Culvert Stream Crossings

Culpeper VDOT

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Raleigh Coleman

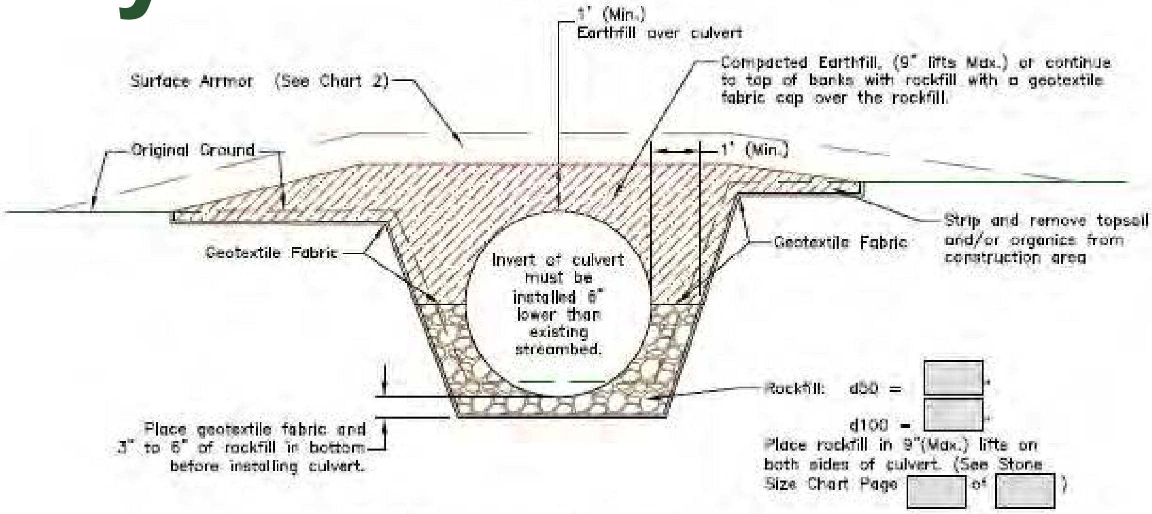
Ag BMP Engineering Specialist

Culvert Stream Crossings - Topics

- Brief Introduction to Culverts
- Ford vs. Culvert Crossings
- Site Selection
- Surveying and Field Data Collection
- Design
- Construction
- As-Built/Certification

What should a culvert crossing look like?

Key Features:



Single–Culvert Crossing Section Detail
Not to Scale

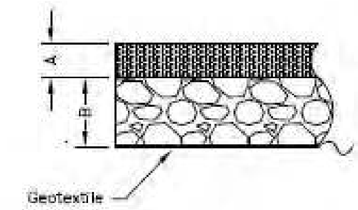
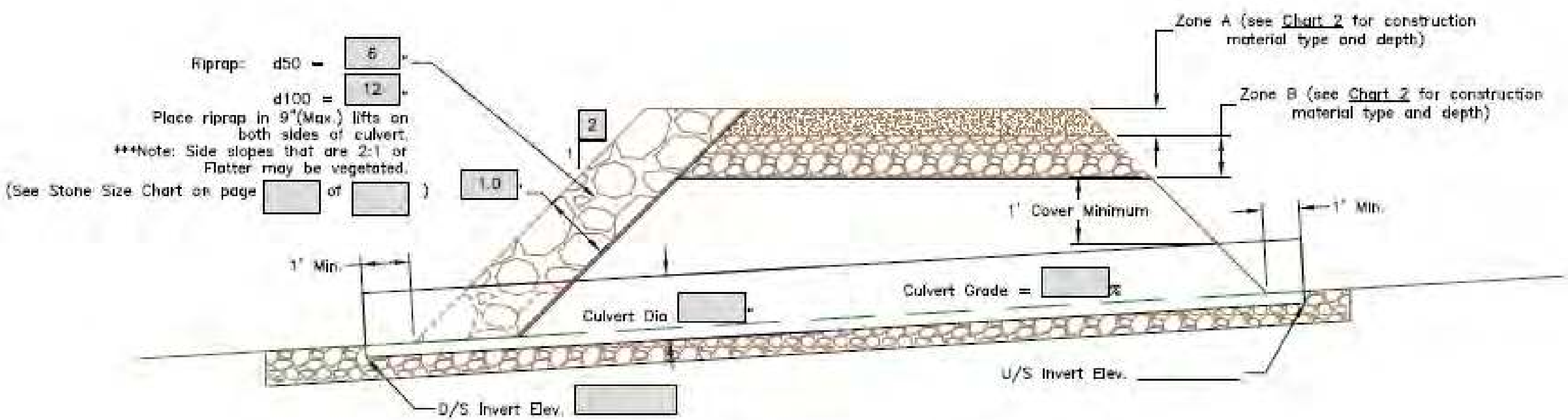
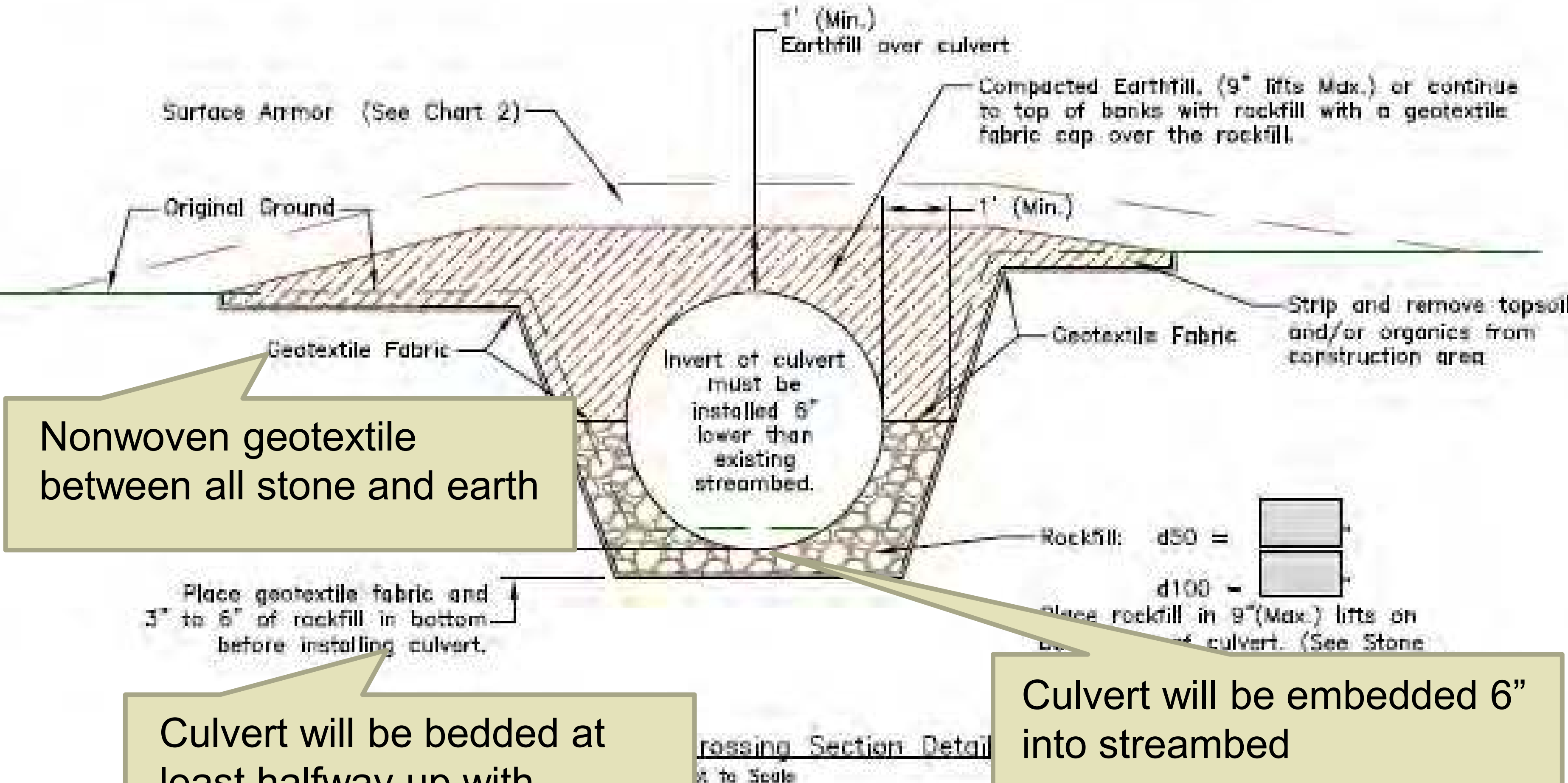


