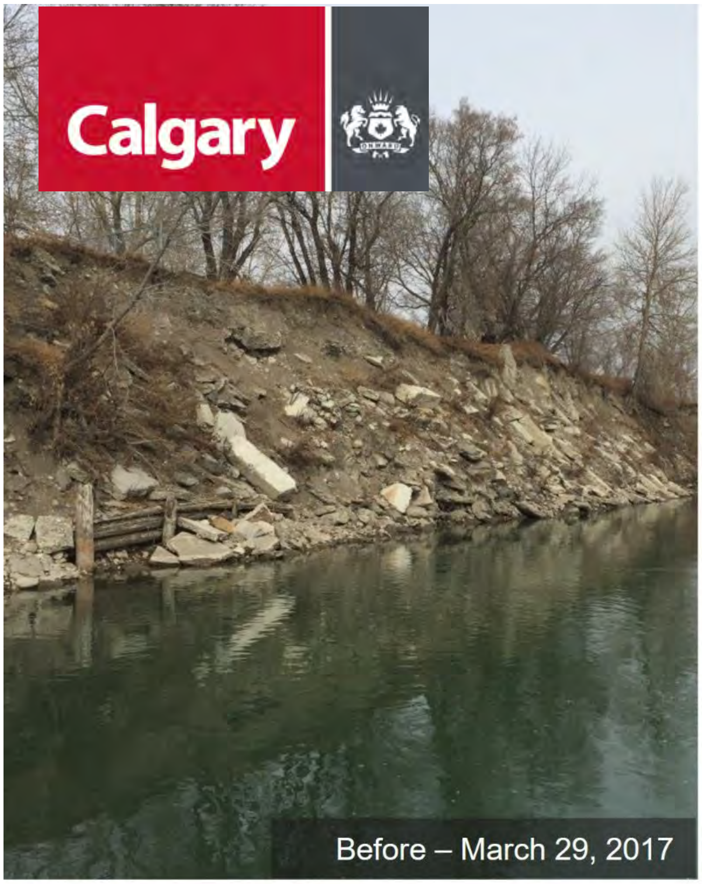

Bioengineering Demonstration and Education Project - 2021 Monitoring Report – Revision 1

The City of Calgary Riparian Monitoring Program

Report prepared for:
The City of Calgary - Water Resources

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Executive Summary

This report is a summary of the third year (2021) of post-construction bioengineering effectiveness monitoring at the Bioengineering Demonstration and Education Project (BDEP) as part of the on-going City of Calgary Riparian Monitoring Program (RMP). Post-construction monitoring activities have previously occurred at the BDEP site in 2019 (KWL, 2020a) and 2020 (KWL, 2021a), and baseline pre-construction data was collected in 2016 (Hemmera, 2017a; Hemmera, 2017b; Hemmera, 2017c). Monitoring activities are conducted in compliance with the Bioengineering Efficacy Monitoring Plan (BEMP) (Hemmera, 2018) that was approved by Alberta Environment and Parks (AEP) and The City of Calgary (The City) in 2018. The BEMP provides guidance to monitor 1) Fish and Fish Habitat; 2) Wildlife; 3) Riparian Health; and 4) Bioengineering Structural Integrity at BDEP Site 1, Site 2 and Site 4 (Figure 1) over a 10-year period, with monitoring activities occurring in 2019, 2020, 2021, 2023 and 2028, or Years 1, 2, 3, 5 and 10 post-construction (Hemmera, 2018). Monitoring activities are intended to meet the goals listed below.

1. 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.
2. 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.
3. To show how the project has improved riparian health and specifically how it has been improved over a conventional riprap design site.
4. To show how the project has improved bank structural integrity and specifically how it has been improved over a conventional riprap design site.

Methods

A brief summary of the methods used to monitor BDEP Sites 1, 2 and 4 are listed below. For detailed information on methodologies see Sections 2.1, 3.1, 4.1 and 5.1 in this report.

- **Fish and Fish Habitat** is being monitored in multiple seasons (spring, summer, fall, and winter) using methods including visual assessments of fish use via underwater photography and snorkel surveys; fish spawning use by redd counts and kick sampling for eggs; fish habitat assessments; water quality sampling; fish sampling via electrofishing and minnow trapping; and, physical condition and stability via photographic monitoring.
- **Wildlife** is being monitored using trail cameras at Site 1 to assess wildlife corridor usage by mammals. Breeding bird surveys and wildlife feature monitoring is also occurring at Sites 1, 2 and 4 to assess habitat suitability and wildlife use.
- **Riparian Health** is being monitored at BDEP using Riparian Health Assessments (RHA) at Sites 1, 2 and 4 and Riparian Health Inventory (RHI) at BOW95 (inclusive of all BDEP sites) to demonstrate if bioengineering treatments are successful in the long-term in affecting continued improvements in riparian health. Riparian health scores generated by RHI and RHA protocols are equivalent (i.e., the same parameters are scored), but additional vegetation, physical and other environmental data is collected to characterize the monitoring site when using the RHI protocol. Each BDEP site was also given a Bank and Riparian Quality Index (BRQI) rating in 2021 (per The City/AEP approved methodology changes). The BRQI was added to address inherent constraints of riparian health score metrics, whereby watershed scale parameters (e.g., upstream dams, water withdrawals and diversions) pose permanent limits to a maximum achievable score, regardless of site-level

improvements. As such the riparian health metrics are not well suited for comparative bioengineering treatment assessments. The BRQI rating provides a relative measure of habitat condition for bioengineering treatment sites where only site-scale factors are considered. All bioengineering projects also have inherent riparian health score deductions due to short-term bank or riparian structural alteration impacts, common to most techniques including both ‘soft’ and ‘hard’ engineering approaches.

- **Bioengineering Structural Integrity** is being monitored using the protocols for The City of Calgary Riparian Monitoring Program that includes a structural assessment (i.e., general site condition assessment for erosion/deposition/damage, construction material condition assessment, hydrologic observations, site dimensions survey, photographic monitoring, etc.) and a vegetation survey to collect data for vegetation survivorship, leader growth, shoot length, vegetation cover, vegetation vigour, and species diversity.

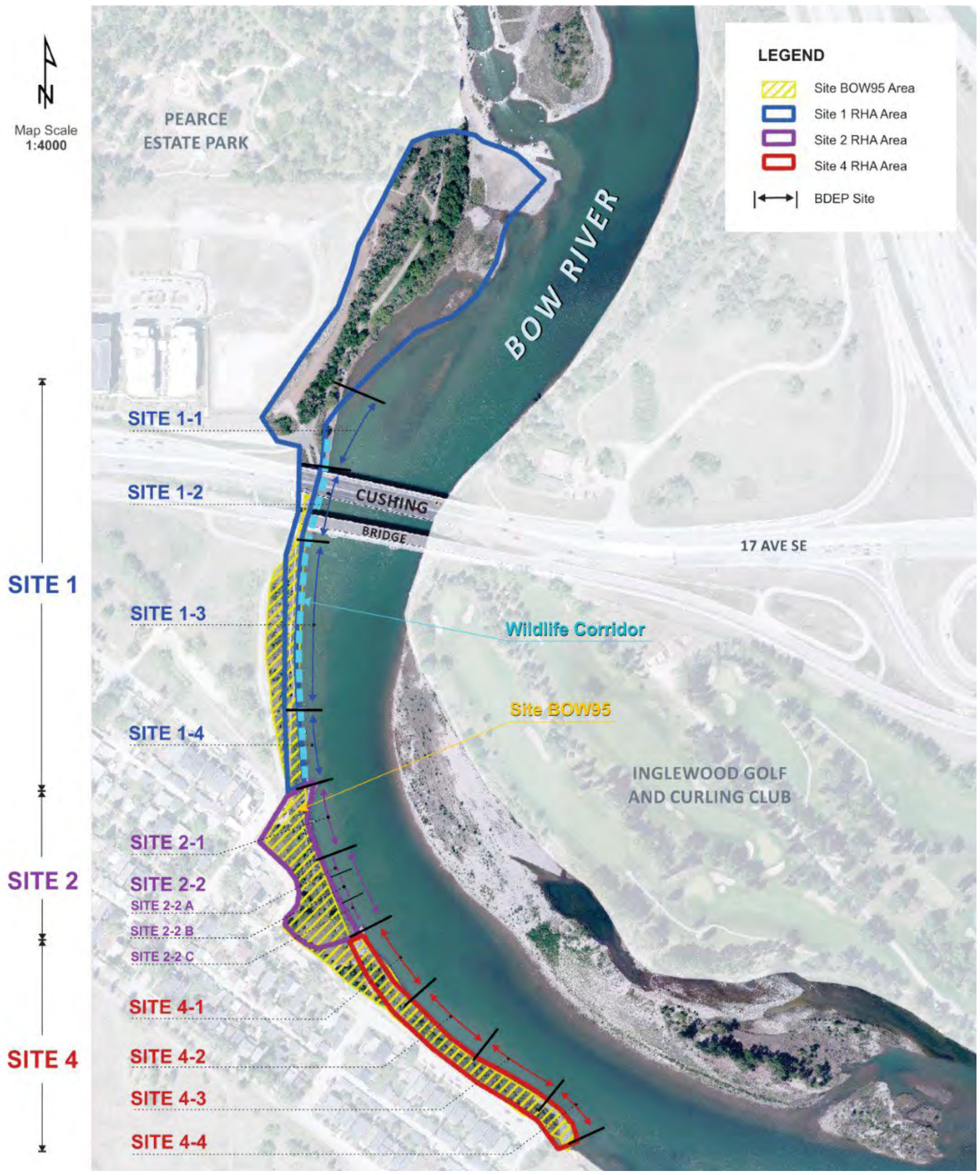

Figure 1: BDEP Sites (Note: Site 1-2 and Site 4-4 are not part of the monitoring program as no bioengineering techniques were applied there)

Key Results

Key results from each component of the 2021 post-construction bioengineering effectiveness monitoring at the BDEP are provided in this section. As discussed in more detail below, the monitoring results from the site show that the BDEP is providing better fish and fish habitat, wildlife habitat and passage, and riparian health over a conventional riprap design site. Bioengineering structural integrity is somewhat harder to compare with a conventional riprap design site in the absence of large flood conditions; however, similar erosion protection between the bioengineering techniques used at the BDEP and a conventional riprap design site is estimated based on literature values for shear stress resistance.

Fish and Fish Habitat Results

For Year 3 (2021) of fish and fish habitat monitoring, results indicate that fish are continuing to use the habitat enhancement structures included in the BDEP. Fish were observed using and were captured within the vicinity of the habitat structures throughout the project area at Site 1 (in past monitoring years), Site 2, and Site 4. Although no fish were observed in the fish shelters, boulder clusters, and surrounding habitats during the fall 2021 assessment, mountain whitefish eggs were documented in the upstream section of Site 1. The highest abundance and diversity of fish species were captured at Site 2 in 2021.

Based on the fish use monitoring results from 2019, 2020, and 2021, Sites 1 and 2 are providing high quality fish habitat in comparison to Site 4, the conventional riprap design site.

Wildlife Results

The Year 3 (2021) breeding bird surveys resulted in the identification of 23 species. 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 again during the 2021 survey; otherwise, no nests were observed at any of the sites in 2021. Site 1 (77 individuals from 19 species) and Site 2 (28 individuals from 11 species) showed increased bird activity relative to Site 4 (13 individuals from 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.

Several trends have been identified as part of the breeding bird surveys as follows:

- The number of bird species observed during breeding bird surveys from Years 1 to 3 has declined slightly from 26 (Year 1) to 23 (Year 3). This observed change in species diversity is small and may be attributed to the number of survey locations and limited Project size. As shrubs and trees planted as part of the Project fully establish along the bank, species diversity is expected to increase.
- Bank swallow use of the nesting habitat at BANS01 has declined annually, while use at BANS02 has varied.
- No raptor nests have been identified at the Project during the first three years of the monitoring period.

The wildlife camera monitoring program identified animals utilizing the wildlife corridor created under the Cushing/17th Avenue SE bridge. A total of 6 wildlife species were identified through observations of 203 individuals in Year 3 (2021). Both large and medium-sized mammals have been photographed at all camera locations and appear to be using the wildlife corridor as intended. Larger mammals (white-tailed deer and coyote) were among the most abundant species, with relatively equal distributions between all camera locations.

The consistently high mean use in Year 2 (2020) and Year 3 (2021) in comparison to Year 1 (2019), indicates that the wildlife corridor at the BDEP is providing effective passage for large mammals. Smaller mammal species were only photographed at Camera 4 (e.g., American beaver, common racoon, eastern gray squirrel, striped skunk) and have not shown movement through the site at this point. This might change over time, as the vegetation establishes enough to provide further cover for small animals.

Riparian Health Results

Results from the Riparian Health Assessments (RHAs) ("Site" scale), a re-visit Riparian Health Inventory (RHI) ("Project" scale), and BRQI are provided below in Tables 1, 2 and 3 respectively.

Table 1: 2016-2021 BDEP RHA Overall Results Summary

Riparian Health Ratings	Site 1				Site 2				Site 4			
	2016[1]	2019	2020	2021	2016[1]	2019	2020	2021	2016[1]	2019	2020	2021
Vegetation rating (%)	54	64	61	61	33	78	81	81	28	75	81	69
Soil / hydrology rating (%)	33	40	40	44	25	44	40	40	29	40	40	40
Overall rating (%)	43	51	49	52	29	58	58	58	29	56	58	53
Trend since Baseline (2016)[2]	**Improving (+9%)**				**Improving (+29%)**				**Improving (+24%)**			

Notes:
1. 2016 data are baseline RHA ratings (Hemmera, 2017c)
2. Overall Riparian Health Trend **since Baseline (2016)**: Improving = >5% score increase, Degrading = >5% score decrease, and Stable = <5% score increase or decrease.

Riparian Health Category:
Healthy (>80% score) *Healthy with Problems* (60-79% score) *Unhealthy* (<60% score)

Table 2: BOW95 RHI Results Summary

Riparian Health Ratings	BOW95 RHI Site (BDEP Site 1 downstream from Cushing Bridge, Site 2 and Site 4)		
	2016	2021	TREND
Vegetation rating (%)	56%	78%	+22%
Soil / hydrology rating (%)	36%	44%	+8%
Overall rating (%)	44%	59%	+15% Improving

Riparian Health Category:
Healthy (>80% score) *Healthy with Problems* (60-79% score) *Unhealthy* (<60% score)

Table 3: BRQI Results Summary

BRQI Parameter	Site 1*		Site 2		Site 4	
	2019	2021	2019	2021	2019	2021
Vegetation						
1. Percent vegetation cover (/12)	11.0	10.9	11.3	10.6	12.0	12.0
2. Percent cover of invasive species (/12)	11.1	9.1	3.2	6.3	7.1	7.1
3. Percent cover of disturbance-increaser species (/12)	1.1	1.3	1.1	0.8	1.6	0
4. Percent cover of native trees and shrubs (/12)	5.9	6.5	7.0	7.0	5.6	3.7
5. Plant community structure (/12)	9.8	5.8	7.6	3.3	6.8	4.0
6. Percent cover of regenerating preferred tree and shrub species (/12)	5.9	6.5	5.2	4.9	5.6	2.5
Physical						
7. Percent cover of human-caused bare ground (/12)	4.6	9.9	1.5	8.1	8.0	8.4
8. Percent cover of riprap and concrete (/16)	16.0	15.5	16.0	16.0	16.0	16.0
Total score (/100 or %)	**65**	**64**	**57**	**62**	**63**	**54**
BRQI Categorical Rating	**FAIR**	**FAIR**	**FAIR**	**FAIR**	**FAIR**	**FAIR**
2019-2021 Trend	**Stable (-1%)**		**Improving (+5%)**		**Degrading (-9%)**	

* Note: Site 1 includes natural, non-restored areas north of Cushing Bridge where no BRQI assessments were completed.

BRQI Categories Legend:

Good (75-100 score) *Fair* (50-74 score) *Poor* (0-49 score)

Based on the RHA and RHI results above, the BDEP area as a whole and individual site treatments (Sites 1, 2, and 4) show substantial improvements in riparian health since baseline 2016 conditions:

- The BDEP area as a whole (i.e., the BOW95 RHI polygon) has improved by 15% since 2016 from a baseline score of 44% (Appendix D). The entire project area (BOW95) now rates as 59%, approaching the *Healthy, with Problems* threshold of 60%. Improvements are mainly from vegetation health enhancements. Watershed-scale factors (e.g., damming and water diversion) and permanent structural alterations from flood/erosion control mitigations and recreation use are contextual constraints to the soil/hydrology score for this site. The current vegetation rating of 78% is about 11% higher than the vegetation health average for the Bow River in Calgary (n=41). Thus, the BDEP has successfully improved local vegetation conditions and achieved an upward trending riparian health score, approaching context-specific, achievable targets as per The City's Riparian Action Program.
- Sites 1, 2 and 4 show riparian health score increases since 2016 ranging from +9% (Site 1), +24% (Site 4) to +29% (Site 2) as confirmed by annual RHA monitoring.
- Overall Riparian Health ratings over the three years of monitoring for sites 1, 2 and 4 range from 34% to 54% higher than the overall rating for a theoretical conventional riprap design site.
- **Riparian health improvements are directly attributable to riparian plantings and bioengineering works since 2018**. This includes improved health scores for tree and shrub regeneration, overall woody cover, reduced cover from disturbance-increaser species, and variable increases in root mass protection.

As shown in Table 3, overall BRQI ratings for Sites 1 and 2 are similar (64% versus 62%), indicating that these sites now have "Fair" habitat quality as a result of successful bioengineering works. Site 4 has the lowest BRQI rating of 54% but still Fair. A "Good" BRQI rating corresponds with a bank or riparian area that is well vegetated with a structurally diverse plant community comprised of multiple life-forms, including preferred native species and regenerating trees/shrubs, and with little to no human-caused bare ground or artificial hardened (impervious) surface (e.g., rock riprap or concrete). A “Fair” BRQI rating is a bank or riparian area with some human-caused bare ground and/or hardened surface and/or intermediate natural vegetation cover (not limited to weedy species); fair habitat structure; and/or at least some regenerating preferred trees/shrubs.

Although Site 1 and Site 2 have mostly shown consistent or sustained improvement since 2016, there has been a very slight riparian health decline since 2020 for Site 4. Some die-off of planted stakes and container plants is apparent in Site 4, likely in part due to drought conditions in Calgary in the summers of 2020-2021. This affected regeneration scores for both RHA and BRQI ratings for Site 4. Replacement plantings were installed in 2021 as a mitigation.

Root mass protection improvements are greatest for Site 1 due to successful implementation of multiple bioengineering techniques (riparian plantings, rooted live cuttings, vegetated soil wraps, vegetated timber crib wall, willow brush mattress and brush layers, and contour fascines). Portions of Site 2 were intentionally not planted to retain naturally steep, unvegetated cutbanks that provide nesting habitat for bank swallows. Unvegetated riprap ‘control’ portions of Site 4 plus mortality of plantings/cuttings limited root mass protection improvement for that site.

Invasive weeds continue to persist in all sites with 1-15% cover; however, weed removal efforts are ongoing. Similarly, disturbance-increaser species (e.g., Kentucky bluegrass and smooth brome) have more than 25% cover in the BDEP site as a whole, including the adjacent upper bench. Invasive weeds and disturbance-caused plants are common limiting factors to the BRQI scores for all sites.

Trends in BRQI ratings over time will demonstrate if bioengineering works are successful in the long-term in affecting continued natural habitat cover, structure and sustained natural regeneration. Those sites with highest BRQI ratings in the long-term will represent successful progress toward meeting wildlife habitat and vegetation enhancement objectives. Site-level maintenance activities (e.g., weeding, watering, access control) and continued vegetated riprap experimental treatments have potential to positively affect BRQI scores going forward.

Bioengineering Structural Integrity Results

Key findings from the 2021 bioengineering structural integrity assessment are listed below.

- 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. Flows in the Bow River at the site in 2021 were below the 2-year flood flow and shear stresses ranged from 10 to 35 N/m². Rainfall in Calgary in 2021 was well below average at 277 mm.
- 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. Curlex® Sediment Logs® were noted in 2021 to be in poor condition and missing in some places but they have served their purpose of providing temporary erosion and sediment control and can be either left in place or removed.
- The fish shelters were observed to have 0.05 m more fine sediment deposited along the bottom compared to 2020 results 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.
- Woody vegetation canopy cover for the live cuttings installed in the bank portion of the BDEP is very good at 89% for Site 1 and 83% at Site 2 in 2021, and is low for Site 4 at 6% due to high mortality of

the plantings and cuttings. The 2021 results for cover are in the same range as compared to 2019, despite the dry and hot conditions during summer 2020 and 2021. Overall woody vegetation canopy cover is 31% over the site, which is low compared to a typical target of 70% woody vegetation cover and is highly influenced by the low density of plantings above the bioengineered bank treatments.

- The vegetation establishment trajectory at Site 1 and Site 2 is in line with expectations for leader growth, shoot length and diameter and no changes to current maintenance practices or remedial actions are required. Replanting at Site 4 has already occurred in 2021 to address the live cutting vegetation establishment issues.
- FAC was issued in October 2021 with the fencing around the site removed about two weeks prior. It is understood that The City has engaged the contractor to provide additional irrigation for the next 2 years to support the newly planted vegetation. Weeding will also be performed by The City.

Key Conclusions

The key conclusions in this report in relation to the monitoring goals listed above are listed below.

- **Fish and Fish Habitat** monitoring results from 2021 continue to show that the bioengineering techniques used at Site 1 and Site 2 have improved fish habitat over the conventional riprap design site at Site 4.
- **Wildlife** monitoring results from 2021 and the findings in the reviewed literature regarding restricted wildlife passage on conventional riprap design site like Site 4, continue to show that Site 1 is providing better wildlife passage than Site 4, the conventional riprap design site.
- **Riparian Health** monitoring results continue to show that overall riparian health at the BDEP has improved over a conventional riprap design site due to the bioengineering techniques used.
- **Bioengineering Structural Integrity** monitoring results continue to show that overall bank structural integrity at the BDEP has improved over a conventional riprap design site due to the bioengineering techniques used. At Year 3 post-construction, many of the bioengineering techniques are providing a similar or better level of shear stress resistance compared to Class 2 riprap, including the vegetated timber crib wall at Site 1, the brush mattress at Site 1 and Site 2, the box fascine at Site 2, and where existing riprap was retrofitted at Site 4.

Key Recommendations

Key recommendations for future monitoring years are listed below.

Fish and Fish Habitat Recommendations

- Recommendations for monitoring in 2023 relate to the timing and equipment of the monitoring program are as follows:
  - the crew should monitor the ice conditions of the Bow River beginning in January to determine safe conditions for completing the winter and spring assessment (i.e., stable and thick ice for on-ice survey or ice-free open water conditions for snorkel survey);
  - fish sampling efforts during the summer assessment should be completed earlier in the year (late spring) or in late summer / early fall to capture fish when all sites are wetted and when adverse conditions for fish handling can be avoided; and,
  - during the summer assessment, the crew should continue to use a smaller boat for more effective sampling of near shore habitats adjacent to Sites 1 and 2.

Wildlife Recommendations

- Conduct more frequent camera checks to assess technical issues such as remaining memory card capacity and vandalism.
- Investigate opportunities to partner with Calgary Captured program for future camera installations.
- Evaluate other options to assess wildlife besides the cameras if additional camera installations are not possible.
- Based on the perceived success of the wildlife corridor at Site 1, it is recommended to consider creating a City-wide design standard to infill riprap void-spaces with smaller sized gravels or topsoil. This would improve wildlife passage under bridges in Calgary (as is standard in Minnesota per Section 5.2), but also at all locations where riprap is used on the riverbank to improve wildlife passage and habitat on riverbanks.

Riparian Health Assessment Recommendations

- Conduct annual BRQI monitoring in lieu of annual Riparian Health Assessments (RHAs) in future monitoring years. As discussed, BRQI metrics are more sensitive to site-level interventions and will allow for better comparative evaluation of bioengineering treatments relative to riparian habitat enhancement objectives. Key vegetation RHA metrics are incorporated in the BRQI. Going forward, BRQI metrics could be calculated by way of ocular estimations (similar to RHA field survey methods) for each site and for the project area as a whole. This would mean that BRQI results could be extrapolated for 2016 using baseline RHA/RHI data, GIS satellite image analysis and other pre-construction survey data to allow for comparison to baseline (2016) conditions. BRQI results presented in this report are derived from pin-point transect data, and thus don't allow for cross-year comparison with RHA survey results. Discontinuing annual treatment scale RHA surveys will require approval from The City of Calgary and AEP.
- Continue to conduct long-term lotic RHI trend monitoring (5-year re-visit intervals) for BOW95 per the RMP (KWL 2018). This will allow BDEP RHI trend data to be integrated into a city-wide dataset aimed at showing progress toward riparian health targets in The City's *Riparian Action Program* (City of Calgary, 2017). It also facilitates riparian health trend evaluations at a comprehensive project scale since baseline conditions. RHI monitoring entails collecting detailed plant species canopy cover, composition and plant community characterization data including tracking the age-class demographics of trees and shrubs (i.e., a break-out of seedling, sapling, mature and dead/dying individuals by species). These data are important for monitoring ongoing natural regeneration and plant community successional trajectories for bioengineering projects. Long-term die-off and other natural or human-caused constraints to riparian health can be better tracked via detailed lotic riparian health inventories. Another important component of RHI trend monitoring is repeat photography to visually track the progression of the site over time, a compelling and important aspect of showing and communicating success. The next RHI would be conducted in 2026.
- Continue invasive weed control and monitoring efforts on an annual basis.
    a. As a priority, focus efforts on **early detection and rapid removal of any *Prohibited Noxious Weeds*** per the Alberta *Weed Control Act.* Provincial regulations are more stringent for invasive plants with this designation, requiring their immediate eradication. **The BDEP site is currently void of *Prohibited Noxious Weeds***; however, such weeds have potential to be introduced by wind, water, wildlife, or human-caused seed dispersion. Nodding thistle (*Carduus nutans*) and spotted knapweed (*Centaurea stoebe* ssp. *micranthos*) are examples of species to watch for as they are emerging threats in Calgary's Bow River sub-basin.

b. Secondly, focus efforts on **hand-removal of isolated, rare invasive weed occurrences** (i.e., five or fewer plants) to prevent further establishment.

c. Lastly, work in collaboration with Calgary Parks, Integrated Pest Management, to **develop long-term integrated weed management strategies** (using a combination of mechanical, biological and/or chemical control options) **for entrenched, locally common invasive weeds** (e.g., Canada thistle [*Cirsium arvense*] and common tansy [*Tanacetum vulgare*]).

- Conduct hand removal of tufted vetch (*Vicia cracca*) where it is evidently suppressing growth of preferred tree/shrub seedlings and saplings. Tufted vetch is not currently a provincially regulated weed, but it is an invasive, introduced species that has spread profusely in Calgary's riparian areas in recent years.
- Ensure any topsoil or fill materials used for restoration purposes are certified to be free of weed seeds. Any equipment brought on site should be clean and weed free. Only certified weed-free seed mixes should be used for rehabilitation projects.
- Continue to monitor planting survival in Site 4 where replacement plantings were done in 2021.
- Monitor the survival success of recent live stakes installed in Site 1-2 (between the Cushing and Bus Rapid Transit bridges) and replace or mitigate with an alternate bioengineering treatment as warranted.
- Augment native shrub understory plantings in upper bench 'naturalized' buffers (e.g., upper bench portions of Site 2).
- Expand and enhance clustered native tree and shrub plantings in manicured lawn areas adjacent to and within the BDEP site.
- Monitor recreational use in the BDEP site. Install signage (e.g., 'trail closed' signs) combined with fencing where necessary to curtail proliferation of foot paths that may damage bioengineering plantings or cause accelerated bank erosion.
- Continue to maintain wood rail fencing to prevent recreational access to bank swallow nest habitat.
- Once beaver and wildlife fencing is removed, monitor beaver and deer use of the bioengineering plantings, and re-instate fencing or other mitigations as needed to prevent excessive herbivory.
- For preventing beaver herbivory of individual trees and shrubs, use 14-gauge galvanized steel wire with a 5 cm (2 inch) mesh size installed to a minimum height of 90 cm (3 feet) around the base of trees or shrubs. Ensure beaver cages do not girdle trees; remove or replace cages as trees mature where necessary.

Bioengineering Structural Integrity Recommendations

- BDEP Site Recommendations
  - It is recommended that The City continue with the current plan of providing on-going irrigation at the BDEP sites for 2-years post FAC. It is also recommended that The City continue with weeding the sites for a similar period of time.
  - More detailed monitoring of the timber in the timber crib wall at Site 1 should be conducted using non-destructive methods such as a Resistograph to provide more detailed understanding of the remaining useful life of the timber. This is in addition to the current methods being used to monitor the BDEP sites as described in Section 5.1.

  - Detailed monitoring of the three techniques used to retrofit existing riprap at Site 4 should be continued to determine the preferred approach. If live cuttings are used in future applications of this type, they should be placed in the openings in the riprap prior to backfilling with growing substrate versus installation after void-filling.
  - Site 4 should be replanted in areas where the survival target of 75% was not achieved. See Section 5.2 in this report.
  - Vegetation parameters (e.g., cover and vigor) should be monitored again in 2023 and 2028 using the transect method to facilitate better data comparison and consistent data with the 2019 and 2021 reports.
  - City should staff perform annual inspections post freshet to monitor the structural condition of the site and later in August / September to assess vegetation establishment and success on non-monitoring years.
- General Recommendations for Future Bioengineering Projects
  - The rooted live cuttings are establishing at Site 1 and they appear to be a viable approach for constructing bioengineering projects. They are recommended to be used within various bioengineering structure types when timing constraints result in construction outside of the recommended period for using dormant live cuttings.
  - 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 that are sized appropriately.
  - For future box fascine installations on the Bow River, it is recommended that the fill placed in the box fascine be larger sized material than pea gravels that were used at Site 2. A good option could be native river gravels excavated during site construction. Also, placing erodible void-fill material on the surface of exposed steep riprap slopes per the conditions observed at Site 4 should be avoided.
  - Hedge brush layers should be where brush layers are being considered despite the additional cost. In a hedge brush layer, potted plants are used in combination with conventional live cuttings which can improve overall biodiversity, habitat for wildlife, and nutrient availability in the soil.

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Appendix B: Hemmera Envirochem Inc.'s 2021 Report: *2021 Monitoring Report – Bioengineering Demonstration and Education Project*, including:

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- **Attachment B: Fish Assessment - Bow River Site Atlas**
- **Attachment C: Bow River Fish Habitat Maps**
- **Attachment D: Raw Fish Data**
- **Attachment E: Wildlife Photo Log**

Appendix C: Riparian Health Assessment Field Data Sheets
Appendix D: Cows and Fish 2021 BOW95 Riparian Health Assessment Report
Appendix E: Bioengineering Structural Integrity Assessment Field Forms
Appendix F: Bioengineering Structural Integrity Assessment Photos

1. Introduction

The purpose of this document is to report on the activities and results of 2021 bioengineering effectiveness monitoring at the Bioengineering Demonstration and Education Project (BDEP) as part of the on-going City of Calgary Riparian Monitoring Program (RMP). This is the third 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/17 Ave SE) 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.

The Final Acceptance Certificate (FAC) under the construction contract was issued in 2021. Effectiveness monitoring will continue until 2028.

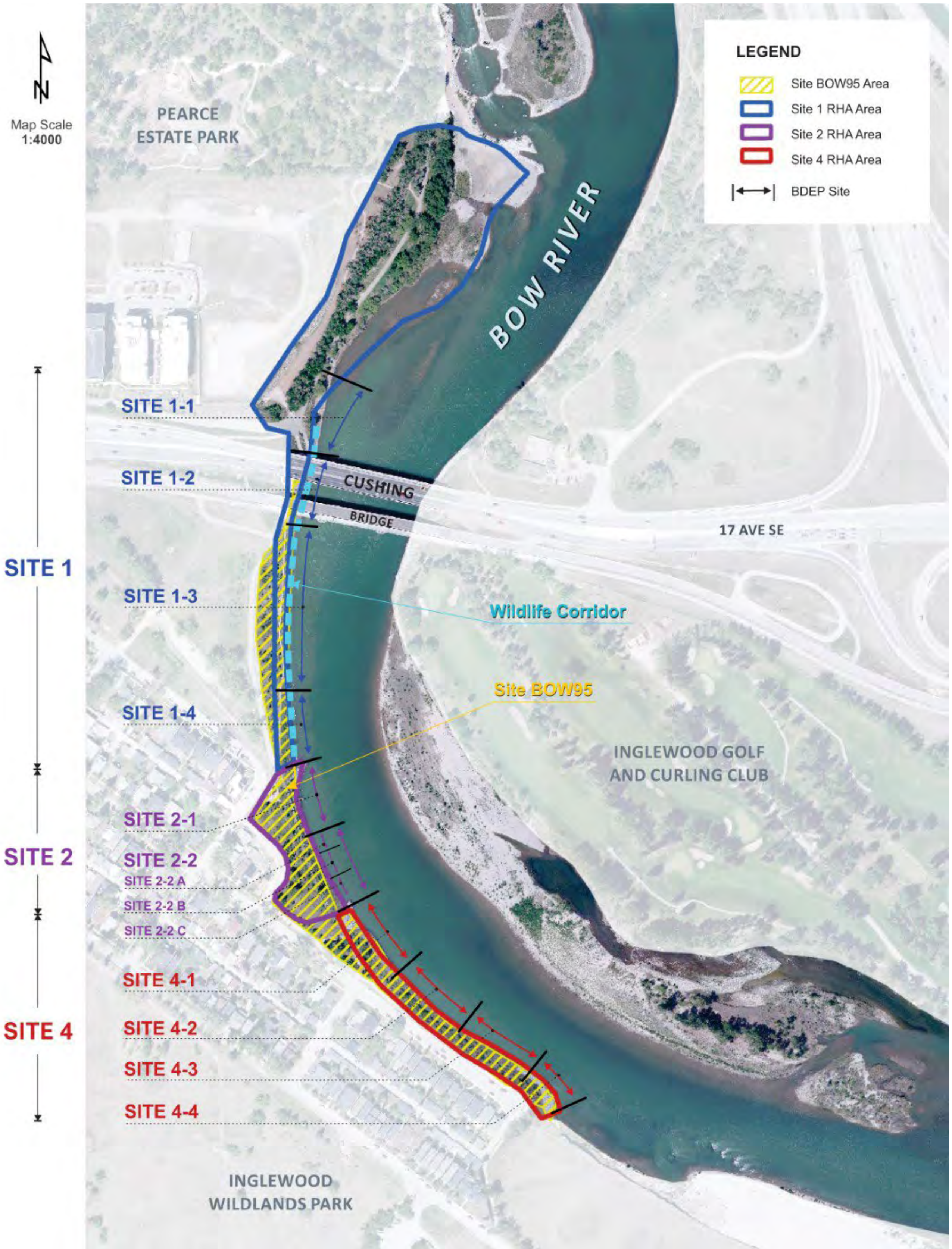
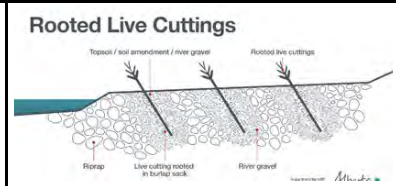
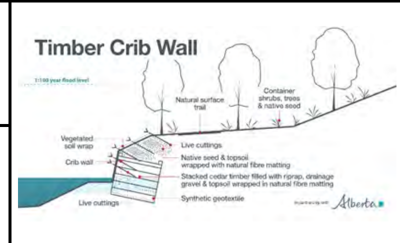
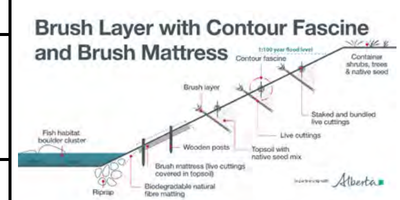
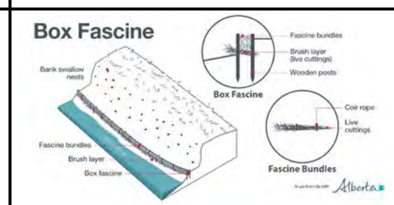
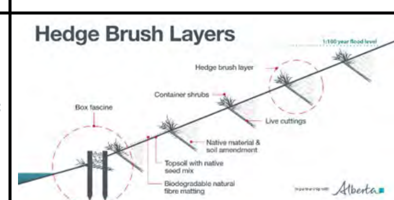
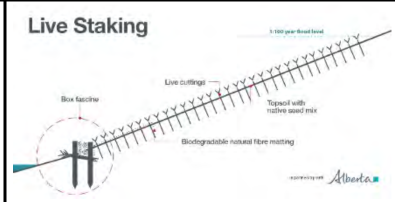
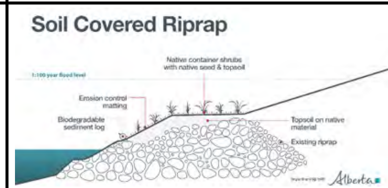
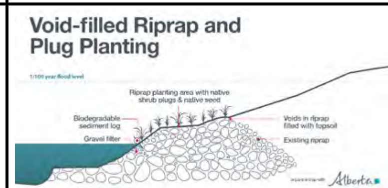
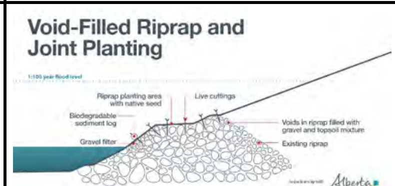


Figure 1-1: BDEP Sites

(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	Technique Schematic
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 outside the 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 soil 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)	Row(s) of live cuttings and rooted stock placed in a criss-cross or overlapping manner between layers of soil, with tips protruding beyond the face of the fill.	

Site	Technique Name	Description	Technique Schematic
Site 2	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.	--

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 return period 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). As discussed in the BDEP 2019 Monitoring Report (KWL, 2020a), it was determined that Site 4 would be suitable for use as a control site for comparison of Fish and Fish Habitat and Wildlife monitoring components. However, as the riprap extent at Site 4 only covers up to the 5-year return period flood elevation, with riparian planting above, it is not suitable for use as a control site for comparing the Riparian Health and Bioengineering Structural Integrity components. Thus, these two components are compared to a theoretical riprap design site, with rock armour installed to a 100-year return period flood elevation.

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) with a vegetation score of 33% (9/27) and soil/hydrology score of 40% (18/45) and would be in Unhealthy condition as discussed in the *BDEP - 2019 Monitoring Report* (KWL, 2020a). The RHA score is equivalent to a Riparian Health Index (RHI) score (i.e., same parameters are scored); therefore, the theoretical conventional riprap design site will also be used to compare RHI scores– see Section 4. The permissible shear stress for a conventional riprap design site with Class 2 riprap (d_{50} = 500 mm) is approximately 400 N/m² (Fischenich, 2001).

Photo 1-1: BDEP Site 2 on July 19, 2021

2. Fish and Fish Habitat

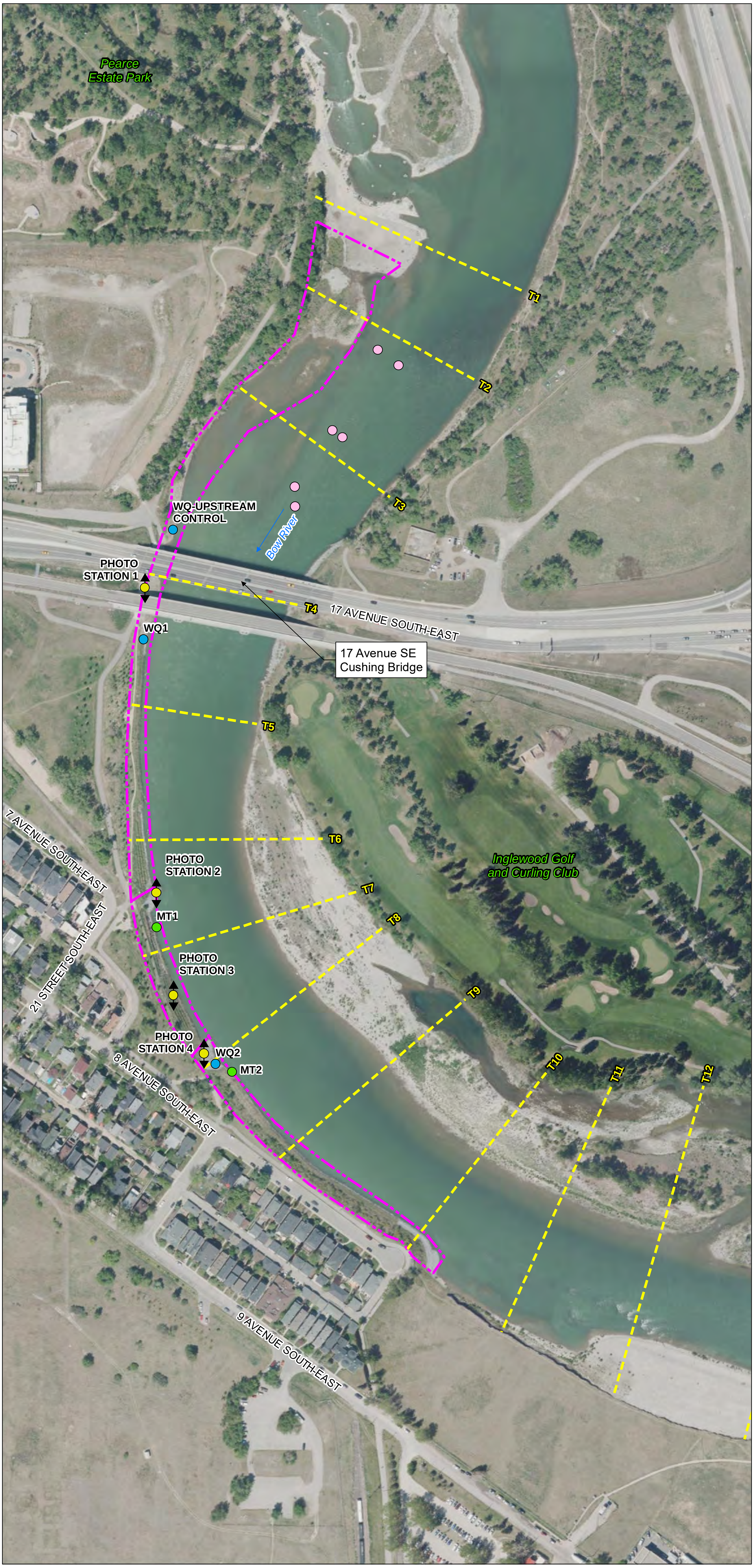
Photo 2-1: BDEP timber crib wall, fish shelters and habitat enhancement rocks at Site 1 (July 21, 2021)

Fish and fish habitat were assessed at BDEP Sites 1, 2, and 4 in a baseline assessment in 2017 as part of the BDEP design and construction contract (Hemmera, 2017a), and in 2019, 2020, and 2021 as part of the RMP. Future fish habitat monitoring under the RMP is planned for 2023 and 2028. The 2021 fish and fish habitat assessment work is described in detail in the *2021 Monitoring Report: Bioengineering Demonstration and Education Project* (Hemmera, 2022) provided in Appendix B. A summary of the report is provided 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).

The 2021 assessments of fish habitat and fish use were completed by a crew of biologists, 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 2021 using methods as summarized in Table 2-1, which are the same as those used in 2019/2020. Sampling locations used were also the same as those established in 2019/2020 and are 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 location
- Minnow Trap
- Transect
- Site Boundary

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 (2020)

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Table 2-1: Summary of Field Assessment Methods and Timing for the 2021 Monitoring Year

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.	Jan 6[1]	-	-	-
Fish Spawning Use	Visual surveys conducted from bank for rainbow trout (Spring) and brown trout (Fall) redds.	-	Jul 19	-	Nov 30
	Sampling of mountain whitefish eggs via kick sampling.	-	-	-	Nov 30[2]
Fish Habitat Assessment	Collection of in-stream and near stream condition, documentation of fish habitat enhancements.	-	-	Jul 13, Jul 29, Aug 31, and Oct 14[3]	-
Water Quality	Collection of water quality parameters from Site 1 and Site 4 and the upstream control location.	Jan 6	Jul 19	Oct 14	Nov 30
Fish Sampling	Fish capture via single pass boat electrofishing and overnight set gee-style minnow traps.	-	-	Nov 8-9[4]	-
Photographic assessment of physical condition and stability	Establishment and assessment of photo monitoring stations.	Jan 6	-	July 13	Oct 14, Nov 8 and Nov 30

Notes:
1. The winter fish use assessment was limited to the fish shelters at Site 1 since Site 2 was ice covered and not safe to access.
2. Survey extents were from 500 m upstream of Site 1, through all riverine habitat adjacent to Site 2 and Site 4, to 500 m downstream of the downstream end of Site 4.
3. Survey extents were from 100 m upstream of Site 1, through all riverine habitat adjacent to Sites 2 and 4, to 600 m downstream of the downstream end of Site 4.
4. Sampling was delayed until the fall and consisted of minnow trapping only. The boat electrofishing effort was removed from the 2021 sampling program due to the high risk to fish health from fish sampling because of low water levels and high ambient air temperatures in July-August and the low likelihood of obtaining a Fish Research licence in the fall during Brown Trout spawning.

2.2 Results

The following outlines the results for fish and fish habitat monitoring. A Summary of Findings is included in Section 2.3, page 26.

Fish Habitat Characteristics

Baseline fish habitat characteristics were collected as part of the fish habitat assessment on March 27, 2017 (Hemmera, 2017a). Post-construction fish habitat characteristics data were collected in 2019 from July 20 to August 1, 2019 (KWL, 2020a), in 2020 from September 17-18, 2020 (KWL, 2021a), and in 2021 on July 13, July 29, August 31, and October 14, 2021.

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, 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 and a detailed fish habitat map of the assessed reach are presented in Hemmera's 2021 report in Appendix B. Fish habitat within each site in the BDEP area (i.e., Site 1, Site 2, and Site 4) is summarized below, including commentary on 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.

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 2019/2020/2021 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. The banks along the upstream section of Site 1 are relatively stable.
- 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 2019/2020/2021 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 2019/2020/2021 are that fish habitat within this reach remains consistent with observations made during the baseline conditions assessment where R1 habitat extends through the downstream section of R1. The RDB is considered stable in this reach.

Water depths in Site 1 have not changed significantly from baseline condition. Maximum water depths observed in 2021 range from 0.4 m in R3 habitat (2019 was 0.40 m; 2020 was 0.53 m) to approximately 7 m in R1 and P1 habitat, consistent with the 2017, 2019, and 2020 observations. The 7 m deep scour hole is in the P1 habitat adjacent to Site 1 downstream of the Cushing Bridge. This deep pool 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 baseline assessment (Hemmera, 2017a).

Baseline, 2019, 2020, and 2021 assessments of instream cover for fish were similar as cover throughout Site 1 is provided primarily by depth and turbulence, with limited overhanging cover provided by woody vegetation along the LDB. Boulder substrates that are present throughout run and pool habitats likely provide instream cover for fish. The constructed fish shelters and boulder clusters along the RDB in the reach downstream of the Cushing Bridge provide additional 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 baseline, 2019, 2020, and 2021 assessments.

Deep run (R1) and pool (P1) habitat is likely used 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 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 B – Attachment C).

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 0.5 m to 4 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 riprap groyne structures.

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, 2019, 2020, and 2021 observations; however, deciduous shrubs were present along the RDB 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. The P1 habitat present downstream of the 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) and during the 2019 and 2020 site assessments (Hemmera, 2020; Hemmera, 2022), 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 100 m to 230 m and 80 m to 170 m respectively. 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 (Appendix B – Attachment C). Site 4 continues to have little to no overhanging cover as a result of bank armouring 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 1.5 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 Site 2 Fish Habitat Comparison with Site 4

The comparison of Site 1 and Site 2 fish habitats to Site 4 habitat is consistent with the findings in the 2019 and 2020 reports (KWL, 2020a; KWL, 2021a). BDEP improved the bank stability and fish habitat at Site 1 and Site 2, 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 Site 2 have the potential to provide overhead cover for fish as they mature. This compares to Site 4 that does not provide cover because of the bank armouring 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, 2020, and 2021 monitoring years, the same data were collected but sampling was conducted over the course of the year (Table 2-1). The locations where water quality sampling stations were established in 2019 are presented in Figure 1-1. These water quality stations were also used for the 2020 and 2021 monitoring to allow for year over year 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 2019/2020/2021 sampling years. 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 Site 4 and the Upstream Control Site were within federal guidelines (CCME, 1999). Results from water quality measurements in 2021 were similar to measurements recorded in 2019 and 2020, with similar seasonal variability in temperature, dissolved oxygen and conductivity except for spring temperature and conductivity measurements which were taken slightly later in the season and are more reflective of summer values. Site 1 and Site 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 to each other and to the Upstream Control Site so no effects on water quality were obviously discernible from the BDEP project.

Table 2-2: Summary of Water Quality Monitoring Data

Site	Season	Temperature(°C)				Dissolved Oxygen (mg/L)				pH				Conductivity (uS/cm)			
		2017[1]	2019	2020	2021	2017	2019	2020	2021	2017	2019	2020	2021	2017	2019	2020	2021
Up-stream Control	Winter	--	0.6	0.5	0.4	--	11.9	12.4	11.9	--	8.3	8.8	8.7	--	413	403	410
	Spring	--	10.4	8.0	17.5	--	10.1	10.9	9.5	--	8.3	8.5	8.1	--	439	449	286
	Summer	--	16.0	15.5	16.6	--	9.5	9.3	9.3	--	8.7	8.8	8.7	--	332	331	224
	Fall	--	2.5	0.6	1.5	--	11.7	13.1	11.9	--	8.7	8.7	8.7	--	406	380	302
Site 1	Winter	0.04	0.3	0.5	0.4	12.8	12.1	13.0	12.2	8.2	8.5	8.8	8.7	192[2]	435[2]	399	400
	Spring	--	10.5	7.7	17.4	--	10.8	11.0	9.6	--	8.4	8.7	8.7	--	444	449	270
	Summer	--	16.4	15.4	16.7	--	9.1	9.3	9.3	--	8.7	8.8	8.8	--	306	316	221
	Fall	--	2.6	0.7	1.5	--	11.8	13.0	12.0	--	8.6	8.7	8.7	--	411	387	313
Site 4	Winter	0.04	1.0	0.01	0.2	12.8	12.1	12.8	12.1	8.2	8.5	8.7	8.8	192[2]	459[2]	404	403
	Spring	--	10.0	8.0	17.4	--	10.5	11.0	9.5	--	8.4	8.7	8.6	--	441	449	268
	Summer	--	16.7	15.8	16.8	--	9.4	9.2	9.6	--	8.5	8.7	8.8	--	331	317	226
	Fall	--	2.8	0.6	1.7	--	11.4	13.0	12.3	--	8.6	8.6	8.7	--	351	394	312

Notes:

1. 2017 was the baseline data collection year
2. Baseline and 2019/2020/2021 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 2021 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. Some assessments were not possible in 2021 due to the following:

- Site 2 was ice covered during the winter assessment and observation of fish use was not possible.
- Low water levels and high water temperatures in the Bow River combined with high ambient air temperatures resulted in postponement of summer fish sampling until the fall assessment.
- Water levels were very low when fish sampling occurred in November 2021. The majority of Site 1 was dry and fish shelters were out of the water at the time of sampling. Where water was present, it was not deep enough to effectively deploy minnow traps. Fish sampling was only conducted at Site 2 and Site 4.

Fish data were collected to determine overall use of habitats within the study area, as well as species richness and abundance (i.e., catch per unit effort [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 2019, including 6 sportfish and 4 non-sportfish species (KWL, 2020), 9 species were captured, including 5 sportfish and 4 non-sportfish species in 2020, and in 2021, 2 non-sportfish species were captured (Table 2-3). Total fish capture data is presented in Table 2-7; unprocessed fish data is presented in Appendix B – Attachment D. Representative photos of each fish species captured in 2021 are presented in Appendix B – Attachment A, photos 31 and 32.

Results for fish sampling are summarized below. More detail is provided in Appendix B.

- A total of 5 fish from 2 species (trout perch and white sucker) were captured using minnow trapping. Overall, white sucker had that the highest CPUE for individual species captured by minnow trapping.
- No boat electrofishing was conducted in 2021 at any site.
- No minnow traps were deployed at Site 1 due to low water levels.
- Site 2 minnow trapping CPUE was 0.0316 fish/trap hour in 2021, compared to 0.0200 fish/trap hour in 2020 and 0.0235 fish/trap hour in 2019.
- Site 4 minnow trapping CPUE was 0.0211 fish/trap hour in 2021, compared to no results in 2020 and 0.0667 fish/trap hour in 2019.
- The highest CPUE for all species at each site was white sucker.

Table 2-3: 2021 Fish Species Diversity Monitoring Data

Common Name[1]	Scientific Name	Historic Presence in the Bow River[1]	BDEP Site[5]		
			Site 1[6]	Site 2	Site 4
SPORTFISH					
brook trout	*Salvelinus fontinalis*	X			
bull trout	*Salvelinus confluentus*	X			
brown trout	*Salmo trutta*	X			
burbot	*Lota lota*	X			
cutthroat trout[2]	*Oncorhynchus clarki*	X			

Common Name[1]	Scientific Name	Historic Presence in the Bow River[1]	BDEP Site[5]		
			Site 1[6]	Site 2	Site 4
lake whitefish	*Coregonus clupeaformis*	X			
mountain whitefish	*Prosopium williamsoni*	X			
northern pike	*Esox lucius*	X			
rainbow trout[3]	*Oncorhynchus mykiss*	X			
yellow perch[4]	*Perca flavescens*	X			
walleye	*Sander vitreus*	X			
NON-SPORTFISH					
brook stickleback	*Culaea inconstans*	X			
fathead minnow	*Pimephales promelas*	X			
lake chub	*Couesius plumbeus*	X			
longnose dace	*Rhinichthys cataractae*	X			
longnose sucker	*Catostomus catostomus*	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		X	
white sucker	*Catostomus commersoni*	X			X
Total		22			
2021 Species Richness			-	1	1
2020 Species Richness			6	8	3
2019 Species Richness			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.
4. 2021 data includes minnow trapping only as it was the only fish sampling method used.
5. No sampling occurred at Site 1 since the majority of Site 1 was dry and fish shelters were out of the water at the time of sampling. Where water was present, it was not deep enough to effectively deploy minnow traps.

