The City of Calgary

RIPARIAN MONITORING PROGRAM PHASE 2 FINAL PROGRAM REPORT

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Technical Summary

This Technical Summary includes detailed descriptions of the methods, data collection and analysis, results, success, and lessons learned for the riparian health trend monitoring, bank effectiveness monitoring, and riparian effectiveness monitoring components of the five-year (2018-2022) City of Calgary Phase 2 Riparian Monitoring Program (RMP). The three components of the RMP are described as follows:

- **Riparian health trend monitoring**: consists of ongoing monitoring of riparian sites in the city using the Riparian Health Inventory (RHI) protocols (Hansen, et al., 2000; Fitch, Adams, & Hale, 2014; Cows and Fish, 2016). Riparian health monitoring has been conducted since 2007 across Calgary's major streams and rivers. Riparian health trend monitoring was incorporated as one of the main objectives for the RMP as a means to inform progress toward achieving the riparian health targets identified in The City of Calgary's *Riparian Action Program* (City of Calgary, 2017). Health targets were established for a city-wide scale and for various riparian management zones corresponding to land use priorities (i.e., conservation, recreation, restoration). Riparian health scores are determined from an evaluation of vegetation, soil and hydrological parameters that are primarily assessed in the field. Riparian health scores fall into one of three broad categories – *unhealthy* (0-59% score), *healthy, with problems* (60-79% score) and *healthy* (80-100% score). RHI sites are monitored on a five-year revisit schedule and are typically large-scale polygons that can encompass one or more bank and/or riparian effectiveness sites.
- **Bank effectiveness monitoring**: consists of monitoring projects where the primary purpose is riverbank stabilization, protection, or erosion mitigation with bioengineering structural- and vegetation-based components. Bank effectiveness sites encompass the riverbank and often a strip as wide as 15 m along the top of bank. The bank effectiveness monitoring component consists of detailed assessments of individual project sites. Some of these projects are located in the trend monitoring areas.
- **Riparian effectiveness monitoring**: consists of monitoring projects where the main purpose is enhancing riparian habitat away from the bank, with little to no structural components. Riparian restoration sites are mostly focused on the top of bank (riparian) areas, and general riparian/floodplain areas but may extend down onto the bank of smaller streams and creeks. The riparian effectiveness monitoring component consists of detailed assessments of individual project sites. Some of these projects are located in the trend monitoring areas.

Program Objectives

Objectives for Riparian Health Trend Monitoring

Riparian health monitoring is important for tracking progress toward The City of Calgary's (The City) commitment to conserving and improving the ecological health of riparian areas in Calgary and for prioritizing future restoration and conservation efforts as part of an adaptive management approach.

The objectives for trend monitoring for this project are listed below.

1. Assess changes in city-wide riparian health primarily for major rivers and streams, excluding private residential land.
2. Measure and inform The City of progress toward meeting the city-wide riparian health target identified in the *Riparian Action Program* (City of Calgary, 2017) of 72% by 2026
3. Expand monitoring sites to be more representative of city-wide conditions for a larger cross section of sites including tributaries and priority source-water protection areas.

Objectives for Bank and Riparian Project Effectiveness Monitoring

The objectives for the bank and riparian effectiveness components of the RMP are listed below.

1. **Project Effectiveness Monitoring**: Determine the effectiveness of riverbank bioengineering and riparian restoration sites against the desired goals and objectives of each project.
2. **Site Selection and Typology**: Select a representative number of riverbank bioengineering and riparian restoration monitoring sites from The City's *Master List – Riparian Restoration Projects* bases on age class (described in the following 3 bullets) and typology (i.e., technique).
3. **Evaluate Success Year 1**: Evaluate vegetation establishment success (i.e., after the first growing season post construction) to determine early plant material establishment, survival rates, plant material quality, potential work structure deficiencies, performance ratings for each typology and bioengineering/planting technique, and adequacy of implementation and maintenance practices.
4. **Evaluate Success Year 3**: For sites that are three years post-construction, evaluate the effectiveness of each project relative to their intended restoration objectives (e.g., improved bank stability, erosion control, and establishment and improvement of native plant cover) and develop performance ratings for each typology and bioengineering/planting technique.
5. **Evaluate Success Year 5**: For sites that are five years or more post-construction, evaluate the effectiveness of each project relative to improvement of key ecological function/riparian health indicators, biodiversity indicators or progress toward a desired reference plant community or habitat type and develop performance ratings for each typology and bioengineering/planting technique.
6. **Techniques**: Identify advantages and limitations of riverbank bioengineering and streambank/riparian restoration techniques and if required, identify preferred techniques and plant species including plant material type (i.e., pot sizes, plugs, bare roots and/ or live cuttings) considered best suited to the site.
7. **Material Supply**: Identify advantages and limitations in plant material supply and make recommendations for involvement of local nurseries in the development of specific plant materials (i.e., species and stock type) to accommodate soil bioengineering design and local climate.
8. **Maintenance**: Evaluate the effectiveness of maintenance procedures.
9. **Citizen Science**: Integrate citizen science opportunities, where possible, into project effectiveness monitoring to support the *Riparian Action Program*'s education and outreach goals for improving community engagement and riparian awareness (City of Calgary, 2017).
10. **Design Improvements**: Provide recommendations for design improvement to develop more adapted techniques/approaches for the Calgary local conditions and watercourses for future applications that can be considered as part of an update to *the Design Guidelines for Erosion and Flood Control Projects for Streambank and Riparian Stability Restoration* (AMEC, 2012).
11. **Monitoring Recommendations**: Provide recommendations for future long-term monitoring needs (e.g., climate change resiliency monitoring).

Riparian Health Trend Monitoring Key Results

Long-term riparian health information is available for a subset of 58 sites along the Bow River, Elbow River, Nose Creek, West Nose Creek, and Beddington Creek in Calgary. These sites were used to support the preparation of the riparian health targets in the *Riparian Action Program* report (City of Calgary, 2017). For these sites, riparian health information was collected between 2007-2010, 2014-2015 and again between 2019-2020. Since 2014 and as part of Phase 2 of the RMP, riparian health monitoring has been expanded across the city to encompass 101 sites along these and three other major tributaries (Forest Lawn Creek, Twelve Mile Coulee and Pine Creek). Some sampling of unnamed ephemeral and intermittent streams in the Bow and Elbow River watersheds have also been done mainly in priority source-water protection areas (in 2016 and in 2021)and are discussed in section 2.1 of this report.

Below is a summary of key results for major creeks and rivers. Results presented here focus on long-term trend results for the 58 site sub-set and the expanded area that includes 101 sites.

Long Term Trend Highlights (subset of 58 sites):

- Compared to baseline conditions[1] for 58 sites with long-term data, **city-wide riparian health scores have increased from 61% to approximately 65% (2019/2020)** (remaining in the *healthy, with problems* category). This is based on an "*area-weighted average*"[2] of riparian health scores, consistent with how The City's *Riparian Action Program* riparian health targets were calculated (City of Calgary, 2017).
- Riparian health gains since baseline[3] were attributed to a combination of factors including beneficial impacts along the Bow and Elbow Rivers from the 2013 flood and improved management or restoration in some sites allowing for natural recovery. Of note, Balsam poplar (*Populus balsamifera*) recruitment (new growth) increased in 10 of 30 Bow River sites following the 2013 flood. This is significant given the importance of poplars as a keystone species that is vital to the foundation of healthy riverine ecosystems. The flow from the June 2013 flood event exceeded 1,700 m^3/s and provided sufficiently high flows to promote conditions suitable for promoting poplar regeneration such as sediment deposition, flood scour and high soil moisture levels co-incident with peaks in poplar seed release.
- By sub-basin, between 2007 and 2015, Bow River riparian health scores increased by approximately 3% from baseline conditions but declined slightly between 2014/15 and 2019/20. These minor score declines were mainly attributed to post-flood landscaping, bank stabilization and repair works and increased recreational use impacts. Bank stabilization projects since 2013 have resulted in a substantial net increase in riprap armouring along both the Bow and lower Elbow Rivers (below the Glenmore Reservoir). However, significant uptake in the use of soil bioengineering partially offsets negative impacts from rock armouring.
- The average Bow River riparian health score is 59% and in the *unhealthy* category, comparatively much lower than for the Elbow River, since the scores on the Bow account for upstream damming, flood berms, and water diversions (i.e., the Western Irrigation District diversion). The Elbow River was assessed as a 'small river' in Calgary, and thus excludes these parameters. The Elbow River riparian health scores are much different for the Upper and Lower reaches (i.e., above and below the Glenmore Reservoir). *Healthy* conditions in Weaselhead Flats and Griffith Woods parks in the Upper Reach have been maintained since 2007. Lower Elbow River health scores are lower but have shown slight improvements since 2007 linked

[1] Baseline assessments were completed between 2007 and 2010.

