North Carolina Department of Transportation
Roadside Environmental Unit
Field Operations

NC STATE UNIVERSITY
Bio&Ag ENGINEERING

NCDOT Level III: Recertification

1. Hydrology
2. Erosion
3. Regulatory Issues
4. Open Channel Design
5. Sediment Retention BMPs
6. Below Water Table Borrow Pits

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Rational Method for Estimating Peak Runoff Rate

$$Q = (C)\,(i)\,(A) \qquad \text{(Equation 1.1)}$$

Q = peak runoff or discharge rate in cubic feet per second (cfs),
C = Rational Method runoff coefficient (decimal ranging from 0 to 1),
i = rainfall intensity for a given return period in inches per hour (in/hr), and
A = watershed drainage area in acres (ac).

NCDOT return periods for design peak discharge:

10-year (most common)

25-year (Environmentally sensitive areas ESA)

Design rainfall intensity (i) need:

Return period and duration (=time of concentration)

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Time of Concentration, t_c

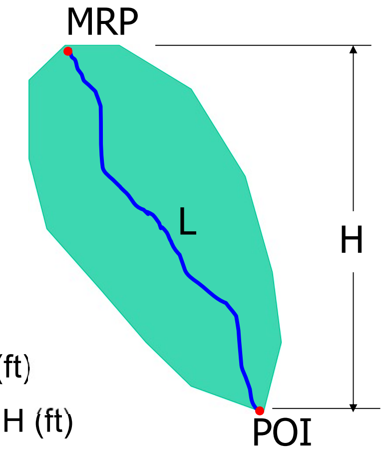
Time for water to travel from the Most Remote Point (MRP) to the Point of Interest (POI)

Methods for estimating t_c

1. Jarrett Shortcut Method
2. Segmental Method (TR-55)

Need to Know:

1. Watershed Area, A (acres)
2. Flow Length from MRP to POI, L (ft)
3. Elevation Drop from MRP to POI, H (ft)
4. Land Use (paved or unpaved)



Compute Time of Concentration: t_c

Jarrett Shortcut: $A_{Jarrett} = 460\ (S)$ (Equation 1.4)

$A_{Jarrett}$ = Jarrett Maximum Area in acres (ac), and
S = average watershed slope (ft/ft).

If the watershed area is less than the Jarrett Maximum Area, then t_c = 5 min

NRCS Segmental Method (TR55) for Shallow Flow

Unpaved Areas: $t_c = 0.001\ (L_{flow}) / S^{0.53}$ (Equation 1.5)

t_c = time of concentration in minutes (min),
L_{flow} = flow length from most remote point to point of interest (ft),
S = average watershed slope (ft/ft).

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Rainfall Data

Need Intensity by Return Period and Duration

Listed for some locations in Table 1.1

POINT PRECIPITATION FREQUENCY (PF) ESTIMATES

WITH 90% CONFIDENCE INTERVALS AND SUPPLEMENTARY INFORMATION
NOAA Atlas 14, Volume 2, Version 3

PF tabular PF graphical Supplementary information Print Pa

AMS-based precipitation frequency estimates with 90% confidence intervals (in inches/hour)[1]

Duration	Annual exceedance probability (1/years)							
	1/2	**1/5**	**1/10**	**1/25**	**1/50**	**1/100**	**1/200**	**1/500**
5-min	**5.18** (4.76-5.66)	**6.34** (5.83-6.91)	**7.14** (6.54-7.76)	**7.92** (7.22-8.63)	**8.46** (7.68-9.19)	**8.94** (8.08-9.72)	**9.34** (8.40-10.2)	**9.79** (8.74-10.7)
10-min	**4.15** (3.82-4.53)	**5.08** (4.67-5.54)	**5.71** (5.23-6.22)	**6.31** (5.76-6.87)	**6.73** (6.11-7.33)	**7.10** (6.41-7.72)	**7.41** (6.66-8.07)	**7.75** (6.91-8.45)
15-min	**3.48** (3.20-3.80)	**4.28** (3.94-4.68)	**4.81** (4.41-5.24)	**5.33** (4.87-5.81)	**5.68** (5.16-6.18)	**5.98** (5.40-6.51)	**6.23** (5.60-6.79)	**6.50** (5.80-7.09)
30-min	**2.40** (2.21-2.63)	**3.04** (2.80-3.32)	**3.49** (3.20-3.80)	**3.95** (3.61-4.30)	**4.28** (3.89-4.66)	**4.58** (4.14-4.98)	**4.85** (4.36-5.29)	**5.18** (4.61-5.64)
60-min	**1.51** (1.39-1.65)	**1.95** (1.79-2.13)	**2.27** (2.08-2.47)	**2.63** (2.40-2.86)	**2.90** (2.63-3.16)	**3.16** (2.85-3.43)	**3.40** (3.06-3.71)	**3.71** (3.31-4.05)

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Runoff Coefficient, C

Table 1.2. Rational Method C for Agricultural Areas. (Taken from Schwab et al., 1971).

Vegetation	Runoff Coefficient, C		
Slope	Sandy Loam[1]	Clay and Silt Loam[2]	Tight Clay[3]
Forest			
0-5% slope	0.10	0.30	0.40
5-10% slope	0.25	0.35	0.50
10-30% slope	0.30	0.50	0.60
Pasture			
0-5% slope	0.10	0.30	0.40
5-10% slope	0.16	0.36	0.55
10-30% slope	0.22	0.42	0.60
Cultivated			
0-5% slope	0.30	0.50	0.60
5-10% slope	0.40	0.60	0.70
10-30% slope	0.52	0.72	0.82

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Example: Rational Method

Determine the 10-year peak runoff rate, Q_{10}, for a 5-acre construction site watershed near Asheville with a flow length = 600 ft and elevation drop = 36 ft. The land uses are shown below:

Land Use	A	C	(A) (C)
Forest, clay (11%)	1	0.60	0.60
Bare soil, clay (7%)	3	0.70	2.10
Grass, clay (3%)	1	0.40	0.40
	sum = 5 ac		sum = 3.10

Weighted Runoff Coefficient: C = 3.10 / 5 = 0.62

Average watershed slope, S = 36 / 600 = 0.06 ft/ft

Jarrett Max Area = 460 (0.06) = 27.6 ac; Since 5 < 27.6, use t_c = 5 min

Rainfall intensity for 10-year storm, i_{10}, is determined from Table 1.1 for a 5-minute rainfall in Asheville: i_{10} = 6.96 in/hr

Peak runoff rate, Q_{10} = (0.62) (6.96) (5) = 21.6 cfs

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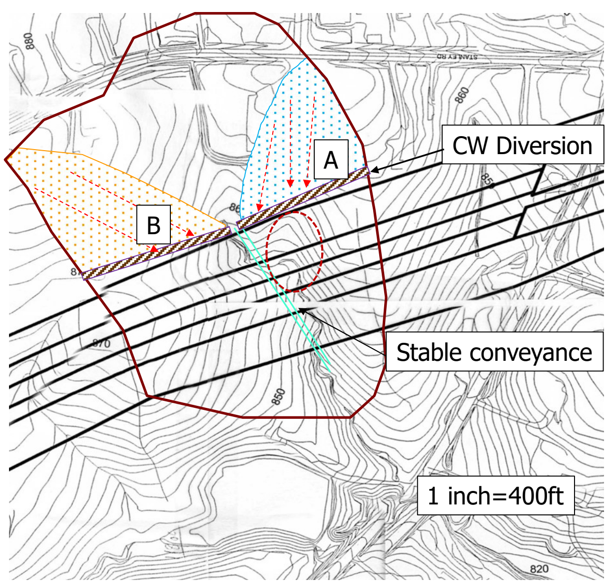
Emphasis on Diverting 'Clean' Runoff



Prioritize need for:

Stable conveyance

Erosion hazard of diverted water

Erosion hazard downslope

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Worksheet

1.2. Estimate the 10-year peak runoff rate, Q_{10}, for a 20-acre construction site watershed near Raleigh with a flow length = 2000 ft and elevation drop = 60 ft. The land uses are 40% forest and 60% bare soil. Soil is sandy loam.

