Center for Watershed Protection

Stormwater Pond & Wetland Maintenance Guidebook

Produced for Tetra Tech, Inc.
DRAFT September, 2004

STORMWATER POND AND WETLAND MAINTENANCE GUIDEBOOK

DRAFT

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EPA Contract 68-C-99-253

September 2004

Acknowledgements

This project was completed for Tetra Tech under a contract from the US EPA Office of Science and Technology. Thanks to Jim Collins at Tetra Tech and Jesse Pritts and Eric Strassler of the EPA for their help and guidance. This Guidebook would not have been possible without significant technical, economic and graphic contributions from Tim Schueler, P.E., of CPJ/EQR Environmental Services Department. Thanks also to Boyd Church of the Montgomery County (Maryland) Department of Environmental Protection for his help and advice in the early stages of the project.

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Introduction

Prior to 1991, a relatively small number of states and municipalities had formal programs in place requiring that Stormwater Treatment Practices (STPs) be constructed to mitigate runoff pollution. Then, beginning in the early 1990's with the advent of Phase I of the federal National Pollutant Discharge Elimination System (NPDES) stormwater program, many additional municipalities began programs to limit stormwater pollution. These programs typically include STPs as one tool to help mitigate pollution from runoff. As a result, numerous STPs have been constructed throughout the United States. Unfortunately, the push to construct them has been substantially stronger than the push to actively maintain them. The realizations of budget constraints, lack of staffing, and limited knowledge about STP maintenance needs is still setting in for many community stormwater programs.

With the preponderance of stormwater ponds and wetlands across community landscapes, the specific need for detailed and representative pond and wetland maintenance guidance that spans the design, construction, and post-construction phases has arisen as a priority for many communities. The current federal stormwater regulations (e.g., Phase I and Phase II NPDES rules) make it incumbent upon permitting authorities and permittees to address stormwater treatment practice operation and maintenance as a major programmatic component.

This Guidebook has been developed expressly to address this need and assist communities in meeting the stormwater pond and wetland maintenance challenges that face them. A set of web-based tools was produced to accompany the Guidebook and can be found on the Stormwater Manager's Resource Center (www.stormwatercenter.net, click on Program Resources then STP Maintenance). The website material focuses on programmatic tools (e.g. inspection checklists, performance bonds) and includes information for STPs other than ponds and wetlands.

Purpose of the Guidebook

This Stormwater Pond and Wetland Maintenance Guidebook (Guidebook) provides guidance for maintenance considerations associated with ponds and wetlands during the design, construction, and post-construction phases aimed at minimizing the burden of long-term maintenance.

The primary audience for the Guidebook is Phase I and Phase II NPDES communities. For Phase I communities that may have a maintenance program in place, the Guidebook provides technical data and information to help improve existing design standards or inspection and maintenance standards. For Phase II communities, the Guidebook provides a technical resource.

This guidebook provides the inspector, program manager, designer, and owner (i.e., responsible party) with an understanding of common stormwater pond and wetland maintenance problems and possible solutions. A secondary audience is community/homeowner's associations, small watershed organizations, or other entities that may own or monitor stormwater ponds and wetlands. These groups may be responsible for routine maintenance and repairs. The Guidebook will help these public and private entities budget for maintenance, supervise routine maintenance, and identify problems that require additional assistance from a contractor or engineer with specialized knowledge.

Organization of the Guidebook

The Guidebook is organized in five chapters, with accompanying technical appendices as follows:

Introduction
Stormwater maintenance programs are put into context with overall stormwater programs, and the organization of the chapters is discussed.

Chapter 1 – Pond and Wetland Maintenance Concerns
This chapter discusses the major pond and wetland maintenance concerns in the framework of the top eight concerns. It is recommended reading for program managers, designers, inspectors and owners to understand the problems that can occur in stormwater ponds and wetlands.

Chapter 2. Designing for Low Maintenance Ponds and Wetlands
Pond and wetland design can reduce maintenance frequency and costs. This chapter is organized by design elements for use by design engineers and plan reviewers.

Chapter 3. Construction for Maintenance Problem Prevention
Good construction practices and stringent construction inspection can prevent future maintenance problems. This chapter highlights critical areas for program managers and construction inspectors. Designers can use this information to clarify construction plans and specifications.

Chapter 4: Post-Construction Inspection of Ponds and Wetlands
Ongoing inspection of stormwater facilities ensures that routine maintenance is occurring and identifies problems to be corrected. This chapter addresses various parties that conduct inspections, suggests maintenance/inspection frequencies, and outlines inspection procedures. While written for the program manager and inspector, this chapter will also be of interest to owners and citizen monitoring groups.

Chapter 5: Maintenance Activities
This chapter provides detailed information about inspection and maintenance activities, focusing on the top eight maintenance concerns for stormwater ponds and wetlands. This information is valuable for inspectors and maintenance crew leaders, as well as program mangers, owners or other decision-makers.

Appendix A. Cost Data
This appendix provides a table of unit costs and recommended frequencies for typical pond and wetland maintenance items.

Appendix B. Inspection Checklists
Sample checklists are presented for construction phase and post-construction.

Terminology

Stormwater management terminology is often confusing and can convey multiple meanings. This Guidebook uses several terms throughout the text that merit upfront explanation and definition to provide the reader with a foundation for the understanding the context of the subsequent text.

*Stormwater **Ponds*** (Figure A) – practices with a permanent pool, or a combination of extended detention (ED) or shallow marsh with a permanent pool that provides storage equivalent to the entire Water Quality Volume (WQv). Stormwater ponds may also provide channel protection storage volume (Cpv) and overbank flood control (Qp) through stormwater detention above the WQv storage. Pond design variants include micropool ED ponds, wet ponds, wet ED ponds, and multiple pond systems.

*Stormwater **wetlands*** (Figure B) – shallow marsh areas that treat urban stormwater, and often incorporate small permanent pools and/or extended detention storage to achieve the full WQv. Stormwater wetlands may also provide peak discharge control (Qp) and channel protection storage volume (Cpv) through stormwater detention above the WQv storage. Wetland design variants include shallow marsh, ED/shallow marsh, and shallow marsh/wet pond.

Extended Detention (ED) **-** Design feature that provides for the gradual release of a volume of water to increase settling of pollutants and protect downstream channels from frequent storm events.

Water Quality Volume (WQ_v) – Storage volume needed to capture and treat runoff associated with smaller, frequently occurring storms (e.g., 0.5” – 1” rainfall depth).

Channel Protection Volume (Cp_v) - Storage volume for the control of downstream channel erosion.

Overbank Flood Control, (i.e., Peak Discharge Protection Volume (Q_p) – Storage volume needed to control the magnitude of flows associated with larger, out of bank flooding events (e.g., 10-year return frequency storm events).

Micropool – Small permanent pool used to avoid resuspension of particles and minimize impact to adjacent natural features.

Permanent Pool – Open area of water impounded by a dam, embankment or berm, designed to retain water at all times.

Shallow Marsh - Human-made wetland with water depths ranging from <6” to 18”, planted with native wetland vegetation.

Forebay – Additional storage space located near a stormwater practice inlet that serves to trap incoming coarse sediments before they accumulate in the main treatment area.

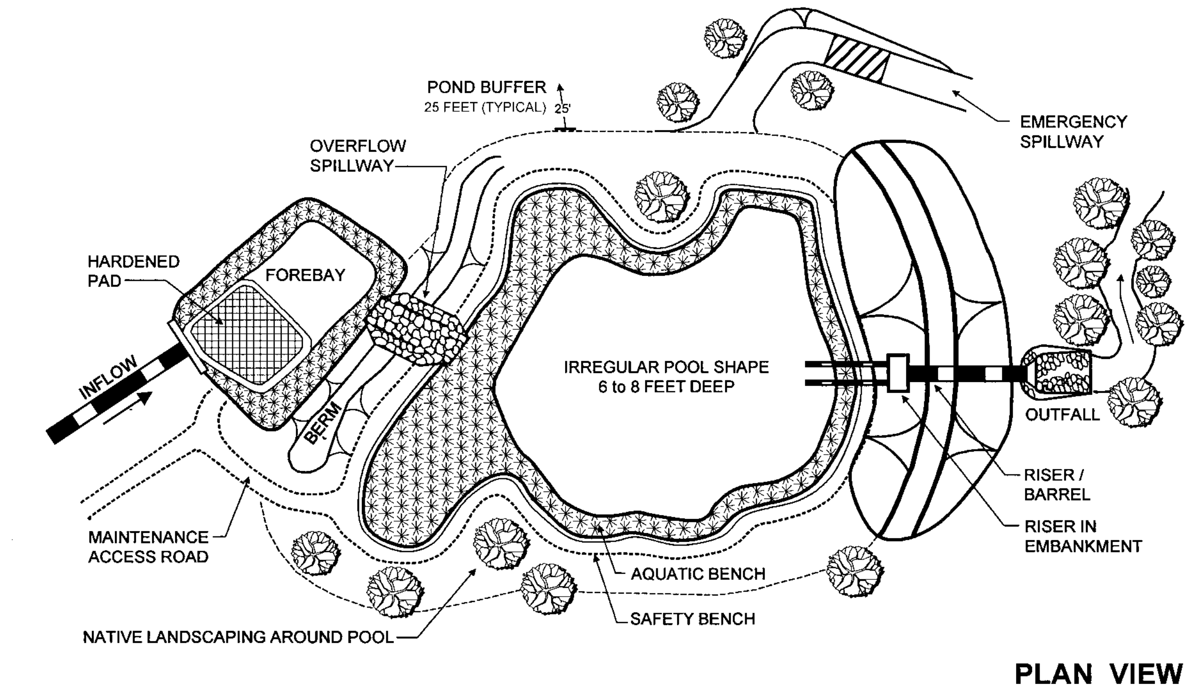
Riser – A vertical pipe which extends from the bottom of a pond stormwater practice and houses the control devices (weirs/orifices) to achieve the discharge rates for specified designs.

Barrel – The closed conduit used to convey water under or through an embankment: part of the principal spillway.

Pond Drain – A pipe or other structure used to drain a permanent pool within a specified time period.

Principal Spillway – The primary pipe or weir that carries baseflow and storm flow through the embankment.

Emergency Spillway – A dam spillway designed and constructed to discharge flow in excess of the principal spillway design discharge.



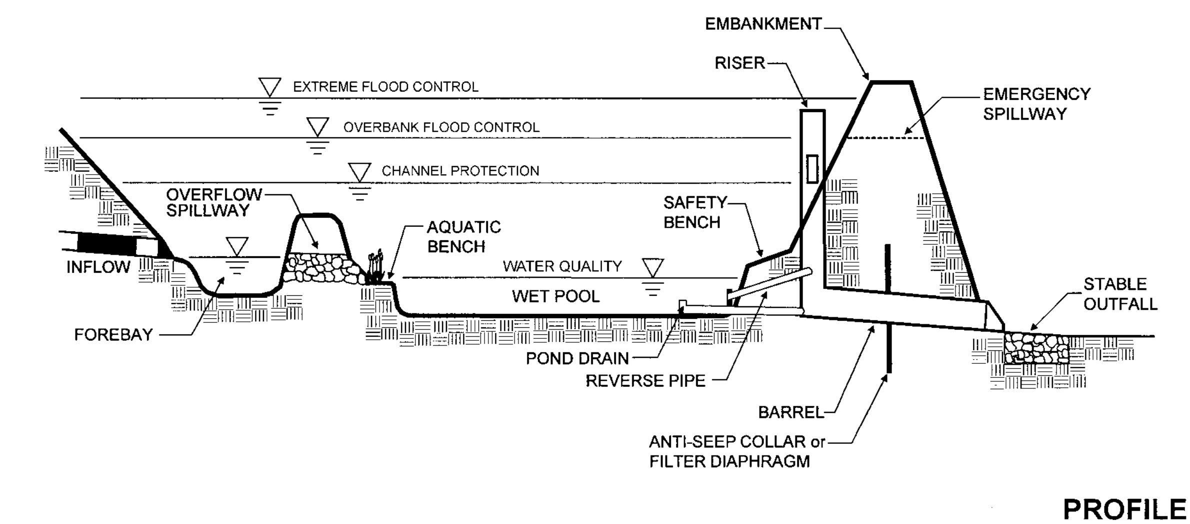


Figure A: Stormwater Pond Schematic

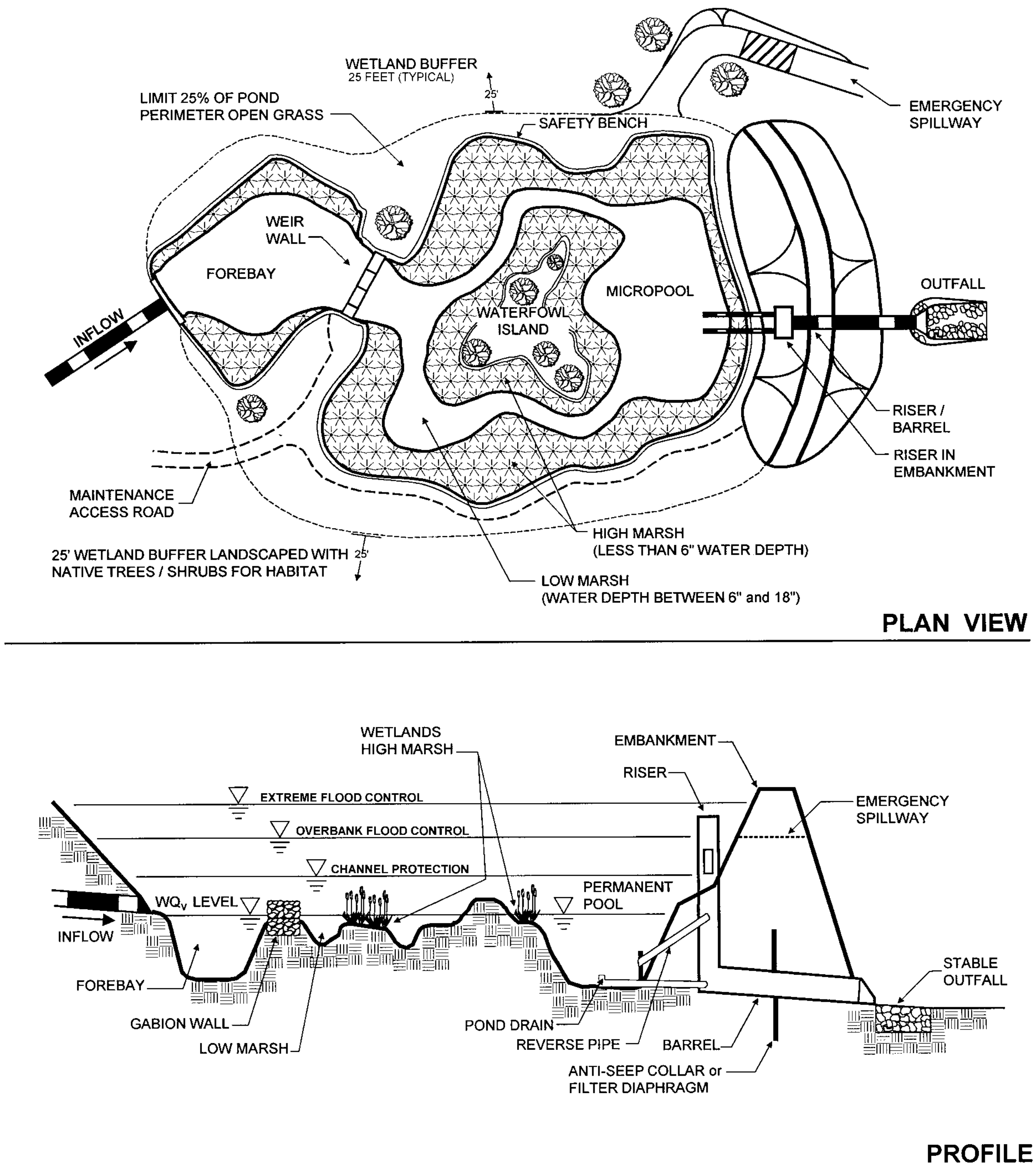


Figure B: Stormwater Wetland Schematic

This Guidebook does not explicitly address maintenance needs of dry ponds or underground detention. These practices are not widely recommended as stand alone practices that provide both water quality and water quantity benefits. Dry ponds, however, exist in many communities, as flood control facilities, and many of the maintenance considerations for stormwater ponds and wetlands presented in this Guidebook are relevant to dry ponds.

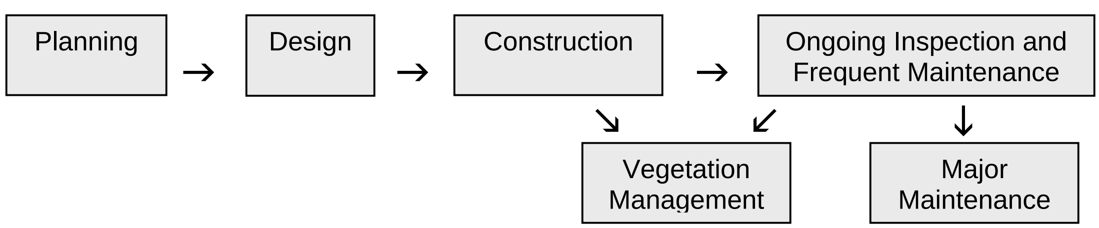
Chapter 1: Pond and Wetland Maintenance Concerns

1.1 Maintaining Pond and Wetland Function

Stormwater ponds and wetlands are popular stormwater treatment practices (STPs) for a number of reasons including aesthetics, pollutant removal capability, habitat value and relatively low maintenance burden. Stormwater ponds can be pleasing to look at, in fact there have been studies linking increases in property value associated with proximity to wet ponds (Brown and Schueler, 1997; CWP, 2001). Stormwater wetlands can provide diverse habitat for aquatic and terrestrial species. The large permanent pool volume of ponds and wetlands enhances pollutant removal because of relatively long residence times[1], reduced flow velocities and their ability to retain settled sediments and pollutants (Winer, 2000). Stormwater wetlands also provide biological uptake of pollutants through contact between wetland plants and stormwater runoff.

Stormwater pond maintenance is related to the entire pond lifecycle, depicted in Figure 1.1.

Figure 1.1 The Pond/Wetland Lifecycle



Maintenance is necessary for a stormwater pond or wetland to operate as designed on a long-term basis. The pollutant removal, channel protection, and flood control capabilities of ponds and wetlands will decrease if:

- Sediment accumulates in the pond, reducing the storage volume
- Debris blocks the outlet structure
- Pipes or the riser are damaged
- Invasive plants out compete the wetland plants
- Slope stabilizing vegetation is lost
- The structural integrity of the embankment, weir, or riser is compromised.

Pond and wetland maintenance activities range in terms of the level of effort and expertise required to perform them. Routine pond and wetland maintenance, such as mowing and removing debris or trash, is needed multiple times each year, but can be performed by citizen volunteers. More significant maintenance such as removing accumulated sediment is needed less frequently, but requires more skilled labor and special equipment. Inspection and repair of critical structural features such as embankments and risers, needs to be performed by a qualified professional (e.g., structural engineer) that has experience in the construction, inspection, and repair of these features.

[1] Residence time is the length of time for water to pass through the pond or wetland.

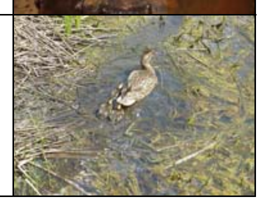
This Guidebook identifies appropriate frequencies and skill levels needed for each maintenance activity to provide program managers and responsible parties with an understanding of the relative effort and expertise that may be required.

