2019 Annual Summary Report

The City of Calgary Riparian Monitoring Program

July 14, 2020

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The City of Calgary - Water Resources

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1. Introduction

The purpose of this technical memorandum is to provide a summary of the 2019 monitoring activities and results for The City of Calgary Riparian Monitoring Program (RMP). The RMP is currently structured as a 5-year monitoring program (2018-2022) with the goal of providing a better understanding of 1) long-term riparian health trends, and 2) the improvements in riparian health resulting from recent and ongoing river bank bioengineering, and riparian planting projects in Calgary. The RMP consists of the following components:

- Riparian health trend monitoring;
- Riverbank bioengineering project effectiveness monitoring;
- Riparian restoration project effectiveness monitoring; and
- Special projects:
    - Geomorphic monitoring of the Elbow River downstream of the Southwest Calgary Ring Road (SWCRR); and,
    - Post-construction monitoring of the Bioengineering Demonstration and Education Project.

Detailed methods, results, and recommendations from the 2019 monitoring activities for each of the above components are provided under separate cover in annual technical reports/memorandums. This annual summary report is derived from the detailed technical reports/memorandums.

1.1 RMP Key Dates – 2019

Activities for the 2019 monitoring program began in January 2019 and ended in May 2020. A summary of key dates and activities is provided in Figure 1-1.

Monitoring Activities	2019												2020				
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
Trend - Riparian Health							Field				Data Analysis/Reporting						
Effectiveness - Riverbank Bioengineering					Desktop		Field		Field		Data Analysis		Reporting				
Effectiveness - Riparian Planting					Desktop/Fld			Field			Data Analysis		Reporting				
Special Project: Elbow River - SWCRR						Field			Field		Data Analysis/Reporting						
Special Project: BDEP	Field											Data Analysis/Reporting					

Figure 1-1: Summary of 2019 RMP Activities

2. Trend Monitoring: Riparian Health

The Alberta Riparian Habitat Management Society (Cows and Fish) has been monitoring riparian health in Calgary since 2007 using the Riparian Health Inventory (RHI) methodology. The continuation of this monitoring is included as part of the RMP, with an overall plan to assess the trend in riparian health of 97 re-visit riparian sites, 3 new (not previously assessed) 'large-scale riparian retrofit' sites, and 10 new sites where key sampling gaps were identified (KWL, 2018).

2.1 2019 RHI Monitoring Results

In 2019, 26 sites were assessed, including 16 Bow River sites, 5 Elbow River sites, and 5 Nose Creek / West Nose Creek sites (Cows and Fish, 2019). All 26 sites from 2019 are classified as 're-visit' sites. The assessed area in 2019 encompassed approximately 26 km of bank length and 190 ha of riparian habitat, the bulk of which (87%) is directly along the Bow River. 2019 RHI results are summarized in Table 2-1. The location of the 2019 trend monitoring sites is provided in Map 1 at the end of this report.

Results show that there have been consistent increases in RHI scores for the Elbow River in 2007-2008, 2014, and 2019 (Table 2-1). However, 2019 scores for the Bow River were slightly lower than 2014 scores, but still higher than the baseline conditions. For Nose/West Nose Creek, 2019 scores were lower than 2014 but the same as baseline conditions. Bow River score declines since 2014 are mostly due to invasive species increases; post-flood landscaping/repair works (e.g. trail repairs; flood debris/deposition removal causing soil compaction); bank stabilization work; and recreational use impacts. When evaluating riparian health, rock riprap, cribwall and retaining wall bank stabilization projects are considered structural alterations, although longer-term negative impacts are expected for 'hard engineering' structures versus bioengineering projects. Increases in invasive species canopy cover have primarily affected Nose Creek basin score declines.

Table 2-1: 2019 RHI Results for the 26 RHI Sites by Watershed (excluding Weaselhead ELB63/64 sites)

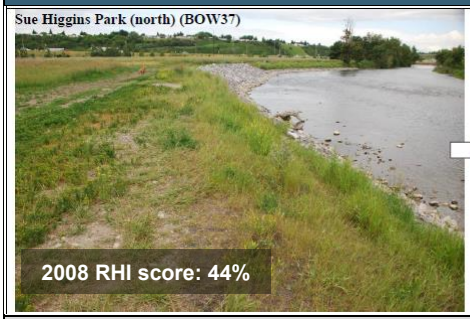
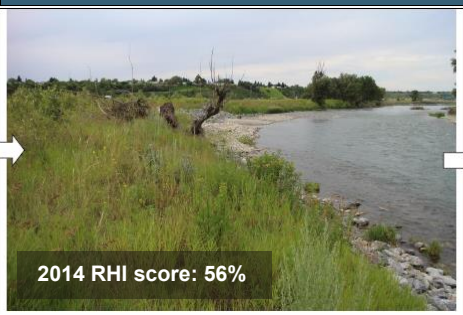
Average RHI Health Rating	Baseline (2007-2010) Overall Score (%)	2014 Overall Score (%)	2014 Trend	2019 Overall Score (%)	2019 Trend (Since baseline)
Bow River (n=16)	52.9	58.4	⬆ (+6%)	56.7	⬌ (+4%)
Elbow River (n=5)	52.9	58.2	⬌ (+5%)	61.0	⬆ (+8%)
Nose/West Nose Creek (n=5)	61.5	65.2	⬌ (+4%)	61.0	⬌ (-1%)

Legend: **RHI Ratings:** **Green** = Healthy (80-100); **Orange** = Healthy, but with problems (60-80); **Red** = Unhealthy (0-60)
Trends: ⬆ Improving >5% increase in score; ⬌ Static <5% change in score; ⬇ Declining >5% decline in score

2.2 Example of Site with Improving Riparian Health

Improving riparian health trends were particularly observed at Sue Higgins Park (BOW37) (Table 2-2). These improvements are partially attributable to long-term riverbank bioengineering and riparian planting projects in 2008-2010 in addition to improved recreational use management, directing use to designated areas.

Table 2-2: BOW37 – Sue Higgins Park Re-visit Monitoring Photography

2008	2014 – Retake Photo 1	2019 – Retake Photo 2
		
High recreational use in the floodplain has created areas of human-caused bare ground (view upstream). Riprap bank stabilization was done here to repair flood damage after the 2005 flood at the B2B stormwater outfall.	Exclusion fencing was installed here in 2009/2010 to restrict recreational access. Poplar plantings were also installed. Beneficial natural recovery and infilling of vegetation has occurred. Minimal erosion resulted here from the 2013 flood.	Natural regeneration of balsam poplars is progressing here in addition to continued growth of planted trees/shrubs, improving riverbank health; however, weedy and disturbance-caused plants continue to be prevalent.

