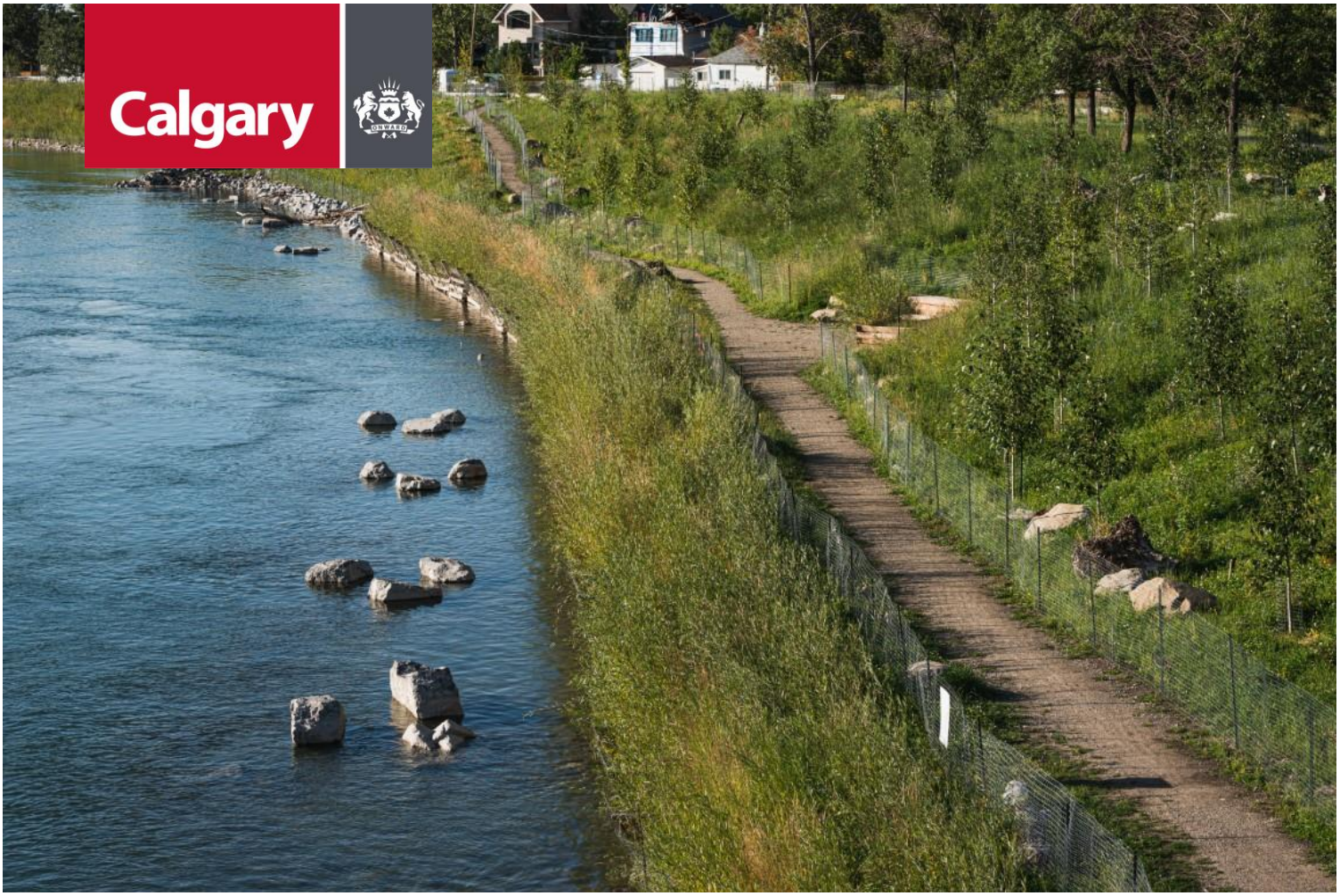

Bioengineering Demonstration and Education Project - 2019 Monitoring Report

The City of Calgary Riparian Monitoring Program

July 14, 2020

Final report prepared for:
The City of Calgary - Water Resources

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1. Introduction

The purpose of this document is to report on the activities and results of 2019 bioengineering effectiveness monitoring at the Bioengineering Demonstration and Education Project (BDEP) as part of The City of Calgary Riparian Monitoring Program (RMP). This is the first year of monitoring at the BDEP site. Long-term monitoring of the BDEP is described in the Bioengineering Efficacy Monitoring Plan (BEMP) and consists of post-construction monitoring of: 1) Fish and Fish Habitat; 2) Wildlife; 3) Riparian Health; and, 4) Bioengineering Structural Integrity at BDEP Site 1, Site 2 and Site 4 over a 10-year period (Hemmera, 2018). The BEMP is provided in Appendix A.

Monitoring activities are intended to meet the goals listed below.

- To show how the bioengineering techniques used in the project have improved fish habitat in the area and specifically over a conventional riprap design site.
- To show how the bioengineering techniques used in the project have improved wildlife habitat in the area and specifically over a conventional riprap design site.
- To show how the project has improved riparian health and specifically how it has been improved over a conventional riprap design site.
- To show how the project has improved bank structural integrity and specifically how it has been improved over a conventional riprap design site.

1.1 Background

Alberta Environment and Parks (AEP) and The City of Calgary (The City) partnered to undertake the BDEP with administration through AEP's Southern Alberta Fisheries Habitat Enhancement and Sustainability (FISHES) Program. The project was conceived after the 2013 flood with design completed between July 2016 and September 2017. Construction occurred from February 2018 to June 2019.

The BDEP includes 680 m of the right bank of the Bow River in the community of Inglewood Calgary. It extends from about 80 m upstream of Cushing Bridge (Blackfoot Trail) to about 600 m downstream. The BDEP is composed of Site 1, Site 2 and Site 4 as shown on Figure 1-1.

A list of bioengineering techniques used in the BDEP is provided in Table 1-1.

1.2 Monitoring Schedule

The monitoring schedule outlined in the BEMP is for monitoring activities to occur in years 2019, 2020, 2021, 2023, and 2028, which correlates to year 1, year 2, year 3, year 5, and year 10 post-construction. In the event of a significant flood(s) (defined as a 10-year flood or greater), contingency monitoring may be required to assess potential damage to the project. Should this occur, a resetting of the monitoring frequency will also be required and will be dependent on the timing of the flood event(s). Reporting of the monitoring results will occur for each monitoring year, as well as discussed cumulatively and comparatively at either the five- or ten-year post-construction monitoring interval (Hemmera, 2018).

1.3 Approach to Compare Monitoring Results

To meet the objective of comparing the monitored data collected at the BDEP site to a conventional riprap design site, the original approach discussed in the BEMP was to compare monitoring results for Sites 1 and 2 to Site 4, which would then be considered a control site (Hemmera, 2018). Upon further review of Site 4 during BDEP design, construction, and long-term monitoring preparation, it was observed that Site 4 includes riprap that extends to the 5-year flood water level and the remainder of the bank is vegetated with native riparian species. Based on this observation, Site 4 is not technically a conventional riprap design since in a conventional design the riprap would extend up to the 100-year flood water level. RMP project team discussions with The City led to the adoption of the following assumptions:

- Site 4 represents similar fish and wildlife habitat as would be found in a conventional riprap design and could still be a control site for Fish and Fish Habitat and Wildlife monitoring components.
- The use of Site 4 as a control site is not suitable for Riparian Health monitoring since the riparian health assessment includes both the riprap and vegetated upper bank and would not be comparable to a conventional riprap design.
- For Bioengineering Structural Integrity, Site 4 also does not represent a conventional riprap design for comparison purposes since the riprap does not extend up to the top of bank and is vegetated.

Based on the above assumptions developed with The City, the two approaches listed below were established to comply with the BEMP but also to generate suitable control site information for comparison with the work completed at the BDEP (Harris, et al., 2005; Harris, et al., 2005; Nossaman, et al., 2007; Cavaille, et al., 2013; Cavaille, et al., 2015).

- **Site 4 is used as the conventional riprap design control site**. Fish and Fish Habitat and Wildlife monitoring results from Site 1 and Site 2 are compared to monitoring results at Site 4 per the direction provided in the BEMP.
- **A theoretical conventional riprap design site is used as a control site**. Riparian Health and Bioengineering Structural Integrity are compared to riparian health and shear stress parameters for a theoretical conventional riprap design site.

Parameters for the theoretical conventional riprap design site were developed based on the RMP project team's experience. The Riparian Health Assessment (RHA) score for a theoretical conventional riprap design site for riparian health is 38% (27/72) and would be in Unhealthy condition as shown in Table 1-2. The RHA score is equivalent to a Riparian Health Index (RHI) score – see Section 4.

Assuming a theoretical conventional riprap design site for the Bow River with Class 2 riprap (d50 = ±500 mm) which is the most common riprap size used on the Bow River, a permissible shear stress would be approximately 364 N/m² (Fischenich, 2001).

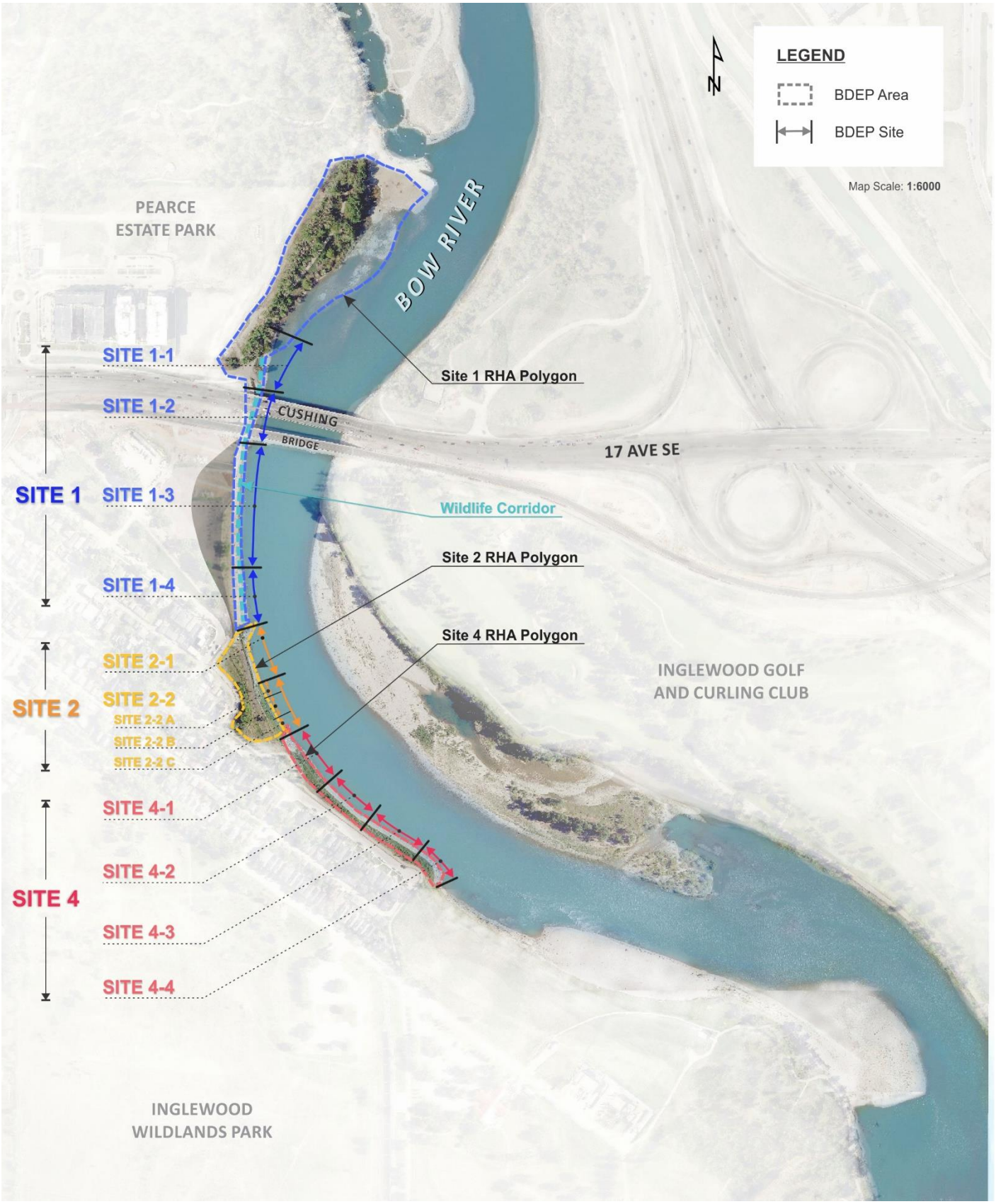

Figure 1-1: BDEP Sites

(Note: Site 1-2 and Site 4-4 are not part of the monitoring program as no bioengineering techniques were applied there – see Table 5-1)

Table 1-1 Summary of Bioengineering Techniques used in the BDEP by Site

Site	Technique Name	Description
Site 1	Rooted Live Cuttings (Site 1-1)	Insertion of long live cuttings that have been rooted out in the lower portion and leafed-out in the top portion. They can be used in a similar manner to live cuttings but can be installed during live cutting dormancy period.
	Vegetated Soil Wraps (Site 1-3)	Consists of brush layers interspersed between layers of soil wrapped in natural geotextile materials that provides reinforcement.
	Vegetated Timber Crib Wall (Site 1-3)	Consists of a hollow, box-like interlocking arrangement of structural timber, filled with suitable backfill material and layers of live cuttings.
	Brush Mattress (Site 1-4)	A layer of interlaced/adjacent live cuttings placed on the face of the riverbank.
	Brush Layer (Site 1-4)	Row(s) of live cuttings placed in a criss-cross or overlapping manner between layers of soil, with tips protruding beyond the face of the fill.
	Contour Fascine (Site 1-4)	Fascines are live cuttings that are tied together in long bundles. Contour fascines are installed in shallow trenches constructed on contour and anchored in the trench using stakes.
Site 2	Box Fascine (Site 2-1, Site 2-2 A/B/C)	Fascine bundles placed at the toe of an eroding bank and secured between wooden poles.
	Brush Mattress (Site 2-2 A)	A layer of interlaced/adjacent live cuttings placed on the face of the riverbank.
	Contour Fascine (Site 2-2 A)	Fascines are live cuttings that are tied together in long bundles. Contour fascines are installed in shallow trenches constructed on contour and anchored in the trench using stakes.
	Hedge Brush Layer (Site 2-2 B)	A layer of interlaced/adjacent live cuttings and rooted stock placed on the face of the riverbank.
	Live Staking (Site 2-2 C)	Insertion of live cuttings into the ground in such a manner as to promote root growth and leaf-out.
Site 4	Soil-Covered Riprap (Site 4-1)	Covering existing riprap bank protection with soil and vegetation to improve riparian, aquatic and terrestrial habitats while also improving aesthetics.
	Void-filled riprap with plugs (Site 4-2)	Planting material inserted into void-spaces in existing riprap bank protection and planted with live cuttings or container shrub plantings to improve riparian, aquatic and terrestrial habitats while also improving aesthetics.
	Void-filled riprap with live staking (Site 4-3)	Live staking of existing riprap to improve riparian, aquatic and terrestrial habitats while also improving aesthetics.
	Riprap control site (Site 4-4)	No bioengineering techniques at this site.
Common to all sites	Container Shrub Planting	Planting of container stock seedling species that are selected for beneficial attributes such as fast-growing, natural colonizer, deep rooting, nitrogen fixing, and food production.
	Native Species Seeding	Planting of native streambank/riparian species that are selected for beneficial attributes such as fast-growing, natural colonizer, deep rooting, nitrogen fixing, and food production.

Table 1-2: Riparian Health Assessment scores for a theoretical conventional riprap design site

Parameter	Score[1,2]
Vegetation	
1. Cottonwood and poplar regeneration from seed	0 / 6
2. Regeneration of other native tree species	0 / 3
3. Regeneration of preferred shrub species	0 / 6
4. Standing decadent and dead woody material	NA
5a. Browsing/utilization of preferred tree and shrub species	NA
5b. Woody vegetation removal by beavers and/or humans	NA
6. Total canopy cover of trees and shrubs	0 / 3
7a. Total canopy cover of invasive plant species	3 / 3
7b. Density distribution pattern of invasive plant species	3 / 3
8. Total canopy cover of disturbance-increaser plant species	3 / 3
Sub-Total Vegetation Score	9 / 27 = 33%
Soil / Hydrology	
9. Riverbank root mass protection	0 / 6
10. Percent cover of human-caused bare ground	6 / 6
11. Removal or addition of water to or from the river system	6 / 9
12. Control of flood peak and timing by upstream dam(s)	0 / 9
13. Percent of riverbank structurally altered by human activity	0 / 6
14. Percent of human alteration to the remainder of the polygon	0 / 3
15. Natural floodplain accessibility	6 / 6
Sub-Total Soil / Hydrology Score	18 / 45 = 40%
Total score	27 / 72 = 38%
Condition	***Unhealthy***

Notes:

1. The calculation above assumes no woody species present (parameters 4, 5a, and 5b.), <1% human-caused bare soil cover (parameter 10), <1% cover of invasive species (parameters 3a and 3b), and <5% cover of disturbance-increaser species (parameter 8).
2. The RHA scores shown are equivalent to an RHI score (i.e., the same parameters are scored); however, for RHIs, additional data is collected to characterize the riparian site.

Photo 1-1: Willow shoots growing from a fascine at the BDEP

2. Fish and Fish Habitat

Fish and Fish habitat were assessed at Sites 1, 2, and 4 in a baseline assessment in 2017 and as part of year 1 monitoring in 2019. Methods and results are described below.

2.1 Methods

Baseline fish and fish habitat data were collected for Sites 1, 2 and 4 via desktop and field assessments in 2017 as described in detail in the *Bow River Fish and Fish Habitat Report* (Hemmera, 2017a) and summarized in the BEMP (Hemmera, 2018).

All 2019 assessments of fish habitat and fish use were completed by a crew of two and led by a Qualified Aquatic Environment Specialist (QAES). Assessments for Sites 1, 2, and 4 were completed in multiple seasons (spring, summer, fall, and winter) in 2019 using methods as summarized in Table 2-1. Sampling locations are provided in Figure 2-1.

Table 2-1: Summary of Field Assessment Methods and Timing

Field Assessment	Methods	Site(s) and Timing			
		Winter	Spring	Summer	Fall
Fish Use	Visual assessment of fish use of near bank habitat via underwater photography and snorkel survey.	Site 1 and 2 / March 12, 2019[1]	All sites / April 30, 2019	-	-
Fish Spawning Use	Visual surveys conducted from bank for rainbow trout (Spring) and brown trout (Fall) redds.	-	All sites[2] / May 9, 2019	-	All sites[4] / November 26, 2019
	Sampling of mountain whitefish eggs via kick sampling.	-	-	-	All sites[4] / November 26, 2019
Fish Habitat Assessment	Collection of in-stream and near stream condition, documentation of fish habitat enhancements.	-	-	All sites[3] / July 31 to August 1, 2019	-
Water Quality	Collection of water quality parameters.	Upstream control site, Site 1 and 4 / Various dates through all seasons			
Fish Sampling	Fish capture via single pass boat electrofishing and overnight set gee-style minnow traps.	-	-	All sites / July 31 to August 1, 2019[5]	-
Photographic assessment of physical condition and stability	Establishment and assessment of photo monitoring stations.	-	-	All sites / Various dates	-

Notes:

1. Originally scheduled for January 2019, however unsafe ice cover and flow conditions delayed the survey.
2. Survey extents were 500 m upstream of Site 1, through all riverine habitat adjacent to Site 2 and Site 4, to 250 m downstream of the downstream extent of Site 4.
3. Survey extents were 100 m upstream of Site 1, through all riverine habitat adjacent to Sites 2 and 4, to 600 m downstream of the downstream extent of Site 4.
4. Survey extents were 500 m upstream of Site 1, through all riverine habitat adjacent to Site 2 and Site 4, to 500 m downstream of the downstream extent of Site 4.
5. The location of the boat electrofishing pass shown in Figure 2-1.

Bio-engineering Demonstration and Education Project -
Bioengineering Efficacy Monitoring Project
Bow River, Calgary Alberta

Bow River Sampling Locations

Legend

- Photo Station
- Water Quality
- Mountain whitefish egg sampling locations
- Minnow Trap
- Snorkel Survey
- Transect
- Boat Electrofishing Pass
- Site Boundary

Pearce Estate Park
WQ-UPSTREAM CONTROL
Bow River
PHOTO STATION 1
WQ1
MT1
17 Avenue SE Cushing Bridge
17 AVENUE SOUTH-EAST
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
T12
7 AVENUE SOUTH-EAST
21 STREET SOUTH-EAST
PHOTO STATION 2
MT2
PHOTO STATION 3
PHOTO STATION 4
WQ2
MT3
8 AVENUE SOUTH-EAST
9 AVENUE SOUTH-EAST
Inglewood Golf and Curling Club
The City of Calgary

Notes

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

Sources

- Contains information licensed under the Open Government Licence - Government of Alberta
- Aerial Image: City of Calgary (2018)

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An Ausenco Company

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2.2 Results

Fish Habitat Characteristics

Baseline fish habitat characteristics were collected as part of the fish habitat assessment (Table 2-1) on March 27, 2017 (Hemmera, 2017a) and 2019 data were collected from July 20 to August 1, 2019. The assessed reach of the Bow River is characterized as low gradient (i.e., 0.2%) with a regular meander pattern that is frequently confined by its valley walls. Representative photographs of the fish assessment are provided in Appendix B. A summary of the fish habitat characteristics observed at each Site (i.e., Site 1, Site 2, and Site 4) during the summer fish habitat assessments are presented in Appendix C. A detailed fish habitat map of the assessed reach is presented in Appendix D. Fish habitat within each site in the BDEP area (i.e., Site 1, Site 2, and Site 4) is presented below, including a summary of the changes from the baseline conditions. A comparison of fish habitat at Site 1 and 2, and the control site at Site 4 is also provided per the monitoring objectives.

The following abbreviations are used below:

- RBD – right downstream bank
- LDB – left downstream bank

Site 1

The location of Site 1 is shown in Figure 1-1. Fish habitat and bank stability conditions are as follows:

- Upstream of Cushing Bridge : Baseline (2017) observations were that fish habitat consisted of riffle (RF) habitat transitioning into deep run (R1) habitat through the mid channel, with alternating deep (P1), moderate (P2) and shallow (P3) pool habitats along the RDB (Hemmera, 2017a). Similar fish habitat conditions to the baseline assessment were observed in 2019 with fish habitat consisting of riffle (RF) habitat transitioning into deep run (R1) habitat through the thalweg and mid channel. A key difference was a shallow run (R3) along the RDB that was partially created as part of the BDEP (Appendix D).
- At Cushing Bridge: Baseline (2017) observations were that fish habitat within the area immediately surrounding the Cushing Bridge consisted of R1 habitat through the mid channel thalweg, and P1 habitats along both the RDB and LDB (Hemmera, 2017a). Similar fish habitat conditions to the baseline assessment were observed in 2019 where fish habitat consisted of R1 habitat through the mid channel thalweg, and P1 habitat along the RDB; however, P1 habitat was not observed along the LDB immediately downstream of the bridge.
- Downstream of Cushing Bridge: Baseline (2017) observations were that R1 habitat extends through the reach downstream of the Cushing Bridge. An abandoned bridge abutment was present mid-channel downstream of Cushing Bridge. Observations from 2019 are that fish habitat within this reach remains consistent with observations made during the baseline conditions assessment where R1 habitat extends through the reach downstream of the Cushing Bridge.

Water depths in Site 1 have not changed from baseline condition. Maximum water depth ranges from 0.40 m in R3 habitat to approximately 7.00 m in R1 and P1 habitat. There is a deep scour hole present in the P1 habitat adjacent to Site 1 downstream of the Cushing Bridge with depths reaching over 7 m. This pool habitat is considered very important habitat, providing overwintering habitat and thermal refuge from summer water temperatures approaching or exceeding tolerance thresholds for trout (Hemmera 2018).

Substrates in Site 1 have not changed from baseline conditions, except for the riprap apron and fish boulders placed along the toe of the bank in the reach downstream of Cushing Bridge. Otherwise, substrates throughout Site 1 consist primarily of boulder and cobbles in R1 and RF habitat. Pool habitat (P1) substrates consist primarily of boulder, cobble, and fines; consistent with substrates observed in the Hemmera Fish and Fish Habitat Assessment (Hemmera, 2017a).

Baseline and 2019 assessments of cover were similar as cover in throughout Site 1 is provided primarily by depth and turbulence, with limited overhanging cover provided by woody vegetation along the LDB. Boulder substrates present throughout run and pool habitats likely provide instream cover for fish. However, the constructed fish shelters and boulder clusters along the RDB in the reach downstream of the Cushing Bridge now also provide instream cover above what was observed during the baseline assessment. Deciduous trees, shrubs, and grasses were present and providing limited cover along both the RDB and LDB during both baseline and 2019 assessments.

Deep run (R1) and pool (P1) habitat is likely utilized as 'suitable' holding, feeding, and overwintering habitat for adult and juvenile fish, with shallower R3 habitat functioning as holding and rearing habitat for juvenile fish. P1 and R1 habitat within the downstream section of Site 1 likely provides 'important' overwintering habitat, with a maximum water depth of approximately 7.00 m. Gravel and cobble substrates located at the downstream end of R3 habitat on RDB above Cushing's Bridge provides 'suitable' spawning habitat for rainbow trout and brown trout, and mountain whitefish spawning likely occurs over cobble and large gravels located in R1 habitat throughout the site.

Site 2

The location of Site 2 is shown in Figure 1-1. Fish habitat within Site 2 remains consistent with observations made during the baseline conditions assessment (Hemmera, 2017a), where fish habitat consists almost entirely of a R1 habitat, with a P1 habitat located immediately downstream of riprap groynes constructed out into the Bow River at the upstream extent of the RDB of Site 2, adjacent to a city of Calgary pathway in Inglewood (Appendix D).

Bankfull width, substrate and cover are also consistent with baseline conditions. Bankfull width and wetted width are relatively uniform throughout Site 2, approximately 170 m and 90 m respectively. Water depth is relatively uniform through this section, ranging from 1 m to 2 m. P1 habitat immediately downstream of the upstream riprap groyne has a maximum depth of 4 m. Substrates consist primarily of boulder and large cobbles in R1 habitat and boulder and riprap within P1 habitat downstream of flood mitigation structures (groynes).

Cover is provided primarily by depth and turbulence, and by boulder and riprap substrates. Large woody debris has accumulated within the P1 habitat immediately downstream of the upstream riprap groyne along the RDB. Large woody debris provides suitable overhanging and instream cover. Overhanging cover was otherwise severely limited throughout Site 2 according to the baseline and 2019 observations; however, deciduous shrubs were present along the RDB during the 2019 assessment and will likely provide cover in the future as they mature.

Deep run (R1) habitat likely provides 'suitable' holding, feeding, and overwintering habitat for adult and juvenile fish. P1 habitat present downstream of riprap groynes provides a velocity refuge for fish as well as 'suitable' holding, feeding, and potential overwintering habitat for juvenile and adult fish. There is 'marginal' spawning habitat for salmonids through this section of the Bow River due to the larger size of substrates.

Site 4

The location of Site 4 is shown on Figure 1-1. Fish habitat within Site 4 remains consistent with observations made during the baseline conditions assessment (Hemmera, 2017a), with fish habitat comprised primarily of R1 habitat, transitioning into R2 habitat at the downstream end of the site (Hemmera 2017).

Bankfull width, substrate and cover conditions are also consistent with baseline conditions. Bankfull width and wetted width are relatively uniform throughout Site 4, ranging from 170 m to 230 m and 83 m to 150 m respectively. Substrate consists primarily of cobble and boulder with a maximum depth of approximately 1 m in the thalweg. Cover is provided primarily by depth and turbulence and partially by large riprap present along the RDB and boulder substrate (Appendix D). Site 4 continues to have little to no overhanging cover as a result of bank armoring along the RDB and lack of mature bank vegetation.

Deep run (R1) habitat provides 'suitable' holding and feeding habitat for adult and juvenile fish. R3 habitat present at the downstream end of Site 4 provides 'suitable' holding and feeding habitat for juvenile fish. Due to the maximum depth of approximately 1 m, this section of the Bow River provides 'marginal' overwintering habitat. There is 'marginal' spawning habitat for salmonids (e.g. brown trout and rainbow trout) due to the lack of suitable gravel substrates through the reach.

Site 1 and 2 Fish Habitat Comparison with Site 4

The BDEP improved the bank stability and fish habitat at Site 1 and 2 as noted above, with key features including the constructed fish shelters and boulder clusters along the RDB in the reach downstream of the Cushing Bridge. Additionally, the deciduous shrubs planted along the RDB at Site 1 and 2 have the potential to provide overhead cover for fish as they mature. This compares to Site 4 that does not provide cover as a result of the bank armoring along the RDB and does not provide refugia within the bank in the form of shelters.

Water Quality Field Parameters

Baseline sampling of in-situ water quality parameters was conducted on March 27, 2017 and included dissolved oxygen, conductivity, pH, and water temperature (Hemmera, 2017a). In 2019, the same data were collected but sampling was conducted over the course of the year (Table 2-1). The locations of water quality sampling stations established in 2019 are presented in Figure 2-1. These water quality stations will be used in subsequent monitoring years for comparison.

The results of water quality sampling of in-situ water quality parameters at the Upstream Control site, Site 1 and Site 4 are shown in Table 2-2 for baseline and 2019 sampling. The results for Site 1 and Site 4 were compared to standards identified in the Canadian Council of Ministers of the Environment (CCME) Guidelines for the Protection of Freshwater Organisms (CCME, 1999) and were also compared with the parameters collected in the upstream Control Reach to confirm that water quality parameters were within the natural variation for the Bow River.

Overall, all water quality parameters measured in Site 1 and 4 and the Control Reach were within federal guidelines (CCME, 1999). Site 1 and 4 values were also within the natural variation of the Bow River as determined by comparison to the Upstream Control site. In addition, Site 1 and Site 4 values were comparable so no effects on water quality were obviously discernible from the BDEP project.

Table 2-2: 2019 BDEP Monitoring Summary of Water Quality Data

Site	Season	Temperature (°C)		Dissolved Oxygen (mg/L)		pH		Conductivity (uS/cm)	
		2017[1]	2019	2017	2019	2017	2019	2017	2019
Upstream Control	Winter	--	0.6	--	11.9	--	8.3	--	413
	Spring	--	10.4	--	10.1	--	8.3	--	439
	Summer	--	16.0	--	9.5	--	8.7	--	332
	Fall	--	2.5	--	11.7	--	8.7	--	406
Site 1	Winter	0.04	0.3	12.8	12.1	8.2	8.5	192[2]	435[2]
	Spring	--	10.5	--	10.8	--	8.4	--	444
	Summer	--	16.4	--	9.1	--	8.7	--	306
	Fall	--	2.6	--	11.8	--	8.6	--	411
Site 4	Winter	0.04	1.0	12.8	12.1	8.2	8.5	192[2]	459[2]
	Spring	--	10.0	--	10.5	--	8.4	--	441
	Summer	--	16.7	--	9.4	--	8.5	--	331
	Fall	--	2.8	--	11.4	--	8.6	--	351

Notes:
1. 2017 was the baseline data collection year
2. Baseline and 2019 values for conductivity are substantially different but are within the natural range of the Bow River where conductivity can range from 83 uS/cm to 662 uS/cm (City of Calgary unpublished data).

Fish Use

The baseline assessment of fish and fish habitat included a desktop review of historical documented fish presence in the project reach using Fisheries and Wildlife Management Information System (FWMIS) (Hemmera, 2017a). Based on the desktop assessment, 22 species of fish, including 11 sportfish species, were found to be likely to occur in proximity to the project as shown in Table 2-3 (ESRD, 2017). Fish sampling surveys were not conducted as part of the baseline assessment.

The 2019 fish observations and sampling included winter, spring, and summer assessments that were conducted at the locations, and according to the methods and timelines shown in Table 2-1. Fish data were collected to determine overall use of habitats within the study area, as well as species richness and abundance (i.e., CPUE) within the project sites.

A summary of the results of the fish use assessments are provided in Table 2-4 for Site 1, Table 2-5 for Site 2, and Table 2-6 for Site 4. Of the 22 species that have a probable potential of occurrence on the Bow River within the vicinity of the project, 10 were captured within the project area in Year 1, including 6 sportfish and 4 non-sportfish species (Table 2-3). Total fish capture data is presented in Table 2-7; raw fish data is presented in Appendix E. Representative photos of each fish species captured in 2019 are presented in Appendix B.

Results for fish sampling are summarized below.

- A total of 9 fish and 4 species were captured using minnow trapping, including longnose sucker, lake chub, longnose dace and yellow perch. Minnow trap CPUE was determined for each trap as number of fish captured per trap-hour (fish/trap-hour). Minnow trap CPUE was greatest in Site 4 (0.0667 fish/trap-hour). Site 1 and Site 2 had equal CPUE (0.0235 fish/trap hour). Figure 2-2 summarizes minnow trap CPUE separated by reach. In addition, CPUE was calculated for individual fish species as the number of fish per species per trap-hour (number per species/trap-hour), separated by reach. Overall, longnose sucker (*Catostomus catostomus*) had the greatest CPUE of all fish captured at each site. Figure 2-3 presents minnow trap CPUE for individual fish species separated by site.

- A total of 39 fish and 8 species were captured using boat electrofishing, including longnose sucker, white sucker, yellow perch, burbot, brown trout, rainbow trout, mountain whitefish and northern pike. Electrofishing CPUE was determined for each site as number of fish captured per second of electrofishing effort (fish/electrofishing second). Electrofishing CPUE was greatest at Site 4 (0.0474 fish/electrofishing-second), followed by Site 2 (0.0203 fish/ electrofishing-second), with Site 1 having the lowest CPUE (0.0167 fish/electrofishing-second). Figure 2-4 summarizes electrofishing CPUE separated by site. In addition, CPUE was calculated for individual fish species as the number of fish per species per electrofishing second (number per species/electrofishing second) and separated by reach. Longnose sucker had the greatest CPUE in Site 4 (0.349 fish/electrofishing second). In Site 2 the only species captured via electrofishing were white sucker (*Catostomus commersonii*) (0.0203 fish/electrofishing second). In Site 1 rainbow trout and yellow perch (*Perca flavescens*) were captured equally while electrofishing with a CPUE of 0.0477 fish/electrofishing second respectively. Figure 2-5 presents electrofishing CPUE for individual fish species separated by site.

Table 2-3: 2019 BDEP Monitoring Fish Species Diversity

Common Name[1]	Scientific Name	Historic Presence in the Bow River[1]	BDEP Site		
			Site 1	Site 2	Site 4
SPORTFISH					
brook trout	*Salvelinus fontinalis*	X			
bull trout	*Salvelinus confluentus*	X			
brown trout	*Salmo trutta*	X	X		
burbot	*Lota lota*	X	X		
cutthroat trout[2]	*Oncorhynchus clarki*	X			
lake whitefish	*Coregonus clupeaformis*	X			
mountain whitefish	*Prosopium williamsoni*	X	X		
northern pike	*Esox lucius*	X			X
rainbow trout[3]	*Oncorhynchus mykiss*	X	X		
yellow perch[4]	*Perca flavescens*	X	X	X	X
walleye	*Sander vitreus*	X			
NON-SPORTFISH					
brook stickleback	*Culaea inconstans*	X			
fathead minnow	*Pimephales promelas*	X			
lake chub	*Couesius plumbeus*	X			X
longnose dace	*Rhinichthys cataractae*	X			X
longnose sucker	*Catostomus catostomus*	X	X		X
mountain sucker	*Catostomus platyrhynchus*	X			
Prussian carp	*Carissius gibclio*	X			
pearl dace	*Margariscus margarita*	X			
spoonhead sculpin	*Cottus ricei*	X			
trout-perch	*Percopsis omiscomaycus*	X			
white sucker	*Catostomus commersoni*	X	X	X	X
Species Richness		22	7	2	6

Sources: List compiled from FWMIS, 2019; Nelson and Paetz, 1992.

Notes:

1. Cutthroat trout in the Bow River near the Project represent introduced stocks and are not considered native stocks of Westslope Cutthroat Trout (Onchorhynchus clarkii lewisi).
2. Rainbow trout in the Bow River near the Project represent introduced stocks and are not considered native stocks of Athabasca Rainbow Trout.
3. The historical range of yellow perch does not include the Bow River, however, numerous specimens have been captured in irrigation canals near the Project area.

Table 2-4: Site 1 Fish Use Assessment Results

Assessment	Observations
Winter – shore based visual assessment (March 12, 2019)	One fish was observed utilizing the Site 1 fish shelters during the winter assessment; the fish could not be identified to species due to high turbidity present at the time of the survey.
Spring - snorkel survey (April 30, 2019)	Two mountain whitefish (approximately 140 mm) were observed at boulder clusters installed as part of the fish habitat enhancement efforts. Additionally, a rainbow trout, (approximately 200 mm), was observed within a fish shelter.
Summer – minnow trap sampling and electrofishing survey (July 31 to August 1, 2019)	16 fish consisting of 7 species were captured as shown in Table 2-3. • 2 fish were captured by minnow trap (1 longnose sucker and 1 yellow perch). • 14 fish were captured using boat electrofishing (2 brown trout, 1 burbot, 1 longnose sucker, 1 mountain whitefish, 4 rainbow trout, 1 white sucker, and 4 yellow perch).

Table 2-5: Site 2 Fish Use Assessment Results

Assessment	Observations
Winter – shore based visual assessment (March 12, 2019)	The fish enhancement structures within Site 2 (i.e. box fascines) were dry at the time of the assessment, preventing overwintering use of the structures by fish.
Spring - snorkel survey (April 30, 2019)	two rainbow trout, (140 mm and 200mm) respectively, were observed in some large woody debris along the bank.
Summer – minnow trap sampling and electrofishing survey (July 31 to August 1, 2019)	8 fish consisting of 2 species were captured as shown in Table 2-3. • 2 fish were captured by minnow trap (2 yellow perch). • 6 fish were captured using boat electrofishing (6 white suckers).

Table 2-6: Site 4 Fish Use Assessment Results

Assessment	Observations
Winter – shore based visual assessment (March 12, 2019)	Site 4 was not surveyed as part of the winter assessment.
Spring - snorkel survey (April 30, 2019)	No fish were observed at Site 4 during the snorkel survey.
Summer – minnow trap and electrofishing sampling (July 31 to August 1, 2019)	24 fish consisting of 6 species were captured as shown in Table 2-3. • 5 fish were captured by minnow trap (1 lake chub, 1 longnose dace, 2 longnose suckers, 1 yellow perch). • 19 fish were captured using boat electrofishing (14 longnose suckers, 1 northern pike, 3 white suckers, and 1 yellow perch).

Table 2-7 2019 BDEP Monitoring Total Fish Numbers Captured Per Species

Site	BNTR	BURB	LKCH	LNDC	LNSC	MNWH	NRPK	RNTR	WHSC	YLPR
Site 1	2	1	0	0	2	1	0	4	1	5
Site 2	0	0	0	0	0	0	0	0	6	2
Site 4	0	0	1	1	16	0	1	0	3	2
Total	2	1	1	1	18	1	1	4	10	9

Notes: BNTR – Brown Trout, BURB – Burbot, LKCH – Lake Chub, LNDC – Longnose Dace, LNSC – Longnose Sucker, MNSC – Mountain Sucker, NRPK – Northern Pike, RNTR – Rainbow Trout, WHSC - White Sucker, YLPR – Yellow Perch

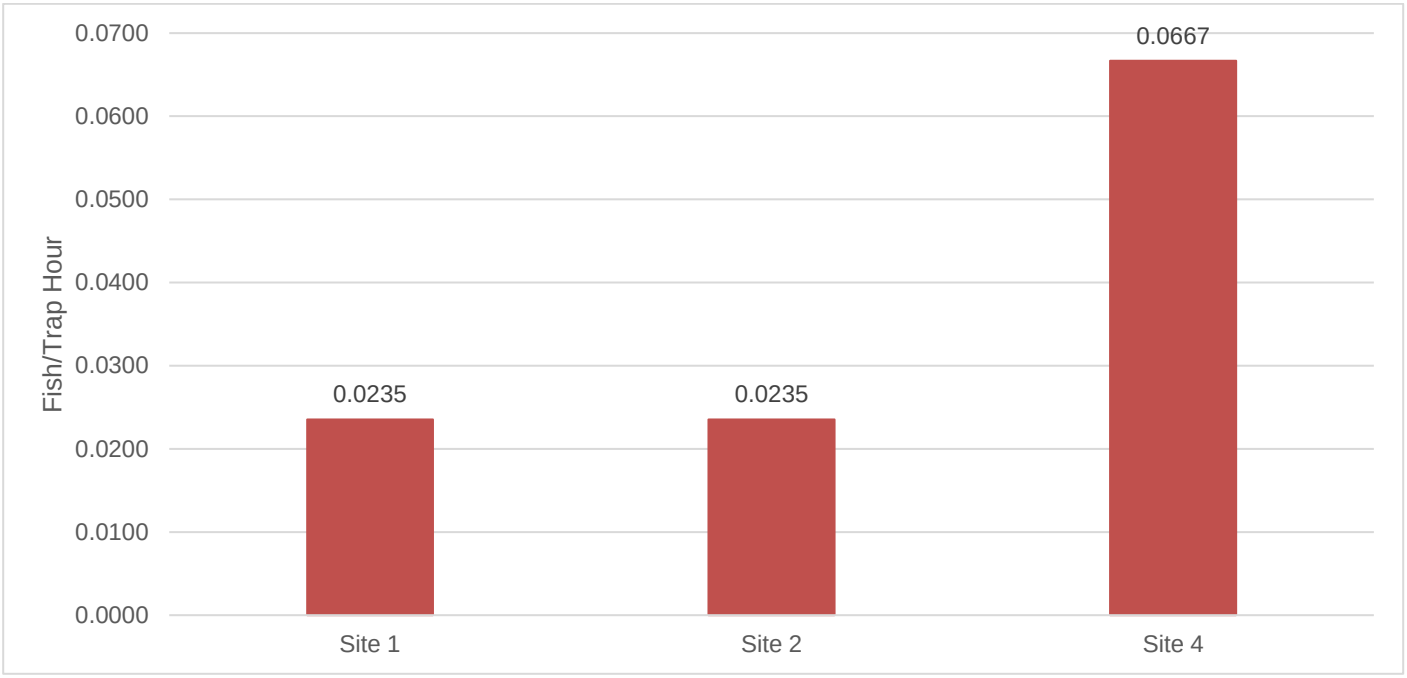

Figure 2-2: 2019 BDEP Monitoring Minnow Trapping CPUE by Site

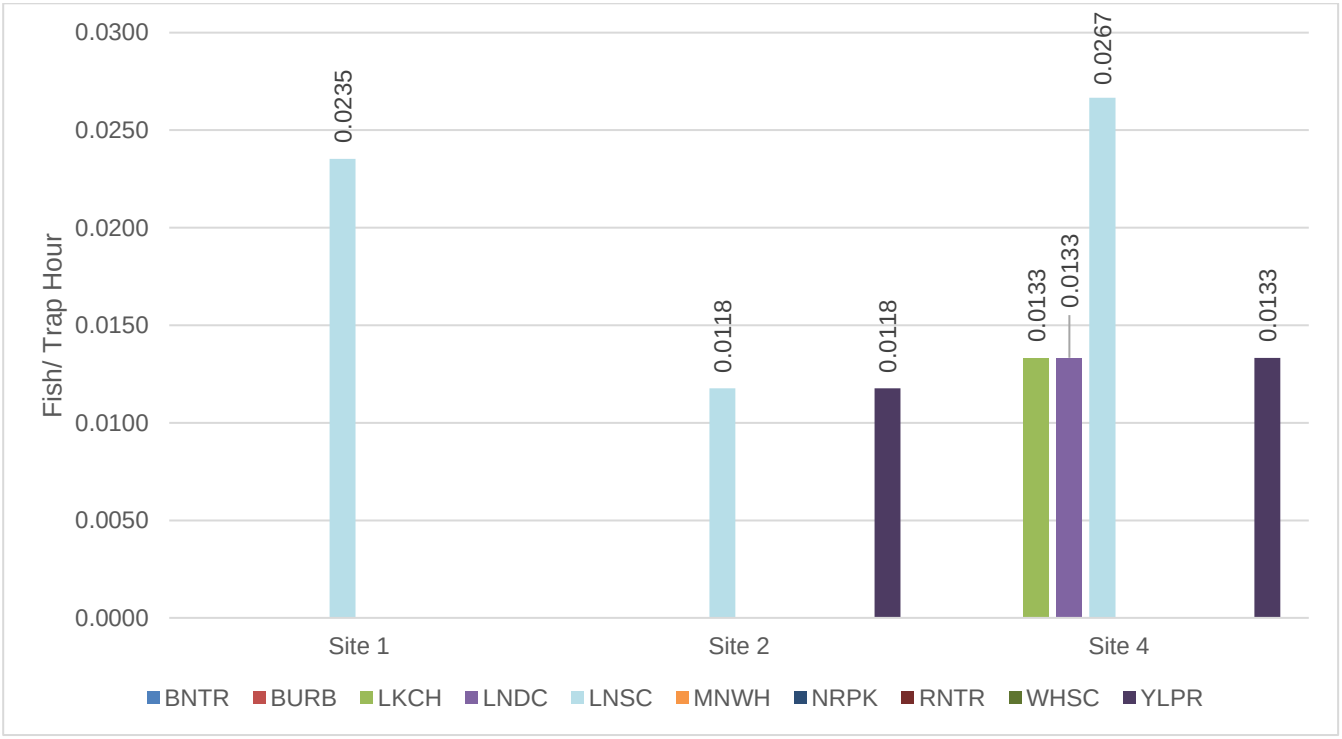

Figure 2-3: 2019 BDEP Monitoring Minnow Trap CPUE for Individual Fish Species Captured

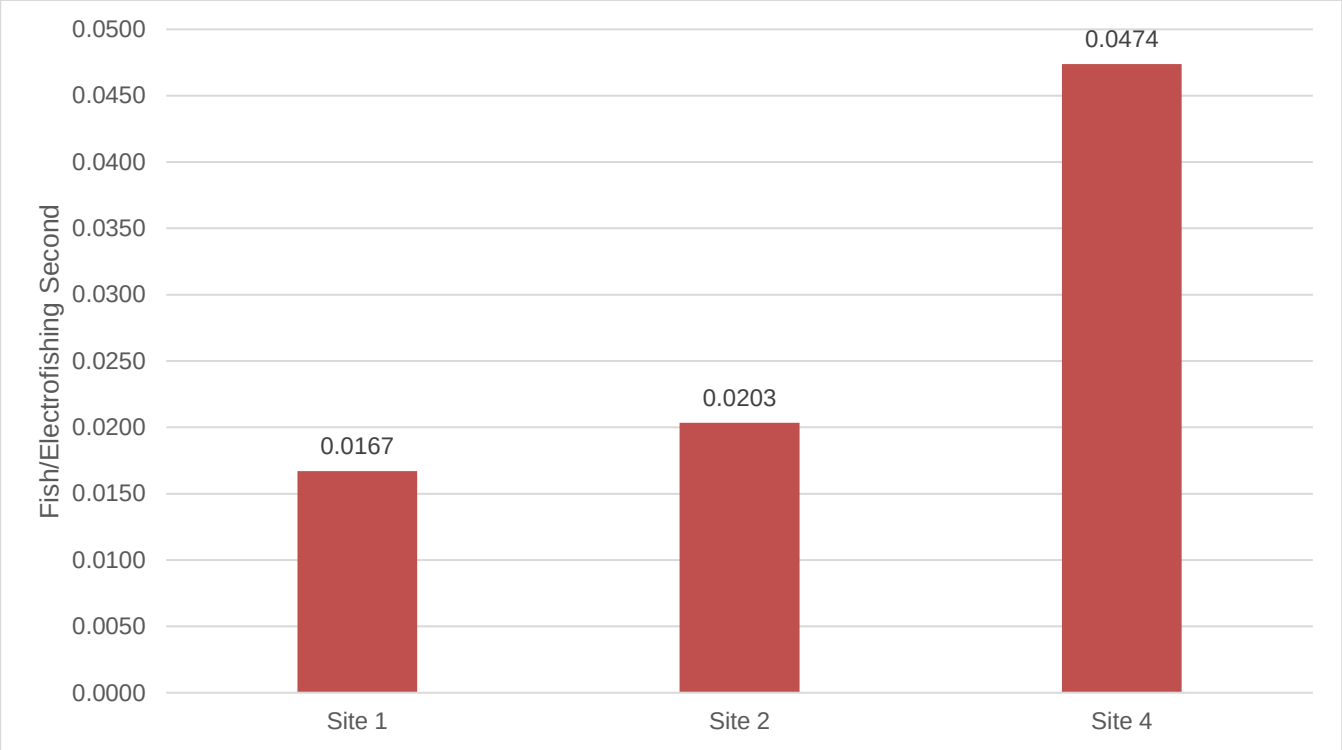

Figure 2-4: 2019 BDEP Monitoring Electrofishing CPUE by Site

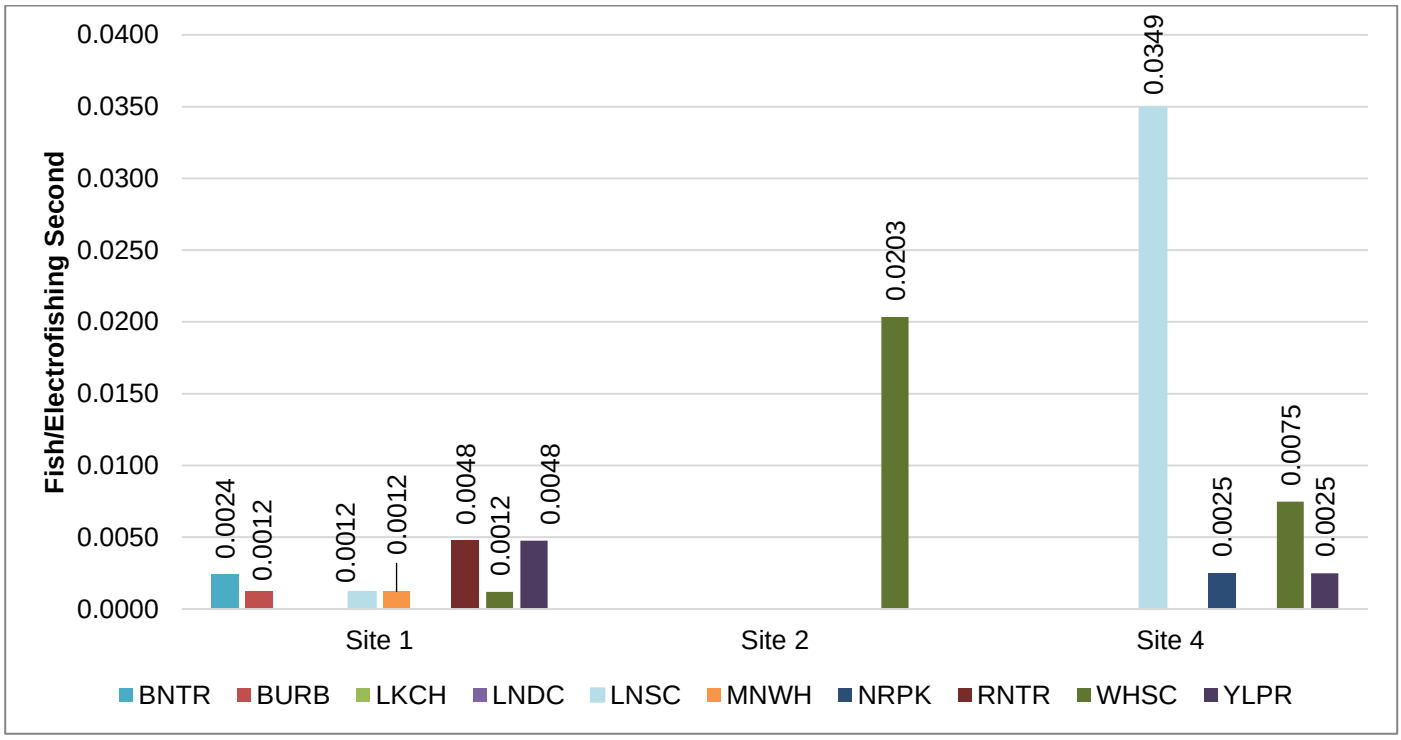

Figure 2-5: 2019 BDEP Monitoring Electrofishing CPUE for Individual Fish Species Captured

Fish Use Comparison

As discussed in Section 1.3, the baseline data and data collected in 2019 for Site 1 and 2 are compared to the data collected for Site 4 in this section to meet the objectives of the BEMP.