[2] Area-weighted averages account for the variance in RHI polygon (site) sizes, where larger riparian polygons have a stronger proportional influence on the average compared to smaller sites.

[3] Baseline assessments were completed between 2007 and 2010.

with ongoing restoration and improved management efforts. Most Nose Creek sites continue to rate as *unhealthy* whereas the West Nose Creek sites continue to rate as *healthy, with problems* on average. Historic impacts from channelization negatively affect Nose Creek riparian health scores, limiting potential for improvement.

- Riparian health trends by management zone show the largest score increase since baseline conditions for the "Restoration Management Zone". The highest average riparian health rating for riparian habitat is the "Conservation Management Zone" (i.e., natural environment parks such as Weaselhead Flats, the Inglewood Bird Sanctuary and Bowmont Park).

Expanded City-Wide Project Area Key Highlights (101 sites)

- Current riparian health scores reported on in Section 2 of this report are for an expanded project area of 101 sites encompassing 591 ha of riparian habitat and 84 km of bank length for eight major streams and rivers. This represents an addition of 44 sites encompassing 237 ha of assessed riparian habitat (a 43% expansion) and 31.8 km of bank length compared to the 58 site long-term sub-set. The expanded project area includes sampling key gaps geographically in the city along the Bow River, Elbow River, Nose Creek, Twelve Mile Coulee, Pine Creek and Forest Lawn Creek. The RMP target was to achieve a 30% minimum target (by length) of representative major stream/river reaches within city limits.
- **The current city-wide area-weighted riparian health score for the expanded area is approximately 69%** (*healthy, with problems*). Four large sites were added from Weaselhead Flats and Clearwater Legacy Park in the Upper Elbow which contributed significantly to the higher city-wide average due to overall healthy conditions in these important natural environment parks. Other sites along Twelve Mile Coulee and Nose Creek also contributed positively to the city-wide score.
- Common limiting factors across all systems are extensive bank and floodplain structural alterations due to recreation use and city infrastructure (pathways, bridges, stormwater outfalls and other park facilities). Permanent impacts have also resulted from channelization and consequent channel incisement along the lower half of Nose Creek (south of Airport Trail NE). Control of flood peak and timing due to upstream damming affects all Bow River riparian health scores in Calgary (an 11% score deduction).
- Widespread incursion of non-native grasses and invasive weeds is another common limitation. Invasive weeds are increasing in cover and distribution city-wide.

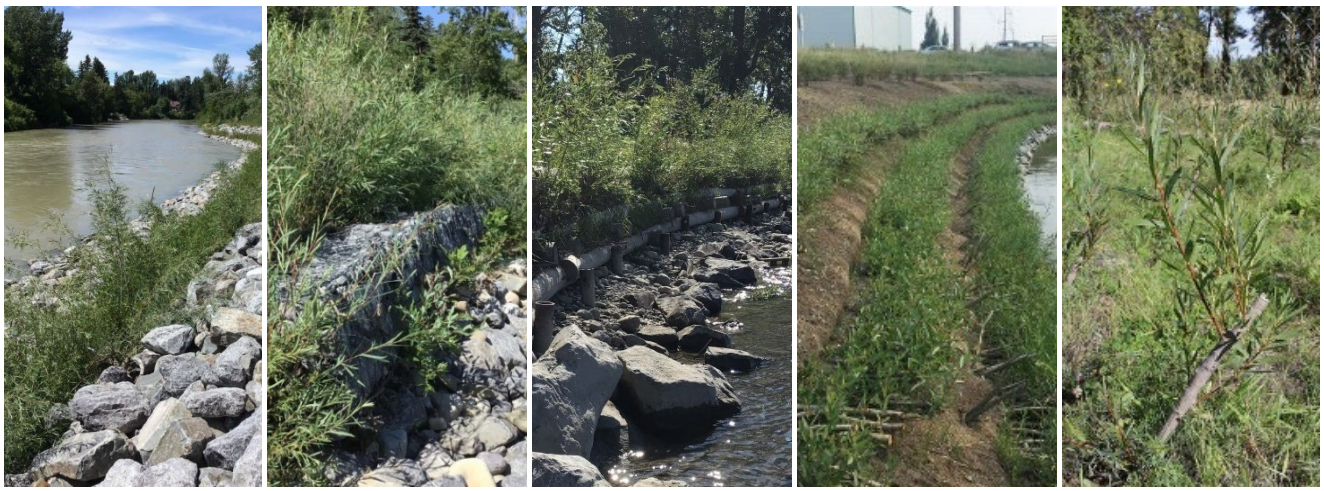
The 2013 Floods- How Did it Influence Riparian Health?

- Balsam poplar regeneration increased in 10 of 30 Bow River sites after the 2013 flood and remains at healthy levels at 10 sites. Poplar recruitment is largely linked to periodic flooding (Mahoney & Rood, 1998) and they require specific conditions for seedling germination and growth. The June 2013 flood event provided sufficiently high flows to promote the establishment and growth of these poplars in co-incident with peaks in poplar seed release.
- While the scour and deposition from the 2013 flood encouraged poplar regeneration it created hazards and risks to infrastructure necessitating the need for repairs and bank stabilization works. Bank alterations have increased along both the Bow and Elbow Rivers since the flood and riprap now accounts for 61% of the alterations along the Bow River compared with 40% in 2008/2010. However, recent bioengineering efforts have helped to partially mitigate adverse fish and wildlife impacts from bank hardening.

Bank Effectiveness Monitoring

Data Collection and Organization, and Methods

A total of 69 sites were assessed either once (42 sites), twice (24 sites), or three times (3 sites) for a total of 99 assessments over the five-year bank effectiveness program. Each site was classified according to five typology categories as shown in Figure 1 and three age classes (Year 1, Year 3, and Year 5+ post-construction). Data was collected for each site based on desktop review of background information and field reviews of functional performance, physical stability and material condition, and vegetation growth and health parameters. Failure site assessments were also completed when required. The data was collected in Microsoft® Excel® forms developed specifically for the RMP. A detailed description of these methods is included in Sections 3.1 and 3.2 of the report.



