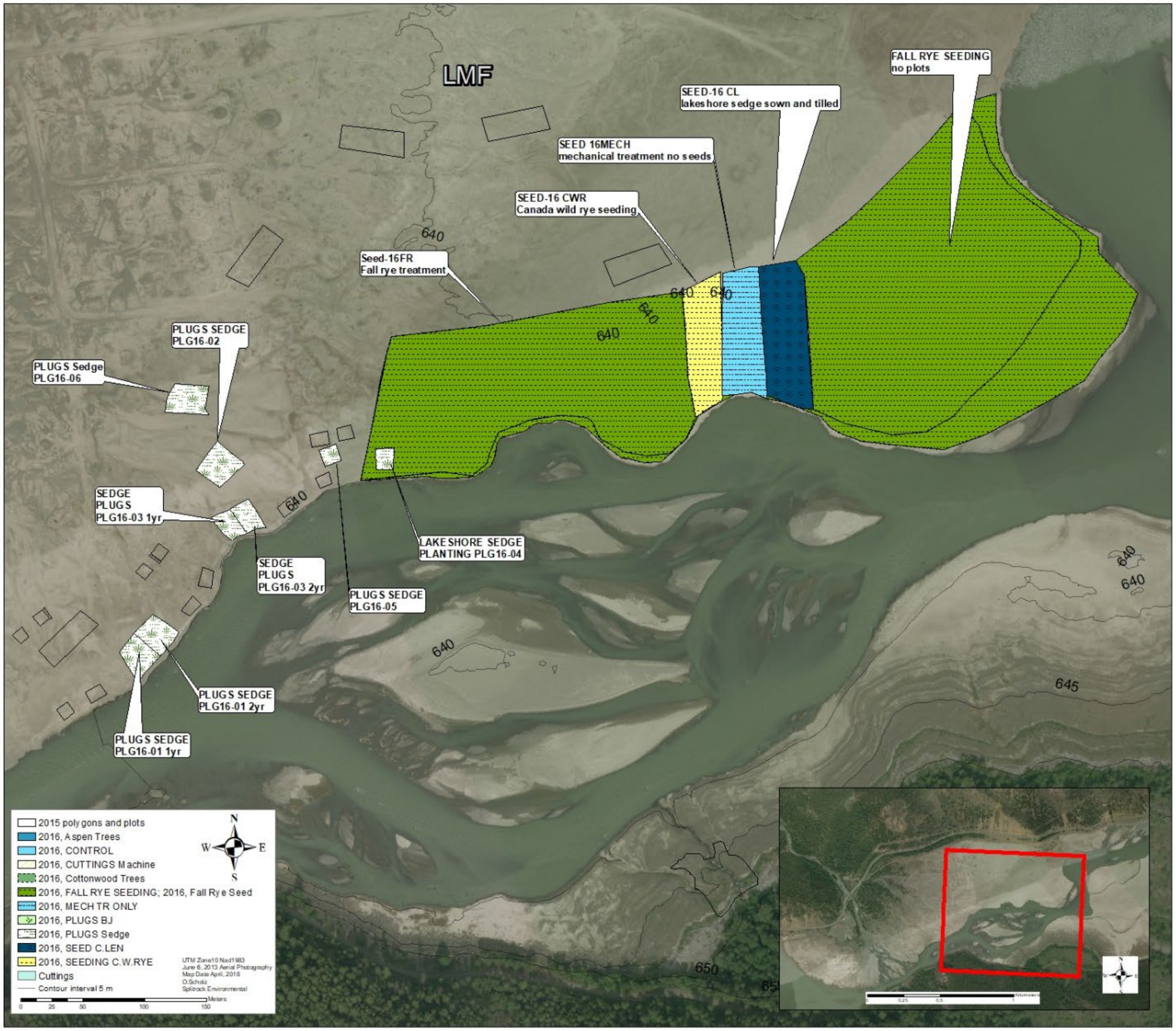

Figure 21 Map showing 2016 seeding and planting treatments on the Low Mud Flat.

Kellogg's sedge (*Carex kelloggii*)

Kellogg's sedge seed was sourced from the western end of Carpenter Reservoir (Mid Mud Flats) and the west end of Downton Reservoir. Seeding trials using collected sedge seed, were first applied in trials across the Low Mud Flat in 2015 (Scholz, 2015). Monitoring results from 2016 did not show any clear sign of seedlings colonizing from these trials. The lack of seeding success from the 2015 trials was hypothesized to lie in the short growing season afforded by the early June inundation of 2015 that truncated the period of germination (Table 6).

In 2016, Kellogg's sedge seed was broadcast over 4000m^2 of the Low Mud Flats (Scholz, 2016). The site was lightly disced and harrowed after seed was sown to cover seed. In 2017, monitoring showed no sign that seedlings had germinated from sown seed (Scholz and Gibeau, 2019a). At the same time in 2017, natural recruitment of sedges was observed on the Low Mud Flats. Kellogg's sedge plants were observed establishing on the Low Mud Flat in areas sown with fall rye (Scholz and Gibeau, 2019). Given the fact that Kellogg's sedge was successfully colonizing Low Mud Flats and that seed may either have come from naturally dispersed seed from higher elevations in the reservoir or possibly from some of the seed introduced to the area via either 2015 and 2016 trials, Kellogg's sedge seeding trials were continued in 2017.

In 2017, Kellogg's sedge seeding trials were done as a co-treatment with physical mounding. Low Mud Flat mounded polygons areas were sown with Kellogg's sedge seed and subsequently raked by hand to cover seed (Scholz, 2018). Monitoring in 2018 found low densities but high frequency of Kellogg's sedge seedlings within the mounded, seeded and raked polygons (MW1701MS, MW1702MS, MW1703MS, MW1704MS) (Figure 22). In contrast, no seedlings were detected in any other mounded and treated polygons save one. The one other exception where Kellogg's sedge seedlings were observed was in mounded and planted polygon MW1704MP, where a rare mature Kellogg's sedge plant was growing and had dropped seed. The plant was a natural, residual survivor from the mounding treatments in 2017 (Scholz and Gibeau, 2019b). The implications of these early observations were:

1. That mounding and raking created beneficial conditions for Kellogg's sedge seed to germinate and grow,
2. That an immediate close source of seed was required,
3. That plants were able to mature and produce viable seed at the Low Mud Flat (at 640m elevation)
4. Seed produced by mature plants could colonize and ultimately become established plants.

By 2019, the 2016 trials with planted Kellogg's sedge plugs had become mature enough to be producing high volumes of seed that could be harvested and resown. Kellogg's sedge seed was harvested from these treatment patches as well as from natural stands to the west. Seeding and raking was carried out in small patches in 2019 at a rate of roughly 15kg/ha, in polygons on both the Low Mud Flats and within Low Mud Flat mounded polygons (Scholz, 2020). Hand seeding and raking was also carried out as part of the final year of treatment within small and larger patches within mounded polygons at the transition zone between the Gun Creek Fan and the Low Mud Flats (Scholz, 2021). With even low establishment from sown sedge seed, surviving plants will provide a long-term local seed source to help colonize mounded sites with sedges. The 2019 and 2020 sedge seeding treatments have not been monitored, but may be as part of the BRMON-2 2022 final field study.

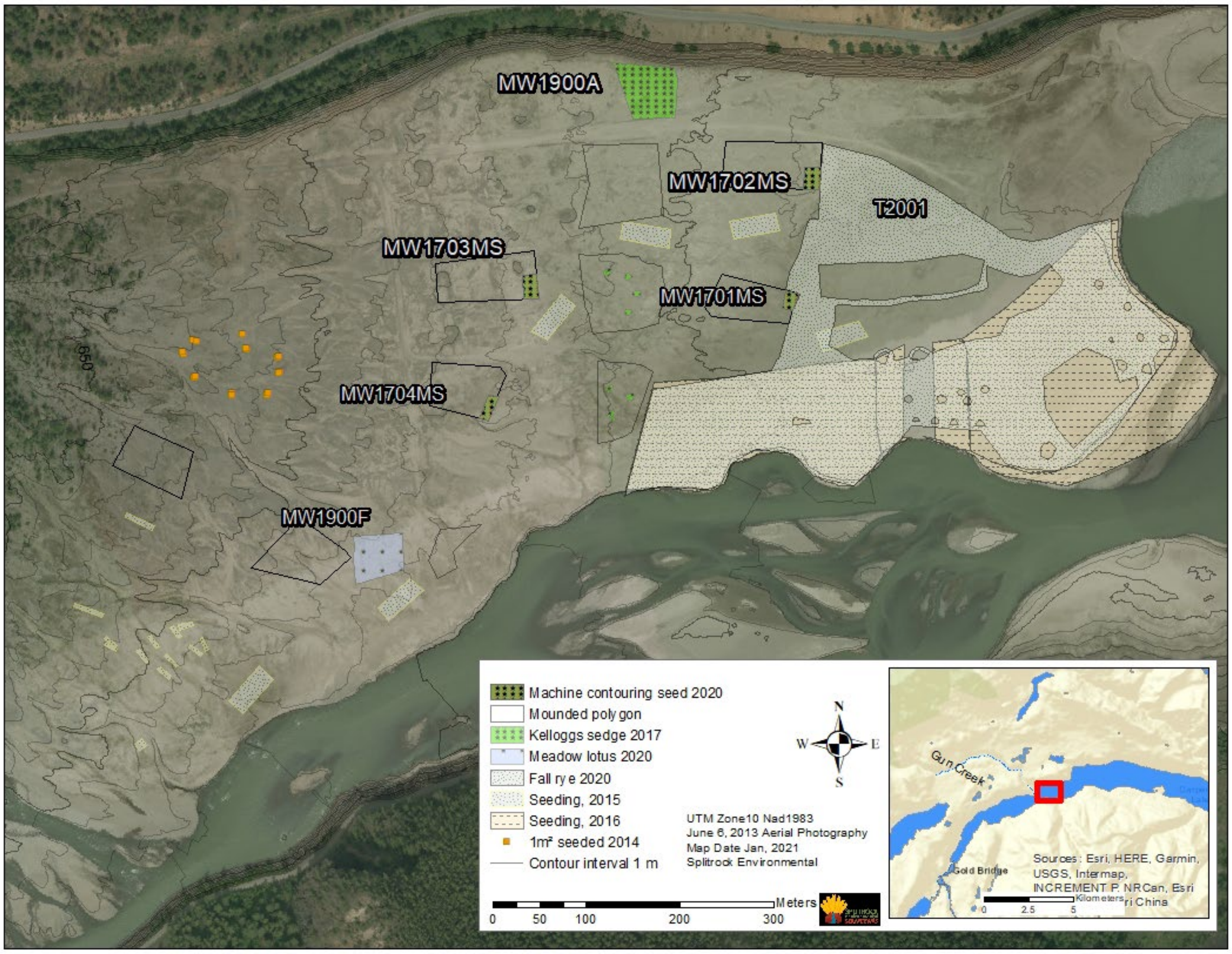

Figure 22 Map of seeding treatment sites on the Gun Creek Fan East and Low Mud Flat.

3.4.2 Planting

In all, 17 different species were planted through the BRGWORKS-1 program (Table 8). The species that were planted as container grown plants that, through the BRGWORKS-1 trials, displayed a potential for surviving in the drawdown zone were Kellogg's sedge, bluejoint reedgrass, fowl bluegrass, foxtail barley and Canada wildrye. Further monitoring is required to assess longer term establishment, vigor and dispersal for these species' trials. Higher peak pool levels in 2020 and 2021 may have had significant impacts on higher elevation plantings that up until then were performing well.

In 2015, monitoring of the 2014 treatments showed that most of the grass species had survival into the second growing season, although often under 50% survival. One exception was **Baltic rush** (*Juncus balticus*) which had almost no survival at any sites. Multiple factors could explain lack of survival, such as timing of planting, pre-handling conditions, planting stock. Due to the obvious lack of survival, the species was dropped from further trials. In 2014, early inundation of lowest elevation treatments was followed by a low peak pool that in the end did not[3] inundate and therefore provide water for any plantings. In 2014, terrestrial environmental stresses, including heat and drought, were more of a factor to plant survival than flooding. **Kellogg's sedge** plantings trials planted in 2014 showed some success and some failures that varied from site to site. It was apparent that unconsolidated sandy soils, while sustaining growth, were easily disturbed through erosion and wave action, as was observed in the two steep beach plots planted at 642m elevation where soils were lowered by about 18-20cm (Figure 23). Kellogg's sedge showed particular promise with early trials, as plants had good survival even with the lack of inundation and the arid conditions on coarse soils.