Table 2-4: Site 1 Fish Use Assessment Results

Assessment	Site 1 Observations
Winter – underwater photography and snorkel survey (January 6, 2021)	No fish were observed using the Site 1 fish shelters in 2021. One fish was observed in each of 2019 and 2020 using the fish shelters; the fish could not be identified to species due to high turbidity present at the time of the survey.
Summer – minnow trap sampling and electrofishing survey (November 8-9, 2021)	No sampling was conducted at Site 1 in 2021.

Table 2-5: Site 2 Fish Use Assessment Results

Assessment	Site 2 Observations
Winter – underwater photography and snorkel survey (January 6, 2021)	Not completed due to ice cover.
Summer – minnow trap sampling and electrofishing survey (November 8-9, 2021)	3 fish from 2 species were captured as shown in Table 2-3. • 3 fish were captured by minnow trap (2 trout perch and 1 white sucker) as shown in Table 2-7. • No boat electrofishing was conducted in 2021.

Table 2-6: Site 4 Fish Use Assessment Results

Assessment	Site 4 Observations
Winter – underwater photography and snorkel survey (January 6, 2021)	Site 4 was not surveyed as part of the winter assessment.
Summer – minnow trap sampling and electrofishing survey (November 8-9, 2021)	2 fish from 1 species were captured as shown in Table 2-3. • 2 fish were captured by minnow trap (2 white suckers) as shown in Table 2-7. • No boat electrofishing was conducted in 2021.

Table 2-7 2021 BDEP Monitoring Total Fish Numbers Captured Per Species

Site	BNTR	BURB	LKCH	LNDC	LNSC	MNWH	NRPK	RNTR	TRPR	WHSC	YLPR	TOTAL
Site 1[1]	-	-	-	-	-	-	-	-	-	-	-	-
Site 2	0	0	0	0	0	0	0	0	2	1	0	3
Site 4	0	0	0	0	0	0	0	0	0	2	0	2
2021 Total[2]	0	0	0	0	0	0	0	0	2	3	0	5
2020 Total	9	2	0	1	46	23	1	30	1	7	0	120
2019 Total	2	1	1	1	18	1	1	4	0	10	9	48

Notes:
1. No sampling occurred at Site 1 since the majority of Site 1 was dry and fish shelters were out of the water at the time of sampling. Where water was present, it was not deep enough to effectively deploy minnow traps.
2. 2021 data includes minnow trapping only as it was the only fish sampling method used.

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

Fish Use Comparison

As discussed in Section 1.3, the baseline data and data collected in 2019/2020/2021 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), 2 of 22 species were captured during 2021 (Year 3) of monitoring, including 2 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.

Although fish sampling was not conducted at Site 1 due to low water levels, in past years, it had the highest number of total fish captured and the single highest number of one species captured (rainbow trout) (KWL, 2021a). Bioengineering enhancements are most diverse at Site 1, with boulder clusters, a riprap apron, crib wall fish shelters, and box fascines. The species abundance observed at Site 1 may have been supported by the variation in cover and microhabitats provided by the habitat enhancements.

In 2021, Site 2 had the highest abundance and diversity of fish species and the highest CPUE for minnow trapping. Site 4 had the lowest CPUE of the sites and lowest abundance and diversity. Site 4 had no habitat enhancements and has the least amount of variation in cover and microhabitats.

Because of the limited sampling that occurred in 2021, species composition and fish abundance cannot be compared directly to past monitoring years. However, it was observed that species composition and fish abundance increased from 2019 to 2020. For example, fish use and population data collected in 2020 indicated a higher overall CPUE of 0.2494 fish/electrofishing-second versus 2019 CPUE of 0.0844 fish/electrofishing-second. This trend was anticipated as the BDEP fish habitat enhancements mature and further naturalize post-construction.

Spawning Use

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

In 2021, spring and fall spawning assessments were completed 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 were observed.
- **Fall redd survey**: No redds or fish were identified in the surveyed reach.
- **Fall kick sampling survey**: Suitable mountain whitefish habitat was identified and kicked sampled for 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 (Appendix B – Attachment A, Photos 33 and 34).

2.3 Summary of Findings

For Year 3 (2021) of fish and fish habitat monitoring, results indicate that fish are continuing to use the habitat enhancement structures included in the BDEP. Fish were observed using and were captured within the vicinity of the habitat structures throughout the project area at Site 1 (in past monitoring years), Site 2, and Site 4. Although no fish were observed in the fish shelters, boulder clusters, and surrounding habitats during the fall assessment, mountain whitefish eggs were documented in the upstream section of Site 1. The highest abundance and diversity of fish species were captured at Site 2 in 2021.

Based on the fish use monitoring results from 2019, 2020, and 2021, Sites 1 and 2 are providing high quality fish habitat in comparison to Site 4.

Photo 2-2: White sucker (left) and trout perch (right) captured in the Bow River on November 9, 2021.

3. Wildlife

Photo 3-1: BDEP wildlife passage corridor looking downstream toward 17th Avenue SE bridge (July 21, 2021)

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). As in 2019 and 2020, wildlife monitoring was conducted again in 2021 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 2021 for Sites 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 completed following Year 3 (2021) monitoring and presented in the 2021 monitoring report.

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 South East Bus Rapid Transit (SEBRT) bridge. The wildlife corridor was a 6 m wide vegetated soil area classified as “wildlife-friendly” riprap to allow for wildlife travel along the edge of the Bow River. 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 has used conventional riprap, including large boulders placed along the bank and into the edge of the Bow River, as a bank restoration method. Site 4 was retrofitted with vegetation as part of BDEP; however, it was selected to represent a control site, where baseline conditions can be used to compare the effectiveness and trends observed in Sites 1 and 2, which are considered the treatment areas of the project.

3.1 Methods

Wildlife monitoring was completed in compliance with the BEMP (Hemmera, 2018). The Year 3 (2021) monitoring scope was composed of trail camera monitoring at Site 1 to assess wildlife corridor usage by mammals, and breeding bird surveys and wildlife feature monitoring at all three Sites to assess habitat suitability and wildlife use. Wildlife features including two known bank swallow colonies previously identified during the *Preliminary Natural Assessment Report* (Hemmera, 2017), and during Year 1 (2019) and Year 2 (2020) of the monitoring program, were also monitored in Year 3 (2021).

Baseline Assessment

A summary of the baseline assessment wildlife assessment from 2017 is provided below (Hemmera, 2017b). No field monitoring or surveys were completed as part of the baseline wildlife assessment.

- A review of FWMIS resulted in 12 provincially or federally listed species that were identified as previously occurring within 1,000 m of the project (Table 3-1).
- 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, 2018; AEP, 2017a).

Breeding habitat for bank swallows and nesting raptors were identified within the project area during the baseline assessment, with two bank swallow colonies identified in Site 2 (BANS01,

Figure 3-1) and Site 4 (BANS02,

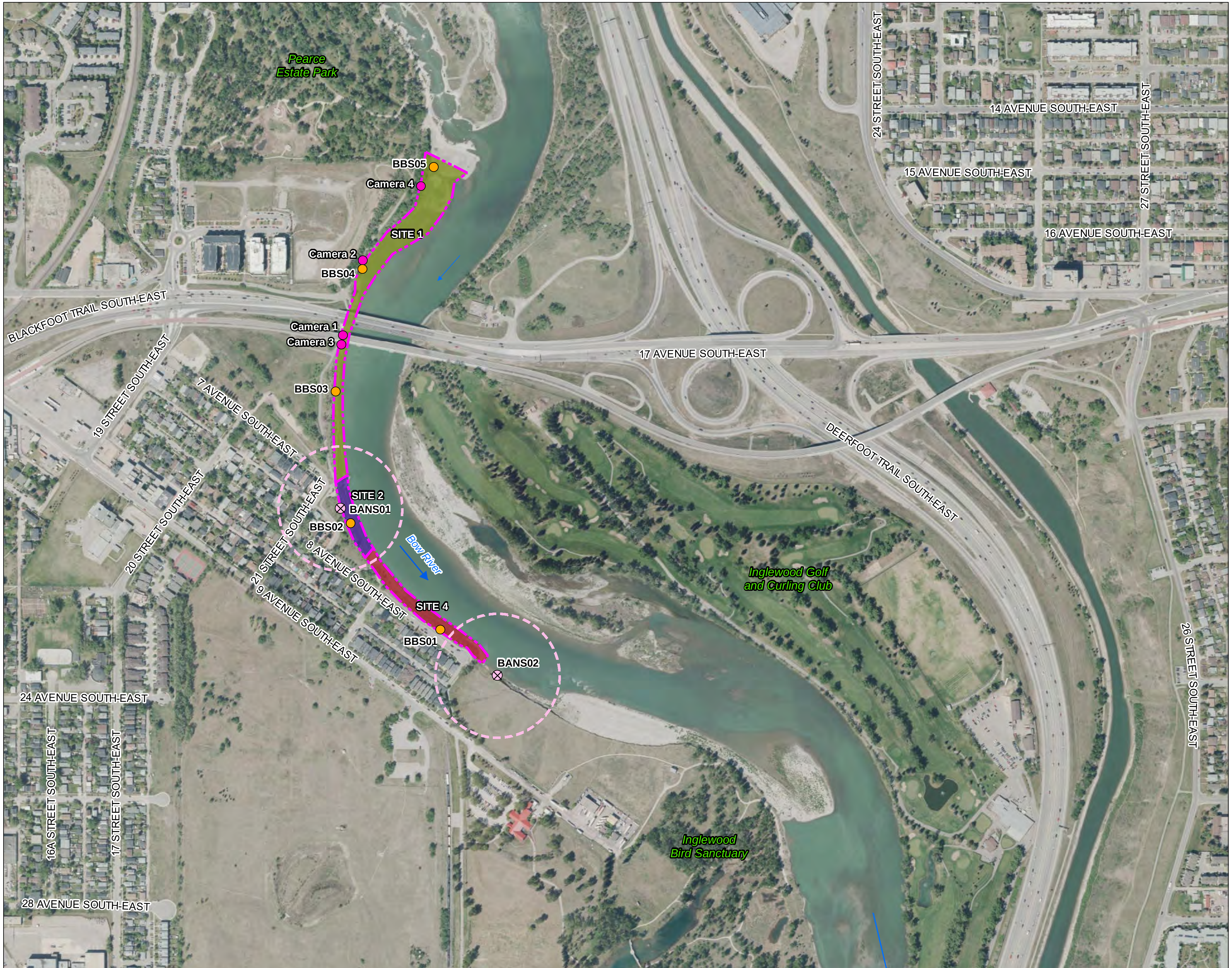
- Figure 3-1). Bank swallows are a listed species by AEP (Sensitive), SARA (Threatened) and COSEWIC (Threatened) due to global population decline (98% population loss in Canada over the last 40 years) (AEP, 2017b; Government of Canada, 2016; COSEWIC, 2008).
- There is suitable habitat present in and 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.

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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2021 Monitoring

Wildlife monitoring included breeding bird and nesting surveys at Sites 1, 2 and 4 and monitoring of four wildlife cameras at Site 1 as described below.

Breeding Bird and Nest Surveys

Year 3 (2021) breeding bird surveys and wildlife feature monitoring consisted of five breeding bird survey plots at the same locations as Year 1 (2019) and Year 2 (2020) monitoring. Survey plots BBS03, BBS04 and BBS05 were located within Site 1, BBS02 located within Site 2, and BBS01 located within Site 4 (Appendix B Figure 7). Two rounds of breeding bird survey point counts were completed at each plot location on June 8 and June 22, 2021. These surveys follow the methods outlined in the *Sensitive Species Inventory Guidelines* (ESRD, 2013) for breeding birds and raptors.

Known wildlife features included active raptor nests and two known bank swallow colonies (Appendix B Figure 7) where monitoring and estimates of use were also completed on June 8 and June 22, 2021. Bank swallow colony use was assessed by recording the total number of bank swallows entering and exiting bank cavities over a five-minute period.

All surveys were conducted under appropriate conditions for the identification breeding birds (i.e., appropriate time of day, temperatures greater than 0°C, winds less than 20 km/hr, and no precipitation).

Wildlife Camera Monitoring (Site 1 only)

Four wildlife monitoring cameras were installed at Site 1 to monitor use of the wildlife corridor under the Cushing Bridge/17th Avenue SE Bridge corridor. Three wildlife monitoring cameras were deployed within Site 1 at the same locations as 2019 and the additional location in 2020 (Appendix B Figure 7) as described below. Camera locations were named following the convention established in the Year 1 report (KWL, 2020a) which differed in Year 2 (KWL, 2021a).

- Camera 1 (11U 709343E 5658206N) was located under the existing 17th Avenue SE Bridge facing east and angled downwards from its elevated mounting location toward the Bow River. Note that Camera 1 was referred to as Camera 3 in the 2020 report. Camera 1 was deployed on January 21, 2021 and removed on November 9, 2021. It was functional for the full study period of 292 days.
- Camera 2 (11U 709370E 5658328N) was located approximately 126 m upstream from the 17th Avenue SE bridge on a storm drain outfall and orientated west toward the Bow River. Note that Camera 2 was referred to as Camera 4 in the 2020 report. Camera 2 was deployed on January 21, 2021 and was found to have been stolen on April 27, 2021 – despite additional security measures including padlocks, lock cables, and electronic code locks on the camera. Camera 2 was not replaced. Camera 2 was functional for 69 days.
- Camera 3 (11U 709341E 5658191N) was located 15 m downstream from the 17th Avenue SE Bridge on a on a metal signpost and was orientated in a northeast direction toward the shoreline underpass and the Bow River. Note that Camera 3 was referred to as Camera 2 in the 2020 report. Camera 3 was deployed on January 21, 2021 and was found to have been stolen on April 27, 2021 – despite additional security measures including padlocks, lock cables, and electronic code locks on the camera. Camera 3 was not replaced. Camera 3 was functional for 69 days.

- Camera 4 (11U 709459E 5658451N) was added in 2020 and included again in 2021. It was situated along a wooded path approximately 148 m upstream from Camera 2, mounted to a tree and oriented in a northeast direction to capture wildlife using a pathway through some shrubs in a more vegetated section of Site 1. Note that Camera 4 was referred to as Camera 5 in the 2020 report. Camera 4 was deployed on January 21, 2021 and was removed on July 2, 2021 due to public privacy concerns and consistent vandalism. It was not replaced and all photographs have been destroyed due to public privacy concerns. Camera 4 was functional for 181 days.

In total, there were 611 active camera days in 2021 compared to 926 in 2020 and 607 in 2019. An additional camera was installed in 2020 and 2021, leading to more active camera days than 2019. The reduction in camera days in 2021 compared to 2020 is due to the vandalism, theft and technical issues noted above, in the detailed monitoring report in Appendix B, and in previous BDEP monitoring reports (KWL, 2020a; KWL, 2021a).

Wildlife cameras were programmed to capture three images with a one second spacing between images when triggered by motion detection. All cameras were programmed not to trigger for five seconds following a motion triggered event, and camera sensitivity was set to the medium/high mode. Wildlife cameras were generally aimed towards the Bow River, away from the adjacent pedestrian pathway to avoid abundant photographs of human activity on the pathway.

The placement of each wildlife trail camera in Site 1 was intended to track wildlife movement and determine the use of the treatment area under the 17th Avenue bridge by terrestrial mammals as a wildlife corridor. The primary focus of the wildlife monitoring was large and medium-sized mammals as they would be more influenced by a functioning wildlife corridor than smaller or mobile species such as birds or squirrels as they could use smaller routes or routes not available to larger mammal species.

The Camera 4 location was new in 2020 and was added to provide coverage of the furthest upstream extent of Site 1. Similar to the Camera 2 location, the Camera 4 location captured the use of reference riparian habitat to compare wildlife usage with the treatment areas adjacent and beneath the 17th Avenue SE Bridge.

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 at the Site 1 wildlife corridor. Also, no data collection on wildlife/vehicle interaction on Blackfoot Trail/17 AVE SE or Cushing Bridge was conducted as part of the study.

3.2 Results

The following outlines the results for wildlife monitoring at each site. A Summary of Findings is included in Section 3.3, page 46.

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 34 species over Year 1 (2019), Year 2 (2020), and Year 3 (2021) including three listed species as shown in Table 3-5.

In addition to the observations recorded during the standardized breeding bird plots, any additional wildlife observations were recorded. These observations included American crow (Corvus brachyrhynchos) in 2019 and 2021, blue-winged teal (Anas discors) in 2020, Brewer's blackbird (Euphagus cyanocephalus) in 2020, pine siskin (Spinus pinus) in 2019 and 2021, ring-billed gull (Larus delawarensis) in 2020, and rock pigeon (Columba livia) in 2020. None of the incidental species observed are listed provincially or federally.

Bank swallow was observed in 2019 and 2020 during the breeding bird surveys, but was only observed incidentally in 2021.

The total number of individual birds recorded in Year 1 (2019) at 182 birds was approximately twice that of Year 2 (2020) at 98 birds and Year 3 (2021) at 118 birds due to a flock of about 70 Franklin's gulls observed in 2019, which were not observed in any other monitoring year. Otherwise, the total number of birds that were recorded in each survey year are in the same range. A total of 36 bird species have been identified over Year 1 to Year 3 breeding bird surveys. Year 1 surveys identified 26 total species, Year 2 surveys identified 24 species, and Year 3 surveys identified 23 species.

For Site 1, Year 3 (2021) surveys recorded 27 more individuals and one fewer species than the Year 2 (2020) survey (Table 3-5). The most prevalent species observed at Site 1 in 2021 was common merganser (13 individuals) followed by house sparrows (10 individuals). For Site 2, Year 3 (2021) surveys recorded 1 fewer individual and 1 more species compared to Year 2 (2020) surveys (Table 3-5). For Site 4, Year 3 (2021) surveys observed a reduction of 6 in number of individuals and 1 species compared to Year 2 (2020) surveys (Table 3-5).

The species of management concern identified in Year 1 (2019) (bank swallow, least flycatcher and western wood-pewee) and Year 2 (2020) (bank swallow) surveys were not recorded in 2021. Bank swallow were observed at Site 1 and Site 2, while least flycatcher and western wood-pewee were observed at Site 1. None of the species of management concern were identified at Site 4.

Similar to results from past monitoring years, Site 1 represented the highest number of individuals and species recorded compared to Site 2 and Site 4 in Year 3 (2021). Site 2 represented about 40% of the number of species observed in Site 1. Site 4 recorded approximately 20% of the total species observed in Site 1. The increased activity at Site 1 and Site 2 over Site 4 could be because Site 1 incorporates a much larger area with 3 breeding bird survey plots compared to a single survey plot for each of the other sites. However, it could also be the result of differences in vegetation and suitable nesting habitat availability between the sites as Site 1 was observed to have the most diverse habitat conditions due to proximity to Pearce Estates Park, followed by Site 2 and Site 4.

The peak number of bank swallow adults observed in Year 1 (2019), Year 2 (2020) and Year 3 (2021) at two bank swallow nesting colonies (Site 2-BANS01, and downstream of Site 4-BANS02) are shown in Table 3-6. Bank swallow use at BANS01 has declined annually. The reasons for this decline are not known. The BANS02 colony was covered in geotextile fabric during the June 8, 2021 survey and was not observed. Interestingly, the same number of individuals were counted at the BANS02 site during the June 22, 2021 survey as in Year 1 (2019); however there is no clear trend since counts have varied over the survey years.

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

Assessment	Site 1 Observations
Species	A total of 77 individuals representing 19 different species were observed in Year 3 (2021) monitoring (Table 3-5). This compares to 50 individuals representing 20 different species in Year 2 (2020), and 129 individuals representing 16 different species in Year 1 (2019) (Table 3-5). No listed species were observed in 2021. Species of management concern were observed in 2020 (bank swallow) and 2019 (least flycatcher and western wood-pewee) as noted in Table 3-5.
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	No active songbird nests were observed at Site 1 in Year 3 (2021) or Year 2 (2020) in comparison to four stick nests that were observed in Year 1 (2019). No active raptor nests were observed in any monitoring year to date.

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

Assessment	Site 2 Observations
Species	A total of 28 individuals representing 11 different species were observed at Site 2 in Year 3 (2021) (Table 3-5). This compares to 29 individuals representing 10 different species in Year 2 (2020), and 68 individuals representing 8 different species in Year 1 (2019) (Table 3-5). No listed species were observed in 2021. Species of management concern were observed in 2020 (bank swallow) and 2019 (bank swallow and least flycatcher) as noted in Table 3-5.
Habitat	The habitat within Site 2 consists of grasses and shrubs with a city park habitat and pedestrian path adjacent to it.
Nesting	No active songbird nests were observed at Site 2 in Year 3 (2021), Year 2 (2020) or Year 1 (2019). The bank swallow colony identified in the baseline assessment and in Year 1 (2019) was observed at the site again in Year 2 (2020) and Year 3 (2021). A total of 12 bank swallows were identified at the colony in 2021 compared to 22 individuals in 2020 and 30 individuals in 2019. No active raptor nests were observed in any monitoring year to date.

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

Assessment	Site 4 Observations
Species	A total of 13 individuals representing 6 different species were observed in Year 3 (2021) (Table 3-5). This compares to 19 individuals representing 7 different species in Year 2 (2020), and 24 individuals representing 6 different species in Year 1 (2019) (Table 3-5). No listed species were observed in any monitoring year.
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 is located south of Site 4. A total of 34 bank swallows were identified at the colony in 2021 compared to 55 individuals in 2020 and 34 individuals in 2019. No active raptor nests were observed in any monitoring year to date.

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		
		2019	2020	2021	2019	2020	2021	2019	2020	2021
American goldfinch	*Carduelis tristis*		1							
American robin	*Turdus migratorius*	5	4	1		1				
American wigeon	*Anas americana*			2	1				1	
bank swallow[1]	*Riparia riparia*		1		43	7				
black-billed magpie	*Pica hudsonia*	2		5	2	1	2	5	1	
black-capped chickadee	*Poecile atricapillus*	1	2	3		1	4			
brown-headed cowbird	*Molothrus ater*	4	1	2			1			
Canada goose	*Branta canadensis*	3	2					6		
cedar waxwing	*Bombycilla cedrorum*		4							
Chipping sparrow	*Spizella passerina*					1				
clay-colored sparrow	*Spizella pallida*		3	5			1	3	6	3
common goldeneye	*Bucephala clangula*	1								
common merganser	*Mergus merganser*	2	3	13						
common raven	*Corvus corax*		3	1						
double-crested cormorant	*Phalacrocorax auritus*	2	1							
European starling	*Sturnus vulgaris*	1		1						
Franklin's gull	*Leucophaeus pipixcan*	70		2	16					
Gadwall	*Anas strepera*	4								
gray catbird	*Dumetella carolinensis*						1			
House finch	*Carpodacus mexicanus*									1
house sparrow	*Passer domesticus*	2		10	3	12	6		6	3
house wren	*Troglodytes aedon*	6	1	1		1				
Killdeer	*Charadrius vociferus*	3	1	2						
least flycatcher[2]	*Empidonax minimus*	3			1					
Lincoln's sparrow	*Melospiza lincolnii*						1			1
Mallard	*Anas platyrhynchos*	2	1	2		2	3	8		
Northern flicker	*Colaptes auratus*		1							
red-winged blackbird	*Agelaius phoeniceus*	4	4	8	1	1	4		1	
song sparrow	*Melospiza melodia*	3	7	6		2	1	1	1	4
spotted sandpiper	*Actitis macularius*	3	3	4	1				3	
tree swallow	*Tachycineta bicolor*		1					1		1
western wood-pewee[3]	*Contopus sordidulus*	1								
warbling vireo	*Vireo gilvus*	2		1						
yellow warbler	*Dendroica petechia*	5	6	8			4			
TOTAL NUMBER OF INDIVIDUALS		**129**	**50**	**77**	**68**	**29**	**28**	**24**	**19**	**13**

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: Bank Swallow Observations

Survey Year	Bank Swallow Count (Maximum)	
	BANS01 (Site 2)	BANS02 (Site 4 D/S)
Year 1 (2019)	30	34
Year 2 (2020)	22	55
Year 3 (2021)	12	34

Wildlife Camera Monitoring (Site 1 only)

As discussed in Section 3.1 above, four wildlife monitoring cameras were installed at Site 1 in 2021 at the locations shown in (Appendix B Figure 7). Camera 1 produced 255 images, Camera 2 produced 283 images, Camera 3 produced 73 images, and Camera 4 produced 1067 images for a total of 1678 photographic observations. Note that images from Camera 4 have since been destroyed due to public privacy concerns. Additionally, many of the camera installations have been subject to vandalism and theft, resulting in loss of data and a reduction in overall active camera days each year. This issue has been communicated to The City and will be addressed in future monitoring years.

The species identified for each wildlife camera are presented in Table 3-8 for Year 1 (2021), Table 3-9 for Year 2 (2020), and Table 3-9 for Year 1 (2019). A total of 6 wildlife species were identified 2021 and 7 in both 2020 and 2019. There were 203 wildlife observations in Year 3 (2021) compared to 317 wildlife observations in 2020 and 212 observations in 2019. Note that Canada goose (*Branta canadensis*) was included in the 2019 analysis but not the 2020 or 2021 analysis. The higher number of observations in 2020 are likely due to the longer active camera days where there were approximately 50% more active camera days than 2021 and 2019.

While direct comparisons between recorded occurrences capture between camera stations due to variable deployment periods, Camera 4 recorded the most mammal occurrences (153 observations) despite not having the most camera days (Table 3-7). This is likely due to the vegetation cover at its location relative to the other camera locations. Camera 4 also observed the most mammal diversity with all 6 mammal species observed in 2021. It was the only camera to capture the American beaver, eastern gray squirrel and striped skunk.

As shown in Table 3-7, eastern gray squirrel had the most observations at 83 observations in Year 3 (2021) but were observed solely at Camera 4. White-tailed deer were observed at two locations (Camera 1 and Camera 4) and were the second-most observed species (64 observations). White-tailed jackrabbit was observed across three cameras (Camera 1, Camera 3, and Camera 4) and had the third highest observations (33 observations), with most occurring at Camera 4 (24 observations). Coyote were also observed at three of the four camera locations (Camera 2, Camera 3, and Camera 4), with the fourth highest observations (18 observations).

Over the three monitoring years, a total of 8 different mammal species have been observed, with white-tailed deer (*Odocoileus virginianus*) (233 total observations), coyote (*Canis latrans*) (131 total observations), and white-tailed jackrabbit (*Lepus townsendii*) mean (113 total observations) being the most prevalent (Table 3-10). Both American beaver (*Castor canadensis*) and common raccoon (*Procyon lotor*) were only photographed once, both a Camera 4. Striped skunk (*Mephitis mephitis*) was photographed on 5 occasions by three different cameras over three years. Mule deer (*Odocoileus hemionus*) were identified at 3 locations for a total of six individual observations over the three monitoring years.

Mean use is a measure of species occurrence which accounts for both the number of individuals and the number of monitoring days. Mean use by species by monitoring year is provided in Table 3-10. The most consistent mammal activity across all three monitoring years at Site 1 consisted of coyote, white-tailed deer and white-tailed jackrabbit. Coyote mean use increased greatly from Year 1 (2019) to Year 2 (2020), but then decreased to approximately Year 1 (2019) levels again during Year 3 (2021). White-tailed deer mean use increased greatly from Year 1 (2019) to Year 2 (2020) and stayed high during Year 3 (2021). On average, white-tailed jackrabbit mean use remained relatively consistent from Year 1 (2019) through Year 3 (2021). Eastern gray squirrel mean use appears high, but it was photographed exclusively by Camera 4 and was likely the same individuals photographed daily within their small home range.

Over the three years of the wildlife monitoring program, deer presence was recorded at all cameras throughout Site 1. Most notably deer were observed at Camera 1 under the 17th Avenue SE bridge, often at night, suggesting that the wildlife corridor is providing effective passage for this species. The results also suggest that deer are using all areas of Site 1 with similar frequency. Coyote observations within Site 1 also show a similar pattern of even distribution across all camera locations. These results suggest that the wildlife corridor at the BDEP provides effective passage for large mammals including both coyote and deer.

While wildlife camera monitoring was not conducted at Site 4, it is expected that conditions at Site 1 are better for wildlife passage than the unvegetated portion of Site 4 since the 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).

Table 3-7 Total Sum of Species occurrences by Camera in Site 1 in 2021

Camera	2021 Species[1]								Total
	American Beaver	Coyote	Deer species[2]	Eastern gray squirrel	Mule deer	Striped skunk	White-tailed deer	White-tailed jack rabbit	
Camera 1	-	-	2	-	-	-	30	7	39
Camera 2	-	1	-	-	-	-	-	-	1
Camera 3	-	8	-	-	-	-	-	2	10
Camera 4	1	9	-	83	-	3	34	24	154
Total[3]	**1**	**18**	**2**	**83**	**-**	**3**	**64**	**33**	**204**

Notes:
1. Species included in this table includes all observations of terrestrial mammals only.
2. Deer species are individuals that could not be differentiated 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.

Table 3-8 Total Sum of Species occurrences by Camera in Site 1 in 2020

Camera	2020 Species[1]							Total
	Common racoon	Coyote	Eastern gray squirrel	Mule deer	Striped skunk	White-tailed deer	White-tailed jack rabbit	
Camera 2	-	39	-	-	1	39	11	90
Camera 3	1	16	-	-	-	60	11	88
Camera 4	-	14	-	-	-	36	-	50
Camera 5	-	31	25	2	-	18	13	89
Total[2]	1	100	25	2	1	153	35	317

Notes:
1. Species included in this table includes all observations of terrestrial mammals. 2020 data does not include Canada goose (Branta canadensis) as they are not limited to terrestrial movement like the mammal species. Canada goose has been observed to use the corridor habitat; however, they are also able to fly or swim through the Project area without relying on the movement corridor. 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. Total is the number of individuals observed in pictures as “new individuals” to avoid any double counting of the same individual.

Table 3-9 Total Sum of Species occurrences by Camera in Site 1 in 2019

Camera	2019 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 differentiated 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

Table 3-10 Species Abundance, Mean Use, and Composition for Site Camera Monitoring Program

Species	Number of Individuals			Mean Use[1]			Composition of Total Species Occurrence[2] (%)		
	2019	2020	2021	2019	2020	2021	2019	2020	2021
American beaver	-	-	1	-	-	<0.01	-	-	0.5
Canada goose[3]	126	n/a	n/a	0.21	n/a	n/a	59	n/a	n/a
Common racoon	-	1	-	-	<0.01	-	-	0.3	-
coyote	13	100	18	0.02	0.11	0.11	6	32	9
deer species	6	-	2	0.01	-	<0.01	3	-	1
Eastern gray squirrel	-	25	83	-	0.03	0.14	-	8	41
great blue heron[3]	1	n/a	n/a	<0.01	n/a	n/a	0.5	n/a	n/a
mule deer	4	2	-	0.01	<0.01	-	2	0.7	-
striped skunk	1	1	3	<0.01	<0.01	<0.01	0.5	0.3	1.5
white-tailed deer	16	153	64	0.03	0.17	0.11	8	48	31
white-tailed jack rabbit	45	35	33	0.07	0.04	0.05	21	11	16
Total	212	317	204	0.35	0.35	0.42	100	100	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.
3. While Canada goose (*Branta canadensis*) and great blue heron were included in the 2019 analysis, these species were not included in the 2020 camera analysis to limit the analysis to mammal species which rely on the corridor to pass through the Project area

3.3 Summary of Findings

The Year 3 (2021) breeding bird surveys resulted in the identification of 23 species. 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 again during the 2021 survey; otherwise, no nests were observed at any of the sites in 2021. Site 1 (77 individuals from 19 species) and Site 2 (28 individuals from 11 species) showed increased bird activity relative to Site 4 (13 individuals from 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.

Several trends have been identified as part of the breeding bird surveys as follows:

- The number of bird species observed during breeding bird surveys from Years 1 to 3 has declined slightly from 26 (Year 1) to 23 (Year 3). This observed change in species diversity is small and may be attributed to the number of survey locations and limited Project size. As shrubs and trees planted as part of the Project fully establish along the bank, species diversity is expected to increase.
- Bank swallow use of the nesting habitat at BANS01 has declined annually, while use at BANS02 has varied.
- No raptor nests have been identified at the Project during the first three years of the monitoring period.

The wildlife camera monitoring program identified animals utilizing the wildlife corridor created under the Cushing/17th Avenue SE bridge. A total of 6 wildlife species were identified through observations of 203 individuals in Year 3 (2021). Both large and medium-sized mammals have been photographed at all camera locations and appear to be using the wildlife corridor as intended. Larger mammals (white-tailed deer and coyote) were among the most abundant species, with relatively equal distributions between all camera locations. White-tailed deer, coyote and white-tailed jackrabbit were most frequently captured by Camera 1 which is located under the 17th Avenue SE bridge; however, image series of these species represented movement north or south along the corridor under the bridge that was primarily at night.

The consistently high mean use in Year 2 (2020) and Year 3 (2021) in comparison to Year 1 (2019), indicates that the wildlife corridor at the BDEP is providing effective passage for large mammals. Smaller mammal species were only photographed at Camera 4 (e.g., American beaver, common racoon, eastern gray squirrel, striped skunk) and have not shown movement through the site at this point. This might change over time, as the vegetation establishes enough to provide further cover for small animals.

Photo 3-2: Two coyotes (Canis latrans) passing under the 17th Avenue SE bridge (February 11, 2021)

4. Riparian Health

Photo 4-1: BDEP Site 1 on June 18, 2021

4.1 Methods

Riparian Health monitoring was completed in compliance with the BEMP (Hemmera, 2018). **Riparian Health Assessments** (RHAs) (**"Site" scale**) and a re-visit **Riparian Health Inventory** (RHI) (**"Project" scale**) were completed at the BDEP in 2021. Each BDEP site was also given a **Bank and Riparian Quality Index (BRQI) rating**. This index, developed as part of the general RMP (KWL 2018), was added to the accepted monitoring protocols for the BDEP in 2021 with approval from The City and AEP. The BRQI was added to address inherent constraints of Riparian Health score metrics, whereby watershed scale parameters (e.g., upstream dams, water withdrawals and diversions) pose permanent limits to a maximum achievable score, regardless of site-level improvements. All bioengineering projects also have inherent Riparian Health score deductions due to short-term bank or riparian structural alteration impacts, common to most techniques including both 'soft' and 'hard' engineering approaches. As such the Riparian Health metrics are not well suited for comparative bioengineering treatment assessments. The BRQI, by comparison, focuses mainly on vegetation cover, composition and plant community structure indicators to better and more directly inform progress toward habitat restoration goals at a local site scale. The BRQI score, unlike the Riparian Health score, is sensitive to local site-level management interventions.

RHA Methodology

Baseline Riparian Health Assessments (RHAs) for Sites 1, 2 and 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 (also known as "Cows and Fish") (Hemmera, 2017c). RHA monitoring at the three BDEP sites was repeated in 2019, 2020 and 2021. The 2021 assessments, discussed below, occurred on September 30 and October 1, 2021 (field data sheets are provided in Appendix C). RHA polygon boundaries for each site are shown in Figure 1-1. RHA monitoring in all years was completed by Longview Ecological.

"Riparian health" refers to the ability of a site to perform certain key ecological functions such as sediment trapping, bank building and maintenance, water storage, aquifer recharge, flow energy dissipation, maintenance of biotic diversity and primary production. In summary, for each RHA, 15 vegetation and soil/hydrology factors were assessed to give an overall rating of how well each particular reach is functioning ecologically (Table 4-1). Each site was rated out of a total possible score of 81 points (Table 4-1) and then placed into one of three riparian health categories: *Healthy*, *Healthy with Problems* or *Unhealthy* (Table 4-2).

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[1]	/ 9
12. Control of flood peak and timing by upstream dam(s)[1]	/ 9
13. Percent of riverbank structurally altered by human activity[2]	/ 6
14. Percent of human alteration to the remainder of the polygon[2]	/ 3
15. Natural floodplain accessibility	/ 6
Total score	**/ 81**

Notes:
1. RHA parameters 11 and 12 cannot be influenced at a site-level scale through interventions such as a riverbank bioengineering site like the BDEP. Low or zeros scores are given on these parameters to RHA/RHI sites in Calgary due to irrigation withdrawals for parameter 11 (Western Irrigation District canal at Harvie Passage) and upstream dams on the Bow River for parameter 12.
2. Regardless of the improvement to other parameters that are a result of bioengineering projects with a structural component (e.g., vegetated crib walls), bioengineering riverbank projects are considered a bank structural alteration in the short term and they receive low scores for parameters 13 and 14.

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.

RHI Methodology

Per the BEMP (Hemmera, 2018), **baseline** (**July 22, 2016**) and **re-visit** (**July 15, 2021**) Riparian Health Inventory (**RHI**) monitoring for the **overall BDEP site ("BOW95")** was completed by the Alberta Riparian Habitat Management Society (Appendix D). The BOW95 RHI polygon is 1.5 ha in size and encompasses BDEP Site 1 downstream of Cushing Bridge, Site 2 and Site 4 (Figure 1-1).

The BOW95 Riparian Health score was based on the same 15 vegetation and soil/hydrology factors given in Table 4-1. **Riparian Health 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.** In addition to riparian health parameter data (Table 4-1), RHIs (i.e., Lotic Inventories) also entail photography monitoring and collection of detailed vegetation data, physical site data, some wildlife data and trend commentary (Hansen, et al., 2000). Vegetation data includes vascular plant species canopy cover estimations, as well as age class breakouts for each tree and shrub species (i.e., proportional cover from seedling/sapling, mature, decadent and/or dead individuals). In addition, riparian plant community types are characterized by comparison to described reference riparian plant community types for the Grassland Natural Region of Alberta (Thompson & Hansen, 2002). Herbivory intensity (i.e., wildlife browse utilization) is assessed for all shrubs and for tree seedlings and saplings. Beaver utilization intensity is tracked at a site level based on numbers of chewed stem observations (1-25, 26-100 or >100) and presence/abundance of dams or lodges. Physical site RHI data includes channel morphology and condition (e.g., bank stability, lateral cutting erosion); non-vegetated ground cover breakouts; as well as qualitative and quantitative data related to causes/kinds of natural versus human-caused bare ground and bank/polygon alterations. Supporting data collected as part of RHIs does not all directly inform Riparian Health scores, but it is useful for monitoring and site management purposes. Unlike an RHA where Riparian Health scores are based directly on ocular field survey scores, RHI scores for vegetation parameters 1 to 5a, are computationally derived based on individual tree and shrub species canopy cover and age class / browse utilization breakouts by species.

Riparian Health Score Limitations

Riparian Health scores (based on RHI/RHA monitoring) represent how effectively a site can perform ecological functions based on the severity of degradation of vegetation and soil/hydrology features **compared to a natural, undisturbed 'reference' state.** Within the context of the City of Calgary, there is a recognition that due to permanent impacts from urban development, upstream damming, flow regulation and diversions, it is impractical to achieve 'healthy' benchmarks in many instances. Thus, despite site-level interventions such as bioengineering or riparian planting projects, maximum achievable Riparian Health scores are ultimately constrained by watershed-scale factors. Moreover, watershed-scale parameters related to removal or addition of water from/to the river system (#11) and control of flood peak and timing by upstream dam(s) (#12) are more heavily weighted than any other riparian health parameters (Table 4-1). This reflects the importance of these factors in influencing natural flows, water availability and natural flooding processes all of which are integral to sustaining large riverine riparian ecosystems. Ultimately, the long-term success and maintenance of site-level projects may be constrained by these watershed factors.

Another limitation affecting achievable Riparian Health scores in Calgary are inherent constraints from bank or riparian structural alterations associated with flood/erosion control and/or recreation, where these management considerations are a priority. Permanent structural alterations from these impacts will dictate achievable scores for parameters #13 and #14 (Table 4-1). In addition, as discussed, both "soft" and "hard" bioengineering techniques with a structural component, are considered a bank/polygon structural alteration in the short-term, regardless of other inherent ecological benefits. Thus, the overall Riparian Health score is not well suited for comparative assessment of bioengineering techniques at least in the short-term.

At a site-specific scale, Riparian Health scores may therefore not be appropriate where the monitoring intent is to evaluate how bioengineering treatments compare in terms of progress toward riparian habitat enhancement objectives. To evaluate and compare bioengineering site treatments on their own merits, eliminating confounding regional scale factors and permanent alteration impacts, a novel index rating was developed, as discussed below.

BRQI Methodology

Instead of a 'natural' (undisturbed) reference condition, the novel Bank and Riparian Quality Index (BRQI) allows bioengineering site treatments to be compared according to a relative naturality gradient. Only site-scale factors are considered, and watershed scale factors are excluded from consideration. This has the advantage of allowing BDEP sites to be directly compared, contrasted, and monitored over time relative to site-specific treatment applications only. The BRQI rating provides a relative measure of habitat condition for control and treatment sites versus comparison to an undisturbed reference habitat. As such the rating is informative to bioengineering practitioners and City of Calgary Parks and Water Resources managers.

The BRQI is based on an assessment of eight criteria as listed in Table 4-3. Many of the vegetation parameters overlap with Riparian Health vegetation metrics. BRQI ratings can be categorized as "Good" (>75%), "Fair" (50-74%) or "Poor" (<50%) as per the criteria described in Table 4-4. The BRQI was developed from several previous ecological health and quality indices for riverbanks including the Riparian Health Inventory (Fitch, et al., 2014), the QBR index[1] (Munne, et al., 2003), Riparian Quality Index (Gonzalez del Tanago & Garcia de Jalon, 2011), Riparian Forest Evaluation index (Magdaleno & Martinez, 2014), and the Alberta Forest Health Assessment scoring for plant community structure (Adams, et al., 2016).

The BRQI is meant specifically to track vegetation changes at a bank or riparian restoration site where native plantings have been installed. It is intended to monitor progress over time toward a desired native plant community type, based on the restoration objectives and environmental conditions of a site (KWL, 2018). Reference conditions for the BDEP sites are assumed to correspond to a native riparian forest that has multiple life form layers (i.e., tree, shrub, forb and graminoid components) and structural height layers (i.e., overstory, understory and ground cover vertical layers).

BRQI assessments were completed at each of the BDEP sites in 2019 and 2021 as part of the ongoing RMP project (KWL, 2020b; KWL, 2022). The vegetation and physical variable data for the BRQI is derived from the pin-point transects. If multiple transects were completed at a particular site, BRQI values were weighted by the total area of each bioengineering technique (if more than one technique was used) or simply averaged if more than one transect was completed in the same technique.

[1] "QBR" derives from the Catalan abbreviation "Qualitat del Bosc de Ribera' (in English, "Riparian Forest Quality").

Table 4-3: BRQI Assessment Criteria

Parameter	Score
Vegetation	
1. Precent vegetation cover	/ 12
2. Percent cover of invasive species	/ 12
3. Percent cover of disturbance-increaser species	/ 12
4. Percent cover of native trees and shrubs	/ 12
5. Plant community structure	/ 12
6. Percent cover of regenerating preferred tree and shrub species	/ 12
Physical	
7. Percent cover of human-caused bare ground	/ 12
8. Percent cover of riprap and concrete	/ 16
Total score	/ 100

Table 4-4: BRQI Scores and Ratings

BRQI Score (%)	Rating	Description
75-100	***Good***	A bank or riparian area that is well vegetated with a structurally diverse plant community comprised of multiple life-forms, including preferred native species and regenerating trees/shrubs, and with little to no human-caused bare ground or artificial hardened (impervious) surface.
50-74	***Fair***	A bank or riparian area with some human-caused bare ground and/or hardened surface and/or intermediate natural vegetation cover (not limited to weedy species); fair habitat structure; and/or at least some regenerating preferred trees/shrubs.
0-49	***Poor***	A bank or riparian area with mainly human-caused bare ground and/or hardened surface and/or little to no natural vegetation cover (other than weedy species), poor habitat structure and few to no regenerating preferred trees/shrubs.

4.2 Results

RHA Results

Results from the 2016 to 2021 RHAs for sites 1, 2 and 4 are summarized in Table 4-5 and Table 4-6. RHA field data sheets are provided in Appendix C. **All three sites have improved substantially since baseline (2016) conditions, with score increases ranging from +9% (Site 1) to +29% (Site 2)**. Improvements are directly attributable to bioengineering and riparian planting treatments conducted in fall 2018/spring 2019 and/or 2015 upper bank plantings (Site 4). **Bioengineering works have beneficially impacted various vegetation health and bank root mass protection parameters**, that have since remained mostly stable since 2019 (Table 4-5). Although Site 1 and Site 2 have mostly shown consistent or sustained improvement since 2016, there has been a very slight riparian health decline since 2020 for Site 4. Some die-off of planted stakes and container plants is apparent in Site 4. **As mentioned, upstream dams and the Western Irrigation District diversion continue to constrain soil/hydrology scores for all sites.** These watershed scale factors result in similar scores for Parameter #11 (6/9) and #12 (0/9) for all sites. Structural alterations from flood/erosion control works and/or recreation also contribute to lower soil and hydrology ratings for all sites as compared to vegetation ratings.

Table 4-5: 2016-2021 BDEP Riparian Health Assessment (RHA) Detailed Results

Riparian Health Parameter	Site 1				Site 2				Site 4			
	2016	2019	2020	2021	2016	2019	2020	2021	2016	2019	2020	2021
Vegetation												
1.Cottonwood and poplar regeneration from seed	4 / 6	4 / 6	4 / 6	4 / 6	2 / 6	6 / 6	6 / 6	6 / 6	0 / 6	6 / 6	6 / 6	6 / 6
2.Regeneration of other native tree species	0 / 3	3 / 3	3 / 3	3 / 3	0 / 3	3 / 3	3 / 3	3 / 3	0 / 3	3 / 3	3 / 3	3 / 3
3.Regeneration of preferred shrub species	6 / 6	4 / 6	2 / 6	2 / 6	0 / 6	6 / 6	6 / 6	6 / 6	2 / 6	4 / 6	6 / 6	2 / 6
4.Standing decadent and dead woody material	2 / 3	2 / 3	2 / 3	2 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	/ 3
5a.Browsing/utilization of preferred tree and shrub species	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	2 / 3	2 / 3	2 / 3	3 / 3
5b.Woody vegetation removal by beavers and/or humans	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	2 / 3
6.Total canopy cover of trees and shrubs	3 / 3	2 / 3	3 / 3	3 / 3	1 / 3	2 / 3	2 / 3	2 / 3	1 / 3	3 / 3	3 / 3	3 / 3
7a.Total canopy cover of invasive plant species	0 / 3	1 / 3	1 / 3	1 / 3	0 / 3	1 / 3	1 / 3	1 / 3	0 / 3	1 / 3	1 / 3	1 / 3
7b.Density distribution pattern of invasive plant species	0 / 3	0 / 3	0 / 3	0 / 3	0 / 3	0 / 3	0 / 3	0 / 3	0 / 3	0 / 3	0 / 3	0 / 3
8.Total canopy cover of disturbance-increaser plant species	0 / 3	1 / 3	1 / 3	1 / 3	1 / 3	1 / 3	2 / 3	2 / 3	0 / 3	2 / 3	2 / 3	2 / 3
Soil / Hydrology												
9.Riverbank root mass protection	0 / 6	2 / 6	2 / 6	4 / 6	0 / 6	2 / 6	2 / 6	2 / 6	0 / 6	2 / 6	2 / 6	2 / 6
10.Percent cover of human-caused bare ground	4 / 6	4 / 6	4 / 6	4 / 6	2 / 6	6 / 6	4 / 6	4 / 6	6 / 6	4 / 6	4 / 6	4 / 6
11.Removal or addition of water to or from the river system	6 / 9	6 / 9	6 / 9	6 / 9	6 / 9	6 / 9	6 / 9	6 / 9	6 / 9	6 / 9	6 / 9	6 / 9
12.Control of flood peak and timing by upstream dam(s)	0 / 9	0 / 9	0 / 9	0 / 9	0 / 9	0 / 9	0 / 9	0 / 9	0 / 9	0 / 9	0 / 9	0 / 9
13.Percent of riverbank structurally altered by human activity	0 / 6	0 / 6	0 / 6	0 / 6	0 / 6	0 / 6	0 / 6	0 / 6	0 / 6	0 / 6	0 / 6	0 / 6
14.Percent of human alteration to the remainder of the polygon	2 / 3	0 / 3	0 / 3	0 / 3	0 / 3	0 / 3	0 / 3	0 / 3	0 / 3	0 / 3	0 / 3	0 / 3
15.Natural floodplain accessibility	4 / 6	6 / 6	6 / 6	6 / 6	4 / 6	6 / 6	6 / 6	6 / 6	2 / 6	6 / 6	6 / 6	6 / 6
Total Riparian Health Score out of 81 points	**37 / 81**	**41 / 81**	**40 / 81**	**42 / 81**	**25 / 81**	**48 / 81**	**45 / 81**	**47 / 81**	**25 / 81**	**45 / 81**	**47 / 81**	**43 / 81**
Total Riparian Health Score (%)	**43**	**51**	**49**	**52**	**29**	**59**	**56**	**58**	**29**	**56**	**58**	**53**

Riparian Health Category: *Healthy* (>80% score) *Healthy with Problems* (60-79% score) *Unhealthy* (<60% score)

Table 4-6: 2016-2021 BDEP RHA Overall Results Summary

Riparian Health Ratings	Site 1				Site 2				Site 4			
	2016[1]	2019	2020	2021	2016[1]	2019	2020	2021	2016[1]	2019	2020	2021
Vegetation rating (%)	54	64	61	61	33	78	81	81	28	75	81	69
Soil / hydrology rating (%)	33	40	40	44	25	44	40	40	29	40	40	40
Overall rating (%)	43	51	49	52	29	58	58	58	29	56	58	53
Trend since Baseline (2016)[2]	**Improving (+9%)**				**Improving (+29%)**				**Improving (+24%)**			

Notes:

3. 2016 data are baseline RHA ratings (Hemmera, 2017c)
4. Overall Riparian Health Trend **since Baseline (2016)**: Improving = >5% score increase, Degrading = >5% score decrease, and Stable = <5% score increase or decrease.

Riparian Health Category:
Healthy (>80% score) *Healthy with Problems* (60-79% score) *Unhealthy* (<60% score)

Site 1 Riparian Health

Site 1 has increased by 9% since 2016, now scoring as 52% (Table 4-6). Score increases are directly linked to beneficial impacts from bioengineering works completed during the fall of 2018 and spring of 2019. The slight score increase since 2020 is related to Parameter #9, riverbank root mass protection (Table 4-5).

Site 1 shows improvement for many tree and shrub health parameters. It has more than 50% cover from woody plants, little browse use of preferred shrubs, and minor amounts of dead and decadent woody material (e.g., ageing poplars north of Cushing Bridge). Woody vegetation removed during bank reconstruction works in 2018 has been fully compensated by successful establishment of bioengineering cuttings and plantings. Parameter #2 rates healthy due to successful aspen (P. tremuloides) plantings and natural Manitoba maple (Acer negundo) recruitment (Table 4-5). However, balsam poplar and willow regeneration scores are lower (Parameters #1 and #3). Despite successful poplar plantings below Cushing Bridge and some natural regeneration on a gravel bar in Site 1-1, most poplar cover is from mature, ageing poplars north of Cushing bridge. Sandbar willow (Salix interior) is suckering in the BDEP site and is naturally regenerating in Site 1-1 gravel bars, **but most willow cuttings below Cushing Bridge have now grown into mature shrubs (i.e., greater than 2 m (6 ft) tall)**.

Vegetation health constraints for Site 1 relate to invasive and disturbance-increaser species, with approximately 1%-15% and 25%-50% cover for these two groups of species, respectively. **Eight invasive species were observed at Site 1 in 2021**, as shown in Table 4-7. Common tansy (Tanacetum vulgare) is especially abundant, primarily north of Cushing Bridge; it continues to be the main problem weed species. Disturbance-increaser species, mainly Smooth brome (Bromus inermis spp. inermis) and quack grass (Elymus repens), are common in Site 1, comprising the main ground cover beneath the mature balsam poplar forest north of the bridge.

Local soil / hydrology parameters: Site 1 generally has no restrictions to floodplain accessibility and less than 5% human-caused bare soil. Beneficial bank reshaping was done below Cushing Bridge to create lower riparian terraces and a wildlife movement corridor. This portion of the site previously had steep vertical banks with concrete rubble and other debris that has since been removed (a beneficial change). Bank reshaping has improved floodwater accessibility in parts of the site. As mentioned, **riverbank root**

mass protection is increasing because of the bioengineering work that has occurred, although there is still some room for improvement, which should occur over time. Some bare soil is present due to the constructed gravel wildlife path as well as various walking trails north of the bridge. Human physical alteration has affected the entire bank and floodplain south of Cushing Bridge and portions upstream. Alterations include two bridges, the regional pathway, two stormwater outfalls, and the vegetated crib wall structure.

2016	2019	2020
 *Photo 4-2: View looking downstream at the top of bank just downstream (south) of the Cushing Bridge. (October 2, 2016) (Hemmera, 2017c)*	 *Photo 4-3: View south of Site #1 from just south of Cushing Bridge showing conditions one year post construction. This portion of bank was re-engineered to create a more gradually sloped riverbank and riparian terrace to accommodate a new wildlife corridor and realignment of the regional paved pathway. (September 17, 2019) (E709336, N5658185)*	 *Photo 4-4: Sandbar willow in the vegetated cribwall shows vigorous growth, but disturbance grasses are prevalent. (September 9, 2020) (E709336, N5658185)*

2021
 *Photo 4-5: Sandbar willow cuttings in the cribwall continue to show vigorous growth and are now mostly mature shrubs. Willows and successful establishment of balsam poplars have contributed to increased root mass protection in this site. (October 1, 2021) (E709336, N5658185)*

Table 4-7: Invasive Species Observed during the 2021 RHA Assessments

Invasive Species		Site Observed			Observed Previously (Y / N)
Common Name	**Scientific Name**	**Site 1**	**Site 2**	**Site 4**	
common burdock	*Arctium minus*	X			Y
common tansy	*Tanacetum vulgare*	X	X	X	Y
creeping bellflower	*Campanula rapunculoides*	X	X	X	Y
creeping (Canada) thistle	*Cirsium arvense*	X	X	X	Y
hound's-tongue	*Cynoglossum officinale*			X	Y
ox-eye daisy	*Leucanthemum vulgare*			X	N
scentless chamomile	*Tripleurospermum inodorum*	X		X	Y
smooth perennial sow-thistle	*Sonchus arvensis* ssp. *uliginosus*	X	X	X	Y
tufted vetch	*Vicia cracca*	X	X	X	Y
white cockle	*Silene latifolia*				Y
yellow clematis	*Clematis tangutica*	X	X		Y
Total number of species		**8**	**6**	**8**	**-**

Site 2 Riparian Health

Site 2 received a Riparian Health score of 58% in 2021 (consistent with 2019-2020 results), a significant improvement from a baseline (2016) score of 29% (Table 4-6). This site is now approaching the Healthy, with Problems threshold of 60%. Bioengineering work completed for the BDEP is directly responsible for the immediate and sustained vegetation health improvements observed at Site 2 since 2016. The vegetation health rating for this site has improved from 33% (Unhealthy) in 2016 to 81% (Healthy) in 2021.

