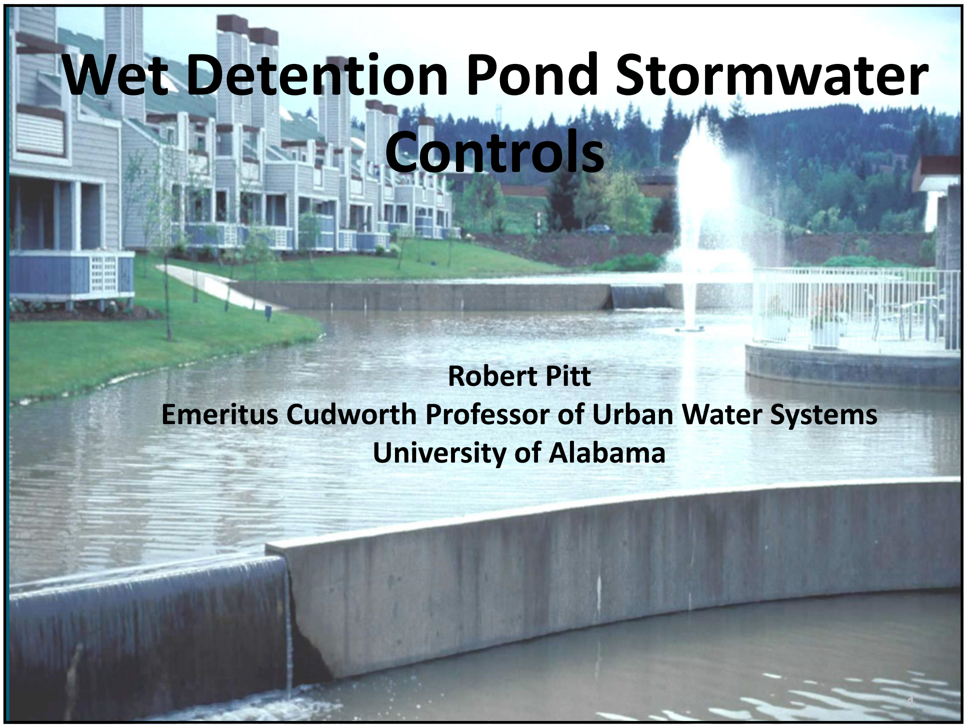
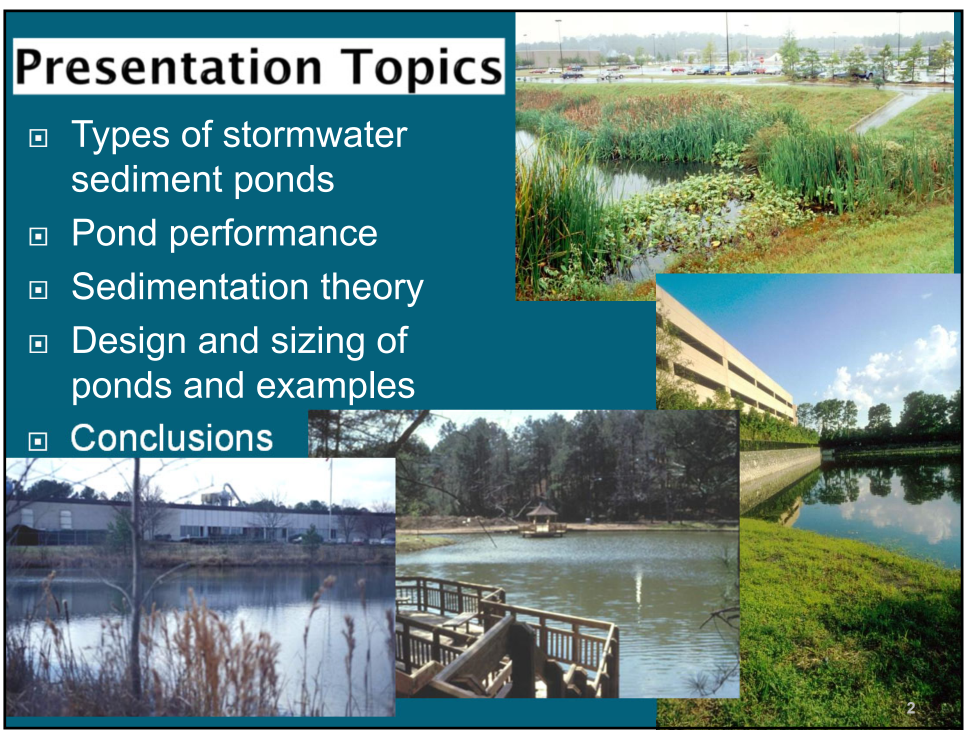

Wet Detention Pond Stormwater Controls
Robert Pitt
Emeritus Cudworth Professor of Urban Water Systems
University of Alabama


Presentation Topics
Types of stormwater sediment ponds
Pond performance
Sedimentation theory
Design and sizing of ponds and examples
Conclusions
2

Wet Basins

Caltrans, San Diego, California

3

Extended Detention Ponds

Caltrans, San Diego and Los Angeles, California

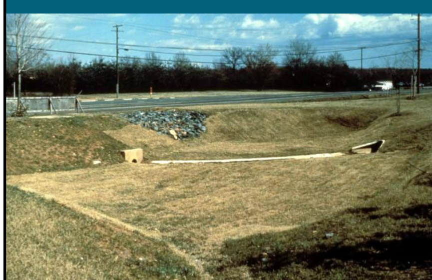
4

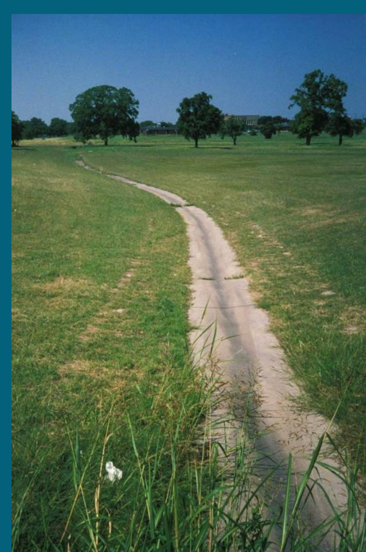
Wet Detention Pond Advantages

- Very good control of particulate pollutants
- Opportunity to utilize biological processes
  - Protozoa as bacteria predators
  - Aquatic plants enable higher levels of nutrient removal
- Outfall ponds capture and treat all storm sewer discharges
  - Wet weather stormwater runoff
  - Dry weather baseflows
  - Snowmelt
  - Industrial spills
  - Illegal discharges

5

Typical Dry Detention Ponds, with Pilot Channels





6

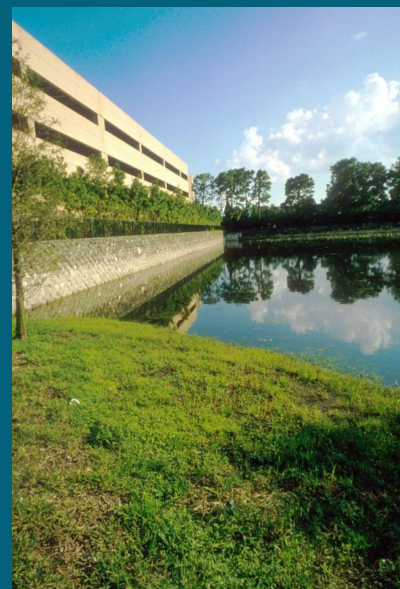
Unusual Dry Detention Pond Located on Hillside to Meet Peak Flow Rate Criterion

Scour and Sediment Transport in Dry Detention Ponds

Wet Detention Ponds

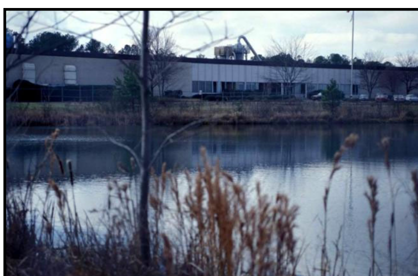
Shopping Center, Birmingham, AL

Shopping Center, Dayton, OH



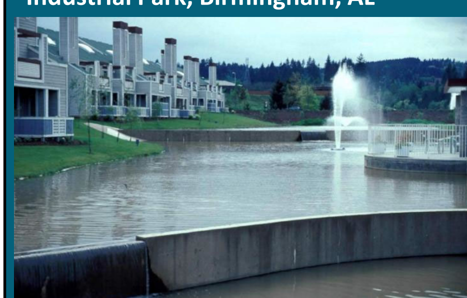
Convention Center, Orlando, FL

9

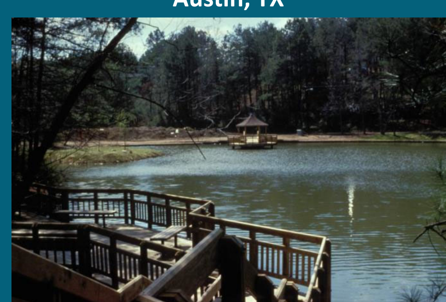


Industrial Park, Birmingham, AL

Advertising for New Wet Ponds, Austin, TX



Apartments, Lake Oswego, OR (Part of Treatment Train)



Residential Area Park, Birmingham, AL

10

Observed Wet Pond Performance (when constructed and operated according to best guidance)

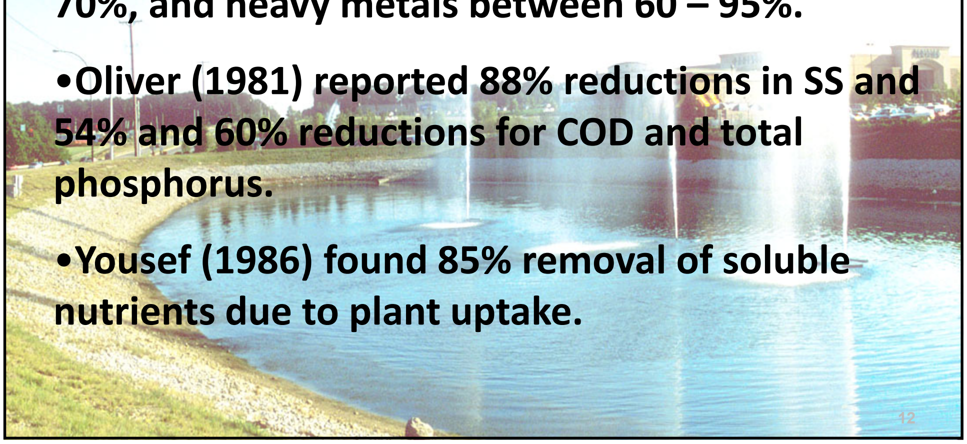
- Suspended solids: 70 to 95%
- COD: 60 to 70%
- BOD_5: 35 to 70%
- Total Kjeldahl nitrogen: 25 to 60%
- Total phosphorus: 35 to 85%
- Bacteria: 50 to 95%
- Copper: 60 to 95%
- Lead: 60 to 95%
- Zinc: 60 to 95%

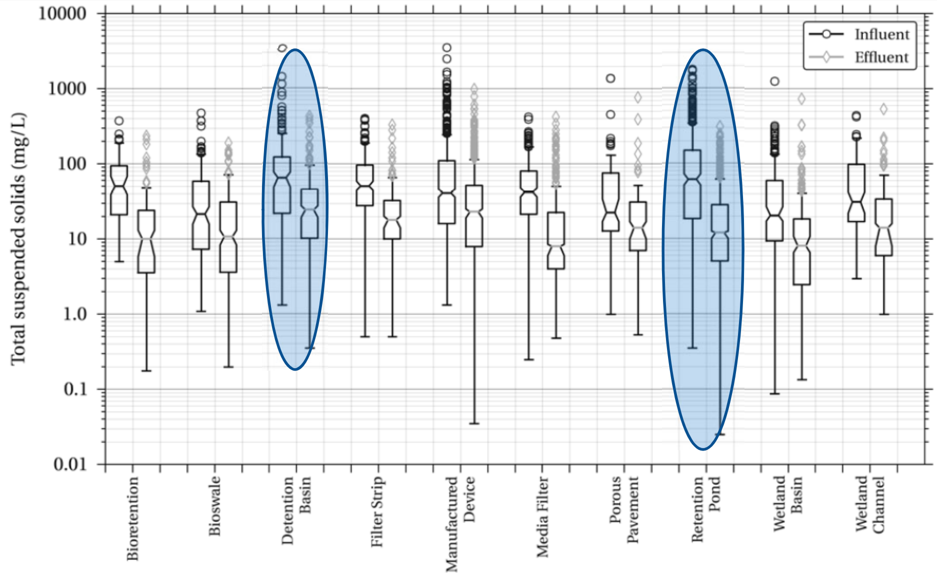
11

•NURP (1983) found particulates reduced by between 0% (for small ponds and large drainage areas) and 90+% for large ponds. For well designed ponds BOD and COD removals were 70%, and heavy metals between 60 – 95%.