Compared with historical fish capture data from the Bow River (ESRD, 2017), 10 of 22 species were captured during Year 1 of monitoring, including 6 sportfish and 4 non-sportfish species. Abundance of fish species within the project area could not be compared with historical data, as fish sampling surveys were not previously conducted in similarly characterized Bow River habitat within proximity to the BDEP sites.

Between sites, the CPUE for minnow trapping and electrofishing was highest at Site 4 (i.e. 0.0667 fish/trap hour; 0.0474 fish/electrofishing second). Site 4 had no instream work associated with the Project and has well established habitat. Site 1 and 2 had relatively similar CPUE for both fish capture methods, with lower CPUE than observed at Site 4. Lower fish abundance at the BDEP sites is expected during Year 1 monitoring as fish habitat enhancements naturalize following construction activities.

Although Site 1 had the lowest fish abundance (i.e. CPUE), fish sampling indicated species richness was highest at this site (Table 2-3). Bioengineering enhancements were most diverse at Site 1, with vegetated riprap, boulder clusters, a riprap apron, crib wall fish shelters, and brush mattress. The species richness observed at Site 1 may have been supported by the variation in cover and microhabitats provided by the habitat enhancements. Additionally, Site 1 had the highest abundance and diversity of sportfish (e.g. brown trout, burbot, mountain whitefish, and rainbow trout). Sites 2 and Site 4 had higher abundance of forage fish, with longnose sucker and white sucker being most prevalent.

Spawning Use

Field observations of spawning use were not conducted as part of the baseline assessment (Hemmera, 2017a).

The 2019 spawning use surveys included spring and fall assessments that were conducted at the locations, and according to the methods and timelines shown in Table 2-1. A summary of the results is provided below.

- **Spring redd survey**: No redds or fish were located in the surveyed reach (although potential spring and fall salmonid spawning habitat was documented during the summer habitat assessment).
- **Fall redd survey**: No redds or fish were located in the surveyed reach (although potential spring and fall salmonid spawning habitat was documented during the summer habitat assessment).
- **Fall kick sampling survey**: No mountain whitefish were observed; however, suitable habitat was identified and kicked sampled for mountain whitefish eggs. Six locations within the upstream extent of Site 1 (i.e., upstream of the Cushing Bridge) were sampled and mountain whitefish eggs were observed at each location (Figure 2-1, and Appendix B, Photos B-10 to B-11).

2.3 Summary of Findings

For Year 1 (2019) of fish and fish habitat monitoring, fish were observed to be using the project area for migration, foraging, overwintering, rearing, and spawning purposes. In particular, monitoring results indicate that fish are utilizing the habitat enhancement structures included in the BDEP. Fish were observed using and were captured within the vicinity of the new habitat structures throughout the project area at Site 1 and Site 2. Fish were observed in the fish shelters, boulder clusters, and surrounding habitats during winter, spring and summer assessments. Although no fish were observed in the fall, mountain whitefish eggs were observed in the upstream section of Site 1.

Based on the fish use monitoring results, Sites 1 and 2 are providing high quality fish habitat in comparison to Site 4. Despite the highest abundance of fish at Site 4, the highest abundance and diversity of sportfish species were captured in Site 1 where bioengineering enhancements were most diverse. Species composition and fish abundance observed during Year 1 are expected to vary in subsequent monitoring years as the BDEP sites naturalize following the construction of the fish habitat enhancements.

Photo 2-1: Timber crib wall and fish habitat enhancement boulders at Site 1-3.

3. Wildlife

Photo 3-1: White-tailed deer photographed using the BDEP wildlife passage corridor

Baseline wildlife data was collected for Site 1, 2 and 4 in 2017 as described in the *Preliminary Natural Assessment Report* (Hemmera, 2017b) and summarized in the BEMP (Hemmera, 2018). In 2019, wildlife monitoring was conducted at Sites 1, 2 and 4 to determine the effectiveness of post-construction conditions for wildlife use resulting from the habitat enhancements within each site. As discussed in Section 1.3, the baseline data and data collected in 2019 for Site 1 and 2 are compared to the data collected for Site 4 in this section to meet the objectives of the BEMP. Trend analysis will be presented in the reports from subsequent monitoring years.

Each of the three BDEP sites had different wildlife monitoring requirements related to the different scopes associated with each site, as described below.

- Site 1 was designed to have a wildlife corridor installed under the existing 17th Avenue Cushing Bridge and the new SEBRT bridge. The wildlife corridor was a 6 m wide vegetated soil area classified as “wildlife-friendly” riprap. Vegetation was planted to create a natural visual screen between the river and public pathway to promote wildlife movement between areas upstream and downstream of the 17th Avenue SE Bridge. The wildlife corridor location is shown on Figure 1-1.
- Site 2 was designed to have riparian vegetation and habitat restored and to provide suitable nesting habitat for breeding birds, including passerines, waterbirds and/or raptors.
- Site 4 was designed to have riparian vegetation and habitat restored to provide suitable nesting habitat for breeding birds, including passerines, waterbirds and/or raptors.

3.1 Methods

Wildlife monitoring included a baseline assessment, trail camera monitoring, breeding bird surveys, and nest searches as summarized below.

Baseline Assessment

The baseline assessment consisted of a desktop review of the FWMIS. The desktop assessment resulted in 12 provincially or federally listed species that were identified as previously occurring within 1,000 m of the project (Table 3-1). Additionally, a review of the Wildlife Sensitivity Maps indicated that Sites 1, 2, and 4 are located within the Sensitive Raptor Range for bald eagles, golden eagles and prairie falcon, and within the Sharp-tailed Grouse range (Hemmera, 2017b; Hemmera, 2018; AEP, 2017a).

During the baseline assessment, as noted in the *Preliminary Natural Assessment Report* (Hemmera, 2017b), breeding habitat for bank swallows and nesting raptors were identified within the project area, with two bank swallow colonies identified in Site 2 (BANS01, Figure 3-1) and Site 4 (BANS02, Figure 3-1).

There is suitable habitat present in and around the project for most of the species listed in Table 3-1. The Bow River provides foraging and breeding habitat for many waterbirds (e.g., sora, harlequin duck, western grebe, great blue heron, etc.) with a riparian zone of deciduous trees suitable for breeding raptors and passerines (e.g. bald eagle, least flycatcher). Bats would be able to forage over the Bow River and roost in the trees present in the riparian zones.

No field monitoring or surveys were completed as part of the baseline wildlife assessment.

Table 3-1 Provincially or Federally Listed Species within 1 km of the Project area

Species	Scientific Name	AEP Ranking [a]	SARA Schedule [b]	COSEWIC Ranking [c]
Bald eagle	*Haliaeetus leucocephalus*	Sensitive	-	-
Baltimore oriole	*Icterus galbula*	Sensitive	-	-
Common nighthawk	*Chordeiles minor*	Sensitive	Schedule 1	Threatened
Eastern kingbird	*Tyrannus tyrannus*	Sensitive	-	-
Great blue heron	*Ardea herodias*	Sensitive	-	-
Harlequin duck	*Histrionicus histrionicus*	Sensitive	-	-
Least flycatcher	*Empidonax minimus*	Sensitive	-	-
Northern goshawk	*Accipiter gentilis*	Sensitive	-	-
Silver-haired bat	*Lasionycteris noctivagans*	Sensitive	-	-
Sora	*Porzana carolina*	Sensitive	-	-
Western grebe	*Aechmophorus occidentalis*	Sensitive	Schedule 1	Special Concern
Western wood-pewee	Contopus sordidulus	May be at Risk	-	-

[a] AEP 2017*b*; [b] Government of Canada 2016; [c] COSEWIC 2008

Bio-engineering Demonstration and Education Project - Bioengineering Efficacy Monitoring Project
Bow River, Calgary Alberta

Survey Locations and Wildlife Features

Legend

- Breeding Bird Survey (BBS) Plot
- Bank Swallow (Bans) Nest
- Wildlife Camera Location
- Flow Direction
- Bank Swallow (Bans) Nest Recommended 100 m Setback
- Site 1
- Site 2
- Site 4
- Site Boundary

Notes

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

Sources

- Contains information licensed under the Open Government Licence - Government of Alberta
- Aerial Image: City of Calgary (2018)
- Inset Basemap: ESRI World Topographic Map

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2019 Monitoring

Wildlife monitoring included breeding bird and nesting surveys at Sites 1, 2 and 4 and monitoring of three wildlife cameras at Site 1 (Camera 1, 2, and 3) as described below and shown in Figure 3-1.

Breeding Bird and Nest Surveys

Breeding bird and nest surveys were conducted at Sites 1, 2, and 4 over two separate rounds on June 12 and 25, 2019 using point counts for breeding bird activity and to identify raptor nests within the project area. Two separate survey rounds were completed following the methodology outlined in the *Sensitive Species Inventory Guidelines* (ESRD, 2013). Surveys were initiated at least one-half hour before sunrise and were completed no later than 11:00 am. Surveys were conducted adjacent to the Bow River, and in conditions suitable to identify breeding birds (i.e. temperatures greater than 0°C, winds less than 20 km/hr and no precipitation). All nesting behaviour and incidental observations were recorded and submitted to AEP through the FWMIS. After the completion of the breeding bird survey window each day (i.e. 11:00 am), field work focused on identifying breeding or nesting behaviour within the site. This included identifying swallow colonies (either in the bank of the Bow River or under the bridge), identifying raptor nests within or adjacent to the project, and/or any observations of waterfowl utilizing the banks or riparian zone of the Bow River for nesting sites.

Five breeding bird survey (BBS) plots were conducted over the three sites, with survey plots BBS03, BBS04 and BBS05 located within Site 1, BBS02 located within Site 2, and BBS01 located within Site 4 (Figure 3-1).

Wildlife Camera Monitoring

Three wildlife monitoring cameras were deployed within Site 1 at locations shown in Figure 3-1 and as described below.

- Camera 1 (11U 709343E 5658206N) was located under the existing 17th Avenue SE Bridge facing east towards the Bow River. Camera 1 was deployed on March 14, 2019 and was functional for 255 days. Camera 1 monitoring ended on November 23, 2019.
- Camera 2 (11U 709370E 5658328N) was located 126 m upriver from Camera 1 on a storm drain outfall, orientated downward at approximately 45-degree angle towards the Bow River. It was intended to serve as a control location for comparing mammalian use of the riparian zone with the newly added substrate material along the south side of the bridge. Camera 2 was deployed on April 4, 2019 and was functional for 234 days. Camera 2 monitoring ended on November 23, 2019.
- Camera 3 (11U 709370E 5658206N) was located 15 m downstream from Camera 1 on a storm drain outfall and was orientated downward at approximately 45-degree angle towards the Bow River (Figure 3-1). Camera 3 was deployed on April 4, 2019 and was functional for 118 days. Camera 3 failed on July 31, 2019 and did not record any photos for between July 31 and November 23, 2019.

Each camera placement was intended to determine use of the additional substrate added to the bank of the Bow River by medium and large mammals (i.e., larger than a rabbit). Cameras were set up for motion detection to capture three images with a one second spacing between images. There was a five second quiet period between each group of three images, and the camera sensitivity was set to medium/high. Wildlife cameras were aimed away from the pedestrian pathway to prevent abundant photos of human activity.

Wildlife camera monitoring was not conducted at Site 2 or Site 4 per the agreed study design described in the BEMP (Hemmera, 2018), as the focus was on wildlife movement on the Site 1wildlife corridor. Also, no data collection on wildlife/vehicle interaction on Barlow Trail or Cushing Bridge was included in the study.

3.2 Results

The following outlines the results for wildlife monitoring at each site.

Breeding Bird and Nest Surveys

The observations from the breeding bird and nesting surveys are provided for Site 1 in Table 3-2, for Site 2 in Table 3-3, and for Site 4 in Table 3-4. The breeding bird surveys resulted in identifying 31 species including three listed species as shown in Table 3-5.

Several bird species were identified during the breeding bird and nesting surveys but were not included in a breeding bird plot based on the requirements for observations in the Sensitive Species Inventory Guidelines (ESRD, 2013). A list of species observed is present in Table 3-6. None of the incidental species observed are listed provincial or federally.

Table 3-2: Site 1 Breeding Bird and Nest Survey Results

Assessment	Observations
Species	A total of 129 individuals representing 22 species were observed (Table 3-5). Two species (least flycatcher and western wood-pewee) are considered listed species (AEP, 2017b). No species identified were listed within the *Species at Risk Act* (SARA), or under the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (Government of Canada, 2016; COSEWIC, 2008).
Habitat	The habitat consists of deciduous trees, riparian area, and revegetated riparian (i.e., *willow sp.*) species. There is a large gravel area in Site 1 as the Bow River water levels drop exposing a large gravel bar. The habitat under the 17th Ave bridge is gravel/rocky substrate with some revegetation effort for willow species underway.
Nesting	Four stick nests that would be appropriately sized for raptors were identified during the survey, and all were observed to be empty at the time of the survey. Two stick nests were located approximately 40 m west of BBS05, one was located approximately 45 m north of BBS04, and one was located approximately 50 m south of BBS03. No other nesting features (e.g. nests, colonies, etc.) were noted during these surveys.

Table 3-3: Site 2 Breeding Bird and Nest Survey Results

Assessment	Observations
Species	A total of 68 individuals from 8 separate species were observed over the two survey periods at this location (Table 3-5). Of the species identified, two species (bank swallow and least flycatcher) are considered listed species (AEP, 2017b) with bank swallow being listed by *SARA* and COWEWIC (Government of Canada, 2016; COSEWIC, 2008).
Habitat	The habitat within Site 2 consists of grasses and shrubs with a city park habitat and pedestrian path adjacent to it.
Nesting	One bank swallow colony was identified (Figure 3-1). A total of 30 individuals were identified at the colony with other individuals noted during the breeding bird survey utilizing nearby habitat. No other nesting features (i.e., raptor stick nests) were identified during the surveys.

Table 3-4: Site 4 Breeding Bird and Nest Survey Results

Assessment	Observations
Species	A total of 24 individuals representing 6 species were observed over the two survey periods at this location (Table 3-5). Of the species identified, none were listed by AEP, SARA or COSEWIC (Government of Canada, 2016; COSEWIC, 2008; AEP, 2017b).
Habitat	The habitat within Site 4 consists of rock riprap, grasses and shrubs with an adjacent city park and pedestrian path adjacent to it.
Nesting	One bank swallow colony was identified south of Site 4 (Figure 3-1). A total of 34 individuals were identified at the colony. These species were not identified during the breeding bird survey due to distance of the colony from the breeding bird survey plot. No other nesting features (i.e., raptor stick nests) were identified during the surveys.

Table 3-5 Species Identified during the Breeding Bird Surveys at Site 1, Site 2 and Site 4

Common Name	Scientific Name	Number of Individuals		
		Site 1	Site 2	Site 4
American robin	*Turdus migratorius*	5		
American wigeon	*Anas americana*		1	
bank swallow[1]	*Riparia riparia*		43	
black-billed magpie	*Pica hudsonia*	2	2	5
black-capped chickadee	*Poecile atricapillus*	1		
brown-headed cowbird	*Molothrus ater*	4		
Canada goose	*Branta canadensis*	3		6
gray catbird	*Dumetella carolinensis*			3
common goldeneye	*Bucephala clangula*	1		
common merganser	*Mergus merganser*	2		
double-crested cormorant	*Phalacrocorax auritus*	2		
European starling	*Sturnus vulgaris*	1		
Franklin's gull	*Leucophaeus pipixcan*	70	16	
Gadwall	*Anas strepera*	4		
house sparrow	*Passer domesticus*	2	3	
house wren	*Troglodytes aedon*	6		
Killdeer	*Charadrius vociferus*	3		
least flycatcher[2]	*Empidonax minimus*	3	1	
Mallard	*Anas platyrhynchos*	2		8
red-winged blackbird	*Agelaius phoeniceus*	4	1	
song sparrow	*Melospiza melodia*	3		1
spotted sandpiper	*Actitis macularius*	3	1	
tree swallow	*Tachycineta bicolor*			1
yellow warbler	*Dendroica petechia*	5		
western wood-pewee[3]	*Contopus sordidulus*	1		
warbling vireo	*Vireo gilvus*	2		

Notes:
1. Listed as “Sensitive” by AEP (AEP, 2017b), “Schedule 1” by SARA (Government of Canada, 2016), and “Threatened’ by COSEWIC (COSEWIC, 2008).
2. Listed as “Sensitive” by AEP (AEP, 2017b).
3. Listed as “May Be at RISK” by AEP (AEP, 2017b).

Table 3-6 Incidental Bird Species Identified during Breeding Bird Surveys

Common Name	Scientific Name	Number of Individuals
American crow	*Corvus brachyrhynchos*	1
cedar waxwing	*Bombycilla cedrorum*	2
gray catbird	*Dumetella carolinensis*	1
northern flicker	*Colaptes auratus*	1
pine siskin	*Carduelis pinus*	1

The baseline desktop assessment showed that more listed species have been documented as using this site historically in comparison to the results from 2019 monitoring (12 identified in the desktop versus 3 identified on site); however, some of these species may have been detected in species specific surveys (e.g., common nighthawk) that were not completed for this project. The two wildlife features (i.e., bank swallow colonies) identified in the baseline were identified in the post-construction monitoring, indicating that construction did not result in fewer breeding colonies in the project area.

Site 1 was found to have the most bird species at 22 separate species (including two listed species) and the most individuals observed at 129, followed by 8 separate species at Site 2 (including two listed species) and 68 individuals observed. Site 4 had the lowest number of bird species at 6 (no listed species) and 24 individuals observed. Four stick nests were observed at Site 1, a bank swallow colony was observed at Site 2, but no nesting features were observed within range of the breeding bird plot at Site 4. The increased activity at Site 1 and Site 2 over Site 4 may be the result of differences in vegetation between the sites, with Site 4 having lower density vegetation. Additionally, Site 1 was found to have the most diverse habitat conditions, followed by Site 2 and Site 4.

Wildlife Camera Monitoring (Site 1 only)

As discussed in Section 3.1 above, three wildlife monitoring cameras were installed at Site 1 in 2019 at the locations shown in (Figure 3-1**)**. Camera 1 produced 9,674 images, Camera 2 produced 10,477 images and Camera 3 produced 9,290 pictures for a total of 29,441 images. Of these images, there were 334 images of targeted terrestrial species (i.e., animals larger than a rabbit), with 92 images showing new individuals (i.e., animals that were not observed in previous images within a one-hour time period). There were 725 images produced of non-terrestrial species (e.g., birds including rock doves [*Columba livia*], house sparrows [*Passer domesticus*]). Non-terrestrial species such as waterfowl or human activity were not counted in the analysis, but observations were noted when abundant images were present.

The species identified for each wildlife camera are presented in Table 3-7**.** A total of 7 wildlife species were identified through observations of 212 individuals during the wildlife camera monitoring period. Species occurrence was captured by 2 of the 3 cameras (as presented by the frequency) for most species, with deer species observed at all three of the cameras.

Camera 1 was placed under the newly constructed 17th Avenue SE bridge, and this location provides the best assessment area of wildlife utilizing the wildlife corridor constructed as part of the restoration. Camera 1 had a total of 40 individuals of 6 different species captured on camera. Additionally, larger sized mammals (i.e., deer species, coyotes) utilized the area under Camera 1 much more frequently than the smaller mammals, indicating these larger animals are utilizing the wildlife corridor. Smaller mammals may have been utilizing the corridor as well but were not captured on camera and could have been utilizing the pedestrian pathway. Camera 1 captured 10 separate coyotes and 19 separate deer species individuals, making up most of the individuals identified during the monitoring program.

Table 3-7 Total Sum of Species occurrences by Camera in Site 1

Camera	Species[1]								Total
	Canada goose	coyote	deer species[2]	great blue heron	mule deer	striped skunk	white-tailed deer	white-tailed jack rabbit	
Camera 1	5	10	3		2		14	6	40
Camera 2	121	3	1	1	2	1	2	39	170
Camera 3	-	-	2	-		-	-	-	2
Total[3]	126	13	6	1	4	1	16	45	212
Frequency[4]	67	67	100	33	67	33	67	67	100

Notes:

1. Species included in this table includes all observations of terrestrial mammals and bird species using the terrestrial habitat as a wildlife passage corridor (i.e., on the substrate and not observed in the water, vegetation or anthropogenic structures). This included Canada goose (*Branta canadensis*) and great blue heron (*Ardea Herodias*). Species such as house sparrow and rock dove were not included in the analysis since they were not using the wildlife corridor for passage but were likely nesting or roosting on the bridge structures.
2. Deer species are individuals that could not be differentiate between white-tailed deer or mule deer.
3. Total is the number of individuals observed in pictures as "new individuals" to avoid any double counting of the same individual.
4. Frequency is the presence of each species captured on each camera compared to the total number of cameras. This was to show if any species was observed at all three cameras, or if a particular species was only observed at one camera

Camera 2 was placed upstream of the bridges and represented the control location. It was assumed that wildlife activity would be high at this location due to the higher quality habitat observed nearby and larger sandbar features and riverbank that could be used for wildlife passage. While Camera 2 had the highest number of species at 8 separate species and the highest abundance of observations with 170 individuals observed, most of these individuals were Canada goose. If this species was removed from the analysis, the total number of wildlife individuals observed would be 49, similar to that observed at Camera 1 (Table 3-7). Larger mammals were present as well (e.g. deer species) but not in the same abundance as Camera 1. This indicates that smaller animals are utilizing the habitat at the Camera 2 location and that movement of larger mammals from upstream to downstream along the Bow may not have been captured initially by Camera 2 due to camera placement.

Camera 3 reported a low number of species occurrences, with only 2 deer species identified. The placement of Camera 3 was on a storm outfall pointed toward the timber crib wall and soil wraps to capture the movement of the deer from Camera 1 to Camera 3 (Table 3-7). However, the willows and other vegetation within view of the camera ended up growing to impede the view of the camera, and also caused an abundance of images by moving in the wind. Because of the vegetation blocking the view of Camera 3, it can not be confirmed if the animals are avoiding utilizing the habitat around Camera 3 or were not captured on Camera.

The number of individuals, mean use, and total composition of each species identified is presented in Table 3-8. The most abundant species identified during the monitoring program was Canada goose (59%) followed by white-tailed jackrabbit (21%) and white-tailed deer (8%).

The water level of the Bow River was monitored on Camera 2 throughout the season to assess the capacity for wildlife passage along the shore. Of the 243 days the wildlife camera was functioning, there were 81 days that the water level was considered high (i.e., less than 1 m of shore visible), and may have partially or fully impeded wildlife passage on the shore.

Table 3-8 Species Abundance, mean use and Composition for Site Camera Monitoring Program

Species	Number of Individuals	Mean Use[1]	Composition of Total Species Occurrence[2] (%)
Canada goose	126	0.21	59
coyote	13	0.02	6
deer species	6	0.01	3
great blue heron	1	<0.01	0.5
mule deer	4	0.01	2
striped skunk	1	<0.01	0.5
white-tailed deer	16	0.03	8
white-tailed jack rabbit	45	0.07	21
Total	212	0.35	100

Notes:
1. Mean use was calculated based on the number of new individuals identified over the number of days the cameras functioned. It represents the use of the habitat overall during the monitoring period.
2. The composition of total species occurrence is the number of one species over the total number of individuals reported in percent.

Most of the animals observed during the wildlife camera monitoring program were observed during crepuscular times (i.e., dawn/dusk) or nocturnally. This may be when the observed species are naturally more active, or this could be a result of human activity and subsequent wildlife avoidance within the project area. Activity of species by hours is presented in Figure 3-2 and Figure 3-3. Canada goose was the exception to this crepuscular and nocturnal activity trend and was observed as primarily active during the middle of the day. This species is diurnal, and tends to be more tolerant of human activity, especially individuals within municipal areas.

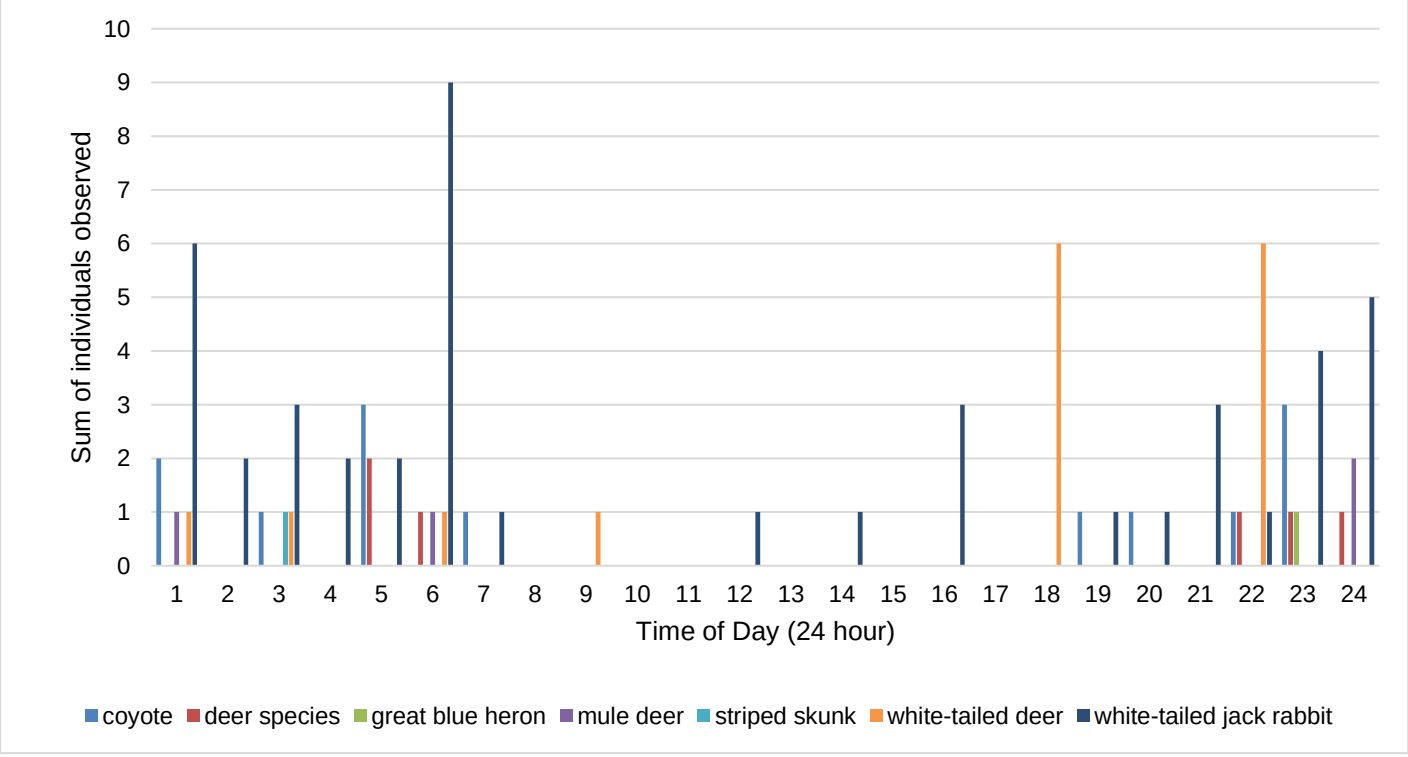


Figure 3-2: Species Occurrence by Time of Day

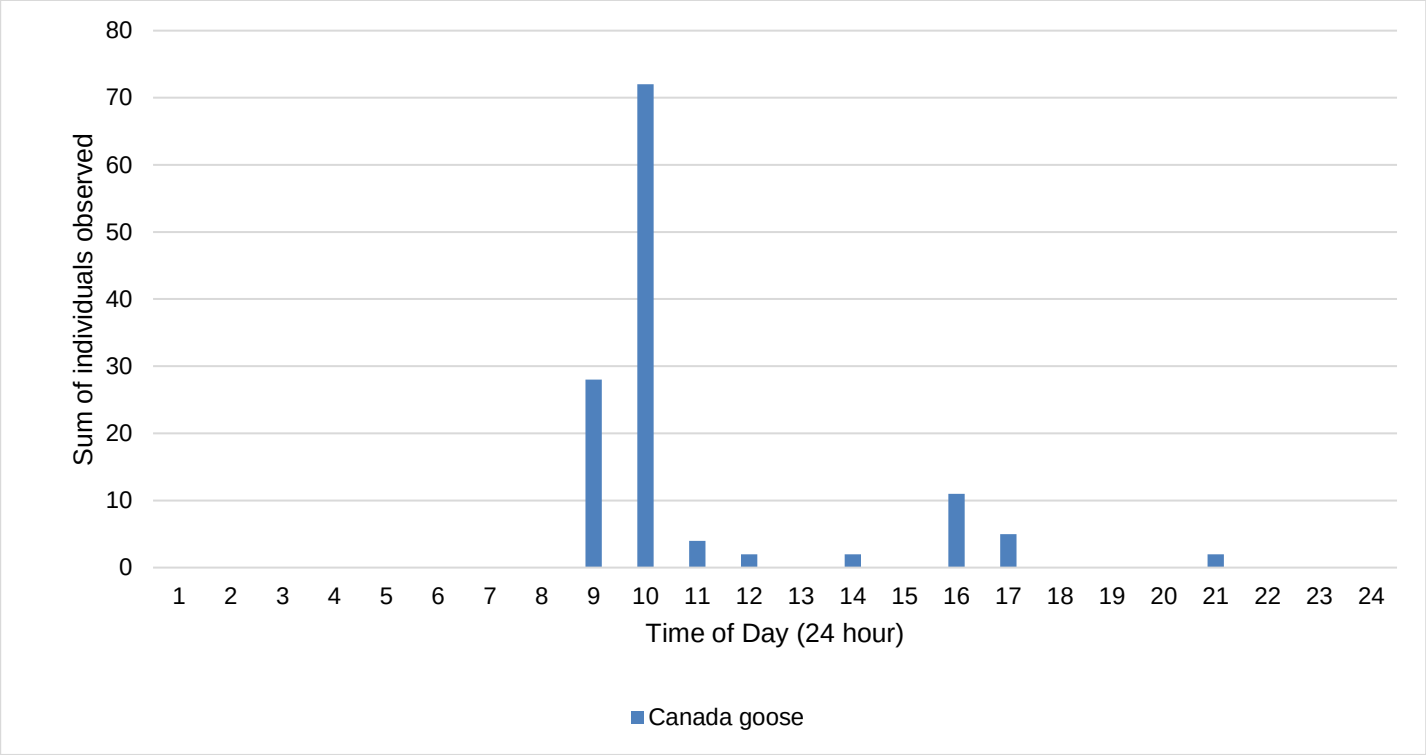


Figure 3-3: Canada Goose occurrence by Time of Day

While wildlife camera monitoring was not conducted at Site 4, it is expected that conditions at Site 1 are better for wildlife passage since riprap surfaces such as found at Site 4 are difficult for many species to traverse, especially ungulates and amphibians (Ruediger & DiGiorgio, 2006; Chisholm, et al., 2010) and the filled-in riprap at Site 1 that is part of the wildlife corridor is clearly being used by a number of large mammals as documented by Camera 1. Also, it is expected that most of the large mammals will now be using the wildlife corridor instead of crossing Blackfoot Trail as research has shown that deer will go the long way under the bridge instead of taking the short way over the highway (Leete, 2016) and that the number of wildlife vehicle collisions reduces on average by 86 percent (Huijser, et al., 2008) when wildlife underpasses are provided. Because of the effectiveness of this technique, wildlife passage benches are standard practice in Minnesota to meet permitting requirements for the repair or reconstruction bridges impacting public waters (Leete, 2014; Leete, 2016).

3.3 Summary of Findings

The Year 1 breeding bird surveys resulted in the identification of 31 species including three listed species at the BDEP sites. The highest number of bird species and individuals identified was at Site 1, followed by Site 2 and Site 4. The bank swallow colony identified during the baseline assessment at Site 2 was observed during the 2019 survey. Stick nests were observed at Site 1. No nests were observed at Site 4. Site 1 (129 individuals over 22 species) and Site 2 (68 individuals over 8 species) showed increased bird activity relative to Site 4 (24 individuals over 6 species) based on the results of the breeding bird and nesting surveys. This increased activity may be the result of differences in vegetation between the sites, with Site 4 having lower density vegetation.

The wildlife camera monitoring program identified animals utilizing the wildlife corridor created under the 17th Avenue SE bridge. A total of 7 wildlife species were identified through observations of 212 individuals. The most abundant species identified during the monitoring program was Canada goose (59%) followed by white-tailed jackrabbit (21%) and white-tailed deer (8%).

Assuming that there was limited passage beneath this bridge prior to the restoration work except for the existing pedestrian pathway, the usage of this wildlife corridor would represent an increase from baseline conditions where passage was previously limited. While there is no wildlife camera data for the bridge location prior to restoration, Camera 1 represented a similar species composition to that of Camera 2 which represented the control camera where passage is not limited. Larger mammals (i.e., deer species and coyotes) appear to be utilizing this wildlife corridor more than other smaller mammals, potentially due the larger range these mammals may require, or because smaller mammals may not have triggered the wildlife cameras to the same extent as larger mammals due to camera positioning or sensitivity.

Although no wildlife camera monitoring was conducted at Site 4, it is expected that better wildlife passage is provided by Site 1 according to research by other organizations on the effectiveness of wildlife passage benches used under bridges. The wildlife corridor at Site 1 is clearly being used by several large mammals including 10 separate coyotes and 19 separate deer species individuals as documented by Camera 1. Based on this perceived success of the wildlife corridor at Site 1, it is recommended to infill riprap void-spaces with smaller sized gravels to improve wildlife passage under bridges in Calgary. This technique could also be used more broadly at all locations where riprap is placed on riverbanks in Calgary to improve wildlife passage and habitat on riverbanks.

Year 1 of the monitoring program showed promising results and indications that wildlife continues to use this habitat. Future monitoring will be required to determine if discrepancies between wildlife camera monitoring locations continue.

Photo 3-2: Trees Planted at Site 1

4. Riparian Health

4.1 Methods

Baseline Riparian Health Assessments (RHA) for Site 1, Site 2, and Site 4 were completed in 2016 according to the Large River Riparian Health Methodology (Cows and Fish, 2018) developed by the Alberta Riparian Habitat Management Society (Cows and Fish) (Hemmera, 2017c). Riparian health at Site 1, Site 2 and Site 4 was reassessed on September 16 and 17, 2019 according to the same RHA methodology and assessment polygon boundaries used in the 2016 assessment. The polygon boundaries are shown in Figure 1-1. In summary, 15 vegetation and soil/hydrology factors were assessed to give an overall rating of how well each particular reach was functioning ecologically (Table 4-1). Based on how well they score for each health indicator, reaches are then placed into one of three riparian health categories (Table 4-2).

Cows and Fish will be conducting a re-visit Riparian Health Inventory (RHI) in 2021 for RHI polygon BOW95 as described in the BEMP (Hemmera, 2018). Scores generated by RHI and RHA protocols are equivalent (i.e., the same parameters are scored), but additional data is collected to characterize the monitoring site when using the RHI protocol. The extent of BOW95 is slightly different than the assessed area described in this section. It includes Site 1 downstream of Cushing Bridge, Site 2 and Site 4 all in one assessment area.

Table 4-1: Cows and Fish Large River Assessment Criteria

Parameter	Score
Vegetation	
1. Cottonwood and poplar regeneration from seed	/ 6
2. Regeneration of other native tree species	/ 3
3. Regeneration of preferred shrub species	/ 6
4. Standing decadent and dead woody material	/ 3
5a. Browsing/utilization of preferred tree and shrub species	/ 3
5b. Woody vegetation removal by beavers and/or humans	/ 3
6. Total canopy cover of trees and shrubs	/ 3
7a. Total canopy cover of invasive plant species	/ 3
7b. Density distribution pattern of invasive plant species	/ 3
8. Total canopy cover of disturbance-increaser plant species	/ 3
Soil / Hydrology	
9. Riverbank root mass protection	/ 6
10. Percent cover of human-caused bare ground	/ 6
11. Removal or addition of water to or from the river system	/ 9
12. Control of flood peak and timing by upstream dam(s)	/ 9
13. Percent of riverbank structurally altered by human activity	/ 6
14. Percent of human alteration to the remainder of the polygon	/ 3
15. Natural floodplain accessibility	/ 6
Total score	**/ 81**

Table 4-2: Riparian Health Scores and Ratings

Health Score (%)	Health Rating	Description
80-100	***Healthy***	Little to no impairment of riparian function.
60-79	***Healthy with Problems***	Some impairment of riparian function due to natural or human causes.
0-59	***Unhealthy***	Substantial impairment to riparian function due to natural or human causes.

4.2 Results

Results from the 2019 RHAs for Site 1, Site 2, and Site 4 are summarized in Table 4-3. RHA field data sheets are provided in Appendix F. All three sites are rated as ***Unhealthy***, which is the same as results obtained in 2016. However, all three sites are showing improving health trends, with higher scores obtained in 2019 compared to 2016. Each site is discussed in detail below.

Table 4-3: 2019 BDEP Riparian Health Results

Rating	Site 1		Site 2		Site 4	
	2016[1]	2019	2016[1]	2019	2016[1]	2019
Vegetation rating (%)	54	64	33	78	28	75
Soil / hydrology rating (%)	33	40	25	44	29	40
Overall rating (%)*	43	51	29	58	29	56
Trend	Improving		Improving		Improving	
Health category	***Unhealthy***	***Unhealthy***	***Unhealthy***	***Unhealthy***	***Unhealthy***	***Unhealthy***

Note:
1. 2016 data are baseline RHAs ratings (Hemmera, 2017c)

Site 1 Riparian Health

Site 1 is shown in Figure 1-1 and Photo 4-1. Site 1 received a riparian health score of 51% (*Unhealthy*) in 2019. The 2019 health score is an improvement from the score of 43% received in 2016, indicating an upward health trend. The bioengineering work completed in Site 1 during the fall of 2018 / spring of 2019 as part of the BDEP has contributed to the improved health score in the last three years.

Site 1 scored higher for vegetation parameters than soil / hydrology parameters (64% vs. 40%), and the vegetation rating increased by about 20% from baseline (2016) conditions. In general, Site 1 has good growth from the planted cottonwoods/poplars (*Populus spp.*), other native trees, and preferred native shrubs, light browsing of preferred trees and shrubs, low amounts of woody vegetation removal, and good overall cover of trees and shrubs. The site also had high cover of invasive (approximately 4%) and disturbance-increaser species (approximately 30%). Ten Invasive species were observed at Site 1 as shown in Table 4-4. Disturbance-increaser species are common in Site 1, with approximately 18 different species observed. Of these, smooth brome (*Bromus inermis spp. inermis*) and quack grass (*Elymus repens*) were common under mature balsam poplar (*Populus balsamifera*) forest north of the bridge, while clovers (*Trifolium spp.*) and black medick (*Medicago lupulina*) were abundant in places south of the bridge.

With respect to soil / hydrology parameters, Site 1 generally had good floodplain accessibility, low cover of human-caused bare soil, and low amounts of water withdrawals from the river system. The reach still has relatively low amounts of root mass protection from trees and shrubs, although this has improved with the BDEP planting work and it will continue to improve as the planted trees and shrubs mature. Human physical alteration has affected the entire bank and floodplain. Alterations include two bridges, the regional

pathways, two stormwater outfalls, and the bank reconstruction work completed for the BDEP. Two of the hydrology indicators (i.e., water removal or addition from the river system and water levels controlled by upstream dams) are broad watershed indicators and cannot be improved by projects such as the BDEP. Bearspaw Dam, located upstream near the western City limits, controls flood peaks and timing of the Bow River, and impacts riparian health downstream, including at the BDEP.

Photo 4-1: View south of Site #1 from just south of Cushing Bridge (September 17, 2019) (E709336, N5658185)

Photo 4-2: View south-southeast from the north end of Site #2 (September 17, 2019) (E709346, N5657964)

Photo 4-3: View southeast from the north end of Site #4 (September 16, 2019) (E709402, N5657842)

Site 2 Riparian Health

Site 2 is shown in Figure 1-1 and Photo 4-2. Site 2 received a riparian health score of 58% (Unhealthy) in 2019, which is an improvement on the score of 29% received in 2016, suggesting an upward trend in health rating. The bioengineering work completed for the BDEP project is directly responsible for the health improvements observed in Site 2.

Vegetation parameters were rated higher than soil / hydrology parameters for Site 2 (78% vs. 44%), and the vegetation rating showed an improvement of about 2.5 times the baseline (2016) rating. Site 2 generally had excellent regeneration of cottonwoods and poplars, other native tree species, and preferred native shrub species. There was little browsing of preferred trees and shrubs, no standing dead or decadent woody material, and no woody vegetation removal. Overall cover of trees and shrubs was good with between 25% and 50% cover. The main reasons for the below optimal vegetation rating for Site 2 was high cover of invasive species (approximately 4%) and disturbance-increaser plant species (approximately 25%

to 50%). Nine invasive species were observed in Site 2 as shown in Table 4-4. High diversity of disturbance-increaser plant species was also observed with 21 different recorded species, including species such as sweet-clovers (*Melilotus alba and M. officinalis*), smooth brome, Kentucky bluegrass, round-leaved mallow (*Malva rotundifolia*), clovers, lamb's-quarters (*Chenopodium album*), and common dandelion (*Taraxacum officinale*).

For soil / hydrology indicators, Site 2 generally had good floodplain accessibility, low cover of human-caused bare soil, and low amounts of water withdrawals from the river system. Riverbank root mass protection is still low because a large section of the mid to upper bank was not rehabilitated and instead was left as unvegetated swallow habitat. Large amounts of the bank (approximately 95%) and floodplain (greater than 90%) have been physically altered by human activities. Bearspaw Dam controls flood peaks and timing along this section of the Bow River, negatively impacting riparian health.