Chart 2 – Culvert Crossing Materials		
Zone	Construction Material	Depth of Material (inches)
A	VDOT # 57	3"
B	VDOT # 1	6"

(See Stone Size Chart on page of)



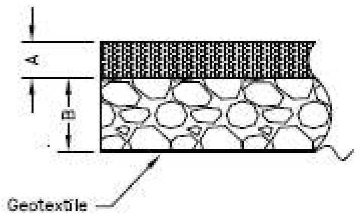


Nonwoven geotextile between all stone and earth

Culvert will be bedded at least halfway up with granular rockfill

Culvert will be embedded 6" into streambed

The stone layers are identical to those for ford crossings because the culvert is only sized for the 2-yr or bankfull flow and will likely be overtopped fairly frequently.



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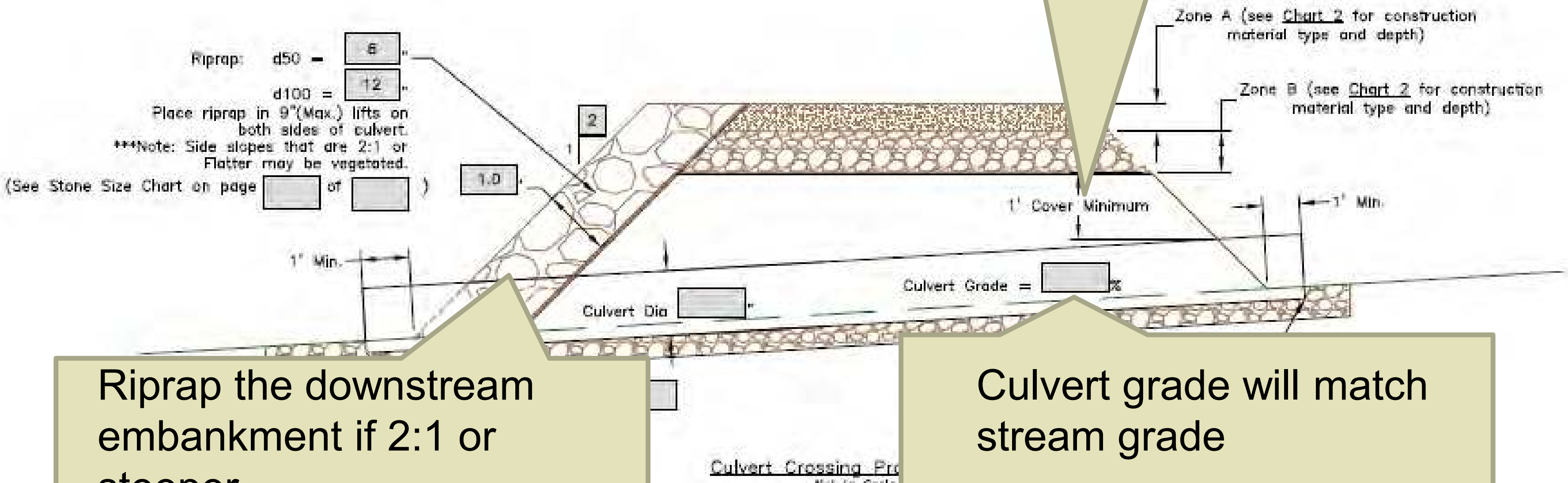
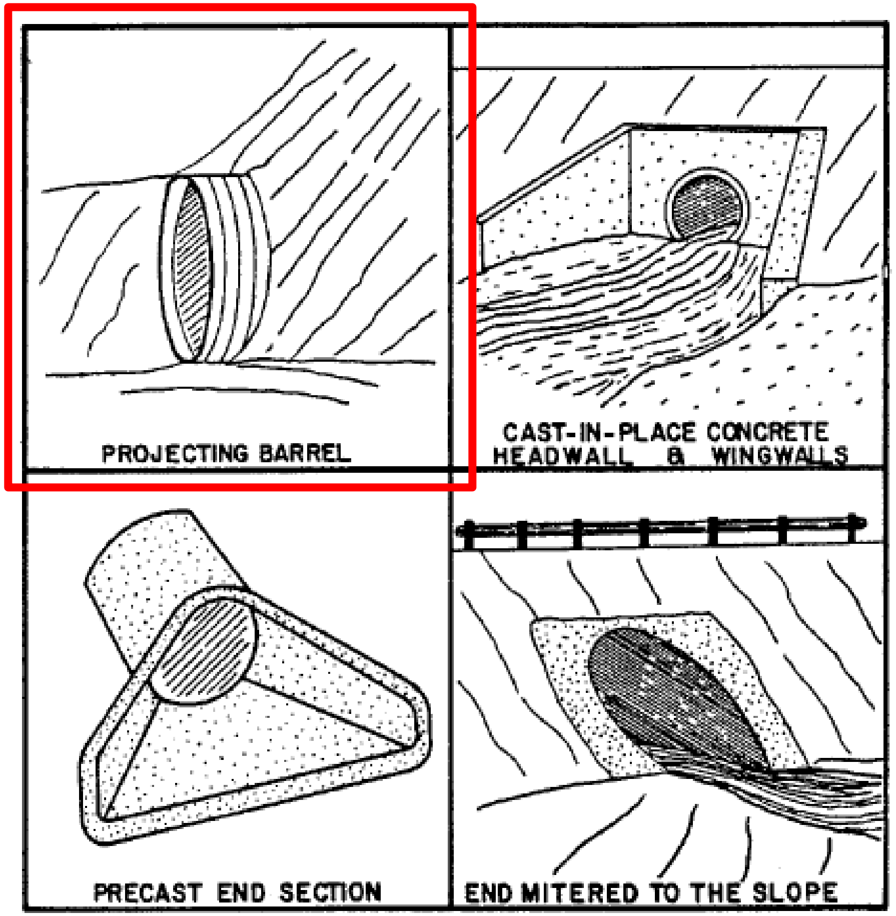


