Okotoks Bioretention Research Project

Overview

Bioretention systems are a key stormwater treatment element, with similar functionality as a wetland, but without standing water. These vegetated depressions attenuate and treat stormwater runoff by infiltrating flows and percolating them through an engineered medium, using physical, chemical and biological processes. They provide stacked benefits, such as aesthetics, habitat, biodiversity, urban heat island mitigation, and improved air quality. Bioretention systems are particularly promising in the retrofit context, where space is at a premium; and in cases where enhanced treatment is sought, such as for finer sediments and dissolved contaminants, especially nutrients and metals.

As a novel vegetated system, there is much to learn about performance and optimization for different objectives. The Okotoks Bioretention Research Project is a long-term installation that aims to examine the functional design elements of bioretention systems and make recommendations for their successful implementation in Alberta.

In 2017, an outdoor research facility was constructed in the Town of Okotoks. The project was made possible by support from the multiple sponsors and partners, including the Bow River Basin Council, Alberta Environment and Parks, University of Calgary, City of Calgary Water Resources, Source2Source Inc., Alberta Low Impact Development Partnership, Environment Canada EcoAction, Natural Sciences and Engineering Research Council, MITACS, TD Bank Friends of Environment Foundation, and FortisAlberta.

Main cells under construction in 2016.

Main Sampling Program

using The facility consists of twenty-four main bioretention mesocosms, planted with different media and vegetation. Two media were based on the City of Calgary's Low Impact Development Guidelines (70 and 40 mm/hr saturated hydraulic conductivity) and the third was a mix of native clay-loam soil and large wood chips. The vegetation was split into two types: native shrubs and a mixture of native grasses and forbs, with conventional turfgrass as a control. The cells are 2m x 2m x 1m deep, fully lined, and equipped with a transparent observation well for observing water levels and rooting characteristics, and a monitoring well for pumping exfiltrate. There is a drainage layer at the bottom of each tote, which consists of 10 cm of 40 mm washed rock, overlaid by 5 cm of 10 mm washed rock (pea gravel) and 5 cm of 3mm sand. The media layer is 60 cm deep, which was placed in three individually compacted lifts. Efforts were made to prevent edge flow by installing a plastic L-shaped bracket on the perimeter of each cell at the interface of the drainage layer/media and at each of the 20 cm media lifts. At the top, each cell has about 20 cm of freeboard to accommodate ponding during the simulated runoff testing.

The program includes applying runoff events of various magnitudes (4, 9, 14 and 24 mm), quantifying the water balance, and analyzing the water quality improvements. Each event involves the application of water from a local stormpond, mixed with a controlled sediment dose derived from street sweepings, with subsequent analysis of hydrological and water quality parameters. During the 2018 to 2020 growing seasons, an extensive research program of physical runoff simulation and sampling was undertaken. In future years, dosing of contaminants other than sediment is anticipated, once the vegetation in the cells is fully established.

Phosphorus Amendment Mesocosms

In freshwater systems, phosphorus in runoff is a key cause of harmful algae blooms in stormwater ponds and in receiving water bodies. Controlling phosphorus on the landscape with bioretention systems may be effective, however, there is evidence that phosphorus may in fact leach from these systems with certain designs under certain conditions. There is more than one mechanism for this leaching. Adding amendments to prevent leaching and to provide phosphorus treatment may be an important way to enhance these systems. The Okotoks facility is therefore also being set up to test a variety of media amendments, using smaller-sized replicates of the main cells and following the same simulation program as the main mesocosms. While amendments can treat phosphorus, they may also have negative impacts, including compromised infiltration rates and plant survival, introduction of trace contaminants, and contaminant leaching. Observing these additional factors is an important part of the amendment investigation.