Site 4 Riparian Health

Site 4 is shown in Figure 1-1 and Photo 4-3. Site 4 received a riparian health score of 56% in 2019 (*Unhealthy*), which improves on the lower score in 2016 (i.e., 29%) that suggests an improving health trend for Site 4. This improvement is attributable to the successful BDEP bioengineering.

Site 4 was similar to the other two sites in having a higher rating for vegetation-related parameters compared to soil / hydrology parameters (75% vs. 40%), and the vegetation rating showed an improvement of about 2.5 times the baseline (2016) rating. The main vegetation-related issue in Site 4 was invasive plant species, where cover was approximately 8%. Eight different invasive plant species were documented as shown in Table 4-4. Other minor health deductions were made for increased cover of disturbance-increaser species (approximately 15%), light browsing of preferred shrub species, and below optimal levels of preferred shrub regeneration.

Soil / hydrology parameters were rated similar for Site 4 as Sites 1 and 2. Riverbank root mass protection is improving as a result of the restoration work, but still below optimal levels, with approximately 55% of the bank having deep-rooted woody vegetation. Similar to Sites 1 and 2, the entire bank and floodplain in Site 4 has been physically altered by human activities. Bare soil cover is slightly above normal levels due to topsoil placement on site and a failure of the seed mix to establish in places. Backfill has also washed away along the shoreline in places. No embankments or other obstructions restrict natural floodplain accessibility. As discussed for Sites 1 and 2, Bearspaw Dam affects water levels in the Bow River, and some water is diverted into an irrigation canal immediately upstream from the BDEP, thereby impacting riparian health at Site 4.

Comparison to a Theoretical Conventional Riprap Design Site

As discussed in Section 1.3, the RHA ratings for Sites 1, 2, and 4 were compared to the RHA ratings for a theoretical conventional riprap design site. The theoretical site was assigned an RHA score of 38% and the corresponding Unhealthy *condition based on the assumptions described in*

Table 1-2. While all BDEP sites and the theoretical conventional riprap design site were found to be *Unhealthy*, significant differences were identified that show marked improvements in riparian health at the BDEP sites over a theoretical conventional riprap design site as described below.

- Vegetation ratings are significantly higher for Sites 1, 2 and 4, ranging from 2 to 2.5 times higher than the vegetation rating for a theoretical conventional riprap design site.
- Overall ratings for Sites 1, 2 and 4 range from 34% to 54% higher than the than the overall rating for a theoretical conventional riprap design site.

Note that soil / hydrology parameter ratings are essentially the same among the BDEP sites and the theoretical conventional riprap design site. This is due to some of the parameters in this category being broad watershed indicators that cannot be influenced by projects such as the BDEP and because most of the riparian areas in Calgary have been physically altered by human activities. Thus, all projects on the Bow River in Calgary will have similar ratings for the soil / hydrology component of the RHA.
Given the limitations of the soil / hydrology RHA ratings for sites on the Bow River in Calgary, other methods to assess improvements in riparian health such as the Bank and Riparian Quality Index (BRQI) that was developed as part of the RMP (KWL, 2018) could be investigated for this purpose.

Table 4-4: Invasive Species Observed during the RHA Assessments

Invasive Species		Site Observed		
Common Name	**Scientific Name**	**Site 1**	**Site 2**	**Site 4**
black henbane	*Hyoscyamus niger*	X	X	X
common burdock	*Arctium minus*	X		X
common mullein	*Verbascum thapsus*	X		
common tansy	*Tanacetum vulgare*	X	X	X
creeping bellflower	*Campanula rapunculoides*	X	X	X
creeping (Canada) thistle	*Cirsium arvense*	X	X	X
hound's-tongue	*Cynoglossum officinale*			X
scentless chamomile	*Tripleurospermum inodorum*	X	X	X
smooth perennial sow-thistle	*Sonchus arvensis ssp. uliginosus*	X	X	X
tufted vetch	*Vicia cracca*	X	X	
white cockle	*Silene latifolia*		X	
yellow clematis	*Clematis tangutica*		X	
yellow toadflax	*Linaria vulgaris*	X		
Total number of species		10	9	8

4.3 Summary of Findings

All three sites are showing improving health trends with increases of 15% to 100% from the ratings obtained in 2016. In particular, at Site 1 the vegetation rating has increased by 20% over the 2016 rating and at Site 2 and Site 4 vegetation ratings are about 2.5 times greater than the 2016 ratings. This shows a marked improvement from the baseline RHAs that is directly attributable to the bioengineering work completed for the BDEP.

Overall RHA ratings for Sites 1, 2, and 4 range from 34% to 54% higher than the RHA rating for a theoretical conventional riprap design site. The main reason for increased RHA scores for Sites 1, 2 and 4 is that their vegetation ratings are 2 to 2.5 times greater than a theoretical conventional riprap design site.

Photo 4-4: Site 4 vegetation growth

5. Bioengineering Structural Integrity

Bioengineering structural integrity monitoring focuses on the long-term structural integrity, stability, and operational effectiveness of the bioengineering structures (i.e., long term performance of physical structures). The results of this monitoring component are intended to show how the BDEP has improved bank structural integrity and specifically how it has been improved over a conventional riprap design site.

5.1 Methods

As indicated in the BEMP (Hemmera, 2018), the methods used to monitor the BDEP bioengineering structures are the protocols developed as part of the RMP riverbank bioengineering effectiveness monitoring component (KWL, 2018). These protocols are separate and distinct from the monitoring of physical works that is required as part of the BDEP construction contract (i.e., monitoring relative to performance stipulations laid out in the BDEP construction contract) and are also not structural engineering assessments of the infrastructure. These protocols are also used to assess the effectiveness of all the riverbank bioengineering effectiveness sites monitored as part of the RMP, of which the BDEP sites are included.

Under RMP protocols, data for riverbank bioengineering effectiveness monitoring sites are collected through either desktop or field-based activities. Desktop activities include compiling general project information and planting design details. Field activities include a structural assessment, vegetation assessment, and failure assessment as described below. Detailed forms are completed for all monitoring activities.

Structural assessment: The RMP structural assessment includes a basic condition assessment of the materials used in the structure (e.g., rock, timber, erosion control matting, fencing), hydrologic observations (e.g., flow at time of survey, high water mark), site measurements (e.g., flow angle relative to the site, aspect, lengths, widths, slopes), a survey of vegetation elevations (native and planted), general observations of bed / bank erosion, sediment deposition, bank stability and geomorphological changes within the project area, an assessment of site conditions that might limit success, recommendations for repairs if needed, suggestions for alternative design options, observed success attributes, and photographic monitoring. A full structural assessment is completed on the BDEP sites for each monitoring year. The results of the hydrologic observations, photographic monitoring, general observations of erosion and bank stability, and materials assessment are reported as part of the BDEP monitoring to meet the requirements of the BEMP. The full results of the structural assessment are reported as part of the RMP.

Vegetation assessment: The RMP vegetation assessment includes three main components:

- 20 m long pinpoint transects at a representative section of each technique within the structure;
- quadrats along each transect at 5 m, 10 m, and 15 m for a total of 3 quadrats per transect; and
- assessments of plant health and survival for typically 50 cuttings and 20 plantings at each site.

These assessments allow a detailed statistical analysis of vegetation survivorship, leader growth, shoot length, vegetation cover, vegetation vigour, and species diversity. To comply with the requirements of the BEMP, only vegetation survivorship results are reported as part of the BDEP monitoring. The other data is reported through the RMP.

Failure assessment: An RMP failure assessment is completed on sites that do not meet the woody vegetation survival threshold of 25% and / or if the structure is found to be missing, degraded or ineffective. The results of failure assessments will be reported through both the RMP and BDEP monitoring if needed.

A detailed description of the protocols developed for the RMP are described in the *Riparian Monitoring Program - Monitoring Plan* (KWL, 2018).

Photographic Monitoring

Baseline photographs of Sites 1, 2, and 4 were taken in 2016 and 2017. Photographic monitoring stations were then established in 2019 in Sites 1, 2, and 4 as shown in Figure 2-1 so that repeated photographic monitoring could occur from the established locations for comparison purposes.

Monitoring Sites and Dates

There are several different bioengineering techniques included in each BDEP site. For RMP monitoring purposes, Sites 1, 2 and 4 were divided into the ten sites shown in Figure 1-1 and described in Table 5-1 below. The RMP monitoring sites were defined according to the techniques that were used.

The RMP site code and design approach that correlates with each BDEP site number are also shown in Table 5-1. However, monitoring results in this report are provided only for Site 1, Site 2, and Site 4 in accordance with the BEMP. More detailed results are provided in the annual monitoring reports for the RMP.

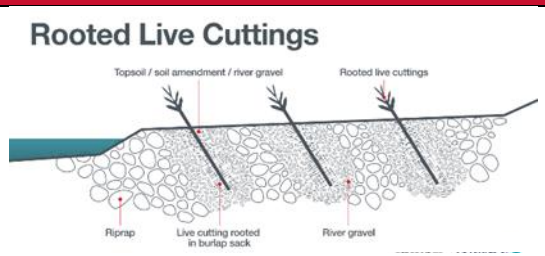
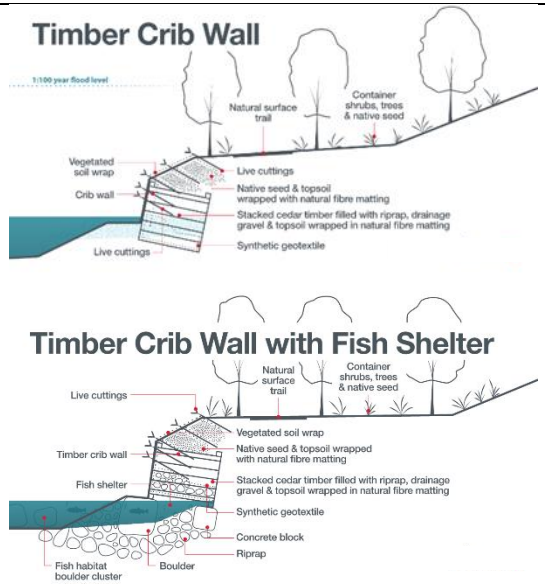
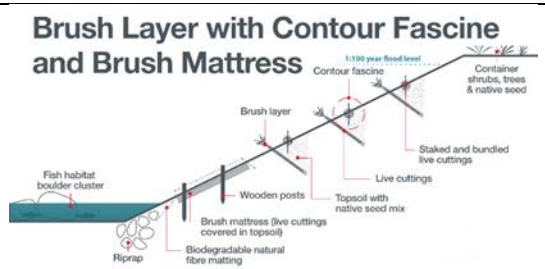
Baseline assessments of the BDEP site occurred in 2016 and 2017 (Hemmera, 2016; Hemmera, 2017a; KWL, 2017). The 2019 monitoring assessments occurred on the dates shown in Table 5-1.

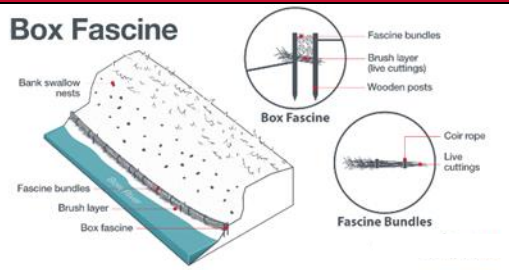
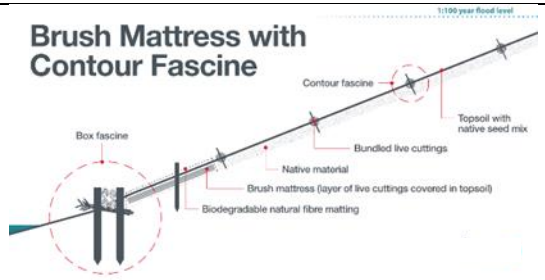
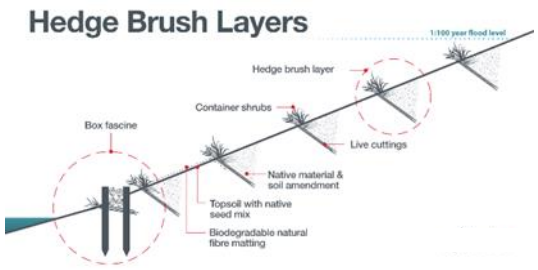
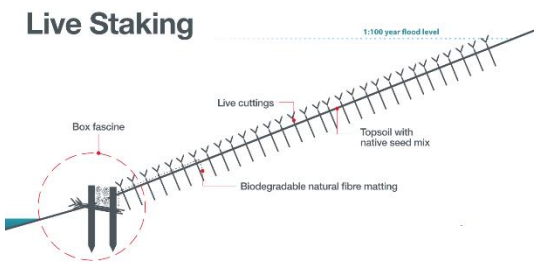
Hydrology and Shear Stress

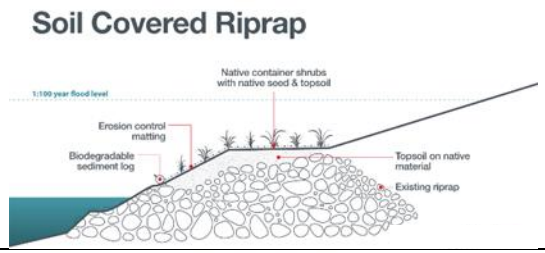
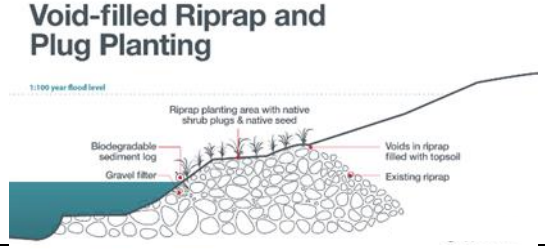
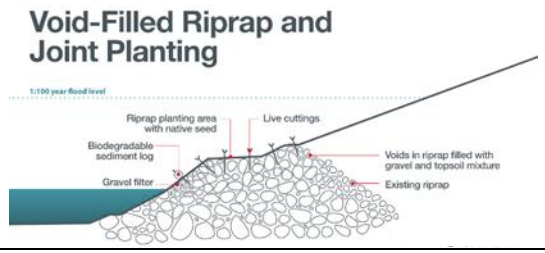
Baseline Bow River flow, velocity, and shear stress for each BDEP site were assumed to be the 100-year event to be consistent with the BDEP design basis. Bow River flow for the 100-year event was taken from the *Bow River and Elbow River Basin-Wide Hydrology Assessment and 2013 Flood Documentation* (Golder, 2014). Velocity and shear stress at each BDEP site was generated using the 100-year flow event in the *2015 Bow River and Elbow River Hydraulic Model* (Golder, 2015).

Maximum Bow River flow since construction for each BDEP site was obtained from the rivers.alberta.ca website. The maximum velocity and shear stress was generated at each BDEP site for the maximum flow event using the *2015 Bow River and Elbow River Hydraulic Model* (Golder, 2015).

Table 5-1: BDEP Site Numbers, Design Approaches, Fieldwork Dates and Vegetation Survival

BDEP Site No.	BDEP Sub-Site No. / RMP Site Code	BDEP Design Approaches	Fieldwork Dates	Vegetation Survival Results (%) (refer to Section 5.2)	Estimated Permissible Shear Stress (N/m²)[1]
Site 1	Site 1-1 / BE-BOW-46A		Structural: July 17, 2019 Vegetation: September 9, 2019	Rooted Live Cuttings: 65%	Live cuttings: 150[4] Class 2 riprap: 364[3]
	Site 1-2 / Not monitored	No bioengineering design applied; however, includes wildlife passage corridor	NA	NA	Class 2 riprap: 364[3]
	Site 1-3 / BE-BOW-46B		Structural: July 18, 2019 Vegetation: September 10, 2019	Live Cuttings: 50% Potted Plants: 100%	Timber crib wall with brush layers: 600[2]
	Site 1-4 / BE-BOW-46C		Structural: July 18, 2019 Vegetation: September 10, 2019	Live Cuttings: 92% Potted Plants: 100%	Brush layer with contour fascine: 141[2] Brush mattress with rock toe: 244[2]

BDEP Site No.	BDEP Sub-Site No. / RMP Site Code	BDEP Design Approaches	Fieldwork Dates	Vegetation Survival Results (%) (refer to Section 5.2)	Estimated Permissible Shear Stress (N/m²)[1]
Site 2	Site 2-1 / BE-BOW-46D1		Structural: July 18, 2019 Vegetation: July 25, 2019	Live Cuttings: 96% Potted Plants: 100%	Box fascine: 141[2]
	Site 2-2 A / BE-BOW-46D2		Structural: July 22, 2019 Vegetation: July 26, 2019	Live Cuttings: 96% Potted Plants: 100%	Box fascine: 141[2] Brush mattress: 244[2] Contour fascine: 50[2]
	Site 2-2 B / BE-BOW-46D3		Structural: July 22, 2019 Vegetation: July 26, 2019	Live Cuttings: 68% Potted Plants: 100%	Box fascine: 141[2] Hedge brush layers: 141[2]
	Site 2-2 C / BE-BOW-46D4		Structural: July 22, 2019 Vegetation: July 26, 2019	Live Cuttings: 82% Potted Plants: 100%	Box fascine: 141[2] Live staking: 150[2]

BDEP Site No.	BDEP Sub-Site No. / RMP Site Code	BDEP Design Approaches	Fieldwork Dates	Vegetation Survival Results (%) (refer to Section 5.2)	Estimated Permissible Shear Stress (N/m²)[1]
Site 4	Site 4-1 / BE-BOW-46E1		Structural: July 17, 2019 Vegetation: September 13, 2019	Potted Plants: 97%	Class 2 riprap: 364[3] Plantings: 100[2]
	Site 4-2 / BE-BOW-46E2		Structural: July 16, 2019 Vegetation: September 13, 2019	Plugs: 96%	Class 2 riprap: 364[3] Plantings: 100[2]
	Site 4-3 / BE-BOW-46E3		Structural: July 16, 2019 Vegetation: September 13, 2019	Live Cuttings: 60%	Class 2 riprap: 364[3] Live cuttings: 100[4]
	Site 4-4 / Not monitored	No design applied as part of the BDEP – left as a control site	NA	NA	Class 2 riprap: 364[3]

Notes:
1. Estimated shear stress resistance at the time of monitoring, i.e., 1-year post construction.
2. Source: Evette, A. et al (2018) *The limits of mechanical resistance in bioengineering for riverbank protection*
3, Source: Fischenich, C. (2001) *Stability Thresholds for Stream Restoration Materials - EMRRP Technical Notes Collection (ERDC TN EMRRP-SR-29)*
4. Source: Lachat, B. (1999). *Guide de protection des berges de cours d'eau en techniques vegetales*.

5.2 Results

Bow River Hydrology

Baseline Bow River flow, velocity and shear stress are shown in Table 5-2 and were taken to be the 100-year flood event per Section 2-1.

The maximum Bow River flow, velocity and shear stress for 2019 are shown in Table 5-2. These represent the most extreme conditions that the monitored sites at the BDEP have experienced from construction to present since flows on the Bow River were lower in 2018. Maximum flows from construction to present have been less than the 2-year return period flow of 439 m^3/s (Golder, 2014) and values of velocity and shear stress at the BDEP sites are all well below the baseline condition. Site 4 has experienced the highest maximum velocity and shear stress. Site 1 has experienced the lowest maximum velocity and shear stress.

Table 5-2: Baseline and 2019 maximum values for Bow River Flow, Velocity and Shear Stress at the BDEP

Parameter	Baseline (100-Year Flood Event)			2019		
	Site 1	Site 2	Site 4	Site 1	Site 2	Site 4
Max. Flow (m/s^3)[1]	2910			391		
Max. Velocity (m/s) [1]	3.5< to 3.9^	3.0	3.1	1.0*	1.1	1.7
Max. Shear Stress (N/m^2)[1]	105> to 126^	79	95	10> to 13<	15	39

Notes:

1. Maximum velocity and shear stress (channel) are calculated from the maximum flow shown using the *2015 Bow River and Elbow River Hydraulic Model* r provided by The City.
2. The symbols shown represent the data from the following locations: < value upstream of Cushing Bridge; ^ value at Cushing Bridge; > value downstream of Cushing Bridge; and, * all values are equal.

2019 Precipitation and Wind

Total precipitation amounts in Calgary at the Calgary International Airport for 2019 (from January to November inclusive) were 510 mm and for 2018 were 425 mm. With average total precipitation of 419 mm, 2019 was a wetter than average year. Average wind speed and direction were approximately 13 km/hr from the southwest for both 2018 and 2019.

Structural Assessment

The structural assessment consisted of a general observations of bank stability and erosion, and a materials assessment. Completed structural assessment field forms for each of the BDEP sites shown in Table 5-1 are provided in Appendix G.

Photographic Monitoring and General Observations

Visual assessments of the baseline conditions at Sites 1, 2 and 4 were conducted in 2016 and 2017 to document the physical condition and stability of the area. A visual assessment of the changes from the baseline and that physical condition of the bioengineering techniques at Sites 1, 2 and 4 was conducted during all four seasonal monitoring periods in 2019. Photographic data collected from the 2016/2017 and 2019 visual assessments at each of the established photo stations are presented in Appendix H.

Results of the 2019 visual assessment and photographic data indicate that the physical condition of the bioengineering techniques, including fish habitat structures (e.g., boulder clusters, fish shelters and box fascines), appear to be stable, with no signs of major erosion, scour, or displacement, in contrast to baseline (2017) where bank stability issues were noted (see below).

Minor, local erosion was observed at several locations: at drainage dips; where irrigation nozzles were leaking; and at the interface between the timber crib wall and the brush mattress / contour fascines (Site 1). Additional observations included fill material wash out of the box fascine at Site 2 (pea gravel was used), placed material washout along the surface of bank toe at Site 4 (void-fill material within the riprap matrix is still present), and settlement of the river gravels in the riprap at Site 1 and Site 4 at a few locations. The issues above were reported to the contractor for repair. At Site 1, it was noted that the non-woven geotextile used for backfill containment in the timber crib wall has gaps (see Photo 5-1). This was brought to the attention of the contractor during construction but did not get completely corrected as observed during the field assessment.

Bank Stability

Baseline (2017) and 2019 observations of bank stability are provided below.

- **Site 1**: Observations for bank stability are as follows:
    - Upstream of Cushing Bridge: Baseline (2017) observations were that bank stability was relatively stable along the bank (Hemmera, 2017a). The same observations as baseline conditions for bank stability were observed in 2019 where the bank was found to be stable.
    - At Cushing Bridge: Baseline (2017) observations were that bank stability was low along the bank immediately downstream of the Cushing Bridge (Hemmera, 2017a). Bank stability is now considered stable along the bank immediately downstream of the Cushing Bridge.
    - Downstream of Cushing Bridge: Baseline (2017) observations were that bank stability was observed to be low along the bank immediately downstream of the Cushing Bridge and into the upstream extent of Site 2, with evidence of extensive erosion. There was existing debris in the form of broken concrete on the bank that was installed as an attempt to stabilize the shoreline in the past (Hemmera, 2017a). In contrast to the bank stability conditions observed in 2017, high stability along the bank downstream of the Cushing Bridge was noted in 2019.
- **Site 2:** Baseline (2017) observations were that bank stability was low through the site, with extensive erosion along the bank. High stability was only present within the immediate vicinity of the riprap groynes present at the upstream and downstream extents of the site (Hemmera, 2017a). In 2019, bank stability was observed to be high along the bank in the site as a result of the BDEP.
- **Site 4**: Bank stability within Site 4 remains consistent with observations made during the baseline conditions assessment (Hemmera, 2017a). Bank stability is very high, with the entire bank composed of Class II riprap (d50 = 500 mm) and Class III riprap (d50 = 800 mm).

Materials Assessment

Materials used in the construction of the BDEP include rock riprap, wood, erosion control matting and geogrids, concrete, and steel. These materials were assessed for post-construction condition with observations as described below.

- **Rock Riprap:** Rock riprap used at the BDEP site remains in excellent condition and there are no concerns for long-term durability. No significant rock movement or displacement was observed.
- **Fill Materials:** Fill materials were observed to be in good condition and contained within the structures except at Site 2 where most of the pea gravel used on the face of the fascines in the box fascine has washed out, and at Site 4 where some of the void-fill material placed on the surface of the toe has washed out. In future, it is recommended to use larger materials such as native river

gravel to fill the box fascine instead of pea gravel. Also, placing void fill material on the surface of exposed steep riprap slopes should be avoided.

- **Wood Materials:** The wood materials used at the site consist of timber for the timber crib wall, posts for the box fascine, and posts for the brush mattress. In general, the condition of the posts used is very good with no concerns for long-term durability. However, there is some concern with the timber quality used in the crib wall at Site 1. It is understood from a review of construction monitoring documentation that standard grade cedar timber was used, which is a low grade of cedar timber. Several timber members (estimated to be 1 in 5 to 1 in 10 members) were observed to have dry rot and insect damage (see Photo 5-2, Photo 5-3, and Photo 5-4) that was found to be present in the original timber supply based on the construction documentation review. While there is no observable change in timber crib wall condition since construction in 2018, there could be a reduction in the estimated remaining useful life from > 20 years for higher grade cedar timber to somewhere in the 8 to 13 years range (Highley, 1995). It is recommended to conduct more detailed monitoring of the timber using non-destructive methods such as a Resistograph to provide more detailed understanding of the remaining useful life of the timber. Also, should this technique be used in the future, it is recommended that structural timber of a larger size be used for the spanning members.
- **Matting, Geogrids and Geotextiles:** Erosion control matting, coir geogrids, and non-woven geotextiles were installed at the BDEP to provide erosion control, material containment and material separation. The erosion control matting is installed at Site 4 to provide erosion control until vegetation established. It was observed to be in good condition. Both woody and herbaceous vegetation have established at Site 1 so the matting has performed its function. The coir geogrid was used at Site 1 in the timber crib wall for material containment, and at Site 1 and Site 2 for erosion control until vegetation establishes. It was observed to be in very good condition and there are no concerns with the coir geogrid providing erosion control until vegetation fully establishes at those sites (woody vegetation is good but herbaceous has not fully grown in at Site 1). The non-woven geotextile is used at Site 1 in the timber crib wall for material containment and separation. It is in very good condition with no observable concerns for durability.

Photo 5-1: Gaps in non-woven geotextile used for material containment in the timber crib wall at Site 1-3

Photo 5-2: Typical vegetated timber crib wall section (shown with rodent fencing attached) (July 18, 2019)

Photo 5-3: *Crib wall timber with signs of insect damage and dry rot (October 25, 2019)*

Photo 5-4: Crib wall timber with signs of dry rot (October 25, 2019)

- **Wattles**: Curlex sediment logs were installed at Site 4 to provide erosion control and material containment along the toe of the bank. The logs are in fair condition as they were displaced by high water levels. They are in need of repair to contain placed topsoil.
- **Hydromulch and Seeding**: Hydromulch was installed at Site 1, Site 2, and Site 4 for erosion control and seeding. The hydromulch was washed away at the upstream end of Site 1 due to water levels inundating the site for several weeks. Low herbaceous establishment was observed at Site 1 and Site 4 with high invasive weed cover. The herbaceous seeding establishment will be assessed in 2020 prior to recommending any remedial action.
- **Concrete**: Concrete blocks were incorporated into the construction timber crib wall at Site 1 in the fish shelters to support the landside of the wall. It was not possible to inspect the blocks this year due to water levels.
- **Steel**: Steel products were used at several locations at the BDEP site: at Site 1, stainless steel plates and bolts were used to secure neighbouring timber cribs together in the timber crib wall, galvanized spiral shank spikes were used to fasten the timber together in the timber crib wall, and steel jacks were used to support the timber crib wall in the fish shelters; at Site 1 and Site 2, steel cables were used to tie down the box fascine and the brush mattress; and, at Site 4, candy cane rebar were used to secure the wattles. All steel products were observed to be in good to excellent condition with no concerns for long-term durability. The steel supports that were placed under the spanning members in the fish shelters are in very good condition. The City conducted an inspection on October 11, 2019 and observed that 5 of the supports were loose but were otherwise working as intended. The contractor has since tightened the supports.
- **Temporary Fencing**: Temporary fencing was placed around the planting areas to limit access to wildlife and the public while the vegetation establishes. The fencing was found to be in very good condition except for a few areas that have been identified to the contractor for repair.
- **Fish Shelters**: The fish shelters were inspected on October 25, 2019. They were observed to have some fine sediment deposited along the bottom but were otherwise clear and providing good fish habitat as shown in Photo 5-5. Some large woody debris was observed on the fish boulders that will provide additional habitat complexity. No significant change in the condition of the timber crib wall was observed from as-constructed conditions per Photo 5-6, and there was no observed change in the deflection of the spanning members that are supported by the steel supports.

Vegetation Assessment

The results of vegetation survival for Sites 1, 2, and 4 are provided in Table 5-3. Overall survival of planted vegetation was highest at Site 2, followed by Site 1 and 4. Overall vegetation survival for all sites was 80%. As has been observed through the RMP at almost all bioengineering sites in Calgary, potted plant survival is higher than live cutting survival at Sites 1, 2 and 4 (KWL, 2019).

Table 5-3: 2019 vegetation survival by Site

Site No.	Overall Vegetation Survival (%)	Live Cutting Survival (%)	Potted Plant Survival (%)
1	77	65	100
2	83	80	100
4	77	60	96
Total	**80**	**74**	**99**

Planted vegetation survival for the 10 treatment areas that roughly correspond to the different bioengineering techniques used at the BDEP site are listed in Table 5-1. Key results and observations from the vegetation assessment of the different bioengineering techniques are listed below. More detailed results are provided in *Riparian Monitoring Program 2019 Annual Report - Bank Effectiveness Monitoring* (KWL, 2020).

- As shown in Table 5-1, survival of rooted live cuttings at Site 1 was 65% which is notable since this is a new technique first attempted at the BDEP. Also, Site 1 was inundated for several weeks. It was observed that the sandbar willow survival was highest and balsam poplar survival the lowest among the rooted live cuttings species used.
- At Site 1, live cutting survival was 30% for the timber crib wall and 74% for the vegetated soil wrap (combined survival of 50%). It is unclear why the survival for the timber crib wall is much lower than the soil wrap because in many cases they were installed at the same time. That said, the survival meets the lower end of the guidelines indicated by Gray and Sotir (1996) for timber crib walls of 30% to 60% growing. The brush mattress, brush layer and contour fascine survival is very high at Site 1.
- At Site 2, the box fascine, brush mattress, contour fascine, and live staking techniques were found to have high survival of live cuttings, while the hedge brush layers survival was lower as shown in Table 5-1.
- At Site 4, the survival of planted vegetation was highest for the soil covered riprap with container plants technique. A comparison of the riprap void-fill techniques to retrofit existing riprap leads to the result that void-fill with topsoil and plug planting with an overall survival of 96% is more successful than void-fill with pitrun and live staking with a survival of 60%. A potential reason for lower survival at the pitrun void-fill and live staking treatment area was the construction method selected by the contractor. The contractor elected to void-fill the riprap prior to installing live cuttings then drilled into the existing riprap to create planting holes. The live cuttings were then placed into the planting holes. It was observed during the botanical assessment in the fall of 2019 that basal ends of cuttings were suspended into empty void spaces between riprap, not in contact with soil or water (Photo 5-7). An alternate and potentially more successful method would have been to lay the cuttings into existing openings in the riprap prior to backfilling with growing substrate. Plugs installation was much simpler as shallower planting holes were required over the live staking.

Photo 5-5: Fish shelter and timber crib supports (October 25, 2019)

Photo 5-6: Fish shelters, fish habitat boulders and large woody debris (rodent protection fencing attached to face of crib wall) (October 25, 2019)

Photo 5-7: Installation of some of the live cuttings at Site 4-3

Comparison with Theoretical Conventional Riprap Design Site

As discussed in Section 1.3, the shear stress resistance of the bioengineering techniques used at BDEP Sites 1, 2, and 4 were compared to the shear stress resistance for a theoretical conventional riprap design site. The theoretical conventional riprap design site was assigned a permissible shear stress of 364 N/m² based on the assumption of Class 2 riprap (d50 = ±500 mm) (Fischenich, 2001).

The estimated permissible shear stresses for year 1 post-construction of the various bioengineering techniques used at Sites 1, 2, and 4 are shown in Table 5-1. Techniques that provide comparable or better shear stress resistance than Class 2 riprap are those that also feature Class 2 riprap such as Site 4. However, the vegetated timber crib wall at Site 1 provides greater shear stress resistance than Class 2 riprap. The remaining techniques range in permissible shear stress from 141 N/m² to 244 N/m² are less than the resistance provided by Class 2 riprap, but all meet the requirement to withstand the design 100-year flood event and 2019 flood event shear stresses shown in Table 5-2.

5.3 Summary of Findings

Key findings from the bioengineering structural integrity assessment are listed below.

- The structural assessment identified that the physical condition of the bioengineering techniques, including fish habitat structures appears to be stable, with no signs of major erosion, scour, or displacement. Minor, local erosion was observed at several locations and was communicated to the contractor for repair.
- Materials used in the construction of the bioengineering techniques at Sites 1, 2, and 4 include rock riprap, wood, erosion control matting and geogrids, concrete and steel and were generally found to be in good to excellent condition.
- There is concern with the timber used in the timber crib wall as several members were observed to have dry rot and insect damage. While there is no observable change in condition since construction in 2018.
- The fish shelters were observed to have some fine sediment deposited along the bottom but were otherwise clear and providing good fish habitat. No significant change in the condition of the timber crib wall was observed from as-constructed conditions, and there was no observed change in the deflection of the spanning members that are supported by the steel supports
- Overall vegetation survival at the BDEP sites was 80%, with Site 1 vegetation survival of 77%, Site 2 vegetation survival of 83%, and Site 4 vegetation survival of 77%.
- The shear stress resistance of Class 2 riprap is higher than the bioengineering techniques used except for the vegetated timber crib wall at Site 1 and where existing riprap was retrofitted at Site 4. However, the shear stress resistance for the bioengineering techniques are all higher than the baseline case (100-year flood event) and the maximum shear stress from 2019 Bow River flows.

Photo 5-8: Site 2 looking downstream from the riprap groyne on September 9, 2019

6. Conclusions and Recommendations

Photo 6-1: Rooted live cuttings at Site 1-1 on September 9, 2019

The key conclusions listed below were noted in this report.

Monitoring Approaches

The goals of the monitoring activities are to show how the bioengineering techniques used in the BDEP have improved fish habitat, wildlife habitat, riparian health, and bank structural integrity compared to a conventional riprap design site. The specific approaches for comparing the monitoring data collected at the BDEP to a conventional riprap design site are as follows:

- Fish habitat and wildlife habitat monitoring results from Site 1 and Site 2 are compared to monitoring results at Site 4 as the conventional riprap design control site.
- Riparian health and bioengineering structural integrity results for Sites 1, 2, and 4 are compared to riparian health and shear stress parameters for a theoretical conventional riprap design site.

Fish and Fish Habitat

- Year 1 fish and fish habitat monitoring activities occurred in the spring, summer, fall and winter and results indicate that fish are using the habitat enhancement structures provided by the BDEP.
- Fish were observed using and were captured within the vicinity of the new habitat structures throughout the project area. Fish were observed in the fish shelters, boulder clusters, and surrounding habitats during winter, spring and summer assessments.

- Compared with the baseline assessment of fish capture data from the Bow River, 10 of the 22 species that were likely to occur in proximity to the project site were captured during Year 1 of monitoring, including 6 sportfish and 4 non-sportfish species.
- Abundance of fish species within the project area could not be compared with baseline data, as fish sampling surveys were not previously conducted in similarly characterized Bow River habitat within proximity to the BDEP sites.
- A total of 16 fish consisting of 7 species were captured at Site 1, 8 fish consisting of 2 species were captured at Site 2, and 24 fish consisting of 6 species were captured at Site 4 using a single boat electrofishing pass. Electrofishing Catch per Unit Effort (CPUE) was greatest at Site 4, followed by Site 2, with Site 1 having the lowest.
- A total of 9 fish and 4 species were captured using minnow trapping, including longnose sucker, lake chub, longnose dace and yellow perch. Minnow trap CPUE was greatest in Site 4. Site 1 and Site 2 had equal CPUE. Overall, longnose sucker had the greatest CPUE of all fish captured at each site.
- Site 1 had the lowest fish abundance; however, lower fish abundance at the BDEP sites is expected during Year 1 monitoring as fish habitat enhancements naturalize following construction activities. Fish sampling also indicated species richness was highest at Site 1 – possibly supported by the variation in cover and microhabitats provided where bioengineering enhancements were most diverse. Additionally, Site 1 had the highest abundance and diversity of sportfish. Sites 2 and Site 4 had higher abundance of forage fish, with longnose sucker and white sucker being most prevalent.
- Species composition and fish abundance observed during Year 1 are expected to vary in subsequent monitoring years as the BDEP sites naturalize following the construction of the fish habitat enhancements.
- Potential spring and fall salmonid spawning habitats were documented, but no redds or salmonid spawning was observed during the spring or fall spawning assessments in 2019. Mountain whitefish eggs were observed during kick sampling within suitable habitat in the upstream extent of Site 1.
- Overall, Site 1 and Site 2 were found to be providing high quality fish habitat in comparison to Site 4. Despite the highest abundance of fish at Site 4, the highest abundance and diversity of sportfish species were captured in Site 1 where bioengineering enhancements were most diverse.

Wildlife

- The breeding bird surveys resulted in identifying 31 species including three listed species: least flycatcher, western wood-pewee, and bank swallow. The highest number of bird species and individuals identified was at Site 1, followed by Site 2 and Site 4.
- The bank swallow colony identified in the baseline assessment at Site 2 was observed during 2019 monitoring, indicating that construction did not result in fewer breeding colonies in the project area. Stick nests were also observed at Site 1.
- Site 1 (129 individuals over 22 species) and Site 2 (68 individuals over 8 species) showed increased bird activity relative to Site 4 (24 individuals over 6 species) based on the results of the breeding bird and nesting surveys. This increased activity may be the result of differences in vegetation between the sites, with Site 4 having lower density vegetation.
- The wildlife camera monitoring program included three cameras that identified animals using the wildlife corridor created under the 17th Avenue SE bridge.

- A total of 212 wildlife species were identified during the wildlife camera analysis. The most abundant species observed was Canada goose (59%) followed by white-tailed jackrabbit (21%), white-tailed deer (8%), and coyote (6%). Larger mammals such as deer species and coyotes appear to be using the BDEP wildlife corridor more than other smaller mammals.
- It is expected that better wildlife passage is provided by Site 1 in comparison to Site 4 since research by other organizations shows the effectiveness of wildlife passage benches used under bridges such as what was included at Site 1. The wildlife corridor at Site 1 is clearly being used by several large mammals including 10 individual coyotes and 19 individual deer as documented by wildlife monitoring cameras.

Riparian Health

- The 2019 Riparian Health Assessment (RHA) results for Sites 1, 2, and 4 are consistent with the baseline assessment where the riparian health conditions is rated as ***Unhealthy*****.**
- The 2019 Riparian Health Assessment (RHA) rating for Site 1 was 51%, for Site 2 was 58%, and for Site 4 was 56%. The 2019 scores show the same condition rating of *Unhealthy* as the baseline results obtained in 2016; however, all three sites are showing improving health trends, with higher scores obtained in 2019 compared to 2016.
- The main increase in RHA ratings is from the vegetation ratings where for Site 1 the vegetation rating has increased by 20% over the 2016 rating and at Site 2 and Site 4 vegetation ratings are about 2.5 times greater than the 2016 ratings. This shows a marked improvement from the baseline RHAs that is directly attributable to the bioengineering work completed for the BDEP.
- Overall RHA ratings for Sites 1, 2, and 4 range from 34% to 54% higher than the RHA rating for a theoretical conventional riprap design site. The main reason for increased RHA scores for the BDEP sites is that vegetation ratings are 2 to 2.5 times greater for Sites 1, 2 and 4 than a theoretical conventional riprap design site
- The improving health trends are attributable to the successful BDEP bioengineering.

Bioengineering Structural Integrity

- In general, the physical condition of the bioengineering techniques, including fish habitat structures appears to be stable, with no signs of major erosion, scour, or displacement. Minor, local erosion was observed at several locations and was communicated to the contractor for repair.
- Materials used in the construction of the BDEP include rock riprap, wood, erosion control matting and geogrids, concrete, and steel and were generally found to be in good to excellent condition.
- There is concern with the timber used in the timber crib wall as several timber members were observed to have dry rot and insect damage. While there is no observable change in condition since construction in 2018, it is recommended to monitor the timber for long-term durability and to use structural quality timber of larger size for the spanning members should this technique be used again.
- The fish shelters were observed to have some fine sediment deposited along the bottom but were otherwise clear and providing good fish habitat. No significant change in the condition of the timber crib wall was observed from as-constructed conditions, and there was no observed change in the deflection of the spanning members that are supported by the steel supports

- Overall vegetation survival at the BDEP sites was 80%, with Site 1 vegetation survival of 77%, Site 2 vegetation survival of 83%, and Site 4 vegetation survival of 77%.
- Survival of rooted live cuttings was 65% which is notable since this is a new technique first attempted at the BDEP.
- At Site 1, live cutting survival was 30% for the timber crib wall and 74% for the vegetated soil wrap (combined survival of 50%). It is unclear why the survival for the timber crib wall is much lower than the soil wrap because in many cases they were installed at the same time. That said, the survival meets the lower end of the guidelines indicated by Gray and Sotir (1996) for timber crib walls of 30% to 60% growing. The brush mattress, brush layer and contour fascine survival is very high at Site 1.
- At Site 2, the box fascine, brush mattress, contour fascine, and live staking techniques were found to have high survival of live cuttings, while the hedge brush layers survival was lower.
- At Site 4, the survival of planted vegetation was highest for the soil covered riprap with container plants technique. A comparison of the riprap void-fill techniques to retrofit existing riprap leads to the result that void-fill with topsoil and plug planting with an overall survival of 96% is more successful than void-fill with pitrun and live staking with a survival of 60%.
- The shear stress resistance of Class 2 riprap is higher than the bioengineering techniques used except for the vegetated timber crib wall at Site 1 and where existing riprap was retrofitted at Site 4. However, the shear stress resistance for the bioengineering techniques are all higher than the baseline case (100-year flood event) and the maximum shear stress from 2019 Bow River flows.

6.1 Recommendations

Recommendations for future monitoring years are listed below.

Approach to Compare Monitoring Results

The comparison of Fish and Fish Habitat and Wildlife monitoring results to Site 4 results, and of Riparian Health and Bioengineering Structural Integrity to a theoretical conventional riprap design site appears to be providing valuable information and is the recommended approach for future monitoring years. This approach will be evaluated during each monitoring year to confirm its effectiveness.

Fish and Fish Habitat

- Use the fish use and population data collected in 2019 to make comparisons and trends with data collected in subsequent monitoring years to meet the requirements of the BEMP (Hemmera, 2018). Any required site improvements to meet the BEMP requirements should be considered.
- The crew should monitor the ice conditions of the Bow River beginning in January to determine safe conditions for completing the winter assessment (i.e., stable and thick ice for on-ice survey or ice-free open water conditions for snorkel survey).
- During the summer assessment, the crew should use a smaller boat for more effective sampling of near shore habitats adjacent to Sites 1 and 2.

Wildlife

- Future monitoring should be conducted to determine if discrepancies between wildlife camera monitoring locations continue.

- Based on the perceived success of the wildlife corridor at Site 1, it is recommended to infill riprap void-spaces with smaller sized gravels to improve wildlife passage under bridges in Calgary (as is standard in Minnesota), but also at all locations where riprap is used on the riverbank as a means to improve wildlife passage and habitat on riverbanks.

Riparian Health Assessment

- Future monitoring should be continued to confirm that BDEP has contributed to long-term improvements in riparian health.
- The results of the 2021 revisit RHI of BOW95 should be compared against the RHA scores collected for Sites 1, 2 and 4 to provide an independent confirmation of the impact that the BDEP has had on riparian health.
- Given the limitations of the soil / hydrology RHA ratings for sites on the Bow River in Calgary, other methods to assess improvements in riparian health could be investigated. The Bank and Riparian Quality Index (BRQI) that was developed as part of the RMP (KWL, 2018) could be investigated for this purpose.
- Better control of weeds should occur at the BDEP sites as many species of invasive weeds and disturbance increaser species were documented.

Bioengineering Structural Integrity

- Based on the success of the rooted live cuttings at Site 1, they appear to be a viable approach for constructing bioengineering projects and are recommended to be considered when timing constraints cause construction to occur outside of the recommended period for using dormant live cuttings.
- Irrigation of the brush layers in the timber crib wall may need to be improved as it could be a key contributor to the observed low survival.
- If the timber crib wall with fish shelters technique is used in the future, it is recommended to construct the spanning members using structural timber with dimensions larger than the timber used in the BDEP timber crib wall.
- More detailed monitoring of the timber in the timber crib wall should be conducted using non-destructive methods such as a Resistograph to provide more detailed understanding of the remaining useful life of the timber.
- Box fascine fill should be larger sized material such as native river gravels instead of the pea gravels that were used at Site 2. Also, placing void-fill material on the surface of exposed steep riprap slopes should be avoided.
- It is recommended to consider combining potted plants with live cuttings in bioengineering techniques such as hedge brush layers as the potted plants improve the overall survival rate, biodiversity and habitat for wildlife.
- It is recommended to continue detailed monitoring of the three techniques used to retrofit existing riprap sites to determine the preferred approach. If live cuttings are used, they should be placed in the openings in the riprap prior to backfilling with growing substrate.

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8. Report Submission

This report has been prepared and reviewed by the personnel listed below.

KERR WOOD LEIDAL ASSOCIATES LTD.

Prepared by:

Mike Gallant, MScE, P.Eng.
Water Resources Engineer, KWL

Reviewed by:

Craig Kipkie, M.Sc., P.Eng.
Principal, Project Manager, KWL

Statement of Limitations

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Revision History

Revision #	Date	Status	Revision	Author
0	July 14, 2020	FINAL	Issued for use	MG

APEGA Permit # P07929

KERR WOOD LEIDAL
consulting engineers

Appendix A

Bioengineering Efficacy Monitoring Plan

Prepared by: Hemmera Envirochem Inc.

August 29, 2018

Mr. David DePape
Senior Manager, FISHES Program
Alberta Environment and Parks
South Saskatchewan Region
1st Floor, Suite 100, 3115 – 12th St. N.E.
Calgary, Alberta
T2E 7J2

Dear Mr. DePape, DAVE

Re: Final Bioefficacy Monitoring Plan (May, 2018)

Thank you for submitting the final Bioefficacy Monitoring Plan (BEMP) for the Bioengineering Demonstration and Education Project. Please consider this letter The City of Calgary's official acceptance of the final plan.

The City of Calgary (The City) is pleased to be part of the Bioengineering Demonstration and Education Project and is committed to fulfilling the financial and project obligations outlined in the *Memorandum of Understanding* and *Project Charter* including the implementation of the BEMP. The City recognizes the importance of this project in achieving fish habitat and riparian restoration and enhancing the knowledge of bioengineering techniques.