Minimum of 1' of earthfill over culvert

Riprap the downstream embankment if 2:1 or steeper

Culvert grade will match stream grade



Common Inlet Types

Source: **DESIGN GUIDE MD #5CULVERT STREAM CROSSINGS**

DCR

Table 3-3 Entrance Loss Coefficients	
Type of Structure and Design of Entrance	**Coefficient K_e**
<u>Pipe, Concrete</u>	
Projecting from fill, socket end (groove-end)	0.2
Projecting from fill, sq. cut end	0.5
Headwall or headwall and wingwalls	
Socket end of pipe (groove-end)	0.2
Square-end	0.5
Rounded (radius = 1/12D)	0.2
Mitered to conform to fill slope	0.7
*End-section conforming to fill slope	0.5
<u>Pipe, or Pipe-Arch, Corrugated Metal</u>	
Projecting from fill (no headwall)	0.9
Headwall or headwall and wingwalls	
Square-edge	0.5
Mitered to conform to fill slope	0.7
*End-section conforming to fill slope	0.5

Note: *"End-section conforming to fill slope," made of either metal or concrete, are the sections commonly available from manufacturers. From limited hydraulic tests they are equivalent in operation to a headwall in both inlet and outlet control.

EFH 3-35

Culverts vs. Fords

- Fords should be the default for planning
  - Least-cost technically feasible alternative to address the resource concern
- Fords: Less expensive, less likely to fail
  - Also serve as a limited access watering point!
- Culverts: More expensive, more likely to fail
- Both require maintenance
  - Fords: Periodic re-surfacing, removal of sediment deposits
    - Repairs typically accomplished with any size tractor with loader
  - Culverts: Removing debris from inlet, repair of periodic overtopping and possible scouring at inlet/outlet
    - Repairs may require heavy construction equipment

