Revegetation Establishment
Monitoring Principles and Practice

A Case Study: Bowker Creek Restoration Demonstration Project

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Assignment and Case Study Statement

Between June and November 2005, the Capital Region District (CRD) with the assistance of interest groups, neighbourhood residents and a range of engineering and restoration professionals, completed work on a creek restoration and bank stabilization project along a 48 m section of Bowker Creek in Victoria, BC.

This project was designed and constructed as a restoration demonstration site, representative of slope stabilization bioengineering principles and best practices and native plant revegetation for a significantly modified urban creek.

A number of results have been observed from this project. Some of the outcomes include:

- regrading and planting with native plant materials along a selected section of Bowker Creek to create a more naturalized riparian environment;
- streambank stabilization using bioengineering principles and practices to improve the riparian environment, including contributing to enhanced water quality and habitat along this section of the creek;
- training of 20 community members in bioengineering techniques through the completion of a course including an in-field practicum at the creek; and
- community involvement in a number of aspects of the project, contributing to increased restoration knowledge and volunteerism.

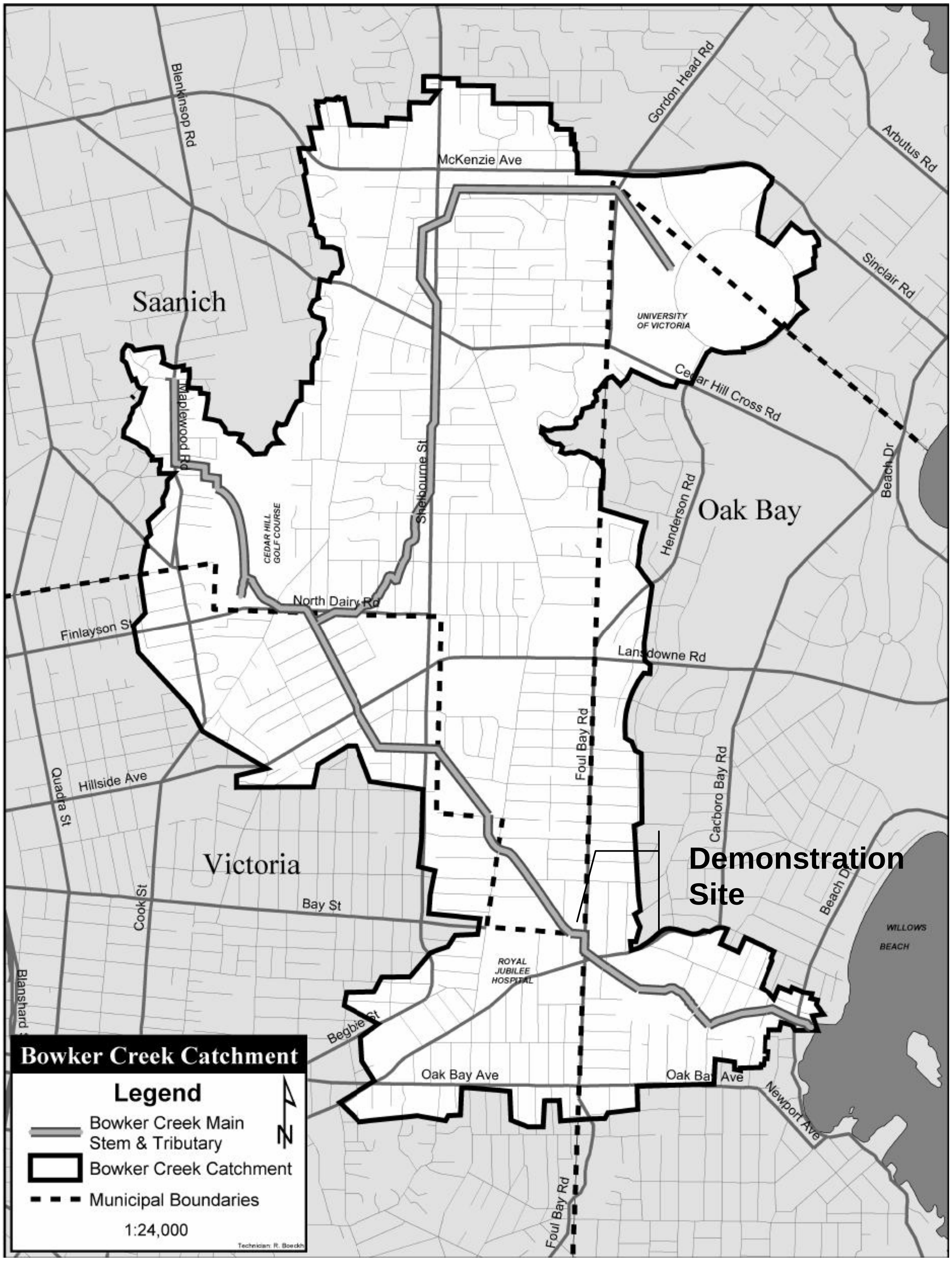
The purpose of this assignment is to demonstrate skills and knowledge acquired during the Field Studies course. Using the Bowker Creek Restoration Demonstration project as a case study, a selected number of site inventory and assessment techniques, and revegetation monitoring approaches have been applied to the site. Upon review of selected publicly available documents and discussion with CRD staff, it was determined that no pre-construction baseline information was available. As a result, research into restoration assessment principles and best practices methods was undertaken, particularly as they relate to revegetation monitoring to develop a post-construction/restoration baseline and site assessment. This information may be considered by the CRD as a starting point for a monitoring protocol.

