Winding Willows

An Ecological Blueprint for Wetland Restoration and Cattail Remediation

By

Angela S. Campbell

A practicum submitted
in partial fullfillment of the requirements
for the degree of
Master of Landscape Architecture
(Natural Resources and Environment)
at the University of Michigan
August 2009

Faculty advisor:
Professor Robert Grese, Chair
Professional Advisor, Catriona Mortell

Table of Contents

Abstract

A restoration plan for a series of wetland ponds and bioswales at the University of Michigan's Matthaei Botanical Gardens was developed in order to return the quality and self sustaining properties that have been compromised due to sedimentation and cattail invasion. The dredging plan for Parker Pond shall remove large areas of sedimentation now overgrown with vegetation and improve water quality by allowing it to circulate throughout the entire pond area. Several methods to remove and aggressively combat the invasion of the narrow-leafed Cattail and the hybrid Cattail (Typha angustifolia and T. x glauca) such as prescribed burning, water level modifications, and chemical and physical control such as herbicides, cutting, and crushing, shading, and a combination of several of these were researched. It was determined that mechanical cutting of the cattails in the fall followed by a spring flooding and fall drawdown for planting would achieve the greatest success at Willow Pond. A variety of native shrubs, grasses, forbs, sedges and rushes shall be planted along the banks of Parker and Willow Ponds in order to serve as erosion and cattail control, create micro habitats, and assimilate pollutants from Fleming Creek while serving as an alluring space for the public to enjoy. Many of the these plants are repeated in a bioswale plan to filter pollutants within runoff from the adjacent parking area for MBGNA.

The Project Site

The University of Michigan's Matthaei Botanical Gardens and Nichols Arboretum (MBGNA) includes over 700 acres of nature preserves and gardens, including the Matthaei Botanical gardens, located several miles east of U of M's Central Campus, and Nichols Arboretum, immediately adjacent to Central Campus. MBGNA's main mission is to promote environmental enjoyment, stewardship and sustainability through education, research, and interaction with the natural world. Matthaei Botanical Gardens (MBG) is an approximate 350 acre site which includes a variety of outdoor display gardens, a 10,000 square foot Conservatory, miles of nature trails, and greenhouse and laboratory facilities. The Gardens offer a wealth of resources to all visitors, from the scientist and student to the general visitor.
Regimen

The University of Michigan's botanical garden was first established in 1907 at what is now the Nichols Arboretum property. In 1916, the Botanical Gardens were moved to an intermediate site on Iroquios Street before being moved again to 1800 N. Dixboro Road, between Geddes Road and Plymouth Road, in 1962 following a generous donation from Frederick C. and Mildred Hague Matthaei. The donation included 200 acres along Fleming Creek and a monetary donation to purchase Matteson Farm on Dixboro Road. Over the years, additional parcels were acquired to form the approximate three hundred-fifty acre site managed today. A map showing the location of the Gardens is shown in **Figure A.**

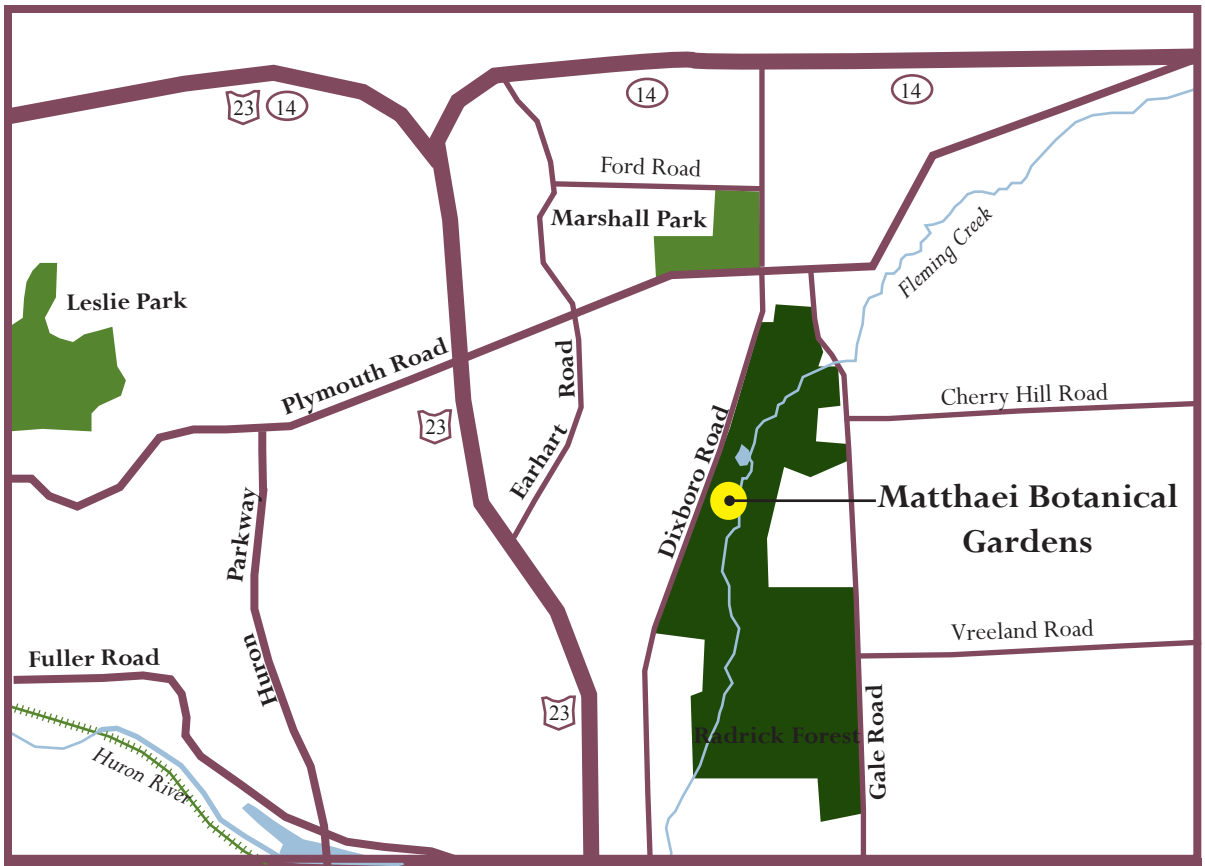


Figure A: Location Map

Today, some of the existing more specialized gardens include the Helen V. Smith Woodland Wildflower Garden, the Perennial Garden, the Alexandra Hicks Herb Knot Garden, the Gateway Garden of New World Plants, the new Gaffield Children's Garden, and four demonstration gardens by local landscape architects. On a larger scale MBG houses a conifer plantation, crabapple grove, floodplain woodlands, prairie, savanna, constructed wetlands, many forested areas, a fen, and miles of nature trails, including the recently created accessible Sue Reichert Discovery Trail and Sam Graham Trees Trail. The Greenhouse showcases plants for arid, temperate and, tropical climates with special displays of orchids, ferns, bromeliads, and carnivorous plants.

In addition to the constructed wetlands, a variety of other natural water features flow through the property. Fleming Creek, a major drainage way for a large watershed, meanders through the center of the gardens. It is among the least impaired urban stream in the Ann Arbor area. The Fleming Creek Watershed is approximately 31 square miles and discharges into the Huron River. Parker Brook and Kirk's Brook are feeder streams that cross the Botanical Gardens property before emptying into Fleming Creek. In recent years the number of homes within the watershed has increased significantly and several large medical facilities have also been constructed. The resulting destruction of woodland, wetland and meadow spaces has lead to significant increase of stormwater runoff threatening in deterioration of the biological and water quality health of Fleming Creek.

A series of wetland ponds and bioswales were constructed to promote natural, clean stormwater management as well as to serve as major aesthetic features of the Gardens. Parker Pond and Willow Pond are the largest open water wetland features in the main garden area and are fed by Parker Brook that drains areas to the west of the Botanical Gardens Property. These ponds were constructed in the early 1960's from areas that were likely wet praire or sedge meadow habitats. In addition to these ponds, one bioswale has been created and another is planned to treat runoff from adjacent parking areas. Collectively, these areas reduce stormwater flow and sediment transport into Fleming Creek by providing low flow areas for infiltration and a place for suspended solids to settle. Plantings within these water features help to improve water quality by assimilating many of the pollutants into their biomass and providing diverse wildlife habitat and food sources. Unfortunately, the quality and function of these ponds have

been compromised by invasive cattail plants, narrow-leafed Cattail and the hybrid Cattail *(Typha angustifolia and T. x glauca)* and sedimentation. Most of the original vegetation surrounding the ponds was originally compromised by Purple Loosestrife *(Lythrum salicaria)*. During the 1980's Galerucella beetles were introduced to control *L. salicaria, and soon thereafter* the invasive cattails quickly dominated the space. The cattails, combined with increased sedimentation from development upstream, limited many of the ecological functions of the wetland. Unlike Willow and Parker Ponds, the existing bioswale, which was built approximately two years ago, has not been compromised. However, in addition, it was not sized to handle the additional runoff from the recent parking lot expansion and paving. Therefore, the construction of an additional bioswale is necessary.

Planning for the future, MBGNA has requested the guidance for the short and long term restoration and maintenance of some of Willow and Parker Ponds and a planting design for an additional bioswale. With MBGNA's mission and values in mind, restoration and design for these areas shall integrate the principles of sustainability, conservation and stewardship. Considerable attention shall be placed on a cohesive integration of these new project areas.

The goal for the stormwater area is essentially to restore the ecological integrity and health of native species in order to enhance wetland micro habitats. The ponds serve as a focal point for the Garden visitor. Therefore, creating an alluring space for the public to enjoy is a key design consideration. Plants shall be selected to create four-season interest through bursts of color, texture and movement. The composition shall provide views from

surrounding trails and create areas for educational display and public gathering. The planting design will be a critical component in creating a sustainable system. Not only will species selection be based on functional elements such as varying water levels, habitat creation, nutrient absorption capabilities, and resistance to cattail invasion, but consideration of design components such as spatial arrangement and complementation to the surrounding gardens will also be a desired aesthetic component. In order to further strengthen the area's water resource stewardship, the trail network (Sue Richert Discovery Trail) that weaves through these hydrologic features will also be improved to promote people's interaction and understanding with the surrounding aquatic habitat. Environmental Consulting and Technology (ECT) has also developed a dredging plan to improve water circulation and reduce sedimentation and siltation in Willow and Parker Ponds. The project is scheduled to occur during the summer of 2009. An analysis of the site is shown in **Figure B**.

Figure B: Site Analysis

Tree

Destination

Aggressive Cattails

Largest Sediment Deposits

Trails

Bridge

Noise

Views

Culvert Crossing

Sun Angles

Wetland Function and Value

According to the Clean Water Act, the definition of a wetland is "those areas that are inundated or saturated by surface or groundwater at a frequency and duration to support and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas." (EPA website). Wetlands are one of the most important and productive ecosystems on the earth. Critical functions, or self-sustaining properties of wetlands include; groundwater recharge and discharge, floodwater alteration, sediment stabilization and toxicant retention, nutrient removal and transformation, production and aquatic and wildlife diversity. Wetlands also create value to a space by performing these functions. These values include recreation, education, aesthetics, endangered species habitat and heritage preservation. The following are examples of wetland spaces where these values are realized.

Cross Winds Marsh, New Boston, Michigan

A 1,000 acre wetland/wildlife preserve restored and created to include submergent, emergent, scrub-shrub and forested areas. The Park includes seven miles of hiking trails, canoeing, fishing, picnic areas and horseback riding and cross-country ski trails.

Fair Park Lagoon, Dallas, Texas

A five block long park designed with the objective to combine water clean- up with sculpture. Fanciful paths, bridges and overlooks undulate and intertwine allowing people to experience the wildlife refuges and microhabitats. In addition to providing wildlife food and cover, the plantings reduced water turbidity and soil erosion.

Coffee Creek Watershed Preserve, Chesterton, Indiana

A 167 acre watershed preserve that is contiguous to a large residential and commercial development. The site includes hiking and biking trails, fishing, concerts and picnic areas.

Wetlands are transitional spaces between aquatic and terrestrial ecosystems and are also transitional in the amount of water that they store and process. **Figure A** is a typical wetland cross-section, highlighting the various species transitions from aquatic to upland spaces. These influences on water flow play an important role in maintaining the balance of the hydrologic cycle. (Mitsch & Gosselink 2000).

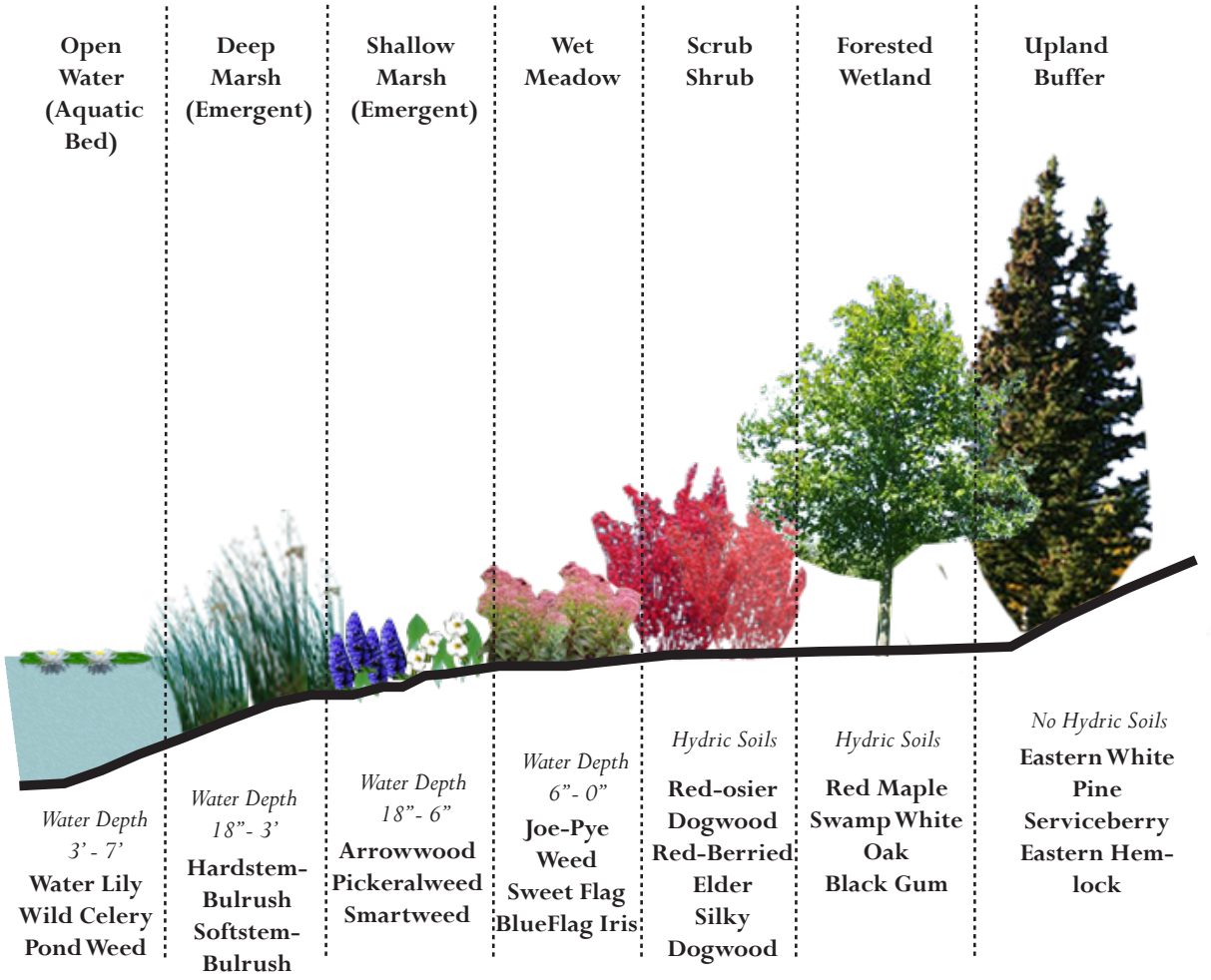


Figure C: Wetland Plant Species Cross-Section

While wetlands can intercept ground and surface water several ways they they often create low flow situations and sometimes have no outlet.
This allows runoff to be stored which can not only reduce flooding downstream, but also allows water to infiltrate, recharge and replenish aquifers. A wetland's influence on ground and surface water recharge, storage and discharge have often been cited as important attributes of a wetland (Mitsch & Gosselink 2000).