Land Use	A	C	(A) (C)
Forest	20*0.4=8.0	0.10	0.8
Bare soil	20*0.6=12.0	0.30	3.6
	sum = 20 ac		sum = 4.4

Weighted Runoff Coefficient: C = 4.4 / 20 = 0.22

Average watershed slope, S = 60 / 2000 = 0.03 ft/ft

Jarrett Max Area = 460 (0.03) = 13.8 ac; Since 13.8 < 20, use other method

Segmental Method: $t_c = 0.001\ (2000) / 0.03^{0.53} = 12.8$ min; use $t_c = 10$ min

Rainfall intensity, $i_{10} = 5.58$ in/hr

Peak runoff rate, Q_{10} = (0.22) (5.58) (20) = 24.6 cfs

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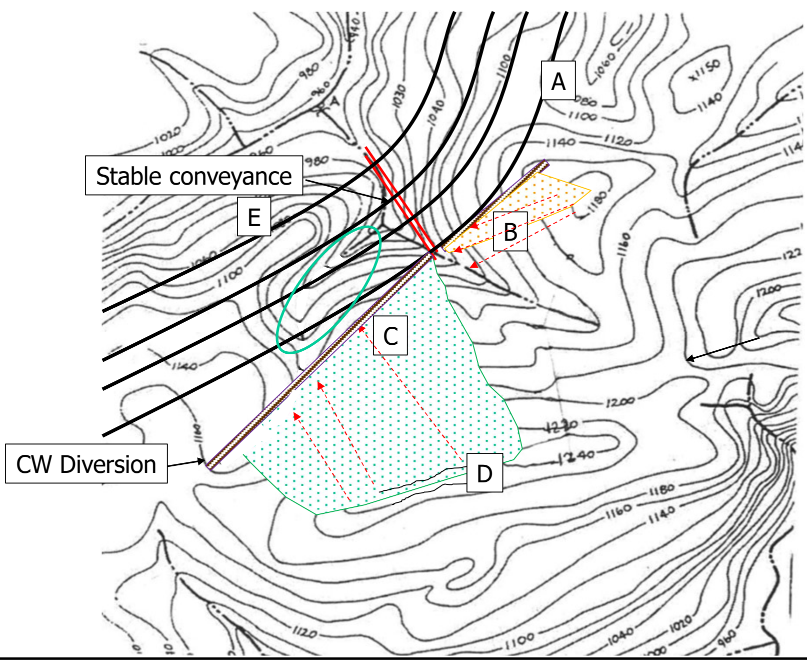
Worksheet Problem 1.3



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MODULE 2. Erosion

- Erosion Principles
- RUSLE: R, K, LS, CP

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Universal Soil Loss Equation
USLE / RUSLE

$A_{erosion}$ = (R) (K) (LS) (CP) (Equation 2.1)

$A_{erosion}$ = longterm annual soil interrill + rill erosion in tons per acre per year (tons/ac-yr),

R = rainfall factor (dimensionless),

K = soil erodibility factor (dimensionless),

LS = slope-length factor (dimensionless),

CP = conservation practices factor (dimensionless).

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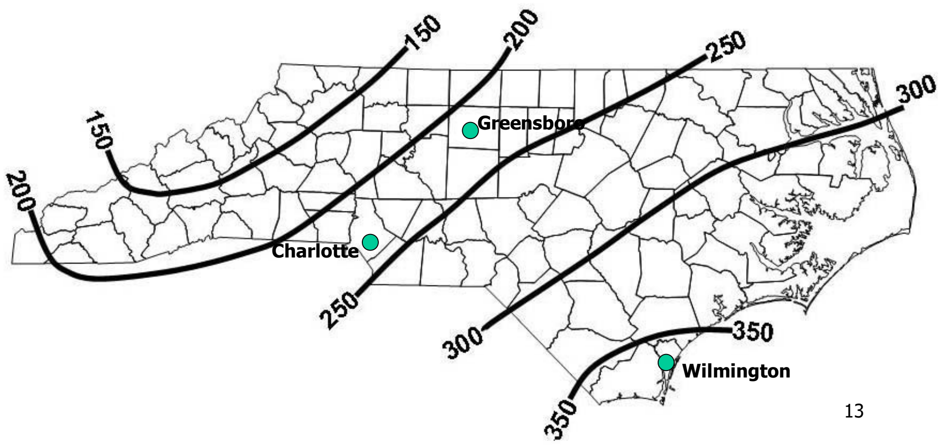
R, Rainfall Factor

- Represents rainfall energy that causes erosion
- Higher R = higher erosion potential
- Annual R values, Figure 2.1



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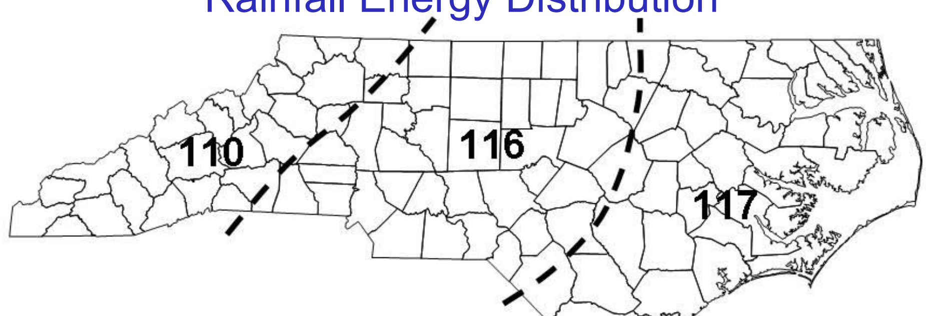
Rainfall Energy Distribution



	Geographic Region, Figure 2.2	
Month	**110 & 116**	**117**
Jan	0.03	0.02
Feb	0.04	0.02
Mar	0.05	0.03
Apr	0.06	0.04
May	0.07	0.06
Jun	0.11	0.14
Jul	0.20	0.23
Aug	0.21	0.20
Sep	0.11	0.15
Oct	0.05	0.06
Nov	0.04	0.03
Dec	0.03	0.02

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K, Soil Erodibility Factor

- Represents soil's tendency to erode
- NRCS tables for most soils (Table 2.2)

Soil Series	HSG	B-Horizon Permeability in/hr	RUSLE T	RUSLE K(A)	RUSLE K(B)	RUSLE K(C)
Ailey	B	0.6 to 2.0	2	0.15	0.24	0.24
Appling	B	0.6 to 2.0	4	0.24	0.28	0.28
Autryville	A	2.0 to 6.0	5	0.10	0.10	0.10
Badin	B	0.6 to 2.0	3	0.15	0.24	0.15
Belhaven	D	0.2 to 6.0	--	--	0.24	0.24
Cecil	B	0.6 to 2.0	4	0.24	0.28	-15

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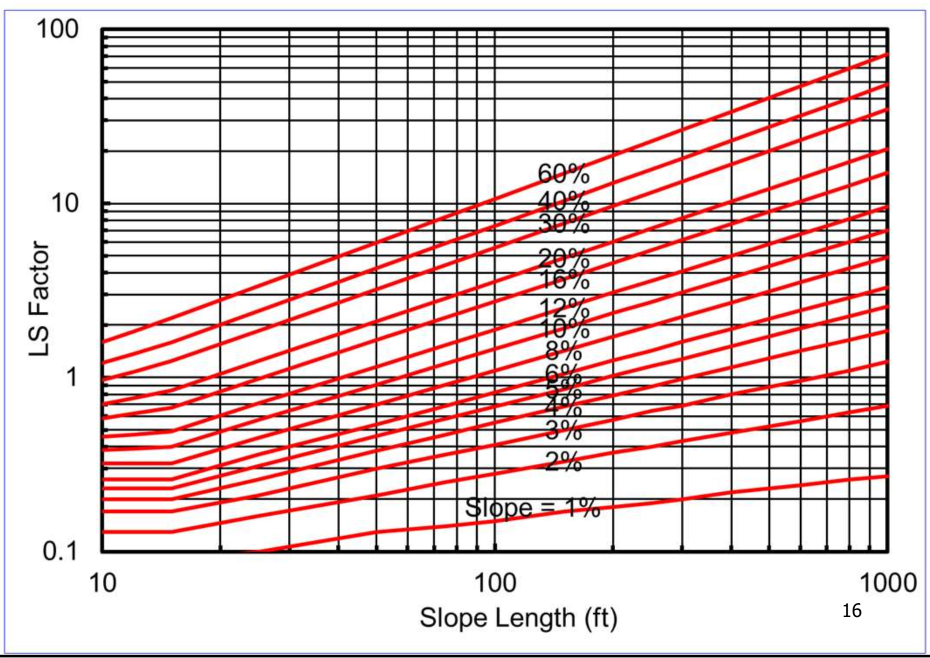
LS, Length Slope Factor (Figure 2.5)



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CP, Cover-Conservation Practices Factor

Represents the effect of land cover & direction of rills/channels

Table 2.3 lists CP values (use high values)

letters denote references

Bare soil condition	CP
Fill	
Packed, smooth	1.00 a
Fresh disked	0.95 a
Rough (offset disk)	0.85 a
Cut	
Loose to 12 inches, smooth	0.90 b
Loose to 12 inches, rough	0.80 b
Compacted by bulldozer	1.00 b
Compacted by bulldozer and tracked parallel to the contour	0.50 c
Rough, irregular tracked all directions	0.90 b
Surface Condition with No Cover	
Compact and smooth, scraped w/ bulldozer or scraper up / down hill	1.3 d
Compact and smooth, raked w/ bulldozer root rake up and down hill	1.2 d
Compact and smooth, scraped w/bulldozer or scraper across slope	1.2 d
Compact and smooth, raked w/bulldozer root rake across slope	0.9 d
Loose as a disked plow layer	1.0 d

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Example: Erosion Estimate

Estimate erosion from a 5-acre site in Raleigh during March-May with R = 49. The site is 600 ft long with elevation drop of 48 ft, and soil type is Creedmoor.

