Sediment Basin
(1064)

Wisconsin Department of Natural Resources
Technical Standard

I. Definition

A sediment control device constructed with an engineered outlet, formed by excavation or embankment to intercept sediment-laden runoff and retain the sediment.

II. Purposes

Detain sediment-laden runoff from disturbed areas for sufficient time to allow the majority of the sediment to settle out.

III. Conditions Where Practice Applies

Sediment basins are utilized in areas of concentrated flow or points of discharge during construction activities. Sediment basins shall be constructed at locations accessible for clean out. Site conditions must allow for runoff to be directed into the basin.

Sediment basins are designed to be in place until the contributory drainage area has been *stabilized*[1]. Sediment basins are temporary and serve drainage areas up to 100 acres however other conservation practices are often more economical for smaller drainage areas. For drainage areas smaller than 5 acres sediment traps or ditch checks may be applicable; for design criteria refer to WDNR Technical Standard Sediment Trap (1063) or Ditch Check (1062).

Design to WDNR Technical Standard Wet Detention Basin (1001) when a permanent stormwater basin is required.

IV. Federal, State, and Local Laws

Users of this standard shall be aware of applicable federal, state, and local laws, rules, regulations, or permit requirements governing the use and placement of sediment basins. This standard does not contain the text of federal, state, or local laws.

V. Criteria

This section establishes the minimum standards for design, installation and performance requirements. Sediment basins meeting these design criteria are deemed 80% effective by design in trapping sediment.

A. **Timing** – Sediment basins shall be constructed prior to disturbance of up-slope areas and placed so they function during all phases of construction. Sediment basins shall be placed in locations where runoff from disturbed areas can be diverted into the basin.

B. **Sizing Criteria** – Properly sized sediment basins are more effective at trapping fine-grained particles than sediment traps. Specific trapping efficiency varies based on the surface area and the particle size distribution of the sediment entering the device. See Figure 1 for clarification of terms. Attachment 1 includes a sample design problem.

1. *Treatment Surface Area* – The surface area of the sediment basin measured at the invert of the lowest outlet. The treatment surface area shall be sized based on the texture of the soil entering the device and the peak outflow during the 1-year, 24-hour design storm using Equation 1:

$$S_a = 1.2 * (q_{out} / v_s)$$

Where:

S_a = Treatment surface area measured at the invert of the lowest outlet of sediment basin (square feet)

q_{out} = Peak outflow (cubic feet / second) during the 1-year, 24-hour design storm for the principal outlet

v_s = Particle settling velocity (feet/second)

1.2 = EPA recommended safety factor.

Technical Standards are reviewed periodically and updated if needed. To obtain the current version of this standard, contact your local WDNR office or the Standards Oversight Council.

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[1] Words in the standard that are shown in italics are described in X. Definitions. The words are italicized the first time they are used in the text.

Particle settling velocities (Vs) shall be based on representative soil class as follows:

  a. Soil Class 1: $v_s = 1.2*10^{-3}$ ft/sec
  b. Soil Class 2: $v_s = 7.3*10^{-5}$ ft/sec
  c. Soil Class 3: $v_s = 1.2*10^{-5}$ ft/sec

Note: Particle settling velocities calculated assuming a specific gravity of 2.65 and a water temperature of 68 degrees Fahrenheit.

Soil Class 1 includes particles greater than 20 microns generally corresponding to sand, loamy sand, and sandy loam.

Soil Class 2 includes particles between 5 and 20 microns generally corresponding to loam, silt, and silt loam aggregates as transported in runoff.

Soil Class 3 includes particles between 2 and 5 microns generally corresponding to clay loam, silty clay, and clay aggregates as transported in runoff.

The representative soil class shall be selected based on the dominant textural class of the soil entering the device.

The treatment surface area of sediment basins can be reduced when used in conjunction with water applied polymers. When employing polymers, size the treatment surface area for controlling fine soils (Class 3) using the settling velocity for medium soils (Class 2). When designing for medium sized soils (Class 2) use the settling velocity for coarse soils (Class 1). See WDNR Technical Standard Sediment Control Water Application of Polymers (1051) for criteria governing the proper use and selection of polymers.

