Bioengineering Demonstration and Education Project

Canadian Consulting Engineering Awards 2020 Submission

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Project Highlights

The Bioengineering Demonstration and Education Project (BDEP) is the next generation of Alberta riverbank bioengineering projects. It is a provincially significant project to showcase bioengineering bank protection techniques as an environmentally preferable alternative to conventional methods such as rock riprap. Borne in response to the 2013 flood, it is the largest initiative of the 11 projects under the Southern Alberta Fisheries Habitat Enhancement and Sustainability program and is the largest bioengineering project in Calgary. It elevates the understanding, acceptance and application of bioengineering design by successfully showcasing seven common techniques and seven new techniques to expand the bioengineering design toolbox, and by openly sharing project technical documentation, research findings, and performance monitoring results.

"The project will enhance the lives of Calgarians and make the City of Calgary a better place to work and live by immediately providing stream bank remediation, stabilization and flood protection, protecting and enhancing water quality, enhancing fish and wildlife habitat, improving riparian and watershed health, contributing to climate change resiliency, enhancing biodiversity and improving green space, trails and aesthetics, and significantly facilitating Calgarians knowledge and stewardship of the river and riparian areas."

– Trevor Rhodes, M.Sc., P.Biol., Leader, Watershed Strategy,City of Calgary

Key project highlights are listed below.

- Fourteen different bioengineering techniques were constructed in 10 treatment areas that have a variety of hydraulic, geotechnical and environmental conditions. Seven of the techniques are new to Calgary.
- The new techniques are advancing the practice of bioengineering by addressing important objectives such as vegetating existing riprap, enabling summer construction outside the vegetation dormancy period, achieving toe (scour) protection using solely vegetative techniques, improving vegetation biodiversity and survival, and creating fish habitat.
- About 100 trees, 2,300 shrubs and 30,000 live cuttings were planted. About 2000 tonnes of concrete, wood, and steel were removed from the riparian area. BDEP has improved the vegetation ratings in the riparian health inventory assessments by 2 to 2.5 times over a conventional riprap design site.
- While vegetation survival is about 50% for most bioengineering projects in Calgary, BDEP vegetation survival is 80%.
- As part of ongoing performance monitoring, it has been observed that the habitat enhancements constructed at the site are being used by:
    - wildlife including white-tailed deer, coyote, and white-tailed jack rabbits;
    - listed bird species including bank swallows, least flycatcher, and western wood peewees; and
    - fish species including brown trout, rainbow trout, burbot, northern pike, and mountain whitefish.
- BDEP fish habitat enhancements are so extensive that extra fish habitat offset credits were generated for application on another City of Calgary project.
- The multiple award winning RiverWatch program teaches thousands of students about bioengineering as they float down the Bow River past the BDEP. This partnership between RiverWatch and the BDEP extends the education reach of BDEP into the Calgary school system.
- In recognition of the magnitude of BDEP's environmental impact, the project has received the following awards:
    - City of Calgary "One City" award for the Environmental Category (2018);
    - Consulting Engineers of Alberta Award of Excellence in the Water Resources Category (2019);
    - Consulting Engineers of Alberta Award of Merit in the Sustainable Design Category (2019); and
    - Association of Professional Engineers and Geoscientists of Alberta Environment and Sustainability Award (2019) (not yet announced publicly due to event cancellation from Covid-19).

Innovation

The Bioengineering Demonstration and Education Project (BDEP) is the next generation of Alberta riverbank protection projects. It is a provincially significant project that showcases bioengineering bank protection techniques as an alternative to conventional methods such as rock riprap. Alberta Environment and Parks partnered with The City of Calgary to undertake BDEP to mitigate the impact to fish habitat and riparian health from the 2013 flood recovery program. The project is located along a 680 m reach of the Bow River in the historic community of Inglewood. As the Design Lead and Engineer of Record, KWL completed the design for the project between July 2016 and September 2017. Construction occurred from February 2018 to June 2019.

Advancements in the Practice of Bioengineering

Bioengineering is an emerging field in Canada. In Alberta, bioengineering projects are not always successful, often due to a low rate of vegetation survival. Professionals typically cite vegetation survival as a key barrier for using bioengineering techniques. BDEP demonstrates how higher vegetation survival rates can be achieved using best practices. Special care was taken to develop detailed contract documents including design drawings and technical specifications and to monitor construction activities with respect to timing, harvesting, storage, soaking and installation of live vegetation materials to ensure successful establishment of the bioengineering treatment.