Program managers and responsible parties need to recognize and understand that neglecting routine maintenance and inspection can lead to more serious problems that threaten public safety, impact water quality, and require more expensive corrective actions. Appendix A of this Guidebook provides program managers with specific maintenance activity unit cost and frequency information.

1.2 Top 8 Maintenance Concerns

Eight broad issues are identified in this Guidebook as the most frequent problems encountered in maintaining stormwater ponds and wetlands (Figure 1.2).

Figure 1.2: Top 8 Maintenance Concerns for Stormwater Ponds and Wetlands

Permanent Pool		**Dredging and Muck Removal**	
Clogging		**Access**	
Pipe Repairs		**Mechanical Components**	
Vegetation Management		**Nuisance Issues**	

Notably absent from the list are structural stability issues associated with embankments and pipes (e.g., earth, concrete and metal repairs). While earth, concrete and metal repairs are essential elements of stormwater pond and wetland maintenance, the assessment and design for repair of such items should be performed by a qualified structural or geotechnical engineer and is beyond the scope of this document. Where applicable, the importance of conducting a more thorough inspection of structural stability is called out in this Guidebook. More detailed guidance on structural inspections and repairs for ponds and wetlands can frequently be obtained from state dam safety agencies or local Natural Resources Conservation Service (NRCS) offices.

Permanent Pool

For stormwater ponds and wetlands, a common maintenance issue is abnormally high or low permanent pool levels.

Permanent pools (Figure 1.3) are normally designed for a stable water surface elevation between storm events that will rise during and shortly after a significant rain event. Pond elevations should not dip appreciably below the specified level unless under extreme conditions, such as drought. Ponds used as an alternative water supply for irrigation or other reuse are also an exception.

Figure 1.3: Permanent pool

Permanent Pools Too Low

Permanent pools provide functions including aquatic habitat, water quality enhancement, and visual aesthetics. When pool levels drop too low water quality is threatened by algal blooms and anoxic conditions, which can lead to fish kills.

Pond and wetland facilities should keep their permanent pool at or near the elevation of the low flow orifice or weir. Low permanent pools that are not drought-induced are usually caused by leaks either (1) in the pond embankment/perimeter, (2) in the principal spillway, or (3) in the pond bottom.

Leaks within the facility embankment or through the bottom of the pond are often difficult to locate unless they are large or severe. Active dam leaks often produce a vortex, an unmistakable indication of a leak. Water may leak through sinkholes formed in pond bottoms or infiltrate through porous underlying soils.

Leaks in the principal spillway riser are fairly easy to spot. Leaks in the barrel are harder to locate, as they require either manual entry or remote TV inspection. Broken or missing valves can also lead toward abnormally low water levels in ponds.

If a low permanent pool occurs during or immediately following construction, it can be a sign of poorly compacted berms or dams or damaged or leaking barrels and risers, items that should be inspected during and immediately following construction. A low pool may also signify that the water budget was miscalculated during design.

Permanent Pools Too High

A clogged low flow orifice is the most common reason for a higher than normal permanent pool level (Figure 1.4). Clogging is discussed in detail in the next section.

The high permanent pool disrupts the pond or wetland function in the following ways:

- Storage volume is decreased, reducing the ability to attenuate flood flows
- Flows leave the pond or wetland at velocities greater than design release rates, increasing downstream channel erosion.

Figure 1.4: Abnormally high permanent pool – Water spills into 2- year weir because beavers have clogged the low flow orifice.

- Water quality is compromised because runoff short-circuits[2] the pond and enters the downstream channel without adequate residence time for quality treatment.
- High pools kill riparian trees by flooding roots that are not normally submerged.
- Public access and safety can be compromised when adjacent pathways and recreational use areas are flooded.
- By saturating areas designed to be outside the permanent pool, mosquito-breeding habitat may be created.

Clogging

Clogged low flow orifices[3] and weirs represent the most frequent, persistent maintenance item common to all types of ponds or wetlands. Serious impacts can easily be minimized through design and retrofit. However, without frequent maintenance, even openings with trash racks can become clogged.

Clogging occurs when debris or sediment accumulates at riser/weir openings or outfalls, blocking the flow of water (Figures 1.5 and 1.6). Debris includes vegetative material such as dead plants, twigs, branches and leaves as well as litter and trash. Large storms transport significant amounts of debris. Vandalism and nuisance problems such as beavers contribute to clogging as well.

Figure 1.5: Flattop riser covered with debris.

Figure 1.6: Riser without trash rack

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[2] Short circuiting is the term used when stormwater runoff residence times in the pond are reduced.
[3] Low flow orifices or openings pass baseflow and control detention time in ponds and wetlands.

In addition to the permanent pool fluctuation problems noted above, clogged orifices can cause the following concerns:

- Obscuring the upstream slope of embankments, preventing adequate inspection.
- Blocking low flow openings causing overtopping of the embankment or dam in the event of a flood.
- Blocking underwater spillway inlets such as ‘reverse slope’ pipes once floating debris becomes waterlogged and sinks

Pipe Repairs

Pipes and riser structures are designed to convey stormwater safely and at a controlled rate. If pipes or risers are damaged, these functions will be affected. Often, risers are made from the same materials as pipes, and therefore can be treated as such with respect to maintenance and repair.

Pipes through the embankment – the principal spillway and other utilities – are designed to be watertight. If damaged, pipes may leak water into the embankment through holes or separated joints (Figure 1.7). This can lead to piping of water along the pipe, which results in erosion (Figure 1.8) and can lead to embankment failure.

Figure 1.7: Pipe invert abrasion

Figure 1.8: Severe erosion around riser and barrel

Pipe damage can occur at any point in a pond or wetland lifecycle: improper design, poor construction practice, inadequate maintenance, or wear and tear. While problems with design and construction are preventable, wear and tear is a wild card. Extreme storm events, chemical attack, abrasion, or other unforeseen circumstances may challenge the longevity of the design.

Table 1.1 presents mechanisms of pipe failure and the lifecycle point where the failure typically occurs.

Table 1.1: Mechanisms of Pipe Failure

Mechanism	Lifecycle Point		
	Design	Construction	Wear and Tear
Joint Separation The physical separation of different sections of pipe along the barrel typically caused by differential settlement or improper pipe compaction.	✓	✓	
Buoyancy Failure Trapped air in the pipe creates uplift forces, bending pipe ends up or displacing entire culverts.	✓	✓	
Static and Dynamic Loading Overburdening (placing too much static weight on the pipe) or inappropriate dynamic loading (e.g. driving a heavy piece of equipment over a pipe with insufficient backfill) causes failure.	✓	✓	
Material Compatibility Designs with several pipe materials may not bond well, especially if dissimilar pipe materials are placed in pre-cast forms on holes, and then grouted to be water-tight. Most noncementatious materials do not bond well to concrete or masonry as these materials tend to shrink over time. It is common to see leaks in the control structures where plastic or steel pipes enter through concrete.	✓	✓	
Installation Technique See Chapter 3 for description.		✓	
Insufficient Compaction See Chapter 3 for description.		✓	
Vandalism Acts include filling with rubble and debris and crushing exposed ends of plastic and clay piping.	✓		✓
Corrosion Fatigue Fatigue type cracking of metal caused by repeated or fluctuating stresses in a corrosive environment characterized by shorter life than would be encountered as a result of either the repeated or fluctuating stress alone or the corrosive environment alone.	✓		✓
U/V Deterioration Plastic piping is susceptible to deterioration from sunlight and even UV resistant material will become brittle and fracture given enough exposure.			✓
Freezing and Cracking Water pockets in the pipes, which are constantly exposed to surface water, freeze and thaw several times each winter, stressing and weakening the pipe.			✓
Internal Corrosion Corrosion that occurs inside a pipe because of the physical, chemical, or biological interactions between the pipe and the water.			✓
Abrasion Deterioration of a surface by the abrasive action of moving fluids - this is accelerated by the presence of solid particles or gas bubbles in suspension			✓

Vegetation Management

Vegetation management involves sustaining the landscaping as designed and preventing the growth of unwanted species. There are three primary types of vegetation that require management and maintenance in stormwater ponds and wetlands.

Turf and Grasses

Native and non-native grasses are the most common vegetative stabilization used in stormwater pond and wetland construction today for reasons of aesthetics, ease of maintenance, and price (Figure 1.9). The root system of any vegetative cover holds the surface soil in place and protects the slopes from wind and surface runoff erosion.

A regularly scheduled program of cutting and trimming of grass at facilities during the growing season will help to maintain a tightly knit turf and will also help prevent diseases, pests and the intrusion of weeds.

Figure 1.9: Mowed dry pond bottom

Wetland Plantings

Native wetland plants promote biological uptake of pollutants (Figure 1.10). Though the natural propagation is desirable, vegetation will still need to be managed to meet the design goals. Depending on the design of the system, vegetation harvesting[4] and control of aquatic plants (such as cattails and phragmites) may be required.

Trees and Forested Areas

Trees are often planted for aesthetic, stabilization and temperature control reasons. They have to be maintained to prevent clogging of orifices with debris and the spread to unwanted areas.

Vegetation management is probably the most frequent maintenance activity that occurs in association with the upkeep of stormwater ponds and wetlands. While the activity requires little expertise or special equipment, there are still important site conditions to be aware of in order to maintain a properly functioning stormwater pond or wetland. Examples of common vegetative problems include:

Figure 1.10: Wetland vegetation

- Trees and brush with extensive woody root systems can destabilize dams, embankments, and side slopes due to the creation of seepage routes (Figure 1.11).
- Monolithic stands of cattails (*Typha sp*) and Common Reed (*Phragmites australis*) can take over shallow marsh wetlands and drainage swales, out-competing other useful native emergent plants that would otherwise establish more varied, mature marsh plant ecology. Nuisance aquatic weeds are like any other pest; they are opportunistic and invasive. Small shallow ponds provide optimal conditions for their proliferation.
- Misunderstanding of which areas of a stormwater pond or wetland require mowing or

[4] Vegetation harvesting is removing vegetation on a routine basis and land applying it in an upland location. The purpose of harvesting is to remove plant material before winter die-off to prevent nutrients from reentering the water column and being flushed downstream.

management can lead to under or over management.
- Unseen areas may be neglected. For example, the downstream dam face of an embankment is the most commonly neglected and most critical area requiring regular clearing.
- Heavy pedestrian use, particularly along the top of dams and along pond edges can create patches of bare soil.
- Industrial pollutants can cause alteration in the chemical composition and pH of the discharge water, which, in turn, can affect plant growth even when the source of contamination is intermittent. Nutrients increase plant growth and acidic discharges can decrease vegetation.
- Un-maintained vegetation can obscure large portions of the dam, preventing adequate visual inspection and limiting access to the dam and surrounding areas. Access is critical in emergency situations (Figure 1.12).
- Excessive vegetation often provides habitat for rodents and burrowing animals. (See Nuisance Issues.)
- Excessive vegetation can affect the flow rates through earthen spillways.

Figure 1.11: Woody vegetation on embankment

Figure 1.12: Excessive vegetative growth obscures riser

Dredging and Muck Removal

Sediment accumulates in stormwater ponds and wetlands by design and eventually requires removal to maintain efficiency and safety (Figure 1.13). The maintenance interval for removing accumulated sediment will vary based on the design parameters.

Stormwater ponds and wetlands are frequently presumed to be 80% efficient in trapping total suspended solids. Sources of solid and semisolid wastes retained in a pond or wetland include:

- Soil loss from lawns and open areas
- Litter and yard waste
- Sand from winter sanding operations
- Natural leaf litter and down branches
- Grit from roofing shingles
- Atmospheric deposition wash off
- Construction sediments
- Erosion from upstream conveyance swales

Figure 1.13: Sediment accumulation in a dry pond

Figure 1.14: Muck removal and slope dressing by long reach backhoe

As sediment accumulation is expected, stormwater ponds and wetlands should be designed with sediment forebays, pond drains, access for sediment removal, and a designated onsite disposal area. These considerations will reduce eventual costs of sediment removal, as major cost items in dredging include dewatering, transport of sediment for off-site disposal, re-establishment of wetland communities, and accessing the site (Figure 1.14).

Access

Access is needed to all parts of the stormwater treatment facility for inspection maintenance. Key access points include:

- Riser structure
- Embankments
- All outfalls and infalls
- Forebays and pond bottoms
- Aerators and electrical panels

Additionally, public access should be limited to some pond or wetland components to prevent vandalism.

Access for Regular Inspection and Maintenance:
Frequent maintenance items usually involve small pieces of equipment such as mowers and light trucks. Access also involves facilitating inspector access to, into and through a stormwater pond or wetland to note items in need of repair. Figure 1.15 shows good maintenance access to a facility. Critical appurtenances should be easily and safely accessed for inspection and minor maintenance, such as lubricating a pond valve. Figure 1.16 shows good manhole access.

Figure 1.15: Pond with good access to public road.

Typical problems that impede maintenance access include:

- Inadequate or unsafe ingress to and egress

from facility components
- Fencing that does not have gates.
- Pond risers installed without provision for access. (The riser may still be entered safely through the barrel under certain conditions.)
- Manhole blocked by debris.
- Air monitoring results are unsafe.
- Steps/ladder are missing, broken, unsecured, non-aligned, or under water.
- Trash racks or valves are blocking safe access to riser.
- Heavy gratings and hatches
- Corroded locks
- Aerators that require special considerations, such as a boat or manual power disconnects.

Figure 1.16: Ladder and steps in riser.

Infrequent Maintenance Access
Less frequent maintenance items, such as dredging, will require site access for heavy equipment (e.g. Figure 1.17) including backhoes, dump trucks, and vacuum trucks. Maintaining ingress and egress points for the facility at all times is wise in case emergency repairs are needed. Lack of a permanent access route necessitates the creation of a temporary route (Figure 1.18) which may be disruptive to plant life and community aesthetics.

Figure 1.17: Typical large maintenance equipment.

Access for major repairs is similar to construction access and involves protecting existing trees, pavement, utilities, and signage against damage while accessing the areas needing repair.

Many older stormwater ponds and wetlands do not adequately provide stable access and staging areas for repair equipment. Older facilities typically include a designated ingress point, but they often suffer from one of the following shortfalls:

Figure1.18: Temporary access road widening

- There is no way to safely move equipment over existing curbs and pavement without damage.
- The slope of the access path is too steep, especially if wet.
- The path is not wide enough to accommodate heavy repair equipment.
- The path is overgrown with significant vegetation or has been planted with landscape quality material.
- Smaller structures such as decks and sheds are built in access areas (gardens and dump areas are also common).
- There is no legal access easement allowing for access from a public right-of-way to the facility;

this can be a contentious issue if the only practical access is across land not owned by the pond or wetland owner.
- No staging or equipment area is available once heavy equipment is onsite (contractors often need material storage space and a place to securely park heavy equipment overnight)

Vandalism protection:
Vandalism protection involves common sense measures such as chaining and locking mechanical components (valves and security manhole accesses). It also includes the use of well-designed trash racks to discourage vandalism and reduce clogging.

Although there are many passive options to keep people away from a facility, including screening with vegetation and locating the pond or wetland out of eyesight, the most common method of exclusion is fencing. Fences can be damaged by many factors, including vandalism and storm events. Timely repair will maintain the security of the site and reduce potential liability.

Appurtenances should be locked with key locks as opposed to more corrosion-prone combination locks. The design life of the typical lock left exposed to the elements is one to five years. They often become corroded and cannot be opened at time of inspection or maintenance. Therefore this often requires that the chain be cut and a new lock placed. For municipalities, one master key should open all stormwater facility locks to avoid confusion if keys are lost.

Typical locations for locks include the following:

- Chaining all valves with hand wheels
- Sluice gates
- Entrance points through fencing

Mechanical Components

Pond and wetland mechanical components tend to be simple and few in numbers. They include:

- Valves
- Sluice gates and flap gates
- Anti-vortex devices
- Pumps
- Access hatches
- Aerators (fountains, bubblers, diffusers)
- Electric control panels for aerators

Figure 1.19: Corroded plumbing and valve.

These components should be inspected at least annually and repaired according to manufacturer's recommendations. Mechanical components may be damaged as a result of:

- Clogging
- Sediment accumulation
- Vandalism
- Weathering or corrosion (Figure 1.19)
- Extended use
- Lack of preventative maintenance such as lubrication

Design considerations and preventative maintenance can address most of these issues. Failure to maintain these items could prevent the pond from functioning as designed, cause the problems described in the Clogging and Access sections, or, in the case of aerators, affect water quality.

Nuisance Issues

The main nuisance issues that concern most stormwater pond and wetland owners and maintenance staff can be broken down into groups, as follows:

<u>Burrows and Dens</u>
Rodents usually damage ponds or wetlands through burrowing or dam building. Burrowing may jeopardize embankment stability for dams and berms; beaver dam building reduces live storage and creates clogging problems.

The following animals routinely cause destruction to embankments and berms: groundhogs/woodchucks, muskrats, prairie dogs, badgers, pocket gophers and Richardson ground squirrels. Animal burrows can deteriorate the structural integrity of dams, embankments and slopes (Figure 1.20). Muskrats in particular will burrow tunnels up to 6 inches in diameter.

Figure 1.20: Animal burrow in pond embankment.

Beaver activity in urban areas usually results in tree and vegetation mortality, flooding from dam building that causes water to encroach into unwanted areas, and impairment of stormwater management facilities. Beaver activity can be either an aesthetic issue that detracts from the visual appeal of the community, or a property damage issue that poses liability concerns. Management options for beaver control include trapping, dam and lodge removal and the use of beaver "baffles".

<u>Waterfowl</u>
Geese and mallards may become undesirable year-round residents of a pond (Figure 1.21) or wetland if structural complexity is not included in the pond design (i.e., features that limit large contiguous open water areas and open short grass loafing areas favored by these birds). Waterfowl residing in vast numbers eat available grasses and emergent plants. Water quality in permanent pools often degrades due to increased fecal coliform counts from geese and duck droppings. Though generally well tolerated by the public, geese behavior can be noisy during breeding seasons.

Figure 1.21: Geese can affect water quality and aesthetics of ponds.

<u>Mosquitoes</u>
Although mosquito populations may have little to do with stormwater pond or wetland function, their presence is none the less perceived by the public to be related to the facility and is held in similar importance to water quality issues. Mosquito population control also factors into many community health issues such as West Nile Virus.

The proliferation of mosquitoes, particularly in dry ponds, is usually an early indication that there is a maintenance problem. Mosquitoes reproduce by laying eggs in still pools of water or on mud or fallen leaves. A few inches of standing water such as found in dry pond depressions, voids in riprap linings, or other inconspicuous places can become mosquito-breeding areas. It is possible for mosquitoes to complete their life cycle in 7 to 10 days, with approximately half being spent in the aquatic stage. Therefore if a shallow pool is stagnant for only 4 to 5 days and no predator habitat is available, one generation of mosquitoes can be bred.

Water Clarity and Excess Nutrients

Most ponds suffer water quality issues such as poor water color/clarity/odor or algal plant problems during warm weather months. Though really symptoms of degraded water quality (not a cause), much time, money and attention from both public and private maintenance entities is given to these perceived water quality problems.

Stormwater ponds and wetlands are designed and constructed to be a repository for pollutants that flush off of the landscape. Among the pollutants typically found in stormwater runoff, excess nutrients, namely nitrogen and phosphorous, that accumulate in stormwater ponds and wetlands can lead to degraded conditions such as low dissolved oxygen, algae blooms, unsightly conditions and odors. Homeowners adjacent to stormwater ponds and wetlands sometimes complain about degraded conditions resulting from excess nutrients during dryer months. When nutrient concentrations exceed certain thresholds, the trophic state[5] of the system can change. Other sources of nutrients to ponds and wetlands are a result of human behavior. The amount of fertilizer applied to lawn areas or the method for disposing of leaves and yard waste in residential and other developed land uses can affect nutrient loads delivered to ponds and wetlands.