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Debris at inlet

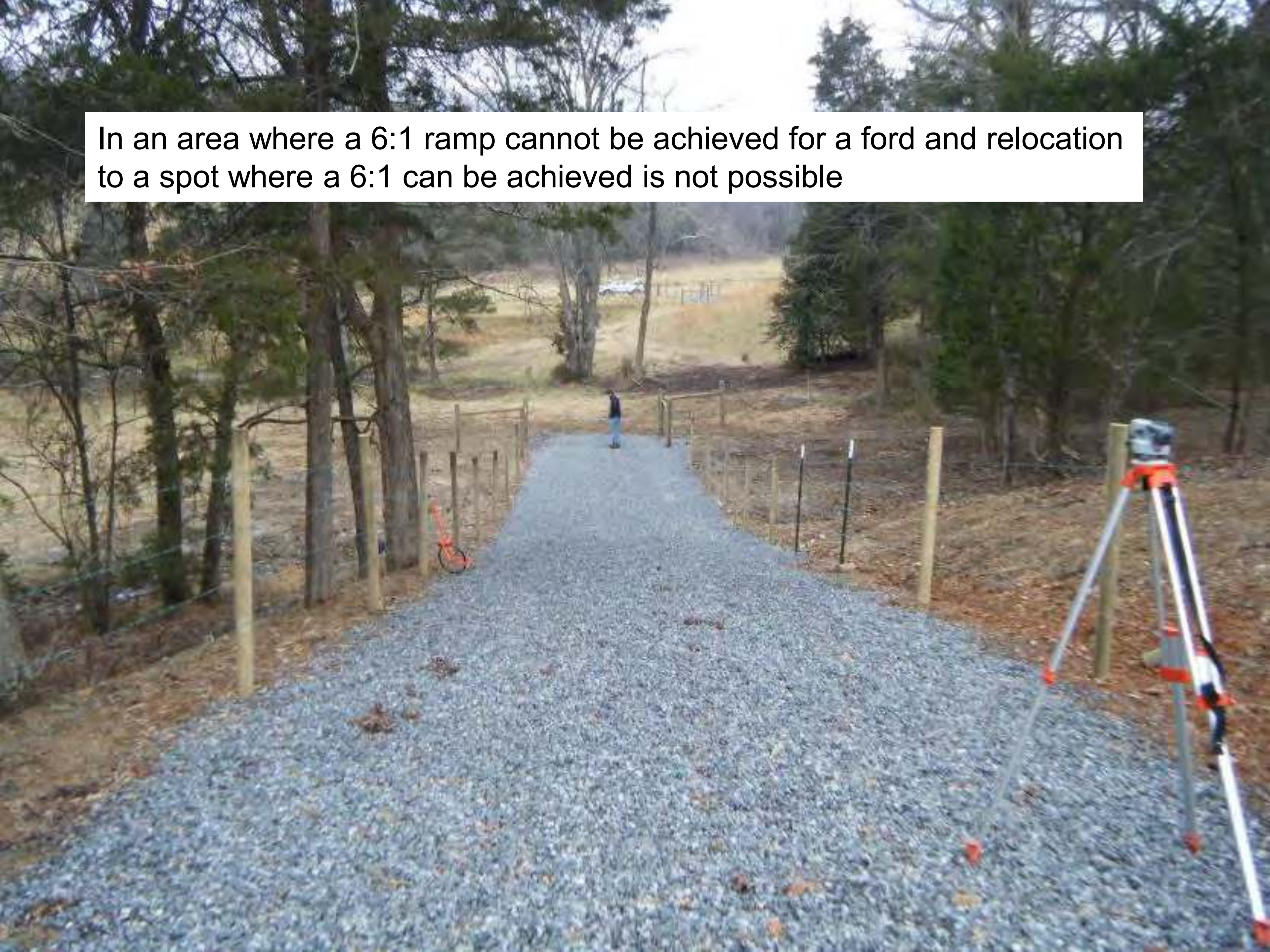
Vegetation growth in spillway


Culverts = Constant Maintenance

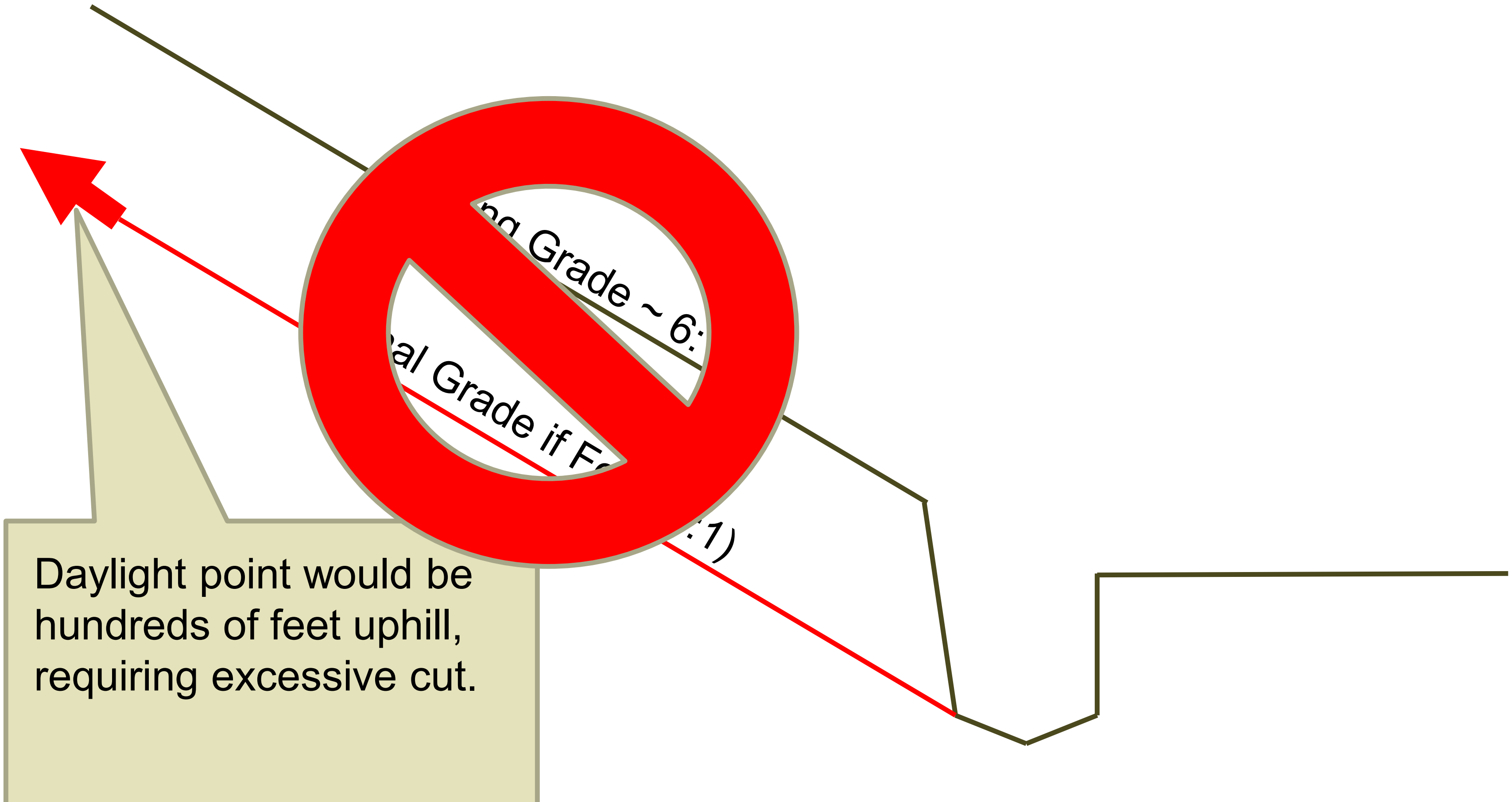
When to use culverts:

- VA-578: “If the stream crossing is to be used frequently, or ***daily***, as in a dairy operation, a culvert crossing…should be used…”
- In a heavily incised channel
- In an area where a 6:1 ramp cannot be achieved for a ford and relocation to a spot where a 6:1 can be achieved is not possible
- When the resource concern requires it (e.g. goats, sheep – animals that will not cross water)

