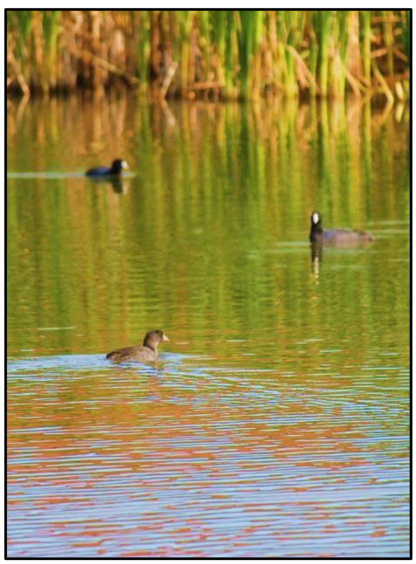
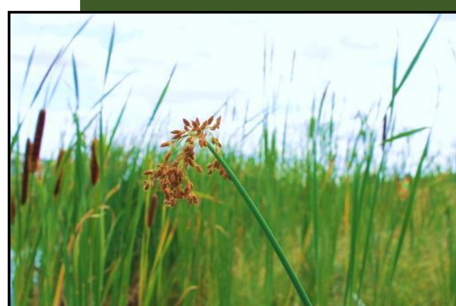
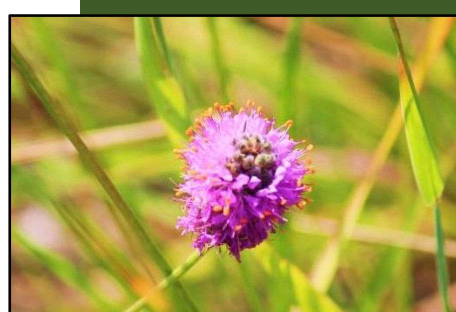
City of Brandon Naturalized Stormwater Pond Guidelines

April 9, 2018







Native Plant Solutions

Prepared by:

L. Ross

L. Dupuis

K. Unterschultz

J. Raizenne

Native Plant Solutions - Ducks Unlimited Canada

Executive Summary

Background

In support of the City's goal of encouraging environmentally sensitive development (Brandon and Area Planning District 2015), the *City of Brandon Naturalized Stormwater Pond Guidelines* provide direction on the development of naturalized stormwater ponds (NSPs). NSPs provide an innovative means to manage stormwater quantity and quality, offering a multitude of benefits to residents, developers and operators. They offer a community amenity that provides habitat, raises environmental awareness and encourages social connection. There are also demonstrated economic benefits including reduced maintenance, increased tax revenue, and construction cost savings.

This guide was developed to complement the City's development guidelines, standards and plans and is intended for use by a broad audience. It provides information to a range of users including land developers, designers, contractors, and operations staff. Table E1 below highlights the sections of this document which will be of primary interest to the various groups.

Table E1. Primary reference for key user groups.

Developers	**Section 1** includes background on naturalized stormwater management, its merits, and key implementation stages. **Section 2** provides basic information on naturalized stormwater management principles.
Designers	**Section 3** provides guidance for engineering practitioners on the design of NSPs. **Section 4** provides guidance for biological practitioners on the design of NSPs. **Section 5** outlines key content to be included in design submissions to the City.
Contractors	**Section 6** offers information on recommended construction practices, ESC measures and timing. **Section 7** provides recommendations on management during the commissioning period prior to handoff.
Operations Staff	**Section 8** provides guidance on the long term operations, maintenance and monitoring of NSPs.

Design

Naturalized facilities are living systems and their successful design and implementation requires expertise from a range of professional disciplines. General design considerations are described below and minimum design parameters are summarized in Table E2 and Table E3. Figure E1 provides a pond schematic.

Hydrology and hydraulic design

Site hydrology is integral to the success of an NSP, facilitating the design of pond geometry and hydraulic elements, and informing plant selection and siting. If water level fluctuations are anticipated either as a result of groundwater flux or outlet condition, a water balance analysis is recommended. This will help ensure that biological design elements are suited to hydrological conditions. With respect to quantity control, NSPs will be designed in accordance with City standards and meet the same requirements as conventional ponds with respect to active storage, freeboard and drawdown time.

Physical parameters

Physical parameters, such as pond geometry and depth, create the environment that will support plant communities. An NSP consists of three key zones: the wetland zone, the open water zone, and the vegetative upland buffer zone, each of which has its own requirements (see Table E2). In addition, a minimum length to width ratio (L:W) of 3:1 is recommended along with a minimum shoreline development index (SDI) of 1.2 to promote enhanced water quality and biodiversity.

Infrastructure

Infrastructure within an NSP should support plant establishment, promote water quality and match the natural aesthetic. To maintain a naturalized look, the use of riprap is discouraged on emergency overflow spillways unless required to prevent erosion; native vegetation is preferred. Care should also be taken to minimize the number of inlet and outlet structures and site them in a manner which avoids short circuiting. Submerged structures are preferred; if an unsubmerged structure is required, placement outside of high visibility areas is preferred. Outlet control structures should enable water level adjustment (NWL ± 0.30 m) to support establishment of wetland vegetation.

Soil considerations

Soil properties are an important design consideration. Factors such as permeability, nutrient content, and susceptibility to erosion will impact hydrology and the ability to support plant growth. It is preferred that either (1) the pond base is constructed of low permeability soil (e.g., with a permeability coefficient in to the order of 1×10^{-6} cm/s) or (2) a constructed clay liner is incorporated into the design. If permeable soils are used, an assessment of groundwater flux is required to ensure that the water balance will support wetland vegetation. It is also necessary that physical and chemical characteristics of the growth medium support plant establishment in the upland and wetland zones.

Vegetation cover

Vegetation cover is directly related to the water quality performance of the pond. It is recommended that between 35% to 65% of the footprint below NWL contain wet meadow, shallow marsh, or deep emergent wetland plants, while still accommodating deeper channel depths of 2 m to 3 m in the most central portions of the pond.

Table E2. Minimum engineering design criteria for NSPs.

Quality Control	
TSS	See Table 2.2 for CCME Guideline
Physical Parameters	
L:W ratio	≥ 3:1
Pond Width	≥ 40 m
Sideslopes	5:1 ≤ slope ≤ 7:1, upland zone
	7:1 ≤ slope ≤ 40:1, wetland zone (ideally greater than 10:1)
	3:1 ≤ slope ≤ 4:1, open water zone
Depths	0-60 cm, wetland zone
	2.0-3.0 m, open water zone
Shoreline complexity	SDI ≥ 1.2
Hydrology	
Permeability of pond base	(a) Submit geotechnical testing demonstrating that in-situ soil is sufficiently impermeable (i.e., 1 x 10-6 cm/s) to neglect groundwater; or
	(b) Incorporate a constructed clay liner into the pond design; or
	(c) Demonstrate (via hydrogeological expertise and/or water balance analysis) that the pond can sustain the target NWL or operating range.
Hydraulics	
Active storage volume	Store 100 year design event
Active storage depth	Level of rise ≤ 1.5 m (NWL to HWL)
Freeboard	≥ 0.3 m from HWL to spillway invert or sufficient depth to contain maximum historical event (whichever is greater)
Drawdown time	≤ 48 hours for 5 year event
	≤ 120 hours for 100 year event
Outlet capacity	Limit discharge during the 1:100 year event to the 1:5 year pre-development discharge rate
Infrastructure	
Spillway	Vegetative recommended unless otherwise required for ESC
Inlet/outlet pipes	Site structures to minimize potential for short-circuiting
	Crown ≥ 0.6 m below NWL if submerged
	Incorporate headwall and grate if unsubmerged
Control structures	Provide elevation range to NWL of ±0.30 m
Safety and access	Use appropriate screens/grates to prevent public access and/or debris blockage
	Incorporate a hinge or other device (equipped with security device) to facilitate access by authorized personnel
	Site any controls or moving parts above ground
	One all-weather vehicle access to control structure

Table E3. Minimum biological design criteria for NSPs.

Composition	
Vegetation cover surface area	≥ 35% of NWL surface area
Open water surface area	≤ 65% of NWL surface area
Plant communities	
Wetland	
Plant Species	≥ 15
Wet meadow zone	0-10 cm depth
	≥ 7:1 slope
	≥ 3 m zone width
Shallow marsh zone	10-30 cm depth
	10:1 ≤ slope ≤ 40:1
	3-10 m zone width
Deep emergent zone	30-60 cm depth
	10:1 ≤ slope ≤ 40:1
	3-10 m zone width
Upland	
Plant Species	≥ 15
Buffer strip	5:1 ≤ slope ≤ 7:1, upland zone
	13-20 m zone width
Growth medium	
see Table 3.2	
Human use	
Pathways	Locate paths at the top of the upland buffer above HWL
Signage	Provide interpretive signage for public education
	Provide safety signage, as appropriate (notification of pesticide use, thin ice, etc.)

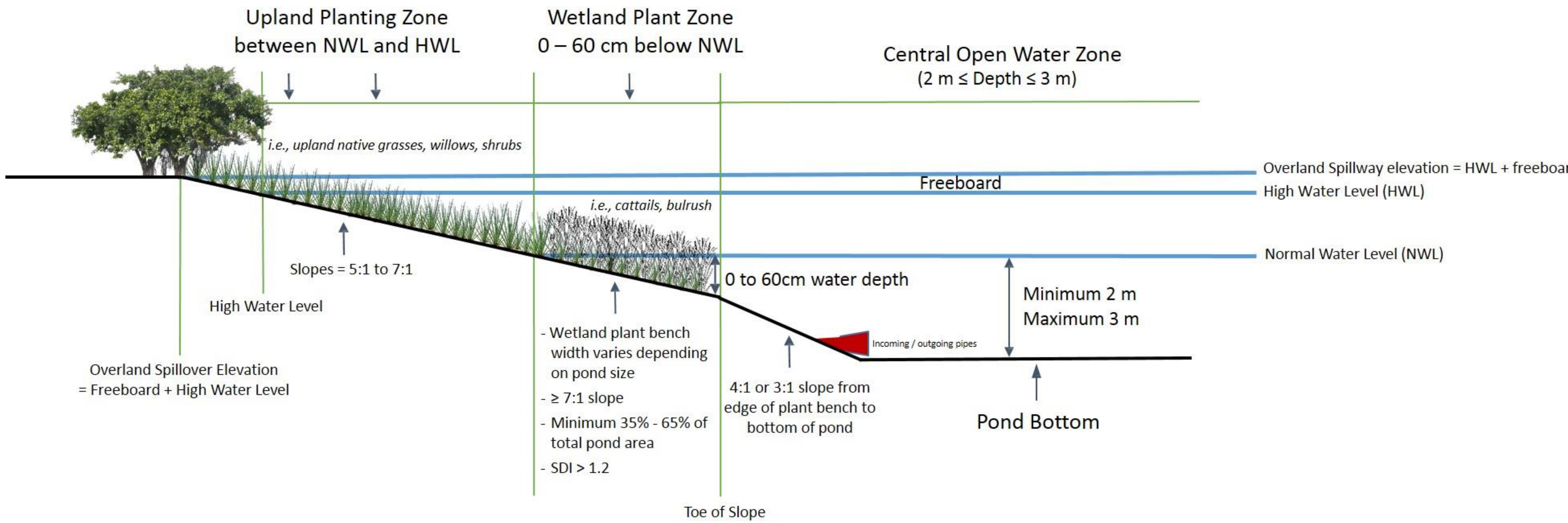


Figure E1. NSP cross-section.

Vegetation communities

NSPs are composed of an upland buffer strip and three types of plant communities, or plant zones:

- Upland buffer: Located between NWL and HWL, this continuous strip of native upland vegetation (approximately 13 - 20 m width) consists of a minimum of 15 native grass and forb species. Trees and shrubs can also be incorporated into the planting plan.
- Wet meadow zone: Located along the uppermost reaches of the wetland edge (0 to 10 cm below NWL), this is a transitional zone between upland and wetland areas.
- Shallow marsh zone: Growing in water depths ranging from 10 to 30 cm below NWL, plants in this community or zone are comprised of a number of grasses and herbs.
- Deep emergent zone: Growing in deeper areas (30 - 60 cm below NWL), deep emergents are the most resilient to prolonged, and stable, flooded environments. Species in this zone will be the workhorses for improving water quality.

Areas flooded > 60 cm below NWL will remain as open water as long as water depths remain stable (e.g., water level sits at NWL in most years).

Project safety

As with conventional pond design, appropriate measures are required to provide safe access for maintenance staff and protect the public. Suitable signage, screens, grates and security devices should be incorporated into design elements.

Design submission

The process and content of a submission package for an NSP will closely match what is already required by the City of Brandon. Submissions will be made to the City at the conceptual design stage and again at the detailed design stage. As presented in Table E4, some additional information is recommended for inclusion with the basic items.

Table E4. Draft submission requirements for NSPs for the City of Brandon. *Reference Section 6.1 of draft City Standards (City of Brandon 2017) for mandatory requirements relating to stormwater management and land drainage system. **Reference Section 7.1 of draft City Standards (City of Brandon 2017) for mandatory requirements relating to stormwater management and land drainage system.

		Conceptual Design Stage*	Detailed Design Stage**	Consideration(s) for Naturalized Facilities
Design Brief/Report	Project Description	General description of the existing site condition, proposed development and proposed drainage system to be developed, identifying contributing drainage area and noting downstream capacity constraints.	Detailed description of each stage of the proposed development, including land use and development staging.	Include reference to any existing natural areas or elements which will be incorporated into the facility design. If development is being staged, describe how staging will impact the pond (e.g. Will pond be staged? What is the approximate timing for each stage to discharge to the pond?)
	Modeling/Calculations	Pre and post development runoff analysis, demonstrating storage of 1:100 year post development runoff volume with 1:5 year pre-development discharge rate.	Confirmation of the hydraulic design of the minor drainage system. Confirmation of the pre and post development runoff requirements, and the related storage requirements. Review of ponding depths and overland flow of the major drainage system, including catch basin inlet design. Inlet and outlet safety requirements where connections to the underground LDS system will be made. Confirmation of attenuation facility design. Confirmation of the pump station capacity and location. Any other relevant design calculations.	Describe how the naturalized facility will perform with respect to its typical range of operating levels and characterize soil conditions at pond base. The proponent should demonstrate (1) that there is sufficient water to support the wetland and (2) that there is sufficient outlet capacity to ensure plant communities are not place at risk via prolonged submergence. Condition 1 can typically be met either by (a) ensuring source water is available to supplement the facility as needed (during initial phases) and/or (b) completing/submitting a water balance assessment. Condition 2 will be met if the City's standard drawdown times are achieved. In systems where this is not possible, a wetland specialist should comment on survivability of proposed plant communities during the drawdown period.
	Supporting Material	All design calculations and hydrologic/hydraulic models should be included. This includes any XPSWMM computer models and water balance analyses completed to support proposed conceptual/detailed design.		Water balance calculations (if completed), geotechnical report and/or (if groundwater is a concern due to permeable soil) hydrogeologist estimation of groundwater flux.
Pond Drawings	Drainage Area	Catchment/subcatchment areas.	Catchment/subcatchment areas	Clearly note any differences in catchment/subcatchment boundaries and hydrological parameters based on (a) major vs. minor drainage system and (b) completed stages of development.
	Conveyance	Drainage Paths and discharge locations.	Detailed plan and profile drawings of inlet/outlet piping connecting to the pond. Cross sections, grade and alignment for overland ditches connecting to the pond.	Any surface conveyance elements (including emergency overflow) should be fully vegetated to provide a more natural and consistent aesthetic. Native plantings are recommended and these areas should be included on the planting plan.
	Attenuation Facility	Location and size of attenuation facilities.	Detailed pond grading plan. Plan view and cross sections of the attenuation facility, including the NWL and HWL.	A planting plan should be submitted that clearly identifies the various native planting zones to be established, and the location of plant zones both above and below NWL. The planting plan should include sufficient contours from the grading plan to clearly show the depth of each planting zone, the slope between contours, and the location and depth of the center channel. Note also that the design grades will need to be achieved to a tolerance of ± 5cm. Given this, the grading plan should consider constructability and potential equipment limitations.
	Structures	Location of inlets, outfalls and gate chambers.	Outfall and gate chamber sections and details, including erosion protection measures as required. Include a gate operation memorandum as a part of the submission identifying operational procedures.	To facilitate water level fluctuations during commissioning, it is recommended that the outlet flow control structure be able to lower the water level at least 0.3 m below NWL. All relevant details (gate mechanism, orifice wall, manhole, etc.) should be shown in plan and profile.
	Pump Station(s)	Locations of pump stations	Confirmation of the pump station location and required capacities, and anticipated operational procedures (on/off, maintenance, etc.). Mechanical, electrical and structural drawings to be submitted to the City for general review.	n/a
	Easements	Easement requirements	Easement requirements.	n/a

Construction and Commissioning

Timelines

There are many components to NSP construction. While each pond will have project-specific requirements, general timing for key components is outlined below.

- Earthworks: This can occur in winter, or as a summer/fall construction. Winter construction should only be undertaken if grading to a ± 5 cm design tolerance can be achieved.
- Wetland Plantings: Winter planting may be more efficient but a guaranteed supply of water to NWL is needed in the following spring to support wetland plant establishment. It can also take place in spring or late summer, once an NSP has been supplied water to its NWL. This process requires a drawdown in late spring to support germination. Hand planting of wetland plants in the late summer is another alternative. In general, spring or summer planting is more labour intensive than winter planting.
- Upland Plantings: It is optimal to seed native grasses and/or transplant tree and shrub species in the spring or the fall when there is sufficient soil moisture. It is recommended that the upland zone be planted after the wetland zone to minimize the potential for damage to upland plants.
- Hydrology: Initial supply to the NWL of the pond is required by spring of the first growing season. If runoff is insufficient and alternative sources are unavailable, wetland planting should be delayed.

Sourcing and preparation of seed and donor material is another important timeline consideration. As wetland plants are not available commercially, seed and donor plant material must be sourced and prepared in advance.

Erosion and sediment control

Sound erosion and sediment control (ESC) is critical to establishment success. In addition to targeted practices such as earth dykes, sediment control fences, check dams and sedimentation ponds, ESC practices may include the use of cover crops, stabilization of disturbed areas and appropriate scheduling of disturbance activities (with respect to seasonal conditions and construction schedule).

Wetland establishment

Three planting techniques are available for vegetating an NSP with wetland plant species below NWL. These include: (1) Seeding, (2) Transplanting whole plants or live-plant propagules, and (3) Using live-donor soils. Wetland seed can be disseminated on planting areas below NWL just before snowfall via a drill-seeder or broadcasting, or in the spring by broadcasting before the pond is wetted. Donor soils are usually spread as topsoil below NWL. If donor plants are used, plants should only be transplanted when the plant's energy reserves exist in the roots (i.e., during the winter months when plants are dormant) or in mid-summer, when energy reserves exist in aboveground leaves and shoots.

Upland establishment

Successful upland plant establishment involves four key steps: (1) pre-plant soil preparation, (2) procurement of locally adapted native seed, (3) seed placement, and (4) monitoring and maintaining new plant growth. During the establishment phase, it is critical to develop and implement an integrated approach to weed management. Typical weed management strategies include physical (e.g., mowing), chemical (e.g., herbicide application, as permitted) and cultural control (e.g., seeding a short term cover crop over to outcompete weeds).

Commissioning

Although NSPs are low maintenance over the long-term, additional monitoring and management activities are needed during the five year commissioning period:

- Grading inspection (± 5 cm);
- Annual inspection and operation of control structures;
- Ongoing water management to promote germination and wetland plant establishment;
- Vegetation inspection and reseeding or hand planting as needed;
- Inspection and application of integrated weed management strategy;
- Wildlife control measures; and
- Qualitative water quality inspection.

Key performance measures to be evaluated at hand-off to the City are summarized in Table E5.

Table E5. NSP performance measures evaluated at hand-off.

Performance Measure	Minimum Requirements	Timeline
Infrastructure	Operating as designed	Evaluation in Commissioning Year 1
Grading	± 5 cm design tolerance	
Vegetation to open water ratio	35% to 65% coverage at NWL	Evaluation in Commissioning Year 5
Wetland vegetation species richness	20	
Wetland vegetation species coverage	≥75%	
Wetland vegetation weed coverage	≤ 10%	
Upland vegetation species richness	15	
Upland vegetation species coverage	43-54 plants per m^2	
Upland vegetation weed coverage	≤ 10%	
Native trees and shrubs	50 - 75% survival	
TSS removal	see Table 2.1	

Long Term Operations, Maintenance and Monitoring

While NSPs are low maintenance, a regular inspection, operation, and monitoring schedule is recommended. Key items include:

- Annual inspection of infrastructure, debris removal and operation of control structures;

- Water level monitoring (visual) after major rainfall events;
- Annual inspection of upland and wetland plant communities for % cover, diversity, weed presence;
- Controlled burn or mow of upland stand (every 5-7 years) to remove litter and revitalize; and
- Annual inspection of paths and signage.

If issues are identified (e.g. high/low water levels, prolonged submergence, declining vegetation, sedimentation/erosion, invasive species, algae), a suite of recommended adaptive management activities is provided in this document.

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1. Introduction

1.1. Background

The City of Brandon, as a part of the Brandon and Area Planning District, has set a direction towards the goal of environmentally sensitive development in its Development Plan (Brandon and Area Planning District 2015). The City of Brandon has also identified a comprehensive stormwater management plan as a key priority in the 2015 – 2018 City Council Strategic Plan (City of Brandon 2014). The impact that an increase in flood events has had on the City of Brandon, coupled with its increasing growth, has led Council to develop strategies to identify drainage conditions, potential environmental impacts and prioritize capital improvements. Jurisdictions across Canada have increasingly turned to naturalized stormwater ponds (NSPs) as one innovative solution to manage and improve stormwater quality beyond that capable by conventional ponds (see Section 1.3). NSPs also have the additional advantages of being low maintenance over the long-term, incorporating naturalized elements into a community as greenspace, as well as being an amenity for education and recreation. With an objective to ensure the highest possible water quality of natural water systems in the Brandon and Area Planning District (2015), Brandon is taking steps to be proactive in increasing awareness and responsibility for water stewardship. In addition, with recommendations to incorporate greenspace features that will minimize maintenance while increasing habitat (City of Brandon 2015a), NSPs will reflect the City of Brandon's vision for the community going forward.

1.2. Definition of naturalized stormwater management

Although conventional stormwater ponds provide stormwater management and settling of suspended solids, they provide little potential for additional water quality improvement. Conventional stormwater ponds, with steep basin topography preventing the growth of aquatic plants (Figure 1.1), contain limited biological capacity for contaminant removal. NSPs, in comparison, contain wetland characteristics such as native upland grasses and wet meadow vegetation along their shorelines, and emergent wetland plants within the water column. These features help to support removal of stormwater pollutants, particularly excess nutrients (Figure 1.2). Conventional stormwater ponds, in comparison, have only short turfgrass (e.g., sod) planted in adjacent upland areas with no emergent deep water plant species established within the water column. This limits: (1) The potential for slowing overland flow and mitigating runoff of urban contaminants (e.g., sediments, fertilizers, road salt), particularly during large rain events into the ponds themselves, and (2) The breakdown and removal of excess contaminants once they enter into the water column of the pond. The dense thatch and deep root structures of the native upland grasses and wet meadow species of NSPs provide water quality improvement before water enters into the pond, while the deeper emergent species, such as cattails, help improve water quality within the pond itself. In addition, the native upland grasses planted upslope of the water's edge are low-maintenance, unlike turfgrasses, requiring minimal inputs and management over the long-term. Together, the native grass upland and wetland elements of an NSP support water quality control, in addition to water quantity control; however, the benefits of NSPs are not restricted only to water quality and quantity improvement.

Why naturalize?

Cost savings

- Potential for less soil removed/displaced than conventional stormwater ponds, as excavated material is used in the construction of wetland planting areas;
- Pond construction activities (e.g., wetland planting) can occur during slower construction times of the year;
- Maintenance of the native upland grasses is a fraction of the cost of maintaining turfgrass; and
- No maintenance required to remove unwanted algal blooms or excess submerged vegetation.

Increased commercial and tax revenue

- Experience in the City of Winnipeg (Native Plant Solutions, pers. comm.) has demonstrated higher property values around NSPs, as compared to conventional ponds, results in good economic returns for developers and higher tax revenues.

Environmental and community benefits

- Improved water quality and watershed health;
- Reduced shoreline erosion, as native plants along the normal water level dissipate wave action;
- No blue-green algal blooms and unwanted submersed vegetation;
- Increased wildlife and habitat biodiversity;
- Improved carbon sequestration and decreased greenhouse gas emissions;
- Fewer problems with loafing Canada Geese; and
- The presence of natural and sustainable landscapes in an urban environment.

Note that an NSP, although it contains wetland elements, is not a natural wetland since stormwater management still remains its primary function. Although jurisdictions across the country may use different terminology for stormwater ponds that contain wetland elements (e.g., constructed stormwater wetlands, naturalized wet ponds; see Section 1.3), the terminology to be used in the City of Brandon for a stormwater pond that contains dead storage below the normal water level (NWL), along with wetland elements and a native grass upland, is an NSP.

Although dry ponds can be naturalized, the focus in these Guidelines is for NSP development of wet ponds. In addition, NSPs can be incorporated into commercial and industrial developments; however, the focus of these Guidelines is for NSPs in residential developments.

1.3. Stormwater naturalization - an approach across jurisdictions

The approach to naturalized stormwater management varies greatly across Canadian jurisdictions. In addition, municipal guidelines for stormwater management can impact the delivery and success of naturalized stormwater projects on the ground. The approach of the Cities of Calgary, Saskatoon, Moncton and Winnipeg is briefly outlined below.