•Oliver (1981) reported 88% reductions in SS and 54% and 60% reductions for COD and total phosphorus.

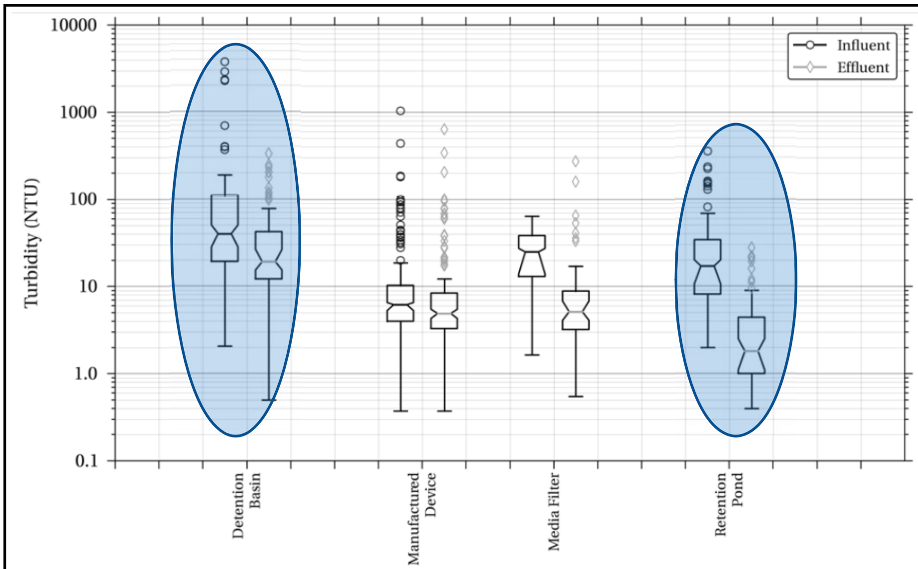
•Yousef (1986) found 85% removal of soluble nutrients due to plant uptake.





TSS influent and effluent for different stormwater practices

International Stormwater BMP Database



Turbidity influent and effluent for different stormwater practices

International Stormwater BMP Database

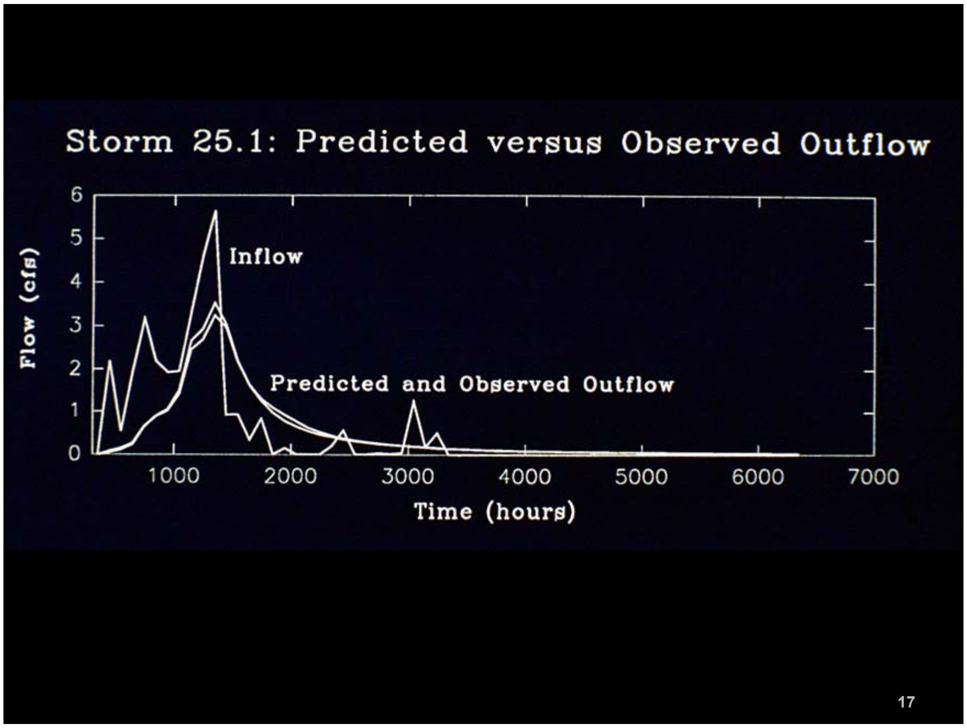
Why is there such a large difference in performance between a dry and a wet pond?

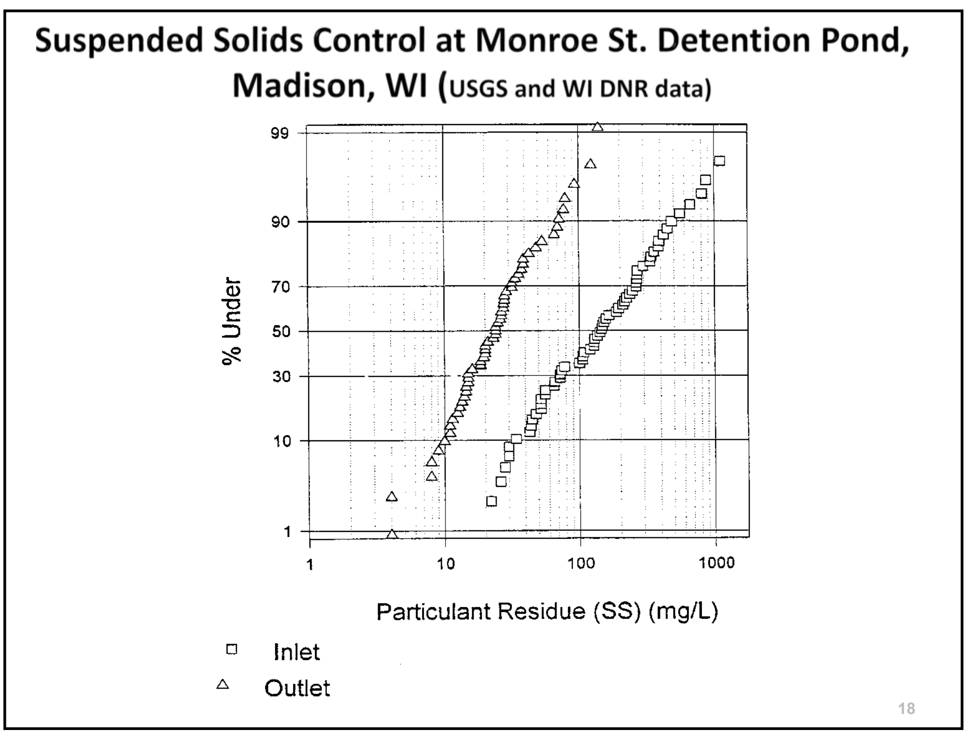
- Usually due to scour
  - Need at least 3 ft for wet ponds to protect previously captured silt
  - Grass filters look like dry ponds (and the grass filters can work well, but require lengthy sheetflows with level spreaders, low slopes, good grass stands, no pilot channels, etc.)
  - Terminology issues (in many areas, dry ponds are actually percolation ponds or infiltration ponds with no surface discharges). HIGs

15

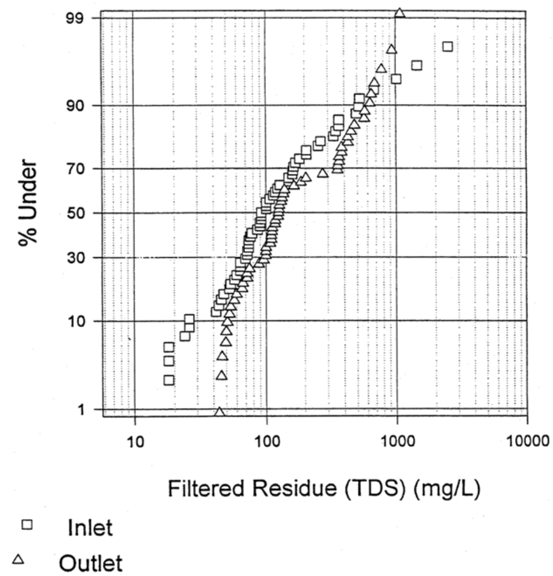
The Monroe St. detention pond in Madison has been monitored by the WI DNR and USGS for many years. The data have been used to verify the wet detention pond routines in WinSLAMM and Detpond (amongst other ponds). Retrofitted to result in 90% SS control, the long-term monitored results were 87%.

16


Storm 25.1: Predicted versus Observed Outflow
Inflow
Predicted and Observed Outflow
Flow (cfs)
Time (hours)
0
1
2
3
4
5
6
1000
2000
3000
4000
5000
6000
7000
17


Suspended Solids Control at Monroe St. Detention Pond, Madison, WI (USGS and WI DNR data)
% Under
99
90
70
50
30
10
1
1
10
100
1000
Particulant Residue (SS) (mg/L)
Inlet
Outlet
18

Total Dissolved Solids Control at Monroe St. Detention Pond, Madison, WI (USGS and WI DNR data)



19

Retrofitted to result in 90% SS control, the long-term monitored results were 87%.

PROBABILITY IN % UNDER	10%	50%	90%
Suspended solids	35	87	97
Total Residue	<0	52	86
Volatile Residue	<0	41	76
Filtered Residue	<0	<0	56
Particulate COD	15	80	95
Total COD	29	60	84
FilteredCOD	<0	24	80
Particulate Phosphorus	-20	60	80
Total Phosphorus	<0	47	81
Filtered Phosphorus	<0	43	83
Particulate TKN	-40	40	80
Total TKN	<0	45	75
Filtered TKN	<0	12	68
Particulate Zinc	-117	70	95
Total Zinc	<0	31	69
Filtered Zinc	<0	<0	59

20

Pond Problems

- Safety
- Nuisance conditions
- Maintenance
- Poorly known site conditions
- Critters

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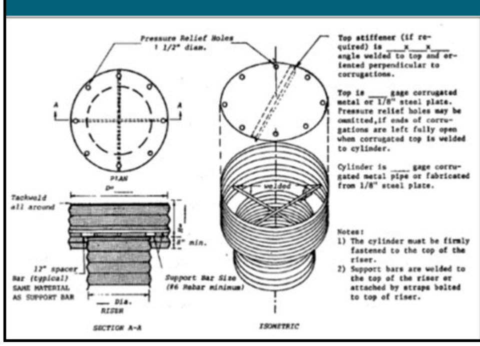
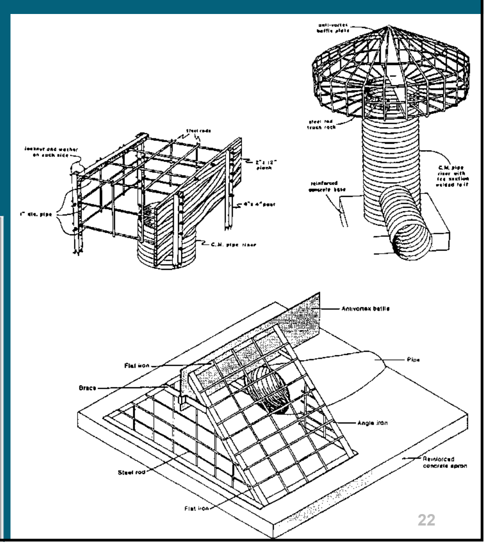
Safety of Detention Ponds

Numerous design features to maximize pond safety:

- Side slopes
- Depth
- Safety ledge
- Accessibility
- Outlet structure protection
- etc.