The results of the field assessment of the restored creek morphology, bioengineering stabilization and native plant revegetation have been documented. With the collection of this data at the completion of the restoration project, it will potentially inform future site maintenance as well as other Bowker Creek initiatives. The research and the assessment results are summarized herein.

Background

The Bowker Creek watershed encompasses 1,028 ha (2,540 ac) in the districts of Saanich, Victoria and Oak Bay on southern Vancouver Island (see Figure 1). It is considered one of the most highly urbanized major watersheds in the CRD with approximately 87% of the watershed developed for urban land uses (CRD 2003). It is estimated that 45% of the watershed is impervious due to this urbanization. The main channels of the creek totals 8 km in length. Much of the creek flows through pipes and culverts with only about 30% remaining above ground. Some of the above ground sections have been modified (deepened and straightened) to carry stormwater runoff and manage flooding potential. Other sections of the creek have been modified with artificial banks constructed in response to moderate erosion. Native vegetation has been, in certain cases, removed to improve drainage. Invasive plant species now limit the growth of native vegetation.

Figure 1, Bowker Creek Watershed Area



CRD 2003, not to scale

The Bowker Creek Urban Watershed Renewal Initiative (BCI) is a coalition of community, government, business and institutions working towards a vision of the watershed where:

> *The varied human uses and natural areas in the Bowker watershed are managed to minimize runoff and pollution, making Bowker Creek a healthy stream that supports habitat for native vegetation and wildlife, and provides a community greenway to connect neighbourhoods* (CRD 2003).

The Bowker Creek Watershed Management Plan was completed in January 2003 and identifies a number of goals, objectives and actions that support the realization of the vision.

At present, the eight open reaches of the creek and adjacent riparian areas provide habitat for certain plants and animals, including birds, small mammals and aquatic invertebrates (CRD 2003). The potential to improve species diversity exists with the further reduction of water pollutants and improvements to streambank design and vegetation (CRD 2000).