City of Calgary: In the City of Calgary's Stormwater Management and Design Manual (2011), design guidelines are given for seven different types of NSPs (referred to as constructed stormwater wetlands in Calgary): shallow marsh, pond-wetland, extended detention wetland, pocket wetland, fringe wetland, emergent wetland and wooded wetland. Each of these design types has variations in the designed water level fluctuations, vegetation zones, size and water quality treatment capabilities. In practice, the success of each of these design types, according to the design guidelines outlined, has not been evaluated. In addition, although some stormwater ponds in Calgary have incorporated natural elements, they often challenged in the field to meet the vegetation requirements outlined in the original pond's design (see Figure 1.3).

City of Saskatoon: The City of Saskatoon developed wetland design guidelines in 2014 for two approaches to naturalized stormwater management: surface flow constructed wetlands and floating wetland islands. Surface flow constructed wetlands are most often used for wastewater treatment and are densely vegetated, with key wetland plant species targeted solely for water quality improvement (see Figure 1.4). For the City of Brandon's stormwater treatment requirements, a surface flow constructed wetland is beyond what is required for water quality improvement. It also lacks some of the key aesthetic features (e.g., open water area, native upland grasses) NSPs provide for the community and for local wildlife. Floating wetland islands only function for water quality improvement, and are applied where site characteristics do not allow for the inclusion of rooted wetland vegetation for water quantity improvement. Research by Ducks Unlimited Canada has shown that our current understanding on the water quality improvement potential and application of these floating systems is still limited and requires further investigation prior to large-scale application (Dupuis, Ross and Robb 2017).

City of Moncton: The City of Moncton finalized naturalized stormwater management guidelines in 2015. Similar to Brandon, this was in advance of any stormwater naturalization approaches being applied on the ground; therefore, recommended guidelines were able to be set in consultation with local developers and their consultants. Moncton's naturalized stormwater management guidelines closely follow the approach of the City of Winnipeg (see below). However, due to regional conditions, Moncton has concerns with sedimentation issues in their stormwater network. Therefore Moncton's design guidelines include the incorporation of forebays within each system to allow for sedimentation and maintenance over time (Figure 1.5). These forebays are designed to look like a natural extension of the NSP.

City of Winnipeg: The City of Winnipeg has been constructing NSPs since 2002. As naturalized stormwater guidelines do not exist for the City of Winnipeg, design and construction has been developer-driven, with the City accepting NSPs on a case-by-case basis. As of 2015, NSPs are now the standard for stormwater pond construction in the City of Winnipeg (see Figure 1.6). With a native grass upland, and a combination of vegetated and open water areas below the normal water level, continued success for water quantity and water quality improvement for these ponds has been observed. In addition, City staff testify to the low maintenance of both the native upland and wetland components of these systems. The City of Brandon's Naturalized Stormwater Pond Guidelines closely follow Winnipeg's design approach, with modifications to consider the regional context, including soil conditions, groundwater positioning and plant species selection appropriate to the region.

1.4. How to use this document

The purpose of the City of Brandon Naturalized Stormwater Pond Guidelines is to: (1) Outline key components that are required for successful NSP development, and (2) Ensure the benefits of these systems (i.e., cost savings, increased tax revenue, environmental and community benefits) are accrued to developers, the City of Brandon and its residents. Part of successful NSP development requires ensuring the key stages, from design to project hand-off, are followed (see Section 1.5). Success is also dependent on a developer possessing the appropriate skill sets in their project team (see Section 1.6). Although existing guidelines are available for stormwater ponds that contain naturalized elements (City of Moncton 2015, City of Calgary 2011, City of Saskatoon 2014), the City of Brandon Naturalized Stormwater Pond Guidelines have been developed with consideration for regional context, including soil conditions, groundwater positioning, and species selection appropriate to the region. Design requirements, where indicated, are required to be met for project hand-off; however, the Guidelines have been written with flexibility to allow a project team to adapt design, construction and commissioning considerations to site conditions in consultation with City of Brandon staff.

Throughout this Guideline document, design, construction and operation recommendations are made with the principles of Minimal Ecological Management (MEM) in mind. MEM, in the context of NSP development, is taking actions that promote the long-term sustainability of a pond's hydrology that is appropriate for the pond's location and intended functions (Ross 2011). MEM requires that three key principles are kept in mind throughout the naturalized stormwater development process:

1. **Goal setting:** Set realistic expectations about what can be accomplished for NSP management over the long-term, particularly during the design stage.
2. **Sustainability:** NSPs should be designed, commissioned and operated with appropriate hydroperiods suitable to support their native grass upland and wetland elements, including the vegetation of these systems. NSPs should be maintained in a manner that requires infrequent interventions that employ a minimum of artificial processes.
3. **Diversity:** Optimal water quality improvement, resilience to disturbances, habitat and aesthetics are achieved in an NSP when a diversity of wetland and upland plant species are incorporated. This requires intended strategies during the design, construction and commissioning stages.

The idea is that an NSP should be as self-sustaining as possible, requiring little maintenance and operations over the long-term. Considering MEM and its three key principles during NSP development will help guide project success.

The City of Brandon Naturalized Stormwater Pond Guidelines have been written to complement existing guidelines and standards, including the draft Stormwater Design Standards Manual (2017) and the Urban and Landscape Design Standards Manual (City of Brandon 2015b). It should be noted that the City of Brandon Design Standards Manual (2017) referenced herein is an unapproved draft document submitted to the City for consideration in January 2017. Users of these guidelines should ensure that this document is used in conjunction with the most up to date versions of all City development guidelines, design standards and plans. Regulatory information related to NSP development is not included in these Guidelines. It is the responsibility of the developer to review, interpret and respect all applicable legislation. A glossary in Appendix A defines key terms associated with NSP development that are used in these Guidelines.

1.5. Naturalized stormwater development: Key stages from design to project hand-off

The City of Brandon Naturalized Stormwater Pond Guidelines are broken down into the following sections based on the key stages for naturalized stormwater development: design, construction, commissioning and project hand-off.

- **Stormwater management principles (Section 2):** Discusses the roles that upland native grasses and wetland plants play in improving water quality in naturalized stormwater systems.
- **Design (Section 3, Section 4, Section 5):** Split into the engineering (Section 3) and biological (Section 4) considerations, these sections enable designers to mimic the elements of natural wetlands that support water quantity and quality improvement (Section 2). Section 5 summarizes key information to be included with design submissions.
- **Construction (Section 6):** Good planning as part of construction includes taking pre-emptive steps to minimize erosion impacts, and establishing timelines for earthworks and grading efficiencies, vegetation establishment and water management. Proper planning for naturalized stormwater construction can save time and money and mitigate negative impacts to native plant establishment.
- **Commissioning and project hand-off (Section 7):** Pond commissioning is a five year process with planned activities to ensure the successful establishment of an NSP, as per its design. During this time period, frequent monitoring of a pond’s infrastructure, hydraulic regime, wetland and upland plants ensures it is functioning as designed and allows for adaptive management activities where required. Undertaken by the developer and their team of experts, this stage demonstrates to the City of Brandon that an NSP is functioning as intended prior to handoff. Following commissioning, an operations manual outlining site specific information is provided to the City of Brandon.

- **Operations, maintenance and monitoring (Section 8):** Following project hand-off, some maintenance will be required on the NSP over the long-term. This section outlines considerations for long-term operation, monitoring and maintenance of the pond.

Following the recommendations in these four key stages ensures that the principles of minimal ecological management (MEM) are met (i.e., goal setting, sustainability and diversity) and sets the standard for a well-functioning and low-maintenance NSP at hand-off to the City of Brandon.

1.6. The project team

The design, construction and commissioning of NSPs requires expertise from a variety of professional disciplines to ensure the pond's success. This includes expertise in engineering, construction, hydrology, soil science, biology/plant ecology (e.g., upland and wetland), landscape architecture, and weed science. It is important to acquire professionals on your team that demonstrate a proven track record in the successful design, construction and commissioning of NSPs.

Engineers play an important role in the hydrological and operational design of the pond, its integration into the surrounding development, construction oversight of the pond, municipal/regulatory submissions, and project handoff. For those locations where the hydrological assessment or operational performance of the pond may be problematic, the expertise of a hydrologist is recommended. Soil scientists/specialists can play a vital role on stormwater projects, especially on those projects where soils may be challenging (e.g., nutrient poor, previously heavily managed), of questionable constructability (e.g., sandy, near groundwater), or where erosion or soil stockpiling may be a concern.

In contrast to conventional stormwater ponds, biologists and plant ecologists play a key role in the design, establishment and commissioning stages of NSPs. They're often responsible for the biological design of the pond, selection of suitable plant species, the positioning of plant communities within the pond footprint, planting strategies and techniques, plant establishment (e.g., upland and wetland), and maintenance requirements and schedules. It is also critical the plant ecologists possess a thorough knowledge of wetland and native upland plants. Many native plant species are unable to outcompete weedy and invasive plants during establishment. Therefore, it is also important that someone on the project team is knowledgeable in weed identification, as well as the timing and methods for weed control.

It is important that the pond be constructed in the field as it is designed on paper. As even small deviations in final grades can affect wetland community establishment, it is critical that grading tolerances (i.e., ± 5 cm) be strictly adhered to within wetland the planting zones (i.e., 0 – 60 cm below the normal water level). A construction specialist (e.g., certified engineering technologist (CET) or construction engineer) can help ensure that final pond grading and infrastructure is accurate. They can also provide input on site grading and excavation efficiencies, topsoil and subsoil placement/management, soil sourcing, and erosion and sediment controls.

Lastly, many NSP designs incorporate an important human use component. Landscape architects can play a key role in designing the connectivity between natural areas, such as the ponds, within the greater development footprint, as well as for the overall design of park spaces, resting nodes, interpretive signs, site access, and pathways within the pond and development footprints.

Figure 1.1. Conventional stormwater pond in the City of Winnipeg, with shorelines edged by rip rap, turfgrass on the upland slopes, and no wetland vegetation.

Figure 1.2. NSP in the City of Winnipeg, containing native upland grasses, wetland plants and an open water zone.

Figure 1.3. Constructed stormwater wetland in the City of Calgary, containing only a periphery of wetland vegetation.

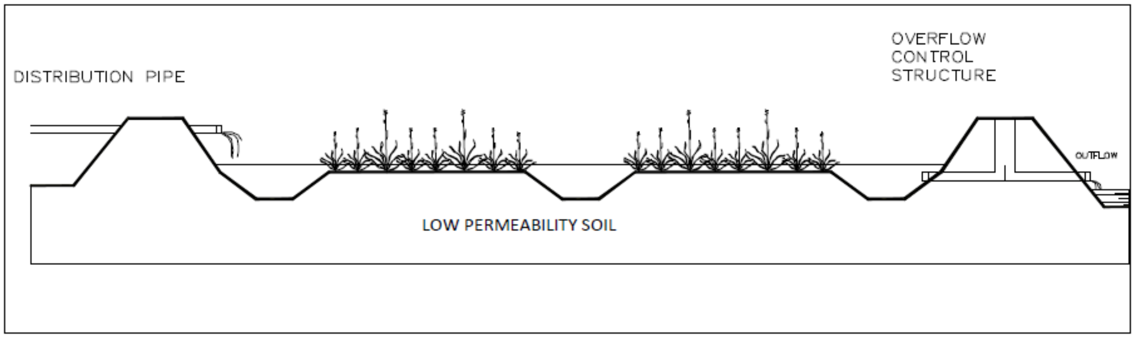

Figure 1.4. High-level design cross-section of a surface flow constructed wetland for naturalized stormwater management in the City of Saskatoon (from City of Saskatoon 2014).

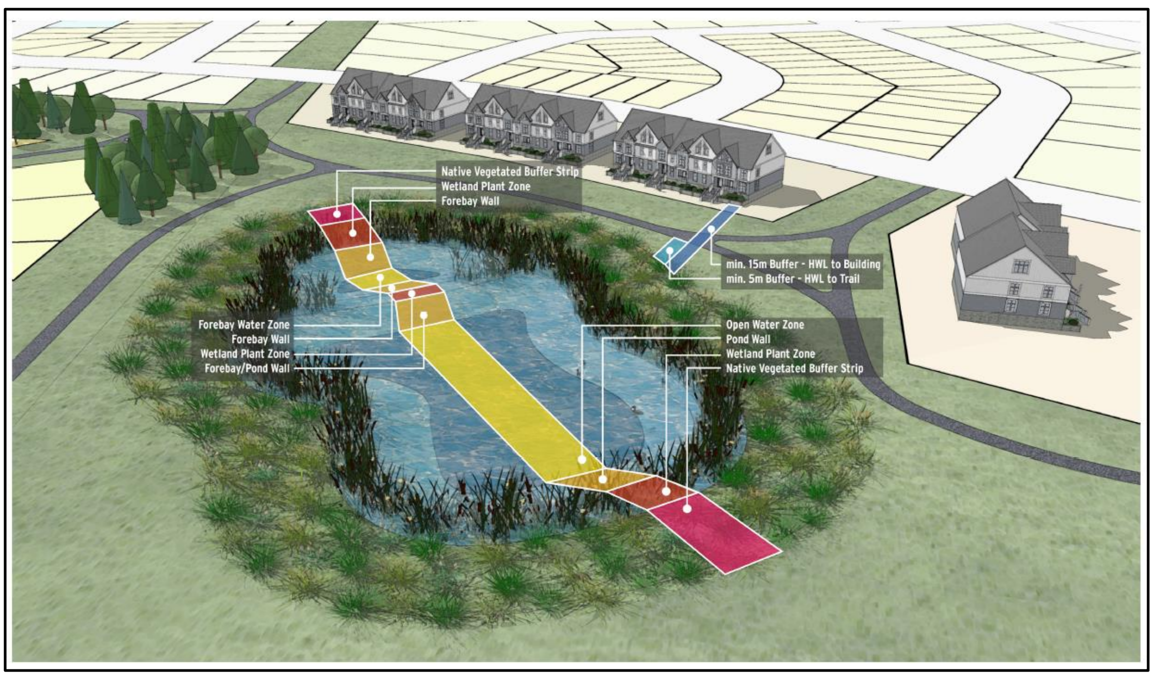

Figure 1.5. Design drawing of the naturalized stormwater approach in the City of Moncton, including the design inclusion of a forebay (from City of Moncton 2015).

Figure 1.6. NSP in the City of Winnipeg, containing a native grass upland, wetland vegetation and an open water zone.

2. Stormwater Management Principles

2.1. Quality control

In the Brandon and Area Planning District's Development Plan (2015), a water quality policy was established to protect receiving waters, fish and fish habitat from the potential runoff of contaminants or sediments from developments and/or activities. The policy's goal is "*To ensure the highest possible water quality of natural water systems in the Brandon Area Planning District.*" The key advantage of an NSP, as compared to a conventional stormwater pond that lacks wetland elements, is its water quality improvement potential. Jurisdictions across Canada have recognized their potential for water quality improvement and, by meeting key design principles, water quality improvement for both sediment and nutrient reduction is possible.

The wetland elements of NSPs have the ability to improve stormwater quality through various physical, chemical and biological processes (Table 2.1). These processes are inherent to the high rate of biological activity in natural wetlands; however, with proper design, reliable stormwater quality improvement can also be achieved in properly designed NSPs. Within the stormwater pond, wetland plants disperse incoming stormwater and slow its velocity to allow sediments to settle. Similarly in the upland grassed buffers, native plants are able to slow the flow of overland stormwater and encourage sediment removal before it reaches the water's edge. For nutrients in stormwater, essential nutrients can be incorporated into biomass (e.g., uptake into wetland plants, algae and bacteria), or permanently stored through sorption into sediments or via sedimentation (Figure 2.1). Additional contaminants in stormwater, such as pesticides, pathogens, hydrocarbons and heavy metals, can also be reduced depending on their rate of loading, via mechanisms such as sorption, sedimentation, predation or solar breakdown (Kadlec and Wallace 2009).

There are two key design principles critical to an NSP's water quality improvement potential. These are the length (L) to width (W) ratio (see Section 3.2.2) and the percent vegetation to open water ratio (see Section 4.1.1). Design guidelines provided for the L:W ratio help prevent short-circuiting of stormwater flow and promote the settling of sediments, as well as the area and volume required to slow stormwater flow and sequester contaminants. Design guidelines provided for the percent vegetation to open water ratio ensure that a minimum vegetated surface area is available to promote the biological activity of wetlands required for water quality improvement.

Guidelines for improving stormwater quality vary across Canadian jurisdictions. At a minimum, targets exist for total suspended solids (TSS) or sediment removal, as maintenance concerns can exist for systems with high sediment loading. For example, in the City of Calgary, the regulatory requirement for TSS removal is 85% for particle sizes greater than or equal to 50 µm (City of Calgary 2011). In comparison, the City of Moncton regulates that TSS in stormwater discharge shall not exceed 25 mg/L (City of Moncton 2015). As a stormwater guideline for the City of Brandon, the Canadian Council of Ministers of the Environment's (CCME) guideline values for suspended sediments for the protection of aquatic life is recommended (Table 2.2; CCME 2002). Unlike TSS, setting specific targets for reduction of nutrients and other contaminants in stormwater is not recommended unless inflow water quality, or outflow to a natural water body, is a concern. While wastewater treatment systems are highly engineered to provide predictable and regulated water quality performance for systems like municipal lagoons, the concentrations of contaminants in stormwater tend to be much lower and more variable depending on the timing, frequency and magnitude of stormwater events, the amount of hard surface runoff entering a system, and community pollution sources. If the key design elements recommended for water quality improvement are followed in NSP design, then quality control should be met in most circumstances.

Additional water quality testing may be required by the City of Brandon under special circumstances. These circumstances may include, but are not restricted to:

- Developments that are deemed by the City of Brandon to place some risk of water contamination (Brandon Area and Planning District 2015; see Section 4.1.1);
- NSPs that will rely on groundwater to meet their hydraulic needs (see Sections 3.1.1 and 3.4.1 for design considerations); and,
- NSPs that will discharge into a natural wetland (see Section 3.5 for design considerations).

In circumstances where additional water quality testing is required, it will be the responsibility of the developer to engage the services of a qualified specialist to demonstrate how risk has been mitigated in the design, construction or commissioning of an NSP, as well as carry the costs of any water quality sampling that is required. The City of Calgary (2011) outlines one potential structure for a stormwater quality monitoring program, including sampling frequency and parameter analysis; however, a standard suite of water quality parameters to analyze may include: total dissolved carbon, total inorganic carbon, total organic carbon, dissolved kjeldahl nitrogen, total kjeldahl nitrogen, total phosphorus, total dissolved phosphorus, total reactive phosphorus, conductivity, hardness, pH, total dissolved solids, alkalinity, ammonia, bicarbonates, carbonates, chloride, hydroxide, nitrate, nitrite, sulfate, calcium, magnesium, potassium, silicon and sodium.

2.2. Quantity control

Urban developments result in more hard surfaces on the landscape. This modifies a site's runoff response. Increased imperviousness increases runoff volumes and peak runoff rates because stormwater is conveyed on more concentrated paths at higher velocities. Without appropriate stormwater management, this can compromise infrastructure, damage receiving watercourses and even threaten public safety. The potential impacts of climate change is also an important consideration. The recent wet climate cycle (and steady development) in Brandon has prompted the City to launch work on a comprehensive stormwater management plan which will identify current and future drainage conditions as well as potential impacts to the stormwater system and environment.

In accordance with the City of Brandon's draft Design Standards Manual (2017), all attenuation facilities must be designed to minimize flood impact and protect the public from safety hazards. As with conventional stormwater facilities, NSPs achieve this primarily by serving as an attenuation facility. During large rainfall events, the surge volume of stormwater runoff is retained within these basins and gradually released at a controlled rate. In addition, NSPs provide supplemental quantity control via several other mechanisms. First, naturalized elements in upland areas will slow overland flow from upslope areas and promote improved infiltration. The presence of wetland and upland plants also improves water/soil infiltration due to improved belowground root structures. Given the right soils and water table depth, infiltration can significantly reduce or even eliminate surface runoff from a given area. Evapotranspiration is also an added benefit of naturalized stormwater management with wetland plants absorbing water, and releasing it to the atmosphere as vapour. The presence of naturalized vegetation in ponds and conveyance channels can also reduce velocities, which can lengthen travel time and reduce peak flows.

It is challenging to accurately quantify the extent of quantity control provided in naturalized ponds via increased infiltration, evapotranspiration, and reduction of overland flow velocities. As these parameters are highly dependent on a variety of factors including local soil parameters, plant communities, coverage and topography, caution should be exercised if these components are incorporated into stormwater calculations. Further, if permeable soils are present, wetland design must consider the impact of potential groundwater interactions (i.e., exfiltration and/or infiltration). See Section 3.4.1 for further guidance on this.

Table 2.1. Range of percent retention for nitrogen, phosphorous, sediment, coliforms and pesticides in wetlands, riparian zones, and native grass uplands (Gabor et al., 2001).

	Wetlands % Retained	Riparian % Retained	Upland Grasslands % Retained
Nitrogen	Up to 95%	67 – 96%	2.8 – 14.4%
Phosphorous	Up to 92%	27 – 97%	Up to 30%
Sediment	Up to 70%	75 – 91%	22 – 37%
Pesticides	< day to months	8 – 100%	Up to 50%
Pathogens	Up to 95%	70 – 74%	-

Table 2.2. Water quality guidelines for total suspended sediments for the protection of aquatic life (CCME 2002).

Event periods	Guideline value
Background (clear) flow periods – not to be confused with low flow periods, clear or background flow is the time period when background TSS levels can be determined, and are site-specific.	Maximum increase of 25mg/L from background levels for any short-term exposure (e.g., 24-h period). Maximum average increase of 5 mg/L from background levels for longer term exposures (e.g., inputs lasting between 24 hours and 30 days).
High flow periods – determined on a site-specific basis, during spring freshets and storm events.	Maximum increase of 25mg/L from background levels at any time when background levels are between 25 and 250 mg/L. Should not increase more than 10% of background levels when background is >250mg/L.

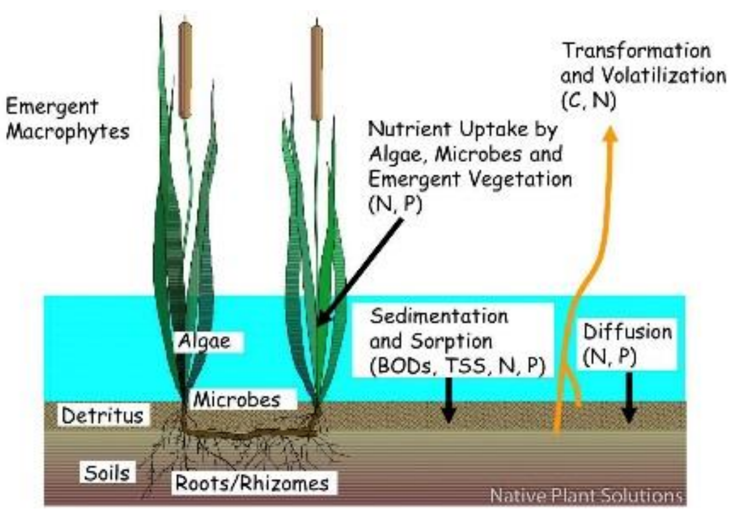

Figure 2.1. Mechanisms for nutrient uptake in wetland systems.

3. Naturalized Stormwater Ponds – Design Guidelines (Engineering)

This section outlines naturalized stormwater design guidelines related to engineering. This includes guidance related to hydraulics and hydrology, physical parameters, control structure design and soil considerations. As all NSPs must meet the City's requirements, the guidance outlined below should be used in conjunction with City design standards. Table 3.1 provides a summary of key engineering design criteria that should be incorporated into naturalized pond design. These are further described in subsequent sections.

3.1. Hydraulic and hydrologic design

3.1.1. Site hydrology

Understanding site hydrology is critical to the success of an NSP, facilitating the design of pond geometry and hydraulic elements, and informing the selection and siting of wetland communities. It is advisable to complete a site water balance assessment to evaluate how the NSP will respond to a variety of moisture conditions. This beneficial tool can help designers determine whether there is sufficient water to support the wetland and identify the expected amplitude and frequency of water level fluctuations.

However, in the case of many NSPs, a water balance may be unnecessary. If a facility has an outlet control structure (see Section 3.3) that fixes the normal water level and soil conditions (see Section 3.4) are such that groundwater interactions can be neglected, the water level will likely remain very stable. In these cases, a designer should still determine and demonstrate the following:

1. There is sufficient water to support wetland vegetation. As stormwater facilities are designed to provide quantity control, this is typically not a concern for the full build out scenario. While the basin is under development, though, less runoff is generated and water may not be sufficient to support wetland plants. Designers should plan for this by either (a) ensuring source water is available to supplement the facility as needed, and/or (b) completing a water balance assessment to determine whether water supply is a concern during initial phases.
2. Conduct soil sampling to (a) demonstrate that the native soil constitutes suitable liner material (see Section 3.4), or (b) design the pond with imported clay liner material.
3. Confirm there are no significant capacity constraints within the pond outlet's receiving system and that the pond complies with City standards in terms of drawdown duration and maximum water level rise.

If the above points cannot be sufficiently demonstrated, development of a water balance analysis is recommended to assess pond hydroperiod. The simplified water balance equation shown below provides a means of quantifying the anticipated fluctuation within an NSP by computing the various inflows and outflows:

$$\Delta S = (P + R + GW_{in} + Q_{in}) - (ET + GW_{out} + O + Q_{out})$$

where:

ΔS represents the volumetric change in pond storage;

P represents the volumetric inflow via direct precipitation (i.e., rain and snow falling directly on the water surface);

R represents the volumetric inflow via runoff from the contributing catchment;

ET represents the volumetric outflow via evaporative losses;

O represents volumetric outflow either via the outlet structure and/or emergency overflow;

GW_{in}/GW_{out} represents the inflow/outflow due to groundwater flux (note that groundwater discharge (GW_{in}) is the movement of water from the subsurface to the surface and groundwater recharge (GW_{out}) is the movement of water from the surface to the subsurface); and

Q_{in} /Q_{out} encompasses any other flows either into (Q_{in}) or out of (Q_{out}) the facility which are not included in the above variables. Q_{in} may include flows from outside the catchment area such as pumped flows while Q_{out} may include any outflows to meet external demands (e.g., reuse, irrigation).