Vegetated Riprap	Vegetated Retaining Wall	Vegetated Crib Wall	Primarily Vegetative	Planting
Riprap bank protection with live cuttings inserted within the rock/joint planting	Mechanically stabilized earth (MSE) walls, or vertical earth/concrete walls with live cuttings inserted	Vegetated Crib Wall with live cuttings	Brush Mattresses/fascines /brush layers/wattle fences /live staking/vegetated soil wraps	Seeding, live staking and/or rooted stock planted along shoreline of river and creek banks

Figure 1: Bank Effectiveness Monitoring Typology

Ratings

A rating system was developed for the effectiveness components of the RMP to help identify individual sites that are successful in meeting project objectives and where there are opportunities to establish learnings and recommendations for better project design, implementation, maintenance, and vegetation success. Ratings for design, implementation, maintenance, success, and Bank and Riparian Quality Index were developed for the bank effectiveness monitoring sites as part of the Monitoring Plan (KWL, 2018). An overall score was developed for each site by combining the five individual ratings and applying a multiplier to achieve a total weighted score out of 100). Projects were subjectively classified into one of three ratings categories: Good (75-100), Fair (50-74), and Poor (0-49). The ratings allowed an understanding of which sites were performing well and which sites could be improved.

Failure Sites

Some monitoring sites are labelled 'failure sites' in this report. The definition of a failure site is based on the RMP project-specific definition in the *Monitoring Plan* (KWL, 2018) where a Year 1 age class site is determined to be a failure if: **1) the works are found to be missing, degraded or ineffective, and/or 2) if the woody vegetation survival is < 25%.** For Year 3 and 5+ age class sites, a site is determined to be a failure only if the works are found to be missing, degraded or ineffective. The vegetation survival failure criteria of < 25% does not apply to Year 3 and Year 5+ age class sites since it is not always possible to accurately assess the survival of planted woody vegetation for Year 3 and older age class sites due to either the growth of other vegetation obscuring dead cuttings/plantings and/or state of decay of the dead cuttings/plantings.

Bioengineering Techniques

Statistical analysis was also conducted on the bioengineering techniques that were identified for each transect at each site as part of the vegetation assessment. The nine techniques that were assessed are listed below.

- **Brush layers**: 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 (Gray & Sotir, 1996).
- **Brush mattress**: A layer of interlaced/adjacent live cuttings placed on the face of the riverbank (AMEC, 2012).
- **Fascine**: Fascines are live cuttings that are tied together in long cylindrical bundles. Contour fascines are installed in shallow trenches constructed on contour, and anchored in the trench using stakes (AMEC, 2012).
- **Live staking**: Insertion of live cuttings into the ground in such a manner as to promote root growth and leaf-out (Gray & Sotir, 1996).
- **Plantings**: 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 (AMEC, 2012).
- **Vegetated crib wall**: Consists of a hollow, box-like interlocking arrangement of structural timber, filled with suitable backfill material and layers of live cuttings (Gray & Sotir, 1996).
- **Vegetated retaining wall**: A vegetated structure used to resist unbalance lateral earth forces, retain earthen masses, and protect against scour and undermining (McCullah & Gray, 2005).
- **Vegetated riprap**: A layer of stone and/or boulder armoring that is vegetated, optimally during construction, using pole planting, brush layering and live staking techniques. (McCullah & Gray, 2005).
- **Wattle fencing**: Short retaining walls built by weaving living cuttings between upright stakes to form a lattice (Polster D. , 2020).

Statistical Analysis and Sample Size

Statistical analysis was completed on the collected data from the 69 individual sites mentioned above (99 assessments) including collected vegetation data where a total of 10,912 individual live cuttings and plantings were sampled via 227 transects and 669 quadrats. Statistical analysis was completed by typology, age class, bioengineering technique, monitoring site (for some data sets), and for various growth characteristics such as survivorship, vigour, condition, leader growth, shoot length, and stem diameter. For statistical analysis that was completed by typology and age class, the target population for each typology and age class was eight (8) sites with a minimum of five (5) sites so that there were enough samples to determine statistical significance.

Groupings of sites by typology and age class met the minimum target sample sizes except for two categories: Vegetated Retaining Wall Year 1 and Year 3 age class. Sample sizes for the nine bioengineering techniques ranged from a total of 55 transects for the plantings technique down to one transect for the wattle fence technique.

Limitations of Data and Assumptions.

Simple, correlative statistical approaches were used in the RMP to disentangle the factors driving project performance and to identify trends, with results that are significant as summarized in Section 3.3.2 of this report. However, there are some limitations regarding the RMP data and analysis that are listed below.

- The lack of documentation provided to the monitoring team limited complete understanding of monitoring sites – particularly maintenance aspects.
- The five-year monitoring timeframe for the program may have limited the ability to capture all relevant learnings, and the observations of the long-term (10 years or greater) effectiveness of the bioengineering approaches is limited.
- A truly independent site sampling approach was not possible because of the requirement to monitor some sites over the monitoring period to meet other project reporting obligations.
- There was limited site availability for some typologies and age classes which reduced the ability to conduct statistical analysis for those populations.
- Not all design, construction, and maintenance activities were able to be assessed by the RMP monitoring team during documentation or field reviews since activities could have been completed.
- Effectiveness analysis did not factor cost, construction complexity, and regulatory approval requirements/timelines in the analysis or recommendations.

These limitations did not significantly reduce the overall ability of the RMP to produce valuable results for bioengineering project effectiveness. Many results from the overall analysis remain statistically significant and those that were not valid were not included in this Final Program Report.

Bank Effectiveness Monitoring Key Results

Key activities, observations, and results from the five-year bank effectiveness monitoring component are listed below. More detailed results are contained in Section 3.3 of this report. The results are divided in General Findings and Statistical Results.

General Findings

Data Filling Key Knowledge Gap

The data that was collected for the bank effectiveness component is helping to fill a key technical, practical, and scientific knowledge gap for bioengineering projects. Until now there have been few monitoring studies conducted for bioengineering projects in Calgary or elsewhere in the province, across North America, or worldwide and none as thorough as the RMP (Stokes, et al., 2014; Zaimes, et al., 2019; Evette, et al., 2021).

Site Stability and Condition of Structural Materials

In general, most monitoring sites were observed to be stable with little to no erosion occurring within, upstream or downstream of the site. For the revisit sites, there was little to no change since the first assessments. However, there were a minority of sites (~10%) that were observed to have specific instances of erosion, undermining,

slope raveling, and backfill material washout. Often, the key reasons for the observed issues were that the materials selected prematurely degraded or the design approach were not suitable to resist the erosive forces.

All permanent or extended life-cycle materials used in the bioengineering sites were in good to very good condition. Temporary structural material such as matting, and wattles were in variable condition and did not always meet their intended function due to premature degradation or poor installation. Additionally, 21 of the 69 monitoring sites (30%) included a synthetic erosion control matting, geogrid, or wattle product where it appeared to not be necessary due to successful vegetation establishment and available alternate biodegradable products. These materials will now persist in a sensitive location in the environment (riverbank and/or riparian area) and will likely pose a hazard for human activities, fish, and wildlife.

Habitat Enhancements

Habitat enhancements such as instream boulders, woody debris, and overhanging vegetation that were incorporated into bioengineering structures are performing well. For example, overhanging cover was observed to be 2 m to 3 m at some locations and providing good overhead shade, cover, and organic debris input for fish habitat.

Vegetation Design, Installation, and Establishment

Most often, vegetation species and stock were selected appropriately. But where best practices for scheduling the installation of live cuttings was not followed, poor vegetation growth and high mortality was observed. A relatively new stock referred to as tall rooted stakes was found to provide a good option for summer construction when the use of dormant live cuttings is no longer recommended.

It was observed over several sites with full canopy closure because of higher density planting that invasive weed growth was limited, root growth from planted vegetation was binding soil, and that natural stabilization and ecological development is occurring over time.

Site-Specific Limiting Factors

The dry climate governs bioengineering design in Calgary overall due to low soil moisture conditions. Because of this, irrigation is needed to support vegetation establishment until an adequate root system is established. For failure sites, the next most often documented site-specific limiting factors for site stability and vegetation establishment were “erosion”, “existing vegetation competition”, and “maintenance issues” (six of seven sites). Over all assessments, the most often noted limiting factors for site stability and vegetation establishment were “maintenance issues” (93 of 99 assessments), “existing vegetation competition” (92 of 99 assessments), and “compacted soils” (76 of 99 assessments). Additionally, soil compaction was found to have a negative impact on vegetation growth.