[5] Trophic state is a measure of algae biomass in the water of a pond or wetland (Brown and Simpson, 2002).

Chapter 2: Designing for Low Maintenance Ponds and Wetlands

Pond and wetland design can minimize the need for maintenance and make regular inspection and maintenance easier. These considerations range through the design process from practice selection to grading to the details of final design and specifications.

The top eight maintenance concerns discussed in the previous chapter can be addressed during multiple parts of the design process. Broad design areas, listed on the left side of Table 2.1, affect maintenance concerns. The design choices in these categories are detailed in this chapter.

Table 2.1: Preventing the Top 8 Maintenance Concerns

	Maintenance Concerns							
Design Category	**Permanent Pool**	**Clogging**	**Pipe Repairs**	**Vegetation Management**	**Sediment Removal**	**Access**	**Mechanical Components**	**Nuisance Issues**
Selecting the Right STP	✓	✓		✓	✓			✓
Site Layout/Grading Plan	✓	✓		✓	✓	✓		✓
Pre-treatment	✓	✓		✓	✓	✓		
Access			✓	✓	✓		✓	✓
Embankments/ Dams	✓		✓	✓		✓	✓	✓
Conveyance	✓	✓	✓	✓		✓		✓
Riser	✓	✓	✓			✓	✓	
Miscellaneous	✓	✓	✓			✓	✓	✓
Landscaping		✓		✓	✓	✓		✓
ESC Plans	✓	✓		✓	✓	✓		

For detailed performance criteria including all aspects of STP design the reader is referred to the Stormwater Manager's Resource Center (SMRC) website at: http://www.stormwatercenter.net (click on "Manual Builder" then "Performance Criteria"). Note that the design elements provided on the website include all elements of design, not just those elements that focus specifically on maintenance.

2.1 Selecting the Right Stormwater Treatment Practice

Selecting the right practice for a site is one key to ensuring the success of the stormwater treatment. Historically, poor practice selection has contributed to large-scale failure and chronic maintenance problems. Some key features to remember when considering a stormwater pond or wetlands for a site from a maintenance perspective include: water budget, nutrient and sediment loading, climate concerns, and public acceptance.

Water Budget

Data regarding the sustainability of a permanent pool must be evaluated, especially in arid and semi-arid regions. Performing a water budget calculation may be necessary. Stormwater ponds should have a minimum contributing drainage area of ten acres or more (25 or more is preferred), unless groundwater is confirmed as the primary water source.

Nutrients and Sediment

The amount and type of sediment and nutrients in the runoff should be considered. Appropriately selecting and sizing a stormwater pond or wetland can prevent excessive vegetation growth. For reducing dredging needs, the more treatment volume or sediment storage volume that is provided in a pond or wetland system, the less frequent maintenance will be required.

Climate Concerns

Both arid and cold climates can affect the performance, and thereby the long term maintenance requirements, of ponds and wetlands. In arid climates, designers should ensure that the permanent pool in pond and wetland designs can be maintained. The arid conditions may also influence landscaping choices. Finally, the high rate of upland erosion in arid climates may call for increased sediment removal.

In cold climates, factors such as frost heaving, freezing of inlet and outlet pipes, and high salinity in meltwater can make continuous operation of stormwater practices challenging. The SMRC Manual Builder highlights cold and arid climate considerations for each stormwater practice type, and can be accessed from the following web address: http://www.stormwatercenter.net

Public Acceptance

If the stormwater facility is in the public eye, it should be an attractive and safe asset to the community. Signage can be a useful way to educate a community on the purpose and benefits of a stormwater pond or wetland. Ongoing education is also important for the long-term upkeep of ponds and wetlands. For example, mosquito control has recently been elevated in importance for various reasons, most notably connections to transmission of West Nile Virus. Disseminating information about the risks associated with ponds and wetlands relative to other breeding sources can increase homeowner awareness and promote participation in routine maintenance activities such as trash removal and vegetation management.

> Studies on stormwater ponds in Florida (Santana, 1994) have shown that mosquitoes are more likely to be found in dry ponds and pockets of standing water, such as old tires behind the garage, than in wet ponds and stormwater wetlands. The reason given for this conclusion is that even the best dry ponds may allow pockets of standing water for up to 3 days following a rainfall event, which is all that is needed for mosquitoes to reproduce.

2.2 Site Layout and Grading Plan

Pre-treatment

Pretreatment refers to various techniques employed to provide storage or filtering of coarse materials, such as sediment and debris, before they enter the stormwater pond or wetland. Nutrients are typically attached to sediment particles; therefore pre-treatment can limit the supply of nutrients to the main body of the pond. Proper pretreatment can enhance practice performance by preserving a greater fraction of the water treatment volume over time, and preventing large particles from clogging orifices.

Pretreatment can be provided in a number of different ways including forebays, sedimentation chambers, grass channels, filter strips, vegetated swales, and proprietary devices. In ponds and wetlands it is typically provided through inclusion of a forebay. Forebays are specifically designed to remove the coarse fraction of sediments from runoff through velocity dissipation, minimizing resuspension of settled materials, and some attenuation. A common forebay sizing criterion is that it should constitute at least 10 percent of the total water quality volume (WQv) or accommodate 0.1 inch of runoff from impervious surfaces in the catchment area.

Pretreatment forebays should be easy to access to perform sediment removal. Hard surfaces for the bottom of the forebay, such as concrete pavers or concrete slabs should be considered. Knowledge of the maintenance equipment to be used for sediment removal can help guide the forebay bottom material selection.

Access
Maintenance access should extend to all the major pond features, including the forebay, safety bench, and outlet/riser area. Risers should be located in embankments for access from land. Access roads should be constructed of load bearing materials. Minimum access road dimensions of 12 feet in width and maximum profile grade of 15% should be observed to facilitate safe equipment access. Turnaround areas may also be needed. Access to a dredge spoil area should also be a design consideration.

Access Paths
The frequency of vehicle access and type of vehicles to be used should be considered when selecting the material for the access path. Ensure that access to the riser structure is possible during a storm event that may submerge the safety benches. If a heavy vehicle such as a pump-truck is needed, consider adding grass pavers for additional stability.

Curvilinear Shores
Employ long, narrow (i.e. length to width ratios of 1.5:1 or greater), curvilinear designs using natural features to break up open water areas such as boulders, large logs or other methods. Geese and other waterfowl need a clear approach, landing and departure zones. If a design inhibits clear access, the geese are likely to move on.

Minimum Depth
Design permanent pools to be at least 4 feet deep to minimize the potential for freezing solid in winter and to allow fish that feed on mosquitoes to survive.

Dead Zones
Ensure that the stormwater pond or wetland design promotes adequate flow circulation throughout the system without creating dead zones where flushing does not occur frequently.

Dredge Spoils Area
Several design features can simplify both the frequent and infrequent removal of sediment and debris from ponds and wetlands. In some cases where the sediment loads are expected to be high, the designer may include an area for placement of dredged sediment on site. At a minimum, a dewatering area should be specified to dewater sediments before wasting or transport to a waste site.

2.3 Embankments/Dams

Dam safety regulations typically provide guidance to ensure that embankments are designed to minimize the potential of dam failure, and to ensure stormwater flows pass safely through the principal spillway and the emergency spillway, if applicable. Proper application of dam design criteria can limit the potential for seepage and leakage through a dam, affecting the permanent pool level.

Many states require use of design guidance developed by the United States Department of Agriculture, Natural Resources Conservation Service (NRCS) in preparing pond embankment designs. State and local regulations may be more stringent than the generic Code 378, so consult the dam safety program in the appropriate jurisdiction prior to beginning embankment design.

Erosion can occur beneath the surface of the practice. A major cause of this erosion is “piping,” which happens when flow travels along the outside of the principal spillway of a pond or wetland. Piping can be prevented through techniques that either interrupt or control the flow path around the principal spillway such as anti-seep collars and filter diaphragms. The Natural Resources Conservation Service (NRCS) Pond Code 378 provides design assistance to minimize the potential for piping and subsequent failures with respect to pond principal spillways.

Appropriate pond lining material may be required to inhibit or prevent infiltration from occurring. A pond liner is typically a synthetic sheet or natural clay material (e.g., bentonite) spread on the pond bottom (and dam face if necessary) and anchored into place. Clay pond liners usually consist of a layer of clay soils laid in a 4” to 12” layer. It is recommended that a qualified geotechnical engineer be involved in the design and specifications of a liner.

Another dam safety issue is fences constructed across the emergency spillway (Figure 2.1). If high flows come that necessitate use of the emergency spillway, they typically carry floatable debris. The debris can load up the fence, inhibit proper emergency spillway functioning and often damage or destroy the fence. Fencing in the vicinity of the emergency spillway should be relocated to the toe of the upstream (preferably) or downstream dam face slope, with the top of fence elevation at or lower than the emergency spillway crest elevation. If relocated to the downstream toe of slope, damage to fencing can be expected.

Figure 2.1: Fence across Emergency Spillway

Table 2.2 summarizes key dam safety design elements that will help minimize long-term maintenance burdens when designed and constructed properly.

Table 2.2: Key Dam Safety Design Elements	
Component	**Design Elements**
Embankment	▪ Minimum Top Width Requirements ▪ Maximum Slopes (front and back) ▪ Maximum Height ▪ Compaction ▪ Material (embankment and impermeable cutoff and core trenches) ▪ Freeboard ▪ Vegetative Stabilization
Principal Spillway	▪ Crest Elevation ▪ Capacity ▪ Material ▪ Seepage Control Requirements ▪ Compaction ▪ Anti-vortex Devices ▪ Trash Racks
Emergency Spillway	▪ Minimum Capacity ▪ Minimum Control Section Width ▪ Stabilization (grass, stone, etc.)
Other Items	▪ Pond Drain ▪ Vegetation Management

2.4 Conveyance

Open Channels

Many of the most common repair items for channels result from erosion caused by concentrated stormwater flows into, through and out of the practice. Key areas of design to minimize erosion include inlet and outlet protection and conveyance channels.

Minimize scouring at inlets and outlets by avoiding steep drop-offs from the pipe to the ground. Features to reduce the velocity of flow leaving a pipe such as a stilling basin, riprap apron, or a partially submerged inlet pipe can also minimize erosion. Permanent stabilization, including hard armoring of inlets and outlets may be needed to reduce the potential for scour.

Conveyance channels can be an important part of the stormwater treatment system, but they can be a maintenance burden if sediment accumulates in the channel or storm flows cause erosion.

Channels should be designed so that velocities within the channel are non-erosive, and preferably with pretreatment such as a small plunge pool or filter diaphragm to prevent coarse sediment from settling within the channel. Relatively flat longitudinal slopes (e.g., 1-2%) can limit velocities within the channel. However, a minimum channel slope should also be observed to minimize the potential for nuisance waters that may impede mowing or promote mosquito habitat. Gently sloping side slopes (3H:1V maximum) typically result in shallower flow depths, which reduces erosion potential, provides greater pollutant removal, and allows for easier access for mowing and other vegetation management.

If stabilization fabrics are used, consult manufacturers and other local practitioners regarding their design requirements and effectiveness. Give attention to the sequence of installation and the placement of topsoil and seed.

Pipes

Problems typically associated with pipe design can most likely be avoided or minimized with adequate consideration during design. Sufficient background information about local soils, groundwater and other environmental features can provide the designer with the information needed to make informed decisions on how to address most of the wear and tear type problems. Researching appropriate pipe and connection properties can minimize the potential for problems associated with joint separation, loadings and displaced linings. Tight construction specifications for backfill, compaction and construction sequencing will minimize the potential for a contractor to install pipes improperly.

Consultation with geotechnical and structural engineers or manufacturers about material applicability and design life is usually time well spent. Geotechnical and structural engineers can provide specifications relative to material thickness and bedding and compaction requirements for maximum longevity. Local town engineers, inspectors, and contractors will also know which materials perform well in your locality. Manufacturers are typically apprised of the latest construction techniques, special coatings, and pipe tolerances so that they are qualified to recommend certain pipe materials for certain applications. Discuss material properties of various pipe types with competing suppliers to obtain sufficient information to make an informed choice.

The following are the different types of pipe materials typically used in stormwater ponds and wetlands.

- *Metal Pipe*: Usually refers to corrugated steel pipe (CSP), which is often coated with protective layers such as zinc-oxide or bituminous asphalt. CSP has ridges (corrugations) going around it to make it stiffer and stronger - the corrugations are usually in the form of a sine wave and are usually made of galvanized steel or aluminum, and may be perforated, if desired. Table 2.3 presents a list of common CSP abbreviations with an expanded title for each.

Table 2.3: Common CSP Abbreviations

CSP Abbreviations	Common Description
CMP or CSP	Galvanized Corrugated Metal Pipe or Corrugated Steel Pipe
BCCMP	Bituminous coated CSP
ACCMP	Aluminum-coated CSP
AL-CMP	Aluminum pipe, little or no steel

- *Ductile iron pipe* (DIP) is another kind of metal pipe used extensively in public water lines and occasionally in stormwater pond and wetland designs. It is known for its high bursting/crushing strength. Often a section of DIP is used in place of a plastic pipe where the end of the plastic pipe sticks through a slope subject to mowing.

- *Clay Pipe*: Vitrified clay pipes are composed of crushed and blended clay that are formed into tubes, then dried and fired at a succession of temperatures. The final firing gives the pipes a glassy, reddish brown finish. Vitrified clay pipes have been used for hundreds of years and are strong, resistant to chemical corrosion, internal abrasion and external chemical attack. They are also heat resistant. However, these pipes have an increased risk of failure when mortar is used in joints because mortar is more susceptible to chemical attack than the clay. Clay pipe was used extensively in the 19th and 20th centuries and was often used for farm field drainage but it is not often used today.

- *Concrete Pipe:* Reinforced concrete pipe (RCP) is pre-cast at a foundry with varying compression strength and joining mechanisms such as tongue and groove or steel bell and spigot. Written code governs the manufacture of all pipe types and in the case of RCP, it specifies parameters such as internal diameter, loadings (classes), and wall thickness (schedule).

- *Plastic Pipe*: Usually refers to either polyvinyl chloride pipe (PVC), which is usually white and inflexible or high-density polyethylene pipe (HDPE) which is often black and flexible. Sometimes PVC and HDPE come perforated with holes at select opening diameters and spacing. Plastic pipe is made from either thermoplastic or thermoset plastics. Fluorocarbon plastics are the most resistant to attack from acids, alkalis, and organic compounds, but other plastics also have high chemical resistance. HDPE pipe is typically corrugated on the outside and can be smooth walled on the inside, and most people are familiar with it for it's use in small diameter underdrain systems. HDPE is gaining wider applicability because it now comes in larger pipe sizes (up to 48").

2.5 Risers

Appropriate pipe and riser materials are essential to pond operation. Improper design or construction can lead to draw down of the permanent pool, clogging, or riser failure.

Figure 2.2: Half round CMP low flow opening and trash rack

Low Flow Orifices

Changes in conventional approaches to stormwater treatment have resulted in smaller orifice sizes, leading to increased clogging risks. A 3-inch diameter hole used as an orifice is the minimum dimension rule of thumb for surface-fed openings. Smaller openings, down to 1-inch diameter, can be used at the release point for orifices (using internal orifice plates).

Non-clogging low-flow orifice designs include the reverse-slope pipe, half-round corrugated metal pipe (Figure 2.2), trash racks, and perforated pipe. The reverse-slope pipe (Figure 2.3) draws water from below the surface, thus preventing floating debris from flowing into the outlet.

Some pond and wetland designs incorporate a perforated horizontal or vertical pipe, usually covered with filter cloth and may be fully or partially covered with gravel or pea stone. Often the low flow control orifice is located at the interface with this perforated pipe and the riser. These designs, although effective at removing particulate pollutants, can become maintenance intensive because they are prone to frequent maintenance due to clogging of the filter cloth and are typically not recommended.

If fitting a perforated pipe with a gravel jacket, consideration should be given to first wrapping the perforated pipe with a galvanized wire mesh having ½ inch square openings, then wrapping with a fairly porous geotextile or filter cloth, before encasing in pea stone or highly porous gravel. The ½ inch "hardware cloth" helps keep the geotextile from sealing against smooth walled pipe (like PVC) and allows lateral movement of water between the geotextile and the pipe wall.

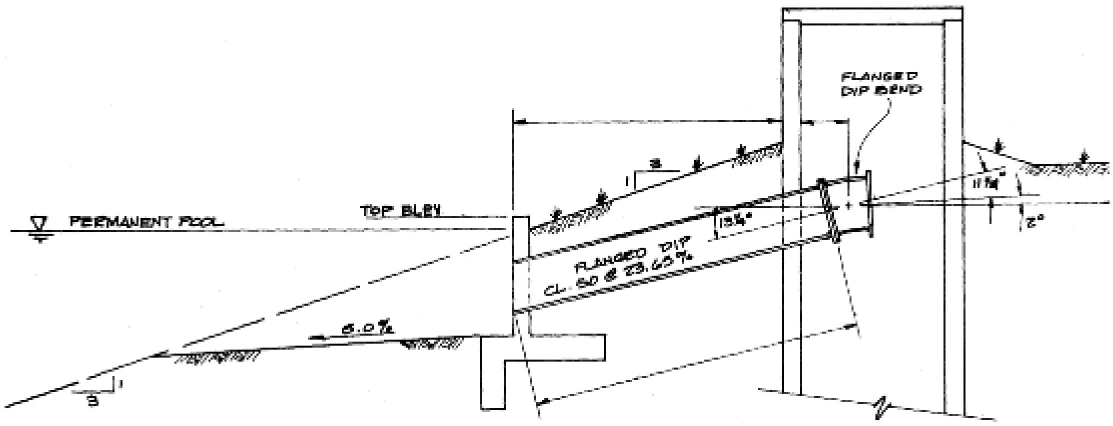

Figure 2.3: Reverse slope pipe design

Trash Racks

For larger orifices such as weir slots in the riser, use of trash racks or similar devices reduces the risk of floating debris clogging the principle spillway. However, poorly designed trash racks can cause clogging.

Trash racks should be included on all riser designs in accordance with local dam safety criteria or stormwater management design criteria to minimize the problems associated with clogging. Design considerations are presented in Table 2.4.

Table 2.4: Design Of Anti-Clogging Trash Racks And Hoods

Design Considerations	Issues
Material Durability	Ensure that corrosion, dissimilar materials and structural properties of trash rack are appropriate for the intended use
Aesthetics	Careful selection of materials, colors and designs to minimize rust stains and other objectionable features.
Connection to riser	How is the device to be connected to the riser? Bolted or welded? Can the connection specified cause damage to the riser?
Access	Does the trash rack inhibit access to the riser? Can a lock and hinge be accommodated?
Minimum Opening Dimensions	Ensure that opening sizes do not violate embankment safety criteria.
Configuration	Dam safety criteria may not allow flat trash racks on top of open-topped risers. Check local dam safety requirements.
Hydraulic Properties	If hood is used, make sure it does not become a flow restriction unless it has intentionally been designed as such.

Pond Drain

Two challenges of removing accumulated sediment and debris in ponds and wetlands are working within a permanent pool of water and accessing small underground pipes. Providing a pond drain is an important design feature that allows maintenance crews to drain ponds or wetlands before removing accumulated sediment. The pond drain should be located at the lowest elevation of the permanent pool with an upturned elbow. The pipe should be protected against maintenance actions such as dredging.