3.1.2. Quantity Control

NSPs must meet all City standards with respect quantity control. Provisions for active storage, freeboard, and drawdown time remain the same for NSPs as conventional retention facilities (see Table 3.2).

3.2. Physical parameters

Physical parameters, such as an NSPs design elevations, slopes and shape, create the environment that will support the growth of wetland vegetation (see Section 4.1). Designing an NSP that is either too small or too narrow to accommodate engineering requirements for construction and naturalization (see Table 3.1) will impede one's ability to meet vegetation targets. Ensuring these physical parameters are accommodated in NSP designs also helps to support the primary function of water quality improvement in an NSP, as well as a secondary function of providing habitat.

3.2.1. Pond cross-section

An NSP consists of three key zones: the wetland zone (see Section 4.1), the open water zone, and the vegetative upland buffer zone (see Section 4.2; Figure 3.1). Each of these zones have depth and slope considerations to support their design. In the wetland zone, the water depth and slope will determine the species that grow and how they position themselves. Wetland plants generally grow in water depths of 0 - 60 cm below NWL. To encourage wetland plants to adjust to their preferred growing conditions over time, as well as support the growth of multiple wetland plant communities (i.e., wet meadow, shallow marsh and deep marsh; see Section 4.1), slopes within the wetland zone should be flatter than 7:1, and ideally between 10:1 and 40:1. In the open water zone, steeper slopes of 3:1 to 4:1 are recommended (if geotechnical conditions permit) to restrict emergent wetland vegetation 'creep' from the wetland zone. In the open water zone, depths of 2 – 3 m are recommended to limit the growth of wetland vegetation while encouraging circulation and flow through the NSP. For the vegetated upland buffer zone above the NWL, slopes of 5:1 to 7:1 are recommended to minimize erosion and to facilitate seeding and ongoing maintenance, including the safe operation of equipment during establishment and maintenance of the NSP.

3.2.2. Length (L) to width (W) ratio

While pond footprints, lengths and widths may vary depending on local site restrictions (e.g., road placement, infrastructure), accommodating the vegetative features below the normal water level will be difficult if the pond is designed too narrow (see Section 4.1.1). In addition to this, NSPs that incorporate greater distances between inlets and outlets maximize exposure time between incoming stormwater and wetland vegetation/sediment. Short distances between the inlet and outlet risk short-circuiting the flow, resulting in less treatment due to reduced contact time with wetland vegetation below NWL and pond soils. The intent should be to direct as much stormwater flow as possible through flooded emergent vegetation from the inlet to the outlet of the NSP.

To prevent short-circuiting, the length to width (L:W) ratio of the pond should be a minimum of 3:1. The length is to be measured as the linear distance along the bottom of the channel from the inlet to the outlet and the width is to be measured as the average distance across the NWL perpendicular to the travel path of stormwater. Pond designs with elongated shapes (Figure 3.2, A) and physical elements (e.g., vegetation benches, Figure 3.2.2, B, D) that disperse flows will have higher treatment efficiencies. In addition, designs that spread the inflow across a pond and through emergent vegetation (Figure 3.2, C, E) will create conditions of improved treatment efficiency. Designs that lead to a short-circuiting of water flow (Figure 3.2, F through H) will result in reduced treatment efficiencies. These pond designs are not recommended.

3.2.3. Shoreline complexity

In addition to considerations for NSP zones (see Section 3.2.1) and length to width ratios in pond designs (see Section 3.2.2), some consideration should be given to how ponds can be configured in terms of their shoreline complexity. Pond performance, both for improved water quality and greater biodiversity, tends to increase with increasing shoreline complexity. Shoreline complexity is calculated as the ratio of shoreline length to the circumference of a circle of the same area as the water surface of the wetland. It can be used as a measure of irregularity or Shoreline Development Index (SDI). The SDI of a perfect circle is 1, with SDI values increasing as complexity is introduced. An SDI of 1.2 is a good target for design if it can be accommodated within the pond footprint. Figure 3.3 provides examples of various pond layouts and their SDI values (McKenna et al. 2014a).

3.3. Infrastructure

3.3.1. Inlets and outlets

It is preferable to minimize the number of structures (inlets and outlets) within a pond to optimize treatment capabilities and reduce maintenance costs. If multiple inlets are required, care should be taken to place inlets far from the outlet(s) in a manner which maximizes travel time. If an inlet must be placed in close proximity to an outlet, the incorporation of peninsulas or contouring below NWL should be included to limit opportunities for short-circuiting.

While both submerged and unsubmerged inlets and outlets are acceptable, submerged structures are preferred. This typically provides a more aesthetically pleasing pond and is usually more economical since neither a headwall nor grate is required. As per City standards (City of Brandon 2017) the crown of any submerged pipe must remain 0.6 m below NWL to reduce the potential for ice damage. To facilitate this, outlet design may incorporate the use of a reverse slope pipe.

3.3.2. Overflow spillways

Emergency overflow spillways provide a safe means of passage in the event that pond capacity is exceeded, either during an extreme event or as a result of a clogged outlet. In accordance with the City's standards (City of Brandon 2017), an NSP will require design of an emergency overflow. The emergency overflow point and capacity should be indicated on the design submission for the attenuation facility. Vegetation is the preferred means of stabilizing overflow spillways. This provides a more natural look which complements the wetland and upland planting design. Riprap should only be used if vegetative treatment, or a combination of vegetation and geotextile, is insufficient to provide the necessary erosion protection.

3.3.3. Control structures

As with any stormwater facility, a control structure is a key feature of an NSP. It fixes the operating level, or operating range, of a pond and controls the rate of discharge to the receiving system. Common control structures include culverts, weirs, orifices, sluice gates and stoplogs.

As noted in the City standards (City of Brandon 2017), a control structure is required at the facility outlet to restrict the release rate of the active storage volume such that the receiving system can accommodate the discharge (see Table 3.1) Where there is a risk of backwater from the receiving system, the structure must also include a gate chamber configured with a flap gate and sluice gate to prevent flood water from entering the system. Further, all structures must be designed to prevent public access and/or debris blockage, incorporating appropriate grating/screens as outlined in the City standards.

3.3.4. Design considerations for plant establishment

In contrast to conventional ponds, where the NWL remains constant, the establishment of wetland plantings will require water level manipulation during the commissioning stage. Raising and lowering of the water level at key times is necessary to promote germination (see Section 7.2). This can typically be achieved via the inclusion of stoplogs or a sliding gate within the control structure design. It is recommended that the outlet control structures allow for the NWL to be raised and lowered by a minimum of 0.3 m from the target operating level. Once vegetation is established, the elevation of the constructed wetland will remain set at NWL in most years. If the control structure cannot be designed to facilitate water level adjustments (e.g., due to topographical or hydraulic constraints), an alternate means of raising/lowering water levels (e.g., utilizing pumps) will be necessary to support vegetation establishment (see Section 6.2.3). This should be clearly described in any design submissions (see Section 5).

3.3.5. Site access for maintenance

All structures must be designed to allow for safe and practical access by staff to conduct basic maintenance. It should be simple to conduct maintenance activities without risk to the public and with minimal damage/disturbance to established plantings. Given this, the following are key considerations for design:

- At least one all-weather vehicle access route should be incorporated into the design. Based on soil conditions and anticipated traffic from maintenance vehicles (i.e., size/weight of maintenance vehicle), site access should be designed to an appropriate width and incorporate suitable substructure design.
- To the extent possible, upland and wetland plantings should be used to naturalize the appearance of any access route. Plantings should be selected to withstand anticipated traffic from maintenance vehicles.
- A boat launch is not required by the City for maintenance purposes.
- All control structures should be located on a berm or flat landing easily accessible at the pond perimeter. Control structures within the middle of the pond (e.g., perforated riser pipe) are not recommended.
- Unless otherwise approved by the City, access to any controls or moving parts shall be provided above ground versus inside the chamber so confined space entry can be avoided.

- In keeping with the City standards (City of Brandon 2017), all inlet and outlet grating must incorporate a hinge or other device to permit periodic access. A suitable security device is also required to prevent unauthorized access.

3.4. Soil considerations

Local soil properties are an important consideration in designing and constructing an NSP. Factors such as the nutrient content, permeability, and susceptibility to erosion will impact anticipated hydrology, whether (and what type of) amendments may be required, whether substrate needs to be imported and what type of erosion and sediment control measures may be appropriate.

3.4.1. Permeability

In the most straightforward scenario, an NSP will be hydraulically isolated from any aquifers. This is because the native soils within which a pond is constructed typically consist of low permeability soil (e.g., with a permeability coefficient in to the order of 1 x 10^{-6} cm/s) or a constructed clay liner is incorporated into the design. This prevents any significant infiltration or exfiltration. In some cases, however, the proposed pond may be connected to the groundwater table by permeable soils. This is a condition which will typically be identified during the geotechnical investigation but some areas of Brandon are known to be particularly prone to sandy soils. Within the North Hill Basin, the upper 6 to 12 meters of the soil profile consists primarily of sands and silty sands, which grade to coarse sand and gravels near the upper edge of the river escarpment (AECOM 2014). Sandy soil coulee formations are known to be present in the Central North Hill Basin and Eastern North Hill Basin with soil infiltration dominating runoff in these zones.

If the installation of a clay liner is not viable at sites with permeable soil, groundwater flux will need to be carefully considered during pond design. As outlined in Section 3.1.1, the potential for groundwater discharge/recharge will need to be considered in the water balance analysis and groundwater flux may represent a significant source or sink within the water budget. As such, it is advisable that a hydrogeologist be engaged to help quantify this variable and/or a sensitivity analysis be completed to determine how significant this variable may be within the overall water budget.

Further, the following should be considered for ponds that are connected to the ground water table:

- If a pond is expected to receive a net influx via groundwater (e.g., the groundwater table is expected to be near or above the NWL), the outlet structure and receiving system should be designed to ensure that NWL can be maintained under normal operating conditions. City requirements (City of Brandon 2017) in terms of drawdown and allowable rise should be met to ensure that flood storage is provided and wetland plantings are not at risk.
- If a pond is expected to receive a net outflux via groundwater, the duration, severity and frequency of this circumstance should be projected during the water balance assessment. If the

projected impact is minor, it may be possible to address this issue during site design by modifying the proposed geometry and/or selecting plant communities which can better handle a periodic dry condition. However, if the proposed impact is more severe, wetland plants may die off. This will produce an undesirable aesthetic and quality control targets may not be achieved. It is recommended that a wetland specialist be engaged throughout this stage to ensure that the proposed wetland plant communities can withstand the projected water level fluctuations.

3.4.2. Topsoil requirements

Crucial to the success of plant establishment in NSPs is the proper preparation and placement of soils. Considerations for plant establishment include soil salvage and stockpiling practices, physical and chemical characteristics, material placement, and protection from erosion (see Section 6.1 on erosion). The physical and chemical composition of the soils used on site will also determine their water holding capacity, nutrient cycling processes, and filtering capacity. It also determines the chemical and organic nature of the soil, its texture, trafficability, biogeochemical pathways and ability to support plant growth (Ross and Gabruch 2015). Table 3.2 provides guidance on surface and subsurface soil characteristics for successful plant establishment in the upland and wetland planting zones (Figure 3.1). All NSP soils should fall into the “good” and “fair” categories as outlined in Table 3.2. Note that all areas planned for plant establishment must be prepared with topsoil before planting occurs.

For those locations planted with wetland plants below the NWL, topsoil depth should be no less than 50 mm. Topsoil depth in naturalized plant zones above NWL should be no less than 150 mm (Table 3.2). Any locations containing shrubs must have a minimum topsoil depth of 200 mm, while minimum topsoil depths for trees is 1000 mm. Testing of topsoils, prior to soil placement, will ensure that soil chemical and nutrient levels are suitable for successful plant growth. Many agricultural soil labs can conduct and interpret these analyses on your behalf and indicate if soil parameters meet plant establishment requirements. Topsoil analysis should include nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg), chloride (Cl), Sodium (Na), carbonate (CO_3), soluble salts, conductivity, soil texture, bulk density, pH, CEC, and % organic matter. Note that poor soil nutrient content and texture can result in failures in upland plant establishment. Therefore, recommendations for remediation or enhancement to correct any soil deficiencies based on test results must identified and corrected before planting activities begin on site.

Fertilizer application to soils in planting zones below NWL is not recommended. Fertilizer applications to topsoils above NWL, if required, should only be applied at the time of native grass seeding. Caution should be given so as to not affect water quality in the pond. Topsoils should contain a minimum of weed seeds, so that herbicide applications to minimize weed growth is kept to a minimum. Stockpiling soils offsite and applying weed treatment to the pile is recommended before placement on site. This will result in a decrease in weed competition with native grass plantings and reduce the need for weed management on site.

While mulch is often used as a soil surface layer in tree and shrub bed plantings to improve soil moisture for young plants, the use of wood mulch products is not recommended. Soil bacteria use nitrogen (N) as an energy source to break down the carbon in wood. This leads to a significant decrease in soil N until the mulch is decomposed. Therefore, if mulch is needed, inert products such as rock or small gravel is recommended.

3.5. Considerations for designing pond networks (aka connectivity)

The City of Brandon recognizes that maintaining a contiguous network of natural areas, parks and open spaces within urban developments facilitates habitat diversity and conservation, enabling wildlife to thrive (Brandon Development Plan 2015). In addition to the habitat and ecosystem benefits afforded by NSPs, incorporating existing natural areas into the development provides added benefits to the community and its residents. In the broadest sense, a natural area is an area of land that is dominated by native vegetation in naturally occurring patterns. Natural areas typically include grasslands, wetlands, forests, riparian areas, lakes and rivers.

Natural corridors or ecological networks contribute to a coherent system of natural and/or semi-natural landscape elements that is configured and managed with the objective of maintaining or restoring ecological functions as a means to conserve biodiversity (City of Edmonton 2007). Interconnecting a series of natural areas, including NSPs, should be a design goal if possible.

Brandon's Greenspace Master Plan (City of Brandon 2015a) encourages that existing vegetation, wetlands and drainage courses be preserved and integrated into the open space designs where possible. While preserving natural wetlands in urban developments is possible, a wetland's watershed will be impacted negatively as a result of urban development (e.g., increased hard surface runoff, decreased water/soil infiltration, urban encroachment along wetland edge, potential for poorer water quality). In such cases, using water from an adjacent NSP may be an effective means of maintaining the natural hydrology of the wetland. Careful analysis of the pre-development, long term, hydrological requirements/cycling of the wetland will be required to ensure the wetland can be incorporated into the development successfully.

It is often beneficial to link a series of NSPs to one another to create an enhanced park space with linkages for trails and wildlife passage. However, system hydraulic performance must be considered in such designs. Prolonged drawdown can be an issue in networks where multiple ponds are linked in series. To address this, "networked ponds" should always be modelled as one hydraulic system and modeling results demonstrating that storage and drawdown requirements are met should be included within the design submission (see Section 5). Construction phasing and the building of pond networks will also determine, to a certain extent, where water level control structures need to be placed in order to commission a series of ponds successfully. Having multiple ponds hydrologically dependent on one control structure makes it difficult to commission naturalized ponds constructed in different years. Therefore, it is recommended that no more than three ponds should be controlled by the same control structure.

3.6. Project safety

Project safety is of critical importance. Planning for safety starts at the design stage and it should remain a primary consideration during the construction, commissioning and maintenance of an NSP. Key guidelines for incorporating safety within a project include the following:

- Cross-section design should incorporate gentle sideslopes which are safe for equipment operators during establishment and maintenance of the NSP (see Section 3.2.1 Pond cross-section)
- Spillways should be incorporated into the design to provide safe passage of flow in the event that the pond overtops (see Section 3.3.2 Overflow spillways)
- All structures should be designed in a manner which facilitates easy and safe access by maintenance personnel and prevents unauthorized access by the public (see Section 3.3.5 Site access for maintenance).
- When a pesticide application has taken place on a property, such as an NSP, appropriate signage is required to be posted in a prominent place on the property and remain for a minimum of 2 days after the pesticide application, as per Section 22 in The Pesticide Management By-law No. 6825 (2006) (see Section 4.2.3 Weed control).
- Any burn management of native upland stands must be conducted by trained personnel (see Section 8.3.2 Upland vegetation)
- All naturalized ponds should be adequately signed to educate the public on the intent and enjoyment of naturalized ponds (see Section 8.4.1 Education and interpretation) and warn residents of potential risks (e.g., thin ice, potential contaminants) (see Section 8.4.2 Public use).

Table 3.1. Minimum engineering design criteria for NSPs.

Quality Control	
TSS	See Table 2.2 for CCME Guideline
Physical Parameters	
L:W ratio	≥ 3:1
Pond Width	≥ 40 m
Sideslopes	5:1 ≤ slope ≤ 7:1, upland zone
	7:1 ≤ slope ≤ 40:1, wetland zone (ideally greater than 10:1)
	3:1 ≤ slope ≤ 4:1, open water zone
Depths	0-60 cm, wetland zone
	2.0-3.0 m, open water zone
Shoreline complexity	SDI ≥ 1.2
Hydrology	
Permeability of pond base	(a) Submit geotechnical testing demonstrating that in-situ soil is sufficiently impermeable (i.e., 1 x 10^{-6} cm/s) to neglect groundwater; or
	(b) Incorporate a constructed clay liner into the pond design; or
	(c) Demonstrate (via hydrogeological expertise and/or water balance analysis) that the pond can sustain the target NWL or operating range.
Hydraulics	
Active storage volume	Store 100 year design event
Active storage depth	Level of rise ≤ 1.5 m (NWL to HWL)
Freeboard	≥ 0.3 m from HWL to spillway invert or sufficient depth to contain maximum historical event (whichever is greater)
Drawdown time	≤ 48 hours for 5 year event
	≤ 120 hours for 100 year event
Outlet capacity	Limit discharge during the 1:100 year event to the 1:5 year pre-development discharge rate
Infrastructure	
Spillway	Vegetative recommended unless otherwise required for ESC
Inlet/outlet pipes	Site structures to minimize potential for short-circuiting
	Crown ≥ 0.6 m below NWL if submerged
	Incorporate headwall and grate if unsubmerged
Control structures	Provide elevation range to NWL of ±0.30 m
Safety and access	Use appropriate screens/grates to prevent public access and/or debris blockage
	Incorporate a hinge or other device (equipped with security device) to facilitate access by authorized personnel
	Site any controls or moving parts above ground
	One all-weather vehicle access to control structure

Table 3.2 Recommended soil parameters and soil placement for topsoil (surface soils) and subsoils for NSPs (Ross and Gabruch 2015). NSP soils should be either good or fair to meet City of Brandon standards.

Rating/Property	Good (G)	Fair (F)	Poor (P)
pH	6.5 to 7.5	7.6 to 8.0	8.1 to 8.5
Salinity (dS/cm)	< 2	2 to 4	5 to 8
Sodicity (SAR)	< 4	4 to 8	9 to 12
Texture	FSL, VFSL, L, SL, SiL	CL, SCL, SiCL	LS, SiC, C, S, HC
Moist consistency	very friable, friable	loose	firm, very firm
Organic Matter (%)	6 to 12	5	< 5
Bulk Density	< 1.35 g cm^3	< 1.45 g cm^3 (clay soils) < 1.60 g cm^3 (sandy soils)	>1.61 g cm^3
Available Rooting Zone (cm) (*Surface soil + Subsoil*)	> 70	40 to 70	< 40
Application depth of surface soils (mm) *Wetland Planting Zones*	> 50 (on soil-like subsoils)	40 - 50 (on soil-like subsoils)	< 40
Application depth of surface soils (mm) *Upland Planting Zones*	> 150 (on soil like subsoils)	130 – 150 (on soil like subsoils	< 130
Soil Stockpile Age (months)	Direct placement	≤ 6	> 6 - 12
Erosion Control Activities	Determined during pond design	Prior to site construction	After construction has begun

Clay (C), silt (Si), sand (S), loam (L), clay loam (CL), sandy loam (SL), fine sandy loam (FSL), very fine sandy loam (VFSL), sandy clay loam (SCL), silty loam (SiL), silty clay (SiC), silty clay loam, loamy sand (LS), hard clay (HC).

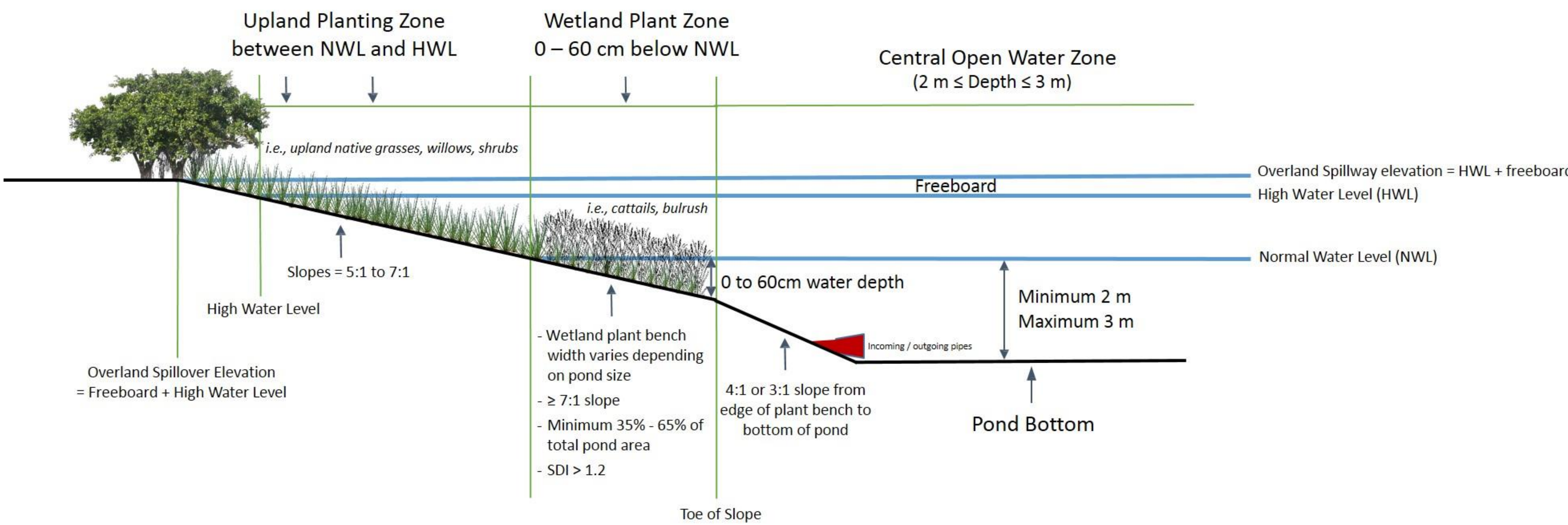

Figure 3.1. NSP cross-section.

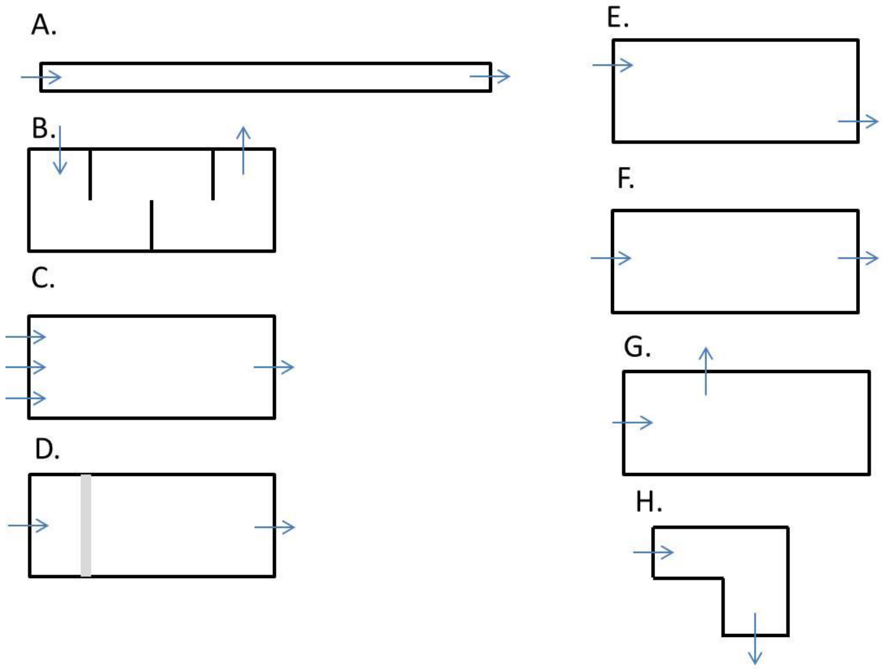

Figure 3.2. Examples of pond hydraulic efficiencies (A to H). Arrows indicate flow direction through inlets and outlets. Grey bar (e.g., Example D) indicates a submerged berm (adapted from Persson et al. 1999).

