APPENDIX D - WISCONSIN STORMWATER MANUAL: WET DETENTION BASINS (G-3691-4)

G3691-4

The Wisconsin Storm Water MANUAL

Wet Detention Basins

Numerous techniques are available to determine design storms and to predict peak flow rates and volumes. (For an example of an alternative method see the *Wet Detention Basin Standard* No. 1001 (WLWCA, 1999).) Design storms and techniques used to predict peak rates and flow are for illustrative purposes and are described in detail in the hydrology section of this manual.

Multiple detention basins within a watershed may greatly change the natural flow conditions in the downstream reaches of receiving waters. Construction of storm water facilities should be part of an overall watershed management plan. The designer should coordinate construction of detention basins or any other storm water facility with local, municipal, county and regional planning representatives to minimize the risk of flooding both upstream and downstream from the facility.

Detention basins are excavated areas or enhanced natural depressions designed to detain storm water runoff. These structures detain or impede flows by storing runoff and releasing the stored volume at a reduced rate. Such structures have historically been employed to reduce peak discharges and provide greater protection to areas that are susceptible to flooding.

With increased public interest in improving water quality, detention basins have gained importance for their ability to remove pollutants from storm water runoff. The objective of this publication is to assist engineers and designers in planning and designing water quality detention basins by presenting sizing and construction design criteria to meet water quality goals.

Flood control and/or peak shaving components are often incorporated into the detention basin. The U.S.D.A. Natural Resources Conservation Service (NRCS), the Army Corps of Engineers, the Department of Natural Resources, and others have design standards for peak flow control; therefore, only the water quality aspects of design will be discussed here.

Recommended design objectives

To obtain water quality improvements for urban water quality basins, the Wisconsin Department of Natural Resources (DNR) recommends that basin design meet the following criteria (WI-DNR, 1997):

- Storm water management practices should remove 80% total suspended solids (TSS) from runoff generated from the developed tributary drainage area on an annual basis.
- Storm water management practices must limit the peak discharge from the post-developed site to the peak discharge of the pre-developed site for the 2-year, 24-hour rainfall event. This requirement is intended to limit streambank erosion downstream from the facility under bankfull flow conditions. In cases where the facility's discharge will have no adverse impact on the downstream conveyance system, this requirement can be waived.

Other criteria may be included where specific pollutants such as metals or pesticides are of concern. Compliance with the above criteria will ensure that a significant amount of the pollutants contained in storm water runoff will be removed.

ypes of detention basins

Detention basins may be categorized as either dry or wet detention. Dry detention basins offer maximum storage potential and reduce the risk of flooding and streambank erosion by attenuating peak flows. However, they have limited ability to permanently remove pollutants because the deposited materials are often re-suspended by succeeding storms. For this reason, dry detention is not recommended as a water quality improvement practice.

Material discussed here concentrates on wet detention. Because no standard definitions of the various storm water storage facilities have been established, the types of wet detention basins used in this manual are defined as follows:

A *wet detention basin* is an impoundment ·taining a permanent pool of water. It ·o has additional storage capacity ..ove the pool's surface to provide temporary storage for runoff peak reduction. Water quality treatment is usually accomplished through physical and biological processes in the permanent pool. Wet detention basins may be used as a single pollutant removal facility or as a pretreatment device in combination with other storm water management practices.

An *extended wet detention* basin is a detention facility designed to store runoff for an extended period of time. The extended detention time of these basins allows more time for physical settling of pollutants. Extended detention systems typically have a shallow marsh in combination with a dry area or have a permanent pool in combination with a dry area. Extended wet detention or a wet detention basin in combination with ›ther practice will be somewhat more ·ective in removing silts, clays, phosphorous and some of the other pollutants from storm water due to the increased detention time.

The design of an extended wet detention basin will incorporate many of the same aspects as the wet detention. The basic design differences between extended wet detention and wet detention is that extended wet detention requires a smaller discharge, longer detention time, a larger storage area and vegetation more tolerant of varying water levels.

Detention basin benefits

Wet detention basins are generally effective storm water quality management structures if designed and maintained correctly. Basins can be used on individual sites or as regional storm water facilities. Use as a regional facility introduces economy of scale, providing advantages over site-by-site installations. Compared to site-by-site facilities over a total drainage area, regional facilities have smaller land area requirements, are less costly to construct than multiple basins, and require less maintenance.

Basins must be designed in a manner that does not increase the chance of flooding downstream; flow routing through the multiple basins may add to the design complexity.

Detention basins can also be used in conjunction with other water quality facilities to enhance pollutant removal capabilities. By reducing discharge and removing sediment in upstream basins, detention basins allow water quality practices downstream to operate more efficiently. For example, artificial wetland storm water management systems and infiltration structures will not operate efficiently if flash flows and sediment from urban areas enter them directly. Installing a detention basin to provide pre-treatment for these practices can reduce flow rates and sediment loads to levels that prevent premature failure, and often provide pollutant removal efficiencies at levels higher than both practices could achieve operating independently.

The design rate of discharge from a detention basin used in conjunction with a downstream practice, such as an artificial wetland storm water management system or infiltration structure, will depend on the inflow requirements and the volumetric capacity of the downstream practice.