Wetlands also play a critical role in improving water quality by removing nitrogen, phosphorus and other pollutants from stormwater runoff and are often referred to as nutrient sinks because of this ability. The quantitative description of inputs (pollutants), outputs (surface and groundwater), and internal cycling (exchange of chemicals within a wetland). **Figure D** shows the components of a wetland mass balance during this cycle. Nutrients enter a wetland through surface water and sediment. The charged particles in nitrogen and phosphorus are attracted to sediment, forming a bond. Because wetlands create low flow situations, suspended particles settle within the wetland, ultimately becoming assimilated into wetland plant biomass or evaporated into the atmosphere.

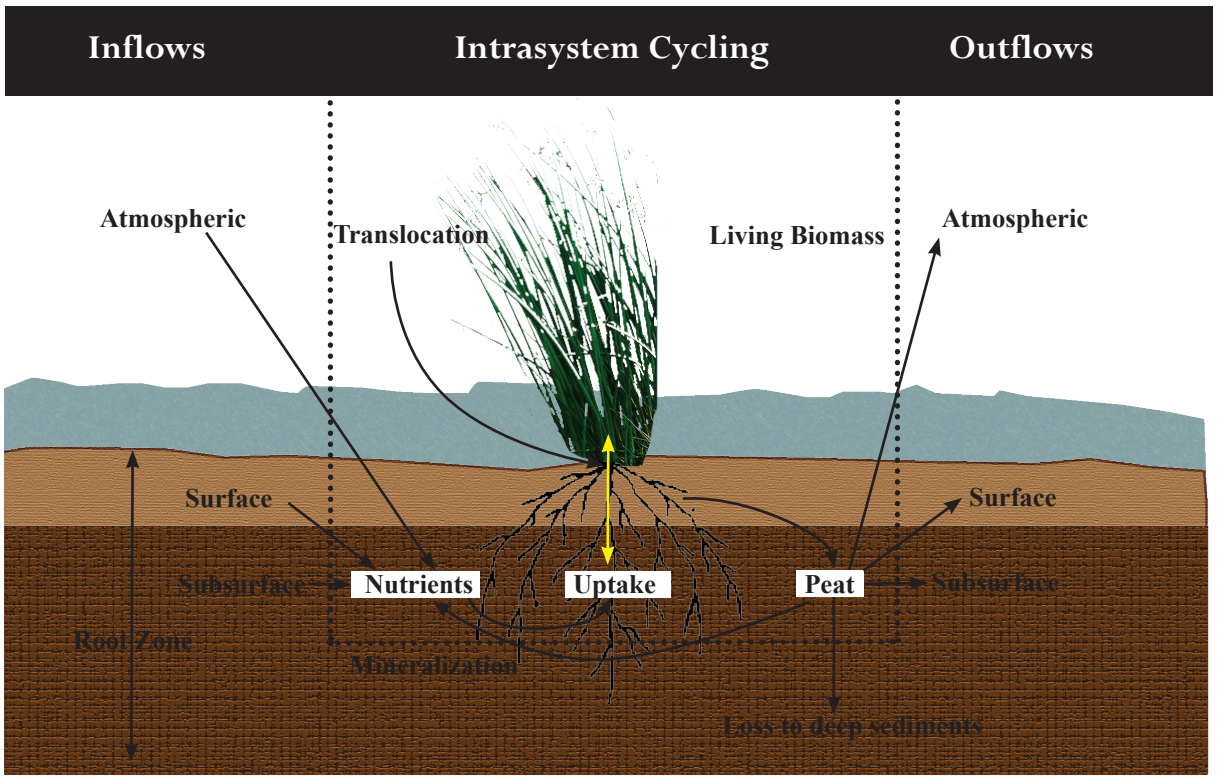


Figure D: Wetland Mass Balance Diagram

In addition to improving water quality, wetlands can also improve air quality. As a part of photosynthesis, wetland plants have the ability to sequester carbon from the atmosphere. The carbon is held in not only the vegetation but also in plant litter, peats, and sediment that has built up within. The magnitude and length of storage can vary based on the size, type of vegetation, depth of wetland soils, pH and many other factors, but in some instances, carbon has been stored for thousands of years in wetlands (Mitsch & Gosselink 2000).

Wetlands not only have technical importance, but their biogeochemistry and continuous hydrologic fluctuations result in a unique and diverse plant

community, ultimately attracting a similar level of wildlife diversity. The plant communities include numerous species of trees and shrubs, forbs and ferns, and grasses sedges and rushes. Wildlife such as small mammals, birds, amphibians and numerous species of insects find are supported by wetlands. In addition to the abundance of biota, wetlands can be aesthetically beautiful places.

Wildlife Species

Red-Winged Blackbird
Agelaius phoeniceus

Green Frog
Rana clamitans

Caddis Fly
Brachycentrus spp.

Muskrat
Ondatra zibethicus

Plant Species

Shrubs

Sandbar Willow
Salix exigua

Red-Osier Dogwood
Cornus stolinifera

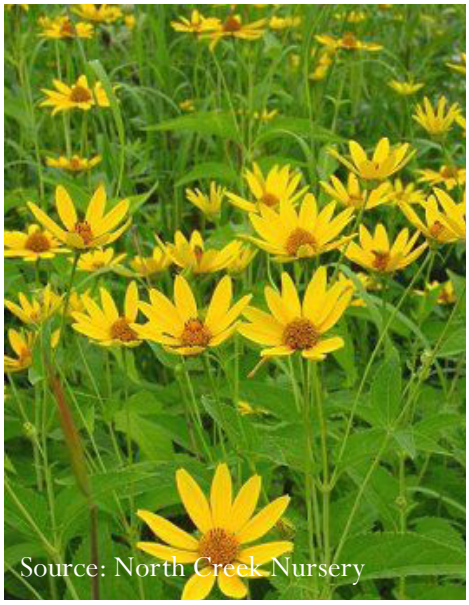
Rushes and Sedges

Hardstem Bulrush
Scirpus acutus

Bottlebrush Sedge,
Carex comosa

Forbs

Blazing Star
Liatris spicata



False Sunflower,
Heliopsis helianthoides

Grasses

Purple Love Grass,
Eragrostis spectabilis

Switch Grass,
Panicum virgatum

Parker and Willow Pond

Parker and Willow Ponds are located just north of the Display Gardens area and are hydrologically fed by Parker Brook. Just upstream a wooded flood plain is north of Parker Brook and wet meadow is due south. Water flows from Parker Brook into Parker Pond, which has a drainage area of approximately 17.34 acres and a storage volume of approximately 22,000 cf. (ECT 2006) An impoundment slows flow between Parker Pond and the larger Willow Pond to the south. In addition to this embankment, a large vegetative island and existing topography within Parker Pond further inhibits water movement. This has lead to significant sedimentation, especially near the outlet of Parker Pond and just beyond the impoundment in Willow Pond.

Parker Pond

A view towards the southerly bank

Parker Pond

A bench beneath the willows on the westerly bank

The Bridge Between Parker and Willow Pond

A bridges crossing the impoundment

The much large pond, Willow Pond is located immediately downstream. Its drainage area is approximately 18.40 acres and has a storage volume of approximately 225,000 cf. A standpipe and 36” diameter CMP, located near the southeast bank of the pond, serve as the main outlet for the wetland system. Five (5) 24” x 36” CMP culverts act an emergency overflow during larger storm events. Both primary and secondary outlets discharge into a wetland located east of the main garden entrance drive. This wetland ultimately discharges into Fleming Creek.

The site offers many views of Willow Pond, making it a focal point of the Gardens. It is visible as people drive or walk along the entrance drive. The northerly elevation of the building also offers many views. The Sue Reichert Discovery trail encompasses the pond, weaving through surrounding open and wooded spaces. Small seating nooks and art installations for education and fun and tucked away throughout the trail. A high hill between Willow and Parker Ponds serves as a lookout area with views of the entire wetland. A small peninsula located on the southwesterly bank has a grouping of conifers that create a quiet place for relaxation. While sedimentation is also present in Willow Pond invasive cattails are the biggest concern for this space from both ecological and aestetic perspectves. As a large monoculture,they provide much reduced wildlife habitat for a variety of species who might otherwise use this space. In addition they form impenetrable walls that block potential views across the pond.

Willow Pond

Cattails invade the edges of Willow Pond

Willow Pond

A series of culverts serve as the Pond's overflow

Willow Pond
The viewing area atop high hills

Sedimentation and Cattail Invasion

Sedimentation

Sedimentation in Parker Pond is a significant problem for water quality both upstream and downstream of the impoundment. According to the USGS is the single largest contributor to pollution in aquatic ecosystems. Sediment carries organic matter, animal and industrial wastes, nutrients and other chemicals. In addition to the toxicity of these wastes, nutrients, such as phosphorus (often the most common pollutant) stimulate algae growth. As the algae die, aquatic organisms feed on it which uses a significant amount of oxygen, necessary to support life.

The additional sediment often makes the water more cloudy or turbid. This ultimately limits photosynthesis necessary for aquatic vegetation to survive. With less plant biomass available for nutrient uptake, pollutant

levels continue to rise and there is less plant material for aquatic species to feed on. This has a significant effect on fish populations. Fine sediments can fill small spaces used for spawning and habitat for macroinvertebrates, further limiting the food source for many fish species. Turbidity often associated with sedimentation, can further harm fish by clogging their gills. Not only can this affect our drink water and food sources such as fish, but also has affects recreational activities such as fishing, boating, and swimming.

Sedimentation affects a wetland's flow regime. It often traps water, reducing circulation and making it stagnant. Low flows cause water temperature to rise, further inhibiting available oxygen. It also alters the total energy balance of a wetland downstream of the problem.

Willow Pond
Sedimentation near the impoundment

Movement of suspended sediment and some turbidity contributes to the health of a wetland. When the suspended sediment load is reduced, it compensates by picking up sediment to reestablish this energy balance, ultimately leading to erosion. Ultimately, sedimentation alters a stream's ecology, causing significant damage to habitat, ultimately compromising habitat diversity (USGS 1998)

Cattail Invasion

There are three types of cattails that typically grow in Michigan. They include the native broad leaf cattail *(T. latifolia)*, the invasive narrow leaf cattail *(T. angustifolia)*, and a hybrid of the two *(T. x glauca)*. The invasive cattails have surrounded the outerbanks of Willow Pond, reaching several feet into the pond. Cattail invasion has been recognized as being one of the leading threats to biodiversity and are responsible for altering numerous

Willow Pond

Cattails are so dense in this area they have significaly reduced the surface area of Willow Pond. Water was once present where cattails now stand.

elements of the ecosystem such as nutrient cycling, habitat diversity, food availability, hydrologic processes, and pest introduction. The ecological impacts have created a significant economic burden as well. Not only have economically important plant species been outcompeted by cattails, but millions of dollars are spent nationally on invasive plant and pest control as well as monitoring, prevention and restoration programs.

Cattails use several weapons to invade a space. A single cattail head can contain as many as 250,000 seeds and almost 1,000 seeds/m2 may exist in the top layer of soil (Apfelbaum 2004) These seeds can remain in the seedbank for up to 100 years. Cattails grow in prolific monotypic stands, often blocking photosynthesis for surrounding plants. Therefore, they outcompete native spaces and eliminate open water, ultimately compromising overall habitat value and altering water levels. Their mass invasioninpairs flood control areas, changing water elevations which further alter

Narrow Leaf Cattail
Typha angustifolia

native plant communities that cannot survive varying flood frequencies and inundation periods. Cattails produce a dense rhizome mat and the clustered leaves create a significant amount of litter. Dense cattail growth and litter may reduce the opportunity for other plants to establish or survive (Weson and Waring 1969). Mineralized substrates necessary for many plants to germinate are buried by this litter. Beneath the litter, substrates are cool and moist, optimal conditions for survival of a seedbank (Van der Valk & Davis 1976) but not for seed germination.

Bioswale Overview

A bioswale is essentially a low gradient open channel stormwater filtration method that uses natural means such as vegetation and soil to treat stormwater and filter out contaminants. Bioswales function by decreasing overland flows by slowing and storing stormwater. This allows suspended solids to settle out and particulates and their pollutants to become immobilized by plants and microbes. Bioswales have the ability to filter silt, inorganic compounds such as lead and other heavy metals, organic chemicals, such as pesticides and pathogens from animal wastes.

Bioswales are designed with a specific geometry sized to treat the first flush or first 6” of rainfall of a storm event. This runoff is considered to contain the majority of pollutants. The optimum design of a bioswale is long narrow channel with steeper side slopes. Meanders are often included in the design to further slow storm water runoff through the system. A specific soil mix which includes sand is essential to allow stormwater to quickly infiltrate into the ground. A perforated pipe lines the bottom of the sand layer and is typically connected to a nearby storm sewer system to

serve as an overflow during larger storm events. A typical cross-section of a bioswale is shown in **Figure C**. In addition to the geometry and soil, plants are also an important element for bioswale design. Plant selection is based on their ability to withstand both drought and inundation.