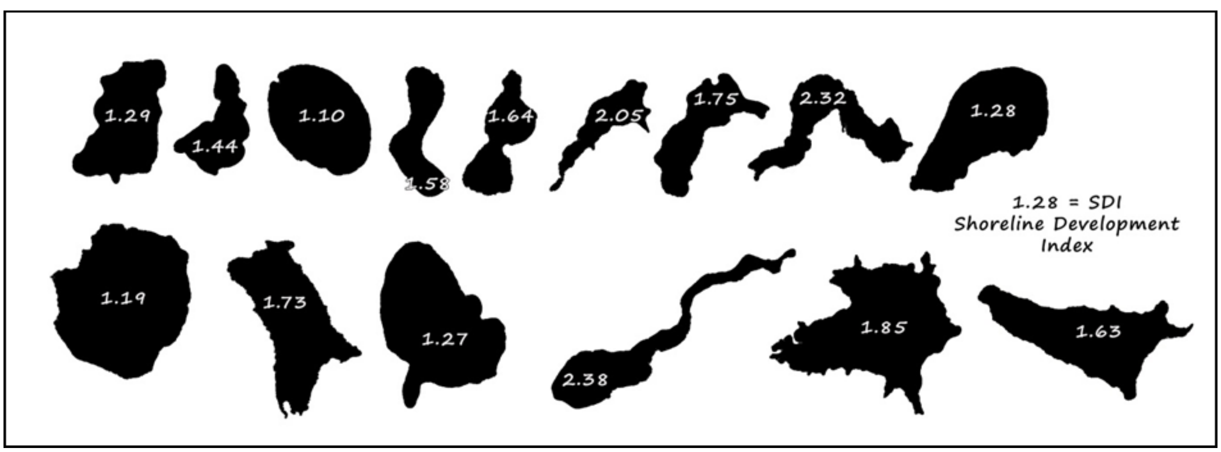

Figure 3.3. Examples of varying shoreline complexity of natural wetlands and their associated SDI values (McKenna et al. 2014a).

4. Naturalized Stormwater Ponds – Design Guidelines (Biological)

In the Brandon and Area Planning District's Development Plan (2015), the utilization of natural vegetation as a complement to man-made features is recognized as a design policy to improve aesthetics and promote quality of life. For NSPs, the incorporation of native wetland and upland vegetation serves to support water quality improvement as a primary function as well as provide habitat as a secondary function.

This section outlines naturalized stormwater design guidelines related to their biological elements. This includes guidance related to plant selection, placement, and cover both below and above NWL. Design guidance is provided for depth and shaping considerations below NWL. As all NSPs must meet the City's requirements, the guidance outlined below links closely with the draft Design Standards Manual (City of Brandon 2017). Table 4.1 outlines the minimum requirements for biological design components for NSPs.

4.1. Guidelines and recommendations for vegetation establishment - wetland

4.1.1. Vegetation cover

Vegetation cover is directly related to the water quality performance of the pond. Vegetative (i.e., plant) cover relates to the % of the pond footprint covered by wetland plant communities growing below NWL (Figure 3.1). Stormwater ponds with little to no vegetation below NWL have little capacity to improve water quality. The same holds true for ponds that contain only an "eyebrow" or "fringe" (e.g., 3 - 4 m wide) of wetland plants adjacent to the NWL edge. It is recommended that between 35% to 65% of the footprint below NWL contain wet meadow, shallow marsh, or deep emergent wetland plants (see Section 4.1.2), while still accommodating deeper channel depths of 2 m to 3 m in the most central portions of the pond. Water depths required to support the establishment and survival of wetland plants must range between 0 to 60 cm below NWL (see Section 4.1.2) in order for the naturalized pond to be successful.

For NSPs expected to receive higher than normal levels of contaminants based on anticipated source inputs (e.g., industrial), an analysis of the vegetative footprint needed to ensure water quality performance will be required prior to finalizing the vegetative footprint in the pond. The findings from this analysis should be included in the design submission to the City of Brandon. If contaminant levels are unknown then representative water samples should be collected and analyzed to aid in this performance analysis.

If a pond is designed too narrow it may be difficult to accommodate both the vegetation cover required (i.e., 35% to 65%) and a center channel depth of 2 m to 3 m (Figure 3.1). Section 3.2.2 provides guidelines on length (L) to width (W) considerations for proper pond functioning. NSPs constructed narrower than 40 m in width may leave little ability to meet both the vegetated (0 to 60 cm) and deep open water requirements (2 m to 3 m) for design. If this is the case then the planned footprint of the pond may need to be revisited and revised in order to fulfill the design guidelines.

4.1.2. Vegetation communities

The wetland plant species that establish within an NSP and their location/placement within the pond below NWL is determined by three factors: (1) The *depth* of water in a particular location, (2) How *often* that location remains flooded (e.g., every year, every second year, etc.), and (3) How *long* that location remains flooded (e.g., entire growing season, spring only, May through August, etc.).

Three types of plant communities, or plant zones, develop depending on the outcome of these three factors. *Wet meadow wetland plants* position themselves along the uppermost reaches of the wetland (i.e., NWL) edge, nearest the upland plant communities, where soils tend to be drier, flooding depths shallower, and shorter lived. In an NSP, the wet meadow zone serves to minimize shoreline erosion, as well as improve plant diversity in the pond. Table 4.2 provides a list of the species suitable for this zone in the Brandon region. The wet meadow zone can be the most challenging community to establish in an NSP. Part of this relates to the fact that the seeds of these plants are not long lived in the seedbank of the soil. Water depths for these communities should range no more than 0 to 10 cm below NWL with the slopes/grades in these locations gentle (e.g., ≥ 7:1). Plant establishment will be more successful if these communities are established in areas where their zone width is wider as well (e.g., ≥ 3 m).

The *shallow marsh plant community*, or zone, is comprised of a number of grasses and herbs (Table 4.2) that prefer growing in water depths ranging from 10 to 30 cm below NWL. This community tends to be more resilient in NSPs than wet meadow species, as they are able to withstand deeper water depths where flooding tends to be more permanent from year to year. Similar to the wet meadow community, shallow marsh plants do best when established on gentler or flatter slopes within the pond (i.e., 10:1 to 40:1; see Section 3.2.1), and in locations where wider footprints (i.e., a zone width of 3 to 10 m) allow this community to be more robust.

While fewer species comprise the *deep emergent community* in NSPs (Table 4.2), these species will be the workhorses for improving water quality, particularly in locations where the physical design of the deep emergent zone, including width and slope (i.e., zone width of 3 to 10 m; slopes of 10:1 to 40:1), allows this community to be more robust. Planted in deeper areas within the pond (e.g., 30 - 60 cm deep), deep emergents are the most resilient to prolonged, and stable, flooded environments (e.g., flooded every year from May through October). Areas within stormwater ponds flooded > 60 cm below NWL will remain as open water as long as water depths remain stable (e.g., water level sits at NWL in most years).

4.1.3. Establishment techniques

Most wetland plants are not available commercially. Sourcing, collecting, and processing the seeds of wetland plants by hand or through the use of live donor plant material will be required. Three planting techniques are available for vegetating an NSP with wetland plant species below NWL. These include: (1) Seeding, (2) Transplanting whole plants or live-plant propagules, and (3) Using live-donor soils (Ross et al. 2014). Regardless of the techniques employed, it is important to clearly outline timelines for the project (see Section 6.2) so that wetland seed and donor plant material can be sourced and prepared well in advance of when it is needed. The sourcing of both seed and live plant material generally occurs from May through August, prior to fall/winter pond construction. Note that a minimum of 15 plant species is recommended in the wetland seed mix to encourage diversity and community resilience/longevity below the NWL.

Wetland seed is collected from mid-summer through early fall when the seeds are mature and ready for harvest. Collected seed is then disseminated on planting areas below NWL just before snowfall in October/November via a drill-seeder or broadcasting, or in the spring by broadcasting before the pond is wetted (see Section 6.2). Hydroseeding of seed within the pond footprint is not recommended as it results in poor soil to seed contact, and thus poorer germination and the potential for increased weed growth. A variety of different techniques can be used to collect and prepare the seed. The techniques used vary depending on the species of interest. A certain degree of trial and error may be required to improve collection techniques. Collected seed will need processing (e.g., debris cleaned and outer seed coats removed/weakened) to prepare the seeds for planting and germination. The outer seed coats of many wetland seeds are extremely hard and therefore they must be softened using temperature and moisture stratification to improve germination success. Seeds may require many months of pre-treatment prior to being sown in the field. Like upland seed, wetland seed should be checked for viability and percent of weed species present prior to being seeded in the pond.

Wetland seed is best used on those ponds where water level manipulation is possible, either through pumping or the use of a water control structure (e.g., variable gate or stoplog structure) to drop or raise water levels when required (see Section 7.2 on Water Management). Wetland seeds are unable to germinate when submerged by water too deep (e.g., ≥ 5 cm). Seed germination is most successful when seeds are exposed to light, warmer temperatures and moist soils. The same holds true for ponds where donor wetland soils are used to establish vegetation below NWL. The seeds within these soils must also be exposed to light and warmer temperatures in order to germinate.

Using donor material, either in the form of live plant propagules or donor soils from disturbed sites, is another tool used for establishing vegetation below the NWL footprint of the pond. Donor soils are usually spread as topsoil below NWL at the end of the construction process, but before the pond is flooded. It is vital that no natural wetlands be disturbed or destroyed in order to revegetate or provide donor soils to a newly constructed pond. It is also important that the soils of the donor location be assessed so that weedy or invasive species are not introduced into the pond. Refrain from using soils where it is difficult to assess the species present. Stockpiling donor soils before they are used in a restoration can negatively influence recruitments in two ways. Short-lived viable seeds may be lost if the soil is stockpiled too long (e.g., > 2 months), and environmental conditions, particularly high temperatures, in stockpiled soil may be so unfavorable that seeds are killed (van der Valk et al 1992).

Live plant propagules are used to help revegetate, or fill in, weak areas of the pond that lack good vegetation coverage or diversity during the commissioning stage, and before handoff of the pond to the City occurs. Donor sites for plants must be carefully sourced in June through August to ensure they contain desirable wetland species, and no invasive or weedy species. If the seed bank present in the soil contains even a small amount of invasive or weedy plant species (e.g., reed canary grass or purple loosestrife), this can affect the successful establishment of native wetland species for the entire life of the pond. To be successful, one should try to preserve the entire structure of the plant (e.g., aboveground growth and below ground roots/rhizomes) during the transplanting process. Plants should only be moved from its original location to the new pond when the plant's energy reserves exist in the roots (i.e., during the winter months when plants are dormant) or in mid-summer, when energy reserves exist in aboveground leaves and shoots. Transplanting a plant when its reserves are in-between these two locations can affect the viability of the plant, and transplant success.

4.2. Guidelines and recommendations for vegetation establishment - uplands

4.2.1. Vegetated upland buffer zone

An important area for improving water quality before it reaches the water's edge is the vegetated upland buffer zone. This zone is located between NWL and HWL/Freeboard of the stormwater pond (Figure 3.1). The incorporation of native grass species helps to support natural biological processes that slow the flow of runoff into the pond, while increasing the uptake of nitrogen and phosphorous before it reaches the waterbody. A floristically diverse native upland also serves as important habitat, and a low-maintenance alternative to conventional turfgrasses.

The upland buffer strip should range between 5:1 and 7:1 (Figure 3.1). Slopes steeper than 5:1 are challenging for both plant establishment and safe mechanical equipment operation, as it can cause increased soil erosion and sedimentation down slope. A continuous strip of native upland vegetation (approximately 13 - 20 m width) should consist of a minimum of 15 native grass and forb species in the seed mix. Trees and shrubs can also be incorporated into the planting plan. Table 4.3 provides planting approaching and a list of suitable native plant species for the upland buffer zone in the Brandon region that attempts to approximate the species that persisted before the land was developed. Deep rooted native grass species are particularly important for providing good soil stability, thereby minimizing erosion while improving water infiltration.

4.2.2. Upland establishment

Good agronomic practices for successful plant establishment include four main approaches: (1) Pre-plant soil preparation, (2) Procurement of locally adapted native seed, (3) Seed placement, and (4) Monitoring and maintaining new plant growth.

- **Pre-plant soil preparation:** A clean seedbed limits the introduction of weedy or invasive species ensuring a virtually weed free bed prior to planting. An integrated weed management strategy for the site's soil in the first year prior to planting sets an important precedent for project success (see Section 4.2.3). The seedbed should be firm and free of debris to accommodate seeding equipment. Extra effort in site preparation at the start by ensuring good quality soil for plant growth will result in a site requiring reduced maintenance over the long-term (See Section 3.4.2; Table 3.2).

- **Procurement of locally adapted native seed:** The seed mix should consist of a variety of native plant species suited for the prairie ecozone. These species are specially adapted to surviving Brandon's climate and soil conditions. When purchasing native upland seed, always ensure a Certificate of Seed Analysis is provided for each seed lot from the supplier and that the seedlot conforms to Canadian seed grades and standards (e.g., Canada Certified # 1 or Common #1), where possible. It is important to know how to interpret seed grades and seed analysis certifications. The analysis report should be examined to ensure quality control and information including seed germination, seed purity, percent inert matter, percent dormant seed, percent pure live seed and percent of each weed species present. Seed lots containing weedy or invasive species, or that do not provide plant names to the species level (e.g., *Agrostis* spp.), should be avoided or used with caution. Table 4.4 provides a list of weedy and invasive species. The seedlot should be avoided or used with caution if any of these species are present in the seed analysis report.
- **Seed placement:** Proper seed placement that provides good seed to soil contact requires the use of a drill-seeder. A drill-seeder should operate at a consistent shallow depth suitable to the species planted, followed by packing the seed to ensure strong soil contact. Hydro-seeding is not recommended as it causes uneven seed placement and unpredictable soil contact. Broadcast seeding is a random method of sowing seed, however, it can be used as a technique to sow seed in certain areas that cannot be easily accessed by a drill-seeder, such as around tree-wells, in narrow areas surrounding the stormwater pond, or in wet soils below NWL. Successful broadcast seeding involves three main steps: (1) Raking soil to create uniform seed-divots, 2) Sowing seed; and 3) Rolling seed in place with a roller drum, ensuring good soil contact. It is important to note that broadcast seeding requires twice the amount of seed (i.e., two-times seeding rate) compared to drill-seeding.
- **Monitoring and maintaining new plant growth:** Sown seed will require monitoring for germination. A successful native grass upland planting is defined as containing an average of 43-54 native plants per square metre. A very good planting is defined as containing an average of >65 native plants per square metre. If native plant yields are low upon evaluation, reseeding or remedial seeding during an appropriate window of time will be crucial for success. Sufficient soil moisture, such as in the spring or fall, is important for this activity. Monitoring will be most intensive in the first few years after planting (see Section 7.4).

4.2.3. Weed control

Successful upland plant establishment will require a detailed management plan using an integrated approach to weed management. Typical weed management strategies include physical (e.g., mowing), chemical (e.g., herbicide application, as permitted) and cultural control (e.g., seeding a short term cover crop over to outcompete weeds). A successful integrated weed management strategy provides timely and sequential control of weed populations affecting native plant establishment using the correct combination of management tools to achieve optimal results. A thorough understanding of plant ecology and plant species identification is important to manage weedy and invasive plants. Site soils should be thoroughly screened for weedy or invasive species and treated for weed populations for approximately one year prior to planting native species. Invasive upland species such as quackgrass (*Elymus repens*), bromegrass (*Bromus inermis*), Canada thistle (*Cirsium arvense*) and perennial sow-thistle (*Sonchus arvensis*) pose a major threat to native plant establishment in upland areas and are challenging to remove from a site once established. Table 4.4 provides a list of weedy and invasive species in stormwater ponds. Soil screening prior to planting accompanied with strategic weed treatment in the first few years of plant establishment will be of critical importance. Manitoba's Non-Essential Pesticide Use Regulation came into effect on January 1st, 2015. This legislation applies to lawns and adjoining areas of residential, commercial, government and institutional properties (Government of Manitoba, 2015). Due to the nature of NSPs these areas are exempt during their commissioning stage (i.e., years 1 through 5). Weed control in NSPs incorporates an integrated approach to weed management and these systems require minimal herbicide treatment. Herbicide use in Manitoba is restricted to persons with a pesticide applicators license and handling should only be conducted by a qualified technician.

4.2.4. Trees and shrubs

The incorporation of tree and shrub species adds structure and diversity to a stormwater pond that attracts wildlife, providing both habitat and food. Shade trees serve as respite from the sun, and have a cooling effect on the surrounding landscape. Trees also add an element of aesthetic by framing the open water of a stormwater pond that will accentuate the view for visitors. The City of Brandon is a well-treed community with an estimated canopy cover of 21% with high standards for preserving its urban forest while striving to increase the canopy coverage to 25% over the next 20-30 years (City of Brandon Draft Urban Forestry Management Plan 2018).

Tree and shrub selection should consist of well-adapted native species hardy to the Brandon region that are disease-free and not imminently at risk to invasive species or disease pressure. Using segments of dormant woody stem-cuttings from species such as willow (*Salix* spp.) and dogwood (*Cornus sericea*) that can grow into new individuals is suitable for planting at or below NWL, so long as the material is disease-free and plantings do not compromise the hydrological operation of the pond.

The minimum diameter of stem-cuttings should be at least 2.5 cm and the length of cuttings should be at least 40 cm long (Polster 2013). The success of live-staking is dependent on the quality of the cutting, timing of planting, and soil moisture. Table 4.3 provides planting approaching and a list of key native tree and shrub species suitable for the Brandon region. Native tree or shrub cultivars can be suitable if they are well adapted to the climate, but should be used with caution if selecting a cultivar for insect or disease prevention as they may not be completely successful. A cultivar is a variety of plant developed in cultivation that has certain stable characteristics. Plant material should be healthy and vigorous, and locally sourced from recognized plant nurseries, where possible. Trees or shrub species that should be avoided in Manitoba because of insect or disease pressure include American elm (*Ulmus americana*), ash (*Fraxinus* spp.), and cherry and plum (*Prunus* spp.).

- American elm is native to the riverbank area of the prairies and is well known for its large vase-shaped canopy and susceptibility to Dutch elm disease (DED). DED kills elm trees and has been a problem in Manitoba for decades. The devastating effects of DED make most elm trees no longer suitable for planting. Elm cultivars that are both hardy and resistant to DED has not yet been completely successful (Skinner and Williams 2004).

- Ash species, including two native species to Manitoba, are susceptible to the emerald ash borer (EAB). The EAB is an invasive species of beetle that cannot be eradicated and kills ash trees. EAB has been detected in Manitoba, making ash trees no longer recommended for planting in the province.
- Cherry and plum trees and shrubs belonging to the *Prunus* genera are susceptible to black knot disease. Black knot is caused by a fungus that forms unsightly black gall-like growths around the branches of the tree or shrub, and dieback may occur. While black knot isn't usually responsible for killing cherry and plum species, it increases their susceptibility to other insect and disease pressures. Increased maintenance costs are usually required to control the disease to a manageable level. Therefore, species belonging to the *Prunus* genera, such as the cultivated Schubert chokecherry (*Prunus virginiana* 'Schubert'), should be avoided.

In addition to considerations for species selection, careful attention to tree/shrub placement must be well-thought-out. Certain jurisdictions (i.e., Winnipeg) do not allow for tree or shrub plantings between NWL and HWL. They do this to facilitate the maintenance of native grasses in this zone either through controlled burns or mowing. If tree and/or shrub beds are proposed as part of the pond design, select species that will not be affected by a controlled spring burn of the native grasses (e.g., deciduous tree species). Group trees and shrubs together in planting beds and locate beds in the upper elevations of the pond (e.g., near walking paths). When planning the placement of planting beds try not to block residents' views of the pond. If placing planting beds in lower slope positions between NWL and HWL, consider how the bed's location affects the use of mowers and other equipment or management activities.

4.2.5. Consideration for public greenspace

Greenspaces provide multiple benefits to local communities and significantly improves overall wellbeing. Within the City of Brandon, leisure greenspaces are the most common type and are centrally located within each neighbourhood (City of Brandon 2015a). These spaces offer parks and recreation, and the potential for ecological education. Land dedicated as greenspace should be contiguous, and provide useful and accessible linkages through the area, and to adjacent areas (City of Brandon Development Plan 2015). Pathways located at the top of the upland buffer zone, slightly above the HWL of an NSP, provides optimal vantage to the open water area and surrounding vegetation. Pathways existing above the HWL are also more practical during the construction and commissioning stage of NSPs for mechanical equipment operation, soil grading and vegetation establishment. Pathway networks that link a series of NSPs together create a network of trails and serve as green corridors. Green corridors connect habitats, plants and wildlife in urban landscapes, while providing sustainable transportation to communities. NSPs offer educational opportunities to visitors. Educational greenspaces provide opportunities for an outdoor classroom that could incorporate hands-on ecology and biodiversity into the curriculum. Displaying interpretive signage enhances the general public's understanding and interest in naturalized greenspaces. Information could include descriptions on the functions of upland and wetland natural areas. Interpretive signs could also describe an NSP's function for water quality, biodiversity and watershed management (Figure 4.1). Passive recreation spaces offering casual uses and activities could consist of low-maintenance native turfgrass (Figure 4.2). Native turfgrass consists of low-growing native species that do not require any inputs such as water, fertilizer or annual mowing, and instead only require management approximately every three to five years. Natural playgrounds and play areas incorporating natural features could combine native landscape elements such as native flowers and trees surrounding the area.

Table 4.1. Minimum biological design criteria for NSPs.

Composition	
Vegetation cover surface area	≥ 35% of NWL surface area
Open water surface area	≤ 65% of NWL surface area
Plant communities	
Wetland	
Plant Species	≥ 15
Wet meadow zone	0-10 cm depth
	≥ 7:1 slope
	≥ 3 m zone width
Shallow marsh zone	10-30 cm depth
	10:1 ≤ slope ≤ 40:1
	3-10 m zone width
Deep emergent zone	30-60 cm depth
	10:1 ≤ slope ≤ 40:1
	3-10 m zone width
Upland	
Plant Species	≥ 15
Buffer strip	5:1 ≤ slope ≤ 7:1, upland zone
	13-20 m zone width
Growth medium	
see Table 3.2	
Human use	
Pathways	Locate paths at the top of the upland buffer above HWL
Signage	Provide interpretive signage for public education
	Provide safety signage, as appropriate (notification of pesticide use, thin ice, etc.)

Table 4.2. Key wetland species for NSP design, including propagation and establishment information. A checkmark indicates a propagation method, with an asterisk denoting the preferred or best method(s).

	Key Species		**Propagation/Establishment Information**									
	Common Name	**Scientific Name**	**Preferred Water Depth**	**Seeding Depth**	**Whole Plants**	**Roots/ Rhizomes**	**Seed**	**Germ. Potential**	**Cuttings**	**Grafting**	**Tubers**	**Corms/ Bulbs**
Emergents	Sweet Flag	*Acorus americanus*	0-30 cm	0 cm	*	*	√					
	Broadleaved Water Plantain	*Alisma triviale*	0-25 cm	0 cm	*	*	*	√				√
	River Bulrush	*Bolboschoenus fluviatilis*	< 100 cm	0 cm	*		*	√				
	Alkali Bulrush	*Bolboschoenus maritimus*	0-30 cm	0 cm	*		*	√				
	Yellow Marsh-marigold	*Caltha palustris*	0-25 cm	0 cm	√	√	√	√				
	Sedge	*Carex* spp.	-50-50 cm	0-5 cm	*	*	√				√	
	Spikerush	*Eleocharis* spp.	< 10 cm	< 1 cm	√	*	√	√				
	Tall mannagrass	*Glyceria grandis*	5-25 cm	0-1 cm	√	√	*	√				
	Rush	*Juncus* spp.	< 20 cm	0 cm	*	*	√	√				
	Arum-leaved Arrowhead	*Sagittaria cuneata*	0-40 cm	0 cm	*	*	√	√			*	
	Hardstem Bulrush	*Schoenoplectus acutus*	< 150 cm	0 cm	*	*	*	√				
	Three-square Rush	*Schoenoplectus pungens*	< 20 cm	0 cm	*	*	√	√				
	Softstem Bulrush	*Schoenoplectus tabernaemontani*	< 40 cm	0-1 cm	*	*	*	√				
	Whitetop	*Scholochloa festucacea*	0-30 cm	0-5 cm	*		*	√				
	Green Bulrush	*Scirpus atrovirens*	<50 cm	< 1 cm	*		*	√				
	Giant Burreed	*Sparganium eurycarpum*	15-45 cm	2-3 cm	*	*	√				√	
	Broadleaf Cattail	*Typa latifolia*	0-30 cm	< 1 cm	*	*	*	√				
Wet Meadow	Swamp Milkweed	*Asclepias incarnata*	< 15 cm	-.5-1 cm	√		*	√	√			
	Sloughgrass	*Beckmannia syzigachne*	0-35 cm	< 1 cm	√		*	√				
	Alkali Bulrush	*Bolboschoenus maritimus*	0-30 cm	0 cm	*		*	√				
	Bluejoint reed grass	*Calamagrostis canadensis*	-15-50 cm	< 1 cm	*	*	√	√				
	Sedge	*Carex* spp.	<50 cm	0-5 cm	*	*	√				√	
	Tufted Hairgrass	*Deschampsia cespitosa*	-7-15 cm	.5-1 cm	√		*	√				
	Joe Pye Weed	*Eupatorium maculatum*	-15-5 cm	0 cm	*		*	√				
	Sweet grass	*Hierochloe odorata*	-10-10 cm	-.5-1 cm	√	√	√					
	Blueflag	*Iris versicolor*	< 15 cm	< 1 cm	√		√					*
	Rush	*Juncus* spp.	< 20 cm	0 cm	*	*	√	√				
	Wild Mint	*Mentha arvensis*	-15-5 cm	0 cm	*	*			*			
	Whitetop	*Scholochloa festucacea*	0-30 cm	0-5 cm	*		*	√				
	Prairie Cordgrass	*Spartina pectinata*	-7-15 cm	1-2 cm	√	*	√					
	Aster	*Symphyotrichum* spp.	< 20 cm	< 1 cm	√		√	√				
	Seaside Arrowgrass	*Triglochin maritima*	< 20 cm	< 1 cm	*		*	√				

	Key Species		Propagation/Establishment Information									
	Common Name	Scientific Name	Preferred Water Depth	Seeding Depth	Whole Plants	Roots/ Rhizomes	Seed	Germ. Potential	Cuttings	Grafting	Tubers	Corms/ Bulbs
Shrubs	Pussy Willow	*Salix discolor*	-15-30 cm	< 1cm	√		√		*			
	Beaked Willow	*Salix bebbiana*	-15-30 cm	< 1cm	√		√		*			
	Sandbar Willow	*Salix exigua*	-15-30 cm	< 1cm	√		√		*			
	Shining Willow	*Salix lucida*	-15-30 cm	< 1cm	√		√		*			

Table 4.3. Key upland species for NSP design, including propagation and establishment information. A checkmark indicates a propagation method, with an asterisk denoting the preferred or best method(s).