Eight amendment mesocosms were constructed in the summer of 2019 in addition to the original twenty-four bioretention cells. The amendment mesocosms used the same media and vegetation as a subset of the main mesocosms to enable a reasonable performance comparison between the main and the amended cells. All eight cells have the same media and vegetation, with the only difference being the amendment of interest or lack thereof. The selected media type was based on the City of Calgary’s Low Impact Development Guidelines (40 mm/hr saturated hydraulic conductivity), it was identified as the most promising with respect to volumetric retention and the ability to support vegetation establishment and growth. The selected vegetation was a mix of sixteen (16) native grasses and forbs. Media and plants for the amendment cells were sourced at the same time as those of the original twenty-four mesocosms in an attempt to reduce the variability between the two sets of cells.

Amendment mesocosms shortly after construction and planting, on July 28, 2019.

Most phosphorus amendments are based on compounds that are rich in iron, aluminum, calcium, or magnesium. There are unique benefits and drawbacks to the different amendments, including sensitivity to pH and saturation, plant toxicity, incident contaminants, and cost considerations. Multiple amendments have been identified as beneficial in retaining phosphorus, some proprietary and some common and even waste materials, such as iron filings, drywall, water-treatment residuals, fly ash, and seashells.

A total of seven different media amendments were selected, with one unamended cell as a control. Amendments were selected based on literature review, discussions with researchers, and pre-testing of some of the products through the U.S. Department of Agriculture. The selected amendments include four proprietary and/or commercially available products, which are:

- Ultratech Ultra-Phos Filter®,
- Imbrium Sorbtive® Media,
- Delta Adsorbents Activated Alumina, and
- Poly-Aluminium Chloride (PAC).

The Ultratech Ultra-Phos Filter® and Imbrium Sorbtive® Media are based on a combination of iron and aluminum compounds. The Activated Alumina and PAC are aluminum-based. The Ultra-Phos Filter®, Sorbtive® Media, and Activated Alumina are all solids, which were mixed with the media at 5% by volume (Sorbtive® Media will be mixed and installed in 2020). PAC is a liquid, which makes direct mixing impracticable; therefore, the decision was to apply it at 5% of the cell volume to the surface of the prepared mesocosm.

The other three amendments, which are waste products that are generally sent to the landfill, include:

- crushed drywall,
- water-treatment residuals (WTRs), and
- eggshells.

Drywall and eggshells are calcium-based, whereas WTRs are aluminum-based. The drywall and the water treatment residuals were manually broken up and passed through a 10 mm sieve prior to mixing with the media. The eggshells came crushed and were mixed in "as-is". The three waste amendments were mixed with the media at 10% by volume.

Each mesocosm is a 1x1x1 m plastic tote with its bottom sloping towards a drain, equipped with a valve and a sump to collect the treated effluent. Similar to the main bioretention mesocosms, there is a drainage layer at the bottom of each tote, which consists of 10 cm of 40 mm washed rock, overlaid by 5 cm of 10 mm washed rock (pea gravel) and 5 cm of 3mm sand. The media layer is 60 cm deep (identical to the main bioretention mesocosms), which was placed in three individually compacted lifts. Efforts were made to prevent edge flow by installing a plastic L-shaped bracket on the perimeter of each cell at the interface of the drainage layer/media and at each of the 20 cm media lifts. At the top, each cell has about 20 cm of freeboard to accommodate ponding during the simulated runoff testing.

Runoff simulation and sampling will be done during the growing season of 2020 and will parallel the ongoing program of the facility's main twenty-four bioretention mesocosms.

A parallel lab-scale study will be done at the University of Calgary, which will analyze the same media and the same set of amendments, as well as go into greater detail on the reactivity of each amendment and its impacts on the media's physical and chemical properties. In addition, sensitivity to the chemistry (e.g., pH levels) of the inflow will be analyzed. Ultimately, performance comparisons between the lab-scale, the amendment mesocosms, and the main bioretention mesocosms will be made. The ultimate goal of the amendment research is to characterize the amendments and make recommendations based on their effectiveness and cost implications.