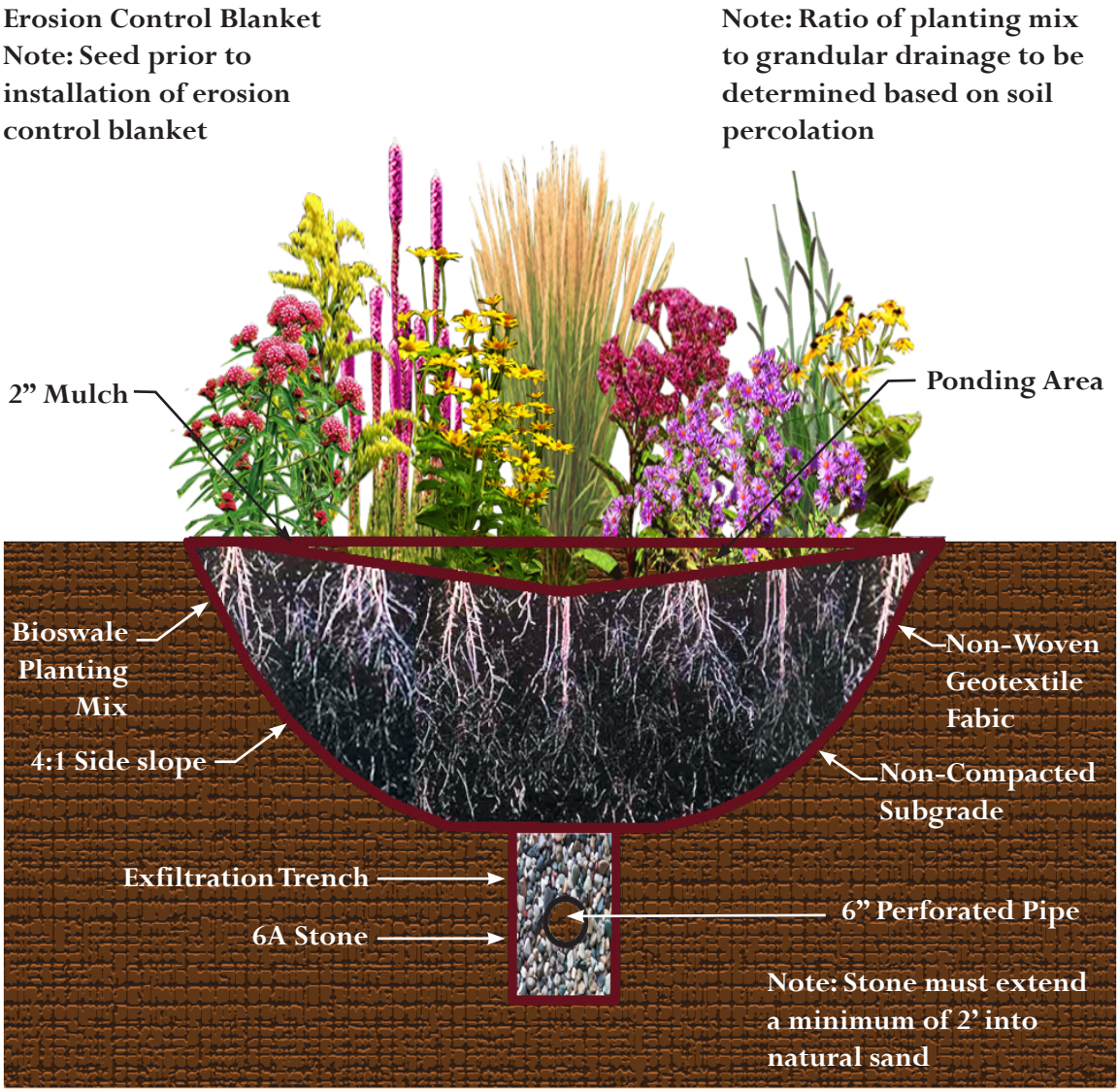


Figure E Bioswale Cross-Section

A typical application for bioswales is to control runoff from parking areas. They are able to store and treat a tremendous amount of automobile pollution that is collected on pavement before it is released into the greater watershed. Bioswales provide a natural and aesthetic alternative to the traditional storm sewer alternative that pipes runoff to nearby streams or lakes.

Restoration Overview

Restoration efforts for Parker and Willow Ponds shall include dredging, cattail removal and planting design. Dredging shall improve water circulation and reduce sedimentation. Cattails shall be removed using techniques that limit the chances of regeneration. Plants for the space shall be selected for not only aesthetic purposes, but to create habitat, improve water quality, aggressively fight cattail regeneration and stabilize slopes to prohibit erosion and sedimentation.

Parker Pond Recommendations

Environmental Consulting Technologies (ECT) has prepared a dredging plan for Parker Pond. As previously stated, dredging shall begin in the summer of 2009. It shall include the removal of mudflats that have been created by sedimentation within both Parker Pond and near the impoundment in Willow Pond. Vegetation has started to grow in these areas and their roots help to hold the soil together making them grow in size. The largest sedimentation buildup area has altered water circulation. It has essentially acted as dam, prohibiting water movement in the westerly side of the pond which has resulted in a small eroded trench.

In order to further assist circulation in the pond, it is recommended that dredging allow water to move in a circular pattern throughout the entire pond area, rather than directly towards the damn at Willow Pond. In order to achieve this, it is recommended that areas along the westerly banks be dredged deeper and in a pattern that forces water to move and circulate through this space before flowing into Willow Pond. Planting recommendations to prevent further erosion and sedimentation shall be discussed in the planting design section.

While dredging these areas shall greatly improve water circulation, it will most likely serve as a temporary solution, with additional maintenance being necessary in the future. Based on the size, and connection the hydrology system of Parker Brook, Parker Pond, and Willow Pond; Parker Pond essentially acts as a sediment forebay for the greater Willow pond. Sediment quickly flows from Parker Brook to Parker Pond. As the water circulates, it is restricted at the impoundment. This restriction limits water movement and allows many of the suspended solids to settle. The proposed dredging pattern takes this into consideration, with the deepest area within the westerly portion of the pond. Since this part of the pond is larger and is further from the impoundment, sediment buildup will have less of a negative impact. While the proposed improvements may slow the build up of sedimentation, it is essentially inevitable. It is recommended that repeat dredging of this space on a several year basis be considered. The existing contours and proposed dredging controus are shown in **Figure E and Figure F**.

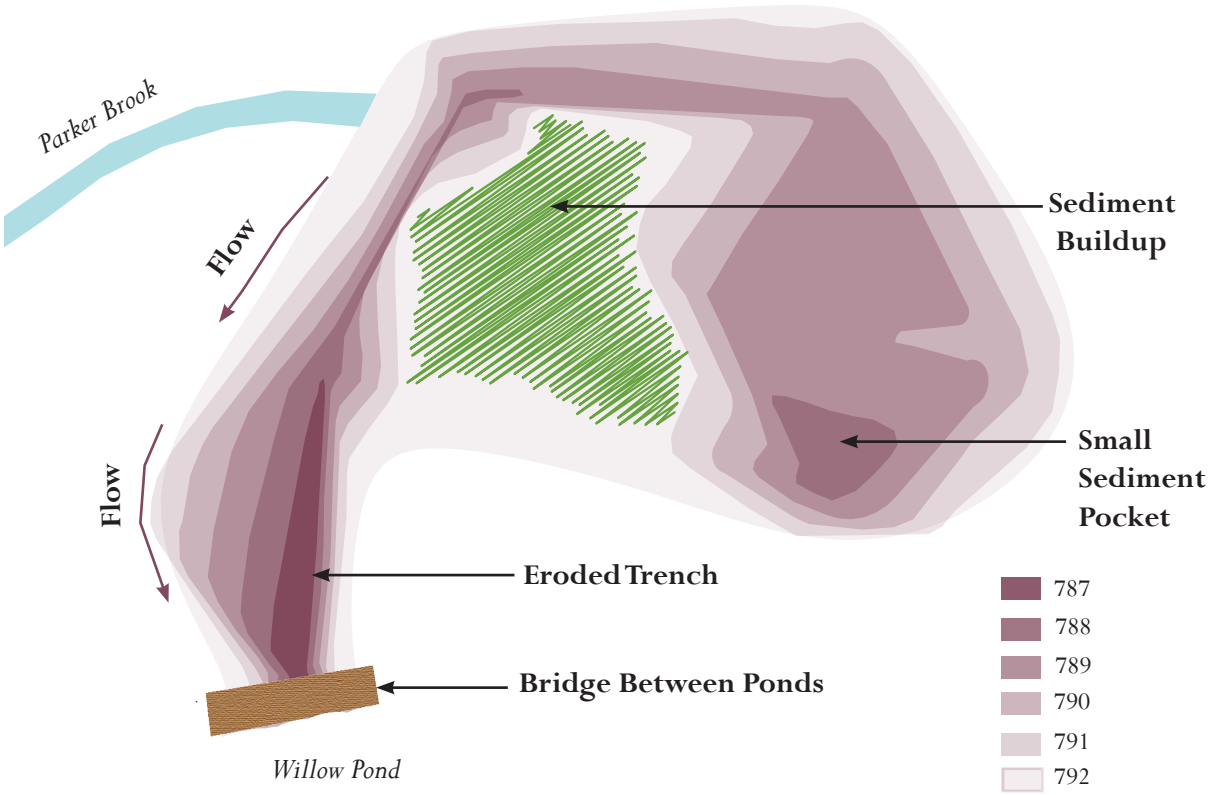


Figure E: Existing Parker Pond Contours

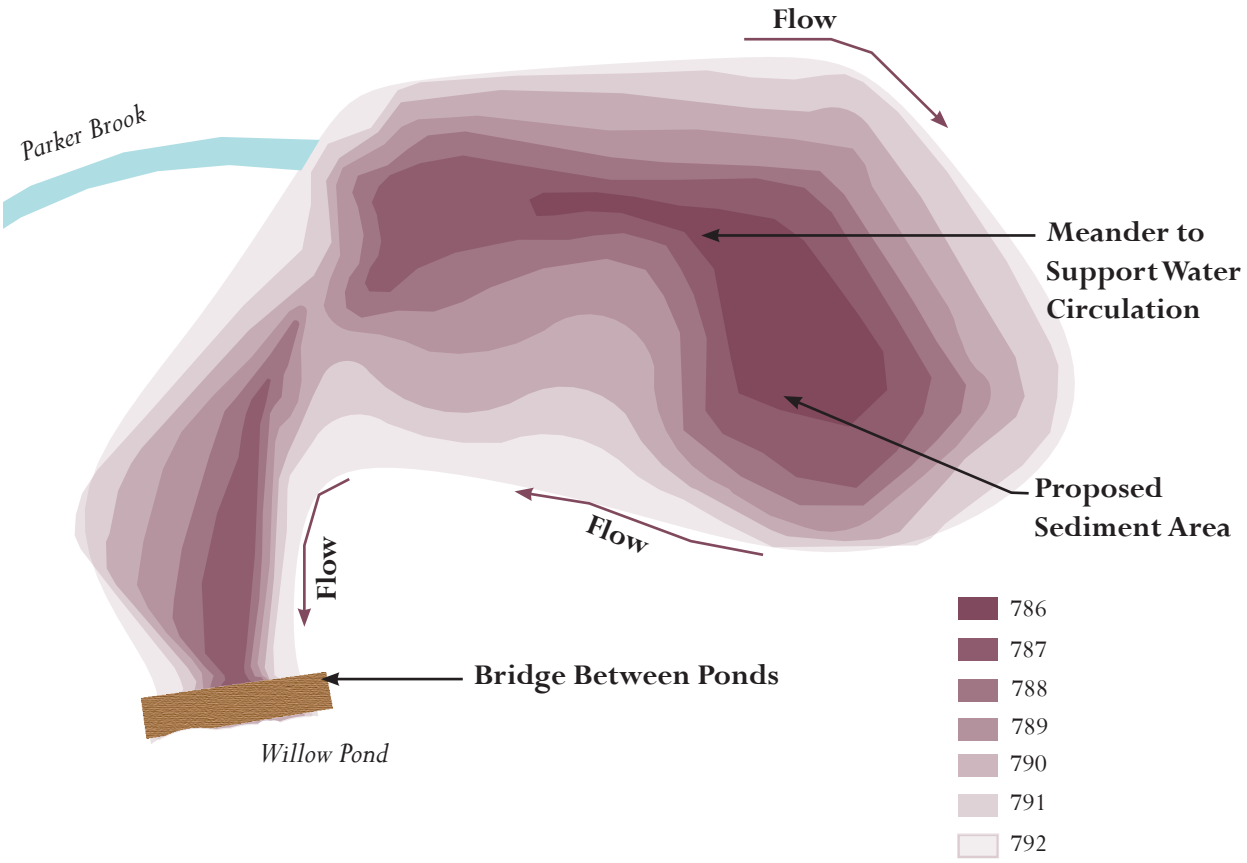


Figure F: Proposed Parker Pond Dredging

Cattail Management Alternatives

Cattails are prolific and can quickly dominate an area, therefore control and management can be quite challenging. Cattail emergence typically occurs in early April, with an inflorescence period between July and September. Senescence of the plant's biomass occurs before late October and seeds remain on the plant through winter, dispersing in the spring where they can be carried far via water and wind.