2.3 Interim 2019 City-Wide Riparian Health Trend Results

An interim City-wide riparian health trend update was calculated for a subset (n=25, 44%) of the 57 RHI monitoring sites that were originally used in the trend calculation referenced in the *Riparian Action Program* (RAP) (City of Calgary, 2017). BOW87 Douglasdale north was not included in this interim calculation as it was not part of the original 57 sites. A City-wide riparian health trend update will be calculated for all 57 RHI sites in the next annual report. A comprehensive, updated, City-wide riparian health trend monitoring analysis will be done in the final year of the 5-year RMP which will include the total number of sites to be monitored as part of the RMP (n=110).

The results of the 2019 interim trend calculations are provided below.

- Compared to baseline conditions, interim City-wide area-weighted RHI scores increased from 2007-2010 to 2019 (remaining in the unhealthy category), although this is a slight decline since 2014 (Table 2 3). As discussed in Section 2.1, invasive species increases city-wide in addition to post-flood repair works and re-instated recreational use impacts have occurred since 2014, constraining riparian health improvement.
- Currently, the highest average riparian health rating in 2019 is for riparian habitat in the "Restoration Management Zone" which is about 10% of the overall monitored area (Table 2-3).

Table 2-3: Interim 2019 Average Area-Weighted Riparian Health Score Trends (n=25)

Management Zone	2007/2008/2010	2014	2019
Conservation (89.5 ha, 51% of monitored area)	55.2%	59.8%	58.4%
Restoration (17.3 ha, 10% of monitored area)	56.5%	61.4%	60.6%
Recreation (55.3 ha, 32% of monitored area)	53.7%	58.8%	58.2%
Flood/Erosion Control (4.2 ha, 2% of monitored area)	49.0%	52.3%	56.0%
City Wide (175.6 ha)	**54.7%**	**59.4%**	**58.5%**

2.4 Management and Monitoring Suggestions

Invasive Plant Species

- Invasive weeds have increased in riparian areas City-wide. Broad, ongoing weed control efforts are needed. Frequent and rigorous monitoring and weed removal programs should focus on ensuring early detection and rapid removal of *Prohibited Noxious Weeds* in Calgary, as well as removing those weeds that are presently limited in distribution/abundance.
- Tufted vetch (*Vicia cracca*) should be locally elevated to *Noxious Weed* status in Calgary and a city-wide control program developed for this species.

Balsam Poplar Forest Health and Sustainability

- Continue to monitor balsam poplar recruitment in Calgary in collaboration with Dr. Stewart Rood and colleagues from the University of Lethbridge.
- Consult with Dr. Stewart Rood and upstream dam operators to implement suitable flow ramping criteria to enhance poplar recruitment into the future.

Native Tree and Shrub Community Health

- Avoid or minimize future clearing or disturbance to riparian forests and other native riparian vegetation.
- Promote expansion of natural riparian buffers city-wide including city-owned lands but also within privately owned/managed lands (e.g. golf courses).
- Continue to conduct native tree/shrub plantings in disturbed habitats, following best management practices per recommendations in the RMP effectiveness monitoring studies (KWL, 2019a; KWL, 2019b; KWL, 2020a; KWL, 2020b).
- Monitor and manage beaver use as appropriate to prevent unsustainable levels of woody plant removal.

Disturbance-Caused Vegetation

- Ensure future restoration projects adhere to Calgary's 2018 seed mix and guidelines document intended to inform revegetation work in Calgary (City of Calgary, 2018).

Soil/Hydrology Health

- Avoid new soil disturbance in riparian habitats to the extent possible and minimize addition of paved, hardened or compacted surfaces in riparian areas.
- Continue to encourage designated trail use only throughout Calgary's riparian park network and created designated river access points where appropriate.
- Continue to support and implement watershed management plan priorities for the Bow River, Elbow River and Nose Creek.
- Continue to participate in the 2020 Nose Creek hydrologic, hydraulic and water quality model project.
- Continue to work with the Alberta Low Impact Development Partnership (ALIDP) to promote more widespread adoption and implementation of low impact development (LID) practices.

- Continue to set progressive stormwater management targets for runoff rates (L/s/ha), runoff volumes (mm/ha), and stormwater quality treatment.
- Continue efforts to strengthen and improve Calgary's stormwater management strategy.
- Continue efforts to strengthen Calgary's riparian protection planning and policy tools to promote better protection of all riparian habitats.

Public Education and Outreach

- Continue public education and outreach efforts in progress as part of the Riparian Action Program.
- Promote new outreach tools such as the City's new webpage dedicated to the Bioengineering Demonstration and Education Project and the newly created "Health Rivers Story Map" (https://maps.calgary.ca/healthyrivers/).
- Where appropriate, continue to install interpretive signage at soil bioengineering and riparian restoration project sites to indicate the purpose and intended beneficial outcomes of the project. Replace interpretive signage (damaged by the 2013 flood) at the Sandy Beach restoration site (ELB35).
- Continue to work with community and local stewardship groups on trail maintenance, weed removal, garbage removal and tree or shrub planting projects (where possible).

3. Effectiveness Monitoring: Riverbank Bioengineering Sites

Under this component of the RMP, the effectiveness of riverbank bioengineering sites is being monitored to determine if the desired goals and objectives of each project are being achieved. Per the current schedule laid out in the Monitoring Plan (KWL, 2018), 55 bioengineering riverbank sites will be monitored for effectiveness at least once over the 5-year RMP.

In 2019, 19 riverbank bioengineering sites underwent detailed effectiveness monitoring as shown in Figure 1 at the end of the report. Sites were selected according to post-construction age class (Year 1, Year 3, or Year 5+) combined with typology (Vegetated Riprap; Vegetated Retaining Wall; Vegetated Crib Wall; Primarily Vegetative; or Planting) to generate statistically valid sampling populations. The location of the sites is shown in Map 1. The list of 2019 riverbank bioengineering monitoring sites is provided in Attachment A. The total number of riverbank bioengineering sites monitored to date is 38.

3.1 Monitoring Methods

A detailed description of monitoring protocols is provided in the Monitoring Plan (KWL, 2018). A summary of the methods is provided below.

- **Desktop assessments**: includes two components – general project information, and planting details
- **Field assessments**: includes three components – Bank Protection / Stabilization Structure Assessment, Technical and Living Plant Structure Assessment, and Failure Assessment (as required).
- **Statistical analysis**: the general approach used is comparison of means.