In 2015, native grasses and Kellogg's sedge trials were continued and expanded with initial trials on Low Mud Flat. Soils with higher rock content on the steep beach helped stabilize plants under inundation, however these more stable soils were nutrient poor. Sedge plants that survived on coarse soils were observed alive, but with somewhat stunted stature and growth. Each year the plants, although alive, were small and stunted.

Based on early observations of grasses and sedge survival in 2015, treatments at the Steep and Shallow Beach sites were expanded with larger patches planted, including the addition of fertilizer trials. These 2015 plantings ended up with very poor survival through 2016. The early inundation and a relatively high peak pool (648.84m) placed high aquatic stresses on plants, especially those on coarse sandy soils. It was observed in early spring 2016 that the shallow beach fertilizer treatment site had been heavily disturbed, and it appeared that the entire area had been dug up or excavated. There was no sign of fertilizer nor plugs at the site (Figure 23). It is speculated that a grizzly bear (*Ursus arctos horribilis*) dug out the plugs, perhaps to get the fertilizer or the sedge and grasses. It is also possible these plants were grubbed out by geese. In either case, the loose sandy soils would have been easy to excavate. Fertilizer treatments were not employed in future trials, but it may be worth trying again, particular in higher elevation mounded sites with poor soils. In 2018, as an alternative to fertilizer, seeding trials were conducted using nitrogen fixing legume species **meadow bird's-foot trefoil** (*Acmispon denticulatus*).

One challenge with the project schedule that conflicted with the experimental, incremental approach was that for each year, treatments had to be planned and carried out before any monitoring or assessment of the previous years' treatments could take place. For example, BRGWORKS-1 treatments were scheduled from mid-April through early June whereas monitoring under BRGMON-2 required waiting for maximum vegetation growth prior to risk of inundation, which meant targeting monitoring to begin in early June. This timing was kept consistent throughout the program. This observation was somewhat addressed in the TOR revision for the program in 2017. In the revised TOR, a lag year was added in 2018 to allow for an assessment of results to date and a plan was devised for the final two years of the program.

By 2016, monitoring observations, particularly from the Steep and Shallow Beach treatment sites, indicated high die back in planted plants and low vigor and growth in surviving plants.

[3] with the exception of two plots that were planted with sedges at 642m elevation on the Steep Beach.

The coarse substrates of the beaches were deemed too loose and marginal to support planted plugs. For future focus, planting container plants was shifted to target the finer soiled Low Mud Flats and the Gun Creek Fan physical works polygons.

Table 8 List of species planted during the BRGWORKS-1 program and summary results.

Ref#	Native Grass Species (Planted)	Summary of Results
1	blue wildrye (*Elymus glaucus*)	Initial trials had minimal survival, has not been used since, may be appropriate species for buffer zone low in mounded polygons.
2	bluejoint wheatgrass (*Calamagrostis canadensis)*	Positive results 644m and higher, particularly in coarse soils. Need follow-up monitoring to assess survival, vigor, and dispersal.
3	Canada wildrye (Elymus canadensis)	Positive results where planted (above 646m), evidence of reproduction, dispersal, colonization and establishment. Needs monitoring post inundation.
4	fowl bluegrass (*Poa palustris)*	Low survival early trials, some survival in mounds, needs more monitoring, tricky to harvest much seed.
5	foxtail barley (*Hordeum jubatum*)	Repeated success, naturally occurring and likely spreading from plantings, pros and cons for wildlife.
6	slender wheatgrass (*Elymus trachycaulus*)	Only used in 2014, minimal survival
	Native Rush	
7	Baltic rush (*Juncus balticus*)	Total failure in 2014 trials, dropped from treatments, could be tested again.
	Horsetails	
8	common horsetail (*Equisetum arvense*)	Initial LMF trials showed survival at low elevations, increased number of plantings in mounds and on LMF in 2020 needs monitoring.
9	scouring rush (*Equisetum hyemale*)	2020 treatment, needs monitoring
	Native Sedge	
10	Kellogg's sedge (*Carex Kelloggii*)	Variable results, can be excellent and has shown capacity to reproduce on site from seed dispersal. Struggles in some areas
	Native Shrub	
11	willow sp. (*Salix sp.*)	Mixed, planted in mounded areas needs monitoring.
12	sandbar willow (*Salix exigua*)	Only in small deep pot trial, needs monitoring initial growth excellent.
13	mountain alder (*Alnus incana*)	Good initial survival, needs to be monitored
14	red osier dogwood (*Cornus stolonifera*)	Planted in mounds,

	Native Trees	
15	black cottonwood (*Populus trichocarpa ssp. balsamifera*)	Best results from plantings in mounded areas, also excellent growth in deep rooted container trial.
16	ponderosa pine (*Pinus ponderosa*)	Later trials, needs more monitoring, some survival for sure
17	trembling aspen (*Populus tremuloides*)	No survivors, only one trial thus far, may warrant another test

Figure 23 photo of plot planted in 2014. 16 sedges would have been planted within 1m² area around the nail. Nail head would have been level with the soil surface when planted.

Figure 24 Early spring 2016, shallow beach test site where fertilizer was applied, polygon outline of the area that was excavated.

Kellogg's sedge was first planted on the Low Mud Flat in 2015. The sedge appeared to have a broad tolerance for surviving drought and flooding. In addition, seed was readily harvestable from nearby sources, making a good riparian enhancement species. Sedges were grown as plugs primarily sized 415D- 77X170ml. Plants were planted out in 100-150m² square plots to test success at elevations from 640m up to 644m. The period of establishment prior to inundation for plants planted in 2015 was short, as the Low Mud Flat was flooded very early in June in 2015. Trial polygons at 640m elevation were flooded within a week of planting. These low elevation polygons were observed to have sustained between 25% and 100% survival through early inundation and into 2016 (Scholz and Gibeau, 2018b). This success under both early inundation and under conditions of no inundation the previous year encouraged continued focus on sedge planting trials into 2016.

In 2017, monitoring of the 2016 Low Mud Flat Kellogg's sedge planting polygons, had mixed survival with several polygons showing 100% survival and excellent vigor after 1 year of growth, while other nearby polygons had marginal survival (Scholz and Gibeau, 2019a). In one polygon in particular, PLG16-01 sedges were observed to be mature and fruiting, and later produced a lot of seed. Looking back from 2017, inundation of the Low Mud Flat in 2016 was late, occurring in August. This provided a full growing season, in contrast to 2015. The relatively late inundation of 2016 shifted challenges on the Low Mud Flat to the terrestrial stress factors, particularly climatic factors, wind exposure, drought, and temperature. Sedge plants were observed as brown and dormant in August, and lots of seed had been dropped in the heat of summer. The annual variation in the timing of inundation of the elevations 639m to 651m means the challenges to re-vegetation in Carpenter Reservoir span the spectrum from early flooding to extended arid conditions. Kellogg's sedge has proven a highly resilient native species under these extremes.

The success of planting Kellogg's sedge led to use of the species in conjunction with other treatments. In 2016, a small plot of sedges was planted within fall rye seeded areas (PLG16-04) (Figure 25) (Scholz, 2016). The sedges planted within the fall rye area had 100% survival in 2017, but were not fruiting like the nearby PLG1601 patch planted outside rye seeded area. Plants were also smaller, though having good vigor (Scholz and Gibeau, 2019a). In 2018 and 2019, PLG16-04 was observed to continue with 100% survival and excellent vigor and cover values equal to that of PLG16-01. Plants were mature and seeding one year later than in areas planted, but not seeded with fall rye. It may be that planting among fall rye slowed initial growth. Though not a statistical measure, after three years in the ground, the plants in PLG1604 (fall rye seeded area) seemed more consistently robust and vigorous than in polygon PLG16-01 (also showing excellent vigor but was not seeded with fall rye). It was hypothesized that there may have been a latent benefit from increased biomass on the site from having had fall rye sown and grown on the planting site. It will be interesting to have follow-up monitoring and comparison of growth from these trials.

Kellogg's sedge planting was maintained as a focal treatment in the final two years of the program, with an emphasis on planting patches of sedges across areas that were treated with mounding, as well as across Low Mud Flat areas that were seeded with fall rye. Areas mounded in 2019 were planted one year later in 2020, a year post inundation. Early observations were that the sedge plugs put on excellent growth after initial planting in 2020 (Scholz and Gibeau, 2021). Follow up monitoring in 2022 through the BRGMON-2 program will be useful in longer term results.

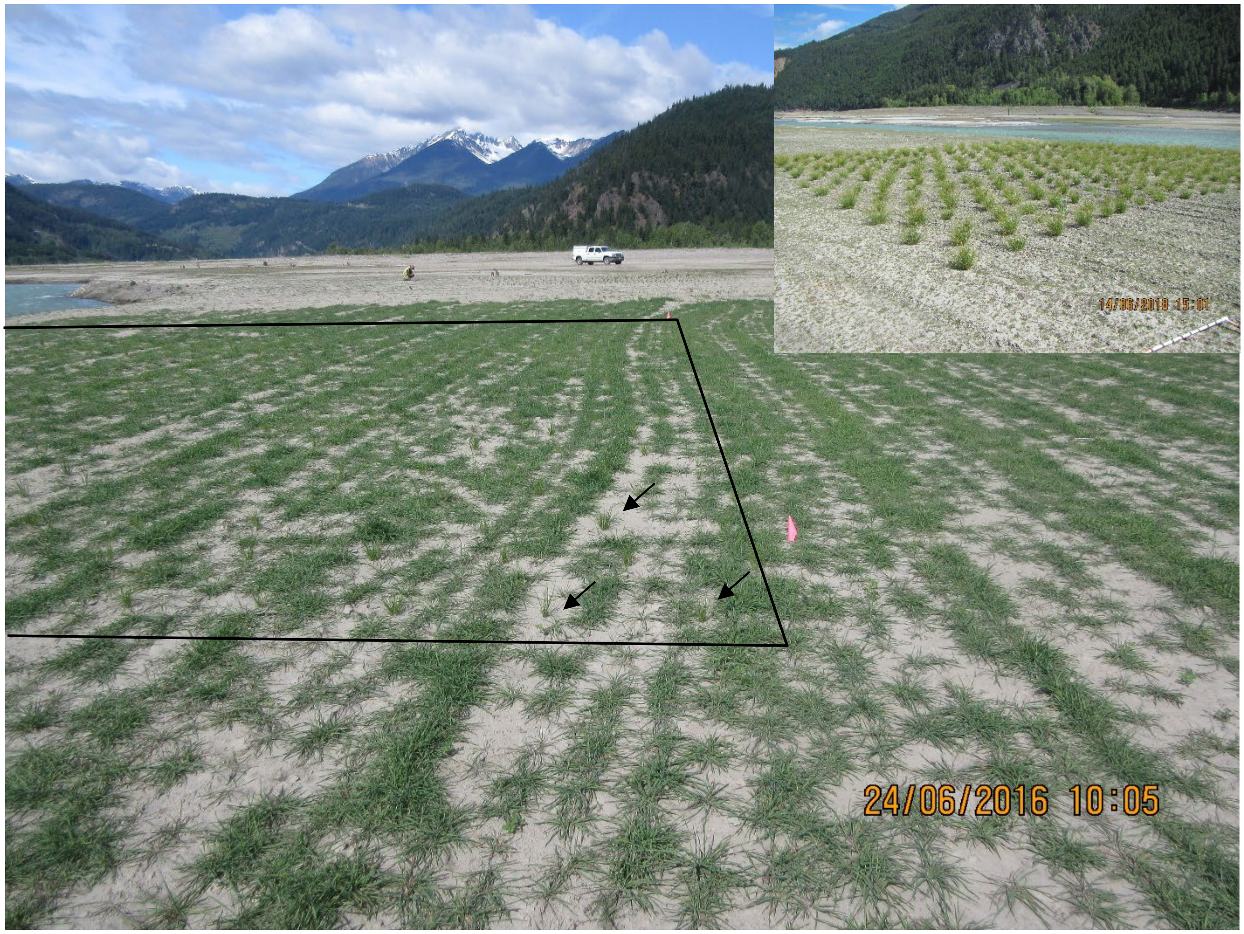

Figure 25 PLG16-04, Kellogg's sedge plugs planted in area seeded with fall rye in 2016. Planted area outlined and several sedges pointed out as visual aid. Inset photo same patch 2 years later in 2018.