2. Depth below Treatment Surface Area – The depth below the treatment surface area as measured from the invert of the lowest outlet of the sediment basin shall be a minimum of 5 feet deep (2 feet for sediment storage plus 3 feet to protect

against scour/ resuspension) and a maximum of 10 feet deep to limit the potential for thermal stratification.

Due to side slope requirements and safety shelf considerations it maybe difficult to maintain 5 feet of depth for the entire treatment surface area. Therefore, 50% of the total treatment surface area shall be a minimum of 5 feet deep. For basins less than 5,000 square feet, maximize the area of 5 feet depth.

Interior side slopes below the lowest invert shall be 2:1 (horizontal: vertical) or flatter to maintain soil stability.

While a permanent pool of water below the lowest invert may form, it is not required to be maintained through irrigation or installation of a liner system.

3. *Active Storage Volume* – The volume above the treatment surface area shall be calculated using one of the following methods:

  a. The method outlined in TR-55 for determining the storage volume for detention basins. This can be accomplished by using Figure 2 where:

  q_o = Peak outflow (cubic feet / second) during the 1-year, 24-hour design storm for the principal outlet calculated using Equation 1 (see section V.B.1).

  q_i = Calculated peak inflow or runoff rate (cubic feet / second) during the 1-year, 24-hour design storm.

  Vr = Calculated volume of runoff from the 1-year 24-hour design storm for the entire contributory area with the maximum area of disturbance characterized as bare soil.

  Vs = Is the required active storage volume determined using Figure 2.

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b. The active storage volume may be calculated based on routing the 1-year, 24-hour storm provided the principal outlet requirements stipulated in section V.D.2 are maintained. This method will require the use of a model.

Note: Both these methods require iterative calculations.

4. Shape – The length to width ratio of the flow path shall be maximized with a goal of 3:1 or greater. The flow path is considered the general direction of water flow within the basin including the treatment surface area and any forebay.

C. **Embankments** – Earthen embankments shall be designed to address potential risk and structural integrity issues such as seepage and saturation. All constructed earthen embankments shall meet the following criteria.

1. The base of the embankment shall be stripped of all vegetation, stumps, topsoil and other organic matter.

2. Side slopes shall be 3:1 or flatter. The minimum embankment top width shall be adequate to provide structural stability. Where applicable the top width shall be wide enough to provide maintenance access.

3. There shall be a core trench or key-way along the embankment.

4. Any pipes extending through the embankment shall be bedded and backfilled with equivalent soils used to construct the embankment. The bedding and backfill shall be compacted in lifts and to the same standard as the original embankment. Excavation through a completed embankment shall have a minimum side slope of 1:1 or flatter.

5. Measures shall be taken to minimize seepage along any conduit buried in the embankment.

D. **Outlet** – Sediment basins shall have both a principal outlet and an overflow spillway.

1. Timing – Outlets must be constructed in conjunction with the remainder of the basin and must be constructed prior to the basin receiving runoff. Sediment basins are ineffective until the outlet is constructed.

2. Principal Water Quality Outlet – The principal water quality outlet shall be designed to pass the 1-year 24-hour storm without use of the overflow spillway or other outlet structures. The maximum outflow (q_o) from the principal water quality outlet shall be less than or equal to the q_o used in Equation 1 (V.B.1). If the sediment basin is to serve as a permanent stormwater basin, the principal outlet structure can be modified (i.e. removable plates) to meet flow requirements encountered during and after construction; separate outlet structures do not need to be constructed.

Note: Local ordinances may require control of larger storm events such as the 2-year 24 hour storms. In these cases, additional or compound outlets maybe required.

3. Overflow (Emergency) Spillway – An overflow spillway shall be provided consisting of an open channel constructed adjacent to the embankment and built over a stabilized area. The spillway shall be designed to carry the peak rate of runoff expected from a 10-year, 24-hour design storm or one commensurate with the degree of hazard, less any reduction due to flow in the principal outlet. The top of the embankment shall be at least one foot above the design high water level and a minimum of 1 foot above the invert of the overflow spillway. The overflow spillway shall be protected from erosion. Flow from the overflow spillway shall be directed away from the embankment.