Compared to other water quality practices, wet detention generally requires less land area and achieves comparable levels of pollutant removal. Because of their storage capability, detention basins are able to handle much larger volumes of flow than other practices such as grassed swales or infiltration structures. In addition, detention basins are less susceptible to failure and require less maintenance than infiltration practices.

The major pollutants contained in storm water include sediment, lead, arsenic, copper, mercury, atrazine, polycyclic aromatic hydrocarbons (PAH), phosphorous, zinc, bacteria and dissolved nutrients (US-EPA, 1983). Estimated removal rates for wet detention basins are shown in table 1.

Table 1. Percent reduction of pollutants for wet detention basins

Pollutant	**Removal rate** (%)
Suspended solids	70–95
Total phosphorous	40–70
Nitrogen	60–90
COD	20–55
Lead	70–90
Iron	43–92
Zinc	40–80
Oxygen demand	50–90
Copper	60–80

Adapted from Pitt, 1991; Schueler, 1987; Stahre and Urbanos, 1990 and MD-DERSSA, 1991

In addition to improving water quality, properly designed wet detention basins may provide other benefits. If additional storage is provided, the peak storm water discharge from larger design storms may be reduced.

A basin may improve the aesthetics of an area through proper siting and use of an irregular shape for the basin edge. In some cases increased recreational opportunities may be created by integrating the detention basin into the surrounding land use.

If located and maintained appropriately, wet detention facilities are an attractive amenity, and in some cases will actually increase the surrounding land values (Schueler, 1987). Accomplishing these benefits usually requires that basin design be a primary element in the development plans.

Detention basin drawbacks

While detention basins effectively remove a number of pollutants, they do not consistently or significantly remove soluble substances such as certain pesticides, zinc and petroleum products. Detention basins also allow sunlight to increase water temperatures, which may have a detrimental effect on aquatic life in the receiving water body.

If thermal impacts to the receiving water body are a concern, some other method of pollutant removal should be used in conjunction with detention. For example, an infiltration basin placed downstream from a detention basin would reduce water temperature and help minimize thermal impacts on the receiving body of water.

Provisions must be made to dredge, test, and properly dispose of sediment on a regular basis. The responsibility for maintenance and long-term accountability for maintenance are often difficult to establish.

A maintenance schedule, statement of procedures and a cost estimate should be a part of the detention basin design. A maintenance agreement should also be developed before constructing the basin to establish the parties responsible for maintenance and repair.

Safety is also a concern with detention basins. Precautions should be taken to discourage swimming and entry to the pool area. Features such as safety shelves will decrease the risk of injury and drowning, but will not eliminate these risks.

Detention basins and water quality

Detention basins are designed to interrupt and detain the normal flow of storm water runoff. Unlike flood control facilities, detention ponds for water quality control are designed for the more frequent or smaller storm. Ideally, in cases where downstream flood control is required or where bank erosion would be intensified through development, the detention facility would be sized for both water quality and peak flow control.

Sediment removal

The primary pollutant removal mechanism used in detention basins is particle settling, supplemented by biological and chemical activity. Settling in detention basins generally takes place at two distinct times and under different hydraulic conditions.

The first type of settling is called dynamic settling and occurs during flow through the pond. The second type, quiescent settling, occurs during the period between rainfall events.

The analysis of settling is often conducted using the assumptions of a "plug flow" system. In a plug flow system, the water that has been held in the pond from the previous rainfall event is displaced by inflow from the current event. Given enough time in a semi-quiescent water body, suspended solids settle to the bottom of the basin through the action of gravity.

In cases of large inflow volumes, however, flow in the pond occurs predominately near the surface, with much slower velocities existing near the bottom of the facility. In this situation, distribution of flow over a large surface area to slow the inflow velocity is a critical factor in removal of suspended solids. Particles settling below the outlet will be captured in the pond; those that do not settle below the outlet will be transported downstream. The relationship between the surface area and the particle removal for an ideal settling basin has been described by numerous authors including Pitt (1994).

The critical particle settling velocity is defined as:

$$v_c = Q_{out}/A_{surface}$$

where:

Q_{out} = pond outflow rate (cubic feet per second),

$A_{surface}$ = pond surface area (square feet: pond length times pond width), and

V_c = upflow velocity, or critical particle settling velocity (feet per second).

For an ideal detention pond, particles with settling velocities greater than this critical settling velocity will be completely removed. Increasing the surface area or decreasing the pond outflow rate will increase pond settling efficiency. Increasing pond depth reduces the possibility of bottom scour and re-suspension of sediments, decreases the amount of attached aquatic plants and decreases the chance for winterkill of fish. Deeper ponds may also be needed to provide sacrificial storage for sediment between dredging operations (Pitt, 1994.)

Therefore, surface area is the critical factor when designing detention basins for settling efficiency, and depth is primarily important only from the aspect of protecting bottom sediments from surface turbulence and providing sediment storage.

the purposes of this manual, the fall velocity of a 5 micron particle, or a settling velocity of 0.00013 feet/second, is used to accomplish an annual 80% removal rate. This 5 micron particle size is based on findings of sampling data taken from runoff in Madison and Milwaukee streets. The research determined that particles equal to and larger than the 5 micron particle comprised approximately 80% of the particle size distribution coming from the streets sampled (WI-DNR, 1997).