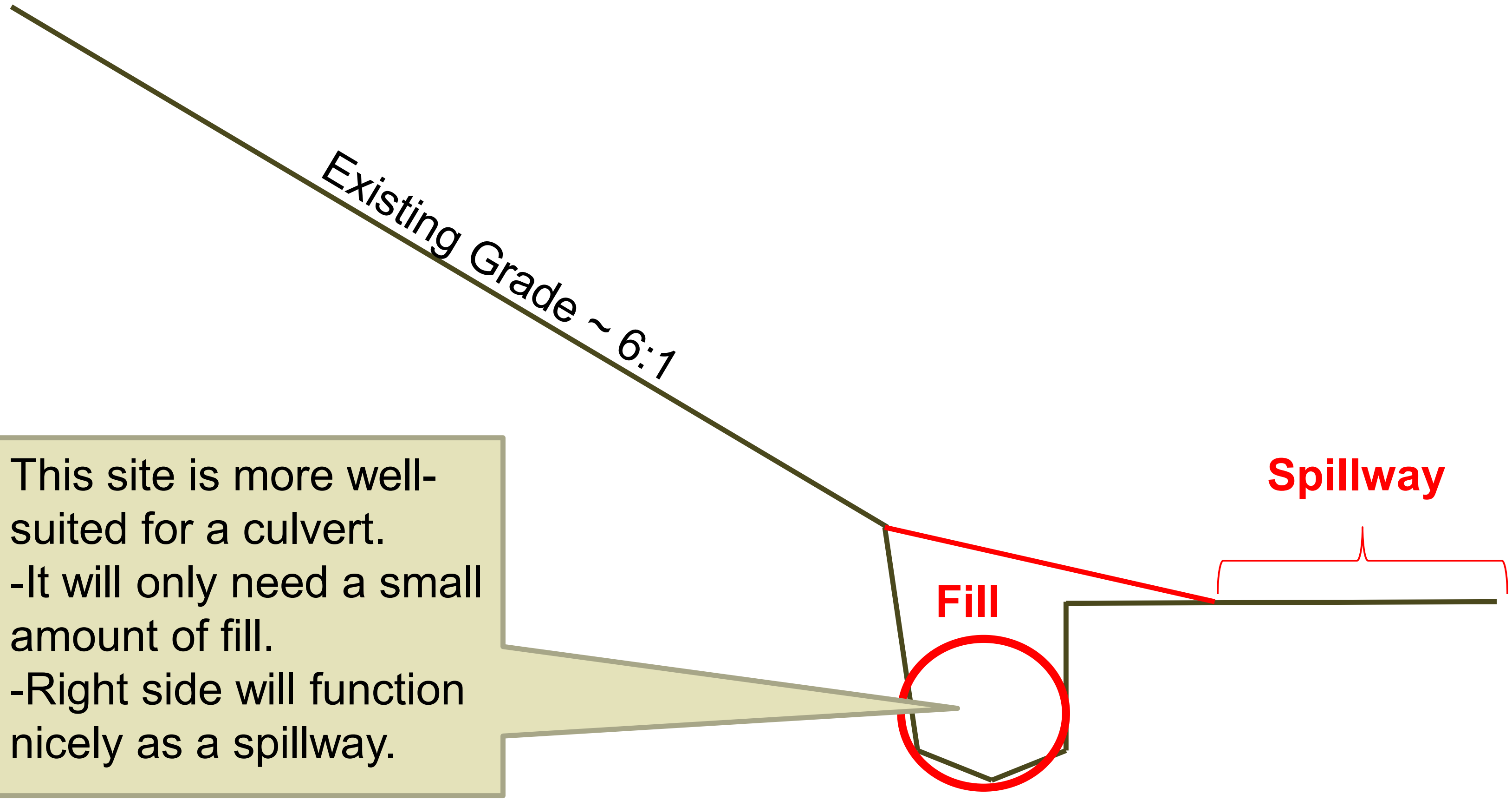
In an area where a 6:1 ramp cannot be achieved for a ford and relocation to a spot where a 6:1 can be achieved is not possible



Sketch of Previous Example:



Sketch of Previous Example:



This site is more well-suited for a culvert.
-It will only need a small amount of fill.
-Right side will function nicely as a spillway.

Another example where a steep grade on one side of an incised channel prevented a ford.

When NOT to use culverts

- When a ford is feasible
  - Least-cost technically feasible alternative
- When the ONLY reason to install it is because the landowner is pushing for it
- When the culvert size needed to carry the design flow cannot fit in the channel
- VA-578:
  - Where large flows of sediment or large woody material are expected
  - Where channel gradient exceeds 6%

Design Differences: Culverts vs. Fords

	Culverts	Fords
EJAA Thresholds Determined By:	Diameter of Culvert	Velocity of Stream
Design Capacity	Flow rate (cubic feet per second)	Flow velocity (feet per second)
Design Criteria from VA-578 Standard	2-yr, 24-hr storm peak discharge, or bankfull flow, whichever is *less;* out-of-bank flows must safely bypass without damaging or eroding	Bankfull Velocity