The management and control of cattails should be timed with the annual cycle of carbohydrate storage. Starches are stored in the plant's rhizomes and fuels

the plant's rapid growth in the early spring. This is where the shoots receive most of their energy for growth. The energy for initiating shoot growth is greatest when the conversion of the starches is aerobic or within the presence of oxygen. This typically occurs when the wetland is dry or when plant litter can supply rhizomes with oxygen via the aerenchyma (a tissue in the roots that allows gas exchange) (Sodja & Solberg 1993). The carboydrate cycle of a cattail is outlined in **Figure G.**

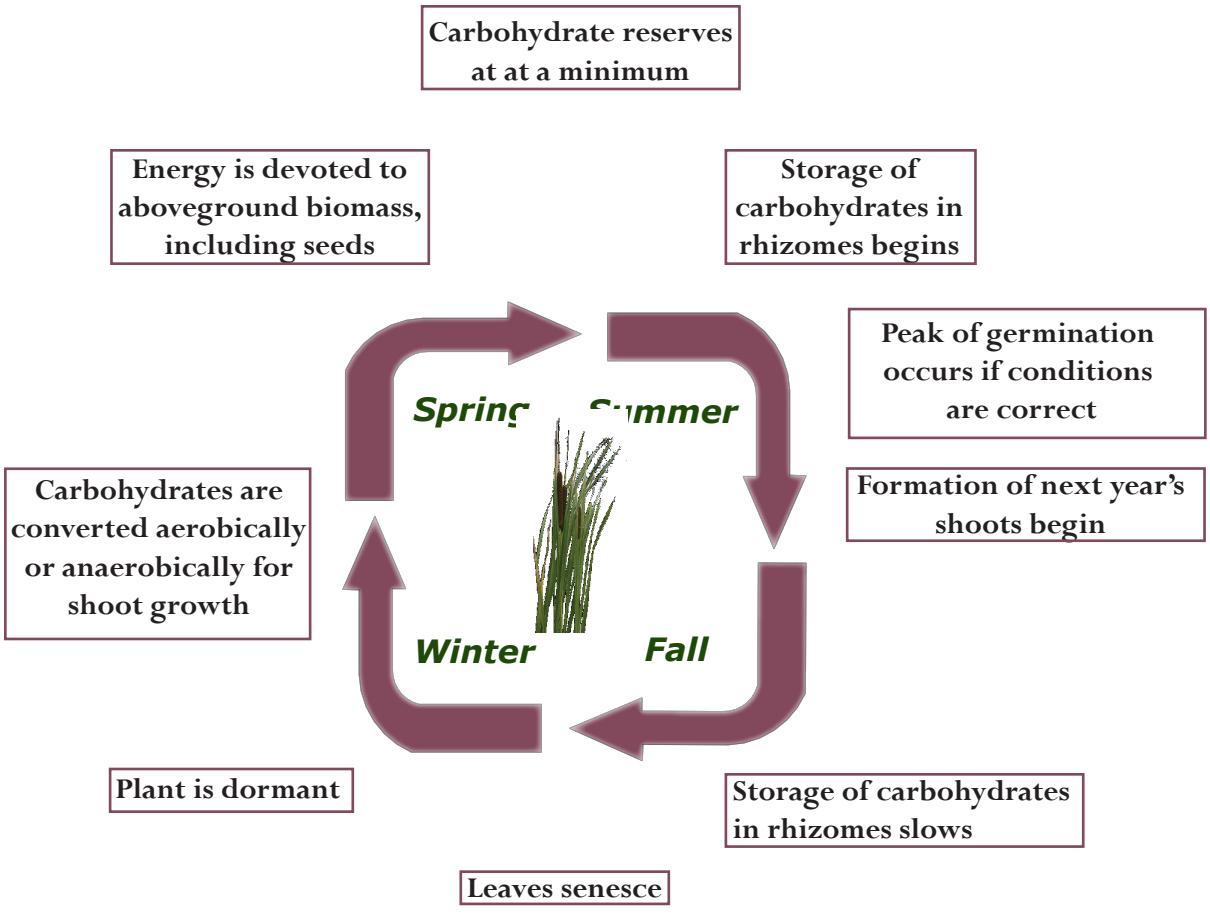


Figure G: Cattail Carbohydrate Cycle

There have been several methods with varying success rates employed to control this invasive plant. These include; prescribed burning, water level modifications, and chemical and physical control such as herbicides, cutting, and crushing, shading, and a combination of several of these.

There seems to be mixed opinions on the success of prescribed burning as a method for cattail control. Many studies do not recommend this method because unless the site is dry during burning as this method cannot kill biomass below water. This makes burning cattails difficult during the growing season. In addition, it has been shown that fires are rarely hot enough for the heat to get deep enough into the soil to penetrate shoot viability and rhizome function (Apfelbaum 2004). In addition, the residual cattail litter can provide enough fuel to carry a fire through growing plants, which can stress their starch storage. One study showed that prescribed burning can be successful if done in the fall or winter before significant growth has occurred, as long as soils are not frozen or saturated. Fire must then be followed by high spring water levels to smother any residual stalks by forcing anaerobic conditions.

Water level modification, such as consecutive years of flooding followed by a drawdown has been used to control cattail invasion and reestablish native plants. It is recommended that flooding be done in early spring to stimulate germination of aquatic annuals, while extending the time which the plant must aerobically convert starches to sugar. Water must be deep enough, typically to a depth above the shoots, and leaf litter which terminates the aerenchyma link between the rhizome and leaf. Spring flooding should be followed by shallow flooding during summer to stimulate growth of these annuals while eliminating germination of the cattails. Cattail control using

only water level modifications can be challenging, because this method is dependant on a combination of temperature, the quantity of starch stored in the plant, and the general vigor of the plant. While there is no prescribed water depth, a rule of thumb according to (Apfelbaum 2004) is to maintain 3-4 feet of water over shoots during the spring season.

Once flooding has successfully killed the cattail stands, it is important that a drawdown occur to reestablish the native plants in seed bank if it is determined that they have remained viable. It was found that after three years of flooding at Horicon Marsh followed by a seasonal draw down, cattails were eliminated and seeds of soft stem bulrush Scirpus validus), nut grass, canary grass, sedges (Carex spp.) and Blue Vervain (Verbena hastata) germinated. Once the normal water levels were returned to the marsh, submersed aquatics also began to appear. (source)

Herbicides, particularly Glyphosate, which translocates to the rhizomes, interrupt metabolic pathways and have been used successfully to kill cattails (Sojda & Solberg 1993). Herbicides are typically applied in mid to late summer when carbohydrates are stored. Therefore, they generally have little effect on seed production during the year of application. There is some concern of how herbicides will affect waterfowl and aquatic invertebrates and how far they travel through the air, possibly impacting other vegetation or wildlife. However, studies have shown that when Glyphsoate is applied at suggested rate it can be done relatively safely, especially when compared to other herbicides (source). In addition, applying the herbicide with a wick sprayer has been known to be more accurate with limited possibility of spray drift. Because the equipment operator can see exactly where the

chemical is being applied with a wick spray, selective areas can be treated. Often a dye is addedd to the herbicide to assist in knowing which plants have been treated.

Herbicide application in combination with flooding and/or mowing has been shown to be quite successful. Spraying the herbicide Dalpan at 4-16 lb/acre after an area was mowed resulted in a 74% – 97% reduction in cattails ten months (Sojda & Solberg 1993). It was found that spraying mature cattails rather than the regrowth after cutting yielded better results. When cattails were sprayed with Dalpan and then flooded, results were most successful when flooding was 4-5 inches or deeper with little to no hydrologic fluctuation. The greatest control occurred where cattail stems were cut below water depths (Sojda & Solberg 1993).

Physical control such as cutting, mowing, crushing, shearing and disking (tillage) can be effective during both the growing season or during dormancy. Using these methods at this time impedes starch storage, ultimately limiting energy for growth. These treatments are generally only effective during a three week period from beginning one week before and after the pistillate spike on the plant is lime green and the staminate spike is dark green (source). The parts of the cattail plant during the growing season are shown in **Figure G.** When the plants are dormant these methods are used to sever the aerenchyma link between the leaves and rhizomes (Sojda & Solberg 1993).

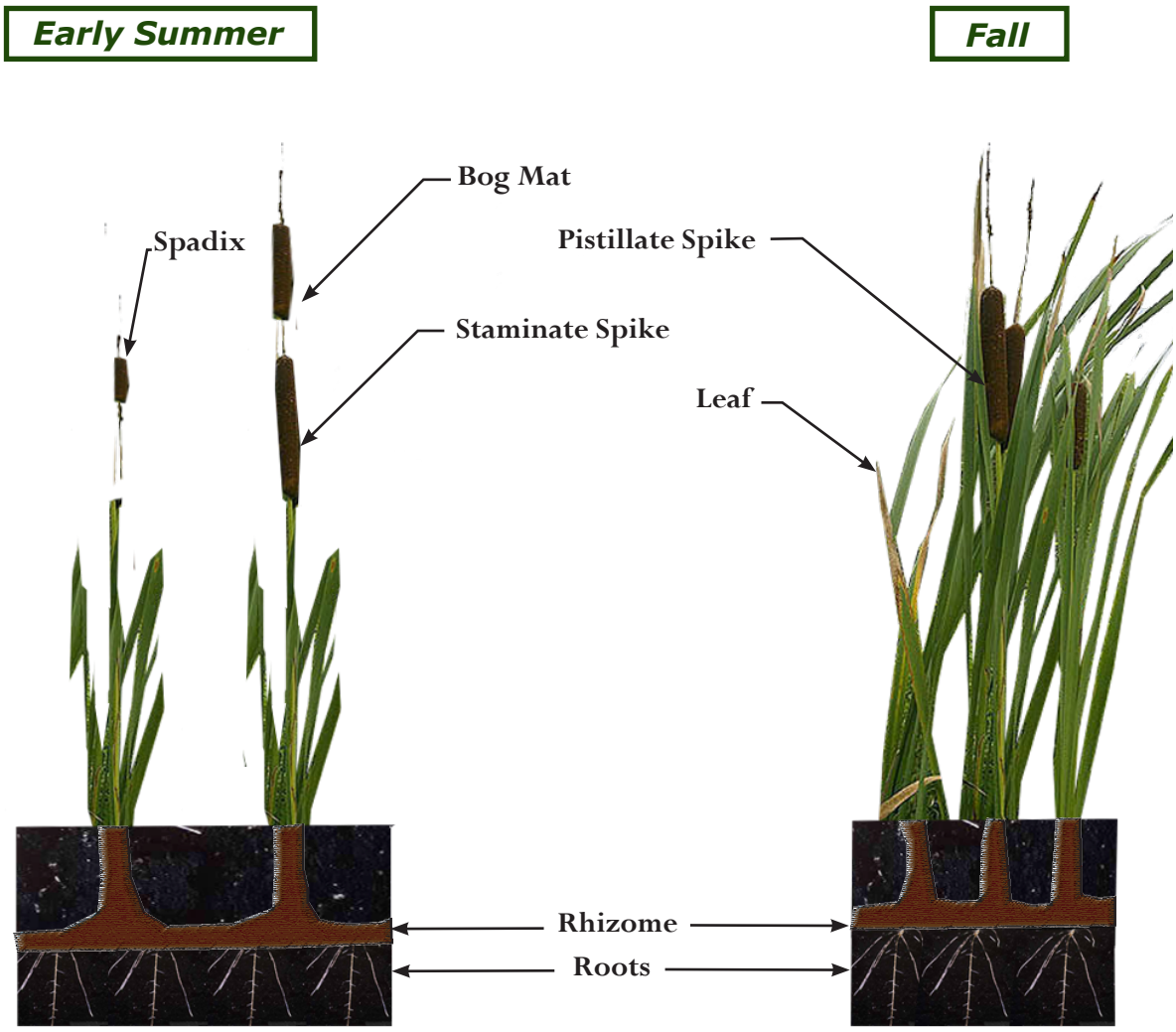


Figure H: Typical Wetland Planting Cross-Section

For the most successful management success, physical control methods are often combined with flooding to induce stress from anaerobic starch conversion. Nelson and Dietz, two scientists studied several methods of cattail management and achieved the highest success rate when mechanical or hand cutting followed by submergence of cattail stems (Apfelbaum 2004). This was achieved with two cuttings in late summer or early fall followed by stem submergence of at least 3 inches. Up to 100% of cattail control was reported two growing seasons after this treatment, no visable cattail regrowth occurred in the following year, and all rhizomes were dead. In Iowa (weller, date) cutting cattails in August and flooding with at least 3.1 inches of standing water over the cattail stems in the spring was effective, yielding approximately 80% of reduction. This study found that cutting cattails too early in the growing season actually produced a negative result; with a 25% increase in stem counts the following year.

Willow Pond Recommendations

It appears that in order to achieve the greatest success for cattail management, a combination of methods should be applied. It seems that flooding cattails in combination with either herbicides or cutting yielded the best results. However, since improving water quality is a goal of this project, the use of herbicides appears to counterintuitive and therefore not recommended. A more ecological and less expensive combination of methods to employ for Willow Pond shall include mechanical cutting, flooding and drawdown.

This process will take at least one growing season to complete. The time line will be as follows:

Schedule		
2009	September	Cattails cut to ground
2010	Mid March - Mid April	Cattail area flooded
	July - Late August	Drawdown will allow for germination of plants from native seedbank or from supplemental planting. Cattail litter shall also be removed in the early stages of this time
	September	Install plant material to restore ecological integrity, create views and promote education

Methodology

The cattail removal process shall begin by impeding the plants ability to store salt. This shall be achieved by mechanically cutting them using a mower during the fall season. It is anticipated that water levels will be low enough in many areas to allow for this. If water levels are too high, portions of the pond will need to be temporarily isolated from water circulation using sandbags. Cattails that reach further out into the pond will be removed during the dredging process.

Once complete, no further treatment of the space will be necessary until spring. This is the opportune time to initiate the flooding process. Since cattail emergence typically occurs in early April, it is important for flooding to take place prior to this time. Based on Michigan weather conditions, mid March is the ideal time, since this also coincides, with natural hydrologic

flooding cycles. Monitoring of this area will be essential. It is ideal for flooding of the space to occur for 3-4 weeks. The outlet structure in Willow Pond is not a traditional standpipe with perforated holes. It is concrete drip structure with a fix spill elevation of 790.65 at the top. Water essentially flows in the top of the structure through a metal grate where it then enters a pipe connecting the system hydrologically to the wetland on the west side of the drive. A series of five (5) culverts, set approximately x feet above the top of the drop structure, extend under the entrance drive and discharge into the wetland as well. These culverts are intended for overflow purposes and generally only carry water for two to three weeks during the spring season. Based on Nelson and Ditez's study, it will be necessary raise water levels in Willow Pond, a mininimum of 6" for a period of 3 weeks (Apfelbaum 2004). It appears that the best way to raise water levels in Willow Pond will be to temporarily cover the existing drop structure, which is approximately 6" above the typical ponding height, and 1.5" below the top of bank, 792.. Since this serves as the only daily outlet for the pond, the overflow culverts will need to be utilized as the primary outlet for the pond. A portion of the Sue Reichert Discovery Trail currently passes through this hydrologic pass, therefore, a temporary signage warning pedestrians of the possible wet and muddy conditions and providing an alternative rout along the road. Once flooding occurs, the cattails will no longer be able to aerobically convert starches, which have been compromised from cutting, to sugars. The flooding further hinders the cattail growth cycle by terminating the aerenchyma link between the rhizome and leaf.

Typically when this process is complete, a drawdown would occur to allow for the seedbank to reestablish. However, based on the long history of

invasive species, such as the purple loosestrife and cattails, it is anticipated that there is little quality species remaining within the bank. Therefore, only a short term drawdown will be necessary extending through the planting only.

In order to achieve greater success and ensure plant viability, it is recommended that a combination of plugs and seeds be used. A greater number of plugs shall be used shall be used for species proposed in spaces interior to the pond. Seeds in these areas would most likely be washed away due to fluctuating water. The outer portion of the banks shall be reserved for the greatest amount of seeding. The following is recommended by JFNew for planting wetland seed mixes in instances where water level controls are not possible (JFNEW Website).

• Sow wet-packaged seed into 4" to 6" of standing water. Mixing seed with damp clay balls aids in distribution and anchoring of seed in desired locations.

• Rake or till lightly an area 6" to 10" above waterline elevation (actual width of seeding area along shore will vary with degree of shoreline slope). If undesirable weed growth is present, mow or kill before tilling.

• Sow dry-packaged seed in areas at and above waterline. If soil moisture conditions permit, press seed firmly into the soil using a roller, cultipacker or similar equipment. Use caution so as not to cover seed more than ¼" deep.

A mix of annual rye and seed oats shall be used as temporary cover until seeds are able to establish. It is also recommended that the proposed bioswale along the parking edge not be connected hydrologically until seeds are given adequate time to establish. While this is site specific, a three week time frame should be adequate for many of the seeds to establish.