Construction and Maintenance Practices

Contractors devised several innovative methods to allow successful construction outside of the dormancy period for live cuttings such as wooden pallets in riprap (not recommended) and creating planting holes using several forks on an excavator bucket. Remote operated solar irrigation and placing material using a telebelt were also observed.

Maintenance documentation needs to be improved, and practices such as weed whacking should be discontinued in favor of hand practices due to the damage to planted vegetation that was observed. While limited irrigation data was available, better irrigation appears to be needed for container plants that are installed above the bank on the terrace. Temporary browsing protection fencing needs to be repaired immediately, otherwise severe browsing has been observed to occur. Browsing during the earlier period of plant establishment was found to reduce plant survival.

Documentation for the watering regime used for irrigating sites was only available for seven of 69 sites and specific data on irrigation method (drip or spray), volume and during were not available. However, observations of moisture stress and irrigation systems during the field inspection resulted in noting that irrigation for container plants on the top of bank needs improvement. It was also noted that impact sprinkler heads installed higher from the ground (i.e., 1.3 m) thoroughly cover larger areas through the plants establishment period and avoid potential erosion created by water spray interfering with vegetation when sprinkler heads are installed closer to the ground.

Deep Binding Root Mass

It was visually estimated that overall, an average of 85% of the streambank for all monitoring sites had deep, binding root mass. A total of 23 sites were observed with 100% of the bank with deep, binding root mass.

Failure Sites

Seven failure (7) sites were identified out of the 99 assessments completed over 2018-2022. The most common reason for failure was due to vegetation survival of less than 25% (5 sites). Other failures are due to the structures no longer being present (one Planting typology site) or failing structurally (one Primarily Vegetated typology site).

Ratings

The average ratings are summarized in Table 1 for all 99 bank effectiveness assessments. The average overall rating for all sites assessed was 67/100 which falls in the **'Fair'** category. The average design rating was highest, with maintenance and BRQI ratings as the lowest.

Many sites were observed with outstanding vegetation establishment and growth across the city that will serve as benchmarks for future bioengineering and riparian planting projects. **The highest-rated site was the Riverdale Avenue Retaining Wall Replacement Phase 2 – Downstream on the Elbow River** (see Photo 1 and Photo 2 below).

Table 1: Mean Ratings

Age Class	Design rating (/18)	Implementation rating (/18)	Maintenance rating (/18)	Success rating (/24)	BRQI (/22)	Overall score (/100)	Number of samples
1	14	12	12	18	13	67	37
3	14	13	11	16	13	65	33
5+	14	12	10	18	14	69	29
Mean	14	12	11	17	12	67	--
Total (/100)	**78**	**67**	**61**	**71**	**55**	**67**	

Photo 1: Bank Effectiveness Highest Rated Site: Riverdale Avenue Retaining Wall Replacement Phase 2 – Downstream (July 21, 2020)

Photo 2: Bank Effectiveness Highest Rated Site: Riverdale Avenue Retaining Wall Replacement Phase 2 – Downstream (July 25, 2022)

Performance Targets

Results for woody vegetation survival, cover, and density of living shoots for several bioengineering techniques were compared to the literature values to validate site performance and confirm if literature targets are applicable to projects in Calgary. Several published targets were met or exceeded, confirmed that the literature values can be used for Calgary bioengineering projects.

Statistical Results

Vegetation Survival and Growth

The 2018-2022 bank effectiveness results for survival of Year 1 age class live cuttings and container plants combined was **76%** (n = 7,280). Analyzed separately, survival success was as follows: Year 1 age class container plants was **94%** (n = 1,982), and Year 1 age class live cuttings was **69%** (n = 5,298).

Year 1 age class survival and vegetation growth data were collected for both live cuttings and container species, as presented in Section 3.3.2 of the report. The species that performed best as both live cutting and container plant was **sandbar willow (*Salix interior*).**

For 10% of monitored sites, woody vegetation canopy cover was **over 70%.** Woody vegetation canopy cover was generally 6% to 10% greater for Year 3 versus Year 1 projects; and by Year 5+, woody vegetation canopy cover was highest for the **brush mattress technique**. The density of living shoots target was achieved for brush layers, fascines, and brush mattress bioengineering techniques.

Year 1 survival and vegetation growth data **by bioengineering technique** is presented in Section 3.3.2 of the report. The highest performing

Seeding Germination Success

Seeding germination success was found to vary widely among the seeded graminoid and forb species. Among the 54 assessed species, three species has a 100% germination success rate in the Year 3 age class sites, and seven species had a 100% germination success rate in the Year 5+ age class sites, most of which were non-native that are not preferred for bioengineering applications. Six native species had germination rates less than

100% but more than 50% for at least one age class, including slender wheat grass (*Elymus trachycaulus* ssp. *trachycaulus*), fowl bluegrass (*Poa palustris*), Canada wild rye (*Elymus canadensis*), wild blue flax (*Linum lewisii*), and northern wheat grass (*Elymus lanceolatus*). More than half (n=28) of the species seeded were not observed, meaning they likely did not establish. In particular, 11 species were seeded 5 or more times and were not found in the surveys.

The seeding method with the highest germination success rate was **drill seeding** at 42%. Broadcast seeding was second at 36%, and hydroseeding was lowest at 31%. The differences were not statistically significant but do possibly point to drill seeding as a best practice, where it is feasible and broadcast seeding under erosion control matting as an efficient and low-cost method.

Herbaceous Species Cover

The mean percent herbaceous cover for Year 1 age class is 33%, for Year 3 age class is 17%, and Year 5+ age class is 14%. A possible explanation for the decrease in herbaceous cover over the three age classes could be that woody vegetation cover is increasing, shading out the herbaceous vegetation, and limiting its growth.

The results for percent herbaceous cover by bioengineering technique show that the seeding technique has the highest mean percent cover for Year 3 and Year 5+ age class sites. This is an intuitive result since this technique targets herbaceous plant growth. The lowest mean percent cover for Year 1 age class sites is the riprap technique at 0%, for Year 3 age class sites is the brush mattress technique at 0%, and for the Year 5+ age class sites are the riprap, vegetated crib wall, and vegetated riprap techniques that are all at 1%.

Matching Native Vegetation Elevation, Soil Amendment, and Fencing

Beneficial practices identified and verified based on statistically significant results include: 1) design the lowest elevation of planted vegetation (woody, herbaceous and emergent) to match the observed lowest elevation of native vegetation at a site; 2) soil amendment use during planting of vegetation; and 3) fencing use to protect against browsing and disturbance.

Soil Compaction

Of the total number of sites that were assessed, 51 of 65 sites (78%) were classified as having significant compaction issues. Soil compaction impedes the growth of planting/cutting roots and shoots, impacts survival rates and vigour, and contributes to increased runoff due to decreased water percolation within the soil.

Invasive Weed Species Monitoring

In total, 19 invasive weed species were observed across all sites, based on transect and quadrat data, consisting of 12 *Noxious* weeds, two *Prohibited noxious* weeds, and five other weeds. The most common invasive weed species observed were creeping thistle (*Cirsium arvense*), observed at 89% of sites (82 of 92 assessments), followed by smooth perennial sow-thistle (*Sonchus arvensis* ssp. *Uliginosus*), observed at 84% of sites (77 of 92 assessments).