Average slope = 48 / 600 = 0.08 ft/ft (8% slope)

Table 2.2: K value is 0.32 (assume B Horizon – subsoil)

Figure 2.3: LS value is 3.5 (slope length = 600 ft; slope = 8%)

Table 2.3: CP value is 1.0 (assume loose surface with no cover)

Erosion rate = (49) (0.32) (3.5) (1.0) = 54.9 tons/ac or 18.3 t/ac-mo. (March-May)

Total erosion for 5 acres = (54.9) (5) = 274.4 tons (March-May)

If the construction period is July-September (partial-year R = 140):

Erosion per acre = (140) (0.32) (3.5) (1.0) = 157 tons/acre (Jul-Sep)

Total erosion for 5 acres = (157) (5) = 786 tons (Jul-Sep)

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Secondary Road Erosion Estimate

$V_{ditch} = (C_{ditch})\ (R)\ (K)\ (S_{ditch})$ (Equation 2.2)

V_{ditch} = secondary road sediment volume expected in cubic feet per acre (ft^3/ac),

C_{ditch} = regression constant for secondary roads dependent on ditch side slopes,

R = Rainfall Factor for the duration of construction,

K = Soil Erodibility Factor (B or C horizon),

S_{ditch} = slope of secondary road ditch (ft/ft).

Values of C_S are determined using Table 2.4 depending on road ditch side slope.

Side Slope	C_{ditch}
4:1	291
3.5:1	341
3:1	399
2.5:1	467
2:1	549
1.5:1	659
1:1	808
0.75:1	916
0.5:1	1067

ERODES Spreadsheet: download software from NCDOT Roadside Field Operations Downloads:
www.ncdot.org/doh/operations/dp_chief_eng/roadside/fieldops/downloads

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Example: Secondary Road Erosion

Estimate erosion volume from a 2-acre secondary roadway construction during June-July in Carteret County with Goldsboro soil. The road ditch has a slope of 0.05 ft/ft and 2:1 side slopes.

Figures 2.1 and 2.2: Annual R = 340, and Carteret County is in Region 117

Table 2.1: During June-July, partial-year R = (0.14 + 0.23) (340) = 126

Table 2.2: K value is 0.24 (assume B Horizon – subsoil)

Table 2.4: C_{ditch} is 549 for 2:1 ditch side slopes

V_{ditch} = (549) (126) (0.24) (0.05) = 830 ft^3/ac (Jun-Jul)

Total erosion for 2 acres = (830) (2) = 1,660 ft^3 (Jun-Jul)

To convert to cubic yards: Erosion = 1,660 / 27 = 61 cubic yards (Jun-Jul)

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Worksheet

2.1. Estimate erosion from a 5-acre site in Wilmington during June-October with Cowee soil. The site is 800 ft long with elevation drop of 24 ft.

Average slope = 24 / 800 = 0.03 ft/ft (3% slope)

Figure 2.1 & 2.2: Annual R value is 350 and Region 117

Partial-year R = (0.14+0.23+0.20+0.15+0.06) (350) = 273

Table 2.2: K value is 0.28 (assume B Horizon – subsoil)

Figure 2.3: LS value is 1.1 (slope length = 800 ft; slope = 3%)

Table 2.3: CP value is 1.0 (assume loose surface with no cover)

Erosion per acre = (273) (0.28) (1.1) (1.0) = 84.1 tons/acre (Jun-Oct)

Total erosion for 5 acres = (84.1) (5) = 420 tons (Jun-Oct)

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MODULE 3. Regulatory Issues

1. NC Sediment Pollution Control Act (E&SC Plans)
2. Self-Inspection
3. Jurisdictional Areas - Conditions and Restrictions
    - US Army Corps of Engineers
    - NC DENR Division of Water Quality
4. Environmentally Sensitive Area (ESA) & Riparian Buffers
5. Reclamation Plans
6. NCG01 General Stormwater Permit

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NC Sediment Pollution Control Act (SPCA) Mandatory Standards

1. E&SC plan must be submitted 30 days prior to disturbance for areas greater than or equal to 1 acre
2. Land disturbing activity must be conducted in accordance with approved E&SC Plan
3. Establish sufficient buffer zone between work zone and water courses
4. Provide groundcover on slopes within 21 calendar days after any phase of grading (NCG-01 takes precedence)
5. The angle of cut and fill slopes shall be no greater than sufficient for proper stabilization

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NCG010000 (NCG01)

Site Area Description	Time Frame	Stabilization Time Frame Exceptions
Perimeter dikes, swales, ditches and slopes	7 days	None
High Quality Water (HQW) Zones	7 days	None
Slopes steeper than 3:1	7 days	If slopes are 10 ft or less in height and are not steeper than 2:1, then 14 days are allowed
Slopes 3:1 or flatter	14 days	7-days for slopes greater than 50 feet in length
All other areas with slopes flatter than 4:1	14 days	None (except for perimeters and HQW Zones)

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During Active Use of Borrow Pits

- Delineate buffer zones
- Install EC devices as per approved E&SC Plan
- Excavate/Build slopes in manner that allows for seeding of slopes
- Stage seed slopes
- Monitor the turbidity of Borrow Pit discharge

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Turbidity

Clarity of water (light passes through) measured in Nephelometric Turbidity Units (NTUs)

Surface Water Classification	**Turbidity Not to Exceed Limit* (NTUs)**
Streams	50
Lakes & Reservoirs	25
Trout Waters	10

** If turbidity exceeds these levels due to natural background conditions, the existing turbidity level cannot be increased*

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MODULE 4. Open Channel Design

Table 4.1. NCDOT guidelines for selecting channel linings.

Channel Slope (%)	Recommended Channel Lining
< 1.5	Seed and Mulch
1.5 to 4.0	Temporary Liners (RECP)
>=4.0	Turf Reinforced Mats or Hard



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Selecting a Channel Lining

$\tau = (\gamma)\ (d_{chan})\ (S_{chan})$ (Equation 4.1, pg 22)

τ = average tractive force acting on the channel lining (lbs/ft^2)
γ = unit weight of water, assumed to be 62.4 lbs/ft^3
d_{chan} = depth of flow in the channel (ft)
S_{chan} = slope of the channel (ft/ft)

Select a channel lining that will resist the tractive force.

Example: Select a lining for a ditch with channel slope of 0.02 ft/ft and flow depth of 0.8 ft. NCDOT guidelines (Table 4.1) recommend temporary liner.

τ = (62.4 lb/ft^3) (0.8 ft) (0.02 ft/ft) = 1.0 lb/ft^2

Table 4.3 (pg 23): Select a RECP with allowable tractive force > 1.0 lb/ft^2

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Worksheet

4.1. Select a suitable channel liner for a triangular ditch with maximum depth of 1.2 ft and slope of 4.2%.

Table 4.1: NCDOT guidelines for >4% slope require TRM.