While the specific weight of soil particles varies, affecting the settling velocity, the particles typically found on urban surfaces have a specific gravity of approximately 2.75 (Pitt, 1994). This value is generally larger than the specific gravity for native soil particles. Due to variations in particle size distribution ~~d density among sites, however, ,igners are encouraged to determine ; particle size distribution and specific gravity for the site before design.

Limiting peak flows

As an area is urbanized, the amount of impervious surface area in the drainage area is usually significantly increased. Storm sewers are installed to quickly convey runoff from developed sites. Landscaping and surface grading remove natural surface depressions that provided storage areas for runoff.

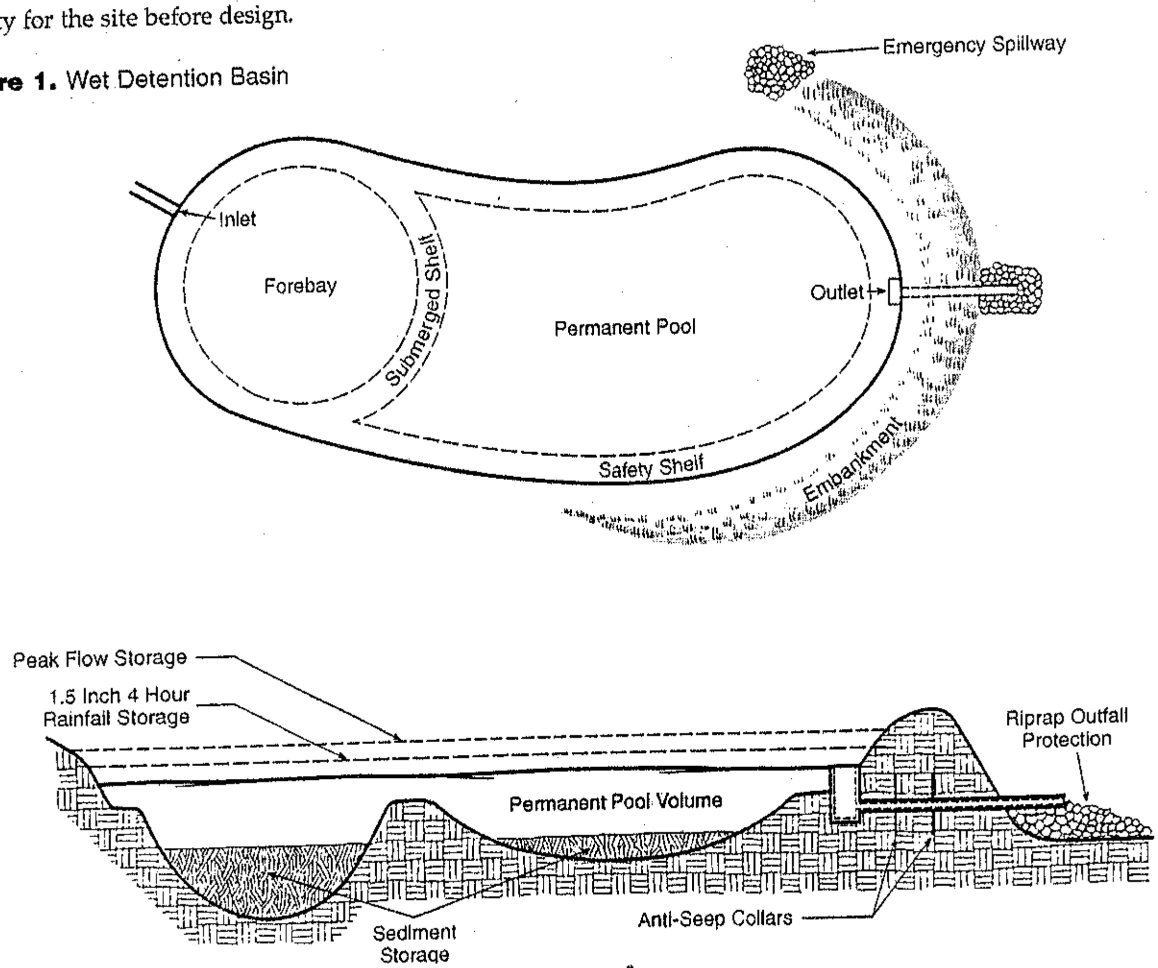
These combined changes have a number of detrimental effects on receiving streams. These effects include:

- Increased runoff peak discharges
- Increased runoff volumes
- Increased flow velocity during storms
- Decreased time of concentration
- Increased frequency and severity of flooding
- Reduction in base flow between storms
- Increased streambank erosion
- Increased water turbidity due to bank erosion and upland erosion
- Increased introduction of toxic chemicals to water bodies

As a result, streams widen and become shallower, sediment fills natural pools and coats the streambed, and the diversity of aquatic species is reduced.