Kellogg's sedge plants planted in 2016 on the Low Mud Flat in PLG1601 grew fast and were vigorous with heavy seed production observed in mature plants at the time of monitoring in June 2018 (Figure 26). In subsequent years, thousands of seedlings were observed germinating from this dropped seed. Most seeds were observed lying below parent plants. In 2020, dozens of young plants (second generation) were observed to have established from this seed (Scholz and Gibeau, 2021). In 2020, seed production was very high in these planted patches. The patches were harvested for the seed, the seed was cleaned and slightly dried, and then was transported and resown across widely spaced patches in 2020. The sedge plantings carried out in 2016 have been some of the most successful treatments through the program and were a large driver in the continued focus on planting patches of Kellogg's sedge.

Small areas within the large healthy patches of sedges planted in 2016, were observed to have plants with smaller growth and low vigor. A follow-up investigation into site conditions was conducted in 2019. A distinct correlation between the depth of the layer of fines and plant vigor was observed (Scholz and Gibeau, 2020). The investigation indicated that plants in fine, silt soils of depth greater than 40cm were growing significantly better than those where soils were shallower than 40cm.

Figure 26 PLG01 Kellogg's sedge patch as seen in June 2017 one year post planting, notable patch with smaller plants with lower vigor indicative of shallower silt layer.

Of the native grass species utilized in BRGWORKS-1 trials, bluejoint reedgrass, showed the most promise in terms of plant establishment and robust growth on dry mid to upper elevation sites. Bluejoint was planted at numerous sites on the Gun Creek Fan East and West. Plants below 642m struggled even in mounded polygons. Patches above 644m have done well in places. Like Kellogg's sedge, some natural plants and stands of bluejoint were observed growing on the Gun Creek Fan West side. Plantings were carried out near natural patches of bluejoint and may expand grass cover on the fine sandier soils of the Gun Creek Fan East and West side. The species provides perennial cover where few if any other species were growing. Follow up visual monitoring of planting sites is recommended for the last year of the BRGMON 2 program.

Canada wildrye has also done very well in the small trial plant of 1-gallon pots at about the 646 m elevation on the Gun Creek Fan East. These plants were observed to survive without inundation, and the species was incorporated into the planting mix for the upper elevation mounded polygons in 2017. In 2020, it was observed that Canada Wildrye was establishing outside of the planted areas. It is apparent that as with Kellogg's sedge in the Low Mud Flat, Canada wildrye is able to reproduce from the seed of mature plants and disperse and grow in the upper elevations above 647m. Plants have survived well in mounded polygons. ***Canada wildrye appears a good candidate native grass species to introduce in the upper drawdown zone areas between 646m and 651m. Caveat: During monitoring period plants had not experienced inundation.*** Since 2020, some of the elevations where Canada wildrye was planted have been inundated. It would be useful to know how well these plants have fared by a visual monitoring of the sites in 2022.

Foxtail barley survived plantings very well. The plants do not bring much biomass to a site and only provide limited browse and cover for wildlife, but are reported to have a fibrous root system. Foxtail barley has survived plantings again at higher elevations >644m.

Fowl bluegrass and **slender wheatgrass** have been observed to have survived in upper elevation plantings. It is difficult to say yet if they are established and dispersing on site. Future monitoring may indicate how well plants hold their vigor in the drawdown zone environment and whether there is any indication of dispersal or expansion and spread.

A small number of **common horsetail** plants were planted on the Low Mud Flat in 2019. Some of these plants survived through to 2020, so several more patches of the plant were planted across the Low Mud Flat and within the 2019 mounded polygons on the LMF in 2020. **Scouring rush** (Equisetum hyemale) was planted in small patches within mounded and LMF sites in 2020. There has yet to be any monitoring of the survival and response to these treatments.

Shrub species including **willow species**, sandbar willow, **mountain alder** and **red-osier dogwood** have been planted into the upper elevation mounded polygons on Gun Creek Fan East and West. These species have shown initial survival in upper polygons monitoring in 2022 and should reveal if plants have established well and are thriving.

Sandbar willow (Salix exigua) cuttings were rooted in deep pots (60cms) and planted in a small trial near Gun Creek on the East side. These plants were showing very strong vigor in the first-year post planting and should be included in the 2022 monitoring to assess plant vigor and growth.

Black cottonwood was assumed to be a key riparian species and important species to include in treatment trials. Container stock cottonwoods were planted in small patches on the Gun Creek Fan East and west sides in 2016 (Scholz, 2016). Subsequent monitoring showed plants struggled to survive. Cottonwoods were planted into upper elevation mounded polygons in 2017. These plants in 2020 were showing very strong vigor and growth. Monitoring in 2022 will inform as to how these plants have persisted post inundation. Some black cottonwood cuttings were also rooted and planted out in 2016 in the same patch as the sandbar willow. Initial results showed good growth in the second growing season on site.

Trembling aspen was planted in one patch on the Gun Creek Fan west side in 2016. All of these plants were observed to have died by the 2017. This was the only use of the species. In retrospect, it would have been good to include some of this species in the uppermost mounded sites in 2020.

3.4.2 Live Stake Cuttings

Survival results were monitored through the BRGMON-2 program. In general observations included;

- Willows tended to show better survival than cottonwoods.
- At all cuttings sites, except the mounded areas, cuttings survival dropped by about 50% the first year then continued a steadily decline. (Mounded sites on the Gun Creek Fan West side are maintaining the highest percentage of survival through2020).
- Extensive staking in 2015, including large diameter cuttings (5-10cm), resulted in very low survival. This result is confounded by the relatively early inundation.
- Arid conditions and coarse substrates of the upper drawdown zone treatment areas add challenging conditions for cuttings establishment, as treatment elevations are well above the water table when not inundated,
- Leaving cuttings long had no observable benefit and likely reduced survival success. Anecdotally, beaver cut some of the cuttings and often these were the cuttings that seemed to be showing the best vigor.
- Deer browse has been observed on cuttings; however, it is unlikely that this was a major factor in the lack of successful establishment. Cuttings in mounded polygons were exposed to the same browsing pressure, but these have performed well.
- It was difficult to replicate the same handling conditions and weather exposure over the years of the treatments. Variations in timing of planting and weather could have been major factors in cuttings survival.
- Mechanical damage from winter ice and driftwood had negative impacts on cuttings and adds reason to keep cuttings cut short when planting.
- Observations lead to a small trial of planting long-rooted cuttings in 2019, Cuttings were rooted in .6m long containers and were planted at depth near Gun Creek. In 2020, observations cuttings were surviving well with good vigor.
- The rebound of cuttings from the low elevation 2014 site is a very interesting result. The site was literally devoid of vegetation for two years before new sprouts were observed. These cuttings were damaged by ice in 2015-2016. It can be assumed that the low elevation cuttings (644m) planted to depths of 1-1.5m in 2014, would have been the only cuttings to receive some moisture (subsurface) from the full pool level when planted in 2014 (642.97

Table 9 Summary of monitoring results from BRGMON-1 studies of Cuttings, Complete monitoring was not done every year.

Year	Monitoring summary 2014 stakes	Monitoring Summary 2015 Stakes	Monitoring Summary 2016 Stakes	Monitoring Summary 2017 in Stakes Mounds	Site Notes	Adjustments
2015	Between 5%-50%, Gun Creek Fan West highest survival, Gun Creek Fan East lowest survival	NA	NA		-Coarse soils had lower survival, -Cottonwoods higher survival than willow on coarse soils. GCFE -2014 Live staking was carried out in the middle of summer,	- Plant early
2016	6%- Overall survival, best patches Steep beach 22%, Gun Creek Fan West 30%,	9% survival overall, best patch survival 70% was hand planted GCFE Close to Gun Creek	Early survey of cuttings 73% showing leaf out.		-Decline in 2014 survival, -Poor take overall from 2015 effort, -Cottonwoods poor survival, -Significant mechanical damage from ice. -Deer browse on 2016 cuttings and beaver cutting on about 5% of 2015 cuttings.	-Located 2016 live staking in the Buffer zone to avoid ice damage. -Emphasis on willow vs cottonwoods.
2017	STB- 13%-22% SHB-				-Most live stems were only green from base of stem. -Beaver cut stems seemed to be alive	-Keep cuttings short,
2019	GCF sub sampled- 6%	GCFE sub sampled 10%	GCFW sub sampled 3%	46% survival	-2017 cuttings all high vigor	-Steady decline in survival and most low vigor. -Notable rebound in cottonwoods at 2014 site observed dead in 2017, now with numerous live cottonwood saplings.
2020	GCFE- 21% surviving at rebound site					

3.4.3 Physical Works

The early trial physical treatment sites where rock mounds were built by hand had no observable impacts on planted cuttings survival or species recruitment (Figure 27). Most of the cuttings planted along with these built features did not survive, and no further hand treatments were applied. It is possible that over a longer period of time, these features may have an effect on vegetation recruitment and may warrant another visual survey of these sites during the BRGMON-2, 2022 survey. During surveys in 2022, particular attention should be paid to any differences in substrate as well as vegetation cover that may be associated with the rock features relative to surrounding substrate.

Figure 27 Example of a hand build rock feature constructed as part of 2015 treatments.

Machine mounding treatments first implemented in 2017 and monitored the following year showed no immediate benefits from the treatment. Total vegetation cover, exotics and native species, was lower in mounded areas in the initial year following treatment than in control areas[4]. Species diversity was higher in mounded treatment areas and, in particular, native species cover was higher in mounded polygons. The occurrence of native species diversity

[4] Control area vegetation was almost entirely made up of exotic, annual, vegetation species.

and cover in mounded sites was almost solely the result of them being planted and seeded (Scholz and Gibeau, 2019b). It was observed that, following the first inundation within the mounding treatments, there was a high degree of soil settling that occurred (Figure 28). Many of the plugs planted immediately after physical works treatment had been lost or partially extruded from the fine soils at the Low Mud Flat polygons (Figure 29). Settling and wave action had; eroded, compacted and smoothed soils. The exposure of roots caused stress and mortality to the plants. These observations lead to the recommendation to wait for one inundation cycle before planting. Post inundation, the soils would be more stable and therefore substrate and plants would be less susceptible to future hydraulic forces (Scholz and Gibeau, 2019b). In 2019, areas mounded in 2017 were re-planted (fill planted) with Kellogg's sedge plugs (Scholz, 2020). This delayed planting approach was carried forward and areas that were mounded at low elevations in 2019 (MW1900B, MW1900C, MW1900D) were left fallow for a year prior to planting and seeding in 2020, the final year of treatments. ***These areas will need to be monitored in 2022 to assess this adaptive management decision.***

Figure 28 Examples of mounding treatment immediately post treatment on the left (MW1900A), and one year post inundation on the right (MW1900B).

Figure 29 Example of sedge plugs extruded from the substrate one year post planting and post inundation on Low Mud Flat Polygon (MW1702)

In 2018, Kellogg's sedge seedlings were observed to have colonized in the mounded and seeded polygons. This was the first time Kellogg's sedge seeding had resulted in observed germination and growth or establishment. The question was raised by project SME's whether the mounding or raking was to account for germination as seeds were raked in. An observation was made of Kellogg's sedge seedlings growing in mounded polygon MW1704MP. The seedlings were situated in a depression directly beneath a mature, residual plant. It was obvious the seedlings were the result of seed produced by the mature plant. This area had not been raked and thereby provided a partial answer to the question. The introduction of seed was more of a critical factor for colonization, germination and sedge establishment at these sites. However, seed alone did not prove successful on the Low Mud Flats based on the 2015 and 2016 seeding trials on the un-mounded low mudflats (Scholz, 2015. Scholz 2016). No detectable germination or colonization of sedge was detected from these trials. It appeared that mounds provided improved physical conditions that increased colonization, either by increasing retention of added seed and/or enhancing microsite growing conditions. ***The combined mounding and seeding treatments have proven to be a method of increasing colonization by at least one native perennial sedge species.*** Mounding alone has not shown much of an increase in native species colonization and establishment up to 3 years post treatment. Several rare occurrences of native species that were observed in lone years included: Arctic lupin (*Lupinus arcticus*), golden corydalis (*Corydalis aurea*), small-winged sedge (*Carex microptera*), and American sloughgrass (*Beckmannia syzigachne*). The colonization of the mounded sites by these 'new' native species is a positive result as some of these species may persist on site and prove successful over the long term relative to the lack of new recruitments on the control areas.