Equation 4.1: τ = (62.4 lbs/ft^3) (1.2 ft) (0.042 ft/ft) = 3.14 lbs/ft^2

Table 4.3: Select a TRM channel lining with a maximum allowable tractive force greater than 3.14 lbs/ft^2 (N. American Green P550)

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MODULE 5. Sediment Retention BMPs for NCDOT

1. Selection & Design Considerations
2. BMP Design Criteria
3. Example Specs and Calculations

NCDOT Roadside Environmental Unit:

http://ncdot.gov/doh/operations/dp%5Fchief%5Feng/roadside/soil%5Fwater/

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Sediment Retention BMPs

Table 1. BMP Selection

BMP	Location	Catchment	Structure	Sed. Ctl. Stone	Surface Area	Volume	Function
T. Rock Sed. Dam A	Swale/large ditch	< 1 ac.	Class I	Yes	$435Q_{10}$	3600 ft^3/ac	Remove sand
T. Rock Sed. Dam B	Drainage outlet	< 1 ac.	Class B	Yes	$435Q_{10}$	3600 ft^3/ac	Remove sand
Silt Basin B	Drainage outlet/ Adjacent to inlet	< 3 ac.	Earth	No	$435Q_{10}$ ($325Q_{10}$ @ inlets)	3600 ft^3/ac (1800 ft^3/ac @ inlets)	Remove sand
Skimmer Basin	Drainage outlet	< 10 ac.	Earth	No	$325Q_{10}$	1800 ft^3/ac	Remove sand
Infiltration Basin	Drainage outlet	< 10 ac.	Earth	No	$325Q_{10}$	1800 ft^3/ac	Remove sand
Riser Basin(non-perforated riser w/ skimmer)	Drainage outlet	< 100 ac.	Earth	No	$435Q_{10}$	1800 ft^3/ac	Remove silt, clay
Stilling Basin/Pumped	Near Borrow Pit/Culvert	N/A	Earth and Stone	No	2:1 L:W ratio	Based on dewatering	Remove silt, clay
Sp. Stilling Basin(Silt Bag)	Near stream	N/A	Filter Fabric	Yes	N/A	Variable	Remove sand
Rock Pipe Inlet Sed. Trap A	Pipe inlet	< 1 ac.	Class B	Yes	N/A	3600 ft^3/ac	Remove sand
Rock Pipe Inlet Sed. Trap B	Pipe inlet	< 1 ac.	Class A	Yes	N/A	3600 ft^3/ac	Remove sand
Slope Drain w/ Berm	Fill Slopes	< ½ ac.	12-inch pipe	No	N/A	N/A	Convey concentrated runoff
Rock Inlet Sed. Trap A	Stormwater Inlet	< 1 ac.	Class B	Yes	N/A	3600 ft^3/ac	Remove sand
Rock Inlet Sed. Trap B	Stormwater Inlet	< 1 ac.	Class A	Yes	N/A	3600 ft^3/ac	Remove sand
Rock Inlet Sed. Trap C	Stormwater Inlet	< 1 ac.	¼" wire mesh	Yes	N/A	N/A	Remove sand
T. Rock Silt Check A	Drainage outlet	< 1 ac.	Class B	Yes	$435Q_{10}$	3600 ft^3/ac	Remove sand
T. Rock Silt Check B	Channel	< ½ ac.	Class B	No	N/A	N/A	Reduce flow velocity
Temporary Earth Berm	Project perimeter	< 5 ac.	Earth	No	N/A	N/A	Divert offsite runoff
Temporary Silt Fence	Bottom of slope	< ¼ acre per 100 feet <2%*	Silt fence	No	N/A	N/A	Create small basin; Remove sand, silt
Special Sediment Control Fence	Bottom of slope	< ½ ac.	¼" wire mesh	Yes	N/A	N/A	Remove sand
Temporary Silt Ditch	Bottom of slope	< 5 ac.	Earth	No	N/A	N/A	Carry sediment/water
Temporary Diversion	Project & Stream perimeter	< 5 ac.	Earth	No	N/A	N/A	Divert turbid water
Earth Berm		< 5 ac.	Earth	No	N/A	N/A	Divert clean or turbid water
Clean Water Diversion	Project perimeter	<5 ac.	Earth & Fabric	No	N/A	N/A	Divert clean water
Construction Entrance	Exit to road	N/A	Class A	No	N/A	N/A	Clean truck tires
Safety Fence	Permitted Areas	N/A	Orange fence	No	N/A	N/A	Define permitted boundary
Borrow Pit Dewatering Basin	Adjacent to Borrow Pits	N/A	Earth	No	N/A	8.02xQxT	Remove Sand and reduce turbidity
Wattle/Coir Fiber Wattle	Channel	< ½ ac.	Natural Fibers	No	N/A	N/A	Incorporate PAM
Silt Check A with Matting and PAM	Channel	< ½ ac.	Class B	Yes	N/A	N/A	Reduce flow velocity and incorporate PAM

*contributing land slope

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Porous Baffle Spacing

Baffles required in Silt Basins at drainage turnouts, Type A and B Temporary Rock Sediment Dams, Skimmer Basins, Stilling Basins:

- 3 baffles evenly-spaced if basin length > 20 ft
- 2 baffles evenly-spaced if basin length 10 - 20 ft
- 1 baffle if basin length ≤ 10 ft (State Forces)

Weir Length for Spillway

Skimmers and Infiltration Basins:

Weir Length = Q_{peak} /0.4

Temporary Sediment Dam - Type B:

Minimum 4ft for 1 acre or less

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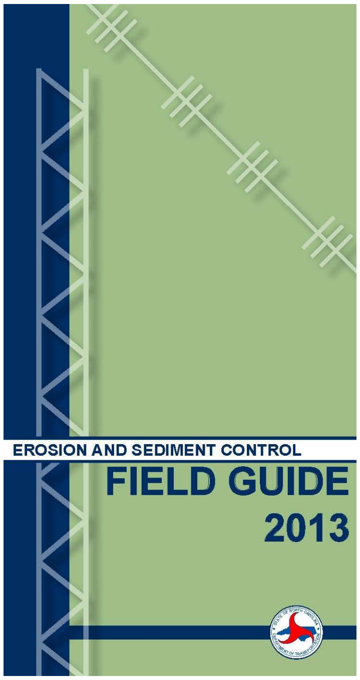

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Skimmer Basin

Drainage area < 10 ac

Surface Area = $325Q_{10}$ or $325Q_{25}$

Volume = 1800 ft^3/ac disturbed

Depth = 3 ft at weir

Coir Baffles (3)

L:W ratio 3:1 to 5:1

Skimmer Basin

IS
A temporary basin with a trapezoidal spillway lined with filter fabric and equipped with a floating skimmer.

USE
In sensitive watershed areas and in locations where the drainage area is too large for standard rock weir outlet.

CONSTRUCT
Basin with a Faircloth Skimmer at the outlet, a trapezoidal emergency spillway lined with filter fabric, and 3 coir fiber baffles. Storage capacity is 1800 cubic ft. per disturbed acre and surface area must accommodate the 10-year storm runoff. Limit the dam height to 5 ft.

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Wattle

Drainage area < 1/2 ac

May add PAM for turbidity control

On NCDOT projects:

Coastal Plain: Spacing = 600 / slope(%)

Example: For 2% slope, space checks 300 ft

Piedmont and West: Spacing = 300 / slope(%)

Example: For 3% slope, space checks 100 ft

without PAM with PAM 24

Wattle with Polyacrylamide (PAM)

IS
A tubular device that consists of excelsior or coir (coconut) fibers encased in all natural or synthetic netting.

USE
In temporary and permanent ditches to reduce runoff velocity and incorporate PAM in the form of powder into the runoff.

CONSTRUCT
Using a minimum size diameter wattle of 12 in. Install wattles using 2 ft. stakes and 12 in. staples on top of a 9 ft. section of erosion control matting. Wattles can be used with or without PAM.