4. Outlet Protection – All outlet designs shall incorporate preventive measures for ice damage, trash accumulation, and erosion at the outfall. For orifices less

than 8-inches in diameter, or equivalent, additional measures to prevent clogging are required.

E. **Inlet Protection** – Inlets shall be designed to prevent scour and reduce velocities during peak flows. Possible design options include flow diffusion, plunge pools, directional berms, baffles, or other energy dissipation structures.

F. **Location** – Temporary sediment basins should be located to provide access for cleanout and disposal of trapped sediment.

G. **Removal** – Temporary sediment basins shall be removed after the contributing drainage area has been stabilized. Complete final grading and restoration according to the site plans. If standing water needs to be removed it shall be done in accordance with WDNR Technical Standard Dewatering (1061).

VI. Considerations

A. When constructing a sediment basin that will also serve as the long-term stormwater detention pond, build the sediment basin to the larger of the two sizes required either for stormwater control or erosion control. In addition, when sizing the outlet structure first design the outlet for the long-term stormwater management requirements then check to satisfy the flow requirements for sediment control during construction. If additional flow restriction is needed consider use of a temporary restriction plates or other measures to avoid having to construct separate outlet structures for the sediment basin and stormwater basin.

B. Over-excavation beyond the required depth in the sediment storage area of the sediment basin may allow for less frequent maintenance. Addition of other measures in the contributing drainage area may reduce sediment accumulation and associated maintenance requirements.

C. The use of a sediment forebay can extend the useful life of the main sediment storage area by trapping the majority of sediment in the forebay area. Separation of the forebay from the rest of the basin requires construction of a submerged shelf (if wet) or

a stone or stabilized earthen embankment. The forebay should have a surface area equal to at least 12% of the total basin area.

D. In addition to soil stability issues, interior slopes of sediment basins should be selected based on safety issues commensurate with the degree of hazard.

VII. Plans and Specifications

A. Plans and specifications for installing sediment basins shall be in keeping with this standard and shall describe the requirements for applying the practice to achieve its intended purpose.

1. Location of sediment basin

2. Schedules and sequence of installation and removal

3. Standard drawings and installation details

4. Control structure detail and layout

5. Sizing of sediment storage area

6. Maintenance requirements

B. All plans, standard detail drawings, or specifications shall include sequence for installation, inspection, and maintenance requirements. The responsible party shall be identified.

VIII. Operation and Maintenance

Sediment basins shall, at a minimum, be inspected weekly and within 24 hours after every precipitation event that produces 0.5 inches of rain or more during a 24-hour period.

A. Sediment shall be removed to maintain the three foot depth of the treatment surface area as measured from the invert of the principal outlet. Sediment may need to be removed more frequently.

B. If the outlet becomes clogged it shall be cleaned to restore flow capacity.

C. Provisions for proper disposal of the sediment removed shall be made.

D. Maintenance shall be completed as soon as possible with consideration to site conditions.

IX. References

Chapter NR 333, Dam and Design Construction.

Hann, Barfield, and Hayes. Design Hydrology and Sedimentology for Small Catchments. Academic Press Inc., 1994.

Robert E. Pitt, Small Storm Hydrology.

US Bureau of Reclamation, Design of Small Dams. http://www.usbr.gov/pmts/hydraulics_lab/pubs/index.cfm.

USDA, Natural Resources Conservation Service, Ponds – Planning, Design, Construction. Agriculture Handbook No. 590, Revised September 1997.

