MIDS Credits: Swales

MIDS Work Group

March 15, 2013

p-gen3-15b

Outline

- Review:
  - Credit Process
  - Calculator
  - Draft Drawings

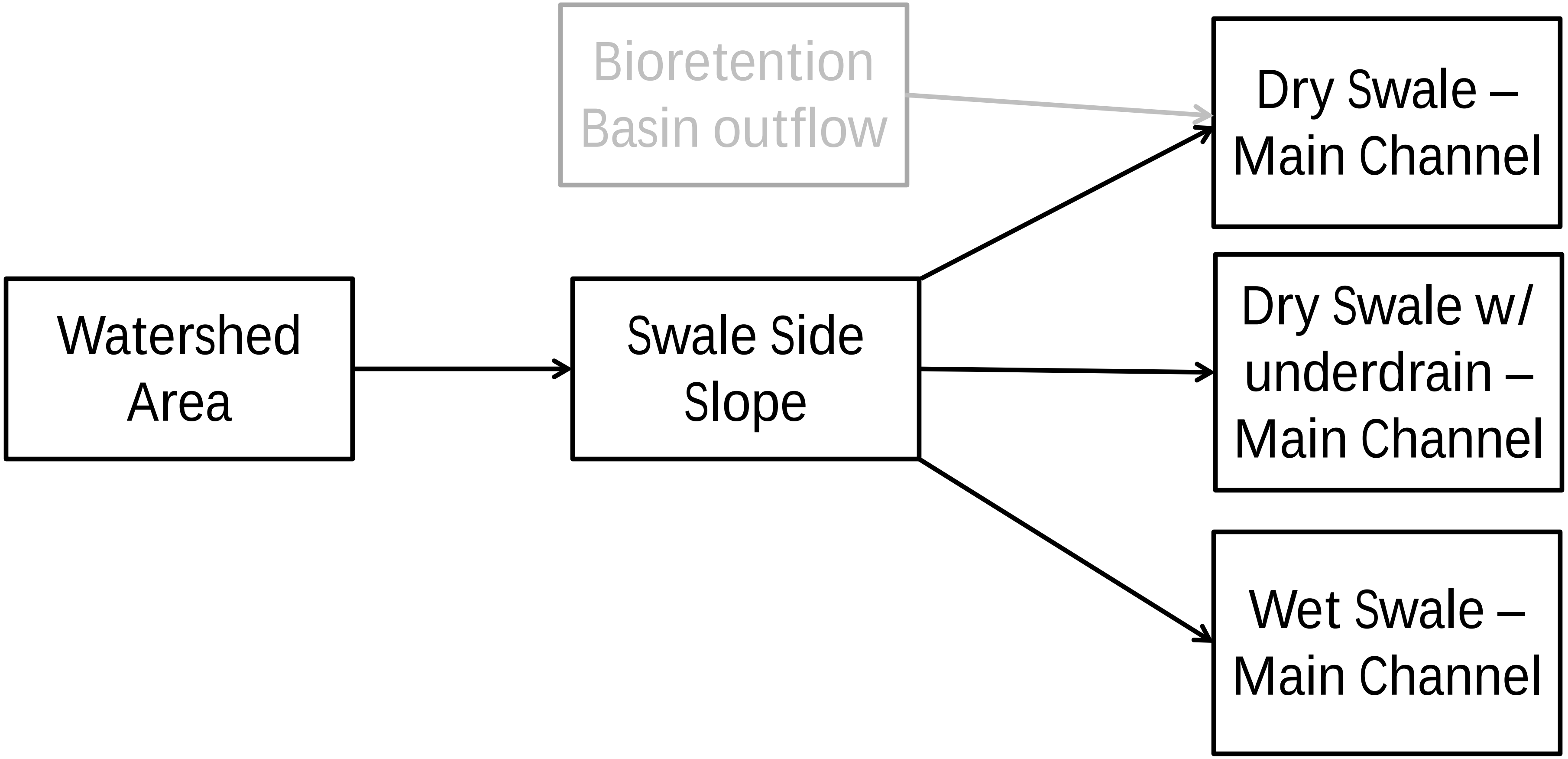
Swale Credit Process

- Step 1: Break swales into components
  - Side slope
  - Main channel
    - Dry swale
    - Dry swale with an under drain
    - Wet swale

Photo: Ray Roemmich

Swale Credit Process

Treat side slopes as individual BMP and route to 1 of the 3 main channel configurations



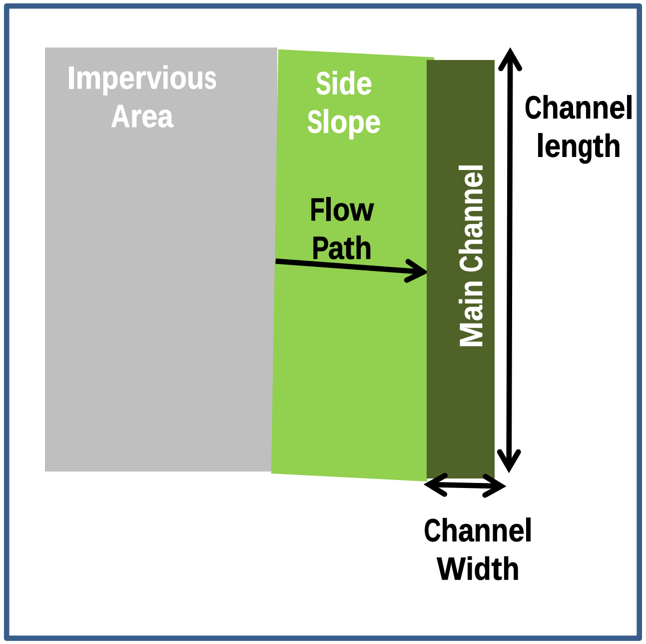
Swale Credit Process

- Step 2: Use modeling to determine annual volume reductions

Swale Credit Process

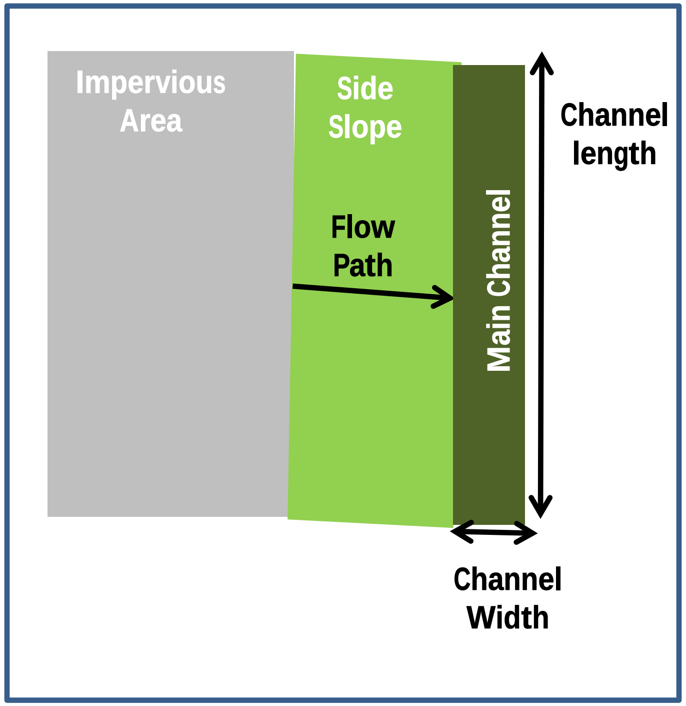
Side Slope annual modeling

- Use P8
- Run 58 years of Twin Cities precipitation
- Parameters (384 model runs)
  - Slope (Side Slope): 3H:1V, 4H:1V, 5H:1V
  - Flow path length: 10, 20, 30, 50 ft
  - Infiltration rate: 0.2, 0.6, 1.0, 1.6 in/hr
  - Impervious area/side slope area: 1, 3, 7
  - Manning’s n: 0.25 (short grass), 0.35 (high grass)



Main channel annual modeling

- Use P8
- Run 58 years of Twin Cities precipitation
- Parameters (total of 432 model runs)
  - Channel slope: 1%, 2%, 3%, 4%
  - Infiltration rate: 0.2, 0.6, 1.0, 1.6 in/hr
  - Impervious Area/Channel Area: 5, 20, 40
  - Manning's n: 0.25 (short grass), 0.35 (high grass)
  - Bottom Width: 4, 8 ft
  - Channel Length: 150, 300, 700 ft