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Design Steps for Basins, Sediment Dams, & Traps

1. Minimum volume and surface area
2. Width and length at the weir/spillway height based on sideslopes
3. Emergency spillway weir length
4. Baffle spacing

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Example: Temp Rock Sediment Dam Type B

Disturbed area = 1 ac; Q_{10} = 2.5 cfs

Interior sideslopes = 1.5:1; L:W = 3:1

1. Minimum Volume and Surface Area:

Minimum Volume = 3600 x 1 ac = 3600 ft^3

Minimum Surface Area = 435 Q_{10} = 435 x 2.5 cfs = 1088 ft^2

Depth = Volume / Area = 3600 ft^3 / 1088 ft^2 = 3.3 ft

For DOT projects, Design Depth = 2 to 3 ft

Therefore, use depth = 3 ft

Adjusted Area = Volume / depth = 3600 / 3 = 1200 ft^2

Surface area must be greater to account for sideslopes

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Example: Temp Rock Sed Dam Type B

2. Width and depth at top and base (trial & error):

Start with area = 1,200 ft^2 and a 3:1 length to width ratio

$$\text{Trial Width, } W_{top} = \sqrt{\frac{A}{\text{L to W ratio}}} = \sqrt{\frac{1200}{3}} = 20 \text{ ft}$$

To account for sideslopes, add to top width (try 3 ft):

Trial W_{top} = 20 + 3 = 23 ft

Trial L_{top} = 3 x W_{top} = 3 x 23 = 69 ft

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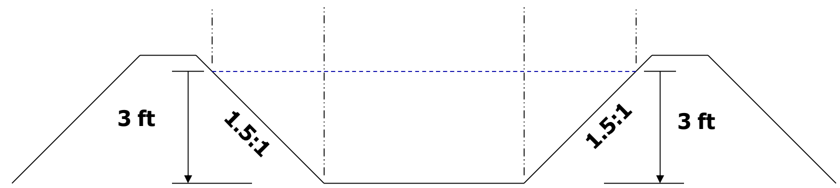
Example: Temp Rock Sed Dam Type B



Calculate base width and base length using 1.5 to 1 sideslopes:

$W_{base} = W_{top} –$ (depth x 1.5 x 2 sides) = 23 – (3x1.5x2) = 14 ft

$L_{base} = L_{top} –$ (depth x 1.5 x 2 sides) = 69 – (3x1.5x2) = 60 ft

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Example: Temp Rock Sed Dam Type B

Calculate volume (minimum required = 3,600 ft^3):

$$\text{Volume} = \frac{d}{3}\left[W_{top}\,L_{top} + W_{base}\,L_{base} + \left(\frac{W_{top}\,L_{base} + W_{base}\,L_{top}}{2}\right)\right]$$

$$\text{Volume} = \frac{3}{3}\left[(23)(69) + (14)(60) + \left(\frac{(23)(60) + (14)(69)}{2}\right)\right]$$

Volume = 3600 ft^3 (meets minimum requirement)

Surface Area (at weir elevation) = 23 x 69 = 1587 ft^2

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Example: Temp Rock Sed Dam Type B

Principal spillway:

Water exits the basin via the Class B stone dam covered with sediment control stone

Rock weir:

Weir must be sized according to weir chart based on total drainage area (1 acre)

Weir Length (1 acre) = 4 ft

Baffles:

Since basin is 69 ft long, use 3 baffles spaced evenly. Divided the basin into 4 quarters, each 17 ft long

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Design Steps: Skimmer Basin with Baffles

1. Minimum volume and surface area
2. Width and length based on sideslopes
3. Dewatering flow rate (top 2 ft in 3 days)
4. Skimmer size and orifice diameter
5. Primary spillway barrel pipe size
6. Emergency spillway weir length
7. Baffle spacing

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Skimmer Basin

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Example: Skimmer Basin with Baffles

Disturbed area = 10 ac; Q_{10} = 17 cfs; Dewater time = 3 days; Interior sideslopes = 1.5:1; L:W = 3:1

1. Minimum Volume and Surface Area:

Minimum Volume = 1800 x 10 acres = 18,000 ft^3

Minimum Surface Area = $325Q_{10}$ = 325 x 17 cfs = 5,525 ft^2

Depth = Volume / Area = 18,000 ft^3 / 5,525 ft^2 = 3.1 ft

For DOT projects, Design Depth = 3 ft

Therefore, adjust minimum surface area up:

$Area_{min}$ = Volume / Design Depth = 18,000 ft^3 / 3 ft = 6,000 ft^2

Surface area must be greater to account for sideslopes

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Example: Skimmer Basin with Baffles

2. Width and length at top and base (trial & error):

Start with area = 6,000 ft^2 and a 3 to 1 length to width ratio

$$\text{Trial Width, } W_{top} = \sqrt{\frac{A}{\text{L to W ratio}}} = \sqrt{\frac{6{,}000}{3}} = 45\text{ ft}$$

To account for sideslopes, add to top width (try 3 ft):

Trial W_{top} = 45 + 3 = 48 ft

Trial L_{top} = 3 x W_{top} = 3 x 48 = 144 ft

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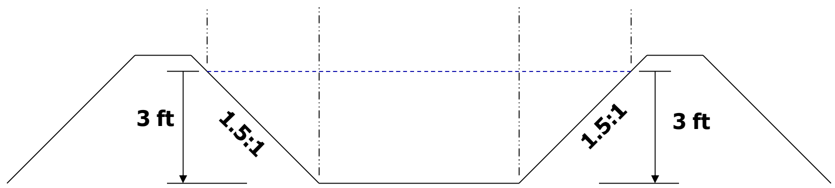
Example: Skimmer Basin with Baffles



Calculate base width and base length using 1.5 to 1 sideslopes:

W_{base} = W_{top} – (depth x 1.5 x 2 sides) = 48 – (3x1.5x2) = 39 ft

L_{base} = L_{top} – (depth x 1.5 x 2 sides) = 144 – (3x1.5x2) = 135 ft

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Example: Skimmer Basin with Baffles

Calculate volume (minimum required = 18,000 ft^3):

$$\text{Volume} = \frac{d}{3}\left[W_{top}L_{top} + W_{base}L_{base} + \left(\frac{W_{top}L_{base} + W_{base}L_{top}}{2}\right)\right]$$

$$\text{Volume} = \frac{3}{3}\left[(48)(144) + (39)(135) + \left(\frac{(48)(135) + (39)(144)}{2}\right)\right]$$

Volume = 18,225 ft^3 (>18,000 ft^3 minimum)

Surface Area (weir elevation) = 48 x 144 = 6,912 ft^2 >5,525 ft^2

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Example: Skimmer Basin with Baffles

3. Dewatering flow rate (<u>top 2 ft in 3 days)</u>

Calculate width & length at depth =1 ft using 1.5:1 sideslopes:

$W_{1ft} = W_{top} –$ (depth x 1.5 x 2 sides) = 48 – (2x1.5x2) = 42 ft

$L_{1ft} = L_{top} –$ (depth x 1.5 x 2 sides) = 144 – (2x1.5x2) = 138 ft

Calculate volume in the top 2 ft

$$\text{Volume} = \frac{d}{3}\left[W_{top}\,L_{top} + W_{1ft}\,L_{1ft} + \left(\frac{W_{top}\,L_{1ft} + W_{1ft}\,L_{top}}{2}\right)\right]$$

$$\text{Volume} = \frac{2}{3}\left[(48)(144) + (42)(138) + \left(\frac{(48)(138) + (42)(144)}{2}\right)\right]$$

Volume in top 2 ft = 12,696 ft^3

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Example: Skimmer Basin with Baffles

4. Select Faircloth Skimmer to dewater <u>top 2 ft in 3 days</u>

Volume in top 2 ft, V_{skim} = 12,696 ft^3

Dewater Rate, $Q_{skim} = V_{skim} / t_{dewater}$ = 12,696 / 3 = 4,232 ft^3 / day

Select the Skimmer Size to carry <u>at least</u> 4,232 ft^3/day

From Table 5.1, a 2.5-inch skimmer carries 6,234 ft^3/day with driving head, H_{skim} = 0.208 ft

Why not use a 2-inch skimmer?

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Select skimmer based on flow rate, Table 5.1

Skimmer Diameter (inches)	$Q_{skimmer}$ Max Outflow Rate (ft^3 / day) *	$H_{skimmer}$ Driving Head (ft) *
1.5	1,728	0.125
2.0	3,283	0.167
2.5	6,234	0.208
3.0	9,774	0.250
4.0	20,109	0.333
5.0	32,832	0.333
6.0	51,840	0.417
8.0	97,978	0.500

* *Updated 2007: www.fairclothskimmer.com*

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Orifice Diameter for Skimmer

(Equation 5.2)

$$D_{orifice} = \sqrt{\frac{Q_{skim}}{2310\sqrt{H_{skim}}}}$$

$D_{orifice}$ = diameter of the skimmer orifice in inches (in)
$Q_{skimmer}$ = basin outflow rate in cubic feet per day (ft^3/day)
$H_{skimmer}$ = driving head at the skimmer orifice from Table 5.1 in feet (ft)

$$D_{orifice} = \sqrt{\frac{Q_{skim}}{2310\sqrt{H_{skim}}}} = \sqrt{\frac{4,232}{2,310\sqrt{0.208}}} = 2.0 \textit{ inches}$$

The orifice in the knockout plug is drilled to a 2-inch diameter.