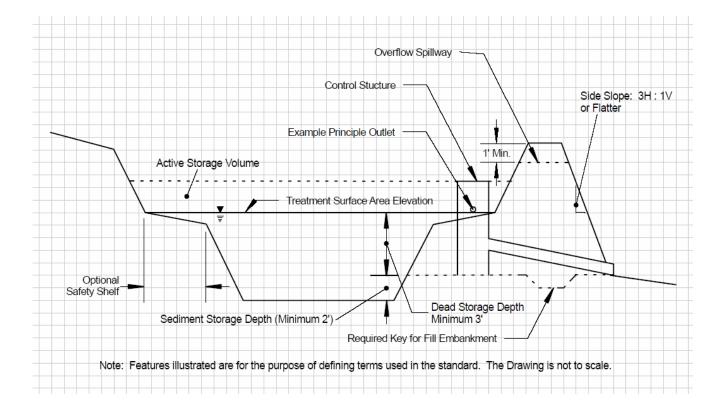WDNR Technical Standard 1001 Wet Detention Basin.

X. Definitions

Active Storage Volume (V.B.3) – Is measured from the invert of the lowest outlet to the invert of the emergency spillway.

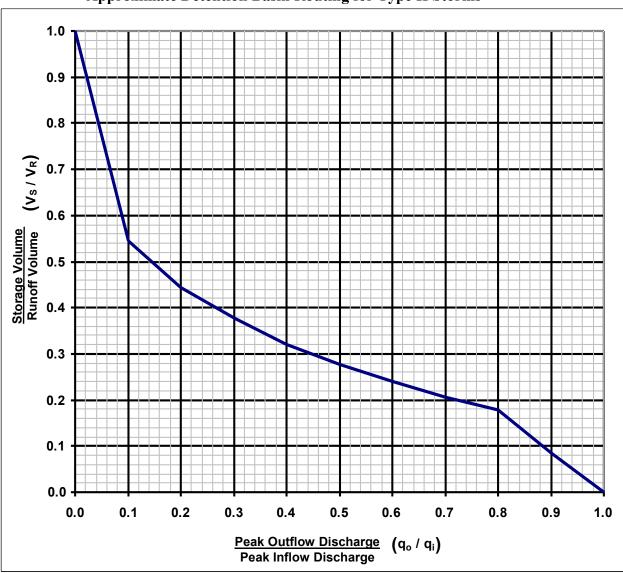*Stabilized* (III) – Means protecting exposed soil from erosion.

Treatment Surface Area (V.B.1) – Is the surface area of the sediment basin measured at the invert of the lowest outlet.

Figure 1:

Clarification of Sediment Basin Terminology

Note: Features illustrated are for the purpose of defining terms used in the standard. The Drawing is not to scale.

Figure 2:

Approximate Detention Basin Routing for Type II Storms

Source: Technical Release 55, United States Department of Agriculture, Natural Resources Conservation Service. Washington D.C. 1988.

Rainfall Quantities:

Table 1 provides a summary of the 1-year, 24-hour rainfall totals using NRCS mandated TP-40 which has not been updated since 1961. Table 2 provides a summary of more current data from the Rainfall Frequency Atlas of the Midwest published in 1992. Local requirements may dictate the use of one dataset over the other.

Table 1 - Rainfall for Wisconsin Counties for a 1 - year, 24 - hour Rainfall[1]	
Inches of Rainfall	County
2.1 in.	Door, Florence, Forest, Kewaunee, Marinette, Oconto, Vilas
2.2 in.	Ashland, Bayfield, Brown, Calumet, Douglas, Iron, Langlade, Lincoln, Manitowoc, Menominee, Oneida, Outagamie, Price, Shawano, Sheboygan
2.3 in.	Barron, Burnett, Dodge, Fond du Lac, Green Lake, Marathon, Milwaukee, Ozaukee, Portage, Racine, Rusk, Sawyer, Taylor, Washburn, Washington, Waukesha, Waupaca, Waushara, Winnebago, Wood
2.4 in.	Adams, Chippewa, Clark, Columbia, Dane, Dunn, Eau Claire, Jackson, Jefferson, Juneau, Kenosha, Marquette, Pepin, Pierce, Polk, Rock, St. Croix, Walworth
2.5 in.	Buffalo, Green, Iowa, La Crosse, Monroe, Richland, Sauk, Trempealeau, Vernon
2.6 in.	Crawford, Grant, Lafayette
[1]TP - 40 - Rainfall Frequency Atlas of the United States, U.S. Department of Commerce Weather Bureau.	