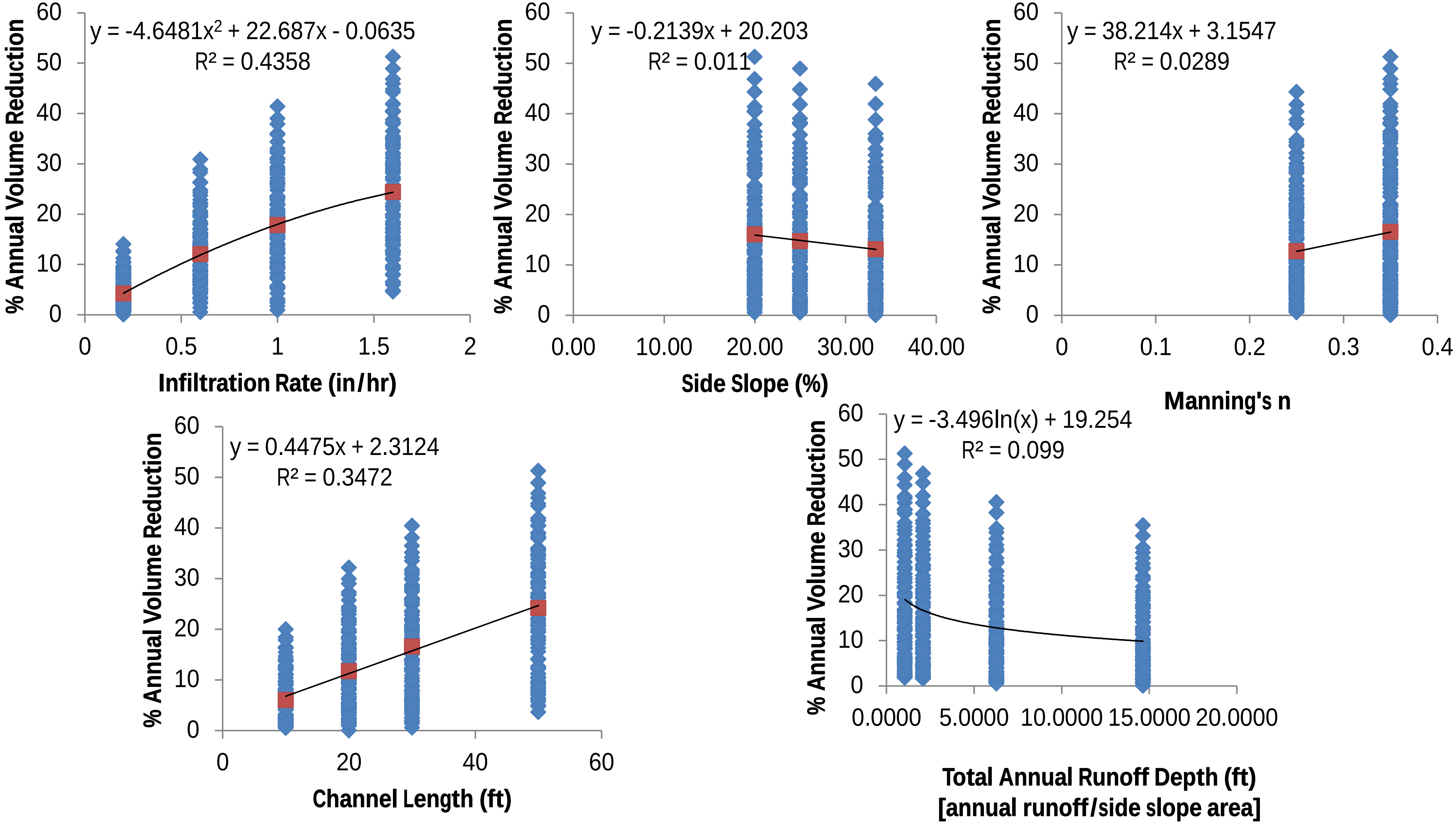
Modeling Procedure

- Run model simulations
- Develop relationship between volume reduction and design parameters using multivariate regression analysis
- Use relationship to calculate annual volume reduction percentage in calculator

Swale Credit Process

Modeling Process Results

Side Slope Annual Volume Reduction by Parameter

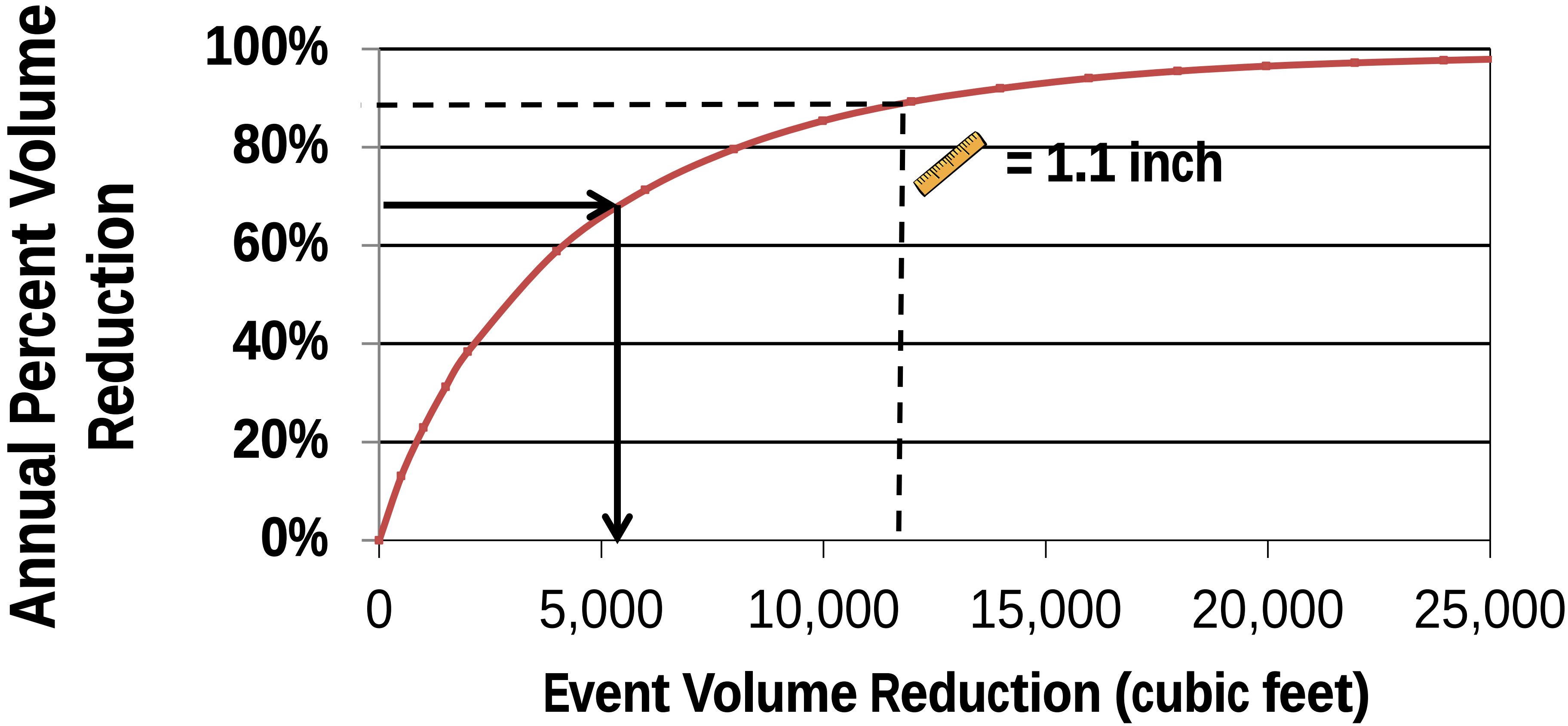


Swale Credit Process

- Step 3: Annual volume reduction are converted to event reductions using performance curves

Swale Credit Process

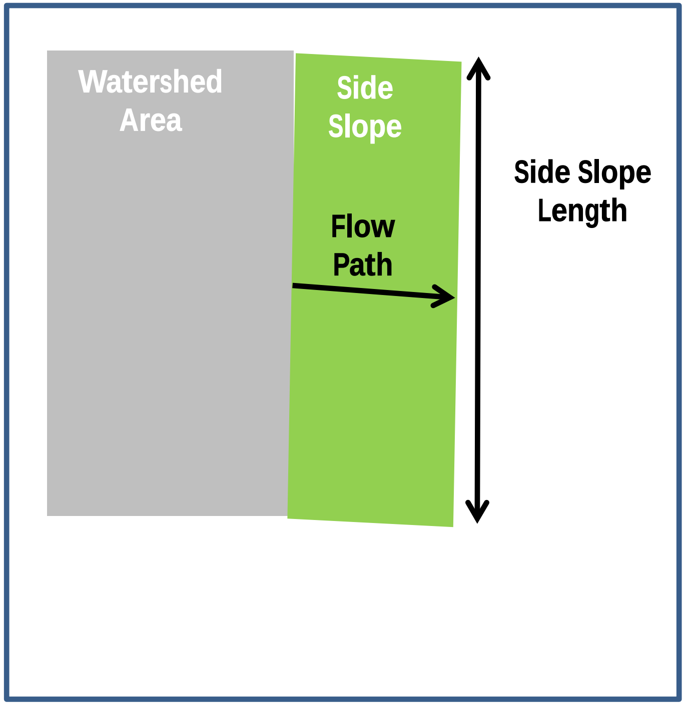
Use performance goal curves to calculate Performance Goal reductions



Note: Performance curve is for a 10 acre site, 30% impervious

Calculator Overview

Calculator Overview
Side Slope



- Calculator Parameters
  - Side Slope (3:1, 4:1, 5:1, 6:1 …..)
  - Flow Path Length (ft)
  - Side Slope Length (ft)
  - Soil Type
  - Manning's n of vegetation (0.25 – mowed turf, 0.35 - native grass)