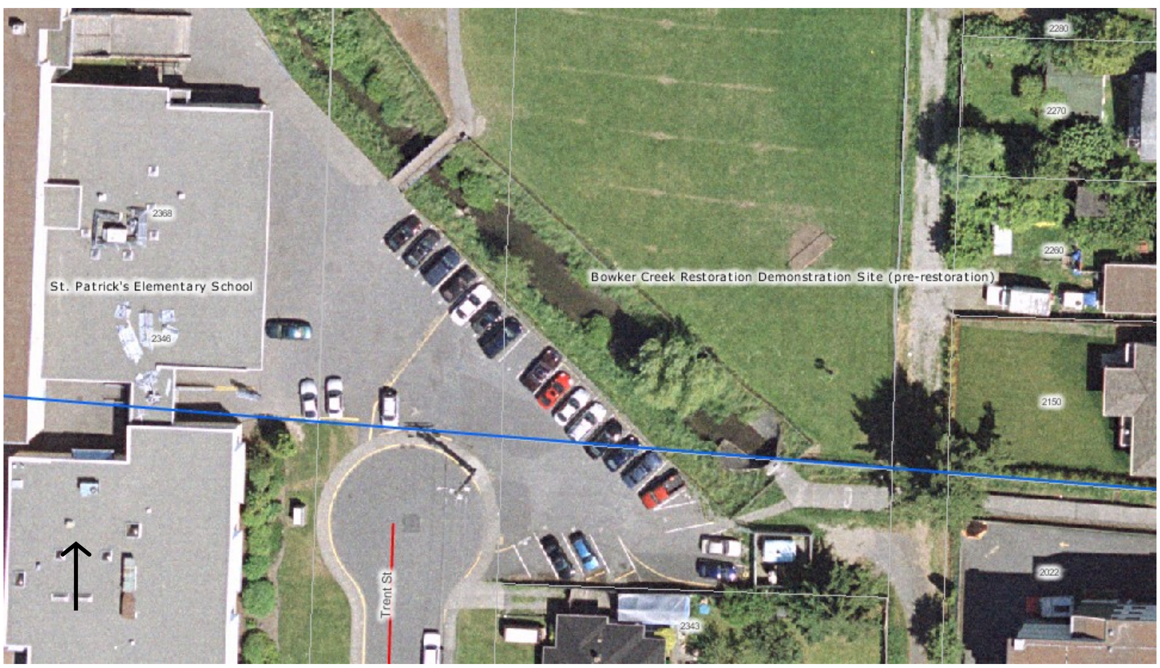
While the water quality has improved with the ongoing separation of sanitary sewer and storm drain cross connections, the water quality is considered to be "fair" based on the type and distribution of benthic invertebrates identified through study. The re-establishment of fish populations in the creek is considered unlikely and as such, was not included as an objective by the BCI (CRD 2000).

The location of the demonstration project is a short section of the creek (approximately 48 m) adjacent to St. Patrick's Elementary School, bordering the districts of Saanich, Victoria and Oak Bay (see Figure 2). This project was part of the Bowker Relief Sewer Project that included the construction of a new sewage line upstream of this section of the creek designed to increase system capacity and eliminate sewage overflows to the creek.

The demonstration site is secured by a chain-link fence that is gated and locked. The area measured within the fence is approximately 550 m² making it ideal as a demonstration site that is relatively secure and accessible for observation and study. Its limited size makes it more manageable for cost-effective maintenance and monitoring. This section of Bowker Creek stands in contrast to a comparable section directly upstream of the site that has not been restored.

Prior to the restoration work, this section of the creek was characterized by eroding banks covered with invasive exotic plant species. Habitat and water quality were compromised due to the persistent erosion. This section of the creek has also been subject to periodic seasonal flooding.

Figure 2, Demonstration Project Site Air photo



Natural Area Atlas, 2005 Colour Orthophoto, not to scale

The implementation of the demonstration project included:

- the removal of all existing vegetation and the regrading and straightening of the creek banks;
- the placement of a block-stone embankment at the toe of both sides of the

creek slopes;

- bioengineering techniques including the construction of two willow wattle fences, providing slope stabilization and planting terraces;
- the installation of biodegradable erosion control mats;
- placement of topsoil;
- the revegetation of creek banks with native riparian vegetation; and
- the application of leaf mulch (CRD 2006).

The arrangement and installation of an irrigation system is nearing completion. The CRD is using a combination of above-ground soaker hoses on the south side and the use of the existing sprinkler system for the playfield on north side. Site irrigation is necessary to ensure plant survival during the dry summer months. This system is anticipated to be in place for a minimum of two years until the plants have become sufficiently established.

Riparian Environment

Plants are dependent on climate, soil moisture and nutrients. These factors help define plant-environment relationships and site quality (Klinka et al.1989).