The BEMP will be an important component of The City's Riparian Monitoring Program and will contribute to improving our understanding of the efficiency of bioengineering restoration practices. This knowledge will support our ongoing work to protect riparian areas in Calgary.

We look forward to initiating the implementation of the BEMP in 2019 and continuing to work with you and the Province on this valuable project.

Sincerely,

Trevor Rhodes, M.Sc., P. Biol.
Leader, Watershed Strategy
Watershed Planning Division| Water Resources
The City of Calgary

Cc: Carolyn Bowen, Manager, Watershed Planning, Water Resources
Harpreet Sandhu, Team Lead, Resource Strategy, Water Resources

Bioengineering Demonstration and Education Project
Bioengineering Efficacy Monitoring Plan

May 2018

Prepared for:

Alberta Environment and Parks
Suite 100, 3115 12 St. NE
Calgary, Alberta T2E 7J2

Prepared by:

Hemmera
An Ausenco Company

THURBER ENGINEERING LTD.

KERR WOOD LEIDAL
consulting engineers

Terra Erosion Control Ltd.

Polster Environmental Services Ltd.

O2 PLANNING + DESIGN

ACKNOWLEDGEMENT

The Bioengineering Efficacy Monitoring Plan (BEMP) is an important component of the Bioengineering Demonstration and Education Project (BDEP). It will provide data to support the use of bioengineering techniques as ecologically valuable and cost-effective alternatives to conventional engineering practices for bank erosion protection and riparian restoration.

The need for a longer term (10 year) monitoring plan to assess the BDEP was always envisioned as an integral part of BDEP. Development of the plan was supported and funded by Alberta Environment and Parks (AEP) as part of the design contract scope of work. Implementation of the Plan is the responsibility of the City of Calgary. Given the partnership between Alberta Environment and Parks and The City of Calgary in the development and implementation of BDEP, the BEMP could not have been developed without the input and guidance of a large number of individuals.

Greg Eisler (Hemmera) and Lisa Rear (Hemmera) were principal authors of the Plan, and supporting budget and schedule, which was informed by input from staff within The City of Calgary and Alberta Environment and Parks. Members of the Technical Team supporting AEP in the delivery of the BDEP also contributed to the Plan.

The following individuals and organizations provided technical input, to ensure the effectiveness of long-term monitoring activities, as well as institutional knowledge to ensure the effective integration of the BEMP and complimentary riparian restoration and monitoring initiatives within the City of Calgary:

- Trevor Rhodes (City of Calgary Water Resources)
- Jon Slaney (City of Calgary Water Resources)
- George Roman (City of Calgary Water Resources)
- Norma Posada (City of Calgary Water Resources)
- Sarah Marshall (City of Calgary Water Resources)
- Tim Walls (City of Calgary Parks)
- Kathryn Hull (Cows and Fish)
- David DePape (Alberta Environment and Parks)
- Kevin Brayford (Alberta Environment and Parks)
- Mike Gallant (Kerr Wood Leidal Associates Ltd.)
- Andrew Szojka (Kerr Wood Leidal Associates Ltd.)
- Pierre Raymond (Tera Erosion Control)
- Mike Magnan (02 Planning + Design)
- Mark Piciacchia (Hemmera)
- Mike Peckford (Hemmera)

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1.0 INTRODUCTION

Hemmera Envirochem Inc. (Hemmera) has prepared a *Bioengineering Efficacy Monitoring Plan* (BEMP) for Alberta Environment and Parks (AEP) Fisheries Habitat Enhancement and Sustainability (FISHES) Program, in partial fulfillment of the requirements of the Bioengineering Demonstration and Education project (the Project). The Project is being delivered under a formal partnership agreement between AEP and the City of Calgary (The City). As part of the partnership understanding, development of the BEMP is the responsibility of AEP, while implementation of the BEMP is the responsibility of The City. This report outlines the details of the proposed BEMP for Sites 1, 2, and 4 (**Figure 1**). It is understood that final refinements to this BEMP may be necessary, pending further discussions between The City and the FISHES Program and/or any changes to the Project's intended footprint occurring at construction.

Hemmera's team understands that AEP's primary goal is to achieve fish habitat enhancement and riparian restoration at flood affected and impacted sites using bioengineering techniques. Integrating education opportunities and objectives during project development will facilitate increased understanding of bioengineering techniques, as effective and ecologically valuable alternatives to hard engineering practices (i.e. controlled disruption of natural processes by using man-made structures) for bank erosion protection and associated riparian restoration, with a range of identified audiences.

The goals for the Project, as per the *Project Charter*, are to meet the following criteria:

- Effectively stabilize an area of unstable, steep bank.
- Initiate measurable restoration of flood affected habitat or creation of new fish habitat (e.g. bank overhangs, in-stream refugia, boulder clusters, large woody debris, shade/cover by riparian plantings, etc.).
- Design and construct methods to facilitate increased awareness and understanding of flood recovery processes, development of new educational programming targeting bioengineering techniques, and related design success factors.
- Improve riverbank aesthetics in the area.

Building on the Project goals, key objectives of the Bioengineering Demonstration and Education Project (BDEP) are:

- To monitor the overall effectiveness and cost of the Project, specifically in relation to a more conventional rip rap bank protection project.
- To evaluate the overall effectiveness and cost of the Project, specifically in relation to a more conventional rip rap bank protection project.
- To report on the overall effectiveness and cost of the Project, specifically in relation to a more conventional rip rap bank protection project.

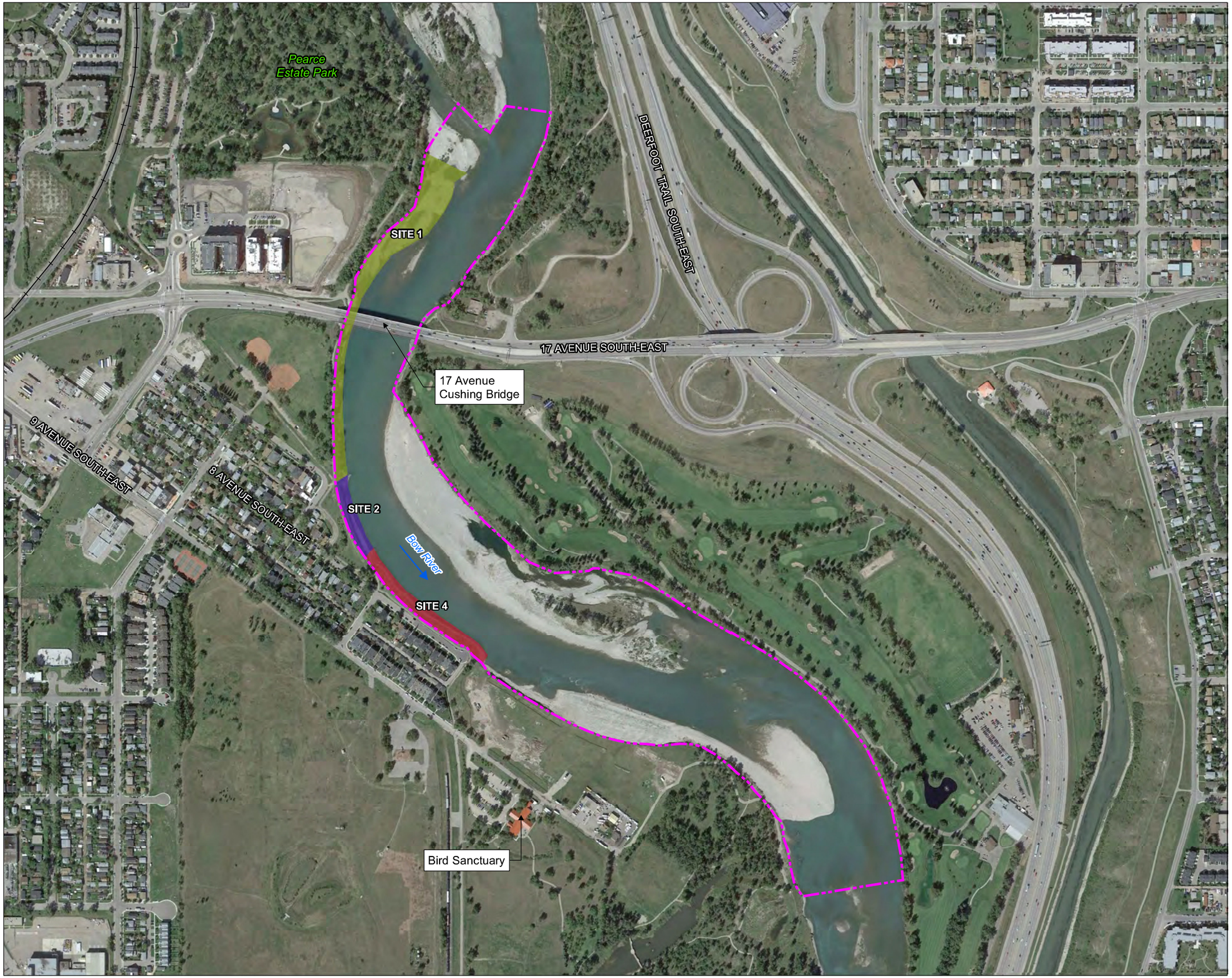
In this context, the BEMP is a critical tool to providing information to support understanding of the effectiveness of the physical works undertaken through the Project, with respect to the goals noted above, and support a comparison with conventional approaches to bank protection. However, an actual cost benefit analysis of the Project in relation to a more conventional riprap bank protection project is outside the scope of the BEMP.

The scope of work for the BEMP involves post-construction monitoring over multiple years, with the first year of monitoring commencing in 2019, after anticipated Project construction is complete in December 2018. Subsequent monitoring will occur in 2020, 2021, 2023, and 2028. It is recommended that a visual inspection of the works be completed following any return event greater than 1:10, given this is the flood level on the Bow River where significant sediment transport will likely be realized. The BEMP also includes a contingency budget to support monitoring immediately following a significant flood event(s) that occurs post-construction and results in significant damage to Project works. A significant flood event is defined as 'a return event that causes enough damage to the works to require major repairs or re-construction'. Should this occur, the monitoring schedule would be reset to include monitoring in years 1, 2, and 4, post-reconstruction. Monitoring will include surveys for fish and fish habitat, riparian health, wildlife, and integrity of the bioengineering structures/installments. Monitoring visits will be conducted during select (and in some cases multiple) seasons in each monitoring year to capture the range of environmental conditions that may exist at the sites, and to ensure that sampling of biotic and abiotic elements occurs with appropriate timing. Details of each component are presented in subsequent sections. A summary of survey timing and level of effort is provided in **Section 4.0**, **Table 6.**

In support of The City's *Riparian Action Program*, The City is currently undertaking a 5-year Riparian Monitoring Program (RMP). An opportunity was identified for The City to undertake implementation of the BEMP, in concert with implementation of the RMP, as both initiatives have overlapping objectives, similar implementation timelines, and draw on similar monitoring activities. Additional detail on how implementation of the BEMP will be undertaken in an integrated manner with the RMP is included in **Section 2.0** (BEMP Implementation).

Bioengineering Efficacy Monitoring Plan
Bow River, Calgary, Alberta

Site Map



Legend

- Assessed Reach
- Site 1
- Site 2
- Site 4
- Direction of Flow
- Railway

Notes

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

Sources

- Basedata: Government of Alberta
- Aerial Image: Google Earth (imagery date: 8/22/2015)
- Inset Basemap: ESRI World Topographic Map

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Hemmera
An Ausenco Company

Alberta Environment and Parks

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2.0 BEMP IMPLEMENTATION

In support of The City's *Riparian Action Program*, The City is currently undertaking a 5-year Riparian Monitoring Program (RMP). During the planning phase of BDEP, an opportunity was identified for The City to undertake implementation of the BEMP in concert with implementation of the RMP. While both initiatives have overlapping objectives, similar implementation timelines and draw on similar monitoring activities, there are also differences in the objectives of the two initiatives, which result, in some cases, in different monitoring activities. This section of the BEMP provides an overview of the overlaps and differences in monitoring approaches between the two programs.

The City's RMP focuses on bioengineering and riparian planting projects implemented by The City in the last ten years, as well as baseline Riparian Health Inventory (RHI) sites assessed since 2007.

The RMP involves two components: *Effectiveness Monitoring* and *Trend Monitoring*.

- **Effectiveness Monitoring** – Effectiveness monitoring will assess post-construction conditions to evaluate changes resulting from implemented restoration projects.
- **Trend Monitoring** – Trend monitoring will be used to establish the nature and direction of riparian health. The table below shows the overlap between the two programs.

A main deliverable of the RMP Phase 1 is a program *Monitoring Plan*, which will include the BDEP as a special project.

Table 1 Comparison of BEMP and RMP Monitoring Approaches: provides an overview of where the monitoring approaches in The City's RMP overlap with the BEMP, and where the objectives of the BEMP require a different approach or frequency of monitoring, relative to that employed in The City's RMP.

Table 1 Comparison of BEMP and RMP Monitoring Approaches

Monitoring Focus	BEMP	RMP
Fish and Fish Habitat	This component is part of the BEMP. The BEMP describes methods for monitoring of fish and fish habitat.	This component is currently not part of the overall RMP. The BEMP methods will be followed as part of the RMP for the BDEP sites.
Riparian Health	This component is part of the BEMP. The monitoring method for riparian health described in the BEMP includes a Riparian Health Assessment (RHA).	Riparian Health is a component of the overall RMP, and BEMP monitoring methods, including frequencies, will be part of the RMP monitoring. There are two monitoring procedures that will be included in the RMP to support the BEMP: • Completion of a revisit Riparian Health Inventory (RHI) in 2021 for the BOW95 Site (Cows and Fish 2016b). • The RMP includes a riparian/top-of-bank assessment component as part of its Bank Effectiveness Monitoring that will be integrated with Riparian Health Assessments (RHA). RHAs were not originally part of the RMP but will be undertaken to be consistent with the BEMP methods. The BEMP monitoring frequencies will be followed for RHAs.
Wildlife	This component is part of the BEMP. The BEMP describes methods for monitoring of wildlife.	This component is currently not part of the overall RMP. The BEMP methods will be followed as part of the RMP for BDEP sites.
Bioengineering Structural Integrity	This component is included in the BEMP. The BEMP describes timelines for monitoring that are more frequent than the RMP.	This component is part of the overall RMP. The BEMP monitoring frequencies will be followed for RMP implementation at BDEP sites. The RMP will define specific methods and analysis that align with the BEMP.
Reporting	BEMP implementation assumes one reporting of results will take place in every year in which monitoring activities are undertaken. A final report, summarizing the conclusions and findings of the overall monitoring programs, as well findings related to the individual components (e.g. fish, wildlife, structural integrity etc.), will be completed and provided to AEP within 6 months of the final monitoring event.	This component is part of the overall RMP, The BEMP monitoring findings will be integrated with the RMP reporting scope. Annual reports will be prepared as part of the RMP.

It should be noted that the RMP is currently structured as a 5-yr program, and the BEMP is a 10-yr monitoring program. However, the RMP is expected to continue beyond 5 years and will provide for the longer term monitoring and reporting requirements of the BEMP.

The City's RMP is intended to be a dynamic program that can be adapted, and modified, in response to the findings of the monitoring activities. As such, specific RMP monitoring requirements and methods may change in the future. The City will engage AEP, prior to making changes to monitoring approaches that apply to the BDEP sites, to ensure new approaches support the long-term objectives of BDEP.

In addition to sharing common monitoring objectives, as noted above, both the RMP and BEMP are aligned with, and supportive of, the goals and objectives of the Bioengineering Demonstration and Education Project Education Plan[1].

[1] Hemmera Envirochem Ltd., "Education Plan", *Bioengineering Demonstration and Education Project* (Prepared for Alberta Environment and Parks, 2017).

3.0 BASELINE DATA

The purpose of the Project's baseline data collection was to assess pre-construction environmental conditions for Sites 1, 2, and 4 (**Figure 1**). These baseline data form a reference condition, upon which project effects (bioengineering structures/installments), on the identified components, will be monitored and documented throughout the BEMP.

In addition to monitoring potential changes at each site, the BEMP is also planning to provide an analysis of the efficacy of the remediation methods, comparing Sites 1 and 2, where intensive bioengineering remediation is intended (e.g. fish shelters, rock clusters, box fascines), to Site 4, where less intensive elements are intended (e.g. vegetating existing riprap armouring). For comparative purposes, Site 4 has been selected to represent baseline conditions, from which anticipated successes at Sites 1 and/or 2 can be benchmarked. In this comparison, Site 4 represents a proxy to the traditional method of flood mitigation (hard armouring), albeit with some minor bioengineering enhancements, whereas Sites 1 and 2 are identified as the treatment reaches. It is expected that only a comparison of overall fish habitat suitability among the three sites will be possible, given the difference between treatments (i.e. the scope of bioengineering elements) designed for Sites 1, 2, and 4.

Hemmera led an on-site reconnaissance, by its Project team on July 18, 2016, to assess the conditions and identify bioengineering design, fish habitat, and education opportunities at each site. Prior to this site reconnaissance meeting, Skymatics Ltd. provided drone technology to document the existing baseline conditions of the Project area, particularly to facilitate the performance evaluation of each site regarding riparian vegetation, riverbank and slope stability, and fish and wildlife habitat. During this drone reconnaissance, aerial imagery of the riverbank and a video of the river's morphological features were obtained. A georeferenced flight path was documented for use in long-term monitoring of the Project. This electronic information is available upon request. While the sampling protocols and budget presented in the BEMP do not provide for visual monitoring of site conditions, the aerial imagery of pre-construction site conditions, collected during drone flights, could be used to support future monitoring of changes in site conditions post-construction.

3.1 FISH AND FISH HABITAT

Hemmera completed a baseline fish habitat assessment of riverine areas encompassing each of the three Project sites on March 27, 2017. Historical documentation of fish presence was determined using FWMIS[2] and aerial imagery from 2002 to 2016 was reviewed[3] to supplement field observations. Due to the existing database of previously documented fish species in the Bow River within the vicinity of the Project, fish

[2] Fisheries and Wildlife Management Information System (FWMIS), "Area-Specific Search Request (2017)", at *Fish and Wildlife Division: Alberta Environment and Sustainable Resource Development,* https://maps.srd.alberta.ca/FWIMT_Pub/Viewer/?TermsOfUseRequired=true&Viewer=FWIMT_Pub (accessed April, 2017).

[3] Google Earth 7.1.5.1557. (2015), "Calgary, Alberta. 50°58'50.17"N 114°01'42.46"W. 3406 ft." *Digital Globe Imagery* (accessed March 2017)

sampling was not conducted. Supplemental information was reviewed, including morphological mapping conducted in 2014 by Klohn Crippen Berger[4], and a bathymetry survey conducted in July 2016 by Kerr Wood Leidal[5]. Detailed descriptions of habitat characteristics and potential, for each Site, are provided in the *Project's Fish and Fish Habitat Assessment Report*[6].

During the baseline fish habitat assessment, data were collected and assessed following Hemmera's protocols for fish habitat assessments[7], which will enable replicative, post-construction monitoring during the BEMP. However, should alternate analytics be preferred during the implementation of the BEMP (e.g. direct reference to Habitat Suitability Indices, or weighted habitat unit values), retroactive concordance of data may be required.

Habitat

In summary, the assessed reach of the Bow River (including Sites 1, 2, and 4) is characterized as a low gradient (2%) and a regular meander pattern that is frequently confined by its valley walls. The entire assessed reach is dominated by Class 1 run habitat (R1) (>1.0 m), alternating with various pool habitats (P1-deep, P2-moderate, and P3-shallow) along the right downstream bank (RDB). Habitat features in the assessed reach also include riffles, a Class 2 run habitat (R2) (0.75-1.0 m), and a backwater pool (BW) habitat. A snye habitat (backwater or side channel) is located along the left downstream bank (LDB), adjacent to the Inglewood Golf and Curling Club (**Figure 1**). The snye habitat likely has connectivity at its upstream extent, during high flow periods (e.g. during spring freshet). P1 habitat is present at the downstream extent of the assessed reach.

Substrate throughout the assessed reach is dominated by boulder and cobble in run habitats (R1 And R2), and cobble and large gravel in riffle habitats. Substrates within pool habitats (P1, P2, and P3) consist primarily of boulder, cobble, and fines. Gravel and fines dominate the snye habitat located along the LDB.. Throughout the assessed reach, maximum water depth ranges from 0.54m to 7.10m, with an average water depth of 1.54m[8].

Bankfull width in the assessed reach ranges from 105m to 230m, with an average width of approximately 163m. Wetted width ranges from 80m to 174m, with an average width of 116m. Bank stability throughout the assessed reach ranges from stable slopes, in areas armoured with riprap, to near vertical and unstable, along the RDB immediately downstream of the 17 Avenue Cushing Bridge. Additionally, some banks consist primarily of fines and cobble.

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4 Klohn Crippen Berger, "Calgary Rivers Morphology and Fish Habitat Study – Draft", *Technical Memo F-1: Existing Fish Habitat*. Draft report prepared for The City of Calgary, (April 2015).

5 Kerr Wood Leidal, "Project Site Topography" for the *Bioengineering Demonstration and Education Project*. Prepared for Hemmera Envirochem Inc., (2016).

6 Hemmera Envirochem Ltd., "Fish and Fish Habitat Assessment: Bow River, Alberta", *Bioengineering Demonstration and Education Project*, (2017).

7 Hemmera Envirochem Ltd., "fish Habitat Assessment".

8 Hemmera Envirochem Ltd., "fish Habitat Assessment".

The concentration of dissolved oxygen and pH were within, or exceeded, the Canadian Council of Ministers of the Environment (CCME) *Guidelines for the Protection of Freshwater Life*[9]. Conductivity and water temperature were within anticipated levels, based on time of year. Detailed water quality measurements were collected at Site 2[10].

Fish

The Bow River, from its headwaters to the confluence with the Oldman River, is known to support 35 fish species[11]. However, within the vicinity of the Project (i.e. between Bearspaw and Carseland Dams), only 22 of these species are likely to occur, including 11 sportfish species (Table 1).

Categorization of fish habitat potential focused on brown trout, rainbow trout, and mountain whitefish. These species were chosen for fish habitat potential ratings based upon presumed relative species abundance[12], being part of a CRA (commercial, recreational, or aboriginal) fishery, and construction effects on spawning season. These species are representative of all spawning seasons that will be affected by construction (both spring and fall). Habitat potential was graded based on the ability to provide spawning, rearing, adult feeding, and overwintering habitat. The fish habitat potentials were rated as:

- Essential: habitat that is rare, highly productive, sensitive, or vital in sustaining commercial, recreational or Aboriginal fisheries, or any species at risk, or is of management concern.
- Important: habitat that is important to the fish population for spawning, feeding, rearing, wintering, and migration and is not deemed to be critical to a specific population.
- Marginal: habitat characterized by low productive capacity that contributes marginally to fish production; includes habitat that is not available to fish due to natural permanent barriers.
- Unsuitable: no suitable habitat present for a specific fish species life history stage.

Ratings were based upon the professional judgement of the QAES, using an adaptation of habitat descriptions from the *BC Oil and Gas Commission*[13] and *BC Ministry of Forests, Lands, and Natural Resource Operations*[14], as well as various known habitat suitability characteristics for each species.

Important fish habitat potential was observed throughout the assessed reach for numerous sportfish species. Overall, wintering, migration, and rearing habitat was rated 'Important' for the species assessed (mountain whitefish, rainbow trout, and brown trout). Moderate depth and deep run habitats (R2 and R1),

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9 Canadian Council of Ministers of the Environment (CCME), "Canadian Water Quality Guidelines for the Protection of Aquatic Life: Summary Table", *Canadian Environmental Quality Guidelines*, revised 2007 (Winnipeg: Canadian Council of Ministers of the Environment, 1999).

10 Hemmera Envirochem Ltd., "fish Habitat Assessment".

11 FWMIS, "Area-Specific Search Request".

12 FWMIS, "Area-Specific Search Request".

13 British Columbia Oil and Gas Commission*, Environmental Protection and Management Guide, Version 1.9,* Fort St. (John: Oil and Gas Commission, 2017).

14 British Columbia Ministry of Forests, Lands, and Natural Resource Operations [FLNRO], BC Ministry of Environment, and Fisheries and Oceans Canada, *Fish-stream Crossing Guidebook, revised ed*. (Victoria: Prac. Invest. Br., 2012).

observed along the entire reach, are likely to provide deep, slow habitat that is suitable for overwintering. Migration was rated 'Important', as no known barriers to fish migration exist between the Bearspaw and Carseland dams. Stream margins and low velocity habitat features, including snyes and backwater areas, offer rearing habitat for multiple species. The spawning potential for mountain whitefish and brown trout was rated 'Important', due to the abundance of suitable substrates, habitat types, and cover availability. Spawning activity by mountain whitefish and brown trout has been documented downstream of the Project area[15]. The spawning potential for rainbow trout was rated 'Marginal', as most of the lower Bow River watershed population spawns in tributaries located downstream of the Project, in the Highwood and Sheep River headwaters. Historically, low levels of spawning have been documented in the Project reach[16].

Table 2 Fish Species Documented in the Bow River near the Project

Common Name[17]	Scientific Name	Spawning Season[18]	Provincial Status[19]	Federal Status[20]
SPORTFISH				
Brook trout	*Salvelinus fontinalis*	Fall	Exotic/Alien	Not Listed
Bull trout	*Salvelinus confluentus*	Fall	At Risk	No Status
Brown trout	*Salmo trutta*	Fall	Exotic/Alien	Not Listed
Burbot	*Lota lota*	Winter	Secure	Not Listed
Cutthroat trout[a]	*Oncorhynchus clarki*	Spring	Exotic/Alien	Not Listed
Lake whitefish	*Coregonus clupeaformis*	Fall / Winter	Secure	Not Listed
Mountain whitefish	*Prosopium williamsoni*	Fall	Secure	Not Listed
Northern pike	*Esox Lucius*	Spring	Secure	Not Listed
Rainbow trout[b]	*Oncorhynchus mykiss*	Spring	Secure	Not Listed
Yellow perch[c]	*Perca flavescens*	Spring	Secure	Not Listed
Walleye	*Sander vitreus*	Spring	Secure	Not Listed

15 FWMIS, "Area-Specific Search Request", 2017; Golder Associates, *Fish Habitat inventory and habitat use assessment for the Bow River from Bearspaw dam to WID weir, volumes I and II.* (Prepared for Fisheries Management Division, Alberta Sust. Res. Dev., Calgary, AB. 2001).

16 Alberta Environment (AE) and Alberta Sustainable Resource Development (ASRD), "Appendix A: Fisheries Management Objectives" *Instream Flow Needs Determinations for the South Saskatchewan River Basin, Alberta, Canada*. http://aep.alberta.ca/water/programs-and-services/south-saskatchewan-river-basin-water-information/studies/instream-flows-needs.aspx (2003).

17 FWMIS, "Area-Specific Search Request"; Joseph S Nelson and Martin J. Paetz, *The Fishes of Alberta* (Edmonton: University of Alberta press, 1992).

18 Amanda Joynt and Michael Gary Sullivan, *Fish of Alberta* (Edmonton: Lone Pine Publishing, 2003); Nelson and Paetz, *The Fishes of Alberta*.

19 Government of Alberta, *Alberta Wild Species General Status Listing -2015, (Government of Alberta, 2017)*. http://aep.alberta.ca/fish-wildlife/species-at-risk/albertas-species-at-risk-strategy/general-status-of-alberta-wild-species/documents/SAR-2015WildSpeciesGeneralStatusList-Mar2017.pdf. (Accessed: March 2017).

20 Government of Canada, *Species at Risk Public Registry, A to Z Species Index,* 2017. https://www.registrelep-sararegistry.gc.ca/sar/index/default_e.cfm (Accessed: March, 2017).

Common Name[17]	Scientific Name	Spawning Season[18]	Provincial Status[19]	Federal Status[20]
NON-SPORTFISH				
Brook stickleback	*Culaea inconstans*	Spring / Summer	Secure	Not Listed
Fathead minnow	*Pimephales promelas*	Summer	Secure	Not Listed
Lake chub	*Couesius plumbeus*	Spring	Secure	Not Listed
Longnose dace	*Rhinichthys cataractae*	Spring / Summer	Secure	Not Listed
Longnose sucker	*Catostomus catostomus*	Spring	Secure	Not Listed
Mountain sucker	*Catostomus platyrhynchus*	Summer	Secure	Not at Risk
Prussian carp	*Carissius gibclio*	Spring / Summer	Exotic/Alien	Not Listed
Pearl dace	*Margariscus margarita*	Spring / Summer	Undetermined	Not Listed
Spoonhead sculpin	*Cottus ricei*	Spring	May be at Risk	Not at Risk
Trout-perch	*Percopsis omiscomaycus*	Spring / Summer	Secure	Not Listed
White sucker	*Catostomus commersoni*	Spring	Secure	Not Listed

Notes:
a Cutthroat trout in the Bow River near the Project represent introduced stocks and are not considered native stocks of Westslope Cutthroat Trout (*Onchorhynchus clarkii lewisi*).
b Rainbow trout in the Bow River near the Project represent introduced stocks and are not considered native stocks of Athabasca Rainbow Trout.
c The historical range of yellow perch does not include the Bow River. However, numerous specimens have been captured in irrigation canals near the Project area.

3.2 RIPARIAN HEALTH

Hemmera conducted a Riparian Health Assessment (RHA) for Sites 1, 2, and 4 on October 2, 2016[21], using the 'Alberta Wetland Health Assessment for Large River Systems methodology'[22]. A summary of the goals and objectives for the riparian component of the Bioengineering Demonstration and Education Project include the following:

- Monitor presence and abundance of invasive species to control their establishment and spread.
- Introduce native plant and shrub species to promote natural regeneration of the sites.
- Monitor the survivorship of riparian plantings.
- Install educational signage to convey key riparian and river health messages and project benefits.

The polygons or assessment boundaries identified for each site are described in **Table 3**.

21 Hemmera Envirochem Ltd., "Riparian Health Assessment: Bow River, Alberta", *Bioengineering Demonstration and Education Project* (2016).
22 Cows and Fish, *Alberta Lotic Wetland Health Assessment for Large River Systems (Survey) User Manual* (2016). http://cowsandfish.org/riparian/documents/AlbertaRiverSurveyManual.pdf

Table 3 Riparian Health Assessment Polygon Characteristics

Polygon	Assessment Boundary	Length (m)	Area (ha)
Site 1	Downstream of Harvie Passage, to upstream of The City of Calgary storm water outfall B-9; approximately 250 m downstream of the Cushing Bridge	591	2.75
Site 2	Adjacent to the downstream boundary of Site 1, at outfall B-9	128	0.44
Site 4	Boundary begins at the upstream edge of the riprap rock groyne and extends to the downstream riprap rock groyne	251	0.36

SITE 1

The overall rating of the riparian health in this polygon is 'degraded', given the presence of invasive weed species throughout the area. The species diversity and richness is greater upstream of Cushing Bridge, where a mature riparian forest with a well-developed canopy and understory is present on the west side of the Bow River, adjacent to the regional pathway. Approximately half of the riverbank length in the polygon (upstream of the Cushing Bridge) is accessible to animals (e.g. deer) for browsing. Historic erosion and unstable banks characterize the half of the site that is downstream of Cushing Bridge. The area continues to be extremely susceptible to erosion, given the nearly vertical banks and lack of stabilizing riparian vegetation. Most of the Site 1 polygon is classified as no land-use apparent (85%), with development and recreation (15%), for the boat launch ramp and the regional pathway, comprising the remainder of land use in the polygon. Hemmera[23] provides a full list of native and invasive plant species.

SITE 2

The overall rating of the riparian health in this polygon is 'static', given the top of bank and upland areas of the polygon are maintained as green spaces by The City of Calgary. There is limited regeneration of balsam poplar along the toe of the riverbank, and the riparian species present are reflective of species that quickly colonize disturbed areas. No land use is apparent for the majority (70%) of the polygon, with the rest of the land use designated as turf grass (mowed lawn) (20%) and recreation (regional pathway) (10%). Adjacent land use is primarily residential development (50%), roads (30%) and turf (lawns) (20%). Hemmera provides a full list of native and invasive plant species[24].

SITE 4

The overall rating of the riparian health in this polygon is 'improving', due to the extensive riparian planting program conducted in 2014 by Golder Associates Ltd. As part of The City of Calgary's 2013 flood remediation and bank stabilization works. Some natural (i.e. not planted) regeneration of sandbar willow was observed among the planted species. The entire polygon is categorized as no land use apparent and

[23] Hemmera Envirochem Ltd. "Riparian Health Assessment".
[24] Hemmera Envirochem Ltd. "Riparian Health Assessment".

serves primarily as green space along the regional pathway. Adjacent land use is comprised of turf lawns (50%), residential development (30%), recreation (regional pathway) (10%) and roads (10%). Hemmera provides a full list of native and invasive plant species[25].

Riparian health was scored based on parameters from the vegetation and soil/hydrology categories, as stated in the referenced methods[26]. Scores are summarized in Table 4. The health ratings are categorized as follows:

- Healthy (80 – 100%): Little or no impairment to riparian functions.
- Healthy but with Problems (60 – 79%): Some impairment to riparian functions due to human or natural causes.
- Unhealthy (<60%): Impairment to many riparian functions due to human or natural causes.

Table 4 Riparian Health Assessment Scores for Project Sites

Parameter	Site		
	1	2	4
Vegetation			
Vegetation Health Rating (%)	54%	33%	28%
Soil / Hydrology			
Soil / Hydrology Health Rating (%)	33%	25%	29%
Overall			
Overall Health Rating (%)	43%	29%	29%
Overall Health Rating Category	Unhealthy	Unhealthy	Unhealthy

The health rating category results of the RHA were compared to the results of the Cows and Fish *Riparian Health Inventory Summary Report* for the BOW95 Site[27], which overlaps with the Project locations. The overall 'Unhealthy' rating of Site 1, Site 2 and Site 4, was consistent with the conclusions of the Cows and Fish *Riparian Assessment* for those areas.

Overall, the riparian health of the current Project area is considered 'Unhealthy' due to the heavily disturbed condition, which resluted from severe bank erosion, historical bank protection efforts, and human use. Site 4 is 'improving' given the riparian planting that was part of stream bank restoration and stabilization work after the 2013 flood. The Project's bioengineering designs and landscape planting plans are intended to improve the riparian health of the Project lands, and contribute to fish and terrestrial wildlife habitat value, ultimately increasing biodiversity in the Project area.

25 Hemmera Envirochem Ltd. "Riparian Health Assessment".
26 Cows and Fish, *Wetland Health Assessment*.
27 Cows and Fish, "Riparian Health Inventory Summary Report: BOW95" Inglewood Bioengineering Demo Proposed Site, Calgary (2016).

3.3 BENTHIC MACROINVERTEBRATES

Background information related to the benthic invertebrate community in Project area, collected in 2017, has been provided below for context only. While it is acknowledged that benthic invertebrates provide an indicator of stream health, monitoring of trends related to benthic invertebrates will not form part of the scope of the BEMP. Studies have shown[28] that benthic invertebrates recover quickly from short-term disturbances, suggesting that there is limited value in monitoring this parameter as part of the BEMP's proposed 10 year monitoring period. Additionally, significant in-stream disturbance has already occurred in this reach of the Bow River from other flood mitigation works (e.g. Harvey Passage), making it very difficult to establish a baseline for benthic macroinvertebrate assessment.

The general aquatic environment for Sites 1, 2, and 4 consist of riffles and Class 1 runs (1.0 m), with boulder, cobble, gravel, and fines[29]. Based on these characteristics, it is expected that a benthic community would be composed largely of benthic invertebrates associated with larger particle size and swift water, such as orders Ephemeroptera (Mayflies), Plecoptera (Stoneflies), and Trichoptera (Caddisflies) (EPT), with some Chironomidae and burrowing species. In general, a higher percentage of EPT in a stream suggests a healthier aquatic ecosystem, as EPT have lower tolerance for environmental changes and pollution, compared to others such as the Chironomidae family, which can survive in areas with a higher fine sediment load and pollutant concentration[30].

A report prepared for Alberta Environment (AENV)[31] on the Bow River, classified the aquatic ecosystem health of primary producers in the upper reaches of this watershed as 'good', and 'marginal' in the middle reach downstream of The City of Calgary. In general, there are limited data for benthic invertebrates in the Bow River at the site locations.

While not required to support BEMP implementation, as part of Phase 1 of The City's RMP, baseline sampling of the benthic invertebrate community at the Project location was conducted in 2017.

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28 Anderson et al. "Impacts and Recovery in a Coldwater Stream Following a Natural Gas Pipeline Crossing Installation" Proceedings of the International Pipeline Conference 1998: American Society of Mechanical Engineers. (1998); Collier et al. "Stream Ecology. Bouncing Back: How fast can stream invertebrates recolonize?" *Water and Atmosphere* 10.2 (2002); Reid, S.M. and P.G. Anderson. "Effects of Sediment Released During Open cut Pipeline Water Crossings". *Canadian Water Resources Journal* 24.3 (1999); Reid, S.M. et al. "Effects of natural gas pipeline water crossing replacement on the benthic invertebrates and fish communities of Big Darby Creek, OH". 7th International Symposium on Environmental Concerns in Right of Way Management, Calgary, AB (2002).

29 Hemmera Envirochem Ltd., "fish Habitat Assessment".

30 Benoit, C. et al. "Aquatic Insects as Water Quality Indicators in the Elbow River Watershed, Alberta".*ENSC 502*. University of Calgary (2016).

31 North/South Consultants, *Summary Report of the Initial Assessment of Ecological Health of Aquatic Ecosystems in Alberta: Water Quality, Sediment Quality and Non-Fish Biota*. Prepared for Alberta Environment (Edmonton, 2007).

3.4 WILDLIFE

A desktop review of available wildlife information was completed using the Fisheries and Wildlife Management Information System[32]. The results are summarized in **Table 5,** and provided in **Appendix A**. This species summary report identified several listed species within 1km of the Project site. A search of the Wildlife Sensitivity Maps indicated that Sites 1, 2, and 4 overlap with key range layers for bald eagles, golden eagles, prairie falcons, and sharp-tailed grouses[33].

Table 5 Provincially or Federally Listed Species with Documented Occurrences within 1 km of Project Sites

Species	Scientific Name	Provincial Ranking[34]	SARA Schedule[35]	COSEWIC Ranking[36]
Bald eagle	*Haliaeetus leucocephalus*	Sensitive	-	-
Baltimore oriole	*Icterus galbula*	Sensitive	-	-
Eastern kingbird	*Tyrannus tyrannus*	Sensitive	-	-
Common nighthawk	*Chordeiles minor*	Sensitive	Schedule 1	Threatened
Great blue heron	*Ardea herodias*	Sensitive	-	-
Harlequin duck	*Histrionicus histrionicus*	Sensitive	-	-
Least flycatcher	*Empidonax minimus*	Sensitive	-	-
Northern goshawk	*Accipiter gentilis*	Sensitive	-	-
Silver-haired bat	*Lasionycteris noctivagans*	Sensitive	-	-
Sora	*Porzana carolina*	Sensitive	-	-
Western grebe	*Aechmophorus occidentalis*	Sensitive	No Schedule	No Status
Western wood-pewee	*Contopus sordidulus*	Sensitive	-	-

A terrestrial assessment,, including wildlife species, was conducted in 2016[37]. This assessment is described in the Project's *Preliminary Natural Assessment Report*[38]. It is notable that wildlife habitat observed at the three sites contained riparian habitat that could provide nesting sites for various breeding bird species, including bank swallows and raptors, such as bald eagles.

32 FWMIS, "Area-Specific Search Request".
33 Alberta Environment and Parks. *Wildlife Sensitivity Maps* (2017). http://aep.alberta.ca/forms-maps-services/maps/wildlife-sensitivity-maps/default.aspx. (accessed on 13 April 2017)
34 Alberta Environment and Parks. *Wild Species Status Search* (2017). http://aep.alberta.ca/fish-wildlife/species-at-risk/wild-species-status-search.aspx. (accessed on 13 April 2017)
35 Environment and Climate Change Canada (ECCC). *Species at Risk Public Registry Species Index* (2017). http://www.registrelep-sararegistry.gc.ca/sar/index/default_e.cfm
36 ECCC, *Species at Risk*.
37 Hemmera Envirochem Ltd. "Riparian Health Assessment".
38 Hemmera Envirochem Ltd.. "Preliminary Natural Site Assessment, Bow River, Alberta". *Bioengineering Demonstration and Education Project*, 2017.

Riparian habitat with exposed banks can provide areas for nesting bank swallow colonies. The *Final Design Report*[39] identified a bank swallow colony near Site 2. This bank swallow colony was also observed during site reconnaissance, along with another bank swallow colony near Site 4[40]. Bank swallows are listed by AEP as Sensitive in Alberta[41] . They are listed as Threatened by COSEWIC, and have no status under SARA[42].

Site 1 contains several mature trees that have the potential to support breeding for some of the avifauna species in **Table 5**. These trees will be removed, as part of Project activities, outside of the nesting season for breeding birds in nesting zone B4 (April 22 - August 17)[43] There are no mature trees in Sites 2 and 4 that would support breeding. No great blue heron rookeries were observed at any of the sites during the site visits. Surrounding habitat at Peace Estate Park and adjacent neighbourhoods to the Sites contained forested areas that may also provide nesting habitat for raptors.

3.5 BIOENGINEERING STRUCTURES/INSTALMENTS

The designed bioengineering bank protection and fish habitat enhancement measures are based on the information, design basis, and analysis presented by KWL[44], and are designed to withstand the assumed river and ice forces described in this report. They are also meant to be relatively resilient and self-healing, as rock riprap shifts and self-launches in response to river and ice forces. In this manner, the proposed works are meant to avoid a catastrophic loss of integrity, but are otherwise categorized as perpetual maintenance structures.

Drone reconnaissance conducted by Skymatics Ltd. documented the existing baseline conditions of the Project area, by collecting photos of the riverbank along a georeferenced flight path. While the sampling protocols and budget presented in the BEMP do not provide for visual monitoring of site conditions, these aerial images of pre-construction conditions could be used to support future monitoring of changes post-cinstruction. This electronic information is available from Skymatics upon request.

The success of the Project depends significantly on quality of installation, quality of live material used (e.g. dormancy of live cuttings, stock handling until placement) and maintenance, including weeding, watering, mulching, mowing, and monitoring. Inspection of these works is important to identify any damage to the works as early as possible, to ensure the structures are repaired in a timely manner. Permanent photo locations should be set when structures are installed. Monitoring and maintenance costs will be included in annual budgets to guarantee lengthy service life of these structures.

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39 Kerr Wood Leidal Associates Ltd., *Final Design Report Bioengineering Demonstration and Education Project (BDEP), Technical Memorandum*. Prepared for Alberta Environment and Parks (2017).

40 Hemmera Envirochem Ltd., “Preliminary Natural Site Assessment”; Hemmera Envirochem Ltd., »Technical Memorandum : Summary of Terrestrial Assessments” *Bioengineering Demonstration and Education Project*. Prepared for Alberta Environment and Parks, 2017.

41 Alberta Environment and Parks. *Wild Species Status.*

42 ECCC, *Species at Risk*

43 Environment and Climate Change Canada (ECCC), *General Nesting Periods of Migratory Birds in Canada* (2016). http://www.ec.gc.ca/paom-itmb/default.asp?lang=En&n=4f39a78f-1#_fig01

44 Kerr Wood Leidal Associsates Ltd., *Final Design Report.*

4.0 BIOENGINEERING EFFICACY MONITORING PLAN

The detailed description of proposed bioengineering treatments for Sites 1, 2, and 4 are provided in the *Final Design Report*[45] and summarized in **Table 5**. All data and site details obtained from the BEMP outlined below will be reported each year in which monitoring occurs, as well as discussed cumulatively and comparatively at either the five or ten year post-construction monitoring interval. Annual monitoring reports will be made available to all stakeholders involved in the educational component of the Project.

The BEMP will focus on evaluating potential enhancement values at and among all of the sites over a ten-year period. Elements that will be included during the BEMP are fish and fish habitat, riparian heath, wildlife, and structural integrity considerations. The scope, frequency and timing of efficacy monitoring visits are unique for each of these elements, and are defined independently below.

Although a total of five monitoring years (2019, 2020, 2021, 2023, and 2028), over a 10-year period, have been scheduled for BEMP activities, it is anticipated that in the event of significant flood event(s) contingency monitoring may be required to assess potential damage to the Project's works. In this instance, a resetting of the BEMP monitoring frequency will be needed and will be dependant on the timing of the flood event(s). Although the timing of this contingency monitoring is not confirmed in the BEMP, a contingency budget is included for this purpose in the Project budget (Appendix B).

4.1 FISH AND FISH HABITAT

All assessments of fish habitat use and potential will be completed by a crew of either two or three, depending on the potential use of a boat, and led by a Qualified Aquatic Environment Specialist (QAES). Assessments for Sites 1, 2, and 4 will be completed in multiple seasons (spring, summer, fall, and winter), in each of 2019, 2020, 2021, 2023, and 2028.

SPRING

A spring assessment of fish use, occurring post-ice-off, but pre-freshet (late April to May), will be completed for all sites. The goal is to document fish presence during the potential spawning period of rainbow trout and to best observe the condition, functionality, and use of underwater elements by fish (e.g. boulder cluster, riprap apron, crib wall fish shelters). Fish sampling (e.g. electrofishing) during the spring period is unlikely, given its concurrence to a presumed spawning period of rainbow trout; all fish observations will be completed by underwater camera or via snorkelling surveys. This assessment will include a spawning survey (redd survey) focussing on rainbow trout, which will extend from 500m upstream of Site 1, through all riverine habitat adjacent to Sites 2 and 4, to 500m downstream of the downstream extent of Site 4. Given the comparatively subjective nature of underwater observations and potential for limited rainbow trout spawning, comparative analysis of pre and post-construction observations will yield limited value. Rather, observations made during these assessments are intended exclusively to provide validation of fish use of the Project's enhancement structures.

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45 Kerr Wood Leidal Associsates Ltd., *Final Design Report.*

SUMMER

A more comprehensive fish habitat assessment, including quantification of in-stream and near-stream characteristics of value to fish, will be completed post-freshet (July – August) in each sampling year (summer assessment). The timing is intended to coincide with declining water levels, increasing water clarity, and the growing season for riparian vegetation. Based on this timing, it is anticipated that permission to sample fish communities will be granted by AEP Fisheries Management staff, since rainbow trout fry emergence (if spawning occurs in the area) will have occurred and that spawning by other species of management concern will not have begun. The same timing (or as near as possible) will be used in each subsequent summer sampling season.