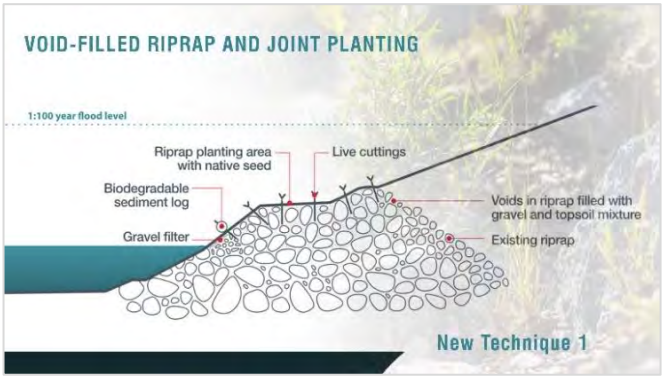
Fourteen different bioengineering techniques were constructed at ten different treatment areas with a variety of hydraulic, geotechnical and environmental conditions such as such as high and low water velocities, steep banks, narrow construction footprint, and existing bank protection. Seven of the fourteen techniques used at BDEP were novel to Calgary and were piloted to expand the bioengineering design toolbox for a wide range of riverbank conditions. These novel techniques advance the practice of bioengineering as listed below.

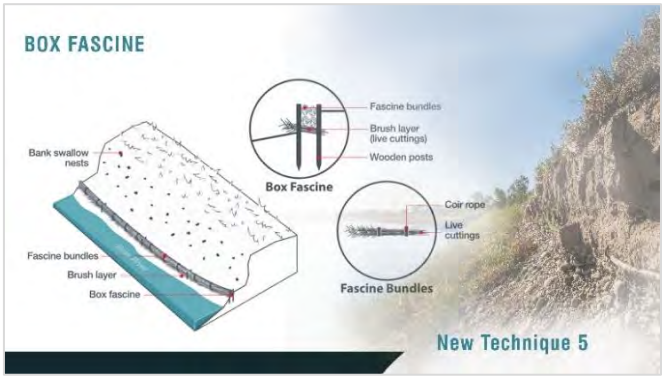
- Three new techniques for vegetating riprap bank protection works: void-filled riprap with live staking (refer to New Technique 1 on next page), void-filled riprap with plug planting (refer to New Technique 2 on next page), and soil covered riprap with container shrub plantings (refer to New Technique 3 on next page). These new techniques enhance aquatic habitat, wildlife passage, riparian health, and aesthetics on previously constructed riprap bank protection. The learnings from these techniques can be applied on existing riprap projects all over Canada.
- New vegetation preparation technique, referred to as rooted live cuttings (refer to New Technique 4 on next page), allows summer construction during hot, dry conditions when live cuttings should not be used. Summer construction has been observed to result in low live cutting survival through on-going City-wide monitoring. This provides construction schedule flexibility by avoiding the need to defer vegetation work until after summer.
- New scour protection technique referred to as a box fascine (refer to New Technique 5 on next page) that uses only vegetation and locally available materials, provides scour protection equivalent to riprap, and improves habitat and aesthetics. Rock riprap is usually used to protect against scour along the toe of a riverbank; however, it can be expensive, availability may be problematic, and it has low habitat value and unfavorable aesthetics.
- New technique referred to as a hedge brush layer (refer to New Technique 6 on next page) that combines live cuttings with rooted plants to increase biodiversity, wildlife habitat, and nitrogen fixing. This allows the use of more species than the traditional 3 or 4 live cutting species that are commonly used and are known to work well.
- New technique referred to as a timber crib wall with fish shelter (refer to New Technique 7 on next page) that incorporates fish shelters into a timber crib wall to provide fish habitat along the bank via the submerged refuges under the crib wall.