By restricting peak flows from a developed site to the peak flow that existed before development, damage to downstream areas can be greatly reduced. Detention basins are an excellent way to diminish the destructive effects listed above. By designing detention basins to restrict flows and temporarily store the increased flows produced by urbanization, downstream flow conditions can more closely approximate the flow regime that existed before urbanization in the watershed.

Figure 1. Wet Detention Basin



Research conducted by Leopold (1968), Wolman and Schick (1967) and others has shown that stream channels and courses are greatly affected by smaller, more frequent rainfalls. In Wisconsin, storm events between the 1-year and 2-year return period generally cause bankfull flow condition.

This flow quantity controls and forms the natural stream channel. Therefore, restricting peak flows from the more common rainfall events can reduce the damaging effects resulting from the increased runoff produced by urbanization.

While determination of the appropriate return period is subject to debate, the 2-year storm event will cover the wide range of stream flow characteristics and, when used with the water quality design guidelines, will adequately protect streams from the negative effects of high frequency storms.

As can be seen from the previous description, peak flow limitations are applied to streams or other water bodies that will be negatively affected by increased flows. Water bodies in which the increase in flow produced by urbanization will have little effect on the receiving water body do not have to conform to these guidelines. For example, a relatively small basin discharging into a large lake such as Lake Winnebago or Lake Michigan may have no significant effect on water quality.

Basin design

To achieve its water quality goals, basin design must incorporate a number of design criteria. These include permanent pool volume, active storage volume, surface size and shape, pond depth, site topography, inlet and outlet structure design, slope stability, and safety.

Guidelines provided in this section will assist engineers and designers in constructing water quality detention basins to meet water quality goals of removing 80% of suspended solids and maintaining the pre-development, 2-year, 24-hour peak flow rate. An example of a wet detention basin with its basic features is illustrated in figure 1.

Planning guidelines

A number of items must be addressed before the design phase. These include identifying unique or sensitive natural areas, expected future land uses, availability of land, permits required and the effects of the proposed structure on downstream flow. A comparison of detention basins to other pollution removal practices should also be conducted.

To thoroughly assess what may be required in managing storm water pollution, a watershed or sub-watershed study should be conducted first. In some watersheds these studies may have been completed. Consult local officials, the regional planning agency, and the DNR to determine the status of watershed plans and other watershed information.

Regional reports may not be detailed enough for a specific site and the surrounding area. In every case the developer has the obligation to contact government organizations to determine how the proposed structure will affect the watershed and whether the structure is consistent with watershed plans. In addition, the contractor or designer is always responsible for ensuring that the risk of flooding is minimized by assessing flooding potential both upstream and downstream from the proposed site.

The design of a detention basin is often an iterative and complex process. The following overview provides a guide to the order and overall process.

1. Check with local officials, regional planning agencies and state and federal agencies to determine zoning restrictions, watershed and/or surface water requirements and permits that may apply to the development site or watershed.
2. Conduct a site evaluation. The initial field inspection should include identification and location of any springs in the immediate vicinity of the proposed basin site. The flow from these springs should be considered and rerouted if necessary to prevent instability of the detention structure.

All utility lines should be located outside the basin site. If necessary plans should be made to move lines outside the basin site. All sanitary pipes should be located outside the basin site and located to minimize the chance of pond contamination should a pipe fail. Check local ordinances for criteria. Manholes in the area where the wet surface will overtop the manhole for the 2-year, 24-hour event should be relocated outside the wet surface area. Determine public and private well locations that may be affected by the detention basin.

Take soil samples from the potential detention sites to help determine:

—In situ soil permeability, to ascertain if the soil is capable of inhibiting seepage. This information will help establish the necessary degree of compaction or whether a liner will be required to prevent large surface water fluctuations.

—The soil's ability to support loads and maintain its shape.

—Depth to groundwater or fractured bedrock. If separation distance is less than 4 feet, special precautions will be necessary to prevent movement of pollutants to groundwater. A basin liner will help minimize pollution potential due to seepage from the basin.

Make sure the watershed and conveyance channels are stabilized to minimize sedimentation in the detention basin.

4. Analyze watershed data to determine the viability of a detention basin.
5. Estimate the wet pond surface area based on future land uses in the drainage area.
6. Using the site survey, calculate the storage volume associated with several elevations or stage levels.
7. Determine if the area can accommodate:

   —A permanent pond volume equal to the runoff volume from the drainage area in the fully developed condition for the water quality design storm (1.5-inch rain).

   —An active storage volume, large enough to remove the 5 micron particle from the runoff volume for the drainage area in the fully developed condition for the 1.5-inch, 4-hour rain. This is approximately equal to one-half the permanent pond volume.