3.2 Key Results

Key results from 2019 monitoring are listed below. Note that more robust and additional relationships will likely be identified as more data is collected over subsequent years of the RMP.

Advances in Understanding / Successes

- Filling voids in riprap with river gravels or growing medium provides a surface that is more easily traversed by wildlife and humans and makes for better growing conditions for riparian vegetation.
- Several new bioengineering techniques were assessed in 2019, including vegetated riprap with rooted live cuttings, vegetation timber crib wall with fish shelters, live grating (or slope timber grid), box fascine, hedge brush layer, soil covered riprap, and void filled riprap. The new techniques were used at BDEP (BE-BOW-46), at Outfall B69 (BE-BOW-116), and at Outfall B73 (BE-BOW-82).
- Three solutions for summer bioengineering construction were assessed in 2019 as listed below:
    - At BE-BOW-60, wooden pallets backfilled with topsoil were installed into the riprap bank protection during summer, then live cuttings were installed in pallets in the fall during the dormancy period. This method appeared to be working well with survivorship of 100%.
    - At BE-BOW-46A, BE-BOW-82, and BE-BOW-116, rooted, non-dormant live cuttings were placed in riprap during the summer construction period with survivorship ranging from 54% to 65% at different sites. It is recommended to use sandbar willow for this technique as survival was higher than other species.

    - At BE-ELB-88, the timber crib wall was constructed and backfilled with topsoil in the summer, then live cuttings were installed in the topsoil backfill in the fall during the dormancy period. Survivorship was 100%.
- Combining live cuttings with container plants in techniques such as hedge brush layers can improve survivorship percentages, enhance biodiversity and wildlife habitat, and provide nitrogen fixing.
- Using a telebelt at BE-BOW-46E2 / 46E3 to void fill riprap with growing medium worked well.
- Designers are making better use of vegetation as erosion control in the Year 1 sites versus the Year 3 sites by matching the lowest elevation of planted woody vegetation to the observed lowest elevation of existing native vegetation.
- Reusing native topsoil appears to result in lower invasive species occurrence.
- Sandbar willow is a good species to select for inundated conditions as it tolerated submergence for up to 18 days with survival of 90%.
- Placing soil amendment around live cuttings results in higher survivorship and longer average leader growth.
- Fencing around live cuttings appears to result in longer average leader growth and higher survival.
- Almost 6,300 individual cuttings and rooted stock container plants have been sampled thus far.
- Planting survivorship was 94% and was higher than live cuttings survivorship at 68%.
- Following best practices as described in The City's design guidelines (AMEC, 2012) and RMP reports (KWL, 2019a; KWL, 2019b) for live cuttings harvest, storage, handling, installation, and maintenance leads to best project outcomes.
- Average overall ratings improved in 2019 at 72 / 100 for 19 assessed sites (2018 ratings were 58 / 100 for 19 assessed sites).
- The 2019 highest rated riverbank bioengineering site received a score of 89 / 100 (see box below).

Areas for Improvement

- Two failure sites[1] (BE-BOW-6 and BE-BOW-89) were identified in 2019 with the main reasons for failure as follows:
    - planting spring-harvested cuttings outside of the recommended window;
    - planting into compacted soils that were composed of pitrun gravel with little growing substrate; and,
    - inadequate maintenance (i.e., irrigation) for very dry sites.
- Erosion control matting with plastic mesh should be avoided for riverbank applications.
- Timber used in crib wall should be high quality construction grade or higher.
- Summer construction remains a challenge for vegetation survivorship – live cutting survivorship was observed to be ±10% at a site constructed in summer 2018.
- Backfill material for box fascines should be river gravels.

[1] For the purposes of the RMP, riverbank bioengineering/riparian planting failure sites are either due to structure failure or due to vegetation survival rates of less than 25%. Failure sites are removed from the program once reasons are documented and replaced with sites where vegetation data can be collected efficiently. The failure sites can be reintroduced into the program if they are repaired and are needed according to the sampling protocols to achieve statistically significant results.

- Installing live cuttings prior to or simultaneously with riprap void-filling is recommended as finding void-spaces to plant live cuttings after the fact is challenging.
- Live cutting survivorship was 68% when 2018 and 2019 data is pooled. Survivorship remains below typical regulatory approvals thresholds (Figure 3-1).
- Red-osier dogwood live cutting survival remains low for Year 1 data.
- Invasive weeds are a common maintenance issue. Sixteen different invasive species were found, and the top three species were found at 26 or more of the 33 monitoring sites from 2018 and 2019.
- Live staking was found to have low survival among the assessed bioengineering techniques. Special care should be made to follow best practices when using this technique.
- Low ratings were often due to low maintenance and Bank and Riparian Quality Index (BRQI) ratings.

Figure 3-1: Year 1 (inner doughnut) and Year 3 (outer doughnut) Post-Construction Survival (%) of Common Live Cutting Species Used in Bioengineering Projects in Calgary (2018 and 2019 data)

Ratings

Each project was assessed a rating for design (/18), implementation (/18), maintenance (/18), success (/24) and BRQI (/22). Average ratings for all sites by assessment component is shown in Figure 3-2. The average overall rating for the 19 sites assessed in 2019 was 72 - Fair ("Good" Category = **Green** with ratings 75-100; "Fair" Category = **Orange** with ratings 50-74; and, "Poor" Category = **Red** with ratings < 49). **When 2018 and 2019 sites are pooled, the average overall rating for the 38 sites was 65 – Fair** (Figure 3-2). When ratings were evaluated by Typology, average scores for all but the Planting typology are in the "Fair" Category (Figure 3-3).