During the summer assessment, habitat data will be collected to quantify in-stream and near-stream conditions and document habitat enhancement values. Enhancement values will be compared to those predicted by the Project's DFO Self Assessment Analysis[46]. Habitat assessment data will be collected at the site location, as well as upstream to 100m and downstream to 600m from the site location, and will include:

- Transect data approximately every 100m in the assessed reach, including measurements of bankfull width, wetted width, and bank height, recorded to the nearest 0.1m.
- A photographic assessment of fish habitat enhancements (e.g. boulder clusters) and bank stabilization features (e.g. bank riprap) installed at the site locations (Site 1-1 to Site 1-4) to support visual assessments of physical habitat quality and stability.
- Collection of water quality data (e.g. dissolved oxygen, temperature, conductivity, and pH) from site locations and reference location. A reference water quality sampling location will be established upstream of the Project area, at the same location used for the benthic invertebrate assessment (**Section 3.1.3**). Water quality parameters (dissolved oxygen, conductivity, pH, and water temperature) can be collected using a handheld water quality meter, such as a YSI 556. and CHEMets Kit (Dissolved Oxygen K-7512). Water quality data will be compared against standards identified in the Canadian Council of Ministers of the Environment (CCME) *Guidelines for the Protection of Freshwater Organisms*[47].
- Channel pattern, substrate type, confinement, embeddedness, stream shading, stage, in-stream and near-stream cover (e.g. overhanging vegetation, woody debris, in-stream vegetation, boulder, undercut banks, and depth), and other water body characteristics. Refer to the Project's QAES report for a complete listing of characteristics to be reported on.

46 Hemmera Envirochem Ltd., "fish Habitat Assessment".
47 CCME, "Canadian Water Quality Guidelines".

Based on data collected, and observations made, during the summer assessment, fish habitat potential ratings will be assigned, using the same qualification as defined in the Project's QAES report, as 'essential', 'important', 'marginal', or 'unsuitable'. Alternatively, habitat data collected during the BEMP can be translated to accommodate other sampling/analytic protocols, particularly if there is a preference to enable evaluation of enhancement values according to HSI indices and weighted habitat unit (WHU) values.

The presence and relative abundance of fish will be assessed during the summer assessment, potentially with a proxy baseline evaluation against values from AEP Resource Management index sampling results from nearby and similarly characterized habitat. Single pass electrofishing and passive trapping methods will be used in each sampling year and will be replicated using equipment and effort as near identical between years as possible (e.g. placement of traps will occur at the same locations and electrofishing effort will be maintained among years). All water quality and fisheries work will follow applicable regulatory guidelines, as cited in the Fish and Fish Habitat Assessment Report[48]. Note that if a motorized boat is used for potential assessments, a Vessel Operation Restriction Regulations Permit approval will be required from the of the Navigation Protection Program (Transport Canada). Fish sampling will use the following methods:

- A portable electrofisher (e.g.,Smith Root™ Type VI-A or 2.5 GPP) mounted on zodiac inflatable boat will be used over the entire length of the site locations.
- G-type minnow traps, placed at site locations as determined by a QAES and at bioengineering instalments (e.g. Site 1-3 and Site 1-4).

Captured fish will be recorded by species, length, and weight, and returned unharmed to the capture location. Catch per Unit Effort (CPUE) by species will be recorded as an indirect measure of fish abundance at the site location and reference site. Location of fish relative to habitat unit types (e.g. riffle, run, back water), and fish habitat enhancements (e.g. boulder clusters) will be documented to determine fish use of differing habitat types and enhancements. Fish species composition and abundance data will be compared with historical data (if available), as well as between the sites.

FALL

Like the spring assessment, observations of the use of Project enhanced elements will be completed in each sampling year, in late October or early November (fall assessment). Using an underwater camera, observations will be collected via boat, shore, or snorkel surveys. The assessment will be used to observe the potential use of habitat within, and adjacent to, in-stream enhancement features (e.g. boulder cluster, riprap apron, crib wall fish shelters), particularly by fall spawning species (e.g. brown trout). The fall assessment will include a spawning survey (redd survey) focussing on brown trout, which will extend from 500m upstream of Site 1, through all riverine habitat adjacent to Sites 2 and 4, to 500m downstream of the downstream extent of Site 4. Sampling of mountain whitefish eggs will also be completed using kick nets or water propulsion pumps at transects downstream from suitable mountain whitefish spawning habitat.

[48] Hemmera Envirochem Ltd., "fish Habitat Assessment".

Transect locations and sampling efforts will be established in the first sampling event and replicated in each subsequent year. As with the spring survey, resulting spawning data is only to provide validation of fish use of the Project's enhancement structures during critical life stages.

WINTER

A shore-based winter assessment (January) will be conducted at Sites 1-3 and Site 1-4, conditions and safety permitting, to confirm or refute the potential of overwinter use of the fish shelter constructed under the vegetated timber crib wall[49]. An assessment will also be conducted at Site 2-1 and Site 2-2 to confirm or refute the potential of overwintering use of near-bank habitat, adjacent to the box fascines. Sampling will likely require the use of underwater camera(s), or opportunistic snorkel observations, ice cover and flow conditions permitting.

4.2 RIPARIAN HEALTH

The RHA for the sites will be conducted in the late summer/early fall of 2019, 2020, 2021, 2023, and 2028 by an ecologist and/or a vegetation/wetland specialist. Given the expected concurrence of The City's RMP (at least over the first five years, post-construction), BEMP methods and analysis of the RHA will be as defined as those employed in The City's RMP. The RHA methods that will be used as part of The City's RMP include:

- RHAs for Sites 1, 2, and 4 are concurrent with the Bank Effectiveness Monitoring of these sites as part of the RMP. This will follow the *Alberta Wetland Health Assessment for Large River Systems* methodology[50]. As the sites are part of a Large River RHA, 15 parameters will be assessed, from which an overall health rating will be determined.
- As part of the Trend Monitoring component of the RMP, a revisit of the 2016 BOW95 RHI Polygon will be conducted at 5-year intervals. This polygon extends from the 17 Avenue SW Bridge to the downstream extent of Site 4. This will entail completion of a detailed Riparian Inventory following the Cows and Fish *Alberta Lotic Wetland Inventory* protocol[51]. A Riparian Health Assessment Score is derived from the detailed vegetation and physical RHI data. Health score ratings for RHI and RHA sites are based on the same scoring convention for the same 15 parameters, but more in-depth monitoring data on plant community composition and structure is collected for RHIs.

49 Kerr Wood Leidal Associsates Ltd., *Final Design Report.*
50 Cows and Fish, *Wetland Health Assessment*.
51 Cows and Fish. *Alberta Lotic Wetland Inventory Form User Manual* (2017). *http://cowsandfish.org/riparian/documents/2017AlbertaLoticInventoryManualCowsandFish.pdf*

4.3 WILDLIFE

Wildlife surveys will occur in the monitoring years 2019, 2020, 2021, 2023, and 2028, during the month of June, to assess breeding bird activity. This assessment will be completed in accordance with the Sensitive Species Inventory Guidelines[52] for breeding bird surveys on each affected site. Other surveys specific to each site include:

SITE 1

- A nest search will be conducted during monitoring years, from Site 1-1 to Site 1-4, to identify any nesting species, including raptors.
- While not provided for in the sampling protocols or budget presented in the BEMP, remote camera installation and/or track counts could be an ancillary wildlife monitoring activity, to determine if wildlife corridors proposed at Site 1-1 and Site 1-2 are actively being used. This would likely require four visits/year to change data cards and batteries. Track counts might be an opportunity for citizen science.

SITE 2

- A nest search will be conducted during monitoring years, from Site 2-1 to Site 2-2, to identify any nesting species, including raptors and bank swallows. Bank swallow colonies will be monitored to determine the number of breeding adults present.

SITE 4

- A nest search will be conducted during monitoring years, from Site 4-1 to Site 4-3, to identify any nesting species, including raptors and bank swallows. Bank swallow colonies will be monitored to determine the number of breeding adults present.

4.4 BIOENGINEERING STRUCTURAL INTEGRITY

The bioengineering structures and instalments are intended to provide long-term bank protection. Bioengineering structures and instalments at Sites 1, 2, and 4 summarized in **Table 6**[53] will be inspected during monitoring years 2019, 2020, 2021, 2023, and 2028 at key intervals, including:

- A high-water inspection during annual freshet events (June/July);
- A summer inspection, during the growing season in late August, will enable vegetation survivorship evaluations.

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52 Environment and Sustainable Resource Development (ESRD), *Wildlife Management: Sensitive Species Inventory Guidelines* (Government of Alberta, 2013) http://aep.alberta.ca/fish-wildlife/wildlife-management/documents/SensitiveSpeciesInventoryGuidelines-Apr18-2019.pdf

53 Kerr Wood Leidal Associsates Ltd., *Final Design Report.*

Monitoring of the structural integrity, stability and operational effectiveness of the bioengineering features will be the priority during these site visits, and remedial needs will be reported immediately so that corrective actions can be implemented. BEMP structural integrity monitoring will focus on the long-term structural integrity of bioengineering structures (i.e. long term performance of physical structures) including identifying typical ongoing maintenance that may be required, such as after the annual freshet.

BEMP structural integrity monitoring will be provided by the RMP, which includes detailed structural integrity monitoring protocols, as part of its Bank Effectiveness Monitoring component, which overlaps with the BEMP Bioengineering Structural Integrity component. BEMP timelines will be followed for the Project as part of the RMP, but the RMP will define specific monitoring methods, analysis, and reporting.

Protocols for monitoring the structural integrity of bioengineering structures, as described above, are separate and distinct from the monitoring of physical works that is required and will be undertaken as part of the BDEP construction contract (i.e. quality monitoring relative to design specifications).

Drone reconnaissance conducted by Skymatics Ltd. documented the existing baseline conditions of the Project area, by collecting photos of the riverbank along a georeferenced flight path. While the sampling protocols and budget presented in the BEMP do not provide for visual monitoring of site conditions, these aerial images of pre-construction conditions could be used to support future monitoring of changes post-cinstruction. This electronic information is available from Skymatics upon request.

Table 6 Summary of Bioengineering Techniques Proposed by the Project

Technique Name	Description	Proposed Location
Box Fascine	Fascine bundles placed at the toe of an eroding bank and secured between wooden poles[54].	Site 2-1, Site 2-2
Brush Layer	Row(s) of live cuttings placed in a crisscrossed or overlapping manner between layers of soil, with tips protruding beyond the face of the fill[55].	Site 1-3, Site 1-4 Site 2-1, Site 2-2
Brush Mattress	A layer of interlaced/adjacent live cuttings placed on the face of the riverbank[56].	Site 1-4 Site 2-2
Container Shrub Planting	Planting container stock seedling species that are selected for beneficial attributes, such as being fast growing, a natural colonizer, deep rooting, a nitrogen fixer, and a food producer[57].	Site 1-2, Site 1-3, Site 1-4 Site 2-2 Site 4-1, Site 4-2

54 AMEC, "Streambank Erosion and Potential Remedial Measures", *Design Guidelines for Erosion and Flood Control Projects Streambank and Riparian Stability Restoration.* Report submitted to The City of Calgary (2012), Guideline A.

55 D. H. Gray and R. Sotir, *Biotechnical & Soil Bioengineering Slope Stabilization: A Practical Guide for Erosion Control* (New York: John Wiley and Sons, 1996); AMEC, "Streambank Erosion", Guideline I1.

56 AMEC, "Streambank Erosion", Guideline I5.

57 AMEC, "Streambank Erosion", Guideline H; AMEC, "Streambank Erosion", Guideline L.

Technique Name	Description	Proposed Location
Contour Fascine	Fascines are live cuttings that are tied together in long bundles. Contour fascines are installed in shallow trenches constructed with a contour, and anchored in the trench using stakes[58].	Site 1-3, Site 1-4 Site 2-2
Live Staking	Insertion of live cuttings into the ground, to promote root growth and leaf-out[59].	Site 1-1, Site 1-2 Site 2-2 Site 4-3
Hedge Brush Layer	Layers of interlaced/adjacent live cuttings and rooted stock placed on the face of the riverbank[60].	Site 1-3, Site 1-4
Joint Planting	Live staking existing riprap to improve riparian, aquatic, and terrestrial habitats, while also improving aesthetics[61].	Site 4-3
Native Species Seeding	Planting of native stream bank and riparian species that are selected for beneficial attributes, such as being fast growing, a natural colonizer, deep rooting, a nitrogen fixer, and food producer[62].	Site 1-2, Site 1-3, Site 1-4 Site 2-2 Site 4-1, Site 4-2, Site 4-3
Soil-Covered Riprap	Covering existing riprap bank protection with soil and vegetation to improve riparian, aquatic, and terrestrial habitats, while also improving aesthetics[63].	Site 4-1
Vegetated Soil Wraps	Consists of brush layers interspersed between layers of soil, wrapped in natural geotextile materials that provide reinforcement[64].	Site 1-3, Site 1-4
Vegetated Timber Crib Wall	Consists of a hollow, box-like, interlocking arrangement of structural timber, filled with suitable backfill material, and layers of live cuttings[65].	Site 1-3, Site 1-4
Void-filled Riprap	Planting material inserted into void-spaces in existing riprap bank protection and planted with live cuttings or container shrub plantings, to improve riparian, aquatic, and terrestrial habitats, while also improving aesthetics[66].	Site 4-2, Site 4-3

58 AMEC, “Streambank Erosion”, Guideline I2.

59 Gray and Sotir, *Bioengineering Slope Stabilization*; AMEC, “Streambank Erosion”, Guideline H.

60 H.M. Schiechtl and R. Stern, *Water Bioengineering Techniques for Watercourse Bank and Shoreline Protection* (Boston: Wiley-Blackwell, 1997); Gay Muhlberg and Nancy Moore, *Streambank Revegetation and Protection: A Guide for Alaska*, revised by Jeanne Walter and Dean Hughes (Juneau: Alaska Department of Fish and Game, 2005).

61 AMEC, “Streambank Erosion”, Guideline F.

62 AMEC, “Streambank Erosion”, Guideline L.

63 John McCullah and Donald Gray, *NCHRP Report 544*: *Environmentally Sensitive Channel- and Bank-Protection Measures* (Washington: Transportation Research Board, 2005).

64 Gray and Sotir, *Bioengineering Slope Stabilization*; McCullah and Gray, *Environmentally Sensitive.*

65 Gray and Sotir, *Bioengineering Slope Stabilization*; AMEC, “Streambank Erosion”, Guideline E.

66 Wulliman J. and D. Johns, *Demonstration Projects Illustrating Void-Filled Riprap Applications in Stream Restoration* (Lakewood: Prepared by Muller Engineering Company, Inc. for Urban Drainage and Flood Control District, 2011).

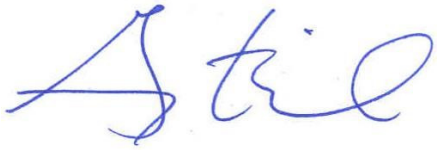
5.0 MONITORING SCHEDULE

The BEMP schedule for the Project Sites is presented in **Appendix C**. The schedule presented does not take into account potentially catastrophic flood events (such as the 2013 flood event), which could impact the ecological features and physical structures constructed as part of BDEP. However, the BEMP budget presented in **Appendix B** does include a contingency for undertaking additional 'baseline' data collection, following a potentially catastrophic flood event. In the case of such an event, and depending on the specific circumstances, the assumed monitoring schedule presented in **Appendix C** could be modified as required to provide for the most effective approach to monitor the long-term bio-efficacy of BDEP.

6.0 CLOSURE

We sincerely appreciate the opportunity to have assisted with this project. If there are any questions regarding the scope of work, or the preliminary budget anticipated to complete the work, please do not hesitate to contact the undersigned by phone.

Report was prepared by:
Hemmera Envirochem Inc.



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APPENDIX A

Fish and Wildlife Species Summary Report

Alberta Environment and Parks

Fish and Wildlife Internet Mapping Tool (FWIMT)

(source database: Fish and Wildlife Management Information System (FWMIS))

Species Summary Report

Report Created: 13-Apr-2017 09:51

Species present within the current extent :

Fish Inventory	Wildlife Inventory	Stocked Inventory
BROWN TROUT	BALD EAGLE	RAINBOW TROUT
LONGNOSE DACE	BALTIMORE ORIOLE	
MOUNTAIN WHITEFISH	COMMON NIGHTHAWK	
RAINBOW TROUT	EASTERN KINGBIRD	
	GREAT BLUE HERON	
	HARLEQUIN DUCK	
	LEAST FLYCATCHER	
	NORTHERN GOSHAWK	
	SILVER-HAIRED BAT	
	SORA	
	WESTERN GREBE	
	WESTERN WOOD-PEWEE	

Buffer Extent

Centroid (X,Y):	Projection	Centroid: (Qtr Sec Twp Rng Mer)	Buffer Radius:
569118, 5651980	10-TM AEP Forest	NW 12 24 1 5	1 kilometers

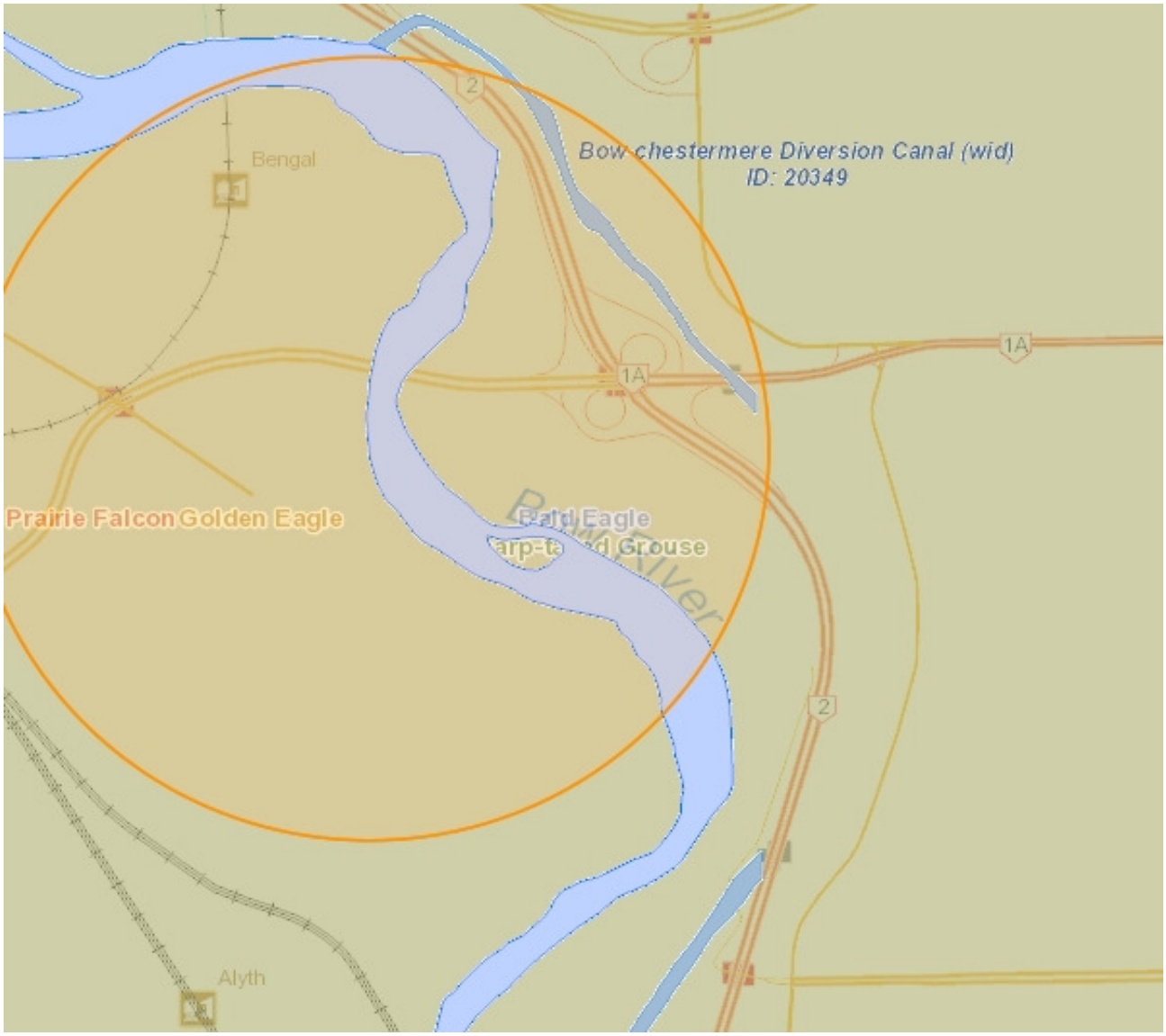
Contact Information

For contact information, please visit:

http://aep.alberta.ca/about-us/contact-us/fisheries-wildlife-management-area-contacts.aspx

13-Apr-2017 09:51

Map Results



APPENDIX B

Bio-Efficacy Monitoring Plan Projected Cost Estimate (December 12, 2017) - Summary

Appendix B: Bio-Efficacy Monitoring Plan Projected Cost Estimate (December 12, 2017) - Summary

Service Description	Details/Amount	TOTAL LABOUR HOURS	TOTAL LABOUR COST	Disbursements (exclusive of markup and GST)				TOTAL DISBURSEMENTS	SERVICE TOTAL
				Field Equipment, Supplies and Sample Shipping	Vehicle Rental	Laboratory Analytical[1]	Utility Locate and Surveying Subcontractor		
2019 Year 1									
Fish Habitat	4 times/year (included management of all other tasks over scope of project)	414	$55,959.75	$11,715.00	$1,250.00			$12,965.00	$68,924.75
Riparian Health	Annual	77	$9,822.75	$60.00	$250.00			$310.00	$10,132.75
Wildlife	Annual	75	$9,591.75	$380.00	$250.00			$630.00	$10,221.75
Bioengineering Structures	2 times/year	70	$9,943.50	$80.00	$500.00			$580.00	$10,523.50
2020 Year 2									$99,802.75
Fish Habitat	4 times/year	414	$55,959.75	$11,715.00	$1,250.00			$12,965.00	$68,924.75
Riparian Health	Annual	77	$9,822.75	$60.00	$250.00			$310.00	$10,132.75
Wildlife	Annual	75	$9,591.75	$380.00	$250.00			$630.00	$10,221.75
Bioengineering Structures	2 times/year	70	$9,943.50	$80.00	$500.00			$580.00	$10,523.50
2021 Year 3									$99,802.75
Fish Habitat	4 times/year	414	$55,959.75	$11,715.00	$1,250.00			$12,965.00	$68,924.75
Riparian Health	Annual	77	$9,822.75	$60.00	$250.00			$310.00	$10,132.75
Wildlife	Annual	75	$9,591.75	$380.00	$250.00			$630.00	$10,221.75
Bioengineering Structures	2 times/year	70	$9,943.50	$80.00	$500.00			$580.00	$10,523.50
2023 Year 5									$99,802.75
Fish Habitat	4 times/year	414	$55,959.75	$11,715.00	$1,250.00			$12,965.00	$68,924.75
Riparian Health	Annual	77	$9,822.75	$60.00	$250.00			$310.00	$10,132.75
Wildlife	Annual	75	$9,591.75	$380.00	$250.00			$630.00	$10,221.75
Bioengineering Structures	2 times/year	70	$9,943.50	$80.00	$500.00			$580.00	$10,523.50
2028 Year 10									$99,802.75
Fish Habitat	4 times/year	414	$55,959.75	$11,715.00	$1,250.00			$12,965.00	$68,924.75
Riparian Health	Annual	77	$9,822.75	$60.00	$250.00			$310.00	$10,132.75
Wildlife	Annual	75	$9,591.75	$380.00	$250.00			$630.00	$10,221.75
Bioengineering Structures	2 times/year	70	$9,943.50	$80.00	$500.00			$580.00	$10,523.50
2028 Cumulative Reporting									$99,802.75
Cumulative Report	Fisheries	140	$16,401.00					$0.00	$16,401.00
Cumulative Report	Riparian	53	$6,210.75					$0.00	$6,210.75
Cumulative Report	Wildlife	53	$6,210.75					$0.00	$6,210.75
Cumulative Report	Bioengineering	53	$6,210.75					$0.00	$6,210.75
									$35,033.25
Contingency Planning (in the event of a flood event at a TBD level)									
Assuming a scenario of a significant flood event (at a level to be determined) in spring 2020 requiring a re-sequencing of the monitoring program while retaining the sunset date of 2027 (tens years post-construction), monitoring would occur as orginally intended in 2020, 2022 and 2027, with the addition of replicated monitoring in 2021. This would enable a 'reset' for trend analysis and result in monitoring in the year of the flood as well as years 1, 2 and 6 post-flood .		636	$85,317.75	$12,235.00	$2,250.00	$0.00	$0.00	$14,485.00	$99,802.75
	TOTAL ESTIMATE	4115	$546,939.75	$61,175.00	$11,250.00	$0.00	$0.00	$72,425.00	$633,849.75
								GST	$31,692.49
	PROJECT TOTAL								$665,542.24

APPENDIX C

Bioengineering Efficacy Monitoring Plan Schedule

Appendix C: Bioengineering Efficacy Monitoring Plan Schedule

Monitoring Component	Season	2019												2020												2021												2023												2028											
		J	F	MA		MJ	J	A	S		ON	D		J	F	MA		MJ	J	A	S		ON	D		J	F	MA		MJ	J	A	S		ON	D		J	F	MA		MJ	J	A	S		ON	D		J	F	MA		MJ	J	A	S		ON	D	
Fish and Fish Habitat	Spring				■												■												■												■												■										
	Summer						■												■												■												■												■								
	Fall								■												■												■												■												■				
	Winter	■												■												■												■												■										
Riparian Health	Fall								■												■												■												■												■				
Wildlife	Summer					■												■												■												■												■								
Bioengineering Structural Stability	Spring					■												■												■												■												■								
	Summer							■												■												■												■												■								

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Appendix B

Fish Assessment Photo Log

Prepared by: Hemmera Envirochem Inc.

Photo B-1: View of a longnose sucker captured in the Bow River on July 31, 2019.

Photo B-2: View of a white sucker captured in the Bow River on July 31, 2019.

Photo B-3: View of a longnose dace captured in the Bow River on July 31, 2019.

Photo B-4: View of a yellow perch captured in the Bow River on July 31, 2019.

Photo B-5: View of a mountain whitefish captured in the Bow River on July 31, 2019.

Photo B-6: View of a juvenile rainbow trout captured in the Bow River on July 31, 2019.

Photo B-7: View of a juvenile brown trout captured in the Bow River in July 31, 2019.

Photo B-8: View of a northern pike captured in the Bow River on July 31, 2019.

Photo B-9: View of a burbot captured in the Bow River on July 31, 2019.

Photo B-10: Mountain whitefish eggs collected in the Bow River on November 26, 2019.

Photo B-11: Mountain whitefish eggs collected in the Bow River on November 26, 2019

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Appendix C

Fish Assessment - Bow River Site Atlas

Prepared by: Hemmera Envirochem Inc.

Watercourse (Site#):	Bow River – Site 1
Habitat Survey Length (# transects):	1,500 m (16)
Restricted Activity Period:	May 1 to July 15, Sept 16 to April 5
Watercourse Class:	Mapped Class C

Field Crew:	M. Piciacchia, C. Davis
Survey Date:	July 31, 2019
Legal Location:	SE/SW-13-24-01 W5M, NE-12-24-01 W5M
UTM (Zone 11):	709435E, 5658357N

Flow Regime	Perennial
Bankfull Width (m): Mean, Range	162.1, 103.0-232.0
Wetted Width (m): Mean, Range	114.0, 78.0-171.0
Depth (m): Mean, Range	1.50, 0.54-6.95
Stream Gradient (%)	2.0
Embeddedness	Low
Beaver Dams	None
Native Channel Width (m)	N/A

Bank Conditions	Left Bank	Right Bank
Bank Shape	Sloping	Vertical
Bank Texture	Cobbles / Fines	Vegetated crib wall
Bank Height (m): Mean, Range	3.3, 2.5-4.0	2.5, 1.5-3.0
Grade of Approach Slopes (%)	4-14	4-10
Riparian Area Width (m)	7	10
Riparian Vegetation Types	Deciduous	Shrubs
Stream Shading	1-10%	

Substrate Composition	Amount
Organics	None
Fines (<2 mm)	Trace
Small Gravel (2-20 mm)	Trace
Large Gravel (21-65 mm)	Subdominant
Cobble (66-250 mm)	Dominant
Boulder (>250 mm)	Subdominant

Water Quality Parameters	
Water Temperature (°C)	16.40
pH	8.72
Dissolved Oxygen (mg/L)	10.80
Conductivity (µS/cm)	443.56
Turbidity (visual)	Clear

Habitat	Length (m)	%
Pool 1 (depth > 1.0 m)	100	8.0
Pool 2 (depth 0.75-1.0 m)	-	-
Pool 3 (depth <0.75 m)	-	-
Run 1 (>1.0 m)	275	41.0
Run 2 (0.75-1.0 m)	-	-
Run 3 (<0.75 m)	123	12.5
Flat 1 (> 1.0 m)	-	-
F lat 2 (0.75-1.0 m)		-
Flat 3 (<0.75 m)	-	-
Riffle	225	38.5
Backwater	-	-
Rapid	-	-
Other	-	-

-

Cover Types	Amount
Boulders	Subdominant
Undercut Banks	None
Overhanging Vegetation	Trace
Woody Debris	Trace
Depth	Dominant
Stain/Turbulence	Dominant
Instream Vegetation	None
Fish Shelters	Trace
Boulder Clusters	Trace
Other	-
Other	-
Other	-
Total Cover	Low

Fish Habitat Potential				
Species	**Spawning Rating**	**Rearing Rating**	**Wintering Rating**	**Adult Holding Rating**
mountain whitefish	Suitable	Suitable	Suitable	Suitable
brown trout	Marginal	Suitable	Suitable	Suitable
rainbow trout	Marginal	Suitable	Suitable	Suitable

Fish species previously documented: brook trout, bull trout, brown trout, burbot, cutthroat trout, lake whitefish, mountain whitefish, northern pike, rainbow trout, yellow perch, walleye, brook stickleback, fathead minnow, lake chub, longnose dace, longnose sucker, mountain sucker, Prussian carp, pearl dace, spoonhead sculpin, trout-perch and white sucker (FWMIS, 2017).

Additional Habitat Comments

The fish habitat within Site 1 (downstream of Harvie Passage and upstream of the Cushing Bridge) consists of alternating deep run (R1) and riffle (RF) habitat. with a shallow run (R3) habitat along the right downstream bank (RDB). Deep pool habitat (P1) is present immediately downstream of the Cushing Bridge. Maximum water depth ranges from 0.40 m in R3 habitat to approximately 7.00 m in R1 and P1 habitat. Substrates throughout Site 1 consist primarily of boulder and cobbles in R1 habitat and cobble and gravel in R3 habitat. Pool habitat (P1) substrates consist primarily of boulder, cobble, and fines. Cover is provided primarily by depth and turbulence, with some overhanging cover provided by woody vegetation along the LDB upstream of the Cushing Bridge, as well as overhanging vegetation from the timber crib wall along the RDB at the enhancement site Boulder substrates present throughout run and pool habitats are likely provide instream cover for fish. Additional instream cover is provided by new constructed fish shelters and boulder clusters. Deep run (R1) and pool (P1) habitat is likely utilized as holding, feeding, and overwintering habitat for adult and juvenile fish, R3 habitat functioning as holding and rearing habitat for juvenile fish. Deep pool (P1) and R1 habitat within the downstream section of Site 1 likely provides excellent overwintering habitat, with a maximum water depth of approximately 7.00 m. Gravel and cobble substrates located at the R3 habitat upstream of Cushing Bridge likely provides suitable spawning habitat for brown trout and rainbow trout. Mountain whitefish spawning habitat is present over cobble and large gravels located in R1 and R3 habitat.

Photo 1: Photo taken at Transect 3, view upstream.

Photo 2: Photo taken at Transect 3, view downstream.

Photo 3: View of left bank at Transect 3.

Photo 4: View of right bank at Transect 3.

Photo 5: Photo taken at Site 1, view downstream of fish shelters and boulder clusters.

Photo 6: Photo taken at Site 1, view upstream of fish shelters and boulder clusters.

Watercourse (Site#):	Bow River – Site 2
Habitat Survey Length (# transects):	1,500 m (16)
Restricted Activity Period:	May 1 to July 15, Sept 16 to April 5
Watercourse Class:	Mapped Class C

Field Crew:	M. Piciacchia, C. Davis
Survey Date:	July 31, 2019
Legal Location:	NW/NE-12-24-01 W5M
UTM (Zone 11):	709374E, 5657892N

Flow Regime	Perennial
Bankfull Width (m): Mean, Range	162.1, 103.0-232.0
Wetted Width (m): Mean, Range	114.0, 78.0-171.0
Depth (m): Mean, Range	1.50, 0.54-6.95
Stream Gradient (%)	2.0
Embeddedness	Low
Beaver Dams	None
Native Channel Width (m)	N/A

Bank Conditions	Left Bank	Right Bank
Bank Shape	Vertical	Vertical
Bank Texture	Cobble / Boulder	Cobble / Boulder
Bank Height (m): Mean, Range	3.3, 2.5-4.0	4.2, 1.5-7.0
Grade of Approach Slopes (%)	4-14	4-14
Riparian Area Width (m)	7	8
Riparian Vegetation Types	Deciduous	Shrub
Stream Shading	1-20%	

Substrate Composition	Amount
Organics	None
Fines (<2 mm)	Trace
Small Gravel (2-20 mm)	Trace
Large Gravel (21-65 mm)	Subdominant
Cobble (66-250 mm)	Dominant
Boulder (>250 mm)	Subdominant

Water Quality Parameters	
Water Temperature (°C)	16.40
pH	8.72
Dissolved Oxygen (mg/L)	10.80
Conductivity (µStem)	443.56
Turbidity (visual)	Clear

Habitat	Length (m)	%
Pool 1 (depth > 1.0 m)	55	8.0
Pool 2 (depth 0.75-1.0 m)	-	-
Pool 3 (depth <0.75 m)	-	-
Run 1 (>1.0 m)	120	92.0
Run 2 (0.75-1.0 m)	-	-
Run 3 (<0.75 m)	-	-
Flat 1 (> 1.0 m)	-	-
Flat 2 (0.75-1.0 m)	-	-
Flat 3 (<0.75 m)	-	-
Riffle	-	-
Backwater	-	-
Rapid	-	-
Other	-	-

Cover Types	Amount
Boulders	Subdominant
Undercut Banks	None
Overhanging Vegetation	Trace
Woody Debris	Trace
Depth	Dominant
Stain/Turbulence	Dominant
Instream Vegetation	Trace
Other	-
Other	-
Other	-
Other	-
Total Cover	Low

Fish Habitat Potential

Species	Spawning Rating	Rearing Rating	Wintering Rating	Adult Holding Rating
mountain whitefish	Suitable	Suitable	Suitable	Suitable
brown trout	Marginal	Suitable	Suitable	Suitable
rainbow trout	Marginal	Suitable	Suitable	Suitable

Fish species previously documented: brook trout, bull trout, brown trout, burbot, cutthroat trout, lake whitefish, mountain whitefish, northern pike, rainbow trout, yellow perch, walleye, brook stickleback, fathead minnow, lake chub, longnose dace, longnose sucker, mountain sucker, Prussian carp, pearl dace, spoonhead sculpin, trout-perch and white sucker (FWMIS, 2017).

Additional Habitat Comments

Site 2 is located approximately 260 m downstream of the 17 Avenue Cushing Bridge at the first riprap groyne constructed along the right downstream bank (RDB), extending for approximately 140 m downstream to a second riprap groyne along the RDB to the upstream boundary of Site 4. Fish habitat within Site 2 consists almost entirely of a deep run (R1) habitat, with deep pool (P1) habitat located immediately downstream of riprap groynes at the upstream and downstream extent of the RDB of Site 2, adjacent to a City of Calgary pathway in Inglewood. Water depth is relatively uniform through this section, ranging from 1.5 m to 2.1 m. Substrates consist primarily of boulder and large cobbles in R1 habitat and boulder and riprap within P1 habitat downstream of flood mitigation structures (groynes). Cover is provided primarily by depth and turbulence, and by boulder and riprap substrates. Large woody debris has accumulated within the P1 habitat immediately downstream of the riprap groyne present at the upstream boundary of Site 2 along the RDB. Large woody debris provides suitable overhanging and instream cover. Overhanging cover is otherwise severely limited throughout Site 2. Deep run (R1) habitat provides excellent holding, feeding, and overwintering habitat for adult and juvenile fish. P1 habitat present downstream of riprap groynes provides a velocity refuge for fish as well as suitable holding and feeding habitat for juvenile fish. There is marginal potential spawning habitat for salmonids throughout Site 2 due to the larger size of substrates. Potential spawning habitat is limited to cobble substrates along a side cobble bar along the LDB. However, spawning habitat is present in Bow River throughout the zone-of-influence.

Photo 1: Photo taken at Transect 7, view upstream.

Photo 2: Photo taken at Transect 7, view downstream.

Photo 3: View of left bank at Transect 7.

Photo 4: View of right bank at Transect 7.

Photo 5: Photo taken at Site 2, cross channel.

Photo 6: Photo taken at Site 2, downstream view.

Watercourse (Site#):	Bow River – Site 4
Habitat Survey Length (# transects):	1,500 m (16)
Restricted Activity Period:	May 1 to July 15, Sept 16 to April 5
Watercourse Class:	Mapped Class C

Field Crew:	M. Piciacchia, C. Davis
Survey Date:	July 31, 2019,
Legal Location:	NW-12-24-01 W5M
UTM (Zone 11):	709488E, 5657767N

Flow Regime	Perennial
Bankfull Width (m): Mean, Range	162.1, 103.0-232.0
Wetted Width (m): Mean, Range	114.0, 78.0-171.0
Depth (m): Mean, Range	1.50, 0.54-6.95
Stream Gradient (%)	2.0
Embeddedness	Low
Beaver Dams	None
Native Channel Width (m)	N/A

Bank Conditions	Left Bank	Right Bank
Bank Shape	Vertical	Vertical
Bank Texture	Boulder / Cobble	Boulder / Cobble
Bank Height (m): Mean, Range	3.3, 2.5-4.0	4.2, 1.5-7.0
Grade of Approach Slopes (%)	4-14	4-14
Riparian Area Width (m)	7	8
Riparian Vegetation Types	Deciduous	Shrubs
Stream Shading	1-20%	

Substrate Composition	Amount
Organics	None
Fines (<2 mm)	Trace
Small Gravel (2-20 mm)	Trace
Large Gravel (21-65 mm)	Subdominant
Cobble (66-250 mm)	Dominant
Boulder (>250 mm)	Subdominant

Water Quality Parameters	
Water Temperature (°C)	16.65
pH	8.46
Dissolved Oxygen (mg/L)	9.36
Conductivity (µStem)	331.25
Turbidity (visual)	Clear

Habitat	Length (m)	%
Pool 1 (depth > 1.0 m)	100	6.8
Pool 2 (depth 0.75-1.0 m)	50	0.5
Pool 3 (depth <0.75 m)	-	-
Run 1 (>1.0 m)	605	43.5
Run 2 (0.75-1.0 m)	-	-
Run 3 (<0.75 m)	55	0.7
Flat 1 (> 1.0 m)	-	-
Flat 2 (0.75-1.0 m)	-	-
Flat 3 (<0.75 m)	-	-
Riffle	595	48.5
Backwater	-	-
Rapid	-	-
Snye	-	-

Cover Types	Amount
Boulders	Subdominant
Undercut Banks	None
Overhanging Vegetation	Trace
Woody Debris	Trace
Depth	Dominant
Stain/Turbulence	Dominant
Instream Vegetation	Trace
Other	-
Other	-
Other	-
Other	-
Total Cover	Low

Fish Habitat Potential				
Species	**Spawning Rating**	**Rearing Rating**	**Wintering Rating**	**Adult Holding Rating**
mountain whitefish	Suitable	Suitable	Marginal	Suitable
brown trout	Marginal	Suitable	Marginal	Suitable
rainbow trout	Marginal	Suitable	Marginal	Suitable

Fish species previously documented: brook trout, bull trout, brown trout, burbot, cutthroat trout, lake whitefish, mountain whitefish, northern pike, rainbow trout, yellow perch, walleye, brook stickleback, fathead minnow, lake chub, longnose dace, longnose sucker, mountain sucker, Prussian carp, pearl dace, spoonhead sculpin, trout-perch and white sucker (FWMIS, 2017).

Additional Habitat Comments

Site 4 is bounded on the upstream end by the second (downstream) riprap groyne constructed along the RDB and extends to the downstream extent of bank riprapping along the RDB. Site 4 extends to the mid channel to the wetted edge of the cobble side bar along the LDB. Fish habitat within Site 4 is comprised primarily of deep run (R1) habitat, transitioning into shallow depth run (R3) habitat at the downstream end of the site. Bank stability is very high, with the entire RDB composed of class II and class III riprap. Substrate consists primarily of cobble and boulder with a maximum depth of approximately 1.5 m in the thalweg. Cover is provided primarily by depth and turbulence and partially by large riprap present along the RDB and boulder substrate. Site 4 has little to no overhanging cover as a result of bank armoring along the RDB and lack of bank vegetation.

Deep run (R1) habitat provides suitable holding and feeding habitat for adult and juvenile fish. R3 habitat present at the downstream end of the reach provides holding and feeding habitat for juvenile fish. Due to the maximum depth of approximately 1.5 m, this section of the Bow River provides marginal to suitable overwintering habitat. There is marginal spawning habitat for salmonids (e.g. brown trout and rainbow trout) due to the lack of suitable gravel substrates through the reach, however, spawning habitat is present in the Bow River .

Photo 1: Photo taken at Transect 11, view upstream.

Photo 2: Photo taken at Transect 11, view downstream

Photo 3: View of left bank at Transect 11.

Photo 4: View of right bank at Transect 11.

Photo 5: Photo taken at Transect 9, view upstream.

Photo 6: Photo taken at Transect 9, view downstream.

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Appendix D

Bow River Fish Habitat Map

Prepared by: Hemmera Envirochem Inc.

Bioengineering Demonstration
and Education Project
Bow River, Calgary, Alberta

Bow River Fish Habitat

Legend

- Transect
- Pool
- Riffle
- Run
- Site Boundary

Channel Unit/Habitat

R1 Class 1 Run; Deep Run >1.0 m
R2 Class 2 Run; Moderate Run 0.75 - 1.0 m
R3 Class 3 Run; Shallow Run < 0.75 m

P1 Class 1; Deep Pool >1.0 m
P2 Class 2; Moderate Pool 0.75 - 1.0 m
P3 Class 3; Shallow Pool < 0.75 m

RF Riffle
SN Syne
BW Backwater

Co Cobble
Gr Gravel
Bl Boulder
F Fines

Notes

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

Sources

- Contains information licensed under the Open Government Licence - Government of Alberta
- Aerial Image: City of Calgary (2018)

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Metres

Calgary 3TM

Page Size: 11" x 17"

103530-01	Production Date: Nov 29, 2019	Figure 3A

Hemmera
An Ausenco Company

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Bio-engineering Demonstration and Education Project -
Bioengineering Efficacy Monitoring Project
Bow River, Calgary Alberta

Bow River Fish Habitat

DEERFOOT TRAIL SOUTH-EAST

T11
T12
T13
T14
T15
T16

R1
Co/Bl

RF
Gr/Co

RF
Gr, Co

RF
Co, Gr

P1
F, Co

R1
Co, Gr

Legend

- Transect
- Pool
- Riffle
- Run

Channel Unit/Habitat

R1 Class 1 Run; Deep Run >1.0 m
R2 Class 2 Run; Moderate Run 0.75 - 1.0 m
R3 Class 3 Run; Shallow Run < 0.75 m

P1 Class 1; Deep Pool >1.0 m
P2 Class 2; Moderate Pool 0.75 - 1.0 m
P3 Class 3; Shallow Pool < 0.75 m

RF Riffle
SN Syne
BW Backwater

Co Cobble
Gr Gravel
Bl Boulder
F Fines

Notes

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

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N

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0 30 60 90 120 150

Metres

Calgary 3TM

Page Size: 11" x 17"

103530-01	Production Date: Nov 29, 2019	Figure 3B

Hemmera
An Ausenco Company

Path: S:\Geomatics\Projects\103530\01\mxd\Fig3B_103530_01_FishHabitat_191125.mxd

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Appendix E

Raw Fish Data

Prepared by: Hemmera Envirochem Inc.

Table E-1 Bow River Raw Fish Data 2019

Species	Fish Count	Length (mm)	Weight (g)	Sex	Life Stage
LNSC	1	214	303	Unknown	Juvenile
LNSC	1	148	52	Unknown	Juvenile
LNSC	1	176	75	Unknown	Juvenile
LNSC	1	225	138	Unknown	Juvenile
LNSC	1	214	138	Unknown	Juvenile
LNSC	1	110	14	Unknown	Juvenile
LNSC	1	223	136	Unknown	Juvenile
LNSC	1	170	67	Unknown	Juvenile
LNSC	1	135	33	Unknown	Juvenile
WHSC	1	114	20	Unknown	Juvenile
WHSC	1	242	215	Unknown	Juvenile
YLPR	1	60	2	Unknown	Juvenile
YLPR	1	56	2	Unknown	Juvenile
YLPR	1	61	2	Unknown	Juvenile
BNTR	1	61	4	Unknown	Juvenile
YLPR	1	74	8	Unknown	Juvenile
BNTR	1	62	3	Unknown	Juvenile
MNWH	1	81	11	Unknown	Juvenile
NRPK	1	690	2421	Unknown	Adult
LNSC	1	267	365	Unknown	Adult
LNSC	1	264	229	Unknown	Adult
LNSC	1	251	210	Unknown	Adult
LNSC	1	254	400	Unknown	Adult
WHSC	1	387	950	Unknown	Adult
LNSC	1	253	176	Unknown	Adult
WHSC	1	445	1330	Unknown	Adult
WHSC	1	478	1777	Unknown	Adult
WHSC	1	461	1530	Unknown	Adult
WHSC	1	425	1140	Unknown	Adult
WHSC	1	441	1241	Unknown	Adult
WHSC	1	437	1370	Unknown	Adult
YLPR	1	118	17	Unknown	Adult
BURB	1	374	244	Unknown	Adult

Species	Fish Count	Length (mm)	Weight (g)	Sex	Life Stage
WHSC	1	375	600	Unknown	Adult
RNTR	1	44	1	Unknown	Young of the Year
RNTR	1	39	1	Unknown	Young of the Year
RNTR	1	45	1	Unknown	Young of the Year
RNTR	1	41	1	Unknown	Young of the Year
LNSC	1	321	400	Unknown	Adult

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Appendix F

Riparian Health Assessment Field Data Sheets

Prepared by: Longview Ecological and Terra Erosion Control Ltd.