   —An active storage volume large enough to meet outflow requirements for the fully developed area runoff from a 2-year, 24-hour storm.
8. Calculate the expected future runoff volume for the 1.5-inch storm and the 2-year, 24-hour storm.
9. Create the hydrograph for the 1.5-inch, 4-hour rainfall and the 2-year, 24-hour storm. These are the inflow design hydrographs for the detention basin. If it is desirable to control flooding from larger magnitude storms, also create the appropriate inflow hydrographs.
10. Determine if the selected sites will accommodate the estimated volumes. If yes, go to step 10. If not, site conditions must be modified and steps 2 through 5 repeated.
11. Design an outlet that will restrict pond discharges from the 1.5-inch, 4-hour storm to 0.00013 cubic feet per second per square foot of pond surface area. If sediment characteristics vary from those used in this manual the flow rate must be revised.
12. Route the 1.5 inch rainfall hydrograph through the basin as a check of the water quality active storage and outlet basin design. If discharge and storage requirements are satisfied, continue to step 13; if not, redesign outlet and/or modify basin to satisfy storage requirements and repeat steps 9 through 11.
13. Determine the peak runoff and the runoff volume from the 2-year, 24-hour storm with the drainage area in its pre-development condition.
14. Develop the runoff hydrograph and the runoff volume from the 2-year, 24-hour storm with the drainage area in its fully-developed condition.
15. Compare the peak flow from the hydrograph developed in step 14 with the peak flow for the outlet designed in steps 9 through 11. Make sure the design of the outlet limits the fully developed peak flow to the pre-developed peak flow. For a first estimate of the storage volume needed to limit the fully developed to the pre-developed peak flow use the difference between the fully developed volume and the pre-developed volume.
16. Route the 2-year, 24-hour rain event hydrograph through the basin as a check of the 2 year storage and outlet design. Determine if the peak discharge and storage requirements are satisfied. If so, continue to step 16; if not, redesign outlet and/or modify basin to satisfy storage requirements and repeat any steps that may apply from steps 9 through 15.
17. Route other peak or flow control storms and check design features.
18. Assess basin flow characteristics as they affect the watershed. This may involve checking with regional and local government staff or with the DNR.
19. Design details of the basin including safety, maintenance and operational features.

Basin sizing calculations

In developing the design requirements for a properly sized basin, DNR staff conducted a study to determine the design storm volume to achieve an 80% removal of total suspended solids (TSS) on an annual basis.

The study determined that a basin with a permanent pond sized to contain the runoff from a 1.5-inch rainfall would perform at the required level of pollutant removal. Other design criteria may be found in the literature; however the design requirements described in this manual use the runoff from the 1.5-inch rainfall for the permanent pond specification. Because the design guidelines given here apply for a wide variety of conditions, the design is necessarily conservative and basins designed for specific conditions may be smaller.

Where there are land area limitations, or where land purchases would be costly, the designer may want to employ a more specific design. A number of computer models may be used to design detention basins. Check with local officials to determine which models are acceptable.

The following sections describe the basic elements of the basin structure and the procedure used to size various basin storage volumes and the outlet structure to meet water quality needs.

While the function of the inlet structure is also described here, specific information on sizing the inlet structure must be obtained from sources such as the NRCS and the Army Corps of

Engineers. The reader is also advised to look to other sources for flood control design elements and for the structural design of the basin.

The design sequence begins with the inlet structure and expected inflow from the drainage area, followed by sizing of the permanent wet pond and the sizing procedure for the water quality active storage volume and the outlet structure. The water quality active storage volume is determined to a large degree by the outlet structure. For this reason the outlet structure and the water quality active storage volumes are determined by flow routing using the runoff hydrograph for the drainage area as the inflow to the basin.

The design method described here is derived from five main sources (Pitt, 1994; WA-DOE, 1992; Walker, 1987; Schueler, 1987; and Barfield et al., 1983).

Inlet structure design

The detention basin inlet is a structure that takes concentrated flow and distributes it so that the energy can be more easily dispersed in the permanent wet pond. When properly designed, the inlet transforms the concentrated incoming flow to a dispersed, surface flow that does not disturb the settled bottom sediments.

To prevent erosion near the inlet, adjacent areas may need to be protected by vegetation, riprap or some other means. Inlet structure sizing is determined by the peak rate of flow generated from the drainage area served by the detention basin.

The inlet should be constructed in a manner consistent with methods described for conveyance structures in NRCS Technical Guides (USDA-SCS 1985,1987,1993). The minimum design storm for the inlet structure should be a 10-year frequency storm unless the maximum expected conditions warrant use of a larger storm model.

Permanent pond surface area calculation

In order to settle the 5 micron particle for a 1.5-inch rainfall, the permanent pond must provide an adequate surface area for the expected incoming flows. Observations noted by Pitt (1994) as modified by the Wet Detention Basis Standard No. 1001 (WLWCA, 1999) may be used to approximate the required surface area. These observations indicate that the surface area recommendations provided in table 2 should be followed when sizing the permanent pool.

In most cases the drainage area consists of mixed land uses, and the pond surface is determined by multiplying the acreage of each land use area by the recommended percent from table 2 and summing the components.

As an example, assume that a 100-acre drainage area has the following land-use characteristics and estimated pond surface area as shown in table 2:

100-acre drainage area

Residential	52 acres @ 0.8%
Manufacturing	13 acres @ 2.1%
Institutional	25 acres @ 1.8%
Open space	10 acres @ 0.6%

The estimated permanent pond surface area for 80% control would be:

(52 acres x 0.008) + (13 acres x 0.021) + (25 acres x 0.018) + (10 acres x 0.006) = 1.2 acres

Permanent volume calculation

The permanent pond is designed to dissipate the energy of the incoming flow, allowing suspended solids to settle as flow velocity decreases. The permanent pond also provides a protective water column over sediments that previously settled. In many cases the permanent pond is excavated below the existing surface to ensure that the pond water volume will not present a flood risk downstream in cases of impoundment failure.