Bioengineering Technique Performance

Based on data from five woody vegetation growth parameters (leader growth, shoot length, diameter, Year 1 age class survival, and woody vegetation canopy cover), each bioengineering technique was ranked from highest to lowest performance as shown in Table 2. **The highest rated technique was brush mattress, followed by the vegetated crib wall, vegetated retaining wall, and brush layers**. The lowest performing technique based on the above listed parameters was **live staking.**

Note that this method only includes the five parameters listed above and does not include considerations such as cost, construction complexity, or regulatory approval requirements/timelines. While results show that certain

bioengineering techniques may be performing better than others based on the data that was collected, a full evaluation of growing performance, cost, construction, and regulatory complexity should be undertaken when evaluating a particular bioengineering approach or technique. Some techniques can still be effective and preferred because of relatively low cost, simple design, and less complex construction. To mitigate low survivorship or growth parameters for a certain technique, the density of installed live cuttings and container plants can be increased so that survivorship, density, or cover targets can still be met. Additionally, it is recommended that projects using lower performing techniques should closely follow best practices described in the main report.

Table 2: Bioengineering Technique Performance Ranking

Bioengineering Technique	Average Rankings[1]			Average Ranking[4]	Overall Ranking[5,6]
	Year 1[2]	Year 3[3]	Year 5+[3]		
Brush layers	5	2	4	3.7	4
Brush mattress	3	3	1	2.3	1
Fascine	6	4	--	5.0	5
Live staking	8	8	6	7.3	8
Plantings	4	7	6	5.7	7
Vegetated crib wall	2	1	5	2.7	2
Vegetated retaining wall	--	5	2	3.5	3
Vegetated riprap	7	6	3	5.3	6
Wattle fencing [6]	1	--	--	--	--

Notes:
1. Rankings are 1 for the highest-and 9 for the lowest.
2. Year 1 age class ranking calculation is the average ranking by bioengineering technique for five Year 1 parameters: mean leader growth, mean shoot length, mean stem diameter, mean woody vegetation canopy cover, and mean survival rate.
3. Year 3 and Year 5+ age class rankings are the average ranking by bioengineering technique for four Year 3 and Year 5+ parameters: mean leader growth, mean shoot length, mean stem diameter, and mean woody vegetation canopy cover.
4. The average ranking was calculated by averaging Year 1, Year 3, and Year 5+ age class rankings for each bioengineering technique.
5. This ranking method only includes the five parameters listed above and does not include considerations such as cost, construction complexity, or regulatory approval requirements/timelines.
6. Wattle fencing was not included in the overall average ranking due to the small sample size for measurements (n = 30) for only one age class.

Riparian Effectiveness Monitoring

Data Collection and Organization, and Methods

In total, 42 reconnaissance and 59 detailed assessments were completed over the course of the five-year program. Of the 31 sites that underwent detailed assessments, 14 were monitored twice and 6 were monitored three times. Each site was classified according to typology (Table 3) and age class (i.e., Year 1, 3, and 5+).

Data was collected for each site based on a desktop review of background information and detailed site assessments. Detailed site assessments included various data collections methods, including pin-point transects, quadrats, and vegetation growth and survivorship assessments. Failure site assessments were also completed when required. Data was collected in analogue form using data sheets developed specifically for the RMP.

Table 3: Riparian Effectiveness Typologies

Typology	Description	Photo
Native Tree and Shrub Cuttings	Projects involving primarily the use of live Native Tree and Shrub Cuttings.	
Native Tree and Shrub Plantings	Projects involving primarily the use of native tree and shrub rooted plugs and/or potted plants.	
Mixed Techniques	Projects involving a mix of techniques, including live cuttings and rooted stock, in addition to either a native seed mix or herbaceous plantings, site preparation such as weed removal, or in combination with one or more unique features such as Waterboxx® planters.	
Large-Scale Riparian Retrofit	Large-scale construction projects, often involving multiple techniques. Includes the following three projects: • **Site #48B** (Harvie Passage – South Side Channel); • **Site #68** (Quarry Park Fish Compensation Project); and • **Site #92** (Bowmont Natural Area East – A).	

Ratings

Similar to the bank effectiveness component of the project, each riparian effectiveness project was rated using the five different rating systems developed specifically for the RMP project: design, implementation, maintenance, success, and BRQI. The individual ratings were also summarized to give projects an overall score out of 100. Projects were subjectively classified into one of three ratings categories: Good (75-100), Fair (50-74), and Poor (0-49).

Failure Sites

As discussed above for the bank effectiveness component of the project, the term 'failure' was applied to some projects, including some riparian effectiveness projects. For the RMP, a site was considered a failure if it had less than 25% survival of installed woody material. The term 'total failure' was used for riparian effectiveness sites where the entre site did not meet the minimum threshold of 25% survivorship. The term 'partial failure' was used for sites where a portion of the site (e.g., one technique) failed but another portion of the site was successful (i.e., it had greater than 25% survival). All sites deemed to be failures underwent a detailed failure analysis to determine potential causes of the poor outcomes.

Statistical Analysis and Sample Size

Statistical analyses were completed on the collected data from 57 assessments spanning 2018 to 2022 (Table 4). Analyses were completed by typology, age class, and monitoring site (for some data sets) for various growth characteristics such as survivorship, vigour, condition, leader growth, shoot length, and stem diameter. A minimum of five sites per typology and age class was required to achieve a statistically significant sample size. Of the 12 possible age class / typology combinations, 50% met this minimum size threshold.

In total, 5,457 individual live cuttings and plantings from 81 transects and 243 quadrats were analyzed. Analyses were also completed on the failure sites, including the proportion of failures by age class and typology as well as the limiting factors to restoration success and the main causal factors for restoration failure.

Table 4: Final Number of Detailed Assessments by Age Class and Typology for Statistical Analysis

Age Class	Typology				
	Cuttings	Mixed	Plantings	Riparian Retrofit	Total
1	2	6	9	3	20
3	5	5	9	3	22
5+	4	3	5	3	15
Total	**11**	**14**	**23**	**9**	**57**

Data Limitations

The data included in the riparian effectiveness analysis does have some limitations, including small sample sizes in some cases that were not always sufficient to make robust statistical conclusions. Additionally, several riparian effectiveness sites were visited several times, including sites from different age classes. As a result, the same re-visit sites can be found in several age classes for the same analyses. The results of these analyses, presented by age class, should be interpreted temporally with caution, as the presence of repeated data does not allow for statistical comparisons. However, these limitations did not significantly reduce the overall ability of the RMP to produce valuable results for riparian project effectiveness. A number of the results from the overall

analysis remain statistically significant. Data limitations were discussed in detail above for the bank effectiveness component of the project.

Riparian Effectiveness Monitoring Key Results

Key activities, observations, and results from the five-year riparian effectiveness monitoring component are listed below. More details on key results are contained in Section 4.3 of this report. The results are divided in General Findings and Statistical Results.

General Findings

Record Keeping

Improved record keeping of project-specific documents was noted as a potential improvement area for future riparian effectiveness projects.

Random Plantings

Random planting as a restoration technique was assessed for evidence of success. Unfortunately, strong evidence is lacking at this time, partly due to the low sample size of projects available for monitoring and partly due to the mixed results of those sites that were monitored.

Site-Specific Failure Factors

The main cause of failure for the riparian effectiveness sites monitored was vegetation competition, which was a contributory factor at 100% of failure sites. Other important factors were poor planting installation (67% of failure sites affected) and damage by wildlife (e.g., beaver cutting) (58% of failure sites affected).

Site-Specific Limiting Factors

Herbaceous species competition, wildlife, and human disturbance were found to be the main limiting factors to restoration success, affecting 83%, 31%, and 26% of sites, respectively.

Failure Sites

Of the 42 unique riparian effectiveness projects assessed over the course of the program, 12 were total failures and 3 were partial failures. Refer to the section above (page vi) for a description of the terms ‘failure’ and ‘partial failure’ as they pertain to this project. The native tree and shrub cuttings typology had the greatest number of failures.