The machine mounded polygons located at the mid and upper drawdown zone elevations (above 647m) on both the Gun Creek Fan East and West sides, as of 2020, had not been exposed to inundation. Planting was applied as a co-treatment to mounding within these polygons in the same year as treatment. This decision to not wait a year was based on the assertion that, given the target maximum full pool was 648m, these upper elevation sites were unlikely to be flooded, and were in fact more likely to experience environmental terrestrial stresses such as drought and invasive species. These mounds were hand-irrigated through the initial growing seasons, and spotted knapweed (*Centaurea stoebe*) was managed by hand-pulling. The soils in the upper elevation polygons on the Gun Creek Fan West are unconsolidated coarse sands and fine gravels. Much of the surficial substrate consists of drift like deposits of a light pumice rock, residual ash from the Mount Meager volcanic eruption approximately 2,400 years ago (Earle, 2019). Over the years of inundation this light weight mineral has accumulated on the upstream side of the Gun Creek Fan. These substrates are highly mobile and susceptible to water erosion and wave action. Water levels in 2020 (post monitoring) and 2021 were high enough to inundate at least parts of the upper elevation mounded polygons on the Gun Creek Fan West. In particular those mounds created in 2017, MW1708 and MW1709 would have been inundated. ***It is recommended that these polygons be monitored as part of the BRGMON-2 final survey in 2022.***

The riparian enhancements implemented in the final years of the BRGWORKS-1 program drew from program observations and experience. Final treatments included combined mounding with seeding and planting. Planting and seeding treatments were applied to mounds constructed in the previous year. These mounds had been inundated over the winter of 2019-2020. In the Buffer Zone mounded polygons, upland and drought tolerant ponderosa pine seedlings were planted in addition to riparian species. It was observed through the project that drought stress was as much or more of a survival factor for vegetation in the upper drawdown zone. Pine was selected over Douglas-fir for its drought and flood tolerance, as numerous observations had been made from around the reservoir as well as from along the lower Bridge River, of young Douglas-fir trees killed by flooding in places where young ponderosa pine had survived. ***The sites planted and seeded in the final year of the BRGWORKS-1 program should be a focus of monitoring in 2022, the final year of the BRGMON-2 program.***

Another observation from the program was that the variation in size of mounds did not seem to have an impact on vegetation colonization response (Scholz and Gibeau, 2021). The large mounds created in 2017 on the Low Mud Flats did not show greater diversity of cover in native species than smaller mounded sites. This leads to the question of how large or small do physical treatments need to be in order to provide conditions for improved recruitment and growth, if paired with other treatments, including seeding and planting? Trials using smaller scale, but broader area physical treatments may be useful to trial in the Carpenter Reservoir drawdown zone. One type of treatment to test on the fine substrate of the Low Mud Flats would be land imprinting (Bainbridge, 1996). Land imprinting is a restoration technique applied to situations of desertification. The treatment involves a mechanical process that converts the smooth-sealed and compacted dry soil into a rough-open surface with a capacity for infiltration and rainwater retention. Imprinters push large angular teeth into the soil surface to form diamond V shaped funnels that improve rainwater infiltration, seed retention, while reducing runoff and erosion and aiding in seed capture and plant establishment (Dixon, 1990). Land imprinting roughens the surface at a 10^{th} of the scale compared with mounding (20-30cm vs 100m) and in the reservoir these features may be temporary due to the flattening effects of repeated inundations. That said, land imprinting in conjunction with seeding Kellogg's sedge and planting sedges may last long enough to provide improved short term microsite conditions enough to facilitate seed germination, and plant establishment. The fine homogenous silt substrates of the Low Mud Flats imprint well . Fine scale furrows made by plough tines and a tractor were still visible several years post treatment (Figure 30). Imprinting may provide enough microtopography to provide improved colonization and recruitment conditions prior to being leveled under repeated inundation.

Figure 30 Left image: furrows created by tractor during 2019, same area furrows one year later, post inundation, diminished microtopography was still apparent in 2021.

3.4 Dust Storms

The first management question for the program is addressed under the null hypothesis:

H_1: The planting of vegetation in the drawdown area does not mitigate the effects of dust storms resulting from reservoir drawdowns, particularly in the western end of the reservoir near the town of Gold Bridge.

Analysis of the photo imagery and weather data gathered from the BRGWORKS-1 treatment area of Carpenter Reservoir drawdown zone from 2016 through 2021 revealed that wind erosion was observed to occur from instream fluvial bars and the river banks when the reservoir was low. These erosion sites are low elevations below 639m and are river erosion and deposition sites. Fine sediments exposed by the river's hydraulic forces are dried and mobilized into the air by the strong westerly winds. Throughout the program we saw dust originating from very specific sites such as identified in Figure 31. Combined data of wind direction and wind speeds (Figure 32) indicate that throughout the year the majority of all stronger wind events occur as westerlies. It was seldom seen that dust was originating directly from the flat surfaces of the mud flats. On the Gun Creek Fan east side and mud flats, small dust events were recorded emanating from access roads that were driven on regularly by site users, including BRGWORKS-1 field crews. Throughout the study the majority of the storms were classified small in size (See summary figures in Appendix). The action of vehicle disturbance of the substrate created physical disturbance to the soils that allowed them to dry and then be mobilized by wind (Figure 33). An additional observation from the study is that, in addition to wind, a secondary disturbance is required to create conditions that generate dust. The prevailing wind direction from the west to east is beneficial in that there are few instances when the town of Gold Bridge is directly affected by dust from Carpenter Reservoir. When all of the mud flats east of Gun Creek are inundated, around 642m, with the exception of vehicles and road surfaces, dust storms cease. Key points resulting from the dust storms study are:

1. Dust originates from very localized sites,
2. Dust is principally generated from within the zone of the bank-full width of the Bridge River during Carpenter Reservoir low pool.
3. The principal winds are westerlies blowing from west to east,
4. Most dust activity ceases when mud flats are inundated to 642m.
5. A secondary or (primary) disturbance is associated with dust generation at the site.

Figure 31 Left image thick dust arising from right bank of the river, dust mobilized and dispersed in an eastward direction as a cloud. Three main dust source sites eroding at once April 28, 2021.

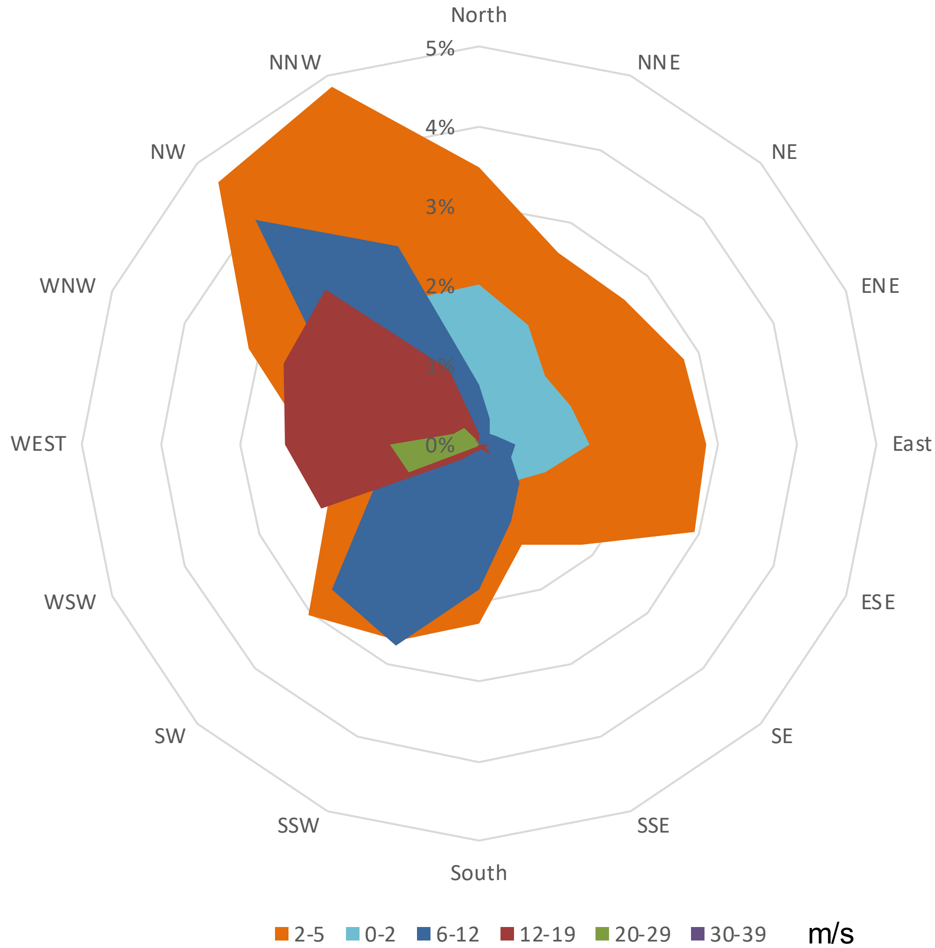

Figure 32 Summary of 2021 anemometer reading data from 5-mile weather station. Wind direction by strength and direction as per cent of all readings. Beauford scale classes in m/s.

Figure 33 Weather station photos from August 1 2020 showing small very localized minor dust events arising from vehicle traffic in top image and from along worn road in fine substrate in lower image.

3.5 Wildlife

Wildlife monitoring and observations were carried out to address the null hypothesis:

N3: The planting of vegetation in the drawdown area does not enhance the quality of riparian habitats nor does it increase their potential to support wildlife populations and provide localized improvements in the quality and productivity of aquatic habitats in Carpenter Reservoir.

It was shown by Perrin et al (2002), that benthic diversity was increased in reservoir drawdown zones where fall rye was sown. Organic matter from vegetation forms the basis for aquatic food chains (Palmer, 1997; Covich et al, 1999). Vegetation established through the BRGWORKS-1 program can be assumed to provide localized improvements in the quality and productivity of aquatic habitats. Quantifying habitat quality enhancement to support wildlife populations is difficult to assess. For large mammals, the current impacts are likely negligible within the scale of the reservoir. Smaller wildlife may benefit from additional biomass provided by seeded and planted vegetation.

Over the BRGWORKS-1 program years many observations of wildlife have been recorded as incidental observations (Table 10).

In addition to incidental observations, wildlife observations have come from other targeted studies (Table 11).

Table 10 List of wildlife species either direct or indirect incidental observations during the BRGWORKS-1 program implementation.