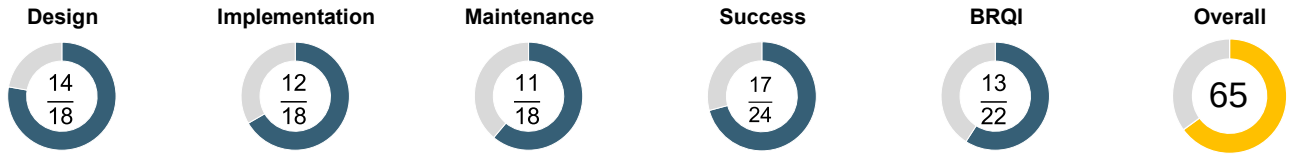


Figure 3-2: Average Ratings for all Sites According to Assessment Components (2018 and 2019 data)

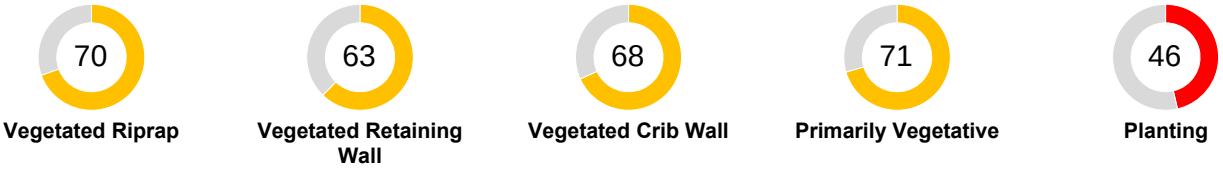


Figure 3-3: Average Ratings for all Sites by Typology (2018 and 2019 data)

Highest Rated Riverbank Bioengineering Monitoring Site - 2019

At site BE-BOW-46E1 (Bioengineering Demonstration and Education Project Site 4-1), the existing riprap was covered with soil and planted with container shrubs. The plantings were handled, stored, and installed according to best practices, including using soil amendments and fencing the site for protection from wildlife. The biodegradable erosion control matting contributed to good seed mix establishment. The site was also constructed according to an appropriate schedule by an experienced contractor. Following best practices yielded excellent survivorship (97%), plant health, and overall structure success. This site received a rating of 89/100.

Typology: Vegetated Riprap **Age Class**: Year 1

Bioengineering technique: Soil Covered Riprap with Container Plantings

Delivery Agency: Alberta Environment and Parks (AEP) / The City of Calgary Water Resources (CoC)

Project Manager: David DePape (AEP) / Jonathan Slaney (CoC)

Photo 3-1: BE-BOW-46E1 (Bioengineering Demonstration and Education Project Site 4-1) looking downstream

4. Effectiveness Monitoring: Riparian Restoration Sites

Under this component of the RMP, the effectiveness of riparian planting sites is being monitored to determine if the desired goals and objectives of each project are being achieved. Per the current schedule laid out in the Monitoring Plan (KWL, 2018), 30 riparian restoration sites will be monitored for effectiveness at least once over the 5-year RMP.

In 2019, 9 riparian restoration sites were initially assessed, with a total of 7 that underwent detailed effectiveness monitoring. The location of the sites is provided in Map 1. The remaining 2 sites were identified as failures as discussed below. Sites were selected according to post-construction age class (Year 1, Year 3, or Year 5+) combined with typology (Native Tree and Shrub Cuttings; Native Tree and Shrub Plantings; Mixed Techniques; or Large-Scale Riparian Retrofit Projects) to generate statistically valid sampling populations. The list of 2019 riparian restoration monitoring sites is provided in Attachment B. A total of 32 sites have been assessed to date, of which 22 underwent detailed monitoring.

4.1 Monitoring Methods

A detailed description of monitoring protocols is provided in the Monitoring Plan (KWL, 2018). A summary of the methods is provided below.

- **Desktop assessments**: includes two components: general project information, and planting details
- **Field assessments**: includes three components: Reconnaissance Assessment, Detailed Vegetation Assessment, and Failure Assessment (as required).
- **Statistical analysis**: the general approach used is comparison of means.

4.2 Key Results

Key results from 2019 monitoring are listed below.

Advances in Understanding / Successes

- Over 2,400 individual cuttings and plantings have been sampled thus far.
- Plantings have been more successful than cuttings, showing higher survivorship rates for both Year 1 and Year 3 projects as shown in Figure 4-1.
- Native tree and shrub plantings were above 90% survival rates for both Year 1 and Year 3 sites as shown in Figure 4-1. Cutting survival rates were less than 40% in Year 1 sites and less than 70% in Year 3 sites.
- Total overall survivorship, including all assessed Year 1 and Year 3 age class cuttings and plantings from 2018 and 2019, is 82%.

Areas for Improvement

- Ten sites were originally scheduled for detailed monitoring in 2019. However, due to a number of failures and a lack of suitable replacement sites, it was not possible to reach this target. Instead, additional transects were sampled at three of the successful 2019 sites in order to increase the amount of vegetation data in the database.

- Two failure sites (RE-NOS-10 and RE-FIS-20) were identified in 2019, where vegetation survival was below the threshold of 25%. Both sites were from the native tree and shrub cuttings typology and Year 3 age class. The exact cause of failure could not be determined. Both sites were completed by volunteers with minimal site maintenance post-installation.
- Herbaceous species competition was the main limiting factor to restoration success for most sites.
- Species such as Balsam Poplar (*Populus balsamifera*), Red-Osier Dogwood (*Cornus stolonifera*), and Sandbar Willow (Salix interior), which the literature suggests all make excellent live cuttings, have unusually low survivorship rates as cuttings at the sites assessed. Possible reasons for the low survivorship of cuttings compared to plantings include Calgary's harsh climate, poor installation practices and/or poor-quality material.
- Herbaceous seed mixes had poor establishment success at 83% of the 2019 sites where they were applied and 75% of all sites assessed to date.
- Invasive plant species were observed at all 22 riparian effectiveness sites that underwent detailed sampling in 2018 and 2019. In total, 19 different invasive plant species were observed including the prohibited noxious weed nodding thistle (*Carduus nutans*).
- The most common reason for low overall scores in 2019 was low Success ratings.

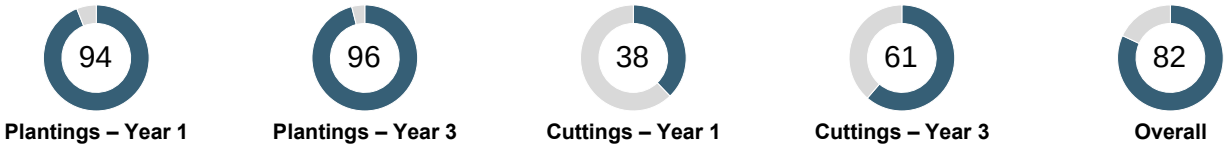


Figure 4-1: Overall Year 1 and Year 3 Post-Construction Survival (%) of Plantings and Live Cutting Species Used in Riparian Restoration Projects in Calgary (2018 and 2019 data)

Photo 4-1: Site BE-ELB-88 (Discovery Ridge)

Ratings

Each project was assessed a rating for design (/18), implementation (/18), maintenance (/18), success (/24) and BRQI (/22). Average ratings for all sites by assessment component is shown in Figure 4-2. The average overall rating for the 9 sites assessed in 2019 was 55- Fair ("Good" Category = **Green** with ratings 75-100; "Fair" Category = **Orange** with ratings 50-74; and, "Poor" Category = **Red** with ratings < 49) Figure 4-3). **When 2018 and 2019 sites are pooled, the average overall rating for the 32 sites was 51 – Fair** (Figure 4-2Figure 3-2). When ratings were evaluated by Typology, average scores for all typologies were in the "Fair" category (Figure 4-3).