22

Deep Water Too Close To Shore

23

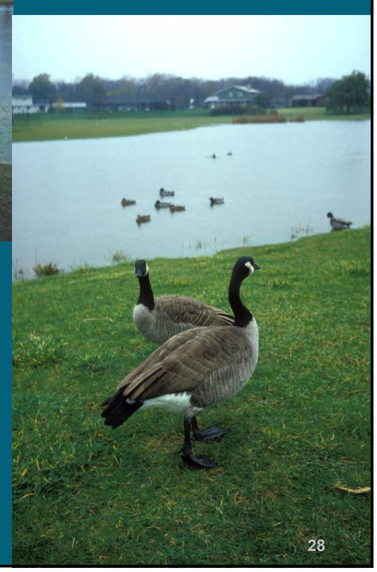
Thin Ice Near Shore

Steve Auger photo

Children are Attracted to Urban Waters

Wet Ponds Located in Areas of Karst Geology may have Sinkholes

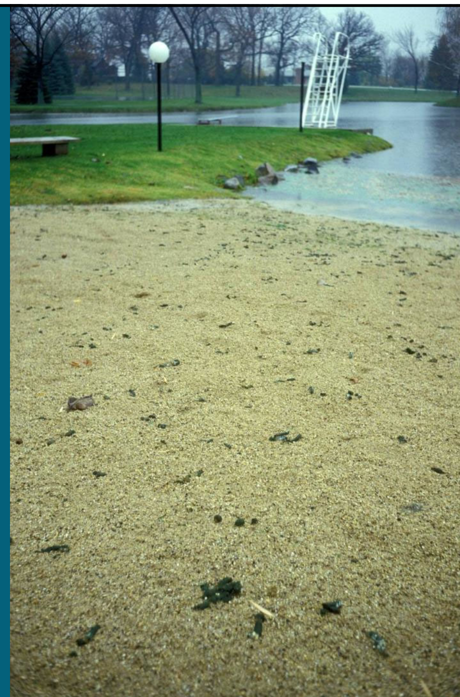
27



Ponds can be attractive and in some areas they actually encourage contact recreation, but water quality is usually poor. Birds and other wildlife are also frequently attracted to ponds.

28

However, they may be mutually exclusive uses



29

Bob Kort photo

Other critters also attracted to ponds (no geese at this pond!)

30

Design Suggestions to Enhance Pollutant Control and to Minimize Problems

Composite list from literature and experience

- Locate and size ponds to minimize hydraulic interferences.
- Keep pond shape simple to minimize short-circuiting.
- Slope ground leading to pond between 5 and 25%.
- Use shallow perimeter shelf as a safety ledge.
- Plant dense emergent vegetation on shelf.
- Plant thick vegetation barrier around pond perimeter.
- Provide at least 3 ft. of permanent pool depth for scour protection.
- Provide at least 2 more feet as sacrificial storage.

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Design Suggestions (cont.)

- Use sub-surface outlets to minimize clogging and to retain floatables.
- Discourage water contact recreation and consumptive fishing.
- Stock mosquito eating fish.
- Minimize water level fluctuations to reduce mosquito problems.
- Place rocks at inlet and outlet areas to minimize scour.
- Use anti-seep collars around outlet pipes to minimize piping.
- Provide trash and safety racks, plus baffles on outlets.
- Provide emergency spillway.

32

Special Stormwater Control Considerations in Areas having Harsh Winters

- Snowmelt can contribute the majority of the annual pollutant loads from urban areas that experience heavy winter snowfalls.
- Summer runoff is typically only considered in the design of stormwater controls
- Cold weather hinders all stormwater control processes (such as infiltration, settling, and plant uptake)
- Deicing salts are a special threat to urban groundwater quality

33

Stormwater Design Considerations for Cold Climates

- "Oversize" wet ponds to accommodate reduced settling rates (can be one-half of the summer rates)
- Protect sediment from scour during snowmelt
- "Oversize" infiltration areas due to reduced soil infiltration rates, but substantial infiltration does occur under snowpacks during long winters
- Divert snowmelt from infiltration areas
- Do not rely on wetlands and other controls utilizing plants during long dormant season
- Follow good snow removal practices
- Reduce the use of deicing salts
- Prevention is especially important in design of land development

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Infiltration Swale in Office Park Area, Downstream of Wet Pond, Lake Oswego, OR, Part of Treatment Train

35

Wet Detention Pond Performance Calculation Data Requirements

- Surface area of pond
- Water quality volume (live storage above lowest pond water surface elevation, usually the pond volume between the water quality outlet and the emergency spillway)
- Depth of water over the sediment to prevent scour
- Stage-discharge relationship for all outlets
- Particle size distribution of inflowing particulates
- Hydrograph of influent flows

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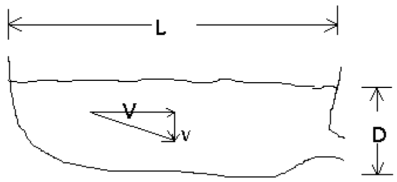
Particulate Settling

- Ideal Settling: Particle path is vector sum of particle velocity through pond and settling (upflow) velocity



$$\frac{V}{v} = \frac{L}{D} \rightarrow v = \frac{Q_{out}}{A}$$

As shown on pages 23-25 of detention pond design.pdf and outlined on the following ppts

- **L = Pond Length**
- **D = Outlet Depth**
- **V = Water Velocity through Pond**
- **v = Settling Velocity**
- **Q_{out} = Outflow from Pond**
- **A = Pond Surface Area**

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Particle Settling Derivation

$$\frac{V}{v} = \frac{L}{D}$$

$$V = \frac{Q}{a}$$

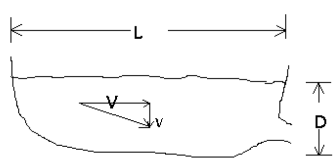
$$V = \frac{Q_{out}}{DW}$$

- L = Pond length
- D = Outlet depth
- V = Water velocity through pond
- v = Settling velocity
- Q_{out} = Outflow from pond
- *a* = Pond cross sectional area
- W = pond width

Substituting this relationship of V into the first equation:

$$\frac{Q_{out}}{DWv} = \frac{L}{D}$$

$$\frac{Q_{out}}{Wv} = L$$



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Particle Settling Derivation (cont.)

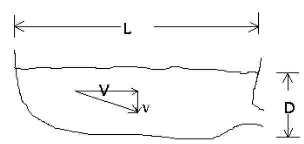
$$\frac{Q_{out}}{v} = LW$$

$$\frac{Q_{out}}{v} = A$$ where A= Pond Surface Area, LW

$$v = \frac{Q_{out}}{A}$$ where Q_{out} = Pond Outflow Rate (ft³/s)

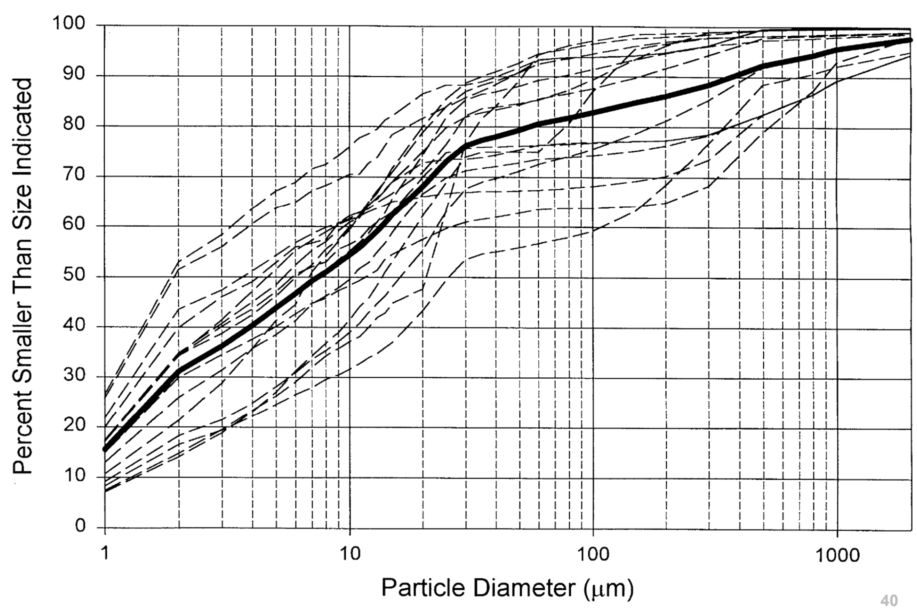
v = Particle Settling Velocity (ft/s)

Therefore, particle settling is a function of the pond outflow rate and the pond surface area only. This can be applied to changing flows entering the pond during continuous modeling.



39

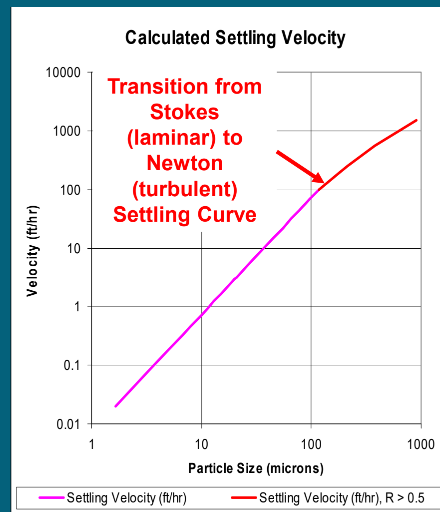
Measured Particle Sizes, Including Bed Load Component, at Monroe St. Detention Pond, Madison, WI



40

Particulate Settling

- Ideal settling is modeled
  - Using Stokes Law (laminar flow) for smaller particles
  - Settling velocity as a function of Reynolds number and particle size for larger particles under turbulent flow conditions
  - Water temperature (can vary monthly) and particle density also affect settling rates and can be changed in WinSLAMM



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Wet Pond Design Criteria for Water Quality

- Surface area should have a minimum area based on land use and desired pollutant control.
- Pond freeboard storage (water quality volume) equal to runoff associated with 1.25 inches of rain for the land use and development is a good value to start with.
- Select outlet device to obtain desired pollutant control for all pond stages based on stage-discharge relationship.
- Incorporate special features for harsh winters and snowmelt loads, if needed

42

1. Pond Area as a Percentage of Drainage Area (assuming "standard" development conditions)

	5 micrometer (about 90% SSC control)	20 micrometer (about 65% SSC control)
Totally paved	2.8	1.0
Industrial	2.0	0.8
Commercial	1.7	0.6
Institutional	1.7	0.6
Residential	0.8	0.3
Open space	0.6	0.2
Construction	1.5	0.5

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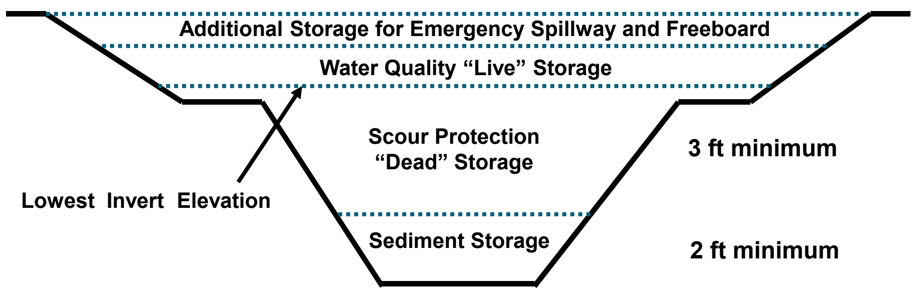
2. Design of Wet Detention Ponds (cont.)