Riser Access

Providing safe access to the riser structure involves the following considerations:

- Place risers in embankments, where the openings or the access hatch can be accessed from shore. If orifices are clogged or a storm event is occurring, inspection and maintenance staff can access risers without requiring a boat or draining the pond. (Figure 2.4)

- Valves and other maintenance items should be located inside the riser, in a location that provides access even under high water conditions. Use of hand wheel extensions should be considered when valves are located a substantial distance below the access hatch.

Figure 2.4: Riser located near pool edge for easier access.

- Oversized manhole covers or access hatches should be provided where feasible to facilitate safe ingress and egress for inspectors carrying a multitude of equipment. Ladder rungs should line up with access hatches and extend the entire height of the riser or manhole. OSHA fall height safety design requirements should be followed. A safe access manhole is one that is clean, clear of debris and well lit. The distance to the first manhole step should be less than 18 inches and the distance between each subsequent step should be 12 inches. Ideally, the steps should each have reflective tape so that they reflect brightly as light is passed over them. Alternatively, a ladder may be employed instead of individual steps

- Riser manholes should be locked and any openings in the riser should be fenced with an appropriate trash rack to prevent public access to the structure. Manhole lids are usually secured by their own weight. Frame and covers with locking bolts are available, however their use is not advised as the bolts corrode over time and not all inspection parties will have the correct set of wrenches to loosen the bolts. The use of a lock bar for anti-vandalism chain is suggested (Figure 2.5).

- Handwheels that operate valves for the low flow orifice and the pond drain should be chained and locked to prevent unauthorized use or vandalism.

Figure 2.5: Lock bars

2.6 Miscellaneous Details

Fencing and Gates

Fencing should be selected to inhibit reasonable access without compromising aesthetics and facility operation and regular maintenance needs. The three most popular fencing materials for stormwater ponds and wetlands are galvanized or plastic-coated chain link (Figure 2.6), three rail wooden fencing with a welded wire mesh backing (Figure 2.7), and plastic fencing.

Figure 2.6: Chain link fence

When selecting gates, identify the type of vehicles to be used for maintenance as well as the type of locking mechanism to be employed. Gates should have sufficient width (possibly considering a turning vehicle) and proper location with respect to access roads and spoil sites.

Staff Gauge

In ponds and wetlands, sediment markers (graded measuring sticks) placed in forebays and/or permanent pools can consistently measure the depth of sediment in the practice so that build-up can be monitored at each inspection. Similar markers can be used to measure the depth of the permanent pool, and ensure that the elevation of the permanent pool remains relatively constant over time.

Figure 2.7: Post and rail with mesh backing

Mechanical Components

Specifying appropriate coatings for weather susceptible components can increase longevity. Coatings include galvanizing, PVC coatings and paint for bare metal pieces. Contracts for installation of mechanical components should include provision for touch up if damage should occur during installation.

2.7 Landscaping

Landscaping can help prevent access of ponds by geese and children, stabilize banks, and prevent upland erosion. In some ponds and wetlands, the vegetation in and around the practice is an important component of practice performance. For example, stormwater wetlands rely on plant uptake for at least a portion of the overall nutrient removal. Ponds may rely on adjacent trees and shrubs for shading to reduce ambient water temperatures. Other factors affecting vegetative establishment to consider during design include climate, wildlife attraction, and pollutant removal capability. Additionally, landscape design is vital to community acceptance of a stormwater pond or wetland.

Designing stormwater ponds and wetlands to minimize vegetative maintenance problems should be the responsibility of landscape architects, aquatic biologists, agronomists, horticulturists, biologists, master gardeners, or some combination thereof. Although there are volumes of publications about plant selection for certain applications, the best advice is generally to find someone with local, native plant experience to address the entire pondscape, within the context of local regulatory requirements.

Climate and Hydrology

Climate and inundation frequency are primary factors to consider when selecting plant material for ponds and wetlands. Careful attention to plant selection should be given to ponds and wetlands affected by substantial fluctuation in groundwater levels or facilities incorporating extended detention (ED). Stresses on plants caused by frequent inundation for short periods can create landscaping challenges.

Wildlife Attraction

Wildlife attraction is another issue that can drive plant selection decisions. Planting tall vertical grasses and shrubs at the waters edge and strategically placing boulders or logs to break up the water surface can inhibit waterfowl from landing and minimize the attraction. Minimize mowing at the perimeter of the practice with a no-mow fringe. With a thick stand of tall vegetation surrounding a pond or wetland, waterfowl access to adjacent areas is limited, and, as a result, they are less likely to land and stay because they fear predators may be in the tall vegetation.

In some cases, wildlife attraction may be encouraged for desired species, such as those that predate on mosquitoes or are pleasing to watch, by carefully selecting vegetative material and managing it through active maintenance routines. In stormwater ponds and wetlands, create a marsh fringe surrounding wet pools to create mosquito predator habitat and refuge for birds, amphibians and insects that are likely to prey on mosquitoes.

Pollutant Removal

Careful plant selection can have an effect on the pollutant removal efficiency of the stormwater pond or wetland. Some dense growing species may be well suited for filtering sediments while others may more easily uptake nutrients. The design should include a plan for supplementing wetland vegetation after the first year of operation, and a detailed plan for species to be included within the wetland.

Figure 2.8: Phragmites dominated wetland plantings

Invasive Plants

Check with the local environmental agency that has jurisdiction over a project site before selecting plant materials, as certain invasive plants may be prohibited. For example, the Maryland Department of the Environment disallows use of Kentucky-31 fescue in non-tidal wetlands and 25-foot buffer areas because K-31 is an aggressive and hearty grass that inhibits natural succession within those areas. Phragmites and cattails commonly dominate wetland areas (Figure 2.8) and can be limited by creating complex microtopography on wetland bottoms and specifying diverse plant communities. Be sure to obtain local lists of invasive species and preferred native plants for stormwater facilities when developing planting plans.

2.8 Erosion and Sediment Control Plans

Converting Sediment Basin

Add notes to the construction drawing clearly indicating that if the stormwater pond or wetland is used as a sediment basin during construction, it will be dredged to design dimensions and planting specification when construction is complete.

Tree Protection

Tree protection is inexpensive and should be used to protect trees adjacent to access roads. The best protection is to keep the tree fenced off from construction/maintenance traffic with a temporary tree-save fence. To protect the critical root zone, place the fence outside the drip line or at least 1-½ feet away from the tree for every inch in diameter at breast height at a minimum. Consider the impacts to root zones when selecting access paths. Root zones should not be more than 1/3 impacted.

Chapter 3: Construction for Maintenance Problem Prevention

Construction methods significantly impact the future maintenance needs and longevity of stormwater ponds and wetlands. Regular inspection of stormwater facilities during construction can ensure proper construction methods are employed and facilities are built to the design specifications. Immediate recourse should be pursued if the facilities are constructed improperly.

Figure 3.1: Barrel laid in concrete cradle

Counties and municipalities may employ construction inspectors trained in the techniques used for specific stormwater treatment practices. Alternatively, the design engineer may be required to supervise construction. Supervision by a geotechnical engineer will also be needed at some points.

It is out of the scope of this Guidebook to provide specific detail and guidance on construction techniques. However, the Natural Resources Conservation Service's Pond Code 378 provides useful specifications, guidance and checklists that can be used during construction to ensure a quality job.

Examples of such guidance are given below:

<u>*Compaction of Backfill*</u>
Compacting the pipe haunches (the area immediately below the pipe from the 5 to 7 o'clock position) is the most difficult aspect of pipe backfilling, as most pipes are installed using trenches that limit access to the haunches. Insufficient compaction can lead to weaker soil strengths adjacent to the pipe where soil strength for piping resistance is most critical. An alternative to compacting the haunch area is backfilling with concrete or flowable fill (Figure 3.1).

Design Engineer to Inspect:
- Core trench dimension and location
- Barrel class, joints, location & dimension
- Concrete cradle dimensions
- Anti-seep collar location, dimension, and rebar
- Riser dimensions, rebar, joints, opening dimensions, integrity
- Valve and orifice plates
- Outfall protection
- Embankment location and dimensions
- Contours and storage volumes

<u>*Pipe Installation*</u>
Many pipe systems age prematurely due to improper care of pipe prior to and during installation. Corrugated steel pipe (relatively light, flexible material) can be damaged by the heavy equipment, chains, and harnesses used in installation. Pipes not aligned correctly at installation are nudged with heavy toothed equipment, stressing and potentially puncturing pipes. Concrete bell and spigot sections are 'brought true' by forcing one end into another section with an excavator or backhoe. The equipment operator may not be aware of the damage; therefore, unless

Geotechnical Engineer to Inspect:
- Dewatering methods
- Core trench excavation, backfill, and compaction
- Pipe subgrade, lifts, and compaction
- Concrete strength tests for concrete collar, concrete cradle, riser footings, and cast-in-place riser
- Filter diaphragm
- Backfilling of principal spillway
- Embankments lifts, compaction, and soil material

vigilant construction inspection is enforced, damage may not be discovered until it has become a problem.

The typical critical construction elements requiring the attention of qualified professionals are listed below, in Table 3.1. For additional details on the sequence and specific inspection items, refer to the sample Stormwater Pond/Stormwater Wetland Construction Inspection Checklist included in Appendix B.

Table 3.1: Key Construction Inspection Items

Pond/Wetland Feature	Key Inspection Points
Erosion and sediment control	▪ Initial installation ▪ Dewatering ▪ Stream diversion ▪ Maintenance of ESC devices
Core Trench	▪ Dimensions ▪ Locations ▪ Backfill and compaction
Principal spillway	▪ Material ▪ Watertight joints ▪ Subgrade ▪ Backfill and compaction ▪ Concrete cradle – dimensions, concrete strength
Riser	▪ Dimensions ▪ Orifice sizes and elevations ▪ Watertight connections to pipes ▪ Trash racks ▪ Materials and structural integrity
Embankments	▪ Soil compaction ▪ Soil material ▪ Location and dimensions
Emergency spillway	▪ Location (should always be in cut) ▪ Dimensions ▪ Linings
Storage volumes and grading	▪ Design volumes for pond are achieved at appropriate elevations ▪ Safety benches are as designed ▪ Microtopography correct for wetland vegetation ▪ Permanent pool elevations correct
Vegetative stabilization	▪ Proper planting material ▪ Proper surface preparation and soil amendments ▪ Timing the delivery and installation of wetland plants with consideration for seasonal requirements ▪ Stabilization prior to removal of ESC measures

Upon completion of construction, as-built drawings of facilities should be prepared by qualified engineers and surveyors for permanent record of the facility. The as-built plans are a critical element of future inspections. As-builts should include orifice sizes, locations and elevations, final pond grading including field changes, appropriately documented pipe sizes/materials/shapes and locations, and

TIP – Require Sign-off
Require sign off from the inspector or engineer at key points to ensure that the contractor will notify these parties prior to proceeding with the key elements, such as placing the core trench or installing the principal spillway. These signatures can be a part of the as-built package for final approval.

constructed elevations for all embankment features. Construction photographs, not usually provided with as-builts, are a useful form of documentation. Construction photographs can answer some of the questions that often arise once a problem has been identified.

Below is an example of a series of construction photographs taken by the design engineer during the embankment construction process. The engineer was on site to document the installation of critical elements of the facility.

Figure 3.2: Dam construction - Photo 1

Figure 3.3 Dam construction – Photo 2

Figure 3.4 Dam construction – Photo 3

Figure 3.5 Dam construction – Photo 4

Chapter 4: Post-Construction Inspection of Ponds and Wetlands

To ensure high quality, long-term functioning stormwater practices, inspections need to occur on a regular basis by community stakeholders and stormwater management professionals. These inspections help the stormwater manager monitor the safety, longevity, and effectiveness of these practices over time. This section outlines some tips for inspecting ponds and wetlands, focusing on the inspection frequency, inspection checklists, documentation photographs, and repair item documentation.

4.1 Inspectors

Ongoing post-construction inspections of stormwater ponds and wetlands can be conducted by a variety of stakeholders including:

- Concerned citizens and adjacent homeowners
- Homeowners Associations
- Property Managers
- Commercial, Institutional, and Municipal Owners
- Municipal Inspectors and Maintenance Crews
- Professional engineers and specialized contractors

Property owners should reach an agreement with the property management, maintenance team or landscaping contractor to conduct frequent inspection and maintenance items such as mowing, checking for clogs, and debris removal. Clearly identify the expectations so that the landscaping design is preserved for optimal stormwater treatment.

Attentive landscapers, adjacent homeowners, and homeowner associations can be the first to identify potential problems. A homeowner checklist is included in Appendix B. Several local maintenance guidebooks aimed at citizens are also available on the SMRC website (www.stormwatercenter.net) under Program Resources, STP Maintenance, STP Maintenance Educational Materials.

The range of experience needed to diagnose a problem during inspection is quantified below in Table 4.1. These skill levels are used to describe the inspection items in Table 4.2 in the next section.

Table 4.1: Inspection Skill Level Descriptions

Skill Level	Description
0	No special skills or prior experience required
1	Inspector, maintenance crew member or citizen with prior experience with ponds and wetlands
2	Inspector or contractor with extensive experience with pond and wetland maintenance issues
3	Professional engineering consultant

4.2 Inspection Frequency

Ponds and wetlands should ideally be inspected on a monthly basis for minor items, and annually for major inspection items, such as structural components. In reality, many communities are unable to inspect all of their ponds this frequently, and a more typical scenario is providing inspection once every three years. This less frequent full inspection can be supplemented with a routine inspection conducted by a property owner or contractor responsible for maintenance. In the case of wetlands, an additional inspection may be required after the first year to ensure that wetland plantings remain viable.

Table 4.2 shows the frequency timeline with typical inspection and maintenance items at these times. Inspection frequency may be refined by the maintenance history of the practice as generated by ground crews charged with maintenance and mowing, or other interested parties. The profile sheets referenced under maintenance items are provided in Chapter 5.

Table 4.2: Typical Inspection/Maintenance Frequencies for Ponds And Wetlands

Frequency	Inspection Items (Skill Level)	Maintenance Items (Related Profile Sheet)
One time - After First Year	▪ Ensure that at least 50% of wetland plants survive (0) ▪ Check for invasive wetland plants. (0)	▪ Replant wetland vegetation (M-4 Vegetation Management)
Monthly to Quarterly or After Major Storms (>1")	▪ Inspect low flow orifices and other pipes for clogging (0) ▪ Check the permanent pool or dry pond area for floating debris, undesirable vegetation. (0) ▪ Investigate the shoreline for erosion (0) ▪ Monitor wetland plant composition and health. (0-1) ▪ Look for broken signs, locks, and other dangerous items. (0)	▪ Mowing – minimum Spring and Fall (M-4 Vegetation Management) ▪ Remove debris (M-2 Clogging) ▪ Repair undercut, eroded, and bare soil areas. (M-4 Vegetation Management)
Semi-annual to annual	▪ Monitor wetland plant composition and health. (0-1) ▪ Identify invasive plants (0-1) ▪ Mechanical components are functional (0-1)	▪ Trash and debris clean-up day ▪ Remove invasive plants (M-4 Vegetation Management) ▪ Harvest wetland plants (M-4 Vegetation Management) ▪ Replant wetland vegetation (M-4 Vegetation Management) ▪ Repair broken mechanical components if needed (M-7 Mechanical Components)
Every 1 to 3 years	▪ All routine inspection items above (0) ▪ Inspect riser, barrel, and embankment for damage (1-2) ▪ Inspect all pipes (2) ▪ Monitor sediment deposition in facility and forebay (2)	▪ Pipe and Riser Repair (M-3 Pipe Repair) ▪ Forebay maintenance and sediment removal when needed (M-5 Dredging and Muck Removal)
2-7 years	▪ Monitor sediment deposition in facility and forebay (2)	▪ Forebay maintenance and sediment removal when needed (M-5 Dredging and Muck Removal)
5-25 years	▪ Remote television inspection of reverse slope pipes, underdrains, and other hard to access piping (2-3)	▪ Sediment removal from main pond/wetland (M-5 Dredging and Muck Removal) ▪ Pipe replacement if needed (M-3 Pipe Repair)

4.3 Inspection Checklists

A community should use standard inspection checklists to record the condition of all practices, and particularly those that need frequent maintenance. Most communities will find it easier to track maintenance electronically, using either a database or spreadsheet, rather than relying on paper files. Well-designed checklists can be integrated with these systems to prioritize maintenance, track performance over time, and relate design characteristics to particular problems. To effectively achieve these goals, the checklist should:

- Be quantitative, so that maintenance can be easily prioritized
- Be very specific about possible problems to reduce subjectivity.
- Limit the use of text, particularly if integrated with a database.
- Link problems to specific actions.
- Where possible, track the function of the pond or wetland over time for future research and design.

Inspection checklists should also be grouped in the order the inspector would inspect the practice. For example, ponds should typically be inspected from downstream to upstream, so the investigation begins with the outfall channel. Sample checklists are presented in Appendix B.

For additional example checklists, consult SMRC (www.stormwatercenter.net). Checklists can be found by clicking “Program Resources” then “STP Maintenance” and “Maintenance Checklists, Reminders, and Notifications.” In addition to providing detailed “professional” checklists for various STPs, it also includes a simplified pond inspection checklist for homeowners.

4.4 Documentation of Inspection Findings

Inspectors should clearly identify the extent and location of problems identified during inspection. In addition to clearly describing problem areas on the checklists, inspectors should help repair crews locate repairs both at the site and on design plans.

Immediate Concerns

While all maintenance and inspection items are important, some maintenance concerns actually pose an immediate safety concern. Many of these are caused by missing or damaged elements that would prevent access by the public. Examples include missing manhole covers or trash racks, missing or damaged fencing when that fence prevents access to a pond with steep side slopes, or a missing or damaged grate at a large inflow or outfall pipe.

Another set of immediate pond and wetland repairs involve dam safety or flooding hazards. If a practice shows signs of embankment failure, or if an inspector is unsure, an appropriately qualified person or engineer should be called in to investigate the situation immediately. Similarly, cracks in a concrete riser that drains a large area may pose a dam safety threat

As-built Drawings

The inspector should bring a copy of the as-built plan of the practice to mark potential corrections and problem areas on this plan. The marked up as-built plan should be stored either digitally or in a paper file system so that it can be brought out to confirm that maintenance was performed correctly on the follow-up inspection.

Photographs
Inspectors should take a core set of documentation photographs of practices being inspected. In addition, specific problem areas should be photo documented. A recommended set of core photographs for ponds and wetlands include:

- Vehicle access points.
- Overview of practice.
- Overview of principal spillway structure.
- Upstream face of dam embankment.
- Downstream face of dam embankment.
- Outfall to practice and downstream outfall from practice.
- Emergency spillway (if applicable).

In addition, because of the large number of photographs that will likely be generated, a digital camera should be used to allow photographs to be stored electronically. (In advanced database programs, these photographs can be retrieved digitally). Finally, photographs should be named using a standard convention. The photograph name should indicate the practice identification number, feature (or problem) being photographed, and date of photograph.

Field Marking
Inspectors can highlight key areas of concern with spray paint or other marker. This is particularly useful for problems that may otherwise be difficult to find by others. Marking should be used as discretely as possible. For example, only dots sprayed at the base of trees should be used to mark limits of clearing for vegetation removal. Figures 4.1 to 4.4 shows examples of helpful spray paint markings.

Figure 4.1: Marking outfall deficiencies.

Figure 4.2: Marking trees to be removed.