Species	Observation Notes	Steep Beach	Shallow Beach	LMF	GCFE	GCFW	SAF
Amphibians and Reptiles							
Western Toad (*Anaxyrus boreas)*	Mostly juveniles, concentrations have been observed along the edges of the Bridge River wilh sparse observations across the Low Mud Flat and mounded terrain. Reproductive ponds were observed in the Mid Mud Flat in 2013 (Scholz and Gibeau, 2014). Young likely disperse from upstream ponds onto mud flats.			X			
	Adults observed along reservoir waters edge and in small tributary creek on SAF.			X			X
Western Long-toed salamander (*Ambystoma macrodactylum*)	Single observation near Gun Creek on the Fan 2015, possibly connected to Gun Creek riparian dispersal.				X		
Western terrestrial garter snake (*Thamnophis elegans vagrans*)	Repeat observations usually juveniles on Gun Creek Fan and Low Mud Flats including in planted sedge plots and mounded areas.			X	X		
Alligator lizard (Elgaria coerulea)	Among Upper Buffer Zone driftwood				X		
Birds							
Ravens (*Corvus corax*)	On mud flats possibly feeding on seeds,			X	X		
Raptors, Osprey (*Pandion haliaetus),* Bald Eagles (*Haliaeetus leucocephalus*)	Often seed along Bridge River, perch on taller dead snags in the drawdown zone.			X	X		
Peregrine falcon (*Falco peregrinus)*	Hunting in area has been observed on Gun Creek Fan east side plucking prey. Evidence of pluck sites observed on stumps on mud flats and fan.				X		
Mountain bluebirds (*Sialia currucoides*)	Observed annually hunting on the Gun Creek Fan east and west side. Observed perching on stumps and planted cuttings.				X	X	
Savannah sparrow (*Passerculus sandwhichensis*)	Observed on Gun Creek Fan west side. Using cover in patches of bluejoint reedgrass.			X	X	X	
Yellow-rumped warbler (*Setophaga coronata*)	on mud flats possibly feeding on seeds,						

Species	Observation Notes	Steep Beach	Shallow Beach	LMF	GCFE	GCFW	SAF
Spotted sandpiper (*Actitis macularius*)	Often observed along shore edges of the Bridge River, a nest was observed with hatched egg in a patch of planted sedges on Low Mud Flat in 2018.			X			
Great Blue Heron (*Ardea herodias*)	Observed in shallow reservoir water on the Low Mud Flat			X	X	X	
Trumpeter Swan (*Cygnus buccinator*)	Observed in waters of reservoir and Bridge River around Gun Creek Fan			X			
Mallard (*Anas platyrhynchos*)	Observed in shallow water of reservoir and Bridge River around Gun Creek Fan			X	X		
Canada geese (*Branta canadensis*)	Observed along the flowing river and upstream west end delta. Scat and heavy browse observed among planted sedges. Scat indicated Kellogg's sedge seeds were being consumed.			X			
Mammals							
Mule deer (*Odocoileus hemionus*)	Tracks, scat and direct observations made on Low Mud Flats and on both Gun Creek Fan East and West side.				X	X	
Moose (*Alces alces*)	Tracks observed on Low Mud Flat			X			
Grizzly Bear (*Ursus arctos horribilis*)	Tracks observed on Low Mud Flat		X	X			
River otter (*Lontra canadensis*)	Scat and tracks along the Low Mud Flat edge of the Bridge River.			X			
Beaver (*Castor canadensis*)	All live stake cuttings sites had some sign of beaver cutting. Beaver stole some willow cuttings that were left soaking in river.	X	X		X	X	
horse (*Equus ferus caballus*)	Domestic horses, rare observed, mostly grazing higher elevations towards West end of the Reservoir.			X	X	X	

Table 11 List of sources of wildlife information gathered through the BRGWORKS-1 program.

Year	Monitoring	Survey notes	Species Notes
2014	Public survey	General reports from around Carpenter Reservoir.	Moose, deer, eagles, swans, other birds, wolves, mountain sheep, horses, coyote, geese, cattle, snow goose, trout, grouse, mountain goat, bobcat, raptors, grizzly and black bear, fowl
2015	BRGMON-2 monitoring plots	1X1m plots, Site specific, presence	Mule deer, Canada geese, cows, crows, tree frog, beaver, bald eagle,
2016	Breeding Bird Surveys BRGMON-2 plots	8 sites including restoration areas and control 1mx1m plots	28 species detected, Buffer Mud Flat highest richness and diversity (13 sp.). Low mud flats and Gun Creek lowest species richness and diversity (2 sp.) (Heinrich, 2016).
2017	BRGMON-2 plots	1mx1m plots- Transect plots surveyed on Gun Creek Fan East and West sides	Tracks and scat; Mule Deer, cougar, coyote, GCFE
2018	Breeding bird point count surveys. Amphibian auditory surveys. And opportunistic encounters BRGMON-2 plots	3 surveys at 8 sites, same sites used for both breeding birds and amphibians. 1mX1m plots	Breeding birds 38species detected, BMF- 22 species LMF- 9 species Amphibians' detections only at, BMF- Pacific chorus frog, MMF- Western Toad
2019	BRGMON-2 plots	1mX1m plots	Mule Deer Tracks and Scat-GCFE, LMF Rodent tunnels scat-MMF
2020	Targeted search for amphibians and reptiles BRGMON-2 plots	Carried out early July	No amphibians observed, Dry hot weather. Canada Goose Scat-GCFE, LMF Mule Deer tracks scat- GCFE, LMF

3.6 Aesthetic and Recreational Use

A summary of the responses made by 32 individuals who filled out surveys in 2014-2015 answering questions about aesthetics and recreation use in the Carpenter drawdown zone area.

Table 12 Summary of public survey and responses from 2014-2015 study.

Survey Questions regarding Aesthetics	**Summary of responses**
How do you rate the aesthetic quality of the Carpenter Reservoir?1 = Least Favourable4 = Most Favourable	Average response: 2.3
What provides the greatest aesthetic appeal to you?	Highlights: Green, Vegetation, Water, Full reservoir, where reservoir is more like a lake, area closer to Gold Bridge, trees, shrubs, mountains
What provides the least aesthetic appeal to you?	-Ocean of Grey, Dead trees, dry reservoir bed, barrenness, industrial look, artificial shorelines, mud flat area, brown mud
What would you change to increase the aesthetic appeal?	More trees, keep filled, more water, less water, plant trees, take out dead trees on shoreline, increase vegetation, more access to water, reduce dust storms
Do you have any other comments regarding aesthetic quality?	More fish

Survey Questions regarding Recreation Use	**Summary of responses**
Do you use Carpenter Reservoir for recreational uses?	60% replied yes
If YES, how many times per year do you use Carpenter Reservoir for recreational use?	Under 20 days = 89% 21-50 = 10.5% 51-80 =0.5%
What months do you use the reservoir for recreation?	July, August were the months most indicated they used the reservoir (Figure 34)
If YES, what recreational activities do you enjoy on Carpenter Reservoir?	Recreational use includes, fishing, kite flying, walking, dirt biking, snowmobiling, 4X4 driving, camping, canoeing, kayak, quad driving, gold panning, photography, cooling off in river, picnicking, beach bathing, mud bogging, bon fires, mountain biking, swimming, bird watching, wildlife viewing, exploring
What are the recreational values for tourists?	
What would you change to increase the recreational values?	

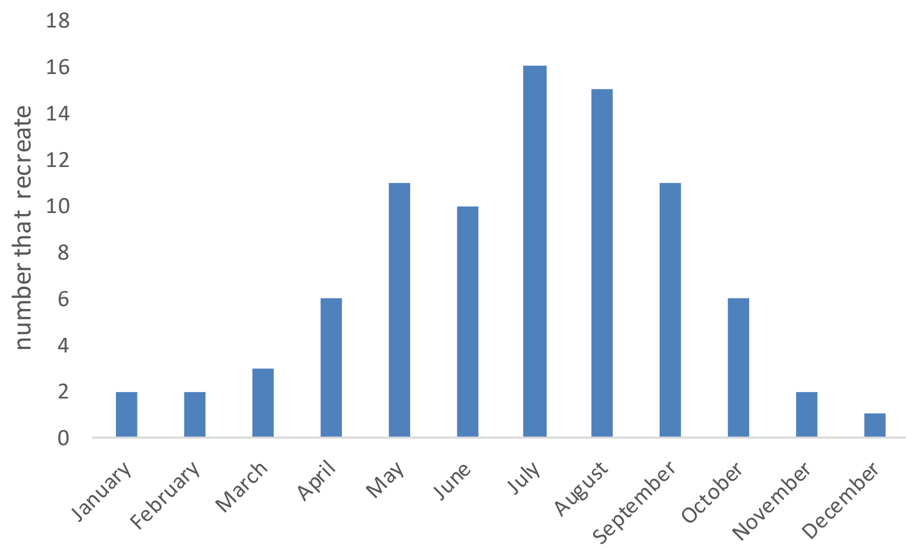

Figure 34 Summary of respondents who indicated months of the year that they recreate on Carpenter Reservoir (n=19).

The null hypothesis H_2: *The planting of vegetation in the drawdown area does not increase the aesthetic quality and recreational opportunities in the western end of Carpenter Reservoir.*

Answering this management question and null hypothesis is a challenge. Aesthetic can be rooted and influenced by both objective and subjective aspects (Lothian, 1999). What some people consider aesthetically pleasing can vary, and what people do for recreation can range broadly and even conflict, i.e. beach bathing, and hiking vs ATV racing. Regarding aesthetic quality, landscape perception has been described as being influenced by factors such as distance, observer position, form, spatial definition, light and sequence (Burton, 1968). Kalivoda et al. (2014) reference landscape elements that tend to influence aesthetic appeal include vegetation, water and meadows, as well as factors such as openness, colour contrast, and naturalness. Ode et al. (2009) found that one's perception of naturalness increased with increasing degrees of natural succession and woodland patches. In the case of the Carpenter Reservoir drawdown zone and the BRGWORKS-1 treatment area, throughout the year the area transforms from barren earth of the mud flats at low pool to a mountain lake when the reservoir is full. The delta mud flats to the west of Gun Creek fit well the description of green meadows. When the water reaches the vegetated Mid Mud Flats (644m), is perhaps the ideal aesthetic portrait of green meadows and green water (Figure 35).

Figure 35 Looking East Western mud flats, west of Gun Creek fan, horsetail, sedge meadows and middle Bridge River. Elevation 646m. A case could be made for high aesthetic values. (02 July 2014. (*O.Scholz*.)

Water and vegetation were emphasized as driving the aesthetic appeal in the 2014 survey results (Scholz, 2015). Aspects of the reservoir that contributed to low aesthetic appeal to survey respondents were: “when water levels are low”, “dead trees”,” barrenness”, “industrial look”, “steep gravel shores and sand flats”, “dead looking earth”. High aesthetic appeal was attributed to; “vegetation or water”,” full reservoir”,” water and trees”,” water and green grass”,” colour of reservoir for full length of reservoir”. The objectives of the BRGWORKS-1 program were to assist the establishment and growth of vegetation further into the reservoir drawdown zone. The more area of the drawdown zone that is vegetated and green, the more area that is more aesthetically appealing, and the shorter the duration that barren mud flat areas are exposed. It may be argued that at the fine scale, the BRGWORKS-1 program has improved the aesthetic of the drawdown zone; over a broader area the impact has likely been negligible. The physical mounding treatments have definitely drawn interest to the site, as members of the public have been drawn to the site and wondered what was being done. Signage added by BC Hydro in 2020 states that “something is growing here” and may have helped inform of the WORKS-1 efforts. Over the course of the program, one member of he public made a point of remarking that the large area of fall rye seeding “made the site look good”. Over the course of the BRGWORKS-1 program, we notice that the green vegetation cover provided by ephemeral exotic annuals varied from year to year Figure 36. While providing low ecological value, there is an aesthetic value to the annuals.

Figure 36 Photos from weather station represent small scale perspective across the BRGWORKS-1 area starting 2016 through 2021. Photos all taken from mid to late June.

Figure 37 Reservoir at full pool October 2021, 647.9 m, 10cm below the target peak 648m.

It was also mentioned several times on public surveys that aesthetically, the reservoir looks best when it is full, when it most would resemble a natural mountain lake (Figure 37).

Recreation use at the treatment site was addressed initially through the 2014 public survey (Scholz, 2015). Incidental observations of recreation use of the site were noted through both the BRGWORKS-1 and BRGMON-2 programs. Off road motor cycles and ATV use were fairly common as was fishing. These uses were also some of the easier activities to observe, perhaps biasing observations, as either the noise made by the activity or the length of time a participant spent in one place made observing the activity more likely. On two occasions, people were observed running a jet boat in the river at low drawdown. Fishers tended to be observed close to the Gun Creek confluence with the Bridge River. The BC Hydro Campground on the Gun Creek Fan, sees regular use and at times is quite full. Most campers appear to spend most of their time in the immediate campground area and along Gun Creek. Motor sport enthusiasts do utilize the mud flats. It is likely that awareness of the historic town site of Minto also draws people out onto the mud flats to explore. It is not out of the question that the mounding treatments have also drawn curious onlookers. It should be noted that recreation use reported also took place in the winter, which includes snowmobiling.