Planting Design

The concept for the planting design, Winding Willows, responds to the greater Willow Pond. It not only reflects the history of the space but represents the intertwining of humans and ecology to the Willow species. Willows not only have benefited wildlife by providing food and habitat and served as a natural biofiltration method, but also benefited humans as serving as a remedy for aches and fevers and used in manufacturing, producing wood for boxes, brooms and furnature. The Sandbar Willow (Salix exigua) is the signature species for the space and winds through various shrubs, forbs, grasses, rushes, and sedges. The Pussy Willow *(S.discolor)* and Prairie Willow *(S. humilus)* provide complementing willows to the space. **Figure I** is a collection of process sketches created which eventually lead to the design in **Figure J and Figure L**. A detailed plan indicating species composition is in **Appendix B**.

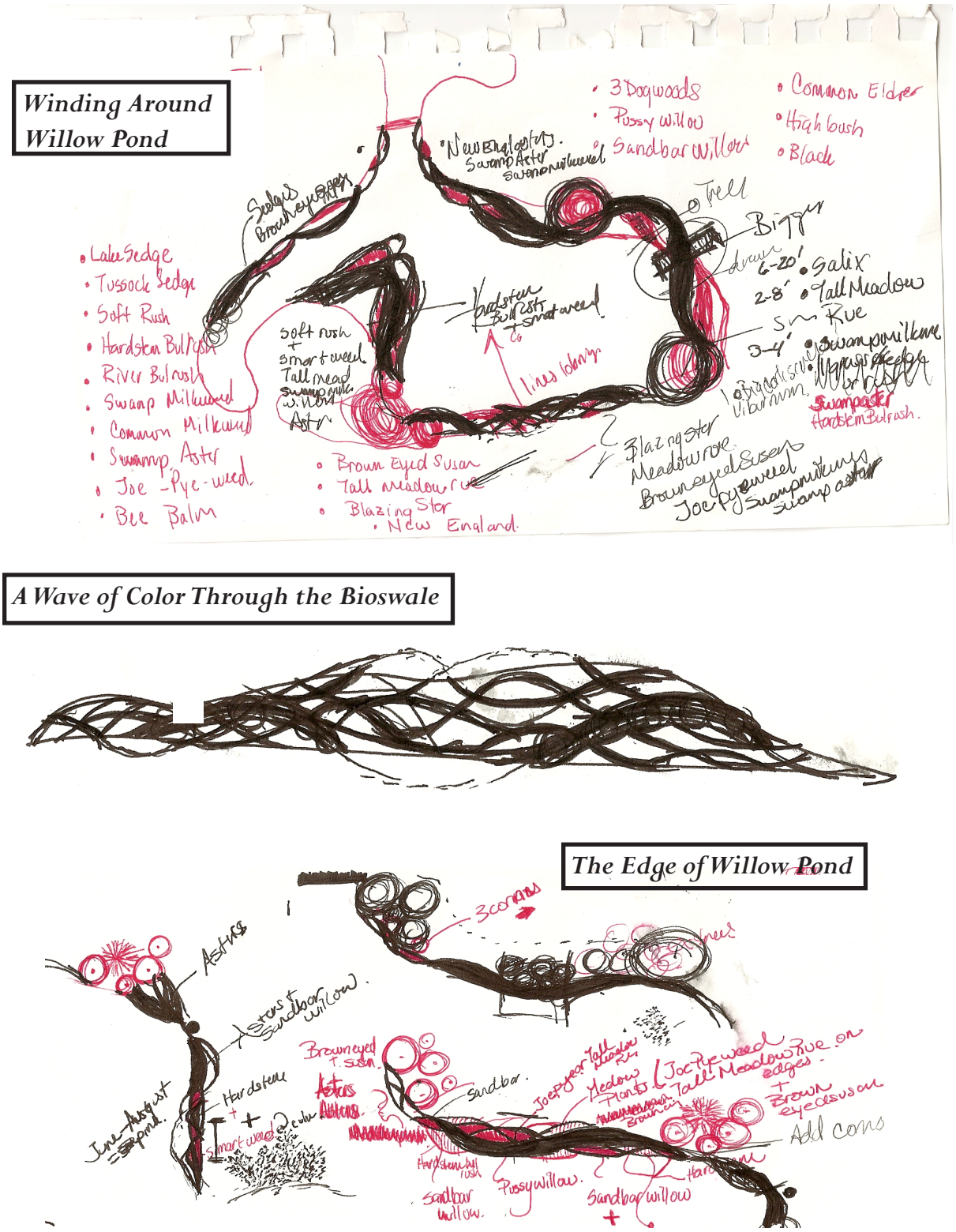


Figure I: Concept Sketches

Figure J:
Willow Pond and Parking Pond Planting Design (NTS)

- Pussy Willow
- Bladdernut, High-bush Cranberry, Red-berried Elder, Red-osier Dogwood, Silky Dogwood,
- Bottonbush, Prairie Rose, Swamp Rose
- Sandbar Willow
- Hardstem Bulrush
- Bottlebrush Sedge, Broadleaf Arrowwood, Lake Sedge, Little Bluestem, Sweet Grass
- Deer Tongue
- Common Milkweed, Joe-Pye Weed, Marsh Milkweed, Smartweed
- Brown-eyed Susan, Early Goldenrod, False Sunflower, Marsh Marigold, Showy Goldenrod, Sneezeweed, Woodland Sunflower
- Blazing Star, Blueflad Iris, New England Aster, Pickerelweed, Swamp Aster
- Mountain Mint, Red-Stemmed Aster
- Michigan Lily

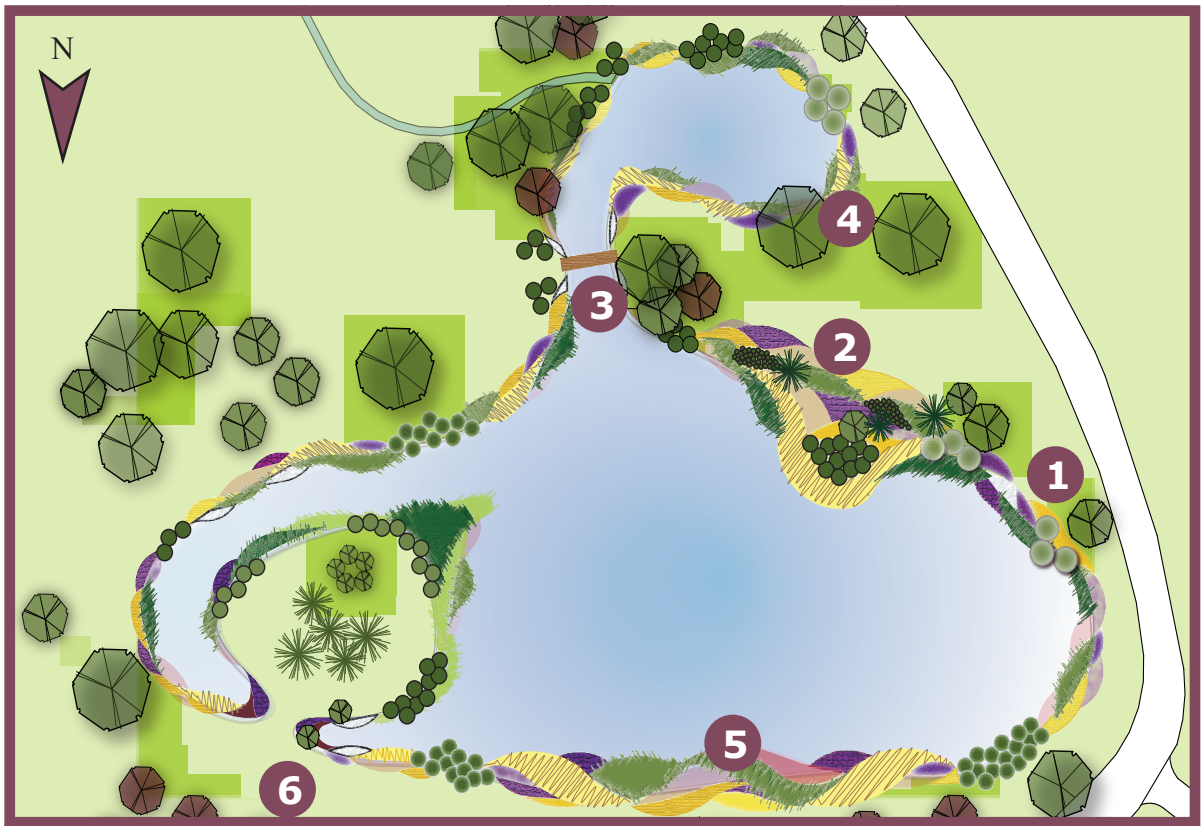


Figure K: Perspective Locations

1. **Serenity at the Stump**
2. **Painted Blooms Atop of High Hill**
3. **A Bridge Between Ponds**
4. **The Edge of Parker Pond**
5. **A View Across Willow Pond**
6. **A Winding Wave of Color**

A variety of shrubs, forbs, grasses, rushes and sedges are chosen for their ecological benefits, bank stabilization and erosion control abilities and most importantly their aggressiveness and ability to limit cattail invasion. One of the best species used to control cattail invasion is Hardstem Bulrush (*Scirpus acutus)*. Other aggressive species such as a variety of Asters *(Aster spp.)*, Willows *(Salix spp.)* and Sedges *(Carex spp.)* also help to suppress cattail dominance. Mass plantings of rushes and willows are proposed in areas near the high hill and along the peninsula are where cattail invasion is the most aggressive.

Serenity at the Stump at Willow Pond

A collection of Asters, such as New England Aster and Red-stemmed Aster, surround the tree stump, creating a small sitting nook. Views from this area are towards the Garden's main building were whispy, colorful plantings such as Sandbar Willows, Lake Sedge, Blazing Star and Joe-Pye Weed sway in the wind.

"I love how my experience of this space changes with the seasons. I look across Willow Pond to the colorful forbes in the summer. In the fall I am surrounded by the blooms of the Asters and maize hues of the Willows."

The planting design enriches the space with ecological diversity. Many of the species provide food and habitat and are nectar sources for a variety of insects. Emergent species such Pickerelweed *(Pontederia cordata)*, Smartweed *(Polygonum amphibium)*, and Broadleaf Arrowhead *(Sagittaria latifolia)* provide excellent habitat and food for various waterfowl that flock to the site. Showy flowers such as Blazing Star *(Liatris spicata)* and Beebalm *(Monarda fistulosa)*, Swamp Milkweed *(Asclepias incarnata)* and Goldenrods *(Solidago spp.)* are known for their nector sources and aromatic character. They attract a variety of bees and butterflies. The Dogwood shrubs *(Cornus stolonifera and C. amomum)* and High-bush Cranberry *(Viburnum trilobum)* are known for being among the best species for habitat and beauty. Their showy white blooms fill the plant in the spring and shiny drupes in the fall. While both boast vibrant red fall foliage, the Dogwoods *(Cornus spp.)* expose shiny red or pink twigs through the winter.

Capturing and highlighting views along the Sue Reichert Discovery Trail are prime considerations in the overall design. Showy shrub massing such as Dogwoods and Roses are proposed in areas where benches designate viewing areas. Spaces such as high hill, the MBG building, the bridge were important areas to bring the viewers eye toward. A mix of showy flowers paint the topographic climb of high hill and large swaths of plants lead the eye toward the bridge. Due to the he size of the ponds, these large swaths of plants are an important design strategy throughout the space. They create a design rhythm of repeated species that are translated from far distances.

Painted Blooms Atop High Hill

Sitting a top a hill, this lookout area is a focal point along the Susan Riechert Discovery Trail. Steep slopes planted with an array of vibrant perennials paint the hill with showy blooms througout the season, making this area the most color space along the trail. Larger shrubs are mixed throughout to help stabilize the hill and further accentuate varying heights and textures. Shorter plants and butterfly favorites such as brown eyed susans and swamp milkweed line the edge of trail while taller species are reserved for lower elevations to ensure that views are not interupted.

"I can sit for hours watching butterflies and humming-birds that frequent this colorful painting of plants"

A View Across Willow Pond

Views from the high hill offer a near mirrow image of the plantings on High Hill, with waves of repeating and coloful textures across Willow Pond. The painted collection of perennials are framed by wispy Sandbar Willows that wind through the space and massings of Buttonbush and Praire Rose. Multiple pink and white blooms fill the shrubs in the summer and are followed by the vibrant golden waves of the willows in the fall.

"The movement of the planting along this edge makes Willow Pond feel alive with activity"

A Bridge Between Ponds

Views of the bridge can be enjoyed while sitting along the edge of Willow Pond. Massings of Hardstem Bulrush, one of the best competitors to cattail invasion, weave between Willows and colorful perennials. White flowering shrubs and perennials such as Red-berried Elders and Mountain Mint frame the edge of the path on either side of the bridge.

"Dusk is my favorite time to cross the bridge between ponds. White flowering shrubs and forbs softly light my way."

The Edge of Parker Pond

Large Weeping Willows line the edge of Parker Pond, creating an intimate space. The sound of these trees in the wind eliminate the sound of the entering traffic. Views from the bench are directed to a massing of Red Osier Dogwoods which provide four season interest to the space. Large creamy white flowers bloom from spring through summer and vibrant red fall foliage senesce to expose shiny red twigs in the winter. Plants that stabize the pond banks are chosen to reduce the rate of sedimentation of this space.

"The sound of the Weepings Willows in the wind makes this my favorite space to sit and relax"

There are several other small design considerations as a part of the Winding Willows planting design. A variety of grasses, sedges and rushes are mixed throughout shrubs and forbs to provide a variety of textures and four season architectural form with their thin leaf blades and wispy seed heads that sway in the wind. Four-season interest was a consideration throughout the design. There are very few areas of forbs masses that are not interrupted with grasses or shrubs to keep the planting for throughout the year. Plantings respond to the both the Parker Brook and Willow Pond overflow. High-bush Cranberry *(Viburnum trilobum)*, is a typical river floodplain species therefore frames the edges where Fleming Creek meets Parker Pond. Also species that were best at thriving with varying water fluctuations such as Smartweed *(Polygonum amphibium)*, Bottlebrush Sedge *(Carex comosa)*, Hardstem Bulrush (Scirpus acutus) and Swamp Aster *(Aster lucidius)* are proposed at Willow Pond's overflow.

The Winding Willows concept is continued in the planting design for the bioswale. Prairie Willow *(Salix humilis)*, a shorter willow variety with drought tolerance, brings the strongest form to the space. Waves of various other plant masses wind through the space while directing stormwater runoff through the swale. The largest massings are New England Asters *(Aster nova-angliae)*. The amethyst blooms that cover this plant are an excellent color compliment to the golden hues of the Praire Willow in the fall. Other plant highlights include; Ironweed *(Vernonia missurica)*, False Sunflower *(Heliopsis helianthoides)*, Fox Sedge *(Carex vulpinoidea)*, and Purple Love Grass *(Panicum virgatum)*. In addition to aesthetics of the design, plants within a bioswale need to be able to be able to withstand numerous fluctuations of flooding and inundation while also being drought tolererant

during the dry season. Wetter species such as Bottlebrush Sedge *(Carex comosa)* and Switchgrass *(Panicum virgatum)* line the center of the swale, while drier species such as Blue Vervain (Verbena hastat) and Brown-eyed Susan *(Rudeckia subtomentosa)* are proposed along the swales slopes. The waves of plants proposed for the bioswale are shown in **Figure L. Appendix B** shows a more detail plan of species composition.