	Key Species		Propagation/Establishment Information						
	Common Name	Scientific Name	Seeding Depth	Whole Plants	Roots/ Rhizomes	Seed	Germ. potential	Cuttings	Grafting
Trees	Manitoba Maple	*Acer negundo*	< 1 cm	*		*	√	√	
	Paper Birch	*Betula papyrifera*	< 1 cm	*		√	√		√
	Delta Hackberry	*Celtis occidentalis var.'Delta'*	< 1.5 cm	*		√		√	√
	Balsam Poplar	*Populus balsamifera*	< 1 cm	*	*	*	√	*	
	Cottonwood	*Populu deltoides 'Jefcot'*	< 1 cm	*					
	Trembling Aspen	*Populus tremuloides*	< 1 cm	*	*	√	√	*	
	Bur Oak	*Quercus macrocarpa*	1.2 – 3.2 cm	*		√	√		
	American Linden	*Tilia americana*	< 1 cm	*		√			
Shrubs	Saskatoon	*Amelanchier alnifolia*	< 1 cm	*		√	√		
	Red-osier Dogwood	*Cornus sericea*	-.5-1 cm	√		*	√	*	
	Silverberry	*Elaeagnus commutata*	~.6 cm	√					
	Shrubby Cinquefoil	*Dasiphora fruticosa*	< 1 cm	√		√	√	√	
	Currant	*Ribes spp.*	< .5 cm	√		*	√	√	
	Wild Rose	*Rosa woodsii*	< 1 cm	*		√		*	*
	Prickly Rose	*Rosa acicularis*	< 1 cm	*		√		*	*
	White Meadowsweet	*Spiraea alba*	0 cm	*	*	√			
	Buffaloberry	*Shepherdia canadensis*	< 1 cm	*	*	√		√	
	Western Snowberry	*Symphoricarpos occidentalis*	.5-1 cm	*		√			
	Highbush Cranberry	*Viburnum opulus var. americanum*	<1cm	√		√	√	√	
	Nannyberry	*Viburnum lentago*	<1cm	√		√	√	√	

	Key Species		Propagation/Establishment Information						
	Common Name	**Scientific Name**	**Seeding Depth**	**Whole Plants**	**Roots/ Rhizomes**	**Seed**	**Germ. potential**	**Cuttings**	**Grafting**
Grasses	Big Bluestem	*Andropogon gerardi*	-.5-1 cm	√		*	√		
	Blue Grama	*Bouteloua gracilis*	-.5-1 cm	√		*	√		
	Side Oats Grama	*Bouteloua curtipendula*	-.5-1 cm	√		*	√		
	Prairie Sandreed	*Calamovilfa longifolia*	-.5-1 cm	√		*			
	Canada Wild Rye	*Elymus canadensis*	-.5-1 cm	√		*	√		
	Northern Wheatgrass	*Elymus lanceolatus* ssp. lanceolatus	-.5-1 cm	√		*	√		
	Slender Wheatgrass	*Elymus trachycaulus*	-.5-1 cm	√		*	√		
	Awned Wheatgrass	*Elymus trachycaulus* ssp. subsecundus	-.5-1 cm	√		*	√		
	June Grass	*Koeleria macrantha*	-.5-1 cm	√		*	√		
	Green Needlegrass	*Nassella viridula*	-.5-1 cm	√		*	√		
	Switchgrass	*Panicum virgatum*	-.5-1 cm	√		*	√		
	Western Wheatgrass	*Pascopyrum smithii*	-.5-1 cm	√		*	√		
	Little Bluestem	*Schizachyrium scoparium*	-.5-1 cm	√		*	√		
	Indian Grass	*Sorghastrum nutans*	-.5-1 cm	√		*	√		
Forbs	Purple Prairie Clover	*Dalea purpurea*	-.5-1 cm	*		*	√		
	White Prairie Clover	*Dalea candida*	-.5-1 cm	*		*	√		
	Dotted Blazing Star	*Liatris punctata*	-.5-1 cm	*		*	√		
	Wild Bergamot	*Monarda fistulosa*	-.5-1 cm	*		*	√		
	Prairie Coneflower	*Ratibida columnifera*	-.5-1 cm	*		*	√		
	Blue-eyed Grass	*Sisyrinchium montanum*	-.5-1 cm	*		*	√		

Table 4.4. List of common weed and/or invasive plant species to avoid introducing in an NSP. OBL - Obligate wetland species (water tolerant plants found in wetlands >99% of the time); FACW - Facultative wetland species (water tolerant plants found in wetlands between 66 and 99% of the time); FAC - Facultative species (wetland and upland plant species that occur in wetlands and non-wetlands); FACU – Facultative upland species (plants that usually occur in non-wetlands, but may also occur in wetlands); UPL - Obligate upland species (upland plants almost never found in wetlands; Lichvar et al. 2012), NDA – No data available.

Common Name	Scientific Name	Origin	Indicator Status	Growth Habit	Growth Form	Invasive	Weed
Agrostis gigantea	Redtop	introduced	FACW	perennial	graminoid	Y	Y
Amaranthus retroflexus	Redroot pigweed	introduced	FACU	annual	forb	Y	Y
Artemisia absinthium	Absinthe	introduced	NDA	perennial	forb	Y	Y
Artemisia biennis	Biennial wormwood	introduced	FACW	annual/biennial /perennial	forb	Y	Y
Avena fatua	Wild oat	introduced	FACW	annual	forb	Y	Y
Bromus inermis	Smooth brome	introduced	FACU	perennial	graminoid	Y	Y
Bromus arvensis	Field brome	Introduced	FACU	Annual	graminoid	Y	Y
Bromus japonicas	Japanese brome	Introduced	FACU	Annual	graminoid	Y	Y
Capsella bursa-pastoris	Shepherd's purse	introduced	FACU	annual	forb	Y	Y
Carduus nutans	Nodding plumeless thistle	introduced	FACU	biennial	forb	Y	Y
Chenopodium album	Lamb's quarters	introduced	FACU	annual	forb	Y	Y
Cirsium arvense	Canada thistle	introduced	FACU	perennial	forb	Y	Y
Cirsium vulgare	Bull thistle	introduced	UPL	biennial	forb	Y	Y
Conyza canadensis	Canada fleabane	native	NDA	Annual	forb	Y	Y
Elymus repens	Quackgrass	introduced	FACU	perennial	graminoid	Y	Y
Equisetum arvense	Field horsetail	native	FAC	perennial	forb	Y	Y
Euphorbia esula	Leafy spurge	introduced	NDA	perennial	forb	Y	Y
Galeopsis tetrahit	Hemp nettle	introduced	FACU	annual	forb	Y	Y
Grindelia squarrosa	Curlycup gumweed	native	UPL	perennial	forb	Y	N
Hordeum jubatum	Foxtail barley	native	FACW	perennial	graminoid	Y	Y
Impatiens glandulifera	Himalayan balsam	introduced	FACW	annual	forb	Y	Y
Iris pseudacorus	Yellow flag-iris	introduced	OBL	perennial	forb	Y	Y
Kochia scoparia	Kochia	introduced	FACU	annual	forb	Y	Y
Lactuca serriola	Prickly lettuce	introduced	FACU	annual	forb	N	Y
Leucanthemum vulgare	Ox-eye daisy	introduced	UPL	perennial	forb	Y	Y
Linaria dalmatica	Toadflax	introduced	NDA	perennial	Forb	Y	Y
Lythrum salicaria	Purple loosestrife	introduced	OBL	perennial	forb	Y	Y
Malva pusilla	Roundleaf mallow	introduced	FACU	annual	forb	Y	Y
Matricaria perforata	Scentless chamomile	introduced	NDA	perennial/ biennial	forb	Y	Y
Medicago lupulina	Black medic	introduced	FACU	annual	forb	N	Y
Melilotus alba	White sweet clover	introduced	FACU	annual/ biennial	forb	Y	Y
Melilotus officinalis	Yellow sweet clover	introduced	FACU	annual/ perennial/ biennial	forb	Y	Y
Phalaris arundinacea	Reed canary grass	native/ introduced	FACW	perennial	graminoid	Y	Y
Phleum pratense	Timothy grass	introduced	FACU	perennial	graminoid	Y	Y
Phragmites australis ssp. australis	Invasive phragmites	introduced	FACW	perennial	graminoid	Y	Y
Plantago major	Common plantain	introduced	FACU	annual/biennial /perennial	forb	N	Y
Poa annua	Annual bluegrass	introduced	FACU	annual	graminoid	Y	Y
Poa compressa	Canada bluegrass	introduced	FACU	perennial	graminoid	Y	Y
Poa pratensis	Kentucky bluegrass	introduced	FACU	perennial	graminoid	Y	N
Polygonum aviculare	Prostrate knotweed	introduced	FACU	annual/ perennial	forb	Y	Y
Polygonum convolvulus	Wild buckwheat	introduced	FAC	annual	forb	Y	Y
Polygonum lapathifolium	Curlytop knotweed	native	OBL	annual	forb	Y	Y
Polygonum persicaria	Ladysthumb	native/ introduced	FACW	annual/ perennial	forb	Y	Y
Portulaca oleracea	Purslane	introduced	FACU	annual	forb	Y	Y
Potamogeton crispus	Curly leaf pondweed	introduced	OBL	perennial	forb	Y	Y

Common Name	Scientific Name	Origin	Indicator Status	Growth Habit	Growth Form	Invasive	Weed
Potentilla norvegica	Norwegion cinquefoil	native/ introduced	FAC	annual/ biennial	forb	Y	Y
Ranunculus sceleratus	Celery-leaved buttercup	native/ introduced	OBL	annual/ perennial	forb	N	N
Raphanus raphanistrum	Wild radish	introduced	FACW	annual/ biennial	forb	Y	Y
Rumex crispus	Curly dock	introduced	FAC	perennial	forb	Y	Y
Rumex maritimus var. fueginus	Golden dock	native	FACW	annual /biennial	forb	N	Y
Rumex pseudonatronatus	Field Dock	introduced	NDA	perennial	forb	N	Y
Salix alba	White willow	introduced	FACW	perennial	shrub/tree	N	Y
Setaria glauca	Yellow foxtail	introduced	FAC	annual	graminoid	Y	Y
Setaria viridis	Green foxtail	introduced	NDA	annual	graminoid	Y	Y
Silene latifolia	While campion	introduced	NDA	biennial/ perennial	forb	N	Y
Sinapis arvensis	Wild mustard	introduced	UPL	annual	forb	Y	Y
Sonchus arvensis	Perennial sow-thistle	introduced	FAC	perennial	forb	Y	Y
Sonchus asper	Annual sow-thistle	introduced	FAC	annual	forb	Y	Y
Tanacetum vulgare	Common tansy	introduced	FACU	perennial	Forb	Y	Y
Taraxacum officinale	Dandelion	introduced	FACU	perennial	forb	Y	Y
Thlaspi arvense	Stinkweed	introduced	FACU	annual	forb	Y	Y
Trifolium pratense	Red clover	introduced	FACU	biennial/ perennial	forb	Y	Y
Trifolium repens	White clover	introduced	FACU	perennial	forb	Y	Y
Typha angustifolia	Narrow-leaved cattail	introduced	OBL	perennial	forb	Y	Y
Typha x *glauca*	Hybrid cattail	native/ introduced	OBL	perennial	forb	Y	Y

Figure 4.1. Example interpretive sign about biodiversity.

Figure 4.2 Park in the City of Winnipeg, containing native turfgrass species.

5. Design Summary/Submission Guidelines

In general, the process and general content of a submission package for a naturalized stormwater management facility will closely match what is currently required by the City of Brandon for an attenuation facility (City of Brandon 2017). As presented in Table 5.1, design information will include a design brief and associated drawings. Submissions will need to be made to the City at the conceptual design stage and again at the detailed design stage. While the basic items to be included in the submission will largely be the same for a naturalized facility as for a conventional facility, some additional information is recommended for naturalized ponds. Recommended engineering design guidelines and biological design guidelines are summarized in Table 3.1 and Table 4.1 respectively. It is suggested that this key design information be incorporated into design submissions to the City.

Table 5.1. Draft submission requirements for NSPs for the City of Brandon. *Reference Section 6.1 of draft City Standards (City of Brandon 2017) for mandatory requirements relating to stormwater management and land drainage system. **Reference Section 7.1 of draft City Standards (City of Brandon 2017) for mandatory requirements relating to stormwater management and land drainage system.

		Conceptual Design Stage*	Detailed Design Stage**	Consideration(s) for Naturalized Facilities
Design Brief/Report	**Project Description**	General description of the existing site condition, proposed development and proposed drainage system to be developed, identifying contributing drainage area and noting downstream capacity constraints.	Detailed description of each stage of the proposed development, including land use and development staging.	Include reference to any existing natural areas or elements which will be incorporated into the facility design. If development is being staged, describe how staging will impact the pond (e.g. Will pond be staged? What is the approximate timing for each stage to discharge to the pond?)
	Modeling/Calculations	Pre and post development runoff analysis, demonstrating storage of 1:100 year post development runoff volume with 1:5 year pre-development discharge rate.	Confirmation of the hydraulic design of the minor drainage system.	Describe how the naturalized facility will perform with respect to its typical range of operating levels and characterize soil conditions at pond base. The proponent should demonstrate (1) that there is sufficient water to support the wetland and (2) that there is sufficient outlet capacity to ensure plant communities are not place at risk via prolonged submergence. Condition 1 can typically be met either by (a) ensuring source water is available to supplement the facility as needed (during initial phases) and/or (b) completing/submitting a water balance assessment. Condition 2 will be met if the City's standard drawdown times are achieved. In systems where this is not possible, a wetland specialist should comment on survivability of proposed plant communities during the drawdown period.
			Confirmation of the pre and post development runoff requirements, and the related storage requirements.	
			Review of ponding depths and overland flow of the major drainage system, including catch basin inlet design.	
			Inlet and outlet safety requirements where connections to the underground LDS system will be made.	
			Confirmation of attenuation facility design.	
			Confirmation of the pump station capacity and location.	
			Any other relevant design calculations.	
	Supporting Material	All design calculations and hydrologic/hydraulic models should be included. This includes any XPSWMM computer models and water balance analyses completed to support proposed conceptual/detailed design.		Water balance calculations (if completed), geotechnical report and/or (if groundwater is a concern due to permeable soil) hydrogeologist estimation of groundwater flux.
Pond Drawings	**Drainage Area**	Catchment/subcatchment areas.	Catchment/subcatchment areas	Clearly note any differences in catchment/subcatchment boundaries and hydrological parameters based on (a) major vs. minor drainage system and (b) completed stages of development.
	Conveyance	Drainage Paths and discharge locations.	Detailed plan and profile drawings of inlet/outlet piping connecting to the pond.	Any surface conveyance elements (including emergency overflow) should be fully vegetated to provide a more natural and consistent aesthetic. Native plantings are recommended and these areas should be included on the planting plan.
			Cross sections, grade and alignment for overland ditches connecting to the pond.	
	Attenuation Facility	Location and size of attenuation facilities.	Detailed pond grading plan.	A planting plan should be submitted that clearly identifies the various native planting zones to be established, and the location of plant zones both above and below NWL. The planting plan should include sufficient contours from the grading plan to clearly show the depth of each planting zone, the slope between contours, and the location and depth of the center channel. Note also that the design grades will need to be achieved to a tolerance of ± 5cm. Given this, the grading plan should consider constructability and potential equipment limitations.
			Plan view and cross sections of the attenuation facility, including the NWL and HWL.	
	Structures	Location of inlets, outfalls and gate chambers.	Outfall and gate chamber sections and details, including erosion protection measures as required. Include a gate operation memorandum as a part of the submission identifying operational procedures.	To facilitate water level fluctuations during commissioning, it is recommended that the outlet flow control structure be able to lower the water level at least 0.3 m below NWL. All relevant details (gate mechanism, orifice wall, manhole, etc.) should be shown in plan and profile.
	Pump Station(s)	Locations of pump stations	Confirmation of the pump station location and required capacities, and anticipated operational procedures (on/off, maintenance, etc.). Mechanical, electrical and structural drawings to be submitted to the City for general review.	n/a
	Easements	Easement requirements	Easement requirements.	n/a

6. Construction of Naturalized Stormwater Ponds

6.1. Erosion and sediment control

Land use practices in residential areas can be a source of erosion and sedimentation to NSPs over their lifetime, including through the application of road sand. A key design feature of NSPs is the wetland vegetated and upland vegetated areas that slow the flow of water and promote sedimentation (see Section 2.1); however, while plants are becoming established during the construction period, their capacity for water quality improvement is limited. Without proper erosion and sediment control practices, construction activities can be large sources of sediments to NSPs. Topsoils are a valuable resource that can be a costly loss from erosion. In addition, erosion and sedimentation into establishing wetland plant zones can jeopardize the viability of establishing plants. In many situations, most wetland plant species are unable to germinate if their seeds are covered by only 1 cm of soil (Ross 2009).

Selection, installation and maintenance of erosion and sediment control techniques on an NSP site are important to the project efficiency and success. Soil erodibility, vegetation cover, topography, climate and season will all guide technique selection. The following are a selection of erosion and sediment control practices that can be applied in various areas on an NSP construction site. Note that many of the recommended techniques below are temporary, and can be removed once construction activities have been completed. Proper monitoring during construction will ensure that any erosion and sediment control practices installed are working as intended, and enable identification of any areas requiring enhanced erosion control, particularly after large storm events.

- **Earth dykes:** Low linear ridges of earth that re-direct surface runoff away from establishing upland and wetland vegetation, and towards sediment traps or ponds (Figure 6.1).
- **Sediment control fences:** A fabric barrier that traps sediments while letting runoff through (Figure 6.2). Similar to an earth dyke, it can prevent sedimentation into establishing wetland and upland areas.
- **Sedimentation ponds:** Temporary ponds designed to encourage settlement of sediments (Figure 6.3). Sedimentation ponds can be temporary measures installed along a flow pathway, or permanent measures installed as a sediment forebay to an NSP.
- **Check dams:** Small dams to slow flow and trap sediments in targeted areas, including drainage ditches or swales (Figure 6.4). Check dams are most appropriate for overland inlets to ponds during construction.

In addition to the targeted practices listed above, there are a number of standard erosion and sediment control practices that should be applied to all NSP construction sites:

- Delay any ground disturbing construction activities until it is necessary for construction to proceed;
- Disturbed areas should be covered or stabilized as soon as possible;
- Where possible, schedule construction activities to limit the impact of seasonal climate or weather on erosion and sedimentation;
- Use cover crops in all exposed upland areas until the installment and establishment of native vegetation is successful; and,
- Incorporate erosion control blankets and the construction of temporary soft berms on steeper slopes.

6.2. Construction timelines

Planning is an important part of the construction process of NSPs. There are many components to NSP construction, including earthworks, plantings and hydrology, some of which have time sensitive elements and require execution under a certain season. In addition, the sequencing of these elements is also important, ensuring the success of one component of an NSP without damaging another. Delays in construction without proper planning may lead to failures of key portions, or additional commissioning years. General timing required is outlined below for three key components of NSP construction: earthworks, planting and hydrology. Note that each NSP will have project-specific requirements for timing that should be considered by the project team.

6.2.1. Earthworks

Earthworks as part of the NSP construction process includes excavation, soil placement, and rough grading. These activities can be conducted in winter, or as a summer/fall construction. Winter construction can be preferable, at a time when construction equipment often sits idle. Frozen conditions in winter can allow for easy movement of equipment; however, this should be verified by the construction specialist on the project team. Unsuitable substrate conditions during winter construction (e.g., soil moisture conditions, frost conditions, timing of construction during winter, working in cut versus fill, etc.) can lead to slumping and settling of graded areas once thawed. Wetland plant species and their preferred water depths can be sensitive to small changes in planting depths as compared to design. As success of NSP construction is highly dependent on the accuracy of grading matching what has been designed for wetland plant success, winter construction should only take place if the project team is confident working in frozen conditions, and that accurate grading can be achieved. It is critical that strict design tolerances (± 5 cm) be achieved within the wetland planting zone (i.e., 0 – 60 cm below the normal water level) to facilitate plant establishment. If the project site is sufficiently dry, or substrate conditions are unsuitable, summer/fall construction may be preferred.

6.2.2. Plantings

Depending on the establishment techniques selected for wetland planting (i.e., seed or donor material; see Section 4.1.3), wetland planting can be conducted as a winter or late summer planting. A winter planting can be more efficient whether using seed and/or donor material. A dormant wetland seeding in late fall or early winter can be done, under dry and frozen substrate conditions, depending on the seeding technique used and seed mix being applied. For donor material, following proper sourcing of a wetland plant donor site in the summer prior to construction, wetland plants can be extracted from the donor site and planted in the wetland zone of the NSP during the winter. Using heavy equipment, this technique moves wetland plants at a time of year when they are dormant, and is particularly effective for larger NSPs where heavy equipment improves planting efficiency. For a winter planting, regardless of the establishment technique used, a guaranteed supply of water to the NWL of the NSP must be available for the following spring to support wetland plants in their first growing season.

Wetland planting can also occur during the spring or late summer, once an NSP has been supplied water to its NWL. In the early spring, wetland seeding can be conducted on an NSP. This process requires a drawdown in late spring to expose the wetland zone to allow seeding to occur, support germination under moist conditions and prevent seed from washing away. As the timing of this technique leads to seeding under moist conditions, only broadcast seeding by hand can be applied. Alternatively, hand planting of wetland plants in the late summer with wetland propagules can occur. When establishing wetland plants via hand planting, water depths at the donor site versus the receiving NSP must be comparable to limit stress to the donor plants. This technique and its timing is generally applied only for smaller sites, or as an enhancement technique in the first or second growing seasons to improve species diversity (see Section 7.3). Generally, timing of planting in spring or late summer is more effective on smaller sites. In addition, spring or summer planting is generally more labour intensive than a winter planting and can leave little time for adaptive management activities should timing be unsuccessful.

When moving plant material, either in winter or in summer, it is important not to stockpile live plant material for more than a day. Stockpiled plant material, even during winter months when daytime temperatures sit well below 0°C, will quickly compost due to elevated temperatures within the pile.

Planting native grasses, trees and shrubs in the upland area must be timed appropriately and in coordination with planting the wetland zone during the construction process. Trees and shrubs planted above the HWL mark of the stormwater pond should be planted first to prevent disturbance to the native grass seedbed. Generally, planting trees or shrubs below HWL should be avoided or accomplished following the establishment of the native grassed buffer. However, in certain circumstances, if tree or shrub beds are to be planted below HWL, close communication between contractors should occur to avoid damage and repair costs to the planting site. Generally, the best time to transplant native tree and shrub species is in the early spring or fall when moisture level in the soil is relatively high and soil is still warm. Likewise for seeding native grasses, it is optimal to seed when there is sufficient soil moisture, such as in the spring or the fall. Plant native grasses between mid-May and mid-June, or late-October. Summer plantings in the upland are not recommended.

The sequencing of wetland planting relative to upland planting is also important in the construction process. Generally, it is recommended that the wetland zone below NWL be planted first, to minimize the potential for damage to establishing upland plants while accessing the wetland zone. However, erosion or sedimentation from the upland zone into the wetland zone can damage new wetland plant growth. Therefore, proper erosion and sedimentation control techniques must be applied when sequencing the revegetation of these two areas (see Section 6.1).

6.2.3. Hydrology

Proper planning of an NSP's hydrology during construction is the most important component leading into its commissioning and a key determinant of project success. Although earthworks are done under dry conditions, water is required for the first growing season after planting to start the commissioning process. To support the growth of the wetland plants, initial supply to the NWL of the pond is required by spring of the first growing season. Planning of NSP hydrology includes identifying when water will be available, where it will be sourced, and how it will be manipulated in the first few years of pond commissioning. Sometimes in new developments, the hard surfaces to generate sufficient runoff to meet the water supply may not be available in early years of commissioning (see Section 3.1.1). Where water supply to NWL in the first few years may be a concern, alternative sources of water should be sourced as part of the design process. This may include pumping from nearby water sources. Note that when accessing alternative water sources to supply an NSP to NWL, the proper permit applications should be met in advance of pumping, where required. Source water should also be of good quality. If there is a risk that water may not be available for the first growing season, or the ability to manipulate water levels has not been confirmed, planting below NWL should be delayed a year until the project team is confident that water will be available for commissioning purposes. Should wetland planting be delayed, temporary erosion and sediment control practices should be applied (see Section 6.1) and a cover crop of native species should be planted within the wetland zone to prevent erosion and minimize the invasion of weedy species. Special consideration should also be given to water availability when an NSP is part of a larger stormwater pond network. The effect of the commissioning of one NSP (e.g., water level manipulations) on upstream or downstream ponds in the same network should be considered. Where possible, NSP levels should be manipulated independently of each other, as poorly timed flooding or drawdowns early in the commissioning process of an NSP can be damaging to both wetland and upland plants (see Section 7.2, 7.3). If stormwater ponds are hydrologically connected without the ability to independently manipulate water levels, then ballooning pond connections and using pumps to manipulate water levels can be considered.

Figure 6.1. Earth dyke installed to redirect surface runoff towards an NSP.

Figure 6.2. A sediment control fence at the wetland/open water interface, preventing erosion into the open water zone.