ALBERTA WETLAND HEALTH ASSESSMENT FOR LARGE RIVERS

Polygon ID: Site #1 (BOEP)

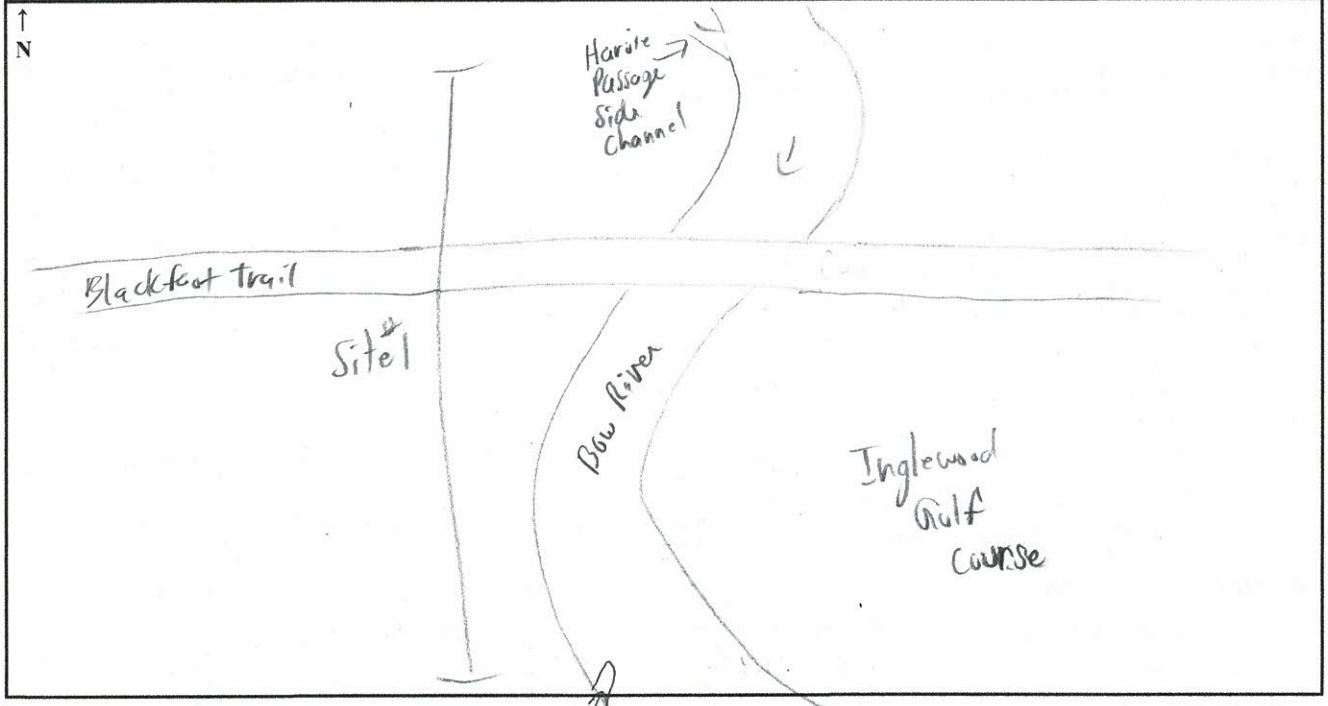
Project: CoC RMP	Observer: AD, PR
Client: CoC	Date: Sept. 17/19
Property Name: NA	Watershed: South Saskatchewan River
Field Name: NA	River Name: Bow River
Legal Land Location: NW 12 + SW 13 + SE 13-24-1 W5M	Photos: 336 – 343
Natural Subregion: Foothills Fescue	
Coordinates: 51.03963, -114.01173 (upstream end) ; 51.03509, -114.01406 (downstream end)	

Comments:
- Could split polygon into 2 parts: 1 south of Cushing Bridge, 1 north of Cushing Bridge

Dominant Plant Species

Graminoids	% Cover	Forbs	% Cover	Shrubs	% Cover	Trees	% Cover
ELYTRA		TRIFSPP		SALINT		POPUBAL	
ELYMCAN		MEDILUP		SALFAM		FRAXPEN	
		MELISPP		CORNSTO	2	POPUTRE	
		LINULEW		ELAECOM	2	SALIFRA	
		TARAVU	3	POTEFRU	1	PICEPUN	
				SYMPOCC	<1		
				VIBUOPU	<1		
				RIBEOXY	1		
				AMELALN	1		

Riparian Area Diagram



Upstream end:
E709488, N5658482
Downstream end:
E709545, N5657969

LONGVIEW ECOLOGICAL

9
14

20/80

RIVER HEALTH EVALUATION

Polygon Number: _____ Record ID No: Site1

	Actual Score	Possible Score	Comment
1. Cottonwood and Poplar Regeneration	4	6	Mostly mature POPUBAL north of bridge + saplings south of bridge
2. Regeneration of other Native Tree Species	3	3	POPUTRE planted (n19) ~ 9 mature FRAPEN
3. Regeneration of Preferred Shrub Species	4	6	~7% saplings, Mostly mature shrubs south of bridge
4. Standing Decadent and Dead Woody Material	2	3	Numerous decadent POPUBAL (~10% cover)
5a. Browse Util. of Preferred Trees and Shrubs	3	3	Essentially none
5b. Woody Veg. Removal other than Browsing	3	3	Some trees were removed for this project
6. Total Canopy Cover of Woody Species	2	3	~45% cover combined
7a. Total Canopy Cover of Invasive Plant Species	1	3	
7b. Density/Distribution Pattern of Invasive Plant Species	0	3	

List Invasive Plant Species present, including Percent Canopy Cover and Density Distribution Class:

	Can.Cov.	Dens.Dist.		Can.Cov.	Dens.Dist.		Can.Cov.	Dens.Dist.
blueweed:			field bindweed:			spotted knapweed:		
* Canada thistle:	<1	6	leafy spurge:			tall buttercup:		
caragana:			nodding thistle:			tamarisk/salt cedar:		
cleavers:			ox-eye daisy:			white cockle:		
* common burdock:	<1	2	perennial sow-thistle:			* yellow toadflax:	<1	2
common hound's-tongue:			purple loosestrife:					
* common tansy:	3	8	Russian knapweed:					
Dalmatian Toadflax:			Russian olive:			Others: CAMPRAP	<1	2
diffuse knapweed:			* scentless chamomile:	<1	2	Others: HYOSNIG	<1	4
downy chess:			* smooth perennial sow-thistle:	<1	8	ULCICRA	<1	4
European buckthorn:						VERBTHA	<1	1

2c. Are there elevated status species for this county? (Yes; No; NC):

Elevated Sps 1: _____ Elevated Sps 2: _____ Elevated Sps 3: _____

8. Disturbance-increaser Undesirable Herbaceous Species	1	3	~30% cover. High BROINE + ELYMREP cover under mature POPUBAL north of bridge. TRIPRAP TARAOFF POLYCON PLAMAJ MEDLUP THLARV, TRIHYB, MEDSAT MELOFF, DESCOSP, HORJUB, CHENALB, SILENOC TRADUB ELYMREP MELALB AVENFAT BROINE High MEDLUP + TRIFSP cover in Site 1-4
Vegetation Subtotal:	23	36	
9. River Bank Root Mass Protection	2	6	~45% cover
10. Human-Caused Bare Ground	4	6	Some along wildlife trail + just north of bridge
11. Removal or Addition of Water from/to River System	6	9	Weir for irrigation located just upstream
12. Control of Flood Peak and Timing by Upstream Dam(s)	0	9	Bearspaw Dam located upstream
13. River Banks Structurally Altered by Human Activity	0	6	Entire bank south of bridge has been altered. 2 bridges
14. Human Physical Alteration to the Rest of the Polygon	0	3	Bridge, pathway, outfall
15. Natural Floodplain Accessibility	6	6	Berm along western edge of POPUBAL trees north of bridge, but this likely does not affect floodplain accessibility
Soil / Hydrology Subtotal:	18	45	
Overall Polygon Total:	41	81	

2%.

RATING CALCULATION

	(Actual Score/Possible Score) X 100 = Rating Percent		Descriptive Category
Vegetation Rating:	23 / 36 x 100 =	64%	Healthy with Problems
Soil / Hydrology:	18 / 45 x 100 =	40%	Unhealthy
OVERALL:	41 / 81 **x 100 =**	51%	Unhealthy

Woody
1-4 - lower - 60% woody (60%) 36
1-4 - upper - 15% " (40%) 6
42

1-3 - lower - 70% (20%) 14
1-3 upper - 15% (80%) 12
26
35

ALBERTA WETLAND HEALTH ASSESSMENT FOR LARGE RIVERS

Polygon ID: Site #2 (BDEP)

Project: CoC RMP	Observer: AD, PR
Client: CoC	Date: Sept. 17/19
Property Name: NA	Watershed: South Saskatchewan River
Field Name: NA	River Name: Bow River
Legal Land Location: NW 12 + NE 12 -24-1 W5M	Photos: 332 - 337
Natural Subregion: Foothills Fescue	

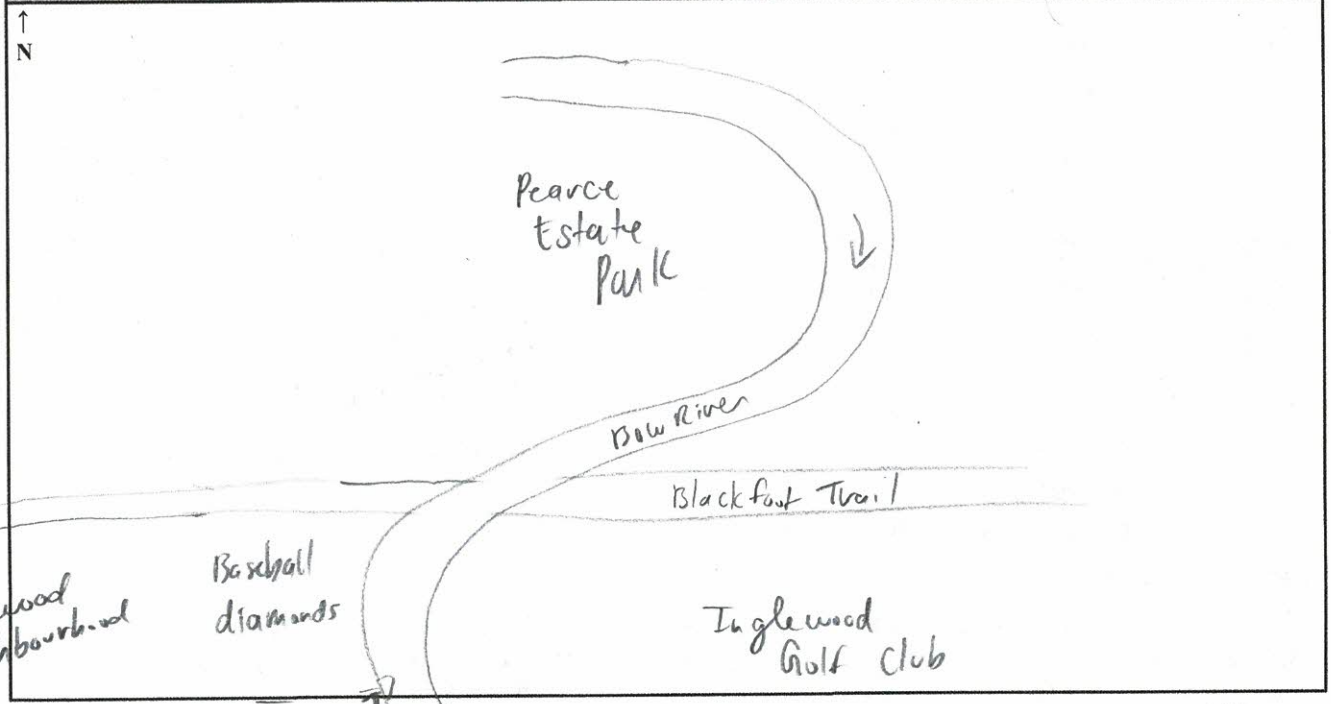
Coordinates: 51.03504 -114.01405 (upstream end); 51.03392 -114.01356 (downstream end)

Comments: E709466, N5657969 " " ; E709399, N5657842

Dominant Plant Species

Graminoids	% Cover	Forbs	% Cover	Shrubs	% Cover	Trees	% Cover
ELYMTRA	5	TRIFSPP	15	SALINT	20	POPUBAL	15
FESTRUB	10	CIRSARV	2	SALPAM	15	ACERNEG	3
LOLPER	10	MELISPP	10	COPRSTO	2	POPUTRE	5
AVENFAT	10	SONCOLI	1	PRUNVIR	2	PICEGLA	<1
ELYMCAN	5			ALNUTEN	1		
BROMINE	3			ELAECOM	1		
POAPRAT	5			RIBEODY	3		
				ROSAWOO	2		

Riparian Area Diagram



LONGVIEW ECOLOGICAL

12.2m

70
15
50

15
12.5
3.75

RIVER HEALTH EVALUATION

Polygon Number: Record ID No: Site #2

	Actual Score	Possible Score	Comment
1. Cottonwood and Poplar Regeneration	6	6	~14 mature POBAL along bench, but mostly saplings - some POBAL cuttings in brush layer
2. Regeneration of other Native Tree Species	3	3	Several mature ACENEG along bench, but numerous POBAL seedlings
3. Regeneration of Preferred Shrub Species	6	6	Some SALINT over 6ft, but most shrubs are saplings saplings
4. Standing Decadent and Dead Woody Material	3	3	None
5a. Browse Util. of Preferred Trees and Shrubs	3	3	≤5% overall moderate on CORNSTO in hedge brush layer shrubs are fenced off
5b. Woody Veg. Removal other than Browsing	3	3	None
6. Total Canopy Cover of Woody Species	2	3	~30% on bench, 15% on north half bank, 70% on south half bank
7a. Total Canopy Cover of Invasive Plant Species	1	3	
7b. Density/Distribution Pattern of Invasive Plant Species	0	3	

List Invasive Plant Species present, including Percent Canopy Cover and Density Distribution Class:

	Can.Cov.	Dens.		Can.Cov.	Dens.		Can.Cov.	Dens.
blueweed:			field bindweed:			spotted knapweed:		
* Canada thistle:	2	8	leafy spurge:			tall buttercup:		
caragana:			nodding thistle:			tamarisk/salt cedar:		
cleavers:			ox-eye daisy:			* white cockle:	<1	2
common burdock:			perennial sow-thistle:			yellow toadflax:		
common hound's-tongue:			purple loosestrife:					
* common tansy:	<1	2	Russian knapweed:					
Dalmatian Toadflax:			Russian olive:					
diffuse knapweed:			* scentless chamomile:	<1	2	Others: CLEMTAN	<1	2
downy chess:			* smooth perennial sow-thistle:	1	8	Others: HYOSNIG	<1	2
European buckthorn:						VICCRA	<1	8
						CAMPRAP	<1	2

2c. Are there elevated status species for this county? (Yes; No; NC):

Elevated Sps 1:	Can.Cov.	Dens.	Elevated Sps 2:	Can.Cov.	Dens.	Elevated Sps 3:	Can.Cov.	Dens.

AGROSTO

BROMINE, CHENALB, LACSER, POAPRAT, DESCSOP, MELOFF

8. Disturbance-increaser Undesirable Herbaceous Species	1	3	TARAOFF, TRIFHYB, MEDIUS PLANMAJ HORDJUB THLARV
Vegetation Subtotal:	28	36	TRIFREP, MALVROT, TRIAMOB, CREPTEC, POTENOR, CAPBUR SONCASP, MEDISAT, CIRVUL, MELALB, AVENFAT, PHLEPRA
9. River Bank Root Mass Protection	2	6	North half of bank largely lacks woody vegetation cover
10. Human-Caused Bare Ground	6	6	Outside bend - naturally high bare soil; minor amount in brush layer
11. Removal or Addition of Water from/to River System	6	9	* Weir for irrigation located just upstream
12. Control of Flood Peak and Timing by Upstream Dam(s)	0	9	Bearspaw Dam
13. River Banks Structurally Altered by Human Activity	0	6	~75% of 4m area has been disturbed
14. Human Physical Alteration to the Rest of the Polygon	0	3	~90% of polygon has been altered
15. Natural Floodplain Accessibility	6	6	No embankments or other restrictions to flow
Soil / Hydrology Subtotal:	20	45	
Overall Polygon Total:	48	81	

RATING CALCULATION

	(Actual Score/Possible Score) X 100 = Rating Percent			Descriptive Category
Vegetation Rating:	28 / 36	x 100 =	78%	Healthy with Problems
Soil / Hydrology:	20 / 45	x 100 =	44%	Unhealthy
OVERALL:	48 / 81	**x 100 =**	58%	Unhealthy

* Check AVENFAT if disturbance

ALBERTA WETLAND HEALTH ASSESSMENT FOR LARGE RIVERS

Polygon ID: Site #4 (BOEP)

Project: CoC RMP	Observer: AD, PR
Client: CoC	Date: Sept. 16/19
Property Name: NA	Watershed: South Saskatchewan River
Field Name: NA	River Name: Bow River
Legal Land Location: NE 12-24-12 W5M	Photos: 328-337
Natural Subregion: Foothills Fescue	

Coordinates: 51.03392 -114.01332 (upstream end); 51.03234 -114.01095 (downstream end)

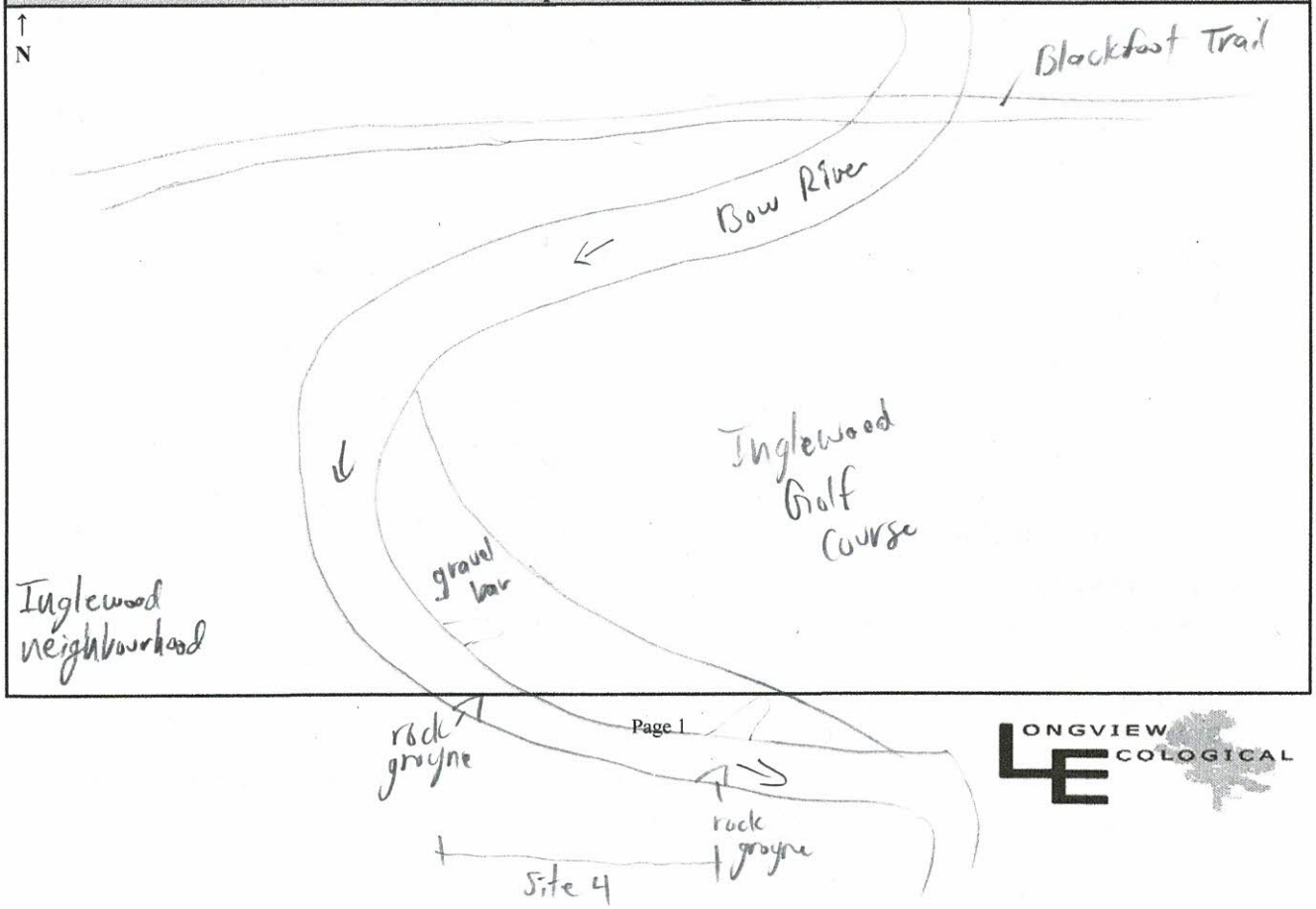
Comments: E709402, N5657642 " " ; E709582, N5657675

RIBEAUR 3

Dominant Plant Species

Graminoids	% Cover	Forbs	% Cover	Shrubs	% Cover	Trees	% Cover
ELYMTRA	15	TRIPINO	3	SALIFAM	25	POPUBAL	2
FESCCES	7	TANAVUL	1	SALINT	20	POPUTRE	3
POAPALU	5	CIRSARV	2	CORNSTO	7		
AGROSCA	5	SONCULI	1	SALIBEB	3		
BROMINE	3	MEDIVUP	3	PRUNVIR	1		
ELYMREP	7	MELIOFF	3	AMELALN	<1		
ELYMCAN	2			BETUOCC	1		
POAPRAT	1			ALNUTEN	1		
				ROSAACI	2		

Riparian Area Diagram



LONGVIEW ECOLOGICAL

RIVER HEALTH EVALUATION

Polygon Number: Record ID No: Site #4

	Actual Score	Possible Score	Comment
1. Cottonwood and Poplar Regeneration	6	6	1 large POPUDEL sapling. Numerous planted POPUTRI (plugs + pots). Only 1 mature tree
2. Regeneration of other Native Tree Species	3	3	Mostly planted. POPUTRE present. A few ACERNEG seedlings
3. Regeneration of Preferred Shrub Species	4	6	Most shrubs on upper half of bank are mature
4. Standing Decadent and Dead Woody Material	3	3	A number of dead trees + shrubs
5a. Browse Util. of Preferred Trees and Shrubs	2	3	Heavy CORNSTO browsing, light willow browsing
5b. Woody Veg. Removal other than Browsing	3	3	A few SALIXES outside of fence were removed by beavers
6. Total Canopy Cover of Woody Species	3	3	Higher shrub cover on upper half of bank
7a. Total Canopy Cover of Invasive Plant Species	1	3	Common throughout site
7b. Density/Distribution Pattern of Invasive Plant Species	0	3	

List Invasive Plant Species present, including Percent Canopy Cover and Density Distribution Class:

	Can.Cov.	Dens.Dist.		Can.Cov.	Dens.Dist.		Can.Cov.	Dens.Dist.
blueweed:			field bindweed:			spotted knapweed:		
* Canada thistle:	3	8	leafy spurge:			tall buttercup:		
caragana:			nodding thistle:			tamarisk/salt cedar:		
cleavers:			ox-eye daisy:			white cockle:		
common burdock:	<1	1	perennial sow-thistle:			* yellow toadflax:	<1	4
common hound's-tongue:	<1	2	purple loosestrife:					
* common tansy:	1	5	Russian knapweed:					
Dalmatian Toadflax:			Russian olive:					
diffuse knapweed:			* scentless chamomile:	2	8	Others: HYOSNIG	<1	2
downy chess:			* smooth perennial sow-thistle:	1	8	Others: CAMPRAP	<1	2
European buckthorn:								

2c. Are there elevated status species for this county? (Yes; No; NC):

Elevated Sps 1:			Elevated Sps 2:			Elevated Sps 3:		

8. Disturbance-increaser Undesirable Herbaceous Species	2	3	~15% total cover TRIFREP, MELOFF, MEDILU, TRAGDU, ELYMREP, POAPRA, BROMINE, CIRVUL, PHLEPRA, TARAOFF, TILAARV, CAPSBUR, CHENOLB, AVENFAT, MALVARO, DESCSOP
Vegetation Subtotal:	27	36	
9. River Bank Root Mass Protection	2	6	~55% of bank has deep-rooted woody vegetation
10. Human-Caused Bare Ground	4	6	Some bare ground where seedmix did not take +
11. Removal or Addition of Water from/to River System	6	9	- weir for irrigation where backfill washed away located just upstream
12. Control of Flood Peak and Timing by Upstream Dam(s)	0	9	- Bearspaw Dam
13. River Banks Structurally Altered by Human Activity	0	6	Entire bank has been altered with riprap
14. Human Physical Alteration to the Rest of the Polygon	0	3	Entire polygon has been altered by construction activities
15. Natural Floodplain Accessibility	6	6	No embankments or other restrictions to flow
Soil / Hydrology Subtotal:	18	45	
Overall Polygon Total:	45	81	

- Only ~1m or so wide if 15m is included as bank

RATING CALCULATION

(Actual Score/Possible Score) X 100 = Rating Percent

					Descriptive Category
Vegetation Rating:	27	/ 36	x 100 =	75%	Healthy with Problems
Soil / Hydrology:	18	/ 45	x 100 =	40%	Unhealthy
OVERALL:	45	/ 81	**x 100 =**	56%	Unhealthy

KERR WOOD LEIDAL
consulting engineers

Appendix G

Bioengineering Structural Integrity Assessment Field Forms

Prepared by: Kerr Wood Leidal Associates Ltd. and Terra Erosion Control Ltd.

Bank Protection/Stabilization Structure Assessment
First Assessment River Reach After Freshet Assessment KWL/Terra

Master Site List No.	46A	RMP Site ID Code (e.g., BE-BOW- 4A)		BE-BOW-46A	
Site Name:	AEP / COC Bioengineering Demonstration Project Site 1-1			Survey year (1/3/5+)	1
Watercourse	Bow River	Weather:	Overcast and 20 degrees		
Crew Initials	MG / PR	Date:	17-Jul-19		

Photo Monitoring

Permanent photo-monitoring location and ID

U/S END		D/S END	
E	709371	E	709358
N	5658318	N	5658260
Photo No.		Photo No.	

Other Photos (min 3)

Photo No.	Description

Hydrology

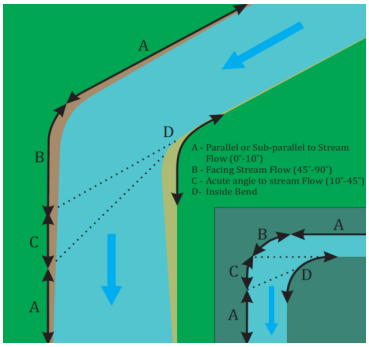
Flow at time of survey: 152 m³/s Source: Rivers.alberta.ca

Aspect (N,E,W,S or combined N/E)

Aspect 1: EES % of site: 100 Aspect 2: % of site: Aspect 3: % of site:

Site Location (Select 1 or more and add percentage of each)

A) Parallel or nearly parallel to flow (0° to 10°)	X	100 %
B) Moderate angle to flow (10° to 45°)		%
C) Directly facing flow (45° to 90°)		%
D) Internal bend		%



MEASUREMENTS

Average longitudinal stream slope at site: 0.54 %

Estimate of stream width for current year flood flow: 134 m

Site Dimensions

Total length of the work (parallel to stream): 69.5 m Total project area: 542.1 m²

Avg width of the work in plan view (perp to stream) including landscaping on top of the bank: 7.8 m

Average slope of the constructed bank: 6 ° Average height of the constructed bank: 1.3 m

Crib wall only

Height of Bioengineering Structure	Bank height (from permanent herbaceous or woody vegetation line)	Ratio % Bioeng structure/ Total Bank Height
		#DIV/0!
Average width of the crib wall into the bank (from engineering plans)		m

Site Elevation Measurements

Hydrology Survey	**Rod Height (m)**	**Elevation (m)**	**Survey Notes**
Elevation Benchmark	1.1	1000	Water level at 12:30pm on July 17, 2019
High water mark*	0.27	1000.83	**Debris on rodent fence**
Water level during survey	1.1	1000	

*Measured at observed debris and/or pollen accumulated on bank

Planted Vegetation Survey*	**Rod Height (m)**	**Elevation (m)**	**Survey Notes**
Elevation Benchmark	1.1	1000	Water level at 12:30pm on July 17, 2019
Elev of lowest woody veg	1.14	999.96	
Elev of lowest herbaceous veg		1001.1	**Hydroseeded but washed away**
Elev of lowest emergent veg		1001.1	

*Lowest elevation of *planted* woody, herbaceous, emergent vegetation along riverbank

Existing Vegetation Survey*	**Rod Height (m)**	**Elevation (m)**	**Survey Notes**
Elevation Benchmark	1.1	1000	
Elev of lowest woody veg	0.98	1000.12	
Elev of lowest herbaceous veg	1.17	999.93	
Elev of lowest emergent veg	1.08	1000.02	

*Lowest elevation of *existing native* woody, herbaceous, emergent vegetation along riverbank (trim line) If not possible, use difference in elevation between current water surface and existing vegetation either across the stream and/or further D/S or U/S.

Difference in elev between Planted and Existing Veg	Difference (m)
Woody vegetation	-0.16
Herbaceous vegetation	
Emergent vegetation	

WORK STRUCTURE ASSESSMENT

Rock Materials

Riprap Size	lm of application (m)*	% of total riprap
Class 1M (d50=175mm)		0
Class 1 (d50=300mm)		0
Class 2 (d50=500mm)	69.5	100
Class 3 (d50=800mm)		0
Other:		0
Total linear metre (m)	69.5	

Fish boulder average diameter mm

Fish boulder arrangement/distribution

Physical Condition	Rating	Riprap	Fish Boulders
Excellent	5 Very new without any defects	X	
Very Good	4 <5% defects without impacting structural integrity		
Good	3 10-20% defects without impacting structural integrity		
Fair	2 20-40% defects without impacting structural integrity		
Poor	1 Condition which needs immediate attention and repair		

Estimate of Remaining Useful Life	Riprap	Fish Boulders
>10 years	**X**	
5-10 years		
<5 years		
Negligible		

Gabion Materials

Gabion dimensions

Length mm Width mm Height mm Mesh Opening Size mm

Physical Condition	Rating	Gabions
Excellent	5 Very new without any defects	
Very Good	4 <5% defects without impacting structural integrity	
Good	3 10-20% defects without impacting structural integrity	
Fair	2 20-40% defects without impacting structural integrity	
Poor	1 Condition which needs immediate attention and repair	

Estimate of Remaining Useful Life	Gabions
>10 years	
5-10 years	
<5 years	
Negligible	

Wood Materials

Wood dimensions

Log diameter mm Log length mm Inclination angle °

Timber width mm Timber height mm Timber length mm

Rootwad diameter mm Rootwad length mm Location of root wad

Physical Condition	Rating	Logs	Timber	Rootwad
Excellent	5 Very new without any defects			
Very Good	4 <5% defects without impacting structural integrity			
Good	3 10-20% defects without impacting structural integrity			
Fair	2 20-40% defects without impacting structural integrity			
Poor	1 Condition which needs immediate attention and repair			

Estimate of Remaining Useful Life	Logs	Timber	Rootwad
4 >10 years			
3 5-10 years			
2 <5 years			
1 Negligible			

Hydromulch with wet meadow seed mix was in poor condition (washed away) with no remaining useful life

Erosion Control Matting and Geotextiles

Biodegradable erosion control matting product name (BECM)	
Biodegradable geogrid product name (BG)	
Synthetic erosion control matting product name (SECM)	
Synthetic geogrid product name (SG)	
Non woven geotextile product name (NWG)	

Physical Condition	Rating	BECM	BG	SECM	SG	NWG
Excellent	5 Very new without any defects					
Very Good	4 <5% defects without impacting structural integrity					
Good	3 10-20% defects without impacting structural integrity					
Fair	2 20-40% defects without impacting structural integrity					
Poor	1 Condition which needs immediate attention and repair					

Estimate of Remaining Useful Life	BECM	BG	SECM	SG	NWG
4 >10 years					
3 5-10 years					
2 <5 years					
1 Negligible					

Erosion Control Wattles

Biodegradable wattle product name (BW)	
Synthetic wattle product name (SW)	

Physical Condition	Rating	BW	SW
Excellent	5 Very new without any defects		
Very Good	4 <5% defects without impacting structural integrity		
Good	3 10-20% defects without impacting structural integrity		
Fair	2 20-40% defects without impacting structural integrity		
Poor	1 Condition which needs immediate attention and repair		

Estimate of Remaining Useful Life	BW	SW
4 >10 years		
3 5-10 years		
2 <5 years		
1 Negligible		

Concrete Materials

Concrete product 1 description (C1)	
Concrete product 2 description (C2)	
Concrete product 3 description (C3)	

Physical Condition	Rating	C1	C2	C3
Excellent	5 Very new without any defects			
Very Good	4 <5% defects without impacting structural integrity			
Good	3 10-20% defects without impacting structural integrity			
Fair	2 20-40% defects without impacting structural integrity			
Poor	1 Condition which needs immediate attention and repair			

Estimate of Remaining Useful Life	C1	C2	C3
4 >10 years			
3 5-10 years			
2 <5 years			
1 Negligible			

Steel Materials

Steel product 1 description (S1)	
Steel product 2 description (S2)	
Steel product 3 description (S3)	
Steel product 4 description (S4)	
Steel product 5 description (S5)	

Physical Condition	Rating	S1	S2	S3	S4	S5
Excellent	5 Very new without any defects					
Very Good	4 <5% defects without impacting structural integrity					
Good	3 10-20% defects without impacting structural integrity					
Fair	2 20-40% defects without impacting structural integrity					
Poor	1 Condition which needs immediate attention and repair					

Estimate of Remaining Useful Life	S1	S2	S3	S4	S5
4 >10 years					
3 5-10 years					
2 <5 years					
1 Negligible					

ENVIRONMENTAL AND CONTEXTUAL FACTORS

Erosion/Deposition Observations

Estimate of toe scour at site
Low [ ] Medium [ ] High [ ] N/A [X] Describe: None

Estimate of U/S bank erosion at site (U/S key)
Low [ ] Medium [ ] High [ ] N/A [X] Describe: None

Estimate of D/S bank erosion at site (D/S key)
Low [ ] Medium [ ] High [ ] N/A [X] Describe: None

Estimate of erosion within site/structure
Low [ ] Medium [ ] High [ ] N/A [X] Describe: None

Estimate of sediment accumulation at site
Low [X] Medium [ ] High [ ] N/A [ ] Describe: Accumulated within cobble

Measurement of sediment accumulation at site
Depth: 1 cm Method: Visual
Describe/Location:

Seeps or spring present Yes [ ] No [✠] Describe:

Ice abrasion None [X] Light [ ] Moderate [ ] Severe [ ]

Visual estimate of channel grain size
Silt [ ] Sand [X] Gravel [X] Cobble [X] Boulder [ ] Bedrock [ ]

SITE MOST LIMITING FACTOR(S)

Select from the list below, limiting factors to success:	**ASSIGN A SEVERITY RATING TO EACH OF THE FACTORS BELOW: NONE(0), LIGHT(1), MODERATE(2), SEVERE(3)**	
	After Treatment	**Comments**
Slope instability	0	
Slope gradient	0	
Erosion	0	
Compacted soils	0	
Anoxic soils	0	
Insect damage and disease	1	
Trampling by people or dogs	0	
Motorized vehicles	0	
Non motorized vehicles	0	
Aspect	0	
Bank profile	0	
Existing vegetation competition[1]	0	
Shade	2	Upper canopy on west side shading side
Maintenance issues[2]	2	Rodent fence
Flooding duration	2	Inundated during high water
Hydraulics (Shear stress)	1	
Infrastructure and available space	0	
Wildlife impact[3]	0	
Comment on wildlife impact:		
Access	0	
Other: 1-		
2-		

[1] e.g. from aggressive, fast spreading grasses or invasive weed species

[2] e.g. weeding, fencing or rodent protection) including inadequate or no irrigation, frequency or coverage

[3] Browsing/girdling by Rodent/Beavers/Muskrats

POTENTIAL REPAIR OPTIONS

	Select one
(1) Minor (hand tools, seeding and manual planting)	X
(2) Moderate, may need small machine and material to be brought in (is there access?)	
(3) Major, site needs to be redesigned and reconstructed.	

Description: Fix rodent fence

ALTERNATIVE DESIGN OPTIONS

Description: Live staking in riprap at correct time of year; alternate to hydroseeding is plugs of emergents; only use salix interior

Success Attributes

Good naturalization of vegetated riprap using River gravels to infill riprap; innovative technique using rooted long live cuttings

Bank Protection/Stabilization Structure Assessment
First Assessment River Reach After Freshet Assessment KWL/Terra

Master Site List No.	46B	RMP Site ID Code (e.g., BE-BOW- 4A)		BE-BOW-46B	
Site Name:	AEP / COC Bioengineering Demonstration Project Site 1-3		Survey year (1/3/5+)		1
Watercourse	Bow River	Weather:	Slightly overcast and 15 degrees		
Crew Initials	MG / PR	Date:	18-Jul-19		

Photo Monitoring

Permanent photo-monitoring location and ID

U/S END		D/S END	
E	709335	E	709338
N	5658174	N	5658048
Photo No.		Photo No.	

Other Photos (min 3)

Photo No.	Description

Hydrology

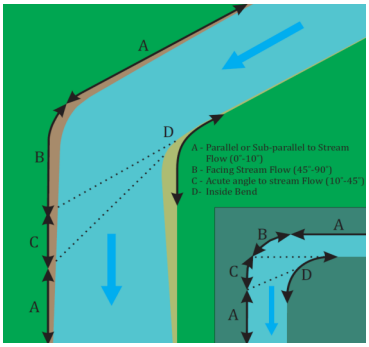
Flow at time of survey: 152 m³/s Source: Rivers.alberta.ca

Aspect (N,E,W,S or combined N/E)

Aspect 1: EES % of site: 100 Aspect 2: % of site: Aspect 3: % of site:

Site Location (Select 1 or more and add percentage of each)

A) Parallel or nearly parallel to flow (0° to 10°)	X	70 %
B) Moderate angle to flow (10° to 45°)	X	30 %
C) Directly facing flow (45° to 90°)		%
D) Internal bend		%



MEASUREMENTS

Average longitudinal stream slope at site: 0.2 %

Estimate of stream width for current year flood flow: 99 m

Site Dimensions

Total length of the work (parallel to stream): 120 m Total project area: 3609.0 m²

Avg width of the work in plan view (perp to stream) including landscaping on top of the bank: 30 m

Average slope of the constructed bank: 15 ° Average height of the constructed bank: 9 m

Crib wall only

Height of Bioengineering Structure	Bank height (from permanent herbaceous or woody vegetation line)	Ratio % Bioeng structure/ Total Bank Height
1.8	5.5	32.72727273
Average width of the crib wall into the bank (from engineering plans)		1.8 m

Site Elevation Measurements

Hydrology Survey	**Rod Height (m)**	**Elevation (m)**	**Survey Notes**
Elevation Benchmark	1.1	1000	Water level at 12:30pm on July 17, 2019 us of sit
High water mark*	0.27	1000.83	
Water level during survey	1.1	1000	

*Measured at observed debris and/or pollen accumulated on bank

Planted Vegetation Survey*	**Rod Height (m)**	**Elevation (m)**	**Survey Notes**
Elevation Benchmark	2.08	1000	**Water level at 1:19pm on July 17, 2019**
Elev of lowest woody veg	1.62	1000.46	
Elev of lowest herbaceous veg	1.59	1000.49	
Elev of lowest emergent veg		1002.08	None

*Lowest elevation of *planted* woody, herbaceous, emergent vegetation along riverbank

Existing Vegetation Survey*	**Rod Height (m)**	**Elevation (m)**	**Survey Notes**
Elevation Benchmark	1.1	1000	Water level at 12:30pm on July 17, 2019 us of sit
Elev of lowest woody veg	0.98	1000.12	
Elev of lowest herbaceous veg	1.17	999.93	
Elev of lowest emergent veg	1.08	1000.02	

*Lowest elevation of *existing native* woody, herbaceous, emergent vegetation along riverbank (trim line) If not possible, use difference in elevation between current water surface and existing vegetation either across the stream and/or further D/S or U/S.

Difference in elev between Planted and Existing Veg	Difference (m)
Woody vegetation	0.34
Herbaceous vegetation	0.56
Emergent vegetation	

WORK STRUCTURE ASSESSMENT

Rock Materials

Riprap Size	lm of application (m)*	% of total riprap
Class 1M (d50=175mm)		0
Class 1 (d50=300mm)		0
Class 2 (d50=500mm)	120.3	100
Class 3 (d50=800mm)		0
Other:		0
Total linear metre (m)	120.3	

Fish boulder average diameter 800 mm

Fish boulder arrangement/distribution 3 rock boulder clusters spaced at 10m

Physical Condition	Rating	Riprap	Fish Boulders
Excellent	5 Very new without any defects	X	**X**
Very Good	4 <5% defects without impacting structural integrity		
Good	3 10-20% defects without impacting structural integrity		
Fair	2 20-40% defects without impacting structural integrity		
Poor	1 Condition which needs immediate attention and repair		

Estimate of Remaining Useful Life	Riprap	Fish Boulders
>10 years	**X**	**X**
5-10 years		
<5 years		
Negligible		

Gabion Materials

Gabion dimensions

Length mm Width mm Height mm Mesh Opening Size mm

Physical Condition	Rating	Gabions
Excellent	5 Very new without any defects	
Very Good	4 <5% defects without impacting structural integrity	
Good	3 10-20% defects without impacting structural integrity	
Fair	2 20-40% defects without impacting structural integrity	
Poor	1 Condition which needs immediate attention and repair	

Estimate of Remaining Useful Life	Gabions
>10 years	
5-10 years	
<5 years	
Negligible	

Wood Materials

Wood dimensions

Log diameter mm Log length mm Inclination angle °

Timber width 150 mm Timber height 150 mm Timber length 6500 mm

Rootwad diameter mm Rootwad length mm Location of root wad

Physical Condition	Rating	Logs	Timber	Rootwad
Excellent	5 Very new without any defects			
Very Good	4 <5% defects without impacting structural integrity			
Good	3 10-20% defects without impacting structural integrity		**X**	
Fair	2 20-40% defects without impacting structural integrity			
Poor	1 Condition which needs immediate attention and repair			

Estimate of Remaining Useful Life	Logs	Timber	Rootwad
4 >10 years			
3 5-10 years		X	
2 <5 years			
1 Negligible			

Erosion Control Matting and Geotextiles

Biodegradable erosion control matting product name (BECM)	
Biodegradable geogrid product name (BG)	Double layered coir 1200 g/m2 - coirwrap 1200
Synthetic erosion control matting product name (SECM)	
Synthetic geogrid product name (SG)	
Non woven geotextile product name (NWG)	Nilex 4512

Physical Condition	Rating	BECM	BG	SECM	SG	NWG
Excellent	5 Very new without any defects					X
Very Good	4 <5% defects without impacting structural integrity		X			
Good	3 10-20% defects without impacting structural integrity					
Fair	2 20-40% defects without impacting structural integrity					
Poor	1 Condition which needs immediate attention and repair					

Estimate of Remaining Useful Life	BECM	BG	SECM	SG	NWG
4 >10 years					X
3 5-10 years		X			
2 <5 years					
1 Negligible					

Erosion Control Wattles

Biodegradable wattle product name (BW)	
Synthetic wattle product name (SW)	

Physical Condition	Rating	BW	SW
Excellent	5 Very new without any defects		
Very Good	4 <5% defects without impacting structural integrity		
Good	3 10-20% defects without impacting structural integrity		
Fair	2 20-40% defects without impacting structural integrity		
Poor	1 Condition which needs immediate attention and repair		

Estimate of Remaining Useful Life	BW	SW
4 >10 years		
3 5-10 years		
2 <5 years		
1 Negligible		

Concrete Materials

Concrete product 1 description (C1)	ocks at back of timber crib wall in fish shelters dim 750x750x1500 (not obs
Concrete product 2 description (C2)	
Concrete product 3 description (C3)	

Physical Condition	Rating	C1	C2	C3
Excellent	5 Very new without any defects	obser		
Very Good	4 <5% defects without impacting structural integrity			
Good	3 10-20% defects without impacting structural integrity			
Fair	2 20-40% defects without impacting structural integrity			
Poor	1 Condition which needs immediate attention and repair			

Estimate of Remaining Useful Life	C1	C2	C3
4 >10 years	obser		
3 5-10 years			
2 <5 years			
1 Negligible			

Steel Materials

Steel product 1 description (S1)	Stainless steel crib connection plates
Steel product 2 description (S2)	Stainless bolts
Steel product 3 description (S3)	Galvanized spiral shank spike
Steel product 4 description (S4)	
Steel product 5 description (S5)	

Physical Condition	Rating	S1	S2	S3	S4	S5
Excellent	5 Very new without any defects	X	X	X		
Very Good	4 <5% defects without impacting structural integrity					
Good	3 10-20% defects without impacting structural integrity					
Fair	2 20-40% defects without impacting structural integrity					
Poor	1 Condition which needs immediate attention and repair					

Estimate of Remaining Useful Life	S1	S2	S3	S4	S5
4 >10 years	X	X	X		
3 5-10 years					
2 <5 years					
1 Negligible					

ENVIRONMENTAL AND CONTEXTUAL FACTORS

Erosion/Deposition Observations

Estimate of toe scour at site
Low [ ] Medium [ ] High [ ] N/A [X] Describe: None

Estimate of U/S bank erosion at site (U/S key)
Low [ ] Medium [ ] High [ ] N/A [X] Describe: None

Estimate of D/S bank erosion at site (D/S key)
Low [ ] Medium [ ] High [ ] N/A [X] Describe: None

Estimate of erosion within site/structure
Low [ ] Medium [ ] High [ ] N/A [X] Describe: None

Estimate of sediment accumulation at site
Low [X] Medium [ ] High [ ] N/A [ ] Describe: On the rock bench at low water

Measurement of sediment accumulation at site
Depth [Na] Method: Underwater
Describe/Location

Seeps or spring present Yes [ ] No [✠] Describe:

Ice abrasion None [X] Light [ ] Moderate [ ] Severe [ ]

Visual estimate of channel grain size
Silt [ ] Sand [X] Gravel [X] Cobble [X] Boulder [ ] Bedrock [ ]

SITE MOST LIMITING FACTOR(S)

Select from the list below, limiting factors to success:	**ASSIGN A SEVERITY RATING TO EACH OF THE FACTORS BELOW: NONE(0), LIGHT(1), MODERATE(2), SEVERE(3)**	
	After Treatment	**Comments**
Slope instability	0	
Slope gradient	0	
Erosion	0	
Compacted soils	0	
Anoxic soils	0	
Insect damage and disease	1	
Trampling by people or dogs	0	
Motorized vehicles	0	
Non motorized vehicles	0	
Aspect	0	
Bank profile	0	
Existing vegetation competition[1]	2	Invasives present high seeding application rate
Shade	0	
Maintenance issues[2]	2	Weeding and fence repair on upstream
Flooding duration	0	
Hydraulics (Shear stress)	2	
Infrastructure and available space	0	
Wildlife impact[3]	0	
Comment on wildlife impact:		
Access	0	
Other: 1-		
2-		

[1] e.g. from aggressive, fast spreading grasses or invasive weed species

[2] e.g. weeding, fencing or rodent protection) including inadequate or no irrigation, frequency or coverage

[3] Browsing/girdling by Rodent/Beavers/Muskrats

POTENTIAL REPAIR OPTIONS

	Select one
(1) Minor (hand tools, seeding and manual planting)	X
(2) Moderate, may need small machine and material to be brought in (is there access?)	
(3) Major, site needs to be redesigned and reconstructed.	