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Example: Skimmer Basin with Baffles

5. Primary spillway barrel pipe size using Q_{skim} = 4,232

NCDOT: Use smooth pipe on 1% slope (minimum 4-inch)

Figure 4.1 (Pipe Chart pg 27): At 1% slope, a 4-inch pipe carries up to 100 gpm = 19,300 ft^3/day

6. Emergency spillway weir length:

NCDOT: L_{weir} = 17 cfs/0.4 = 42.5 ft or 43 ft

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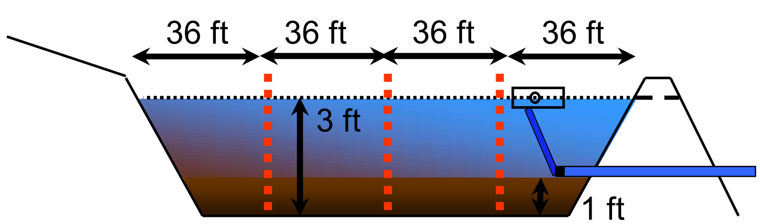
Example: Skimmer Basin with Baffles

7. Baffle Spacing:

For L_{top} > 20 ft, use 3 baffles to divide into 4 chambers:

Baffle spacing = L_{top} / 4 = 144 / 4 = 36 ft



Not to Scale

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Worksheet 5.1. Infiltration Basin

Infiltration basin on Rains soil (permeability= 0.55 in/hr) with drainage area of 8 acres?

Drainage area = 8 ac; permeability = 0.55 in/hr

For NCDOT maximum depth = 3ft

Dewatering time = 3ft x hr/0.55 in x 12 in/ft = 65.5 hr or 2.7 days

Design volume = 1800 x 8 = 14,400 ft^3

*NCDOT guidelines: drains in 3 days, drainage area <10ac., soil permeability at least 0.5 in/hr

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Worksheet 5.3. Skimmer Basin

Design: For a 5.5-acre construction site with Q_{10} = 12 cfs, design a basin to be dewatered in 3 days. Use 1.5:1 interior sideslopes and 3:1 length:width ratio.

1. Minimum Volume and Surface Area:

Minimum Volume = 1800 x 5.5 acres = 9,900 ft^3

Minimum Surface Area = $325Q_{10}$ = 325 x 12 cfs = 3,900 ft^2

Depth = Volume / Area = 9,900 ft^3 / 3,900 ft^2 = 2.5 ft

For DOT projects, <u>Design Depth = 3 ft</u>

Surface area must be greater to account for sideslopes

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Worksheet 5.3. Skimmer Basin

2. Width and Length at top and base (trial & error):

Start with area = 3,900 ft^2 and a 3:1 length:width ratio

$$\text{Trial Width, } W_{top} = \sqrt{\frac{A}{\text{L to W ratio}}} = \sqrt{\frac{3{,}900}{3}} = 36\,\text{ft}$$

Trial width add 1ft to width W_{top} = 36 +1 = 37 ft

Trial Length, L_{top} = 3 x 37 = 111 ft

Try this width and length with 1.5:1 sideslopes to check if volume > 9,900 ft^3

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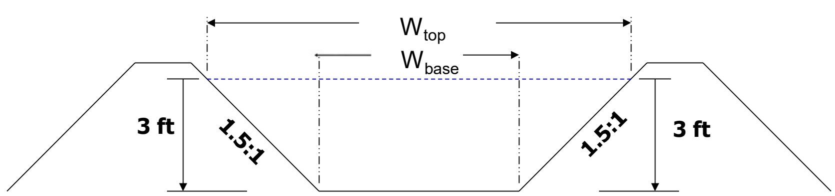
Worksheet 5.3. Skimmer Basin



Calculate base width and base length using 1.5 to 1 sideslopes:

W_{base} = W_{top} – (depth x 1.5 x 2 sides) = 37 – (3x1.5x2) = 28 ft

L_{base} = L_{top} – (depth x 1.5 x 2 sides) = 111 – (3x1.5x2) = 102 ft

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Worksheet 5.3. Skimmer Basin

Calculate volume (minimum required = 9,900 ft^3):

$$\text{Volume} = \frac{d}{3}\left[W_{top}\,L_{top} + W_{base}\,L_{base} + \left(\frac{W_{top}\,L_{base} + W_{base}\,L_{top}}{2}\right)\right]$$

$$\text{Volume} = \frac{3}{3}\left[(37)(111) + (28)(102) + \left(\frac{(37)(102) + (28)(111)}{2}\right)\right]$$

Volume = 10,404 ft^3 (meets minimum requirement)

Surface Area (at weir elevation) = 37 x 111 = 4,107 ft^2

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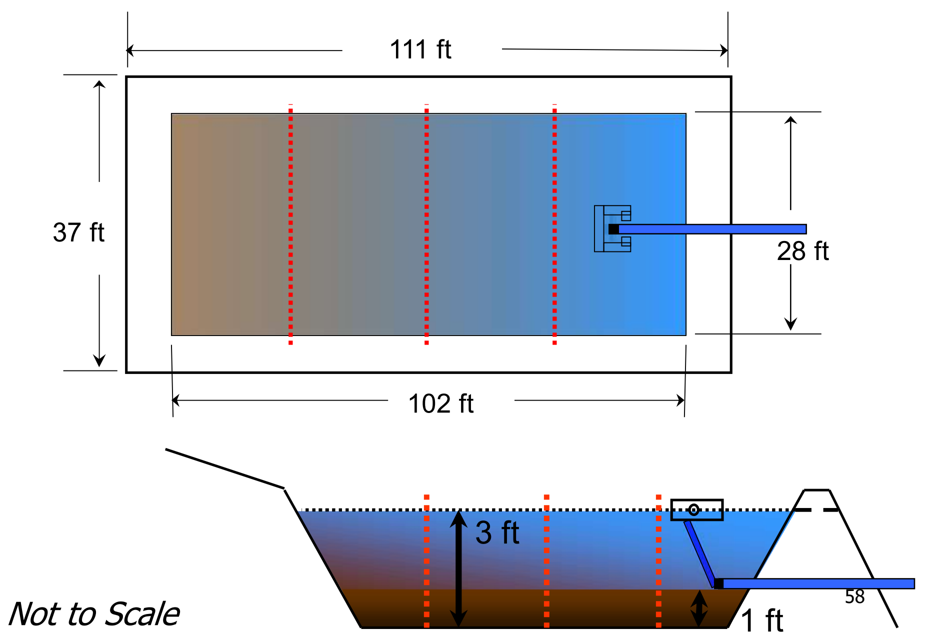
Worksheet 5.3. Skimmer Basin



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Worksheet 5.3. Skimmer Basin

3. Dewatering flow rate (<u>top 2 ft in 3 days)</u>

Calculate width & length at depth =1 ft using 1.5:1 sideslopes:

$W_{1ft} = W_{top}$ – (depth x 1.5 x 2 sides) = 37 – (2x1.5x2) = 31 ft

$L_{1ft} = L_{top}$ – (depth x 1.5 x 2 sides) = 111 – (2x1.5x2) = 105 ft

Calculate volume in the top 2 ft

$$\text{Volume} = \frac{d}{3}\left[W_{top}L_{top} + W_{1ft}L_{1ft} + \left(\frac{W_{top}L_{1ft} + W_{1ft}L_{top}}{2}\right)\right]$$

$$\text{Volume} = \frac{2}{3}\left[(37)(111) + (31)(105) + \left(\frac{(37)(105) + (31)(111)}{2}\right)\right]$$

Volume in top 2 ft = 7,350 ft^3

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Worksheet 5.3. Skimmer Basin

4. Select Faircloth Skimmer to dewater <u>top 2 ft in 3 days</u>

Volume in top 2 ft, V_{skim} = 7,350 ft^3

Daily Q_{skim} = 7,350 / 3 = 2,450 ft^3 / day

Select the Skimmer Size to carry <u>at least</u> 2,450 ft^3/day

From Table 5.1, a 2-inch skimmer carries 3,283 ft^3/day with driving head, H_{skim} = 0.167 ft

$$D_{orifice} = \sqrt{\frac{Q_{skim}}{2310\sqrt{H_{skim}}}} = \sqrt{\frac{2,450}{2,310\sqrt{0.167}}} = 1.6 \textit{ inches}$$

The orifice in the knockout plug is drilled to a 1.6-inch diameter.