Riparian areas are ecosystems situated between aquatic and upland environments that can be periodically impacted by flooding. These zones often have a rich diversity of plant species and several vegetative layers. The vegetation composition and structure is primarily regulated by the frequency, magnitude, duration, and seasonal timing of stream flooding; and subsurface moisture conditions.

Riparian vegetation species are typically classified as phreatophytes or water-loving plants whose roots generally extend downward to the water table and customarily feed on the capillary fringe (U of Arizona website 2006). To achieve success in plant establishment, knowledge of a species relationship to the stream and water table is essential. Typically:

- wetland herbaceous species can be found throughout the streambank cross section, although most emergent aquatics are found in the toe zone;
- plants with flexible stems and rhizomatous root systems are usually located from the water-line to mid-bank zone;
- larger shrubs are found from mid-bank zone to the top of the overbank zone; and
- tree species are usually found above the overbank zone in the floodplain (Bentrup and Hoag 1998).

The principal concern of most restoration projects is to stabilize the streambank with vegetation (Platts et al. 1987). Vegetated riparian areas provide many more important benefits. The function of riparian vegetation includes:

- water quality protection – sediments and nutrients from surface runoff are trapped by vegetation root structures;
- flood control – vegetation secures banks and acts as a sponge by absorbing floodwaters;
- streamflow maintenance – vegetation can regulate water storage capacity of the soil;
- water temperature regulation – vegetation regulates the microclimate of streams by maintaining cooler water temperatures with shading;
- wildlife habitat – riparian corridors are among the most productive wildlife habitats and food sources for aquatic and terrestrial life;
- recreation benefits – aesthetic values and opportunities are increased; and

- economic benefits – including improved property values and recreation potential, and cost avoidance and/or mitigation through the reduction of pollution and flooding (Bentrup and Hoag 1998, Donat 1995).

Table 1 provides a partial list, compiled by the author from CRD information and site assessment, of the native vegetation species planted in the Bowker Creek Restoration Demonstration project (CRD 2006). The species growth habit and riparian characteristics are also indicated. Plant species were selected for their adaptive characteristics to riparian sites. Planting was primarily completed in October 2005 and mulching of the site was completed in May 2006. The site was over-planted to compensate for the anticipated high plant mortality.

Riparian Bioengineering

Bioengineering is the integration of living plant materials to perform an engineering function by increasing the strength and structure of the soil, particularly along embankments and streambanks. The finished bioengineered product responds to the in-situ problem and complements the other native riparian vegetation (Polster 2002 and Bentrup and Hoag 1998).

Bentrup and Hoag (1998) list a number of advantages to using bioengineering techniques over traditional engineering techniques, i.e. concrete revetments and rip-rap, including:

- cost effectiveness;
- improved environmental compatibility;
- use of indigenous, natural material; and
- labour-skill requirements can be met, to a relatively greater extent, with volunteer labour.

Table 1, Native Plant Material List

Name	Growing Habit	Riparian Characteristics
Acer ssp. Maple	+7 m ht., both tree and shrub form	Low-mid elevation range, moist, well-drained sites
Cornus stolonifera Red-osier dogwood	1-6 m ht., spreading	Roots freely, low-mid elevation range, tolerates fluctuating groundwater table
Holodiscus discolor Oceanspray	4 m ht., erect, several main stems	Low-mid elevation range, characteristic of moisture-deficient sites
Oemleria cerasiformis Indian-plum	1.5-5 m ht., small tree	Low elevation range, tolerates fluctuating groundwater table
Philadelphus lewisii Mock-orange	3 m ht., loosely branched	Low-mid elevation range, frequently on water-shedding sites
Polystichum munitum Sword fern	1.5 m ht., erect crown	Woody, scaly rhizome, low-mid elevation range, frequently on water receiving and colluvial sites
Ribes sanguineum Red-flowering currant	1-3 m ht., erect, unarmed	Low-mid elevation range, characteristic of moisture-deficient sites
Rosa nutkana Nootka rose	3 m ht., spindly	Low-mid elevation range, very moist nitrogen-rich soils
Rubus spectabilis Salmonberry	4 m ht., erect, forms dense thickets	Branching rhizomes, low-sub-alpine elevation range, tolerates fluctuating groundwater table
Spirea douglasii ssp. *Douglasii* Hardhack	2 m ht., erect, forms thickets	Low-mid elevation range, tolerates fluctuating groundwater table
Salix ssp. Willow	A number of willow species evident in the wattle	Wide range of soil moisture regimes
Symphoricarpos albus Snowberry	0.5-2 m ht., erect	Rhizomatous, low-mid elevation range, tolerates fluctuating groundwater table