Figure 4-2: Average Ratings for all Sites According to Assessment Components (2018 and 2019 datay)

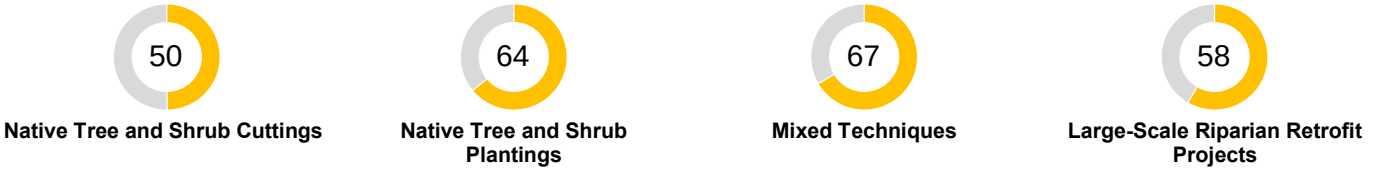


Figure 4-3: Average Ratings for all Sites by Typology (2018 and 2019 data)

Highest Rated Riparian Planting Monitoring Site

At site RE-BOW-R9 (Edworthy, Shaganappi, Crescent Heights), success factors included good seed mix establishment, species selection, and seeding prescription; high shrub survivorship; shrubs were planted well for the most part; and, good planting design and plant species selection.

This site received a rating of 70/100.

Typology: Native tree and shrub plantings

Age Class: Year 1

Delivery Agency: The City of Calgary Parks

Project Manager: Tricia Striker

Photo 4-2: Site RE-BOW-R9: View Along the Pinpoint Transect

5. Effectiveness Monitoring Recommendations

An initial list of recommendations for riverbank bioengineering and riparian planting projects was provided in the 2018 RMP Annual Summary Report. A brief summary of the 2018 list is provided below.

- Improve project documentation, record keeping and information sharing to the RMP team.
- Improve riverbank bioengineering and riparian planting project design practices.
- Improve riverbank bioengineering and riparian planting project maintenance practices.
- Continue to investigate low survivorship of live cuttings.
- Continue the RMP monitoring program.
- Conduct bioengineering research for soil moisture monitoring and crib wall timber durability.

New recommendations from the 2019 riverbank bioengineering and riparian planting effectiveness monitoring results are compiled together since many are held in common and are listed below.

Provide project completion documentation to the RMP team. As-builts or record drawings, and completion reports (or for smaller projects, a record of what was planted, where it was planted, and how it was handled/planted) are also important to the monitoring team to effectively determine project success.

Avoid the use of non-biodegradable erosion control products. The use of non-biodegradable erosion control products should be avoided in riverbank and riparian areas wherever possible. Exposed non-functional plastic erosion control materials should be removed where warranted.

Use rooted species in combination with live cuttings. Evidence to date suggests that survival and general health of plantings is much better than live cuttings. While there are many important reasons to continue using live cuttings, more container plants should be used within bioengineering structures, preferably in combination with live cuttings such as in hedge brush layers.

Avoid using red-osier dogwood live cuttings. Using rooted stock for red-osier dogwood and planting them in partial to full shade, at an elevation slightly higher than the toe of bank is recommended due to low survival rates of live cuttings.

Include emergent vegetation. Using plugs of emergent species such as sedges and rushes is recommended when emergent vegetation is desired in locations that are inundated during peak flows.

Provide seeding rate specification in contracts. Project specifications going forward should include a written procedure on how to calculate and apply a prescribed seeding application rate.

Follow best practices to improve live staking survivorship. Live staking was found to have a low survivorship (49%) for combined 2018 and 2019 data. Projects using this technique should closely follow best practices such as live cutting harvesting/handling/storage/soaking/installation, construction scheduling, soil compaction, and soil amendment use per The City's design guidelines (AMEC, 2012) and RMP reports (KWL, 2019a; KWL, 2019b).

Preferentially use high density live cutting bioengineering techniques. Techniques that use higher density of live cuttings such as brush layers, hedge brush layers, fascines, and brush mattresses appear to be good technique choices based on the results from the RMP.

Use high quality timber in crib walls. It is recommended that the dimensional cedar timber used in timber crib walls be Select Structural, No.1/ No.2, or Construction.

Hire experienced contractors and well-trained crews. Site observations of subpar and inexperienced workmanship included approximately 50% of the plantings installed improperly, with exposed roots, air pockets and/or improper backfilling at one site, and careless weed control activities that damaged plantings.

Reduce the occurrence of compacted soils: Where appropriate, compaction between 80% and 85% of the standard Proctor maximum dry density is recommended for areas where vegetation is planted. Designated travel corridors could be established to reduce soil compaction caused by machines on site.

Provide irrigation during initial establishment. Reduced success of plantings and cuttings was observed in sites exposed to direct sunlight during initial establishment. For riparian planting projects, ongoing irrigation was confirmed to be occurring for approximately 37% of projects, could not be confirmed for 16% of projects, and was not occurring for 47% of projects.

Improve herbaceous seed mix establishment. The poor establishment of herbaceous seed mixes continues to be an issue. Best practices should be followed as provided in the 2018 riparian effectiveness monitoring annual report (KWL, 2019a). Contractors should also be referred to The City of Calgary *Seed Mixes* document (The City of Calgary 2018), and records should be kept by contractors and project managers of when the seeding occurred, final seed mixes used, seed certificates, irrigation activities, etc.

Install rodent fencing around planted vegetation. Rodent fencing should be placed around planted shrubs as well as live cuttings as the results from 2019 show that rodent fencing has a significant effect on container plant survivorship and leader growth.

Improve invasive weed control: Better weeding/removal of invasive weeds is required, including better understanding by contractors regarding: what species to target, when to schedule removal, what methods to use, and how many workers are required to properly complete the work. This might be accomplished with better enforcement by contract administrators, through penalties in the contract, or by withholding payment.

Include weeding around planted shrubs as part of regular maintenance activities. Weeding of grasses immediately around planted trees and shrubs (container and live cuttings) should be included in contract specifications for maintenance when grasses are competing with planted trees and shrubs establishment.