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Select skimmer based on flow rate, Table 5.1

Skimmer Diameter (inches)	$Q_{skimmer}$ Max Outflow Rate (ft^3 / day) *	$H_{skimmer}$ Driving Head (ft) *
1.5	1,728	0.125
2.0	3,283	0.167
2.5	6,234	0.208
3.0	9,774	0.250
4.0	20,109	0.333
5.0	32,832	0.333
6.0	51,840	0.417
8.0	97,978	0.500

* Updated 2007: www.fairclothskimmer.com

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Worksheet 5.3. Skimmer Basin

5. Primary spillway barrel pipe size using Q_{skim} = 2,450

NCDOT: Use smooth pipe on 1% slope (minimum 4-inch)

Figure 4.1 (Pipe Chart): At 1% slope, a 4-inch pipe carries up to 100 gpm = 19,300 ft^3/day

6. Emergency spillway weir length:

NCDOT: L_{weir} = 12 cfs/0.4 = 30 ft

7. Baffle Spacing:

Baffle spacing = L_{top} / 4 = 111 / 4 = 28 ft

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MODULE 6: Below Water Table Borrow Pits Dewatering Options

Tier I Methods

- Borrow Pit Dewatering Basin
- Land Application (Irrigation)
- Geotextile Bags
- Alum
- Gypsum
- Polyacrylamide (PAM)

Tier II Methods [rare & unique resources]

- Well Point Pumping
- Impoundments
- Cell Mining
- Sand Media Filtration
- Wet Mining

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Borrow Pit Dewatering Basin

- Basin at pump outlet to settle sediment
- No area requirement
- Volume = pump rate x detention time:
  - Detention time = 2 hours minimum
  - $V_{still} = 16(Q_{still})$ Q = pump rate in gpm
  - Max pump rate = 1,000 gpm (2.2 cfs)
- Maximum depth = 3 ft
- Earthen embankments are fill above grade
- L:W = 2:1 minimum
- Surface outlet:
  - Non-perforated riser pipe (12-inch)
  - Flashboard riser

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Turbidity Reduction: PAM at 1 mg/L in stilling basin

Powder: mix 1 pound of PAM per 100 gallons of water

Figure 6.1: At Q_{still} = 1000 gpm, inject liquid PAM mix at 1.3 gpm

Inject mix at pump intake (suction line) or just after water leaves pump

Floc-Log: turbulent flow 60-80 gpm inside corrugated plastic pipe (no inner liner)

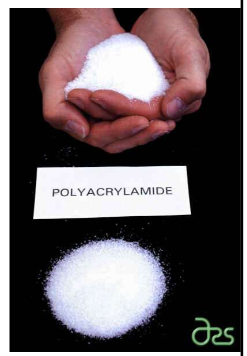

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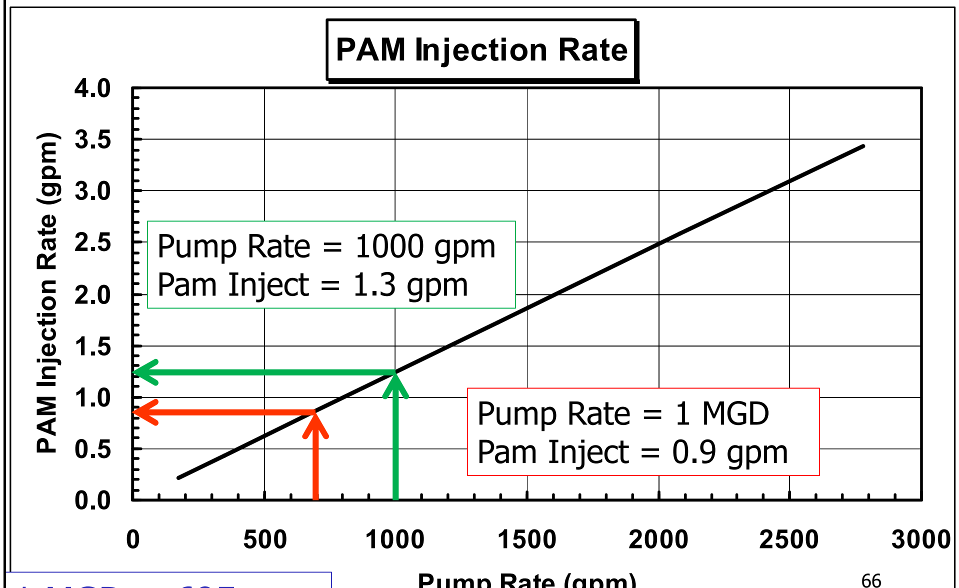
Figure 6.1. PAM Injection (liquid mix)



1 MGD = 695 gpm

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Below Water Table Sites: Wetland Protection

Type 1: Flow from wetland to pit

Type 2: Flow from pit to wetland

Does not require Skaggs Method calculations

Minimum 25 ft buffer (setback) from wetland

Minimum 50 ft buffer from stream

Type 3: Flow-through pits: wetland to pit on one side, pit to wetland on other side

For Types 1 & 3 or uncertain flow direction:

- 400 ft buffer OR
- Skaggs Method calculations

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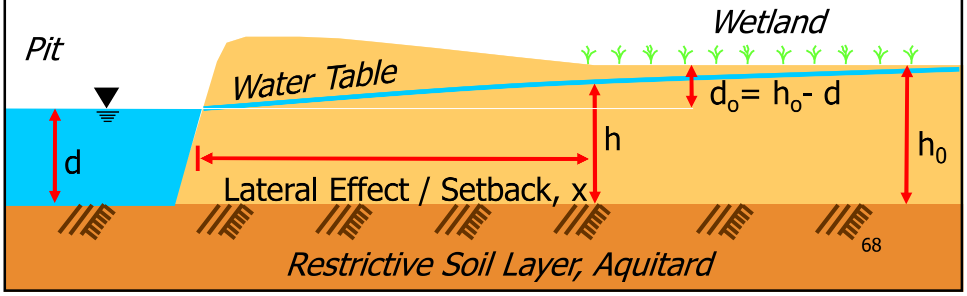
Skaggs Method: Determine Setback

Wetland hydrology is defined as an area where the water table is normally within 1.0 ft of the soil surface for a continuous critical duration, defined as 5-12.5% of the growing season. The 5% was used in the Skaggs method.

Calculate “Lateral Effect,” or setback, x



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Skaggs Method: Determine Setback

Soil Characteristics:

- Effective hydraulic conductivity, $\mathbf{K_e}$ (Soil Survey or site investigation)
- Drainable porosity, **f = 0.035 for DOT applications**

Climate:

Threshold Time for water table drawdown of 0.83 ft, $\mathbf{T_{25} = t}$

Depth to water table at borrow pit: $\mathbf{d_o = 2}$ **ft**

Surface Depressional Storage:

1 inch if area is relatively smooth

2 inches if area is rough with shallow depressions

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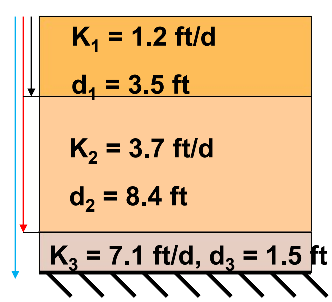
Effective Hydraulic Conductivity

$L1=d_1=3.5$ ft

$L2=L1+d_2=11.9$ ft

$L3=L2+d_3=13.4$ ft



$$K_e = \frac{K_1 d_1 + K_2 d_2 + K_3 d_3}{d_1 + d_2 + d_3}$$

$$K_e = \frac{1.2(3.5) + 3.7(8.4) + 7.1(1.5)}{3.5 + 8.4 + 1.5} = 3.4\ ft/d$$

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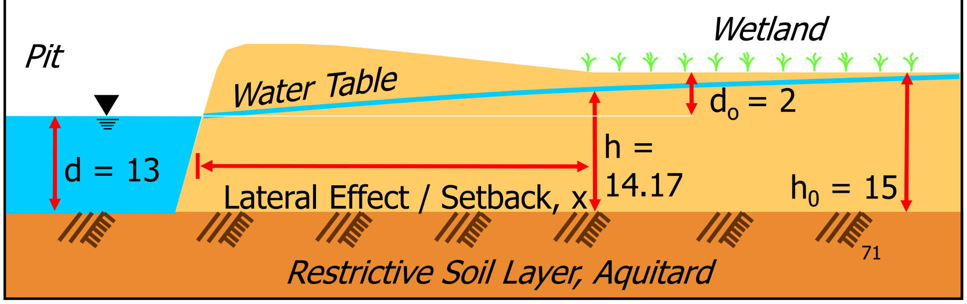
Example: Skaggs Method

The wetland is located in Johnston County on a Rains soil. From wetland soil surface to impermeable/restrictive layer is 15 ft. Soil hydraulic conductivity is 4ft/day. The wetland has a natural rough surface. What is the minimum lateral setback?