Ratings

Average overall rating of the 57 assessments completed over the course of the program was 55 out of 100 (Fair), indicating moderate overall success. Generally speaking, riparian effectiveness sites scored well for design ratings, but suffered with low implementation and maintenance ratings. The highest rated site was **Griffiths Woods – RBC and Other Plantings** site (see Photo 3 and Photo 4 below).

Photo 3: Riparian Effectiveness Highest Rated Site: Griffiths Woods – RBC and Other Plantings site (2018)

Photo 4: Riparian Effectiveness Highest Rated Site: Griffiths Woods – RBC and Other Plantings site (2018)

BRQI

Similar to the overall rating, BRQI scores rated moderately overall (53 out of 100). In general, riparian effectiveness sites tended to have high vegetation cover and low amounts of riprap and concrete. BRQI scores often scored below optimally for factors such as high invasive species cover and poor regeneration of preferred woody plant species.

Statistical Results

Performance of Individual Woody Species

A large amount of data was collected on the growth performance of individual live cutting and container shrub species, data which will be useful to practitioners when selecting woody species for future restoration projects. In general, most native species tended to perform well when installed as container shrubs. Sample sizes are limited for some species.

Year 1 Survivorship of Live Cuttings and Container Plants

Year 1 survivorship was found to be much higher for container plants (93%, n=1,701) compared to live cuttings (47%, n=621). Commonly used species such as balsam poplar, red-osier dogwood (*Cornus sericea*), and sandbar willow had low Year 1 survivorship values (range = 25% to 51%) when installed as live cuttings. All three species had greater than 80% survival when installed as container shrubs. As well, a number of native shrub and tree species monitored had estimated Year 1 survivorship values of 100% (e.g., northern gooseberry [*Ribes oxyacanthoides*]), although sample sizes were small for some species.

Woody Species Survivorship Based on Aspect and Shade

Although there were some significant findings, Year 1 survivorship of cuttings and plantings showed a clear results with respect aspect. While survivorship of plantings was significantly higher in sunny versus shady locations, the same relationship was not true for cuttings.

Woody Species Growth Measurements

Stem diameters and shoot lengths of woody species as a whole were generally higher for older age class sites, indicating successful establishment over time. Leader growth tended to be higher for Year 1 and Year 3 age class sites compared to Year 5+ age class sites, a trend which reflects natural slowing of growth as vegetation ages. However, these relationships could not be tested statistically due to the presence of the same sites in multiple age classes (sample dependence).

Woody Species Performance by Site

Sites monitored were highly variable both in terms of Year 1 age class woody species survivorship and total woody canopy cover over time. Year 1 survivorship ranged from 30% to 100%. Woody canopy cover is improving at a number of sites, which is the goal of all riparian restoration projects; however, some sites have actually seen declining canopy cover over time.

Woody Species Performance Over Time

For sites assessed multiple times during the course of the program, there was a wide variability in growth performance of woody species over time. Average shoot growth of container shrubs was 10 cm per year, whereas live cuttings showed growth of 13 cm per year. A few sites had negative growth over time.

Herbaceous Seed Mixes

Grass species that established best when used in herbaceous seed mixes included: slender wheat grass (*Elymus trachycaulus* ssp. *trachycaulus*), northern wheat grass (*E. lanceolatus*), Canda wild rye (*E. canadensis*), fowl bluegrass (*Poa palustris*), and western wheat grass (*Pascopyrum smithii*). Forb species that established best included: tall goldenrod (*Solidago altissimus*), Canada milk vetch (*Astragalus canadensis*), purple prairie clover (*Dalea purpurea*), wild blue flax (*Linum lewisii*), and wild vetch (*Vicia americana*).

Invasive Plant Species

Invasive plant species were observed at every riparian effectiveness site. The mean number of invasive species was five (range: 1 to 13). Creeping (Canada) thistle (*Cirsium arvense*) and smooth perennial sow-thistle (*Sonchus arvensis* ssp. *uliginosus*) were the most commonly observed species.

Soil Compaction

Compacted soil was generally not a concern at most riparian effectiveness sites. Most projects involved plantings and cuttings being installed into existing vegetation with no major construction works. The exceptions were the three Large-Scale Riparian Retrofit. Not coincidentally, these retrofit sites had significantly higher soil compaction compared to the other three typologies.

Key RMP Conclusions

The following section includes the key conclusions from the trend monitoring and effectiveness monitoring components of the RMP. The conclusions are organized according to the RMP objectives as listed in Section 1.1.

Trend Monitoring Key Conclusions

Trend Monitoring Objective 1 and 2: The first objective of the trend monitoring component was to assess changes in city-wide riparian health primarily for major rivers and streams, excluding private residential land. The second objective of the trend monitoring component was to measure and inform The City of progress toward the city-wide riparian health target identified in the *Riparian Action Program* (City of Calgary, 2017): an average city-wide riparian health score of 72% by 2026. Key conclusions related to this objective are listed below.

The average city-wide riparian health score has improved compared to baseline and has increased from 61% to approximately 65% for the 58 sites with long-term data (remaining in the *healthy, with problems* category). Riparian health gains since 2007 were attributed to a combination of factors including beneficial impacts along the Bow and Elbow Rivers from the 2013 flood and improved management or restoration in some sites allowing for natural recovery.

The current city-wide riparian health score is approximately 69% (*healthy, with problems*) for the total expanded area representing 101 sites. This score does not represent entirely a long-term monitoring result, but it is a representation of the current city-wide score based on the expanded area. The addition of four large natural environment park sites influenced the increase of the score due to the overall healthy condition of these sites. Common limiting factors are extensive bank and floodplain structural alterations due to recreation use and city infrastructure (pathways, bridges, stormwater outfalls and other park facilities) as well as widespread incursion of non-native grasses and invasive weeds.

These trend analysis results are currently informing the progress to meet the 2026 target and the results show that great strides have been made to improve riparian health in the city. However, the current city-wide riparian health score is 69% and the 2026 target has not yet been achieved. This indicates that **enhanced efforts such as riparian restoration and the conservation of existing undeveloped riparian areas are needed to accelerate the improvement trend to meet the 2026 target**. Proactive conservation of existing undeveloped riparian areas is essential to achieving The City's Riparian Action Program goals including the Land Use Planning target of “No Net Loss” of riparian open spaces along major perennial creeks and rivers at a city-wide scale. Monitoring riparian health trends is integral to assessing success/failure and for informing and directing ongoing riparian restoration, stewardship and management efforts in Calgary.

Trend Monitoring Objective 3: The third objective of the trend monitoring component was to expand monitoring sites to be more representative of city-wide conditions for a larger cross section of sites including tributaries and priority source-water protection areas. Key conclusions related to this objective are listed below.

In addition to the expanded area encompassing 101 sites, there were an additional 21 sites assessed which including 18 sites on ephemeral and intermittent streams in priority source-water areas for a total of 122 sites city wide. Gap analyses identified areas where additional sites were needed in order to meet a target of a city-wide representative sample for riparian health (30% coverage by length of named permanent streams/rivers). Sites identified in this analysis were completed as part of the 2018-2022 project achieving this 30% target.

Effectiveness Monitoring Key Conclusions

Key Conclusions by RMP Objectives

Conclusions for bank and riparian effectiveness monitoring have been summarized below with respect to project objectives. Key conclusions are listed below.

Effectiveness Monitoring Objective 1 – Project Effectiveness Monitoring: The first objective of the RMP was to determine the effectiveness of bank and riparian sites against the desired goals and objectives of each project. Key conclusions are summarized below.