Discuss survival targets with regulators. While it is recommended to maintain the typical year 1 post-construction survival target of 70% to 80%, pursuing live cuttings survival targets that are bioengineering technique-based for years two to five post-construction as recommended by Gray and Sotir (1996) will allow for vegetation self-thinning over time and allow for more realistic survival targets.

Follow individual site repair recommendations. Site specific recommendations for upgrades or repairs of sampled sites should be followed up by the City on a timely matter to improve project outcomes

Measure soil compaction as part of the RMP. Measuring compaction at monitoring sites could be included in the RMP (for the 2020-2022 field seasons) by using a simple probe device in planting areas.

Publish RMP results in scientific journal. Given the original data collected in the RMP and the benefit to the overall practice of bioengineering and riparian planting of sharing the results with other practitioners and researchers, it is recommended to publish the results of the RMP in a scientific journal.

Continue to conduct workshops and tours to showcase bioengineering and riparian planting success and failure examples and key lessons learned. Sharing RMP lessons learned via field visits and workshops with City project managers, practitioners, contractors, etc. would provide an important means to improve bioengineering project outcomes in Calgary.

Update Calgary's soil bioengineering design guideline. Continue to update Calgary's soil bioengineering design guidelines based on the findings of ongoing monitoring projects.

6. Special Projects

6.1 Monitoring of the Elbow River Downstream of the Southwest Calgary Ring Road

The Southwest Calgary Ring Road (SWCRR) crosses a realigned reach of the Elbow River outside of City limits, and upstream of Weaselhead Flats and the Glenmore Reservoir. The realignment was commissioned on April 25, 2018. The KWL team is monitoring the geomorphology and riparian health of the Elbow River in Weaselhead Flats downstream of the SWCRR realignment on an annual basis over the 5-year RMP (KWL, 2020d). This is the second year of monitoring.

Scope and Methods

The scope of Year 2 work of the monitoring program consists of the following tasks:

- Location and mapping of planform channel changes between 2018 and 2019 along the active channel of the Elbow River using aerial photographs.
- Repeat survey of 12 cross-sections and channel thalweg on the Elbow River to map the morphology changes (e.g., bank erosion, scour, etc.) that may have occurred between 2018 and 2019.
- Repeat sampling of the Elbow River bed material at 6 sites to assess any changes in sediment size distributions downstream following realignment.
- Visual assessment of hydraulic conditions to assess changes in flow conveyance conditions, comparison of 2019 peak flow to reference flows, and observations of site hydraulics during the field assessment.
- Results summary of the 2019 riparian health assessment (RHA) of ELB63 and ELB64 in the Elbow River study reach by Cows and Fish.

Key Results

The geomorphic assessment findings from Year 2 of the Elbow River monitoring program downstream from the SWCRR crossing are summarized below.

- While bank erosion was observed at Area of Interest (AOI) #1 and AOI #2 between 2016 and 2018, no notable changes were observed at these locations between 2018 and 2019 (pre-freshet) (Figure 6-1).
- Geomorphic changes at AOI # 3 were consistent for both monitoring years (2018 and 2019), with notable erosion observed along the right bank (Figure 6-1).
- The mid channel sediment bar at AOI #4 has undergone significant planform changes each year (Figure 6-1). It is suspected that local hydraulics that relate to the meander cut-off that was initiated in 2006 is likely governing the changes observed here.
- Three new areas of interest have been identified in 2019. AOI #5 and #6 are isolated locations where bank erosion has occurred, whereas Area #7 is a long section of bank erosion that occurs on the outside bend of a large meander (Figure 6-1).
- Results of the cross-section comparison between 2018 and 2019 show, with few exceptions, erosion of both the left bank and right bank occurring at each cross-section.

- With the exception of deposition observed at one cross-section (#10), scouring of the bed sediment occurred at all other cross-sections, with a mean reduction of 0.11 m in elevation across all cross sections.
- With two notable exceptions, the 2019 thalweg is mainly in the same planform position as the 2018 thalweg location. The thalweg appears to have shifted towards the eroding bank at chainage 400 to 600 m and shifted eastward between chainage 850 and 1100 m (AOI #3 and #4).
- There are two sections on the thalweg profile that show the 2019 profile plotting consistently lower in elevation than the 2018 thalweg profile.
- Bed material sampling sites 1 through 4 showed an increase in sediment size when 2019 results were compared to the 2018 size distributions. Sites 5 and 6, showed no change or a small decrease, respectively. There also appears to be a slight decreasing trend in D50 downstream toward the Glenmore Reservoir for all three sample years (2017, 2018, and 2019).
- There appears to have been a general increase in the channel capacity overall between 2018 and 2019. The increase in channel capacity could relate to an increase in flow conveyance as its directly related to the net erosion of sediment that has been observed for most cross-sections in the Elbow River study reach.
- The peak flow in 2019 exceeded the 2-year flow for the Elbow River in the vicinity of the study reach. Field observations show that the bank erosion areas occurred primarily along outside meander bends where the sediment appears to be unconsolidated and highly erodible. Field observations also showed that significant changes occurred at AOI #3 and #4 as a result of the 2019 freshet, which is not evident in the 2019 pre-freshet imagery that was used in the planform analysis.
- The RHA score remained consistent at 94% for ELB63 and 90% for ELB64 for both 2017 and 2019. The riparian health between 2017 and 2019 remains ‘healthy’ in the study area.

Conclusion

- The observations in Year 2 of this monitoring study indicate that the dominant geomorphic process in the study reach was erosion (e.g., bank erosion, bed erosion), which contrasts with observations of sedimentation related processes that occurred in Year 1. The bank erosion observed in Year 2 of this study is less than historical values, with the exception of AOI #3 where high levels of erosion are likely related to ongoing natural disturbances in the study reach.
- The natural disturbances in the study reach, and the geomorphic responses of these disturbances, make it challenging to differentiate the potential geomorphic responses related to the channel realignment upstream, and the potential effects this may have to City infrastructure. Additional analyses could provide more insight on the morphological response of the study reach to the channel realignment; however, it may still be difficult to determine the magnitude of this response compared to natural channel changes that are occurring.

Figure 6-1: 2018 and 2019 Areas of Interest (AOI)

6.2 Monitoring of the Bioengineering Demonstration and Education Project

The activities and results of 2019 effectiveness monitoring at the Bioengineering Demonstration and Education Project (BDEP) are summarized below. This is the first year of a 10-year post-construction monitoring program at the BDEP site (KWL, 2020c). The scope and methods for the BDEP monitoring program are described in the Bioengineering Efficacy Monitoring Plan (BEMP) and consist 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).