Figure L: Bioswale Planting Design

Prairie Willow

Bottlebrush Sedge,Fox Sedge

Little Bluestem

Purple Love Grass

Switch Grass

Blazing Star, Blue Vervain, Ironweed, New England Aster, Ohio Spiderwort

Joe-Pye Weed, Swamp Milkweed

Brown-eyed Susan False Sunflower, Sneezeweed

Culver's Root, Smooth Aster

A Winding Wave of Color

A wave of color moves water through this bioswale. Strings of Praire Willow provide structure and height between the forbs, grasses and sedges. This space has an abudance of color. Purple blooms of Asters, Blazing Star, and Ironweed mix with cheery yellows of the False Sunflower and Brown-Eyed Susan. Softer tones from the Joe-Pye Weed and Purple Mooly Grass weave throughout. Greens from the Bottlebush Sedge and Fox Sedge accent the colorful blooms.

"The winding wave of color feels so welcoming every time I visit the Matthaei Botanical Gardens."

Conclusion

Sedimentation and cattail invasion have altered the hydrologic cycle and significantly impaired biodiversity and food availability in Parker and Willow Ponds. In order to restore the quality and self sustaining properties of these spaces, the excessive sediment and invasive narrow leaf cattail (T. angustifolia), and a hybrid of the two (T. x glauca) must be removed. The prolific nature of the invasive cattails makes it difficult to permanently control their regeneration; therefore, simply cutting them back will not be sufficient.

In order to successfully eliminate cattails from Willow and Parker Ponds, their removal shall be timed with the plant's annual cycle of carbohydrate storage. With their growth cycle impaired, flooding or raising the water level in the ponds shall terminate the aerenchyma link between the rhizome and leaf, prohibiting their regeneration. A collection of aggressive native shrubs, grasses, rushes, sedges and forbs shall be planted to control erosion and possible cattail re-invasion, create micro habitats and assimilate pollutants from the greater watershed, while creating an alluring space for the public to enjoy. The plant palette will be repeated in the bioswale construction which shall filter pollutants from parking lot runoff for the MBGNA.

MBGNA has seized the opportunity to set an example for the community and potential developers by protecting and managing the biological integrity of the landscape through the demonstration of sustainable principles. These principles encourage people to engage in environmentally sound practices and serve as land stewards. Enhancing MBGNA Willow and Parker Ponds will produce a safe and welcoming environment, which offers its visitors

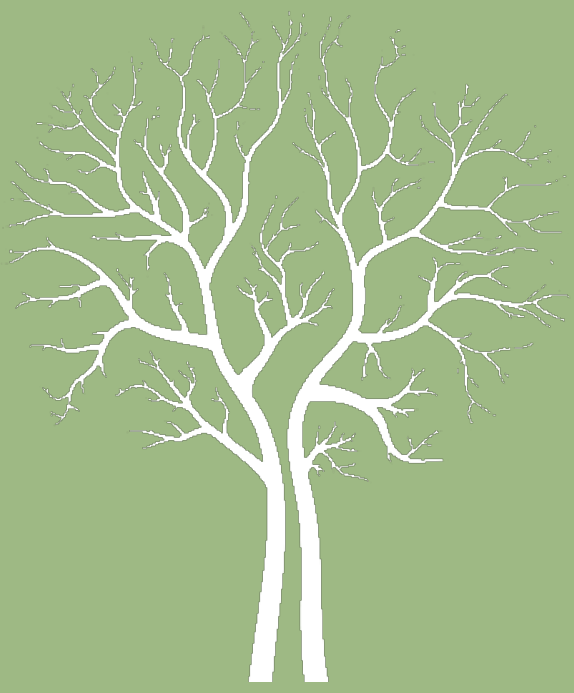
a place of beauty and natural surroundings to be enjoyed in solitude or celebration.

Appendix A
Plant Profiles

All plant information was obtained from the following:
JFNEW Resource Catalog
Plants for Stormwater Design Volumes I & II
Michigan Gardener's Guide

Trees & Shrubs

Woody plants adding height and form



These plants are the signature species of Willow Pond. They quickly colonize areas and are an excellent soil stabilizer. The buds and twigs of these plants are a wildlife favorite. The long narrow leaves with silver backs of the willow provide movement and contrast in the wind.


Source: NPS.gov


Source: Farmfresh Living


Source: Western New Mexicon University


Source: Pbase

Pussy Willow (*Salix discolor*)

This columber plant brings unique spring blooms to a space. Small fuzzy catkins appear from May to June.

Sandbar Willow (*Salix exigua*)

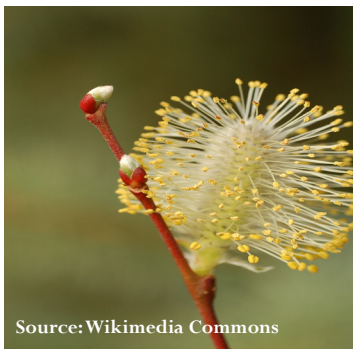
This plant can be slightly aggressive, therefore, is often used to keep out invasives. Though, this plant brings four season interest, the golden fall foliage color followed by the exposure of a maize colored twig are the most spectacular elements.


Source: Western New Mexicon University


Source: Garden Action

Prairie Willow (*Salix humilis*)

A softer looking willow, this species is more drought tolerant and much shorter than many of the other willow species. It grows 3' - 6' in height.


Source: Wikimedia Commons


Source: Wikimedia Commons

These plants are one of the better species for habitat and beauty. Their buds and fruit are an excellent food source for a variety of bird species. Their seasonal transformation provide interest to the space all year long. Large fluffy white flowers fill the plant from spring through summer. Fall brings brilliant red color foliage and creamy white of shiny blue drupes. Winter exposes shiny red twigs that provide rare color at this time.


Source: Greendreams Farm


Source:
BigHorn Mountain County Coalition

Silky Dogwood (*Cornus amomum*)

This plant is often used to provide wildlife cover in wetland restorations. Its white fruits and less shiney red twig help distingush it from the Red- Osier Dogwood


Source: Flickr.com


Source: University of Wisconsin-Green Bay


Source: Duke University

Red-osier dogwood (*Cornus stolonifera*)

This dogwood is slightly more showy. Its white flowers last longer through the summer, its leaves are deep red and its red twig is often shiny, which provides greater contrast to the snow.

These plants bring quite differenty, but equally interesting white flowers to the space. They are both excellent food sources for a variety of bird species.


Source:
East Tennessee State University


Source:
Conner Nurseries

Red-berried Elder
(Sambucus pubens)

Large elongate, pyramidal clusters of white flowers fill the plant in the spring. An early fruiting shrub, large clusters of shiny red drupes fill the plant in June. Large compound leaves with narrow leaflets create a graceful appearance through the summer.


Source:
Home-and-Garden

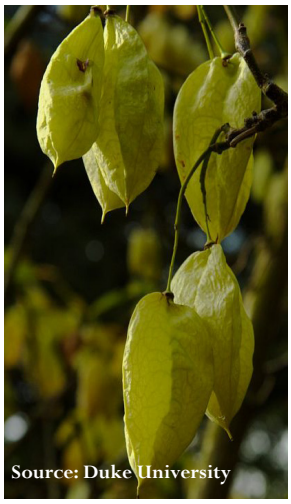
Buttonbush
(Cephalanthus occidentalis)

Due to this shrubs aggressive colonal growth, it is an excellent selection for wetland restorations. This shrub is a nector source and provides habitat for insects and hummingbirds. While this plant does not provide four season excitement, its white globose ball flowers resembling the New Year's Eve ball are a unique feature throughout the summer.


Source:
birdmom.net

Individually, these plants are quite different. They do however share a preference for river flood plains, architectural form and unique fruits


Source: Vanderbilt University


Source: Duke University


Source: Olympic Views


Source: The Monday Garden

High-bush Cranberry (*Viburnum trilobum*)

This plant makes beautiful transformations throughout the year. Large creamy white blooms create fan-like appearance through the spring. Dark green three loabed leaves are accented by clusters of shiny red drupes in early fall. Deep red fall foliage accent the drupes that remain persistant throughout the winter. This plant not only provides willdlife cover, but is also an excellent food source and a indicator of environmental

Bladder Nut (*Staphylea trifolia*)

This plant is best known for its "whacky" fruit that resemble raddles. While this plant doesn't provide much wildlife value to the space, it is quite lovely with trifolate leaves and white and grey-green striped bark.


Source: Natural Landscape Nursery


Source: Portland Nursery

Rosas have always been known for their beauty. Pink flowers fill these shrubs throughout the summer, adding fragrance to the air. The nector of these plants attact a variety of native bees and butterflies. The hips, that form in early fall are a food source for birds. Both Roses and Shrubby Cinquefoil provide excellent wildlife cover.

Swamp Rose (*Rosa palustris*)

This plant has has a graceful arching form. It spreads slowely through root suckers and provide cover for a variety of wildlife. Large pink floppy flowers fill the plant through the summer.

Shrubby Cinquefoil (*Potentilla fruticosa*)

This plant is landscape favorite due to is dense form and long blossoming period. Cheery yellow blooms fill the plant from May to october. This plant is also pest free and resistant to many diseases. While it prefers a moist habitat, Shurbby Cinquefoil can tolerate lengthy drought period.

Praire Rose (*Rosa setigera*)

This rose shrub grows taller than the swamp rose, often reaching up to 12'. Its clusters of flowers are initially bright pink, but fade to near white as the summer passes.

Grasses, Rushes & Sedges

Textural form provides movement

Rushes and sedges are one of the best food sources for wildlife. They are aggressive, keeping a number of invasives at bay and are also excellent at protexting silt movement and preventing erosion. In addition to these ecological benefits, rushes and sedges provide interesting architectural form, texture and movement to space.


Source: KG Nature Photography

Lake Sedge
(Carix lacustris)

Well adapted to restorations, this plant forms persistant clonal thickets. Pistillate spikelets, sessile to the blade bloom from spring to mid-summer.


Source: Flickr.com


Source: Flickr.com

Hardstem Bulrush
(Scirpus acutus)

This plant is one of the best competitors to the cattail invasion of affecting Willow Pond. The striking green leaf blades produce brown spikelets from spring to fall.


Source: NPS.gov

Fox Sedge
(Carex vulpinoidea)

Resembling a fox tail, this sedge is a cool-season plant blooming from late Spring to mid Summer.


Source: Ron D. Porely


Source: Prairie Nursery

Bottlebrush Sedge
(Carix comosa)

The dense form of this plant make it an excellent soil stabilizer. Its dangling bottle brush spikes bloom from Spring to mid Summer and slender green spikes bring color to a space through the winter season.

Grasses provide four season form and ever changing color to any space. Their long roots make them excellent soil staibilzers and the seed heads and dense form provide food and cover for a variety of wildlife.


Source: EPA


Source: Illinois Wildflowers

Deer Tongue (*Panicum clandestinum*)

This low growing grass provides has long leaves that pinweel around the base of the plant. Often grown in masses, these low growing grasses bear soft white flowers in late Summer through early Fall.

Purple Love Grass (*Panicum virgatum*)

This grass's light and fluffy texture makes it a unique addition to any space. Blooming in midSummer, the foliage of this grass turns a striking reddish bronze color in the fall. A lower growing grass, it reaches 18" - 24" in height


Source: Sparkle Springs

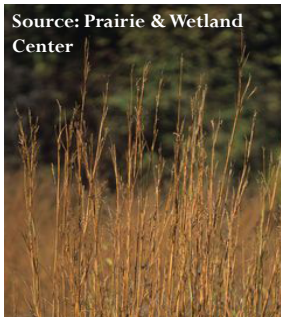

Source: Burpee


Source:
Spirit Connection Store

Sweet Grass (*Hierocloe odorata*)

This low growing grass provides a soft accent along walkways. It wisphy white blooms appear in late spring through early summer.

Swithgrass (*Panicum virgatum*)
This erect native grass climbs to over 6' in height. Its beige pyramidal inflorescense freely branches during mid-Summer and coarse form makes it an excellent filler plant.



Big Bluestem (*Andropogon gerardii*)
This is one of the more dominant of the tall prairie grasses, reaching up to 9' in height. Bronze colored flowers fill the tips of the grass in July. The stout stems turn a steel gray-blue color to the plant in the fall.

Little Bluestem
(*Schizachyrium scoparium*)
This clump forming native ornamental grass is reaches only 2' - 3' in height. Long reddish-brown racemes with spikelets bloom from July - September. The amberfoliage of this grass remains through the winter

Forbs

Seasonal bursts of color bring excitement

These yellow flowers are tucked into larger swaths of plantings to provide small bursts of color along the pond edge from summer to fall. In addition to their wildlife benefits, they are able to withstand short fluctuations of flooding during the spring season.


Source: Garden Stew

Brown-eyed Susan

(Rudbeckia subtomoentosa)

Used in many restorations, this plant is an excellent food source to butterflies and birds. Although slightly less showy than the sunflowers, its yellow blooms appear from mid to late summer.


Source: Tony Northrup

False Sunflower

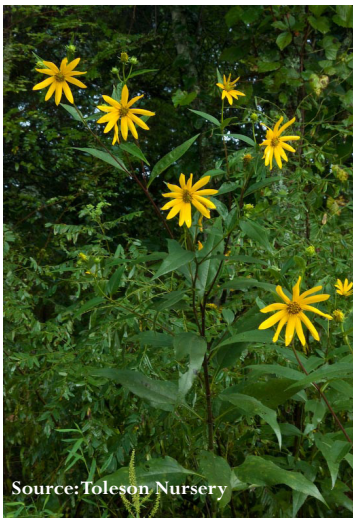
(Heliopsis helianthoides)

This showy plant produces cheery yellow blooms from June to October. It is a butterfly and songbird favorite and provides an attractive perennial border to the space.


Source: Northcreek Nursery


Source: American Natives


Source: Karen & Rachel's Wildflowers


Source: Toleson Nursery

Woodland Sunflower

(Helianthus stromosus)

This showy plant produces cheery yellow blooms from June to October. It is a butterfly and songbird favorite and creates an attractive perennial border to the space.

These plants are known for their showy yellow flowers and their ability to colonize spaces quickly. The flowers are especially attractive to butterflies. They are planted to add small bursts of bright color to the pond edges. While Showy Goldenrod and Sneezeweed can tolerate short periods of inudation, Early Goldernrod prefers drier areas.