Table 2. Estimating pond surface area as a percent of tributary drainage area

Land use/ Description/ Management	Total impervious (%)	Miniumum surface area of the permanent pool (% of watershed area)
Residential		
• <2.0 units/acre (>1/2 acre lots)	8–28	0.7
• 2.0–6.0 units/acre	28–41	0.8
• >6.0 units/acre (high density)	41–68	1.0
Office park/Institutional/Warehouse (Non-retail related business, multi-storied buildings, usually more lawn/landscaping not heavily traveled, no outdoor storage/manufacturing	<60	1.6
	60–80	1.8
	>80	2.0
Shopping/Manufacuring/Storage (Large heavily used outdoor parking areas, material storage or manufacturing operations)	<60	1.8
	60–80	2.1
	>80	2.4
Parks/Open space/Woodland/Cemeteries	0–12	0.6
Highways/Freeways (Includes right-of-way area)		
• Typically grass banks/conveyance	<60	1.4
• Mixture of grass and curb/gutter	60–90	2.1
• Typically curb/gutter conveyance	>90	2.8

he permanent pond volumetric calculation described is a simplified method to size the permanent pool for water quality improvement. This method results in a permanent pool volume that may be slightly conservative. A reduced permanent pool volume may be obtained by using a water quality detention basin model. The basin should be sized for an 80% TSS removal.

The permanent pool consists of three volumes—a sediment storage volume, a forebay volume, and a main pool volume. The total permanent pool volume should be equal to the total runoff volume generated from a 1.5-inch rainfall on the drainage area in its fully developed condition plus the sediment storage volume.

To capture the majority of sediment entering the pond, a sediment forebay ~rea is located adjacent to the inlet. By ,pping and holding the majority of :diment in the forebay area, sediment may be more easily removed, thereby lengthening the useful life of the main pond. Containing sediments in the forebay requires that a submerged shelf be constructed to separate the forebay from the main pool. The surface area of the forebay should be approximately 12% of the permanent pond surface area.

Confining the sediments in the forebay requires that it include a sacrificial storage volume for sediment in addition to the storm water volume. The sediment storage volume should have a minimum wet pond depth of 3 feet above the projected maximum sediment storage volume to prevent resuspension of settled sediments.

Experience indicates that urban detention basins have an annual sediment deposition approximately equal to 1% ·f the permanent pool volume ,Schueler, 1987). This volume multiplied by the desired maintenance design life provides an estimate of the design sacrificial sediment storage volume in the forebay area.

The sediment removal frequency should normally be 5 to 10 years. So, a pond design life of 10 years requires a sediment storage volume of 10% of the permanent pool volume. It should be noted that in order to lengthen the life of the main permanent pond area, the pond should initially be constructed to allow at least 1 foot of sacrificial storage.

To summarize, the permanent pond volume:

- Contains the runoff volume from 1.5 inches of rain falling on the drainage area in the developed condition
- Possesses a sediment forebay with a surface area equal to about 12% of the permanent pond surface area
- Has a sediment forebay capable of storing sediment between cleanout periods equaling 1% of the permanent pool volume multiplied by the time between cleanouts.

At this point in the design sequence the designer should make the first of many checks to be sure that the site selected will accommodate the pond volumes and flows.

Active storage volume for water quality control

While there may be several layers of active storage above the permanent pond in detention basins, this manual is concerned only with the water quality storage volume, which involves two storage volumes. One limits the flow rate to a discharge of 0.00013 cubic feet per second per square foot of pond surface area for a 1.5-inch, 4-hour rainfall to ensure adequate settling. The second storage volume limits the 2-year, 24-hour storm developed area peak flow to the pre-development 2-year, 24-hour peak flow.

Additional capacity may be required if control of larger storms is desired. The designer should assess the basin over the entire range of storms for which the structure is designed.

The 1.5-inch, 4-hour active storage volume is the first storage volume above the permanent pond of the detention basin. In conjunction with the permanent storage pond, this storage volume is responsible for removing suspended solids. The peak shaving volume for the 2-year, 24-hour storm is above the 1.5-inch, 4-hour pond stage and is used to limit streambank erosion downstream from the basin. Both of these volumes are determined by calculating the relationship between the flow hydrograph and the outlet structure's release characteristics.

Conveyance structures

- Inlets and outlets should allow for authorized access for maintenance and general repair, restrict entry by unauthorized persons, and use materials and designs that inhibit vandalism. The design should incorporate erosion protection and provide a sufficient foundation to reduce settling and frost heave.
- Code requirements for minimum pipe size, slope and cover should be determined if the basin is a component of a public storm drainage system. To enhance self-cleaning characteristics, pipe should not be laid on less than a 1% slope. However, if it is documented that 1% is not obtainable, then actual slope may be as low as 0.5%. When pipe is laid on an area with a slope greater than 20%, the pipe should be anchored and particular attention given to pipe joint areas. Check local ordinances to determine if the design is in compliance.