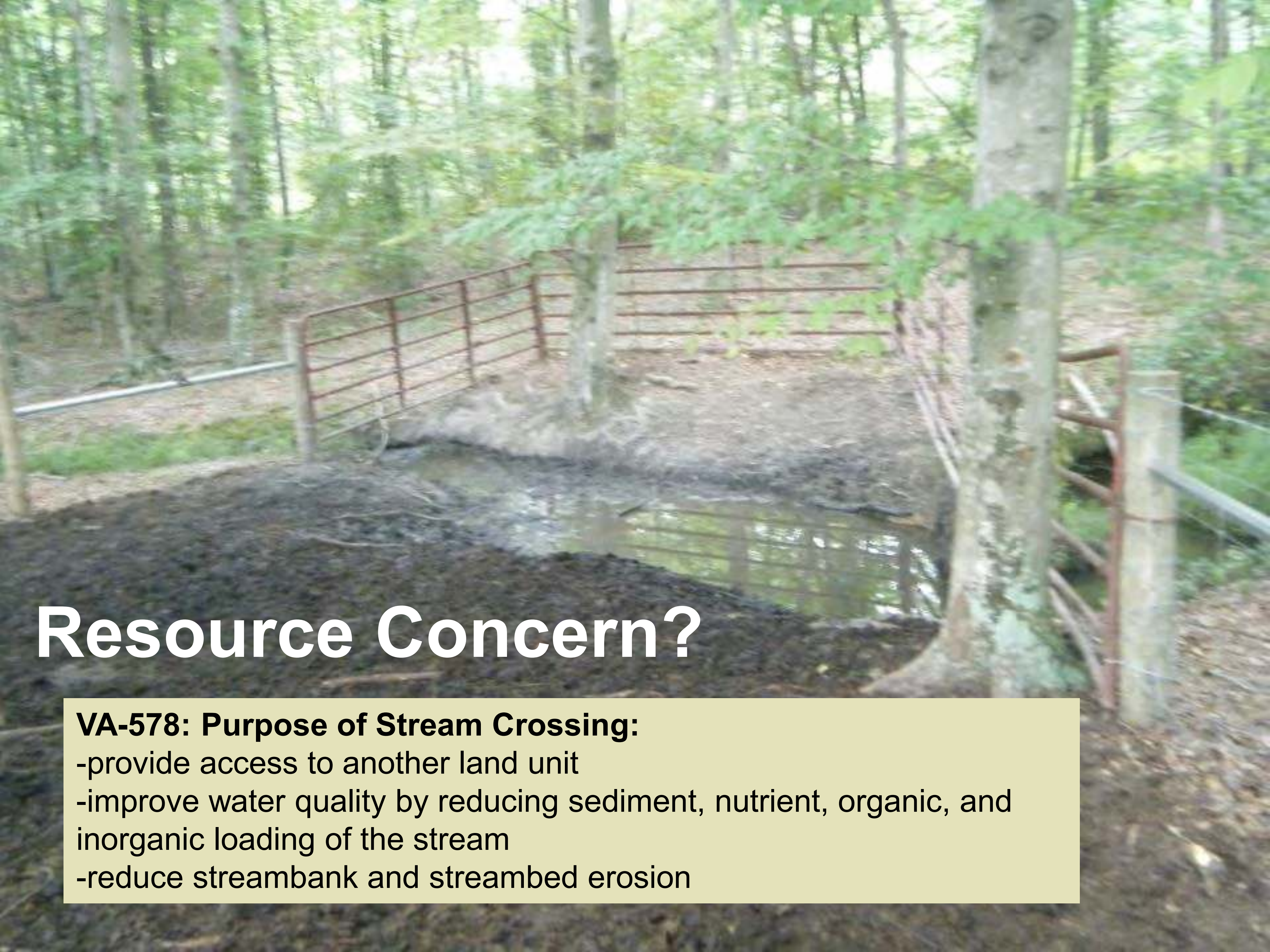
Site Selection

- Conservation Planning Considerations
- Existing vs. New
- Topography
- Wetlands/High Water Table
- Stream Stability
- Stream Bottom
- Watershed/Drainage Area

Conservation Planning Considerations

Before planning/authorizing a crossing:

- Is there an existing resource concern?
- Will a resource concern be created by a fencing project?
- Are there any alternative solutions?
  - VA-578: “Avoid or minimize the use of or number of stream crossings, when possible, through evaluation of alternative trail or travel-way locations.”
- Is a crossing justifiable?
  - What’s on the other side of the stream? Must be Existing Pasture for VACS Program projects



Resource Concern?

VA-578: Purpose of Stream Crossing:

-provide access to another land unit

-improve water quality by reducing sediment, nutrient, organic, and inorganic loading of the stream

-reduce streambank and streambed erosion

Conservation Planning Considerations

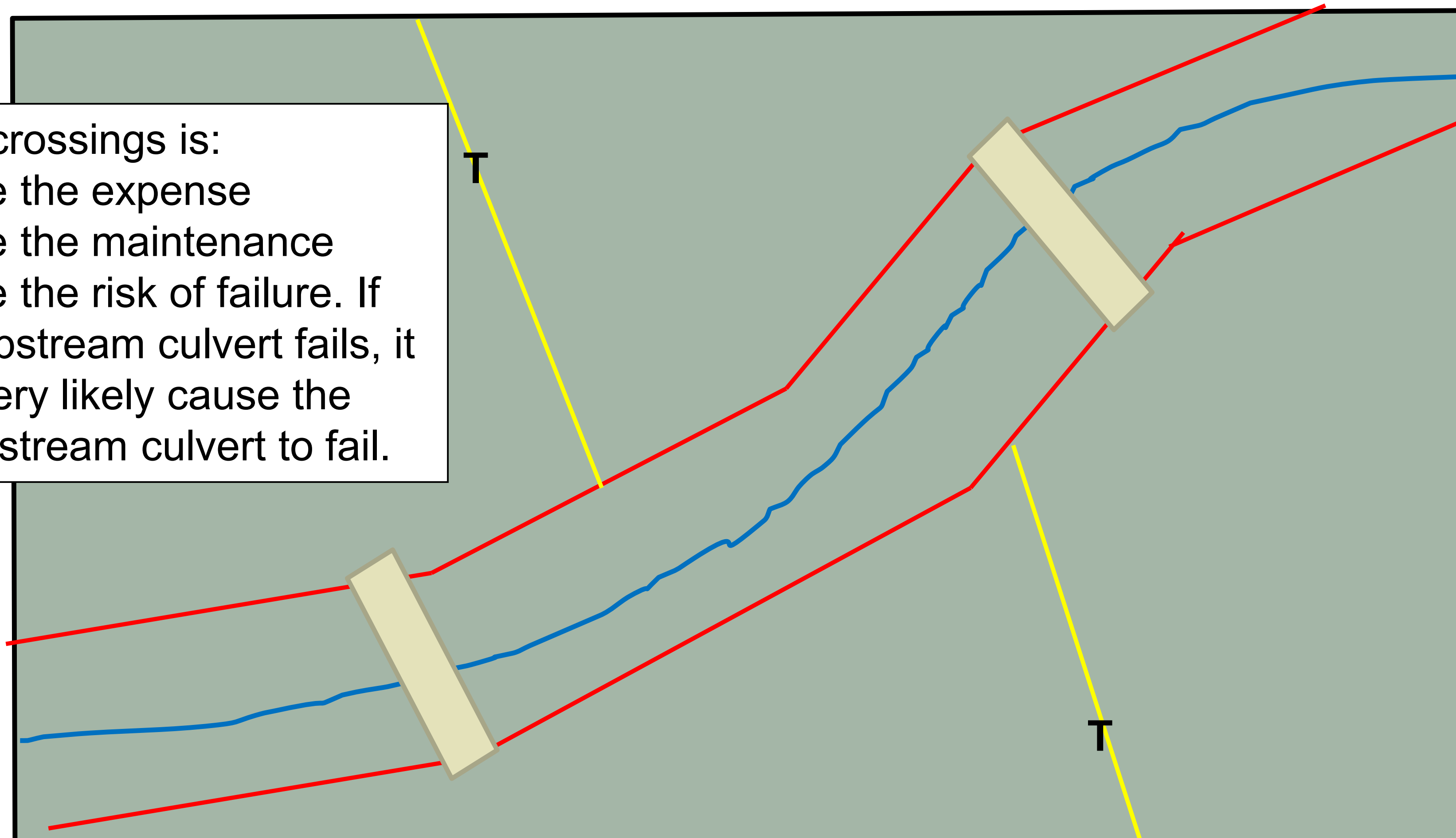
- Avoid areas that will require excessively long walkways (adds to initial cost and maintenance)