Source: Flickr.com

Early Goldenrod (*Solidago juncea*)
This earliest blooming goldenrod has a delicate appearance. Its upward and outward arching yellow blooms resemble a firework. It like, all goldenrods attracts many insects.


Source: Circusimage.com


Source: Illinois Wildflowers

Showy Goldenrod (*Solidago speciosa*)
Large colomns of terminal clusters of erect yellow flowers are in bloom in August and September. These blooms are a food source for catipillers of many moth species. This species is known as one of the most beautiful goldenrod.

Sneezeweed (*Helenium autumnalep*)
This late blooming plant has an abundance of yellow flowers well into the fall. This dense massing of flowers provide cover for many wildlife specis. Its fiberous root system make it an excellent soil stabilizing plant.


Source: Chicago Wilderness Magazine

Asters are considered rubust, hearty plants. These varieties are particularly aggressive, which make them strong competitors to potential invasive plants. Not only do asters, bring wildlife benefits to the space, but they also provide dense patches of brilliant fall color.


Source: Home-and-Garden


Source: Home-and-Garden

Red-stemmed Aster ***(Aster puniceus)***
This plant is oftern used in wetland restorations and is an excellent source of nector. Its whispy deep lavender flowers that last through the fall season are accented by red stems.


Source: JFNEW

Swamp Aster (*Aster lucidius*)
One of the most common wetland asters, this plant produces a multitude of pale blue to lavender blooms from late summer to well into the fall season.


Source: Flickr.com

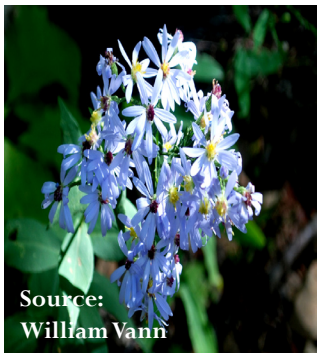
New England Aster (*Aster novae-angliae*)

This hearty plan is a butterfly favorite. Planted often in wet meadows, amethyst blooms highlighted by yellow disks fill the plant from late Summer to mid Fall.

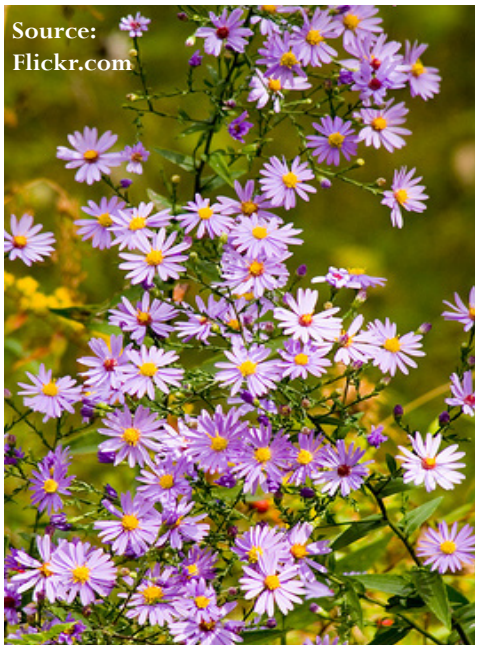

Source:
EastTennesseeWildflowers.com


Source: JFNEW


Source:
Northcreek Nursery


Source:
William Vann


Source:
Beauty Beyond Belief


Source:
Flickr.com

Smooth Aster *(Aster laevis)*

This lower growing aster has vibrant blue flowers that are showy from late Summer to mid Fall. While it attracts many insects, it is favorite of the orange sulphur butterfly.

These plants are best known for their nectar sources and aromatic character. Mixing hues of purple and lavendar in to the garden, these blooms are atrractive cut flowers. They all share some spike-like quality, whether it be through form such as blazing star or from small pollen sacs of the mountain mint and bee balm inflorescense.


Source:
Ecologic Consulting

Mountain Mint *(Pycnanthemum virginianum)*

Numerous insects are attracted to the mint aroma and clusters of white flowers that bloom from summer through fall.


Source:
Jim Frazier


Source:
US Forest Service


Source:
Flowers-org

Blazing Star *(Liatris spicata)*

This erect plant produces long narrow purple spikes from mid to late summer. Its sweet nector is a favorite of butterflies.


Source:
Maryland Sierra Club


Source:
Missouriplants.com


Source:
Ken Keefover


Source:
Village Garden Web


Source:
Publications International

Bee balm (*Monarda fistulosa*)

Used in many wetland restorations, this mint plant is an excellent source of nector. Lavender spider-like blooms emit a citrus or mint aroma from throughout the summer.

These flowers not only bring elegance and beauty to a space, but are tolerant of frequent flooding conditions, making them a rainwater garden favorite. Bees, butterflies, and a variety of birds are attracted to the nector and seeds from these plants.


Source:
Illinois Wildflowers

Ironweed (*Vernonia missurica*)

This native herb produces deep blue falt top blooms from mid to late summer. Its strong rootstock make it a good candidate for a soil stabilization plant.


Source:
Minnesota Wildflowers


Source:
State of Michigan

Blue Vervain (*Verbena hastata*)

Butterflies and bees frequent this plant for its nectar. Pencil-thin purple flowers bloom from bottom up in mid to late summer.

Culver's Root (*Veronicastrum virginicum*)

This native brings height to a space and produces long curving spikes of white flowers throughout the summer.


Source:
The Praire Flower

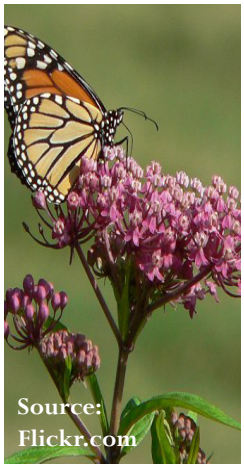

Source:
Missouri Wildflowers


Source:
The Edge of the Praire

Spiderwort (*Tradescantia ohiensis*)

One must rise early to catch a glimpse of this plant's graceful flowers, for they are only open in the morning. Though blooms don't last throughout the day, they return each morning from early summer to fall.

These large, dense clusters of pink inflorence provide a decorative element to the space throughout the summer. However, the largest contribution of these plants is found in their wildlife value. The aromatic blooms and milky substance are a favorite of birds, bees, butterflies and many other insects. The fibers from these plants are also used by birds to build nests.


Source: Flickr.com

Marsh Milkweed (*Asclepias incarnata*)

This striking, aromatic plant is the host and nector source for monarch butterflies. Large decorative bright pink flowers fill the plant throughout the summer.


Source: Carolinanature.com


Source: WhatIcaught.com


Source: American Beauties


Source: Courdite Coutry

Joe-pye-weed (*Eupatorium maculatum*)

Deep rose, fuzzy inflorence fill the space from mid to late summer. Although taller than many other species, this plant's columber growth allows views between blooms.


Source: Iowa State University

Common Milkweed (*Asclepias syriaca*)

This dull leaved plant produces fragrant balls of inflorensce during mid-summer. The milky substance produced by this plant is an insect favorite, especially attracting the long-tongue bee.

These emergent plants are able to withstand flooding for prolonged periods. They are a waterfowel favorite, providing food and habitat. Not only do these plants bring ecological benefits to a space, but are also quite decorative, providing color amongst many of the complimentary rushes and sedges


Source:
Ohio University


Source:
York County

Pickerelweed (*Pontederia cordata*)

Dense violet blue flowers fill this plant's spikes throughout the summer. Its graceful heart shaped leaves provide excellent contrast. This plant is the only nector source for the Halictoides novae-angliae.


Source:
Sandhill Fen

Marsh Marigold (*Caltha palustris*)

Although marsh marigold is a slow spreading plant, its early bursts of yellow blooms (April - May) make it an excellent addition to space. This plant is a frog favorite and is visited by insects and waterfowl species.


Source:
Brandeis University


Source:
Wildflowers of Ontario


Source: Flicker.com

Broadleaf Arrowhead (*Sagittaria latifolia*)

This plants shield-shaped leaves sway as the catch the wind and are accented with small white blooms during midsummer. While ducks enjoy feeding on this plants leaves, its tubers provide the greatest foodsource for waterfowl.


Source: NPS.gov

Smartweed (*Polygonum amphibium*)

Similar to Pickerelweed, this plant also has spikes of dense clusters of flowers that bloom throughout the summer.However, the pink blossoms and long narrow leafs create a more delicate appearance. This plants aggressive growth make it an excellent competitor to invsiave species.

These emergent and wet meadow plants prefert habitats with permanet moisture. Their unique flowers provide interest therefore, are planted in areas where the viewer can get up close and personal with the plants.


Source:
Univ Cal Berkley


Source: josef hlasek

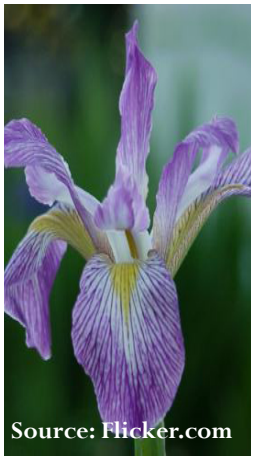

Source: OntarioWildflower.com.

Sweetflag (*Acorus calamus*)

This plant is an herb that is often used for soil stabilization. Its dense rhizomes form a mat in the soil and are also a food source for muskrats. A msall dense green/brown cluster of flowers emerge from the sword-like leafs in June.

Blueflag Iris (*Iris versicolor*)

This native perennial is recognized by many. Its decorative purple folded down sepals emerge from sword-like leafs in early summer. Hrummingbirds and butterflies feast on this plants nector.


Source: Flicker.com


Source: Wikimedia Commons


Source: US Forest Service

Michigan Lily (*Lilium michigense*)

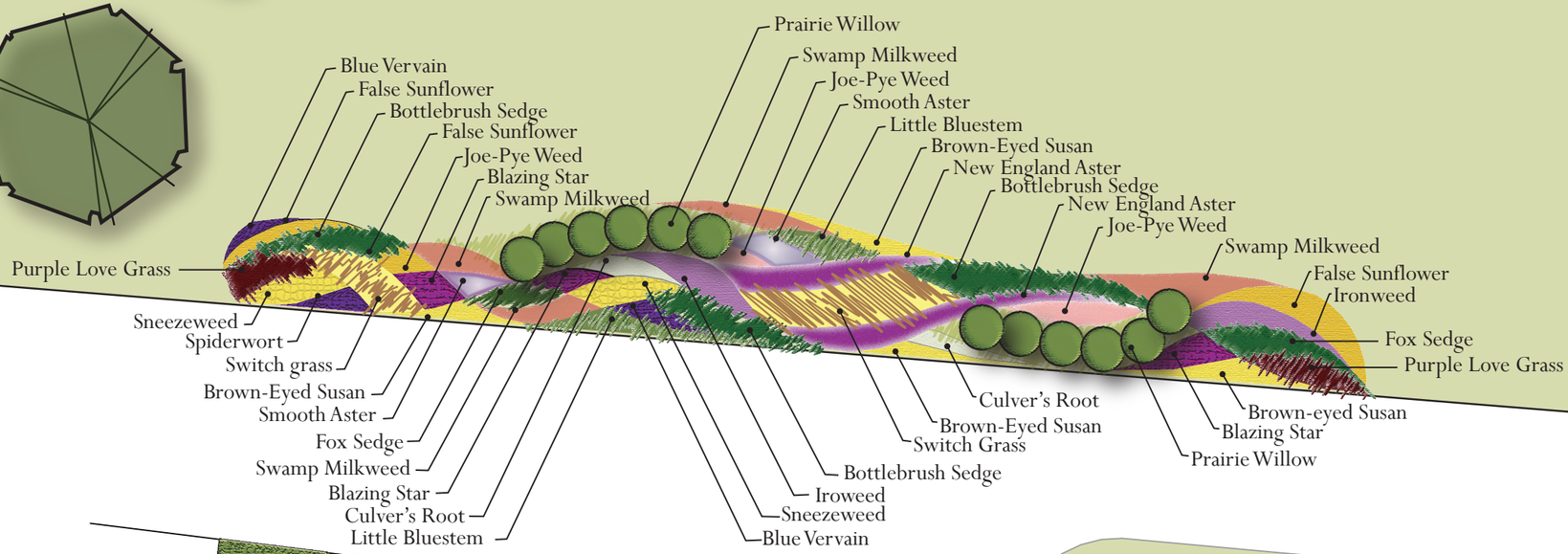
Large orange-red showy flowers emerge from a series of fan-like of leaves in mid summer. Long stamens and large anthers attract a variety of butterflies, hummingbirds and long-tongued bees. The arching form provides interest to wet planting areas.

Appendix B
Planting Design Willow Pond, Parker Pond & Bioswale

Willow & Parker Ponds

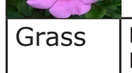
Marsh Marigold
Woodland Sunflower
Little Bluestem
High-bush Cranberry
High-bush Cranberry
Marsh Marigold
Sandbar Willow
Little Bluestem
Woodland Sunflower
Sweet Flag
Marsh Milkweed
Red-Berried Elder
False Sunflower
Hardstem Bulrush
New England Aster
Smartweed
False Sunflower
Sandbar Willow
Little Bluestem
Swamp Rose
New England Aster
Bottlebrush Sedge
Sandbar Willow
Red Stemmed Aster
Brown-eyed Susan
Joe-pye-weed
Bottlebrush Sedge
Red-Stemmed Aster
Brown-eyed Susan
Bladdernut
Blazing Star
Swamp Aster
Hardstem Bulrush
Early Goldenrod
Blazing Star
Marsh Milkweed
Early Goldenrod
Marsh Milkweed
Early Goldenrod
Sandbar Willow
Michigan Lily
Michigan Lily
Red-stemmed Aster
NE Aster
Sandbar Willow
Joe-pye-weed
False Sunflower
Deer Tongue
Deer Tongue
Smartweed
Hardstem Bulrush
Deer Tongue
Bottlebrush Sedge
Smartweed
Deer Tongue
Buttonbush
Praire Rose
Hardstem Bulrush
Pickeralweed
Lake Sedge
Marsh Milkweed
Blue Flag Iris
Joe-pye-weed
Blazing Star
False Sunflower
Blue Flag Iris
Sandbar Willow
Bottlebrush sedge
Red Osier Dogwood
Broadleaf Arrowood
New England Aster
Sweet Grass
Hardstem Bulrush
Swamp Aster
Marsh Marigold
Pussy Willow
Sandbar Willow
NE Aster
Bottlebrush Sedge
False Sunflower
Marsh Milkweed
New England Aster
Sandbar Willow
Swamp Aster
Sweet Grass
Marsh Milkweed
Little Bluestem
Swamp Aster
Sandbar Willow
Mt Mint
Mt Mint
Mt Mint
Sweet Flag(x)
Marsh Milkweed
Red-berried Elder
Beebalm
Showy Goldenrod
Blazing Star
Marsh Milkweed
Little Bluestem
Smartweed
Hardstem Bulrush
Joe-pye-weed
Showy Goldenrod
Silky Dogwood
Sandbar Willow
Hardstem Bulrush
Swamp Milkweed
Little Bluestem
Brown-eyed Susan
Blazing Star
Shrubby Potentilla
Common Milkweed
Big Bluesteam
Beebalm
Pussy Willow
New England Aster
Pickeralweed
Red-stemmed Aster
Hardstem Bulrush
New England
Showy Goldenrod
Hardstem Bulrush
Swamp Aster
Water Smartweed
Sneezeweed
Bottlebrush Sedge
Swamp Aster
Water Smartweed
Sneezeweed
Buttonbush
Praire Rose
Pickerelweed
Lake Sedge
Blazing Star
Brown-eyed Susan
Marsh Milkweed
False Sunflower
Brown-eyed Susan
NE Aster
Joe-pye-weed
Sandbar Willow
Blueflag Iris