The pond freeboard storage (water quality volume) should be equal to the runoff associated with 1.25 inches of rain for the land use and development type. For example:

Example site	Land Area (acres)	Pond WQ Volume Factor	Pond WQ Volume
Paved area	0.6	1.1 inches	0.66 ac-in
Undeveloped area (clayey soils)	3.8	0.3	1.14
Construction site (clayey soils)	27.6	0.6	16.56
Total	32.0		18.36 ac-in (1.53 ac-ft)

44



3. The "dead" storage is needed to prevent scour of previously deposited material and should be at least 3 ft. deep over the sediment. Sediment storage volume is also needed and can be estimated based on sediment accumulation; it should be at least 2 ft. deep.

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Runoff Depth Corresponding to 1.25 Inches of Rain

Based on small storm hydrology

	Sandy	Clayey
Freeways	0.35	0.40
Totally paved	1.1	1.1
Industrial	0.85	0.9
Commercial	0.75	0.85
Schools	0.2	0.4
Low density residential	0.1	0.3
Medium density residential	0.15	0.35
High density residential	0.2	0.4
Developed parks	0.5	0.6
Construction sites	0.5	0.6

Pitt 1987

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4. Selection of Outlet Control Device (only showing two small V-notch weirs here)

Head (ft)	Flow (cfs)	22.5° Storage (ac-ft)	Reqd. min. area (acres)	Flow (cfs)	30° Storage (ac-ft)	Reqd. min. area (acres)
0.5	0.1	<0.01	0.01	0.1	<0.01	0.02
1	0.5	0.03	0.1	0.7	0.05	0.1
1.5	1.4	0.1	0.2	1.9	0.2	0.3
2	2.8	0.3	0.5	3.8	0.3	0.7
3	7.8	1.2	1.4	11	1.6	1.8
4	16	3.3	2.8	22	4.4	3.8
5	28	7.2	4.9	38	9.6	6.6
6	44	14	7.7	60	18	10

If have 3 ft of head over the water quality outlet below the emergency spillway and the pond surface area at that depth is 2 acres, then use 30° V-notch weir.

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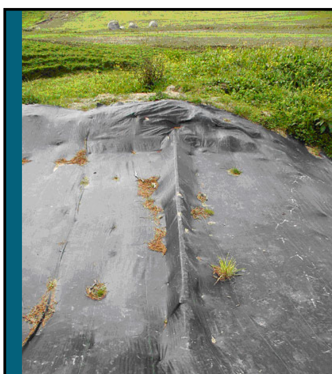
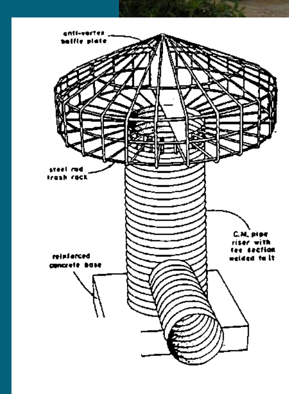


Temporary and permanent pond outlet structures



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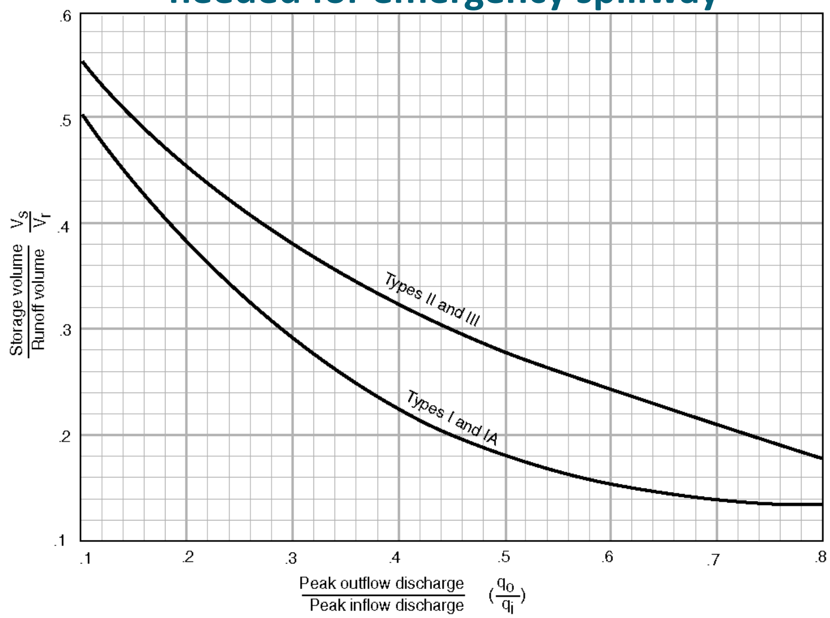
SCS TR-55 plot used to size additional freeboard needed for emergency spillway



49

Vs = 1.53 acre-ft
Vr = 7.5 acre-ft
and Vs/Vr = 0.20

for type II or III rain categories:
qo/qi = 0.72

if the calculated peak discharge rate entering the pond (qi) = 8.7 cfs, the resulting peak discharge rate leaving the pond, qo, (through the water quality primary outlet plus the emergency spillway) is therefore: 0.72 (8.7) = 6.3 cfs

50

Rain and watershed characteristics for the emergency spillway design:

- P = 8 inches
- CN = 86; therefore the Ia = 0.0366
- Q = 6.2 inches and Ia/P = 0.041
- Area (Am) = 0.021 mi^2 (13.2 acres)
- Tc = 20 min (0.3 hr)

The peak unit discharge rate from the tabular hydrograph method is 498 csm/in, and the peak discharge is therefore:

Q_{peak} = (498 csm/in)(0.021 mi^2)(6.2 in) = 63.7 ft^3/sec

Also, the volume of runoff for this event is:

V_r = [(6.2 in)(13.2 ac)]/12 in/ft = 6.82 ac-ft

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The maximum desired discharge rate for this pond (for both the water quality outlet plus the emergency spillway) is given as 46.5 ft^3/sec.

The ratio of the outlet to the inlet flow rate is therefore: q_o/q_i = 46.5/63.7 = 0.73

The ratio of the storage volume (V_s) to the runoff volume (V_r), for Type II rains is 0.2, for this ratio of outlet to inlet peak flow rates. Therefore the storage for the pond to meet this peak discharge rate goal is:

V_s = 0.2 (6.82 acre-ft) = 1.34 acre-ft

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The length (LW in feet) of a rectangular weir, for a given stage (HW in feet) and desired outflow rate (qo in ft³/sec) can be expressed as:

$$L_w = \frac{q_o}{3.2H_w^{1.5}}$$

The desired q_o for the rectangular weir is 46.5 – 2.2 = 44.3 ft³/sec. If the maximum stage for the emergency spillway is 1 ft, then length for the emergency spillway is:

$$L_w = \frac{q_o}{3.2H_w^{1.5}} = \frac{44\,ft^3/\sec}{3.2(1\,ft)^{1.5}} = 13.8\,ft$$

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Example Sizing of Wet Detention Pond

- the basic pond area,
- the “live” storage volume,
- the pond side slopes, top surface area, and “dead storage” volume,
- the selection of the primary discharge device,
- the additional storage volume needed for the emergency spillway,
- the sizing of the emergency spillway, and
- the sacrificial storage volume for sediment accumulation.

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the basic pond area and "live" storage volume

The following are the areas associated with each surface in the drainage area:

- paved areas: 0.2 acres
- undeveloped areas: 1.2 acres
- construction area: 32 acres
- total site area: 33.4 acres

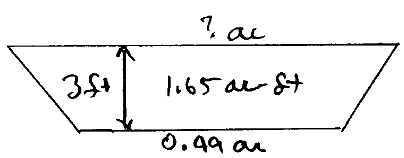
Site Subarea	Pond Surface Area (acres)	Pond "Live" Volume, runoff from 1.25 inches of rain fall (acre- inches of runoff)
paved area (0.2 acres)	3% of 0.2 acres = 0.006 acres	1.1 inches x 0.2 acres = 0.22 ac-in
undeveloped area (1.2 acres)	0.6% of 1.2 acres = 0.007 acres	0.3 inches x 1.2 acres = 0.36 ac-in
construction area (32 acres)	1.5% of 32 acres = 0.48 acres	0.6 inches x 32 acres = 19.2 ac-in
Total:	0.49 acres	19.8 ac-in = 1.65 ac-ft

55

pond side slopes, top surface area, and "dead storage" volume

1) If 3 ft deep:

Top area:

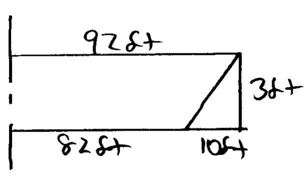


$$\frac{(0.49acres + X)3ft}{2} = 1.65ac - ft$$

$$X = 0.61acres$$

at 0.61 acres: $\pi r^2 = 26{,}570 ft^2$ r = 92 ft

at 0.49 acres: $\pi r^2 = 21{,}340 ft^2$ r = 82 ft



side slope = 3 ft/(92-82 ft) = 3 ft/10 ft = 0.3 = 30% too steep

56

Therefore, try different pond depths and calculate diameters and slopes:

If 1 ft deep; top area = 2.81 acres and r = 197 ft and side slope = 1.2%   too shallow

If 2 ft deep; top area = 1.16 acres and r = 126 ft and side slope = 4.5%   suitable, but on the low side

etc.….

The "pond sizer" spreadsheet does this (and evaluates different outlet devices) for you.

57

the selection of the primary discharge device

At the top of the live storage volume, this pond will have 2 ft of stage and 1.16 acres maximum pond area:

- 45° V-notch weir requires at least 1.0 acres of pond surface at 2 feet of stage in order to provide about 90% control of sediment.
- 30° V-notch weir would require only 0.7 acres, 60° V-notch weir would require 1.4 acres.
- None of the rectangular weirs would be suitable, as the smallest 2 ft weir requires at least 2.6 acres at 2 feet of stage.
- The 45° weir is closest to the area available and is therefore selected for this pond.
- Another suitable outlet structure would be an 18" drop tube structure which requires at least 1.1 acres.

58

the sacrificial storage volume for sediment accumulation

Using RUSLE, calculate the sediment loss for the complete construction period for the site area draining to the pond:

R = 350
LS = 1.28 (based on typical slope lengths of 300 ft at 5% slope)
k = 0.28
C = 0.24 (assuming that 5 of the 32 acres of the construction area is being actively worked with a C=1, and the other 27 acres of the construction area is effectively protected with a C=0.1)

A = (350)(1.28)(0.28)(0.24) = 30 tons per acre per year.

Since the construction period is for one year and the active construction area is 32 acres, the total sediment loss is estimated to be about 960 tons. For a loam soil, this sediment volume is about 980 yd^3, or 0.8 acre-ft. At least 1 or 2 ft should be used for stabilized areas.

59

The pond water surface is about 0.5 acres. With a three feet deep dead storage depth to minimize scour, the surface area at the bottom of this 3 ft scour protection zone (and the top of the sediment storage zone), can be about 0.35 acres (about 25% underwater slope).