Description: Remove invasives including root system from site before gone to seed and cut down all grasses that are competing with cutting; repair fence

ALTERNATIVE DESIGN OPTIONS

Description: Vegetated riprap with soil wrap above

Success Attributes

Deep buried cuttings at 35 degree in brush layer within structures ; innovative fish shelter included in timber crib wall

Bank Protection/Stabilization Structure Assessment
First Assessment River Reach After Freshet Assessment KWL/Terra

Master Site List No.	46C	RMP Site ID Code (e.g., BE-BOW- 4A)		BE-BOW-46C	
Site Name:	AEP / COC Bioengineering Demonstration Project Site 1-4		Survey year (1/3/5+)		1
Watercourse	Bow River	Weather:	Sunny 18 degrees		
Crew Initials	MG / PR	Date:	18-Jul-19		

Photo Monitoring

Permanent photo-monitoring location and ID

U/S END		D/S END	
E	709340	E	709343
N	5658037	N	5657978
Photo No.		Photo No.	

Other Photos (min 3)

Photo No.	Description

Hydrology

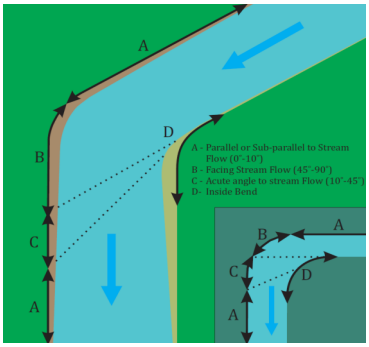
Flow at time of survey: 152 m³/s Source: Rivers.alberta.ca

Aspect (N,E,W,S or combined N/E)

Aspect 1: EES % of site: 100 Aspect 2: % of site: Aspect 3: % of site:

Site Location (Select 1 or more and add percentage of each)

A) Parallel or nearly parallel to flow (0° to 10°)		%
B) Moderate angle to flow (10° to 45°)	X	100 %
C) Directly facing flow (45° to 90°)		%
D) Internal bend		%



MEASUREMENTS

Average longitudinal stream slope at site: 0.2 %

Estimate of stream width for current year flood flow: 147 m

Site Dimensions

Total length of the work (parallel to stream): 65.5 m Total project area: 1441.0 m²

Avg width of the work in plan view (perp to stream) including landscaping on top of the bank: 22 m

Average slope of the constructed bank: 20 ° Average height of the constructed bank: 8.5 m

Crib wall only

Height of Bioengineering Structure	Bank height (from permanent herbaceous or woody vegetation line)	Ratio % Bioeng structure/ Total Bank Height
		#DIV/0!
Average width of the crib wall into the bank (from engineering plans)		m

Site Elevation Measurements

Hydrology Survey	**Rod Height (m)**	**Elevation (m)**	**Survey Notes**
Elevation Benchmark	1.1	1000	Water level at 12:30pm on july 17, 2019 us of site
High water mark*	0.27	1000.83	**1.24 at Site 1-3 and 1-4**
Water level during survey	1.1	1000	

*Measured at observed debris and/or

Planted Vegetation Survey*	**Rod Height (m)**	**Elevation (m)**	**Survey Notes**
Elevation Benchmark	2.08	1000	**Water level at 140pm on July 17, 2019 at Site**
Elev of lowest woody veg	1.84	1000.24	
Elev of lowest herbaceous veg	1.1	1000.98	
Elev of lowest emergent veg		1002.08	

*Lowest elevation of ***planted*** woody, herbaceous, emergent vegetation along riverbank

Existing Vegetation Survey*	**Rod Height (m)**	**Elevation (m)**	**Survey Notes**
Elevation Benchmark	1.1	1000	Water level at 12:30pm on july 17, 2019 us of site
Elev of lowest woody veg	0.98	1000.12	
Elev of lowest herbaceous veg	1.17	999.93	
Elev of lowest emergent veg	1.08	1000.02	

*Lowest elevation of ***existing native*** woody, herbaceous, emergent vegetation along riverbank (trim line) If not possible, use difference in elevation between current water surface and existing vegetation either across the stream and/or further D/S or U/S.

Difference in elev between Planted and Existing Veg	Difference (m)
Woody vegetation	0.12
Herbaceous vegetation	1.05
Emergent vegetation	

WORK STRUCTURE ASSESSMENT

Rock Materials

Riprap Size	lm of application (m)*	% of total riprap
Class 1M (d50=175mm)		0
Class 1 (d50=300mm)		0
Class 2 (d50=500mm)	65.5	100
Class 3 (d50=800mm)		0
Other:		0
Total linear metre (m)	65.5	

Fish boulder average diameter 800 mm

Fish boulder arrangement/distribution 3 rock boulder cluster spaced 10m

Physical Condition	Rating	Riprap	Fish Boulders
Excellent	5 Very new without any defects	X	**X**
Very Good	4 <5% defects without impacting structural integrity		
Good	3 10-20% defects without impacting structural integrity		
Fair	2 20-40% defects without impacting structural integrity		
Poor	1 Condition which needs immediate attention and repair		

Estimate of Remaining Useful Life	Riprap	Fish Boulders
>10 years	**X**	**X**
5-10 years		
<5 years		
Negligible		

Gabion Materials

Gabion dimensions

Length mm Width mm Height mm Mesh Opening Size mm

Physical Condition	Rating	Gabions
Excellent	5 Very new without any defects	
Very Good	4 <5% defects without impacting structural integrity	
Good	3 10-20% defects without impacting structural integrity	
Fair	2 20-40% defects without impacting structural integrity	
Poor	1 Condition which needs immediate attention and repair	

Estimate of Remaining Useful Life	Gabions
>10 years	
5-10 years	
<5 years	
Negligible	

Wood Materials

Wood dimensions

Log diameter mm Log length mm Inclination angle °

Timber width mm Timber height mm Timber length mm

Rootwad diameter mm Rootwad length mm Location of root wad

Physical Condition	Rating	Logs	Timber	Rootwad
Excellent	5 Very new without any defects			
Very Good	4 <5% defects without impacting structural integrity			
Good	3 10-20% defects without impacting structural integrity			
Fair	2 20-40% defects without impacting structural integrity			
Poor	1 Condition which needs immediate attention and repair			

Estimate of Remaining Useful Life	Logs	Timber	Rootwad
4 >10 years			
3 5-10 years			
2 <5 years			
1 Negligible			

Erosion Control Matting and Geotextiles

Biodegradable erosion control matting product name (BECM)	
Biodegradable geogrid product name (BG)	900 g/m2 coir geotextile
Synthetic erosion control matting product name (SECM)	
Synthetic geogrid product name (SG)	
Non woven geotextile product name (NWG)	

Physical Condition	Rating	BECM	BG	SECM	SG	NWG
Excellent	5 Very new without any defects					
Very Good	4 <5% defects without impacting structural integrity		X			
Good	3 10-20% defects without impacting structural integrity					
Fair	2 20-40% defects without impacting structural integrity					
Poor	1 Condition which needs immediate attention and repair					

Estimate of Remaining Useful Life	BECM	BG	SECM	SG	NWG
4 >10 years					
3 5-10 years		X			
2 <5 years					
1 Negligible					

Hydro seeding ; low grass establishment and high weed cover

Erosion Control Wattles

Biodegradable wattle product name (BW)	
Synthetic wattle product name (SW)	

Physical Condition	Rating	BW	SW
Excellent	5 Very new without any defects		
Very Good	4 <5% defects without impacting structural integrity		
Good	3 10-20% defects without impacting structural integrity		
Fair	2 20-40% defects without impacting structural integrity		
Poor	1 Condition which needs immediate attention and repair		

Estimate of Remaining Useful Life	BW	SW
4 >10 years		
3 5-10 years		
2 <5 years		
1 Negligible		

Concrete Materials

Concrete product 1 description (C1)	
Concrete product 2 description (C2)	
Concrete product 3 description (C3)	

Physical Condition	Rating	C1	C2	C3
Excellent	5 Very new without any defects			
Very Good	4 <5% defects without impacting structural integrity			
Good	3 10-20% defects without impacting structural integrity			
Fair	2 20-40% defects without impacting structural integrity			
Poor	1 Condition which needs immediate attention and repair			

Estimate of Remaining Useful Life	C1	C2	C3
4 >10 years			
3 5-10 years			
2 <5 years			
1 Negligible			

Steel Materials

Steel product 1 description (S1)	
Steel product 2 description (S2)	
Steel product 3 description (S3)	
Steel product 4 description (S4)	
Steel product 5 description (S5)	

Physical Condition	Rating	S1	S2	S3	S4	S5
Excellent	5 Very new without any defects					
Very Good	4 <5% defects without impacting structural integrity					
Good	3 10-20% defects without impacting structural integrity					
Fair	2 20-40% defects without impacting structural integrity					
Poor	1 Condition which needs immediate attention and repair					

Estimate of Remaining Useful Life	S1	S2	S3	S4	S5
4 >10 years					
3 5-10 years					
2 <5 years					
1 Negligible					

ENVIRONMENTAL AND CONTEXTUAL FACTORS

Erosion/Deposition Observations

Estimate of toe scour at site
Low [ ] Medium [ ] High [ ] N/A [X] Describe: None

Estimate of U/S bank erosion at site (U/S key)
Low [ ] Medium [ ] High [ ] N/A [X] Describe: None

Estimate of D/S bank erosion at site (D/S key)
Low [ ] Medium [ ] High [ ] N/A [X] Describe: None

Estimate of erosion within site/structure
Low [X] Medium [ ] High [ ] N/A [ ] Describe: Minor rilling

Estimate of sediment accumulation at site
Low [X] Medium [ ] High [ ] N/A [ ] Describe: Sediment and debris on matting

Measurement of sediment accumulation at site
Depth [ ] Method: Visual
Describe/Location

Seeps or spring present Yes [ ] No [✠] Describe

Ice abrasion None [X] Light [ ] Moderate [ ] Severe [ ]

Visual estimate of channel grain size
Silt [ ] Sand [X] Gravel [X] Cobble [X] Boulder [ ] Bedrock [ ]

SITE MOST LIMITING FACTOR(S)

Select from the list below, limiting factors to success:	**ASSIGN A SEVERITY RATING TO EACH OF THE FACTORS BELOW: NONE(0), LIGHT(1), MODERATE(2), SEVERE(3)**	
	After Treatment	**Comments**
Slope instability	0	
Slope gradient	0	
Erosion	1	
Compacted soils	0	
Anoxic soils	0	
Insect damage and disease	1	
Trampling by people or dogs	0	
Motorized vehicles	0	
Non motorized vehicles	0	
Aspect	0	
Bank profile	0	
Existing vegetation competition[1]	2	Some weeds
Shade	0	
Maintenance issues[2]	2	Weeding and light erosion; filling end of fascine
Flooding duration	1	Brush layer
Hydraulics (Shear stress)	2	
Infrastructure and available space	0	
Wildlife impact[3]	0	
Comment on wildlife impact:		
Access	0	
Other: 1-		
2-		

[1] e.g. from aggressive, fast spreading grasses or invasive weed species

[2] e.g. weeding, fencing or rodent protection) including inadequate or no irrigation, frequency or coverage

[3] Browsing/girdling by Rodent/Beavers/Muskrats

POTENTIAL REPAIR OPTIONS

	Select one
(1) Minor (hand tools, seeding and manual planting)	X
(2) Moderate, may need small machine and material to be brought in (is there access?)	
(3) Major, site needs to be redesigned and reconstructed.	

Description: Weeding ; repair of minor erosion and straw wattle along top of slope; fill fascine at us end with soil; fix leaking sprinkler heads and level ground surface where rolling is occurring; raise sprinkler heads to 1m

ALTERNATIVE DESIGN OPTIONS

Description: Vegetated riprap toe with vegetated soil wrap above ; coir matting with live staking

Success Attributes

Techniques such as contour fascine and brush mattress; seeding application rate appears to be correct

Bank Protection/Stabilization Structure Assessment
First Assessment River Reach After Freshet Assessment KWL/Terra

Master Site List No.	46D-1	RMP Site ID Code (e.g., BE-BOW- 4A)		BE-BOW-46D-1	
Site Name:	AEP / COC Bioengineering Demonstration Project Site 2-1 - box fascin			Survey year (1/3/5+)	1
Watercourse	Bow River	Weather:	Sunny 19 degrees		
Crew Initials	MG / PR	Date:	18-Jul-19		

Photo Monitoring

Permanent photo-monitoring location and ID

U/S END		D/S END	
E	709351	E	709363
N	5657963	N	5657912
Photo No.		Photo No.	

Other Photos (min 3)

Photo No.	Description

Hydrology

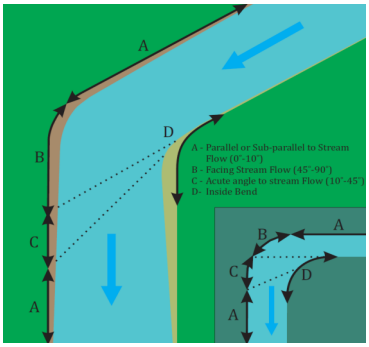
Flow at time of survey: 152 m³/s Source: Rivers.alberta.ca

Aspect (N,E,W,S or combined N/E)

Aspect 1: EES % of site: 100 Aspect 2: % of site: Aspect 3: % of site:

Site Location (Select 1 or more and add percentage of each)

A) Parallel or nearly parallel to flow (0° to 10°)	X	70 %
B) Moderate angle to flow (10° to 45°)	X	39 %
C) Directly facing flow (45° to 90°)		%
D) Internal bend		%



MEASUREMENTS

Average longitudinal stream slope at site: 0.2 %

Estimate of stream width for current year flood flow: 147 m

Site Dimensions

Total length of the work (parallel to stream): 50.7 m Total project area: 111.5 m²

Avg width of the work in plan view (perp to stream) including landscaping on top of the bank: 2.2 m

Average slope of the constructed bank: 8 ° Average height of the constructed bank: 0.5 m

Crib wall only

Height of Bioengineering Structure	Bank height (from permanent herbaceous or woody vegetation line)	Ratio % Bioeng structure/ Total Bank Height
		#DIV/0!
Average width of the crib wall into the bank (from engineering plans)		m

Site Elevation Measurements

Hydrology Survey	**Rod Height (m)**	**Elevation (m)**	**Survey Notes**
Elevation Benchmark	1.1	1000	Water level at 12:30pm on July 17, 2019 us site
High water mark*	0.27	1000.83	**High water mark at site 2-1 = 0.9**
Water level during survey	1.1	1000	

*Measured at observed debris and/or pollen accumulated on bank

Planted Vegetation Survey*	**Rod Height (m)**	**Elevation (m)**	**Survey Notes**
Elevation Benchmark	1.54	1000	**Water level at 213pm on July 17, 2019 at Site**
Elev of lowest woody veg	1.54	1000	Brush layer under box fascine
Elev of lowest herbaceous veg		1001.54	**None**
Elev of lowest emergent veg		1001.54	None

*Lowest elevation of ***planted*** woody, herbaceous, emergent vegetation along riverbank

Existing Vegetation Survey*	**Rod Height (m)**	**Elevation (m)**	**Survey Notes**
Elevation Benchmark	1.1	1000	Water level at 12:30pm on July 17, 2019 us site
Elev of lowest woody veg	0.98	1000.12	
Elev of lowest herbaceous veg	1.17	999.93	
Elev of lowest emergent veg	1.08	1000.02	

*Lowest elevation of ***existing native*** woody, herbaceous, emergent vegetation along riverbank (trim line) If not possible, use difference in elevation between current water surface and existing vegetation either across the stream and/or further D/S or U/S.

Difference in elev between Planted and Existing Veg	Difference (m)
Woody vegetation	-0.12
Herbaceous vegetation	
Emergent vegetation	

WORK STRUCTURE ASSESSMENT

Rock Materials

Riprap Size	lm of application (m)*	% of total riprap
Class 1M (d50=175mm)		0
Class 1 (d50=300mm)		0
Class 2 (d50=500mm)		0
Class 3 (d50=800mm)		0
Other: Pea gravel	50.7	100
Total linear metre (m)	50.7	

Fish boulder average diameter ____ mm

Fish boulder arrangement/distribution ____

Physical Condition	Rating	Riprap	Fish Boulders
Excellent	5 Very new without any defects		
Very Good	4 <5% defects without impacting structural integrity	X	
Good	3 10-20% defects without impacting structural integrity		
Fair	2 20-40% defects without impacting structural integrity		
Poor	1 Condition which needs immediate attention and repair		

Estimate of Remaining Useful Life	Riprap	Fish Boulders
>10 years	X	
5-10 years		
<5 years		
Negligible		

Gabion Materials

Gabion dimensions

Length ____ mm Width ____ mm Height ____ mm Mesh Opening Size ____ mm

Physical Condition	Rating	Gabions
Excellent	5 Very new without any defects	
Very Good	4 <5% defects without impacting structural integrity	
Good	3 10-20% defects without impacting structural integrity	
Fair	2 20-40% defects without impacting structural integrity	
Poor	1 Condition which needs immediate attention and repair	

Estimate of Remaining Useful Life	Gabions
>10 years	
5-10 years	
<5 years	
Negligible	

Wood Materials

Wood dimensions

Log diameter 120 mm Log length 1500 mm Inclination angle 90 °

Timber width ____ mm Timber height ____ mm Timber length ____ mm

Rootwad diameter ____ mm Rootwad length ____ mm Location of root wad ____

Physical Condition	Rating	Logs	Timber	Rootwad
Excellent	5 Very new without any defects			
Very Good	4 <5% defects without impacting structural integrity	X		
Good	3 10-20% defects without impacting structural integrity			
Fair	2 20-40% defects without impacting structural integrity			
Poor	1 Condition which needs immediate attention and repair			

Estimate of Remaining Useful Life	Logs	Timber	Rootwad
4 >10 years			
3 5-10 years	X		
2 <5 years			
1 Negligible			

Erosion Control Matting and Geotextiles

Biodegradable erosion control matting product name (BECM)	
Biodegradable geogrid product name (BG)	
Synthetic erosion control matting product name (SECM)	
Synthetic geogrid product name (SG)	
Non woven geotextile product name (NWG)	

Physical Condition	Rating	BECM	BG	SECM	SG	NWG
Excellent	5 Very new without any defects					
Very Good	4 <5% defects without impacting structural integrity					
Good	3 10-20% defects without impacting structural integrity					
Fair	2 20-40% defects without impacting structural integrity					
Poor	1 Condition which needs immediate attention and repair					

Estimate of Remaining Useful Life	BECM	BG	SECM	SG	NWG
4 >10 years					
3 5-10 years					
2 <5 years					
1 Negligible					

Erosion Control Wattles

Biodegradable wattle product name (BW)	
Synthetic wattle product name (SW)	

Physical Condition	Rating	BW	SW
Excellent	5 Very new without any defects		
Very Good	4 <5% defects without impacting structural integrity		
Good	3 10-20% defects without impacting structural integrity		
Fair	2 20-40% defects without impacting structural integrity		
Poor	1 Condition which needs immediate attention and repair		

Estimate of Remaining Useful Life	BW	SW
4 >10 years		
3 5-10 years		
2 <5 years		
1 Negligible		

Concrete Materials

Concrete product 1 description (C1)	
Concrete product 2 description (C2)	
Concrete product 3 description (C3)	

Physical Condition	Rating	C1	C2	C3
Excellent	5 Very new without any defects			
Very Good	4 <5% defects without impacting structural integrity			
Good	3 10-20% defects without impacting structural integrity			
Fair	2 20-40% defects without impacting structural integrity			
Poor	1 Condition which needs immediate attention and repair			

Estimate of Remaining Useful Life	C1	C2	C3
4 >10 years			
3 5-10 years			
2 <5 years			
1 Negligible			

Steel Materials

Steel product 1 description (S1)	Galvanized steel cable on top of fascine
Steel product 2 description (S2)	
Steel product 3 description (S3)	
Steel product 4 description (S4)	
Steel product 5 description (S5)	

Physical Condition	Rating	S1	S2	S3	S4	S5
Excellent	5 Very new without any defects					
Very Good	4 <5% defects without impacting structural integrity	X				
Good	3 10-20% defects without impacting structural integrity					
Fair	2 20-40% defects without impacting structural integrity					
Poor	1 Condition which needs immediate attention and repair					

Estimate of Remaining Useful Life	S1	S2	S3	S4	S5
4 >10 years					
3 5-10 years	X				
2 <5 years					
1 Negligible					

ENVIRONMENTAL AND CONTEXTUAL FACTORS

Erosion/Deposition Observations

Estimate of toe scour at site
Low [ ] Medium [ ] High [ ] N/A [X] Describe: None

Estimate of U/S bank erosion at site (U/S key)
Low [ ] Medium [ ] High [ ] N/A [X] Describe: None

Estimate of D/S bank erosion at site (D/S key)
Low [ ] Medium [ ] High [ ] N/A [X] Describe: None

Estimate of erosion within site/structure
Low [ ] Medium [X] High [ ] N/A [ ] Describe: fill washout at face and behind at some lo

Estimate of sediment accumulation at site
Low [X] Medium [ ] High [ ] N/A [ ] Describe: Behind box fascine

Measurement of sediment accumulation at site
Depth: 1cm Method: Visual
Describe/Location: Behind box fascine

Seeps or spring present Yes [ ] No [✠] Describe:

Ice abrasion None [X] Light [ ] Moderate [ ] Severe [ ]

Visual estimate of channel grain size
Silt [ ] Sand [X] Gravel [X] Cobble [X] Boulder [ ] Bedrock [ ]

SITE MOST LIMITING FACTOR(S)

Select from the list below, limiting factors to success:	ASSIGN A SEVERITY RATING TO EACH OF THE FACTORS BELOW: NONE(0), LIGHT(1), MODERATE(2), SEVERE(3)	
	After Treatment	Comments
Slope instability	1	Natural steep slope behind structure
Slope gradient	1	Natural steep slope behind structure
Erosion	2	Slope ravelling behind structure
Compacted soils	0	
Anoxic soils	0	
Insect damage and disease	0	
Trampling by people or dogs	0	
Motorized vehicles	0	
Non motorized vehicles	0	
Aspect	0	
Bank profile	0	
Existing vegetation competition[1]	2	Weeds on slope behind structure
Shade	2	
Maintenance issues[2]	1	Weeding
Flooding duration	2	Impacted survival of brush layer
Hydraulics (Shear stress)	1	
Infrastructure and available space	0	
Wildlife impact[3]	0	
Comment on wildlife impact:		
Access	0	
Other: 1-		
2-		

[1] e.g. from aggressive, fast spreading grasses or invasive weed species

[2] e.g. weeding, fencing or rodent protection) including inadequate or no irrigation, frequency or coverage

[3] Browsing/girdling by Rodent/Beavers/Muskrats

POTENTIAL REPAIR OPTIONS

	Select one
(1) Minor (hand tools, seeding and manual planting)	X
(2) Moderate, may need small machine and material to be brought in (is there access?)	
(3) Major, site needs to be redesigned and reconstructed.	

Description: Weeding and removal of plants

ALTERNATIVE DESIGN OPTIONS

Description: B69 toe fascine was better with tie in ; buried contour fascine

Success Attributes

Innovative toe stabilization technique - first in Calgary

Bank Protection/Stabilization Structure Assessment
First Assessment River Reach After Freshet Assessment KWL/Terra

Master Site List No.	46D-2	RMP Site ID Code (e.g., BE-BOW- 4A)	BE-BOW-46D-2
Site Name:	ineering Demonstration Project Site 2-2 (box fascine, brush mattress a	Survey year (1/3/5+)	
Watercourse	Bow	Weather:	Sunny, clear sky, 17C
Crew Initials	MG / PR	Date:	22-Jul-19

Photo Monitoring

Permanent photo-monitoring location and ID

U/S END		D/S END	
E	709376	E	709377
N	5657919	N	5657901
Photo No.		Photo No.	

Other Photos (min 3)

Photo No.	Description

Hydrology

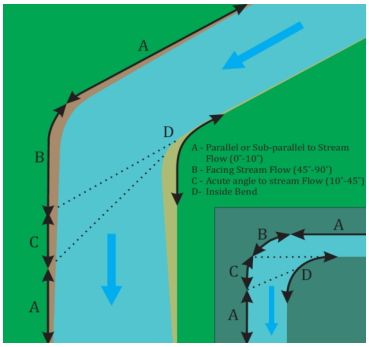
Flow at time of survey: 149 m³/s Source: Alberta.rivers.ca

Aspect (N,E,W,S or combined N/E)

Aspect 1: E/NE % of site: Aspect 2: % of site: Aspect 3: % of site:

Site Location (Select 1 or more and add percentage of each)

A) Parallel or nearly parallel to flow (0° to 10°)	A	100 %
B) Moderate angle to flow (10° to 45°)		%
C) Directly facing flow (45° to 90°)		%
D) Internal bend		%



MEASUREMENTS

Average longitudinal stream slope at site: 0.2 %

Estimate of stream width for current year flood flow: 147 m

Site Dimensions

Total length of the work (parallel to stream): 18.8 m Total project area: 230.3 m²

Avg width of the work in plan view (perp to stream) including landscaping on top of the bank: 12.25 m

Average slope of the constructed bank: 20 ° Average height of the constructed bank: 5.6 m

Crib wall only

Height of Bioengineering Structure	Bank height (from permanent herbaceous or woody vegetation line)	Ratio % Bioeng structure/ Total Bank Height
		#DIV/0!
Average width of the crib wall into the bank (from engineering plans)		m

Site Elevation Measurements

Hydrology Survey	**Rod Height (m)**	**Elevation (m)**	**Survey Notes**
Elevation Benchmark	1.1	1000	Water level at 12:30pm on July 17, 2019 us of sit
High water mark*	0.27	1000.83	**Water level at 0.86 at site 2-2**
Water level during survey	1.1	1000	

*Measured at observed debris and/or pollen accumulated on bank

Planted Vegetation Survey*	**Rod Height (m)**	**Elevation (m)**	**Survey Notes**
Elevation Benchmark	1.54	1000	**Water level at 2:26pm on July 17, 2019 at site**
Elev of lowest woody veg	1.54	1000	Brush layer under box fascine
Elev of lowest herbaceous veg	0.13	1001.41	
Elev of lowest emergent veg		1001.54	

*Lowest elevation of *planted* woody, herbaceous, emergent vegetation along riverbank

Existing Vegetation Survey*	**Rod Height (m)**	**Elevation (m)**	**Survey Notes**
Elevation Benchmark	1.1	1000	Water level at 12:30pm on July 17, 2019 us of sit
Elev of lowest woody veg	0.98	1000.12	
Elev of lowest herbaceous veg	1.17	999.93	
Elev of lowest emergent veg	1.08	1000.02	

*Lowest elevation of *existing native* woody, herbaceous, emergent vegetation along riverbank (trim line) If not possible, use difference in elevation between current water surface and existing vegetation either across the stream and/or further D/S or U/S.

Difference in elev between Planted and Existing Veg	Difference (m)
Woody vegetation	-0.12
Herbaceous vegetation	1.48
Emergent vegetation	

WORK STRUCTURE ASSESSMENT

Rock Materials

Riprap Size	lm of application (m)*	% of total riprap
Class 1M (d50=175mm)		#DIV/0!
Class 1 (d50=300mm)		#DIV/0!
Class 2 (d50=500mm)		#DIV/0!
Class 3 (d50=800mm)		#DIV/0!
Other:		#DIV/0!
Total linear metre (m)		

Fish boulder average diameter mm

Fish boulder arrangement/distribution

Physical Condition	Rating	Riprap	Fish Boulders
Excellent	5 Very new without any defects		
Very Good	4 <5% defects without impacting structural integrity		
Good	3 10-20% defects without impacting structural integrity		
Fair	2 20-40% defects without impacting structural integrity		
Poor	1 Condition which needs immediate attention and repair		

Estimate of Remaining Useful Life	Riprap	Fish Boulders
>10 years		
5-10 years		
<5 years		
Negligible		

Gabion Materials

Gabion dimensions

Length mm Width mm Height mm Mesh Opening Size mm

Physical Condition	Rating	Gabions
Excellent	5 Very new without any defects	
Very Good	4 <5% defects without impacting structural integrity	
Good	3 10-20% defects without impacting structural integrity	
Fair	2 20-40% defects without impacting structural integrity	
Poor	1 Condition which needs immediate attention and repair	

Estimate of Remaining Useful Life	Gabions
>10 years	
5-10 years	
<5 years	
Negligible	

Wood Materials

Wood dimensions

Log diameter 100 mm Log length 1500 mm Inclination angle 90 °

Timber width mm Timber height mm Timber length mm

Rootwad diameter mm Rootwad length mm Location of root wad

Physical Condition	Rating	Logs	Timber	Rootwad
Excellent	5 Very new without any defects			
Very Good	4 <5% defects without impacting structural integrity	X		
Good	3 10-20% defects without impacting structural integrity			
Fair	2 20-40% defects without impacting structural integrity			
Poor	1 Condition which needs immediate attention and repair			

Estimate of Remaining Useful Life	Logs	Timber	Rootwad
4 >10 years			
3 5-10 years	X		
2 <5 years			
1 Negligible			

Erosion Control Matting and Geotextiles

Biodegradable erosion control matting product name (BECM)	
Biodegradable geogrid product name (BG)	Coir 900
Synthetic erosion control matting product name (SECM)	
Synthetic geogrid product name (SG)	
Non woven geotextile product name (NWG)	

Physical Condition	Rating	BECM	BG	SECM	SG	NWG
Excellent	5 Very new without any defects					
Very Good	4 <5% defects without impacting structural integrity		X			
Good	3 10-20% defects without impacting structural integrity					
Fair	2 20-40% defects without impacting structural integrity					
Poor	1 Condition which needs immediate attention and repair					

Estimate of Remaining Useful Life	BECM	BG	SECM	SG	NWG
4 >10 years					
3 5-10 years		X			
2 <5 years					
1 Negligible					

Erosion Control Wattles

Biodegradable wattle product name (BW)	
Synthetic wattle product name (SW)	

Physical Condition	Rating	BW	SW
Excellent	5 Very new without any defects		
Very Good	4 <5% defects without impacting structural integrity		
Good	3 10-20% defects without impacting structural integrity		
Fair	2 20-40% defects without impacting structural integrity		
Poor	1 Condition which needs immediate attention and repair		

Estimate of Remaining Useful Life	BW	SW
4 >10 years		
3 5-10 years		
2 <5 years		
1 Negligible		

Concrete Materials

Concrete product 1 description (C1)	
Concrete product 2 description (C2)	
Concrete product 3 description (C3)	

Physical Condition	Rating	C1	C2	C3
Excellent	5 Very new without any defects			
Very Good	4 <5% defects without impacting structural integrity			
Good	3 10-20% defects without impacting structural integrity			
Fair	2 20-40% defects without impacting structural integrity			
Poor	1 Condition which needs immediate attention and repair			

Estimate of Remaining Useful Life	C1	C2	C3
4 >10 years			
3 5-10 years			
2 <5 years			
1 Negligible			

Steel Materials

Steel product 1 description (S1)	Galvanized wire
Steel product 2 description (S2)	
Steel product 3 description (S3)	
Steel product 4 description (S4)	
Steel product 5 description (S5)	

Physical Condition	Rating	S1	S2	S3	S4	S5
Excellent	5 Very new without any defects					
Very Good	4 <5% defects without impacting structural integrity	X				
Good	3 10-20% defects without impacting structural integrity					
Fair	2 20-40% defects without impacting structural integrity					
Poor	1 Condition which needs immediate attention and repair					

Estimate of Remaining Useful Life	S1	S2	S3	S4	S5
4 >10 years	X				
3 5-10 years					
2 <5 years					
1 Negligible					

ENVIRONMENTAL AND CONTEXTUAL FACTORS

Erosion/Deposition Observations

Estimate of toe scour at site
Low [ ] Medium [ ] High [ ] N/A [X] Describe [ ]

Estimate of U/S bank erosion at site (U/S key)
Low [ ] Medium [X] High [ ] N/A [ ] Describe [Natural bank swallow exposed bank]

Estimate of D/S bank erosion at site (D/S key)
Low [ ] Medium [ ] High [ ] N/A [X] Describe [ ]

Estimate of erosion within site/structure
Low [ ] Medium [X] High [ ] N/A [ ] Describe [out of sediment on face and some areas b]

Estimate of sediment accumulation at site
Low [X] Medium [ ] High [ ] N/A [ ] Describe [Within coir Matt brush mattress toe]

Measurement of sediment accumulation at site
Depth [Trace] Method: [ ]
Describe/Location [ ]

Seeps or spring present Yes [ ] No [✠] Describe [ ]

Ice abrasion None [X] Light [ ] Moderate [ ] Severe [ ]

Visual estimate of channel grain size
Silt [ ] Sand [X] Gravel [X] Cobble [X] Boulder [ ] Bedrock [ ]

SITE MOST LIMITING FACTOR(S)

Select from the list below, limiting factors to success:	ASSIGN A SEVERITY RATING TO EACH OF THE FACTORS BELOW: NONE(0), LIGHT(1), MODERATE(2), SEVERE(3)	
	After Treatment	Comments
Slope instability	0	
Slope gradient	0	
Erosion	1	At fascine face
Compacted soils	2	At toe of brush mattress
Anoxic soils	0	
Insect damage and disease	1	Insect damage on leaves
Trampling by people or dogs	2	Toe of brush mattress from walking
Motorized vehicles	0	
Non motorized vehicles	0	
Aspect	0	
Bank profile	0	
Existing vegetation competition[1]	2	Invasive weed present
Shade	0	
Maintenance issues[2]	2	Weeding required
Flooding duration	2	Toe fascine
Hydraulics (Shear stress)	1	Protected by groyne
Infrastructure and available space	0	
Wildlife impact[3]	0	
Comment on wildlife impact:		
Access	0	
Other: 1-		
2-		

[1] e.g. from aggressive, fast spreading grasses or invasive weed species

[2] e.g. weeding, fencing or rodent protection) including inadequate or no irrigation, frequency or coverage

[3] Browsing/girdling by Rodent/Beavers/Muskrats

POTENTIAL REPAIR OPTIONS

	Select one
(1) Minor (hand tools, seeding and manual planting)	X
(2) Moderate, may need small machine and material to be brought in (is there access?)	
(3) Major, site needs to be redesigned and reconstructed.	

Description: Manual weeding before turning into seed and remove from site

ALTERNATIVE DESIGN OPTIONS

Description: Other options used on site 2-2, similar treatment but toe fascine placement into bank, similar treatment but with fascine wall at toe

Success Attributes

Brush mattress and box fascine innovative toe protection technique combination - first trial in Calgary. Good growth in brush mattress. Very good balsam poplar survival

Bank Protection/Stabilization Structure Assessment
First Assessment River Reach After Freshet Assessment KWL/Terra

Master Site List No.	46D-3	RMP Site ID Code (e.g., BE-BOW- 4A)		BE-BOW-46D-3	
Site Name:	C Bioengineering Demonstration Project Site 2-2 (box fascine, hedge b			Survey year (1/3/5+)	1
Watercourse	Bow	Weather:	21 C, sunny		
Crew Initials	MG / PR	Date:	22-Jul-19		

Photo Monitoring

Permanent photo-monitoring location and ID

U/S END		D/S END	
E	709377	E	709395
N	5657892	N	5657867
Photo No.		Photo No.	

Other Photos (min 3)

Photo No.	Description

Hydrology

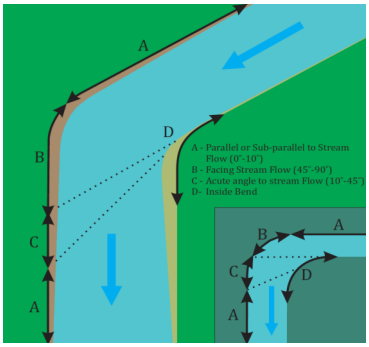
Flow at time of survey: 149 m³/s Source: Rivers.alberta.ca

Aspect (N,E,W,S or combined N/E)

Aspect 1: E/NE % of site: 100 Aspect 2: % of site: Aspect 3: % of site:

Site Location (Select 1 or more and add percentage of each)

A) Parallel or nearly parallel to flow (0° to 10°)	B	100 %
B) Moderate angle to flow (10° to 45°)		%
C) Directly facing flow (45° to 90°)		%
D) Internal bend		%



MEASUREMENTS

Average longitudinal stream slope at site: 0.6 %

Estimate of stream width for current year flood flow: 166 m

Site Dimensions

Total length of the work (parallel to stream): 24 m Total project area: 292.8 m²

Avg width of the work in plan view (perp to stream) including landscaping on top of the bank: 12.2 m

Average slope of the constructed bank: 20 ° Average height of the constructed bank: 5.6 m

Crib wall only

Height of Bioengineering Structure	Bank height (from permanent herbaceous or woody vegetation line)	Ratio % Bioeng structure/ Total Bank Height
		#DIV/0!
Average width of the crib wall into the bank (from engineering plans)		m

Site Elevation Measurements

Hydrology Survey	**Rod Height (m)**	**Elevation (m)**	**Survey Notes**
Elevation Benchmark	1.1	1000	Water level at 12:30pm on July 17, 2019 us of site 1-1
High water mark*	0.27	1000.83	**Hwm at 0.84 at site 2-2_B**
Water level during survey	1.1	1000	

*Measured at observed debris and/or pollen accumulated on bank

Planted Vegetation Survey*	**Rod Height (m)**	**Elevation (m)**	**Survey Notes**
Elevation Benchmark	1.53	1000	**Water level at 2:47pm on July 17, 2019 @ Site**
Elev of lowest woody veg	1.53	1000	
Elev of lowest herbaceous veg	1.22	1000.31	
Elev of lowest emergent veg		1001.53	

*Lowest elevation of *planted* woody, herbaceous, emergent vegetation along riverbank

Existing Vegetation Survey*	**Rod Height (m)**	**Elevation (m)**	**Survey Notes**
Elevation Benchmark	1.1	1000	Water level at 12:30pm on July 17, 2019 us of site 1-1
Elev of lowest woody veg	0.98	1000.12	
Elev of lowest herbaceous veg	1.17	999.93	
Elev of lowest emergent veg	1.08	1000.02	

*Lowest elevation of *existing native* woody, herbaceous, emergent vegetation along riverbank (trim line) If not possible, use difference in elevation between current water surface and existing vegetation either across the stream and/or further D/S or U/S.

Difference in elev between Planted and Existing Veg	Difference (m)
Woody vegetation	-0.12
Herbaceous vegetation	0.38
Emergent vegetation	

WORK STRUCTURE ASSESSMENT

Rock Materials

Riprap Size	lm of application (m)*	% of total riprap
Class 1M (d50=175mm)		#DIV/0!
Class 1 (d50=300mm)		#DIV/0!
Class 2 (d50=500mm)		#DIV/0!
Class 3 (d50=800mm)		#DIV/0!
Other:		#DIV/0!
Total linear metre (m)		

Fish boulder average diameter mm

Fish boulder arrangement/distribution

Physical Condition	Rating	Riprap	Fish Boulders
Excellent	5 Very new without any defects		
Very Good	4 <5% defects without impacting structural integrity		
Good	3 10-20% defects without impacting structural integrity		
Fair	2 20-40% defects without impacting structural integrity		
Poor	1 Condition which needs immediate attention and repair		

Estimate of Remaining Useful Life	Riprap	Fish Boulders
>10 years		
5-10 years		
<5 years		
Negligible		

Gabion Materials

Gabion dimensions

Length mm Width mm Height mm Mesh Opening Size mm

Physical Condition	Rating	Gabions
Excellent	5 Very new without any defects	
Very Good	4 <5% defects without impacting structural integrity	
Good	3 10-20% defects without impacting structural integrity	
Fair	2 20-40% defects without impacting structural integrity	
Poor	1 Condition which needs immediate attention and repair	

Estimate of Remaining Useful Life	Gabions
>10 years	
5-10 years	
<5 years	
Negligible	

Wood Materials

Wood dimensions

Log diameter 100 mm Log length 1500 mm Inclination angle 90 °

Timber width mm Timber height mm Timber length mm

Rootwad diameter mm Rootwad length mm Location of root wad

Physical Condition	Rating	Logs	Timber	Rootwad
Excellent	5 Very new without any defects			
Very Good	4 <5% defects without impacting structural integrity	X		
Good	3 10-20% defects without impacting structural integrity			
Fair	2 20-40% defects without impacting structural integrity			
Poor	1 Condition which needs immediate attention and repair			

Estimate of Remaining Useful Life	Logs	Timber	Rootwad
4 >10 years			
3 5-10 years	X		
2 <5 years			
1 Negligible			

Erosion Control Matting and Geotextiles

Biodegradable erosion control matting product name (BECM)	
Biodegradable geogrid product name (BG)	Coir wrap 1200
Synthetic erosion control matting product name (SECM)	
Synthetic geogrid product name (SG)	
Non woven geotextile product name (NWG)	

Physical Condition	Rating	BECM	BG	SECM	SG	NWG
Excellent	5 Very new without any defects					
Very Good	4 <5% defects without impacting structural integrity		X			
Good	3 10-20% defects without impacting structural integrity					
Fair	2 20-40% defects without impacting structural integrity					
Poor	1 Condition which needs immediate attention and repair					

Estimate of Remaining Useful Life	BECM	BG	SECM	SG	NWG
4 >10 years					
3 5-10 years		X			
2 <5 years					
1 Negligible					

Erosion Control Wattles

Biodegradable wattle product name (BW)	
Synthetic wattle product name (SW)	

Physical Condition	Rating	BW	SW
Excellent	5 Very new without any defects		
Very Good	4 <5% defects without impacting structural integrity		
Good	3 10-20% defects without impacting structural integrity		
Fair	2 20-40% defects without impacting structural integrity		
Poor	1 Condition which needs immediate attention and repair		

Estimate of Remaining Useful Life	BW	SW
4 >10 years		
3 5-10 years		
2 <5 years		
1 Negligible		

Concrete Materials

Concrete product 1 description (C1)	
Concrete product 2 description (C2)	
Concrete product 3 description (C3)	

Physical Condition	Rating	C1	C2	C3
Excellent	5 Very new without any defects			
Very Good	4 <5% defects without impacting structural integrity			
Good	3 10-20% defects without impacting structural integrity			
Fair	2 20-40% defects without impacting structural integrity			
Poor	1 Condition which needs immediate attention and repair			

Estimate of Remaining Useful Life	C1	C2	C3
4 >10 years			
3 5-10 years			
2 <5 years			
1 Negligible			

Steel Materials

Steel product 1 description (S1)	Galvanized wire
Steel product 2 description (S2)	
Steel product 3 description (S3)	
Steel product 4 description (S4)	
Steel product 5 description (S5)	

Physical Condition	Rating	S1	S2	S3	S4	S5
Excellent	5 Very new without any defects					
Very Good	4 <5% defects without impacting structural integrity	X				
Good	3 10-20% defects without impacting structural integrity					
Fair	2 20-40% defects without impacting structural integrity					
Poor	1 Condition which needs immediate attention and repair					

Estimate of Remaining Useful Life	S1	S2	S3	S4	S5
4 >10 years	X				
3 5-10 years					
2 <5 years					
1 Negligible					

ENVIRONMENTAL AND CONTEXTUAL FACTORS

Erosion/Deposition Observations

Estimate of toe scour at site
Low [ ] Medium [ ] High [ ] N/A [X] Describe

Estimate of U/S bank erosion at site (U/S key)
Low [ ] Medium [ ] High [ ] N/A [X] Describe

Estimate of D/S bank erosion at site (D/S key)
Low [ ] Medium [ ] High [ ] N/A [X] Describe

Estimate of erosion within site/structure
Low [ ] Medium [X] High [ ] N/A [ ] Describe erial washed out of fascine and behind toe

Estimate of sediment accumulation at site
Low [X] Medium [ ] High [ ] N/A [ ] Describe Trace

Measurement of sediment accumulation at site
Depth 1cm Method: Visual
Describe/Location

Seeps or spring present Yes [ ] No [✠] Describe

Ice abrasion None [X] Light [ ] Moderate [ ] Severe [ ]

Visual estimate of channel grain size
Silt [ ] Sand [X] Gravel [X] Cobble [X] Boulder [ ] Bedrock [ ]

SITE MOST LIMITING FACTOR(S)

Select from the list below, limiting factors to success:	ASSIGN A SEVERITY RATING TO EACH OF THE FACTORS BELOW: NONE(0), LIGHT(1), MODERATE(2), SEVERE(3)	
	After Treatment	Comments
Slope instability	0	
Slope gradient	0	
Erosion	1	At toe of fascine
Compacted soils	1	At toe of slope from top face
Anoxic soils	0	
Insect damage and disease	1	On foliage
Trampling by people or dogs	1	At toe of coir matting
Motorized vehicles	0	
Non motorized vehicles	0	
Aspect	0	
Bank profile	0	
Existing vegetation competition[1]	2	Invasive weeds present and high seed application rate
Shade	0	
Maintenance issues[2]	2	Weeding
Flooding duration	1.5	At toe of structure
Hydraulics (Shear stress)	1	Between groynes
Infrastructure and available space	0	
Wildlife impact[3]	0	
Comment on wildlife impact:		
Access	0	
Other: 1-		
2-		

[1] e.g. from aggressive, fast spreading grasses or invasive weed species

[2] e.g. weeding, fencing or rodent protection) including inadequate or no irrigation, frequency or coverage

[3] Browsing/girdling by Rodent/Beavers/Muskrats

POTENTIAL REPAIR OPTIONS

	Select one
(1) Minor (hand tools, seeding and manual planting)	X
(2) Moderate, may need small machine and material to be brought in (is there access?)	
(3) Major, site needs to be redesigned and reconstructed.	

Description: Manual weeding and remove weeds from site prior to weeds begin to seed

ALTERNATIVE DESIGN OPTIONS

Description: Other options used at site 2-2, same treatment with toe fascine cuttings placed into the bank, same treatment but with toe fascine wall

Success Attributes

Innovative bank protection technique by combining fascine with brush layer, very good balsam poplar growth, first brush layer design in city of Calgary, good growth on dogwood, cherry, alder

Bank Protection/Stabilization Structure Assessment
First Assessment River Reach After Freshet Assessment KWL/Terra

Master Site List No.	46D-4	RMP Site ID Code (e.g., BE-BOW- 4A)		BE-BOW-46D-4	
Site Name:	COC Bioengineering Demonstration Project Site 2-2 (box fascine, live s			Survey year (1/3/5+)	1
Watercourse	Bow	Weather:	Sunny, partially cloudy, 24C		
Crew Initials	MG / PR	Date:	22-Jul-19		

Photo Monitoring

Permanent photo-monitoring location and ID

U/S END		D/S END	
E	789393	E	709397
N	5657878	N	5657856
Photo No.		Photo No.	