Sources: CRD 2006, Pojar and MacKinnon 1994, Klinka, et al.1989

Polster (2002) identifies some limitations to the use of bioengineering techniques. The plant material selected for bioengineering:

- must be strong enough to withstand the forces acting on them;
- must be in a condition that will promote growth; and
- must be capable of forming roots in situ.

According to Polster (2002) wattle fences are short retaining walls constructed from living cuttings of woody material. Both the stout cuttings that act as support and the cross pieces can root and contribute to the vegetation on the slope by providing a dense cover of pioneering wood species. In British Columbia, riparian species that reliably root from stem cuttings include native willows (*Salix* ssp.), cottonwood (*Populus balsamifera L*.) and red-osier dogwood (*Cornus stolonifera Michx.*)

Wattle fences have been constructed along both sides of the Bowker Creek Restoration Demonstration project. The structure of these fences creates lower slope-angled terraces that increase soil stability and revegetation growth potential. A number of species have been used in the construction of the wattle and sprouting is already evident.

Geotextiles within a bioengineering context are used primarily to stabilize loose top soil layers on slopes until the roots of planted vegetation can become established. Factors that affect the choice of geotextiles can include: the slope of area to be secured; soil characteristics; type of vegetation and time of planting; and, the duration until the development of a root-system occurs (Donat 1995). Biodegradable erosion control mats were reportedly used on this site.

The block-stone embankment along the toe of the slope secures the base of the slope and minimizes the undermining and scouring action of the water. It also provides a structural element for vegetative cover. Some sedge and grass growth is already evident.

Revegetation Monitoring

Monitoring of restoration projects is important to assess whether project objectives are being or have been achieved, i.e. bank stabilization, revegetation of native plant material, and an improved riparian environment. It also provides valuable information, i.e. best practices, for future restoration projects. Monitoring is dependant upon the establishment of a clear set of objectives to set benchmarks and to design a pragmatic evaluation program. The collection of baseline data of the prior conditions of a site is also necessary to assess project success (Kondolf 1995). While the extent of quantitative baseline information specifically collected for this site is not fully documented by the BCI, the creek and its watershed have been studied extensively by the CRD and others.

To assess the achievement of the project objectives, a monitoring program, including criteria, should be established. Potential monitoring criteria for different restoration project objectives can generally be categorized as follows:

- channel capacity and stability – criteria may include channel cross-sections, flood stage surveys, rates of bank or bed erosion, longitudinal profile, and aerial photography interpretation;
- improve aquatic habitat – criteria may include water depth, water velocities, percentage of overhanging cover, increases in large woody debris, shading, stream temperatures, bed material composition, and population assessments for fish and invertebrates;
- improve riparian habitat – criteria may include percentage of vegetative cover, species diversity, species densities, survival of plantings, size distribution, age-class distribution, and wildlife use;

- improve water quality – criteria may include temperature, pH level, conductivity, dissolved oxygen concentration, nitrogen and phosphorus concentrations, and turbidity; and
- recreation and community involvement – criteria may include visual resource improvement and recreational use surveys (Bentrup and Hoag 1998).

In the case of the demonstration site, monitoring will provide valuable insight into the streambank stabilization process, an opportunity for adaptive management based on the results and potentially improve the management of the resource (Bentrup and Hoag 1998, Bash and Ryan 2002). It may also provide important information for future projects.

Monitoring of this site has not been initiated by the CRD at this time. Effectively, this project is undergoing a number of final implementation measures and resources (either by CRD staff or volunteers) have not as yet been applied to monitoring. It is anticipated that ongoing maintenance will provide, at a minimum, some visual and qualitative monitoring of the successes and failures of the restoration project.