The sacrificial storage zone can be about 3 ft deep also, and the bottom pond area would be about 0.18 acre, as shown in the following calculations:
Top of sacrificial storage area is 0.35 acres,
at 0.35 acres:

$\pi r^2 = 15{,}250\, ft^2$ r = 70 ft

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Therefore, the area of the bottom of the sacrificial storage area needed to provide 0.8 acre-ft of storage, if 3 feet deep can be approximated by:

$$\frac{(0.35acres + X)3ft}{2} = 0.8ac - ft$$

$$X = 0.18acres$$

at 0.18 acres, r = 50 ft
side slope = 3 ft/(70-50 ft) = 3 ft/20 ft = 0.15 = 15%

61

the additional storage volume needed for the emergency spillway

Therefore, this example will only consider the capacity of the emergency spillway to meet the design storm flow rate, the 25-year event. Other watershed characteristics are:

- watershed area: construction area (32 acres), paved area (0.2 acres), and undeveloped area (1.2 acres) = 33.4 acres = 0.052 mi^2
- clayey (hydrologic soil group D) soils (weighted curve number = 94)
- time of concentration (Tc): 12 minutes (0.2 hours). Since the pond is at the bottom of this watershed, there is no "travel time" through down-gradient subwatershed areas.
- rain intensity for a "25-year" rain for the Birmingham, AL, area, with a 15 minute time of concentration (from the local IDF curve): 6.6 inches/hour (type III rain)

62

- Ia for this curve number is 0.128 inches.
-24-hour, 25-year rain has a total rain depth (P) of 6.9 inches.
-Ia/P ratio is therefore: 0.128/6.9 = 0.019, which is much less than 0.1.

Therefore the tabular hydrograph table to be used would be Exhibit III, corresponding to a Tc of 0.2 hour. The top segment of "csm/in" (cubic feet per second per square mile of watershed per inch of direct runoff) values are therefore used, corresponding to Ia/P values of 0.1, or less. The top row is also selected as there is no travel time through downstream subwatersheds. Examining this row, the largest value is 565 csm/in, occurring at 12.3 hours. The amount of direct runoff for a site having a CN of 94 and a 24-hr rain depth of 6.9 inches is 6.2 inches. The AmQ value (area in square miles times the direct runoff in inches) for this site is: (0.052 mi^2)(6.2 inches) = 0.32 mi^2-in. This value is multiplied by the csm value to obtain the peak runoff rate for this design storm: (0.32 mi2-in)(565 csm/in) = 182 ft^3/sec.

63

The first trial for an emergency spillway will be a rectangular weir, with one foot of maximum stage. At the one foot of stage on this weir, the 45° V-notch weir will have 3 feet of stage. The V-notch weir will discharge 16 ft^3/sec at this stage. Therefore, the rectangular weir will need to handle: 182 – 16 ft^3/sec = 166 ft^3/sec. The rectangular weir can be sized from the rectangular weir equation:

$$L_w = \frac{q_o}{(3.2)(H_w)^{1.5}} = \frac{166\,ft^3/\sec}{(3.2)(1)^{1.5}} = 52\,ft$$

This may be large for this pond, so another alternative is to try for a rectangular weir having 2 ft of maximum stage.

64

Another alternative is to try for a rectangular weir having 2 ft of maximum stage. At this elevation (4 ft total), the 45° V-notch weir will discharge 33 ft³/sec. Therefore, the rectangular weir will need to handle: 182 – 33 ft³/sec = 149 ft³/sec. The rectangular weir can be sized from the rectangular weir equation:

$$L_w = \frac{q_o}{(3.2)(H_w)^{1.5}} = \frac{149\, ft^3/\sec}{(3.2)(2)^{1.5}} = 16\, ft$$

This is a suitable length, but does result in an additional foot of pond depth. For this example, the 52 foot long weir is selected.

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Final pond profile and expected performance

Pond Depth (ft from bottom of pond, the datum)	Surface Area at Depth (acres)	Pond Storage below Elevation (calculated by Detpond) (acre-ft)	Pond slope between this elevation and next highest noted elevation	notes
0	0	0	-	the pond bottom (datum) must be 0 acres for the routing calculations
0.1	0.18	-	15%	the area close to the bottom can be the calculated/desired pond bottom area. This is the bottom of the sacrificial storage area for the sediment
3	0.35	0.8	25%	this is the top of the sacrificial storage area for the sediment
6	0.49	2.0	4.5%	this is the bottom of the “dead” storage area, at least 3 feet above the pond bottom (this is 6 feet above the absolute bottom, but is 3 feet above the top of the maximum sediment accumulation depth)

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Final pond profile (continued)

Pond Depth (ft from bottom of pond, the datum)	Surface Area at Depth (acres)	Pond Storage below Elevation (calculated by Detpond) (acre-ft)	Pond slope between this elevation and next highest noted elevation	notes
8	1.16	3.7	4.5%	this is the bottom (invert) of the water quality outlet structure (and live storage volume), a 45° V-notch weir
9	1.5	5.0	4.5%	this is the top of live storage volume, and the bottom of the emergency spillway, a 52 ft long rectangular weir
10	1.8	6.7	-	1 foot of freeboard above maximum expected water depth, the top of the pond

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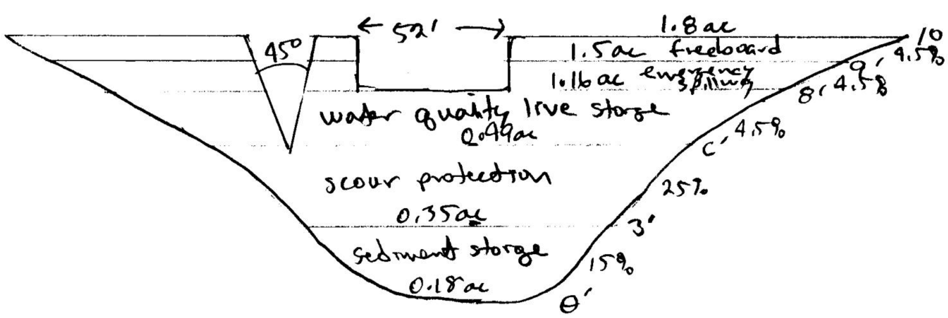
Example pond profile and expected performance



68

The pond performance for a 30-year period of rain (3,346 events, ranging from 0.01 to 13.6 inches) was calculated using DETPOND. During these 30 years, the expected maximum pond stage is slightly more 8 ft. The emergency spillway was used a total of four times in this period. The flow-weighted particulate solids removal rate was about 92%.

	Max. Pond Stage (ft)	Event Inflow Volume (ac-ft)	Event Flushing Ratio	Flow-weighted Particle Size (µm)	Partic. Solids Removed (%)
Maximum	8.1	23	11	6.8	100
Flow-weighted avg.	n/a	n/a	1.4	2.6	92
Median	6.1	0.012	0.0057	0.39	99.6
COV	0.035	5.1	5.1	1.1	0.019

The pond design was sized for a target 80 to 90% SSC removal rate. Therefore, the calculated SSC removal in the pond surpasses the goal, and the emergency spillway was infrequently used. The pond is therefore somewhat over-sized.

69

Pond Sizer and Shaper Spreadsheet Aid for Wet Ponds

1) Enter the areas of each land use in the appropriate section corresponding to the general soil type, for 5 or 20 µm control objectives. This example is for 5 µm control in an area having silty soils and has 10 acres of commercial and 95 acres of medium density residential land use areas:

soil	land use and area:	area (acres)	pond surface area (ac)	wet storage volume (ac-ft)
silty	Totally paved areas	0	0.00	0.000
silty	Freeways	0	0.00	0.000
silty	Industrial	0	0.00	0.000
silty	Commercial	10	0.17	0.667
silty	Institutional	0	0.00	0.000
silty	Low den resid	0	0.00	0.000
silty	Med den resid	95	0.76	1.979
silty	High den resid	0	0.00	0.000
silty	Open space/parks	0	0.00	0.000
silty	Construction sites	0	0.00	0.000
	Total:	105	0.93	2.646

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2) Select the pond depth corresponding to an average side slope of between about 10 to 25%. In this example, 2.5 ft depth for the water quality volume section has a side slope of about 17% (the pond surface area is about 0.9 to 1.2 acres over this depth):

pond surface area (acres):			0.93	radius (ft):
pond wet storage volume (acre-ft):			2.646	114
pond storage depth (ft)	top surface area (acres)	radius of top area (ft)	average side slope (%)*	max discharge for 5 um (cfs)
0.25	20.237	530	0.1	114.6
0.5	9.653	366	0.2	54.7
0.75	6.126	291	0.4	34.7
1	4.362	246	0.8	24.7
1.5	2.598	190	2.0	14.7
2	1.716	154	4.9	9.7
2.5	1.187	128	17.0	6.7
3	0.834	108	-49.8	4.7
3.5	0.582	90	-14.7	3.3
4	0.393	74	-10.1	2.2

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3) For the selected water quality volume depth, find an outlet structure that matches the needed discharge rate. This table shows the minimum surface area needed at the depth, and also compares this to the available surface area. Therefore, select an outlet that has the smallest positive "delta" value. In this case, that is a 30º V-notch weir.

Pond storage depth (ft)	max weir length (ft)	max orifice dia (ft)	min surface area (ac) required for v-notch weirs:					
			22.50	22.5 delta	30	30 delta	45	45 delta
0.25	275.4	2.73	0.00	20.23	0.00	20.23	0.01	20.23
0.50	46.5	1.58	0.02	9.64	0.02	9.63	0.03	9.62
0.75	16.2	1.14	0.04	6.08	0.06	6.07	0.09	6.04
1.0	7.6	0.89	0.09	4.27	0.12	4.24	0.18	4.18
1.5	2.7	0.62	0.24	2.36	0.33	2.27	0.50	2.09
2.0	1.4	0.47	0.50	1.22	0.68	1.04	1.03	0.68
2.5	1.0	0.37	0.87	0.32	1.18	0.01	1.81	-0.62

4) Continue to size the remaining pond attributes for the full profile.

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Conclusions

- Wet detention ponds have been used and studied longer than most other stormwater quality practices.
- Wet detention ponds are robust and provide excellent control of particulate-bound pollutants for a wide range of conditions.
- Wet detention ponds can be used in conjunction with other controls for broader water quality objectives.
- Wet detention pond performance can be calculated using traditional pond routing and sedimentation procedures.

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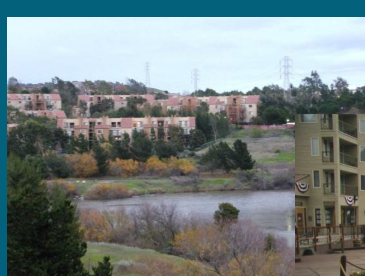
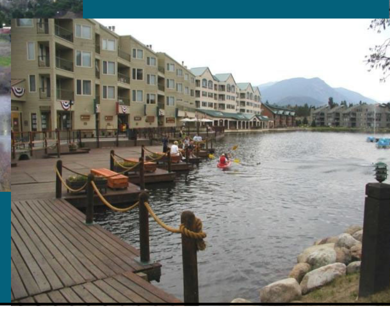
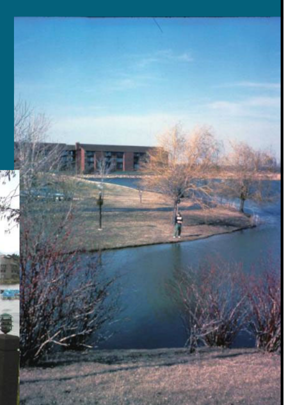
Three Categories of Data Needed for Modeling Wet Detention Ponds