Figure 4.3: Marking pipe joint separation

Figure 4.4: Marking a hole in gabion fabric

Chapter 5: Maintenance Activities

Specific activities for maintaining stormwater ponds and wetlands are detailed in the following profile sheets, which are organized by the top eight maintenance concerns introduced in Chapter 1. Each profile sheet provides the following major sections:

- Problems to Inspect For
- Corrective Actions
- Cautions and Safety Tips

In addition, a subjective rating of skill level is presented with many of the maintenance activities to aid the program managers and responsible parties in understanding the severity of the problems described. Ratings and descriptions of the required skill levels can be found in Table 5.1 below.

Table 5.1: STP Maintenance Skill Level Descriptions

Skill Level	Description
0	No special skills required.
1	Ordinary maintenance crew skill level.
2	Contractor familiar with pond and wetland maintenance issues.
3	Professional engineering consultant.

Lastly, Appendix A provides useful unit cost information for specific maintenance activities along with typical maintenance frequencies to be expected.

A directory of maintenance activity profile sheets is provided below.

Profile Sheet Page

M-1 Permanent Pool

Problems to Inspect For

An important aspect of any pond or wetland inspection is having sufficient background information. In the absence of familiarity, a good set of as-built drawings can present a considerable amount of information about the way a pond was built and how it should function. Construction drawings or as-built drawings will include anticipated levels for permanent pools and sizes and locations of orifices.

The best tool for confirming pool elevation fluctuation is familiarity. Abnormally high or low levels are more likely to be noticed in a pond that has been frequently inspected at normal levels. Signs that the permanent pool is too high include:

- Water levels remain high for more than 2 or 3 days after a storm.
- Pond edges normally visible are covered in water and plant species normally above permanent pool are now immersed in water.

INSPECTION TIP:

Stormwater ponds and wetlands often have higher than normal water surface elevations after storm events, sometimes for a number of days. This is a normal part of the design. Consider the last significant rainfall event when determining your inspection schedule. Try to avoid examining permanent pool levels within 2 to 3 days of a significant rainstorm to give the facility time to discharge the runoff temporarily stored in the pond. Exceptions to this rule apply if vortexing or another problem that may be more apparent at higher stage is suspected.

If a stormwater pond or wetland is well constructed, with an adequately sized and protected low flow orifice, it will only suffer from an abnormally high pool when outside forces act on it. Examples are clogging, vandalism (damaged riser or low flow valve being opened), or rodent activity.

Signs that the permanent pool is too low include:

- Stain marks on the riser or flow control structure
- Exposure of a non-vegetated pond bottom around the pool perimeter.

To review a dam embankment for possible seepage, look for vegetative color, species and density, particularly in dry weather. The presence of some or all of these features may indicate seepage or leaking on the downstream dam face. Embankment leaks on the downstream side of a berm or dam are usually easily discovered if the vegetative cover has been recently mowed and the slope is not too steep (generally, 2H:1V or flatter). Leaks on the upstream dam face are usually impossible to locate visually, unless it is at the surface (such as a flooded animal burrow) or there is an active vortex. Slow leaks that are only apparent over long time periods are particularly difficult to observe and may require a dye test or complete pond dewatering.

Often, inspections of stormwater ponds and wetlands falsely report leaks during warm weather when droughts or improper water budget analysis may be the problem. This latter scenario makes a pond prone to frequent lowered pools due to natural evaporation.

Conversely, larger facilities or facilities fed by constant inflow (surface streams, springs, or seeps) may have leaks or excessive seepage that is masked by the apparent normal permanent pool supported by a strong water source. Recorded measurements over time are the best way to confirm this problem.

Corrective Actions

Fixing the problems associated with permanent pool fluctuation can vary in difficulty, from relatively simple to complex and expensive. Regardless of the level of skill required for fixing the problem, only properly trained and authorized personnel should perform the maintenance.

Table 5.2 includes a list of problems, potential solutions, a subjective analysis of problem classification, and an estimate of the skill level recommended to correct problems associated with permanent pool issues. Estimated costs to fix the types of problems outlined here are included in the Maintenance Cost / Frequency Table in Appendix A.

Table 5.2: Permanent Pool Fluctuation Diagnoses

Finding	Solution	Classification	Level of Skill Recommended
Clogged low flow	Clear low flow, install trash rack if not present or inadequate. See M-2 – Clogging.	Minor maintenance	(0) See cautions in M-2.
Low flow or pond drain valve opened	Shut valve and lock shut with chain and lock. See M-2 – Clogging.	Minor maintenance	(0) See cautions in M-2.
Rodent activity (dams, lodges, burrows)	Fill burrows. See M-8 – Nuisance Issues	Minor to major repair	(1)
Leak in riser	Seal leak. See M-3 – Pipe Repairs.	Major repair	(2)
Leak in barrel	Seal leak. See M-3 – Pipe Repairs.	Major repair	(2)
Leak in upstream dam face or pond bottom	Drain remainder of permanent pool and install waterproof liner; dye test recommended.	Major repair	(2)
Leak or seepage in downstream dam face	Dye test recommended; seal leak source if found; liner may need to be installed and dam or principal spillway repair or replacement may be required depending on leak severity.	Major repair	(3)
Vortexing[1]	Consider a call to civil authorities immediately as dam failure may be imminent and down stream evacuation may be necessary; do not attempt to repair without professional help.	Usually major repair	(3)

Inspection frequency beyond typical annual inspection should be set by the pond or wetland maintenance history and/or its use. For example, ponds with chronic clogging due to beaver activity should be put on a more frequent inspection schedule.

[1] Swirling action of water caused by submerged orifice flow, usually in the vicinity of the dam, riser or principal spillway.

Cautions and Safety Tips

Risers near the shore or located in the embankment are often easy to examine from the surface (See Figure 5.1). Normal personal protection equipment (PPE) as defined by the U.S. Occupational Safety and Health Administration (OSHA) is sufficient to view from the top and photograph and/or measure with a drop tape. Risers located out in the permanent pool, or those with inaccessible tops (such as the typical round anti-vortex shell CMP riser) are more difficult and may require confined space entry and/or boat access. Similarly, barrels may require confined space entry to examine for leaks or to gain access to the riser itself; some barrels are too small for entry or are damaged or clogged. In these situations, remote TV inspection from either or both ends may be the only practical way to examine for leaks. However, if a leak in a riser or barrel is large and obvious, it may be easy to spot, particularly if it is a hole in a metal riser that now acts as a “low flow orifice”.

Figure 5.1: Riser located near pool edge for easier access.

M-2 Clogging

Problems to Inspect For

External clogging can easily be identified through routine visual inspection. Clogging within low flow pipes and underdrains can be more difficult to find. A well functioning opening and trash rack should be clear of debris. Trash racks should show little or no corrosion and should be completely visible. Examine design or as-built records to determine which weir/orifice is supposed to set the permanent pool.

Figure 5.2: Clogged valve

Record water surface elevations by leaving a stake or marker at a high water mark and recheck at regular intervals to determine if pond or wetland permanent pool levels are staying higher than designed for longer periods than expected following a rainfall event (see Profile Sheet M-1). If pool levels are higher than expected for long durations, then a clogged low flow pipe or orifice, or internal clogging of a low flow drain may be the problem.

Corrective Actions

Trash and debris removal should occur during the regularly scheduled inspection and maintenance to reduce the chance of outlet structures, trash racks, and other components becoming clogged and inoperable during storm events. Proper preventative maintenance includes removal of debris from pond bottoms, embankments and side slopes, perimeter areas, and access areas that can lead to clogging, as well as debris jams at outlet structures and trash racks.

Figure 5.3: Clogged low flow orifice (before maintenance)

Metal trash racks should be inspected, and any exposed steel should be brushed free of corrosion and coated or spray coated with protectant or water sealant.

Techniques for removing clogs depend on the accessibility and severity of the clog. They include:

- Manual removal of debris by hand or by machine (Figures 5.3 and 5.4)
- Jetting, back flushing, or routing a clogged pipe. High velocity spray and hydraulic head pressure devices include high velocity jet cleaners, cleaning balls, and hinged disc cleaners.
- Sediment or muck removal around the low flow structure, to locate the opening and return it to design conditions. (See M-5 – Dredging and Muck Removal)
- A professional diver may be needed for deeply clogged facilities.
- Dewatering of facility via pumping or other means to reveal the source of clogging and allow access (if regulatory laws permit).

Disposal of debris and trash must comply with all local, county, state, and federal waste regulations. Only suitable disposal and recycling sites should be utilized.

Cautions and Safety Tips

Figure 5.4: After clog is removed

Clearing clogged openings may be easy or difficult depending on access to the opening. If removing an obstruction or clog seems like it might be unsafe, it probably is - leave it to a qualified contractor. Clogged openings can cause dangerous headwater conditions behind the blocked orifice. In addition to the normal hazards associated with low flow maintenance (confined space entry, poor footing, and potential for sharp objects including syringes and glass), strong flow can be generated instantaneously.

If a facility has had deep backwater for a long period of time, sudden de-clogging may actually cause damage due to the slumping of un-vegetated, waterlogged slopes. Further, the downstream receiving swale, storm drain or stream may not be stable enough to withstand the instantaneous plug of release water. The released water will probably be silt-laden, passing an unacceptable amount of sediment, nutrients and possibly toxics. Employ a professional to conduct slow, safe draw-down and probable muck removal.

OSHA approved personal protection equipment will be needed and confined space entry may be required. See M-6 Access for additional riser and manhole access concerns.

M-3 Pipe Repairs

Problems to Inspect For

Pipes are the most challenging feature of ponds and wetlands to thoroughly inspect. Repairs are often expensive and require specialized equipment. Table 5.3 presents a summary of maintenance concerns typical for different pipe materials. Following Table 5.3 are a number of inspection tips to inform an inspector or lay person about things to look for with respect to pipes when inspecting stormwater ponds and wetlands:

Table 5.3: Common Pipe Uses, Material and Maintenance Concerns

Use	Most Common Material	Typical Maintenance Concerns
Principal spillway or barrel	CSP and RCP	Scour damage, leaking joints, misaligned joints
Under drains, internal drains	PVC, HDPE and Clay	Filter media failure, crushing
Infalls	RCP and CSP	Blockages, frost heave, undercutting
Hydraulic control	All types	Clogging, corrosion, vandalism
Quantity control	CSP	Construction rips and tears, misalignments and non-soil-tight joints

Notes:
CSP – corrugated steel pipe; RCP – reinforced concrete pipe; PVC - polyvinyl chloride pipe; HDPE – high density polyethylene pipe

Figure 5.5: Improper pipe joint but rubber seal is visible.

Joint Tightness: All pipe sections should abut evenly with little or no gap. In particular, no barrel should leak. Barrel pipes for ponds should not pass soil or water. CSP joints should meet smoothly, be free of rough or jagged edges, and have a butyl rubber seal surrounding the outside of the joint (Figure 5.5). The seal should not be torn, dry-rotted or bulging. CSP joints are not expected to be watertight (only soil tight[2]) except when used as principal spillways. Figure 5.6 illustrates a joint that is neither soil nor watertight.

Concrete bell and spigot pipe joints may have a gap up to the allowable dimension as described by local ordinance or as determined by the manufacturer. Joints are usually parged with high strength non-shrink grout, but this does not guarantee water

[2] Soil tight means that pipe joints can pass water but they do not allow soil intrusion.

tightness. The tongue and groove end sections of individual pipe sections should be free from damage, especially damage that exposes the underlying re-enforcing steel.

Figure 5.6: Soil entering open pipe joint.

Plastic and clay piping are used in small diameter applications such as underdrains and splitter pipes. HDPE piping is usually installed in long sections without joints but PVC is usually installed with a rubber-coated bell and spigot connections similar to RCP. The use of clay pipes for the principal spillway is discouraged as clay joints are not watertight.

Misalignment: Pipe misalignment (Figure 5.7) is one of the main pipe repair items. Misalignment is often apparent at or shortly after construction. Otherwise, alignment changes occur due to differential settlement, freeze-thaw cycles, or dynamic loads such as traffic.

Figure 5.7: Misalignment in RCP (left and right) and CSP (center) applications.

Pitting and corrosion: Unprotected CSP usually has a relatively long design life on its soil side but is very susceptible to erosive scour, pitting and corrosion on its flow side, particularly along the invert of the pipe. Pitting is highly localized corrosion causing perforations large enough to infiltrate or exfiltrate water. Soil side design life often exceeds 50 years, but flow side design life is usually between 20 and 35 years before the first pitting appears. CSP manufacturers coat piping with various substances to lengthen design life such as bituminous asphalt, aluminum, or concrete poured along the invert of the pipe.

Staining and Calcification: Rust stains inside RCP often indicate infiltration (and probable repair need) due to acidic groundwater leaching in through a crack or hole, slowly dissolving the steel rebar and precipitating it back into a ferrous oxide form on the inside of the pipe (Figure 5.8). Once the anaerobic water comes in contact with the oxygen within the pipe interior the reaction occurs.

Figure 5.8: Rust intrusion demonstrates improper pipe joint.

Figure 5.9: Calcification.

Calcification occurs when acidic water enters concrete cracks from the inside of the pipe, dissolving and reconstituting the hydrated Portland cement in the RCP (Figure 5.9). Calcification may or may not mean that a crack has breached the entire thickness of the pipe and adequate experience is necessary to determine when repairs are truly necessary.

Root Intrusion: Root intrusion into pipe systems is an especially difficult and damaging phenomenon but fortunately is relatively easy to observe. Roots typically enter loose pipe joints and can cause clogging by snagging debris. Willows (*Salix sp*.) are notorious for root intrusion.

By following the described pipe inspection tips above, the lay person or inspector can better understand the types of problems likely to be encountered during stormwater pond and wetland maintenance inspection. Once experience is gained in performing inspections, inspectors can foresee potential problems and plan preventative maintenance.

Corrective Actions

Fixing pipe problems can be approached from two directions: repair or replacement. Different methods for pipe repair and replacement are presented below, as well as a recommended skill level. All involve the need for professional contractor or engineer assistance. Consult an engineer to determine the most appropriate technique.

Common pipe repair methods include:

> *Joint Sealing*: In the injection grouting method, RCP leaking joints and concrete cracks can be sealed with high strength non-shrink grout or epoxy. Holes are drilled all the way through the pipe to the soil beyond. The grout is injected to the other side where it reacts with groundwater and hardens. This method is often used for difficult access areas such as a buried concrete pipe barrel joints. OSHA confined space entry training may be required. CSP joints are similarly sealed, except polyurethane foam water stop material is injected. Recommended skill level (3).
>
> Another joint sealing method utilizes an inflatable packer inserted into a pipeline to span a leaking joint. Resin or grout is then injected into cracks and cavities until the joint is sealed, after which the packer is removed. This localized repair of pipes prevents leakage and further deterioration and may increase the structural strength of the pipeline. Recommended skill level (3).
>
> *Invert Protection*: This method involves protecting the lower segment of a corrugated metal pipe by lining it with a smooth bituminous or concrete material that completely fills the corrugations. This approach is intended to give resistance to scour/erosion and to improve flow. Recommended skill level (2).
>
> *Chemical Stabilization*: Chemical stabilization involves isolating a length of pipeline between two access points by sealing the access points. One or more compounds in solution is introduced into the pipe, and the surrounding ground produces a chemical reaction that forms a stable protective coating over cracks and cavities. Recommended skill level (3).

Pipe rehabilitation typically involves more intensive and comprehensive correction of pipe problems aimed at restoring or upgrading the performance of an existing pipe system. Often, rehabilitation is needed when there is major structural and/or hydraulic weakness. Common pipe rehabilitation methods, all involving the need for professional contractor or engineer assistance, include:

Folded Liners: A PVC or HDPE liner is folded to reduce its cross sectional area. The liner is pulled into a failing pipe system and reverted to its original size using pressure and heat to form a tight fit with the host pipe wall. Recommended skill level (3).

Cured-in-place pipe (CIPP): CIPP is a thin flexible tube of polymer or glass fiber fabric that is impregnated with thermoset resin and expanded by means of fluid pressure onto the inner wall of a defective pipeline before curing the resin to harden the material. Recommended skill level (3).

Ferro-cement: Steel fabric mesh, usually in multiple layers, is fixed to the existing pipe, then covered in high strength grout. It is either placed in situ to form a structural lining (in large diameter pipes with human access) or pre-formed into segments for later installation. Recommended skill level (3).

Pipe bursting: Also known as in-line expansion, this is a method by which the existing pipe is demolished and a new pipe is installed in its void. Recommended skill level (3).

Pipe eating: A pipe replacement technique usually based on micro tunneling to excavate defective pipe with the surrounding soil as for a new installation. Recommended skill level (3).

Pipe pulling: Method of replacing small diameter pipes where a new product pipe is attached to the existing pipe which is then pulled out of the ground. Recommended skill level (3).

Slip-lining: Insertion of a new pipe by pulling or pushing it into the existing pipe and grouting the annular space. The new pipe may be continuous or a string of discrete pipe sections. The latter is also referred to as segmental slip-lining. Recommended skill level (3).

Modified slip-lining: A range of techniques in which the liner is reduced in diameter before insertion into the carrier pipe, then restored to its original diameter, forming a close fit with the original pipe. Recommended skill level (3).

Spray lining: A technique for applying a lining of cement mortar or resin by rotating a spray head, which is winched through the existing pipeline. Recommended skill level (3).

Table 5.4 summarizes the limitations of the different types of pipe rehabilitation methods mentioned above.

Table 5.4: Limitations of common pipe rehabilitation methods

Method	Limitations
CIPP	• Bypass or diversion of flow required • Curing can be difficult for long pipe segments • Must allow adequate curing time • Defective installation may be difficult to rectify • Resin may clump together on bottom of pipe • Reduces pipe diameter
Pipe bursting	• Bypass or diversion of flow required • Insertion pit required • Percussive action can cause significant ground movement • May not be suitable for all materials
Slip-lining	• Insertion pit required • Reduces pipe diameter • Not well suited for small diameter pipes
Modified Slip-lining	• Bypass or diversion of flow required • Cross section may shrink or unfold after expansion • Reduces pipe diameter • Infiltration may occur between liner and host pipe unless sealed • Liner may not provide adequate structural support

Cautions and Safety Tips

Most stormwater pond and wetland pipe work can be visually inspected from a daylighted end or manhole access. However, some piping is difficult to inspect due to being buried, flooded, cramped, or deteriorated. In this case, inspection work should be left to qualified professionals versed in confined space entry and exit as defined and regulated by state and federal OSHA standards. Some piping is impossible to inspect manually (such as a 6-inch underdrain), and remote TV video inspection or complete unearthing are the only options.

M-4 Vegetation Management

Problems to Inspect For

Vegetation management is the most frequent type of maintenance conducted on stormwater ponds and wetlands. In most instances, vegetation management is straightforward and does not require special expertise or equipment. However, if facilities have gone long periods of time without proper vegetation maintenance, then the level of effort and complexity of the activity can become significant.