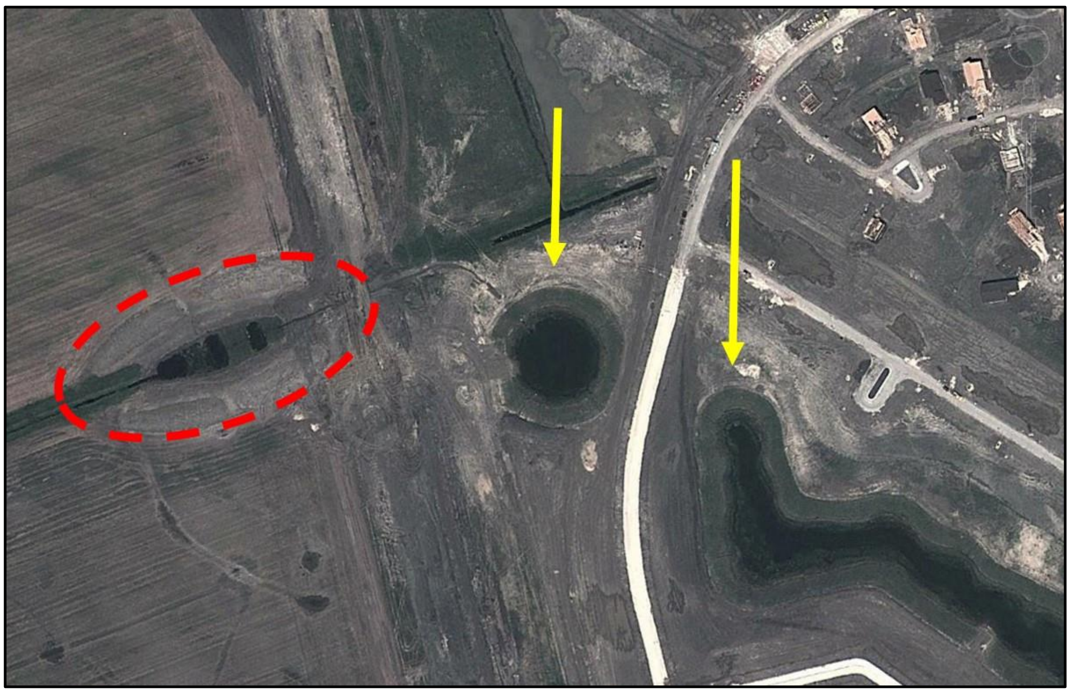

Figure 6.3. Sedimentation pond (indicated by dashed red oval) installed as a temporary sediment control measure upstream of an NSP network (indicated by yellow arrows) during the construction phase.

Figure 6.4. Check dam installed in upland area of an NSP, in conjunction with erosion control blanket, prior to the installation of wetland vegetation.

7. Site Commissioning

Although NSPs are low maintenance over the long-term, their first few years of operation are more intensive, requiring monitoring and management activities for successful establishment (Table 7.1). Following NSP construction, site commissioning will ensure that an NSP meets key engineering and biological design criteria (Table 3.1 and Table 4.1). In addition, performance measures for establishing wetland and upland vegetation will be assessed to ensure these communities are on a trajectory to success (Table 7.2; Section 7.7). This will also help ensure that the pond will remain low-maintenance over the long-term. The timeline for commissioning starts with initial filling of the NSP in preparation for the first growing season, and typically ends once the upland vegetation has been established. Led by the developer and their team, commissioning is a five year process with specific planned activities, where water levels are adjusted to support the establishment of wetland plants, and weedy and invasive species controlled to support upland native plant establishment.

This section outlines the recommended monitoring and maintenance that should occur for key components of the NSP during the first five years of pond commissioning. This includes monitoring grading and infrastructure performance, water management, wetland vegetation, upland vegetation, wildlife control and water quality. Monitoring for each of these components can identify issues that may affect an NSP's success, since it is during this commissioning stage when a pond is most vulnerable to small disturbances. For example, a faulty control structure can result in unexpected flooding of the pond, leading to the death of young wetland plants. By conducting timely monitoring, adaptive management activities can be taken to perform corrective maintenance. Note that monitoring activities recommended for each of these components often occur concurrently. For example, on a single site visit, NSP monitoring can include: inspection of pond water levels; assessment of wetland/upland vegetation growth, coverage, species present and occurrence of weeds; checks for nuisance wildlife; inspection of goose deterrence fencing; an upland stand inspection; and qualitative observations of water quality.

Activities taken by the developer during this stage should be timely and purposeful to ensure that an NSP will function as it is designed. For the City of Brandon, site commissioning serves as a checkpoint to ensure that a pond is performing as intended and designed prior to handoff. Section 7.7 outlines the performance measures to be met during the commissioning stage, as well as the operations manual required at pond/project handoff.

7.1. Engineering - grading and infrastructure performance

Little monitoring is required that is specific to the engineering performance of an NSP; however, there are two key components whose performance should be investigated early in the commissioning process, as their failure to operate as designed could jeopardize an NSP's success.

First, the grading of the pond must be checked to ensure it is within a design tolerances (Table 7.2; see Section 7.7). It is critical that grading tolerances (i.e., ± 5 cm) be strictly adhered to within wetland the planting zones (i.e., 0 – 60 cm below the normal water level). This is because plant establishment is highly dependent on pond bathymetry matching the original design elevations. Errors in site grading, if caught early, can be addressed via adaptive management activities to ensure successful wetland plant establishment below NWL. This may include operating pond water levels higher or lower than as designed, adjusting the proposed plant communities or regrading.

Second, any infrastructure installed, particularly control structures, must be annually inspected and operated, particularly for control structures with adjustable gates (Table 7.2; see Section 7.7). A faulty control structure can risk flooding young wetland plants, or prevent an NSP from functioning as designed. In addition, adjustable control structures in NSPs are susceptible to seizing, due to the buildup of hydrogen sulfide gas as a result of decomposing vegetation. Annual operation of these gates will work to prevent this.

7.2. Water management

Water management of an NSP is the most important activity a developer can take during the commissioning stage. Although an NSP should be designed with little water management required over the long-term, some amount of management is required in the first few years of pond operation to encourage plant growth. The seeds of wetland plants require managed drawdowns to establish. Conversely, young wetland plants are very vulnerable to die-off if pond water levels rise beyond the height of the plant and remain there for too long (e.g., > 10 days). Therefore monitoring and managing pond water levels during the commissioning stage is critical to the establishment of wetland vegetation (Table 7.1). Vegetation establishment is also linked to the water quality improvement capabilities of a pond. Prior to the commissioning stage, as outlined in Section 6.2.3, a developer and their project team must confirm that their NSP will be supplied with water to fill to NWL by May 1st in the first year of pond operation. How water levels will be managed (i.e., the ability to raise or draw down) to support commissioning of the wetland vegetation during the commissioning stage must also be clearly identified to the entire project team.

Monitoring during the first few years of commissioning must include weekly to biweekly visual inspections of pond water levels, particularly after large rain events. Change in water levels between inspections can be noted qualitatively, through the annual installation of a stake indicating the NWL elevation, or using more quantitative measures such as a staff gauge or data logger. For NSPs where water management is dependent on pumping (i.e., a balloon has been installed at the outlet or between connecting ponds), inspection after all rain events is recommended to determine the flooding potential, and required drawdown via pumping. Once a pond has been successfully commissioned, water levels should never remain above NWL for periods longer than 30 days, as this can cause complete die-off of wetland vegetation. Regular monitoring allows for adaptive management activities to be taken, particularly when water levels remain high for an extended period of time. Pumping water down in the NSP or adjusting the control structure elevation to allow water release may be required if the problem cannot be rectified in a timely manner. Following drawdown, the cause for extended duration of flooding must be identified and resolved (e.g., control structure failure, obstructions, beaver activity, changes to upstream sources or downstream outlets).

Manipulation of the water levels during commissioning is also critical to encourage new wetland plant growth. As an NSP is composed of wetland elements, a flood-up to NWL for a pond's first growing season is critical to establishment, particularly in early-May to moisten soils. A drawdown, particularly during the late summer, can encourage wetland seed to germinate and promote new vegetative growth (Table 7.1). A flood-up to NWL, when appropriately timed, can also assist with weed management in the wetland zone, as well as prepare wetland vegetation for a new growing season. However, the water management process to encourage wetland plant growth is not simply the raising and lowering of water levels, but requires a thorough understanding of plant ecology specific to the NSP, its engineering and biological design and the species selected. Is it recommended that a developer have the appropriate expertise on their project team (see Section 1.6) to lead the water management commissioning process, as the risks of poor water management to the pond are great. Note that following the first two to three years of water management for commissioning, wetland vegetation typically becomes sufficiently established to withstand water levels as they have been designed for long-term operation. At this point, water management monitoring can be decreased to occasional site inspections.

7.3. Wetland vegetation

Although water management commissioning activities are targeted at supporting the establishment of wetland vegetation, some additional wetland vegetation commissioning activities may be required. Regardless of the approach selected for wetland vegetation establishment, wetland vegetation enhancement is often required. Enhancement activities are conducted to either improve the plant coverage in the wetland zone, or increase species diversity. Enhancement activities should be selected and conducted in response to monitoring results, in order to meet performance parameters at hand-off (Table 7.2; see Section 7.7).

When performing weekly to biweekly visits of the NSP to inform water management activities, visual inspections of the wetland vegetation should also be made in order to guide enhancement activities. Areas of poor coverage should be noted for wetland vegetation enhancement (see Table 7.1). Hand planting of wetland plant propagules can be used in mid- to late-summer as an approach for enhancement. Alternatively, additional wetland seed can be spread in either late spring, or late fall, following a water level drawdown. Monitoring of wetland vegetation can also identify where species diversity in the wetland is not matching the biological design. The success of establishment of some wetland plant species depends on the establishment technique selected (Table 4.2). Often times, hand planting of targeted species can be effective at improving the diversity of a plant community. As with water level monitoring, if wetland vegetation appears to be establishing as designed following the first two years after construction, then less frequent site visits can be made.

In addition to monitoring of the wetland vegetation to inform enhancement activities, inspection to inform weed management in the wetland zone is also recommended. Increases in weed pressure in the wetland zone can occur during the commissioning stage when water levels are lowered to allow for the germination of wetland seed. During this time, mechanical and cultural control strategies are best used as young wetland seedlings can be particularly vulnerable to herbicide treatment. Cultural control practices aim to decrease weed establishment through habitat modifications that make the environment less suitable. In the wetland zone, this strategy could include the raising of water levels to promote the growth of wetland plants while discouraging the growth or expansion of certain weed species. Combining both cultural control with mechanical control (e.g., mowing) can be particularly successful when correct timing and duration is used. For example, selective mowing of weed species followed by flooding overtop of the mown plants for a duration of time is an effective strategy to reduce vigor on targeted species by inhibiting oxygen exchange to the roots. When employed effectively, this technique can terminate targeted plants.

Continual monitoring is necessary, particularly when using water level manipulations as a weed control strategy, to ensure that the wetland seedlings are not compromised. A good understanding of plant ecology and plant species identification will be important to manage weedy and invasive plants. Invasive wetland species such as purple loosestrife (*Lythrum salicaria*), reed canary grass (*Phalaris arundinacea*), curly dock (*Rumex crispus*), invasive phragmities (*Phragmites australis* ssp. *australis*), redtop (*Agrostis gigantea*), Canada thistle (*Cirsium arvense*), and weedy species such as foxtail barley (*Hordeum jubatum*), pose a major threat to native plant establishment in wetland areas and are challenging to remove from a site once established. Regular monitoring for weedy or invasive species in the wetland zone and implementing timely and effective weed control strategies will be important to prevent these species from becoming established. Table 4.4 provides a list of common weedy and invasive species that can grow in the wetland zone of stormwater ponds.

In order to inform the NSP handoff stage and submission of the operations manual (see Section 7.7; Table 7.2), quantitative vegetation monitoring of the wetland zone is required in the final (i.e., fifth) year of commissioning. Vegetation data must be collected between mid-July and mid-August when plants are most mature. Appendix C outlines the belt transect methodology that must be used for the vegetation survey. This will collect information on the performance measures for the NSP's wetland vegetation, including species richness (i.e., greater than 20) and species coverage (i.e., greater than 75% coverage of native vegetation; less than 10% coverage of weed species).

7.4. Upland vegetation

Monitoring the upland buffer zone of the NSP will be most intensive in the first few years after planting to ensure the native upland community progresses as planned. The upland buffer zone commissioning stage is up to five years. The first two or three weeks after seeding will involve intensive monitoring for successful seed germination (see Section 4.2.2). As noted in Section 4.2.2, a successful native grass upland planting is defined as containing an average of 43-54 native plants per square metre and a very good planting is defined as containing an average of >65 native plants per square metre. If native plant yields are low upon evaluation, reseeding or remedial seeding during an appropriate window of time when there is sufficient soil moisture, such as in the spring or fall, will be crucial for success. Weekly or biweekly visits to a new site during the commissioning stage are also required to monitor the status of weedy or invasive species, as well as areas of erosion that may form following large precipitation events. Regular monitoring for weedy or invasive species in the upland buffer zone will assist in performing timely and effective weed control, so that these species can be controlled before they set seed or spread vegetatively (see Section 4.2.3). Following large precipitation events, monitoring for erosion and implementing timely and effective erosion control measures is crucial to avoid compromising the integrity of the slope, and the establishing vegetation.

In order to inform the NSP hand-off stage and submission of the operations manual (see Section 7.7; Table 7.2), quantitative vegetation monitoring of the upland zone is required in the final (i.e., fifth) year of commissioning. Vegetation data is collected at the same time as data is collected on plants growing below NWL. Appendix C outlines the belt transect methodology that must be used for the vegetation survey. This will collect information on the performance measures for the NSP's upland vegetation, including species richness (i.e., greater than 15) and species coverage (i.e., 43 - 53 plants per m^2; less than 10% coverage of weed species).

7.5. Wildlife control

An established NSP can be valuable habitat for waterfowl, songbirds and amphibians; however, during the commissioning stage wetland plants can be vulnerable to grazing by Canada Geese. Within as little as a few days, a pair of Canada Geese can easily decimate large areas of establishing wetland vegetation (Figure 7.1). Temporary fencing can be installed around the inner and outer edges of establishing wetland vegetation areas to prevent grazing of the tender plant shoots by Canada Geese (see Figure 7.2). When installed, entry and exit points must be included to allow movement of Canada Geese from the upland area to the open water zone during molting and limit predation. This fence should not be installed in response to the presence of Canada Geese, but rather as a preventative measure prior to the first year of commissioning. As noted in Section 7.2, water levels that overtop establishing wetland plants, including those plants that have been grazed by wildlife, can put a wetland area at risk.

In addition to grazing by waterfowl, muskrat activity can be detrimental to an establishing NSP. Muskrats can harvest large areas of establishing wetland vegetation in a short period of time. In addition, construction of muskrat lodges within wetland vegetation areas can prevent the growth and spread of new wetland plants. Once established, NSPs are fairly resilient to muskrat activity, with wetland vegetation re-establishing the following growing season as long as muskrat populations do not flourish. However, in the commissioning years, muskrat activity may damage establishing wetland plants. Temporary fencing for Canada Geese around the inner and outer edges of establishing wetland vegetation will not limit muskrat damage. Trapping may need to be considered as a control measure. Municipal and provincial legislation around trapping must be adhered to prior to applying any control measures. Although beavers are common wildlife pests in constructed wetlands, the lack of flow in NSPs makes these systems less desirable to beaver populations; therefore, this species is generally not a concern.

Regular monitoring, as part of wildlife control during commissioning, will ensure that nuisance species are identified and adaptive management techniques to control problem species applied. In addition, any techniques that have been applied for wildlife control must be inspected on a regular basis to ensure they are functioning as designed.

7.6. Water quality

To determine an NSP's effectiveness for TSS removal, a developer must collect quantitative water quality data that confirms an NSP is meeting the CCME guidelines outlined in Table 2.1 (see Section 7.7; Table 7.2). Sufficient samples to demonstrate a pond's effectiveness for TSS removal at background and high flow events may be collected within a year; however, a developer may want to allow sufficient time for adaptive management activities to be applied should TSS be outside of an acceptable range.

During the commissioning period, qualitative observations of water quality are often sufficient for other water quality parameters, noting issues such as turbidity, blue green algal blooms, excessive growth of duckweed or fish kills. Often, if water quality issues are encountered following construction, there are few known remedies to rectify the situation (McKenna et al. 2014b). If the naturalized stormwater pond guidelines presented in this document have been followed, water quality will improve over time as vegetation becomes established.

In situations where a developer or the City of Brandon has noted site-specific concerns with water quality at the start of a project (see Section 2.1), quantitative water quality monitoring may be required to confirm the success of NSP design and construction for water quality control.

7.7. Project hand-off

7.7.1. Performance measures

Once the pond is operational hydrologically, performance measures for infrastructure and grading (Table 7.2) will be evaluated. During Year 5, performance measures of the vegetation and water quality improvement potential of the NSP will be evaluated, including the vegetation to open water ratio that has developed, wetland vegetation species richness and coverage, upland vegetation species richness and coverage, weed species coverage in both the wetland and upland zone, native tree and shrub survival and TSS removal (Table 7.2).

It is the responsibility of the NSP's developer and their project team to collect sufficient information to demonstrate that a pond meets all performance measures. Should an NSP not meet a particular performance measure at evaluation, it is the responsibility of the developer to demonstrate to the City of Brandon that adaptive management strategies have been undertaken to rectify the situation prior to hand-off, ensuring that the pond's key functions (i.e., water quantity and water quality improvement; see Section 2) are not jeopardized. For example, if an NSP does not meet the grading design tolerance of ± 5cm, it is the responsibility of the developer to undertake adaptive management strategies that will rectify the effect of grading errors on wetland vegetation establishment (Table 8.1). This could include less intensive strategies such as operating the NWL at a different elevation than designed, or more intensive strategies such as re-contouring a pond's bathymetry.

Performance measure information should be compiled and summarized as part of the operations manual (see Section 7.7.2).

7.7.2. Operations manual

NSPs will typically be handed over to the City of Brandon to manage after the end of the five year commissioning stage. Each pond handoff should be accompanied by an operations manual. The intent of this manual is to provide information to those responsible with pond management in future years. It should clearly define and describe the pond so that anyone can understand what the site was like at the time of project handoff, and the information used to identify and determine how well the pond is performing and when inspection and management activities will be required. It is important that the document identifies and details the original pond design, the plant communities established and the species planted (i.e., for all locations), the entire project team, recommended monitoring and management schedules, and site hydrology, including pond connectivity, infrastructure and pond operation. The operations manual also serves to document that an NSP meets performance measures at hand-off (see Table 7.2). The operations manual provided at hand-off must include:

1. Project background
    a. Development name, pond name, developer, engineering firm, landscape architect firm, naturalized wet pond designers and revegetation specialists, construction dates, contractor, dates of upland and pond plantings;
2. Pond design and site establishment activities
    a. Project location, pond placement within the development and connectivity with adjacent pond systems and natural waterways;

    b. Infrastructure locations, design details (e.g., inlet(s), outlet(s), control structure), pond operation, volume of available storage between the NWL and freeboard elevation;
    c. Design drawings are required for all ponds. Drawings will show all inlet/outlet information including size, material, slope, length, details of the control structure, and finished grades of the pond. As-built drawings must be included where deviations from the original design drawings have been made. Includes both plan view and cross-section.
    d. Pond plantings and species used in both upland and pond plantings, including design drawings detailing contour and elevation information and plant zones, planting timelines, planting techniques/sources, commissioning timeframe, and water level manipulations/management activities (e.g., weed control, controlled burns) for successful plant establishment;
    e. Dates of water quality testing (if applicable) along with parameters tested, and water quality results;
    f. Wildlife control techniques and timing of activities; and
    g. Site photos showing pond establishment from construction through to project hand-off.
3. Vegetation management recommendations and timelines
    a. Recommended maintenance and management techniques - wetland and upland vegetation; and
    b. Vegetation survey results, to be conducted the summer before project hand-off.
4. Summary of how NSP meets hand-off performance measures
5. Monitoring/inspection requirements and schedules - future years
    a. Vegetation;
    b. Infrastructure;
    c. Pond operating requirements;
    d. Water quality;
    e. Pathways and human use; and
    f. Reporting/documentation requirements.
6. Problem solving decision matrix, including management approaches, for future years

Table 7.1. Example of commissioning activities in an NSP.

Commissioning Activity	Winter (Nov to Mar)	Spring (Apr to May)	Summer (Jun to Aug)	Fall (Sep to Oct)
YEAR 1				
Engineering – Grading and infrastructure performance		Grading inspection Annual inspection of control structures		
Water management	Dry until April	Fill to normal water level (NWL) in spring	Reset below NWL in June to encourage new plant growth	Reset to NWL if conditions allow
Wetland vegetation	Mechanical planting, as part of construction	Broadcast seeding	Assess and enhance with transplanting using hand planting	Inspect and assess
Upland vegetation		Site inspection and application of integrated weed management strategy (i.e., chemical, cultural or mechanical practices and timing)		
Widlife control	Fence all newly vegetated wetland areas (Canada Goose control)	Inspect	Inspect	
Water quality		Qualitative inspection		
YEAR 2				
Engineering – Grading and infrastructure performance		Annual inspection of control structures		
Water management	Water level set at NWL	Assess level to determine performance	Manipulate water levels (i.e., raising or lowering) to encourage plant establishment if required	Reset to NWL if conditions allow
Wetland vegetation	Mechanical planting, if required for enhancement	Seeding	Assess and enhance with transplanting using hand planting	Inspect and assess
Upland vegetation	Data analysis	Site inspection and application of integrated weed management strategy (i.e., chemical, cultural or mechanical practices and timing)		
Wildlife control		Inspect	Inspect	Remove fencing only if wetland plants are mature
Water quality		Qualitative inspection		

Table 7.2. NSP performance measures evaluated at hand-off.

Performance Measure	Minimum Requirements	Timeline
Infrastructure	Operating as designed	Evaluation in Commissioning Year 1
Grading	± 5 cm design tolerance	
Vegetation to open water ratio	35% to 65% coverage at NWL	Evaluation in Commissioning Year 5
Wetland vegetation species richness	20	
Wetland vegetation species coverage	≥75%	
Wetland vegetation weed coverage	≤ 10%	
Upland vegetation species richness	15	
Upland vegetation species coverage	43-54 plants per m^2	
Upland vegetation weed coverage	≤ 10%	
Native trees and shrubs	50 - 75% survival	
TSS removal	see Table 2.1	

Figure 7.1. Example of goose grazing on young wetland vegetation.

Figure 7.2. Goose deterrence fencing installed around the wetland zone of an NSP in its first commissioning year, including an entry/exit point to the open water zone from then upland area.

8. Long-term Operations, Maintenance and Monitoring

Following the completion of the commissioning stage at the end of year 5, and after successful project handoff to the City, NSPs move into the long-term operations, maintenance and monitoring stage of the project. While NSPs require little maintenance on an annual basis, some operations, maintenance and monitoring activities should occur to maintain the performance of the pond. An operation, maintenance and monitoring schedule will help to identify and support any adaptive management activities that may need to occur (Table 8.1), and identify when these interventions may be required (Table 8.2; Table 8.3).

Operations: are planned field activities that aid in the management of water levels, and the quality and quantity of water flowing through the naturalized pond. It includes the inspection of all pond infrastructure including, but not exclusive to, inlets, outlets, and control structures. Inspection of ponds is particularly important in the early years after large precipitation events. It is important that operation inspections include documentation on maintenance and monitoring activities, as part of the long-term recordkeeping on these systems.

Maintenance: includes regular adaptive management activities to maintain or repair infrastructure (e.g., control structures, pipes, fences, paths, lookout areas, etc.) and the naturalized stormwater components of the pond (e.g., wetland and upland vegetation) to ensure they function as originally designed. The maintenance cycle will vary from year to year. A small degree of maintenance is always required on an annual basis, with certain years requiring more maintenance than others (e.g., a 1 in 5 year burn of the upland native grasses to maintain the vigor of the stand). Record keeping of maintenance activities is required.

Monitoring: is defined as the periodic surveillance and data collection that includes both visual field inspections and field surveys of the pond. Monitoring helps to inform when maintenance activities may be required.

8.1. Infrastructure

8.1.1. Control structures

Control structures with moving parts (e.g., sliding gates/valves, weirs with stop logs) need to be operated and inspected every year to ensure their proper functioning in addition to any other inspection and maintenance recommended by the manufacturer. NSPs produce additional hydrogen sulfide as a byproduct of vegetation decomposition. As a result, control structures that are not regularly maintained will seize over time. Control structures should also be inspected for any leaks or debris on an annual basis, especially if the hydrological performance of the pond changes without an apparent cause (Table 8.1). Using an anti-seize product to ensure control structure performance may be needed.

8.1.2. Inlet/Outlet pipes

As with control structures, grates, emergency overflows, spillways and inlet/outlet pipes should be inspected annually, and particularly after significant rain events. Garbage, debris or any other blockages that affect the proper functioning of the pond needs to be removed and disposed of in a proper location.

8.1.3. Overland swales/channels

Not all NSPs will have drain swales carrying flow either into, or out of, the pond. For those that do, swales should be inspected every year, preferably in the spring, and after significant rainfall events for debris and possible erosion.

8.1.4. Sediment

Factors that can affect sedimentation rates within stormwater ponds include the size of the upstream drainage area, land cover within the drainage footprint (e.g., agriculture, hard surface, grassed, ongoing construction, etc.), precipitation patterns, erosion/sediment control practices, and winter road maintenance. As a result, it is difficult to predict the rate at which sediment may build up in the pond.

Sediment buildup within the pond should be determined during the commissioning stage and noted at the time of project handoff if there is a concern for excess sediment buildup in future years. The inspection frequency for each pond will be site specific, noted at the time of project handoff (e.g., at Year 5), and updated in the operation and maintenance manual as required.

Note that sediment may accumulate very slowly in the main channel of the pond over time. As a result, the main section of the pond should be checked for depth of sediment every 10 years at a minimum and that information recorded for future inspections.