Table 2 - Rainfall for Wisconsin Counties for a 1 - year, 24 - hour Rainfall[2]		
Zone	Inches of Rainfall	County
1	2.22	Douglas, Bayfield, Burnett, Washburn, Sawyer, Polk, Barron, Rusk, Chippewa, Eau Claire
2	2.21	Ashland, Iron, Vilas, Price, Oneida, Taylor, Lincoln, Clark, Marathon
3	1.90	Florence, Forest, Marinette, Langlade, Menominee, Oconto, Door, Shawano
4	2.23	St. Croix, Dunn, Pierce, Pepin, Buffalo, Trempealeau, Jackson, La Crosse, Monroe
5	2.15	Wood, Portage, Waupaca, Juneau, Adams, Waushara, Marquette, Green Lake
6	1.96	Outagamie, Brown, Kewaunee, Winnebago, Calumet, Manitowac, Fond Du Lac, Sheboygan
7	2.25	Vernon, Crawford, Richland, Sauk, Grant, Iowa, Lafayette
8	2.25	Columbia, Dodge, Dane, Jefferson, Green, Rock
9	2.18	Ozaukee, Washington, Waukesha, Milwaukee, Walworth, Racine, Kenosha
[2]Bulletin 71: Rainfall Frequency Atlas of the Midwest, Midwest Climate Center and Illinois State Water Survey, 1992.		

Attachment 1:
Sample Sediment Basin Design Problem

The proper sizing and design of a sediment basin will often require iterative calculations. The technical standard for sizing sediment basins was written to give the designer as much flexibility as possible in designing the basin while meeting water quality requirements. The governing equation relates the surface area of the sediment basin to the outflow and critical particle settling velocity. The larger the sediment basin outflow, the larger the surface area required to settle the particle. As the outflow is reduced, a smaller surface area is required however the required storage volume dictates how small a surface area can become through the storage depth or hydraulic head acting on the outlet.

The particle settling velocities are listed in the standard requiring the designer to either start with a desired outflow based on an outlet size or an estimated starting surface area. The sample equation below starts with an estimated surface area.

Sample Problem:

A 10 acre site is being developed into condos. Eight acres of the site are being disturbed while 2 acres of forest are remaining undisturbed. The dominate soils on the site are silt loam. The 1-year, 24-hour design storm is 2.25 inches.

Step 1: Calculate runoff volume and peak using TR-55 or approved method.

From TR-55 the curve number (CN) for the disturbed area is 86 and the CN for the forested area is 55 resulting in a composite CN of 80. Using TR-55, the runoff volume calculated for the 1-year 24-hour design storm is 0.7 inches (0.6 acre-feet for the entire 10-acre site). The time of concentration was calculated as 0.4 hours resulting in a peak flow of 6 cfs.

Step 2: Begin sizing sediment basin using Equation 1. The technical standard lists silt loam under particle class 2 with a settling velocity of $7.3*10^{-5}$ ft/sec. We are also going to assume a starting surface area of 0.25 acres (10,890 ft^2). An alternative approach is to assume an outflow velocity.

$SA = 1.2 * (q_{out} / v_s)$
Solve for q_{out}:   10,980 ft^2 = 1.2 * (q_{out} / $7.3*10^{-5}$ ft/sec)
q_{out} = 0.67 cfs

Step 3: Using Figure 2: Approximate Detention Basin Routing for Type II Storms determines the volume of storage (V_S) needed.

q_{out} = 0.67 cfs (calculated in Step 2)
q_{in} = 6.0 cfs (peak flow calculated using TR-55 in Step 1)
V_R = 0.6 acre-feet (volume of runoff calculated using TR-55 in Step 1)
q_{out} / q_{in} = 0.67 cfs / 6.0 cfs = 0.11. Using Figure 2 with a q_{out} / q_{in} = 0.11, the V_S/V_R is determined to be 0.54. Therefore the V_S = 0.54 * 0.6 acre-feet = 0.324 acre-feet (14,113 ft^3)

Step 4: Check configuration: Calculate maximum head on outlet using surface area and volume.