Other Photos (min 3)

Photo No.	Description

Hydrology

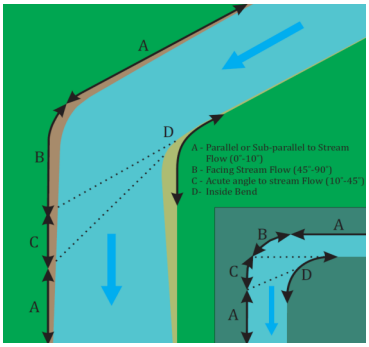
Flow at time of survey: 149 m³/s Source: Rivers.alberta.ca

Aspect (N,E,W,S or combined N/E)

Aspect 1: 100 % of site: E/NE Aspect 2: % of site: Aspect 3: % of site:

Site Location (Select 1 or more and add percentage of each)

A) Parallel or nearly parallel to flow (0° to 10°)		%
B) Moderate angle to flow (10° to 45°)	B	80 %
C) Directly facing flow (45° to 90°)	C	20 %
D) Internal bend		%



MEASUREMENTS

Average longitudinal stream slope at site: 0.2 %

Estimate of stream width for current year flood flow: 147 m

Site Dimensions

Total length of the work (parallel to stream): 20.3 m Total project area: 247.7 m²

Avg width of the work in plan view (perp to stream) including landscaping on top of the bank: 12.2 m

Average slope of the constructed bank: 20 ° Average height of the constructed bank: 5.6 m

Crib wall only

Height of Bioengineering Structure	Bank height (from permanent herbaceous or woody vegetation line)	Ratio % Bioeng structure/ Total Bank Height
		#DIV/0!
Average width of the crib wall into the bank (from engineering plans)		m

Site Elevation Measurements

Hydrology Survey	**Rod Height (m)**	**Elevation (m)**	**Survey Notes**
Elevation Benchmark	1.1	1000	Water level at 12:30pm on July 17, 2019 us of sit
High water mark*	0.27	1000.83	
Water level during survey	1.1	1000	

*Measured at observed debris and/or pollen accumulated on bank

Planted Vegetation Survey*	**Rod Height (m)**	**Elevation (m)**	**Survey Notes**
Elevation Benchmark	1.54	1000	**Water level at 3pm on July 16, 2019 at site 2-2**
Elev of lowest woody veg	1.57	999.97	
Elev of lowest herbaceous veg	1.26	1000.28	
Elev of lowest emergent veg		1001.54	

*Lowest elevation of *planted* woody, herbaceous, emergent vegetation along riverbank

Existing Vegetation Survey*	**Rod Height (m)**	**Elevation (m)**	**Survey Notes**
Elevation Benchmark	1.1	1000	
Elev of lowest woody veg	0.98	1000.12	
Elev of lowest herbaceous veg	1.17	999.93	
Elev of lowest emergent veg	1.08	1000.02	

*Lowest elevation of *existing native* woody, herbaceous, emergent vegetation along riverbank (trim line) If not possible, use difference in elevation between current water surface and existing vegetation either across the stream and/or further D/S or U/S.

Difference in elev between Planted and Existing Veg	Difference (m)
Woody vegetation	-0.15
Herbaceous vegetation	0.35
Emergent vegetation	

WORK STRUCTURE ASSESSMENT

Rock Materials

Riprap Size	lm of application (m)*	% of total riprap
Class 1M (d50=175mm)		#DIV/0!
Class 1 (d50=300mm)		#DIV/0!
Class 2 (d50=500mm)		#DIV/0!
Class 3 (d50=800mm)		#DIV/0!
Other:		#DIV/0!
Total linear metre (m)		

Fish boulder average diameter mm

Fish boulder arrangement/distribution

Physical Condition	Rating	Riprap	Fish Boulders
Excellent	5 Very new without any defects		
Very Good	4 <5% defects without impacting structural integrity		
Good	3 10-20% defects without impacting structural integrity		
Fair	2 20-40% defects without impacting structural integrity		
Poor	1 Condition which needs immediate attention and repair		

Estimate of Remaining Useful Life	Riprap	Fish Boulders
>10 years		
5-10 years		
<5 years		
Negligible		

Gabion Materials

Gabion dimensions

Length mm Width mm Height mm Mesh Opening Size mm

Physical Condition	Rating	Gabions
Excellent	5 Very new without any defects	
Very Good	4 <5% defects without impacting structural integrity	
Good	3 10-20% defects without impacting structural integrity	
Fair	2 20-40% defects without impacting structural integrity	
Poor	1 Condition which needs immediate attention and repair	

Estimate of Remaining Useful Life	Gabions
>10 years	
5-10 years	
<5 years	
Negligible	

Wood Materials

Wood dimensions

Log diameter 115 mm Log length 1500 mm Inclination angle 90 °

Timber width mm Timber height mm Timber length mm

Rootwad diameter mm Rootwad length mm Location of root wad

Physical Condition	Rating	Logs	Timber	Rootwad
Excellent	5 Very new without any defects			
Very Good	4 <5% defects without impacting structural integrity	X		
Good	3 10-20% defects without impacting structural integrity			
Fair	2 20-40% defects without impacting structural integrity			
Poor	1 Condition which needs immediate attention and repair			

Estimate of Remaining Useful Life	Logs	Timber	Rootwad
4 >10 years			
3 5-10 years	X		
2 <5 years			
1 Negligible			

Erosion Control Matting and Geotextiles

Biodegradable erosion control matting product name (BECM)	
Biodegradable geogrid product name (BG)	Coir wrap 1200
Synthetic erosion control matting product name (SECM)	
Synthetic geogrid product name (SG)	
Non woven geotextile product name (NWG)	

Physical Condition	Rating	BECM	BG	SECM	SG	NWG
Excellent	5 Very new without any defects					
Very Good	4 <5% defects without impacting structural integrity		X			
Good	3 10-20% defects without impacting structural integrity					
Fair	2 20-40% defects without impacting structural integrity					
Poor	1 Condition which needs immediate attention and repair					

Estimate of Remaining Useful Life	BECM	BG	SECM	SG	NWG
4 >10 years					
3 5-10 years		X			
2 <5 years					
1 Negligible					

Erosion Control Wattles

Biodegradable wattle product name (BW)	
Synthetic wattle product name (SW)	

Physical Condition	Rating	BW	SW
Excellent	5 Very new without any defects		
Very Good	4 <5% defects without impacting structural integrity		
Good	3 10-20% defects without impacting structural integrity		
Fair	2 20-40% defects without impacting structural integrity		
Poor	1 Condition which needs immediate attention and repair		

Estimate of Remaining Useful Life	BW	SW
4 >10 years		
3 5-10 years		
2 <5 years		
1 Negligible		

Concrete Materials

Concrete product 1 description (C1)	
Concrete product 2 description (C2)	
Concrete product 3 description (C3)	

Physical Condition	Rating	C1	C2	C3
Excellent	5 Very new without any defects			
Very Good	4 <5% defects without impacting structural integrity			
Good	3 10-20% defects without impacting structural integrity			
Fair	2 20-40% defects without impacting structural integrity			
Poor	1 Condition which needs immediate attention and repair			

Estimate of Remaining Useful Life	C1	C2	C3
4 >10 years			
3 5-10 years			
2 <5 years			
1 Negligible			

Steel Materials

Steel product 1 description (S1)	Galvanized wire
Steel product 2 description (S2)	
Steel product 3 description (S3)	
Steel product 4 description (S4)	
Steel product 5 description (S5)	

Physical Condition	Rating	S1	S2	S3	S4	S5
Excellent	5 Very new without any defects					
Very Good	4 <5% defects without impacting structural integrity	X				
Good	3 10-20% defects without impacting structural integrity					
Fair	2 20-40% defects without impacting structural integrity					
Poor	1 Condition which needs immediate attention and repair					

Estimate of Remaining Useful Life	S1	S2	S3	S4	S5
4 >10 years	X				
3 5-10 years					
2 <5 years					
1 Negligible					

ENVIRONMENTAL AND CONTEXTUAL FACTORS

Erosion/Deposition Observations

Estimate of toe scour at site
Low [ ] Medium [ ] High [ ] N/A [X] Describe [ ]

Estimate of U/S bank erosion at site (U/S key)
Low [ ] Medium [ ] High [ ] N/A [X] Describe [ ]

Estimate of D/S bank erosion at site (D/S key)
Low [ ] Medium [ ] High [ ] N/A [X] Describe [ ]

Estimate of erosion within site/structure
Low [ ] Medium [X] High [ ] N/A [ ] Describe [ed out fill within toe fascine and behind str]

Estimate of sediment accumulation at site
Low [X] Medium [ ] High [ ] N/A [ ] Describe [Trace]

Measurement of sediment accumulation at site
Depth [Trace] Method: [Visual]
Describe/Location [ ]

Seeps or spring present Yes [ ] No [✠] Describe [ ]

Ice abrasion None [X] Light [ ] Moderate [ ] Severe [ ]

Visual estimate of channel grain size
Silt [ ] Sand [X] Gravel [X] Cobble [X] Boulder [ ] Bedrock [ ]

SITE MOST LIMITING FACTOR(S)

Select from the list below, limiting factors to success:	ASSIGN A SEVERITY RATING TO EACH OF THE FACTORS BELOW: NONE(0), LIGHT(1), MODERATE(2), SEVERE(3)	
	After Treatment	Comments
Slope instability	0	
Slope gradient	0	
Erosion	1	Within toe fascine
Compacted soils	1	At bottom of coir matt
Anoxic soils	0	
Insect damage and disease	1	On foliage
Trampling by people or dogs	1	At toe of matting
Motorized vehicles	0	
Non motorized vehicles	0	
Aspect	0	
Bank profile	0	
Existing vegetation competition[1]	2	Invasive weeds present and high seed application rate
Shade	0	
Maintenance issues[2]	2	Weeding
Flooding duration	1.5	At toe causing washout of material in toe fascine
Hydraulics (Shear stress)	1	Between spurs
Infrastructure and available space	0	
Wildlife impact[3]	0	
Comment on wildlife impact:		
Access	0	
Other: 1-		
2-		

[1] e.g. from aggressive, fast spreading grasses or invasive weed species

[2] e.g. weeding, fencing or rodent protection) including inadequate or no irrigation, frequency or coverage

[3] Browsing/girdling by Rodent/Beavers/Muskrats

POTENTIAL REPAIR OPTIONS

	Select one
(1) Minor (hand tools, seeding and manual planting)	X
(2) Moderate, may need small machine and material to be brought in (is there access?)	
(3) Major, site needs to be redesigned and reconstructed.	

Description: Weeding of invasive plants before plants start to seed and remove plant material from site

ALTERNATIVE DESIGN OPTIONS

Description: Other options used at site 2-2, same treatment with toe fascine cuttings placed into the bank, same treatment but with toe fascine wall

Success Attributes

Innovative toe protection technique, balsam poplar survival is good, good survival overall

Bank Protection/Stabilization Structure Assessment
First Assessment River Reach After Freshet Assessment KWL/Terra

Master Site List No.	46E-1	RMP Site ID Code (e.g., BE-BOW- 4A)		BE-BOW-46E-1	
Site Name:	Bioengineering Demonstration Project Site 4-1 (soil covered riprap an		Survey year (1/3/5+)		1
Watercourse	Bow River	Weather:	Sunny and 18 degrees		
Crew Initials	MG / PR	Date:	17-Jul-19		

Photo Monitoring

Permanent photo-monitoring location and ID

U/S END		D/S END	
E	709403	E	709448
N	5657840	N	5657798
Photo No.		Photo No.	

Other Photos (min 3)

Photo No.	Description

Hydrology

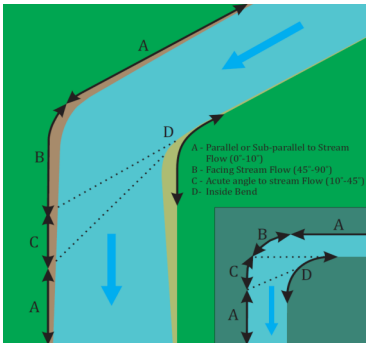
Flow at time of survey: 154 m³/s Source: Rivers.alberta.ca

Aspect (N,E,W,S or combined N/E)

Aspect 1: NE % of site: 100 Aspect 2: % of site: Aspect 3: % of site:

Site Location (Select 1 or more and add percentage of each)

A) Parallel or nearly parallel to flow (0° to 10°)		%
B) Moderate angle to flow (10° to 45°)	X	100 %
C) Directly facing flow (45° to 90°)		%
D) Internal bend		%



MEASUREMENTS

Average longitudinal stream slope at site: 0.2 %

Estimate of stream width for current year flood flow: 150 m

Site Dimensions

Total length of the work (parallel to stream): 57 m Total project area: 701.1 m²

Avg width of the work in plan view (perp to stream) including landscaping on top of the bank: 12.3 m

Average slope of the constructed bank: 13 ° Average height of the constructed bank: 3.8 m

Crib wall only

Height of Bioengineering Structure	Bank height (from permanent herbaceous or woody vegetation line)	Ratio % Bioeng structure/ Total Bank Height
		#DIV/0!
Average width of the crib wall into the bank (from engineering plans)		m

Site Elevation Measurements

Hydrology Survey	**Rod Height (m)**	**Elevation (m)**	**Survey Notes**
Elevation Benchmark	1.29	1000	Water level at 11:43 am
High water mark*	0.95	1000.34	
Water level during survey	1.29	1000	

*Measured at observed debris and/or pollen accumulated on bank

Planted Vegetation Survey*	**Rod Height (m)**	**Elevation (m)**	**Survey Notes**
Elevation Benchmark	2.42	1000	**Water level at 12:24pm**
Elev of lowest woody veg	2.03	1000.39	
Elev of lowest herbaceous veg	2.13	1000.29	
Elev of lowest emergent veg		1002.42	

*Lowest elevation of *planted* woody, herbaceous, emergent vegetation along riverbank

Existing Vegetation Survey*	**Rod Height (m)**	**Elevation (m)**	**Survey Notes**
Elevation Benchmark	1.29	1000	Downstream of site 4-4
Elev of lowest woody veg	1.1	1000.19	
Elev of lowest herbaceous veg	1.18	1000.11	
Elev of lowest emergent veg		1001.29	

*Lowest elevation of *existing native* woody, herbaceous, emergent vegetation along riverbank (trim line) If not possible, use difference in elevation between current water surface and existing vegetation either across the stream and/or further D/S or U/S.

Difference in elev between Planted and Existing Veg	Difference (m)
Woody vegetation	0.2
Herbaceous vegetation	0.18
Emergent vegetation	

WORK STRUCTURE ASSESSMENT

Rock Materials

Riprap Size	lm of application (m)*	% of total riprap
Class 1M (d50=175mm)		0
Class 1 (d50=300mm)		0
Class 2 (d50=500mm)	57	100
Class 3 (d50=800mm)		0
Other:		0
Total linear metre (m)	57	

Fish boulder average diameter mm

Fish boulder arrangement/distribution

Physical Condition	Rating	Riprap	Fish Boulders
Excellent	5 Very new without any defects	X	
Very Good	4 <5% defects without impacting structural integrity		
Good	3 10-20% defects without impacting structural integrity		
Fair	2 20-40% defects without impacting structural integrity		
Poor	1 Condition which needs immediate attention and repair		

Estimate of Remaining Useful Life	Riprap	Fish Boulders
>10 years	**X**	
5-10 years		
<5 years		
Negligible		

Gabion Materials

Gabion dimensions

Length mm Width mm Height mm Mesh Opening Size mm

Physical Condition	Rating	Gabions
Excellent	5 Very new without any defects	
Very Good	4 <5% defects without impacting structural integrity	
Good	3 10-20% defects without impacting structural integrity	
Fair	2 20-40% defects without impacting structural integrity	
Poor	1 Condition which needs immediate attention and repair	

Estimate of Remaining Useful Life	Gabions
>10 years	
5-10 years	
<5 years	
Negligible	

Wood Materials

Wood dimensions

Log diameter mm Log length mm Inclination angle °

Timber width mm Timber height mm Timber length mm

Rootwad diameter mm Rootwad length mm Location of root wad

Physical Condition	Rating	Logs	Timber	Rootwad
Excellent	5 Very new without any defects			
Very Good	4 <5% defects without impacting structural integrity			
Good	3 10-20% defects without impacting structural integrity			
Fair	2 20-40% defects without impacting structural integrity			
Poor	1 Condition which needs immediate attention and repair			

Estimate of Remaining Useful Life	Logs	Timber	Rootwad
4 >10 years			
3 5-10 years			
2 <5 years			
1 Negligible			

Erosion Control Matting and Geotextiles

Biodegradable erosion control matting product name (BECM)	C125BN
Biodegradable geogrid product name (BG)	
Synthetic erosion control matting product name (SECM)	
Synthetic geogrid product name (SG)	
Non woven geotextile product name (NWG)	

Physical Condition	Rating	BECM	BG	SECM	SG	NWG
Excellent	5 Very new without any defects					
Very Good	4 <5% defects without impacting structural integrity					
Good	3 10-20% defects without impacting structural integrity	X				
Fair	2 20-40% defects without impacting structural integrity					
Poor	1 Condition which needs immediate attention and repair					

Estimate of Remaining Useful Life	BECM	BG	SECM	SG	NWG
4 >10 years					
3 5-10 years					
2 <5 years	X				
1 Negligible					

Erosion Control Wattles

Biodegradable wattle product name (BW)	Curlex 300mm diameter
Synthetic wattle product name (SW)	

Physical Condition	Rating	BW	SW
Excellent	5 Very new without any defects		
Very Good	4 <5% defects without impacting structural integrity		
Good	3 10-20% defects without impacting structural integrity	X	
Fair	2 20-40% defects without impacting structural integrity		
Poor	1 Condition which needs immediate attention and repair		

Estimate of Remaining Useful Life	BW	SW
4 >10 years		
3 5-10 years		
2 <5 years	X	
1 Negligible		

Concrete Materials

Concrete product 1 description (C1)	
Concrete product 2 description (C2)	
Concrete product 3 description (C3)	

Physical Condition	Rating	C1	C2	C3
Excellent	5 Very new without any defects			
Very Good	4 <5% defects without impacting structural integrity			
Good	3 10-20% defects without impacting structural integrity			
Fair	2 20-40% defects without impacting structural integrity			
Poor	1 Condition which needs immediate attention and repair			

Estimate of Remaining Useful Life	C1	C2	C3
4 >10 years			
3 5-10 years			
2 <5 years			
1 Negligible			

Steel Materials

Steel product 1 description (S1)	Rebar candy canes
Steel product 2 description (S2)	
Steel product 3 description (S3)	
Steel product 4 description (S4)	
Steel product 5 description (S5)	

Physical Condition	Rating	S1	S2	S3	S4	S5
Excellent	5 Very new without any defects					
Very Good	4 <5% defects without impacting structural integrity	X				
Good	3 10-20% defects without impacting structural integrity					
Fair	2 20-40% defects without impacting structural integrity					
Poor	1 Condition which needs immediate attention and repair					

Estimate of Remaining Useful Life	S1	S2	S3	S4	S5
4 >10 years	X				
3 5-10 years					
2 <5 years					
1 Negligible					

ENVIRONMENTAL AND CONTEXTUAL FACTORS

Erosion/Deposition Observations

Estimate of toe scour at site
Low [ ] Medium [ ] High [ ] N/A [X] Describe: None

Estimate of U/S bank erosion at site (U/S key)
Low [ ] Medium [ ] High [ ] N/A [X] Describe: None

Estimate of D/S bank erosion at site (D/S key)
Low [ ] Medium [X] High [ ] N/A [ ] Describe: Toe erosion

Estimate of erosion within site/structure
Low [X] Medium [ ] High [ ] N/A [ ] Describe: At toe between wattle and slope

Estimate of sediment accumulation at site
Low [ ] Medium [ ] High [ ] N/A [X] Describe:

Measurement of sediment accumulation at site
Depth [ ] Method:
Describe/Location

Seeps or spring present Yes [ ] No [✠] Describe:

Ice abrasion None [X] Light [ ] Moderate [ ] Severe [ ]

Visual estimate of channel grain size
Silt [ ] Sand [X] Gravel [X] Cobble [X] Boulder [ ] Bedrock [ ]

SITE MOST LIMITING FACTOR(S)

Select from the list below, limiting factors to success:	ASSIGN A SEVERITY RATING TO EACH OF THE FACTORS BELOW: NONE(0), LIGHT(1), MODERATE(2), SEVERE(3)	
	After Treatment	Comments
Slope instability	0	
Slope gradient	0	
Erosion	1	
Compacted soils	0	
Anoxic soils	0	
Insect damage and disease	1	On salix interior
Trampling by people or dogs	0	
Motorized vehicles	0	
Non motorized vehicles	0	
Aspect	0	
Bank profile	0	
Existing vegetation competition[1]	3	invasives and seeding competing with native shrubs (
Shade	0	
Maintenance issues[2]	2	Straw wattle missing and rodent fence
Flooding duration	0	
Hydraulics (Shear stress)	2	Groyne protection
Infrastructure and available space	0	
Wildlife impact[3]	0	
Comment on wildlife impact:		
Access	0	
Other: 1-		
2-		

[1] e.g. from aggressive, fast spreading grasses or invasive weed species

[2] e.g. weeding, fencing or rodent protection) including inadequate or no irrigation, frequency or coverage

[3] Browsing/girdling by Rodent/Beavers/Muskrats

POTENTIAL REPAIR OPTIONS

	Select one
(1) Minor (hand tools, seeding and manual planting)	X
(2) Moderate, may need small machine and material to be brought in (is there access?)	
(3) Major, site needs to be redesigned and reconstructed.	

Description: Fixing rodent fence and straw wattle ; weeding invasives ; mow grasses and mulch around plants and place millorganite (flag shrubs and trees prior to mowing)

ALTERNATIVE DESIGN OPTIONS

Description: Apply site 46D_2 or 46D_3

Success Attributes

Innovative method to vegetate riprap; container shrubs appear to be surviving well at the Site is stablizing at the time of survey

Bank Protection/Stabilization Structure Assessment
First Assessment River Reach After Freshet Assessment KWL/Terra

Master Site List No.	46E-2	RMP Site ID Code (e.g., BE-BOW- 4A)	BE-BOW-46E-2
Site Name:	OC Bioengineering Demonstration Project Site 4-2 (void filled riprap ar	Survey year (1/3/5+)	
Watercourse	Bow River	Weather:	18 C, partially cloudy
Crew Initials	MG / PR	Date:	16-Jul-19

Photo Monitoring

Permanent photo-monitoring location and ID

U/S END		D/S END	
E	709443	E	709498
N	5657802	N	5657762
Photo No.		Photo No.	

Other Photos (min 3)

Photo No.	Description

Hydrology

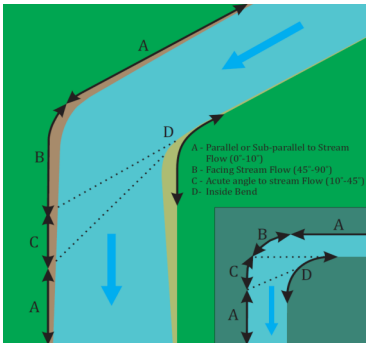
Flow at time of survey: 158 m³/s Source: Rivers.alberta.ca

Aspect (N,E,W,S or combined N/E)

Aspect 1: NNE % of site: 80 Aspect 2: NE % of site: 20 Aspect 3: % of site:

Site Location (Select 1 or more and add percentage of each)

A) Parallel or nearly parallel to flow (0° to 10°)	C	100 %
B) Moderate angle to flow (10° to 45°)		%
C) Directly facing flow (45° to 90°)		%
D) Internal bend		%



MEASUREMENTS

Average longitudinal stream slope at site: 0.2 %

Estimate of stream width for current year flood flow: 150 m

Site Dimensions

Total length of the work (parallel to stream): 65.6 m Total project area: 754.4 m²

Avg width of the work in plan view (perp to stream) including landscaping on top of the bank: 11.5 m

Average slope of the constructed bank: 20 ° Average height of the constructed bank: 4 m

Crib wall only

Height of Bioengineering Structure	Bank height (from permanent herbaceous or woody vegetation line)	Ratio % Bioeng structure/ Total Bank Height
		#DIV/0!
Average width of the crib wall into the bank (from engineering plans)		m

Site Elevation Measurements

Hydrology Survey	**Rod Height (m)**	**Elevation (m)**	**Survey Notes**
Elevation Benchmark	1.29	1000	Water level at 11:43 am
High water mark*	0.95	1000.34	**Sediment standing on veg**
Water level during survey	1.29	1000	

*Measured at observed debris and/or pollen accumulated on bank

Planted Vegetation Survey*	**Rod Height (m)**	**Elevation (m)**	**Survey Notes**
Elevation Benchmark	2.42	1000	**Water level at 12:14pm**
Elev of lowest woody veg	2	1000.42	
Elev of lowest herbaceous veg	2.14	1000.28	
Elev of lowest emergent veg		1002.42	None

*Lowest elevation of ***planted*** woody, herbaceous, emergent vegetation along riverbank

Existing Vegetation Survey*	**Rod Height (m)**	**Elevation (m)**	**Survey Notes**
Elevation Benchmark	1.29	1000	
Elev of lowest woody veg	1.1	1000.19	
Elev of lowest herbaceous veg	1.18	1000.11	
Elev of lowest emergent veg		1001.29	**None**

*Lowest elevation of ***existing native*** woody, herbaceous, emergent vegetation along riverbank (trim line) If not possible, use difference in elevation between current water surface and existing vegetation either across the stream and/or further D/S or U/S.

Difference in elev between Planted and Existing Veg	Difference (m)
Woody vegetation	0.23
Herbaceous vegetation	0.17
Emergent vegetation	

WORK STRUCTURE ASSESSMENT

Rock Materials

Riprap Size	lm of application (m)*	% of total riprap
Class 1M (d50=175mm)		0
Class 1 (d50=300mm)		0
Class 2 (d50=500mm)	65.2	100
Class 3 (d50=800mm)		0
Other:		0
Total linear metre (m)	65.2	

Fish boulder average diameter mm

Fish boulder arrangement/distribution

Physical Condition	Rating	Riprap	Fish Boulders
Excellent	5 Very new without any defects	5	
Very Good	4 <5% defects without impacting structural integrity		
Good	3 10-20% defects without impacting structural integrity		
Fair	2 20-40% defects without impacting structural integrity		
Poor	1 Condition which needs immediate attention and repair		

Estimate of Remaining Useful Life	Riprap	Fish Boulders
>10 years	X	
5-10 years		
<5 years		
Negligible		

Gabion Materials

Gabion dimensions

Length mm Width mm Height mm Mesh Opening Size mm

Physical Condition	Rating	Gabions
Excellent	5 Very new without any defects	
Very Good	4 <5% defects without impacting structural integrity	
Good	3 10-20% defects without impacting structural integrity	
Fair	2 20-40% defects without impacting structural integrity	
Poor	1 Condition which needs immediate attention and repair	

Estimate of Remaining Useful Life	Gabions
>10 years	
5-10 years	
<5 years	
Negligible	

Wood Materials

Wood dimensions

Log diameter mm Log length mm Inclination angle °

Timber width mm Timber height mm Timber length mm

Rootwad diameter mm Rootwad length mm Location of root wad

Physical Condition	Rating	Logs	Timber	Rootwad
Excellent	5 Very new without any defects			
Very Good	4 <5% defects without impacting structural integrity			
Good	3 10-20% defects without impacting structural integrity			
Fair	2 20-40% defects without impacting structural integrity			
Poor	1 Condition which needs immediate attention and repair			

Estimate of Remaining Useful Life	Logs	Timber	Rootwad
4 >10 years			
3 5-10 years			
2 <5 years			
1 Negligible			

Erosion Control Matting and Geotextiles

Biodegradable erosion control matting product name (BECM)	
Biodegradable geogrid product name (BG)	
Synthetic erosion control matting product name (SECM)	
Synthetic geogrid product name (SG)	
Non woven geotextile product name (NWG)	

Physical Condition	Rating	BECM	BG	SECM	SG	NWG
Excellent	5 Very new without any defects					
Very Good	4 <5% defects without impacting structural integrity					
Good	3 10-20% defects without impacting structural integrity					
Fair	2 20-40% defects without impacting structural integrity					
Poor	1 Condition which needs immediate attention and repair					

Estimate of Remaining Useful Life	BECM	BG	SECM	SG	NWG
4 >10 years					
3 5-10 years					
2 <5 years					
1 Negligible					

Erosion Control Wattles

Biodegradable wattle product name (BW)	Curlex log
Synthetic wattle product name (SW)	

Physical Condition	Rating	BW	SW
Excellent	5 Very new without any defects		
Very Good	4 <5% defects without impacting structural integrity		
Good	3 10-20% defects without impacting structural integrity		
Fair	2 20-40% defects without impacting structural integrity	X	
Poor	1 Condition which needs immediate attention and repair		

Estimate of Remaining Useful Life	BW	SW
4 >10 years		
3 5-10 years		
2 <5 years	X	
1 Negligible		

Concrete Materials

Concrete product 1 description (C1)	
Concrete product 2 description (C2)	
Concrete product 3 description (C3)	

Physical Condition	Rating	C1	C2	C3
Excellent	5 Very new without any defects			
Very Good	4 <5% defects without impacting structural integrity			
Good	3 10-20% defects without impacting structural integrity			
Fair	2 20-40% defects without impacting structural integrity			
Poor	1 Condition which needs immediate attention and repair			

Estimate of Remaining Useful Life	C1	C2	C3
4 >10 years			
3 5-10 years			
2 <5 years			
1 Negligible			

Steel Materials

Steel product 1 description (S1)	
Steel product 2 description (S2)	
Steel product 3 description (S3)	
Steel product 4 description (S4)	
Steel product 5 description (S5)	

Physical Condition	Rating	S1	S2	S3	S4	S5
Excellent	5 Very new without any defects					
Very Good	4 <5% defects without impacting structural integrity					
Good	3 10-20% defects without impacting structural integrity					
Fair	2 20-40% defects without impacting structural integrity					
Poor	1 Condition which needs immediate attention and repair					

Estimate of Remaining Useful Life	S1	S2	S3	S4	S5
4 >10 years					
3 5-10 years					
2 <5 years					
1 Negligible					

ENVIRONMENTAL AND CONTEXTUAL FACTORS

Erosion/Deposition Observations

Estimate of toe scour at site
Low [ ] Medium [ ] High [ ] N/A [X] Describe [ ]

Estimate of U/S bank erosion at site (U/S key)
Low [ ] Medium [ ] High [ ] N/A [X] Describe [ ]

Estimate of D/S bank erosion at site (D/S key)
Low [ ] Medium [X] High [ ] N/A [ ] Describe [Eroded fill at the toe]

Estimate of erosion within site/structure
Low [ ] Medium [X] High [ ] N/A [ ] Describe [Eroded fill at toe]

Estimate of sediment accumulation at site
Low [ ] Medium [ ] High [ ] N/A [X] Describe [ ]

Measurement of sediment accumulation at site
Depth [ ] Method: [ ]
Describe/Location [ ]

Seeps or spring present Yes [ ] No [✠] Describe [ ]

Ice abrasion None [X] Light [ ] Moderate [ ] Severe [ ]

Visual estimate of channel grain size
Silt [ ] Sand [X] Gravel [X] Cobble [X] Boulder [ ] Bedrock [ ]

SITE MOST LIMITING FACTOR(S)

Select from the list below, limiting factors to success:	**ASSIGN A SEVERITY RATING TO EACH OF THE FACTORS BELOW: NONE(0), LIGHT(1), MODERATE(2), SEVERE(3)**	
	After Treatment	**Comments**
Slope instability	0	
Slope gradient	0	
Erosion	2	Eroded fill at the toe of treatment
Compacted soils	0	
Anoxic soils	0	
Insect damage and disease	0	
Trampling by people or dogs	0	
Motorized vehicles	0	
Non motorized vehicles	0	
Aspect	0	
Bank profile	2	Toe is steep
Existing vegetation competition[1]	2	Invasive weeds present
Shade	0	
Maintenance issues[2]	2	Weeding required, rodent fence to be secure at the
Flooding duration	0	
Hydraulics (Shear stress)	2	
Infrastructure and available space	0	
Wildlife impact[3]	0	
Comment on wildlife impact:		
Access	0	
Other: 1-		
2-		

[1] e.g. from aggressive, fast spreading grasses or invasive weed species

[2] e.g. weeding, fencing or rodent protection) including inadequate or no irrigation, frequency or coverage

[3] Browsing/girdling by Rodent/Beavers/Muskrats

POTENTIAL REPAIR OPTIONS

	Select one
(1) Minor (hand tools, seeding and manual planting)	X
(2) Moderate, may need small machine and material to be brought in (is there access?)	
(3) Major, site needs to be redesigned and reconstructed.	

Description

Repair the rodent fence at toe ; move up the wattle and secure it against existing soil; weeding

ALTERNATIVE DESIGN OPTIONS

Description

Treatment as 46E1 and 46E3

Success Attributes

To date good approach to vegetate existing riprap

Bank Protection/Stabilization Structure Assessment
First Assessment River Reach After Freshet Assessment KWL/Terra

Master Site List No.	46E-3	RMP Site ID Code (e.g., BE-BOW- 4A)	BE-BOW-46E-3
Site Name:	Bioengineering Demonstration Project Site 4-3 (void filled riprap and l	Survey year (1/3/5+)	
Watercourse	Bow River	Weather:	Overcast and 13 degrees
Crew Initials	MG / PR	Date:	16-Jul-19

Photo Monitoring

Permanent photo-monitoring location and ID

U/S END		D/S END	
E	709499	E	709554
N	5657755	N	5657726
Photo No.		Photo No.	

Other Photos (min 3)

Photo No.	Description

Hydrology

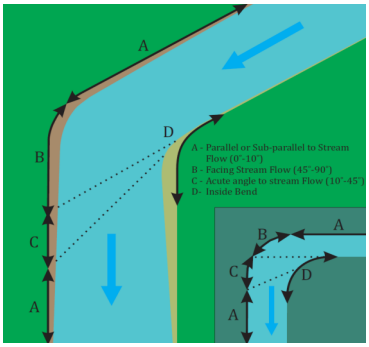
Flow at time of survey: 158 m³/s Source: Rivers.alberta.ca

Aspect (N,E,W,S or combined N/E)

Aspect 1: NNE % of site: 100 Aspect 2: % of site: Aspect 3: % of site:

Site Location (Select 1 or more and add percentage of each)

A) Parallel or nearly parallel to flow (0° to 10°)	X	70 %
B) Moderate angle to flow (10° to 45°)	X	30 %
C) Directly facing flow (45° to 90°)		%
D) Internal bend		%



MEASUREMENTS

Average longitudinal stream slope at site: 0.2 %

Estimate of stream width for current year flood flow: 150 m

Site Dimensions

Total length of the work (parallel to stream): 64 m Total project area: 592.0 m²

Avg width of the work in plan view (perp to stream) including landscaping on top of the bank: 9.25 m

Average slope of the constructed bank: 21 ° Average height of the constructed bank: 3.5 m

Crib wall only

Height of Bioengineering Structure	Bank height (from permanent herbaceous or woody vegetation line)	Ratio % Bioeng structure/ Total Bank Height
		#DIV/0!
Average width of the crib wall into the bank (from engineering plans)		m

Site Elevation Measurements

Hydrology Survey	**Rod Height (m)**	**Elevation (m)**	**Survey Notes**
Elevation Benchmark	1.29	1000	Water level at 11:43am
High water mark*	0.95	1000.34	
Water level during survey	1.29	1000	

*Measured at observed debris and/or pollen accumulated on bank

Planted Vegetation Survey*	**Rod Height (m)**	**Elevation (m)**	**Survey Notes**
Elevation Benchmark	2.45	1000	**Water level at 12:33pm - water level dropped**
Elev of lowest woody veg	2.15	1000.3	
Elev of lowest herbaceous veg	2.2	1000.25	
Elev of lowest emergent veg		1002.45	

*Lowest elevation of *planted* woody, herbaceous, emergent vegetation along riverbank

Existing Vegetation Survey*	**Rod Height (m)**	**Elevation (m)**	**Survey Notes**
Elevation Benchmark	1.29	1000	Downstream of site 4-4
Elev of lowest woody veg	1.1	1000.19	
Elev of lowest herbaceous veg	1.18	1000.11	
Elev of lowest emergent veg		1001.29	

*Lowest elevation of *existing native* woody, herbaceous, emergent vegetation along riverbank (trim line) If not possible, use difference in elevation between current water surface and existing vegetation either across the stream and/or further D/S or U/S.

Difference in elev between Planted and Existing Veg	Difference (m)
Woody vegetation	0.11
Herbaceous vegetation	0.14
Emergent vegetation	

WORK STRUCTURE ASSESSMENT

Rock Materials

Riprap Size	lm of application (m)*	% of total riprap
Class 1M (d50=175mm)		0
Class 1 (d50=300mm)		0
Class 2 (d50=500mm)	64	100
Class 3 (d50=800mm)		0
Other:		0
Total linear metre (m)	64	

Fish boulder average diameter mm

Fish boulder arrangement/distribution

Physical Condition	Rating	Riprap	Fish Boulders
Excellent	5 Very new without any defects	X	
Very Good	4 <5% defects without impacting structural integrity		
Good	3 10-20% defects without impacting structural integrity		
Fair	2 20-40% defects without impacting structural integrity		
Poor	1 Condition which needs immediate attention and repair		

Estimate of Remaining Useful Life	Riprap	Fish Boulders
>10 years	X	
5-10 years		
<5 years		
Negligible		

Gabion Materials

Gabion dimensions

Length mm Width mm Height mm Mesh Opening Size mm

Physical Condition	Rating	Gabions
Excellent	5 Very new without any defects	
Very Good	4 <5% defects without impacting structural integrity	
Good	3 10-20% defects without impacting structural integrity	
Fair	2 20-40% defects without impacting structural integrity	
Poor	1 Condition which needs immediate attention and repair	

Estimate of Remaining Useful Life	Gabions
>10 years	
5-10 years	
<5 years	
Negligible	

Wood Materials

Wood dimensions

Log diameter mm Log length mm Inclination angle °

Timber width mm Timber height mm Timber length mm

Rootwad diameter mm Rootwad length mm Location of root wad

Physical Condition	Rating	Logs	Timber	Rootwad
Excellent	5 Very new without any defects			
Very Good	4 <5% defects without impacting structural integrity			
Good	3 10-20% defects without impacting structural integrity			
Fair	2 20-40% defects without impacting structural integrity			
Poor	1 Condition which needs immediate attention and repair			

Estimate of Remaining Useful Life	Logs	Timber	Rootwad
4 >10 years			
3 5-10 years			
2 <5 years			
1 Negligible			

Erosion Control Matting and Geotextiles

Biodegradable erosion control matting product name (BECM)	
Biodegradable geogrid product name (BG)	
Synthetic erosion control matting product name (SECM)	
Synthetic geogrid product name (SG)	
Non woven geotextile product name (NWG)	

Physical Condition	Rating	BECM	BG	SECM	SG	NWG
Excellent	5 Very new without any defects					
Very Good	4 <5% defects without impacting structural integrity					
Good	3 10-20% defects without impacting structural integrity					
Fair	2 20-40% defects without impacting structural integrity					
Poor	1 Condition which needs immediate attention and repair					

Estimate of Remaining Useful Life	BECM	BG	SECM	SG	NWG
4 >10 years					
3 5-10 years					
2 <5 years					
1 Negligible					

Erosion Control Wattles

Biodegradable wattle product name (BW)	Curlex logs - 300mm diameter
Synthetic wattle product name (SW)	

Physical Condition	Rating	BW	SW
Excellent	5 Very new without any defects		
Very Good	4 <5% defects without impacting structural integrity		
Good	3 10-20% defects without impacting structural integrity		
Fair	2 20-40% defects without impacting structural integrity	X	
Poor	1 Condition which needs immediate attention and repair		

Estimate of Remaining Useful Life	BW	SW
4 >10 years		
3 5-10 years		
2 <5 years	X	
1 Negligible		

Concrete Materials

Concrete product 1 description (C1)	
Concrete product 2 description (C2)	
Concrete product 3 description (C3)	

Physical Condition	Rating	C1	C2	C3
Excellent	5 Very new without any defects			
Very Good	4 <5% defects without impacting structural integrity			
Good	3 10-20% defects without impacting structural integrity			
Fair	2 20-40% defects without impacting structural integrity			
Poor	1 Condition which needs immediate attention and repair			

Estimate of Remaining Useful Life	C1	C2	C3
4 >10 years			
3 5-10 years			
2 <5 years			
1 Negligible			

Steel Materials

Steel product 1 description (S1)	Rebar canes for wattle tie downs
Steel product 2 description (S2)	
Steel product 3 description (S3)	
Steel product 4 description (S4)	
Steel product 5 description (S5)	

Physical Condition	Rating	S1	S2	S3	S4	S5
Excellent	5 Very new without any defects					
Very Good	4 <5% defects without impacting structural integrity	X				
Good	3 10-20% defects without impacting structural integrity					
Fair	2 20-40% defects without impacting structural integrity					
Poor	1 Condition which needs immediate attention and repair					

Estimate of Remaining Useful Life	S1	S2	S3	S4	S5
4 >10 years	X				
3 5-10 years					
2 <5 years					
1 Negligible					

ENVIRONMENTAL AND CONTEXTUAL FACTORS

Erosion/Deposition Observations

Estimate of toe scour at site
Low [ ] Medium [ ] High [ ] N/A [X] Describe: None

Estimate of U/S bank erosion at site (U/S key)
Low [ ] Medium [X] High [ ] N/A [ ] Describe: Material washed out from toe at us site

Estimate of D/S bank erosion at site (D/S key)
Low [ ] Medium [ ] High [ ] N/A [X] Describe: None

Estimate of erosion within site/structure
Low [ ] Medium [X] High [ ] N/A [ ] Describe: Placed fill at toe

Estimate of sediment accumulation at site
Low [ ] Medium [ ] High [ ] N/A [X] Describe: None

Measurement of sediment accumulation at site
Depth [ ] Method:
Describe/Location

Seeps or spring present Yes [ ] No [✠] Describe:

Ice abrasion None [X] Light [ ] Moderate [ ] Severe [ ]

Visual estimate of channel grain size
Silt [ ] Sand [X] Gravel [X] Cobble [X] Boulder [ ] Bedrock [ ]

SITE MOST LIMITING FACTOR(S)

Select from the list below, limiting factors to success:	**ASSIGN A SEVERITY RATING TO EACH OF THE FACTORS BELOW: NONE(0), LIGHT(1), MODERATE(2), SEVERE(3)**	
	After Treatment	**Comments**
Slope instability	0	
Slope gradient	0	
Erosion	1	At toe
Compacted soils	0	
Anoxic soils	0	
Insect damage and disease	0	
Trampling by people or dogs	0	
Motorized vehicles	0	
Non motorized vehicles	0	
Aspect	0	
Bank profile	0	
Existing vegetation competition[1]	2	Invasive weeds
Shade	0	
Maintenance issues[2]	2	Rodent fence and toe wattle
Flooding duration	0	
Hydraulics (Shear stress)	2	
Infrastructure and available space	0	
Wildlife impact[3]	0	
Comment on wildlife impact:		
Access	0	
Other: 1-		
2-		

[1] e.g. from aggressive, fast spreading grasses or invasive weed species

[2] e.g. weeding, fencing or rodent protection) including inadequate or no irrigation, frequency or coverage

[3] Browsing/girdling by Rodent/Beavers/Muskrats

POTENTIAL REPAIR OPTIONS

	Select one
(1) Minor (hand tools, seeding and manual planting)	X
(2) Moderate, may need small machine and material to be brought in (is there access?)	
(3) Major, site needs to be redesigned and reconstructed.	

Description

Repair the rodent fence ; move up the wattle and secure it against existing soil; weeding

ALTERNATIVE DESIGN OPTIONS

Description

Design options could be 46E_1 and 46E_2

Success Attributes

To date, successful existing riprap retrofit with void fill and live cuttings ; telebelt void food install

KERR WOOD LEIDAL
consulting engineers

Appendix H

Bioengineering Structural Integrity Assessment Photos

Prepared by: Kerr Wood Leidal Associates Ltd. and Hemmera Envirochem Inc.

Appendix H – Baseline (2016-2017) Photographs

Photo H-1: Photo Station 1 -Facing Upstream (March 29, 2017)

Photo H-2: Photo Station 1 -Facing Downstream (March 29, 2017)

Photo H-3: Photo Station 2 -Facing Upstream (March 29, 2017)

Photo H-4: Photo Station 2 -Facing Downstream (June 2, 2016)

Appendix H – Baseline (2016-2017) Photographs

Photo H-5: Photo Station 3 -Facing Upstream (June 2, 2016)

Photo H-6: Photo Station 3 -Facing Downstream (June 2, 2016)

Photo H-7: Photo Station 4 -Facing Upstream (June 2, 2016)

Photo H-8: Photo Station 4 -Facing Downstream (June 2, 2016)

Photo H-9: View upstream from Photo Station 1 (Site 1) on March 11, 2019.

Photo H-10: View upstream from Photo Station 1 (Site 1) on May 9, 2019.

Photo H-11: View upstream from Photo Station 1 (Site 1) on August 1, 2019.

Photo H-12: View upstream from Photo Station 1 (Site 1) on November 26, 2019.

Photo H-13: View downstream from Photo Station 1 (Site 1) on March 11, 2019.

Photo H-14: View downstream from Photo Station 1 (Site 1) on May 9, 2019.

Photo H-15: View downstream from Photo Station 1 (Site 1) on August 1, 2019.

Photo H-16: View downstream from Photo Station 1 (Site 1) on November 26, 2019.

Photo H-17: View upstream from Photo Station 2 (Site 1) on March 11, 2019.

Photo H-18: View upstream from Photo Station 2 (Site 1) on May 9, 2019.

Photo H-19: View upstream from Photo Station 2 (Site 1) on August 1, 2019.

Photo H-20: View upstream from Photo Station 2 (Site 1) on November 26, 2019

Photo H-21: View downstream from Photo Station 2 (Site 1) on March 11, 2019.

Photo H-22: View downstream from Photo Station 2 (Site 1) on May 9, 2019.

Photo H-23: View downstream from Photo Station 2 (Site 1) on August 1, 2019.

Photo H-24: View downstream from Photo Station 2 (Site 1) on November 26, 2019.

Photo H-25: View upstream from Photo Station 3 (Site 2) on March 11, 2019.

Photo H-26: View upstream from Photo Station 3 (Site 2) on May 9, 2019.

Photo H-27: View upstream from Photo Station 3 (Site 2) on August 1, 2019.

Photo H-28: View upstream from Photo Station 3 (Site 2) on November 26, 2019

Photo H-29: View downstream from Photo Station 3 (Site 2) on March 11, 2019.

Photo H-30: View downstream from Photo Station 3 (Site 2) on May 9, 2019.

Photo H-31: View downstream from Photo Station 3 (Site 2) on August 1, 2019.

Photo H-32: View downstream from Photo Station 3 (Site 2) on November 26, 2019.

Photo H-33: View upstream from Photo Station 4 (Site 4) on March 11, 2019.

Photo H-34: View upstream from Photo Station 4 (Site 4) on May 9, 2019.

Photo H-35: View upstream from Photo Station 4 (Site 4) on August 1, 2019.

Photo H-36: View upstream from Photo Station 4 (Site 4) on November 26, 2019

Photo H-37: View downstream from Photo Station 4 (Site 4) on March 11, 2019.

Photo H-38: View downstream from Photo Station 4 (Site 4) on May 9, 2019.

Photo H-39: View downstream from Photo Station 4 (Site 4) on August 1, 2019.

Photo H-40: View downstream from Photo Station 4 (Site 4) on November 26, 2019.