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.

Key Results

The key results from Year 1 post-construction monitoring at the BDEP are summarized below.

Fish and Fish Habitat

- Year 1 fish and fish habitat monitoring activities occurred in the spring, summer, fall and winter., and results indicate that fish are using the habitat enhancement structures provided by the BDEP.
- Fish were observed using and were captured within the vicinity of the new habitat structures throughout the project area (Photo 6-1). Fish were observed in the fish shelters, boulder clusters, and surrounding habitats during winter, spring and summer assessments.
- Compared with the baseline assessment of fish capture data from the Bow River, 10 of the 22 species that were likely to occur in proximity to the project site were captured during Year 1 of monitoring, including 6 sportfish and 4 non-sportfish species.
- Abundance of fish species within the project area could not be compared with baseline data, as fish sampling surveys were not previously conducted in similarly characterized Bow River habitat within proximity to the BDEP sites.
- A total of 16 fish consisting of 7 species were captured at Site 1, 8 fish consisting of 2 species were captured at Site 2, and 24 fish consisting of 6 species were captured at Site 4 using a single boat electrofishing pass. Electrofishing Catch per Unit Effort (CPUE) was greatest at Site 4, followed by Site 2, with Site 1 having the lowest.
- A total of 9 fish and 4 species were captured using minnow trapping, including longnose sucker, lake chub, longnose dace and yellow perch. Minnow trap CPUE was greatest in Site 4. Site 1 and Site 2 had equal CPUE. Overall, longnose sucker had the greatest CPUE of all fish captured at each site.

- Site 1 had the lowest fish abundance, but the highest abundance of sportfish species. Lower total fish abundance at the BDEP sites is expected during Year 1 monitoring as fish habitat enhancements naturalize following construction activities. Fish sampling also indicated species richness was highest at Site 1. Sites 2 and Site 4 had higher abundance of forage fish, with longnose sucker and white sucker being most prevalent.
- Species composition and fish abundance observed during Year 1 are expected to vary in subsequent monitoring years as the BDEP sites naturalize following the construction of the fish habitat enhancements.
- Potential spring and fall salmonid spawning habitats were documented, but no redds or salmonid spawning was observed during the spring or fall spawning assessments in 2019. Mountain whitefish eggs were observed during kick sampling within suitable habitat in the upstream extent of Site 1.
- Overall, Site 1 and Site 2 were found to be providing high quality fish habitat in comparison to Site 4 (assumed to be the conventional riprap design site). Despite the highest abundance of fish at Site 4, the highest abundance and diversity of sportfish species were captured in Site 1 where bioengineering enhancements were most diverse.

Wildlife

- The breeding bird surveys resulted in identifying 31 species including three listed species: least flycatcher, western wood-pewee, and bank swallow. The highest number of bird species and individuals identified was at Site 1, followed by Site 2 and Site 4.
- The bank swallow colony identified in the baseline assessment at Site 2 was observed during 2019 monitoring, indicating that construction did not result in fewer breeding colonies in the project area. Stick nests were also observed at Site 1.
- Site 1 (129 individuals over 22 species) and Site 2 (68 individuals over 8 species) showed increased bird activity relative to Site 4 (24 individuals over 6 species) based on the results of the breeding bird and nesting surveys. This increased activity may be the result of differences in vegetation between the sites, with Site 4 having lower density vegetation.
- The wildlife camera monitoring program included three cameras that identified animals using the wildlife corridor created under the 17th Avenue SE bridge.
- A total of 212 wildlife species were identified during the wildlife camera analysis. The most abundant species observed was Canada goose (59%) followed by white-tailed jackrabbit (21%), white-tailed deer (8%) (Photo 6-2), and coyote (6%). Larger mammals such as deer species and coyotes appear to be using the BDEP wildlife corridor more than other smaller mammals.
- It is expected that better wildlife passage is provided by Site 1 in comparison to Site 4 (assumed to be the conventional riprap design site) since research by other organizations on the effectiveness of wildlife passage benches under bridges such as what was included at Site1. The wildlife corridor at Site 1 is clearly being used by several large mammals including 10 coyotes individuals and 19 deer individuals as documented by wildlife monitoring cameras.

Photo 6-1: Northern pike captured during summer fish sampling

Photo 6-2: White-tailed deer photographed on the BDEP wildlife passage corridor

Riparian Health

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

Bioengineering Structural Integrity

- In general, the physical condition of the site structures, including fish habitat structures appears to be stable, with no signs of major erosion, scour, or displacement. Minor, local erosion was observed at several locations and was communicated to the contractor for repair.
- Materials used in the construction of the BDEP include rock riprap, wood, erosion control matting and geogrids, concrete, and steel and were generally found to be in good to excellent condition.
- The fish shelters were observed to have some fine sediment deposited along the bottom but were otherwise clear and providing good fish habitat. No significant change in the condition of the timber crib wall was observed from as-constructed conditions, and there was no observed change in the deflection of the spanning members that are supported by the steel supports. It is recommended to monitor the timber for long-term durability and to use structural quality timber of larger size for the spanning members should this technique be used again.
- Overall vegetation survival at the BDEP sites was 80%, with Site 1 vegetation survival of 77%, Site 2 vegetation survival of 83%, and Site 4 vegetation survival of 77%.
- Survival of rooted live cuttings at Site 1 was 65% which is notable since this is a new technique first attempted at the BDEP.

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

7. 2020 Monitoring Activities

The planned monitoring activities for 2020 RMP are listed below.

- RHI Trend Monitoring: 40 RHI polygons, including 2 polygons that were deferred from 2019 (Harvey Passage Divide Island and BOW45 - Urban Reserve, north of the Glenmore Tr SE).
- Riverbank bioengineering site effectiveness monitoring: 21 sites of which 10 are revisit sites from 2018 and 11 are new sites.
- Riparian restoration site effectiveness monitoring: 20 sites of which 15 are revisit sites from 2018 and 5 are new sites.
- Special projects
    - Annual geomorphic monitoring of the Elbow River downstream of the SWCRR including aerial photograph analysis, cross-section and longitudinal profile surveying, bed material sampling, and qualitative site hydraulic conditions assessment.
    - Post-construction effectiveness monitoring of the BDEP including fish and fish habitat, wildlife, riparian health, and bioengineering structural integrity monitoring activities.

Photo 7-1: Timber crib wall and fish habitat enhancement boulders at BDEP.