1. Pond Geometry
2. Flow, Initial Stage and Particle Size Data
3. Outlet Information



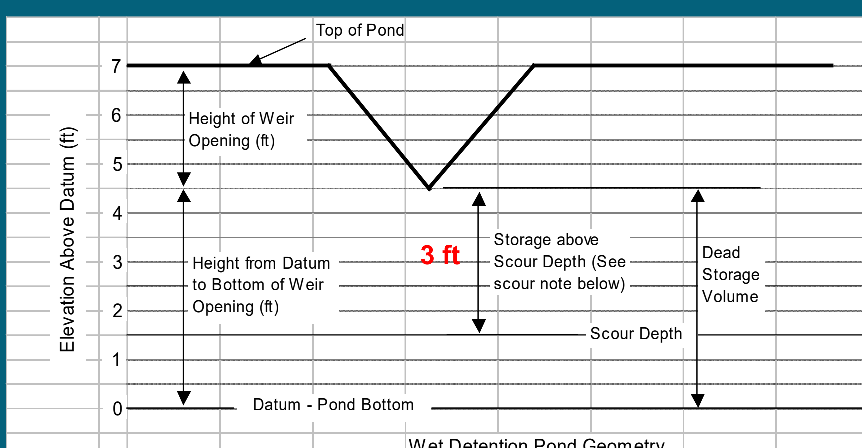




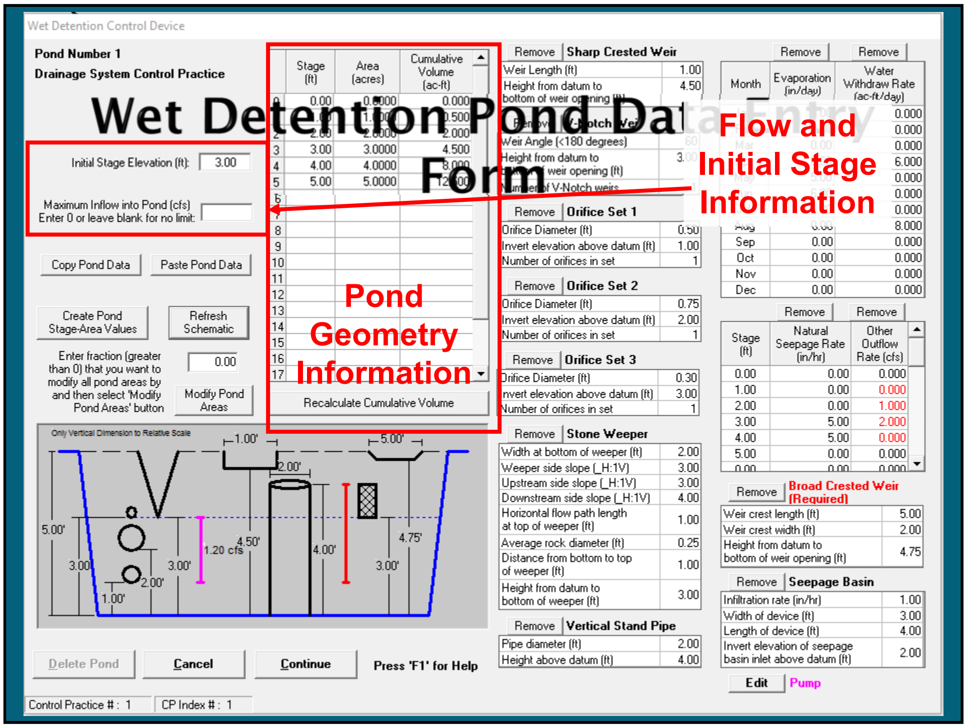
Wet Detention Pond Performance Calculation Data Requirements

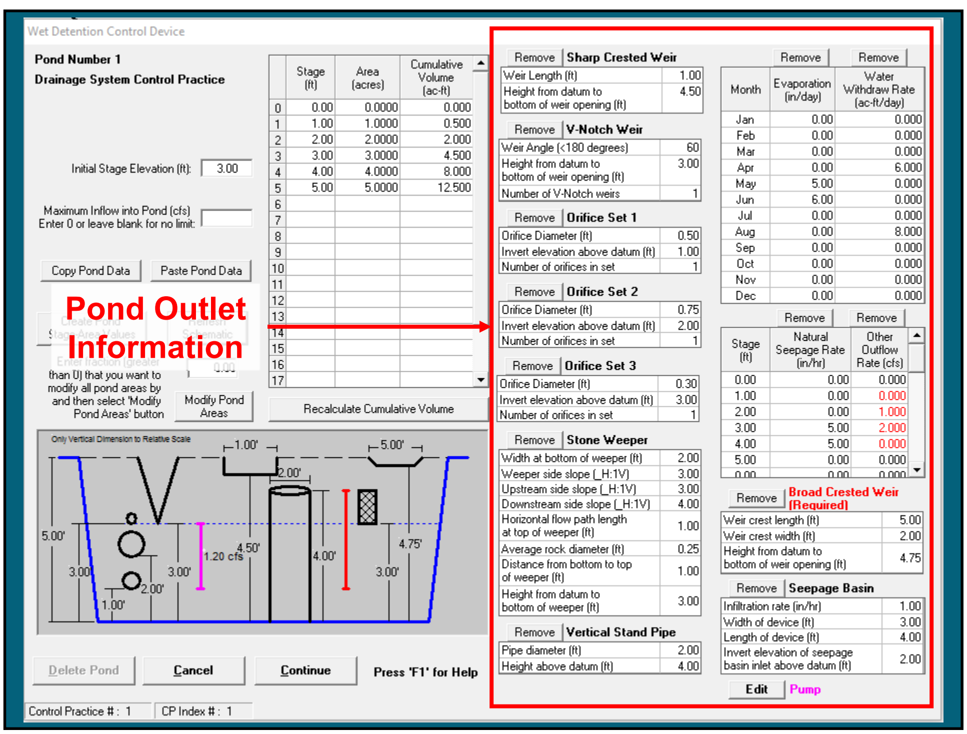
- Surface area of pond
- Water quality volume (live storage above lowest pond water surface elevation, usually the pond volume between the water quality outlet and the emergency spillway)
- Depth of water over the sediment to prevent scour
- Stage-discharge relationship for all outlets
- Particle size distribution of inflowing particulates
- Hydrograph of influent flows

Pond Geometry

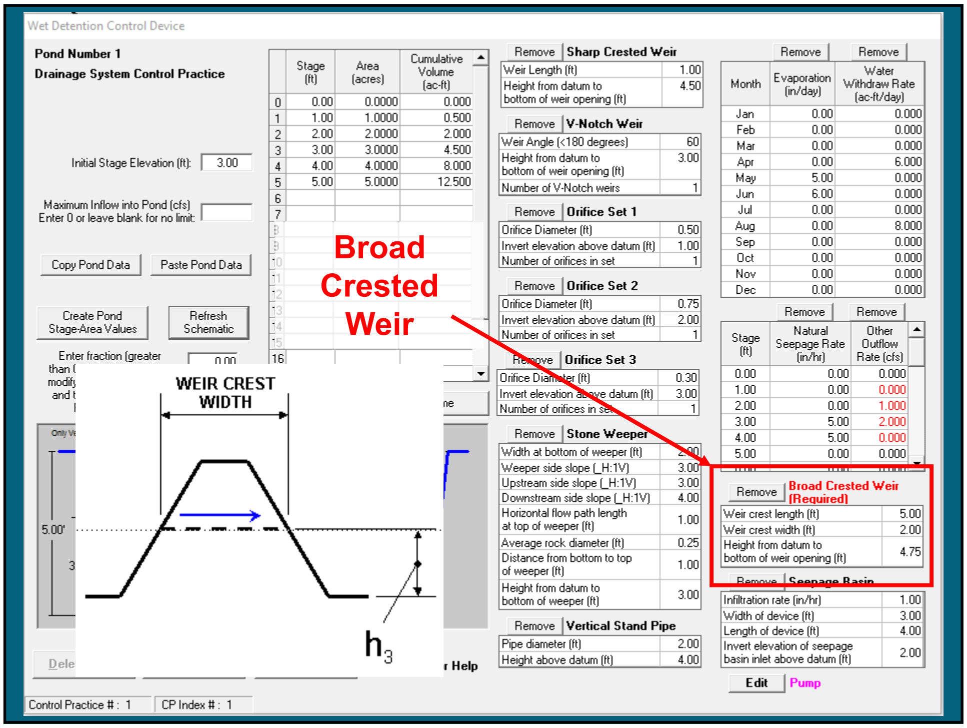


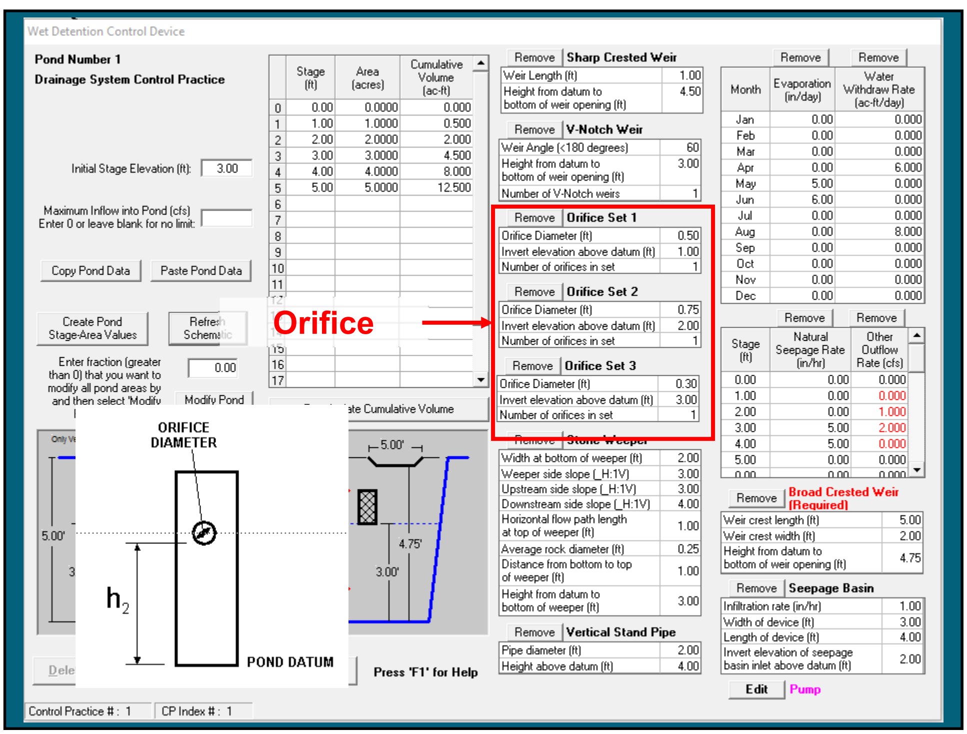
Pond Datum is always zero ft.

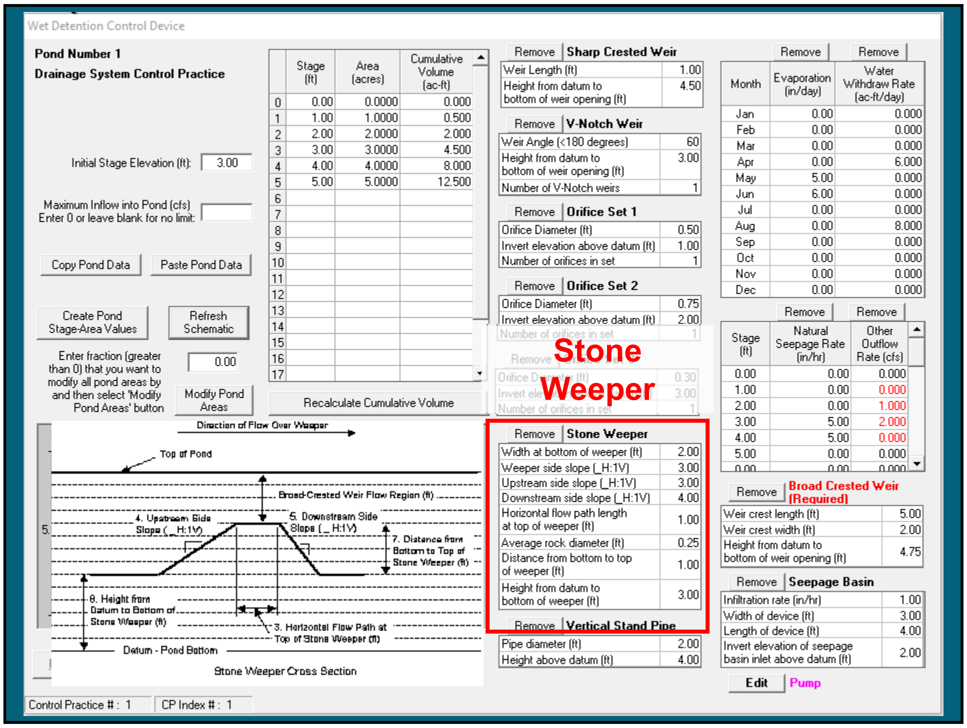

Wet Detention Control Device
Pond Number 1
Drainage System Control Practice
Wet Detention Pond Data Entry Form
Flow and Initial Stage Information
Pond Geometry Information
Initial Stage Elevation (ft): 3.00
Maximum Inflow into Pond (cfs) Enter 0 or leave blank for no limit:
Copy Pond Data
Paste Pond Data
Create Pond Stage-Area Values
Refresh Schematic
Modify Pond Areas
Recalculate Cumulative Volume
Sharp Crested Weir
Orifice Set 1
Orifice Set 2
Orifice Set 3
Stone Weeper
Vertical Stand Pipe
Broad Crested Weir (Required)
Seepage Basin
Delete Pond
Cancel
Continue
Press 'F1' for Help
Control Practice # : 1
CP Index # : 1