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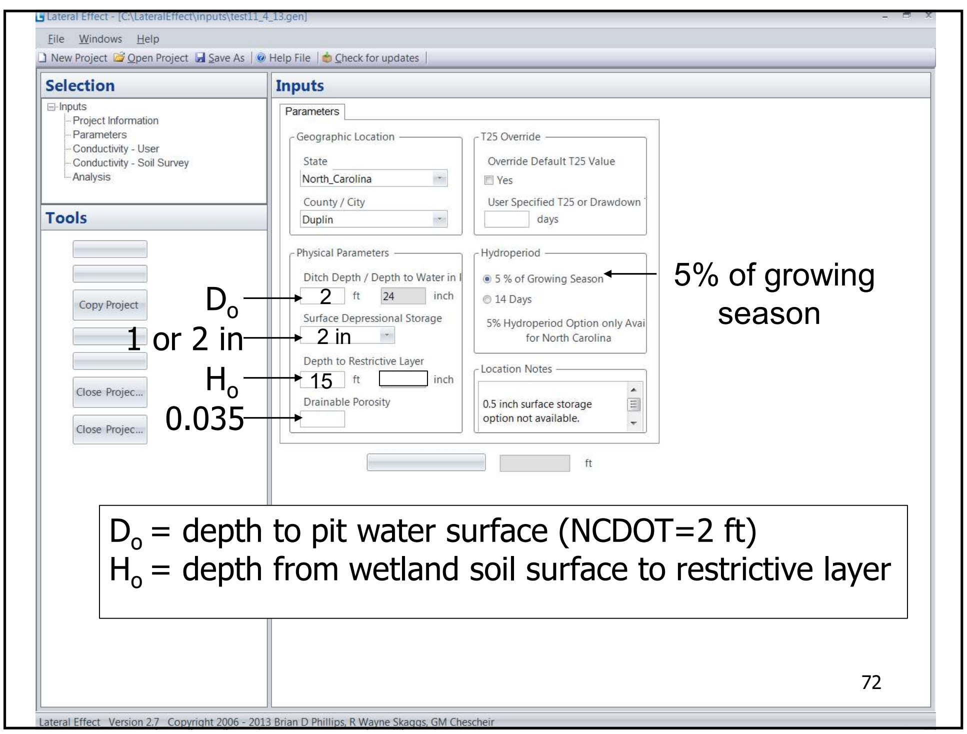

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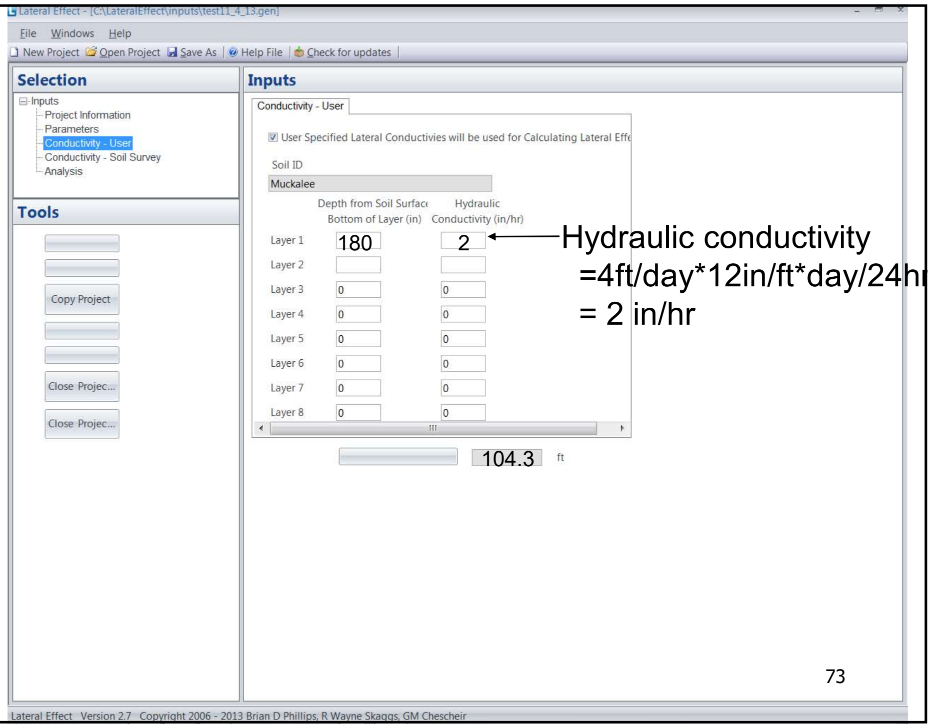

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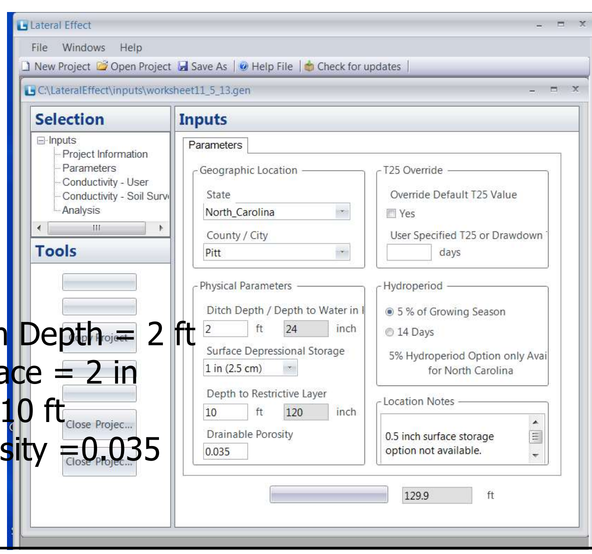
Worksheet 6.2. Skaggs Method Software Input

For a borrow pit in Pitt County with soil (6ft deep K = 6 ft/day; rest K=4 ft/day), depth from natural wetland soil surface to the impermeable layer is 10 ft, Fill in the inputs for the Skaggs Method software program.



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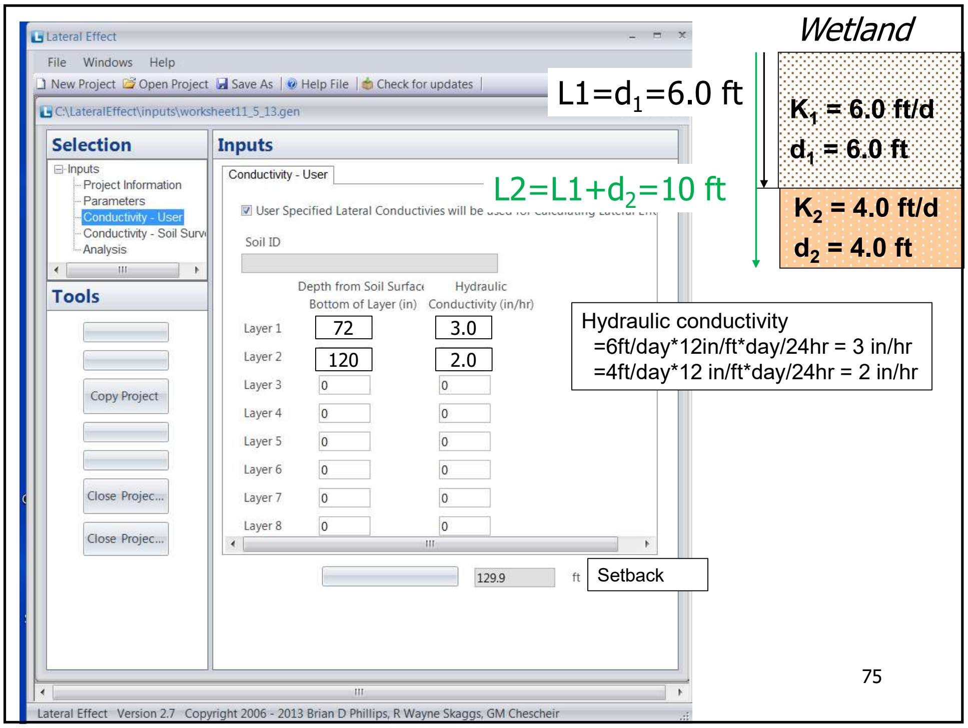

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