Encl.: Map 1 - 2019 Riparian Monitoring Program Sites

Attachment A: List of 2019 Riverbank Bioengineering Effectiveness Monitoring Sites
Attachment B: List of 2019 Riparian Restoration Effectiveness Monitoring Sites

8. References

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Riparian Monitoring Program

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Legend

Riparian Project
- Large-scale riparian retrofit
- Mixed techniques
- Native tree and shrub cuttings
- Native tree and shrub plantings

Riparian Bank Project
- Planting
- Primarily Vegetative
- Vegetated Cribwall
- Vegetated Retaining Wall
- Vegetated Riprap

Riparian Health Inventory Site

City of Calgary City Limits

WNO21 WNO19 NOS21 10 NOS20 NOS23 NOS5 40 91 BOW50 BOW99 BOW31 42 R9M 41 BOW98 89 82 116 BOW33 116A BOW44 6 ELB25 BOW80 48B ELB26 ELB33 BOW48 31 86 BOW74 ELB27 ELB35 88 ELB64 ELB63 87 BOW35 BOW46 BOW39 BOW37 BOW40 BOW38 BOW100 60 BOW79 BOW87 BOW78 BOW101 20 FOR9 (FOR1) FOR7 FOR3 FOR10

46A 46B 46C 46D1 46D2 46D3 46D4 46E1 46E2 46E3

Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Coordinate System: Calgary 3TM WGS 1984 W114

Scale Disclaimer: The map scale of 1:125,000 is only valid on a 11"x17" print.

Project No.	810-064
Date	May 2020
Scale	1:125,000

2019 Riparian Monitoring Program Sites

Map 1

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Attachment A

2019 Riverbank Bioengineering Effectiveness Monitoring Sites

Table A-1: 2019 Riverbank Bioengineering Effectiveness Monitoring Sites

Site #	Site Name	Delivery Agency	Typology	Age Class	Date of Assmts [1]	Success/ Failure [2]
6	Centre Street Bridge	WR	Primarily Vegetative	Year 1	a. July 23 b. Sept 24	F
46A[3]	AEP/COC BDEP Site 1-1	External	Vegetated Riprap	Year 1	a. July 17 b. Sept 9	S
46B[3]	AEP/COC BDEP Site 1-3	External	Vegetated Crib Wall	Year 1	a. July 18 b. Sept 10	S
46C[3]	AEP/COC BDEP Site 1-4	External	Primarily Vegetative	Year 1	a. July 18 b. Sept 10	S
46D1[3]	AEP/COC BDEP Site 2-1	External	Primarily Vegetative	Year 1	a. July 18 b. July 25	S
46D2[3]	AEP/COC BDEP Site 2-2 A	External	Primarily Vegetative	Year 1	a. July 22 b. July 26	S
46D3[3]	AEP/COC BDEP Site 2-2 B	External	Primarily Vegetative	Year 1	a. July 22 b. July 26	S
46D4[3]	AEP/COC BDEP Site 2-2 C	External	Primarily Vegetative	Year 1	a. July 22 b. July 26	S
46E1[3]	AEP/COC BDEP Site 4-1	External	Vegetated Riprap	Year 1	a. July 17 b. Sept 13	S
46E2[3]	AEP/COC BDEP Site 4-2	External	Vegetated Riprap	Year 1	a. July 16 b. Sept 13	S
46E3[3]	AEP/COC BDEP Site 4-3	External	Vegetated Riprap	Year 1	a. July 16 b. Sept 16	S
60	South Lafarge Pathway – BOW 79	Parks	Vegetated Riprap	Year 3	a. July 12 b. Oct 2	S
82	Memorial Off-Ramp – Outfall B73	WR	Vegetated Crib Wall	Year 1	a. July 16 b. Sept 23	S
86	Inglewood Golf Course B (9th Tee Bank)	WR	Vegetated Retaining Wall	Year 3	a. July 23 b. Sept 26	S
87	South Highfield Project: Bonnybrook (BB) Landfill, BB at Calf Robe, U/S of Lafarge & South Highfield Remainder	WR	Vegetated Crib Wall	Year 3	a. July 12 b. Sept 28	S
88	Discovery Ridge	WR	Vegetated Crib Wall	Year 3	a. July 15 b. Sept 25	S
89	Parkdale Blvd.	WR	Vegetated Crib Wall	Year 3	a. July 11 b. Sept 27	F
116	Outfall B69 U/S	WR	Primarily Vegetative	Year 1	a. July 19 b. Sept 18	S
116A	Outfall B69 D/S	WR	Vegetated Crib Wall	Year 1	a. July 19 b. Sept 19	S

Notes:
1. Assessments: a. Structure Assessment; b. Vegetation Assessment.
2. Failure sites are defined in KWL (2020b) *Riparian Monitoring Program 2019 Annual Report - Bank Effectiveness Monitoring*
3. See BOX 3 in KWL (2020b) *Riparian Monitoring Program 2019 Annual Report - Bank Effectiveness Monitoring*.

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Attachment B

2019 Riparian Restoration Effectiveness Monitoring Sites

Table B-1: 2019 Riparian Restoration Effectiveness Monitoring Sites

Master Site #	Site Descriptor	Site Name	Typology	Delivering Agency	Date of Detailed Assessment	Success/ Failure [1]
10	RE-NOS-10	Nose Creek – South of Beddington Trail	Native tree and shrub cuttings	Bow Valley Habitat Development	10	F
20	RE-FIS-20	Friends of Fish Creek – C	Native tree and shrub cuttings	Friends of Fish Creek	20	F
31	RE-BOW-31	Inglewood Bird Sanctuary	Native tree and shrub cuttings	City of Calgary, Parks	September 3 and 4, 2019	S
40	RE-BOW-40	TransAlta	Native tree and shrub plantings	Water Resources – RPP	August 26, 2019	S
41	RE-BOW-41	Wildwood	Native tree and shrub plantings	Water Resources – RPP	August 27, 2019	S
42	RE-BOW-42	Edworthy	Native tree and shrub plantings	Water Resources – RPP	August 29 and October 3, 2019	S
48B	RE-BOW-48B	Harvie Passage – south side channel	Large-scale riparian retrofit	Alberta Transportation	September 5 and 6, 2019	S
91	RE-BOW-91	Valley Ridge Golf Course	Native tree and shrub plantings	Water Resources – RPP	August 28, 2019	S
R9	RE-BOW-R9	Edworthy, Shaganappi, Crescent Heights	Native tree and shrub plantings	City of Calgary, Parks	August 30, 2019	S

Notes:
1. Failure sites are defined in KWL (2020a) *Riparian Monitoring Program: Riparian Effectiveness Annual Report.*