Like Site 1, Site 2 shows substantial improvement for tree and shrub health parameters: it has only minor amounts of browse use, little dead or decadent woody material, and no woody vegetation removal. Successful establishment of young native tree and shrub plantings mean that regeneration parameters (#1, #2 and #3) now rate as Healthy (Table 4-5). However, unlike Site 1, the total canopy cover of woody species is less than 50%. This is in part a function of the natural characteristics of the site, including a steep cutbank that provides Bank Swallow nesting habitat. This habitat feature was retained and intentionally not altered or planted. A portion of the site encompasses upper bench grassy habitat as well. Both disturbance-increaser plants, such as Kentucky bluegrass (Poa pratensis), and invasive plants, such as creeping (Canada) thistle (Cirsium arvense), appear to be somewhat less prevalent than in 2016. Weed control efforts by The City have been ongoing since 2019, with some success (i.e., four invasive species have been eliminated from the site since 2020). Six invasive species persist in Site 2 (Table 4-7).

Local soil / hydrology parameters: Site 2 generally has no restrictions to floodplain accessibility and less than 5% human-caused bare soil cover. Riverbank root mass protection is still relatively low due to the aforementioned unplanted swallow habitat, as well as portions of the bank with pre-existing riprap groynes and grass (i.e., no deep-rooted woody species). The majority of the bank and floodplain have been physically altered by human activities. Riprap groynes installed in 2014, cover about 5% of the bank. Small amounts of human-caused bare soil are present in the contour fascine area as well as along the walking path on the bench.

2016	2019	2020
		
Photo 4-6: View south-southeast from the north end of Site #2. The existing bank was a naturally steep unvegetated cutbank with bank swallow nesting habitat. (June 2, 2016)	*Photo 4-7: View south-southeast from the north end of Site #2. Various bioengineering treatments were done at the base of the bank; however a naturally steep unvegetated cutbank with bank swallow nesting habitat was left unaltered. (September 17, 2019) (E709346, N5657964)*	*Photo 4-8: Successful bioengineering plantings have improved tree/shrub health parameters, although disturbance-increaser and invasive species continue to be a management concern. (September 9, 2020) (E709346, N5657964)*
2021		
		
Photo 4-9: Wood rail fencing has been installed since 2020 to curtail recreation access to sensitive swallow nest habitat and bioengineering plantings. Woody plants continue to show excellent vigour and new growth. (September 30, 2021) (E709346, N5657964)		

Site 4 Riparian Health

Site 4 received a Riparian Health score of 53% in 2021, a 24% increase from the baseline (2016) score (Table 4-6). This improvement is again directly attributable to bioengineering works (vegetated riprap treatments) completed since 2018 and pre-existing plantings installed in 2015 on the upper bank. Successfully established plantings have mainly benefitted woody vegetation health parameter scores (i.e., tree regeneration and woody cover). Since this site includes upper bank shrub plantings from 2015, many of these shrubs are now considered to be 'mature'. Compared to 2020, Parameter #3 (regeneration of preferred shrub species) has declined since a number of recently installed young plantings have died since the 2020 assessment. As well, most live stakes have not survived. Nonetheless, dead or dying plants comprise less than 5% of the total woody cover in Site 4. Deer use is apparent in the site, with mature red-osier dogwood (Cornus stolonifera) and Saskatoon (Amelanchier alnifolia) shrubs having been browsed; however, browse use is light overall since most willows seem to be unaffected. Wildlife fencing was installed at all BDEP sites in 2018, but deer had free access prior to that. There has been no removal of woody vegetation by beaver in Site 4; beaver exclusion fencing remains intact at the base of the bank for all BDEP sites.

Both disturbance-increaser plants, such as Kentucky bluegrass and invasive plants appear to be somewhat less prevalent than in 2016. Eight invasive species were documented at Site 4 in 2021; two more than in 2020 (Table 4-7). Common tansy (Tanacetum vulgare) and creeping (Canada) thistle are especially abundant.

The soil/hydrology score for Site 4 has remained constant at 40% since 2019, an 11% increase since baseline (2016) conditions. Pre-existing plantings and recent vegetated riprap treatments have somewhat improved root mass protection. However, about 20% of the bank in the untreated control (Site 4-4) continues to have unvegetated riprap. Moreover, conditions in the mid-bank have not shown much improvement since 2019 due to failure of more recently installed plantings/cuttings. Thus, more than a third of the bank continues to have little to no root mass protection. Bare soil cover is slightly above normal levels (1-5% cover) due to topsoil placement and a failure of the seed mix to establish in places, particularly in the downstream third of the site. New walking trails with compacted bare soil are also starting to develop. This site has been extensively structurally altered due to flood and erosion control mitigations (riprap, bank engineering) since 2014.

2016

Photo 4-10:: View southeast from the north end of Site #4. Existing riprap and tree and shrub plantings on the upper bank. (June 2, 2016)

2019

Photo 4-11:: View southeast from the north end of Site #4. Tree and shrub plantings on the upper bank show successful establishment since 2015. (September 16, 2019) (E709402, N5657842)

2020

Photo 4-12:: Successful vegetated riprap treatments have improved woody cover and tree regeneration scores as well as enhancing wildlife habitat. (September 8, 2020) (E709402, N5657842)

2021

Photo 4-13:: Some of the more recently installed cuttings and plantings have died off since 2019 along the mid portion of the bank. New compacted walking trails have also developed. (September 30, 2021) (E709402, N5657842)

Riparian Health Inventory Results

The detailed RHI report for the BOW95, BDEP entire site is given in Appendix D. The BOW95 RHI polygon, 580 m in length and about 1.5 ha in size, encompasses BDEP Site 1 (downstream of Cushing Bridge only, excluding Site 1-1), Site 2 and Site 4 (Figure 1-1). This polygon also includes a portion of the adjacent upper bench adjacent to Site 2, including some manicured lawn areas and graveled pathways. The paved regional pathway is largely outside of the RHI boundary except for 45 m of pathway at the 17th Avenue bridge underpass where the pathway is at a lower elevation.

RHI results for the BDEP site as a whole (BOW95) are summarized in Table 4-8, below. Similar to RHA results by Site, **the overall BDEP area shows an improving riparian heath trend, having increased by 15% since 2016.** The entire project area now rates as 59%, approaching the *healthy, with problems* threshold. As with individual site results, this is mainly due to tree and shrub vegetation health improvements.

Table 4-8: BOW95 RHI Results Summary

Riparian Health Ratings	BOW95 RHI Site (BDEP Site 1 downstream from Cushing Bridge, Site 2 and Site 4)		
	2016	2021	TREND
Vegetation rating (%)	56%	78%	+22%
Soil / hydrology rating (%)	36%	44%	+8%
Overall rating (%)	44%	59%	+15% Improving
Riparian Health Category: *Healthy* (>80% score) *Healthy with Problems* (60-79% score) *Unhealthy* (<60% score)			

2016 – BOW95, BDEP Site 4-1, Baseline Conditions	2021– BOW95, BDEP Site 4-1, Current Conditions
	
Photo 4-14:Conventional riprap was installed here in 2014 as an emergency erosion control mitigation to address severe erosion from the 2013 flood. Scentless chamomile and other invasive and disturbance-increaser species were pervasive along parts of the reconstructed, engineered bank in 2016. (July 22, 2016)	Photo 4-15:Successful vegetated riprap with vigorous establishment of sandbar (*Salix interior*) and hungry willow (*Salix famelica*) since 2018 in BDEP, Site 4-1. (July 15, 2021)

2016 – BOW95, BDEP 1-4, Baseline Conditions	2021– BOW95, BDEP Site 1-4, Current Conditions
	
Photo 4-16:Baseline (2016) conditions at BDEP Site 1-4, downstream from Cushing Bridge. This was previously a very steeply sloping portion of bank with concrete rubble and other debris. (July 22, 2016)	Photo 4-17:This portion of bank was pulled back (re-contoured) in 2018 to create a more gently sloping riverbank and riparian terrace that accommodates a new wildlife corridor. Pre-existing concrete rubble was removed in the process. Bioengineering techniques successfully applied here (BDEP, Site 1-4) included brush layers, brush mattresses and contour fascines. (July 15, 2021)

Riparian plantings done in 2015 in addition to bioengineering works since 2018 have successfully improved multiple riparian health parameters, creating substantial habitat enhancement in the BOW95 site. This has included successful establishment of balsam poplar (Populus balsamifera), aspen (Populus tremuloides) and willow (Salix spp.) seedlings and saplings; a dramatic increase in preferred native woody cover (from 10% in 2016 to 80% in 2021); substantially reduced disturbance-caused herbaceous species (from 80% in 2016 to 40% cover in 2021) and improved root mass protection. Although invasive weeds continue to have about 10% combined canopy cover (similar to 2016) from 12 weed species, weed removal efforts are ongoing. As tree and shrub plantings mature, shaded conditions may help keep invasive weeds in check in the long-term. For example, there are few invasive weeds in portions of the site with dense willow cover in Site 1.

As discussed, upstream dams and the Western Irrigation District diversion continue to constrain the overall soil/hydrology rating for the entire BOW95 site. Structural alterations from flood/erosion control works since 2014, gravel paths, manicured lawns and recreation foot trails also contribute to limited to no improvement to the soil/hydrology rating since 2016.

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% (*Unhealthy*) based on the assumptions described in the *BDEP - 2019 Monitoring Report* (KWL, 2020a). This comparative analysis yielded the following results:

- Vegetation ratings over the three years of monitoring are substantially 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.
- Soil/hydrology ratings are comparable across sites and a conventional riprap site due to watershed-scale factors (as discussed) and structural alterations common to all sites. An exception is riverbank

root mass protection ratings where Sites 1, 2 and 4 scored either 2/6 or 4/6 compared to a theoretical conventional riprap design site that scored 0/6.

- **Overall Riparian Health ratings** over the three years of monitoring for Sites 1, 2 and 4 range from **34% to 54% higher than** the overall rating for a theoretical **conventional riprap** design site.

Bank and Riparian Quality Index (BRQI) Results

Comparative 2019 versus 2021 BRQI results for Sites 1, 2 and 4 are summarized in Table 4-9. BRQI was not assessed in 2016, 2018 or 2020. In general, all three sites had consistently high scores for having >95% vegetation cover and low cover or riprap and/or concrete. All three sites scored poorly across years for having high cover from disturbance-increaser species and low cover of regenerating preferred woody plant species. The other four BRQI indicators had mixed results, varying by year and site. All three sites are considered Fair, with moderate overall BRQI scores. In 2021, Site 1 has the highest BRQI score (64%), followed by Site 2 (62%) and Site 4 (54%).

Although trend data is very preliminary with only two assessments completed to date, results appear to be mixed, with Site 1 showing a stable trend, Site 2 showing an improving trend, and Site 4 showing a degrading trend. Between 2019 and 2021, Site 1 saw an increase in cover of native woody species and regenerating preferred woody species as well as a decrease in cover of human-caused bare soil. However, these improvements were largely offset by minor reductions in some of the other BRQI indicators (e.g., invasive plant species and plant community structure). Site 2 has seen a decrease in human-caused bare soil and invasive species, but also reduced plant community structure since 2019. A die-off of planted woody vegetation at Site 4 has resulted in lower scores for native tree and shrub cover, plant community structure and cover of regenerating preferred trees and shrubs in 2021 compared to 2019.

Table 4-9: BRQI Results Summary[2]

BRQI Parameter	Site 1*		Site 2		Site 4	
	2019	2021	2019	2021	2019	2021
Vegetation						
1. Percent vegetation cover (/12)	11.0	10.9	11.3	10.6	12.0	12.0
2. Percent cover of invasive species (/12)	11.1	9.1	3.2	6.3	7.1	7.1
3. Percent cover of disturbance-increaser species (/12)	1.1	1.3	1.1	0.8	1.6	0
4. Percent cover of native trees and shrubs (/12)	5.9	6.5	7.0	7.0	5.6	3.7
5. Plant community structure (/12)	9.8	5.8	7.6	3.3	6.8	4.0
6. Percent cover of regenerating preferred tree and shrub species (/12)	5.9	6.5	5.2	4.9	5.6	2.5
Physical						
7. Percent cover of human-caused bare ground (/12)	4.6	9.9	1.5	8.1	8.0	8.4
8. Percent cover of riprap and concrete (/16)	16.0	15.5	16.0	16.0	16.0	16.0
Total score (/100 or %)	**65**	**64**	**57**	**62**	**63**	**54**
BRQI Categorical Rating	**FAIR**	**FAIR**	**FAIR**	**FAIR**	**FAIR**	**FAIR**
2019-2021 Trend	**Stable (-1%)**		**Improving (+5%)**		**Degrading (-9%)**	

* Note: Site 1 includes natural, non-restored areas north of Cushing Bridge where no BRQI assessments were completed.

BRQI Categories Legend:
Good (75-100 score) *Fair* (50-74 score) *Poor* (0-49 score)

[2] **BRQI scores shown in Table 4-9 were calculated from pin-point transect data**. A limitation of this method is that BRQI values are contingent on pin-point transect placement; thus, **some parameters may not be representative of the entire site conditions**.

4.3 Summary of Findings

The BDEP area as a whole and individual site treatments (Sites 1, 2, and 4) show substantial improvements in riparian health since baseline 2016 conditions. The BDEP area as a whole (i.e., the BOW95 RHI polygon which excludes Site 1-1 north of Cushing Bridge) has improved by 15% since 2016 (Appendix D). The entire project area (BOW95) now rates as 59%, approaching the *Healthy, with Problems* threshold of 60%.

Similarly, Sites 1, 2 and 4 show riparian health score increases ranging from +9% (Site 1) to +29% (Site 2) as confirmed by annual RHA monitoring. These improvements are directly attributable to riparian plantings and bioengineering works completed in 2018 and early 2019 and/or 2015 upper bank plantings (Site 4). Improvements mostly affect vegetation health parameters related to tree and shrub regeneration, overall woody cover, reduced cover from disturbance-increaser species, and variable increases in root mass protection. Root mass protection improvements are greatest for Site 1 due to successful vegetated crib wall, vegetated soil wraps, brush mattress, brush layers, contour fascines, and riparian plantings. Some mortality of recent plantings has occurred at Site 4 (mid bank) since 2020, but new shrub plugs have been planted to try to offset these losses. Portions of Site 2 were intentionally not planted to retain naturally steep, unvegetated cutbanks that provide nesting habitat for bank swallows. Unvegetated riprap 'control' portions of Site 4 limit root mass protection improvement and overall BRQI ratings for that site.

Invasive weedy species continue to persist in all sites with 1-15% cover; however, weed removal efforts are ongoing. Similarly, disturbance-increaser species (e.g., Kentucky bluegrass and smooth brome) have more than 25% cover in the BDEP site as a whole, including the adjacent upper bench. Continued growth and successful tree and shrub establishment may help to shade-out and keep weeds and disturbance grasses in check in the long-term.

Except for some improvement potential with respect to reducing the cover and/or density of invasive weeds and disturbance-increaser plants, the overall riparian health score for the entire BDEP site has little room for further improvement from site-level interventions. Watershed-scale factors (e.g., damming and water diversion) and permanent structural alterations from flood/erosion control mitigations and recreation use mean that *Healthy* conditions are unattainable. However, trends in BRQI ratings over time will demonstrate if bioengineering works are successful in the long-term in affecting continued natural habitat cover, structure and sustained natural regeneration. Those sites with highest BRQI ratings in the long-term will represent successful progress toward meeting wildlife habitat and vegetation enhancement objectives. Site-level maintenance activities (e.g., weeding, watering, access control) and continued vegetated riprap experimental treatments have potential to positively affect BRQI scores going forward.

Photo 4-18: Vegetation establishment on BDEP Site 2 (July 20, 2021)

5. Bioengineering Structural Integrity

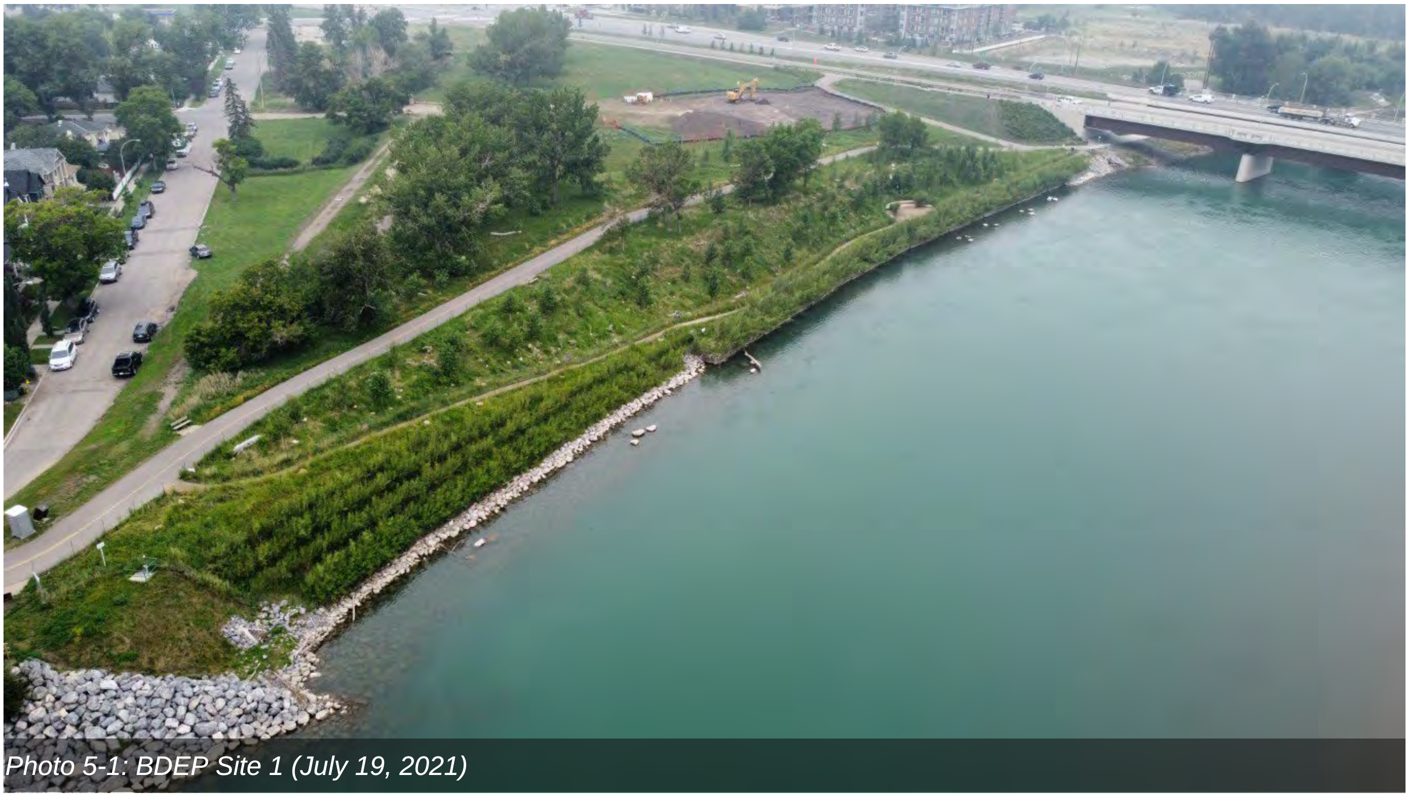


Photo 5-1: BDEP Site 1 (July 19, 2021)

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., warranty inspections) and are also not structural engineering assessments of the infrastructure. These protocols are also used to assess the effectiveness of <u>all</u> 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 RMP 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 also reported as part of the RMP reporting requirements.

Vegetation Assessment: The RMP vegetation assessment includes three main components listed below.

- 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.
- Assessments of plant health and survival for typically 50 cuttings and 20 plantings of each species at Year 1 post-construction age class sites. Plant health and survival assessments for Year 3 and Year 5+ post-construction age class sites include 10 cuttings and 10 plantings of each species.

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.

BOX 1: 2019/2021 vs. 2020 Planted Woody Vegetation Assessment Methods

Methods used to assess vegetation parameters differed between 2019/2021 and 2020 monitoring years as listed below.

- In 2019 woody vegetation survival was measured via individual live cutting and planting *counts* at each transect location for each bioengineering technique to be consistent with both the BEMP (Hemmera, 2018) and RMP protocols (KWL, 2018).
- In both 2019 and 2021, woody vegetation canopy cover and vigor were measured during the *pinpoint transect surveys* to be consistent with both the BEMP (Hemmera, 2018) and RMP protocols (KWL, 2018).
- In 2020, woody vegetation survival at BDEP was measured by *visual estimate* at each bioengineering technique used, and woody vegetation canopy cover and vigor assessments were measured visually by *quadrat sampling* at each bioengineering technique used to comply with the BEMP (Hemmera, 2018).

While many parameters are being collected on an annual basis as listed above, the measure for vegetation establishment *performance* of the site has transitioned from woody vegetation survival in Year 1 (2019), to woody vegetation survival and canopy cover in Year 2 (2020), and then to woody vegetation density and canopy cover in Year 3 (2021). As noted above, vegetation survival was not measured in 2021. This change in method was made because it is no longer possible to count individual stems after Year 1 monitoring due to site growth and state of decay of the dead cuttings. This is a normal process as the site ages where it becomes more challenging to identify surviving planted vegetation (live cuttings and container plants) versus either natural regrowth or dead planted vegetation. It is also due to natural competition between individual plants, where a site with successful vegetation establishment will have reduced woody vegetation survival and a higher woody canopy cover over time. Vegetation establishment performance results by site are presented in Table 5-4, Table 5-5, and Table 5-6.

Failure Assessment: An RMP failure assessment is completed on Year 1 post-construction 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. An RMP failure assessment is completed on Year 3 or Year 5+ post-construction sites 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. This protocol was not used during the 2019 or 2020 assessments as the sites at the BDEP were all found to be successful.

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 at Sites 1, 2, and 4. Photographs were taken again in 2021 from the established locations for comparison purposes and are provided in Appendix B – Attachment A, photos 1 – 30 and Appendix E.

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 2021 structural assessments for the BDEP sites were competed on July 19-21, 2021 and September 13, 2021 by M. Gallant and P. Raymond. The 2021 vegetation assessment was completed during May 26 to June 2, 2021 and August 31 to September 3, 2021 by P. Raymond and A. Dodd. Field data sheets from these inspections can be found in Appendix D.

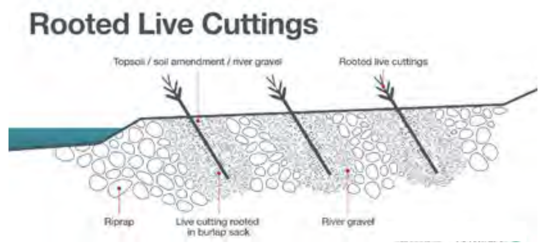
Warranty inspections as part of the construction contract were completed by J. Slaney from The City of Calgary throughout 2021 with a Final Acceptance Certificate (FAC) inspection conducted in October 2021.

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. Flow data was obtained for the Water Survey Canada stations Bow River at Calgary (05BH004), Elbow River Below Glenmore Dam (05BJ001), and Western Irrigation District Canal near Headgates (05BM015). The maximum velocity and shear stress associated with the annual maximum flow event was generated at each BDEP site using the *2015 Bow River and Elbow River Hydraulic Model* (Golder, 2015).

Table 5-1: BDEP Site Numbers, Design Approaches, and Vegetation Assessment Parameters

<table>
<tr><th>BDEP Site No.</th><th>BDEP Sub-Site No. / RMP Site Code</th><th>BDEP Design Approaches[1]</th><th>Vegetation Establishment Parameters Assessed at Each BDEP Sub-Site[2]</th></tr>
<tr><td rowspan="4">Site 1</td><td>Site 1-1 / BE-BOW-46A</td><td>


</td><td>
<table>
<tr><th rowspan="2">Vegetation Establishment Parameter</th><th colspan="3">Rooted Live Cuttings</th></tr>
<tr><th>2019</th><th>2020</th><th>2021</th></tr>
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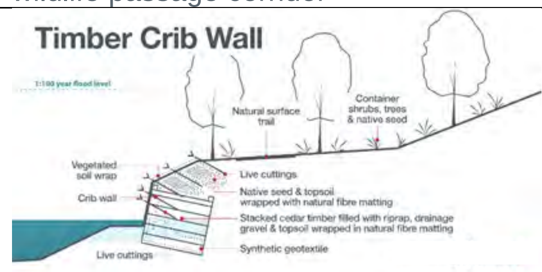

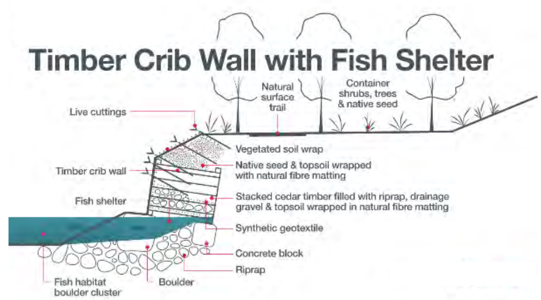

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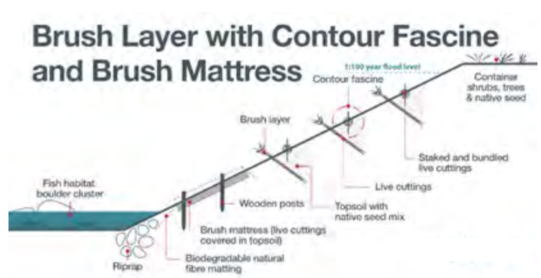

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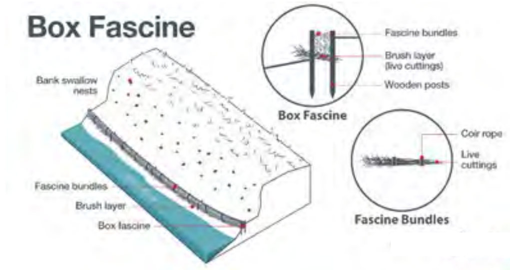
<tr><td rowspan="3">Site 2</td><td>Site 2-1 / BE-BOW-46D1</td><td>
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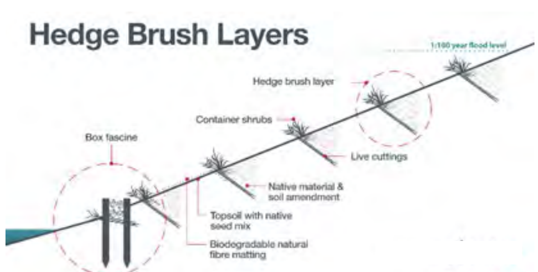
<tr><td>Site 2-2 B / BE-BOW-46D3</td><td>
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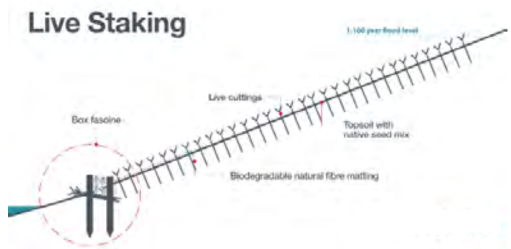
<tr><td></td><td>Site 2-2 C / BE-BOW-46D4</td><td>
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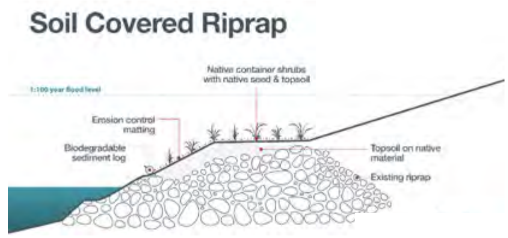
<tr><td rowspan="4">Site 4</td><td>Site 4-1 / BE-BOW-46E1</td><td>
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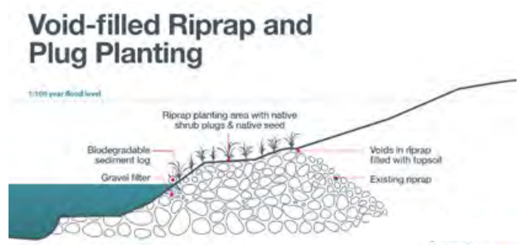
<tr><td>Site 4-2 / BE-BOW-46E2</td><td>
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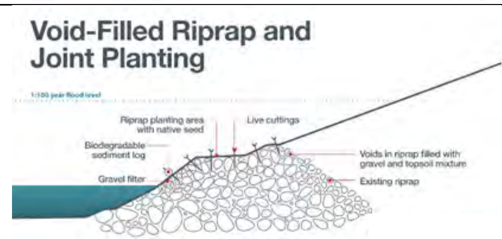
<tr><td>Site 4-3 / BE-BOW-46E3</td><td>
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Notes:
1. More information on each bioengineering technique is provided in Table 1-1.
2. BDEP sub-sites are shown in Figure 1-1.

5.2 Results

The following outlines the results for structural integrity monitoring. A Summary of Findings is included in Section 5.3, page 70.

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 5.1.

The maximum Bow River flow, velocity and shear stress for 2019, 2020, and 2021 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. The maximum flow in 2021 was 355 m^3/s on June 5, 2021. 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, 2019, 2020 and 2021 maximum values for Bow River Flow, Velocity and Shear Stress

Parameter	Baseline (100-Year Flood Event)			2019			2020			2021		
	Site 1	Site 2	Site 4	Site 1	Site 2	Site 4	Site 1	Site 2	Site 4	Site 1	Site 2	Site 4
Max. Flow (m/s^3)[1]	2910				391		388				355	
Max. Velocity (m/s)[1]	3.5$^{<}$ to 3.9$^{\wedge}$	3.0	3.1	1.0*	1.1	1.7	0.9^ to 1.2$^{<}$	1.0	1.5	0.8$^{>}$ to 0.9$^{<}$	1.0	1.4
Max. Shear Stress (N/m^2)[1]	105$^{>}$ to 126$^{\wedge}$	79	95	10$^{>}$ to 13$^{<}$	15	39	10$^{>}$ to 13$^{<}$	15	35	9$^{>}$ to 11.7$^{<}$	13	32

Notes:
1. Maximum velocity and shear stress (channel) are calculated from the maximum flow shown in Table 5-2 using the *2015 Bow River and Elbow River Hydraulic Model* 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.

2021 Precipitation and Wind

Total precipitation amounts in Calgary at the Calgary International Airport for the past four years are summarized in Table 5-3. With total precipitation of 277 mm, 2021 was a drier than average year compared to the yearly average of 410 mm. Average precipitation and temperatures for 2018 to 2021 are shown in Figure 5-1. Monthly precipitation amounts from May to October were below average in 2021 except for in August where precipitation was higher than the average. Of note was that June 2021 precipitation amounts were near historic lows. Temperature was above average for most of 2021 during the growing season (May to October). Wind speed and direction data for 2019-2021 are shown in Figure 5-2. The prevailing wind direction is from the south, with higher velocity winds more often coming from the north and west.

Table 5-3: Climate data for Calgary Airport - 2018 - 2021

Parameter	2018	2019	2020	2021
Rainfall (mm)[1]	425	416	479	277
Rainfall % Above/ Below Average	+4%	+1%	+17%	-32%

Notes:
1. Average precipitation at Calgary airport is 410 mm/year.

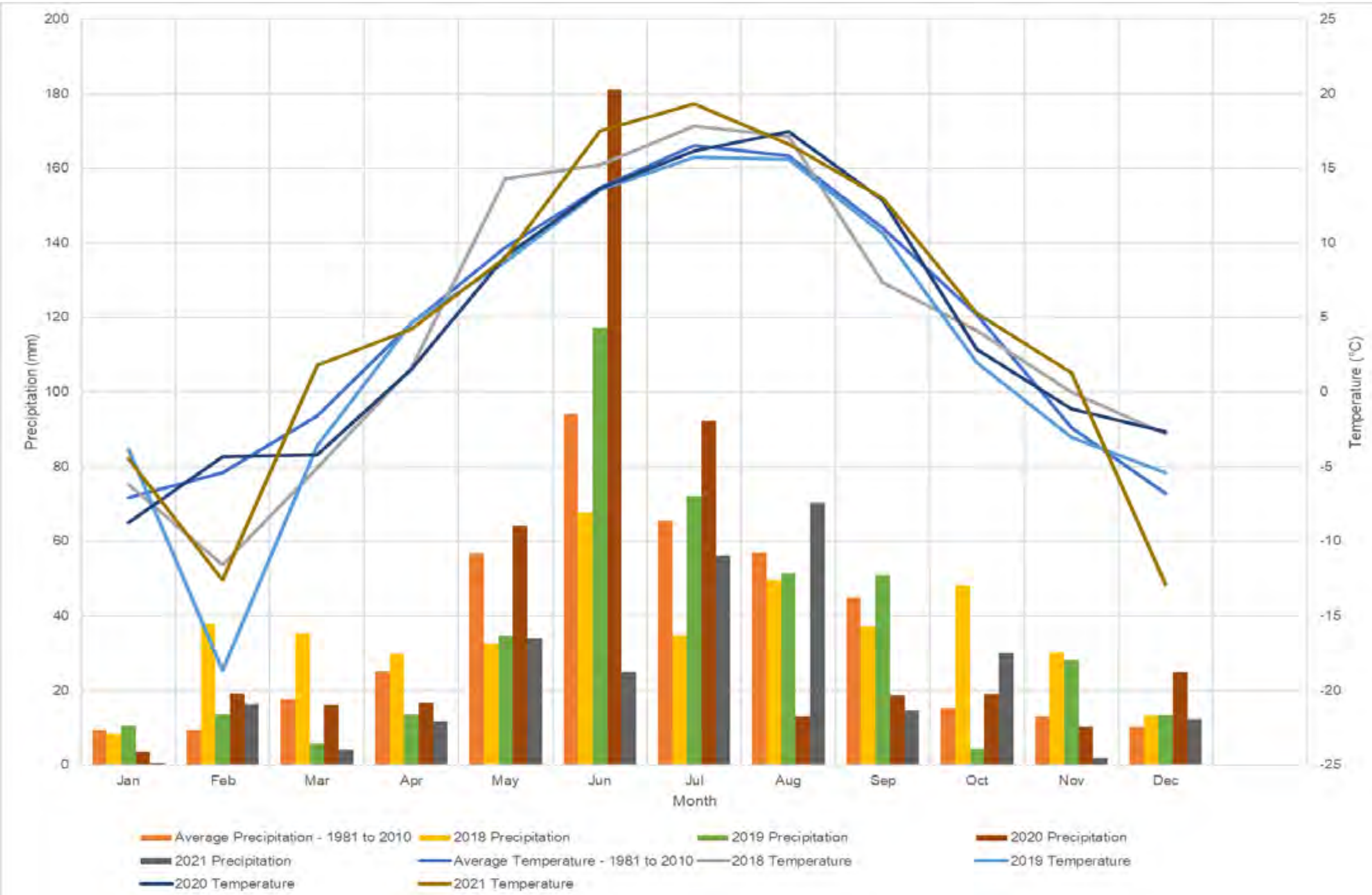

Figure 5-1: Calgary Precipitation and Temperature Data at Calgary International Airport - 2018, 2019 and 2020

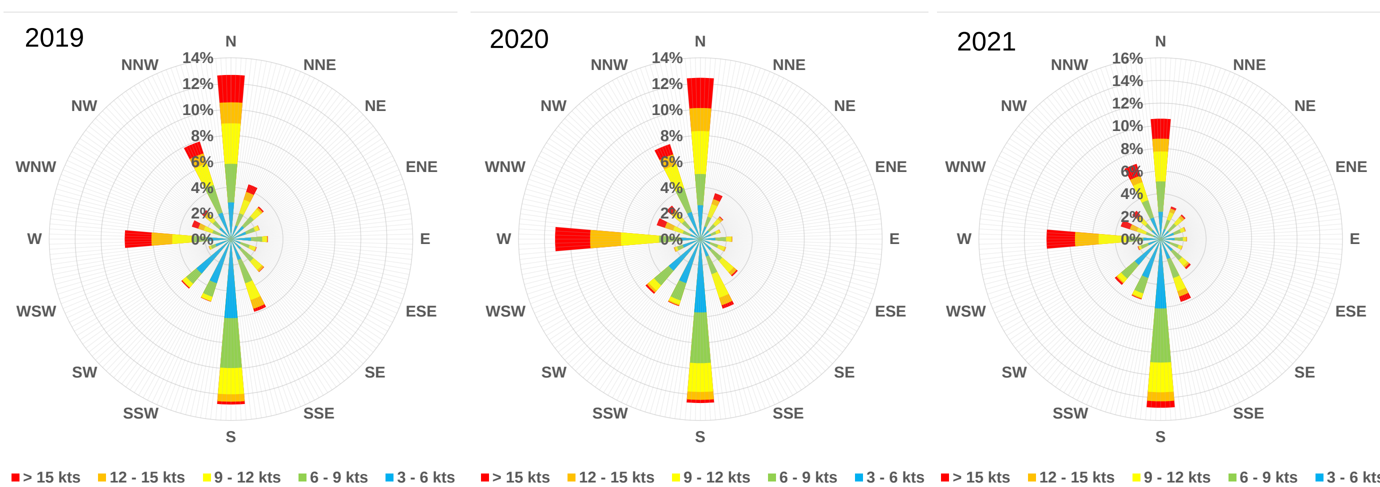

Figure 5-2: Wind roses from 2019, 2020, and 2021 for wind data from the Calgary International Airport

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 D.

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 physical condition of the bioengineering techniques at Sites 1, 2 and 4 was conducted during all four seasonal monitoring periods in 2021. Photographic data collected from the 2016/2017, 2019, 2020, and 2021 visual assessments at each of the established photo stations are presented in Appendix B – Attachment A, photos 1 – 30 and Appendix E.

Results of the 2021 visual assessment and photographic data indicate that the physical condition of the treatments, including fish habitat structures (e.g., boulder clusters, fish shelters and box fascines), continue to be stable, with no signs of erosion, scour, or displacement.

Additional observations are listed below.

- Minor, local erosion that was observed in 2019 was no longer observed in 2020 or 2021. Vegetation has established in any minor eroded areas that were observed in 2019.
- No additional washout of placed material along the surface of bank toe at Site 4 in 2020 or 2021 from what was observed in 2019.
- A permanent wood fence was built along the top of the steep slope at Site 2 in September 2020 as a safety measure for the public. The fence was in good repair when observed in 2021.
- A solar drip irrigation system was installed at Site 1 in 2021 to water the vegetation in the timber crib wall and soil wraps. A pressurized sprinkler system watered the remainder of the site. According to maintenance records provided by the contractor, irrigation from the sprinkler system occurred 3 times per week at 3am for a duration of 45mins.
- 1000 live cuttings were installed in the timber crib wall at Site 1 in May 2021 to replace dead cuttings that were planted in the timber crib wall in 2020.
- Shrub plugs were installed at Site 4 to supplement the existing planted shrub plugs and live cuttings.
- One 10m long section of fascine that was not establishing at Site 2 was replaced with #5 sized balsam poplar container plants.
- Herbicide was applied to Site 1, Site 2, and Site 4 for weed control for several weed species (see Vegetation Assessment section below for more details) in July 2021.
- Shrubs on the bench at Site 1 and Site 2 were marked with stakes and flagging tape so that maintenance crews could easily identify their location and avoid damaging them.
- Roots from the planted live cuttings were observed growing around substrates at Site 2 and through spaces in the timbers in the crib wall at Site 1 towards the river. These roots will aid in binding the substrates together, increasing soil cohesion and erosion resistance. Also, suckering from sandbar willow and balsam poplar was observed between rows of contour fascine, brush layers and hedge brush layers and in front of the box fascine at Site 1 and Site 2.
- The temporary rodent fencing was removed from all sites in October 2021 as part of the Final Acceptance Certificate requirements. This occurred after 2021 monitoring activities.
- The Final Acceptance Certificate for the site was issued in October 2021. Additional watering and weeding will occur at the site for 2 more years.

Bank Stability

Baseline (2017), 2019, 2020, and 2021 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 stability was relatively stable along the bank (Hemmera, 2017a). The same observations as baseline conditions for bank stability were observed in 2019, 2020, and 2021 where the bank was found to be relatively stable.
    - At Cushing Bridge: Baseline (2017) observations were that stability was low along the bank immediately downstream of the Cushing Bridge (Hemmera, 2017a). Bank stability was considered good immediately downstream of the Cushing Bridge in 2019, 2020, and 2021.
    - Downstream of Cushing Bridge: Baseline (2017) observations were that bank stability was observed to be low 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 bank in the past (Hemmera, 2017a). In contrast to the conditions observed in 2017, high bank stability and deciduous trees, shrubs and grasses along the bank were noted downstream of the Cushing Bridge in 2019, 2020, and 2021.
- **Site 2:** Baseline (2017) observations were that bank stability was low throughout 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, 2020, and 2021, bank stability was observed to be high 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 2021 observations described below.

- **Rock Riprap and Fish Boulders:** Rock riprap and fish boulders 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 (Photo 5-2).
- **Fill Materials:** Fill materials were observed to be in good condition and contained within the structures. Pea gravel washout from the box fascine at Site 2 and void-fill material washout from the surface of the toe at Site 4 was noted during the 2019 assessment (occurred mostly in 2018) and was noted to be unchanged in 2020 and 2021.
- **Wood Materials:** The wood materials used at the site consist of timber for the timber crib wall, posts for the box fascine, posts for the brush mattress, and permanent wood fence at Site 2. In general, the condition of the posts and fence used is very good with no concerns for long-term durability. Concern with the timber quality used in the crib wall at Site 1 was noted during the 2019 assessment. The timber crib wall was observed to be stable with no observable change in condition during the 2021 assessment (Photo 5-2, Photo 5-6 and Photo 5-7).

- **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 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 established. It was observed to be in good condition and there are no concerns with the coir geogrid continuing to provide erosion control as vegetation has fully established at those sites (Photo 5-3).
    - The non-woven geotextile was installed at Site 1 in the timber crib wall for material containment and separation. It was observed to be in very good condition with no concerns for long-term durability.
    - The erosion control matting was installed at Site 4 to provide protection for the placed topsoil until vegetation established. It was observed in 2021 that it had almost fully disintegrated with no remaining useful life. Both woody and herbaceous vegetation have established at Site 4, so the matting performed its function within its expected product longevity.
- **Wattles**: Curlex® Sediment Logs® were installed at Site 4 to provide erosion control and material containment along the toe of the bank. The logs were noted in 2021 to be in poor condition and missing in some places (Photo 5-4) but they have served their purpose of providing temporary erosion and sediment control and can be either left in place or removed as follows: sections that are intact should either be supported with wooden stakes or removed; sections that are actively disintegrating should be left to biodegrade at their current location.
- **Hydromulch and Seeding**: Hydromulch was installed at Site 1, Site 2, and Site 4 for erosion control and seeding. The hydromulch had washed away at the upstream end of Site 1; however, natural regeneration is occurring at this location as shown in Photo 5-5. It was noted that the seeding application rate was higher than the design, which has resulted in herbaceous vegetation competition with woody vegetation and girdling by rodents such as field mice and voles who benefit from the thick herbaceous vegetation for their habitat.
- **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. Concrete blocks were observed in one section of the timber crib wall and they appeared to be in very good condition (Photo 5-6).
- **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 wire was 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 very good 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 with one loose support at the south end of the crib wall (Photo 5-7). This was communicated to The City for rectification. The candy cane rebar should be removed from the site as it is no longer needed to secure the wattles.
- **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 (Photo 5-8). This fencing was reported by The City to have been removed in October 2021 (not observed during assessments in July or September 2021).

- **Fish Shelters**: The fish shelters were inspected on September 13, 2021. Fine sediment was observed to have deposited along the bottom of 10 of 12 shelters in a layer ranging from 0.01 m to 0.2 m depth, with an average depth of 0.1 m. There was an average of 0.05 m more sediment deposited in the fish shelters from 2020 observations. Otherwise, the fish shelters were open and providing good fish habitat as shown in Photo 5-7. The large woody debris that was observed on the fish boulders in 2019 and 2020 was observed again in 2021. No significant change in the condition of the timber crib wall was observed from as-constructed conditions per Photo 5-9, and there was no change in the deflection of the spanning members that are supported by the steel supports.

Photo 5-2: Timber crib wall, rock riprap (submerged), and fish boulders (July 21, 2021).

Photo 5-3: Coir matting at Site 2 (July 21, 2021)

Photo 5-4: Degraded Curlex® Sediment Log® and temporary rodent fence at Site 4 (July 19, 2021)

Photo 5-5: Natural regeneration at upstream end of Site 1 (July 21, 2021)

Photo 5-6: View under the fish shelter structure in the timber crib wall. Note the roots growing through the structure and extending into the water (Sept 13, 2021)

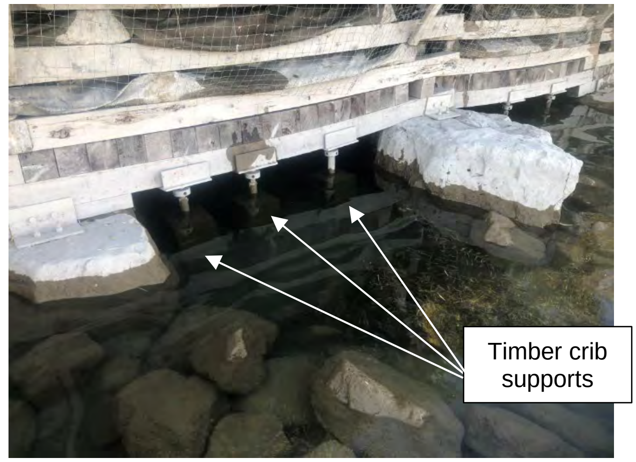

Photo 5-7: Fish shelter and timber crib wall supports (September 13, 2021)

Photo 5-8: Temporary rodent fencing at Site 2 (July 20, 2021)

Photo 5-9: Timber crib wall at Site 1 on September 13, 2021

Vegetation Assessment

Woody Vegetation Survival, Canopy Cover and Density (Sites 1, 2 and 4)

The results of woody vegetation canopy cover (2019, 2020 and 2021), woody vegetation density (2021), and woody vegetation survival (2019 and 2020) for Sites 1, 2, and 4 are provided in Table 5-4, Table 5-5, and Table 5-6, respectively. Key results and observations from the Vegetation Assessment are summarized in Section 5.3.

As noted in Table 5-4, woody vegetation canopy cover for the live cuttings installed in the bank portion of the BDEP is very good at 89% for Site 1 and 83% at Site 2 in 2021**.** The 2021 results for cover are in the same range as compared to 2019 (2020 results are different due to the use of a different measurement method and are not comparable as discussed in Box 1), despite the dry and hot conditions during summer 2020 and 2021. Overall woody vegetation canopy cover is 31% over the site. The lower value for overall vegetation canopy cover is mostly due to the results from the planting in the upper / top of bank areas where density of installed vegetation was in the range of 1 planting/m² and is facing competition from dense herbaceous vegetation growth.

As noted in Table 5-5, the woody vegetation density is highest at Site 2 for the linear techniques[3], and highest at Site 1 for the areal techniques[4]. Density is lowest for both categories at Site 4. Site 1 and Site 2 woody vegetation density per linear metre meets the target of, on average, showing five, and at least two, vigorous shoots per linear metre (Schiechtl & Stern, 1997). There is not a clear density target per square metre for areal techniques except for brush mattresses, where the target is to show on average 10, and at least five, shoots per square metre, evenly distributed (Schiechtl & Stern, 1997). While the brush mattresses at Site 1 and Site 2 meet this target (refer to Table 5-1), if it is applied more broadly, live staking at Site 2 will meet this target as well, but none of the overall Site 1, Site 2 or Site 4 density results will meet the target due to the low density of plantings at the site (density of ±0.2 plantings/m^2).

As discussed in the 2020 BDEP report (KWL, 2021a) and shown in Table 5-6,, survival of planted vegetation was highest at Site 4, followed by Site 1 and 2, which is in contrast to 2019, where overall survival of planted vegetation was highest at Site 2, followed by Site 1 and 4 (KWL, 2020b). Overall vegetation survival for all sites in 2020 was estimated to be 76% in comparison to 2019 survival of 80%. Vegetation survival was not measured in 2021 as discussed in Box 1.

Table 5-4: 2019-2021 Woody Vegetation Canopy Cover by Site

Site No.	Overall Woody Vegetation Canopy Cover[1] (%)			Live Cutting Canopy Cover[2] (%)			Potted Plant Canopy Cover[3] (%)		
	2019	2020	2021	2019	2020	2021	2019	2020	2021
1	33	31	38	88	53	89	16	24	25
2	34	21	26	89	69	83	13	4	5
4	18	6	14	6	1	6	17	5	13
Total	**31**	**24**	**31**	**70**	**45**	**67**	**15**	**15**	**17**

Notes:
1. Woody vegetation canopy **cover** was measured at the BDEP by pinpoint transect in 2019 and 2021 and by quadrat in 2020. The different techniques have resulted in slightly different results as discussed in Box 1 above. The cover targets were established to be 70% (2021) for Year 3 post-construction and 90% (2023) for Year 5 post-construction assessments. The overall woody vegetation canopy cover calculation includes a weighted average of woody vegetation canopy cover for both live cuttings and planting areas.
2. For Site 1, live cuttings areas include portions of the site where vegetated riprap, vegetated soil wraps, vegetated timber crib wall, and brush mattress/brush layers and contour fascines were installed. For Site 2, live cuttings areas include portions of the site where box fascine, brush mattress, contour fascines, hedge brush layers, and live staking were installed. For Site 4, live cuttings areas include portions of the site where live staking was installed. This is located along the riverbank.
3. For Site 1, Site 2 and Site 4, potted plant areas include portions of the site where only container plants or plugs were installed. This is typically located along the upper bank or on the top of bank.

[3] Linear techniques include brush layers, hedge brush layers, fascines or wattle fences.

[4] Areal techniques include live staking, planting, and brush mattresses.

Table 5-5: 2021 Woody Vegetation Density by Site

Site No.	Woody Vegetation Density by Site - 2021[1,2]	
	Linear Techniques (/m) [3]	Areal Techniques (/m²) [4]
1	5.5	2.2
2	30	1.9
4	1.3	0.8
Site Average	**11.5**	**1.9**

Notes:

1. Data collected only for 2021 per RMP methods for Year 1, Year 3, and Year 5+ post-construction age classes (BDEP was Year 3 in 2021). Density data will again be collected in 2023 and 2028 assessment.
2. **Density** of woody vegetation refers to the total number of living stems (planted, natural or from root suckering) found within a quadrat and averaged by linear metre for techniques such as brush layers, hedge brush layers, fascines or wattle fences, or by square metre for techniques such as live staking, planting, and brush mattresses. Density in the RMP is measured in Year 3 and Year 5+ post-construction age class sites. Density at the BDEP was first measured in 2021. The density target for fascines, brush layers, hedge brush layers, and wattle fences is to, on average, show five, and at least two, vigorous shoots per linear metre. The density target for brush mattresses is to show on average 10, and at least five, shoots per square metre, evenly distributed. The target for planted trees and shrubs is for failure to not exceed 30% of the total numbers planted, and the revegetation objective must be achieved in spite of the failures. The target for live cuttings/live staking is for at least two-thirds to have evenly distributed shoots. Source for targets: Schiechtl, H., and Stern, R. (1997) *Water Bioengineering Techniques for Watercourse Bank* and Shoreline Protection.
3. Linear techniques include brush layers, hedge brush layers, fascines or wattle fences. The density target for fascines, brush layers, hedge brush layers, and wattle fences is to, on average, show five, and at least two, vigorous shoots per linear metre (Schiechtl & Stern, 1997).
4. Areal techniques include live staking, planting, and brush mattresses. The density target for brush mattresses is to show on average 10, and at least five, shoots per square metre, evenly distributed. Failure for planted trees and shrubs should not exceed 30% of the total numbers planted, and the objective must be achieved in spite of the failures. Two-thirds of all live cuttings and truncheons or stakes must have evenly distributed shoots. (Schiechtl & Stern, 1997).

Table 5-6: 2019-2020 Woody Vegetation Survival by Site

Site No.	Overall Woody Vegetation Survival (%)		Live Cutting Survival (%)		Potted Plant Survival (%)	
	2019	2020	2019	2020	2019	2020
1	77	74	65	56	100	98
2	83	68	80	36	100	100
4	77	85	60	54	96	100
Total	**80**	**76**	**74**	**50**	**99**	**99**

Notes:

- Data collected only for 2019 and 2020. Data will no longer be collected due to difficulty establishing the number of dead versus live cuttings.
- **Survival** of woody vegetation was measured in 2019 and 2020, but not in 2021 as discussed in Box 1 above. Survival is reduced slightly in 2020 in comparison to 2019 due to either the different methods that were used to measure survival between the 2 years and/or due to an expected reduction in survival as the site ages and natural competition occurs between the planted woody vegetation. Refer to Box 1 above. Contractual Year 1 survival target for woody vegetation was 70%.