4. Discussion

4.1 Reservoir operations and local site conditions

The 7-year program on Carpenter Reservoir has provided the opportunity to conduct numerous riparian enhancement trials. The biogeoclimatic conditions for the area and the unique reservoir operations under the Bridge-Seton WUP program created unique conditions for vegetation growing in the Carpenter drawdown zone and hence challenges to the riparian enhancement program. The program focus was on identifying where and what native species and what techniques could be successful in promoting colonization of more of the Reservoir Drawdown zone. Treatments were implemented to address wind erosion, aesthetics, recreation opportunities and both aquatic and terrestrial habitat values. In the case of all values, increasing native vegetation cover through riparian enhancements was the goal.

A key factor driving the elevation that vegetation can grow down into the drawdown zone, is the length of time a plant has to complete its seasonal growth cycle prior to inundation (i.e. Accumulated Growing Degree Days). Growing season length, while dictated by climate, is by and large driven by timing of inundation in a drawdown zone. The WUP focus is on maximum and minimum elevations for Carpenter Reservoir, normal operations are to be between 606.5m and 651.08m. With 'reasonable effort', target full pool is not to exceed 648 mASL for the end of freshet in mid August (BC Hydro, 2011). Allowances and conditions are made for higher maximums and lower minimums. Within the maximum and minimum levels there are no guidelines. Through the BRGWORKS-1 program, we have seen that the timing of achieving full pool can vary by up to 4 months. With the variation in full pool there is also a variation in the timing the vegetated elevations are inundated in any given year. An early assumption for the program was that the heartiest plants (particularly sedges) would need approximately 50% of the actual growing season to survive in the drawdown zone. The associated elevation for this was estimated to be 643m (Scholz, 2015). From this assessment program, trials were targeted to be carried out to as low as 639.5m up to upper buffer zone 651m.

During the baseline BRGMON-2 study of the Carpenter Reservoir drawdown zone vegetation cover, it was observed that vegetation cover on the reservoir mud flats was as low as 644m and predominantly west of the Gun Creek Fan. BRGWORKS-1 efforts have been targeted for the Gun Creek fan east and west sides and for the mudflats to the east of the fan down to 639m. Also, two beach sites and one other alluvial fan on the south side of the reservoir were treated to assess whether riparian enhancements could be effective to increase native vegetation cover.

The median and average inundation dates through the 7-year period of the BRGWORKS-1 program (2014-2020) are different, when compared to the previous WUP period dating back to 2000, as well as the 10-year sample period prior to the inception of the WUP in 2000 (Figure 18). The WUP period prior to 2014 and the pre-WUP period had very similar mean and median dates for inundation of the 639m-640m elevations. The seven-year BRGWORKS-1 period had an additional 2 weeks prior to inundation of this low elevation (i.e. more growing degree days for vegetation). Perhaps even more relevant, in the latter 5 years of the program, inundation of 639m occurred in mid-July, a month longer growing season than in the previous periods (Figure 11). This longer growing season is beneficial to the establishment of vegetation lower into the Carpenter drawdown zone as the area is increased where plants experience enough growing degree days to complete life cycles including reduced periods of inundation. Longer growing degree days allows for seeds to germinate establish and mature plants time to complete reproductive cycles. The difference in inundation timing during the BRGWORKS-1 period has provided more positive conditions (except 2014-2015) for elevations where treatments have been implemented. Corresponding to inundation timing, the median low pool elevations for Carpenter were lower than the WUP and pre WUP averages during the BRGWORKS-1 program and particularly so for 2016-2020. It would be worth further study to determine if lower drawdowns in Carpenter mean later inundation at 639m. More investigation, perhaps through BRGMON-2 study, to determine if lower Carpenter low pool levels equate to a longer growing season for a greater area of vegetated drawdown zone would be worthwhile. If so, it may possible to identify a low pool target that could result in maintaining a broader area of vegetated drawdown zone. This type of target could be included in future WUP planning. Without question, future hydrographs and reservoir operations will, for better or worse, have a major influence on the persistence of low elevation vegetation in Carpenter Reservoir.

Within the BRGWORKS-1 program, annual treatments were initiated as early as mid April soon after snow melt, and they ran as late as early July. Implementing treatments as early in the year as possible, was important for early plant establishment and survival, and was the only treatment parameter that could try to address the stresses of early inundation particularly for Low Mud Flat elevation treatments. Early planting and seed sowing maximized the time available for germination and growth prior to inundation. It also allowed plants to take advantage of the higher soil moisture levels in the early spring. This would be particularly the case with young seedlings with limited root volume and area. More mature plants would be more tolerant of arid late spring conditions prior to inundation. April is the driest month in the region, and late spring and summer precipitation can vary annually. In general, the IDFxc is a dry biogeoclimatic zone. When exposed the barren conditions of the targeted drawdown zone area of the riparian enhancement project, late inundation means stresses such as weather, low precipitation, browse and other disturbance become bigger factors in plant survival particularly for young plants. Our program shifted to include more irrigation, particularly for higher elevation polygons planted with trees and shrubs that were unlikely to be inundated.

4.2 Seeding treatments

Several species were seeded through the BRGWORKS-1 program. Domestic annual grass fall rye was seeded over the broadest area of the Low Mud Flat. Being an annual, the grass needs a fairly long amount of time to put on enough biomass to exceed the biomass produced by ephemeral exotic annuals. Structurally, fall rye produces more cover than the naturally occurring annuals, so may warrant continued use. Further, it was found that the fall rye seeded areas had higher recruitment of sedge seedlings and may have had a latent beneficial effect on sedge plugs planted on the Low Mud Flats. The grasses may have trapped wind-blown dust and reduced re-suspension. Under inundation, the created biomass provides nutrients to the aquatic ecosystem. The big caveat is that if inundation occurs early in the year, there is very little biomass and therefore minimal benefit from seeding. The final year of BRGMON-2 monitoring may shed light on whether fall rye seeding is beneficial to native species colonization, establishment and growth.

Seeding native species, particularly perennial species, was more preferable than domestic species. Kellogg's sedge seeding has shown to result in increased sedge colonization in mounded sites, though actual seedling densities were low. Higher densities were sown in trials in 2020, and these sites need follow-up monitoring. Even with low densities, once established, mature plants will continue to produce seed annually and thereby raise the likelihood of future colonization, as other variables, such as inundation timing, allow. This process was observed as dispersed seed from planted sedge plants on the Low Mud Flat produced 1000's of seedlings, some surviving through to 2020. Planted sedge patches produced enough seed to enable harvesting from said patches and redistribution of the seed across broader areas of the mud flat. This is an ideal situation for restoration when it is difficult to gather enough quantity of seed from the local area to enable large areas to be seeded at once.

Seeding trials with Canada wildrye were carried out in 2014, and trials showed successful germination. Broader area low elevation seeding trials were carried out with Canada wildrye seed in 2016 in the hope that the wildrye may produce enough biomass. This trial proved unsuccessful; elevation was low and there was no evidence of seed germination. Planted Canada wildrye plants have dispersed seed in the buffer zone of the Gun Creek Fan, and this seed has colonized and produced mature plants. This observation, coupled with earlier trials, suggests Canada wildrye should be retained as a riparian enhancement species that can be seeded into upper elevations.

Monitoring of treatments sown at mid elevations of the Gun Creek Fan East in 2015 were only monitored in 2017, with no sign of seedling colonization. Theses sites may be worth looking at in 2022 to assess if any of these species – ticklegrass, northern wheatgrass, slender wheatgrass, fowl bluegrass - established over time.

Finally, meadow bird's foot trefoil was sown in trials in 2019 and 2020. The species is of particular interest as it is native, is an annual and a legume species. Further, it has been observed growing naturally in dense patches on the Low Mud Flats and at mid and upper drawdown zone elevations (642m- 647m) on steep beaches and alluvial fans. This has enabled seeds to be gathered with reasonable ease. Treatments need to be monitored, particularly the heavy seeding carried out in polygon MW1900F (Scholz, 2021). Ideally this species will be successful if plants from sown seed mature and seed themselves on site.

4.3 Planting Container Grown Plants

Kellogg's sedge was by far the most effective planted native species treatment for the lower elevations down to 640m. The ideal elevation range for planting sedges is between 640m and 644m on the Low Mud Flats. These areas are fine silt soils, and plants are doing best where the blanket of silts is deeper than 40cm, caveat being these observations are based on the BRGWORKS-1 inundation patterns. Seeding sedges has shown effective when applied in mounded treatment sites. Larger area seeding trials will require monitoring in 2022, but should result in colonization. Again, the annual uncertainty with water levels and inundation timing is a major factor in plant survival, particularly with young seedlings.

Planting Kellogg's sedge on the Low Mud Flats and in mounded polygons has been observed to result in plant establishment, survival, reproduction, dispersal, colonization and establishment, one of the key objectives of the program. Planting treatments also resulted in seed production in quantities that enabled their harvest and resowing as part of the broader area enhancement effort. Wildlife have utilized planted sedge patches for nesting, cover and browse. Several other treatments involving native species have included planting common horsetail and smooth scouring rush as well as seeding with the native annual meadow bird's-foot trefoil. Initial observations have shown some potential for success but these treatments require more monitoring

A mixture of grasses, including bluejoint reedgrass, fowl bluegrass, foxtail barley, was planted into the Low Mud Flat mounds in 2017, but none of these species has been observed surviving at this low elevation (640m).

At mid to upper elevation sites (644m-650m), planting native perennial grasses such as bluejoint reedgrass, fowl bluegrass, foxtail barley and Canada wildrye, have shown to be successful, particularly with Canada wildrye and foxtail barley which have, like Kellogg's sedge, dispersed seed and seedlings have established. Further monitoring to assess success under varied hydrographs and higher peak pools of 2020 and 2021 is necessary. Bluejoint reedgrass has the potential to spread vegetatively through rhizomes. Further assessment of planted sites will be necessary to assess the plant dispersal and vigor over time.

At upper elevations, planting native tree and shrub species within mounded polygons has had positive results. These species need to have some drought tolerance, in addition to being able to survive flooding. Further monitoring is required, as plants need several years to establish after planting. Irrigation of planted plants was adopted more rigorously through the program, and it is recommended that it be continued until plants are established in their 2nd or 3rd growing season. Bark mulch was also added in patches around planted plants in the mounded sites in the buffer zone elevations to improve moisture retention in coarse soils. This was only done in the buffer zone elevations, as mulch was less likely to be washed away than at lower elevations. The very low natural recruitment rate meant that planting was key to increasing native species presence and cover in mounded areas, at least in the short term.

4.4 Live staking

Using live stake cuttings has met with relatively poor results within the program. While staking willows, cottonwoods and red-osier dogwood is a common riparian enhancement and restoration technique, the dry conditions and coarse rocky soils have made it difficult for them to establish. Cuttings needed to have survived 3 years before they could be considered successful. Cuttings planted in mounded areas have proved more successful in certain polygons, which seems at this point to be limited to elevations just under the buffer zone target at 646-647m. If this proves to be a 'sweet spot' for live staking it may be worth considering targeted treatments at said elevation. Further monitoring is necessary to determine longer term success of these cuttings' treatments. Container rooted cuttings of cottonwood and sandbar willow planted on the Gun Creek Fan East side showed excellent initial success after one year, but this will need follow up monitoring to assess if plants have survived 4 years to determine whether this is a successful technique. If these plants have survived well, this technique may be the best approach to getting vegetation established on the coarse unconsolidated soils of the steep and shallow beaches.

4.5 Physical treatments

Physical mounding appears to have created better conditions for survival of planted plants and live stakes at upper elevations. The treatment seems to be necessary for more consistent survival at the upper elevations. These sites had not experienced inundation when monitoring was last conducted and reassessing sites will be necessary. At lower elevations, mounding alone had no immediate benefits to vegetation cover, but when coupled with planting and seeding treatments, results were improved. This suggests there is no immediate recruitment effect from mounding alone. This could change over longer periods, as the annual variability in inundation timing could bring in propagules when timing is right. Adding seeds and plants was viewed necessary, in addition to mounding, in order to speed up recruitment of native species. Treatment of mounded sites that were going to be inundated were delayed one year, so soils could settle, and plantings would be struck in firmer soils less susceptible to erosion from inundation and wave action. The deep loosening and mixing of the substrate that occurs through mounding creates better substrate conditions and should through decompaction, avoid the observed die-off of plants that were planted on the Low Mud Flat in un-mounded soils shallower than 40cm. The results of the shift in treatment approach to waiting a year before planting has yet to be monitored, and monitoring may shed light on this delayed approach to low elevation mounding. Seed colonization and seedling growth has been observed in both mounded and non-mounded treatments (the latter with seed dropped by planted plants). We first observed seedling growth from sown seed in mounded polygons. Mounded sites provide more varied microsites and places for seed, sediment and nutrient capture, and may result in increased diversity of native species over time. BRGMON-2 monitoring results to come in 2021 well be needed to assess 2020 mounded area seed treatments and confirm this treatment approach.