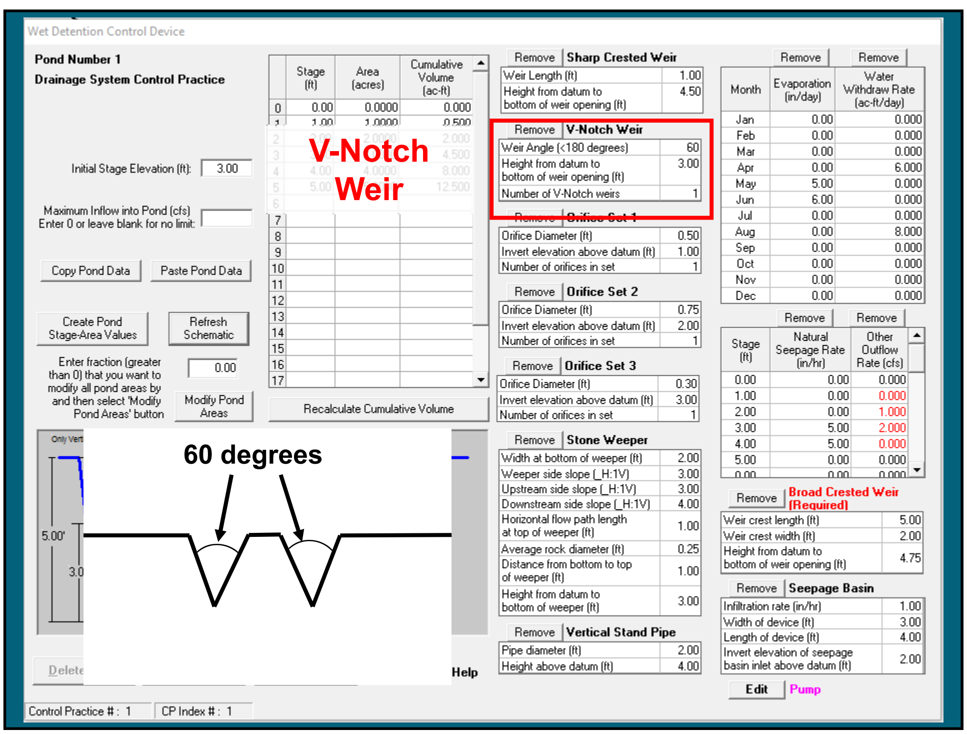

Wet Detention Control Device
Pond Number 1
Drainage System Control Practice
Pond Outlet Information
Initial Stage Elevation (ft): 3.00
Maximum Inflow into Pond (cfs) Enter 0 or leave blank for no limit:
Copy Pond Data
Paste Pond Data
Modify Pond Areas
Recalculate Cumulative Volume
Sharp Crested Weir
V-Notch Weir
Orifice Set 1
Orifice Set 2
Orifice Set 3
Stone Weeper
Vertical Stand Pipe
Broad Crested Weir (Required)
Seepage Basin
Delete Pond
Cancel
Continue
Press 'F1' for Help
Control Practice # : 1
CP Index # : 1

Tab 5a - Wet Detention Control Practices

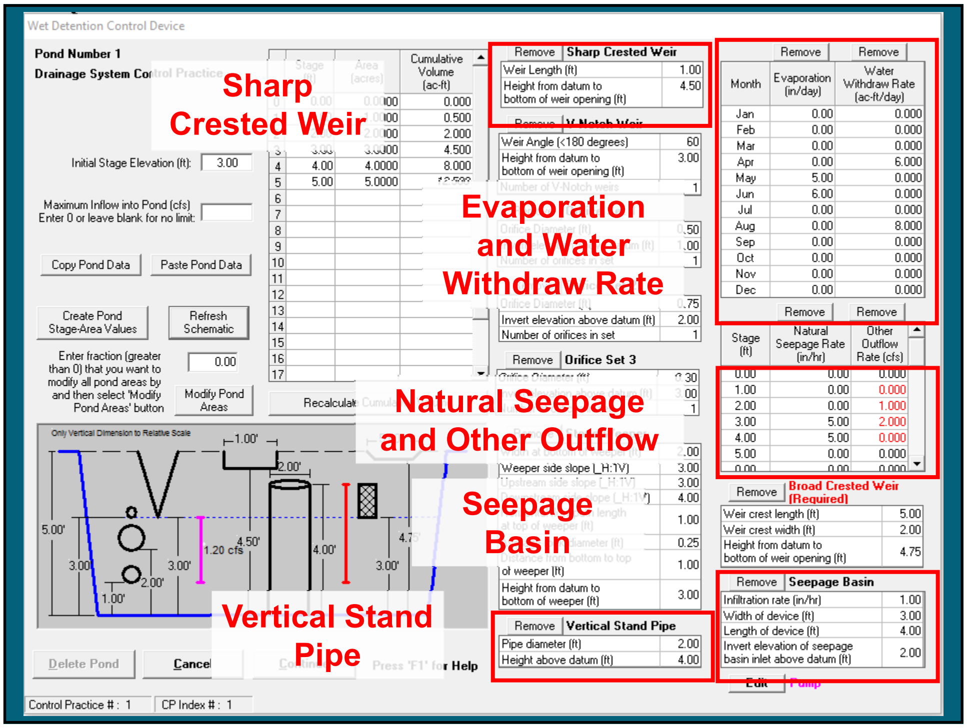


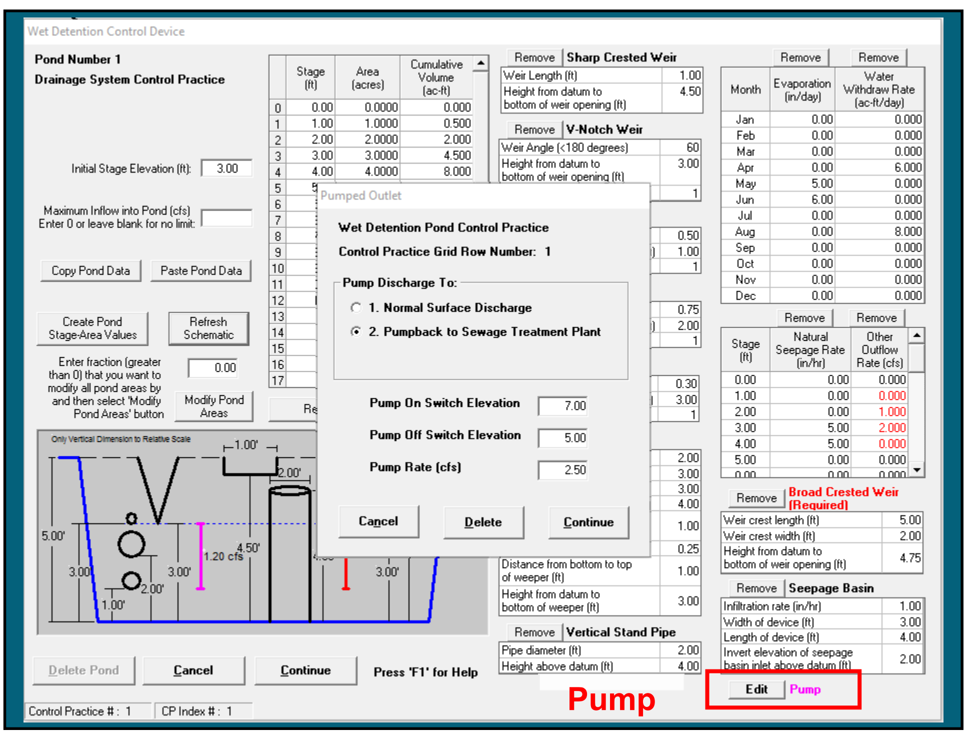


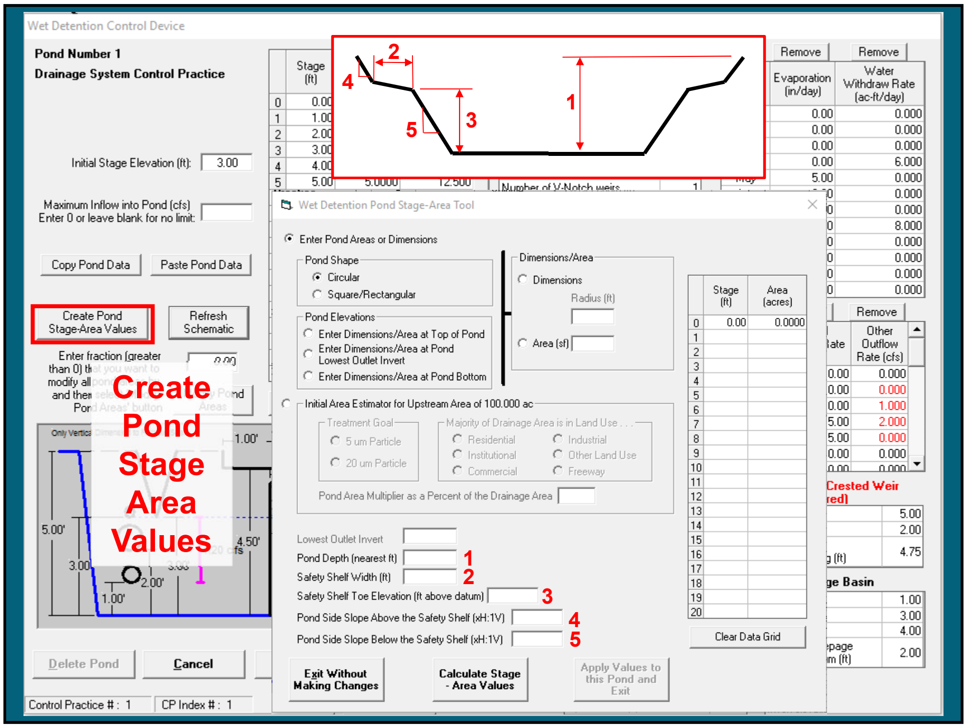

Wet Detention Control Device
Pond Number 1
Drainage System Control Practice
Stone Weeper
Sharp Crested Weir
V-Notch Weir
Orifice Set 1
Orifice Set 2
Vertical Stand Pipe
Broad Crested Weir (Required)
Seepage Basin
Stone Weeper Cross Section
Control Practice # : 1
CP Index # : 1