Bioswale along Parking



Appendix C
Plant List

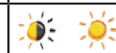
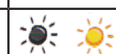
Plant List

Type	Common Name	Botanical Name	Remarks	Height	Inudation Frequency	Duration	Depth	Light	Bloom Time/Color	Design & Restoration Considerations	Wildlife Value
Shrub	Bladdernut	*Staphylea trifolia*	10′ O.C.	6′ - 25′	Moderate	Medium short (3 days)	24″		May - Aug white	floatable seed pods that raddle bring interest to a space	host to larvea of butterfly.
	Buttonbush	*Cephalanthus trifolia*	8′ O.C.	3′ - 12′	Moderate	Long (45+ days)	24″		June - Aug white	wetland restoration; aggressive to fight cattail invasion	nector source & habitat for insects; seeds eaten by birds
	High-bush Cranberry	*Viburnum trilobum*	8′ O.C.	10′ - 12′	High	Medium short (3 days)	18″		June white	improve wildlife habitat in mitigation and slope/soil stabilization	indicator of environ. health, a food source for wildlilfe
	Pussy Willow	*Salix discolor*	10′ O.C.	6′ - 20′	Moderate	Long (6 days)	24″		May - June white	known of its beauty, but also planted to stabilize soil	seeds/twig are food staple for grouse, songbirds, & waterfowl
	Praire Rose	*Rosa setigera*	10′ O.C.	6′ - 12′	Moderate	Medium short (3 days)	18″		June pink/white	numerous blooms provide color; hearty species	food source for birds; flowers attract butterflies and bees
	Prairie Willow	*Salix Humilis*	5′ O.C.	5′ - 8′	Moderate	Medium short (3 days)	12″		Sept - Oct maize	aggressively colonizes & responds well to water fluctuactions	seeds are food for grouse, songbirds, & waterfowl
	Red-Berried Elder	*Sambucus pubens*	10′ O.C.	6′ - 12′	Moderate	Medium short (3 days)	18″		June - July white	fast grower, tolerates short flooding; known for beauty	fruit is important food source for birds & small mammels
	Red-Osier Dogwood	*Cornus stolonifera*	10′ O.C.	8 - 10′	Moderate	Long (30+ days)	36″		May - Aug white	restoration & erosion control; slow spreading/less aggressive	nector for butterflies & fruit for birds; home to chipmunk
	Sandbar Willow	*Salix exigua*	10′ O.C.	6′ - 20′	High	Long (30+ days)	36″		Sept - Oct maize	aggressively colonizes & responds well to water fluctuactions	buds are food for grouse, songbirds & waterfowel
	Shrubby Cinquefoil	*Potentilla fruticosa*	3′ O.C.	3′ - 4′	Low	Short (2 days)	6″		June - Aug yellow	dense growth is good for soil stabilization	nector source for bees & butterflies; wildlife cover
	Silky Dogwood	*Cornus amomum*	12′ O.C.	6′ - 12′	Low	Long (30+ days)	36″		May - June white	restoration, wildlife cover, & streambank stabilization;	Fruit & buds eaten by ducks, marsh birds & shorebirds
	Swamp Rose	*Rosa Palustris*	4′ O.C.	4′ - 6′	Low	Short (2 days)	6″		June pink	numerous rhizomes stabilize soil	food source for birds; flowers attract butterflies and bees
Grass	Big Bluestem	*Andropogan gerardii*	6′ O.C.	3′ - 9′	Moderate	Short (2days)	12″		July - March brown/grey	soil stabilzer & slows runoff; color & form to a space through winter	cover for game & songbirds; food for larger mammels
	Deer Tongue	*Panicum clandestinum*	3′ O.C.	1′ - 4′	Moderate	Medium short (3 days)	6″		May - June white	soil stabilizes; unique winding foliage provides iterest in massing	provides cover; seeds are a food source for birds
	Little Bluestem	*Schizachyrium scoparium*	2′ O.C.	2′ - 3′	Low	Short (1 day)	12″		July - Mar red/amber	erosion control; provides color & form to a space through winter	food source for songbirds; nutritious food for grazers
	Purple Love Grass	*Erogrostis spectabilis*	2′ O.C.	2′ - 3′	Moderate	Medium short (3 days)	6″		Aug - Sept purple	soil stabilizer; provides color and form through late fall	provides cover; seeds are excellent food source
	Sweet Grass	*Hierocloe odorata*	2′ O.C.	1′ - 2′	Low	Short (2 days)	6″		July - Aug white	soil stabilizer; soft whispy foliage adds texture	cover for mammels; seeds are a food source for many birds
	Switchgrass	*Panicum virgatum*	5′ O.C.	5′ - 10′	High	Medium short (3 days)	18″		July - Sept beige	slope & streambank stabilizer; airy foliage provides texture	winter cover; important food source for song & gamebirds
Rush	Hardstem Bulrush	*Scirpus acutus*	3′ O.C.	3′ - 9′	High	Moderate long (4 days)	24 ‟		May - Sept red/brown	the best competitor to cattail invasion	bird habitat, nesting & food source; fish spawning area
Sedge	Bottlebrush Sedge	*Carex comosa*	2′ O.C	1′ - 4′	High	Medium short (3 days)	36″		May - June green	clump former & soil stabilizer; difficult to grow from seed	achenes are essential birds & waterfowl food source
	Fox Sedge	*Carex vulpinoiedea*	3′ O.C	3′	High	Medium long (4 days)	24″		May - July brown	excellent colonizer & soil stabilier	achenes are food source for birds; spawing habitat

Plant List

Type	Common Name	Botanical Name	Remarks	Height	Inudation Frequency	Duration	Depth	Light	Bloom Time/Color	Design & Restoration Considerations	Wildlife Value
	Lake Sedge	*Carex lacustris*	2′ O.C	2′ - 3′	Moderate	Long (8 days)	24″		May - June white	aggressive; used to outcompete invasives	achenes are food source for birds, beavers & muscrats
Forbs	Bee Balm	*Monarda fistulosa*	3′ O.C.	3′ - 4′	Moderate	Short (2 days)	12″		July - Aug lavendar	used in restoration along slopes; can be very aggressive	nector source for butterflies, bees & humingbirds
	Blazing Star	*Liatris spicata*	3′ O.C.	3′ - 4′	Low	Medium short (3 days)	18″		July - Sept purple	used in moist/wet restorations	nector source for butterflies & bees
	Blue Vervain	*Verbena hastata*	2′ O.C.	2′ - 4′	High	Long (5 days)	12″		July - Aug purple	flood tolerance makes it excellent for bioswale	seeds are food source for birds; nector for insects
	Blueflag Iris	*Iris versicolor*	2′ O.C.	1′- 3′	Medium	Medium long (4 days)	12″		May - June blue	decorative plant suited for bio-swales & wetland restorations	nector for hummingbirs & butterflies
	Broadleaf Arrowhead	*Sagittaria latifolia*	3′ O.C.	1′ - 4′	Moderate	Medium short (3 days)	18″		July - Aug white	excellent for wetland restorations; persists in seedbank	seeds & tubers are excellent waterfowl food & habitat
	Brown-Eyed Susan	*Rudbekiadcia subtomentosa*	3′ O.C.	2′ - 3′	High	Medium short (3 days)	18″		July - Sept yellow	used for restorations with heavy or sandy soil; a bioswale staple	food and habitat for birds & butterflies; ground cover
	Common Milkweed	*Asclepius syriaca*	3′ O.C.	3′ - 4′	Moderate	Medium short (3 days)	12″		June - Aug dull pink	aromatic; often used in rain-gardesn & bioswales	milky substance is food source for butterflies & bees
	Culver's Root	*Veronicastrum virginicum*	3′ O.C.	3′ - 6′	Moderate	Medium short (3 days)	18″		July - Aug white	can withstand significatn water fluctuatoins; used in restorations	nector source for bees and butterflies
	Early Golden rod	*Solidago juncea*	5′ O.C.	4′ - 5′	Low - Moderate	Short (2 days)	12″		Aug - Sept yellow	often planted as upland buffer; aggressively fights invasives	seeds are food source; nector source for butterflies &bees
	False Sunflower	*Heliopsis helian-thoides*	3′ O.C.	2′ - 5′	Moderate	Medium short (3 days)	12″		July - Oct yellow	easily propogated, oftern used in raingardens & bioswales	nector source for bees & other insects
	Ironweed	*Vernonia fasciculata*	5′ O.C.	5′	Moderate	Medium long (4 days)	18″		July - Aug purple	good rootstock & excellent soil stabilizer; aggressive growth	nector source for birds, butterflies, & bees
	Joe-Pye-Weed	*Eupatorium maculatum*	4′ O.C.	3′ - 5′	High	Medium long (3.5 days)	24″		July - Sept pink	outcompetes non-natives; withstand water fluctuations	seeds for birds, nector source for butterflies; habitat & cover
	Marsh Marigold	*Caltha palustris*	2′ O.C.	1′ - 2′	Moderate	Medium short (3 days)	6″		April - May yellow	successfully planted in any moist habitat; used in estorations	seeds are food source for frogs & game birds
	Marsh Milkweed	*Asclepisus incar-nata*	3′ O.C.	3′ - 4′	Moderate	Medium short (3 days)	18″		June - Aug pink	aromatic & decorative; excellent for bioswales, & wetlands	host & nector plant for monarch butterfly; fibers for nest
	Michigan Lily	*Lilium michiganense*	3′ O.C.	3′ - 5′	Moderate	Medium short (3 days)	18″		June - Aug orange	decorative plant that thrives in wetlands and pond edges	nector source for bees, butterflies and other insects
	Mountain Mint	*Pycnanthemum virginianum*	3′ O.C.	2′ - 3′	Low	Short (2 days)	12″		June - Oct white	stolons stabilize soil; excellent for bioswales & wetland restorations	attracts an assortment of butterflies
	New England Aster	*Aster novae-angliae*	5′ O.C.	1′ - 6′	Moderate	Medium short (3 days)	24″		Aug - Oct amathyst	aggressively outcompetes invasives; soil stabilizer	waterfowl cover; late season nector source for butterflies
	Ohio Spiderwort	*Tradescantia ohiensis*	3′ O.C.	1′ - 3′	Low	Short (2 days)	12″		June - Sept purple	buffer and slope stabilizer; excellent for bioswales	attracts bees, butterflies & insects
	Pickerel-weed	*Pontederia cordata*	3′ O.C.	3.5′	Moderate	Medium long (4days)	12″		June - Aug purple	decorative plant often used along wetland & lakeshore edges	seeds are foodsource for wood duck; cover for frogs & fish
	Red-Stem Aster	*Aster puniceus*	5′ O.C.	1′ - 5′	Moderate	Long (5 days)	18″		Aug - Oct white/laven	aggressively outcompetes invasives; tolerence to water fluc.	waterfowl cover; late season nector source for butterflies

Plant List

Type	Common Name	Botanical Name	Remarks	Height	Inudation Frequency	Duration	Depth	Light	Bloom Time/Color	Design & Restoration Considerations	Wildlife Value
	Showy Goldenrod	*Solidago speciosa*	5′ O.C.	3′ - 5′	Low	Short (2 days)	12″		Aug - Sept yellow	aggressively outcompetes invasives; easy to propogate	attracts bees & butterflies; food source for many birds
	Smartweed	*Polygonum amphibium*	3′ O.C.	3′	High	Short (2 days)	12″		June - Aug pink	planted for soil stabilization; establishes easily in seedbank	a songbird favorite; excellent wildlife cover & food source
	Smooth Aster	*Aster laevis*	4′ O.C.	2′ - 4′	High	Short (1 day)	12″		Aug - Oct blue	aggressively outcompetes invasives; easily propogated	late season nector source for orange sulphur butterfly
	Sneezeweed	*Helenium autumnale*	5′ O.C.	3′ - 5′	Moderate	Medium short (3 days)	18″		Aug - Sept yellow	fiborous roots stabilize soil; bioswale staple	seeds food for birds; attracts butterflies & insects
	Swamp Aster	*Aster lucidulus*	3. O.C.	1′ - 8′	High	Long (5 days)	18″		Aug - Oct white	aggressively outcompetes invasives; slope stabilizer	waterfowl cover; late season nector source for butterflies
	Sweetflag	*Acorus calamus*	3′ O.C.	2′ - 6′	Low	Medium short (3 days)	12″		May - June green	rhizomes/roots form mat; aggressively outcompetes invasives	cover for small mammels; food & cover for waterfowl
	Woodland Sunflower	*Helianthus strumosis*	3′ O.C	3′ - 6′	Low	Short (1 day)	6″		July - Oct yellow	stablizes soil; propogates easily; long lasting blooms	seeds are food source for a variet of birds; attracts insects

Cited Literature

Cited Literature

Apfelbaum, S. . 2004 Cattail (*Typha spp.*) *Management,* Brodhead, WI, Applied Ecological Services

Boland, T., Coit, L., Hair, M. 2002. Michigan Gardeners Guide. Cool Springs Press, Nashville, Tennessee Pages 88 - 152

Environmental Consulting Technology (2006) *University of Michigan East Campus Basin Report,* Ann Arbor, MI: Environmental Consulting Technology

EPA Website. http://www.epa.gov/owow/wetlands/what/definitions/htm 2007 JFNEW. Internet website http://www.jfnew.com/resourcecatalog

Mitsch, W., Gosselink, J., 2000. Wetlands 3rd Edition. John Wiley & Sons, Inc.

Schmidt, R., Shaw, D. 2003. Plants for Stormwater Design Volumes I & II. Minnesota Pollution Control Agency. St. Paul, Minnesota.

Sojda, R., K. Solberg 2003. US Fish & Wildlife Handbook: Managment and Control of Cattails, University of Nebraska, Lincoln, Nebraska. Page 1-7.

USGS website. 1998. http://water.usgs.gov/wrri/97grants/ga97sei2.html

Van der Valk, AG. and Davis, CB.. 1976. The seed banks of praire glacial marshes. Can J. Bot. 54::1832-1838.

Wesson, G. and P.F. Waring. 1969. The role of light in germination of natrually occuring populations of buried weed seeds. J Exp. Bot 20:402-413