Woody Vegetation Survival, Canopy Cover and Density (by Sub-Site/Treatment Areas)

The results of woody vegetation canopy cover (2019, 2020 and 2021), woody vegetation density (2021), and woody vegetation survival (2019 and 2020) for the 10 treatment areas (sub-sites) shown in Figure 1-1 that roughly correspond to the different bioengineering techniques used at the BDEP site are provided in Table 5-7, Table 5-8, and Table 5-9, respectively. As noted in Table 5-7, the 2021 woody vegetation canopy cover for the live cuttings installed in the bank portion of the BDEP is very good at 90% for Site 1-3 (timber crib wall and soil wraps), 86% at Site 1-4 (brush mattress, brush layers, and contour fascines), 90% at Site 2-1 (box fascine), 87% at Site 2-2A (box fascine, brush mattress, and contour fascine), and 94% at Site 2-2B (box fascine and hedge brush layer). Woody vegetation canopy cover for the planting in the upper / top of bank areas is low and ranges from 2% at Site 2-1 to 40% at Site 1-4. As noted above, the density of plantings was in the range of 1 planting/m², which is commonly used for planting sites in Calgary; however, the plantings at BDEP are facing competition from dense herbaceous vegetation growth and have been damaged by mechanical weeding and are thus more slowly increasing canopy cover than at other sites in Calgary.

As noted in Table 5-8, the woody vegetation density is very high for the linear techniques (box fascines, contour fascines, and hedge brush layer) at 45 stems/m for Site 2-2A (box fascine and contour fascine), 29 stems/m for Site 2-1 (box fascine), 26 stems/m for Site 2-2B (box fascine and hedge brush layer), and 25 stem/m for Site 2-2C (box fascine). Density is also high for the brush mattress technique at 32 stems/m² for Site 1-4 and 30 stems/m² at Site 2-2A. Density is lowest for the planting techniques and ranges from 0 stems/m² to 2.3 stems/m².

As discussed in the 2020 BDEP report (KWL, 2021a) and shown in Table 5-9, survival of potted plants was much higher than live cuttings and ranged from 97% to 100%. The highest survival for live cuttings was 70% at Site 1-1 (rooted live cuttings), followed by 62% at Site 2-2C (live staking). As noted above, hot and dry conditions were observed in 2020 that led to reduced survival between 2019 and 2020. Vegetation survival was not measured in 2021 as discussed in Box 1.

Table 5-7: 2019-2021 Woody Vegetation Canopy Cover by BDEP Sub-Site

Site No.	Live Cutting Canopy Cover[1] (%)			Potted Plant Canopy Cover[2] (%)		
	2019	2020	2021	2019	2020	2021
1-1	12	7	10	n/a	n/a	n/a
1-2	n/a	n/a	n/a	n/a	n/a	n/a
1-3	95	50	90	22	28	22
1-4	76	56	86	8	24	40
2-1	92	79	90	10	8	2
2-2A	96	66	87	12	5	20
2-2B	100	61	94	34	n/a	6
2-2C	69	62	58	0	n/a	6
4-1	n/a	n/a	n/a	30	10	6
4-2	n/a	n/a	n/a	14	4	32
4-3	6	1	6	n/a	n/a	n/a
4-4	n/a	n/a	n/a	n/a	n/a	n/a

Notes:

1. For Site 1 sub-sites, live cuttings areas include portions of the site where vegetated riprap, vegetated soil wraps, vegetated timber crib wall, and brush mattress/brush layers and contour fascines were installed. For Site 2 sub-sites, live cuttings areas include portions of the site where box fascine, brush mattress, contour fascines, hedge brush layers, and live staking were installed. For Site 4 sub-sites, live cuttings areas include portions of the site where live staking was installed. This is located along the riverbank.
2. For Site 1, Site 2 and Site 4 sub-sites, potted plant areas include portions of the site where only container plants or plugs were installed. This is typically located along the upper bank or on the top of bank.

Table 5-8: 2021 Woody Vegetation Density by BDEP Sub-Site

Site No.	Woody Vegetation Density – 2021[1]	
	Linear Techniques (/m) [2]	Areal Techniques (/m²) [3]
1-1	n/a	2.3
1-2	n/a	n/a
1-3	3.3	1.0
1-4	9.3	Potted plants: 0.3 / Brush mattress: 32
2-1	29	0.3
2-2A	45	Potted plants: 0.7 / Brush mattress: 30
2-2B	26	0.7
2-2C	25	Potted plants: 0.7 / Live staking: 6.7
4-1	n/a	0
4-2	n/a	3
4-3	n/a	1.3
4-4	n/a	n/a

Notes:
1. Data collected only for 2021 per RMP methods for Year 1, Year 3, and Year 5+ post-construction age classes (BDEP was Year 3 in 2021). Density data will again be collected in 2023 and 2028 assessment.
2. Linear techniques include brush layers, hedge brush layers, fascines or wattle fences. The density target for fascines, brush layers, hedge brush layers, and wattle fences is to, on average, show five, and at least two, vigorous shoots per linear metre (Schiechtl & Stern, 1997).
3. Areal techniques include live staking, planting, and brush mattresses. The density target for brush mattresses is to show on average 10, and at least five, shoots per square metre, evenly distributed. Failure for planted trees and shrubs should not exceed 30% of the total numbers planted, and the objective must be achieved in spite of the failures. Two-thirds of all live cuttings and truncheons or stakes must have evenly distributed shoots. (Schiechtl & Stern, 1997).

Table 5-9: 2019-2020 Woody Vegetation Survival by BDEP Sub-Site

Site No.	Live Cutting Survival (%)		Potted Plant Survival (%)	
	2019	2020	2019	2020
1-1	65	70	n/a	n/a
1-2	n/a	n/a	n/a	n/a
1-3	50	48	100	97
1-4	92	57	100	100
2-1	96	15	100	100
2-2A	96	43	100	100
2-2B	68	57	100	100
2-2C	82	62	100	100
4-1	n/a	n/a	97	100
4-2	n/a	n/a	96	100
4-3	60	54	n/a	n/a
4-4	n/a	n/a	n/a	n/a

Notes:
- Data collected only for 2019 and 2020. Data will no longer be collected due to difficulty establishing the number of dead versus live cuttings.

Woody Vegetation Leader Growth, Mean Diameter and Shoot Length

Comparison of leader growth, mean diameter, and shoot length for woody vegetation installed at Site 1, Site 2 and Site 4 to median, 25th percentile and 75th percentile RMP data from 2018-2021 are shown in Figure 5-3 for live cuttings and in Figure 5-4 for plantings. In Year 1 (2019), Site 1 and Site 2 live cutting leader growth, shoot length, and diameter were above the median and are all higher than Site 4. Results for Site 4 were at or near the 25th percentile. In Year 3 (2021), the results for leader growth were closer to the median for Site 1 and Site 2, and the results for Site 4 were higher than the other sites. The Year 3 results for diameter show that Site 1 and Site 4 mean diameter are both less than the median, while Site 2 is slightly above. Year 3 results for the live cuttings shoot length at Site 1 and Site 2 is larger than the median, which indicates above-average vegetation establishment at Site 1 and Site 2. However, Site 4 results are below the median and indicate that remedial actions, including replanting, may be required.

As shown in Figure 5-4, the Year 1 (2019) plantings leader growth for Site 4 is higher than for Site 1 and Site 2, whereas the diameter and shoot length for Site 1 and Site 2 plantings are higher than Site 4. While Site 1 and Site 2 leader growth results are closer to the median, results for diameter and shoot length are well above the 75th percentile for both Year 1 and Year 3 results. Results for Site 4 plantings range between the median and the 75th percentile, with the exception of Year 1 leader growth and Year 1 shoot length that were both greater than the 75th percentile.

These results indicate that the vegetation establishment trajectory at Site 1 and Site 2 is in line with expectations for leader growth, shoot length and diameter for both live cuttings and plantings. No changes to current maintenance practices or remedial actions are recommended for these sites. The vegetation establishment trajectory for plantings at Site 4 is also meeting expectations; however, the establishment of live cuttings at Site 4 is not meeting expectations. Replanting has already occurred in 2021 to address the live cutting establishment issues at Site 4.

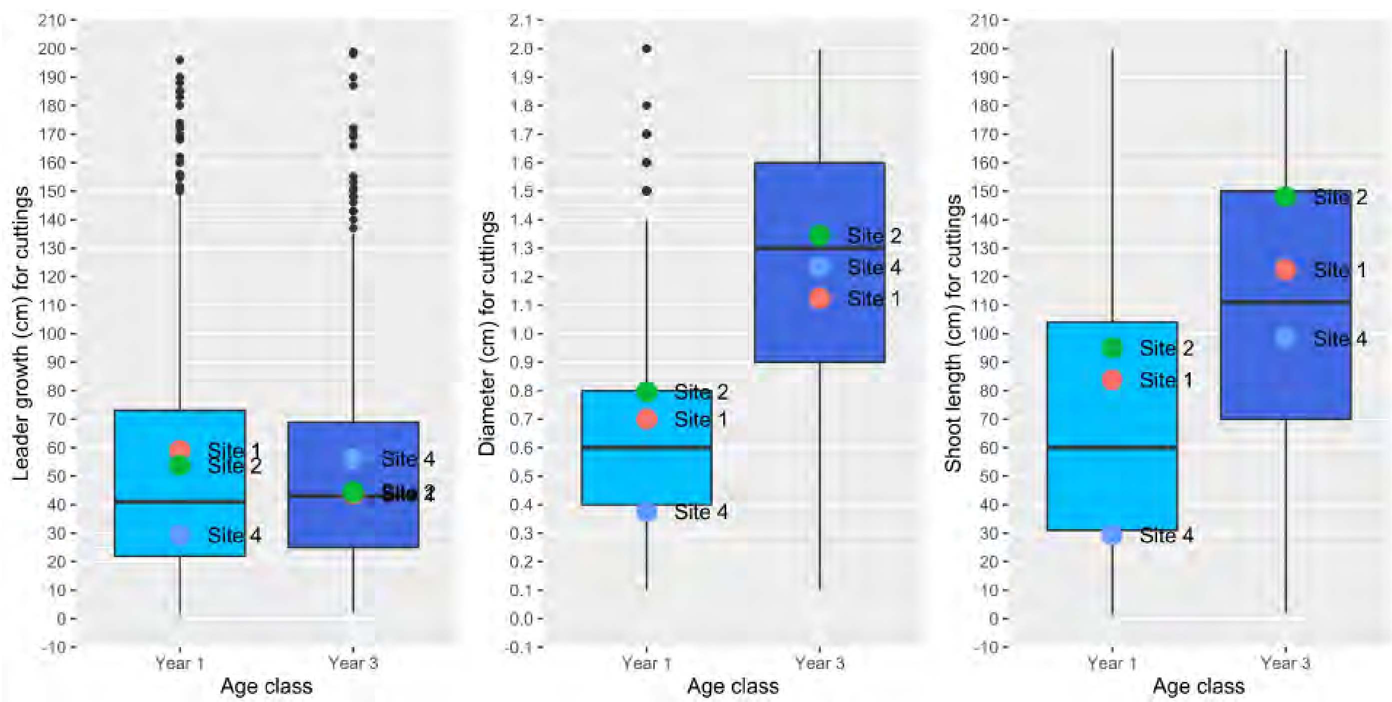

Figure 5-3: Live Cuttings Establishment at BDEP Site 1, 2, and 4 Compared to Mean Year 1 and Year 3 Data from the Riparian Monitoring Program for Mean Leader Growth (left); Diameter (middle); and Shoot Length (right) [5]

[5] The bottom of the box in the box plots is the 25th percentile value, the top of the box is the 75th percentile value, the band near the middle of the box shows the 50th percentile (median) value; thus, 50% of the data values are within the box. The upper whisker shows the statistical maximum (upper

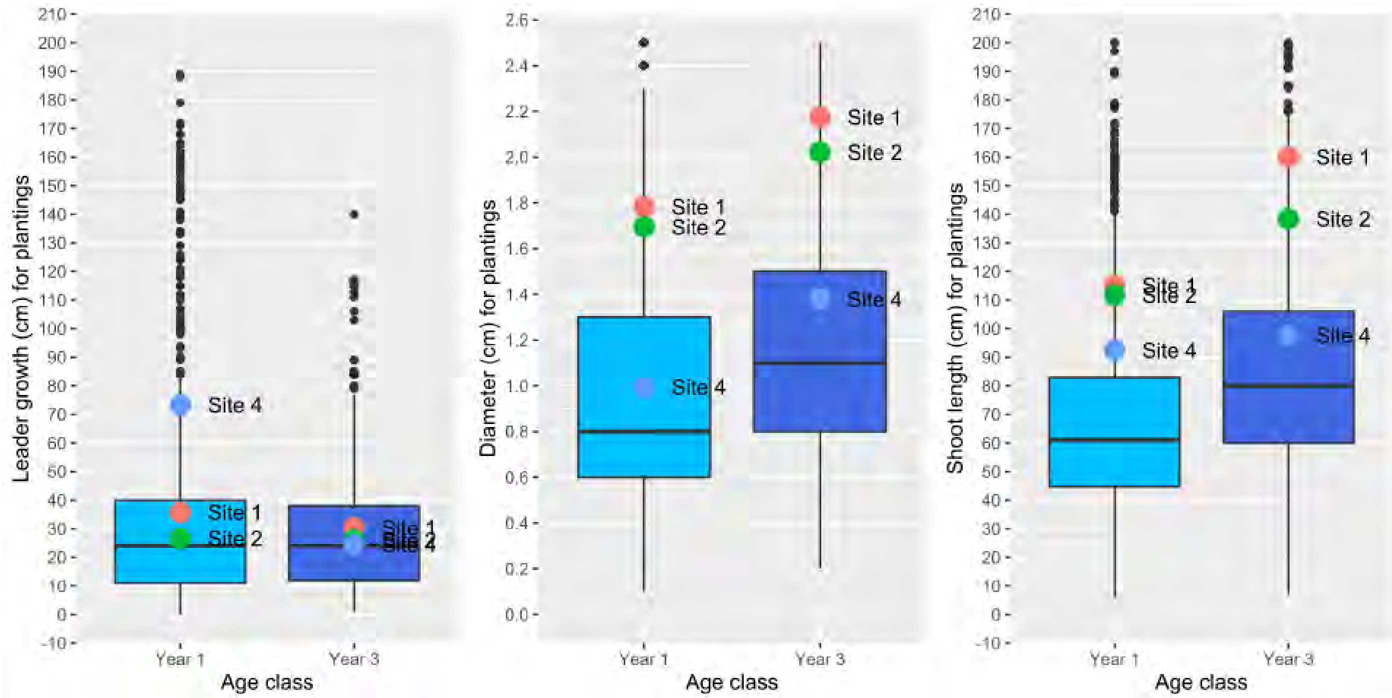

Figure 5-4: Plantings Establishment at BDEP Site 1, 2, and 4 Compared to Mean Year 1 and Year 3 Data from the Riparian Monitoring Program for (a) Mean Leader Growth and Shoot Length; and (b) Mean Diameter [2]

Key Results and Observations

Key results and observations from the Vegetation Assessment of the different bioengineering techniques are listed below.

- At **Site 1**, overall woody vegetation canopy cover was 38% in 2021, which is higher than in 2020 (31%) and 2019 (33%). This result is highly influenced by the potted plant canopy cover (25% in 2021, 24% in 2020, and 16% in 2019) since potted plants were installed in about three-quarters of the overall site in the riparian area above the bank. The potted plant canopy cover has increased over the 3 years of monitoring, partially due to maintenance measures including cutting herbaceous vegetation around the woody plants, installing hemp mats around the plants to reduce competition (Photo 5-10), weeding, and irrigation (Photo 5-11). Many of the planted shrubs were also staked to help identify their location and keep them upright.
- The live cutting canopy cover at **Site 1** was measured to be 89% in 2021, 53% in 2020 (may not be representative due to the use of a different measurement method as described in Box 1), and 88% in 2019 and indicates successful establishment of the cuttings in the timber crib wall and vegetated soil wraps in the middle section the site (Photo 5-12). Woody vegetation canopy cover for the timber crib wall and soil wrap techniques were 80% and 94%, respectively, in 2021. Woody vegetation canopy cover for the brush layers and brush mattress techniques at the downstream end of Site 1 (Photo 5-13) were 82% and 98%, respectively, in 2021.
- The timber crib wall in **Site 1** was replanted with 1000 live stakes in May 2021 to address the low establishment rate mentioned in the 2020 BDEP report (KWL, 2021a).

quartile + 1.5 * interquartile range) and the lower whisker shows the statistical minimum (lower quartile – 1.5 * interquartile range). Outliers are shown as dots above or below the whiskers.

- At **Site 2**, overall woody vegetation canopy cover was 26% in 2021, which is higher than in 2020 (21%) but lower than in 2019 (34%). The results for Site 2 are similarly affected by the potted plant canopy cover (5% in 2021, 4% in 2020, and 13% in 2019) since potted plants were installed in about three-quarters of the site in the riparian area above the bank. The decrease in potted plant canopy cover over the 3 years of monitoring is partially due to lack of regular maintenance, mechanical damage from weed wacking, weed competition, and limited irrigation coverage. Also, some mortality and theft was noted.
- The live cutting canopy cover at **Site 2** was measured to be 83% in 2021, 69% in 2020 (may not be representative due to the use of a different measurement method as discussed in Box 1), and 89% in 2019 and indicates successful establishment of the cuttings in the box fascine (Photo 5-14), brush mattress, contour fascine, hedge brush layer, and live staking (Photo 5-15). Woody vegetation canopy cover for the box fascine, brush mattress, contour fascine, hedge brush layer, and live staking techniques was 91%, 94%, 84%, 94%, and 56%, respectively, in 2021. Dense vegetation growth was observed at Site 2, as shown in Photo 5-16, with root growth observed into native substrates at the toe of the site as shown in Photo 5-17. These photos indicate that the vegetation canopy is protecting the soil surface from erosion and the roots are binding the soil below the surface.
- At **Site 2**, the approximately 11 m long section of contour fascine in upper northwest corner of the site that was identified for replacement due to poor establishment was replaced with 5-gallon balsam poplar container plants. Additional potted shrubs were planted along the riparian area above the bank. Most of the planted shrubs in this area were staked to help identify their location and keep them upright.
- At **Site 4**, overall woody vegetation canopy cover was 14% in 2021, which is higher than in 2020 (6%) but lower than in 2019 (18%). Woody vegetation canopy cover for both live cuttings and potted plants is lower than expected, which is assumed to be at least partially due to herbaceous vegetation competition (Photo 5-18), but also due to the challenging growing conditions in the existing riprap. A comparison of the techniques used to retrofit existing riprap at Site 4 leads to the result that void-fill with topsoil and plug planting with a 2021 woody vegetation canopy cover of 32% (up from 4% in 2020 and 14% in 2019) is performing better than soil covered riprap with a 2021 woody vegetation canopy cover of 6% (down from 10% in 2020 and 30% in 2019) or void-fill with pitrun and live staking with a 2021 woody vegetation canopy cover of 6% (1% in 2020 and 6% in 2019).
- **Site 4** was replanted with 208 shrub plugs in 2021 to address low establishment at the site (Photo 5-19). High mortality of newly planted shrub plugs was observed in the fall of 2021. The mortality appears to be due to small plug size, shallow planting, and desiccation.
- The bioengineering techniques that are achieving the highest woody vegetation canopy cover, density and survival are the brush mattresses at Site 1-4 and Site 2-2A, hedge brush layer at Site 2-2B, and box fascine at Site 2-1 and Site 2-2A/B/C.
- Weed management in 2021 occurred as follows:
    - Upstream end of Site 1: Common tansy, cut and bag (mechanical) on August 11, 2021;
    - Middle section of Site 1 and all of Site 2: perennial sowthistle, Canada thistle, broadleaf weeds spot treatment with herbicide (Lontrel 360-23545) on July 22, 2021;

- Site 4: perennial sowthistle, Canada thistle, common tansy, Canadian vetch, absinthe wormwood, scentless chamomile, creeping bellflower, cut and bag (mechanical), spot treatment with herbicide (Lontrel 360-23545) on July 22, 2021;
  - Site 4 within 10m of water: common tansy, Canada thistle, cut and bag (mechanical) treatment on 10 June 2021; and,
  - Site 4: perennial sowthistle, Canada thistle, common tansy, Canadian vetch, absinthe wormwood, scentless chamomile, creeping bellflower, cut and bag (mechanical), herbicide (Lontrel 360-23545) spot mechanical treatment on July 6, 2021 and herbicide treatment on July 22, 2021.
- The Final Acceptance Certificate (FAC) was issued in October 2021, with the fencing around the site removed about two weeks prior. It is understood that The City has engaged the contractor to provide additional irrigation for the next 2 years using the pressurized sprinkler system to support the newly planted vegetation. Weeding will also be performed by The City during this time period.

Photo 5-10: Hemp squares as an herbaceous vegetation suppressant at Site 1 (May 14, 2021)

Photo 5-11: Drip irrigation system at Site 1 (June 18, 2021)

Photo 5-12: Good and vigorous growth at timber crib wall, vegetated soil wraps and riparian area of Site 1 – looking downstream (June 18, 2021)

Photo 5-13: Good and vigorous growth in brush layers and brush mattress at downstream end of Site 1 – looking upstream (June 18, 2021)

Photo 5-14: Good and vigorous growth at Site 2 – looking downstream from upstream end (July 20, 2021)

Photo 5-15: Good and vigorous growth at Site 2 – looking upstream from downstream end (July 20, 2021)

Photo 5-16: Vegetation establishment Site 2 (July 20, 2021)

Photo 5-17: Root growth into native substrates at the toe of Site 2 (July 20, 2021)

Photo 5-18: Vegetation growth at Site 4 (July 19, 2021)

Photo 5-19: Replacement shrub plug plantings at Site 4 (June 18, 2021)

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 (d_{50} = ±500 mm) (Fischenich, 2001).

The estimated permissible shear stresses for Year 3 (2021) post-construction of the various bioengineering techniques used at Sites 1, 2, and 4 are shown in Table 5-10. Techniques that provide comparable or better shear stress resistance than Class 2 riprap are bolded in Table 5-10 and include the vegetated timber crib wall and brush mattress at Site 1, the box fascine and brush mattress at Site 2, and the vegetated riprap techniques at Site 4. The remaining techniques range in permissible shear stress from 80 N/m^2 to 165 N/m^2 and are less than the resistance provided by Class 2 riprap, but all meet the requirement to withstand the 100-year design flood event and 2021 peak annual flow event shear stresses shown in Table 5-2 where they are installed.

Table 5-10: Estimated Permissible Shear Stress by BDEP Sub-Site

Site No.	Bioengineering Technique	Estimated Permissible Shear Stress Resistance (N/m^2)[1]		
		2019	2020	2021
1-1	Rooted live cuttings in riprap	100[2]	300[2]	**>350**[2]
1-2	Class 2 riprap	364[3]	364[3]	364[3]
1-3	Timber crib wall with brush layers	**600**[4]	**600**[4]	**600**[4]
1-4	Brush layer with contour fascine / Brush mattress with rock toe	141[4] / 244[4]	141[4] / 244[4]	116[4] **/ 450**[4]
2-1	Box fascine	100[2]	200[2]	**>350**[2]
2-2A	Box fascine / Brush mattress / Contour fascine	100[2] / 244[4] / 50[4]	200[2] / 244[4] / 50[4]	**>350**[2] / **450**[4] / 80[4]
2-2B	Box fascine / Hedge brush layers	100[2] / 244[4]	200[2] / 244[4]	**>350**[2] / 116[4]
2-2C	Box fascine / Live staking	100[2] / 150[4]	200[2] / 150[4]	**>350**[2] / 165[4]
4-1	Vegetated Class 2 riprap / Plantings	**364**[3] / 100[4]	**364**[3] / 100[4]	**364**[3] / 140[4]
4-2	Vegetated Class 2 riprap / Plantings	**364**[3] / 100[4]	**364**[3] / 100[4]	**364**[3] / 140[4]
4-3	Willow staking in placed riprap	100[2]	300[2]	**>350**[2]
4-4	Class 2 riprap	364[3]	364[3]	364[3]

Notes:
1. Estimated shear stress resistance at the time of monitoring, i.e., 1 year post construction (2019), 2 years post-construction (2020) and 3 years post construction (2021).
2. Source: Lachat, B. (1999). *Guide de protection des berges de cours d'eau en techniques vegetales*.
3. Source: Fischenich, C. (2001) *Stability Thresholds for Stream Restoration Materials - EMRRP Technical Notes Collection (ERDC TN EMRRP-SR-29)*
4. Source: Evette, A. et al (2018) *The limits of mechanical resistance in bioengineering for riverbank protection*

5.3 Summary of Findings

Key findings from the 2021 bioengineering structural integrity assessment are listed below.

- Flows in the Bow River at the site were below the 2-year flood flow and shear stresses ranged from 9 to 32 N/m^2. Total precipitation in Calgary was 277 mm, which is well below the average precipitation of 410 mm. In particular, rainfall amounts during the growing season (May to October) were well below monthly averages, with the exception of August. June and July were also very hot and dry, with warmer than average temperatures and with about ¼ of the normal June average monthly rainfall.
- 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.

- 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. Curlex® Sediment Logs® were noted in 2021 to be in poor condition and missing in some places but they have served their purpose of providing temporary erosion and sediment control and can be either left in place or removed.
- Fine sediment was observed to have deposited along the bottom of 10 of 12 fish shelters in a layer ranging from 0.01 m to 0.2 m depth, with an average depth of 0.1 m. There was an average of 0.05 m more sediment deposited in the fish shelters from 2020 observations. Otherwise, the fish shelters were open 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.
- Woody vegetation canopy cover for the live cuttings installed in the bank portion of the BDEP is very good at 89% for Site 1 and 83% at Site 2 in 2021, but is low at Site 4 at 6%. The 2021 results for cover are in the same range as compared to 2019, despite the dry and hot conditions during summer 2020 and 2021. Overall woody vegetation canopy cover for 2021 is 31% over the site. An increasing trend in woody vegetation canopy cover was observed for Site 1 (+5%), while both Site 2 (-8%) and Site 4 (-4%) have shown a decreasing trend from 2019 to 2021.
- Potted plant survival ranged from 96% (Site 4) to 100% (Site 1 and Site 2) in 2019 and from 98% (Site 1) to 100% (Site 2 and Site 4 [due to replanting]) in 2020 and was higher than live cutting survival which is consistent with the results of the Riparian Monitoring Program (KWL, 2022). Live cutting survival ranges from 60% (Site 4) to 80% (Site 2) in 2019 and 36% (Site 2) to 56% (Site 1) in 2020, which is consistent with the naturally occurring trend of reduced survival over time for live cutting due to competition and natural thinning (see Box 1)
- Results for the BDEP sub-sites provide some additional insights to the effectiveness of the bioengineering techniques used within each overall site. Live cutting canopy cover was reduced over most sub-sites from 2019 to 2021 except for Site 1-4 (brush mattress, contour fascine and brush layer) where it increased from 76% to 86%. Vegetation density is well above targets for the box fascines (Site 2-1, Site 2-2A/B/C), contour fascines (Site 1-4 and Site 2-2A), hedge brush layers (Site 2-2B) and brush mattresses (Site 1-4 and Site 2-2A). Density was measured for the first time in 2021, so no trends are available. Live cutting survival most often decreased at the sub-sites with the except of Site 1-1 (rooted live cuttings), likely due to remedial planting in 2020. As mentioned above, hot and dry conditions during the summer of 2020-2021 had a negative influence on vegetation growth at the BDEP and most indicators were reduced, despite irrigation efforts.
- The vegetation establishment trajectory at Site 1 and Site 2 is in line with expectations for leader growth, shoot length and diameter and no changes to current maintenance practices or remedial actions are required. Replanting at Site 4 has already occurred in 2021 to address the live cutting establishment issues.
- 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, the brush mattress at Site 2, and where existing riprap was retrofitted at Site 4. However, the shear stress resistance for the bioengineering techniques is all higher than the baseline case (100-year flood event) and the maximum shear stress from 2019, 2020, and 2021 Bow River flows.

- FAC was issued in October 2021 with the fencing around the site removed about two weeks prior. It is understood that The City has engaged the contractor to provide additional irrigation for the next 2 years to support the newly planted vegetation. Weeding will also be performed by The City.

Photo 5-20: BDEP Site 2 (July 19, 2021)

6. Conclusions and Recommendations

Photo 6-1: Looking upstream towards BDEP site on June 18, 2021

6.1 Conclusions

The key conclusions listed below were noted in this report.

Fish and Fish Habitat Results

Per Goal 1 of the monitoring program (see Section 1), monitoring results that show how the bioengineering techniques used in the project have improved fish habitat in the area are listed below.

- All water quality parameters measured in Site 1, Site 4, and the Upstream Control Site were within federal guidelines (CCME, 1999). Results from water quality measurements in 2021 were similar to measurements recorded in 2020 and 2019, with similar seasonal variability in temperature, dissolved oxygen and conductivity except for spring temperature and conductivity measurements which were taken slightly later in the season and are more reflective of summer values. Site 1 and Site 4 values were also within the natural seasonal variation of the Bow River as determined by comparison to the Upstream Control Site. In addition, Site 1 and Site 4 values were comparable to each other and to the Upstream Control Site so no effects on water quality were obviously discernible from the BDEP project.

- Fish are continuing to use the habitat enhancement structures provided by the BDEP as observed in Year 1 (2019) and Year 2 (2020). Fish were observed using and were captured within the vicinity of the habitat structures throughout the project area; however, in contrast to Year 1 (2019) and Year 2 (2020) monitoring results, no fish were observed in the fish shelters, boulder clusters, and surrounding habitats in 2021 during the fall assessment. Mountain whitefish eggs were documented in the upstream section of Site 1.
- Compared with the baseline desktop assessment of historic fish capture data from the Bow River, of the 22 species that have a probable potential of occurrence on the Bow River within the vicinity of the project, 2 species were captured during 2021 (Year 3) monitoring, both of which are non-sportfish species. In 2020, 9 species were captured, including 5 sportfish and 4 non-sportfish species. In 2019, 10 species were captured within the project area, 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, so comparison was limited to the baseline desktop assessment, as noted above.
- As noted above, no electrofishing was conducted in 2021 due to due to low water levels and high water temperatures in the Bow River and high ambient air temperatures. In 2020, a total of 45 fish from 6 species were captured at Site 1, 42 fish from 8 species were captured at Site 2, and 33 fish from 3 species were captured at Site 4 using a single boat electrofishing pass. In 2019, a total of 16 fish from 7 species were captured at Site 1, 8 fish from 2 species were captured at Site 2, and 24 fish from 6 species were captured from Site 4.
- In 2021, minnow trapping Catch per Unit Effort (CPUE) was greatest at Site 2, followed by Site 4. No minnow trapping was conducted at Site 1 in 2021. In 2020, both minnow trapping and electrofishing CPUE was greatest at Site 2, followed by Site 1, with Site 4 having the lowest. In 2019, minnow trapping and electrofishing CPUE was highest at Site 4, followed by Site 2, then Site 1 (Site 1 and Site 2 had equal minnow trapping CPUE).
- In 2021, the highest CPUE by species from minnow trapping (no electrofishing was conducted) was white sucker. In 2020, the highest electrofishing CPUE by species was rainbow trout at Site 1, mountain whitefish at Site 2, and longnose sucker at Site 4. In 2019, the highest CPUE was rainbow trout and perch at Site 1 (equal CPUE), white sucker at Site 2, and longnose sucker at Site 4.
- In 2021, Site 2 had the highest abundance and diversity of fish species and Site 4 had the lowest (no data from Site 1). In 2020, Site 2 had the highest abundance and diversity of fish species, including five sportfish species (i.e., brown trout, burbot, mountain whitefish, northern pike, and rainbow trout). This is a change from 2019 results where only forage fish were captured at Site 2.
- Because of the limited sampling that occurred in 2021, species composition and fish abundance cannot be compared directly to past monitoring years. However, it was observed that species composition and fish abundance increased from 2019 to 2020.
- In 2021, no redds were observed during either the spring or fall spawning assessments. These results are consistent with past spawning assessments from 2020 and 2019.
- Six locations within the upstream extent of Site 1 (i.e., upstream of the Cushing Bridge) were sampled during the fall kick sampling survey and mountain whitefish eggs were observed at each location during each monitoring year (2019-2021).

Based on the above results from monitoring fish and fish habitat over 2019-2021, **the bioengineering techniques used at Site 1 and Site 2 have improved fish habitat over the conventional riprap design site at Site 4**.

Wildlife Results

Per Goal 2 of the monitoring program (see Section 1), monitoring results that show how the bioengineering techniques used in the project have improved wildlife habitat in the area are listed below.

- The Year 3 (2021) breeding bird surveys resulted in the identification of 23 species compared to 24 species in 2020 and 26 species in 2019. The highest number of bird species and individuals identified in 2021 was at Site 1, followed by Site 2 and Site 4, which was consistent with 2020 and 2019 results.
- One listed species was observed in each of 2020 and 2021 (bank swallows) and three listed species (least flycatcher, western wood-pewee, and bank swallow) were observed in 2019.
- The bank swallow colony identified in the baseline assessment at Site 2 was observed during 2019, 2020 and again in 2021 monitoring.
- No nests were observed at any of the sites in 2021 or 2020 where stick nests were observed at Site 1 in 2019.
- Site 1 (77 individuals from 19 species) and Site 2 (28 individuals from 11 species) showed increased bird activity relative to Site 4 (13 individuals from 6 species) based on the results of the breeding bird and nesting surveys in 2021. This is consistent with 2020 bird activity results where Site 1 had 50 individuals from 23 species, Site 2 had 29 individuals from 10 species, and Site 4 (19 individuals from 7 species), and 2019 bird activity results where Site 1 had 129 individuals from 22 species, Site 2 had 68 individuals from 8 species and Site 4 had 24 individuals from 6 species.
- The increased activity at Site 1 and Site 2 over Site 4 could be because Site 1 incorporates a much larger area with 3 breeding bird survey plots compared to a single survey plot for each of the other sites. However, it could also be the result of differences in vegetation and suitable nesting habitat availability between the sites as Site 1 was observed to have the most diverse habitat conditions due to proximity to Pearce Estates Park, followed by Site 2 and Site 4.
- The wildlife camera monitoring program included four cameras that identified animals using the wildlife corridor created as part of the BDEP under the Cushing Bridge/17th Avenue SE bridge. In total, there were 611 active camera days in 2021 compared to 926 in 2020 and 607 in 2019. An additional camera was installed in 2020 and 2021, leading to more active camera days than 2019. The reduction in camera days in 2021 compared to 2020 is due to the vandalism, theft and technical issues.
- In 2021, a total of 6 wildlife species were identified through observations of 203 individuals, with white-tailed deer (31%) followed by white-tailed jackrabbit (16%) and coyote (9%) as the most identified species[6]. This compares to 2020 results where a total of 317 individuals from 7 wildlife species were observed, the most common of which was white-tailed deer (48%) followed by coyote (32%) and white-tailed jackrabbit (11%). Results from 2019 included a total of 212 individuals from

[6] Excluding eastern gray squirrel as they were photographed exclusively by Camera 4 and was likely the same individuals photographed daily within their small home range.

8 species, the most common of which was the white-tailed jackrabbit (21%), white-tailed deer (8%) and coyote (6%). American beaver was newly identified in 2021 and was captured by Camera 4.

- The higher number of observations in 2020 are likely due to the longer active camera days where there were approximately 50% more active camera days than 2021 and 2019.
- Deer and coyote presence observed on all four of the cameras throughout Site 1 over the three years of the wildlife monitoring program and the increased mean use from 2019 to 2021, suggests that the wildlife corridor in the Project area is providing effective passage for large mammals.

Based on the above results from monitoring wildlife over 2019-2021 and based on the findings in the reviewed literature that the riprap surfaces such as found at Site 4 are difficult for many species to traverse, especially ungulates and amphibians, **Site 1 is providing better wildlife passage than Site 4, the conventional riprap design site**.

Riparian Health Results

Per Goal 3 of the monitoring program (see Section 1), monitoring results that show how the bioengineering techniques used in the project have improved riparian health in the area are listed below.

- All three BDEP sites show significantly improved riparian health in comparison to the baseline conditions (2016), with Riparian Health Assessment (RHA) score increases ranging from +9% (Site 1) to +29% (Site 2). The 2021 RHA rating for Site 1 was 52% compared to 43% in 2016, for Site 2 was 58% compared to 29% in 2016, and for Site 4 was 53% compared to 29% in 2016. Improvements are directly attributable to bioengineering and riparian planting treatments conducted in fall 2018/spring 2019 and/or 2015 upper bank plantings at Site 4.
- All three sites have shown relatively stable health trends over Year 1 (2019), Year 2 (2020), and Year 3 (2021) monitoring years, with only minor increases or decreases since the first post-construction RHA assessments in 2019. There was a slight increase in RHA scores between 2019 and 2021 assessments for Site 1, stable scores for Site 2, and a slight reduction for Site 4. The main reason for the slightly increased RHA score for Site 1 was an increase in river bank root mass protection. All parameters scored the same for the 2019-2021 RHA assessments at Site 2. The main reason for the slightly reduced RHA scores for Site 4 were slightly lower regeneration of preferred shrub species due to some die-off of planted stakes and container plants.
- The 2021 RHA scores for Sites 1, 2, and 4 result in the sites being categorized as *Unhealthy* (same category as the baseline, 2019, and 2020 assessments).
- Similar to RHA results by Site, the overall BDEP area shows an improving riparian heath trend via the Riparian Health Inventory (RHI), having increased by 15% since 2016. The entire project area now rates as 59%, approaching the *Healthy, with problems* threshold for RHI-assessed sites of 60%. As with individual site results from the RHA scoring, this is mainly due to tree and shrub vegetation health improvements.
- Limitations in the RHA and RHI method due to the manner in which permanent impacts from urban development, upstream damming, and flow regulation and diversions are scored make it impractical to achieve ‘healthy’ benchmarks (scores greater than 80%) for the BDEP. Thus, despite site-level interventions such as bioengineering or riparian planting projects, maximum achievable Riparian Health scores are ultimately constrained by watershed-scale factors. However, there is room for improvement in terms of weed control, bank root mass protection, and preferred shrub regeneration that could push all three sites into the *Healthy with Problems* category.

- Increases in the vegetation component of the RHA scores was the key factor in the increased 2021 RHA ratings compared to baseline (2016) results. At Site 1 the vegetation rating has increased by 13% and at Site 2 and Site 4 the vegetation rating has increased by 146% over the 2016 rating. The key vegetation parameters that have led to improved RHA scores are increased tree regeneration of balsam poplar (*Populus balsamifera*) and aspen (*P. tremuloides*) (RHA parameters 1 and 2), increased regeneration of preferred shrub species (RHA parameter 3) and increased total canopy cover of woody species (RHA parameter 6). These increases in the vegetation rating parameters are directly attributable to the bioengineering work completed for the BDEP.
- Results from the RMP BRQI assessments in 2021 show that all three sites are considered Fair, with moderate overall BRQI scores. In 2021, Site 1 has the highest BRQI score (64%), followed by Site 2 (62%) and Site 4 (54%). Although trend data is very preliminary with only 2019 and 2021 assessments completed to date, results appear to be mixed, with Site 1 showing a stable trend, Site 2 showing an improving trend, and Site 4 showing a degrading trend.
- RHA ratings over the three years of monitoring at 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 over the three years of monitoring are substantially 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.

Based on the above results from monitoring riparian health over 2019-2021, **overall riparian health at the BDEP has improved over a conventional riprap design site due to the bioengineering techniques used.**

Bioengineering Structural Integrity Results

Per Goal 4 of the monitoring program (see Section 1), monitoring results that show how the bioengineering techniques used in the project have improved bank structural integrity are listed below.

- 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. Note that flows in the Bow River at the site in 2021 were below the 2-year flood flow and shear stresses ranged from 10 to 35 N/m^2. Rainfall in Calgary in 2021 was well below average at 277 mm.
- Materials used in the construction of the BDEP include rock riprap, wood, erosion control matting and geogrids, concrete, and steel. These materials were generally found to be in good to excellent condition. Curlex® Sediment Logs® were noted in 2021 to be in poor condition and missing in some places, but they have served their purpose of providing temporary erosion and sediment control and can be either left in place or removed.
- The fish shelters were observed to have 0.05 m more fine sediment deposited along the bottom compared to 2020 results, 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.
- Woody vegetation canopy cover for the live cuttings installed in the bank portion of the BDEP is very good at 89% for Site 1 and 83% at Site 2 in 2021, but is low at Site 4 at 6%. The 2021 results for cover are in the same range as compared to 2019, despite the dry and hot conditions during summer 2020 and 2021. Overall woody vegetation canopy cover is 31% over the site.

- The vegetation establishment trajectory at Site 1 and Site 2 is in line with expectations for leader growth, shoot length and diameter, and no changes to current maintenance practices or remedial actions are required. Replanting at Site 4 has already occurred in 2021 to address the live cutting establishment issues.
- FAC was issued in October 2021 with the fencing around the site removed about two weeks prior. It is understood that The City has engaged the contractor to provide additional irrigation for the next 2 years to support the newly planted vegetation. Weeding will also be performed by The City.

Based on the above results from monitoring bioengineering structural integrity over 2019-2021, **overall bank structural integrity at the BDEP has improved over a conventional riprap design site due to the bioengineering techniques used.** At Year 3 post-construction, many of the bioengineering techniques are providing a similar level of shear stress resistance compared to Class 2 riprap is including the vegetated timber crib wall at Site 1, the brush mattress at Site 1 and Site 2, the box fascine at Site 2, and where existing riprap was retrofitted at Site 4. The inclusion of vegetation improves the overall soil cohesion due to root growth and near surface velocity reduction due to canopy growth. In addition, 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, 2020, and 2021 Bow River flows.

6.1 Recommendations

Recommendations for future monitoring years are listed below.

Fish and Fish Habitat Recommendations

- Any future remedial actions needed to meet the BEMP requirements that are identified for the site by the monitoring team should be considered for implementation by The City.
- Recommendations for monitoring in 2023 relate to the timing and equipment of the monitoring program are as follows:
    - the crew will monitor the ice conditions of the Bow River beginning in January to determine safe conditions for completing the winter and spring assessment (i.e., stable and thick ice for on-ice survey or ice-free open water conditions for snorkel survey);
    - fish sampling efforts during the summer assessment should be completed earlier in the year (late spring) or in late summer / early fall to capture fish when all sites are wetted and when adverse conditions for fish handling can be avoided; and,
    - during the summer assessment, the crew will continue to use a smaller boat for more effective sampling of near shore habitats adjacent to Sites 1 and 2.

Wildlife Recommendations

- Conduct more frequent camera checks to assess technical issues such as remaining memory card capacity and vandalism.
- Investigate opportunities to partner with Calgary Captured program for future camera installations.
- Evaluate other options to assess wildlife besides the cameras if additional camera installations are not possible.
- Based on the perceived success of the wildlife corridor at Site 1, it is recommended to consider creating a City-wide design standard to infill riprap void-spaces with smaller sized gravels or topsoil.

This would improve wildlife passage under bridges in Calgary (as is standard in Minnesota per Section 5.2), but also at all locations where riprap is used on the riverbank to improve wildlife passage and habitat on riverbanks.

Riparian Health Assessment Recommendations

- Conduct annual BRQI monitoring in lieu of annual Riparian Health Assessments (RHAs). As discussed, BRQI metrics are more sensitive to site-level interventions and will allow for better comparative evaluation of bioengineering treatments relative to riparian habitat enhancement objectives. Key vegetation RHA metrics are incorporated in the BRQI. Going forward, BRQI metrics could be calculated by way of ocular estimations (similar to RHA field survey methods) for each site and for the project area as a whole. This would mean that BRQI results could be extrapolated for 2016 using baseline RHA/RHI data, GIS satellite image analysis and other pre-construction survey data to allow for comparison to baseline (2016) conditions. BRQI results presented in this report are derived from pin-point transect data, and thus, don't allow for cross-year comparison with RHA survey results.
- Continue to conduct long-term RHI trend monitoring (5-year re-visit intervals) as per the RMP (KWL 2018). This will allow BDEP RHI trend data to be integrated into a city-wide dataset aimed at showing progress toward riparian health targets in The City's *Riparian Action Program* (City of Calgary, 2017). It also facilitates riparian health trend evaluations at a comprehensive project scale since baseline conditions. RHI monitoring entails collecting detailed plant species canopy cover, composition and plant community characterization data including tracking the age-class demographics of trees and shrubs (i.e., a break-out of seedling, sapling, mature and dead/dying individuals by species). These data are important for monitoring ongoing natural regeneration and plant community successional trajectories for bioengineering projects. Long-term die-off and other natural or human-caused constraints to riparian health can be better tracked via detailed lotic riparian health inventories. Another important component of RHI trend monitoring is repeat photography to visually track the progression of the site over time, a compelling and important aspect of showing and communicating success. The next RHI would be conducted in 2026.
- Continue invasive weed control and monitoring efforts on an annual basis.
    a. As a priority, focus efforts on **early detection and rapid removal of any *Prohibited Noxious Weeds*** as per the Alberta *Weed Control Act.* Provincial regulations are more stringent for invasive plants with this designation, requiring their immediate eradication. **The BDEP site is currently void of *Prohibited Noxious Weeds*,** however, such weeds have potential to be introduced by wind, water, wildlife, or human-caused seed dispersion. Nodding thistle (*Carduus nutans*) and spotted knapweed (*Centaurea stoebe* ssp. *micranthos*) are examples to watch for. These species are emerging threats in Calgary's Bow River sub-basin.
    b. Secondly, focus efforts on **hand-removal of isolated, rare invasive weed occurrences** (i.e., five or fewer plants) to prevent further establishment.
    c. Lastly, work in collaboration with Calgary Parks, Integrated Pest Management, to **develop long-term integrated weed management strategies** (using a combination of mechanical, biological and/or chemical control options) **for entrenched, locally common invasive weeds** (e.g., Canada thistle [*Cirsium arvense*] and common tansy [*Tanacetum vulgare*]).

- Conduct hand removal of tufted vetch (*Vicia cracca*) where it is evidently suppressing growth of preferred tree/shrub seedlings and saplings. Tufted vetch is not currently a provincially regulated weed, but it is an invasive, introduced species that has spread profusely in Calgary's riparian areas in recent years.
- Ensure any topsoil or fill materials used for restoration purposes are certified to be free of weed seeds. Any equipment brought on site should be clean and weed free. Only certified weed-free seed mixes should be used for rehabilitation projects.
- Continue to monitor planting survival in Site 4 where replacement plantings were done in 2021.
- Monitor the survival success of recent live stakes installed in Site 1-2 (between the Cushing and Bus Rapid Transit bridges) and replace or mitigate with an alternate bioengineering treatment as warranted.
- Augment native shrub understory plantings in upper bench 'naturalized' buffers (e.g., upper bench portions of Site 2).
- Expand and enhance clustered native tree and shrub plantings in manicured lawn areas adjacent to and within the BDEP site.
- Monitor recreational use in the BDEP site. Install signage (e.g., 'trail closed' signs) combined with fencing where necessary to curtail proliferation of foot paths that may damage bioengineering plantings or cause accelerated bank erosion.
- Continue to maintain wood rail fencing to prevent recreational access to bank swallow nest habitat.
- Once beaver and wildlife fencing is removed, monitor beaver and deer use of the bioengineering plantings, and re-instate fencing or other mitigations as needed to prevent excessive herbivory.
- For preventing beaver herbivory of individual trees and shrubs, use 14-gauge galvanized steel wire with a 5 cm (2 inch) mesh size installed to a minimum height of 90 cm (3 feet) around the base of trees or shrubs. Ensure beaver cages do not girdle trees; remove or replace cages as trees mature where necessary.

Bioengineering Structural Integrity Recommendations

- BDEP Site Recommendations
    - It is recommended that The City continue with the current plan of providing on-going irrigation for 2-years post FAC. It is also recommended that The City continue with weeding the sites for a similar period of time. Replanting of failure areas on the bench is recommended with 5-gallon sized shrubs and trees (or similar large stock) to increase density and shade herbaceous vegetation to reduce competition.
    - 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. This is in addition to the current methods being used to monitor the BDEP sites as described in Section 5.1.
    - It is recommended to continue detailed monitoring of the three techniques used to retrofit existing riprap at Site 4 to determine the preferred approach. If live cuttings are used in future applications of this type, they should be placed in the openings in the riprap prior to backfilling with growing substrate versus installation after void-filling and drilling through existing riprap to place live cuttings should be avoided.

  - It is recommended to replant Site 4 in areas where the survival target of 75% was not achieved. See section 5.2.
  - It is recommended to measure vegetation parameters (e.g., cover and vigor) again in 2023 and 2028 using the transect method to facilitate better data comparison and consistent data with the 2019 and 2021 reports.
  - As noted in the 2020 BDEP report (KWL, 2021a), it is recommended that The City staff perform annual post-flood inspections to monitor the structural condition of the site and later in August / September to monitor continued vegetation establishment and success after the FAC has been issued and in years when the BDEP is not being monitored by the RMP team, such as in 2022 (inspections will occur in 2023 and 2028).
  - It would also be prudent for The City to consider setting aside a budget to address possible maintenance concerns that are identified by the BDEP monitoring team during the remaining monitoring years in 2023 and 2028 as the FAC has been issued and the contractor is no longer under contractual obligations to address any possible issues.
- General Recommendations for Future Bioengineering Projects
  - The rooted live cuttings are establishing at Site 1 and they appear to be a viable approach for constructing bioengineering projects. They are recommended to be used within various bioengineering structure types when timing constraints result in construction outside of the recommended period for using dormant live cuttings.
  - 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 that are sized appropriately.
  - For future box fascine installations on the Bow River, it is recommended that the fill placed in the box fascine be larger sized material than pea gravels that were used at Site 2. A good option could be native river gravels excavated during site construction. It is also recommended to insert live cuttings from the box fascine into the bank during construction. Also, placing erodible void-fill material on the surface of exposed steep riprap slopes per the conditions observed at Site 4 should be avoided.
  - It is recommended to use hedge brush layers where brush layers are being considered despite the additional cost. In a hedge brush layer, potted plants are used in combination with conventional live cuttings which can improve overall plant species biodiversity, habitat and food for wildlife, and additional nutrient availability in the soil via nitrogen fixing species.

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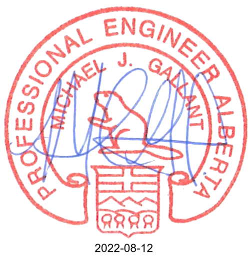
8. Report Submission

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

KERR WOOD LEIDAL ASSOCIATES LTD.

Prepared by:



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Principal, Project Manager, KWL

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PERMIT TO PRACTICE
KERR WOOD LEIDAL ASSOCIATES LTD

RM SIGNATURE:

RM APEGA ID #: 90096

DATE: 2022-08-12

PERMIT NUMBER: P007929
The Association of Professional Engineers and Geoscientists of Alberta (APEGA)

Statement of Limitations

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Revision History

Revision #	Date	Status	Revision	Author
1	August 11, 2022	FINAL	Correct table legends and include Appendix D.	MG
O	June 27, 2022	FINAL	Issued for use	MG/KH/AD

APEGA Permit # P07929

KERR WOOD LEIDAL
consulting engineers

Appendix A

Bioengineering Efficacy Monitoring Plan

Prepared by: Hemmera Envirochem Inc.

Calgary

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.

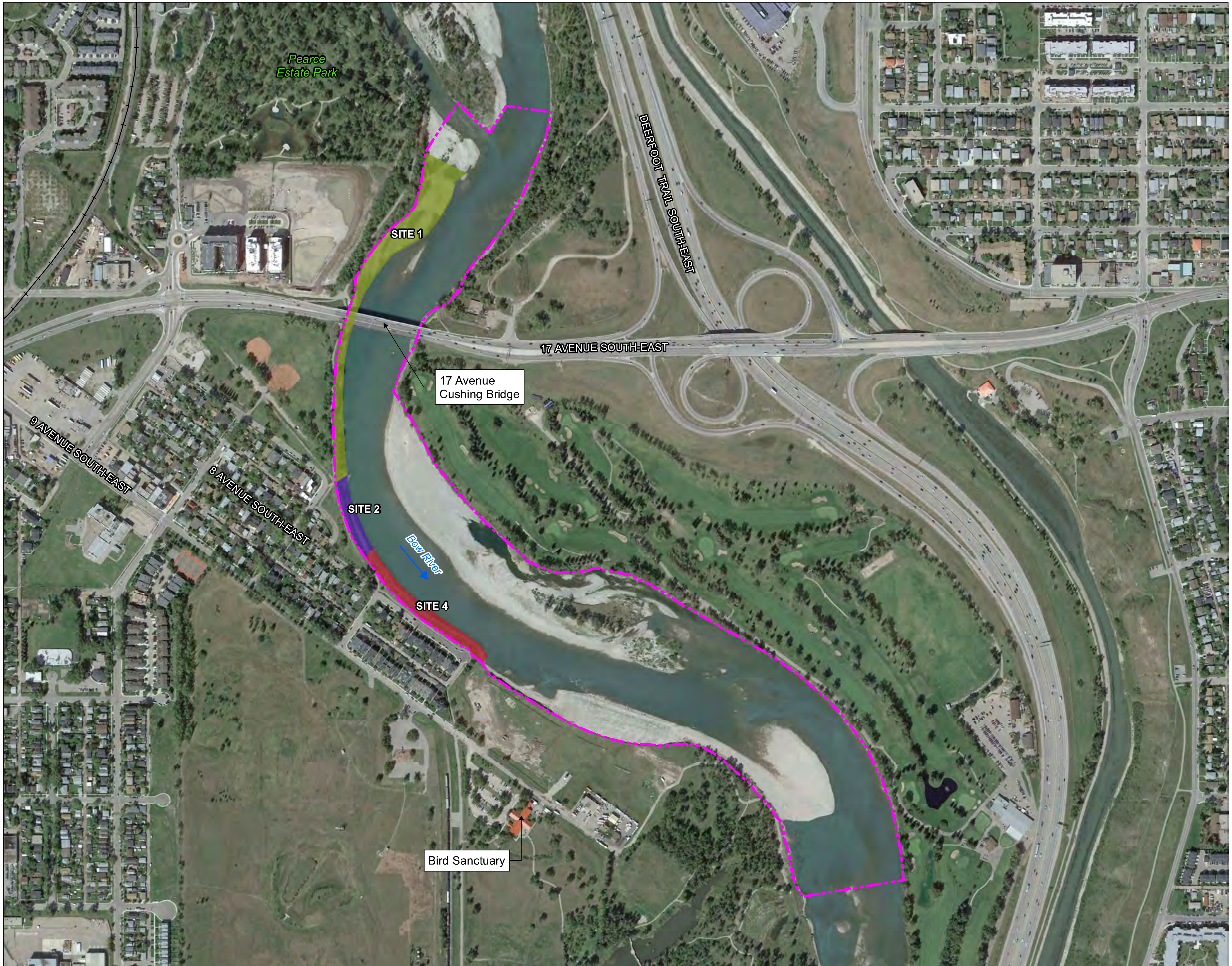
In this context, the BEMP is a critical tool to providing information to support understanding of the effectiveness of the physical works undertaken through the Project, with respect to the goals noted above, and support a comparison with conventional approaches to bank protection. However, an actual 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

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

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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.