8.2. Hydrology

NSPs are intended to support a variety of vegetative communities based on the bathymetry built below NWL (see Section 4.1.2). This contouring provides a range of water depths for different wetland plants, helping to support greater plant diversity within the pond while making the pond more resilient to the stable water levels stormwater ponds often experience. Consequently, water level manipulation is not usually required to maintain the vegetative communities in these systems after the commissioning stage. The hydrological performance of the pond should be verified on an annual basis, at a minimum, and generally at the same time that infrastructure and control structures are inspected. If extreme precipitation events do occur then monitoring the pond's hydrological performance during this time period is recommended to ensure that plant communities are not compromised by higher than normal (e.g., ≥ HWL), and sustained (e.g., > 14 days), water levels. While most plants can sustain high water levels for up to 30 days, any pond whose water level has remained high for longer than 14 days consecutively should be investigated to determine the reason (Table 8.1).

If vegetation cover begins to decline (Table 8.2) then a drawdown of water levels within the pond may be required in order to revitalize the vegetative community. In this case, drawing down water levels by mid- to late June is recommended. Drawdowns should strive to expose mudflat areas where plants once provided cover. Exposing soils will allow seeds present in the soil seedbank to germinate resulting in new plant growth and increased plant cover within the pond. Leaving the soils dry for too long, or raising water levels at the wrong time during this activity, may compromise the pond's plant response. It is recommended that one consults a wetland plant specialist before a drawdown is scheduled.

While upland and wetland native plant species can handle above-normal water levels for up to a maximum of 30 days, if flooding conditions persist beyond this time frame then pumping water levels down to NWL will be required, otherwise both wetland and upland native plant species will begin to die.

8.3. Vegetation

8.3.1. Wetland vegetation

The design recommendations described in this guide help to support the development of a floristically diverse native wetland plant community below NWL. This diversity helps to support long-term stability and resilience within this plant community. When a resilient system is established, ponds should require minimal maintenance over their lifetime. There should be no need to harvest vegetation or to manipulate water levels. In order to maintain a healthy stand of wetland vegetation around the ponds, once the pond is established, it is recommended that the pond be operated at, or near, NWL in most years and that water levels not remain flooded higher than the designed NWL for longer than 30 days in one consecutive stretch.

At the time of pond handoff to the City of Brandon (e.g., year 5 of pond commissioning), wetland vegetation should be surveyed (see Sections 7.3 and 7.7), compared to how it meets the performance measures, and summarized in the operations manual (see Section 7.7.2). These surveys can then be used as a baseline to determine plant health and diversity of the pond in future years. Vegetation below NWL should be visually inspected for cover and resilience every year, generally during the summer months (e.g., mid-June through mid-August) (Table 8.1). Information gathered at this time can then be compared to the vegetation survey conducted at pond handoff. Special attention should be given, and management activities undertaken, if any weedy or invasive species (e.g., reed canary grass or purple loosestrife) become established. Table 8.2 provides management options if changes in vegetation are observed in the plant community below NWL or pond performance appears to be compromised (e.g., lack of wetland vegetation, decrease in wetland vegetation diversity, presence of harmful algal blooms).

8.3.2. Upland vegetation

As with the wetland plant communities, native upland vegetation is very hardy to disturbance once the plant stand is established. Management activities should be targeted to maintain plant diversity and reduce the establishment of weedy (e.g., foxtail barley) or invasive species (e.g., Canada thistle). Annual visual inspections should be made to assess stand health (e.g., soil coverage), species richness and diversity (e.g., number of species/m^2), and the presence of weeds or invasives. Results from upland vegetation survey completed prior to site handoff (e.g., at year 5), including how it met the performance measures, should be used as a baseline during the annual summer inspections to determine how the plant stand is responding and when a management intervention may be required. Ongoing annual visual inspections on upland plant health should be conducted at the same time as the inspection of emergent vegetation in the pond (i.e., mid-June through mid-August) (Table 8.1).

Upland plant densities may decrease overall as excess dead litter accumulates at the soil surface at the end of each growing season. This occurs when the aboveground parts of grasses die off. While litter is valuable as cover and nesting material for many birds, it can cut off the soil from precipitation and decrease the diversity of the plant stand. Monitoring for excess litter accumulation (i.e., greater than 5 cm) in the upland should occur from mid- to late June when litter accumulation is easiest to measure. A number of management treatment options are available to help maintain litter accumulation. These include controlled burns (Figure 8.1) and mowing. For managing litter accumulation in the upland, controlled burns are recommended, and under certain conditions, mowing can be used as an alternative to burning. Although mowing removes excess litter accumulation, additional benefits can be achieved through a controlled burn, such as the ability to stimulate seed germination and vigorous new plant growth. These techniques can also be used to maintain/decrease weedy and invasive species. The application of herbicides can also be effective in controlling weedy and invasive species in native plantings, but only when used as an integrated approach to stand management, and in a manner that follows Brandon's guideline for herbicide use. An herbicide can be applied as a spot spray following a burn management or mowing to reduce potential weed invasion. Overall, it is important that management occurs before stand vigor declines greatly or competitive weedy and invasive species overrun a planting. As a result, the annual monitoring program for on-site of stand health is very important for guiding management decisions.

There are three important factors to consider for managing upland native plant areas. These include: (1) The types of plants being managed and how they differ from one another, (2) The correct combination of management tools to achieve optimal results, and (3) Strategic timing of management decisions. A good understanding of plant ecology and species identification will be important when determining the type of management strategy to use and the best time to apply it. For this reason, it is recommended that an experienced plant ecologist assess the site to determine if a management intervention is required (Table 8.3).

Timing can significantly influence management outcomes in the upland. A properly timed management strategy (e.g., burning, mowing) promotes a greater selection of warm (C4) or cool (C3) season grass species; it also reduces ground litter and weeds. In terms of timing, most native grass upland plantings benefit from mowing or a controlled burn every 5 to 7 years (Table 8.1). A controlled burn should occur in either the spring or fall to promote the growth of either cool or warm season species, and timing will be dependent on plant type, growth characteristics and temperature. A mid-summer mow will produce the best results. Mowing earlier than this can affect species composition within the stand and it may also harm wildlife that use the grass for cover to raise and to protect their young. Excessive mowing will weaken the root structure, causing the native grasses to die back and allowing weedy or invasive species to move in. It is advised that you do not mow more than once or twice per season and never below a height of 4 inches or 10 cm. Always remove all grass cuttings.

Upland locations that produce high annual biomass may require complete removal of the litter layer by burning to rejuvenate native stands on a fairly regular (e.g., 5 to 7 years) basis. Native grass stands may benefit from a burn management early in its establishment (e.g., 4 years after initial plant establishment). This first burn can strengthen the stand and lessen the initial competition by weedy species. Exposing growth points to sunlight and recycling the nutrients tied up in old plant growth through a controlled burn will stimulate vigorous new growth. Fire is also an inexpensive management technique and can be conducted safely, even in urban environments, by trained personnel. Consulting with a plant ecologist to determine when a burn is required, and using experienced burn specialists, is a must in this circumstance. Burn permits will also be required.

It is important to note that there may be an initial weed invasion after a mow or controlled burn. This results from opening up the plant canopy and exposing the soil to sunlight, warmth and precipitation. It is very important to manage this initial flush of weeds so that it does not overshadow the growth of new native grasses. Following a controlled burn, monitoring for any weed invasion and conducting integrated weed control strategies, such as applying spot treatment of herbicide, may be required. Consult an upland plant specialist to determine which control techniques will work best based on the weed species that respond.

8.4. Public use and education

The naturalized stormwater design outlined in this guide helps to support the City of Brandon's commitment to a healthier community through the addition of natural areas, more open space, and trail systems around ponds leading to improved health and social benefits, community connectivity and inclusivity (City of Brandon 2015a). NSPs help to enhance appreciation and understanding of the natural environment through providing educational opportunities. These locations also lend themselves to interpretive opportunities and signage.

8.4.1. Education and interpretation

Public education on the benefits and ecology of NSPs will not only help to educate local residents on what to expect, but it creates an opportunity to promote conservation and environmental initiatives supported by the developer and the City of Brandon. Signage can help mitigate complaints and questions on topics such as the naturalization of the pond, plant management, wildlife use, water quality, mosquito use, odor, etc. Interpretive signage placed around naturalized ponds as part of the pathway network is one approach for education (Figure 4.1), as signage can draw attention to the unique features and ecology of these ponds and associated benefits. Potential topics for interpretation include: (1) Naturalized pond design features and construction, (2) Plant identification, (3) Water storage and water quality benefits, (4) Wildlife identification/use, (5) Watershed/riparian health, (6) Prairie pollinators, (7) Ponds in winter, (8) The water cycle, and (9) Do's/Don't around naturalized ponds. Signage should follow the City's guidelines for sign use, construction and placement (City of Brandon 2015a, 2015b). Consider trailheads, paths and gathering nodes as locations for where interpretive signs can be placed.

Many newer developments that possess NSPs in other communities have created neighborhood forums and websites to promote and inform residents on the naturalized elements and habitats within their communities. These communication tools will not only improve your ability to communicate the ecosystem benefits of these habitats, it can also be a useful tool when communicating management activities such as controlled burns.

8.4.2. Public use

The clearing of vegetation to improve water access or the construction of boat docks is not recommended. Nor is the use of ponds for public skating, swimming (e.g., public or pets), or boating. While these ponds are designed to improve water quality, water consumption either by the public or pets, is not recommended. While there may be some desire to use the ponds as public skating areas in winter, NSPs do not freeze uniformly because of the vegetation planted below NWL. For public safety, it is important to post a minimum of 2 signs around each pond warning the public of the risks of these potential uses. Figure 8.2 shows the possible design of these signs.

8.4.3. Algae

A variety of algal communities, including epiphyton, metaphyton and epipelon occur naturally in NSPs (Figure 8.3a). Together with the emergent vegetation present in these ponds, these algal communities help to regulate and improve the water quality performance of the system, in addition to providing important habitat and support to birds and other wildlife species through the bacterial and aquatic insect communities associated with algae (Figure 8.3b). Throughout the summer season, algal presence and abundance will vary based on the time of year (e.g., spring versus summer), the temperature of the water column, and the nutrients present within the system.

Available nutrients produced over the winter are quickly taken up in the spring by wetland plants for new summer growth. Whatever nutrients remain are then utilized by algae, bacteria and fungi. Naturally occurring algae communities will exist in harmony with the plants in NSPs. Only when available nutrients exist in abundance within the water column will toxic algal blooms of blue green algae possibly develop in the place of healthier communities of algae. This imbalance in nutrients is often experienced in conventional stormwater ponds where no emergent vegetation exists below NWL. The presence of blue-green algal blooms in any waterbody is sometimes accompanied with a distinct change in odor in the pond. This may indicate that maintenance is required. Algal communities should be visually inspected at the same time emergent vegetation in the pond and uplands are inspected (i.e., mid-June through mid-August). Table 8.2 identifies management options if algal communities appear to become unbalanced in the pond.

Maximum algae growth within all communities will occur in July when maximum water temperatures are reached. At this same time emergent vegetation (e.g., cattail, bulrush and sedges) will also require maximum nutrient uptake for aboveground growth of leaves and shoots. Together the two groups create a dynamic aquatic system that supports diverse aquatic and terrestrial wildlife species.

8.4.4. Mosquitoes

Mosquitos may be a concern raised by residents. It is therefore important to prepare a communique should this need arise. Shallow, stagnant waters such as in temporary pools, ditches, bird baths and tires are prime breeding habitats for mosquitoes. Most of these water bodies contain no natural mosquito predators. NSPs, in comparison, are designed to support a large underwater community of aquatic beetles, water bugs, dragonflies and damselflies, all of which easily predate on defenseless mosquito larvae and pupae. As a result, NSPs contain very few, if any mosquito larvae. These ponds also experience a slight amount of directional flow that is created by their inlets and outlet, which further discourages egg laying by female mosquitoes.

8.4.5. Odor

Like natural wetlands, NSPs may possess a natural sulfur smell (e.g., rotten egg) at certain times of the year. While this odor is often difficult to detect unless one is standing near or within the pond itself, it is important to note this sulfur smell does not indicate poor health or an overabundance of algae in the pond. Like wetlands, NSPs serve as “recycling stations”. They collect organic litter in the form of dead plant matter and reduce it to usable nutrients again. Through this process, bacteria and fungi break down the structural elements of leaves and other plant materials, creating byproducts that either enrich the soil with nutrients or escape in the form of gasses. This escaped gas is what we smell.

8.5. Project documentation and reporting

Project documentation is an essential activity on each naturalized stormwater project (Ross 2011), both pre- and post-project handoff. There are two important periods for project documentation and reporting. The first is the documentation that details and describes the project up to the time of project handoff to the City (i.e., at the end of 5 years; see Section 7.7.2). The second important documentation and reporting period occurs throughout the remaining life of the pond.

Monitoring schedules for pond infrastructure, pond operation, and vegetation maintenance have been described in Section 8 and presented in Table 8.1. The documentation and availability of site information collected annually is important for assessing and maintaining both pond performance and plant health. Documentation will help to: (1) Inform colleagues on site/pond status, (2) Identify recommendations and describe solutions for action when modifications or management is required, (3) Identify and solve problems in a timely basis, (4) Record the timing/type of management activities applied and progress, and (5) Help assess the results from management activities. Documentation and report submissions should follow City of Brandon requirements.

Table 8.1. Recommended inspection, operation, and monitoring schedules.

Activity	Inspection Record Required	Spring (Apr to May)	Summer (Jun to Aug)	Fall (Sep to Oct)
		Infrastructure		
Control Structure	Yes	• Annual visual inspection • Operated annually		
Inlets/Outlets, Grates, Emergency spillways, etc.	Yes	• Annual visual inspection • Visually inspected after major rainfall events for performance (e.g., > 1 in 25 year event)		
Overland swales, Open channels	Yes	• Annual visual inspection • Visually inspected after major rainfall events for debris and performance (e.g., > 1 in 25 year event)		
Sediments	Yes	• Annual visual site inspection • Sediment depth check of center channel every 10 years		
		Hydrology		
Water Level Management (Water level set to operate at NWL)	Yes	• Annual visual inspection • Visual inspection after major rainfall events (e.g., > 1 in 25 year event) • Action required if water level sits above NWL for 14 consecutive days, with water level returned to NWL by day 30.	• Visual inspection after major rainfall events (e.g., > 1 in 25 year event) • Action required if water level sits above NWL for 14 consecutive days, with water level returned to NWL by day 30.	• Visual inspection after major rainfall events (e.g., > 1 in 25 year event) • Action required if water level sits above NWL for 14 consecutive days, with water level returned to NWL by day 30.

Activity	Inspection Record Required	Spring (Apr to May)	Summer (Jun to Aug)	Fall (Sep to Oct)
		Vegetation		
Wetland Vegetation	Yes		• Annual visual inspection of plant communities growing below NWL • If inspection indicates an increase in exposed soils, a reduction in % cover, a decrease in plant diversity, or change in weed presence, then re-survey site using belt transect method to determine management action required (Table 8.2)	
Upland Vegetation	Yes		• Annual visual inspection of plant communities growing between NWL and HWL • If inspection indicates an increase in exposed soils, a reduction in % cover, a decrease in plant diversity, or change in weed presence, then re-survey site using belt transect method to determine management action required (Table 8.3) • Apply a controlled burn, or mow and remove litter every 5 to 7 years to restore vitality of the stand • Spot treat weeds as needed	
		Paths and Signage		
Paths and Walkways	Yes	• Annual visual inspection		
Signage	Yes	• Annual visual inspection		

Table 8.2. Potential issues that may arise within NSPs (e.g., within NWL footprint) and associated adaptive management strategies for correction (adapted from McKenna et al. 2014b). Observations may be encountered over the short (i.e., ≤ 5 years post-construction) or long-term (i.e., > 5 years post-construction).

Observation	Habitat/Pond Indicators	Adaptive Management Strategies
Unexplained drawdown of water levels for an extended period (e.g., drought conditions ≥ 30 days)	Exposed soils observed below NWL for extended periods (e.g., ≥ 30 days) Extensive salts present at/near NWL boundary Decrease in native plant cover Increase in weedy/invasive plant coverage	Assess if pond is experiencing normal precipitation conditions? Inspect control structure for performance/leaks Inspects inlets for performance/blockage Assess and reduce outflows (e.g., manipulation of control structure) Conduct as-built assessment to evaluate accuracy of wetland surface elevations to original design Convert drier areas from wetland plant species to upland plant species by re--seeding/transplanting Incorporate fine-grained substrate if possible to reduce surface to sub-surface flows Adapt water management practices to acquire water when available Manage weedy species, if present, under the advice of a weed specialist/plant ecologist Record management actions
Unexplained increase in water levels for an extended period (e.g., flooded conditions ≥ 14 days)	Water levels sit above NWL ≥ 14 days Flooding overtop of emergent plant shoots/leaves Decrease in plant cover and plant diversity Evident die-off of plants below NWL Increase in open water areas Plant litter floating on pond surface	Inspect control structure and outlets for performance/blockage Assess hydrological conditions upstream and downstream that may affect inflows or outflows to/from the pond Reduce water levels by either managing inflows/control structure, or by ballooning and pumping the system down Re-seed and re-plant below NWL as necessary to restore plant community to original design specifications Record management actions
Infilling with sediments through overland and in-pipe flows	Evidence if increased turbidity in the water column Decrease in plant cover and plant diversity Increase in weedy/invasive plants Evidence that inlets or outfalls may be blocked Evidence of excessive erosion (e.g., rills, gullies, sediment deposition) in areas above and below NWL	Locate and assess cause(s) of sedimentation Dredge and reclaim affected areas if required Restore and reclaim eroded upslope areas Stabilize upland soils with fast-growing vegetation using appropriate species Add sediment traps upland/upstream to reduce in-pipe deposition (e.g., bioswales with native vegetation, forebays) Encourage the establishment of plant cover throughout watershed, especially during the construction activities Slow flows to help sediments settle out prior to pond deposition Record management actions
Water depths sit deeper than designed under normal operating conditions	Water level sits above NWL under normal operating conditions for the pond Water sits at NWL under normal operating conditions, however, plants are flooded deeper than outlined in the original pond design Increase in open water areas Decrease in plant cover below NWL	Inspect control structure and outlets for performance/blockage Assess hydrological upstream and downstream conditions that could affect inflows or outflows into/out of the pond Conduct as-built assessment to determine existing pond elevations/contours If pond is built too low, source additional sediment and add to the sediment cap (i.e., infill back to original design depths) If possible, manage water levels at a lower elevation than originally designed and note new operating conditions Re-seed/re-plant plants below NWL to re-establish plant cover and diversity Record management actions
Water depths sit shallower than designed under normal operating conditions	Water level sits below NWL under normal operating conditions for the pond Vegetation below NWL sits in water shallower than designed Vegetation established immediately below NWL is not flooded even under normal precipitation conditions Expansion of vegetation into areas not designed to support plant growth	Inspect control structure and outlets for performance/blockage/leakage Assess hydrological upstream and downstream conditions that could affect inflows or outflows from the pond Conduct as-built assessment to determine existing pond elevations/contours If pond is built too high, reduce water levels during the pond in fall or winter periods, and excavate to original design elevations If possible, manage water levels at a higher elevation than originally designed and note new operating conditions Re-seed/re-plant vegetation below NWL in newly excavated or impacted areas Record management actions
Elevated salinity	Evidence of salts on soil surface Change in plant composition from freshwater species to saline species Decrease in plant cover/diversity over time Presence of a permanent saline ring at upland-water interface	Increase flushing/dilution within the pond Control/increase surface input sources Increase/change cap on bottom substrates to remove/replace saline soils or seal in salts Establish saline-tolerant communities if no other options exist Record management actions

Observation	Habitat/Pond Indicators	Adaptive Management Strategies
Toxicity	Fish and wildlife die-offs Plant die-off	Collect and analyze water and soil samples from the pond for organic content, excess nutrients/chemicals (e.g., fertilizers, metals) Investigate for increased microbial community activity (e.g., botulism, blue-green algal species)
Gradual decrease in plant cover over time	Annual visual inspections indicate a gradual decrease in plant cover after 3rd annual inspection Increase in open water areas where plants once grew	Conduct plant surveys. Compare current conditions to plant data collected from the most recent survey of the site, or to the survey conducted prior to project handoff (i.e., at year 5) Conduct summer drawdown (e.g., mid-June to September) to expose pond soils to oxygen and sunlight Decrease the time (e.g., # of years) between summer drawdowns If plant decrease is the result of herbivory (e.g., muskrats), then trap and remove muskrats Re-seed and re-plant the pond as necessary to re-establish community cover Record management actions
Low plant diversity	Annual visual inspections indicate a decrease in plant diversity after 5th annual inspection Monotypic stands of plant species present	Conduct plant surveys. Compare current conditions to plant data from the most recent survey of the site, or to the survey conducted prior to project handoff (i.e., at year 5) Control invasive species to encourage native plant growth Conduct summer drawdown (e.g., mid-June to September) to expose pond soils to oxygen and sunlight Decrease time (e.g., # of years) between summer drawdowns Introduce plant species which have low rates of natural dispersal Re-seed and re-plant as necessary to re-establish community diversity Record management actions
Increase in algal cover or presence of harmful algae communities	Annual visual inspection indicates a significant increase in algal coverage compared to previous inspections Toxic blue-green algae becomes dominant algal community	Assess summer climate conditions. If summer conditions are drier and hotter than normal then increased algal growth may be a normal response No management required if dominant algal communities are epiphyton, metaphyton and/or epipelon If a concern continues to exist then collect and analyze water samples to determine dominant algal communities Determine/investigate if a change in water quality entering the pond has changed from previous years Determine/investigate if land use around the pond has changed from previous years Seek out second opinion if phytoplankton is dominant community to determine if community is harmful and whether it is a sporadic occurrence or the result of a permanent shift in pond conditions Add additional plantings below NWL to offset nutrient imbalance if possible Record management actions

Table 8.3. Potential issues that may arise in upland native grassed areas and associated adaptive management strategies for correction (adapted from McKenna et al. 2014b). Observations may be encountered over the short (i.e., ≤ 5 years post-construction) or long-term (i.e., > 5 years post-construction).

Observation	Habitat/Site Indicators	Adaptive Management Strategies
Duff/Litter (i.e., dead plant material) accumulation on soil surface	Lack of plant cover (i.e., < 40 plants per m^2) Low plant diversity (e.g., monotypic stands of plants present) Increase cover by weeds and/or invasive plant species	Review land management history If required, repeat plant surveys comparing current upland conditions to most recent survey data, or to the survey conducted prior to project handoff (i.e., at year 5) Apply a controlled burn or mow management If site is mowed, bale and remove mowed material Record management actions
Low plant diversity	Monotypic stands of plant communities present High abundance of weedy/invasive plant species	Review land management history If required, repeat plant surveys comparing current upland conditions to most recent survey data, or to the survey conducted prior to project handoff (i.e., at year 5) Apply a controlled burn or mow management If site is mowed, bale and remove mowed material Control weedy/invasive species using one or more of the following methods: (1) Mow or weed-whack before weeds/invasives set seed, (2) Remove weeds and invasive by hand pulling, and (3) Spot treat area with herbicide if allowed Re-vegetate native grass stand Record management actions
Lack of plant cover	Soil surface is exposed in > 40% of the site	Assess land management history to determine cause of poor plant response (e.g., last management action ≥ 8 years) Control weedy/invasive plants Amend soil with peat to improve nutrient and soil health if required Re-vegetate plant stand to increase plant cover and introduce biodiversity Record management actions
Elevated salinity	Evidence of salts on soil surface (e.g., white crust from elevated salinity) Change in species composition from native upland to introduced plant species that are salt tolerant Decrease in plant diversity over time Decrease in plant cover over time	Control salinity at the source (i.e., source waters) Assess soil health and amend soils with peat Establish appropriate salt tolerant plant communities if no other options are available Record management actions
Rill Erosion (i.e., runoff leading to the formation of shallow depressions and/or gullies on exposed soil surface)	Soil and site stability compromised by either wind and water erosion Physical evidence including excessive sedimentation in downslope areas, formation of rills and/or gullies Decrease in plant cover in affected areas (e.g., upland and pond)	Assess site conditions and strategize restoration strategies (e.g., erosion blanket, temporary berms, re-direction of flows) Stabilize upland areas within the watershed using permanent cover that may include annual or cover crops, native grasses/trees, etc. Re-vegetate upland and pond plant stands as needed Monitor sediment control activities closely, and frequently, after they are introduced Record management actions

Figure 8.1. Controlled burns conducted by burn specialists on an NSP.

Figure 8.2. Example of public use signs around NSPs (courtesy of City of London, Ontario and City of Winnipeg, Manitoba).

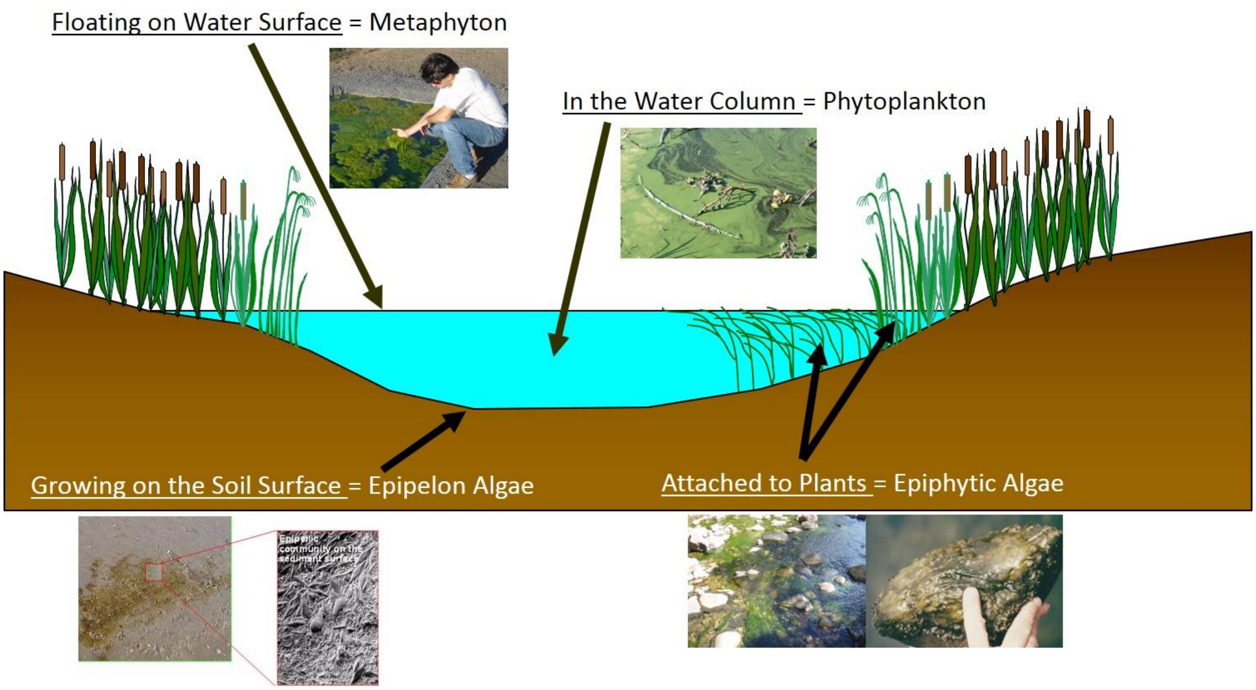

Figure 8.3a. Algal communities naturally present in NSPs.