SA = 10,890 ft^2 and a V_S = 14,113 ft^3 we get a depth (H) of 1.29 feet = 14,113 ft^3 / 10,890 ft^2

Step 5: Size Outlet: Assuming an orifice type outlet calculate the size needed to meet the q_{out} calculated in Step 1 and the H calculated in Step 4.

Using the orifice equation: $q_{out} = C*A*(2gH)^{1/2}$ with C=0.6 (coefficient) , A = Area = ft^2, g = 32.2, and H = hydraulic head expressed in feet.

$q_{out} = 0.6*A*(2*32.2*H)^{1/2}$ so $0.66 = 0.6*A*(2*32.2*1.29)^{1/2}$ therefore A = .12 ft^2

An area of 0.12 ft^2 corresponds to an orifice outlet of 4.7 inches in diameter.

Step 6: Iteration: While the above solution works, the sediment basin has not been optimally sized and we have an orifice diameter that is not a standard pipe size. An iterative approach can be used to reduce the surface area of the sediment basin and obtain a more common orifice diameter. We can assume a 4-inch orifice since it is close to diameter calculated in Step 5 and we can start with the depth we calculated in Step 4. The iterations below each represent Steps 2 through 5.

Iteration 1:

$q_{out} = 0.43 (H)^{1/2} = 0.43 (1.29)^{1/2} = 0.48$ cfs which is less than the 0.66 cfs calculated in Step 1. Therefore, we can go back to Step 1 and repeat the sizing procedure and downsize the sediment basin.

SA = 1.2 * (q_{out} / v_s) = 1.2 * (0.48 cfs / 7.3*10^{-5} ft/sec) = 7,890 ft^2

Using Figure 2:
$q_{out} = 0.48$ cfs
$q_{in} = 6.0$ cfs (peak flow calculated using TR-55 in Step 1)
$V_R = 0.6$ acre-feet (volume of runoff calculated using TR-55 in Step 1)

$q_{out} / q_{in} = 0.48$ cfs / 6.0 cfs = 0.08. Using Figure 2 with a $q_{out} / q_{in} = 0.08$, the V_S/V_R is determined to be 0.62. Therefore the $V_S = 0.62 * 0.6$ acre-feet = 0.372 acre-feet (16,204 ft^3)

SA = 7,890 ft^2 and a $V_S = 16,204$ ft^3 we get a depth (H) of 2.05 feet = 16,204 ft^3 / 7,890 ft^2

$q_{out} = 0.43 (H)^{1/2} = 0.43 (2.05)^{1/2} = 0.61$ cfs which is more than the 0.48 cfs we used so iterate.

Iteration 2:

SA = 1.2 * (q_{out} / v_s) = 1.2 * (0.61 cfs / 7.3*10^{-5} ft/sec) = 10,027 ft^2

Using Figure 2:
$q_{out} = 0.61$ cfs
$q_{in} = 6.0$ cfs (peak flow calculated using TR-55 in Step 1)
$V_R = 0.6$ acre-feet (volume of runoff calculated using TR-55 in Step 1)

$q_{out} / q_{in} = 0.61$ cfs / 6.0 cfs = 0.10 Using Figure 2 with a $q_{out} / q_{in} = 0.10$, the V_S/V_R is determined to be 0.54. Therefore the $V_S = 0.54 * 0.6$ acre-feet = 0.324 acre-feet (14,113 ft^3)

SA = 10,027 ft^2 and a $V_S = 14,113$ ft^3 we get a depth (H) of 1.41 feet = 14,113 ft^3 / 10,027 ft^2

$q_{out} = 0.43 (H)^{1/2} = 0.43 (1.41)^{1/2} = 0.51$ cfs which is less than the 0.61 cfs we used so we are OK or we can iterate again until we have q_{out} that are almost identical.

After Iteration 2, we have a sediment basin with a SA = 10,027 ft^2 and a $V_S = 14,113$ ft^3. We have a principal water quality outlet consisting of a 4-inch orifice. This design meets the water quality requirements of the technical standard.