- Based on the ratings system developed for the RMP, the overall average ratings for all bank and riparian effectiveness sites were in the 'Fair' category (67 / 100 and 60 / 100 respectively) which means that there is room for improvement in the way that bioengineering and riparian restoration projects in Calgary are delivered. Based on the ratings, projects were designed better than they were implemented and maintained. Improving best practices for plant installation and schedule or appropriate stock selection would improve long-term survival. Improving maintenance practices such as weeding, irrigation, and documentation will also improve BRQI ratings, which points to improved maintenance as the focus for overall bioengineering and riparian restoration project improvement.
- Mean design, implementation, maintenance, success, and BRQI ratings were relatively consistent between Year 1, Year 3 and Year 5+ age classes for both bank and riparian effectiveness. So the age of the site did not have a strong influence on the ratings.
- Many sites were observed to have outstanding vegetation establishment and growth across the City that will serve as benchmarks for future bioengineering and riparian planting projects. The Riverdale Avenue Retaining Wall Replacement Phase 2 – Downstream (Age Class: Year 1, Typology: Vegetated Crib Wall) on the Elbow River was identified as the highest rated bank effectiveness site and is featured in Box 11 in the main report. The Griffiths Woods – RBC and Other Plantings site (Age Class: Year 1, Typology: Native Tree and Shrub Plantings) on the Elbow River was the highest rated riparian effectiveness site and is shown in Box 12 in the main report.

Effectiveness Monitoring Objective 2 – Site Selection and Typology: The second objective of the RMP was to select a representative number of bank and riparian effectiveness monitoring sites from The City's *Master List – Riparian Restoration Projects* based on age class and typology. Key conclusions related to this objective are listed below.

- There were adequate monitoring sites available to develop protocols and categorize bank effectiveness sites into five typologies (Vegetated Riprap, Vegetated Retaining Wall, Vegetated Crib Wall, Primarily Vegetative, and Planting) and three age classes (Year 1, Year 3 and Year 5+) and riparian effectiveness sites into four typologies (Native Tree and Shrub Cuttings, Native Tree and Shrub Plantings, Mixed Techniques, and Large-scale Riparian Retrofit) and three age classes (Year 1, Year 3 and Year 5+).
- There were adequate sample sizes for most combinations of typology and age class for bank effectiveness statistical analysis.
- Only half of the age class / typology combinations had adequate sample sizes for the riparian effectiveness component.

Effectiveness Monitoring Objectives 3, 4 and 5 – Evaluate Success of Year 1, Year 3 and Year 5+ Age Class Sites: The third, fourth and fifth objective are combined due to data similarities. The third objective of the RMP was to evaluate vegetation establishment success after the first growing season post construction. The fourth objective of the RMP was to evaluate the effectiveness of each Year 3 age class project relative to their intended restoration objectives (e.g., improved bank stability, erosion control, and establishment and

improvement of native plant cover). The fifth objective of the RMP was to evaluate the effectiveness of each Year 5 and older age class project relative to improvement of key ecological function/riparian health indicators, biodiversity indicators or progress toward a desired reference plant community or habitat type. Key conclusions related to these objectives are listed below.

Bank Effectiveness Key Conclusions

- Year 1, Year 3 and Year 5+ age class bank effectiveness projects have mostly been successful in relation to vegetation establishment and structure effectiveness with no major erosion or scour issues observed at most sites (exceptions have been classified as failure sites).
- The design, construction and maintenance of permanent materials appears to be satisfactory as almost all of the permanent materials used at the bank sites remain in good to very good condition, with the exception of decaying timber at the older timber crib wall sites prior to woody vegetation establishment. The implementation of temporary erosion and sediment control materials could be improved since they were observed to be in variable condition and did not always meet their intended function due to premature degradation, not using the material for its intended purpose, or poor installation. Additionally, synthetic materials were observed to have been used when biodegradable products would have been suitable and would have less impact on the environment.
- Live cutting survival rates were found to be typically lower than container plants. The brush mattresses technique and plantings technique were the highest Year 1 age class survivorship out of all the techniques with a large number of samples. Woody vegetation canopy cover was measured to increase over the Year 1, Year 3, and Year 5+ age classes; however, the overall mean canopy cover was not measured to be as high as expected in comparison to the literature values.
- Based on leader growth, shoot length, stem diameter, and condition data, **sandbar willow** was the best performing species for both container plants and live cuttings.
- Higher soil moisture conditions are typically found at locations with lower sun exposure which can lead to higher growth, which was observed in the results for measured growth parameters for the “North, North-East, East” aspect category.
- Top herbaceous species performers with good germination success that are native species were slender wheat grass, fowl bluegrass, Canada wild rye, wild blue flax, and northern wheat grass. Many native seed species did not germinate which confirms the general understanding that native herbaceous species are difficult to establish.
- Poor vegetation growth and high mortality was observed at sites where best practices for plant installation schedule or appropriate stock selection were not followed. High vegetation mortality was also the most often reason for failure sites. Site stability and vegetation success were also limited by erosion, existing vegetation competition, and maintenance issues.

Riparian Effectiveness Key Conclusions

- Container plants were found to have high survival rates that were much higher than live cuttings survival rates. However, when live cuttings successfully established, they were measured to have higher growth performance than container plants.
- **Sandbar willow** was the best performing species for container plants as it consistently measured in the top two or three for all measured parameters. For live cuttings species, hungry willow and beaked willow performed well for the Year 1 age class, shining willow and false mountain willow performed well for the Year 3 age class, and shining willow performed well for the Year 5+ age class.

- The majority of sites that were assessed multiple times had increasing shoot lengths over the monitoring period. This data provides a quantitative indication of the shoot growth that might be expected for riparian restoration projects.
- Top herbaceous species performers with good germination success that are native species included slender wheat grass, tall goldenrod, northern wheat grass, Canada wild rye, and fowl bluegrass. Otherwise, many native seed species were not recorded on sites.
- The most common reason for failure was low survival of live cuttings that was often a result of existing vegetation competition in the form of non-native perennial grasses such as reed canary grass. Failure was also observed when best practices for plant installation were not followed.

Effectiveness Monitoring Objective 6 – Techniques: The sixth objective of the RMP was to identify advantages and limitations of riverbank bioengineering and streambank/riparian restoration techniques and if required, identify preferred techniques and plant species including plant material type (i.e., pot sizes, plugs, bare roots and/ or live cuttings) considered best suited to the site. Key conclusions related to this objective are listed below.

Bank Effectiveness Key Conclusions

- Based on the data, the highest rated technique was **brush mattress**, followed by the vegetated crib wall, vegetated retaining wall, and brush layers. The lowest performing technique was **live staking**. Note that this analysis does not include cost, construction complexity, and regulatory approval requirements/timelines which may affect the technique selected for a project.
- Observation of installation of container plants in exposed, high velocity locations were that they were easily eroded and displaced. This wasn't the case for cuttings as they resisted high velocity flows.
- There was limited site data for tall rooted stakes (TRS) but where they were installed properly they were observed to be establishing well. The use of TRS as substitution for live cuttings during summer construction appears to be confirmed.

Riparian Effectiveness Key Conclusions

- Based on Year 1 survivorship data, plantings are the preferred restoration technique over live staking.
- Based on the data collected, the effectiveness of the new planting technique where small plugs of native tree and shrub species are randomly planted on a site in large quantities with minimal follow-up maintenance or monitoring cannot be confirmed. More research on the effectiveness of this technique is needed.

Effectiveness Monitoring Objective 7 – Material Supply: The seventh objective of the RMP was to identify advantages and limitations in plant material supply and make recommendations for involvement of local nurseries in the development of specific plant materials (i.e., species and stock type) to accommodate soil bioengineering design and local climate. Key conclusions related to this objective are listed below.

- TRS were observed to successfully support construction of bioengineering projects outside of the typical dormancy period for live cuttings. Note that TRS must have adequate root mass development prior to installation.