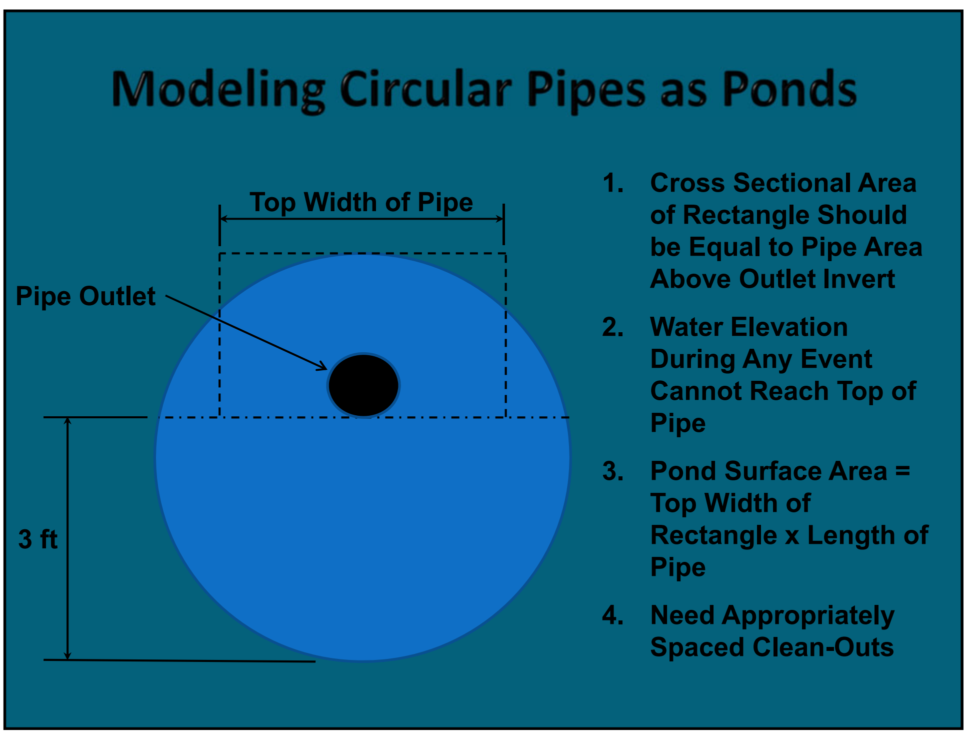

Wet Detention Control Device
Pond Number 1
Drainage System Control Practice
V-Notch Weir
60 degrees
Sharp Crested Weir
Orifice Set 1
Orifice Set 2
Orifice Set 3
Stone Weeper
Vertical Stand Pipe
Broad Crested Weir (Required)
Seepage Basin
Control Practice # : 1
CP Index # : 1

Tab 5a - Wet Detention Control Practices

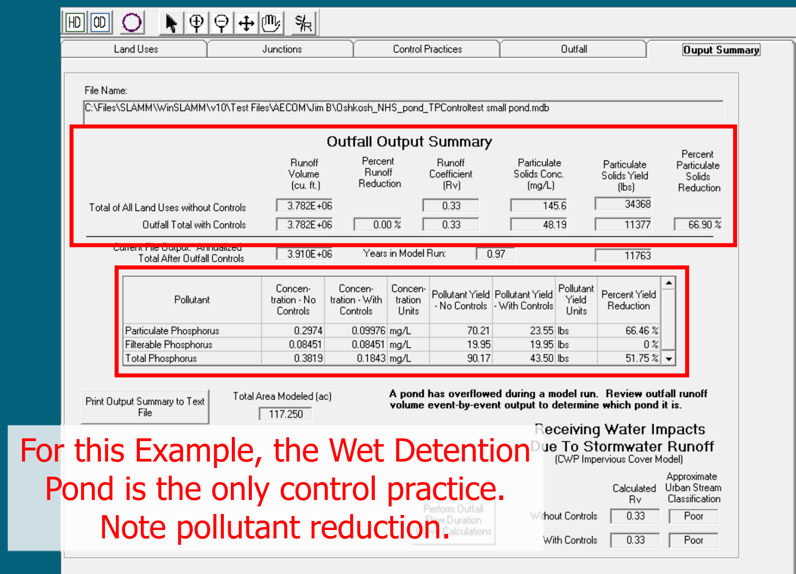





Wet Detention Control Device
Pond Number 1
Drainage System Control Practice
Initial Stage Elevation (ft): 3.00
Maximum Inflow into Pond (cfs)
Enter 0 or leave blank for no limit:
Copy Pond Data
Paste Pond Data
Create Pond Stage-Area Values
Refresh Schematic
Create Pond Stage Area Values
Delete Pond
Cancel
Control Practice # : 1
CP Index # : 1
Wet Detention Pond Stage-Area Tool
Enter Pond Areas or Dimensions
Pond Shape
Circular
Square/Rectangular
Dimensions/Area
Dimensions
Radius (ft)
Area (sf)
Pond Elevations
Enter Dimensions/Area at Top of Pond
Enter Dimensions/Area at Pond Lowest Outlet Invert
Enter Dimensions/Area at Pond Bottom
Initial Area Estimator for Upstream Area of 100.000 ac
Treatment Goal
5 um Particle
20 um Particle
Majority of Drainage Area is in Land Use . . .
Residential
Industrial
Institutional
Other Land Use
Commercial
Freeway
Pond Area Multiplier as a Percent of the Drainage Area
Lowest Outlet Invert
Pond Depth (nearest ft) 1
Safety Shelf Width (ft) 2
Safety Shelf Toe Elevation (ft above datum) 3
Pond Side Slope Above the Safety Shelf (xH:1V) 4
Pond Side Slope Below the Safety Shelf (xH:1V) 5
Exit Without Making Changes
Calculate Stage - Area Values
Apply Values to this Pond and Exit
Clear Data Grid
Stage (ft)
Area (acres)
Evaporation (in/day)
Water Withdraw Rate (ac-ft/day)
Other Outflow Rate (cfs)
Remove
Crested Weir
1 2 3 4 5

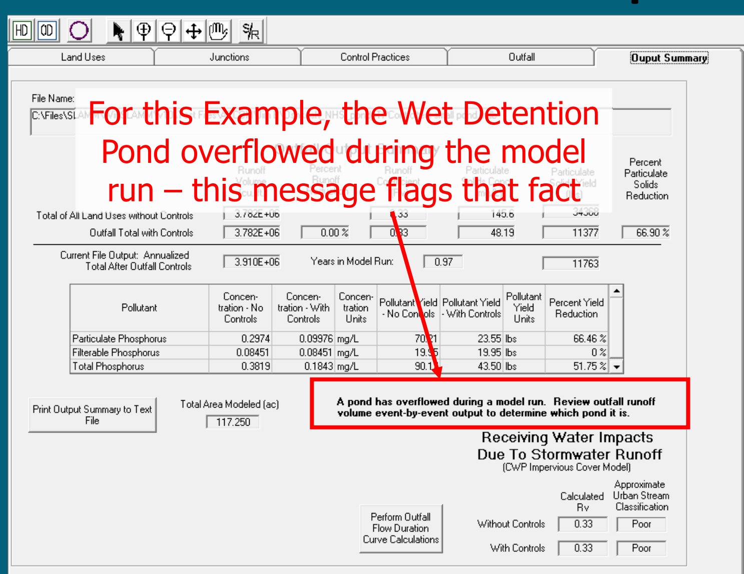

Modeling Circular Pipes as Ponds
Top Width of Pipe
Pipe Outlet
3 ft
1. Cross Sectional Area of Rectangle Should be Equal to Pipe Area Above Outlet Invert
2. Water Elevation During Any Event Cannot Reach Top of Pipe
3. Pond Surface Area = Top Width of Rectangle x Length of Pipe
4. Need Appropriately Spaced Clean-Outs

Wet Detention Pond Output



Wet Detention Pond Model Results

Wet Detention Pond Output



Wet Detention Pond Model Results

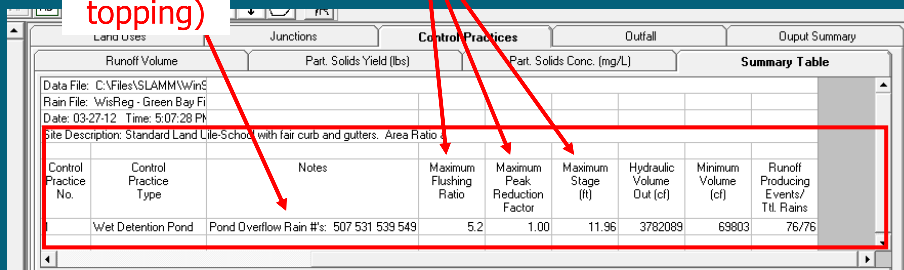
Outfall Runoff Volume

Pond Outlet Structure Failure (over-topping)

Maximum Flushing Ratio

Maximum Peak Reduction Factor

Maximum Stage



Additional Output

- Stage Outflow
- Stone Weeper Flow
- Detailed Output by Time Step
- Pond Water Balance
- Stage Area Storage Values

Detention Pond Source Area Number	Pond Rain Number	Water Rain Depth (in)	Balance Time (Julian Date)	Performan Maximum Pond Stage (ft)	Summary, Minimum Pond Stage (ft)	by Event Inflow Volume (ac-ft)	Event Event Hydr Ouflow (ac-ft)	Event Infil Ouflow (ac-ft)	Event Evap Ouflow (ac-ft)	Event Wtr_Wdrl Outflow (ac-ft)	Event Total Ouflow (ac-ft)	Event Flow Balance (ac-ft)	Total Outflow (ac-ft)	Cum Flow Balance (ac-ft)
162	1	0.46	0	3.67	3	0.63	0.6	0	0	0	0.6	0.03	0.6	0.03
162	2	0.58	5	3.57	3.06	0.843	0.834	0	0	0	0.834	0.009	1.434	0.039
162	3	0.25	9	3.38	3.08	0.277	0.249	0	0	0	0.249	0.029	1.683	0.068
162	4	0.03	11	3.14	3.12	0.009	0.013	0	0	0	0.013	-0.004	1.696	0.064
162	5	0.39	11	3.55	3.08	0.476	0.501	0	0	0	0.501	-0.025	2.198	0.039
162	6	0.01	14	3.08	3.03	0	0.026	0	0	0	0.026	-0.026	2.224	0.013
162	7	0.05	18	3.08	3.03	0.029	0.029	0	0	0	0.029	0	2.253	0.013
162	8	0.03	22	3.04	3.03	0.009	0.006	0	0	0	0.006	0.003	2.259	0.016
162	9	2.33	23	4.35	3.03	5.329	5.326	0	0	0	5.326	0.004	7.585	0.02
162	10	0.01	30	3.04	3.03	0	0.002	0	0	0	0.002	-0.002	7.587	0.017
162	11	0.01	30	3.03	3.01	0	0.012	0	0	0	0.012	-0.012	7.599	0.006
162	12	0.51	34	3.57	3.01	0.71	0.694	0	0	0	0.694	0.015	8.293	0.021
162	13	0.01	40	3.04	3.01	0	0.018	0	0	0	0.018	-0.018	8.312	0.003
162	14	0.01	46	3.01	3.01	0	0	0	0	0	0	0	8.312	0.003
162	15	0.67	47	3.94	3.01	1.026	0.991	0	0	0	0.991	0.035	9.303	0.038
162	16	0.61	50	3.86	3.08	0.896	0.8	0	0	0	0.8	0.096	10.103	0.134
162	17	0.01	51	3.25	3	0	0.133	0	0	0	0.133	-0.133	10.236	0.001
162	18	0.85	63	3.78	3	1.28	1.22	0	0	0	1.22	0.06	11.455	0.062
162	19	0.01	66	3.12	3.1	0	0.013	0	0	0	0.013	-0.013	11.468	0.049
162	20	1.02	66	3.94	3.1	1.56	1.402	0	0	0	1.402	0.158	12.87	0.207
162	21	0.01	67	3.38	3.08	0	0.166	0	0	0	0.166	-0.166	13.036	0.041
162	22	1.48	70	4.23	3.08	2.524	2.442	0	0	0	2.442	0.082	15.479	0.123
162	23	0.01	71	3.24	3.15	0	0.046	0	0	0	0.046	-0.046	15.524	0.078
162	24	0.01	72	3.15	3.1	0	0.028	0	0	0	0.028	-0.028	15.552	0.05
162	25	3.64	73	4.82	3.06	11.492	11.511	0	0	0	11.511	-0.019	27.063	0.031
162	26	0.04	78	3.1	3.06	0.022	0.008	0	0	0	0.008	0.014	27.071	0.045