The mid and upper elevations of the Gun Creek Fan east side are very coarse and rocky, largely skeletal substrates. Mounding in these areas exposed a lot of rock, so only sections of these mounded sites were actually plantable. Longer term, these sites may capture seed and promote vegetation growth.

Mechanical treatments of discing and tilling only was carried out on the Low Mud Flat to determine if this shallow physical treatment alone may result in benefits to seed recruitment. There did not appear to be a benefit from this treatment alone in the short term. There may be room to test some mid-level physical treatments, such as land imprinting used in desert restoration projects (Bainbridge, 1996). Imprinting may produce deeper substrate modifications than tilling, smaller than mounding, but still provide enough texture and microsite creation for seed capture, germination and growth.

4.6 Disturbances, Invasive species

The upper mounded polygons on the west side of the Gun Creek Fan were coarse but not as rocky. On the west fan exotic species invasion has proved a problem for mounded polygons. Spotted knapweed is invading the site in high densities, and yellow toadflax is also present. Both are provincial noxious weed species. Spotted knapweed is known to have allelopathic effects on at least some species (Rice, 1984). Knapweed needs long term management due to extended seed viability. Both species are reinvading the mounded areas post mounding. The plants were treated by pulling and removing them from site in 2020 and 2021.

Dust storm monitoring through the program indicates that the source sites for dust generation are along the banks of the Bridge River. These sites are below 639m elevation, and with current reservoir operations, would not support vegetation that would protect the substrate. The dust generation is also dependent on the hydraulic erosion taking place by the river. Erosion of the unprotected river banks has been noted through the BRGWORKS-1 project where literally meters of river bank can be eroded in a season (Scholz and Gibeau, 2021). Sedge plantings along the Low Mud Flat can do little to protect the soft, fine river banks from erosion (Figure 38), as their root system does not have enough tensile strength to resist the erosive forces of the river.

Figure 38 Patch of planted sedges on the Low Mud Flat being eroded by river flows.

Site disturbance was also caused by all-terrain vehicles, 4x4's and off-road motorcycle recreational uses. . Repeat vehicle disturbance has caused soil disturbance on the Low Mud Flats and some pressure on mounded areas. It is difficult to say if there were major losses to the disturbance, as sedges do seem resilient. More off-road vehicle disturbance was observed in the larger mounding polygon in MW1701, created in 2017. The larger mounds were an attempt to create riverbank-like contours that may promote seedling establishment (Figure 39). The larger mounds were surrounded by a more typical mounding pattern to discourage access by vehicles. Some vehicle access has occurred, mostly off-road motorcycles. Damage from access has been relatively minor. More extensive disturbance from motorcycles, all-terrain vehicles and 4X4's has occurred on the surrounding mud flats where flag markers used for marking treatment sites were used as racing targets by motorbikes. All flags and obvious markers were removed after this. Some of the more methodical mounding has had some entry by motorcycles, although this has been limited. The potential for physical works sites to be utilized by off road vehicle recreation enthusiasts must be considered in physical works treatments when sites are frequented by off road vehicles. The Low Mud Flat drawdown may be a good site for testing smaller physical treatments, such as land imprinting as a treatment that would be less attractive to off road vehicles, as there would be no banks or jumps, and just consistently very rough ride.

Figure 39 MW1701 mounding. Tire tracks can be seen within mounding treatment.

Revisiting Management Questions

MQ1: Will riparian enhancement in the drawdown area mitigate the effects of dust storms resulting from reservoir drawdowns particularly in the western end of the reservoir near the Town of Gold Bridge?

It has been observed that the majority of dust events originate from within the bankfull width of the Bridge River. These elevations are below 639m and unlikely to support vegetation making it difficult to halt the erosion with vegetation. The herbaceous vegetation that is proving to be able to grow at low elevations would not provide enough root strength to resist erosion. Vegetation established at low elevations does help to reduces secondary suspension of eroded particles and hence has some positive impact on dust generation.

MQ2: Will riparian enhancement in the drawdown area increase the aesthetic quality and recreational opportunities in the western end of the reservoir?

Increasing the amount of vegetation growing in the drawdown zone also increases the aesthetic of the landscape. The greater the area that is vegetated the more the aesthetic appeal is increased. Aesthetics has been increased at a fine scale with the BRGWORKS-1 treatments.

MQ3: Will the program enhance the quality of riparian habitats to increase their potential to support wildlife populations and provide localized improvements in the quality and productivity of aquatic habitats in the reservoirs?

As with dust mitigation and aesthetics, riparian habitat has been improved where vegetation has established. Sedges provide cover and forage at low elevations that are otherwise relatively barren. Spotted sandpiper have nested among planted sedges, Canada geese have grazed and grubbed on planted sedges, planted willow and cottonwoods have (for better or worse) provided forage for mule deer and beaver. Savannah sparrows have foraged among planted bluejoint reedgrass. As riparian habitat improves the increased vegetation biomass also has beneficial effects on local aquatic ecosystems.

5. Successes and Observations

- Recommendations have been included throughout this synthesis report with an emphasis on the short duration of this project and the value in having the final years monitoring results planned for 2022 under the BRGMON-2 program. Some of the highlight successes of the BRGWORKS-1 program thus far include;
- Through the BRGWORKS-1 program years, Kellogg's sedge has proven to be the best perennial native herb species for colonizing low elevations in the Carpenter drawdown zone.
- Kellogg's sedge has established at elevations between 644m and 639m under reservoir operations.
- Sedges have survived at elevations where the AGDD was at least 40% of the total annual AGDD (Figure 14).

- Kellogg's sedge has been planted at low elevation treatment sites (640m) where it has established and successfully reproduced. These patches have produced enough seed to enable collection for seeding in other locations.
- Kellogg's sedge plants grew successfully in fine silt substrates when the silt blanket layer was > 40cm deep. Plants performed poorly when fine soils were shallower.
- Kellogg's sedge plants grew well in mounded rough and loose terrain, and mature plants have been observed to successfully reproduce in mounds.
- Seedlings colonizing in the drawdown zone struggle to survive through the often-arid conditions of late spring and early summer, prior to inundation. Delayed inundation while increasing the growing season may also increase drought stress. Younger seedlings are the most vulnerable.
- Rough and loose treatments alone did not result in recruitment of native species. Planting and or seeding was required to in combination with mounding to provide seed and recruit native species.
- Hand seeding of Kellogg's sedge was only observed to result in germination in mounded terrain. High densities of seed are required for sowing.
- Physical treatments perform best when combined with seeding and planting.
- Rough and loose treatments are best planted after an inundation cycle to create a more receptive rooting substrate, firmer and less subject to wave and water erosion.
- Of the native grass species planted in BRGWORKS-1 trials, bluejoint reedgrass, showed the most promise in terms of plant establishment and robust growth on dry mid to upper elevation sites.
- Canada wildrye appears a good candidate native grass species to introduce in the upper drawdown zone areas between 646m and 651m. Planted plants have successfully reproduced and spreading from seed.
- Container grown black cottonwood seedlings planted into mounded areas are preforming well in the Upper drawdown elevations 646-648m
- Live stake cuttings of willow have performed well in upper drawdown elevation mounded polygons.

- A possible confounding variable to assessing the success of the BRGWORKS-1 program has been that the inundation timing for the BRGWORKS-1 targeted riparian enhancement sites has occurred later in the year than during the previous WUP and pre WUP periods. Findings made during the 2022 BRGMON-2 study may shed more light on which are more effective riparian enhancement treatments. Many positive impacts to values of ecosystem function, wildlife habitat, dust mitigation, recreation and aesthetics have been realized at a fine scale through the BRGWORKS-1 program.

6. Conclusion

Over the seven-year BRGWORKS-1 riparian enhancement program, multiple riparian enhancement treatments were applied and tested to attempt to increase vegetation colonization and establishment in the Carpenter Reservoir drawdown zone. The program objectives were to mitigate for dust storms, improve aesthetics and recreational opportunities and improve both terrestrial and aquatic habitat. All values were assumed to improve through improved native vegetation colonization, establishment and cover. The program employed planting, seeding, live staking and physical treatments at 5 terrain sites on the Carpenter Reservoir. Under the reservoir operations and seasonal weather conditions in the drawdown zone, successes were realized with planting and seeding native species particularly, when combined with physical works. The success of all of the riparian enhancement efforts are heavily tied to annual inundation timing, which defines growing season length and plant survival. Through the program the origin and predominant direction of movement of dust storms was determined. Dust storms are perhaps, in a minor way, reduced by riparian enhancement treatments, as are site aesthetics, recreation and habitat values. The planned BRGMON-2 follow up monitoring in 2022 may better inform how lasting, effective and extensive the BRGWORKS-1 riparian enhancements have been.

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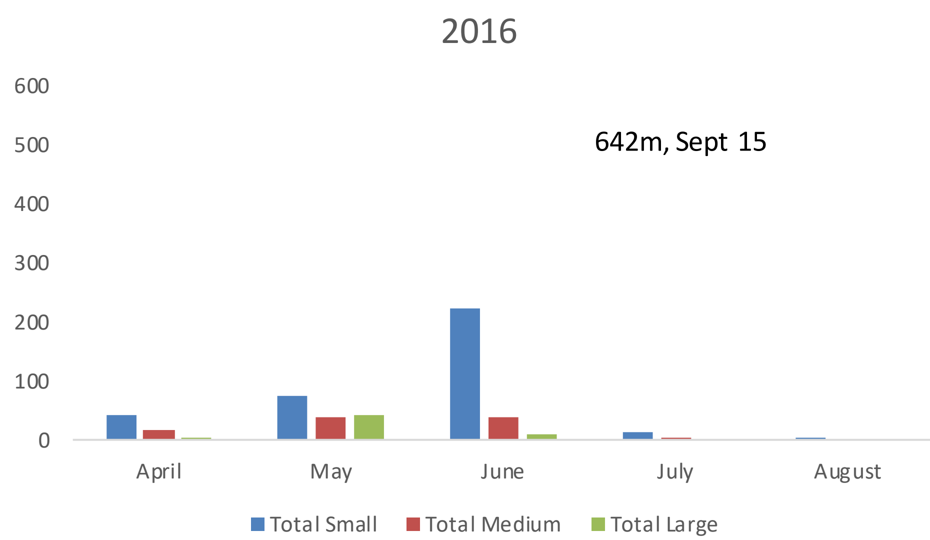
Appendix

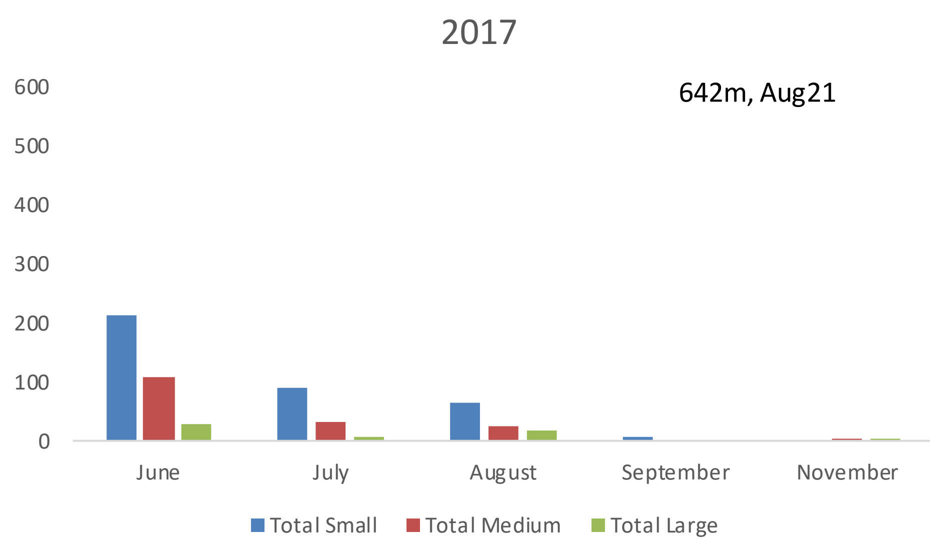
Summary table of BRGWORKS-1 Treatments.