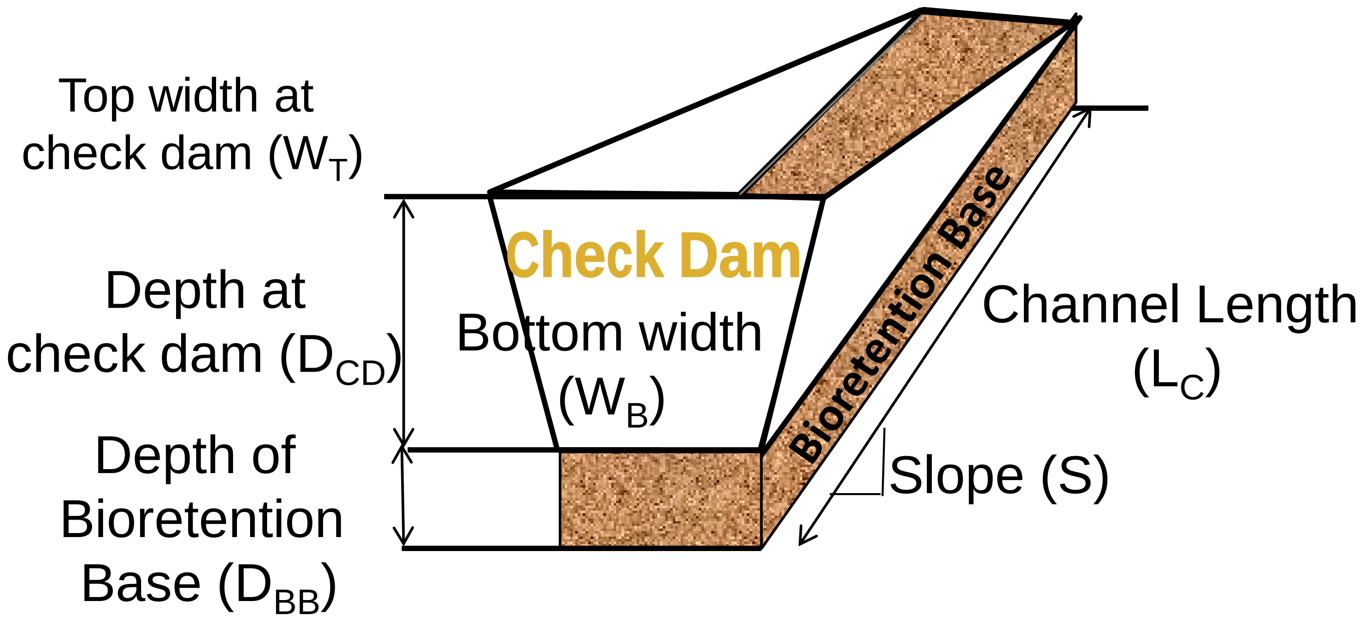
Calculator Overview

Side Slope

- Use parameters to calculate % annual volume reduction based on modeling relationship
- Use performance goal curve to convert % annual volume reduction to event volume reduction
- Route remaining runoff to one of three main channel configurations
- Pollutant removal will be applied based on main channel configuration
- Restriction: Watershed flow must be routed as sheet flow over side slope to obtain credit

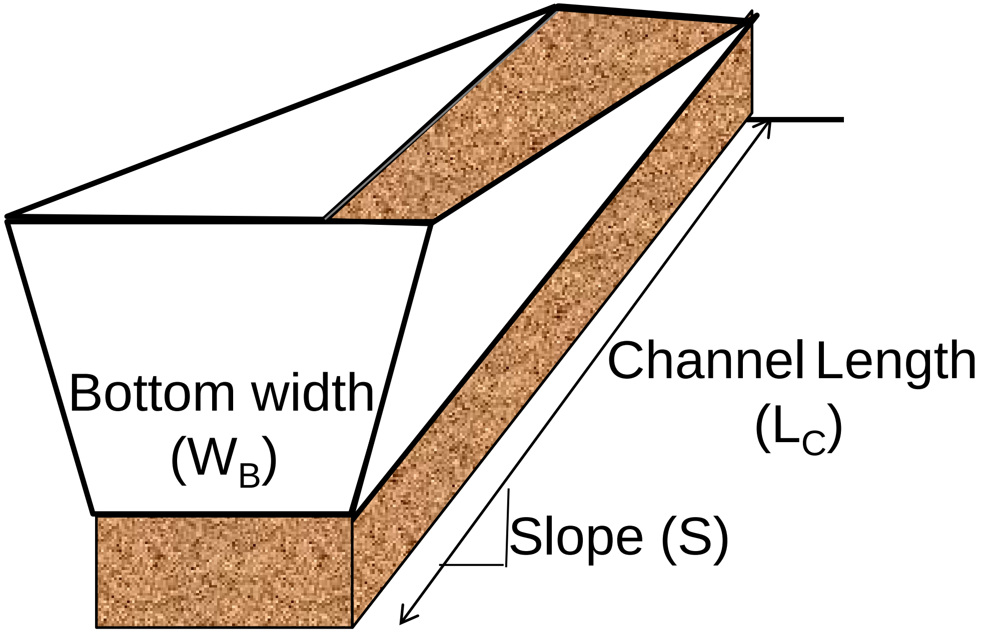
Calculator Overview

Dry Swale - Main Channel



- Volume reduction calculated using 3 components
  - Grass Channel
  - Check Dam
  - Bioretention Base

Grass Channel Volume Reduction



- Calculator Parameters
  - Channel Length (L_C)
  - Bottom width (W_B)
  - Channel Slope (S)
  - Soil type
  - Manning's n of vegetation (0.25: mowed turf, 0.35: native grass)

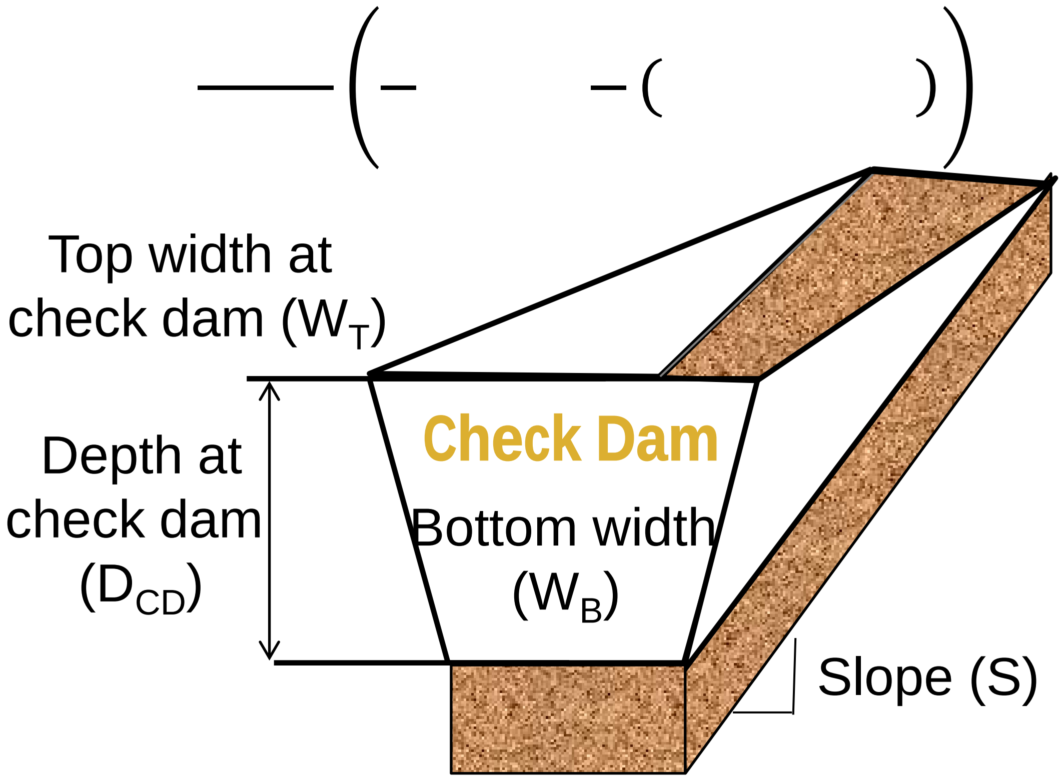
Grass Channel Volume Reduction

- Use parameters to calculate % annual volume reduction based on modeling relationship

- Use performance goal (PG) curves to convert % annual volume reduction to event volume reduction

Calculator Overview

Check Dam Volume Reduction



- Calculate volume of water held behind check dam
- Parameters:
  - Channel width (W_B)
  - Top width of check dam (W_T)
  - Depth of check dam (D_{CD})
  - Channel slope (%)