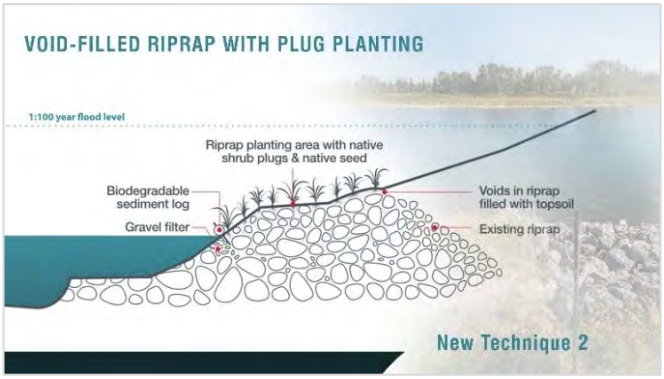
A Living Laboratory

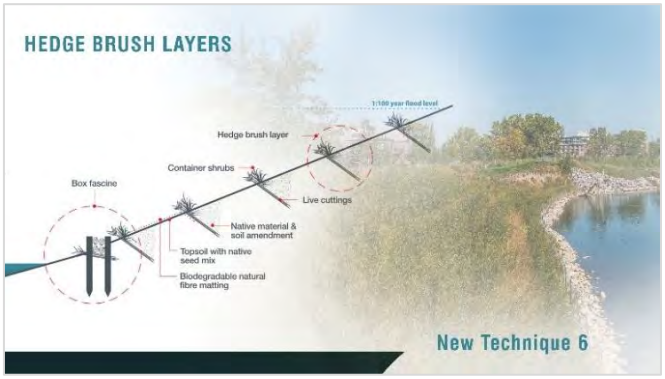
BDEP is a living laboratory, with documentation of design and construction activities, and a commitment to maintenance and long-term monitoring. The project generates important information about project successes and challenges that is **openly shared**. This allows professionals to improve bioengineering project design, tendering, construction, and maintenance.

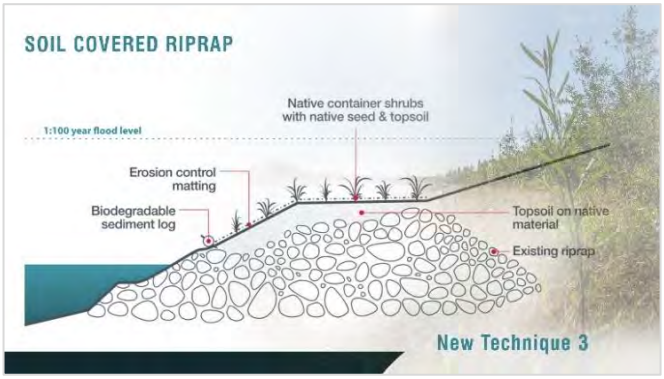
Seven New Techniques

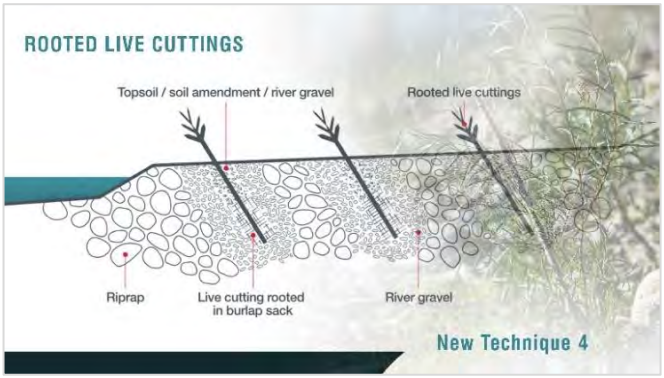












Complexity

Key project challenges and resolutions:

Calgary's Deepest Scour Hole: During the 2013 flood, the river velocity was 4-5 m/s and the riverbed lowered by about 4.5 m at the site, forming the deepest scour hole on the Bow River in Calgary. KWL conducted a detailed scour analysis to design a self-launching riprap scour apron along one part of the site. To maintain consistency with project environmental objectives, the scour apron was enhanced for fish habitat using boulder clusters and rock spurs.

Surprise New Bridge Project: A new transit bridge within the site was announced when BDEP design was nearly complete. The new bridge was part of the Southeast Bus Rapid Transit (SEBRT) project and twinned the existing Cushing Bridge. The project was a surprise to Alberta Environment and Parks, The City of Calgary, and the BDEP design team. Collaboration between the BDEP and SEBRT design team resulted in minimal redesign of the BDEP, an increase in the bridge opening dimensions to accommodate a wildlife corridor and two BDEP viewpoints from the bridge, with minimal impact to bridge cost and construction schedule.

Debris Removal: Removal and disposal of historic construction debris from the riverbank was included in the original construction contract. During construction, the extent of debris was larger than expected. Several change orders were issued to facilitate removal and disposal of about 2000 tonnes of concrete, wood and steel.

Selecting an Experienced Contractor: To secure an experienced contractor and reduce construction risk, the design team developed a custom tender evaluation based on price, experience and project understanding. Even with this effort, 27 site instructions and 54 requests for information were administered over 9 months during construction.