Figure 8.3b. Example of the natural interspersion existing between algae and emergent plants within an NSP.

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Appendix A - Glossary

5 Year Event (1 in 5 year) - A storm event that statistically has a 20% chance of occurring in any given year.

25 Year Event (1 in 25 year) - A storm event that statistically has a 4% chance of occurring in any given year.

100 Year Event (1 in 100 year) - A storm event that statistically has a 1% chance of occurring in any given year.

Active Storage - Stormwater that is temporarily stored in a pond during and following a storm event. The design active storage constitutes the volume between NWL and HWL.

Ammonia (NH_3) - A colourless gas with a strong odour that is harmful to human health, ammonia is also a form of nitrogen that occurs naturally in waterways. Ammonia is produced by the bacterial decomposition of aquatic plants and animals, then oxidized into nitrates and nitrites by specialist bacteria. Large amounts of ammonia indicate that a recent pollution event has occurred.

Algae - A simple non-flowering plant of a large group that includes the seaweeds and many single-celled forms. Algae contain chlorophyll but lack true stems, roots, leaves, and vascular tissue. In wetlands, algae exist as metaphyton (floating), epiphyton (attached to substrates), epipelon (in/on soils) and phytoplankton (within the water column).

Algal Bloom - An overabundance of algae (e.g., cyanobacteria, bluegreen) in a waterbody. An algal bloom usually indicates that there is an imbalance of nutrients in the system.

As-built - The record drawing of the stormwater pond that is representative of constructed conditions. As-built drawings highlight any deviations between the project design and constructed works.

Bathymetry - Grading of the NSP below the normal water level (NWL).

Belt-Transect Method (BTM) - A surveying technique for vegetation in which a series of quadrats are created along a linear transect. The BTM provides information on plant species present, as well as species abundance, and is informative to mapping plant zonation.

Buffer Strip - A strip of permanent vegetation between the pond's normal water level (NWL) and high water level (HWL) that improves water and soil quality by slowing runoff, filtering pollutants, and stabilizing soil.

Commissioning - The process of planned activities (e.g., water management, wildlife control) to assist wetland vegetation in establishing, and inspection of the NSP components prior to handing off from construction to owner, in order to ensure reliable operation.

Conventional Stormwater Pond - A stormwater management facility that is partially inundated on a permanent basis, as dead storage, and is primarily designed and built to provide flood storage and attenuate peak flows. While a conventional stormwater pond may provide some sediment reduction, it has limited ability to improve water quality. The pond edge may be lined with riprap, and the active storage zone is usually top soiled and seeded with Kentucky bluegrass. Little to no vegetation grows below the normal water level (NWL).

Cover Crop - A temporary crop that is planted primarily to reduce soil erosion by wind and water, and manage nutrient levels until the site is ready for permanent native cover.

Cool Season Plant (C3) - Plants which are adapted to cooler temperate climates and produce a 3-carbon compound in the first step of photosynthesis. C3 plants typically are able to tolerate lower temperatures, frost, and lower light levels; however, they have higher moisture requirements and do not produce as much biomass. The optimum temperature range is around 20°C and growth begins when soil temperatures reach around 5°C.

Controlled Burn - A prescribed fire applied to native upland grasses in the prairie ecozone, used as a valuable stand management technique for native grass maintenance. The objective is to apply fire at a specific time of plant physiological growth, in order to promote plant stand vigor and diversity.

Cultural Control - A technique that uses landscape management practices to decrease weed establishment, reproduction, dispersal, or survival. This can be accomplished through habitat modifications that make the environment less suitable for weed populations.

Culvert - A short section of drainage pipe that facilitates drainage between open channel drainage courses (e.g., ditches) under roads or railway embankments, etc. A culvert by definition, cannot be connected to a closed conduit drainage system.

Cultivar - A plant variety developed in cultivation that has certain stable characteristics.

Dead Storage Zone - Permanent pool of water in a stormwater pond below the normal water level (NWL).

Deep Emergent Plant Community - Wetland plants that position themselves in the deep emergent zone and prefer to grow between 30 cm and 60 cm of water. Includes genera such as *Schoenoplectus* and *Bolboschoenus* (bulrushes) and *Typha* (cattails).

Donor Site - An area of healthy natural vegetation containing desired plant species which may be harvested and transplanted to other areas to aid in NSP enhancement. No naturally occurring sites should be degraded or destroyed in order to provide donor material to a stormwater pond.

Drill-seeder - Specialized mechanical equipment that creates long uniform divots (rows) using a drill. Seed is placed into the rows at a consistent shallow depth, then firmly packed into the soil for strong contact.

Emergency Overflow Spillway - A channel or notch in the berm of a pond that provides a safe mode of failure if the outlet is clogged or if a storm event higher than the maximum design storm event occurs.

Emergent Zone - The area of shallow standing water dominated by wetland vegetation that is rooted, with leaves and stems that grow above (emerge from) the water surface, with water depths ranging between 0 cm and 60 cm. Includes genera such as *Schoenoplectus* (bulrushes), *Typha* (cattails) and *Carex* (sedges).

Epipelon - Aquatic organisms (including bacteria and algae) that live on or in fine-grained sediments (e.g., mud).

Epiphyton - Aquatic organisms (including bacteria and algae) that live on other plants.

Erosion - The wearing away of soils by the natural forces of water, wind and land practices such as construction, tillage, etc.

Evapotranspiration - The loss of water to the atmosphere through the combined processes of evaporation and transpiration, the process by which plants release water they have absorbed into the atmosphere.

Facultative Upland Species (FACU) - Species that are adapted to growing in dry conditions/dry soils.

Facultative Wetland Species (FACW) - Species that are adapted to growing in wet conditions/wet soils.

Freeboard - 0.3 m, height above HWL to top of berm or emergency spillway.

Grate - Vertical or horizontal bars over the opening of an inlet/outlet pipe or headwall that help prevent trash, debris, animals and humans from entering pipes.

Guideline - Recommended practice of NSP design, construction, commissioning, operations, maintenance and monitoring.

Headwall - A concrete wall with an opening at which an inlet or outlet pipe terminates. It usually provides slope stabilization and land helps prevent scour.

Herbicide - A substance that is used to inhibit or destroy unwanted vegetation.

High Water Level (HWL) - The theoretical elevation of the water surface resulting from the 100 year design storm event.

Hydroperiod - The duration and frequency a waterbody or wetland is flooded or saturated.

Hydroseeding - A planting process where a slurry of water, seed and mulch is sprayed onto the planting surface for quick seeding and establishment of large areas.

Importance Value (IV) - A measure of how dominant a species is within a specified area. The IV is calculated by adding the relative frequency (RF) of a species and the relative cover (RC) of a species. A species is considered to be dominant if their IV is ≥ 20.

Inlet - A pipe or channel that carries water into a constructed wetland. There can easily be confusion here since stormwater flows out of the inlet and not into the inlet. For the purposes of this document, the term inlet/outlet is relative to the pond and not to the direction of flow in or out of the pipe or channel.

Introduced Species - An organism that is not native to a specific region and has the potential to outcompete native species.

Invasive Species - An organism that is not native to a specific region and is detrimental to the native biodiversity.

Land Drainage System (LDS) - A network of underground pipes used to convey surface runoff to a receiving body.

Length to Width Ratio (L:W) - The L:W ratio is the quotient between the length of a pond, forebay or swale and its width.

Litter - Undecomposed dead plant materials such as leaves, twigs and bark that fall and accumulate on the soil surface. Sometimes referred to as duff. This litter layer eventually decomposes and is added to the top layer of soil. In grassland ecosystems the litter layer is removed every 5 to 7 years through natural disturbances such as fire and grazing, allowing establishment of new grasses. In NSPs, the litter layer should be removed approximately every five years via a controlled burn or mow, as advised by an upland specialist.

Maintenance - The process of conducting regular adaptive management activities to preserve or repair the naturalized stormwater system. This includes maintaining the pond's infrastructure (control structures, pipes, fences, paths, lookout areas) and vegetation in both the upland and wetland areas to ensure they function as designed.

Metaphyton - Filamentous green algae which can form dense mats and float at the surface.

Minimal Ecological Management (MEM) - Taking actions that promote the long-term sustainability of a pond's hydrology that is appropriate for the pond's location and intended functions.

Molting - For birds, this is the process in which old feathers are shed to make way for new growth.

Monitoring - Periodic surveillance and data collection that includes visual field inspections and field surveys. Used as a process to inform future actions.

Mowing - To cut down plants mechanically, either by hand (e.g., hand scythe) or machine (e.g., string trimmer, lawn mower).

Native Plant Species - A plant species that is indigenous to a given region as a result of natural processes, is adapted to the local environment and has evolved relationships with other organisms in the region.

Native Turfgrass - Consists of short- and mixed-native grass species that grow anywhere between 10 cm and 45 cm in height. Native grasses require considerably fewer inputs and do not require water, fertilizer or annual mowing.

Naturalized Stormwater Pond (NSP) - Constructed stormwater pond that is designed to mimic the appearance and function of a natural wetland through the incorporation of native plant species and natural design principles.

Natural Wetland - Any area that holds water either temporarily or permanently. Often a naturally occurring transition zone between terrestrial and aquatic systems where the water table is near, at, or just above the soil surface. Wetland boundaries are delineated using three basic parameters:

1. Presence of plant species adapted to life in moist or saturated soil.
2. Presence of soils displaying characteristics that develop due to lack of oxygen.
3. Evidence of hydrologic input from surface water and/or groundwater creating conditions. favourable to water loving and water tolerant plants and to the development of wetland soils.

Normal Water Level (NWL) - The permanent or normal operating level in a retention facility (stormwater pond).

Noxious Weed - A plant that has been designated by provincial government legislation to be harmful to agricultural or horticultural crops, natural ecosystems, humans or livestock. Most, but not all, noxious weeds are introduced or invasive.

Obligate Upland Species (UPL) - Species that are adapted to growing in dry conditions/dry soils and almost never occur in wetlands.

Obligate Wetland Species (OBL) - Species that are adapted to growing in wet conditions/wet soils and almost always occur in wetlands.

Open Water - In an NSP, the open water zone is the area outside of the wetland plant zone, varying from 60 cm to maximum depth (i.e., 2 - 3 m), designed with depths and slopes to inhibit the growth/spread of wetland vegetation.

Operations - Activities that oversee the performance of NSPs, including the inspection of all pond infrastructure and pond management.

Orifices - A well-defined, sharp-edged opening in a wall through which flow occurs. Orifices are often incorporated in control structures to measure or control the rate of flow.

Outlet - Pipe that carries stormwater out of a pond. There can easily be confusion here since stormwater flows into the outlet and not out of the outlet. For the purposes of this document, the term inlet/outlet is relative to the pond and not to the direction of flow in or out of the pipe or channel.

Pathogen - A biological agent such as a virus, bacteria or other microorganism that can cause disease or illness in its host.

Pesticide - A substance that is used to destroy plants, animals or other organisms that are harmful to desired plants or animals.

Practices - Activities to support NSP design and construction, including NSP guidelines and design standards.

Principles - Provide the rationale and basis for NSP design guidelines and standards.

Propagules - Live wetland plants, including rhizomes and stems, transplanted for the purposes of establishing vegetation in a wetland plant zone.

Pure Live Seed (PLS) - The percentage of seed in a given amount that will germinate

Relative Cover (RC) - The abundance of plant species within a specified area. This is calculated by dividing the species of interest's percent cover by the sum of the percent cover of all species present.

Relative Frequency (RF) - The frequency of a plant species within a specified area. This is calculated by dividing the species of interest's frequency by the sum of the frequency of all species present.

Rhizome - A horizontal creeping underground plant stem that is different from a plant root in that it is capable of producing a new aboveground plant shoot.

Sedimentation - The process by which soil, sand, and minerals wash from land to collect in water, usually after a precipitation event. Sediment can destroy fish-nesting areas, clog animal habitats, and cloud waters so that sunlight does not reach aquatic plants.

Seed Germination - The process in which a seed develops into a plant. For example, the sprouting of a seedling.

Seed Purity - Seed purity assessment determines the proportion of pure seed by weight in a given sample compared to the label, and will determine how much chaff, weed seed, or other undesirable material is present.

Seedbank - Dormant viable seeds which are naturally stored in the soil for a number of years, until conditions are appropriate for germination, or the seed loses viability.

Sequestration - The collection, breakdown and storage of organic nutrients or pollutants such as carbon, nitrogen and phosphorus.

Shallow Marsh Plant Community - An area of the emergent zone that is dominated by wetland vegetation that prefer to grow between 10 and 30 cm of water. Includes genera such as *Carex* (sedges), *Schoenoplectus* (bulrushes), and *Typha* (cattails).

Shoreline Development Index (SDI) - Used as a measure of the irregularity of a shoreline. It is the ratio of shoreline length to the circumference of a circle of the same area as the water surface of a wetland.

Sluice Gates - A sliding gate that controls water levels and flow rates within a waterway.

Soft Berm - A temporary sediment barrier placed at the edge of a slope to protect against erosion and redirect runoff.

Sorption - The term used to refer to both absorption and adsorption. Sorption is the process by which one substance takes up or holds another.

Species Diversity - The number of different species that are represented in a community or ecosystem and the relative abundance of each species. Species diversity can be represented by a number of indices, including the Simpson or Shannon Diversity Index.

Species Richness - The number of species in a community. It does not weight rare or more common species differently.

Spillway - A structure that allows the controlled release of excess water into a downstream overflow collection area.

Standard - Required as part of NSP design.

Stoplog - Boards made of wood, steel, or other materials which are placed horizontally within flood gates or control structures to adjust the water level or rate of flow.

Stormwater Runoff - All surface water runoff from rainfall and snowmelt that “runs off” the land rather than infiltrating into the ground surface.

Subsoil - The layer of soil present below the topsoil layer.

Swale - An open channel that typically provides surface conveyance of stormwater runoff.

Thatch - A loose intermingled layer of dead and living stems, leaves and roots produced by dense grassy vegetation.

Topsoil - The uppermost layer of soil where most nutrients for plants are found.

Total Phosphorus (TP) - A water quality measurement of the total amount of phosphorus found in a water sample, including inorganic and organic forms.

Total Suspended Solids (TSS) - A water quality measurement that determines the amount of particles, consisting of silt, clay, fine particles of organic and inorganic matter, soluble organic compounds, plankton and other microscopic organisms, that are suspended in the water and will not settle out. TSS is usually accepted as the fraction that will pass through a 0.45 µm pore diameter glass fibre filter.

Trafficability - The capacity of a soil to withstand traffic by vehicles.

Turfgrass - Grass species (e.g., Kentucky bluegrass) that form a dense even vegetative layer held together by its roots if mown and maintained.

Warm Season Plant (C4) - Plants that are adapted to warmer climates and produce a 4-carbon compound in the first step of photosynthesis. C4 plants have higher temperature and light requirements; however, they produce more biomass and are more drought tolerant. The optimum temperature range is around 35°C and growth begins when soil temperatures reach around 15°C.

Weed - A species that has the potential to outcompete and overpopulate an area interrupting the natural ecological plant composition of an area. Weed species tend to grow and reproduce quickly and outcompete other vegetation. Most, but not all, noxious weeds are tame or native.

Weir - A weir consists of a wall or dam over which flow occurs. Weirs are often incorporated in control structures to measure or control the rate of flow. A weir structure may or may not incorporate the use of stoplogs.

Wet Meadow Plant Community - Plants that position themselves in the transitional zone between wetlands and uplands where soils are saturated with water just below the surface (i.e., 0 to 10 cm). The wet meadow zone is positioned between the emergent marsh zone and the upland zone, it often contains the most diversity of all wetland zones.

Appendix B - Summary of Public Engagement

Appendix C - Belt Transect Methodology

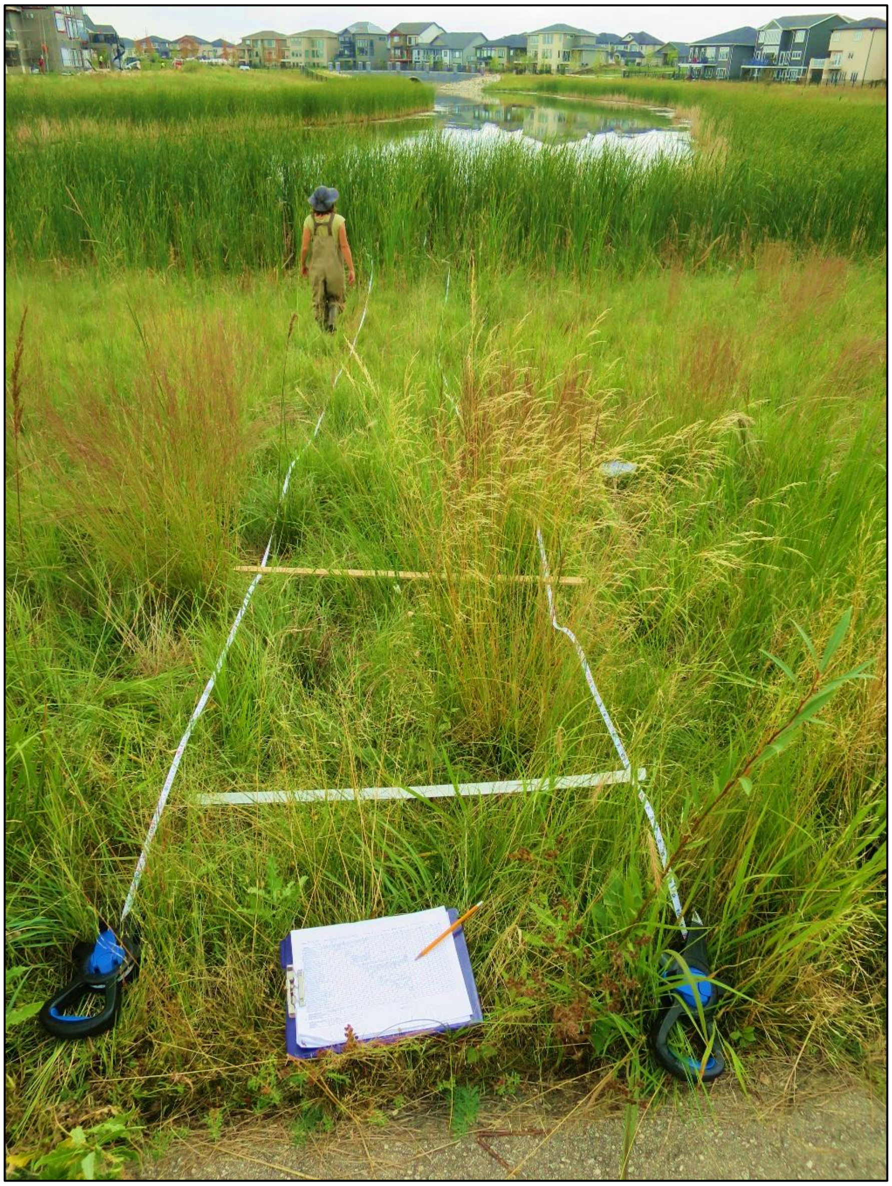
The Belt-transect Method (BTM) establishes three vegetation transects perpendicular to the water's edge of the NSP and extends from the deepest emergent vegetation zone at the open-water interface to the top of the upland buffer strip at the HWL mark of the pond. Each transect is a maximum of 30 metres in length by 1 metre in width and contains a succession of 1 m^2 survey quadrats. Within each survey quadrat (i.e., 1 m^2) all plants are identified to the species level. Unknown species are identified to the genus level when possible. The percent cover of each species is recorded and water depths are measured, as applicable. Each transect is divided into an upland zone and a wetland zone based on the plant species observed and their Wetland Indicator Status (WIS) for the Great Plains Regions. The WIS was developed by the United States Army Corps of Engineers for wetland determination and delineation (Lichvar 2013). The wetland zone includes species growing at lower elevations, which contain obligate wetland (OBL) species and a high proportion of facultative wetland (FACW) species. These species are adapted to growing in wet conditions/wet soils. The upland zone exists at higher elevations and contain obligate upland (UPL) species and a majority of facultative upland (FACU) species. These species are adapted to growing in drier/well-drained soils. If a higher proportion of OBL or UPL species are present in a section of a transect then it is delineated and classified as either a wetland or upland zone. The percent cover and frequency of each species observed is used to determine the importance value (IV). The IV is calculated for each species in the transect using the following formulas (Mueller-Dombois and Ellenberg 1974; Doumlele 1981; Perry and Hershner 1999):

Relative Frequency (RF) = (Species frequency/Σ frequencies for all species) *100

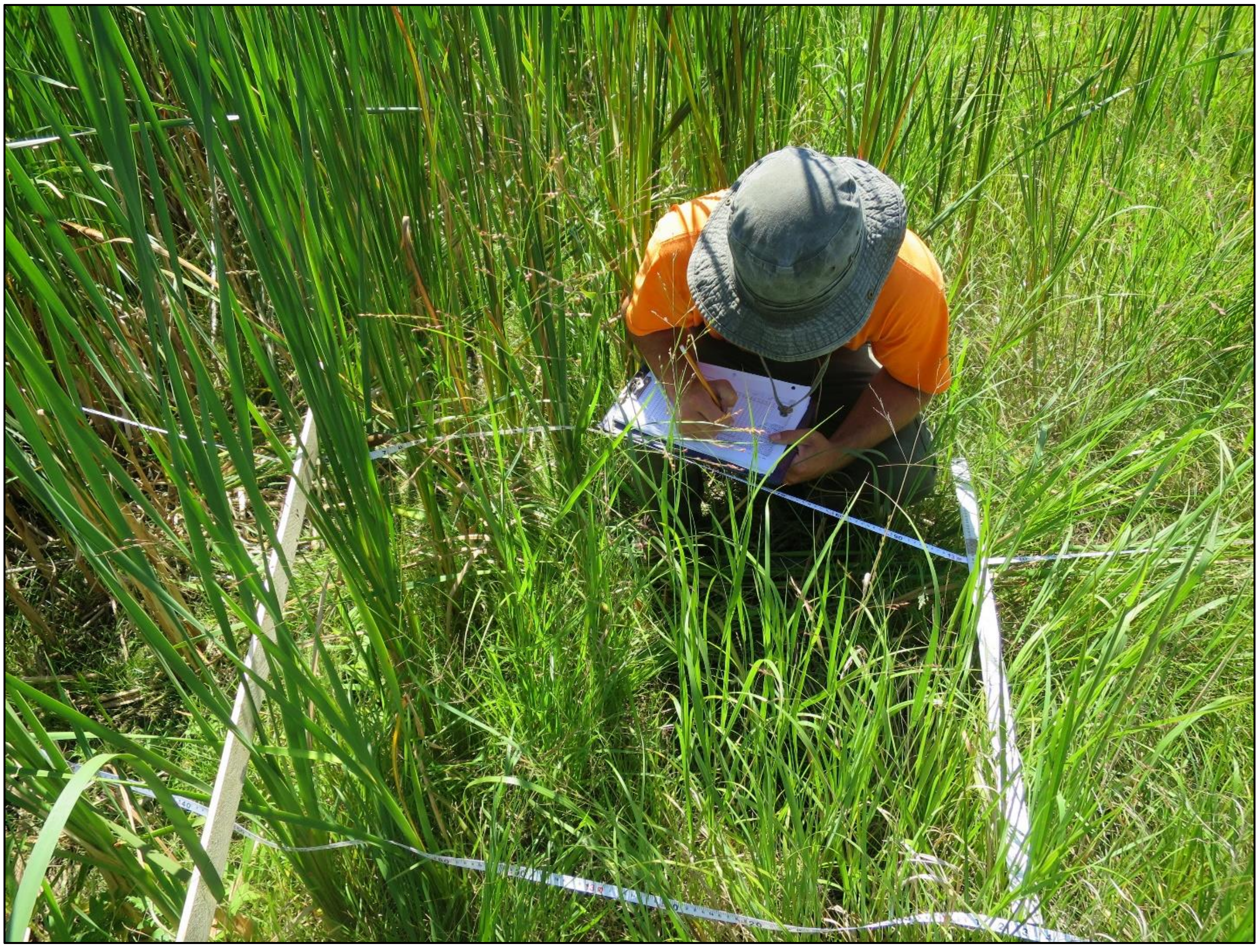
Relative Cover (RC) = (Species mean/Σ means for all species) *100

Importance Value (IV) = RC + RF

An IV ≥ 20 indicates that a plant species is dominant within either the wetland or upland zone in a transect. The IV is used to help determine the start and end of the vegetation zone along each transect and the dominant plant species within each vegetation zone (i.e., wetland or upland).



Appendix C – Figure C1. Example of a belt-transect overview of an NSP in Winnipeg.



Appendix C – Figure C2. Example of a survey quadrat ($1m^2$) in a belt-transect on an NSP in Winnipeg.