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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.

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.

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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.

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.

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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
- BROWN TROUT
- LONGNOSE DACE
- MOUNTAIN WHITEFISH
- RAINBOW TROUT

Wildlife Inventory
- BALD EAGLE
- BALTIMORE ORIOLE
- COMMON NIGHTHAWK
- EASTERN KINGBIRD
- GREAT BLUE HERON
- HARLEQUIN DUCK
- LEAST FLYCATCHER
- NORTHERN GOSHAWK
- SILVER-HAIRED BAT
- SORA
- WESTERN GREBE
- WESTERN WOOD-PEWEE

Stocked Inventory
- RAINBOW TROUT

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

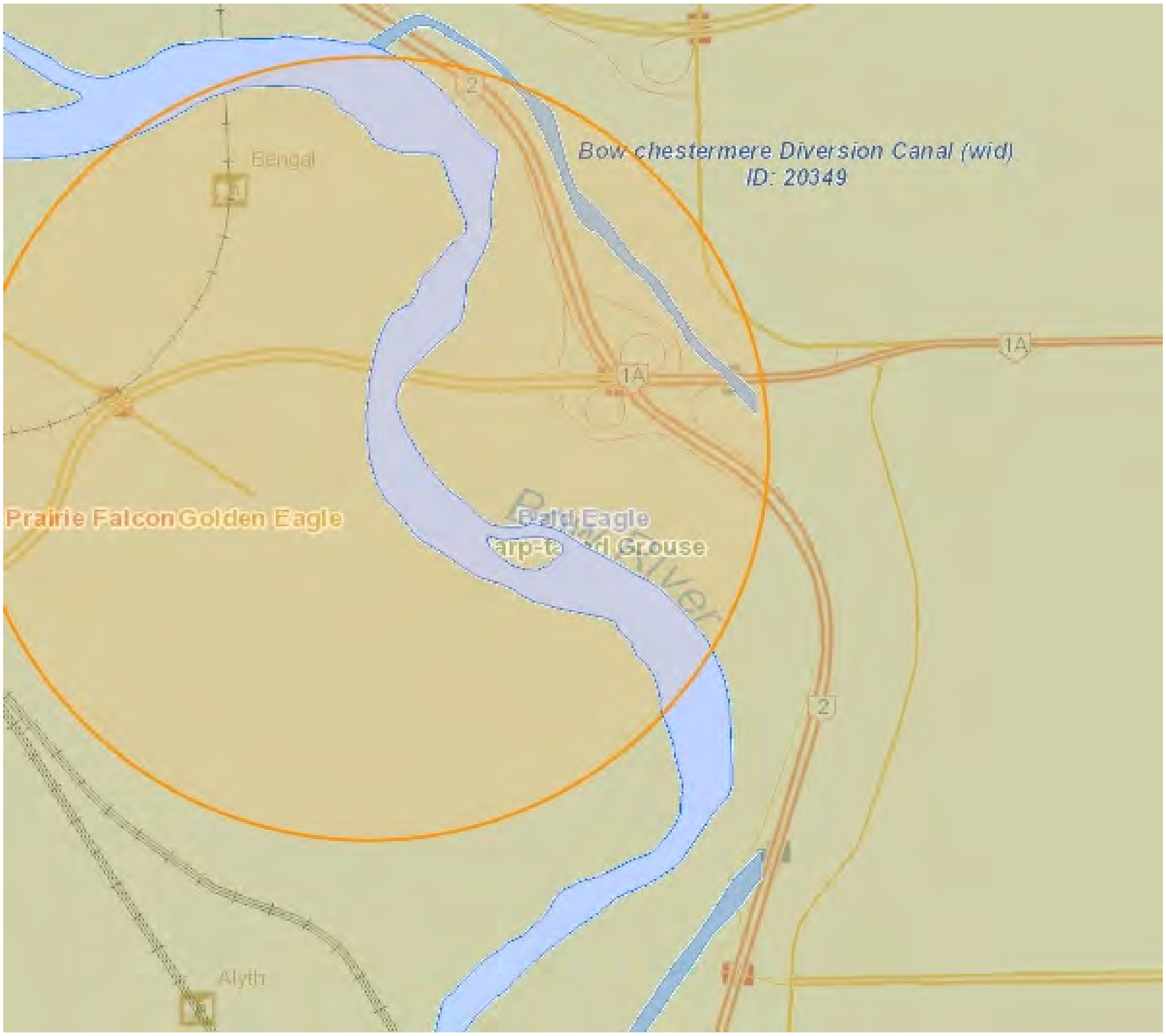
Contact Information

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



Display may contain: Base Map Data provided by the Government of Alberta under the Alberta Open Government Licence. Cadastral and Dispositions Data provided by Alberta Data Partnerships.©GeoEye, all rights reserved. Information as depicted is subject to change, therefore the Government of Alberta assumes no responsibility for discrepancies at time of use.

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 J	F	M	A	M	J	J	A	S	O	N	D
Fish and Fish Habitat	Spring				■								
	Summer							■					
	Fall										■		
	Winter	■											
Riparian Health	Fall									■			
Wildlife	Summer						■						
Bioengineering Structural Stability	Spring						■						
	Summer								■				

Monitoring Component	Season	2020 J	F	M	A	M	J	J	A	S	O	N	D
Fish and Fish Habitat	Spring				■								
	Summer							■					
	Fall										■		
	Winter	■											
Riparian Health	Fall									■			
Wildlife	Summer						■						
Bioengineering Structural Stability	Spring						■						
	Summer								■				

Monitoring Component	Season	2021 J	F	M	A	M	J	J	A	S	O	N	D
Fish and Fish Habitat	Spring				■								
	Summer							■					
	Fall										■		
	Winter	■											
Riparian Health	Fall									■			
Wildlife	Summer						■						
Bioengineering Structural Stability	Spring						■						
	Summer								■				

Monitoring Component	Season	2023 J	F	M	A	M	J	J	A	S	O	N	D
Fish and Fish Habitat	Spring				■								
	Summer							■					
	Fall										■		
	Winter	■											
Riparian Health	Fall									■			
Wildlife	Summer						■						
Bioengineering Structural Stability	Spring						■						
	Summer								■				

Monitoring Component	Season	2028 J	F	M	A	M	J	J	A	S	O	N	D
Fish and Fish Habitat	Spring				■								
	Summer							■					
	Fall										■		
	Winter	■											
Riparian Health	Fall									■			
Wildlife	Summer						■						
Bioengineering Structural Stability	Spring						■						
	Summer								■				

KERR WOOD LEIDAL
consulting engineers

Appendix B

2021 Monitoring Report Bioengineering Demonstration and Education Project

Including:

- **Attachment A: Fish Assessment Photo Log**
- **Attachment B: Fish Assessment - Bow River Site Atlas**
- **Attachment C: Bow River Fish Habitat Maps**
- **Attachment D: Raw Fish Data**
- **Attachment E: Wildlife Photo Log**

Prepared by: Hemmera Envirochem Inc.

Hemmera
An Ausenco Company

2021 Monitoring Report – Bioengineering Demonstration and Education Project

Prepared for:

City of Calgary

Project No. 103530-03

January 21, 2022

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1.0 FISH AND FISH HABITAT

1.1 Introduction

Hemmera Envirochem Inc's (Hemmera) has been retained by Kerr Wood Leidal Consulting Engineers (KWL) to implement the aquatics monitoring section of the Bio-efficacy Monitoring Program for the Bioengineering Demonstration and Education Project (BDEP) (**Figure 1**). Bio-efficacy monitoring at the BDEP site is being commissioned by the City of Calgary, as part of their larger Riparian Monitoring Program (a component of a Riparian Action Program), which is evaluating riparian habitat recovery at numerous sites within the city limits.

The following fish habitat enhancement and bioengineering structures were constructed at the BDEP site in Site 1, Site 2 and Site 4, and are presented in **Table 1** and **Figure 1**.

Bio-efficacy monitoring at the BDEP site by Hemmera is to include evaluation of fish habitat use and potential of the fish habitat enhancements at Sites 1, 2 and 4 as defined by the Bioengineering Demonstration and Education Project Efficacy Monitoring Plan (Hemmera 2018). 2021 was the third year of a multi year program (2019, 2020, 2021, 2023, and 2028), monitoring and reporting in 2021 will be limited to effectiveness monitoring for 2019, 2020, 2021 and comparison to baseline conditions. Limited trend analysis from 2019 to 2021 will be reported in this year's report, and trend analysis over multiple years post-construction will be presented in subsequent reports.

Hemmera's team understands that the primary goal of BDEP is to achieve fish habitat enhancement and riparian restoration at flood affected and impacted sites using bioengineering techniques.

The goals for the Project, as per the Project Charter (Hemmera 2018), 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.

Table 1 Summary of Bioengineering Techniques used in the Project

Technical Name	Description	Proposed Location
Box Fascine	Fascine bundles placed at the toe of an eroding bank and secured between wooden poles.	Site 2
Brush Layer	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.	Site 1, Site 2
Brush Mattress	A layer of interlaced/adjacent live cuttings placed on the face of the riverbank.	Site 1, Site 2
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.	Site 1, Site 2, Site 4
Contour Fascine	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 1, Site 2
Live Staking	Insertion of live cuttings into the ground in such a manner as to promote root growth and leaf-out.	Site 1, Site 2, Site 4
Hedge Brush Layer	Row(s) of live cuttings mixed with rooted stock placed in a crisscross or overlapping manner between layers of soil, with tips protruding beyond the face of the fill.	Site 1, Site 2
Joint Planting	Live staking of existing riprap to improve riparian, aquatic and terrestrial habitats while also improving aesthetics.	Site 4
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.	Site 1, Site 2, Site 4
Soil-Covered Riprap	Covering existing riprap bank protection with soil and vegetation to improve riparian, aquatic and terrestrial habitats while also improving aesthetics.	Site 4
Vegetated Soil Wraps	Consists of brush layers interspersed between layers of soil wrapped in natural geotextile materials that provides reinforcement.	Site 1
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.	Site 1
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.	Site 4

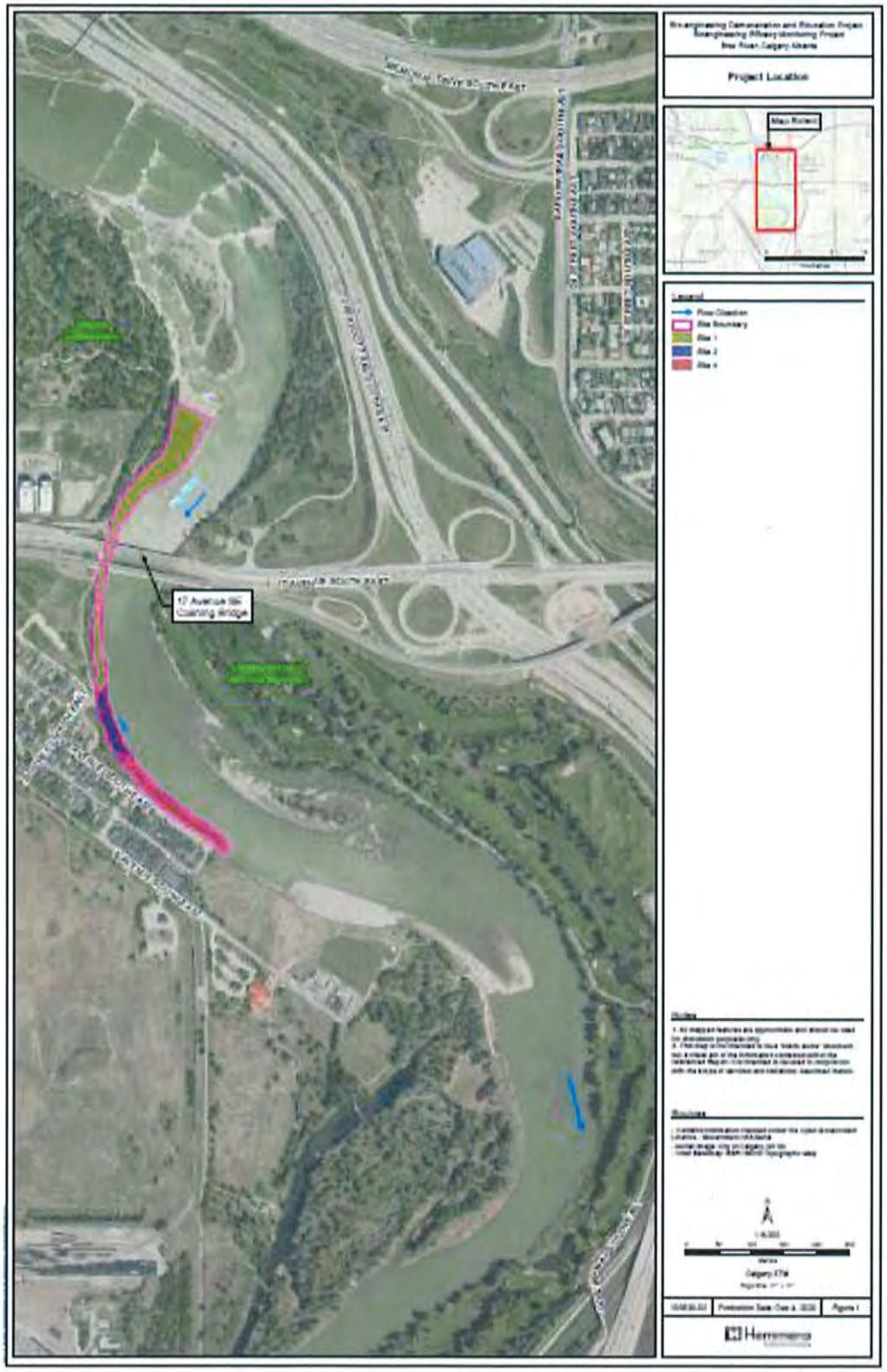


Figure 1 Project Location

1.2 Methods

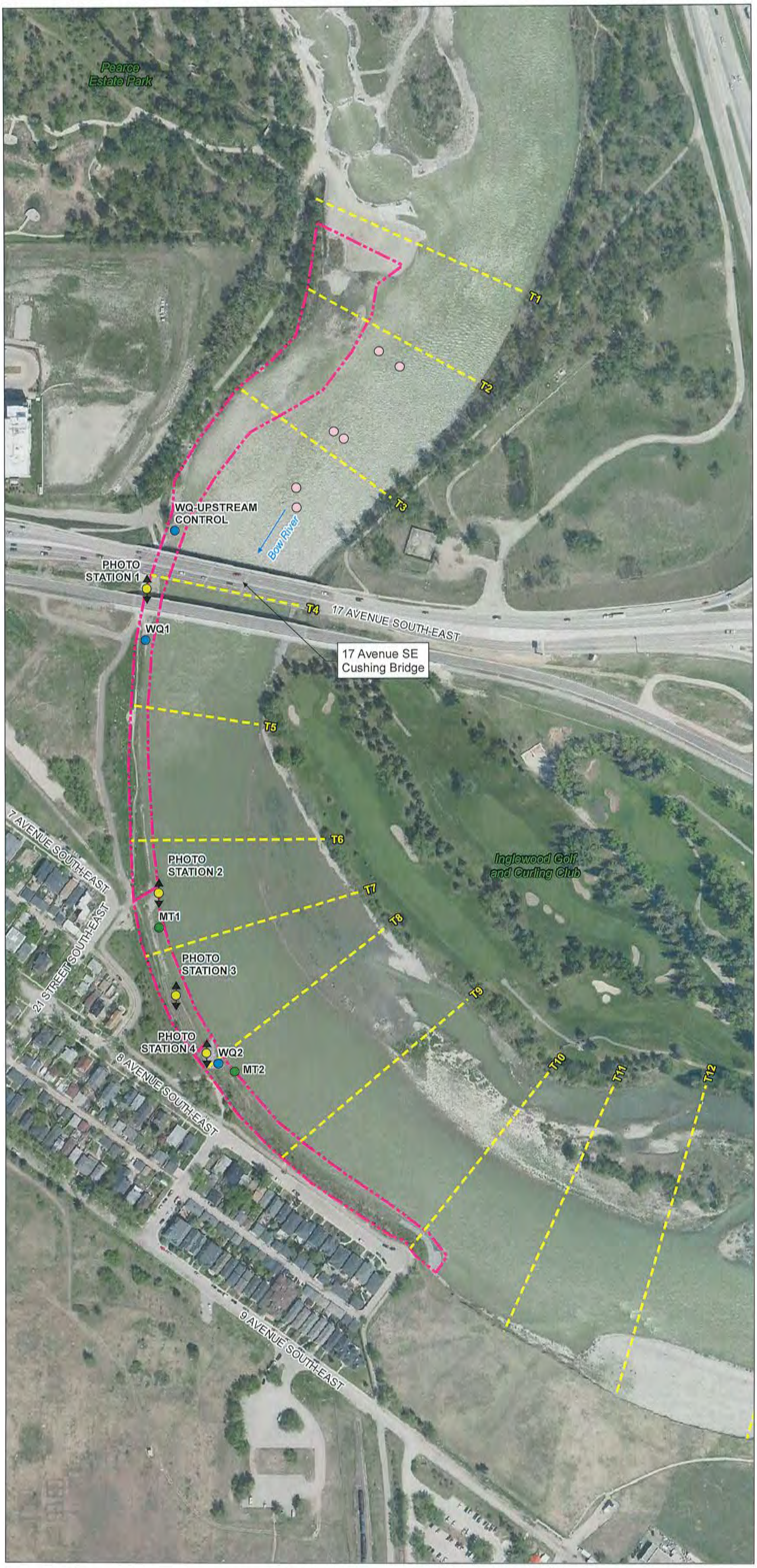
All assessments of fish habitat and fish use were completed by a crew of two and led by a Qualified Aquatic Environment Specialist (QAES). Assessments for Sites 1, 2, and 4 were completed in multiple seasons (spring, summer, fall, and winter) in 2021 as shown in **Table 2**. Sampling locations are provided in **Figure 2**.

Table 2 Schedule of Field Assessments

Field Assessment	Details	Timing			
		Winter	Spring	Summer	Fall
Fish Use	Visual assessment of fish use of near bank habitat via underwater photography and snorkel survey	x	-	-	-
Fish Spawning Use	Visual surveys conducted from bank for rainbow trout (Spring) and brown trout (Fall) redds	-	x	-	x
	Sampling of mountain whitefish eggs via kick sampling	-	-	-	x
Fish Habitat Assessment	Collection of in-stream and near stream condition, documentation of fish habitat enhancements	-	-	x	-
Water Quality	Collection of water quality parameters from Site 1 and Site 4 and the upstream control location	x	x	x	x
Fish Sampling	Overnight set Gee-style minnow traps	-	-	-	x
Photographic assessment of physical condition and stability	Establishment and assessment of photo monitoring stations	-	-	x	-

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 location
- Minnow Trap
- Transect
- Site Boundary

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 (2020)

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Hemmera
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1.2.1 Winter

A shore-based winter assessment was required to document the potential of overwinter use of the within the fish habitat enhancement structures (i.e., vegetated timber crib wall and box fascines) at Sites 1 and 2. Sampling was conducted by a crew of three biologists, led by a QAES on January 6, 2021. Sampling required the use of an underwater camera (Go Pro™), and snorkel observations to document the potential of overwinter use of the fish shelter constructed under the vegetated timber crib wall at Site 1, and the near-bank habitat adjacent to the box fascines at Sites 2.

This assessment was limited to the fish shelters at Site 1, as Site 2 and Site 4 were ice covered and created unsafe conditions.

1.2.2 Spring

A spring assessment of fish use occurred post-freshet on July 19, 2021 by walking along the bank and making visual observations. This assessment included site photos and in situ water quality parameters, assessment of substrate size/type, and habitat type (e.g., run, riffle, flat) that would facilitate or impede spawning efforts.

The goal of this survey was to document fish presence during the potential spawning period of rainbow trout (*Oncorhynchus mykiss*) and to observe the condition, functionality, and use of underwater enhancement structures (e.g., boulder cluster, riprap apron, crib wall fish shelters) by fish. No fish sampling (e.g., electrofishing) occurred during the spring survey, given its concurrence to a presumed spawning period of rainbow trout.

1.2.3 Summer

Fish Habitat

A more comprehensive fish habitat assessment, including quantification of in-stream and near-stream characteristics of value to fish, was completed using data collected on site visits on July 13, July 29, August 31 and October 14, 2021. The timing was intended to coincide with declining water levels, increasing water clarity, and the growing season for riparian vegetation.

During the late summer assessment, habitat data was 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. Habitat assessment data was collected from 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, and included:

- Transect data approximately every 100 m in the assessed reach, including measurements of bankfull width, wetted width, and bank height, recorded to the nearest 0.1 m.
- A photographic assessment of fish habitat enhancements (e.g. boulder clusters) and bank stabilization features (e.g. bank riprap) installed at the Sites 1 to 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 1 and Site 4 and from the upstream control site location established upstream of the Project area. Water quality parameters (dissolved oxygen, conductivity, pH, and water temperature) was collected using a handheld water quality meter, such as an Aquatroll 500 and CHEMets Kit (Dissolved Oxygen K-7512). Water quality data were compared against standards identified in the Canadian Council of Ministers of the Environment (CCME) Guidelines for the Protection of Freshwater Organisms.
- 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 was also documented throughout the reach.

Based on data collected, and observations made, during the summer assessment, fish habitat potential ratings were assigned, using the qualification as defined in the Hemmera's Fish Habitat Sampling Field Guide V3.0 (2019), as 'preferred', 'suitable', 'marginal', or 'unsuitable'.

Fish Sampling

During the summer months (i.e., middle of June until the middle of August), daily water temperatures in the Bow River were recorded to be >15C. Water levels were also lower than mean levels during most of July and August and many of the fish enhancement structures at all sites were dry during this time.

Due to adverse water conditions (i.e., low water levels and high temperatures) and high ambient air temperatures, Hemmera determined that it was a high risk to fish health to conduct fish sampling (including the holding, handling and release of fish) during the summer. In consideration of low water levels, water conditions and fish health, a decision was made to postpone the fish sampling by minnow trapping until fall, and remove the boat electrofishing effort from 2021 sampling.

Minnow trapping was conducted on November 8-9, 2021 by a field crew of two fisheries biologists, led by a QAES, along a 750 m section of the Project area. Fish were sampled to determine fish presence and relative abundance within the Project sites. Fish sampling locations established in 2019 were sampled in 2021 using baited Gee-type minnow traps adjacent to the habitat enhancement structures at Sites 1, 2, and 4. All traps were baited with dry cat food and allowed to fish overnight to maximize fishing effort and efficiency. Traps were set for a maximum of 18 hours per the conditions of the Project's Fish Research Licence (No. RL-PAAS 21-5016-7-COC, Government of Alberta 2019). Minnow traps were set in locations with low velocity to maintain the health and minimize the stress of the captured fish. The planned location of all minnow traps is shown in **Figure 2**.

No boat electrofishing of the main channel of the Bow River was conducted in 2021 as fish presence information in the Bow River is already well-documented and the collection of fish capture information by electrofishing in the main channel would not provide any additional information specific to the fish habitat enhancement structures. An FRL for boat electrofishing would not have been granted during high temperatures in the summer and was unlikely to be granted in the fall during the brown trout spawning period.

Fish captured during the assessment were held for processing in buckets containing water from the Bow River. Buckets were continually aerated with a bubbler and supplemented or replaced with oxygenated water as needed. All captured fish were enumerated, identified to species and life stage, measured (fork length), weighed, and released into a suitable area near the capture location. Fish capture data was analyzed to determine overall use of habitats within the study area, as well as species richness and abundance (i.e., CPUE). Fish species composition and abundance was compared between Sites 1 to 4 using Site 4 as the control site for the project.

1.2.4 Fall

Similar to the spring assessment, the purpose of the fall assessment was to document evidence of spawning brown trout (*Salmo trutta*) and mountain whitefish (*Prosopium williamsoni*) relative to the location of the underwater enhancement structures. The fall assessment was completed on November 30, 2021 after brown trout and mountain whitefish spawning periods. The assessment observed the potential use of habitat within, and adjacent to, in-stream enhancement structures (e.g., boulder cluster, riprap apron, crib wall fish shelters), particularly by fall spawning species (e.g., brown trout and mountain whitefish). The fall assessment included a spawning survey (redd survey) focusing on brown trout, which extended from 500 m upstream of Site 1, through all riverine habitat adjacent to Sites 2 and 4, to 500 m downstream of the downstream extent of Site 4. Sampling of mountain whitefish eggs was completed using kick nets at transects downstream from suitable mountain whitefish spawning habitat. Transect locations and sampling efforts established in 2019 will be 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.

1.3 Results

1.3.1 Physical Condition Stability

A visual assessment of the bio-engineering treatments along the RDB of the Bow River at Sites 1, 2 and 4 was conducted during all four seasonal monitoring periods, to document the physical condition and stability of the area.

Results of the 2021 visual assessment and photographic data indicate that the physical condition of the treatments, including fish habitat structures (e.g., boulder clusters, fish shelters and box fascines), continue to be stable, with no signs of erosion, scour, or displacement. As a result of lower flows experience in the Bow River, the fish structures in Site 1 and box fascines in Site 2 were out of the water. Photographic data collected from each of the established photo stations are presented in **Attachment A, Photos 1 to 30**.

1.3.2 Fish Habitat Characteristics

The assessed reach of the Bow River is characterized as a low gradient (i.e., <1%) and a regular meander pattern that is frequently confined by its valley walls. A summary of the fish habitat characteristics observed at each Site (i.e., Site 1, Site 2, and Site 4) during the fish habitat assessments are presented in **Attachment B**. Fish habitat within each site in the Project area (i.e., Site 1, Site 2, and Site 4) is presented below, along with a summary of fish habitat for the entire assessed reach.

1.3.2.1 Site 1

The upstream boundary of Site 1 is located approximately 280 m upstream of the 17 Avenue Cushing Bridge, immediately downstream of Harvie Passage, with the downstream boundary located approximately 200 m downstream of the Cushing Bridge (**Figure 1**).

Fish habitat within the upstream section of Site 1 (downstream of Harvie Passage and upstream of the Cushing Bridge) consists of deep run (R1) habitat transitioning into riffle (RF) habitat back into deep run (R1) habitat through the thalweg and mid channel, with a shallow run (R3) along the RDB (**Attachment C**). Fish habitat within the area immediately surrounding the Cushing Bridge consists of R1 habitat through the mid channel thalweg, and P1 habitat along the RDB. R1 habitat extends through the downstream section of Site 1. Bankfull width and wetted width range from 232 m to 103 m and 164 m to 60 m, respectively. Bank stability is relatively stable along both banks in the upstream section of Site 1, with high stability along the left downstream bank (LDB) downstream of the Cushing Bridge. Bank stability is considered stable along the RDB immediately downstream of the Cushing Bridge. Deciduous trees, shrubs, and grasses are present along both the RDB and LDB.

Maximum water depth in 2021 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 6.5 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 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 (2017). Cover 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. Constructed fish shelters and boulder clusters also provide instream cover.

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 6.950 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.

1.3.2.2 Site 2

Site 2 is located approximately 260 m downstream of the 17 Avenue Cushing Bridge at the first riprap groyne constructed along the RDB, extending for approximately 140 m downstream to the downstream riprap groyne along the RDB to the upstream boundary of Site 4 (**Figure 1**).

Fish habitat within Site 2 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 (**Attachment C**). Bankfull width and wetted width are relatively uniform throughout Site 2, approximately 162 m and 106 m, respectively. Bank stability along the RDB is high through the site as a result of the installation of box fascines and brush mattresses.

Water depth is relatively uniform through this section, ranging from 0.5 m to 4 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 is otherwise severely limited throughout Site 2.

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.

1.3.2.3 Site 4

Site 4 is bounded on the upstream end by the downstream riprap groyne constructed along the RDB and extends to the downstream extent of bank armoring (**Figure 1**).

Fish habitat within Site 4 remains consistent with observations made during the Hemmera 2017, 2019 and 2020 assessment, with fish habitat comprised primarily of R1 habitat, transitioning into R2 habitat at the downstream end of the site (Hemmera 2017). Bankfull width and wetted width are relatively uniform throughout Site 4, ranging from 103 m to 232 m and 76 m to 168 m, respectively. Bank stability is very high, with the entire RDB composed of class II and class III riprap, and LDB heavily vegetated with shrubs and grasses. 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 (**Attachment C**). Site 4 has 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 1.5 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.

1.3.2.4 Summary

Fish habitat at all sites remains consistent with observations made during the 2019 and 2020 assessment. The entire assessed reach is dominated by R1 habitat alternating with various pool habitat (P1 and P2), along the RDB. The detailed fish habitat map of the assessed reach remains unchanged from 2020 and is presented in **Attachment C**.

Substrate throughout the assessed reach is dominated by boulder and cobble in run habitats (R1, R2, and R3), and cobble and large gravel in riffle habitat. Substrates within pool habitats (P1 and P2) consist primarily of boulder, cobble, and fines. Maximum water depth throughout the assessed reach ranges from 0.50 m to 6.95 m with an average of 1.548 m.

Bankfull width throughout the assessed reach ranges from 103 m to 232 m, with an average width of approximately 162 m. Wetted width ranges from 60 m to 168 m, with an average width of 108 m. Bank stability and shape throughout the assessed reach ranges from sloped and stable in areas armoured with riprap, to near vertical and stable along the RDB immediately downstream of the 17 Avenue Cushing Bridge. Banks consisted primarily of fines and cobble. Riparian vegetation is dominated by mature deciduous forest, with areas armoured by riprap dominated by shrubs and grasses.

1.3.3 Water Quality Field Parameters

Water quality parameters were collected at three water quality sampling stations throughout the four seasonal monitoring periods. Water quality stations established in 2019 were sampled in 2021. Two water quality stations were located in Site 1 and Site 4. A third station was established as a control site upstream of Cushing Bridge. The location of water quality sampling stations is presented in **Figure 2**.

In situ water quality parameters collected at each station included dissolved oxygen, pH, conductivity, and water temperature. The results of water quality sampling in 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). Water quality parameters collected in Site 1 and 4 were also compared with the parameters collected in the upstream Control Reach to confirm that water quality in Sites 1 and 4 were similar to natural variation within the river.

Seasonal water quality parameters measured in 2021 are presented in **Table 3**. Overall, all water quality parameters measured in Site 1 and 4 and Control Reach were within federal guidelines (CCME 1999). Water quality measurements in 2021 were similar to measurements recorded in Year 1 and 2, showing similar seasonal variability in temperature, dissolved oxygen, and conductivity.

Table 3 Summary of Water Quality Data During the 2020 Bio-Efficacy Post-Construction Monitoring Program

Site	Season	Temperature (°C)	Dissolved Oxygen (mg/L)	pH	Conductivity (µS/cm)
Upstream Control	Winter	0.35	11.90	8.68	410.33
	Spring	17.5	9.47	8.07	285.71
	Summer	16.60	9.32	8.73	223.5
	Fall	1.47	11.94	8.68	302.45
Site 1	Winter	0.37	12.22	8.73	400.41
	Spring	17.4	9.56	8.68	270.20
	Summer	16.65	9.29	8.76	220.56
	Fall	1.53	12.02	8.66	312.56
Site 4	Winter	0.23	12.08	8.75	403.44
	Spring	17.4	9.47	8.60	269.20
	Summer	16.76	9.56	8.70	225.78
	Fall	1.68	12.34	8.75	312.45

1.3.4 Fish Use

The fish enhancement structures within Site 2 (i.e., box fascines) were ice covered at the time of the winter assessment, preventing observation of overwintering use of the structures by fish. No fish were observed utilizing the Site 1 fish shelters during the winter assessment.

No fish sampling was completed during the summer assessment due to adverse water conditions and high ambient air temperatures. As a result, fish sampling was postponed until the fall assessment. Minnow trapping occurred on November 8 - 9, 2021 at Site 2 and Site 4. The majority of Site 1 was dry and fish shelters were out of the water at the time of sampling and where water was present was not deep enough to effectively deploy minnow traps. A total of five fish were captured. Fish species richness separated by site within the Project area is presented in **Table 4**. No boat electrofishing of the main channel of the Bow River was conducted in 2021. An FRL for boat electrofishing was unlikely to be issued in the fall during the brown trout spawning period.

The Bow River, from its headwaters to the confluence with the Oldman River, is known to support 35 fish species (Fisheries and Wildlife Management Information System [FWMIS], 2019), however, within the vicinity of the Project (i.e., between Bearspaw and Carseland Dams) only 22 of these species, including 11 sportfish species, have a probable potential of occurrence. Of these 22 species, 10 were captured within the Project area in Year 1, including 6 sportfish and 4 non-sportfish species. In Year 2, 9 species were captured, including 5 sportfish and 4 non-sportfish species. In Year 3, 2 non-sportfish species were captured (**Table 4**). Total fish capture data is presented in **Table 5**; raw fish data is presented in **Attachment D**. Representative photos of each fish species captured in 2021 are presented in **Attachment A, Photos 31 to 32**.

A total of 5 fish and 2 species (i.e., trout perch and white sucker) were captured using minnow trapping. 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 2 (0.0316 fish/trap-hour) while CPUE at Site 4 was 0.0211 fish/trap hour. **Figure 3** summarizes minnow trap CPUE separated by site. 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, white sucker (*Catostomus commersoni*) had the greatest CPUE of all fish captured at each site. **Figure 4** presents minnow trap CPUE for individual fish species separated by site.

Table 4 2021 Bio-Efficacy Post-Construction Monitoring Program Fish Species Diversity

Common Name[1]	Scientific Name	Historic Presence in the Bow River[1]	BDEP Site in 2021[5]		
			Site 1	Site 2	Site 3
SPORTFISH					
brook trout	*Salvelinus fontinalis*	X			
bull trout	*Salvelinus confluentus*	X			
brown trout	*Salmo trutta*	X			
burbot	*Lota lota*	X			
cutthroat trout[2]	*Oncorhynchus clarki*	X			
lake whitefish	*Coregonus clupeaformis*	X			
mountain whitefish	*Prosopium williamsoni*	X			
northern pike	*Esox lucius*	X			
rainbow trout[3]	*Oncorhynchus mykiss*	X			
yellow perch[4]	*Perca flavescens*	X			
walleye	*Sander vitreus*	X			
NON-SPORTFISH					
brook stickleback	*Culaea inconstans*	X			
fathead minnow	*Pimephales promelas*	X			
lake chub	*Couesius plumbeus*	X			
longnose dace	*Rhinichthys cataractae*	X			
longnose sucker	*Catostomus catostomus*	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		x	
white sucker	*Catostomus commersoni*	X			x
2021 Species Richness			*	1	1
2020 Species Richness			6	8	3
2019 Species Richness			7	2	6

*** Site 1 was dry and fish shelters were out of the water during sampling in 2021**

Notes:

1. List compiled from FWMIS, 2019; Nelson and Paetz, 1992.
2. 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*).
3. Rainbow trout in the Bow River near the Project represent introduced stocks and are not considered native stocks of Athabasca Rainbow Trout.
4. 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.
5. 2021 data includes minnow trapping data only. In 2021, minnow trapping was the only fish sampling method used.

Table 5 2021 Bio-Efficacy Post-Construction Monitoring Program Total Fish Numbers Captured Per Species

Site	BNTR	BURB	LKCH	LNDC	LNSC	MNWH	NRPK	RNTR	TRPR	WHSC	YLPR	Total
Site 1	*	*	*	*	*	*	*	*	*	*	*	*
Site 2	0	0	0	0	0	0	0	0	2	1	0	3
Site 4	0	0	0	0	0	0	0	0	0	2	0	2
2021 Total[1]	0	0	0	0	0	0	0	0	2	3	0	5
2020 Total	9	2	0	1	46	23	1	30	1	7	0	120
2019 Total	2	1	1	1	18	1	1	4	0	10	9	48

*** Site 1 was dry and fish shelters were out of the water during sampling in 2021**

1. 2021 data includes minnow trapping data only. In 2021, minnow trapping was the only fish sampling method used.

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

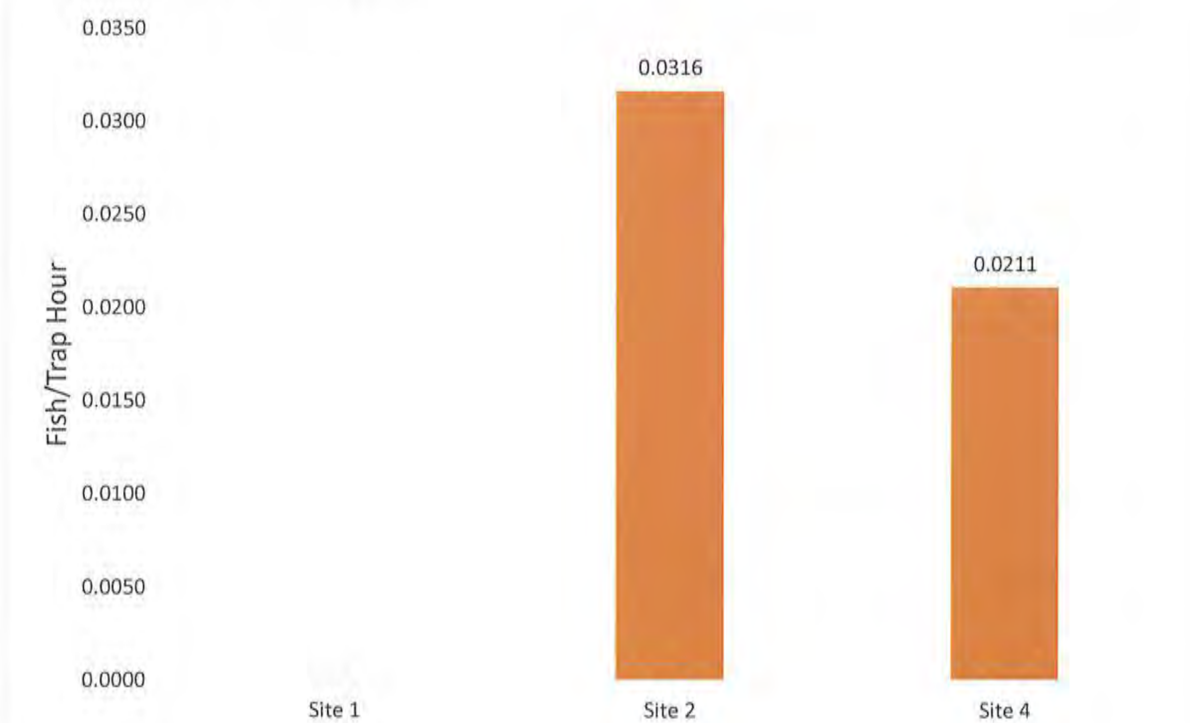

Figure 3 2020 Bio-Efficacy Post-Construction Monitoring Program Minnow Trapping CPUE. Site 1 was dry and fish shelters were out of the water during sampling in 2021.

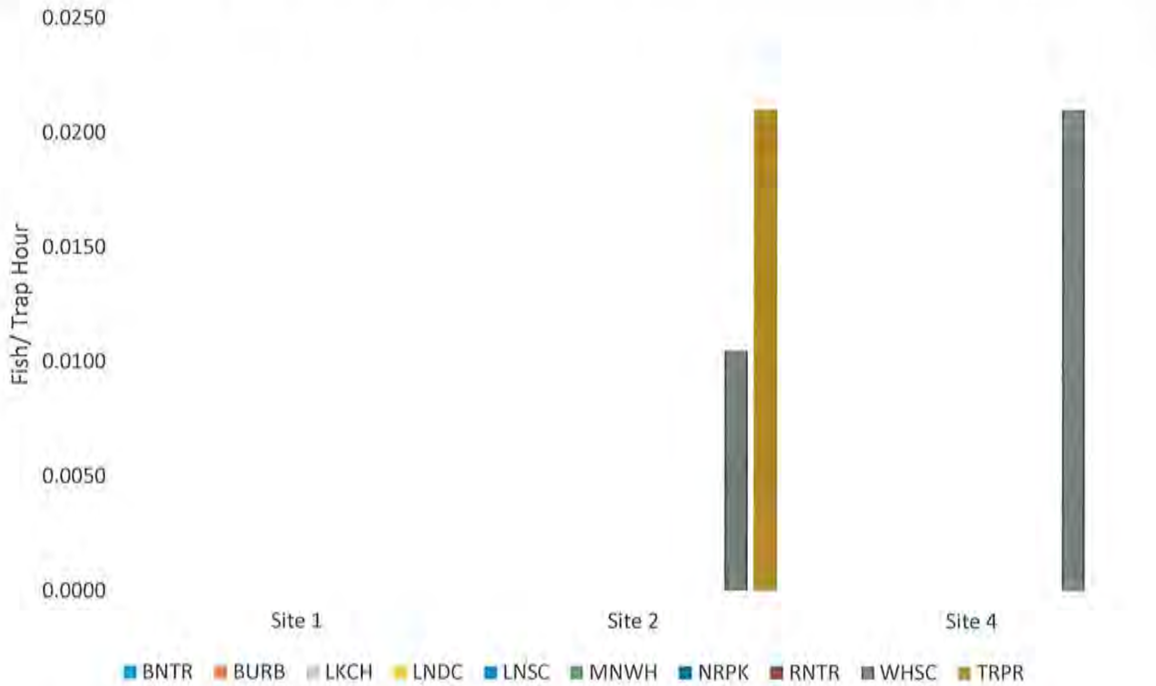

Figure 4 2020 Bio-Efficacy Post-Construction Monitoring Program Minnow Trap CPUE for Individual Fish. Site 1 was dry and fish shelters were out of the water during sampling in 2021.

1.3.4.1 Summary

Monitoring data collected throughout 2019, 2020 and 2021 indicate that fish residing in the Bow River are utilizing fish habitat enhancement structures within Site 2 and 4. Site 2 did not provide winter habitat to fish, as the site was dry during the winter assessment. During the fall assessment, fish were captured in the vicinity of fish habitat enhancement structures within Site 2 and 4 as Site 1 was dry.

In subsequent monitoring years, fish sampling efforts during the summer assessment should be completed either earlier in the year (late spring) or in late summer/early fall when all sites are wetted. This approach will avoid adverse conditions and enable safe handling of fish during cooler air and water temperatures and higher water levels.

1.3.5 Spawning Use

A spring spawning assessment was conducted in 2021 and no redds were observed.

The fall spawning assessment included a brown trout redd survey and kick-net sampling to identify mountain whitefish eggs. The assessment was conducted on November 30, 2021 following the conclusion of brown trout and mountain whitefish spawning periods. No redds were identified within the surveyed reach. Suitable mountain whitefish spawning 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**, and **Attachment A, Photos 33 to 34**).

1.3.5.1 Summary

Although potential spring and fall salmonid spawning habitat was documented during the summer habitat assessment, no redds or salmonid spawning was observed during the fall spawning assessments in 2021. Mountain whitefish eggs were observed during kick sampling within suitable habitat in the upstream extent (above Cushings Bridge) of Site 1.

1.4 Summary

The overall Project goals were to effectively stabilize unstable and steep banks; restore flood affected habitat with new fish habitats (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, and improve riverbank aesthetics in the area. The Project was not expected to permanently destroy or alter fish habitat at a spatial scale intensity that would limit or diminish the ability of fish to use the Project area for migration, foraging, overwintering, rearing, and spawning purposes. The purpose of the fish and fish habitat monitoring component is to evaluate the fisheries habitat use and potential of the habitat enhancements at Sites 1, 2 and 4 (Hemmera 2018).

The results of the Year 3 (2021) monitoring indicate that fish are continuing to use the Project's habitat enhancement structures. Fish were observed using and were captured within the vicinity of the new habitat structures at Sites 2 and 4. Although no fish were observed in the fish shelters, boulder clusters, and surrounding habitats during the fall assessment, mountain whitefish eggs were observed in the upstream section of Site 1. The highest abundance of fish was captured in Site 2 and the highest diversity of species were captured in Site 2.

Overall, the Project has not permanently altered or destroyed fish habitat. Fish are still using the Project area for migration, foraging, overwintering, rearing, and spawning purposes.

Recommendations for monitoring in 2023 are related to the timing of the monitoring program:

- the crew will monitor the ice conditions of the Bow River beginning in January to determine safe conditions for completing the winter and spring assessment (i.e., stable and thick ice for on-ice survey or ice-free open water conditions for snorkel survey).
- fish sampling efforts during the summer assessment should be completed earlier in the year (late spring) or in late summer or early fall to capture fish when all sites are wetted and avoid adverse conditions for fish handling.
- during the fish sampling, the crew will plan to use a smaller boat for more effective sampling of near shore habitats adjacent to Sites 1 and 2.

1.5 References

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2.0 WILDLIFE

2.1 Introduction

The Bio-efficacy Monitoring Program at the Bioengineering Demonstration and Education Project (Project) site at the Bow River (a component of the City of Calgary's Riparian Action Program), has the goal of determining long-term riparian health trends by evaluating riparian habitat recovery at numerous flood-affected and restored sites along the Bow River within city limits. The objectives to monitor, evaluate, and report on the overall effectiveness of the Project in relation to a more conventional riprap bank protection mitigation (i.e., hard armouring) project are to be completed over a ten-year post-construction monitoring program initiated in 2019. This monitoring program involves both Effectiveness Monitoring and Trend Monitoring, as defined in previous reports below:

- **Effectiveness Monitoring:** effectiveness monitoring assesses post-restoration conditions at both treatment and control sites to evaluate changes in riparian habitat recovery resulting from the Riparian Action Program implementation.
- **Trend Monitoring:** trend monitoring will be used to understand the riparian health in the restoration areas and whether it is improving, remaining constant, or deteriorating over the monitoring period.

The ten-year wildlife monitoring component of the Project is to occur over five separate monitoring years, with the first year of monitoring completed in 2019 (i.e., monitoring will occur in 2019, 2020, 2021, 2023, and 2028), and across three separate sites (Site 1, Site 2 and Site 4), as described below and shown in **Figure 5**. To provide clarity when referencing survey terms, survey Year 1 (2019) will be referred to as Year 1, survey Year 2 (2020) will be referred to as Year 2, and survey Year 3 (2021) will be referred to as Year 3.

Site 1 (approximately 591 metres (m) in length, and 2.75 hectares (ha) in area) is located adjacent to the pedestrian pathway, extending north of the 17th Avenue Southeast (SE) bridge and Calgary Transit bridge. The riprap substrates installed during restoration activities were identified as potentially inhibiting terrestrial wildlife passage. To provide for an improved wildlife corridor between the habitats to the south and north of the bridge, substrate was added under the bridge, consisting of a vegetated soil area approximately 6 m in width, designated as "wildlife-friendly" riprap to allow for wildlife to travel along the edge of the Bow River. Vegetation was planted to create a natural visual screen between the Bow River and the pedestrian pathway to help facilitate wildlife movement through the area.

Site 2 (approximately 0.44 ha) is located adjacent to Site 1, extending approximately 128 m to the south of the 17th Avenue SE bridge. Bank restoration at this site resulted in less riparian habitat compared to Site 1. This site was designed to have riparian vegetation and habitat restored to pre-restoration conditions to provide for suitable nesting habitat for breeding birds, including passerines, waterbirds and raptor species known to occur within the Project area.

Site 4 (approximately 0.49 ha) is located south of Site 2, used conventional riprap, including large boulders placed along the bank and into the edge of the Bow River, as a bank restoration method. Site 4 was selected to represent a control site, where baseline conditions can be used to compare the effectiveness and trend monitoring observed in Sites 1 and 2, which are considered the treatment areas of the Project.

This report provides a summary of Year 3 of the wildlife monitoring program, including an analysis of trends between Year 1 to Year 3.

2.2 Methods

Wildlife monitoring was conducted in compliance with the *Bioengineering Efficacy Monitoring Plan* (Hemmera 2018). The Year 3 monitoring scope was comprised of trail camera monitoring at Site 1 to assess wildlife corridor usage by mammals, in addition to breeding bird surveys and wildlife feature monitoring at all three sites to assess habitat suitability and wildlife use. Two bank swallow (*Riparia riparia*) colonies previously identified during the *Preliminary Natural Assessment Report* (Hemmera 2017) were also monitored.

2.2.1 Desktop Assessment

A desktop assessment to identify known sensitive wildlife features was conducted for the *Bioengineering Efficacy Monitoring Plan* (Hemmera 2018) in Year 1 and consisted of a search of the Alberta Environment and Parks (AEP) Fisheries and Wildlife Management Information System (FWMIS) and the Fish and Wildlife Internet Mapping Tool (Government of Alberta 2021).

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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Hemmera
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2.2.2 Wildlife Field Monitoring

2.2.2.1 Wildlife Camera Monitoring

To support identification of wildlife species using the Site 1 restoration area as a corridor, 4 wildlife cameras were installed (**Figure 5**). No wildlife trail cameras were installed within Site 2 or Site 4 as monitoring focused on suitable bird nesting and breeding habitat and not constraints to mammal corridor movement.

Wildlife cameras monitored large and medium-sized mammals to determine if they were using the potential wildlife corridor under the 17th Avenue bridge crossing along the west bank of the Bow River after restoration activities were completed. Large and medium-sized mammals were the primary focus of the camera program as they would be more influenced by a functioning wildlife corridor than smaller or more mobile species such as birds or squirrels, which could use smaller routes or routes not available to larger mammal species.

Each wildlife camera was programmed to capture three images with a one second spacing between images when triggered by motion. All cameras were programmed not to trigger for five seconds following a motion triggered event, and camera sensitivity was initially set to the medium/high sensitivity mode. If the number of photos taken appeared to be unexpectedly low during each check, camera sensitivity was subsequently set to high. Wildlife cameras were generally aimed east towards the Bow River away from the adjacent paved pedestrian pathway to avoid abundant photographs of human activity where expected.

Site 1

All 4 Reconyx HyperFire 2 wildlife cameras were installed at Site 1 (i.e., Camera 1, Camera 2, Camera 3, and Camera 4; **Figure 5**). The placement of each wildlife trail camera in Site 1 was intended to measure use of the treatment area by terrestrial mammals as a wildlife corridor. Data downloads and general camera condition checks were completed monthly when possible. However, three of the four cameras during the Year 3 assessment were stolen or removed, resulting in only one active camera (BDEP03) remaining for the entire assessment period to record activity passing under the bridge (**Table 6**). For consistency, camera locations were named following the naming conventions established in Year 1 (KWL 2020a), which differed in Year 2 (KWL 2020b).

Table 6 Camera Names and Years Monitored at the Project

Camera Name	Site	Easting	Northing	Years Active			Year 3 (2021) Dates Active
				2019	2020	2021	
Camera 1	1	709343	5658206	Yes	Yes	Yes	January 21 to November 9
Camera 2	1	709370	5658328	Yes	Yes	Yes	January 21 to March 31
Camera 3	1	709341	5658191	Yes	Yes	Yes	January 21 to March 31
Camera 4	1	709459	5658451	No	Yes	Yes	January 21 to July 6

Camera 1 was located under the 17th Avenue SE bridge facing east and angled downwards from its elevated mounting location towards the Bow River. Camera 2 was located approximately 126 m upstream from the 17th Avenue SE bridge on a storm drain outfall, oriented west towards the Bow River. Camera 3 was located approximately 15 m downstream of the 17th Avenue SE bridge on a metal signpost and was oriented in a northeast direction towards the shoreline underpass and the Bow River. Camera 4 was added in 2020 and repeated in 2021, situated along a wooded path approximately 148 m upstream from Camera 2, mounted to a tree and oriented in a northeast direction to capture wildlife using a pathway through some shrubs in a more vegetated section of Site 1.

Breeding Bird Surveys

Breeding bird surveys were conducted on June 8 and 22, 2021, at the same locations as Year 1 and Year 2. All surveys were conducted under appropriate conditions following the *Sensitive Species Inventory Guidelines* (Government of Alberta 2013) for the identification breeding birds (i.e., appropriate time of day, temperatures greater than 0°C, winds less than 20 km/hr, and no precipitation).

Site 1

Breeding bird point count surveys were conducted at three locations in Site 1 (BBS03, BBS04, and BBS05; **Figure 5**.

Site 2

Breeding bird surveys were conducted at one point count location in Site 2 (BBS02).

Site 4

Breeding bird surveys were conducted at one point count location in Site 4 (BBS01).

2.2.2.2 *Wildlife Feature Surveys*

Raptor nest surveys were conducted following the *Sensitive Species Inventory Guidelines* (Government of Alberta 2013) for Prairie Raptors (i.e., surveying in daylight hours, winds less than 50 km/hr, and no precipitation). If any waterfowl were observed using the banks or riparian zones of the Bow River for nesting sites during surveys, they were documented. Active bank swallow colonies were monitored and counted in accordance with protocols established in Year 1, where the number of individuals using the colonies were counted twice each breeding season. Bank swallow colony use was assessed by counting the number of bank swallows present at bank cavities over a five-minute period. All nesting behaviour and incidental species observations were recorded and submitted to AEP through the FWMIS.

Site 1

Site 1 was surveyed for raptor nests and nesting waterfowl following completion of the breeding bird plots. No bank swallow colonies were previously identified at the Project (KWL 2020a, 2020b), perhaps due lack of available nesting habitat (i.e., exposed and soft-soiled steep banks).

Site 2

Site 2 was surveyed for raptor nests and nesting waterfowl following completion of the breeding bird plots. One bank swallow colony previously monitored in 2019 and 2020 (BANS01) was surveyed.