Telltale signs of vegetative problems include the following:

- Standing water and emergent plant growth where none should be present
- Poor or spotty grass growth or completely bare areas (Figure 5.10)
- Soggy surfaces
- Excessive sedimentation at pond infalls or outfalls with corresponding emergent plant growth (Figure 5.11)
- Limited visibility or access to the principal spillway or embankment areas due to vegetation
- Deep-rooted woody vegetation (trees and shrubs) on any areas of a dam
- Woody vegetation growing in riprap on slope areas meant for erosion protection
- Signs of seepage around any tree stumps or decaying root systems on embankment areas
- Changes in vegetative color, species or height due to possible groundwater or seepage problems
- Areas where local residents have been dumping yard waste
- Pond embankments with newly planted ornamental trees or shrubs not originally included in the design
- Damaged or torn erosion control matting (ECM)
- Ruts or erosion channels in vegetated swales or level spillways
- Tree or shrub growth in or around major pond appurtenances such as the principal spillway
- Monoculture vegetation in wetland

Figure 5.10: Bare soils on embankment and slopes

Figure 5.11: Excessive vegetation near an outfall

Corrective Actions

The following describe specific activities associated with maintaining the vegetation in and around stormwater ponds and wetlands as well as the recommended skill level of the person performing the maintenance in parentheses (reference Table 5.1):

Grass and Turf
Consistent mowing and monitoring should control any unwanted vegetation. Typical mowing areas include pond bottoms (dry ponds), embankments, side slopes, perimeter areas, and access areas (Figure 5.12). The actual mowing requirements of an area should be tailored to the specific condition and grass type. Other actions to maintain grassed areas include periodic fertilizing, de-thatching, soil conditioning and re-seeding.

Figure 5.12: Representative mowing for wetland

Most grass is hardiest when maintained as an upland meadow, cut no shorter than 6 to 8 inches. If a more manicured look is desired, special attention to the health of the turf is needed. Grass should not be cut below 4 inches. Typical mowing schedules for grass on embankments are at least twice during both the spring and fall growing seasons and once during the summer. Recommended skill level (0).

Vegetated Buffer
A 10-foot un-maintained vegetated buffer around the perimeter of the pond or wetland (exclusive of the dam embankment) may be established to filter pollutants from adjacent properties and help prevent shoreline erosion (Figure 5.13). Areas set aside for pond access such as fishing can be secured with stone, timber wall or one of many commercially available plastic retaining wall products. Recommended skill level (0).

Figure 5.13: Vegetated buffer

Vegetation Harvesting
In stormwater wetlands, vegetation harvesting[3] may be required. To perform wetland harvesting, selected plant materials are tagged for removal by a qualified professional, then cut and hauled to an upland disposal location. Recommended skill level (1 - 2).

[3] Vegetation harvesting is removing vegetation on a routine basis and land applying it in an upland location. The purpose for vegetation harvesting is to remove plant material before winter die-off to prevent nutrients from reentering the water column and being flushed downstream.

Bare areas

Vegetation can be established by any of five methods: mulching; allowing volunteer vegetation to become established; planting nursery vegetation; planting underground dormant parts of a plant; and seeding. Seeding can come in the form of broad-cast seeding, hydro-seeding or sodding. Donor soils from existing wetlands can be used to establish vegetation within a wetland. If the soil has become compacted, it will require aeration. Areas without grass or vegetation should be vigorously raked, backfilled if needed, and covered with topsoil. Disturbed areas should be seeded and mulched if necessary. A tall fescue grass seed is often recommended; however consult the local NRCS office for the best native mixes for the project location. Recommended skill level (0).

Bare or monoculture stormwater pond and wetland slopes and bottoms offer the best opportunities to enhance areas with native trees, shrubs, and groundcovers to help the water soak into the ground. Select species that need little fertilizer or pest control and are adapted to specific site conditions. Again, contact your local NRCS office for guidance.

Unwanted vegetation

Some vegetation, such as that on embankments (Figure 5.14), requires complete removal, including root masses, to ensure that it does not return; this is often best done with landscaping Brush Hogs™ or small earthmoving equipment. Stump removal may also require tractor and chain. The removal of large trees may require the skills of a professional arborist. The use of herbicides should be avoided; however if deemed necessary, they must be applied by a state-licensed herbicide applicator. Recommended skill level range (0 - 2).

Figure 5.14: Unwanted vegetation - tree on embankment

Root removal

Roots shall be removed in the designated sections where root intrusion is a problem. To remove roots from a pipe, use mechanical devices such as rodding machines, bucket machines, and winches using root cutters and ‘porcupines’ or equipment such as high-velocity jet cleaners. Chemical root treatment is available but discouraged and herbicides must be applied by licensed applicators.

Roots should be removed from the embankment to prevent their decomposition within the embankment. Excavate to remove roots, then plug or cap root voids. Recommended skill level (2).

Dumping areas

Grass clippings, leaves, soil and trash are often dumped directly into storm drain inlets or stormwater ponds and wetlands. Any of these items can lead to clogging, and leaves and grass clippings release bacteria, oxygen consuming materials, and nutrients. Removal is easy assuming a suitable disposal area or trash pickup location is available. Posting signage explaining the importance of non-dumping will help dissuade the good intentioned. Signage may also advise natural lawn care to minimize the use of chemicals and pesticides. Recommended skill level (0).

Inadequate drainage slopes

To promote proper conveyance and to prevent standing water, conveyances to and from ponds and wetlands should have a minimum slope of one to two percent. Inadequate slopes typically result in the conveyances filling with sediment and vegetation (Figure 5.15). Removal of muck and vegetation from conveyances can be accomplished with small equipment. See Section M-5 – Dredging and Muck Removal. Recommended skill level range (1 - 2).

Figure 5.15: Vegetation establishment where the inflow channel slope is inadequate to drain properly.

Cautions and Safety Tips

Although the removal of unwanted vegetation is not a professional skill, it is not without hazards. Possible hazards include cuts and scrapes from the brambles and thorns of species such as Multiflora Rose (*Rosa multiflora*) and Tear thumb (*Polygonum perfoliatum*). Overgrown vegetation can also obscure ledges, burrows, drop-offs, stumps and wasp nests.

M-5 Dredging and Muck Removal

Problems to Inspect For

The need for dredging may be indicated by sediment plumes or deltas at storm drain infalls that feed stormwater ponds and wetlands, as most sediment falls to the pond floor quickly and within a short distance from storm drain inflow points (Figure 5.16). Alternatively, accumulated sediment can be measured through use of a staff gauge[4].

Figure 5.16: Sediment delta.

The best way to estimate dredging needs for a pond or wetland with is to perform a bathymetric study. A bathymetric survey involves taking field measurements to calculate the volume of water within a pond or lake. The survey is similar to a topographic measurement of the contours below the permanent pool surface of a pond. The end result of the survey is a two-dimensional map indicating depth contours at all locations within the permanent pool. Bathymetric surveys indicate the amount of silt or muck that has accumulated within a pond or lake; consequently, estimates of remaining stormwater pond life, dredging volumes and associated costs can be made. A pond that appears full may still have adequate volume for settling suspended solids and for meeting stormwater management design criteria purposes, yet the owner may wish to have the pond dredged for aesthetic value.

Bathymetric surveys require use of level rods, electric distance measurement equipment (EDM), small watercraft, sediment probes or depth finders to gather pond depth information (Figure 5.17). Usually, staff measures the depth with a canoe or johnboat. On shore, another staff uses EDM equipment to determine distance and azimuth (angle) measurements to the test location. Existing volume measurements can be compared against design volumes to determine the amount of muck requiring removal (Figure 5.18). If no previous design records exist, the procedure is basically the same, but additional sediment depth probing must be done to measure muck levels.

Figure 5.17: Measuring pond depth from canoe.

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[4] A staff gauge is a fixed marker rod that enables easy reading of sediment levels in a pond once the pond has been drained.

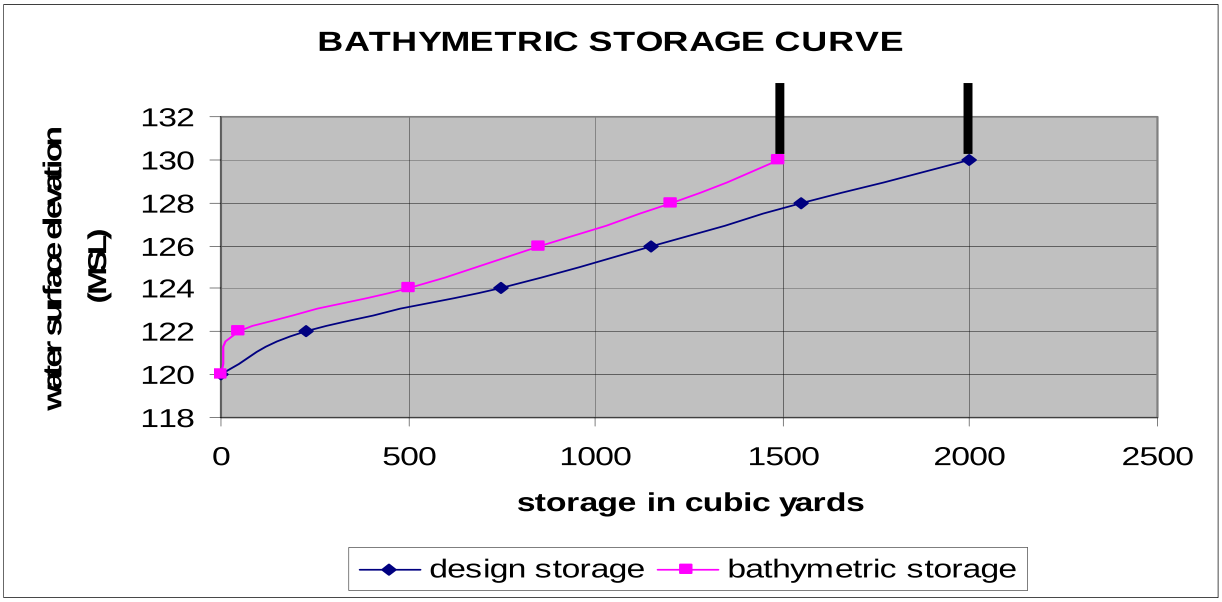

Figure 5.18: Plot of elevation vs. storage for existing and design conditions.

Dredging needs for dry ponds are easier to identify. There may be a profusion of vegetation, particularly wetland species, at the bottom of the facility. Pilot channels may disappear due to the accumulation of sediment and trash. An obvious sign for quick action is a buried low flow opening. Sediment in a dry pond can also be measured with a preset staff gauge; but hand-taped or simple field surveys can also suffice.

Corrective Actions

In smaller ponds and wetlands, the pond level may be drawn down to a point where the residuals can begin to dry in place. After the material is dried, heavy equipment can remove the sediment from the bottom of the pond, a process referred to as mechanical dredging. Mechanical dredging may be accomplished with a standard or long reach backhoe, front end loader, dipper, bucket dredge, drag line or clamshell dredge (Figure 5.19).

Figure 5.19: Mechanical dredging with backhoe.

Where dredging cannot be accomplished mechanically from the shore, it may be necessary to remove sediment using hydraulic dredging methods[5]. Larger ponds that cannot be drained are often de-mucked via hydraulic suction or with the use of draglines operated from barges. In ponds not

[5] Hydraulic dredging uses a combination of water jet and vacuum to resuspend settled material and pump it to an upland location or other place for dewatering.

large enough to warrant hydraulic dredging, mechanical dredge methods are used and removed material is de-watered to minimize trucking requirements and potential spilling.

Dry ponds are typically dredged with conventional earth moving equipment such as backhoes, trackhoes, dozers, and excavators. Material is disposed of in a similar fashion to wet ponds but removal is often easier as muck has already had an appreciable time to de-water.

WETLAND DREDGING TIP:

Maintenance dredging of a stormwater wetland can significantly damage the wetland community that has developed over the life of the practice, and may be met with resistance from regulators and adjacent property owners. Typically, if a wetland was constructed specifically for stormwater treatment and not as mitigation for other wetland impacts, owners can maintain them without permits. However, permitting authorities having jurisdiction over the site should be informed prior to disturbing any wetland area for maintenance or other purposes.

If a diverse native wetland plant community is present in a stormwater wetland, for maintenance purposes it may be advisable to scrape and stockpile the surface soil layer in a designated location for future reapplication. The surface layer may contain seedbank that, when reapplied, can help the wetland plant material reestablish after the excess sediment has been removed. If a non-native or invasive wetland plant community has been established, conduct removal with care or during a dormant season to discourage seed distribution.

Sediments from ponds and wetlands are usually dewatered and then disposed of onsite or land filled. It is not unusual to spread this material out on a site for use as a soil amendment. Onsite disposal usually entails digging a pit, wasting the muck material, covering the pit with previously removed topsoil and planting the appropriate native plantings. Once a dredge area disposal site is established, it cannot be used for structural support or building foundations as long-term settlement will occur.

If on-site storage is not specified, sediment can typically be landfilled. Wet sediment is not accepted at many disposal sites; therefore, the material must be dewatered prior to disposal. This extra step adds to the cost and requires a location where wet material can be temporarily and safely placed to dry.

If the practice drains a stormwater hotspot, such as a gas station, a Toxic Contaminant Leachate Procedure (TCLP) or other analytical analysis should be performed in accordance with receiving landfill requirements to determine if the removed sediment should be considered a hazardous waste. If the residual solids are determined to be hazardous, they must be managed according to Resource Conservation and Recovery Act of 1976 (RCRA), which requires either treatment to decrease the concentration of the hazardous constituent or disposal in a hazardous waste landfill.

Cautions and Safety Tips

Economic and safety risks involved in dredging and muck removal include proper disposal, confined space work, permitting and utility damage. This work is best left to general contractors and specialty maintenance companies with adequate training and bonding. The recommended skill level range for all dredging issues is (3).

M-6 Access

Problems to Inspect For

Inadequate access is typically discovered by inspectors or maintenance contractors who cannot enter a site or particular site features (e.g. risers). Inspectors should be cognizant of the types of equipment needed to maintain a stormwater pond or wetland, so they can note potential access issues (Figure 5.20). If potential access issues are noted up front, the maintenance contractor can be warned and can plan accordingly.

Figure 5.20: Poor vehicle access.

Risers and manhole access can be particularly challenging and dangerous, particularly when access steps are missing (Figure 5.21) or no manhole access has been provided. In these cases, it is necessary to lower staff by winch once the atmosphere has been tested. Therefore, mandatory fall protection should be used when accessing risers or manholes.

Figure 5.21: Missing manhole step

If no manhole access is provided and water enters a riser through weirs or orifices that are too small to allow direct access, the riser may still be entered safely through the barrel (principal spillway) if certain conditions are present. In Howard and Montgomery Counties, Maryland, safe barrel access is defined by the following conditions:

- Conducted by qualified confined space entry-trained staff (team of two with proper equipment).
- The barrel is open to daylight at both ends and no atmospheric dangers are present.
- The diameter of the barrel is 36 inches or greater.
- There is little to no tailwater making access unsafe, defined as blocking more than a third of the opening (Figure 5.22).

Figure 5.22: Forced access location.

Given these conditions, the barrel may be crawled. Verbal contact should be kept with the crawler at all times. Each joint may be examined by hand for leaks and discontinuities. The inspector may enter the riser to inspect it once he or she has traversed the barrel.

Corrective Actions

Figure 5.23: Tree scar protection

Many access issues are best addressed during the design of ponds and wetlands (see Chapter 2). However, there are routine maintenance activities that will also be required. Most notably, it is important and advisable to maintain primary access features as they were designed. This typically involves removal of woody vegetation from access roads and the upkeep of gravel areas. Risers with missing steps, manhole covers, or trash racks that present unsafe situations should also be repaired so that future access for inspection is not compromised.

In some cases, where major work needs to be performed, temporary construction access for large, heavy equipment will need to be provided. In these situations, special provisions should be taken to minimize impacts to adjacent areas, particularly if they are forested. Common tree protection measures include fencing that is sufficiently set off to provide protection of the critical root zone and protective sheathing (Figure 5.23).

Figure 5.24: Paved access road

Heavy vehicle access will also impact areas with paving, curbs and decking (Figure 5.24). For the mutual protection of both the owner and contractor, these access points should be clearly marked or flagged and then photographed prior to equipment arrival onsite. Temporary pavement protection devices include:

- Steel sheeting
- Timbering and mats
- Stabilized stone and gravel construction accesses and mountable berms
- Unloading and ‘walking’ equipment in on rubber tires

If a fenced pond or wetland does not have vehicle gates large enough to accommodate heavy equipment, sections of fence will need to be temporarily removed to allow access.

Cautions and Safety Tips

Mandatory fall protection should be used when accessing risers or manholes. Risers and manholes may be missing access steps, and lowering staff by winch may be required once the atmosphere has been tested.

M-7 Mechanical Components

Problems to Inspect For

Early identification of problems and speedy repair is important to ensure the maximum design life of mechanical components, most of which are metal. Signs of common mechanical failures include:

- Loose trash rack pieces
- Rust and corrosion
- Original lift lugs still in place for pre cast concrete structures
- Nicks and cuts in protective coatings
- Loose or corroded bolts
- Form nails and ties still present for cast-in-place concrete structures
- Leaking valves
- Corroded locks
- Hand wheels that won't turn
- Missing tools necessary for valve maintenance
- Pock marks
- Standing water
- Flaking

Corrective Actions

Although most mechanical component maintenance is straightforward, it is usually out of the range of normal services provided by landscaping staff. Therefore, repairing and replacing these components should be left up to general contractors. For mechanical component problems external to confined spaces (Figure 5.25), the recommended maintenance skill level would be (1). For mechanical components in confined spaces, the recommended maintenance skill level would be (2).

Figure 5.25: Valve outside riser.

Valves

Appurtenances with moving parts, especially valves, require annual exercising and lubrication. Most valves are hand-wheel valves that take several turns to completely open (often over thirty turns); however, exercising or temporarily opening a valve does not necessarily involve opening it completely. Staff need only rotate the wheel enough times to make sure the metal gate moves up and down. This procedure may involve two or three wheel rotations and a small amount of water may be released. After the valve is exercised, the staff should slowly close the valve, making sure the gate properly re-seats to a watertight closure position or to the appropriate opening dimension. If a valve gate won't move, it may need to be serviced or replaced. If the valve won't close after being opened a few turns, it will also need service.

Valve service typically means applying lubrication. Lubrication involves greasing the valve corkscrew stem and should only be done once it is determined that the valve will safely close again. Water will be released during this five to 15 minute operation as most valves must be completely open during lubrication.

Most valves draw water from at or near the pond bottom where sediment accumulates. Avoid the quick opening of valves as water released will be turbid and sediment will be introduced to downstream receiving areas. Open the valve slowly and allow the conditions at the permanent pool end to stabilize prior to complete opening.

Extended length and non-hand wheel valves
Some valves are installed with extended stems to allow safer opening from well-above the actual valve itself. Some valve types do not have hand wheels and are more vandal-resistant but require either a cog or 'T' key to open. The key may or may not be present in the riser box. If it is, it should be securely stored in a place where it cannot be removed and preferably as far removed from running water as possible. If the key is stored off-site, this may pose a problem if the pond needs to be dewatered in an emergency.

Rust-proofing
Although some plastic, aluminum or PVC appurtenances are available, most mechanical components are galvanized metal. Metal oxidization is an inherent maintenance concern in stormwater pond and wetland environments, so several methods of rust protection are employed including painting with zinc-rich or galvanizing paint, coating with bituminous tar or rubber and the use of stainless steel. Water chemistry, temperature extremes, clogging and vandalism will speed oxidization.

Repair work usually involves the removal of all rust with a wire brush to expose clean metal, if still present. Exposed metal is painted with a rust-proofing agent. Metal that has rusted through should be patch welded or replaced.

Securing bolts
The weakest metal component is usually the bolts securing the metal to a concrete wall. An under-strength or under-protected bolt may meet temperature and shear stress extremes, as well as the concrete chemistry or other potential chemical attack. Often, bolts securing a trash rack or orifice plate fail long before the appurtenance fails. Once bolts have rusted through, they must be replaced. Usually the original drill hole has been compromised and a new drill hole must be installed.