Calculating basin storage volume

The flow-routing method is used to calculate both the basin storage volume for the 1.5-inch rainfall and the basin storage volume for the 2-year, 24-hour peak shaving. The two methods are slightly different and the steps for both are listed below. Examples of routing procedures are presented in the Hydrology section of this manual.

Calculation for the 1.5-inch, 4-hour rainfall active storage volume

1. Develop the hydrograph for the 1.5-inch, 4-hour storm with the drainage area in its fully developed condition.
2. Using basin site surveys, calculate the stage-storage volumes and stage-surface area relationships at several stage elevations to a height above the expected maximum storage volume. To establish accurate storage volumes, break points where the land surface changes slope should be identified and used as a storage stage height.
3. Using the permanent pond area and the stage-storage relationship from step 2, choose an outlet structure that will approximate the allowable discharge rate of 0.00013 cubic feet per second per square foot of pond surface area. Recognize that the surface area of the pond increases as the pond elevation rises. Usually a good first estimate of the needed volume of storage for the 1.5 inch rainfall is one-half the volume of the permanent pond volume. Using the designed outlet, develop a stage-discharge relationship.
4. Route the runoff hydrograph developed in step 1 through the pond to check discharge limits and storage.

A pond outflow hydrograph and a pond stage-storage curve are used to determine if water quality goals for the pond will be met, if a larger storage volume will be required, or if the outlet structure will require alteration. This is an iterative process for determining if the outlet and active storage volume will meet the outflow-surface area ratio requirement. For example, if a chosen outlet and the consequent pond have an outlet release rate/surface area ratio that is greater than the required 0.00013 cubic feet per second outflow per square foot of pond surface area, the outlet opening must be reduced or the pond active surface area must increased. The resulting design must then be assessed again to determine if the outlet release-surface area ratio requirement is met.

Calculation for active storage for streambank protection

In reducing the peak flow for streambank protection, pre-development flow from the 2-year, 24-hour storm should be maintained. To design a structure that will limit peak flows to the pre-developed condition, use the following procedure:

1. Calculate the pre-development inflow peak for the 2-year, 24-hour storm using the tabular method in TR-55 (USDA-SCS 1986). This will determine the design peak outflow for the post development condition.
2. Calculate the post-development inflow hydrograph for the 2-year, 24-hour storm using the tabular method in TR-55 (USDA-SCS 1986).
3. Choose an outlet that will limit the peak flow from the detention pond with the drainage area in its developed condition to the peak flow calculated in the pre-development hydrograph. Ideally the flow from the detention basin should replicate the pre-developed inflow hydrograph as closely as possible, including the base stream flow.
4. Using the permanent pond area and the stage-storage relationship from step 2, choose an outlet structure that will approximate the allowable discharge rate of 0.00013 cubic feet per second per square foot of pond surface area. Recognize that the surface area of the pond increases as the pond elevation rises. Usually a good first estimate of the needed volume of storage for the 1.5-inch rainfall is one-half the volume of the permanent pond. Using the designed outlet, develop a stage-discharge relationship.
5. Route the runoff hydrograph developed in step 1 through the pond to check discharge limits and storage.

- Anti-seep collars should be provided for pipe inlets and outlets where pipes pass through berms. The collars should have watertight connections to the pipes. Maximum spacing should be approximately 14 times the minimum projection of the collar measured perpendicular to the pipe. Collar material should be compatible with pipe materials. The anti-seep collars should increase by at least 15% the seepage path along the pipe.
- Pipe outlets, both the principle outlet and the de-watering outlet, should ensure stability. For outlets 10 feet or less in height, a square concrete base 18 inches thick and a width twice the diameter of the pipe width may be used to anchor the outlet. The pipe should be placed at the center and embedded 6 inches into the concrete. Other approved methods may be used.
- Outlet structures should provide a skimmer type shield around perforated risers. A device or configuration that reduces the risk of outlet blockage should be provided on all outlet structures.
- To prevent structural damage to the basin facility, an emergency outlet capable of passing the flow equal to the flow capacity of the downstream conveyance system should be installed. To reduce the risk of erosion and structural failure, spillways should be placed on undisturbed ground. For most communities, the storm sewer system is designed for the 10-year, 24-hour event, and most communities have provisions to pass the 25 year storm event. Check with local officials to determine the proper design storm for the emergency outlet.
- To prevent clogging, trash racks should be installed to filter material that may be caught in the conveyance system downstream from the outlet. The spacing in the opening of the trash rack should be smaller than the outlet diameter. A general rule is to provide a trash rack that has a net open area no less than four times the open area of the outlet.
- Easements should be provided for all structures in need of regular maintenance. This is especially important for manhole facilities.

Additional design criteria

In addition to the basic basin design calculations, the designer should keep several other considerations in mind to ensure that the basin removes pollutants at the design levels, and that safety and aesthetic issues are adequately addressed.