Site 4

Site 4 was surveyed for raptor nests and nesting waterfowl following completion of the breeding bird plots. One bank swallow colony previously monitored in 2019 and 2020 (BANS02) was surveyed.

2.3 Results

2.3.1 Desktop Assessment

The desktop assessment conducted for the Project in 2018 resulted in the identification of 12 listed species observed within 1,000 m of the Project (**Table 7**). A review of FWIMT data identifies the Project as being located within the sensitive raptor range for bald eagles, golden eagles, and prairie falcon, and within the sharp-tailed grouse range.

Table 7 Provincially or Federally Listed Species Recorded within 1 km of the Project Area as of 2018

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	-	-

Sources: [a] = Government of Alberta 2015; [b] = Government of Canada 2020; [c] = COSEWIC 2021.

In the desktop review, suitable breeding habitat for bank swallows and nesting raptors was also identified within the Project area in the *Preliminary Natural Site Assessment Report* (Hemmera 2017). Suitable habitat to support various life stages has been identified in and adjacent to the Project for all of the species listed in **Table 7**. The Bow River, in general, provides foraging and breeding habitat for several waterbird species (e.g., sora (*Porzana carolina*), harlequin duck (*Histrionicus histrionicus*), western grebe (*Aechmophorus occidentalis*), and great blue heron (*Ardea Herodias*)), while deciduous trees in the riparian zones provide suitable raptor (e.g., bald eagle) and passerine (e.g., least flycatcher) breeding habitat. Bat habitat (i.e., summer roosting and foraging) is present in the deciduous trees in the riparian zone at the Bow River.

2.3.2 Wildlife Field Monitoring

The following sections summarize the results of wildlife monitoring at each site. Representative photos of wildlife species captured on the remote cameras are provided in **Attachment E**.

2.3.2.1 *Wildlife Camera Monitoring*

Site 1

Year 3 (2021) Results

A total of 611 camera-days of monitoring was conducted at Site 1, resulting in a total of 1,678 photographs taken between four cameras (**Table 8**). All cameras recorded photographs; however, except for Camera 1 that recorded for the entire 611-day period, each of the other three cameras experienced circumstances that resulted in a reduced sampling period. On April 27, field staff discovered that Camera 2 and Camera 3 had been stolen despite extra security measure being taken for this area (e.g., additional padlocks, python lock cables, electronic code locks on the camera). On July 6, Camera 4 was removed due to public privacy concerns and consistent vandalism observed across monitoring years.

Table 8 Active Camera Days During Deployment at Site 1 of Year 3

Camera Location	Active Camera Days	Percentage (%) of Monitoring Period Camera was Active	Number of Photographs Taken
Camera 1	292	100	255
Camera 2	69	24	283
Camera 3	69	24	73
Camera 4	181	62	1067
All cameras combined	611	-	1678

In total, six species of mammals were identified at Site 1 (**Table 9**). Direct comparisons of mammal occurrences captured between camera stations cannot be made as the number of active camera days (days the camera has been able to take photographs) varied by location. However, Camera 4 had the most mammal occurrences (154 observations) despite not having the most active camera days. This is likely due to the prevalence vegetation cover (willow shrubs, cottonwood trees) relative to the other camera locations. Camera 4 also observed the most mammal diversity with all six mammal species observed in 2021, and was the only camera to capture American beaver, eastern gray squirrel and striped skunk.

Table 9 Site 1 Terrestrial Mammal Species Occurrence by Camera Location in Year 3

Camera Location	American Beaver	Coyote	Eastern Gray Squirrel	Striped Skunk	White-tailed Deer	Deer Species (unidentified)	White-tailed Jackrabbit	Total Number of Mammal Observations
Camera 1	-	-	-	-	30	2	7	39
Camera 2	-	1	-	-	-	-		1
Camera 3	-	8	-	-	-	-	2	10
Camera 4	1	9	83	3	34	-	24	154
All Cameras Combined	1	18	83	3	64	2	33	204

Note: - = no observations.

White-tailed jackrabbit (*Lepus townsendii*) was the most common species observed across all cameras (33 observations), with most observations occurring at Camera 4 (24 observations). Coyote were observed at three of the four locations. Although only observed at two locations (Camera 1 and Camera 4), white-tailed deer (*Odocoileus virginianus*) were the second-most observed species photographed.

Results from Years 1 to 3 (2019 – 2021)

Wildlife camera monitoring within the Project has presented challenges, primarily with respect to vandalism and theft of the remote cameras by the public. As a result, many of the camera stations have experienced data loss, resulting in a reduction in overall active camera days each year (**Table 10**).

Camera 1, installed under the 17th Avenue bridge, was the least disturbed and most consistent camera location, as it is mounted up high and generally out of reach for most people. This camera was active throughout each monitoring year as it was never disturbed. Of the four cameras, this location is perhaps the most important for observing wildlife passage through the Project area, as it photographs activity directly under the bridge, inferencing the passage of wildlife from one side of the underpass to the other.

Camera 4 was only active 41% of the monitoring period during the three-years of monitoring, as it was only installed for the first time in Year 2, and subsequently removed early in Year 3. Cameras 2 and 3 also yielded low active days due to Camera 2 being vandalized during Year 2, and both Camera 2 and Camera 3 were discovered as missing during the April field check.

Despite these setbacks, a total of 2,144 active remote camera monitoring days were recorded between four locations across the 3 years of monitoring to date.

Table 10 Annual Active Camera Days by Location from Years 1 to 3

Camera Location	Year 1 (2019)	Year 2 (2020)	Year 3 (2021)	Year 1 to 3 Subtotal	Percentage (%) of Monitoring Period Camera was Active	Percentage (%) of Active Camera Days Contributing to Overall Data Capture
Camera 1	255	304	292	851	100	40
Camera 2	234	195	69	498	59	23
Camera 3	118	256	69	443	52	21
Camera 4	-	171	181	352	41	16
Total	**607**	**926**	**611**	**2144**	**100**	**100**

Note: - = no observations.

During the three-years of the monitoring program from 2019 through 2021, a total of eight different mammal species have been photographed, with white-tailed deer (*Odocoileus virginianus*) (233 total observations), coyote (*Canis latrans*) (131 total observations) and white-tailed jackrabbit (*Lepus townsendii*) (113 total observations) being the most prevalent (**Table 11**). Both American beaver (*Castor canadensis*) and common raccoon (*Procyon lotor*) were only photographed once, both at Camera 4 (**Table 12**) which was situated in a wooded riparian area north of the17th Avenue SE bridge. Striped skunk (*Mephitis mephitis*) was photographed on five occasions by three different cameras and mule deer (*Odocoileus hemionus*) were identified at three locations for a total of six individual observations within the three-year monitoring period. Eight deer photographed between three different stations were not identifiable to species (i.e., either white-tailed or mule deer).

Table 11 Individual Mammals Observed from Years 1 to 3

Survey Year	American Beaver	Common racoon	Coyote	Deer species a	Eastern gray squirrel	Mule deer	Striped skunk	White-tailed deer	White-tailed jack rabbit	Total Individual Mammal Observations
Year 1	-	-	13	6	-	4	1	16	45	85
Year 2	-	1	100	-	25	2	1	153	35	317
Year 3	1	-	18	2	83	-	3	64	33	204
Total	**1**	**1**	**131**	**8**	**108**	**6**	**5**	**233**	**113**	**606**

Notes: [a] Deer species = inconclusive white-tailed deer or mule deer; - = no observations.

Table 12 Individual Mammals Observed per Camera Location from Years 1 to 3

Camera	American Beaver	Common racoon	Coyote	Deer species a	Eastern gray squirrel	Mule deer	Striped skunk	White-tailed deer	White-tailed jack rabbit	Total Individual Mammal Observations
Camera 1	0	1	26	5	0	2	0	104	24	162
Camera 2	0	0	18	1	0	2	1	38	39	99
Camera 3	-	0	47	2	0	0	1	39	13	102
Camera 4	1	0	40	0	108	2	3	52	37	243
Total	**1**	**1**	**131**	**8**	**108**	**6**	**5**	**233**	**113**	**606**

Notes: [a] Deer species = inconclusive white-tailed deer or mule deer; - = no observations.

Mean use is a measure of species occurrence which accounts for both the number of individuals and the number of monitoring days. For example, mean use of white-tailed deer is calculated as the total number of individuals photographed (at all cameras) divided by the total number of active camera days (the total days the cameras were taking photographs). Mean use calculations for Site 1 for each species across all three monitoring years is provided in **Figure 6**.

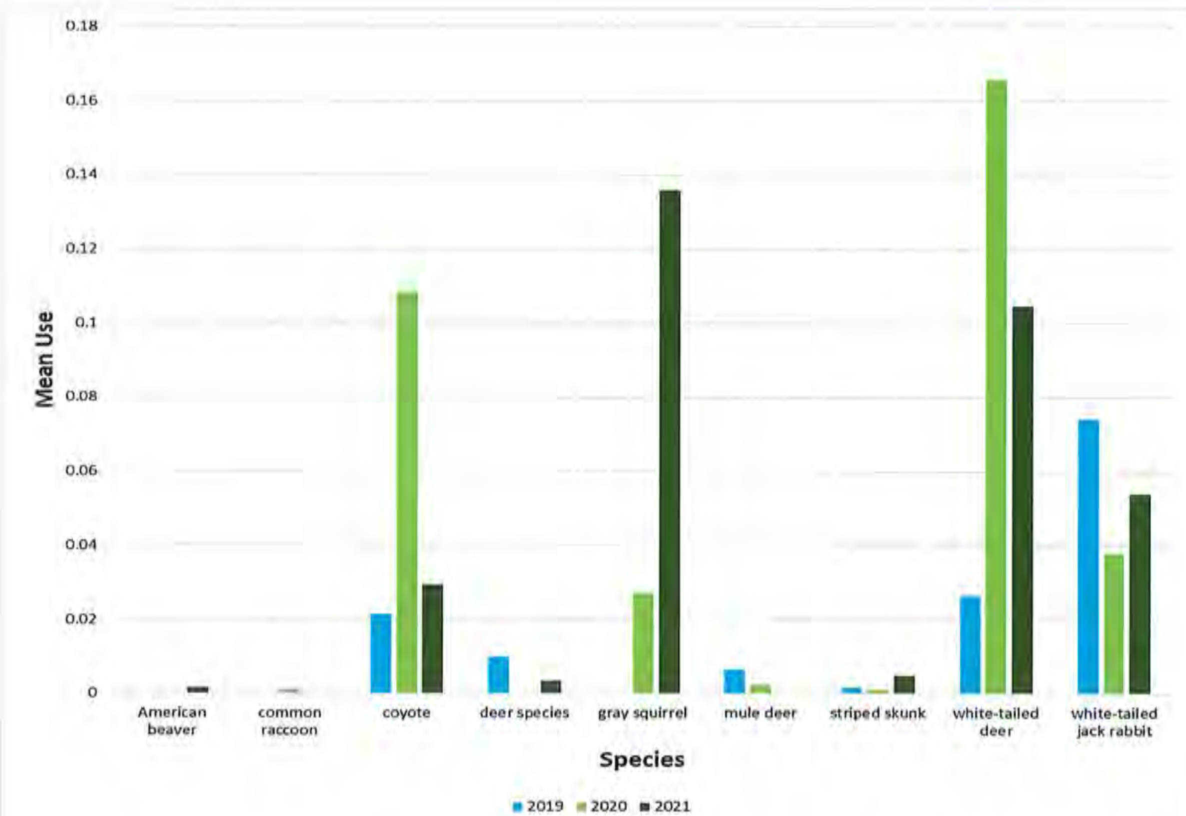

Figure 6 Site 1 Mammal Species Mean Use Comparison from Years 1 to 3

The most consistent mammal activity across all three monitoring years at Site 1 consisted of coyote, white-tailed deer, and white-tailed jackrabbit (**Figure 6**). Coyote mean use increased greatly from Year 1 to Year 2, but then decreased to approximately Year 1 levels again during Year 3. White-tailed deer mean use increased greatly from Year 1 to Year 2 and stayed consistently high in Year 3. On average, white-tailed jackrabbit mean use remained relatively consistent from Year 1 through Year 3. Although the eastern gray squirrel appears to show a high mean use, it was photographed exclusively at the location of Camera 4 and was likely the same individuals photographed daily within their small home range.

The soil and vegetation treatment areas associated the 17 Avenue SE bridge within Site 1 were primarily intended to promote the passage of large-bodied terrestrial mammals. Deer presence was recorded at all cameras throughout Site 1, and most notably at Camera 1 (almost exclusively at night) under the 17th Avenue SE bridge, suggesting that the wildlife corridor in the Project area is providing effective passage for this species, and that deer are using all areas of Site 1 with similar frequency. Coyote observations within Site 1 show a similar pattern of even distribution across all camera locations, suggesting that the wildlife corridor area provides effective passage for large mammals including both coyote and deer.

2.3.2.2 *Breeding Bird Surveys*

Site 1

Two rounds of breeding bird survey point counts were completed at each plot location, with the first round conducted on June 8, 2021, and the second on June 22, 2021. These surveys followed the methods outlined in the *Sensitive Species Inventory Guidelines* (Government of Alberta 2013) for breeding birds and prairie raptors.

At Site 1, Year 3 surveys recorded 27 more individuals and one fewer species than the Year 2 surveys (**Table 13**). Year 1 had the highest individual bird count at 129 individuals. The most prevalent species observed in Year 3 at Site 1 was common merganser (13 individuals), followed by house sparrow (10 individuals). None of the listed species previously observed at Site 1 were observed during Year 3 surveys.

Table 13 Species Identified in Site 1 Breeding Bird Surveys from Year 1 to 3

Common Name	Scientific Name	Number of Individuals			Species Status		
		Year 1 (2019)	Year 2 (2020)	Year 3 (2021)	AEP	SARA	COSEWIC
American goldfinch	*Carduelis tristis*	-	1	-	-	-	-
American robin	*Turdus migratorius*	5	4	1	-	-	-
American wigeon	*Anas americana*	-	-	2	-	-	-
bank swallow	*Riparia riparia*	-	1	-	Sensitive		Threatened
black-billed magpie	*Pica hudsonia*	2	-	5	-	-	-
black-capped chickadee	*Poecile atricapillus*	1	2	3	-	-	-
brown-headed cowbird	*Molothrus ater*	4	1	2	-	-	-
Canada goose	*Branta canadensis*	3	2	-	-	-	-
cedar waxwing	*Bombycilla cedrorum*	-	4	-	-	-	-
clay-colored sparrow	*Spizella pallida*	-	3	5	-	-	-
common goldeneye	*Bucephala clangula*	1	-	-	-	-	-
common merganser	*Mergus merganser*	2	3	13	-	-	-
common raven	*Corvus corax*	-	3	1	-	-	-
double-crested cormorant	*Phalacrocorax auritus*	2	1	-	-	-	Not at Risk
European starling	*Sturnus vulgaris*	1	-	1	Exotic/ Alien	-	-
Franklin's gull	*Leucophaeus pipixcan*	70	-	2	-	-	-
gadwall	*Anas strepera*	4	-	-	-	-	-
house sparrow	*Passer domesticus*	2	-	10	Exotic/ Alien	-	-
house wren	*Troglodytes aedon*	6	1	1	-	-	-
killdeer	*Charadrius vociferus*	3	1	2	-	-	-
least flycatcher	*Empidonax minimus*	3	-	-	Sensitive	-	-
mallard	*Anas platyrhynchos*	2	1	2	-	-	-
northern flicker	*Colaptes auratus*	-	1	-	-	-	-
red-winged blackbird	*Agelaius phoeniceus*	4	4	8	-	-	-

Common Name	Scientific Name	Number of Individuals			Species Status		
		Year 1 (2019)	Year 2 (2020)	Year 3 (2021)	AEP	SARA	COSEWIC
song sparrow	*Melospiza melodia*	3	7	6	-	-	-
spotted sandpiper	*Actitis macularius*	3	3	4	-	-	-
tree swallow	*Tachycineta bicolor*	-	1	-	-	-	-
warbling vireo	*Vireo gilvus*	2	-	1	-	-	-
western wood-pewee	*Contopus sordidulus*	1	-	-	May Be at Risk	-	-
yellow warbler	*Dendroica petechia*	5	6	8	-	-	-
Grand Total		***129***	***50***	***77***	-	-	-

Note: "-" = no observations or not applicable.

Site 2

There was a total of 28 individuals representing 11 different species observed within Site 2 in Year 3, which is very similar to the 29 individuals representing 10 different species observed in Year 2 (**Table 14**). None of the listed species previously observed at Site 2 were observed during Year 3 surveys.

Table 14 Species Identified in Site 2 Breeding Bird Surveys from Year 1 to 3

Common Name	Scientific Name	Number of Individuals			Species Status		
		Year 1 (2019)	Year 2 (2020)	Year 3 (2021)	AEP	SARA	COSEWIC
American robin	*Turdus migratorius*	-	1	-	-	-	-
American wigeon	*Anas americana*	1	-	-	-	-	-
bank swallow	*Riparia riparia*	43	7	-	Sensitive	Threat ened	Threatened
black-billed magpie	*Pica hudsonia*	2	1	2	-	-	-
black-capped chickadee	*Poecile atricapillus*	-	1	4	-	-	-
brown-headed cowbird	*Molothrus ater*	-	-	1	-	-	-
chipping sparrow	*Spizella passerina*	-	1	-	-	-	-
clay-colored sparrow	*Spizella pallida*	-	-	1	-	-	-
Franklin's gull	*Leucophaeus pipixcan*	16	-	-	-	-	-
gray catbird	*Dumetella carolinensis*	-	-	1	-	-	-
house sparrow	*Passer domesticus*	3	12	6	Exotic/ Alien	-	-
house wren	*Troglodytes aedon*	-	1	-	-	-	-
least flycatcher	*Empidonax minimus*	1	-	-	Sensitive	-	-
Lincoln's sparrow	*Melospiza lincolnii*	-	-	1	-	-	-
mallard	*Anas platyrhynchos*	-	2	3	-	-	-
red-winged blackbird	*Agelaius phoeniceus*	1	1	4	-	-	-
song sparrow	*Melospiza melodia*	-	2	1	-	-	-
spotted sandpiper	*Actitis macularius*	1	-	-	-	-	-
yellow warbler	*Dendroica petechia*	-	-	4	-	-	-
Grand Total	-	***68***	***29***	***28***	-	-	-

Note: "-" = no observations or not applicable.

Site 4

At Site 4 the number of individuals observed (13) was lower, but comparable to previous years. As well the number of species observed (6) was also similar (**Table 15**). No listed species were identified during breeding bird surveys at Site 4 in Year 3.

Table 15 Species Identified in Site 4 Breeding Bird Surveys from Year 1 to 3

Common Name	Scientific Name	Number of Individuals			Species Status		
		Year 1 (2019)	Year 2 (2020)	Year 3 (2021)	AEP	SARA	COSEWIC
American wigeon	*Anas americana*	-	1	-	-	-	-
black-billed magpie	*Pica hudsonia*	5	1	-	-	-	-
Canada goose	*Branta canadensis*	6	-	-	-	-	-
clay-colored sparrow	*Spizella pallida*	3	6	3	-	-	-
house finch	*Carpodacus mexicanus*	-	-	1	-	-	-
house sparrow	*Passer domesticus*	-	6	3	Exotic/Alien	-	-
Lincoln's sparrow	*Melospiza lincolnii*	-	-	1	-	-	-
mallard	*Anas platyrhynchos*	8	-	-	-	-	-
red-winged blackbird	*Agelaius phoeniceus*	-	1	-	-	-	-
song sparrow	*Melospiza melodia*	1	1	4	-	-	-
spotted sandpiper	*Actitis macularius*	-	3	-	-	-	-
tree swallow	*Tachycineta bicolor*	1	-	1	-	-	-
Grand Total	**-**	***24***	***19***	***13***	**-**	**-**	**-**

Note: "-" = no observations or not applicable.

Breeding Bird Surveys from Years 1 to 3 (2019 – 2021)

Site 1 had the highest number of individual birds observed, followed by Site 2 and Site 4. Site 1 incorporates a much larger area with 3 individual breeding bird survey plots compared to a single survey plot in each of the other two sites (**Figure 5**). As well, there were differences observed in suitable nesting habitat availability and habitat complexity between Site 1 and the other sites. This is related to the proximity of Site 1 to Pearce Estate Park, which offers more extensive tree cover and understory relative to the other sites.

A total of 34 bird species have been identified during breeding bird surveys throughout Years 1 to 3 (**Table 16**). Year 1 surveys identified 26 total species, while Year 2 surveys identified 24 species and Year 3 surveys identified 23 species (**Table 16**). In Year 1, the number of individual birds counted were approximately two times higher than the number observed in Years 2 and 3 due to a Franklin's gull flock observed in Year 1. Three listed species have been observed at the Project, which were bank swallow, least flycatcher and western wood-pewee.

Table 16 Combined Project Site Avian Species identified During Breeding Bird Surveys from Year 1 to 3

Common Name	Scientific Name	Number of Individuals			Species Status		
		Year 1 (2019)	Year 2 (2020)	Year 3 (2021)	AEP	SARA	COSEWIC
American goldfinch	*Carduelis tristis*	-	1	-	-	-	-
American robin	*Turdus migratorius*	5	5	1	-	-	-
American wigeon	*Anas americana*	1	1	2	-	-	-
bank swallow	*Riparia riparia*	43	8	-	Sensitive	Threatened	Threatened
black-billed magpie	*Pica hudsonia*	9	2	7	-	-	-
black-capped chickadee	*Poecile atricapillus*	1	3	7	-	-	-
brown-headed cowbird	*Molothrus ater*	4	1	3	-	-	-
Canada goose	*Branta canadensis*	9	2	-	-	-	-
cedar waxwing	*Bombycilla cedrorum*	-	4	-	-	-	-
chipping sparrow	*Spizella passerina*	-	1	-	-	-	-
clay-colored sparrow	*Spizella pallida*	3	9	9	-	-	-
common goldeneye	*Bucephala clangula*	1	-	-	-	-	-
common merganser	*Mergus merganser*	2	3	13	-	-	-
common raven	*Corvus corax*	-	3	1	-	-	-
double-crested cormorant	*Phalacrocorax auritus*	2	1	-	-	-	Not at Risk
European starling	*Sturnus vulgaris*	1	-	1	Exotic/ Alien	-	-
Franklin's gull	*Leucophaeus pipixcan*	86	-	2	-	-	-
gadwall	*Anas strepera*	4	-	-	-	-	-
gray catbird	*Dumetella carolinensis*	-	-	1	-	-	-
house finch	*Carpodacus mexicanus*	-	-	1	-	-	-
house sparrow	*Passer domesticus*	5	18	19	Exotic/ Alien	-	-
house wren	*Troglodytes aedon*	6	2	1	-	-	-
killdeer	*Charadrius vociferus*	3	1	2	-	-	-
least flycatcher	*Empidonax minimus*	4	-	-	Sensitive	-	-
Lincoln's sparrow	*Melospiza lincolnii*	-	-	2	-	-	-

Common Name	Scientific Name	Number of Individuals			Species Status		
		Year 1 (2019)	Year 2 (2020)	Year 3 (2021)	AEP	SARA	COSEWIC
mallard	*Anas platyrhynchos*	10	3	5	-	-	-
northern flicker	*Colaptes auratus*	-	1	-	-	-	-
red-winged blackbird	*Agelaius phoeniceus*	5	6	12	-	-	-
song sparrow	*Melospiza melodia*	4	10	11	-	-	-
spotted sandpiper	*Actitis macularius*	4	6	4	-	-	-
tree swallow	*Tachycineta bicolor*	1	1	1	-	-	-
warbling vireo	*Vireo gilvus*	2	-	1	-	-	-
western wood-pewee	*Contopus sordidulus*	1	-	-	May Be at Risk	-	-
yellow warbler	*Dendroica petechia*	5	6	12	-	-	-
Grand Total	-	**221**	**98**	**118**	-	-	-

Incidental Observations during Breeding Bird Surveys from Years 1 to 3

In addition to the observations recorded during the standardized breeding bird plots, any additional bird observations made outside of the bird plot timing window, or when birds flying through or above the study area were recorded as incidental observations (**Table 17**). During Years 1 to 3, incidental observations were American crow (*Corvus brachyrhynchos*), blue-winged teal (*Anas discors*), Brewer's blackbird (*Euphagus cyanocephalus*), pine siskin (*Carduelis pinus)*, ring-billed gull (*Larus delawarensis*) and rock pigeon (*Columba livia*). Bank swallow was observed in Year 1 and 2 during the breeding bird surveys, but was only observed incidentally in Year 3.

Table 17 Incidental Bird Species Observations from Year 1 to 3

Common Name	Scientific Name	Observation Year			Species Status		
		Year 1 (2019)	Year 2 (2020)	Year 3 (2021)	AEP	SARA	COSEWIC
American crow	*Corvus brachyrhynchos*	yes	-	yes	-	-	-
blue-winged teal	*Spatula discors*	-	yes	-	-	-	-
Brewer's blackbird	*Euphagus cyanocephalus*	-	yes	-	-	-	-
pine siskin	*Spinus pinus*	yes	-	yes	-	-	-
ring-billed gull	*Larus delawarensis*	-	yes	-	-	-	-
rock pigeon	*Columba livia*	-	yes	-	-	-	-

2.3.3 Wildlife Feature Surveys

2.3.3.1 Raptor Nests

No active raptor nests were observed during field surveys conducted in any of the monitoring years.

2.3.3.2 Swallow Surveys

An assessment of the two previously identified bank swallow colonies (i.e., BANS01 in Site 2, and BANS02 just outside of Site 4) (**Figure 5**) was conducted on June 8 and 22, 2021. No colonies have been identified at Site 1. Bank swallows are a listed species by AEP (Sensitive), SARA (Threatened) and COSEWIC (Threatened). The peak number of bank swallow adults observed in Years 1 to 3 is presented in **Table 18**.

Table 18 Bank Swallow Observations from Years 1 to 3 at Sites BANS01 and BANS02

Survey Year	Bank Swallow Count (Maximum)	
	BANS01 (Site 2)	BANS02 (Site 4)
1 (2019)	30	34
2 (2020)	22	55
3 (2021)	12	34

Site 2

A maximum of 12 adult bank swallows were observed during the site visit to BANS01 in Year 3 on June 8 with 5 adults on June 22. Overall, the number of bank swallows has declined during each monitoring year at BANS01 (**Table 18**) Site 4

The BANS02 colony was not observed as active on June 8 as it was covered in geotextile fabric. During the June 22 visit, the fabric was not present, and 34 adult bank swallows were observed. The number of bank swallows at BANS02 has no clear trend (**Table 18**).

2.4 Summary

The bank restoration completed at Site 1 appears to be functioning as a wildlife corridor for mammal species in the Project area. Both large and medium-sized mammals have been photographed at all camera locations and appear to be using the under-bridge corridor as intended. Larger mammals (white-tailed deer and coyote) were the most abundant species, with relatively equal distributions between all camera locations. White-tailed deer, coyote and white-tailed jackrabbit were most frequently captured by Camera 1, which is located under the 17th Avenue SE bridge. Image series of these species represented movement north or south along the corridor (i.e., under the bridge) primarily at night, indicating wildlife are not averse to using the shoreline available under the bridge for passage. Smaller mammal species captured only at Camera 4 (e.g., American beaver, common raccoon, eastern gray squirrel, striped skunk) have not shown movement through the site; however, these species may use the under-bridge corridor once the planted willow vegetation provides increased cover for small mammal species.

The number of species observed during breeding bird surveys from Years 1 to 3 has declined slightly from 26 (Year 1) to 23 (Year 3). This observed change in species diversity is very small and may be attributed to the number of survey locations and limited Project size. As shrubs and trees planted during reclamation become established along the banks, species diversity is anticipated to increase. Song sparrow and yellow warbler observations are already increasing annually, which should be expected from enhanced riparian shrub habitat. The only listed species identified within the three-year monitoring term have been bank swallow, least flycatcher and western wood-pewee.

Bank swallows have been present and counted annually at the two initially identified nesting colonies. Bank swallow use at BANS01 has declined annually, while BANS02 has varied. Interestingly, despite the geotextile fabric covering the nesting area of BANS02 during the timing of the first survey in Year 3, the same number of individuals were counted using it as in Year 1.

Bank swallows are listed and declining in population globally (98% population loss in Canada over the last 40 years) (Government of Canada 2020). The protections put in place at this Project to preserve these features are contributing to conservation efforts for this species.

No raptor nests have been identified at the Project during the first three years of the monitoring period.

Recommendations for encouraging wildlife corridor use under the 17th Avenue bridge are already being implemented by the City of Calgary in the form of riparian area enhancement with willow shrub saplings to address cover habitat for smaller mammal species. Inner city wildlife species are generally well adapted to human presence and activities; however, a contiguous area of natural vegetation may encourage more consistent corridor use by both large and small mammals, primarily at night when human presence is lowest.

2.5 References

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Kerr Wood Leidal Consulting Engineers (KWL). 2020b. Bioengineering Demonstration and Education Project - 2020 Monitoring Report.

ATTACHMENT A
Fisheries Photolog

Photo 1 View downstream from Photo Station 1 (Site 1) on January 6, 2021.

Photo 2 View downstream from Photo Station 1 (Site 1) on July 13, 2021.

Photo 3 View downstream from Photo Station 1 (Site 1) on October 14, 2021.

Photo 4 View downstream from Photo Station 1 (Site 1) on November 30 ,2021.

Photo 5 View upstream from Photo Station 1 (Site 1) on January 6, 2021.

Photo 6 View upstream from Photo Station 1 (Site 1) on July 13, 2021.

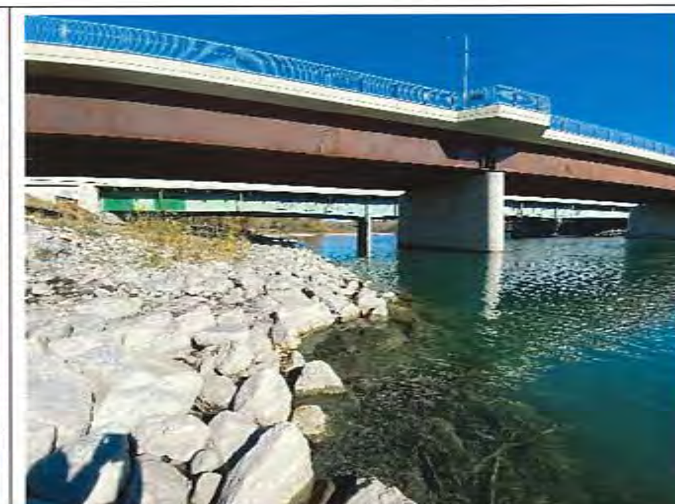


Photo 7 View upstream from Photo Station 1 (Site 1) on October 14, 2021.

Photo 8 View Upstream from Photo Station 1 (Site 1) on November 30, 2021.

Photo 9 View upstream from Photo Station 2 (Site 1) on January 6, 2021.

Photo 10 View upstream from Photo Station 2 (Site 1) on July 13, 2021.

Photo 11 View upstream from Photo Station 2 (Site 1) on November 8, 2021.

Photo 12 View upstream from Photo Station 2 (Site 1) on November 30, 2021.

Photo 13 View downstream from Photo Station 2 (Site 1) on January 6, 2021.

Photo 14 View downstream from Photo Station 2 (Site 1) on July 13, 2021.

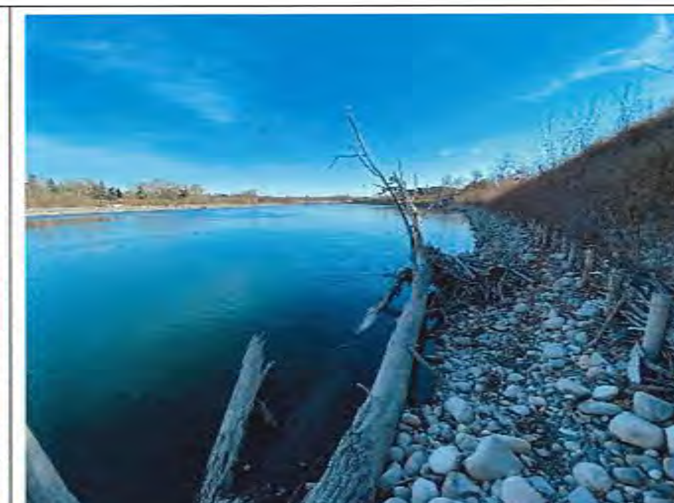


Photo 15 View downstream from Photo Station 2 (Site 1) on November 8, 2021.

Photo 16 View downstream from Photo Station 2 (Site 1) on November 30, 2021.

Photo 17 View upstream from Photo Station 3 (Site 2) on January 6, 2021.

Photo 18 View upstream from Photo Station 3 (Site 2) on July 13, 2021.

Photo 19 View upstream from Photo Station 3 (Site 2) on November 8, 2021.

Photo 20 View upstream from Photo Station 3 (Site 2) on November 30, 2021.

Photo 21 View downstream from Photo Station 3 (Site 2) on January 6, 2021.

Photo 22 View downstream from Photo Station 3 (Site 2) on July 13, 2021.

Photo 23 View downstream from Photo Station 3 (Site 2) November 8, 2021.

Photo 24 View downstream from Photo Station 3 (Site 2) on November 30, 2021.

Photo 25 View upstream from Photo Station 4 (Site 4) on January 6, 2021.

Photo 26 View upstream from Photo Station 4 (Site 4) on November 9, 2021.

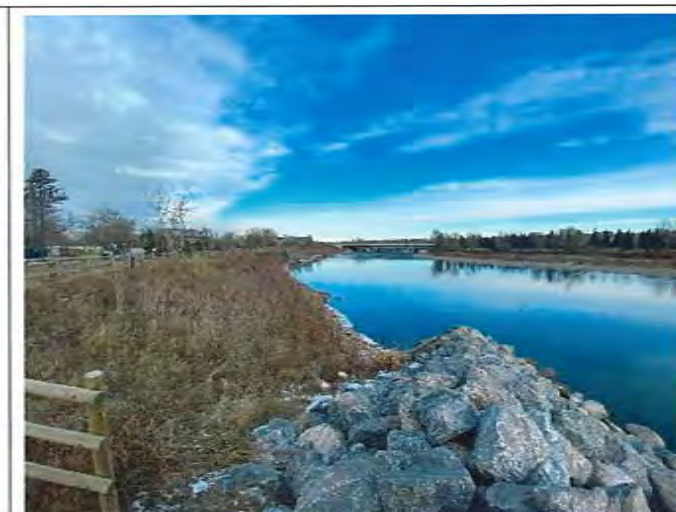


Photo 27 View upstream from Photo Station 4 (Site 4) on November 30, 2021

Photo 28 View downstream from Photo Station 4 (Site 4) on January 6, 2021.

Photo 29 View downstream from Photo Station 4 (Site 4) on November 9, 2021.

Photo 30 View downstream from Photo Station 4 (Site 4) on November 30 ,2021.

Photo 31 View of a trout perch captured in the Bow River on November 9, 2021.

Photo 32 View of a white sucker captured in the Bow River on November 9, 2021.

	
Photo 33 Mountain whitefish eggs collected in the Bow River on November 30,2021.	**Photo 34** Mountain whitefish eggs collected in the Bow River on November 30,2021.

ATTACHMENT B
Site Atlas

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:	C. Davis,
Survey Date:	October 14, 2021
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	162.0, 103.0-232.0
Wetted Width (m): Mean, Range	108.0, 60.0-164.0
Depth (m): Mean, Range	1.50, 0.50-6.95
Stream Gradient (%)	<1
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)	16.60
pH	8.73
Dissolved Oxygen (mg/L)	9.32
Conductivity (µS/cm)	223.50
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)	-	-
Flat 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.

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:	C. Davis,
Survey Date:	October 14, 2021
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	162.0, 103.0-232.0
Wetted Width (m): Mean, Range	108.0, 60.0-164.0
Depth (m): Mean, Range	1.50, 0.50-6.95
Stream Gradient (%)	<1
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)	16.60
pH	8.73
Dissolved Oxygen (mg/L)	9.32
Conductivity (µS/cm)	223.50
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)	-	-
Flat 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.

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:	C.Davis
Survey Date:	October 14, 2021
Legal Location:	NW-12-24-01 W5M
UTM (Zone 11):	709488E, 5657767N

Flow Regime	Perennial
Bankfull Width (m): Mean, Range	162.0, 103.0-232.0
Wetted Width (m): Mean, Range	111.0, 76.0-168.0
Depth (m): Mean, Range	1.50, 0.50-6.50
Stream Gradient (%)	<1
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)	16.76
pH	8.70
Dissolved Oxygen (mg/L)	9.56
Conductivity (µS/cm)	225.78
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	-
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

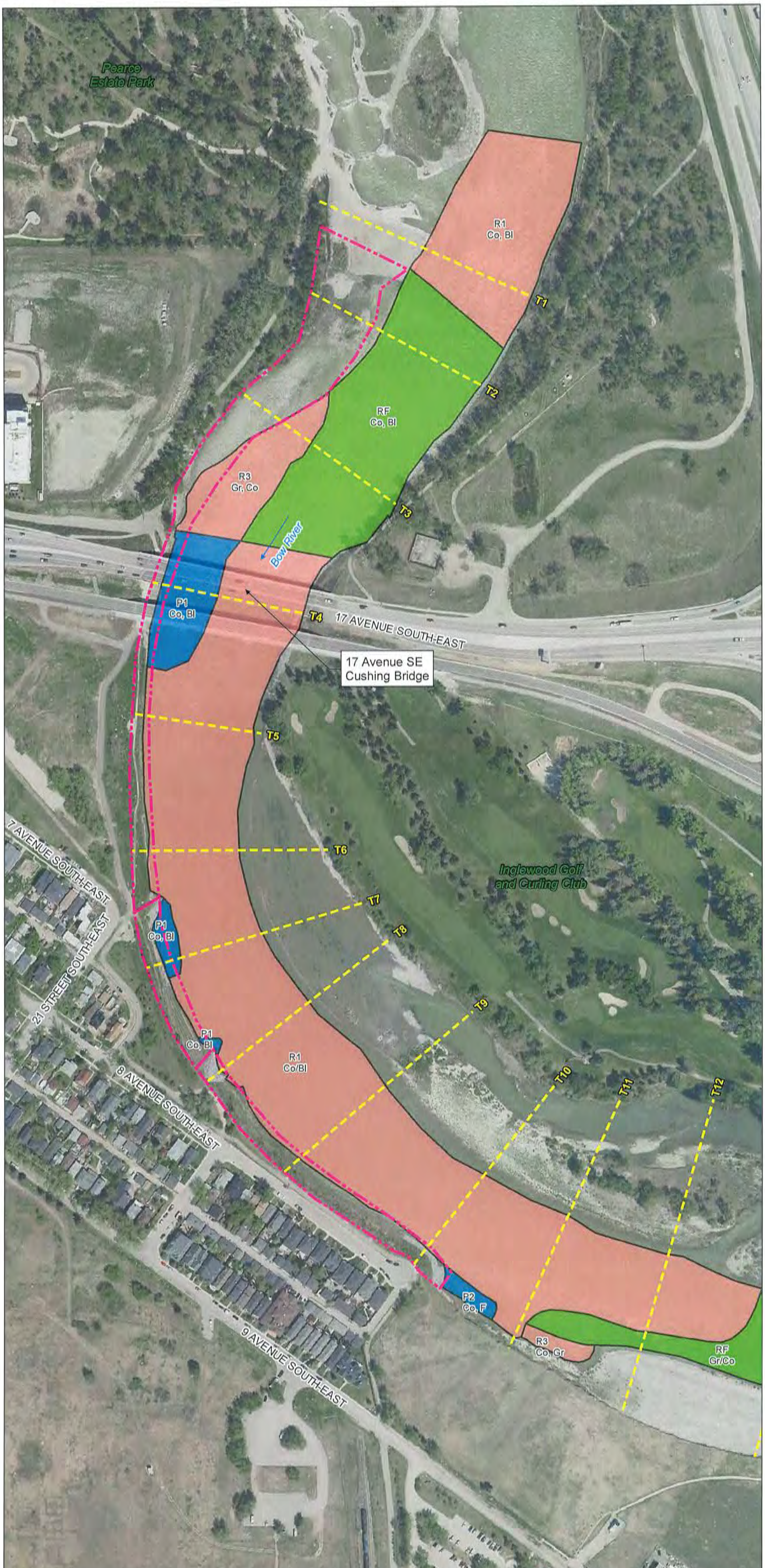
Site 4 is bounded on the upstream end by the second (downstream) riprap groyne constructed along the RDB and extends to the downstream extent of bank riprapping along the RDB. Site 4 extends to the mid channel to the wetted edge of the cobble side bar along the LDB. Fish habitat within Site 4 is comprised 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 .

ATTACHMENT C
Habitat Maps

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 (2019)

N
1:3,000
0 30 60 90 120 150
Metres
Calgary 3TM
Page Size: 11" x 17"

103530-02 | Production Date: Dec 22, 2021 | Figure 3A

Hemmera
An Ausenco Company

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

Bow River Fish Habitat

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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- Aerial Image: City of Calgary (2019)

N

1:3,000

0 30 60 90 120 150

Metres

Calgary 3TM

Page Size: 11" x 17"

103530-02	Production Date: Dec 22, 2021	Figure 3B

Hemmera
An Ausenco Company

ATTACHMENT D
Raw Fish Data

Table D-1 Bow River Raw Fish Data 2021

Species	Fish Count	Length (mm)	Weight (g)	Sex	Life Stage
WHSC	1	45	2	Unknown	Juvenile
WHSC	1	48	2	Unknown	Juvenile
WHSC	1	48	2	Unknown	Juvenile
TRPR	1	51	2	Unknown	Juvenile
TRPR	1	49	2	Unknown	Juvenile

ATTACHMENT E
Wildlife Photolog

Location: Camera 1

Description: White-tailed deer (*Odocoileus virginianus*) doe and fawn crossing under the 17th Avenue bridge from north to south between the pedestrian path and the Bow River water line.

Location: Camera 1

Description: White-tailed jackrabbit (*Lepus townsendii*) under the 17th Avenue bridge between the pedestrian path and the Bow River water line.

Location: Camera 3

Description: Two coyotes (*Canis latrans*) passing under the 17th Avenue bridge from north to south next a section of fenced in willow stakes (reclamation).

Location: Camera 4

Description: A black-coloured eastern gray squirrel (*Sciurus carolinensis*) travelling north to south on an undeveloped nature path within the riparian area along the Bow River.

Location: Camera 4

Description: A striped skunk (*Mephitis mephitis*) travelling north to south on an undeveloped nature path within the riparian area along the Bow River.

Location: Camera 4

Description: An American beaver (*Castor canadensis*) travelling south to north on an undeveloped nature path within the riparian area along the Bow River.

KERR WOOD LEIDAL
consulting engineers

Appendix C

Riparian Health Assessment Field Data Sheets

Prepared by: Longview Ecological

ALBERTA WETLAND HEALTH ASSESSMENT FOR LARGE RIVERS

Polygon ID: BDEP RHA - Site #1

Project: CoC RMP	Observer: AD
Client: CoC	Date: Oct.1/21
Property Name: -	Watershed: South Saskatchewan River
Field Name: -	River Name: Bow River
Legal Land Location: -	Photos: 193 - 187
Natural Subregion: Foothills Fescue	

Coordinates: E709488, N5658485 , E709345, N5657969 (lower end)

Comments: - Fence around site has now been removed
- 1 Mature FRAXPEN tree has died
- POPUBAL cover increasing along upper slope S of bridge
- A possible ↑ in decadent POPUBAL this year due to drought

Dominant Plant Species

Graminoids	% Cover	Forbs	% Cover	Shrubs	% Cover	Trees	% Cover
				VIBUOPU	<1		
ELYMTRA	15	TANAVUL	5	SALIINT	25	POPUBAL	50
ELYMREP	15	CIRSARV	1	SALIFAM	15	POPUTRE	3
BROMINE	25	MEDISAT	2	CORNSTO	5	FRAXPEN	3
ELYMCAN	1	ARTEABS	<1	DASIFRU	1	SALIFRA	3
POAPALU	1	TARAOFF	<1	ELAECOM	2	ULMUAME	<1
DESCCES	<1	LINULEW	<1	RIBEOXY	1	ACERPLA	<1
AGROSTO	2	SONCULI	<1	ROSAWOO	2	ACERNEG	<1
PHALARU	<1	VEROAME	<1	SYMPOCC	<1		
POAPRAT	2	ARCTMIN	<1	AMELALN	<1		

Riparian Area Diagram

↑
N

See diagram from previous assessment

LONGVIEW ECOLOGICAL

Planted POPUBAL are suckering

RIVER HEALTH EVALUATION

Polygon Number: Site #1 Record ID No:

	Actual Score	Possible Score	Comment
1. Cottonwood and Poplar Regeneration	4	6	POPUBAL N of bridge are all mature; POPUBAL planted S of bridge are still mostly <7.5cm dbh
2. Regeneration of other Native Tree Species	3	3	Numerous ACERNEG seedlings; planted POPUTRE are still <7.5cm dbh
3. Regeneration of Preferred Shrub Species	2	6	Most cuttings are now >6ft tall (mature); some suckering by SALAINT
4. Standing Decadent and Dead Woody Material	2	3	A few dead willows, some decadent POPUBAL N of bridge
5a. Browse Util. of Preferred Trees and Shrubs	3	3	Little browsing evident
5b. Woody Veg. Removal other than Browsing	3	3	None
6. Total Canopy Cover of Woody Species	3	3	Excellent willow cover along lower slope - high tree/shrub cover N of bridge
7a. Total Canopy Cover of Invasive Plant Species	1	3	As below
7b. Density/Distribution Pattern of Invasive Plant Species	0	3	As below

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

Species	Can.Cov.	Dens.Dist.	Species	Can.Cov.	Dens.Dist.	Species	Can.Cov	Dens.Dist.
blueweed:			field bindweed:			spotted knapweed:		
* Canada thistle:	1	8	leafy spurge:			tall buttercup:		
caragana:			nodding thistle:			tamarisk/salt cedar:		
cleavers:			ox-eye daisy:			white cockle:		
* common burdock:	<1	6	perennial sow-thistle:			yellow toadflax:		
common hound's-tongue:			purple loosestrife:					
* common tansy:	5	8	Russian knapweed:					
Dalmatian Toadflax:			Russian olive:					
diffuse knapweed:			* scentless chamomile:	<1	2	Others: VICICRA	<1	2
downy chess:			smooth perennial * sow-thistle:	<1	6	Others: CAMPRAP	<1	2
European buckthorn:						CLEMTAN	<1	2

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

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

	Actual Score	Possible Score	Comment
8. Disturbance-increaser Undesirable Herbaceous Species	1	3	TRAGDUB, TRIFHYB, TRIFREP, MELIALB, LACTSER, RUMECRI, ARTEABS, POTEANS, TARAOFF, ELYMREP, BROMINE, MEDISAT, HORDJUB, CIRSVUL, POAPRAT, PHLEPRA, PLANMAJ, CREPTEC
Vegetation Subtotal:	22	36	
9. River Bank Root Mass Protection	4	6	Tree + shrub cover increasing on upper slope S of bridge; High grass cover along upper slope S of bridge; riprap at S end
10. Human-Caused Bare Ground	4	6	Some along wildlife trail; walking trails N of bridge
11. Removal or Addition of Water from/to River System	6	9	Irrigation weir located upstream near Harvie Passage
12. Control of Flood Peak and Timing by Upstream Dam(s)	0	9	Bearspaw Dam + others located upstream
13. River Banks Structurally Altered by Human Activity	0	6	Entire bank S of bridge has been reconstructed; outfalls, boat launch
14. Human Physical Alteration to the Rest of the Polygon	0	3	" " " " " " " " , 2 bridges + concrete pathway
15. Natural Floodplain Accessibility	6	6	No restrictions to floodplain accessibility
Soil / Hydrology Subtotal:	20	45	
Overall Polygon Total:	42	81	

RATING CALCULATION

(Actual Score/Possible Score) X 100 = Rating Percent — Descriptive Category

			x 100 =	Descriptive Category
Vegetation Rating:	22	36	61	Healthy with Problems
Soil / Hydrology:	20	45	44	Unhealthy
OVERALL:	42	81	52	Unhealthy

- It appears recent weeding work has taken place

3. Some willow + POPUBAL natural regen. along gravel bar near N end

20
6
26

ALBERTA WETLAND HEALTH ASSESSMENT FOR LARGE RIVERS

Polygon ID: BDEP RHA - Site #2	
Project: CoC RMP	Observer: AD
Client: CoC	Date: Sept. 30/21
Property Name: —	Watershed:
Field Name: —	River Name: Bow River
Legal Land Location: —	Photos: 181-182
Natural Subregion: Foothills Fescue	

Coordinates: E769344, N5657966 (upper end); E769398, N5657843 (lower end)

Comments: - Fence around site has now been removed

Dominant Plant Species

Graminoids	% Cover	Forbs	% Cover	Shrubs	% Cover	Trees	% Cover
BROMINE	5	MEDISAT	5	SALIINT	20	POPUBAL	10
ELYMTRA	5	TARAOFF	2	SALIFAM	15	POPUTRE	2
POAPRAT	10	TRIFHYB	2	CORNSTO	5	PICEGLA	<1
AGROSTO	15	VICICRA	3	ROSAWOO	3	ACERNEG	1
PHLEPRA	<1	MEDILUP	1	RIBEOXY	3	PINUCON	<1
PHALARU	<1	CIRSARV	1	ELAECOM	<1	LARISIB	<1
AGROSCA	<1	SONCULI	1	AMELALN	<1		
				SYMPOCC	<1		
				ALNUINC	1		

Riparian Area Diagram

↑
N

See diagram from previous assessment

ONGVIEW ECOLOGICAL

Large (non-riparian) bench area included in original polygon that is mostly turf grass
- Some SALUINT sprouting between brush layers; a number of the live staking willows are <6ft
- contour fascine willows + POPUBAL are still mostly <6ft
- toe fascine willows are nearly all >6ft.

RIVER HEALTH EVALUATION

Polygon Number: Site #2 Record ID No:

	Actual Score	Possible Score	Comment
1. Cottonwood and Poplar Regeneration	6	6	POPUBAL cuttings present along bank. Planted POPUBAL are still mostly <3 in.
2. Regeneration of other Native Tree Species	3	3	Planted POPUTRE still <3m dbh; some ACERNEG seedlings
3. Regeneration of Preferred Shrub Species	6	6	Many willow cuttings are now >6ft (i.e. mature)
4. Standing Decadent and Dead Woody Material	3	3	A few dead willows, but overall <5% cover
5a. Browse Util. of Preferred Trees and Shrubs	3	3	Little willow browsing; minor CORNSTO browsing
5b. Woody Veg. Removal other than Browsing	3	3	None occurring
6. Total Canopy Cover of Woody Species	2	3	Good willow cover except along swallow habitat,
7a. Total Canopy Cover of Invasive Plant Species	1	3	As below
7b. Density/Distribution Pattern of Invasive Plant Species	0	3	" "

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

Species	Can.Cov.	Dens.Dist.	Species	Can.Cov.	Dens.Dist.	Species	Can.Cov.	Dens.Dist.
blueweed:			field bindweed:			spotted knapweed:		
* Canada thistle:	1	5	leafy spurge:			tall buttercup:		
caragana:			nodding thistle:			tamarisk/salt cedar:		
cleavers:			ox-eye daisy:			white cockle:		
common burdock:			perennial sow-thistle:			yellow toadflax:		
common hound's-tongue:			purple loosestrife:					
* common tansy:	<1	2	Russian knapweed:					
Dalmatian Toadflax:			Russian olive:			Others: VICICRA	3	8
diffuse knapweed:			scentless chamomile:			Others: CLEMTAN	<1	7
downy chess:			* smooth perennial sow-thistle:	<1	8	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:

	Actual Score	Possible Score	Comment
8. Disturbance-increaser Undesirable Herbaceous Species	2	3	MEDILUP, MELIALB, ~~TRIFRA~~, ~~CIRSVUL~~, AGROCRI, BROMINE, MEDISAT, ARTEABS, POAPRAT, TARAOFF, TRAGDUB, HORDJUB, PLANMAJ, PILEPRA, TRIFHYB, MELIOFF
Vegetation Subtotal:	29	36	Portion of bank not planted + left for swallow habitat.
9. River Bank Root Mass Protection (- includes ~3m of bench)	2	6	Riprap covers ~5% of bank; high willow cover mostly
10. Human-Caused Bare Ground	4	6	Walking path along bench; still some bare soil in contour fascines
11. Removal or Addition of Water from/to River System	6	9	Irrigation weir present upstream near Harvie Passage
12. Control of Flood Peak and Timing by Upstream Dam(s)	0	9	Bearspaw Dam and other located upstream
13. River Banks Structurally Altered by Human Activity	0	6	Most of bank has been altered
14. Human Physical Alteration to the Rest of the Polygon	0	3	" " " " " "
15. Natural Floodplain Accessibility	6	6	No restrictions to floodplain accessibility
Soil / Hydrology Subtotal:	18	45	
Overall Polygon Total:	47	81	

40

RATING CALCULATION

(Actual Score/Possible Score) X 100 = Rating Percent — Descriptive Category

	Actual	Possible	x 100 =	Descriptive Category
Vegetation Rating:	29	36	81	Healthy
Soil / Hydrology:	18	45	40	Unhealthy
OVERALL:	47	81	58	Unhealthy

- High MEDISAT, BROMINE, + POAPRAT cover on bench
- New POPUBAL planted in upper contour fascine section that died; new bare soil created

ALBERTA WETLAND HEALTH ASSESSMENT FOR LARGE RIVERS

Polygon ID: BDFP RHA – Site #4	
Project: CoC RMP	Observer: AD
Client: CoC	Date: Sept. 30/21
Property Name: —	Watershed:
Field Name: —	River Name: Bow River
Legal Land Location: —	Photos: 178–180
Natural Subregion: Foothills Fescue	
Coordinates: E709403, N5657842 (upstream end), E709581, N5657672 (lower end)	
Comments:	

SALIFAM 5

Dominant Plant Species

Graminoids	% Cover	Forbs	% Cover	Shrubs	% Cover	Trees	% Cover
ELYMTRIA	10	TARAOFF	5	SALIINT	25	POPUTRE	5
POAPALU	10	TANAVUL	1	RIBEAUR	7	POPUBAL	3
BROMINE	10	MEDISAT	1	CORNSTO	10	ACERNEG	<1
ELYMCAN	3	LINULEW	<1	ALNUINC	1	POPUDEL	<1
ELYMREP	10	CIRSARV	1	SALIBEB	3	FRAXPEN	<1
AGROSTO	1	SONCUL	<1	DASIFRU	2		
PHLEPRAT	1	TRIFINO	<1	ROSAWOO	2		
				PRUNVIR	1		
				ELAECOM	1		

Riparian Area Diagram

↑
N

See diagram from previous assessment

LONGVIEW ECOLOGICAL

POPUTRE appears to be spreading from planted stock

RIVER HEALTH EVALUATION

Polygon Number: Site #4 Record ID No:

	Actual Score	Possible Score	Comment
			A few mature POPUBAL trees
1. Cottonwood and Poplar Regeneration	6	6	Some natural POPUBAL regen. + plantings
2. Regeneration of other Native Tree Species	3	3	A number of ACERNEG seedlings colonizing, FRAXPENA as well
3. Regeneration of Preferred Shrub Species	2	6	Some SALIINT, CORNSTO, SALIFAM, but high mature shrub cover on upper bank
4. Standing Decadent and Dead Woody Material	3	3	Some dead cuttings + plantings, but <5% cover
5a. Browse Util. of Preferred Trees and Shrubs	2	3	Most CORNSTO have been browsed, little willow browsing; AMELALN also browsed
5b. Woody Veg. Removal other than Browsing	3	3	None
6. Total Canopy Cover of Woody Species	3	3	Good shrub + tree cover along upper bank, low cover on mid-bank
7a. Total Canopy Cover of Invasive Plant Species	1	3	As below
7b. Density/Distribution Pattern of Invasive Plant Species	0	3	" "

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

Species	Can.Cov.	Dens.Dist.	Species	Can.Cov.	Dens.Dist.	Species	Can.Cov	Dens.Dist.
blueweed:			field bindweed:			spotted knapweed:		
* Canada thistle:	1	8	leafy spurge:			tall buttercup:		
caragana:			nodding thistle:			tamarisk/salt cedar:		
cleavers:			* ox-eye daisy:	<1	2	white cockle:		
common burdock:			perennial sow-thistle:			* yellow toadflax:	<1	2
* common hound's-tongue:	<1	2	purple loosestrife:					
* common tansy:	1	5	Russian knapweed:					
Dalmatian Toadflax:			Russian olive:					
diffuse knapweed:			* scentless chamomile:	<1	2	Others: VICICRA	<1	7
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:

	Actual Score	Possible Score	Comment
8. Disturbance-increaser Undesirable Herbaceous Species	2	3	~~TRAGDUB, PLANMAJ~~ PALEPRA, BROMINE, TARAOFF, ELYMREP, CIRSVUL, MEDISAT, MEDILUP, ARTEABS, POAPRAT, TRIFREP, TRIFHYB, MELIALB
Vegetation Subtotal:	25	36	
9. River Bank Root Mass Protection	2	6	Good shrub + tree cover on upper bank. Riprap covers ~20% of bank; mid-bank lacking shrubs
10. Human-Caused Bare Ground	4	6	Some near S end of site on midbank
11. Removal or Addition of Water from/to River System	6	9	Irrigation weir located upstream of site near Harvie Passage
12. Control of Flood Peak and Timing by Upstream Dam(s)	0	9	Bearspaw Dam + others situated upstream of site
13. River Banks Structurally Altered by Human Activity	0	6	Entire bank has been reconstructed; human trailing as well
14. Human Physical Alteration to the Rest of the Polygon	0	3	" " " " "
15. Natural Floodplain Accessibility	6	6	No restrictions to floodplain accessibility
Soil / Hydrology Subtotal:	18	45	
Overall Polygon Total:	43	81	

RATING CALCULATION

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

			Descriptive Category
Vegetation Rating:	25 / 36	x 100 = 69	Healthy with Problems
Soil / Hydrology:	18 / 45	x 100 = 40	Unhealthy
OVERALL:	43 / 81	**x 100 =** 53	Unhealthy

- Most live cuttings did not survive -> recently replanted with plugs

3. - A number of plantings died last winter, lowering overall cover of regenerating preferred shrub spp.