Calculator

Bioretention Base Volume Reduction

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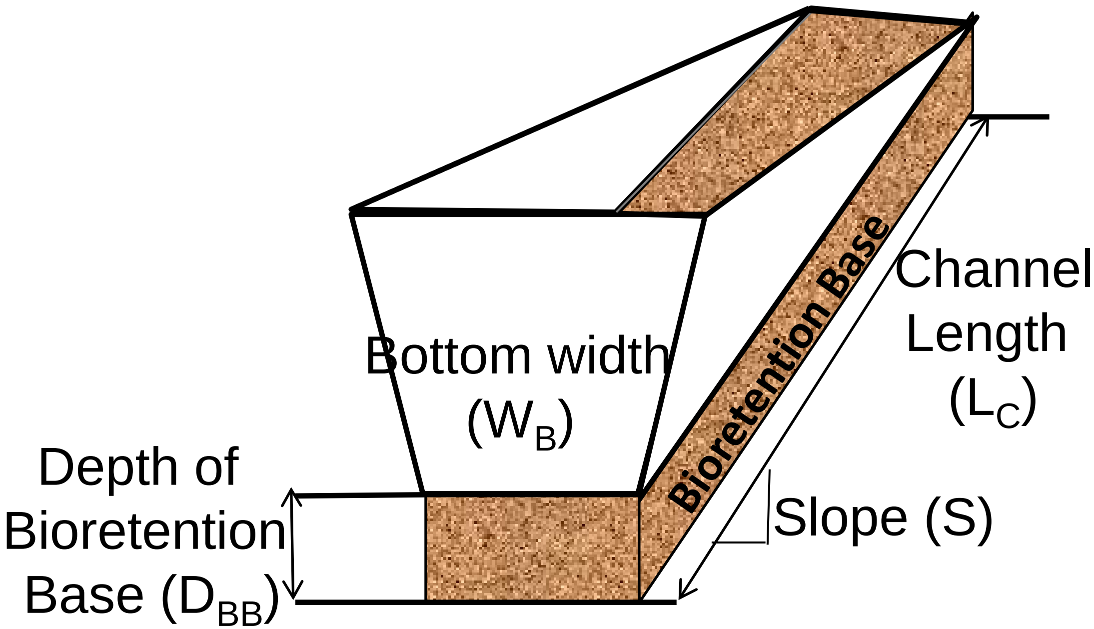
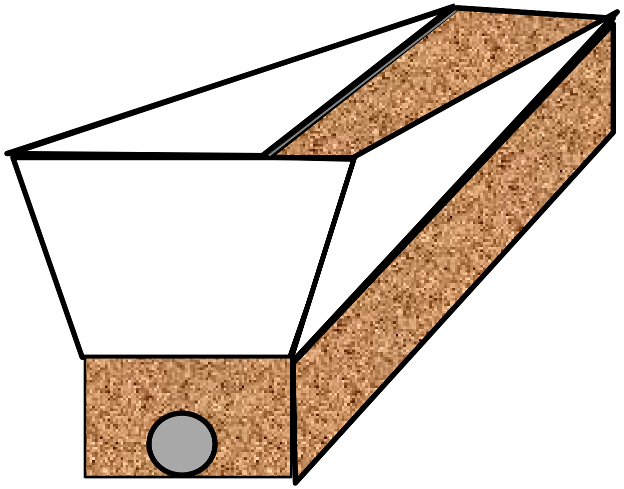


- Calculate the volume of water that can be held in the pore spaces of the bioretention base
- Parameters
  - Depth of bioretention base (D_{BB})
  - Channel length (L_C)
  - Channel width (W_B)
  - Porosity (n)

Final Credit Calculation: Dry Swale – Main Channel

- Grass Channel
  - Calculate PG volume reduction from modeling
- Grass Channel with check dam
  - Calculate PG volume reduction from modeling
  - Add water volume stored behind check dam
- Dry Swale with bioretention base
  - Calculate water stored in pore space of bioretention base
- Dry Swale with bioretention base and check dam
  - Calculate water stored in pore space of bioretention base
  - Add water volume stored behind check dam

Dry Swale – Main Channel with an Underdrain



- No volume reduction
- With or without a check dam
- 36% Particulate P reduction[1]
- 68% TSS reduction[1]
- 0% Dissolved P reduction unless iron enhanced

[1]Center for Watershed Protection & Chesapeake Stormwater Network (CWP & CSN), 2008. *Technical Memorandum: The Runoff Reduction Method*. April 18, 2008

Wet Swale – Main Channel

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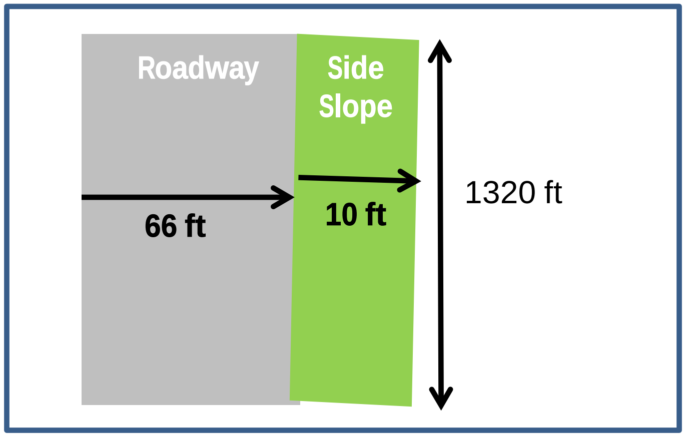
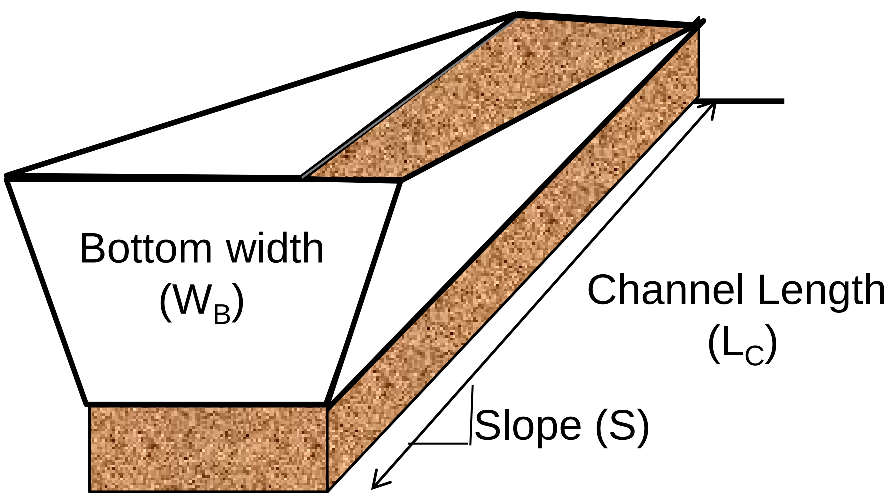
Photo: Ray Roemmich

- No Volume Reduction
- 0% Particulate P reduction[1]
- 68% TSS reduction[1]
- 0% dissolved P reduction unless iron enhanced

[1]Center for Watershed Protection & Chesapeake Stormwater Network (CWP & CSN), 2008. *Technical Memorandum: The Runoff Reduction Method*. April 18, 2008

Credit Example 1a: Road Side/Highway Grass Channel





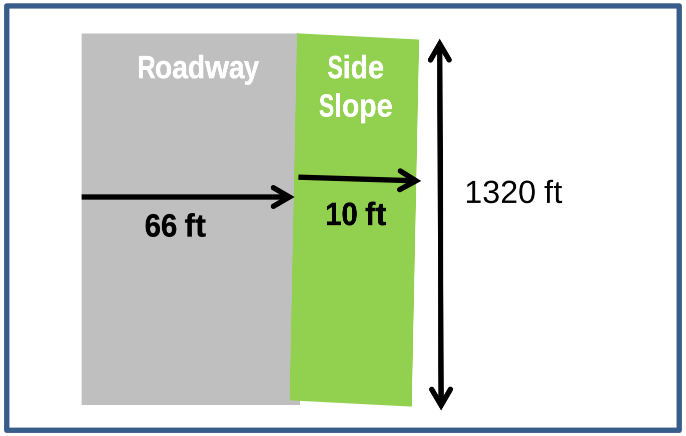
Parameter	Value
Impervious Area	2 acres
Channel length	1320 ft
Side slope flow path	10 ft
Side slope	4:1 (25%)
Swale bottom width	5 ft
Channel slope	2 %
Manning's n	0.35 (long grass)

MIDS Performance Goal Credit:
Type A soils (1.6 in/hr) = 34%
Type B soils (0.6 in/hr) = 23%
Type C soils (0.2 in/hr) = 17%

Credit Example 1a: Road Side/Highway Grass Channel

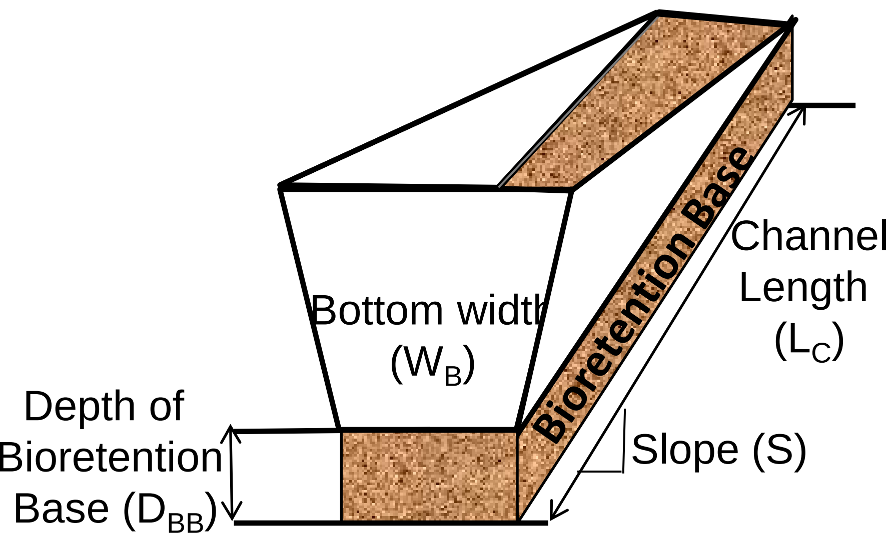
Soils & Infiltration Rate	MIDS Performance Goal Credit	Annual Volume Reduction
A (1.6 in/hr)	34%	77%
B (0.6 in/hr)	23%	51%
C (0.2 in/hr)	17%	35%