- A detention basin should blend with the surrounding landscape and community as much as possible. While the placement of the facility may be limited due to hydraulic constraints, properly designed basins can be aesthetically pleasing and help serve community recreational needs.
- The surface shape of the pond should have a length to width ratio of 3 to 1 or greater. If this arrangement is not possible, baffles or gabions should be installed to lengthen the flow path. Shapes should conform to the natural contour of the site to the greatest extent practical. Shapes that avoid dead or stagnant zones are encouraged because stagnant zones reduce sediment trap efficiency, often become overgrown with vegetation, and can increase mosquitos.
- The inlet and outlet structure should be at opposite ends of the pond to discourage short- circuiting of incoming water. This arrangement tends to maximize detention time, which allows for greater treatment of polluted water. If the inlet and outlet cannot be placed at opposite ends, baffles or gabions should be installed to lengthen the flow path.
- For elongated ponds in the direction of strong prevailing winds, consideration should be given to reinforcing banks, extending safety shelves, or other measures to prevent embankment deterioration due to wave action.
- Special design precautions may be needed to protect outlet structures from ice damage.
- Earthen embankments should meet all local and state regulations. Precautions must be taken to prevent flood damage in cases of embankment or dam failure. Dam regulations should be consulted to determine if the detention basin is subject to such regulations. For information contact the NRCS or DNR.
- Vegetation or some other type of slope protection may be needed to prevent soil erosion along banks in the zone where pool surface water fluctuates.
- The slope contours of detention basins outside of the live storage pool to the wet pond edge may vary from 4 feet horizontally to 1 foot vertically (4:1) to 10 feet horizontally to 1 foot vertically (10:1). Slopes steeper than 4:1 can cause safety problems due to slippery footing and hazardous operating conditions during maintenance. Slopes flatter than 10:1 may present drainage problems and provide mosquito habitat.

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Publication of this manual was partially funded by the Wisconsin Department of Natural Resources.

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The Wisconsin Storm Water Manual: Wet Detention Basins (G3691-4)

In the wet pond, the slope near the water's edge should be somewhat steep (4:1) to reduce mosquito problems and to provide relatively fast pond drawdown after most common storms. This slope should not exceed 18 vertical inches to reduce the risk of drowning. An area around the perimeter of the facility should have a safety shelf 10 feet wide. This shelved section should be relatively flat, 10:1 or flatter, to allow persons who may fall in a chance to regain their footing and pull themselves out. The sloped zone toward the center of the pond beyond the shelf region should be sloped as steeply as soil stability will allow to provide for the maximum volume of wet detention storage.

- Wet ponds should have a minimum three foot depth in the center section of the pool. This three foot requirement is in addition to any sediment storage that may be required.
- Planned vegetation is often overlooked in detention basin design. Vegetation can be a critical factor in determining the basin's water quality efficiency. For example, waterfowl manure can create significant biological oxygen demand (BOD) demands on the facility. Vegetation that completely surrounds the pond can be incorporated into the design to discourage waterfowl habitation. Vegetation can also provide an additional safety factor by restricting access to unsafe deep water, and may be used to enhance the appearance of the detention basin.

10 Varying the water depth can be an effective means of achieving a variety of vegetation. Safety shelves that surround the edges of detention ponds often have water depths less than 6 inches and may support emergent plants. Submerged plants require water depths between 1 and 2 feet. Open water is obtained with a design depth of four feet or greater.

- To ensure that a detention basin is properly sized, existing and planned future land uses must be known. The detention basin designed to take care of today's storm water needs may be undersized after 10 or 20 years of development in the drainage area. Likewise, a basin designed only to handle an area's future land use without regard to its existing condition may have an insufficient inflow and low water levels with stagnant water.
- A utility easement should be provided to allow maintenance access for sediment removal from the basin and forebay area.
- A dewatering outlet with a shutoff valve should be installed in the basin to allow the permanent pond and sediment forebay to be drained for structural maintenance.

Maintenance

Maintenance plans must be developed as a part of the planning process and agreements must be in place for inspection and maintenance. Maintenance programs should include provisions for routine inspections and housekeeping maintenance, special inspection and repair, nuisance control and sediment removal.

Routine inspection and housekeeping maintenance should be performed regularly and frequently. Activities should include removal and disposal of litter from the landscaped areas and any materials floating on the surface, removal of any materials clogging inlets or outlets and maintenance of vegetated areas through reseeding damaged areas, mowing and removal of tree seedlings.

Special inspection and repairs should be conducted annually and after each significant runoff event. Inspect and repair any eroded or slumping areas on or around the embankment, emergency spillway, inlet and outlet. Inspect for excessive deposition and identify and correct the source area. Inspect all inlets and outlets for needed repairs or clogging and repair if necessary.

Control of nuisance aquatic plants and mosquitos is critical to public acceptance of detention basins. These activities should only be conducted if a nuisance occurs or threatens. Mechanical controls should be used where feasible. Chemical control should be used sparingly and only if necessary.

Any maintenance plan must include provisions for sediment removal. Survey bottom elevations to determine the permanent pool depth and sediment depths in the basin. Remove and safely dispose of sediment as needed to maintain minimum acceptable depth for sediment storage. If the basin has a forebay, frequent cleaning may be necessary to prolong the life of the basin.