Appendix D

Appendix D: Cows and Fish 2021 BOW95 Riparian Health Assessment Report

Cows and Fish

Alberta Riparian Habitat Management Society

Riparian Health Inventory Summary Report

Bow River, west (right[1]) bank

BOW95 (Bioengineering Demonstration and Education Project, Calgary)

2021 RE-VISIT RESULTS

Report Contents:

[1] As viewed facing downstream

1 Introduction

A Riparian Health Inventory (RHI) re-visit of the Bioengineering Demonstration and Education Project (BDEP) (BOW95) was conducted on July 15, 2021. The BOW95 RHI site overlaps with the majority of the BDEP extent, encompassing about 580 m (approximate) of the west (right) bank of the Bow River downstream from the 17 Avenue SE, Cushing Bridge. This 1.5 ha site ranges from approximately 5 m to 45 m wide, averaging 16 m in width. A baseline RHI was conducted here in 2016. Riparian health parameters were assessed for the entire extent of the BOW95 polygon (as shown on the airphoto on page 6), encompassing multiple bioengineering 'site' treatments with the exception of Site 1-1 upstream from Cushing Bridge (Appendices B and C).

2 Riparian Health Trend (2016 and 2021)

This site has increased by 15% from a baseline score of 44% (*unhealthy*) in 2016 due to extensive bioengineering bank treatments and riparian plantings conducted in 2015 and 2018. Successful establishment of native trees and shrubs and other habitat enhancements have contributed to improved scores for multiple parameters as shown below. The present rating of 59% is just below the *healthy, with problems* threshold. Refer to Appendix D for riparian health parameter scoring criteria.

Waterbody: Bow River	**Location:** Bioengineering Demonstration and Education Project
Site Code: BOW95	**Inventory Dates:** July 22, 2016; July 15, 2021
Bank Length: 580 m **Avg Width:** 16 m	**RHI Polygon Area:** 1.5 ha

RIPARIAN HEALTH PARAMETER	2016 SCORE	2021 SCORE	Trend
Vegetation (Plants)			
1. Cottonwood and Balsam Poplar Regeneration	0 / 6	6 / 6	
2. Regeneration of Other Native Tree Species	3 / 3	3 / 3	
3. Regeneration of Preferred Shrub Species	6 / 6	6 / 6	
4. Standing Decadent and Dead Woody Material	3 / 3	3 / 3	
5a. Browse Utilization of Preferred Trees and Shrubs	3 / 3	2 / 3	
5b. Live Woody Vegetation Removal by Beaver or Human Clearing	3 / 3	3 / 3	
6. Total Canopy Cover of Woody Species	1 / 3	3 / 3	
7a. Total Canopy Cover of Invasive Plant Species (Weeds)	1 / 3	1 / 3	
7b. Density/Distribution Pattern of Invasive Plant Species (Weeds)	0 / 3	0 / 3	
8. Disturbance-Increaser Undesirable Herbaceous Species	0 / 3	1 / 3	
Vegetation Rating	**20/36 (56%)**	**28/36 (78%)**	⇧
Soil/Hydrology			
9. Riverbank Root Mass Protection	0 / 6	4 / 6	
10. Human-Caused Bare Ground	6 / 6	4 / 6	
11. Removal or Addition of Water from/to River System	6 / 9	6 / 9	
12. Control of Flood Peak and Timing by Upstream Dam(s)	0 / 9	0 / 9	
13. Riverbank Structurally Altered by Human Activity	0 / 6	0 / 6	
14. Human Physical Alteration to the Rest of the Polygon	0 / 3	0 / 3	
15. Natural Floodplain Accessibility	4 / 6	6 / 6	
Soil/Hydrology Rating	**16/45 (36%)**	**20/45 (44%)**	⇧
OVERALL RATING	**36/81 (44%)**	**48/81 (59%)**	⇧

Trend symbols: ⬄ Static (<5% score change); ⇧ Improving (>5% score increase); ⇩ Declining (>5% score decline)

(green)	**Healthy (80-100%)** – Little or no impairment to riparian functions.
(yellow)	**Healthy, but with problems (60-79%)** – Some impairment to riparian functions due to human or natural causes.
(red)	**Unhealthy (<60%)** – Impairment to many riparian functions due to human or natural causes.

3 Riparian Health Trend Discussion

2021 Riparian Health Comments	*Overall Comments* • Riparian plantings done in 2015 in addition to bioengineering works since 2018 have successfully improved multiple riparian health parameters, creating substantial habitat enhancement. This has included successful establishment of balsam poplar (*Populus balsamifera*) seedlings and saplings; a dramatic increase in preferred native woody cover (from 10% to 80%); reduced disturbance-caused herbaceous species; and improved root mass protection. Another beneficial change has been creation of riparian terraces and a new wildlife travel corridor downstream from the 17th Avenue SE (Cushing) Bridge. The pre-existing vertical bank in the lower portions of Site 1 (Appendix B) between the B10 and B009 outfalls was pulled back in places to create a flood terrace and a more usable corridor for wildlife. Aquatic (in-stream) fish habitat enhancements were also incorporated into the BDEP design. This included creation of fish shelters beneath new timber crib walls and strategic placement of bolder clusters in the channel. • A diagram showing the BDEP site treatments is given in Appendix B (as per KWL 2021b). A summary of bioengineering techniques used in the BDEP by site is given in Appendix C (per KWL 2021b). Technical details are also available from: https://www.calgary.ca/uep/water/watersheds-and-rivers/riverbank-health/bioengineering-demonstration-and-education-project-technical-project-details.html. • Overall this successful bioengineering and restoration project exhibits much greater habitat complexity and ecological functionality due to a diversity of native plantings along the riverbank. Efforts are ongoing to remove invasive weeds within this reach. Shading from planted trees and shrubs and a gradual shift in the soil microbiology of the site over time may help to keep invasive weeds in check. Enhanced root mass protection from established willows and poplars along the bank not only provides improved wildlife habitat structure it also improves erosion resilience while benefitting sheltering habitat for fish. • Riparian plantings all show vigorous growth. At the time of this RHI, fencing was in place to exclude wildlife (deer and beavers) and people from bioengineering treatments. This fencing is scheduled to be removed after the maintenance period. Artistic interpretive signage has been installed along designated pathways and at seating areas. • The regional paved pathway adjacent to this site is largely outside of this RHI polygon boundary except for 45 m at the 17th Avenue bridge underpass where the pathway is at a lower elevation. • Riparian health constraints at a watershed scale are due to diversion of water due to the Western Irrigation Canal and upstream damming. • Of interest, Wandering Garter Snakes, were observed adjacent to Site 4-4, immediately downstream from the site. Future bioengineering mitigations should take appropriate measures to avoid harm to potential garter snake hibernacula (e.g., steep cutbanks with cavities). *Vegetation Parameter Comments:* • Plantings installed in 2015 (in the downstream extent above the riprap toe) did not initially contribute to riparian health scores in 2016 since these were not yet considered successfully established at that time. This includes those species whose canopy covers are listed in red bold text for 2016 in Table 9-1, page 31. Only those plantings that have survived for more than one full growing season count toward riparian health parameters and vegetation cover. • Excluding 2015 plantings, Manitoba maple (*Acer negundo*) was the dominant tree cover in 2016 comprising 10% cover (mainly mature plants). A few mature balsam poplar trees

	were also present near the upstream end in that year. Manitoba maple trees are native to southeastern Alberta but were historically planted in Calgary. • Due to bioengineering plantings since 2018, balsam poplar now comprises about 20% cover, mostly sapling and seedling aged plants. Balsam poplar plantings were incorporated into most of the bioengineering treatment sites. • Aspen (*Populus balsamifera*) have now successfully established and show excellent growth mainly along the mid to upper bank in Site 4 (Appendix B). Aspen now comprise about 10% canopy cover (mainly saplings). • Manitoba maple in addition to four other tree species are also present on the site, including recent plantings of ornamental species in manicured lawn areas (Table 9-1). • Excluding 2015 plantings, six shrub species comprised less than 5% of the site in 2016, only three of which were preferred native species. A diversity of 15 native shrubs are now established due to successful plantings (Table 8-1). Shrubs now comprise 80% cover. Since many of the plantings are 3 years old, they are considered sapling-aged. • The majority of plantings showed excellent vigour with minimal dead or decadence in 2021. Use of a soil amendment, frequent irrigation, exclusion fencing, and other maintenance works have contributed to reducing mortality and improving vigour. • Several of the more mature red-osier dogwood shrubs (installed in 2015) showed browse evidence from past use by wildlife (deer); however, most of the 2018 BDEP sites have exclusion fencing in place. Exclusion fencing has prevented herbivory and recreational use damage to recent plantings. • A beaver exclusion fence is in place at the toe of the bank below BDEP site treatments to prevent beaver access. As such beaver damage is not apparent. • Some pre-existing woody vegetation was impacted at the upstream end (Site 1) by the construction of the Bus Rapid Transit (SE BRT) bridge and by bank reshaping engineering works. However, the net increase in native tree and shrub vegetation due to successful bioengineering treatments and plantings have compensated for this loss of woody vegetation. As mentioned, total woody canopy cover in the site is now about 80% compared to only 10% in 2016. • Invasive weeds continue to have high densities in some portions of the site and about 10% combined canopy cover, similar to 2016. Weed removal efforts are ongoing. As tree and shrub plantings mature, shaded conditions may help keep invasive weeds in check in the long-term. There are few invasive weeds in portions of the site with dense willow cover in Site 1. • Disturbance-caused plants have substantially declined in cover since 2016 due to establishment of dense tree and shrub plantings. These plants, mainly foxtail barley (*Hordeum jubatum*), quackgrass (*Elymus repens*) and Kentucky bluegrass (*Poa pratensis*) comprised about 80% cover (the dominant ground cover) in 2016. Disturbance-herbaceous plants now comprise about 40% cover. Manicured lawn areas have largely not been renovated and have maintained Kentucky bluegrass and quackgrass cover. Foxtail barley (previously prolific along the mid and upper banks) has now been largely displaced by woody plantings and seeded grasses. *Soil/Hydrology Parameter Comments:* • Due to successful establishment of native tree and shrub plantings, root mass protection has substantially improved. In 2016 less than 35% of the bank had root mass protection from deeply rooted trees and shrubs. In 2021, 66-85% of the bank now has dense willow, poplar and native shrub plantings within a 15 m band. This excludes portions of the bank with retained rock groynes, bridge infrastructure and without bioengineering treatments or where live cuttings are less than 1-year-old.

	• Human-caused bare ground has increased to about 3% cover (from less than 1%) mainly due to addition of new gravel pathways and sitting areas plus more heavily compacted foot paths. Although some live cuttings have recently been installed in the disturbed area between the Cushing and BRT bridges, this portion of bank is largely unvegetated. • Since this site is located downstream from the Western Irrigation District diversion and is downstream from several large dam facilities it continues to have reduced ratings for parameters #11 and #12. • The majority of the bank length has been structurally altered due to bank stabilization works since the 2013 flood. Recent bioengineering works at this site have included three vegetated riprap treatments to attempt to establish native vegetation in pre-existing areas of rock riprap. A vegetated timber cribwall structure was built downstream from the 17th Ave SE bridge as part of the 370 m "Site 1" treatment. Except for purely vegetative techniques (e.g., live staking; willow brush mattress), all other bioengineering treatments that result in physical alteration of the natural bank profile are counted toward 'human-caused alterations'. Although the bank alteration score is unchanged since 2016, there may be some potential for improved scores in the long-term where structures such as vegetated timber crib walls decompose and naturalize. Vegetated riprap treatments, if successful in the long-term, are beneficial for ameliorating and enhancing fish and wildlife habitat, wildlife accessibility, shelter and root mass protection. However, portions of the site with rock groynes, unvegetated riprap, bridge abutments and other similar permanent 'hard engineering' alterations will continue to detract from the score. Positively contributing to reduced bank alterations from baseline conditions has been extensive removal of concrete rubble and other debris within Site 1. • Approximately 36% of the site area (excluding the bank) has soil compaction structural alterations from newly built gravel pathways and sitting areas, mowed lawn areas and informal foot paths. The adjacent paved regional pathway was largely <u>excluded from the polygon area</u> except for 45 m of pathway beneath the bridges at the upstream end of the site. Thus, a small portion of impervious (paved) surface is another contributor to structural alterations in this site. Engineered riparian terraces and landscaped portions of the site that have since been fully reclaimed and successfully revegetated with preferred native tree and shrub species were not detracted from the physical alteration score. • Beneficial bank reshaping was done in the upstream third of the site to create lower riparian terraces and a wildlife movement corridor. This portion of the site previously had steep vertical banks with concrete rubble and other debris. Bank reshaping has improved floodwater accessibility in parts of the site. The natural floodplain is mostly on the east side of the river through this reach, which does not have artificial berms.

3.2 *Invasive Plant Species Trends*

- There has been a slight increase from 10 to 12 invasive species in this site since 2016 (Table 3.1). New occurrences of ox-eye daisy (*Leucanthemum vulgare*), tufted vetch (*Vicia cracca*), and yellow toadflax (*Linaria vulgaris*) were observed in 2021. Tall buttercup (*Rananculus acris*) recorded in 2016, was not observed in 2021.
- The combined canopy cover of invasive species continues to be about 10%.
- Dense native tree and shrub plantings and seeded areas have displaced some pre-existing weed patches, but there continues to be more than a few patches and 1-5% cover from common tansy (*Tanacetum vulgare*), perennial sow-thistle (*Sonchus arvensis*) and scentless chamomile (*Tripleurospermum inodorum*).
- Tufted vetch has established as fairly dense patches between willow plantings in Site 2 and Site 4. Dense patches of tufted vetch are also apparent along alluvial bars adjacent to Inglewood Northfield, immediately downstream of the BDEP site. Although not a regulated weed, this legume has spread profusely along the Bow and Elbow rivers in Calgary since 2007 based on RHI data. In high densities it tends to displace preferred species, although it may offer some soil enhancement as well due to its nitrogen fixing capabilities.
- All other species listed in Table 3.1 occur in trace amounts (<1%) as rare occurrences or several sporadic individuals.

Table 3.1 – BOW95 (BDEP) Invasive Species Trends

Invasive Species Name[1]	**Weed Designation**[2]	**2016**		**2021**	
		Canopy Cover (%)	**Density Distribution Class**[3]	**Canopy Cover (%)**	**Density Distribution Class**[3]
Canada thistle (*Cirsium arvense*)	*Noxious*	0.5	8	0.5	8
Cleavers (*Galium aparine)*	*Noxious*	0.5	4	0.5	1
common burdock (*Arctium minus*)	*Noxious*	0.5	5	0.5	1
common tansy (*Tanacetum vulgare*)	*Noxious*	3	8	3	8
creeping bellflower; garden bluebell (*Campanula rapunculoides*)	*Noxious*	0.5	4	0.5	1
ox-eye daisy (*Leucanthemum vulgare* syn. *Chrysanthemum leucanthemum*)	*Noxious*	Not observed		0.5	5
perennial sow-thistle (*Sonchus arvensis* and *Sonchus arvensis* ssp. *uliginosus*)	*Noxious*	3	8	3	8
scentless chamomile (*Tripleurospermum inodorum* syn. *Matricaria perforata*)	*Noxious*	3	8	3	8
tall buttercup (*Ranunculus acris*)	*Noxious*	0.5	4	Not observed	
tufted vetch (*Vicia cracca*)	Unregulated	Not observed		3	8
white cockle (*Silene latifolia ssp. alba* syn. *S. pratensis*)	*Noxious*	0.5	3	0.5	1
yellow clematis (*Clematis tangutica*)	*Noxious*	0.5	3	0.5	5
yellow toadflax (*Linaria vulgaris*)	*Noxious*	Not observed		0.5	5

[1] Invasive species nomenclature primarily follows Kershaw and Allen (2020); species are listed alphabetically.

[2] As per the *Alberta Weed Control Act, Weed Control Regulation*

[3] See density distribution table diagram (Table D-1), Appendix D.

BOW95 (BDEP) Invasive Weed Map
(incidental observations only; not exhaustive)

4 Management, Monitoring and Restoration Suggestions

Invasive Species

- Continue efforts to control and monitor invasive plant species on an annual basis.
- As a priority, weed control efforts should be focused on **early detection and rapid eradication of *Prohibited Noxious Weeds***. As per Alberta's *Weed Control Act* there are more stringent 'eradication' requirements for *Prohibited Noxious Weeds*. *Prohibited Noxious* Weeds are currently absent in the site.
- A second emphasis should be **immediate removal of localized weed patches or isolated (rare) individual species occurrences**. A long-term, integrated weed control strategy is needed to manage more widespread and abundant species (e.g., common tansy and tufted vetch).
- Incidental *Noxious Weed* locations recorded in 2021 were reported to Calgary Parks, Integrated Pest Management directly for follow-up monitoring and control efforts.
- For detailed invasive plant species identification and management information refer to the Alberta Invasive Species Council Website: https://abinvasives.ca/.
- Investigate biological control methods for common tansy in addition to mechanical control techniques (such as several years of repeated mowing during the bolting/budding stage prior to flowering or seed set).
- Conduct annual hand pulling of tufted vetch when in flower to curb continued spread of this prolific non-native invasive species. This species is very easily identified and distinguished from native vetch species when in flower.
- Ensure any topsoil or fill materials used for restoration purposes are certified to be free of weed seeds. Any equipment brought on site should be clean and weed free. Only certified weed-free seed mixes should be used for rehabilitation projects.

Riparian Habitat Enhancement

- Follow and implement recommendations for bioengineering repairs and maintenance works as per KWL 2021b.
- Augment native shrub understory plantings within upper bench 'naturalized' buffers (for example, see Waypoint 2B, photos RHIP95BOW052 and 053, page 24).
- Expand and enhance clustered native tree and shrub plantings within manicured lawn portions of the site.

Recreational Use

- Monitor recreational use in the long-term to take early mitigation actions as needed to protect sensitive habitat features (e.g. swallow nests and garter snake hibernacula), prevent bank erosion, and maintain the integrity of bioengineering treatments.
- Use wood rail fencing and/or large woody debris to prevent recreational access into steep, unstable or ecologically sensitive banks and to encourage users to stay on the existing regional pathway and gravel pathways.
- Continue to maintain interpretive signage installed as part of the BDEP project to educate users about bioengineering treatments and their intended erosion mitigation and ecological benefits.

Wildlife Use

- Continue to monitor wildlife herbivory of riparian plantings and use an adaptive management approach to mitigate impacts as needed with the use of exclusion fencing or other tools as warranted in the long-term.
- For preventing beaver herbivory, use 14-gauge galvanized steel wire with a 5 cm (2 inch) mesh size installed to a minimum height of 90 cm (3 feet) around the base of trees or shrubs. Ensure beaver cages do not girdle trees; remove or replace cages as trees mature where necessary.
- Ensure any future bank bioengineering or stabilization works avoids impacts to active swallow nests or potential garter snake hibernacula. Garter snakes were observed adjacent to the downstream end of the site.
- Continue to avoid the use of non-biodegradable (plastic) erosion control netting that may pose a hazard to reptiles, birds, fish and other wildlife.

Monitoring

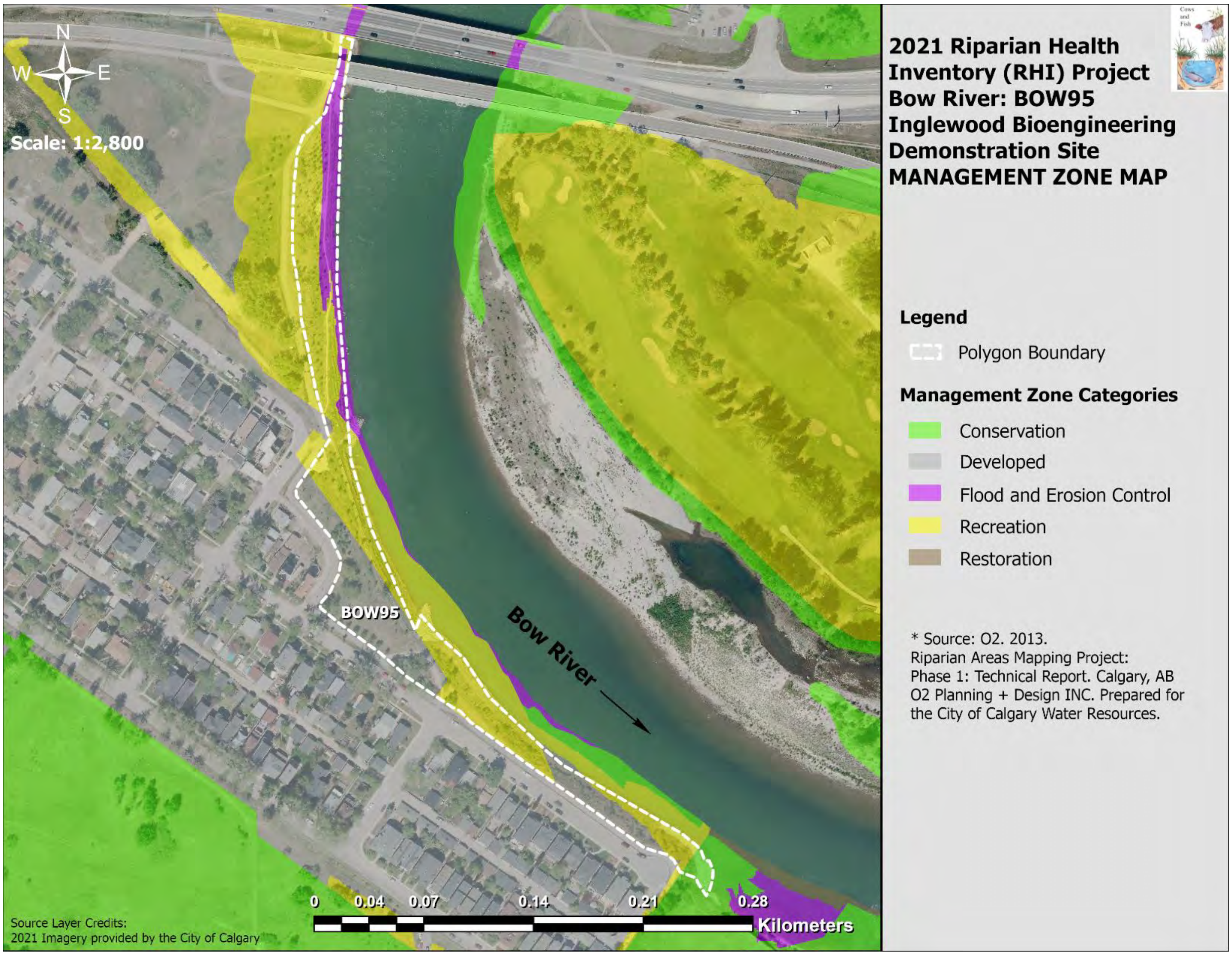
- Continue to implement the ***Bioengineering and Efficacy Monitoring Plan (BEMP)*** (as per Hemmera 2018) approved by Alberta Environment and Parks and The City of Calgary in 2018. The BEMP provides monitoring guidance for the following items:
    - Fish and Fish Habitat
    - Wildlife
    - Riparian Health Assessments (at a bioengineering treatment site scale)
    - Bioengineering Structural Integrity at BDP Site 1, Site 2 and Site 4 with monitoring occurring in Years 1, 2, 3, 5 and 10-years post construction.
- Per recommendations from KWL (2021b), use the Bank and Riparian Quality Index (BRQI) as an additional monitoring tool to assess long-term success of bioengineering treatments specifically. The BRQI was developed as part of The City's Riparian Monitoring Program (KWL 2018) to focus mainly on vegetation cover and composition indictors on a local site scale. This index can more easily show progress toward habitat restoration goals. This will address inherent constraints of the Cows and Fish Riparian Health Assessment/Inventory tool, whereby watershed scale parameters (e.g., upstream dams, water withdrawals and diversions) pose permanent limits to a maximum achievable score at a site level.
- Monitor the survival success of recent live stakes installed in Site 1-2 (between the Cushing and BRT bridges) and replace or mitigate with an alternate bioengineering treatment as warranted.
- Continue to engage with the Southern Alberta Institute of Technology's (SAIT) Integrated Water Management Program by involving students with various components of the BEMP and related research projects.

Education and Outreach

- Continue with ongoing efforts to disseminate key learnings and management recommendations stemming from the BDEP project with City project managers, consultants and other municipal, regional and provincial stakeholders and watershed partners. Continue to participate in bioengineering conferences and seminars at a national and international scale.
- Continue efforts to partner with RiverWatch, the Alberta Low Impact Development Partnership, the Bow River Basin Council and others to promote education events and site tours of the BDEP project.
- Continue to implement other education outcomes and recommendations as per the BDEP "Education Plan" (Hemmera 2017).

6 BOW95 Photo Waypoint Map (2020 Imagery)

7 BOW95 Management Zone Map (2020 Imagery)



8 Monitoring Photography

<table>
<tr><th>Upstream Benchmark - 2016</th><th>Upstream Benchmark - 2021</th></tr>
<tr><td></td><td></td></tr>
<tr><td>RHIP95BOW003 (2016, Waypoint U) – Upstream end, view downstream from the 17 Ave SE (Cushing) Bridge into the site. A small portion of the bank at the upstream end was not impacted by the 2013 flood and had some sandbar willow and mature balsam poplar cover in 2016. (Photographer: M. Laing)</td><td>RHIP95BOW030 (2021, Retake of RHIP95BOW003) – The recently constructed Bus Rapid Transit Bridge resulted in some removal of preferred woody cover. Willow cuttings have been newly installed in this disturbed area which also has weedy species present, mainly scentless chamomile. (Photographer: K. Hull)</td></tr>
<tr><td></td><td></td></tr>
<tr><td>RHIP95BOW001 (2016, Waypoint U) – Upstream end (OUT of the assessed site), view upstream under the 17th Avenue SE bridge showing pre-existing riprap rock armouring. (Photographer: M. Laing)</td><td>RHIP95BOW028 (2021, Retake of RHIP95BOW001) – Native river gravels were used to infill void-spaces between the riprap rocks and provides a surface that is suitable for wildlife passage. (Photographer: K. Hull)</td></tr>
</table>

Upstream Benchmark - 2016	Upstream Benchmark - 2021
	
RHIP95BOW002 (2016, Waypoint U) – **Upstream end**, view east to the opposite bank beneath the 17th Ave SE (Cushing) Bridge. (Photographer: M. Laing)	**RHIP95BOW029 (2021, Retake of RHIP95BOW002)** – The Bus Rapid Transit Bridge has been newly installed here since 2016 impacting a small portion of the bank. (*Photographer: K. Hull*)

Downstream Benchmark - 2016	Downstream Benchmark - 2021
	
RHIP95BOW007 (2016, Waypoint L) – View upstream from the **downstream** end of the site. Extensive bank stabilization works were conducted here after the 2013 flood including bank reshaping, installation of a riprap toe and installation of tree and shrub plantings above the riprap. Exposed geotextile fabric and scentless chamomile (a *Noxious weed*) were present above the riprap base in 2016. (*Photographer: M. Laing*)	**RHIP95BOW034 (2021, Retake of RHIP95BOW007)** – **Site 4-4:** This 40 m length of bank was left as an **untreated 'control'**; no modifications were made to the bank configuration since 2014. Geotextile fabric continues to be exposed above the rock layer; noxious weeds continue to persist on the upper bank. (*Photographer: K. Hull*)
	
RHIP95BOW004 (2016, Waypoint L) – **Downstream end**, view downstream **out of** the BDEP site toward the Inglewood Northfield Site (BOW91). The cutbank to the back provides swallow nesting habitat. (*Photographer: M. Laing*)	**RHIP95BOW031 (2021, Retake of RHIP95BOW004)** – This control site shows little change since 2016 except for fair native grass establishment in the BDEP site where a seed mix was applied above the riprap toe. Noxious weeds continue to persist here including Canada thistle, ox-eye daisy and scentless chamomile. (*Photographer: K. Hull*)

Downstream Benchmark - 2016	Downstream Benchmark - 2021
	
RHIP95BOW005 (2016, Waypoint L) – **Downstream end**, view downstream **out of** the BDEP site toward the Inglewood Northfield Site (BOW91). The cutbank to the back provides swallow nesting habitat. (*Photographer: M. Laing*)	**RHIP95BOW033 (2021, Retake of RHIP95BOW005)** – Balsam poplar has naturally established along low lying alluvial bars downstream from the BDEP site except where gravel bars were artificially raised. (*Photographer: K. Hull*)
	
RHIP95BOW009 (2016, Waypoint A) – View upstream from Site 4-4 showing baseline (2016) conditions – native plantings above a wide riprap toe. (*Photographer: M. Laing*)	**RHIP95BOW038 (2021, Retake of RHIP95BOW009)** – View upstream from Site 4-4 the unmodified 'control' reach. Native plantings (installed in 2015) have successfully established above the riprap toe and show vigorous tall growth since 2016 contributing to improved wildlife habitat and bank root mass protection. (*Photographer: K. Hull*)

2016	2021
	
RHIP95BOW010 (2016, Waypoint B) – View 312^0 NW from the regional paved pathway above the top of the bank. This paved pathway was excluded from the RHI polygon boundary and thus does not factor into RHI scoring. (*Photographer: M. Laing*)	**RHIP95BOW040 (2021, Retake of RHIP95BOW010)** – Photo taken above the control Site 4-4. Tree and shrub plantings originally installed in 2015 show excellent growth and establishment success. The paved regional pathway (outside of the RHI site) remains in the same configuration as in 2016 in the downstream reach. (*Photographer: K. Hull*)
	
RHIP95BOW013 (2016, Waypoint D) – View upstream. Scentless chamomile, in addition to other invasive *noxious weed* species, were pervasive along parts of the reconstructed, engineered bank in 2016. (*Photographer: M. Laing*)	**RHIP95BOW044 (2021, Retake of RHIP95BOW013)** – View upstream. Successful vegetated riprap with vigorous establishment of sandbar and hungry (yellow) willow since 2018 in **Site 4-1.** (*Photographer: K. Hull*)

2016	2021
	
RHIP95BOW012 (2016, Waypoint B) – View downstream showing dense cover from invasive weeds and disturbances grasses above the riprap toe in 2016. (*Photographer: M. Laing*)	**RHIP95BOW043 (2021, Retake of RHIP95BOW012)** – View 95^0 E, successful vegetated riprap with vigorous establishment of sandbar and hungry (yellow) willow since 2018 in **Site 4-2** (void filled riprap with plugs). (*Photographer: K. Hull*)
	
RHIP95BOW016 (2016, Waypoint E) – This mowed and heavily disturbed upper bench was included within the RHI site extent in 2016. Gravel paths and lawns create compacted soil conditions, limiting to moisture infiltration and natural recovery of native vegetation. (*Photographer: M. Laing*)	**RHIP95BOW048 (2021, Retake of RHIP95BOW016)** – A 10 to 15 m band extending back from the top of the bank has been naturalized since 2018 including native tree and shrub installations. Manicured lawn areas continue to be maintained adjacent to the street side. (*Photographer: K. Hull*)

2016	2021
	
RHIP95BOW014 (2016, Waypoint E) – View 91^0E, showing the 2 m wide gravel pathway maintained for recreational access above the top of the bank. Foxtail barley, a native disturbance grass was prevalent along the upper bank in 2016, comprising 30% cover overall. (*Photographer: M. Laing*)	**RHIP95BOW049 (2021, Retake of RHIP95BOW014)** – **Site 4-1** (soil covered riprap) is shown on the left where there is excellent establishment success of plantings. Fencing will remain in place to curtail wildlife herbivory and recreational access during the maintenance period. (*Photographer: K. Hull*)
	
RHIP95BOW015 (2016, Waypoint E) – Riprap rock groynes were installed as an erosion mitigation following the 2013 flood. This bank had mainly herbaceous (non-woody) cover in 2016. (*Photographer: M. Laing*)	**RHIP95BOW050 (2021, Retake of RHIP95BOW015)** – Footpaths have been maintained here above the top of the bank which are now bare ground due to heavy use and compaction. A 10 to 15 m wide area at the top of the bank has been naturalized upstream of the rock groyne where wood rail fencing has been installed to preclude access. (*Photographer: K. Hull*)

<table>
<tr><th>2016</th><th>2021</th></tr>
<tr><td></td><td></td></tr>
<tr><td>RHIP95BOW017 (2016, Waypoint F) – View downstream toward a riprap groyne showing baseline (2016) unvegetated, steep bank conditions. (Photographer: M. Laing)</td><td>RHIP95BOW055 (2021, Retake of RHIP95BOW0017) – Site 2-2 Box fascine with slope treatment. Dense willow plantings (mainly sandbar and hungry willow) have successfully established here, contributing to improved root mass protection and enhanced fish and wildlife habitat. (Photographer: K. Hull)</td></tr>
<tr><td></td><td></td></tr>
<tr><td>RHIP95BOW018 (2016, Waypoint F) – Baseline conditions within Site 2-1 (2016) showing the pre-existing steep, largely unvegetated bank. (Photographer: M. Laing)</td><td>RHIP95BOW054 (2021, Retake of RHIP95BOW018) – Site 2-1, dense vigorous growth of sandbar willow, red osier dogwood, and some young poplars installed as part of slope bioengineering treatments in 2018. (Photographer: K. Hull)</td></tr>
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<table>
<tr><th>2016</th><th>2021</th></tr>
<tr><td></td><td></td></tr>
<tr><td>RHIP95BOW021 (2016, Waypoint H) – A disturbed portion of steep, unstable bank at the B9 stormwater outfall. (Photographer: M. Laing)</td><td>RHIP95BOW060 (2021, Retake of RHIP95BOW021) – Bioengineering slope treatments have been applied successfully immediately upstream from the B9 outfall in Site 1-4. (Photographer: K. Hull)</td></tr>
<tr><td></td><td></td></tr>
<tr><td>RHIP95BOW020 (2016, Waypoint H) – The B9 outfall and riprap groyne, baseline 2016 conditions including cover from mostly invasive and disturbance weeds. (Photographer: M. Laing)</td><td>RHIP95BOW059 (2021, Retake of RHIP95BOW020) – Bank recontouring was done upstream from the B9 outfall to create a lower riparian terrace and ameliorate steeply sloping banks. (Photographer: K. Hull)</td></tr>
</table>

2016	2021
	
RHIP95BOW019 (2016, Waypoint G) – Kentucky bluegrass mowed lawns and disturbed grass areas along paved pathways made up about 40% of the plant composition in 2016. (*Photographer: M. Laing*)	**RHIP95BOW051 (2021, Retake of RHIP95BOW019)** – Several new plantings of ornamental trees have been installed here since 2016 including purple sand cherry, paper birch and American elm. A more naturalized 10-15 m buffer with native plantings is visible along the top of bank to the back. (*Photographer: K. Hull*)
	
RHIP95BOW022 (2016, Waypoint I) – The 2013 flood damaged portions of this regional pathway that have since been repaired. The paved pathway was excluded from the RHI polygon boundary. (*Photographer: M. Laing*)	**RHIP95BOW062 (2021, Retake of RHIP95BOW022)** – Bank reshaping done here resulted in some loss of mature tree cover, but dense tree and shrub plantings within **Site 1** have compensated for this. The regional pathway (outside of the RHI polygon) has been realigned through this part of the site. (*Photographer: K. Hull*)

2016	2021
	
RHIP95BOW023 (2016, Waypoint J) – Remnants of old concrete rubble and exposed rebar are indicative of historic bank disturbance in the upstream part of the site. (*Photographer: M. Laing*)	**RHIP95BOW064 (2021, Retake of RHIP95BOW023)** – A large amount of concrete rubble was removed from the bank during bank reshaping. Bioengineering techniques successfully applied here (**Site 1-4**) included willow brush layers, brush mattresses and contour fascines. Dense seeded grass may be a limiting factor though in portions of Site 1. (*Photographer: K. Hull*)
	
RHIP95BOW025 (2016, Waypoint M) – View upstream below the 17 Ave SE (Cushing) Bridge at the upstream end of the site showing the pre-existing (2016) paved pathway alignment. (*Photographer: M. Laing*)	**RHIP95BOW067 (2021, Retake of RHIP95BOW025)** – Pathway realignment was done here in addition to creation of a wider wildlife passage on the river side below the bridge. (*Photographer: K. Hull*)

2021 NEW PHOTOGRAPHY

RHIP95BOW037 (2021, Waypoint L) – View upstream at the **downstream end** of the site, toward the unmodified 'control' site (**Site 4-4**). Some dead balsam poplar saplings need to be replaced here. This disturbed bank has residual scentless chamomile, ox-eye daisy and Canada thistle plants. Of note, wandering garter snakes were seen near here immediately downstream from the BOW95 site. (*Photographer: K. Hull*)

RHIP95BOW036 (2021, Waypoint BOW95 "OUT") – A dense tufted vetch and Canada thistle infestation immediately downstream from the BDEP site, requiring management intervention. (*Photographer: K. Hull*)

RHIP95BOW047 (2021, Waypoint 2A) – In addition to unvegetated riprap at the downstream end, two large riprap rock groynes were unmodified since 2016. Structural alterations like these detract from the riparian health score. (*Photographer: K. Hull*)

RHIP95BOW046 (2021, Waypoint 2A) – View downstream from the upper end of **Site 4** - successful vegetated rip-rap treatment. There has been excellent establishment of native trees and shrubs in Site 4, especially at mid to upper slope positions, although there are dead willow cuttings at the base. There is a consistent row of common tansy along the lower terrace within Site 4. (*Photographer: K. Hull*)

RHIP95BOW052 (2021, Waypoint 2B) – View 287^0 NW showing a naturalization area (10 to 20 m wide) on the upper bench above top of bank. This area has a mix of rose, saskatoon, silverberry and currant native shrub plantings intermixed with balsam poplar plantings. Herbaceous competition may be a limiting factor to shrub survival due to dense wheatgrass, alfalfa, dandelion and intermixed common tansy weeds (*Photographer: K. Hull*)

RHIP95BOW053 (2021, Waypoint 2B) – View 170^{0}S showing a riparian planting area adjacent to the top of the bank where additional native shrub plantings should be installed to enhance biodiversity and habitat structure. Dense herbaceous cover may be a limiting factor to success of plantings. (*Photographer: K. Hull*)

RHIP95BOW056 (2021, Waypoint 2C) – View downstream in **Site 2 –** successful implementation of box fascine with brush layering and slope treatment. Wood rail fencing at the top of the bank should be retained to curtail recreational access to bank bioengineering treatments in the long-term. (*Photographer: K. Hull*)

RHIP95BOW057 (2021, Waypoint 2C) – View upstream within Site 2 – successful box fascine at the toe, no slope treatment above due to steep exposed cutbank with swallow nests. (*Photographer: K. Hull*)

RHIP95BOW066 (2021, Waypoint 2E) – The BDEP site incorporates new seating areas and a gravel path that also serves as a wildlife corridor. (*Photographer: K. Hull*)

RHIP95BOW077 (2021, Waypoint 2E) – Example of BDEP interpretive bolder signage for education purposes. (*Photographer: K. Hull*)

RHIP95BOW069 (2021, Waypoint 2F) – View downstream at the lower end of **Site 1-2**. This disturbed area below the BRT bridge requires ongoing monitoring and maintenance to ensure survival success targets are reached for willow cuttings and to remove scentless chamomile infestations. (*Photographer: K. Hull*)

RHIP95BOW070 (2021, Waypoint 2G) – View upstream to the Cushing Bridge in **Site 1-2**. This disturbed area requires ongoing monitoring and maintenance to ensure survival success targets are reached for willow cuttings and to remove scentless chamomile infestations. (*Photographer: K. Hull*)

RHIP95BOW071 (2021, Waypoint 2H) – View downstream at the upper end of Site 1-3 – showing excellent establishment of sandbar willows within the timber crib wall. Fencing in the foreground at the base of the bank has been built to exclude beaver access. (*Photographer: K. Hull*)

RHIP95BOW063 (2021, Waypoint I) – View upstream to the Cushing and BRT bridges from the lower end of **Site 1-4**. This portion of bank was reshaped to accommodate a wildlife corridor and lower riparian terrace. Dense cover from seeded grasses may be limiting to riparian plantings here. (*Photographer: K. Hull*)

RHIP95BOW065 (2021, Waypoint J) – View toward the Cushing and BRT bridges from within Site 1-3 showing successful balsam poplar and willow establishment on either side of a newly constructed gravel path (recreational access and wildlife passage). (*Photographer: K. Hull*)

Additional Photos of the Riparian Area from August 5th 2021

MONT95BOW0002 (2021) – View upstream from the BRT bridge viewing platform showing the BDEP site and successfully established plantings in addition to the reshaped bank and wildlife corridor and repositioned regional paved pathway. (*Photographer: K. Boehler*)

MONT95BOW0005 (2021) – View upstream from the BRT bridge viewing platform showing **Site 1-3**, timber crib wall. Excellent establishment of native plantings have augmented root mass protection, enhanced overall woody cover and wildlife habitat structure. (*Photographer: K. Boehler*)

9 Riparian Plant Species List

A total of 88 plant species were recorded in this site in 2021, including 7 tree, 17 shrub, 20 grass/grass-like, and 44 forb (broad-leaf plant) species (Table 9-1). Of these species, 52% (i.e., 46) are native species. Canopy covers listed in **red bold text** were recorded in 2016 but did not contribute to scoring for any of the 2016 riparian health parameters (including woody cover) since these represented new plantings less than 1-year-old. Only those plantings more than one-year-old contribute to vegetation canopy cover tallies and riparian health parameter scoring.

Table 9-1 BOW95, BDEP Riparian Plant Species List

Category	Species Common Name *(Scientific Name)*[1]	Plant Status[2]	2016	2021
Trees	aspen (*Populus tremuloides*)	native	**0.5**	10
	balsam poplar *(Populus balsamifera)*	native	0.5	20
	green ash *(Fraxinus pennsylvanica)*	native	0.5	NO
	larch (*Larix spp.*)	unknown, not unique	**0.5**	0.5
	lodgepole pine (*Pinus contorta*)	native	**0.5**	0.5
	Manitoba maple *(Acer negundo)*	native	10	0.5
	white birch (*Betula papyrifera*)	native	NO	0.5
	white elm *(Ulmus americana)*	*introduced*	0.5	0.5

Category	Species Common Name *(Scientific Name)*[1]	Plant Status[2]	2016	2021
Shrubs	beaked willow (*Salix bebbiana*)	native	**0.5**	0.5
	buckbrush/snowberry *(Symphoricarpos occidentalis)*	native	0.5	NO
	chokecherry *(Prunus virginiana)*	native	**0.5**	0.5
	common wild rose (*Rosa woodsii*)	native	**0.5**	3
	false mountain willow (*Salix pseudomonticola*)	native	**3**	3
	golden currant (*Ribes aureum*)	native	**0.5**	3
	high-bush cranberry (*Viburnum opulus*)	native	NO	0.5
	northern gooseberry (*Ribes oxyacanthoides*)	native	**0.5**	0.5
	purple-leafed sandcherry (*Prunus X cistena*)	*introduced*	NO	0.5
	red-osier dogwood (*Cornus stolonifera acc. Cornus sericea*)	native	NO	20
	river alder (*Alnus tenuifolia*)	native	NO	3
	sandbar willow (*Salix exigua* acc. *interior*)	native	**3**	40
	saskatoon *(Amelanchier alnifolia)*	native	0.5	0.5
	shrubby cinquefoil (*Potentilla fruticosa*)	native	**0.5**	0.5
	silverberry (*Elaeagnus commutata*)	native	**0.5**	0.5
	tatarian honeysuckle *(Lonicera tatarica)*	*introduced*	0.5	NO
	water birch (*Betula occidentalis*)	native	NO	0.5
	yellow clematis *(Clematis tangutica)*	***invasive,*** *introduced*	0.5	0.5
	yellow willow (hungry willow) (*Salix lutea acc. famelica*)	native	NO	20

Category	Species Common Name *(Scientific Name)*[1]	Plant Status[2]	2016	2021
Grasses (and grass-like species)	bluebunch fescue (*Festuca idahoensis*)	native	NO	3
	Canada wild rye (*Elymus canadensis*)	native	NO	0.5
	crested wheat grass (*Agropyron pectiniforme acc. Agropyron cristatum*)	*disturbance, introduced*	NO	0.5
	fowl bluegrass (*Poa palustris*)	native	NO	3
	foxtail barley (*Hordeum jubatum*)	*disturbance*, native	30	0.5
Grasses (and grass-like species) cont'd	fringed brome *(Bromus ciliatus)*	native	0.5	NO
	green needle grass (*Stipa viridula acc. Nassella viridula*)	native	NO	3
	June grass (*Koeleria macrantha*)	native	NO	0.5
	Kentucky bluegrass *(Poa pratensis)*	*disturbance, introduced*	20	20.0
	meadow fescue *(Festuca pratensis)*	*introduced*	0.5	NO
	narrow reed grass (*Calamagrostis stricta*)	native	NO	0.5
	northern wheat grass *(Agropyron dasystachyum)*	native	0.5	NO
	orchard grass (*Dactylis glomerata*)	*introduced*	NO	0.5
	plains rough fescue (*Festuca hallii*)	native	NO	0.5
	quack grass (*Agropyron repens acc. Elymus repens*)	*disturbance, introduced*	30	3
	red fescue (*Festuca rubra*)	native or *introduced*	NO	0.5
	redtop (*Agrostis stolonifera*)	*introduced*	NO	3
	reed canary grass *(Phalaris arundinacea)*	native	0.5	0.5
	rough hair grass (*Agrostis scabra*)	native	NO	0.5
	slender wheat grass (*Agropyron trachycaulum*)	native	3	20
	smooth brome *(Bromus inermis)*	*disturbance, introduced*	3	30.0
	timothy *(Phleum pratense)*	*disturbance, introduced*	0.5	3.0
	tufted hair grass (*Deschampsia cespitosa*)	native	NO	3

Forbs (broad leaf plants)	absinthe wormwood *(Artemisia absinthium)*	*introduced*	3	0.5
	alfalfa *(Medicago sativa)*	*introduced*	3	20.0
	alsike clover *(Trifolium hybridum)*	*disturbance, introduced*	0.5	NO
	annual hawk's-beard *(Crepis tectorum)*	*disturbance, introduced*	0.5	0.5
	bird's-foot trefoil (*Lotus corniculatus*)	*introduced*	NO	0.5
	black medick *(Medicago lupulina)*	*disturbance, introduced*	3	0.5
	bull thistle *(Cirsium vulgare)*	*introduced*	0.5	0.5
	Canada goldenrod (*Solidago canadensis*)	native	NO	0.5
	Canada thistle *(Cirsium arvense)*	***invasive,*** *introduced*	0.5	0.5
	Canadian milk vetch *(Astragalus canadensis)*	native	3	0.5
	cleavers *(Galium aparine)*	***invasive,*** *introduced*	0.5	0.5
	common burdock/lesser burdock *(Arctium minus)*	***invasive,*** *introduced*	0.5	0.5
	common dandelion *(Taraxacum officinale)*	*disturbance, introduced*	0.5	10.0
	common fireweed (*Epilobium angustifolium*)	native	NO	0.5
	common goat's-beard *(Tragopogon dubius)*	*introduced*	0.5	0.5

Category	Species Common Name *(Scientific Name)*[1]	Plant Status[2]	2016	2021
Forbs (broad-leaf plants) cont'd	common plantain (*Plantago major*)	*disturbance, introduced*	NO	0.5
	common tansy *(Tanacetum vulgare)*	***invasive,*** *introduced*	3	3.0
	common yarrow (*Achillea millefolium*)	native	NO	0.5
	creeping bellflower; garden bluebell *(Campanula rapunculoides)*	***invasive,*** *introduced*	0.5	0.5
	curled dock *(Rumex crispus)*	*introduced*	0.5	0.5
	gaillardia (*Gaillardia aristata*)	native	NO	0.5
	lamb's-quarters *(Chenopodium album)*	*disturbance, introduced*	0.5	0.5
	narrow-leaved dock (*Rumex triangulivalvis*)	native	NO	0.5
	northern willowherb *(Epilobium ciliatum)*	native	0.5	NO
	ox-eye daisy (*Chrysanthemum leucanthemum acc. Leucanthemum vulgare*)	***invasive,*** *introduced*	NO	0.5
	perennial sow-thistle (*Sonchus arvensis*)	***invasive***, *introduced*	NO	3
	pineappleweed (*Matricaria matricarioides*)	*introduced*	NO	0.5
	prickly lettuce *(Lactuca serriola)*	*introduced*	0.5	0.5
	purple prairie-clover (*Petalostemon purpureum*)	native	NO	0.5
	purple-stemmed aster *(Aster puniceus)*	native	0.5	NO
	red-root pigweed (*Amaranthus retroflexus*)	*disturbance, introduced*	NO	0.5
	rough cinquefoil (*Potentilla norvegica*)	*disturbance*, native	NO	0.5
	scentless chamomile (*Matricaria perforata acc. Tripleurospermum inodorum*)	***invasive***, *introduced*	3.0	3
	shepherd's-purse *(Capsella bursa-pastoris)*	*disturbance, introduced*	0.5	0.5
	smooth perennial sow-thistle *(Sonchus arvensis ssp. uliginosus)*	***invasive,*** *introduced*	3	NO
	stinkweed *(Thlaspi arvense)*	*disturbance, introduced*	0.5	0.5
	tall buttercup *(Ranunculus acris)*	***invasive,*** *introduced*	0.5	NO
	tall hedge mustard (*Sisymbrium loeselii*)	*introduced*	NO	0.5
	tufted vetch (*Vicia cracca*)	***invasive,*** *introduced*	NO	3
	tumbling mustard *(Sisymbrium altissimum)*	*introduced*	3.0	NO
	water smartweed (*Polygonum amphibium*)	native	NO	0.5
	western dock (*Rumex occidentalis*)	native	NO	0.5
	white clover (*Trifolium repens*)	*disturbance, introduced*	NO	3
	white cockle (*Silene pratensis acc. Silene latifolia*)	***invasive,*** *introduced*	0.5	0.5
	white sweet-clover *(Melilotus alba)*	*disturbance, introduced*	3	3.0
	wild blue flax *(Linum lewisii)*	native	0.5	3.0
	wild licorice (*Glycyrrhiza lepidota*)	native	NO	0.5
	wild vetch (*Vicia americana*)	native	NO	0.5
	yellow sweet-clover *(Melilotus officinalis)*	*disturbance, introduced*	0.5	3.0
	yellow toadflax/butter-and-eggs (*Linaria vulgaris*)	***invasive***, *introduced*	NO	0.5

[1] Plant species nomenclature primarily follows Kershaw and Allen 2020. For consistency with prior reports, newly accepted ("acc") names (per Kershaw and Allen 2020) are given in addition to original naming conventions (as per Moss 1983).