The purpose of this assignment is primarily intended to consider appropriate monitoring of the demonstration site, particularly creek morphology and bioengineering stabilization, and native plant revegetation. Methods for assessing and measuring revegetation restoration projects include:

- photo-point photography;
- visual estimation and measurements;
- line intercepts; and
- quadrats (Bentrup and Hoag 1998).

Bioengineered components of a project, i.e. wattles, can be assessed and measured by a number of methods, including the average number of shoots per linear meter and the average height of shoots per linear meter (Bentrup and Hoag 1998).

Photo-point Photography

Photo-points are easily identifiable locations, ideally geo-referenced by GPS, at the project site from which a series of photographs can be taken to document the restoration progress. Photo-point photography is an inexpensive and easy method of monitoring changes to the site over time. The frequency of the photography can be every few years, or as conditions may necessitate.

Visual Estimation and Measurements

Visual estimation of the vegetative cover (in percent) is a recommended monitoring method for streambanks with canopy vegetation. In the case of the demonstration project, trees with significant canopy have been removed and transplants do not yet provide sufficient canopy for meaningful measurement.

Stem height and stem density of transplants are simple measurements that can be recorded within line transects or quadrats. These measurements can be compared to measurements taken at the time of planting. These measurements can also be recorded for wattle fencing.

Wattle measurements can include the average number and height of shoots per linear meter. A transect can be established along the fenceline and visual counts taken. Wattle failure and erosion points can also be documented for maintenance purposes.

Line Intercepts

Cross-section measurements perpendicular to the stream flow of the creek can help assess changes to bank morphology over time. These measurements can include slope gradient, bank height, water level, and channel width. The number of cross-sections recorded in each treatment area depends on the scale of the project. Measurements taken at the same locations at regular intervals, i.e. bi-annually, help to inform future maintenance requirements.

As the site stabilizes, the composition of vegetation along the greenline, that is the perennial vegetation that forms a lineal grouping at or near the water's edge, can be sampled. This measurement provides an indication of the health of the watershed (Winward 2000).

<u>Quadrats</u>

Quadrats are used to define sample areas within the study area. The 1 m^2 quadrat measurements can include cover density, plant survival/mortality, species diversity and invasive plant composition. It should be noted here that weed pulling by the BCI volunteers is ongoing at the project site.

Assessment and Monitoring Protocol

The assessment and monitoring protocol established for this assignment, was as follows:

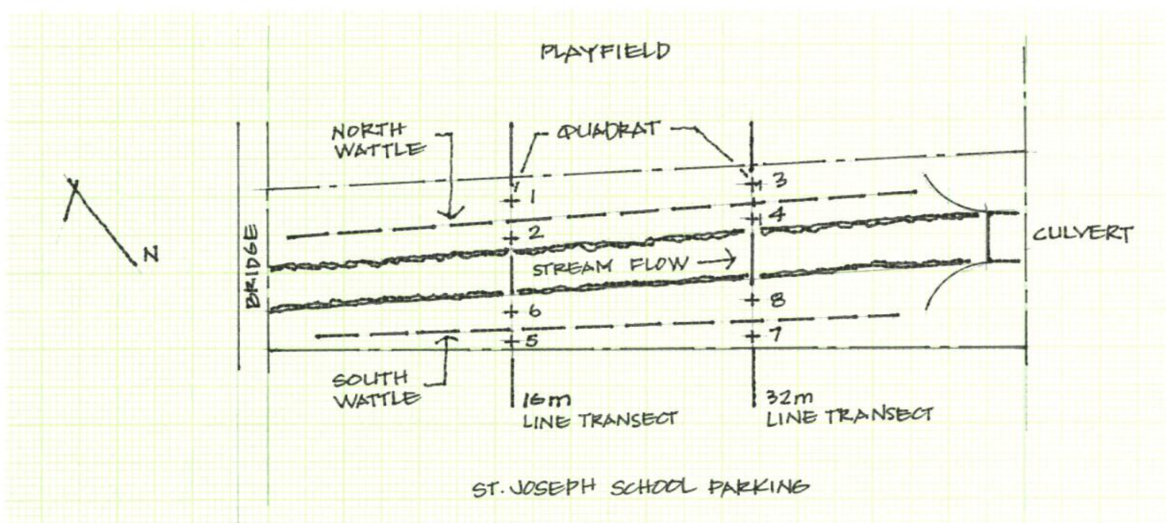
- With a GPS unit, record waypoint and elevation readings at the four chain-link fence posts and at other necessary locations to ensure valid geo-referencing;
- Identify any other distinguishing landmarks and features, i.e. bridge, culvert diameter, direction of creek flow;
- At photo-points, take photographs of the site and key features;
- Locate cross-section line intercepts at 16 m and 32 m (approximately ⅓ and ⅔ the distance from established baseline);
- With a measuring tape, graduated measuring rod and clinometer, record bank profile, horizontal width of slopes and channel;