Credit Example 1b: Road Side/Highway Dry Swale (Bioretention Base)



Instead of grass channel add bioretention base to previous example

Parameter	Value
Depth of bioretention base	2 ft
Porosity of media	0.4



MIDS Performance Goal Credit = 68%

Credit Example 1b: Road Side/Highway Dry Swale (Bioretention Base)

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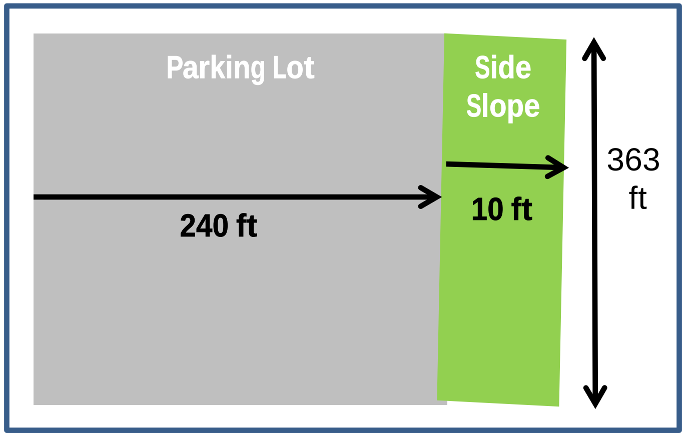
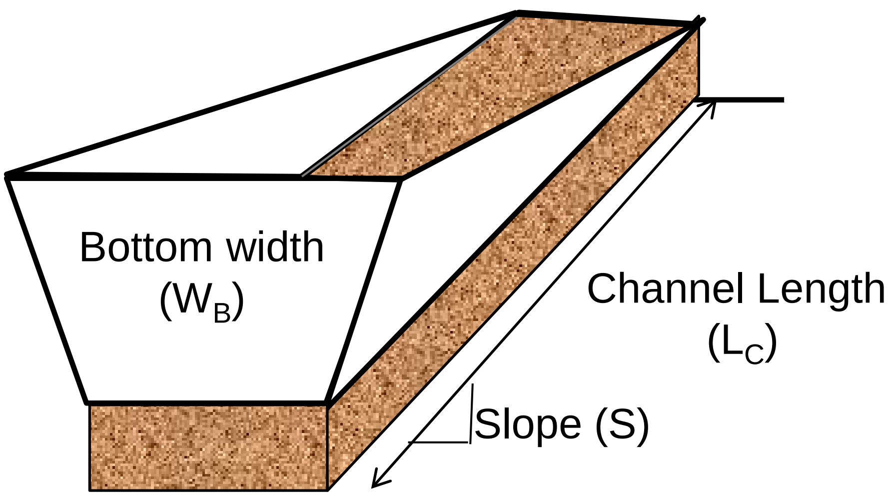
Soil & Infiltration rate	MIDS Performance Goal Credit	Annual Volume Reduction
A (1.6 in/hr)	68%	93%
B (0.6 in/hr)	67%	85%
C (0.2 in/hr)	66%	81%

Credit Example 2a: Parking Lot Grass Channel





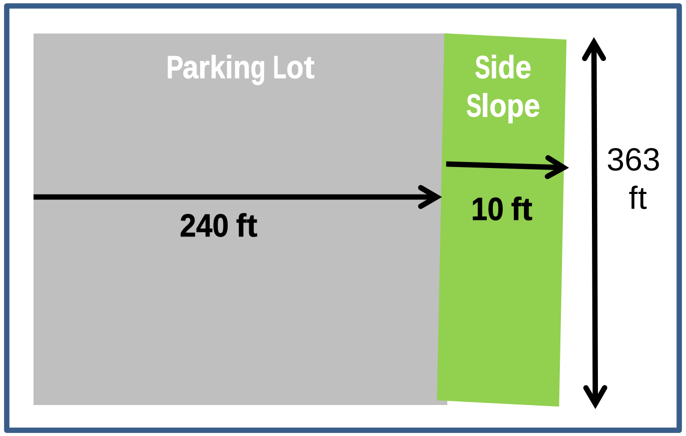
Parameter	Value
Impervious Area	2 acres
Channel length	363 ft
Side slope flow path	10 ft
Side slope	4:1 (25%)
Swale bottom width	5 ft
Channel slope	2 %
Manning's n	0.35 (long grass)

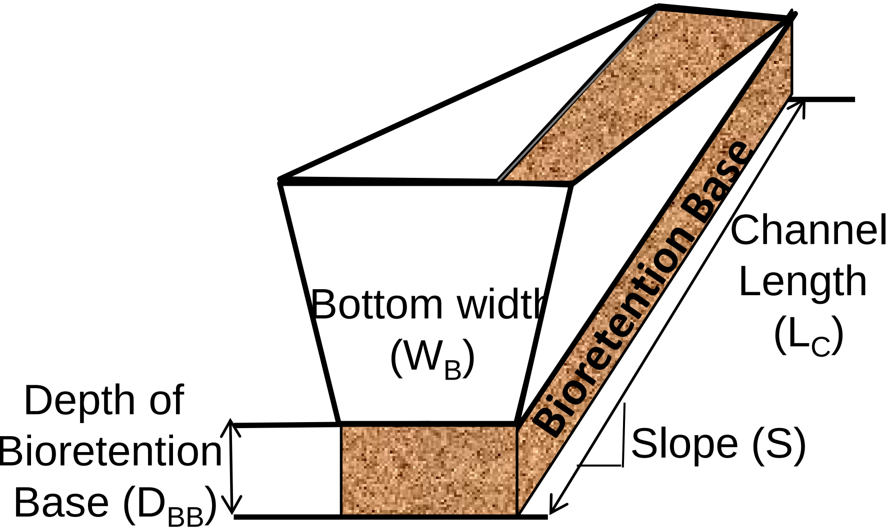
MIDS Performance Goal Credit:
Type A soils (1.6 in/hr) = 11%
Type B soils (0.6 in/hr) = 6%
Type C soils (0.2 in/hr) = <1%

Credit Example 2a: Parking Lot Grass Channel

Soils & Infiltration Rate	MIDS Performance Goal Credit	Annual Volume Reduction
A (1.6 in/hr)	11%	44%
B (0.6 in/hr)	6%	16%
C (0.2 in/hr)	<1%	1%

Credit Example 2b: Parking Lot Dry Swale (Bioretention Base)





Instead of grass channel add bioretention base to previous example

Parameter	Value
Depth of bioretention base	2 ft
Porosity of media	0.4

MIDS Performance Goal Credit = 20%

Credit Example 2b: Parking Lot Dry Swale (Bioretention Base)

Soil & Infiltration rate	MIDS Performance Goal Credit	Annual Volume Reduction
A (1.6 in/hr)	20%	60%
B (0.6 in/hr)	18%	44%
C (0.2 in/hr)	18%	37%

Swale Credits

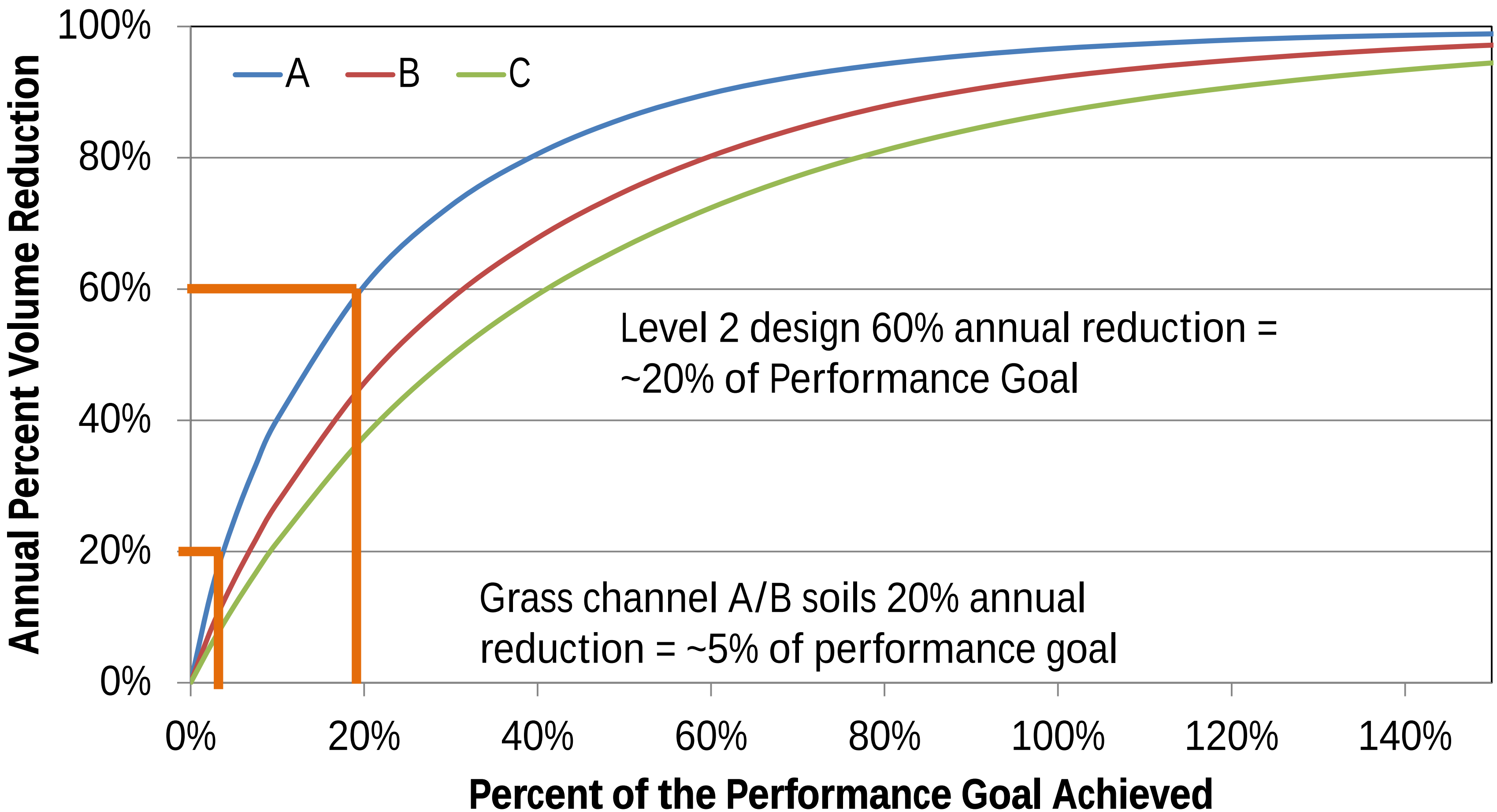
What about Virginia?