[2] Native / introduced plant status is based on designations by Kershaw and Allen 2020; invasive status generally conforms with Noxious/Prohibited Noxious Weed listings as per Alberta's *Weed Control Act* and *Weed Control Regulations* with some exceptions.

[3] Based on visual estimates of the amount of ground the canopy of the plant covers. The percent cover values presented are the mid-values for the following ranges: 0.5=less than 1%; 3.0=1%-5%; 10.0=5%-15%; 20.0=15%-25%; 30.0=25%-35%; 40.0=35%-45%; 50.0=45%-55%; 60.0=55%-65%; 70.0=65%-75%; 80.0=75%-85%; 90.0=85%-95%; 97.5=greater than 95%.

NO= Not Observed

Note: The plant species listed in the table above are based on incidental ocular observations only, not a rigorous, systematic transect or plot-based plant survey. Thus, especially for uncommon plants, variations in observations and canopy cover in different years does not necessarily indicate a trend. Although efforts are made to survey representative areas within a polygon, and photo-monitoring waypoints are re-visited, observers do not follow a predetermined survey route or path within polygons. Efforts are focused on recording commonly occurring plants as a priority, not on searching for or documenting rare plant species occurrences. Re-visits are scheduled to occur at a similar time of year; however, seasonal and inter-annual variation in climate (temperature / precipitation conditions) can influence plant phenology. This means that in some years, certain species may come into flower earlier or later than in other years, influencing their detectability.

10 Explanation of Riparian Health Parameters

RIPARIAN HEALTH PARAMETER	WHY IS THIS IMPORTANT?
VEGETATION HEALTH PARAMETERS	
1. Cottonwood and Balsam Poplar Regeneration	• Cottonwood and balsam poplar trees are an important natural element of the floodplain of large rivers in southern Alberta. Trees stabilize banks, dissipate flood energy, and provide fish and wildlife habitat.
2. Regeneration of Other Native Tree Species	• A diversity of native trees adds strength to root mass protection along riverbanks. Healthy tree communities have young and mature aged trees. Multiple tree age classes improve the diversity of wildlife habitat structural layers and the longevity of the forest community.
3. Regeneration of Preferred Shrub Species	• Native shrubs such as willows, saskatoon, choke cherry, and red-osier dogwood are examples of "preferred" woody species. These species are deeply rooted and provide preferred forage for wildlife. Evidence of young seedling or sapling establishment is an indicator that these species are thriving and will persist in a site in the long-term. • All non-native shrubs and 'increaser' native shrubs (e.g., shrubby cinquefoil, rose species, buckbrush, and silverberry) are not considered "preferred" species; regeneration of these types of woody species is ignored for this parameter. These types of shrubs generally proliferate rapidly even in disturbed sites.
4. Standing Decadent and Dead Woody Material	• A small percentage of dead or dying trees is natural and can benefit fish and wildlife, but high levels may indicate stresses such as insect infestations or de-watering of a riparian area as a result of upstream dams or diversions.
5a / b. Browse Utilization and Removal of Preferred Trees and Shrubs by Beaver or Human Clearing	• River valleys provide important travel corridors and refuge habitat for wildlife such as deer and beaver. These animals rely on woody plants for food and shelter. A minor level of wildlife browse and beaver cuttings will not harm riparian plants and can help stimulate new growth. However, prolonged heavy browse or extensive beaver cuttings due to concentrated wildlife use (often due to land use pressures) can negatively impact riparian health in the short-term by causing die-out of preferred woody species. Similarly, extensive human removal of trees and shrubs reduces the ability of the bank to withstand erosion and removes wildlife habitat.
6. Total Canopy Cover of Woody Species	• Retention of naturally occurring trees and shrubs will benefit fish and wildlife. Overhanging branches provide secure hiding cover, a source of food, and shaded refuge areas for fish. Trees and shrubs are also vital for bank stability.
7. Invasive Plant Species	• Invasive plants are non-native, introduced species that are listed on Alberta's *Weed Control Act* as *prohibited noxious* and *noxious weeds* and others known to be problematic in riparian areas (e.g., caragana, Russian olive, and tufted vetch). These weeds aggressively outcompete preferred native species and disrupt natural ecological succession patterns. Weedy invasive plants often have poor forage value for wildlife and livestock and many are shallow rooted, leading to reduced bank stability and accelerated bank erosion. In other cases, invasive shrubs can densely shade out understory plants, creating unprotected soil subject to runoff and erosion. If left unchecked, invasive plants can create monocultures, reducing biodiversity and climate change resiliency.
8. Disturbance-Increaser Undesirable Herbaceous Species	• Disturbance-increasers are fast spreading, early colonizer introduced plants like common dandelion, Kentucky bluegrass (the main grass used for lawns), and smooth brome. Examples of native disturbance-increasers (i.e. pioneer

	species) include wild strawberry and foxtail barley. If these species are abundant on a site, this is usually an indication that human or natural-caused ground disturbance has recently occurred. In an urban setting, persistence of plant communities dominated by disturbance-increasers is typical for manicured lawns, former agricultural lands, or areas with perpetual ground disturbance, mowing or compaction. Kentucky bluegrass lawns or smooth brome hayfields lack biodiversity and habitat structure in addition to having minimal root mass protection functionality for maintaining bank stability.
SOIL / HYDROLOGY HEALTH PARAMETERS	
9. Riverbank Root Mass Protection	• Riverbank stability depends in large part on deeply rooted plants that hold the soil together and resist erosive forces of floods. Among riparian herbaceous species, annual plants lack deep, binding roots. Perennial species offer a wide range of root mass qualities. Some rhizomatous species such as deeply rooted sedges are excellent bank stabilizers. Others, such as Kentucky bluegrass, have only shallow roots and are poor bank stabilizers. Still others, such as wire rush, are intermediate in their ability to stabilize banks. The size and nature of the stream or river will determine which herbaceous species can be effective. When rating this parameter, root mass protection is assessed within a 15 m band width for large rivers. For large rivers a combination of native, deeply rooted trees and shrubs in addition to a diverse native herbaceous understory is needed to provide adequate root mass protection to resist erosive forces.
10. Human-Caused Bare Ground	• Bare ground is soil not covered by plants, litter or duff, downed wood, or rocks larger than 6 cm (2.5 in). Hardened, impervious surfaces (e.g., asphalt, concrete, etc.) are not considered bare ground because these do not readily erode or allow weeds to establish. Sediment deposits (from flooding) and other natural bare ground features are excluded when scoring this parameter. Bare ground caused by human activity indicates a deterioration of riparian health. Examples of common land uses which create bare ground include livestock grazing, recreation, roads, and industrial activities. Bare ground is prone to erosion and establishment of weeds.
11. Removal or Addition of Water from/to River System	• Substantial changes to river flow volumes due to upstream dams/ diversions along the mainstem of the Bow River or its tributaries can impact fish habitat and the health of riparian vegetation.
12. Control of Flood Peak and Timing by Upstream Dam(s)	• Reservoirs and hydroelectric dams and diversions upstream of Calgary have resulted in substantial changes to the natural flow regime of the Bow River. Compared to historic data, flows are substantially lower in spring and summer. This limits natural flooding necessary for regeneration of riparian vegetation such as balsam poplars. Flow changes can also impact natural channel scouring and fish habitat as well as modify channel migration.
13. Riverbank Structurally Altered **14. Human Physical Alteration to Polygon**	• Structural alterations are any human-caused features that affect soil/hydrology functions or natural properties. Pathways, rip-rap bank armouring, and concrete structures are examples of common structural alterations in Calgary. Rip-rap and concrete structures on the bank accelerate erosion downstream and remove important fish and wildlife habitat. Heavily used foot paths result in compacted soil, reduced water infiltration, loss of natural riparian vegetation, and elevated runoff. Impervious (paved) surfaces in a riparian zone remove beneficial habitat and negatively impact water infiltration and runoff filtration.
15. Floodplain Accessibility Within the Polygon	• Periodic flood events replenish critical moisture reserves that sustain riparian vegetation. Floodplain access also slows the flow of floodwater, reducing its erosive force downstream. This parameter assesses the percent of the floodplain that remains accessible to floodwater (i.e., unimpeded by berms or other topographic structural alterations).

11 Monitoring

Riparian health trend monitoring for this site was funded by The City of Calgary as part of the 2018-2022 Riparian Monitoring Program (RMP) led by Kerr Wood Leidal Associates Ltd. (KWL 2018). The RMP consists of five key elements:

- Effectiveness monitoring of bank restoration sites within the City of Calgary;
- Effectiveness monitoring of riparian restoration sites within the City of Calgary;
- Trend monitoring of Riparian Health Inventory (RHI) sites within the City of Calgary;
- Geomorphic and hydraulic monitoring of the Elbow River realignment downstream of the Southwest Calgary Ring Road within Weaselhead Flats Park; and
- Post-construction environmental monitoring of the Bioengineering Demonstration and Education Project per the *Bioengineering Efficacy Monitoring Plan* (Hemmera 2018).

The full 2018-2022 scope of RHI trend monitoring is described in the Monitoring Plan developed for the RMP including a detailed discussion of RHI site selection criteria (KWL 2017, 2018). A key objective of the trend monitoring component of the RMP is to track progress toward riparian health targets outlined in the City's *Riparian Action Program* (City of Calgary 2017). RHI synthesis reports will be prepared for each year of the RMP by Cows and Fish, with a comprehensive synthesis of all sites presented in the final year.

To assess riparian health trend, we generally recommend that riparian health inventories be repeated every five years; however, for sites with minimal change, the re-visit period can be longer.

For further information on any aspect of this summary, please contact:

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APPENDIX A BASELINE AIRPHOTO (2013 IMAGERY)

APPENDIX B
BDEP BIOENGINEERING TREATMENT "SITE" DIAGRAM

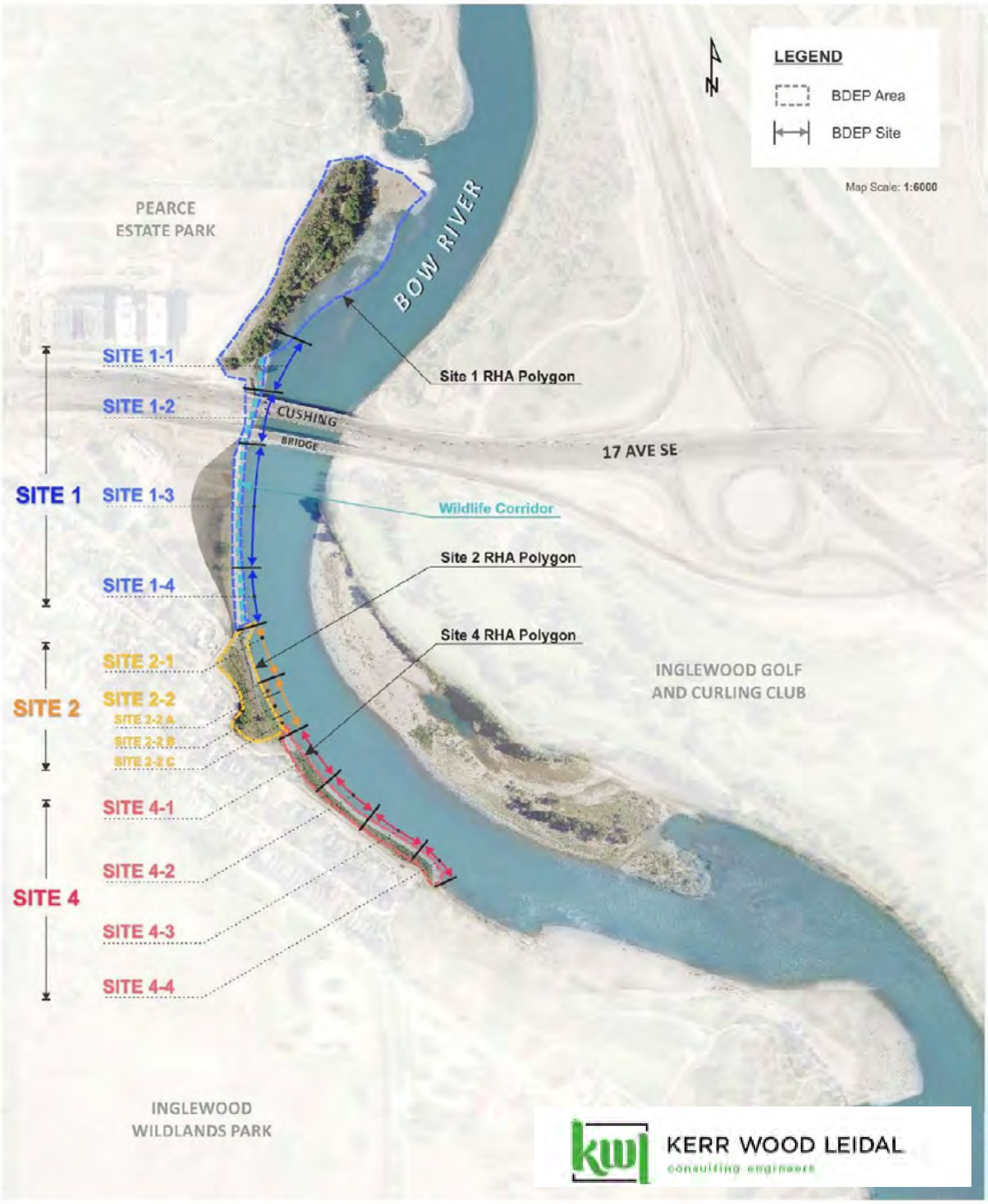

Figure source: KWL 2021b

APPENDIX C
SUMMARY OF BIOENGINEERING TECHNIQUES USED IN THE BDEP BY SITE

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 outside the 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 soil 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)	Row(s) of live cuttings and rooted stock placed in a criss-cross or overlapping manner between layers of soil, with tips protruding beyond the face of the fill.
	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.

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Source: KWL 2021b

APPENDIX D

RIPARIAN HEALTH SCORE SHEET CATEGORIES FOR LARGE RIVER SYSTEMS

For more details on how large river health parameters are assessed, refer to the ***Large River Health Assessment User Manual****:* https://cowsandfish.org/health-assessment-and-inventory-forms/

Each riparian health parameter is rated according to conditions observed on the site at the time of evaluation. Parameters are assessed using ocular estimates by trained practitioners. The parameter breakout groupings and point weightings were developed by a collaboration of riparian scientists, fisheries biologists, range professionals and land managers. Note, parameters #11 and #12 pertaining to control of flood peak and timing by upstream dam(s) and removal or addition of water from/to the river system were evaluated using data provided by Alberta Environment and Parks.

Note: *Changes were made in 2018 to reduce the weighting of Parameter 6 (Invasive Species Canopy Cover) and Parameter 14 (Human physical Alteration to the Rest of the Polygon). These parameters were formerly weighted out of 6 points but are now weighted out of 3 points to bring consistency with Small Stream / Small River scoring. These changes were done in consultation with Dr. Paul Hansen and William Thompson (formerly of University of Montana's Riparian and Wetland Research Program).* *Current parameter weightings attempt to better balance the contribution of each of the 15 vegetation and soil/hydrology indicators in consideration of their relative influence on riparian ecosystem health and function.*

1. Cottonwood and Balsam Poplar Regeneration

- **6** = More than 15% of the cottonwood and/or balsam poplar cover is established seedlings and/or saplings.
- **4** = 5% to 15% of the cottonwood and/or balsam poplar cover is established seedlings and/or saplings.
- **2** = Up to 5% of the cottonwood and/or balsam poplar cover is established seedlings and/or saplings.
- **0** = None (the site has the potential for cottonwood and/or balsam poplar cover, but seedlings and/or saplings are absent from the site).

2. Regeneration of Other Native Tree Species

- **3** = More than 5% of the other (non-cottonwood/balsam poplar) tree cover is seedlings and/or saplings.
- **2** = 1% to 5% of the other (non-cottonwood/balsam poplar) tree cover is seedlings and/or saplings.
- **1** = Less than 1% of the other (non-cottonwood/balsam poplar) tree cover is seedlings and/or saplings.
- **0** = None (the site has the potential for native trees other than cottonwood and/or balsam poplar, but seedlings and/or saplings of other native tree species are absent from the site).

3. Regeneration of Preferred Shrub Species

- **6** = More than 15% of the preferred shrub species cover is seedlings and/or saplings.
- **4** = 5% to 15% of the preferred shrub species cover is seedlings and/or saplings.
- **2** = Less than 5% of the preferred shrub species cover is seedlings and/or saplings.
- **0** = None (the site has the potential for preferred shrub species, but seedlings and/or saplings of preferred shrubs are absent from the site).

4. Standing Decadent and Dead Woody Material

- **3** = Less than 5% of the total canopy cover of woody species is decadent and/or dead.
- **2** = 5% to 25% of total canopy cover of woody species is decadent and/or dead.
- **1** = 25% to 50% of total canopy cover of woody species is decadent and/or dead.
- **0** = More than 50% of total canopy cover of woody species is decadent and/or dead.

5a. Browse Utilization of Preferred Trees and Shrubs

- **3** = None (0% to 5% of available second year and older leaders of preferred species are browsed).
- **2** = Light (5% to 25% of available second year and older leaders of preferred species are browsed).
- **1** = Moderate (25% to 50% of available second year and older leaders of preferred species are browsed).
- **0** = Heavy (More than 50% of available second year and older leaders of preferred species are browsed).

5b. Live Woody Vegetation Removal by Beaver or Human Cutting / Clearing

3 = None (0% to 5% of live woody vegetation expected on the site is lacking due to cutting and/or removal by beaver).
2 = Light (5% to 25% of live woody vegetation expected on the site is lacking due to cutting and/or removal by beaver).
1 = Moderate (25% to 50% of live woody vegetation expected on the site is lacking due to cutting and/or removal by beaver).
0 = Heavy (More than 50% of live woody vegetation expected on the site is lacking due to cutting and/or removal by beaver).

6. Total Canopy Cover of Woody Species

3 = More than 50% of the total area is occupied by all woody species.
2 = 25% to 50% of the total area is occupied by all woody species.
1 = 5% to 25% of the total area is occupied by all woody species.
0 = Less than 5% of the total area is occupied by all woody species.

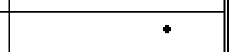
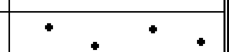
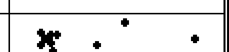
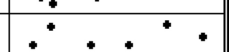
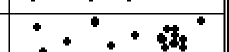
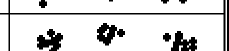
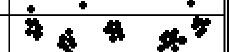
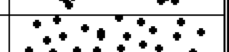
7a. Total Canopy Cover of Invasive Plant Species

3 = No invasive plant species (weeds) on the site.
2= Invasive plants present with total canopy cover less than 1% of the polygon area.
1 = Invasive plants present with total canopy cover between 1% and 15% of the polygon area.
0 = Invasive plants present with total canopy cover more than 15% of the polygon area.

7b. Density/Distribution Pattern of Invasive Plant Species (Table 1)

3 = No invasive plant species (weeds) on the site.
2 = Invasive plants present with density/distribution in categories 1, 2, or 3.
1 = Invasive plants present with density/distribution in categories 4, 5, 6, or 7.
0 = Invasive plants present with density/distribution in categories 8 or higher.

Table D-1. Density/distribution of invasive plant species.

Class	Description of Abundance	Distribution Pattern
0	No invasive plants on the site	
1	Rare occurrence	
2	A few sporadically occurring individual plants	
3	A single patch	
4	A single patch plus a few sporadically occurring plants	
5	Several sporadically occurring plants	
6	A single patch plus several sporadically occurring plants	
7	A few patches	
8	A few patches plus several sporadically occurring plants	
9	Several well-spaced patches	
10	Continuous uniform occurrence of well-spaced plants	
11	Continuous occurrence of plants with a few gaps in the distribution	
12	Continuous dense occurrence of plants	
13	Continuous occurrence of plants associated with a wetter or drier zone within the site	

8. **Disturbance-Increaser Undesirable Herbaceous Species**
   3 = Less than 5% of the site is covered by disturbance-increaser undesirable herbaceous species.
   2 = 5% to 25% of the site is covered by disturbance-increaser undesirable herbaceous species.
   1 = 25% to 49% of the site is covered by disturbance-increaser undesirable herbaceous species.
   0 = More than 50% of the site is covered by disturbance-increaser undesirable herbaceous species.

9. **Riverbank Root Mass Protection**
   6 = More than 85% of the riverbank has deep, binding root mass.
   4 = 65% to 85% of the riverbank has deep, binding root mass.
   2 = 35% to 65% of the riverbank has deep, binding root mass.
   0 = Less than 35% of the riverbank has deep, binding root mass.

10. **Human-Caused Bare Ground**
   6 = Less than 1% of the polygon is human-caused bare ground.
   4 = 1% to 5% of the polygon is human-caused bare ground.
   2 = 5% to 15% of the polygon is human-caused bare ground.
   0 = More than 15% of the polygon is human-caused bare ground.

11. **Removal or Addition of Water from/to the River System**
   9 = Less than 10% of average river flow volume during the critical growing season is changed.
   6 = 10% to 25% of average river flow volume during the critical growing season is changed.
   3 = 25% to 50% of average river flow volume during the critical growing season is changed.
   0 = More than 50% of average river flow volume during the critical growing season is changed.

12. **Control of Flood Peak and Timing by Upstream Dam(s)**
   9 = Less than 10% of the watershed upstream of the reach is controlled by dams.
   6 = 10% to 25% of the watershed upstream of the reach is controlled by dams.
   3 = 25% to 50% of the watershed upstream of the reach is controlled by dams.
   0 = More than 50% of the watershed upstream of the reach is controlled by dams.

13. **Riverbanks Structurally Altered by Human Causes**
   6 = Less than 5% of the bank length has been structurally altered by human causes.
   4 = 5% to 15% of the bank length has been structurally altered by human causes.
   2 = 15% to 35% of the bank length has been structurally altered by human causes.
   0 = More than 35% of the bank length has been structurally altered by human causes.

14. **Human Physical Alteration to the Rest of the Polygon**
   3 = Less than 5% of the polygon is altered by human causes.
   2 = 5% to 15% of the polygon is altered by human causes.
   1 = 15% to 25% of the polygon is altered by human causes.
   0 = More than 25% of the polygon is altered by human causes.

15. **Floodplain Accessibility Within the Polygon**
   6 = More than 85% of the floodplain is accessible to flood flows.
   4 = 65% to 85% of the floodplain is accessible to flood flows.
   2 = 35% to 65% of the floodplain is accessible to flood flows.
   0 = Less than 35% of the floodplain is accessible to flood flows.

KERR WOOD LEIDAL
consulting engineers

Appendix E

Bioengineering Structural Integrity Assessment Field Forms

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+)	3
Watercourse	Bow River	Weather:	Overcast, smokey and 20 degrees
Crew Initials	MG / PR	Date:	21-Jul-21

Photo Monitoring

Permanent photo-monitoring location and ID

	U/S END		D/S END
E	709371	E	709358
N	5658318	N	5658260
Photo No.	46A_US	Photo No.	46A_DS

Other Photos (min 3)

Photo No.	Description
1	View from u/s
3	Salix interior growth
7	LWD accumulations on site

Hydrology

Flow at time of survey 121 m³/s Source: Rivers.alberta.ca

Aspect

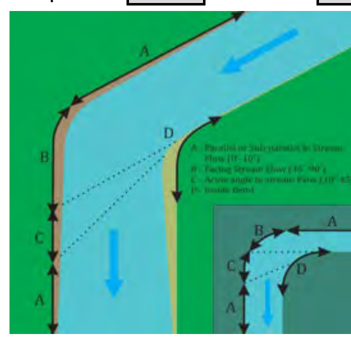
(N,E,W,S or combined N/E)

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 0.01 %
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
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	1.37	1000	Water level at 10:25am on July 21, 2021 at DS end of site 46C
High water mark*	0.43	1000.94	Debris on rodent fence
Water level during survey	1.37	1000	

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

Results below are consistent with 2019 so survey not updated in 2021

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	Salix int.
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	Water level at 12:30pm on July 17, 2019
Elev of lowest woody veg	0.98	1000.12	Salix int.
Elev of lowest herbaceous veg	1.17	999.93	Grasses
Elev of lowest emergent veg	1.08	1000.02	Bulrush / Scorpus

*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	Filled in with river gravel
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		
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 ______ 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)	

Hydromulch with wet meadow mix seed applied mostly washed out

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 [X] 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	N/A riprap
Anoxic soils	0	
Insect damage and disease	1	Insect on foliage of Salix int.
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; 2021 removed from river side of site
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- Species selection	3	Species such as Balsam poplar, red osier dogwood and hungry willow (Sali fam) are not flood tolerant and should of not be included, only Salix interior should have been selected for this site base on location and flooding conditions.
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; 2021 weeding

ALTERNATIVE DESIGN OPTIONS

Description

Live staking in riprap at correct time of year for dormancy; alternate to hydroseeding is plugs of emergents with protection for geese; only use salix interior as a species 2021; poplar and osier should have been planted on upper part of side or only use Salix interior

Success Attributes

Good naturalization of vegetated riprap usingriver gravels to infill riprap; innovative technique using rooted long live cuttings 2021 good at trapping woody debris

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+)	3
Watercourse	Bow River	Weather:	Slightly overcast smokey and 20 degrees
Crew Initials	MG / PR	Date:	21-Jul-21

Photo Monitoring

Permanent photo-monitoring location and ID

	U/S END		D/S END
E	709335	E	709338
N	5658174	N	5658048
Photo No.	46B_US	Photo No.	46B_DS

Other Photos (min 3)

Photo No.	Description
5	Veg crib wall looking d/s
14	Veg crib wall looking u/s
5A	Fish shelter view at low water

Hydrology

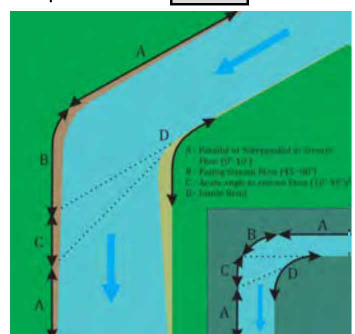
Flow at time of survey 119 m³/s Source: Rivers.alberta.ca

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 0.01 %
Estimate of stream width for current year flood flow 94 m

Site Dimensions

Total length of the work (parallel to stream) 120.3 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

Refer to 46A form for water level survey data

Hydrology Survey	Rod Height (m)	Elevation (m)	Survey Notes
Elevation Benchmark	1.37	1000	Water level at 10:27am on July 21, 2021 site 46-D3
High water mark*	0.43	1000.94	
Water level during survey	1.37	1000	

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

Results below are consistent with 2019 so survey not updated in 2021

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	Dead red osier dogwood
Elev of lowest herbaceous veg	1.59	1000.49	Grasses under coir matting on veg. crib wall
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 site 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	0.34

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 1.0m apart

Physical Condition	Rating	Riprap	Fish Boulders
Excellent	5 Very new without any defects		
Very Good	4 <5% defects without impacting structural integrity	X	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	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					
Very Good	4 <5% defects without impacting structural integrity					X
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					X
3 5-10 years					
2 <5 years		x			
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)	Lock blocks at back of timber crib wall in fish shelters dim 750x750x1500 (not observed)
Concrete product 2 description (C2)	
Concrete product 3 description (C3)	

Physical Condition	Rating	C1	C2	C3
Excellent	5 Very new without any defects	Not observed		
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	Not observed		
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					
Very Good	4 <5% defects without impacting structural integrity	X	X	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	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: ench at low water; 2021 add average fish shel

Measurement of sediment accumulation at site
Depth: 6.2 Method: Underwater using survey rod
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	2	
Anoxic soils	0	
Insect damage and disease	1	On foliage
Trampling by people or dogs	0	
Motorized vehicles	0	
Non motorized vehicles	0	
Aspect	0	
Bank profile	0	
Existing vegetation competition[1]	3	Invasives present high seeding application rate
Shade	0	
Maintenance issues[2]	3	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:	0	
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 remove from site, cut down all grasses that are competing with cutting and leave on site as mulch for woody veg; repair fence and remove portion protruding u/s. 2021 removing root system too difficult because of matting; remove weeds by cutting 3 times per year + cut down all vegetation adjacent to woody shrubs or trees.

ALTERNATIVE DESIGN OPTIONS

Description

Vegetated riprap with soil wrap above; 2021 Crib wall design using biodegradable geotextile, gravel filter at base and back of structure, exposed riprap in front lower portion and gradation of agregates within fill structures with soil amendment. Overall structure slopeback more than existing.

Success Attributes

Deep buried cuttings at 35 degree in brush layer within structures ; innovative fish shelter included in timber crib wall to create habitat; 2020 overhanging cover at crib wall face; 2021 cuttings establishing in upper crib wall and soil wraps , fish boulders providing fish and bird habitat and catching woody debris, overhanging cover at crib wall face increasing.

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+)	3
Watercourse	Bow River	Weather:	Overcast smokey 20 degrees
Crew Initials	MG / PR	Date:	21-Jul-21

Photo Monitoring

Permanent photo-monitoring location and ID

	U/S END		D/S END
E	709340	E	709343
N	5658037	N	5657978
Photo No.	46C_US	Photo No.	46C_DS

Other Photos (min 3)

Photo No.	Description
2	View from u/s looking d/s
4	View from d/s looking u/s
6	View from bench looking u/s

Hydrology

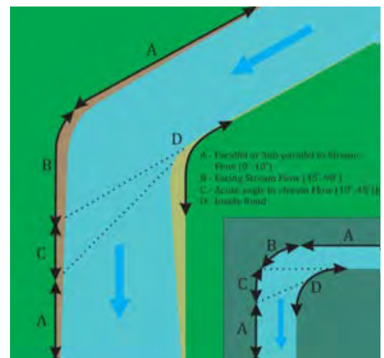
Flow at time of survey 121 m³/s Source: Rivers.alberta.ca

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 0.01 %
Estimate of stream width for current year flood flow 92 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

See survey results from 46A

Hydrology Survey	Rod Height (m)	Elevation (m)	Survey Notes
Elevation Benchmark	1.37	1000	Water level at 10:27am on july 21, 2021 at DS e
High water mark*	0.43	1000.94	Debris on rodent fence
Water level during survey	1.37	1000	

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

Results below are consistent with 2019 so survey not updated in 2021

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 1-
Elev of lowest woody veg	1.84	1000.24	Brush mattress Salix int.
Elev of lowest herbaceous veg	1.1	1000.98	Up slope from B/M under coir matting
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 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	1.05
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		
Very Good	4 <5% defects without impacting structural integrity	X	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	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 50 mm Timber height 50 mm Timber length 1000 mm Brush mattress pegs

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)	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					
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		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 [ ] Medium [ ] High [ ] N/A [X] Describe: Minor rilling, 2021 NA

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: <2cm Method: Visual
Describe/Location:

Seeps or spring present Yes [ ] No [X] 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	Rilling on upper slope; 2021 Na now
Compacted soils	2	
Anoxic soils	0	
Insect damage and disease	1	Insects on leaves
Trampling by people or dogs	0	
Motorized vehicles	0	
Non motorized vehicles	0	
Aspect	0	
Bank profile	0	
Existing vegetation competition[1]	3	Some weeds / existing invasives; 2021 increased from 2 to 3 because of high herbaceous density over brush layers and contour fascines mostly from grassess.
Shade	0	
Maintenance issues[2]	3	Weeding of grasses and light erosion, rilling; filling end of contour fascine. 2021 increased from 2 to 3
Flooding duration	1	Brush mattress coverd with debris
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; cover / fill fascine at us end with soil; fix leaking sprinkler heads and level ground surface where rilling is occurring; raise sprinkler heads to 1m on t posts; 2021 weeding and weed removal from brush layers and contour fascines, could use a plastic mulch to kill the grasses.

ALTERNATIVE DESIGN OPTIONS

Description: Vegetated riprap toe filled in with river gravel with vegetated soil wrap above ; coir matting (on lower 2m) of slope with live staking on entire slope.

Success Attributes

Techniques such as contour fascine and brush mattress; Seeding application at 25kg/ha appears to be correct, therefore less competeition for plant establishment.; 2021 seeding, actual applied rate appears to have been higher than design resulting in high high herbaceous density competing with establishing planted woody plants. fish boulders appear to be working well (lots of fish jumping in front of us)

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 fascine	Survey year (1/3/5+)	3
Watercourse	Bow River	Weather:	Overcast and drizzle 17 degrees
Crew Initials	MG / PR	Date:	20-Jul-21

Photo Monitoring

Permanent photo-monitoring location and ID

	U/S END		D/S END
E	709351	E	709363
N	5657963	N	5657912
Photo No.	46D1_US	Photo No.	46D1_DS

Other Photos (min 3)

Photo No.	Description
3	View of site from u/s to d/s
11	View of site from d/s to u/s
15	View of growth showing preserved

Hydrology

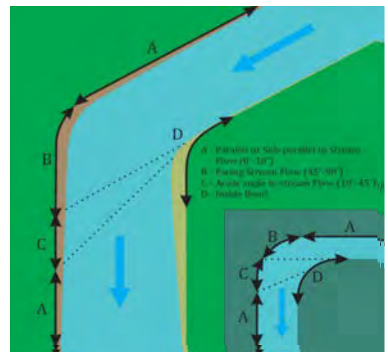
Flow at time of survey 120 m³/s Source: Rivers.alberta.ca

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 0.02 %
Estimate of stream width for current year flood flow 135 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	1.145	1000	Water level at 9:13am, on July 20, 2021 DS site 2
High water mark*	0.56	1000.585	Debris in rodent fence
Water level during survey	1.145	1000	

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

Results below are consistent with 2019 so survey not updated in 2021

Planted Vegetation Survey*	**Rod Height (m)**	**Elevation (m)**	**Survey Notes**
Elevation Benchmark	1.54	1000	Water level at 2:13pm on July 17, 2019 at Site 2-1
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 <u>planted</u> 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 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 <u>existing native</u> 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		

No riprap use

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

No riprap used (pea gravel) fines are washing

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			
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)	
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	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 [X] High [ ] N/A [ ] Describe: Placed fill washout at face and behind at some locations

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 and at toe in front of fascine.

Seeps or spring present Yes [ ] No [X] 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	2		
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	1		
Maintenance issues[2]	2	Weeding ; 2021 weeding behind box fascine	
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 on slope behind toe fascine structure

ALTERNATIVE DESIGN OPTIONS

Description

Outfall B69 toe fascine was installed better with tie in ; buried contour fascine behing post and use of native river gravel as fill (better soil contact and less eroded fill material)

Success Attributes

Innovative toe stabilization technique - first in Calgary ; 2021 suckering of Salix interior in front of the structure and rooting through the native cobble on riverside toe of structure: natural regen of poplars behind the structure on lower slope.

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:	jineering Demonstration Project Site 2-2 (box fascine, brush mattress a	Survey year (1/3/5+)	3
Watercourse	Bow	Weather:	Overcast and misty, 17C
Crew Initials	MG / PR	Date:	20-Jul-21

Photo Monitoring

Permanent photo-monitoring location and ID

	U/S END		D/S END
E	709376	E	709377
N	5657919	N	5657901
Photo No.	46D2_US	Photo No.	46D2_DS

Other Photos (min 3)

Photo No.	Description
4	Box fascine from d/s looking u/s
5	Bench looking u/s
6	Slope treatment area

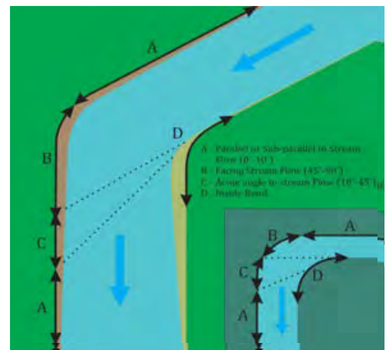
Hydrology

Flow at time of survey 120 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 0.02 %

Estimate of stream width for current year flood flow 134 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 See survey from site 46D1

Hydrology Survey	Rod Height (m)	Elevation (m)	Survey Notes
Elevation Benchmark	1.145	1000	Water level at 9:13am, on July 20, 2021 DS site 2
High water mark*	0.56	1000.585	Debris in rodent fence
Water level during survey	1.145	1000	

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

Results below are consistent with 2019 so survey not updated in 2021

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 2-2
Elev of lowest woody veg	1.54	1000	Brush layer under box fascine
Elev of lowest herbaceous veg	0.13	1001.41	grasses above brush mattress
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 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	1.48
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			
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)	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					
2 <5 years		X			
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 [Washout of sediment on face and some areas behind toe fascine]

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: [Visual]
Describe/Location [Toe of brush mattress; 2021 and in cobble below toe fascine]

Seeps or spring present Yes [ ] No [X] 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	3	At toe of brush mattress / from walking on slope and bench
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]	1	Invasive weed present + high seeding application rate
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 plants flowers turning into seed and remove plants from site; 2020 10m long fascine to be replaced; 2021 fascine was replaced by replanting of balsam poplar 5 gl container plants

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; 2021 possibly could have included wattle fence as a test site; also could have included plugs of various other species between fascines to improve species diversity

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; 2021 suckering of interior and poplar between contour fascine rows and Salix interior in front of box fascine , also roots observed emerging at ground level along the front of box fascine

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 br Survey year (1/3/5+) 3
Watercourse Bow Weather: 17 C, overcast and misty
Crew Initials MG / PR Date: 20-Jul-21

Photo Monitoring

Permanent photo-monitoring location and ID

	U/S END		D/S END
E	709377	E	709395
N	5657892	N	5657867
Photo No.	46D3_US	Photo No.	46D3_DS

Other Photos (min 3)

Photo No.	Description
2	Box fascine looking d/s
4	Root growth in front of box fascines
6	Slope treatment hedge brush layer looking u/s

Hydrology

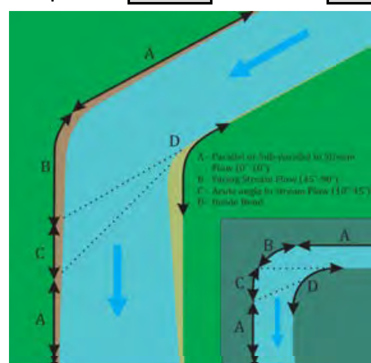
Flow at time of survey 118.5 m³/s Source: Rivers.alberta.ca

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 0.02 %
Estimate of stream width for current year flood flow 134 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 See survey from site 46D1

Hydrology Survey	Rod Height (m)	Elevation (m)	Survey Notes
Elevation Benchmark	1.145	1000	Water level at 9:13am, on July 20, 2021 DS site 2-2
High water mark*	0.27	1000.875	Debris in rodent fence
Water level during survey	1.145	1000	

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

Results below are consistent with 2019 so survey not updated in 2021

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 2
Elev of lowest woody veg	1.53	1000	Salix int.
Elev of lowest herbaceous veg	1.22	1000.31	Grasses unde coir mat
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			
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)	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					
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)	
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: Fill material washed out of fascine and behind toe fascine

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: at toe of coir matt up slope from toe fascine; 2021 in front of toe fascine in cobble

Seeps or spring present Yes [ ] No [X] 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 and front of toe fascine
Compacted soils	3	bench and hedge b/l
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]	1	Invasive weeds present and high seeding 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 plants from site prior to weeds begin to seed; 2021 cut section of rodent fence to be repaired.

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; 2021 possibly could have added a wattle fence test section

Success Attributes

Innovative bank protection technique by combining fascine with brush layer, very good balsam poplar growth, first hedge brush layer design in city of Calgary, good growth on dogwood, cherry, moderate on alder due to poor quality nursery stock.; 2021 suckering of Salix interior and poplar in between rows of hedge brush layers and in front of toe fascine (S. Interior) and emergence of roots in cobbles

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:	OC Bioengineering Demonstration Project Site 2-2 (box fascine, live s	Survey year (1/3/5+)	3
Watercourse	Bow	Weather:	Overcast and misty,18C
Crew Initials	MG / PR	Date:	20-Jul-21

Photo Monitoring

Permanent photo-monitoring location and ID

	U/S END		D/S END
E	789393	E	709397
N	5657878	N	5657856
Photo No.	46D4_US	Photo No.	46D4_DS

Other Photos (min 3)

Photo No.	Description
2	View of site looking d/s
3	View of site looking u/s
4	View of site on slope / live staking

Hydrology

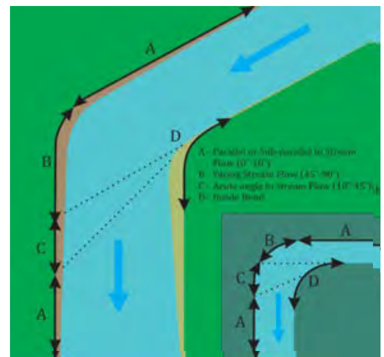
Flow at time of survey 118.5 m³/s Source: Rivers.alberta.ca

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 0.02 %
Estimate of stream width for current year flood flow 134 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 See results from 46D1

Hydrology Survey	**Rod Height (m)**	**Elevation (m)**	**Survey Notes**
Elevation Benchmark	1.145	1000	Water level at 9:13am, on July 20, 2021 DS site
High water mark*	0.56	1000.585	Debris in rodent fence
Water level during survey	1.145	1000	

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

Results below are consistent with 2019 so survey not updated in 2021

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-C
Elev of lowest woody veg	1.57	999.97	Salix int.
Elev of lowest herbaceous veg	1.26	1000.28	Grasses seeded under coir matting
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			
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)	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					
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)	
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: Placed fill washout at face and behind at some locations

Estimate of sediment accumulation at site

Low [X] Medium [ ] High [ ] N/A [ ] Describe: Behind box fascine and onto matting

Measurement of sediment accumulation at site

Depth: Trace Method: Visual

Describe/Location: At toe of matting; 2021 in front of toe fascine over cobble and behind box fascine and onto matting

Seeps or spring present Yes [ ] No [X] 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	3	At bottom of coir matt, slope and bench
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 seeding application rate, planted trees and shrubs are slowly shading out
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; 2021 opening in the rodent fence needs repair.

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 (Schiechtl); 2021 could have added wattle fence trial section, could also have divided the site into threee different trial for spacings of live staking- 0.3(as done), 0.6m and 1m

Success Attributes

Innovative toe protection technique, balsam poplar survival is good, good survival overall; 2021 good canopy cover percentage achieved by higher density live staking (0.3m spacing) should results in high root density and increased soil cohesion vs typical spacing at 1m.

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:	Smokey and 16 degrees
Crew Initials	MG / PR	Date:	19-Jul-21

Photo Monitoring

Permanent photo-monitoring location and ID

	U/S END		D/S END
E	709403	E	709448
N	5657840	N	5657798
Photo No.	46E1_US	Photo No.	46E1_DS

Other Photos (min 3)

Photo No.	Description
2	Site looking u/s
4	Site looking d/s
8	Desicated dogwood sprouting from the base

Hydrology

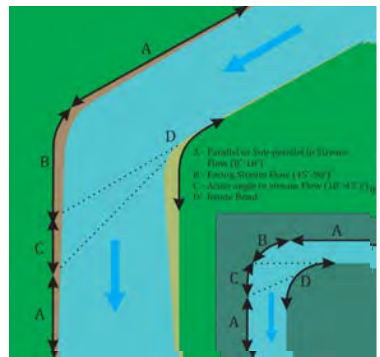
Flow at time of survey 132.6 m³/s Source: Rivers.alberta.ca

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 136 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	1.38	1000	Water level at 11:33 am
High water mark*	0.52	1000.86	Debris on rodent fence
Water level during survey	1.38	1000	Water level at 11:33 am

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

Results below are consistent with 2019 so survey not updated in 2021

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	Red osier plug
Elev of lowest herbaceous veg	2.13	1000.29	Grasses
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	Balsam poplar
Elev of lowest herbaceous veg	1.18	1000.11	grasses
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		
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 ____ 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					
Fair	2 20-40% defects without impacting structural integrity					
Poor	1 Condition which needs immediate attention and repair	X				

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

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		
Fair	2 20-40% defects without impacting structural integrity		
Poor	1 Condition which needs immediate attention and repair	X	

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

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 (eroded/washed out fill placed over riprap)

Estimate of erosion within site/structure

Low [ ] Medium [ ] High [ ] N/A [X] Describe: At toe between wattle and slope. 2021 - none

Estimate of sediment accumulation at site

Low [ ] Medium [ ] High [ ] N/A [X] Describe:

Measurement of sediment accumulation at site

Depth: Low Method: Visual

Describe/Location: Trace at toe

Seeps or spring present Yes [ ] No [X] 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	Toe erosion (eroded/washed out fill placed over riprap)
Compacted soils	3	
Anoxic soils	0	
Insect damage and disease	1	On salix interior leaves
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 (high seeding application) 2021, still current
Shade	0	
Maintenance issues[2]	3	Straw wattle missing and rodent fence; 2021: weeding needed, high herbaceous competition and no plant replacement
Flooding duration	0	
Hydraulics (Shear stress)	2	Groyne protection
Infrastructure and available space	0	
Wildlife impact[3]	1	2021 Rodent girdling stems of planted woody, vole nest found at base of planted shrub on site.
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 at base of stems (flag shrubs and trees prior to mowing); 2021: weeding and replanting and otherwise same as 2019

ALTERNATIVE DESIGN OPTIONS

Description: As applied site 46E_2 or 46E_3 and using pit run / gravel and live cuttings on slope adjacent to river i.e. no top soil

Success Attributes

Innovative method to vegetate existing riprap; container shrubs appear to be surviving well at the Site is stablizing at the time of survey. Inovative method to place top soil and fill material using telebelt. 2021: seeding application rate was higher than prescribed and competing with plantings also survival not as high in 2021

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+) 3
Watercourse: Bow River Weather: 20 C, partially sunny & smokey
Crew Initials: MG / PR Date: 19-Jul-21

Photo Monitoring

Permanent photo-monitoring location and ID

	U/S END	D/S END
E	709443	709498
N	5657802	5657762
Photo No.	46E2_US	46E2_DS

Other Photos (min 3)

Photo No.	Description
2	Site looking d/s
3	Site looking u/s
9	Eroded bank showing riprap

Hydrology

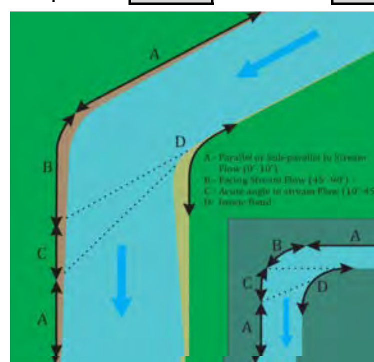
Flow at time of survey 132.6 m³/s Source: Rivers.alberta.ca

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 136 m

Site Dimensions

Total length of the work (parallel to stream) 65.6 m Total project area 754.4 m^2
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	1.38	1000	Water level at 11:33 am
High water mark*	0.57	1000.81	Vegetation debris in rodent fence
Water level during survey	1.38	1000	Water level at 11:33 am

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

Results below are consistent with 2019 so survey not updated in 2021

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	Red osier potted
Elev of lowest herbaceous veg	2.14	1000.28	grasses
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	Water level at 11:43 am
Elev of lowest woody veg	1.1	1000.19	Balsam poplar
Elev of lowest herbaceous veg	1.18	1000.11	grasses
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)	65.6	100
Class 3 (d50=800mm)		0
Other:		0
Total linear metre (m)	65.6	

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 ____ 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		
Poor	1 Condition which needs immediate attention and repair	X	

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

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 cane
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 [X] High [ ] N/A [ ] Describe: Eroded fill at the toe

Estimate of erosion within site/structure

Lo w [ ] M ed [X] Hi gh [ ] N/ A [ ] D es: Eroded fill at toe; 2021 topsoil washed out from riprap at toe

Estimate of sediment accumulation at site

Low [ ] Medium [ ] High [ ] N/A [X] Describe [ ]

Measurement of sediment accumulation at site

Depth: Trace Method: Visual

Describe/Location:

Seeps or spring present Yes [ ] No [X] 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	3	
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 and placed top soil eroding
Existing vegetation competition[1]	2	Invasive weeds present; 2021 density of seeded grass competing with planted veg
Shade	0	
Maintenance issues[2]	2	Weeding required, rodent fence to be secure at the bottom and leaning out. Straw wattles to secure to toe of slope; 2021 same
Flooding duration	0	
Hydraulics (Shear stress)	2	
Infrastructure and available space	0	
Wildlife impact[3]	0	
Comment on wildlife impact:		
Access	0	
Other: 1-		2021, Air void under riprap may not be conducive to plant growth; temperature fluctuations may be affecting plant growth?
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 is needed; 2021: same but wattle has disintegrated + remove fencing and candy re-bar at AFC

ALTERNATIVE DESIGN OPTIONS

Description: Treatment as 46E1 and 46E3 without top soil (pit run / river gravel) planted with live cuttings

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+)	3
Watercourse	Bow River	Weather:	Smokey and 22 degrees
Crew Initials	MG / PR	Date:	19-Jul-21

Photo Monitoring

Permanent photo-monitoring location and ID

	U/S END		D/S END
E	709499	E	709554
N	5657755	N	5657726
Photo No.	46E3_US	Photo No.	46E3_DS

Other Photos (min 3)

Photo No.	Description
2	Site looking d/s
3	Bench looking d/s
8	Site looking u/s

Hydrology

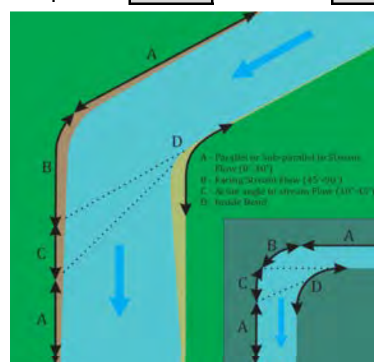
Flow at time of survey 129.4 m³/s Source: Rivers.alberta.ca

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 136 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	1.38	1000	Water level at 11:33am
High water mark*	0.52	1000.86	Debris on rodent fence
Water level during survey	1.38	1000	Water level at 11:33am

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

Results below are consistent with 2019 so survey not updated in 2021

Planted Vegetation Survey*	**Rod Height (m)**	**Elevation (m)**	**Survey Notes**
Elevation Benchmark	2.45	1000	Water level at 12:33pm - water level dropped 3 cr
Elev of lowest woody veg	2.15	1000.3	Salix int.
Elev of lowest herbaceous veg	2.2	1000.25	grasses
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	Balsam poplar
Elev of lowest herbaceous veg	1.18	1000.11	Grasses
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		
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 ____ 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		
Poor	1 Condition which needs immediate attention and repair	X	

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

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					

To be removed from site

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; 2021 same

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; 2021 same

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

Measurement of sediment accumulation at site
Depth: Trace Method: Visual
Describe/Location: At toe of slope

Seeps or spring present Yes [ ] No [X] 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	3	2021 increased to 3 from 1
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 wattles to repair; 2021 did replant (fill in)
Flooding duration	0	
Hydraulics (Shear stress)	2	
Infrastructure and available space	0	
Wildlife impact[3]	0	
Comment on wildlife impact:		
Access	0	
Other: 1-		Void spaces below cuttings might not be conducive for veg growth
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 required before plants going to seeds; 2021 same and add remove candy cane rebar

ALTERNATIVE DESIGN OPTIONS

Description: Design options could be 46E_1 and 46E_2 without top soil on side slope (bank) planted with live cuttings.

Success Attributes

To date, successful existing riprap retrofit with void fill and live cuttings ; With 3 years of irrigation plants should establish. telebelt innovative method use to place material in void; 2021 remove statement about live cuttings being successful. Lots of mortality and plugs are being used for replanting.

KERR WOOD LEIDAL
consulting engineers

Appendix F

Bioengineering Structural Integrity Assessment Photos

Appendix F – Baseline (2016/2017) and Post-Construction[1] Photographic Monitoring

	BASELINE (2016/2017)	2019	2020	2021	2023	2028
PHOTO STATION 1	 March 29, 2017 – View upstream	 Sept 4, 2019 – View upstream	 June 18, 2020 – View upstream	 July 13, 2021 – View upstream		
PHOTO STATION 1	 March 29, 2017 - View downstream	 Sept 4, 2019 – View downstream	 July 9, 2020 – View downstream	 July 21, 2021 – View downstream		
PHOTO STATION 2	 March 29, 2017 – View upstream	 Sept 4, 2019 – View upstream	 July 31, 2020 – View upstream	 June 18, 2021 – View upstream		

[1] Construction occurred from January 2018 to July 2019. Post-construction monitoring is occurring in 2019 (Year 1), 2020 (Year 2), 2021 (Year 3), 2023 (Year 5), and 2028 (Year 10).

	BASELINE (2016/2017)	2019	2020	2021	2023	2028
PHOTO STATION 2	 **June 2, 2016 - Facing downstream**	 **July 10, 2019 – View downstream**	 **May 25, 2020 – View downstream**	 **June 18, 2021 – View downstream**		
PHOTO STATION 3	 **June 2, 2016 - Facing upstream**	 **Sept 4, 2019 – View upstream**	 **Sept 25, 2020 – View upstream**	 **July 20, 2021 – View upstream**		
PHOTO STATION 3	 **June 2, 2016 - Facing downstream**	 **June 6, 2019 – View downstream**	 **Sept 25, 2020 – View downstream**	 **July 20, 2021 – View downstream**		

	BASELINE (2016/2017)	2019	2020	2021	2023	2028
PHOTO STATION 4	 June 2, 2016 - Facing upstream	 Sept 4, 2019 – View upstream	 July 31, 2020 – View upstream	 June 18, 2021 – View upstream		
PHOTO STATION 4	 June 2, 2016 - Facing downstream	 Sept 4, 2019 – View downstream	 July 31, 2020 – View downstream	 June 18, 2021 – View downstream		