Effectiveness Monitoring Objective 8 – Maintenance: The eighth objective of the RMP was to evaluate the effectiveness of maintenance procedures. In general, improvements to maintenance practices were noted for many of the assessed sites with irrigation, existing vegetation competition, herbaceous species competition, weeding, and site repairs were often noted. Key conclusions related to this objective are listed below.

- The lack of documentation was a common reason for low maintenance ratings that contributed to lower overall ratings. Improvements to contractor requirements for documentation and more stringent maintenance requirements would have quickly increased overall maintenance ratings.
- Specific data on irrigation method (drip or spray), volume, and duration were not available so specific conclusions were not possible. However, it was observed that moisture stress was occurring on some vegetation, particularly container plants on the top of bank. It was also noted that impact sprinkler heads installed higher from the ground (i.e., 1.3 m) cover larger areas than other methods and avoid potential erosion created by water spray interfering with vegetation when sprinkler heads are installed closer to the ground.
- Competition from herbaceous plant species was the most common site-specific limiting factor for vegetation establishment success cited at both the bank effectiveness and riparian effectiveness monitored sites. In many cases, high seeding application rates appear to be the main source of herbaceous competition with woody vegetation.
- Mechanical weeding using a weed whacker resulted in damage to the planted vegetation. Manual weed removal provided better results. The mowing of native grasses did not allow for proper establishment and reseeding.
- *Noxious* weeds are prevalent on bank effectiveness sites, but *Prohibited Noxious* weeds are currently not.
- Temporary browsing protection fencing has an important influence on vegetation establishment. Browsing by beavers was observed when the fencing was in disrepair. Depending on the site, damaged fencing was causing a safety risk to the public.

Effectiveness Monitoring Objective 9 – Citizen Science: The ninth objective of the RMP was to integrate citizen science opportunities, where possible, into project effectiveness monitoring to support the *Riparian Action Program*'s education and outreach goals for improving community engagement and riparian awareness (City of Calgary, 2017).

Due to changes in the work program, this objective was no longer completed under the effectiveness monitoring component.

Effectiveness Monitoring Objective 10 – Design Improvements: The tenth objective of the RMP was to provide recommendations for design improvement to develop more adapted techniques/approaches for the Calgary local conditions and watercourses for future applications that can be considered as part of an update to *the Design Guidelines for Erosion and Flood Control Projects for Streambank and Riparian Stability Restoration* (Bioengineering Design Guidelines) (AMEC, 2012).

The results of Phase 2 of the RMP provided valuable information for updating the Bioengineering Design Guidelines including significant data and results to improve design, implementation, and maintenance practices. Recommendations are discussed in the Key Effectiveness Monitoring Recommendations section of this Technical Summary and in Section 7.2.3 of the main report.

Effectiveness Monitoring Objective 11 – Monitoring Recommendations: The eleventh objective of the RMP was to provide recommendations for future long-term monitoring needs.

Recommendations for future long-term monitoring needs were developed based on the results of the program and are discussed below and in Section 7 of this report.

Key RMP Recommendations

Key Trend Monitoring Recommendations

In general, RHI monitoring is recommended to continue on a five-year revisit interval. This allows for tracking the progression of riparian health over time in response to ongoing management efforts and land use pressures. As a field-based monitoring tool, RHIs can provide comprehensive, site-specific information coupled with on the ground photography monitoring. However, like all ground-based monitoring methods, these can be costly and as such generally cannot be applied at a geographic scale to capture comprehensive riparian conditions with full coverage across the city. Moreover, to date, RHI polygon boundaries conform to discrete management units primarily within the inner riparian zone (O2, 2014). Riparian habitat in the mid to outer floodplain zones is generally not well represented by RHI polygons. Consequently, net loss or change to riparian habitat at a city-wide scale is not readily captured by RHI data. Another limitation of continuing forward with the RHI metric on its own is that it is premised on comparison to an undisturbed, natural reference condition. This can limit the ability to detect smaller project specific changes in an urban context where some watershed parameters are unable to be influenced at a smaller scale (i.e. damming & dewatering on large rivers).

To address the limitations of the RHI method described above and fully capture the required data to track the *Riparian Action Program* riparian health targets, a hybrid approach may be warranted moving forward that better accounts for the urban context (Ehrenfeld, 2000). To allow more flexibility and judicious use of funding resources, a combination of monitoring approaches at various spatial scales is recommended for the long-term.

In determining a long-term riparian health monitoring framework, it is recommended that there is consistency and alignment among the monitoring approaches being applied by various City Business Units responsible for jointly managing natural assets (e.g. riparian city parks). *Riparian Action Program* targets linked to riparian health should be reviewed to reflect a more comprehensive monitoring approach.

Key Effectiveness Monitoring Recommendations

Based on the results of 2018 to 2022 bank and riparian effectiveness monitoring activities, recommendations have been developed to improve project implementation.

The top recommendations are shown below. These recommendations were prioritized according to their perceived priority based on the RMP team's site observations, understanding of the results, and professional judgement. Additional recommendations for each of the categories are provided in Section 7 of this report.

Recommendations are provided for the following:

- Improvements to structural design practices (Table 5);
- Improvements to vegetation design, installation, and maintenance practices (Table 6);
- General program recommendations (Table 7); and,
- Improvements to City of Calgary project management practices (Table 8).

Recommendation for updates to The City's Bioengineering Design Guidelines include updates to existing sections, tables, figures, appendices, and bioengineering technique design guidelines; recommended new sections; and additional recommendations to include specific results and observations from the RMP. These recommendations are provided in Section 7.2.3 of the main report.

Table 5: Top Recommendations for Improved Structural Design Practices

No.	Item	Report Section
S1	Provide Irrigation for Two to Three Years Post-Construction	3.3.1, p. 3-44
S2	Install Fencing Around Planted Vegetation to Protect from Browsing and Disturbance until Vegetation is Established	3.3.1, p.3-46 3.3.2, p. 3-63
S3	Reduce Soil Compaction due to Construction Activities	3.3.2, p. 3-84 4.3.27, p. 4-33
S4	Use Biodegradable Erosion Control Matting Products	3.3.15, p. 3-22

Table 6: Top Recommendations for Improvements to Vegetation Design, Installation, & Maintenance Practices

No.	Item	Report Section
V1	Use Recommended Bioengineering Techniques and Species	3.3.1, p. 3-20 3.3.2, p. 3-55 4.3.1, p. 4-8 4.3.2, p. 4-29
V2	Increase the Use of Container Plants in Combination with Live Cuttings Where Possible	3.5, p. 3-55 4.6, p. 4-29
V3	Use Best Practices for Live Cuttings, Potted Plants, and Seed Mix Installation	3.3.1, p. 3-38 3.3.1, p. 3-39
V4	Use Tall Rooted Stakes when Construction is Outside of the Live Cutting Dormancy Period	3.3.1, p. 3-30
V5	Better Invasive Weed Control Needed	3.3.2, p. 3-72
V6	Use Soil Amendment on Live Cuttings and Container Plants	3.3.2, p. 3-60

Table 7: Top General Program Recommendations

No.	Item	Report Section
G1	Continue BDEP Monitoring	Refer to bank effectiveness annual summary reports
G2	Share RMP Results via Field Days/Workshops	Refer to bank effectiveness annual summary reports
G3	Update Bioengineering Design Guidelines	7.2.3, p. 7-11

Table 8: Top Recommendations for Improved City of Calgary Project Management Practices

No.	Item	Report Section
PM1	Improve Document Control and Record Keeping	3.3.1, p. 3-21 4.3.1, p. 4-28
PM2	Address Failure Sites and Implement Remedial Measures	Appendix D
PM3	Incorporate Survival and Woody Vegetation Canopy Cover Targets	3.3.1, p. 3-49