- Locate tape measure along both wattle fences and inspect for failure or erosion evidence. At 10 m intervals, measure 1 m lengths to count approximate number and maximum height of shoots;
- Using a quadrat at 4 sites (centered along top and bottom terraces at 16 and 32 m) on each side of the creek, visually estimate the percent cover of all plant material, native transplant survival/mortality, species diversity and invasive plant composition; and
- Document and organize the above information.

Assessment and Monitoring Results

Literature review and communication with CRD staff were undertaken between April 27 and May 21. The field assessment and measurements were completed by the author on May 22, 2006. The weather conditions (14°C, rain) created some challenges as the wet conditions softened the streambanks and raised the creek water level. Figure 3 is a sketch of the site layout features and key monitoring points.

Figure 3, Bowker Creek Demonstration Site Plan



Scale: 1:500

To assess the contribution of the willow wattle to the site stabilization through vegetative growth, the number and height of live stems sprouting along the wattle on both sides of the creek were recorded by line intercept. Readings were taken at 1 m intervals, every 10 m along the length of the fenceline. The number of wattle uprights (posts) were also measured as it was found that the greatest concentration of sprouting is occurring on the uprights. The posts are spaced approximately 75 cm on centre. The north wattle is about 41.4 m in length and the south wattle is approximately 38 m. The wattle was observed to be generally in very good condition with no failure or erosion evident. The results of the measurements are summarized in Table 2.

Table 2, Wattle Measurements

Interval (m)	Number of Wattle Posts		Number of Live Stems		Maximum height of Stems (cm)	
	North	South	North	South	North	South
0-1	3	3	44	24	70	54
10-11	2	1	33	27	80	48
20-21	2	1	30	22	85	70
30-31	1	1	25	17	80	40
40-41	2	-	28	-	65	-
Average	2.0	1.2	32.0	18.0	76.0	42.4

Overall, the north side of the creek has more wattle posts; a greater concentration of live stems; and, taller growth. While all posts and many stems are sprouting, some factors that may be affecting the growth rate of the wattle include:

- soil moisture variation - the north side of the creek is adjacent to a grass playfield that allows rainfall absorption to permeate the surrounding soils providing greater moisture availability; whereas the south side is adjacent to the impervious parking lot surface where moisture is collected and piped through storm drains;
- species selection – adaptation of wattle material species may differ in their rate of sprouting and growth; and

- light variations – the north side (south aspect) may receive more light than the south side with a north aspect.

The objective of the Bowker Creek Demonstration project photo-point photography is to assess the ecological impact of the restoration measures, including native vegetation growth rates, bioengineering stabilization monitoring and invasive weed management. With this objective in mind, photo-point photographs were taken primarily at the corner locations of the site providing views of both sides of the creek. These photographs are documented in Appendix A.