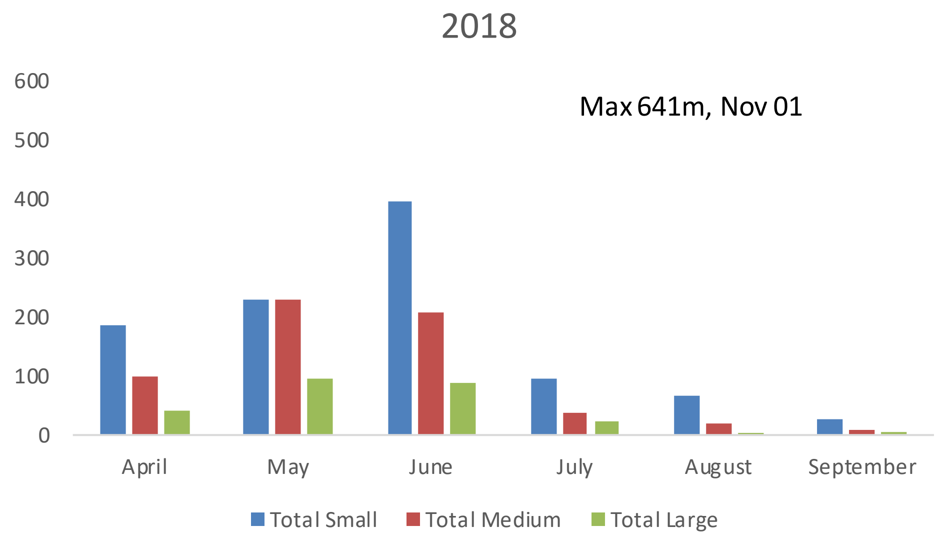
TERRAIN TYPE	CODE	Total Terrain Area (ha)	Treatment Year	Machine Work Area (ha)	Sedge Plugs	BJ Plugs	Foxtail Plugs	Fowl bluegrass	CWR	Horsetail	Mix Native Grasses	Aspen trees	cottonwood trees	Ponderosa Pine	Alder sp.	Willow sp.	Red Osier dogwood	Rooted Cuttings	Number Cuttings Willow	Number Cuttings Cottonwood	Area Seeded Fall Rye (ha)	Area Seeded Fall Rye/Carex Lenticularis (ha)	Area Seeded Carex Lenticularis (ha)	Area Mechanical treatment only (ha)	Meadow Bird's foot trefoil seed (ha)	Area seeded Upper Reservoir Grass Mix (ha)	Area seeded Upper Reservoir Grass Mix and Fall Rye (ha)
Low Mud Flat	LMF	192 (35ha polygon off Gun Creek Fan)	2014	NO TREATMENTS																							
			2015	0	1,647	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1457	0.1457	0.1457	0.1457	0	0	0
			2016	0	10,312	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9.6	0.4	0.32	0.3	0	0	0
			2017	0.88	5,629	168	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			2018	NO TREATMENTS*																							
			2019	1.9	7,295	0	0	0	0	50	0	0	0	0	0	0	0	0	0	0	3.3	0	0.2	0.78	0.13	0	0
			2020	0.32	17,602	1,990	0	0	0	100	0	0	220	0	0	240	0	0	0	0	8.9	0.36	0.32	0	0	0	0
Gun Creek Fan East	GCFE	35	2014	0	1,570	0	0	0	0	0	486	0	0	0	0	0	0	0	220	530	0	0	0	0	0	0	0
			2015	0	2,610	1,253	0	0	0	0	0	0	0	0	0	0	0	0	482	266	0.143	0	0	0	0	469	219
			2016	0	0	2,360	2960	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			2017	2.08	4,758	1,554	282	288	50	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			2018	NO TREATMENTS*																							
			2019	0.04	300	450	0	0	0	0	0	0	25	25	25	25	0	12	0	0	0	0	0	0	0.084	0	0
			2020	0.24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.24	0	0
Gun Creek Fan West	GCFW	19	2014	0	2,692	0	0	0	0	0	126	0	0	0	0	0	0	0	262	0	0	0	0	0	0	0	0
			2015	0	1,263	3512	50	50	1050	0	0	0	0	0	0	0	0	0	308	243	0	0	0	0	0	0	0
			2016	0	0	9225	0	0	0	0	0	25	25	0	0	0	0	0	360	629	0	0	0	0	0	0	0
			2017	0.54	0	738	240	150	91	0	0	0	75	0	0	0	0	0	246	0	0	0	0	0	0	0	0
			2018	NO TREATMENTS*																							
			2019	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			2020	0.38	0	822	0	0	0	0	0	0	130	125	0	74	50	0	0	0	0	0	0	0	0	0	0
Shallow Beach	SHB	3.85	2014	0	453	0	0	0	0	0	288	0	0	0	0	0	0	0	86	0	0	0	0	0	0	0	0
			2015	0	2864	1956	0	0	0	0	0	0	0	0	0	0	0	0	22	94	0	0	0	0	0	0	0
			2016	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	132	73	0	0	0	0	0	0	0
			2017	NO TREATMENTS																							
			2018	NO TREATMENTS *																							
			2019	NO TREATMENTS																							
			2020	NO TREATMENTS																							
Steep Alluvial Fan	SAF	22.3	2014	0	1,136	0	0	0	0	0	0	0	0	0	0	0	0	0	245	0	0	0	0	0	0	0	0
			2015	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	500	33	0	0	0	0	0	0	0
			2016	NO TREATMENTS																							
			2017	NO TREATMENTS																							
			2018	NO TREATMENTS*																							
			2019	NO TREATMENTS																							
			2020	NO TREATMENTS																							
Steep Beach	STB	3.8	2014	0	658	0	0	0	0	0	261	0	0	0	0	0	0	0	178	0	0	0	0	0	0	0	0
			2015	0	991	1219	0	0	0	0	0	0	0	0	0	0	0	0	185	30	0	0	0	0	0	0	0
			2016	NO TREATMENTS																							
			2017	NO TREATMENTS																							
			2018	NO TREATMENTS*																							
			2019	NO TREATMENTS																							
			2020	NO TREATMENTS																							
TOTAL		267.65		6.38	61,780	25,247	3532	488	1241	150	1161	25	575	150	25	339	50	12	3226	1898	22.0887	0.9057	0.9857	1.2257	0.454	469	219

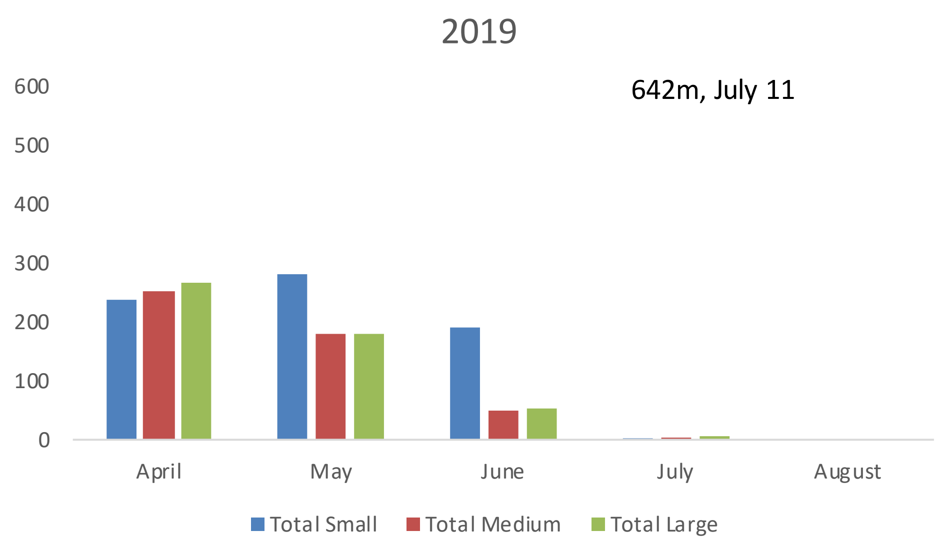
* 2018 was a lag year for the project with no field treatments.

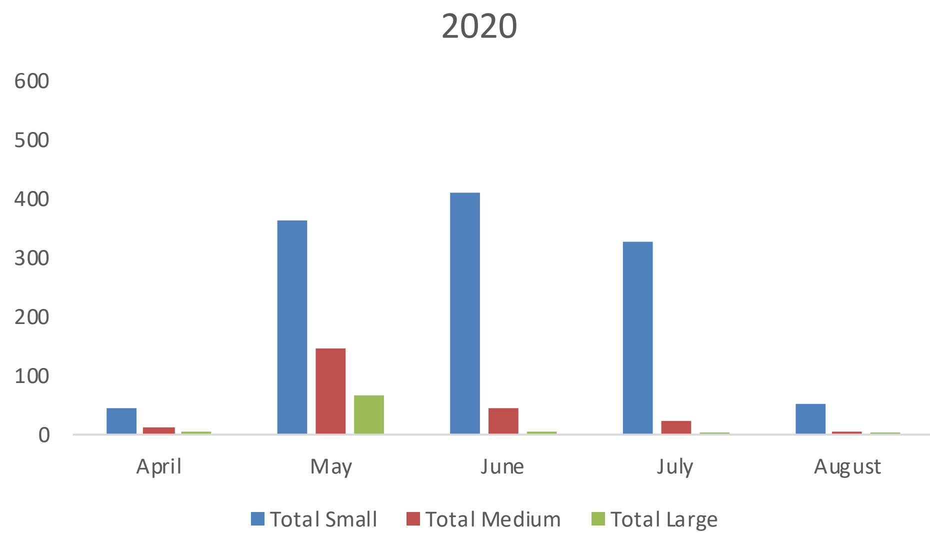
Summary figures of dust storm events observed 2016-2021.

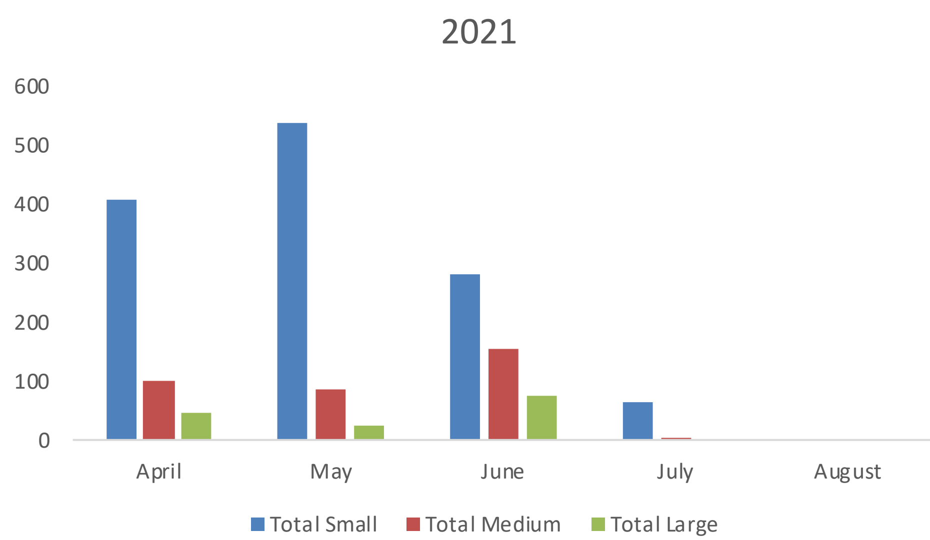





2018
Max 641m, Nov 01
600
500
400
300
200
100
0
April
May
June
July
August
September
Total Small
Total Medium
Total Large


2019
642m, July 11
600
500
400
300
200
100
0
April
May
June
July
August
Total Small
Total Medium
Total Large


2020
600
500
400
300
200
100
0
April
May
June
July
August
Total Small
Total Medium
Total Large


2021
600
500
400
300
200
100
0
April
May
June
July
August
Total Small
Total Medium
Total Large