Aerators
Aerators will be wired to an outside electricity source and they will most likely have an air hose running out to the underwater diffuser head (Figure 5.26). Both types of lines (electrical and air) should be inspected for kinks, exposed wire and dry rot and replaced as necessary.

Figure 5.26: Surface aerator / fountain.

Ponds having bubblers, aerators, fountains or diffusers may require specialty contractors or manufacturer representatives for repairing severe maintenance problems. Pump clogging, air hose deterioration or diffuser head clogging may be simple repair items, but an assessment of the difficulty must be made prior to making a judgment call about who is suited to perform the maintenance activity.

Cautions and Safety Tips

The opening of valves is an inherently risky procedure, especially when carried out in under confined space conditions. There is a small potential that valve opening may cause an uncontrolled quick release of ponded water, which will flood the access area. Therefore, it is critical that correct confined space procedures be adhered to and suitable removal gear (such as a winch and harness system) be employed for emergency retrieval of maintenance staff that may be momentarily overcome by water under high pressure flow, slick, or cold conditions.

Servicing of electrical components and welding repairs should be performed by professional contractors. Inherent wet conditions can pose safety threats to inexperienced inspectors and maintenance crews where electricity is involved. If inspecting electric-dependent mechanical components, shut off power prior to inspection and use full body rubber coverage, including gloves.

M-8 Nuisance Issues

Animals

Problems to Inspect For

Animal burrows, dams, and dens can be significant maintenance issues associated with proper pond and wetland operation and structural stability (Figure 5.27).

Figure 5.27: Animal burrow in pond embankment.

Groundhog/woodchuck burrows are above the permanent pool and are easier to spot than muskrat burrows, which are located both at and below the permanent pool. Overgrown dam embankments may be riddled with burrow complexes that are not visible to the eye until the brush has been cleared. Usually, if one burrow is found, more are present, as rodent burrowing complexes usually have several ingress/egress points.

Beaver dams and dens (Figure 5.28) tend to be obvious in all but the most neglected stormwater ponds and wetlands where damming may have been present for so long that the original appearance has been almost permanently altered.

Figure 5.28: Beaver dam.

Muskrats tend to be elusive but are occasionally visible. Groundhogs tend to be less shy and sometimes can be seen either feeding or loafing in grassy areas. Beavers are visible in relation to how comfortable they are with human presence. Another indication of rodent activity is the 'slide trail' located on slopes where rodents have created paths for commuting and dragging brush.

Corrective Actions

Rodent management is a contentious issue with strong feelings both for and against the presence of these animals in a suburban setting.

Existing burrows should be plugged by filling with material similar to the existing material and capped just below grade with a 50/50 mix of soil and concrete. If plugging of burrows does not discourage the animals from returning, further measures should be taken to either remove the animal population or make critical areas of the facility unattractive to them.

Management options for beaver control include complete tolerance, evaluation on a site-by-site basis, and complete removal. Beaver populations typically will only respond to trapping, dam and lodge removal, or the use of beaver “baffles”. Beavers usually do not remain in unsuitable areas. If their dams are breached and their lodges are damaged on a regular basis, the animals typically move on to another location. For instance, their lodges and dams may be removed by simple mechanical methods over two to three seasons. Once these structures are destroyed, regular maintenance of the facilities is often adequate to prevent their activity from becoming a future problem.

However, maintenance staff should be prepared for the displaced animals to be persistent in their efforts to maintain their dams and lodges. Monthly site checks are recommended to ensure that dams and lodges are not rebuilt in the weeks after the initial removal. Once there is no evidence of recent beaver activity, normal less frequent maintenance usually suffices to keep the facility functioning properly.

If there can be no tolerance of beaver activity, then the parties responsible for beaver control must consider trapping or relocating the unwanted animals. It is important to keep in mind that whatever features make the community appealing to one beaver will also make the area desirable to other beaver. Once one animal or family is removed, the pond will likely be re-occupied by other beaver, as young males are forced to find their own habitat areas each spring. Animal specialists perform trapping. If removal or trapping is utilized as a management tool, expect to continue trapping the area on a regular (i.e., seasonal) basis to maintain the level of control desired by the community. There are two additional points to consider concerning trapping:

- Beaver relocation is much more expensive and challenging than straight trapping (killing beaver with standard beaver traps).
- The existence of jurisdictions willing to accept relocated beavers is limited.

The final option for minimizing the impact of beaver activity is the use of proprietary beaver baffles. The baffles do not eliminate the beaver impoundments, but are intended to minimize their size. The purpose of the baffle is to reduce the impact of rising water levels on real property (bridges, open areas, private property, pathways, etc.) by providing a manual method for changing the water level in the ponds (thus, making dam building more difficult).

Waterfowl

Problems to Inspect For

Waterfowl damage usually takes the form of either reduced vegetative species due to overgrazing, or poor water quality due to high fecal coliform counts. Waterfowl issues usually involve the overpopulation of year-round duck (Figure 5.29) and geese populations (usually Canadian Geese, *Branta canadensis*). Geese and duck droppings on asphalt paths, pond side slopes, docks and cart ways are also easy aesthetic nuisances to spot.

Figure 5.29: Duck family.

Corrective Actions

In addition to the design options presented in Chapter 2, the following actions can control waterfowl impacts:

- Adding shoreline vegetation and no-mow zones.
- Proprietary products for managing/discouraging waterfowl/goose populations
- Trained canines to intimidate geese - Border Collies are the most common species used.
- Egg addling - shaking the eggs of nesting geese to make the eggs nonviable while still allowing the female goose to perform her breeding duties.
- Predator introduction such as hunters and snapping turtles.

Mosquitoes

Problems to Inspect For

Mosquito problems are usually brought to the attention of the maintenance authority by adjacent homeowners. Judgment and education are necessary for maintenance staff to assess whether existing mosquito populations near stormwater ponds and wetlands are out of balance with normal populations for the area. Well designed stormwater ponds and wetlands often provide enough predator habitat that mosquito populations are kept in check.

Corrective Actions

The most effective mosquito control program is one that eliminates potential breeding habitats. Most stagnant pools of water can be attractive to mosquitoes, and the source of a large mosquito population. Ponded water such as open cans and bottles, debris and sediment accumulations, and areas of ground settlement provide ideal locations for mosquito breeding. A maintenance program dedicated to eliminating potential breeding areas is preferable to controlling the health and nuisance effects of flying mosquitoes.

Contract with a private company to perform the work or participate in a state mosquito control program, if available. State programs typically provide comprehensive adulticide and larvicide programs, whereas private companies tend to be restricted to the larvicide program. Adulticide programs often employ evening spray applications using restricted use pesticides. Larvicide programs target potential breeding areas and treat them with non-restricted-use pesticides or biological controls such as specific bacteria, mosquito fish, and growth regulators. Seasonal stocking of predator fish keeps mosquito populations under control by reducing the number of mosquito larvae. Gambusia fish are typically used in warmer climates and black striped top minnow (*Notrophus fundulus*) is used in colder climates.

Undesirable Plant Communities

Problems to Inspect For

Diverse plant communities support diverse and balanced aquatic communities that host beneficial species such as mosquito predators. Poorly maintained ponds and wetlands are particularly susceptible to the establishment of undesirable plant communities that include monocultures and non-native invasives. Aquatic plant species such as cattails and common reed are typical monocultures seen in ponds and wetlands. Similarly, side slopes and embankments are susceptible to rapid colonization by non-natives such as multiflora rose, kudzu (southeastern states), purple loosestrife, and porcelain berry.

Corrective Actions

Management of monolithic plant communities and weeds requires a long-term commitment to action to prevent large-scale problems. Mechanical and hand removal of monocultures such as cattails and common reed is often necessary in conjunction with replanting with other appropriate native emergent species. Algaecides and herbicides are often used to eradicate existing weed species. This method treats the problem as an ongoing maintenance issue and generally requires multiple treatments throughout the growing season. It is often the most effective method of maintaining the desired aesthetic standard for a pond.

Caution should be exercised in performing chemical applications in that some applications may have the desired affect of removing unwanted vegetation, but may increase toxic risks to other resident species. The removal of one weed species creates an opportunity for the growth of another. Once the initial weed is eliminated, the ecological niche previously occupied by the species becomes available to other opportunistic species. Note that multiple applications may be necessary to maintain the desired aesthetic standard for a stormwater pond or wetland.

Maintaining and/or planting upland buffer zones can help to reduce the introduction of nuisance plant species. Planting emergent vegetation may also reduce nuisance algae blooms and waterfowl access. These plants compete with the algae for the available nutrients stored in the pond substrate. As fewer nutrients are available for the algae, their prolific growth potential can be suppressed. Another vegetation management technique is through the establishment of buffer strips or "no mow areas" around the perimeter of stormwater wet ponds and wetlands. These zones help intercept and filter nutrient laden runoff as well as stabilize pond banks. To minimize the protection mosquitoes are offered by taller plants, the use of low growing plants is recommended.

Water Quality Degradation
Problems to Inspect For

Stormwater ponds and wetlands are susceptible to poor water quality when upland land uses are highly urbanized, deliver large quantities of nutrients, or contain illicit discharges containing high concentrations of bacteria and other pollutants. Pond and wetland designs with inefficient turn over (i.e., poor flow circulation) also contribute to water quality degradation. Common indications of poor water quality include an off color (e.g., bright green sheen from algae) or unpleasant odor (e.g., presence of bacteria).

Corrective Actions

Maintaining water quality in stormwater ponds and wetlands is challenging, as they are designed to retain constituents in stormwater that can degrade receiving waters. However, a number of water quality related fixes are noted below:

Dyes and shading
As a photosynthetic organism, algae requires the presence of light to survive. Dyes artificially shade the pond reducing light transmission through the water column. This limits the available habitat conducive to algae growth within the pond to the top first inches of the pond. If water clarity is maintained low enough, bottom growing weeds and algae can be controlled. However, rainfall can dilute the dyes and force repeat applications. Also some people find that the dyes create an objectionable artificial color to the water.

Bacterial Improvements
Excessive sediments in a pond can contribute to algae problems. If sediment layers become anaerobic, harmful chemicals, noxious odors, and phosphorus can be released into the water column. These conditions can be minimized through the introduction of bacteria in the pond. The bacteria, in the presence of adequate aeration, "digest" the muck layer without producing the harmful side effects, such as odor, associated with anaerobic decomposition. Through the reduction of available phosphorus, algae growth can be limited. Treatments usually start in early April and continue through September.

Barley Straw
Introduction of bales of barley straw to the pond can help control algae blooms. When barley straw is placed into the water, it decomposes releasing chemicals, which inhibit the growth of algae. It takes usually from six to eight weeks to work when water temperatures are below 50 degrees Fahrenheit, and one to two weeks when the water is above 68 degrees Fahrenheit (Newman, 1997).

Diffusers and surface aerators
Air can be introduced into the pond or wetland through various systems to facilitate biological decomposition of pond muck, de-stratify thermal layers in the water and improve the ecological health of the system. In general air promotes biological activity, which reduces the amount of available nutrients for algae.

Diffusers use an air compressor and hoses to bring air into the water column of the pond or wetland. Diffuser systems are low maintenance and are often compared to aquarium compressors on a larger scale. They require annual maintenance and are not recommended for permanent pools less than eight feet deep.

Aerators resemble fountains in their appearance. They require a motor mounted to an impeller or other type of agitator to "splash" the water. This physical action introduces air to the water. They should be removed from the pond in the late fall to prevent freeze damage and returned to the pond in the spring, after the last freeze. Trash, debris, algae, pond weeds and aquatic plants can bind up moving parts, causing excessive wear and generally cause motors to burn out prematurely. Because these aerators typically draw from the surface of the pond, they are generally not recommended for reducing algae bloom potential or increasing dissolved oxygen in the system, but may provide visual enhancement.

Flocculants
Flocculants are chemicals applied to ponds to act indirectly on the algae through promotion of settling. The application of flocculates of buffered alum products to the water causes phosphorus and other materials suspended in the water column to settle. Removal of the phosphorus from the water column limits the amount of this nutrient available to support algal growth. This works best when water clarity is greater than 24 inches. However, soils with excessive nutrients introduce phosphorous with every rain event and as a result, phosphorus levels are quickly recharged and the value of floccing the pond is minimized.

Cautions and Safety Tips

Addressing nuisance issues has few associated safety hazards when appropriately trained individuals conduct the specific tasks (e.g., trapping, chemical application).

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Appendix A:

Unit Costs for Pond and Wetland Maintenance

TABLE A-1. UNIT COSTS FOR POND AND WETLAND MAINTENANCE[1]

Maintenance Item	Unit Price ($)	Unit	Mobilization Cost ($)[2]	Maintenance Interval (yrs)[3]
Permanent Pool Issues				
Dam/ Embankment				
unclog internal drains for embankments	10	lf	1,500	R (10)
repair low spots in dam or berm	170	cy	1,500	R (5)
Clogging				
debris removal (preventative)	350	event	0	0.25-1
clear outfall channel of sediment	130	cy	0	5-15
clogged low flow	750	event	800	0.25-1
Pipe Repairs				
Structural - Riser and Barrel				
re-tar CMP barrel	11	sf	800	15-20
install new elbow underground	1,200	ea	800	R
repair CMP barrel joint leak	530	ea	800	R (3-5)
repair leaking concrete principal spillway joint	1,200	ea	0	R (5-10)
replace riser (CMP)	12,000	ea	>2,500	R (25)
replace riser (concrete)	20,000	ea	>2,500	R (50)
replace barrel	1,000	lf	>2,500	R (25-50)

1) These costs were largely derived from data from the Maryland region, based on bid proposal and actual project data.
2) Cost at four levels: $0 for no mobilization; $800 for minimal mobilization; $1,500 for small project mobilization; >$2,500 for large project mobilization. Note that these are approximations. For items with no mobilization cost, it is assumed that the mobilization cost is incorporated into the overall unit cost, or that the maintenance can be completed during inspection.
3) Bottom number in range represents ideal maintenance interval. Top number represents maximum interval between maintenance activities. R indicates repair items, whose frequency is somewhat unpredictable. The frequencies sometimes reported in parentheses represent an estimate of typical repair frequency.

Maintenance Item	Unit Price ($)	Unit	Mobilization Cost ($)[2]	Maintenance Interval (yrs)[3]
Structural - Pipes				
replace existing underground elbow	1,400	ea	800	R (10)
slip line failing pipes	90	lf	>2,500	R
replace end sections <36"	600	ea	1,500	R
remote control TV video pipes	1	lf	800	5-25
Structural - Other Concrete				
concrete work under ground	600	cy	1,500	R
concrete work above ground	450	cy	1,500	R
grout cracks	50	lf	0	R
parge spalling	25	sf	0	R
repair gutter spalling	230	event	800	R
injection grout concrete leaks	180	lf	800	R
Structural: Metal				
new low flow trash rack	1,700	ea	800	R (5-10)
install high stage trash rack 4'x2'	1,100	ea	1,500	R (20+)
replace CMP anti-vortex device <48"	1,500	ea	1,500	R (10-15)
replace CMP anti-vortex device >48"	4,600	ea	1,500	R (10-15)
remove bolts, lift lugs, form nails	80	ea	800	R

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3. Bottom number in range represents ideal maintenance interval. Top number represents maximum interval between maintenance activities. R indicates repair items, whose frequency is somewhat unpredictable. The frequencies sometimes reported in parentheses represent an estimate of typical repair frequency.

Maintenance Item	Unit Price ($)	Unit	Mobilization Cost ($)[2]	Maintenance Interval (yrs)[3]
Vegetation Management				
sod	3.30	sy	800	1-2
seed and top soil bare areas (3 inch depth)	4.40	sy	800	1-2
plant 1.5 inch tree	84	ea	0	R[3]
plant shrub	15	ea	0	R
mowing	300	ac	0	0.5-1
clear outfall and channel of trees	5.50	sy	800	0.5-1
clear embankment of small trees by hand	3.30	sy	800	0.5-1
clear embankment trees with Ambusher or Brushhog	0.90	sy	800	0.5-1
remove live tree (<12 inches)	130	ea	800	R (1-10)
remove live trees larger than 12 inches, <24 inches	250	ea	800	R (10-25)
remove downed timber (up to 40 cy of material)	2,200	event	0	0.25-1
remove dumped vegetative material (up to 40 cy)	2,600	event	0	0.25-1
install wetland plant	6	ea	800	R (3-5)
remove invasive wetland vegetation (machine remove phragmites) (up to 40 cy)	3,000	event	0	R
spray for algae (0.25 ac pond)	600	ea	0	R
spray for cattails (0.25 ac pond)	330	ea	0	R
repair low spots in dry pond bottom	25	sy	1,500	R
remove woody vegetation from dry pond bottom	1,700	event	0	5-10

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3. Bottom number in range represents ideal maintenance interval. Top number represents maximum interval between maintenance activities. R indicates repair items, whose frequency is somewhat unpredictable. The frequencies sometimes reported in parentheses represent an estimate of typical repair frequency.

Maintenance Item	Unit Price ($)	Unit	Mobilization Cost ($)[2]	Maintenance Interval (yrs)[3]
Dredging and Mucking				
dredge wet ponds (jobs larger than 1000 cy) haul offsite	60	cy	>2,500	5-15
dry pond sediment removal	7,600	event	0	15-25
dewater pond	900	event	0	15-25
muck out undergrounds	390	cy	0	0.5-1
dewater and remove sludge from underground facilities	1	gal	0	0.25-1
typical sediment dump fee (not including trucking)	66	ton	0	NA
truck day for landfill to transport underground dredge materials (minimum, assume 2 to 4 trips in one day)	800	trip-day	0	NA
Access/ Safety				
install warning signs	210	ea	0	R
add manhole steps	100	ea	800	R
new manhole cover	250	ea	0	R
create 12' access road (permanent, cut/fill balances)	40	lf	1,500	R
create 12' access road (permanent, cut/fill non-balance)	65	lf	1,500	R
create 12' access road (temp)	12	lf	1,500	R
install chainlink fence	26	lf	800	R
install ladder (8 foot)	220	each	800	R
install three rail fence	15	lf	800	R
repair asphalt path	26	cy	800	R
supply lock and chain for first one (additional at $30 apiece)	130	ea	0	4-8

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2. Cost at four levels: $0 for no mobilization; $800 for minimal mobilization; $1,500 for small project mobilization; >$2,500 for large project mobilization. Note that these are approximations. For items with no mobilization cost, it is assumed that the mobilization cost is incorporated into the overall unit cost, or that the maintenance can be completed during inspection.
3. Bottom number in range represents ideal maintenance interval. Top number represents maximum interval between maintenance activities. R indicates repair items, whose frequency is somewhat unpredictable. The frequencies sometimes reported in parentheses represent an estimate of typical repair frequency.