Eight quadrat measurements, four at each of the 16 m and 32 m line intercepts were completed at the site. See Figure 3 for the quadrat location and number. Generally, the 1 m^2 quadrat was centered along the line intercepts between the fence and wattle and the wattle and block-stone embankment on each side of the creek. Table 3, Quadrat Measurements, summarizes the observations of the percent cover and species diversity. The quadrat results are organized to compare the quadrat analysis from comparable locations on either side of the creek. A number of observations are evident:

- native revegetation species coverage is relatively low as measurements have been taken at the start of the first growing season – many of the shrub transplants are young (small) specimens;
- no stratification of plant species is immediately evident – it appears that all species have been planted on both the upper and lower terraces on both sides of the creek;
- there is great variation in the species selected for this site and over-planting was completed due to the expected high rate of plant mortality; and
- it appears that *Equisetum arvense* and grass species are the dominant invasive weeds in the first growing season. *Equisetum*

Table 3, Quadrat Measurements

Quadrat: # 1
Location: North side, upper terrace, 16 m from baseline

Species	Percent Cover
Rosa	1
Polystichum	1
Oemleria	4
Equisetum	40
Grass ssp.	3
Mulch (bare)	51

Quadrat: # 2
Location: North side, lower terrace 16 m from baseline

Species	Percent Cover
Ribes	10
Equisetum	15
Vicia	1
Grass ssp.	5
Mulch (bare)	69

Quadrat: # 3
Location: North side, upper terrace, 32 m from baseline

Species	Percent Cover
Oemleria	5
Cornus	2
Ribes	10
Spirea	15
Equisetum	6
Grass ssp.	3
Mulch (bare)	59

Quadrat: # 4
Location: North side, lower terrace, 32 m from baseline

Species	Percent Cover
Cornus	5
Mulch (bare)	95

Quadrat: # 5
Location: South side, upper terrace, 16 m from baseline

Species	Percent Cover
Symphoricarpos	9
Philadelphus	10
Equisetum	25
Geranium	5
Mulch (bare)	51

Quadrat: # 6
Location: South side, lower terrace, 16 m from baseline

Species	Percent Cover
Cornus	30
Ribes	10
Rubus	5
Mulch (bare)	55

Quadrat: # 7
Location: South side, upper terrace, 32 m from baseline

Species	Percent Cover
Rosa	20
Symphoricarpos	8
Polystichum	10
Equisetum	40
Grass ssp.	8
Mulch (bare)	14

Quadrat: # 8
Location: South side, lower terrace 32 m from baseline

Species	Percent Cover
Cornus	20
Ribes	5
Acer	10
Grass ssp.	10
Mulch (bare)	55

was not present at the site prior to the addition of topsoil (CRD 2006). The presence of *Equisetum* (a native plant) is characteristic of disturbed, water-receiving sites (Klinka et al. 1989);

- other invasive species include thistle and geranium; and
- to date, the survival rate of the native shrub revegetation is observed to be extremely good. All transplanted plant material counted within each quadrat locations is currently showing 95-100% survival. Transplanted trees (*Acer* ssp.) at the site corners on the upper banks have shown some stress with winter dieback.

Monitoring Observations

Project monitoring is recommended in order to document the regraded slope characteristics and changes, native plant revegetation success and invasive plant growth. Water quality monitoring is another important consideration in achieving an improved riparian environment. This is more difficult to assess due to the location of the demonstration project, relative to the watershed and its upstream impacts. Also, unless initial pre-construction/ restoration baseline data was collected at this site, specific changes to water quality cannot be directly attributed to the restoration project and comparative analysis of data with other sections of the creek cannot be undertaken.

Comparative monitoring using the established methodology may be undertaken after one full growing season to assess restoration successes and failures. This monitoring will assist in revising planting, irrigation and weeding schedules on this and future projects.

Due to its status as a demonstration site that has benefited from community involvement, the Bowker Creek Restoration project may require, at a minimum during the establishment period, a higher level of maintenance to ensure it adequately showcases creek restoration procedures and practices. General site clean-up, invasive weed management and irrigation to minimize revegetation mortality are all important site maintenance issues. Signage will complement the recognition and understanding of the restoration efforts underway at the site.

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Photo-Point Photographs

Date: May 2006
Camera: Olympus, C-7000, digital

Looking east from middle of bridge

Looking west from top of culvert

Looking east along north side

Looking east along south side

Looking west along lower slope, north side

Storm drain from parking lot