Exceeding Vegetation Survival Expectations: Vegetation survival is typically about 50% for bioengineering projects in Calgary. Through focused attention to vegetation design, installation, and maintenance, performance monitoring shows BDEP vegetation survival is 80%.

Social and/or Economic Benefits

Social Benefits

BDEP provides the social benefits listed below.

- Protects the adjacent historic neighbourhood of Inglewood from the next big flood.
- Provides access to green space and social spaces including an educational amphitheatre, gathering space, and lookout points from the new transit bridge.
- Educates the public about bioengineering and riparian health through interpretive signage located throughout the site.
- Improves riparian health and water quality by replacing debris on the riverbank with native vegetation.
- Provides a vital wildlife and public linkage between two regionally significant parks (Inglewood Bird Sanctuary and Pearce Estate Park) through a wildlife corridor, nature trail and regional pathway.
- Provides safe passage for wildlife under Cushing Bridge and the new transit bridge to reduce motorist and wildlife interactions on Blackfoot Trail.
- Increases biodiversity and generates a lower carbon footprint by using bioengineering techniques instead of conventional techniques.
- Shares key project information so that other professionals can learn, increasingly incorporate bioengineering techniques into engineering designs, and improve bioengineering project outcomes.

Economic Benefits

The BDEP provided a significant cost saving compared to a conventional approach. The final construction cost for the BDEP was $4.15 million. A conventional riprap design covering the same project footprint would likely have costed about $1 million more. Most of the additional cost would be due to the import of rock riprap. Additional, unquantified economic benefits to consider from using bioengineering techniques include enhanced fish and wildlife habitats, water quality improvement, and recreation opportunities.

Environmental Benefits

Several significant environmental enhancements were achieved by the BDEP as listed below.

Fish Habitat Enhancements: BDEP fish habitat enhancements are so extensive that the project created fish habitat offset credits for application on another City of Calgary project. Habitat enhancements include fish shelters, overhanging vegetation, boulder clusters, and rock spurs.

White-tailed deer using the BDEP wildlife passage corridor under the Cushing and SEBRT bridges

Wildlife Corridor: A wildlife corridor was constructed under the Cushing Bridge and the new SEBRT bridge to improve wildlife passage and reduce the risk of wildlife / motorist collisions. The wildlife corridor connects Pearce Estates Park and the Inglewood Bird Sanctuary. Ongoing performance monitoring confirms that wildlife are using these corridors.

Protecting Bank Swallow Nests: The design team incorporated an existing nesting area for federally protected bank swallows into the design. During construction, the nesting area was screened off to limit disturbance. Bank swallows were observed returning to their nests after construction.

Debris Removal: About 2000 tonnes of concrete rubble, wood debris, and rusting steel were removed from the bank and riparian area of the Bow River, leading to improved riparian health and water quality.

Retrofitting Existing Rock Riprap with Vegetation: Three techniques for retrofitting existing rock riprap erosion protection with vegetation were piloted in the BDEP. Ongoing performance monitoring showed vegetation survival ranging from 60% to 97% for these techniques.

Sustainability: BDEP bioengineering techniques address many sustainability issues that conventional bank protection approaches do not, including enhanced fish habitat, improved water quality, higher vegetation and wildlife biodiversity, lower invasive species cover, and lower construction carbon footprint.

Environmental Awards: BDEP has been recognized by four awards for its environmental impact.

BEFORE

AFTER

Meeting Client's Needs

"BDEP was a unique initiative which required an atypical and diverse set of skills; expertise in bioengineering, erosion control in extreme conditions, fish habitat restoration, and public education were all essential to the success of the project. Additionally, the project required a high degree of innovation, flexibility under changing environmental conditions, and an ability to work collaboratively with a diverse group of project partners. KWL brought the diverse skill sets required to complete this unique project to the team and was well qualified to deliver the project."

- David DePape, Senior Manager, FISHES Program, Alberta Environment and Parks

Project objectives and how they were achieved or exceeded are summarised below.

Re-establish fish habitat: Bioengineering techniques effectively add overhanging vegetation to provide shade, shelter, and food sources for fish. Additionally, fish shelters provide refuge in a reach with limited overhead cover.

Protect eroding riverbanks: The existing unstable riverbanks were regraded to stable angles. Bioengineering techniques effectively control erosion.