Maintenance Item	Unit Price ($)	Unit	Mobilization Cost ($)[2]	Maintenance Interval (yrs)[3]
Mechanical Components				
remove old valve	300	ea	800	R (10)
install new valve (<36 inches)	4,600	ea	1,500	R
install new valve (< 24 inches)	3,100	ea	1,500	R
install new valve (<11 inches)	1,300	ea	1,500	R
install new valve (<7 inches)	460	ea	800	R
lubricate valves (same price for first four)	300	ea	0	1-2
Nuisance Issues				
pond/ wetland aeration	560	ea	0	1
treat pond for mosquitoes	1,000	acre	0	R
trap beavers (one week, one location, family of 6)	1,000	event	0	R
fill animal burrows	23	sy	800	R (5-10)
remove graffiti	310	day	800	1-3
Erosion/ Channel Maintenance				
establish new riprap pilot channels (8' wide, 1' deep)	38	lf	1,500	5-15
remove and replace rip rap or pea gravel	160	sy	1,500	15-25
shoreline protection	50	lf	1,500	R
new riprap (general)	80	cy	1,500	R (5-10)
erosion repair	1,100	event	0	R (2-5)
jet clean rip rap (6X 15, 1' silt)	2,500	event	0	15-25

4) These costs were largely derived from data from the Maryland region, based on bid proposal and actual project data.
5) Cost at four levels: $0 for no mobilization; $800 for minimal mobilization; $1,500 for small project mobilization; >$2,500 for large project mobilization. Note that these are approximations. For items with no mobilization cost, it is assumed that the mobilization cost is incorporated into the overall unit cost, or that the maintenance can be completed during inspection.
6) Bottom number in range represents ideal maintenance interval. Top number represents maximum interval between maintenance activities. R indicates repair items, whose frequency is somewhat unpredictable. The frequencies sometimes reported in parentheses represent an estimate of typical repair frequency.

Appendix B:

Pond and Wetland Checklists

STORMWATER POND / STORMWATER WETLAND CONSTRUCTION INSPECTION CHECKLIST

Date: Time:

Project:

Location:

Site Status (active, inactive, completed):

Inspector(s):

Type of Practice:

☐ Micropool ED Pond ☐ Shallow Wetland

☐ Wet Pond ☐ Shallow ED Wetland

☐ Multiple Pond System ☐ Pond / Wetland System

☐ Pocket Pond ☐ Pocket Wetland

Construction Sequence	Satisfactory	Unsatisfactory	Comments
I. Pre-Construction / Materials and Equipment			
Pre-construction meeting			
Pipe and appurtenances on-site prior to construction and dimensions checked			
1. Material (including protective coating, if specified)			
2. Diameter			
3. Dimensions of metal or pre-cast concrete riser			
4. Required dimensions between water control structures (orifices, weirs, etc.) are in accordance with approved plans			
5. Barrel stub for prefabricated pipe structures at proper angle for design barrel slope			
6. Number and dimensions of prefabricated anti-seep collars			
7. Watertight connectors and gaskets			
8. Outlet drain valve			
Project benchmark near pond site			
Equipment for temporary de-watering / sediment and erosion control			
II. Subgrade Preparation			
Area beneath embankment stripped of all vegetation, topsoil, and organic matter			
Core trench excavated and backfilled			
III. Pipe Spillway Installation			
Method of installation detailed on plans			
A. Bed preparation			
Installation trench excavated with specified side slopes			
Stable, uniform, dry subgrade of relatively impervious material (If subgrade is wet, contractor shall have defined steps before proceeding with installation)			
Invert at proper elevation and grade			

Construction Sequence	Satisfactory	Unsatisfactory	Comments
B. Pipe placement			
Metal / plastic pipe			
1. Watertight connectors and gaskets properly installed			
2. Anti-seep collars properly spaced and having watertight connections to pipe			
3. Backfill placed and tamped by hand under “haunches” of pipe			
4. Remaining backfill placed in max. 8 inch lifts using small power tamping equipment until 2 feet cover over pipe is reached			
Concrete pipe			
1. Pipe set on blocks or concrete slab for pouring of low cradle			
2. Pipe installed with rubber gasket joints with no spalling in gasket interface area			
3. Excavation for lower half of anti-seep collar(s) with reinforcing steel set			
4. Entire area where anti-seep collar(s) will come in contact with pipe coated with mastic or other approved waterproof sealant			
5. Low cradle and bottom half of anti-seep collar installed as monolithic pour and of an approved mix			
6. Upper half of anti-seep collar(s) formed with reinforcing steel set			
7. Concrete for collar of an approved mix and vibrated into place (protected from freezing while curing, if necessary)			
8. Forms stripped and collar inspected for honeycomb prior to backfilling. Parge if necessary.			
C. Backfilling			
Fill placed in maximum 8 inch lifts			
Backfill taken minimum 2 feet above top of anti-seep collar elevation before traversing with heavy equipment			
IV. Riser / Outlet Structure Installation			
Riser located within embankment			
A. Metal riser			
Riser base excavated or formed on stable subgrade to design dimensions			
Set on blocks to design elevations and plumbed			
Reinforcing bars placed at right angles and projecting into sides of riser			
Concrete poured so as to fill inside of riser to invert of barrel			
B. Pre-cast concrete structure			

Construction Sequence	Satisfactory	Unsatisfactory	Comments
Dry and stable subgrade			
Riser base set to design elevation			
If more than one section, no spalling in gasket interface area; gasket or approved caulking material placed securely			
Watertight and structurally sound collar or gasket joint where structure connects to pipe spillway			
C. Poured concrete structure			
Footing excavated or formed on stable subgrade, to design dimensions with reinforcing steel set			
Structure formed to design dimensions, with reinforcing steel set as per plan			
Concrete of an approved mix and vibrated into place (protected from freezing while curing, if necessary)			
Forms stripped & inspected for honeycomb prior to backfilling; parge if necessary			
V. Embankment Construction			
Fill material			
Compaction			
Embankment			
1. Fill placed in specified lifts and compacted with appropriate equipment			
2. Constructed to design cross-section, side slopes and top width			
3. Constructed to design elevation plus allowance for settlement			
VI. Impounded Area Construction			
Excavated / graded to design contours and side slopes			
Inlet pipes have adequate outfall protection			
Forebay(s)			
Pond benches			
VII. Earth Emergency Spillway Construction			
Spillway located in cut or structurally stabilized with riprap, gabions, concrete, etc.			
Excavated to proper cross-section, side slopes and bottom width			
Entrance channel, crest, and exit channel constructed to design grades and elevations			
VIII. Outlet Protection			
A. End section			
Securely in place and properly backfilled			
B. Endwall			
Footing excavated or formed on stable subgrade, to design dimensions and reinforcing steel set, if specified			

Construction Sequence	Satisfactory	Unsatisfactory	Comments
Endwall formed to design dimensions with reinforcing steel set as per plan			
Concrete of an approved mix and vibrated into place (protected from freezing, if necessary)			
Forms stripped and structure inspected for honeycomb prior to backfilling; parge if necessary			
C. Riprap apron / channel			
Apron / channel excavated to design cross-section with proper transition to existing ground			
Filter fabric in place			
Stone sized as per plan and uniformly place at the thickness specified			
IX. Vegetative Stabilization			
Approved seed mixture or sod			
Proper surface preparation and required soil amendments			
Excelsior mat or other stabilization, as per plan			
X. Miscellaneous			
Drain for ponds having a permanent pool			
Trash rack / anti-vortex device secured to outlet structure			
Trash protection for low flow pipes, orifices, etc.			
Fencing (when required)			
Access road			
Set aside for clean-out maintenance			

Additional Comments:

Action to be Taken:

No action necessary. Continue routine inspections.

Correct noted site deficiencies by

1st notice

2nd notice

Submit plan modifications as noted in written comments by

Notice to Comply issued

Final inspection, project completed

POND / WETLAND MAINTENANCE INSPECTION FORM

Facility Number:______________________ Date:____________ Time:____________

Subdivision Name:______________________ Watershed:______________________

Weather:______________________ Inspector(s):______________________

Date of Last Rainfall:__________ Amount:______ Inches Streets:______________________

Mapbook Location:______________________ GPS Coordinates:______________________

Property Classification: Residential 9 Government 9 Commercial 9 Other:__________

Type of Practice: Wet Pond 9 Dry Pond 9 Micropool ED 9 Multiple Pond System 9 Pocket Pond 9

Shallow Wetland 9 Shallow ED 9 Pond/ Wetland 9 Pocket Wetland 9

Confined 9 Unconfined 9 Barrel Size__________ As-built Plan Available? Yes 9 No 9

Is Facility Inspectable? Yes 9 No 9 Why?__________ Comments Specific Location(s):__________

Scoring Breakdown:

N/A = Not Applicable	**1 = Monitor (potential for future problem exists)**	* **Use open space in each section to further explain scoring as needed**
N/I = Not Investigated	**2 = Routine Maintenance Required**	
0 = Not a Problem	**3 = Immediate Repair Necessary**	

1. Outfall Channel(s) from Pond							
Woody growth within 5' of outfall barrel	N/A	N/I	0	1	2	3	
Outfall channel functioning	N/A	N/I	0	1	2	3	
Manholes, Frames and Covers	N/A	N/I	0	1	2	3	
Released water undercutting outlet	N/A	N/I	0	1	2	3	
Erosion	N/A	N/I	0	1	2	3	
Displaced rip rap	N/A	N/I	0	1	2	3	
Excessive sediment deposits	N/A	N/I	0	1	2	3	
Other:	N/A	N/I	0	1	2	3	
2. Downstream Dam Bank							
Cracking, bulging, or sloughing of dam	N/A	N/I	0	1	2	3	
Erosion and/or loss of dam material	N/A	N/I	0	1	2	3	
Animal burrows	N/A	N/I	0	1	2	3	
Soft spots or boggy areas	N/A	N/I	0	1	2	3	
Woody growth or unauthorized plantings on dam	N/A	N/I	0	1	2	3	
Other:	N/A	N/I	0	1	2	3	
3. Upstream Dam Bank							
Cracking, bulging, or sloughing of dam	N/A	N/I	0	1	2	3	
Erosion and/or loss of dam material	N/A	N/I	0	1	2	3	
Animal Burrows	N/A	N/I	0	1	2	3	
Soft spots or boggy areas	N/A	N/I	0	1	2	3	
Woody growth or unauthorized plantings on dam	N/A	N/I	0	1	2	3	
Other:	N/A	N/I	0	1	2	3	

4. Emergency Spillway						
Woody growth or unauthorized plantings	N/A	N/I	0	1	2	3
Erosion or back cutting	N/A	N/I	0	1	2	3
Soft or boggy areas	N/A	N/I	0	1	2	3
Obstructions / debris	N/A	N/I	0	1	2	3

5. Principal Spillway Built to Plans

# of Barrels:______ Size:____________ RCP CMP PVC STEEL or MASONRY (Circle One)

Confined space entry permit required for entry into all riser and barrels Entry Approved 9 Entry Denied 9

Minor spalling or parging (<1")	N/A	N/I	0	1	2	3
Major spalling (exposed rebar)	N/A	N/I	0	1	2	3
Joint failure	N/A	N/I	0	1	2	3
Loss of joint material	N/A	N/I	0	1	2	3
Leaking	N/A	N/I	0	1	2	3
Corrosion	N/A	N/I	0	1	2	3
Protective material deficient	N/A	N/I	0	1	2	3
Misalignment or split seams / joints	N/A	N/I	0	1	2	3
Other:	N/A	N/I	0	1	2	3

6. Riser Built to Plans

Size:____________________ CONC CMP or MASONRY (Circle One)

Minor spalling or parging (<1")	N/A	N/I	0	1	2	3
Major spalling (exposed rebar)	N/A	N/I	0	1	2	3
Joint failure	N/A	N/I	0	1	2	3
Loss of joint material	N/A	N/I	0	1	2	3
Leaking	N/A	N/I	0	1	2	3
Manhole access and steps acceptable	N/A	N/I	0	1	2	3
Corrosion	N/A	N/I	0	1	2	3
Protective material deficient	N/A	N/I	0	1	2	3
Misalignment or split seams / joints	N/A	N/I	0	1	2	3
Anti-vortex device secure / acceptable	N/A	N/I	0	1	2	3
Sediment Accumulation within riser	N/A	N/I	0	1	2	3
Woody or vegetative growth within 25' of riser	N/A	N/I	0	1	2	3
Safety Rebar/pipes in place	N/A	N/I	0	1	2	3
Safety Rebar/pipes corroded	N/A	N/I	0	1	2	3
Other:	N/A	N/I	0	1	2	3

7. Low Flow Built to Plans						
Orifice and/or trash rack obstructed	N/A	N/I	0	1	2	3
Trash Rack Corrosion	N/A	N/I	0	1	2	3
Other:	N/A	N/I	0	1	2	3

8. Weir Trash Rack						
Structurally sound	N/A	N/I	0	1	2	3
Debris removal necessary	N/A	N/I	0	1	2	3
Corrosion	N/A	N/I	0	1	2	3

N/A = Not Applicable **1 = Monitor for Future Repairs**
N/I = Not Investigated **2 = Routine Repairs Needed**
0 = Not a Problem **3 = Immediate Repair Needed**

9. Control Valve(s) Built to Plans							
Size:____________________ Type:____________________							
Operation limited	N/A	N/I	0	1	2	3	
Exercised	N/A	N/I	0	1	2	3	
Leaks	N/A	N/I	0	1	2	3	
Chains & Locks	N/A	N/I	0	1	2	3	
Set to design opening	N/A	N/I	0	1	2	3	
Other:	N/A	N/I	0	1	2	3	
10. Pond Drain Valve							
Operation limited	N/A	N/I	0	1	2	3	
Exercised	N/A	N/I	0	1	2	3	
Leaks	N/A	N/I	0	1	2	3	
Chained & locked correctly	N/A	N/I	0	1	2	3	
Other:	N/A	N/I	0	1	2	3	
11. Toe & Chimney Drains Clear & Functioning	N/A	N/I	0	1	2	3	
12. Rip-Rap Pilot Channel (Micropool only)							
Sediment or debris build up	N/A	N/I	0	1	2	3	
Erosion/ Undermining	N/A	N/I	0	1	2	3	
13. Permanent Pool							
Visible pollution	N/A	N/I	0	1	2	3	
Shoreline and / or side slope erosion	N/A	N/I	0	1	2	3	
Aquatic bench inadequately vegetated	N/A	N/I	0	1	2	3	
Abnormally high or low water (pool) levels	N/A	N/I	0	1	2	3	
Sediment / debris accumulation	N/A	N/I	0	1	2	3	
Bathometric study recommended			No		Yes		
Other?	N/A	N/I	0	1	2	3	
14. Dry Storage							
Vegetation sparse	N/A	N/I	0	1	2	3	
Undesirable woody or vegetative growth	N/A	N/I	0	1	2	3	
Low flow channels obstructed	N/A	N/I	0	1	2	3	
Standing water or spots	N/A	N/I	0	1	2	3	
Sediment or debris accumulation	N/A	N/I	0	1	2	3	
Bathometric study recommended			No		Yes		
Other:	N/A	N/I	0	1	2	3	
15. Pretreatment							
Maintenance access	N/A	N/I	0	1	2	3	
Is pretreatment a practice other than a forebay			No		Yes		Of so,___________________(code)
Dredging required			No		Yes		
Hard pad condition (Wet pond only)	N/A	N/I	0	1	2	3	
Fixed vertical sediment depth marker present			No		Yes		
Marker Reading____________________________							
Sediment accumulation	N/A	N/I	0	1	2	3	Estimated % full___________%

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N/I = Not Investigated **2 = Routine Repairs Needed**
0 = Not a Problem **3 = Immediate Repair Needed**

16. Inflow Points								
Number of inflow pipes:____________________	Direction:		N	E	W	S		
Endwalls, headwalls, end sections	N/A	N/I	0	1	2	3		
Outfall pipes	N/A	N/I	0	1	2	3		
Discharge undercutting outlet or displacing rip-rap	N/A	N/I	0	1	2	3		
Discharge water is causing outfall to erode	N/A	N/I	0	1	2	3		
Sediment accumulation	N/A	N/I	0	1	2	3		
17. Wet Pond Vegetation								
Invasive plants	N/A	N/I	0	1	2	3		
% cover______________________________								
Vegetation matches landscape design plan	N/A	N/I	0	1	2	3		
Planting needed	N/A	N/I	0	1	2	3		
Shore erosion	N/A	N/I	0	1	2	3		
Coverage needs improvement	N/A	N/I	0	1	2	3		
18. Pond Buffer								
Encroachment by structures	N/A	N/I	0	1	2	3		
Clearing of vegetation	N/A	N/I	0	1	2	3		
Planting needed	N/A	N/I	0	1	2	3		
Predominant vegetation types:	Forested 9		Shrubs 9		Meadow 9		Maintained Grass 9	Other:___
19. Special Structures								
Manhole access (steps, ladders)	N/A	N/I	0	1	2	3		
Vehicular access	N/A	N/I	0	1	2	3		
Concrete/masonry condition	N/A	N/I	0	1	2	3		
Trash racks	N/A	N/I	0	1	2	3		
Elbows	N/A	N/I	0	1	2	3		
Sediment / trash removal	N/A	N/I	0	1	2	3		
Manhole lockable nuts	N/A	N/I	0	1	2	3		
20. Miscellaneous								
Encroachment in pond area and/or easement area	N/A	N/I	0	1	2	3		
Fence condition	N/A	N/I	0	1	2	3		
Safety signs	N/A	N/I	0	1	2	3		
Complaints from local residents	N/A	N/I	0	1	2	3		
Graffiti	N/A	N/I	0	1	2	3		
Public hazards	N/A	N/I	0	1	2	3		
Were any pad locks cut and replaced			No		Yes		How Many?____________________	

N/A = Not Applicable **1 = Monitor for Future Repairs**
N/I = Not Investigated **2 = Routine Repairs Needed**
0 = Not a Problem **3 = Immediate Repair Needed**

Overall Condition of Facility

Total number of concerns receiving a: **(1)_______ - Need Monitoring**
(2)_______ - Routine Repair
(3)_______ - Immediate Repair Needed

Inspector's Summary

___
___
___
___
___
___
___
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___
___
___

Pictures	Clock/Degrees	Prin. Spill. Barrel Joints	Clock/Degrees
1.		1.	
2.		2.	
3.		3.	
4.		4.	
5.		5.	
6.		6.	
7.		7.	
8.		8.	
9.		9.	
10.		10.	
11.		11.	
12.		12.	
13.		13.	
14.		14.	
15.		15.	

N/A = Not Applicable
N/I = Not Investigated
0 = Not a Problem
1 = Monitor for Future Repairs
2 = Routine Repairs Needed
3 = Immediate Repair Needed

Sketches, If Necessary:

Home Owner Pond Inspection Checklist

We encourage you to copy this checklist and maintain a record of your inspections. (Adapted from Hampton Roads: A Guide for Maintaining and Operating BMPs.) Answering YES to any of these questions indicates a need for corrective action or consultation with a professional inspector.

Date:_______________ Inspected by:____

	What to look for . . .	Yes	No
°	Does the facility show signs of settling, cracking, bulging, misalignment or other structural deterioration?	‘	‘
°	Do the embankments, emergency spillways, side slopes or inlet/outlet structures show signs of erosion?	‘	‘
°	Are the pipes going into and/or out of the pond clogged or obstructed?	‘	‘
°	Do the impoundment and inlet areas show erosion, low spots or lack of stabilization?	‘	‘
°	Are there trees present on the banks?	‘	‘
°	Is there evidence of animal burrows?	‘	‘
°	Are contributing areas unstabilized with evidence or erosion?	‘	‘
°	Do vegetated areas need mowing or is there a build up of clippings that could clog the facility?	‘	‘
°	Does sedimentation greatly decrease the BMPs capacity to hold water within the structure?	‘	‘
°	Is there standing water in appropriate or inappropriate areas?	‘	‘
°	Is there accumulation of trash or debris?	‘	‘
°	Is there evidence of encroachment or improper use of the impounded areas?	‘	‘
°	Are there signs of vandalism?	‘	‘
°	Do any safety devices such as fences, gates or locks need repair?	‘	‘
°	Is there excessive algae or dominance of one type of vegetation?	‘	‘
°	Is there evidence of automotive fluids entering or clogging the facility?	‘	‘
°	Is there evidence of a fish kill?	‘	‘

Additional Observations: ____