Table D-4. Dry Swale Design Guidance	
Level 1 Design (RR:40; TP:20; TN:25)	**Level 2 Design (RR:60; TP:40; TN: 35)**
TV= (1.0)(Rv)(A)	TV= (1.1)(Rv)(A)
Swale slopes from <0.5% or >2.0%	Swale slopes from 0.5% to 2.0%
Soil infiltration rates less than 0.5 in	Soil infiltration rates exceed one inch
Swale served by underdrain	Lacks underdrain or uses underground stone sump
On-line design	Off-line or multiple treatment cells
Media depth less than 18 inches	Media depth more than 24 inches
Turf cover	Turf cover, with trees, shrubs, or herbaceous plantings
All Designs: acceptable media mix tested for phosphorus index	

- Grass Channel A/B soils = 20% annual reduction
- Grass Channel C/D soils = 10% annual reduction

Swale Credits

Conversion of Virginia *Annual* Credits to MIDS Performance Goal credits



Note: Performance curve is for a 50% impervious site

Swale Credits

Comparison of MIDS to Virginia

	Virginia	MIDS
Design	Fixed	Flexible
Annual Volume Reductions	40% or 60% for dry swales 10% or 20% for grass channels	0-100%, depending on design, soils, and imperviousness
MIDS Performance Goal %	>0-100%, depending on soils and imperviousness	0-100%, depending on design, soils, and imperviousness

Drawings

See Anne for copies

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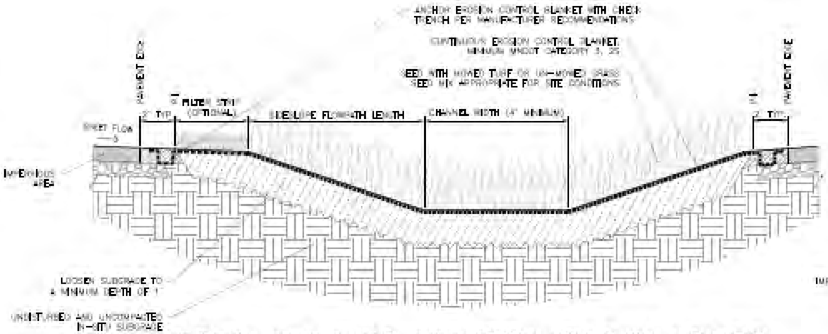
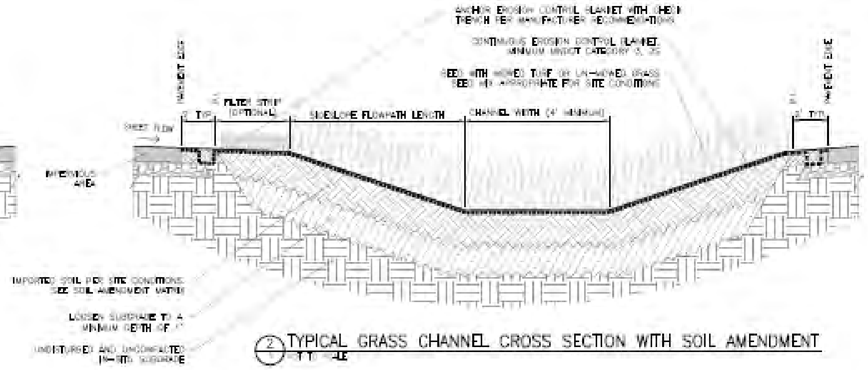


1 TYPICAL GRASS CHANNEL CROSS SECTION WITHOUT SOIL AMENDMENT



2 TYPICAL GRASS CHANNEL CROSS SECTION WITH SOIL AMENDMENT

TABLE 1: MIDS GRASS CHANNEL SOIL AMENDMENT MATRIX

Vegetation Type	*In-Situ Soil Type*			
	A	B	C	D
MOWED TURF SWALE	Place 6" MNDOT Topsoil Borrow. Mix imported soil into subsoil by loosening subsoil to a minimum depth of 12"	Loosen subsoil to a minimum depth of 12"	Place 12" Filtration Soil*. Mix imported soil into subsoil by loosening subsoil to a minimum depth of 12"	Loosen subsoil to a minimum depth of 12". Place 12" clean, coarse sand. Place 12" Filtration Soil*.
NATIVE GRASS SWALE	Place 6" MNDOT Topsoil Borrow. Mix imported soil into subsoil by loosening subsoil to a minimum depth of 12"	Loosen subsoil to a minimum depth of 12"	Place 12" Filtration Soil*. Mix imported soil into subsoil by loosening subsoil to a minimum depth of 12"	Loosen subsoil to a minimum depth of 12". Place 12" clean, coarse sand. Place 12" Filtration Soil*.

*Filtration Soil is defined as 80% clean sand mixed with 20% organic compost by volume

GENERAL NOTES - GRASS CHANNELS AND DRY SWALES:

1. INSTALL ALL TEMPORARY EROSION CONTROL MEASURES IN ACCORDANCE WITH THE SWPPP, PROJECT PLANS, AND SPECIFICATIONS IN ORDER TO EFFECTIVELY REDUCE THE VOLUME AND VELOCITY OF RUNOFF AND REDUCE EROSION OF SURFACE SOILS AND TO CONTROL SEDIMENT TRANSPORT OFF SITE DURING THE CONSTRUCTION PERIOD.
2. INSPECT AND MAINTAIN ALL EROSION CONTROL MEASURES DURING THE DURATION OF THE PROJECT.
3. SEED MIX SHALL BE SELECTED BASED ON SITE CONDITIONS INCLUDING SOIL TYPE, MOISTURE CONDITIONS, FLOW CONDITIONS, SUN VS. SHADE CONDITIONS, AESTHETICS, AND MAINTENANCE REQUIREMENTS. MNDOT SPECIFICATION 3876 PROVIDES USEFUL CRITERIA FOR SELECTING APPROPRIATE SEED MIXTURES.
4. EROSION CONTROL BLANKET SHALL BE SELECTED IN ACCORDANCE WITH MNDOT SPECIFICATION 3885 FOR THE SPECIFIC SITE CONDITIONS. THE MINIMUM RECOMMENDED EROSION CONTROL BLANKET IS CATEGORY 3, 2S. MORE PERMANENT EROSION CONTROL BLANKET MAY BE REQUIRED BASED ON SWALE GRADIENT, FLOW VELOCITY, AND FLOW DEPTH.
5. EROSION CONTROL BLANKETS INSTALLATION SHALL BE IN ACCORDANCE WITH MNDOT SPECIFICATION 3885 AND MANUFACTURERS RECOMMENDATIONS FOR ANCHORING, CHECK TRENCHES, AND EDGE AND END OVERLAPS.
6. AVOID COMPACTION OF ALL IN-SITU SOILS AND IMPORTED SOILS UNLESS DIRECTED OTHERWISE. DO NOT LOOSEN SUBSOIL UNDER CHECK DAMS.