Restore riparian health to improve watershed resiliency: About 100 trees, 2,300 shrubs and 30,000 live cuttings were planted to improve riparian health. About 2000 tonnes of concrete, wood, and steel were removed from the riparian area.

Northern pike captured during ongoing BDEP performance monitoring

Demonstrate a range of bioengineering techniques: Fourteen different bioengineering techniques were constructed in 10 treatment areas. Seven of the techniques are new to Calgary.

Increase awareness and understanding, and facilitate knowledge transfer, research, and partnerships: Several BDEP initiatives achieve this objective, including (see more detail in the section below):

- technical presentations delivered on site, and at local and international conferences;
- City of Calgary BDEP website launching in April/Map 2020 (www.calgary.ca/BDEP) to openly share project technical information;
- KWL-initiated research with the University of Calgary; and
- contract documents used as a template for 10 other projects under the same flood recovery program.

Monitor, evaluate, and report on project effectiveness and cost compared to a conventional riprap design: A 10-year performance monitoring program is underway to evaluate the impact on fish habitat, wildlife, riparian health and bioengineering structural integrity. Year 1 monitoring results show that project effectiveness is exceeding expectations. The BDEP saved the client approximately $1M compared to a conventional approach.

Provide benefits to Calgarians: In addition to the primary benefits of bank protection and bioengineering approaches, the project provides additional benefits such as recreational and educational opportunities.

Openly Sharing Project Information to Improve Future Bioengineering Projects

A key BDEP objective was to create a demonstration project that increases awareness and understanding of bioengineering among professionals and the public. BDEP benefits the practice of bioengineering through on-the-ground successful examples of common and novel techniques. While a certain amount can be learned when observing the end result of a project, BDEP takes the sharing of project information several steps further so that others can go behind the scenes to more deeply understand what was accomplished at the site . Design drawings, technical specifications, design reports, construction contract documents, construction photos and videos, and performance monitoring reports will be openly shared through The City of Calgary's BDEP website (www.calgary.ca/BDEP). This allows the learnings of successful design and construction practices to extend outside of BDEP and into the public realm to help elevate the practice of bioengineering in Alberta and beyond.

Other examples of BDEP activities that demonstrate the commitment to increasing awareness and understanding of bioengineering, open sharing of project learnings, and furthering the practice of bioengineering are listed below.

Research Activities: The project is a living laboratory where research initiatives are currently underway, including a partnership between KWL, The City of Calgary, and the University of Calgary to monitor soil moisture in the treatment areas at BDEP. This long-term research project is intended to improve the understanding of soil moisture on riverbanks in southern Alberta, and to improve contractor irrigation practices, a critical limiting factor for successful vegetation establishment and survival. It is intended that a University of Calgary graduate student under the supervision of Dr. Masaki Hayashi will conduct the research with support from KWL. It is intended that the research will inform design guidelines for riverbank stabilization and riparian enhancement projects in Calgary (and beyond) and will be presented at technical conferences and published in peer-reviewed journals.

Technical Tours and Presentations: KWL has led tours of the BDEP site for University of Calgary students and City of Calgary staff to share key project learnings. Future tours for The City of Calgary and Alberta Environment and Parks are in planning stages. Technical presentations have been made locally and around the world including at World Water Week in Stockholm, Sweden.

Mike Gallant from KWL at the BDEP amphitheater educating University of Calgary students about bioengineering.

Site Signage and Education Facilities: The City of Calgary has developed project interpretive signage for the site based on KWL's design drawings (refer to watercolour figures within this submission). The signage will feature design graphics showing the different bioengineering techniques. Signs with higher level information describing project goals and objectives will be installed at the education facilities including the gathering area, amphitheatre, and at a lookout point on the SEBRT bridge .

BDEP Website: The City of Calgary is launching a project website in April / May 2020 (www.calgary.ca/BDEP) to openly share project technical documentation to the public and design professionals so best practices and learnings are freely available.

Construction Videos: Time lapse cameras were installed during BDEP construction and pre- and post-construction drone flight photos and videos were recorded. Several videos have been prepared from the footage showing installation practices for specific bioengineering techniques. These videos will be openly shared on The City of Calgary's BDEP website.

RiverWatch: The multiple award winning RiverWatch program teaches thousands of students on an annual basis about bioengineering as they float down the Bow River past the BDEP. This partnership between RiverWatch and the BDEP extends the education reach of BDEP into the Calgary school system.

Riverwatch floating past BDEP and educating high school students about bioengineering.