TYPICAL CONSTRUCTION SEQUENCING-GRASS CHANNEL:

1. EXCAVATE CHANNEL TO SUBGRADE ELEVATIONS PER THE PLAN.
2. CONSTRUCTION SEQUENCE VARIES DEPENDING ON IN-SITU SOIL TYPE. SEE TABLE 1 FOR PROPER SEQUENCE FOR LOOSENING SUBSOILS AND ADDING SOIL AMENDMENTS.
3. LOOSEN SOIL IN A MANNER THAT AVOIDS RECOMPACTION OF THE SOIL BY CONSTRUCTION TRAFFIC.
4. AFTER SOIL LOOSENING AND ADDITION OF SOIL AMENDMENTS THE SURFACE OF THE SWALE WILL BE ROUGH.
5. STABILIZE ALL UPSTREAM TRIBUTARY AREAS BEFORE COMPLETING FINISH GRADING OF SWALES. THIS WILL MINIMIZE THE DEPOSITION OF SEDIMENT IN THE FINISHED SWALE.
6. FINISH GRADE THE SWALE USING METHODS THAT AVOID RECOMPACTION OF LOOSENED SOIL. ACCEPTABLE METHODS INCLUDE HAND RAKING, SMOOTHING WITH A BACKHOE BUCKET FROM OUTSIDE THE LIMITS OF THE SWALE, AND/OR PULLING A DRAG BEHIND LOW GROUND PRESSURE EQUIPMENT LIKE AN ATV.
7. SOW SEED AND PLACE EROSION CONTROL BLANKET AFTER FINISH GRADING AND BEFORE THE FIRST RAINFALL EVENT (WITHIN 24 HOURS IS PREFERRED). DEPOSITION OF SEDIMENT ON TOP OF THE EROSION CONTROL BLANKET MAY KILL SEED AND BECOME A SOURCE OF SEDIMENT WASHING OFF SITE. SEDIMENT ON TOP OF THE EROSION CONTROL BLANKET SHALL BE REMOVED TO A DEPTH LESS THAN ONE INCH.
8. IF STEP 6 IS NOT COMPLETED BEFORE THE FIRST RAINFALL EVENT, REPAIR RESULTING EROSION AND REMOVE ALL ACCUMULATED SEDIMENT FROM THE SWALE BEFORE SOWING SEED AND PLACING EROSION CONTROL BLANKET. EROSION REPAIR AND SEDIMENT REMOVAL SHALL BE COMPLETED WITHOUT COMPACTING THE SOIL (SEE STEP 5).

TYPICAL CONSTRUCTION SEQUENCING-DRY SWALES:

1. EXCAVATE CHANNEL TO SUBGRADE ELEVATIONS PER THE PLAN.
2. CONSTRUCT CHECK DAMS AT THE LOCATIONS AND TO THE ELEVATIONS SHOWN ON THE PLANS.
3. CONSTRUCTION SEQUENCE VARIES DEPENDING ON IN-SITU SOIL TYPE. SEE TABLE 1 FOR PROPER SEQUENCE FOR LOOSENING SUBSOILS AND ADDING SOIL AMENDMENTS.
4. LOOSEN SOIL IN A MANNER THAT AVOIDS RECOMPACTION OF THE SOIL BY CONSTRUCTION TRAFFIC. DO NOT LOOSEN SOILS UNDER CHECK DAMS.
5. INSTALL UNDERDRAIN (IF SPECIFIED) AFTER LOOSENING SUBGRADE SOILS. CAREFULLY COVER UNDERDRAIN WITH SAND TO AVOID COMPACTION AND DAMAGE TO THE PIPE. MARK THE LOCATION OF UNDERDRAIN AS NECESSARY TO AVOID DAMAGING THE PIPE DURING SUBSEQUENT CONSTRUCTION ACTIVITIES.
6. STABILIZE ALL UPSTREAM TRIBUTARY AREAS BEFORE COMPLETING FINISH GRADING OF SWALES. THIS WILL MINIMIZE THE DEPOSITION OF SEDIMENT IN THE FINISHED SWALE.
7. FINISH GRADE THE SWALE USING METHODS THAT AVOID RECOMPACTION OF LOOSENED SOIL. ACCEPTABLE METHODS INCLUDE HAND RAKING, SMOOTHING WITH A BACKHOE BUCKET FROM OUTSIDE THE LIMITS OF THE SWALE, AND/OR PULLING A DRAG BEHIND LOW GROUND PRESSURE EQUIPMENT LIKE AN ATV.
8. SOW SEED AND PLACE EROSION CONTROL BLANKET AFTER FINISH GRADING AND BEFORE THE FIRST RAINFALL EVENT (WITHIN 24 HOURS IS PREFERRED). DEPOSITION OF SEDIMENT ON TOP OF THE EROSION CONTROL BLANKET MAY KILL SEED AND BECOME A SOURCE OF SEDIMENT WASHING OFF SITE. SEDIMENT ON TOP OF THE EROSION CONTROL BLANKET SHALL BE REMOVED TO A DEPTH LESS THAN ONE INCH.
9. IF STEP 6 IS NOT COMPLETED BEFORE THE FIRST RAINFALL EVENT, REPAIR RESULTING EROSION AND REMOVE ALL ACCUMULATED SEDIMENT FROM THE SWALE BEFORE SOWING SEED AND PLACING EROSION CONTROL BLANKET. EROSION REPAIR AND SEDIMENT REMOVAL SHALL BE COMPLETED WITHOUT COMPACTING THE SOIL (SEE STEP 5).

TYPICAL GRASS CHANNEL SECTIONS AND DESIGN MATRIX

2

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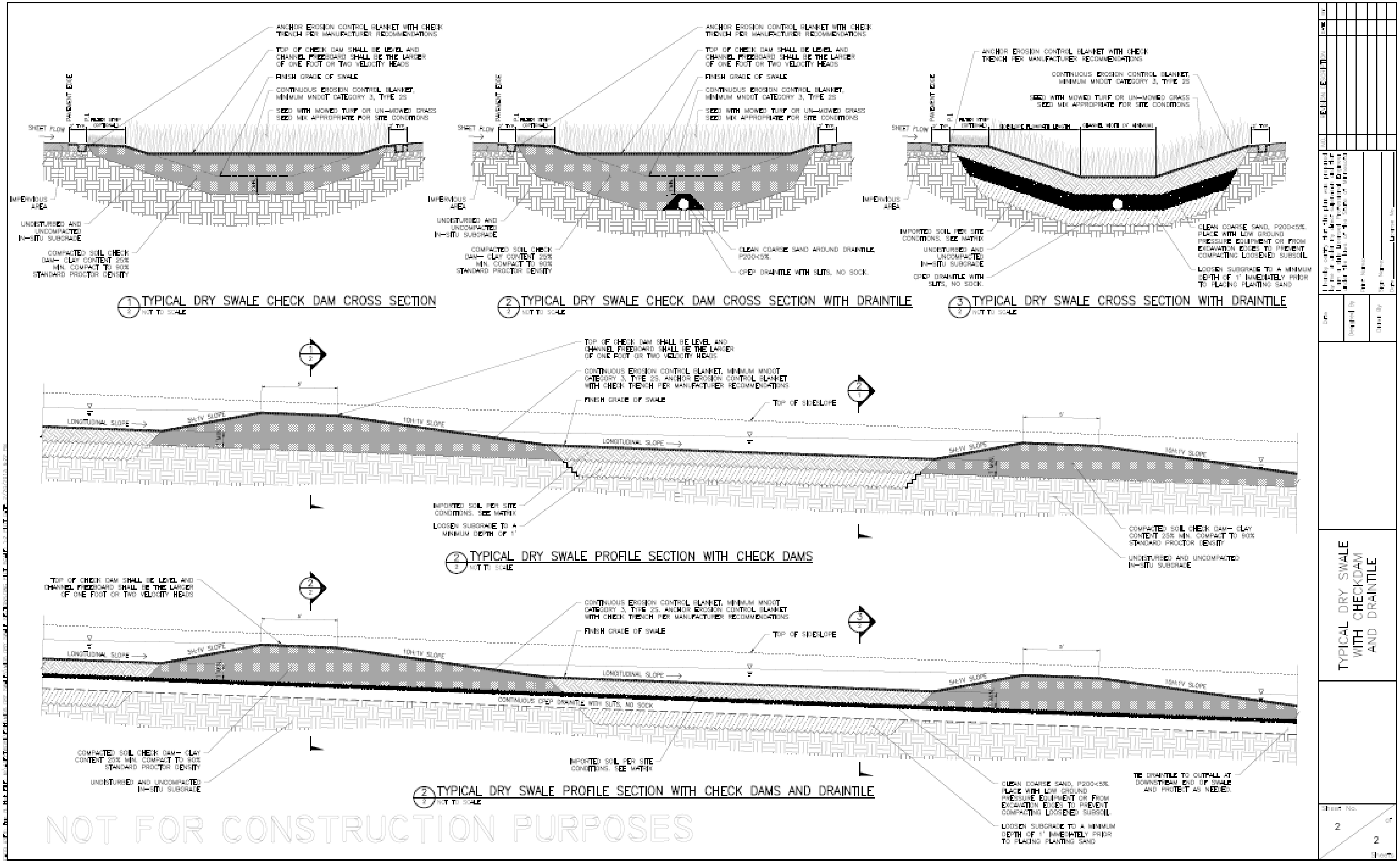

ANCHOR EROSION CONTROL BLANKET WITH CHECK TRENCH PER MANUFACTURER RECOMMENDATIONS
TOP OF CHECK DAM SHALL BE LEVEL AND CHANNEL FREEBOARD SHALL BE THE LARGER OF ONE FOOT OR TWO VELOCITY HEADS
FINISH GRADE OF SWALE
CONTINUOUS EROSION CONTROL BLANKET, MINIMUM MNDOT CATEGORY 3, TYPE 25
SEED WITH MOWED TURF OR UN-MOWED GRASS SEED MIX APPROPRIATE FOR SITE CONDITIONS
PAVEMENT EDGE
SHEET FLOW
IMPERVIOUS AREA
UNDISTURBED AND UNCOMPACTED IN-SITU SUBGRADE
COMPACTED SOIL CHECK DAM- CLAY CONTENT 25% MIN. COMPACT TO 90% STANDARD PROCTOR DENSITY
TYPICAL DRY SWALE CHECK DAM CROSS SECTION
NOT TO SCALE
CLEAN COARSE SAND AROUND DRAINTILE. P200<5%.
CPEP DRAINTILE WITH SLITS, NO SOCK.
TYPICAL DRY SWALE CHECK DAM CROSS SECTION WITH DRAINTILE
IMPORTED SOIL PER SITE CONDITIONS. SEE MATRIX
CPEP DRAINTILE WITH SLITS, NO SOCK.
CLEAN COARSE SAND, P200<5%. PLACE WITH LOW GROUND PRESSURE EQUIPMENT OR FROM EXCAVATION EDGES TO PREVENT COMPACTING LOOSENED SUBSOIL
LOOSEN SUBGRADE TO A MINIMUM DEPTH OF 1' IMMEDIATELY PRIOR TO PLACING PLANTING SAND
TYPICAL DRY SWALE CROSS SECTION WITH DRAINTILE
CONTINUOUS EROSION CONTROL BLANKET, MINIMUM MNDOT CATEGORY 3, TYPE 25. ANCHOR EROSION CONTROL BLANKET WITH CHECK TRENCH PER MANUFACTURER RECOMMENDATIONS
TOP OF SIDESLOPE
LONGITUDINAL SLOPE
5H:1V SLOPE
10H:1V SLOPE
IMPORTED SOIL PER SITE CONDITIONS. SEE MATRIX
LOOSEN SUBGRADE TO A MINIMUM DEPTH OF 1'
COMPACTED SOIL CHECK DAM- CLAY CONTENT 25% MIN. COMPACT TO 90% STANDARD PROCTOR DENSITY
UNDISTURBED AND UNCOMPACTED IN-SITU SUBGRADE
TYPICAL DRY SWALE PROFILE SECTION WITH CHECK DAMS
NOT TO SCALE
CONTINUOUS CPEP DRAINTILE WITH SLITS, NO SOCK
TIE DRAINTILE TO OUTFALL AT DOWNSTREAM END OF SWALE AND PROTECT AS NEEDED.
TYPICAL DRY SWALE PROFILE SECTION WITH CHECK DAMS AND DRAINTILE
NOT TO SCALE
NOT FOR CONSTRUCTION PURPOSES
TYPICAL DRY SWALE WITH CHECKDAM AND DRAINTILE
Sheet No.
2
of
2
Sheets

MIDS Credits: Swales

MIDS Work Group

March 15, 2013

This slide won't be used. It's here just for internal questions/comments.

- The ET calculations are not included. We need to review all the BMPs and figure out which ones should get ET credit, etc. We'll develop a list and recommendations to review with the MPCA. For swales, this will affect the swales with a bioretention base and underdrain only.
- Currently in the calculator ET is not included with any of the BMPs.

- Next slides are old slides that we might or might not need—depending on the discussion

Volume Reduction Summary

Reference	Grass Channel	Dry Swale
Virginia Design specifications (Grass Channels)	**10% - HSG Soils C and D** **20% - HSG Soils A and B** **30% - with Compost Amended Soils**	
Virginia Design specifications (Dry Swales)		**40% - Level Design 1** **60% - Level Design 2**
Weiss, Gulliver and Erickson (2010).	**50%** (Barrett 20[illegible], semiar[illegible] regions) **30%** (Rus[illegible] 200[illegible] FL)	
CSN (2009) Virginia Calculator	**0%** (Schueler 19[illegible], VA) **40%** (Strecker et a[illegible] 2004, USA) **0%** (UNHSC 2007[illegible]) **[illegible]%** (Liptan and Murase 2000, OR)	**98%** (Horner et al. 2003, WA) **46 to 54%** (Stagge 2006, MD) **90%?**(Barrett et al, 1998, TX)
Rossman (2009) SWMM model (K_{sat} 1.0 in/hr, slope 1.3%, I inch precip)	**11%**	
International Stormwater Database (2011)	**[illegible]8%** = Average (13 studies, 84 events) **41%, 85%** (Yu et al. 1993, VA) **19%, 27%, 35%, 42%, 65%** (City of Portland 1999, OR) **60%** (Wa State 1999, WA) **27%, 41%, 46% 65%, 76%** (CA DOT, 2002)	

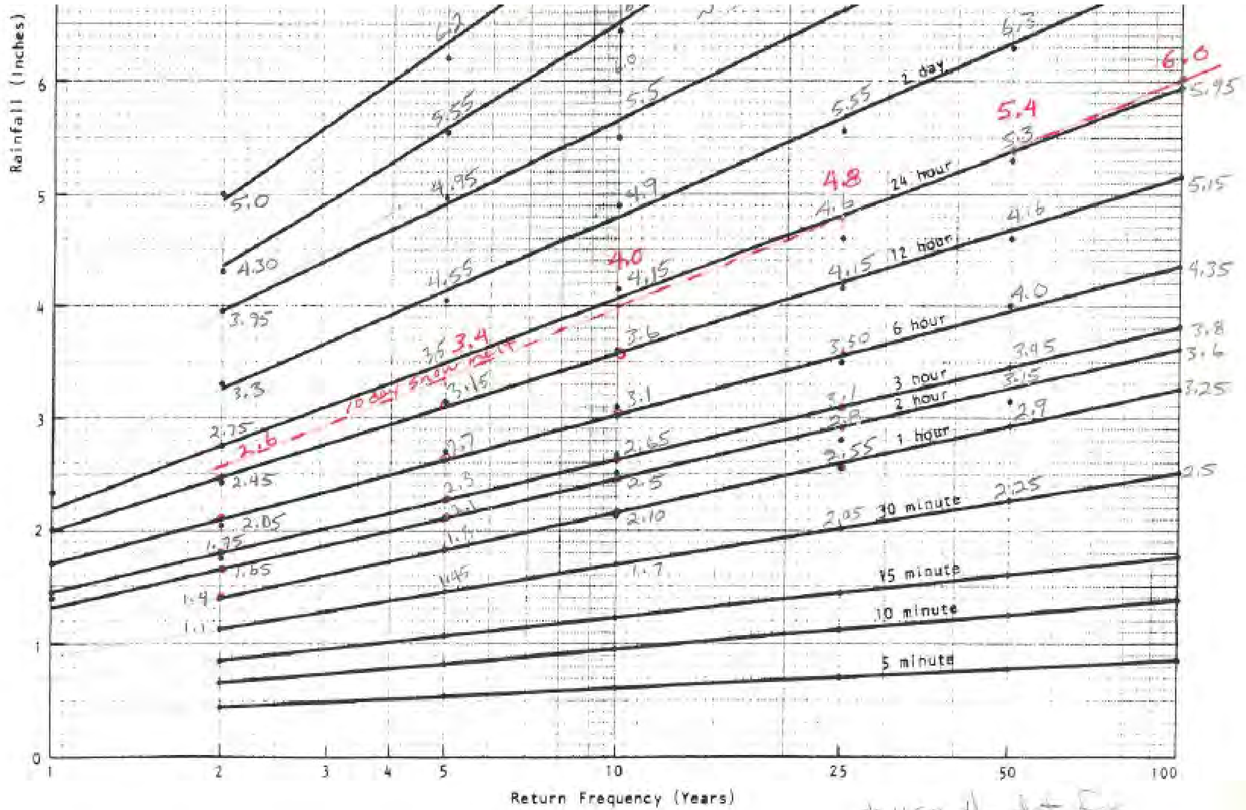
0-98%

Some Differences Between LRRB Method and MIDS Method

	U of MN/LRRB	Barr/MIDS
Infiltration Modeling Process	Green Ampt method	Constant infiltration rate
Infiltration Rate	Initially faster infiltration rate (some cells in grid >39 in/hr) and mean final rates of 1.3-0.4 in/hr, depending on measured rate at cells	Rates in MN Stormwater Manual: 1.63 - <0.2 in/hr, depending on soil
Precipitation	Various rainfall intensities, including a 1-inch 24-hour event	58 continuous years of real storms at 1-hour time increments
	Unclear if intense events were analyzed	1.1 inches in 15 minutes (~10 year event) and 1.1 inches in 30 minutes (~2 year event)
Real Life Volume Reduction Monitoring	None	None

BARR

What about storm events (e.g., 1.1-inch 15-minute, 1.1-inch 30-minute, and 1.1-inch 6 hour)?



Sources of Data: 5 Minute - 1 Hour Durations: NOAA Technical Memorandum NWS Hydro-35
2 Hour - 24 Hour Durations: National Weather Service Technical Paper No. 40
2 Day - 10 Day Durations: National Weather Service Technical Paper No. 49

Figure 2-3

PRECIPITATION - FREQUENCY CURVES FOR MINNEAPOLIS, - ST. PAUL AREA

Swale Credits

What about events?

Storm	Probability	Return Frequency "Year"
1.1-inch 15-minute	20%	5
1.1-inch 30-minute	50%	2
1.1-inch 6-hour	>99%	<1

Source:
NOAA Technical Memorandum NWS Hydro-35 for 15-minute and 30-minute durations
NWS Technical Paper 40 for 6-hour duration
Minneapolis-St. Paul Airport area