Sometimes, your best option may still be a long road…

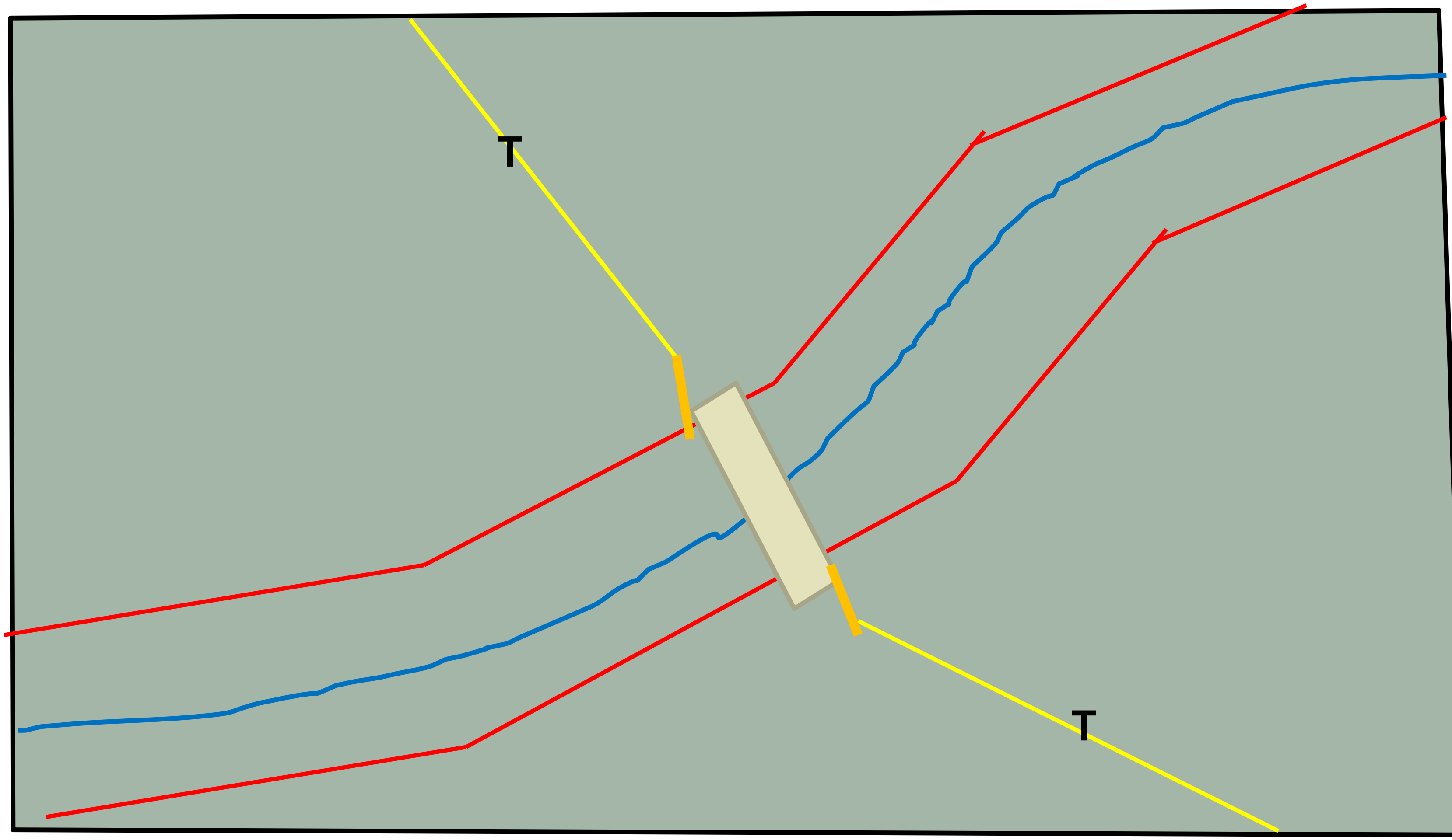
- Planning new infrastructure around crossing locations can maximize use while minimizing cost

Consider this farm:

Two crossings is:
-twice the expense
-twice the maintenance
-twice the risk of failure. If the upstream culvert fails, it will very likely cause the downstream culvert to fail.



Consider this farm:



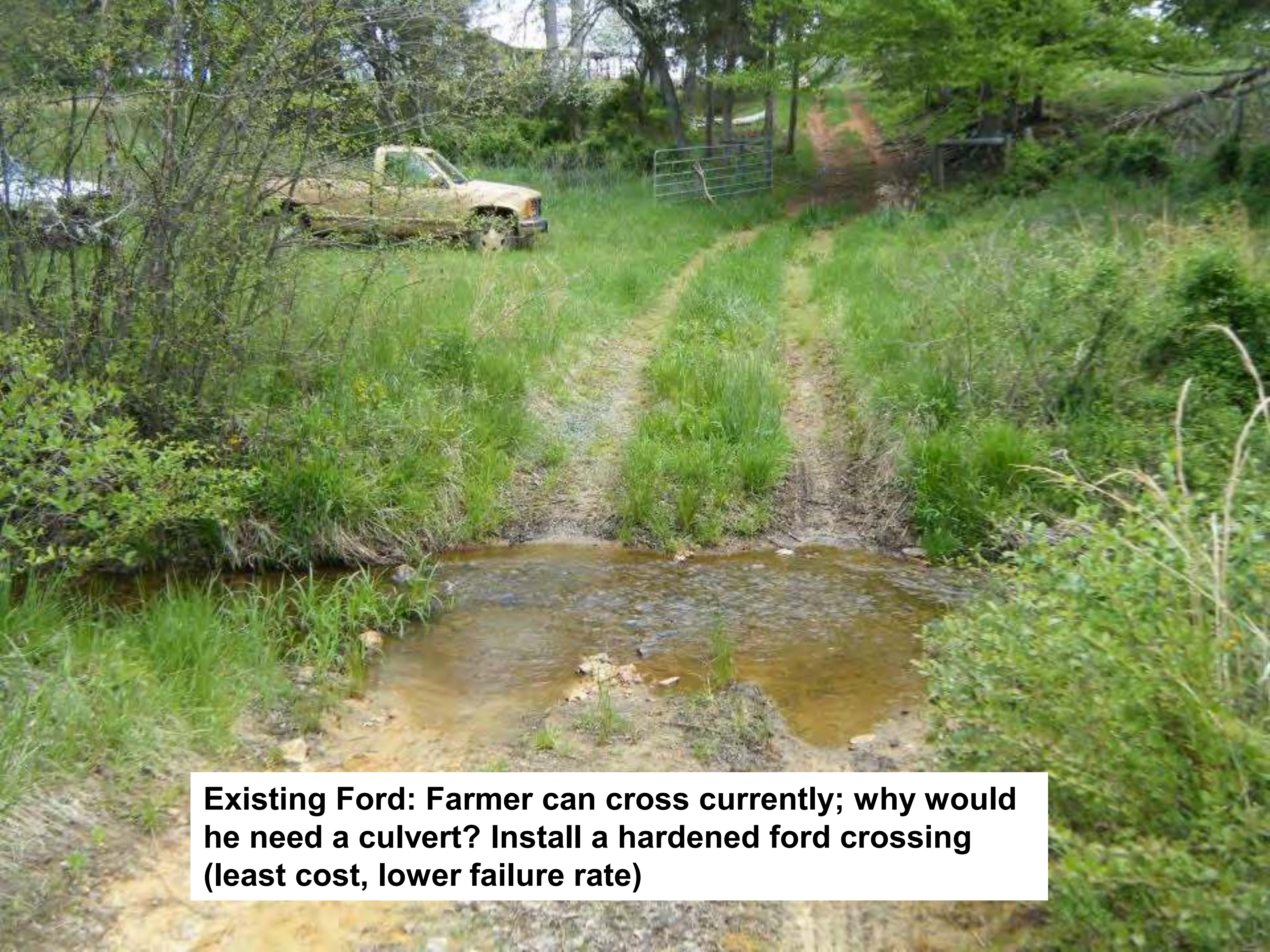
Beware of potential management issues…

Sometimes the best engineered solution is not an engineered one.

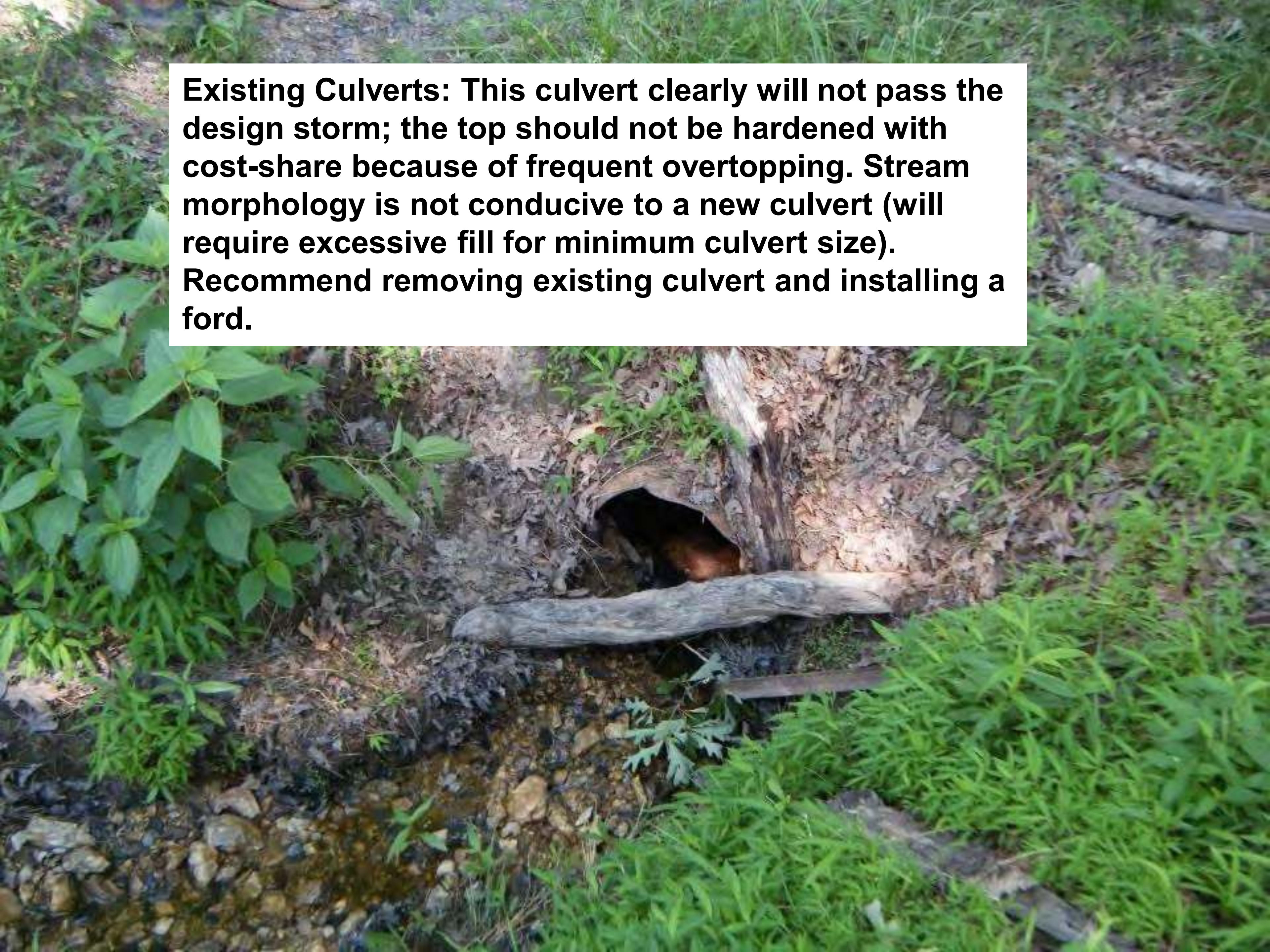
Not every site is suitable for a stream crossing. Look for management alternatives.

Existing vs. "New" Crossing Sites

- If there is an existing ford that can be hardened, why would there be a need for a culvert?
- If there is an existing culvert crossing that has failed, why did it fail?
  - Opportunity to convince landowner of problems with culverts!
- If there is an existing culvert that is in good condition, take measurements to see if it can pass design storm – may only need to harden the surface.



Existing Ford: Farmer can cross currently; why would he need a culvert? Install a hardened ford crossing (least cost, lower failure rate)



Existing Culverts: This culvert clearly will not pass the design storm; the top should not be hardened with cost-share because of frequent overtopping. Stream morphology is not conducive to a new culvert (will require excessive fill for minimum culvert size). Recommend removing existing culvert and installing a ford.

Topography

- VA-578: “Do not use culverts…where the channel gradient exceeds 6 percent”
- Ideally one side of the crossing location will be relatively flat to function as a spillway
- Avoid areas where the stream crossing will have a steep slope or begin/end at base of a steep slope
  - 6:1 H:V max. slope and 8:1 recommended max. slope still apply to culvert crossings
  - Also may not be able to properly construct an emergency spillway without excessive fill

Beware of upland drainage. Here is an instance where a swale discharges across the armored portion of the crossing and it has started to wash away. Some of this can be corrected by ditches/diversions, but all else being equal, avoid areas such as this.

Wetlands/High Water Tables

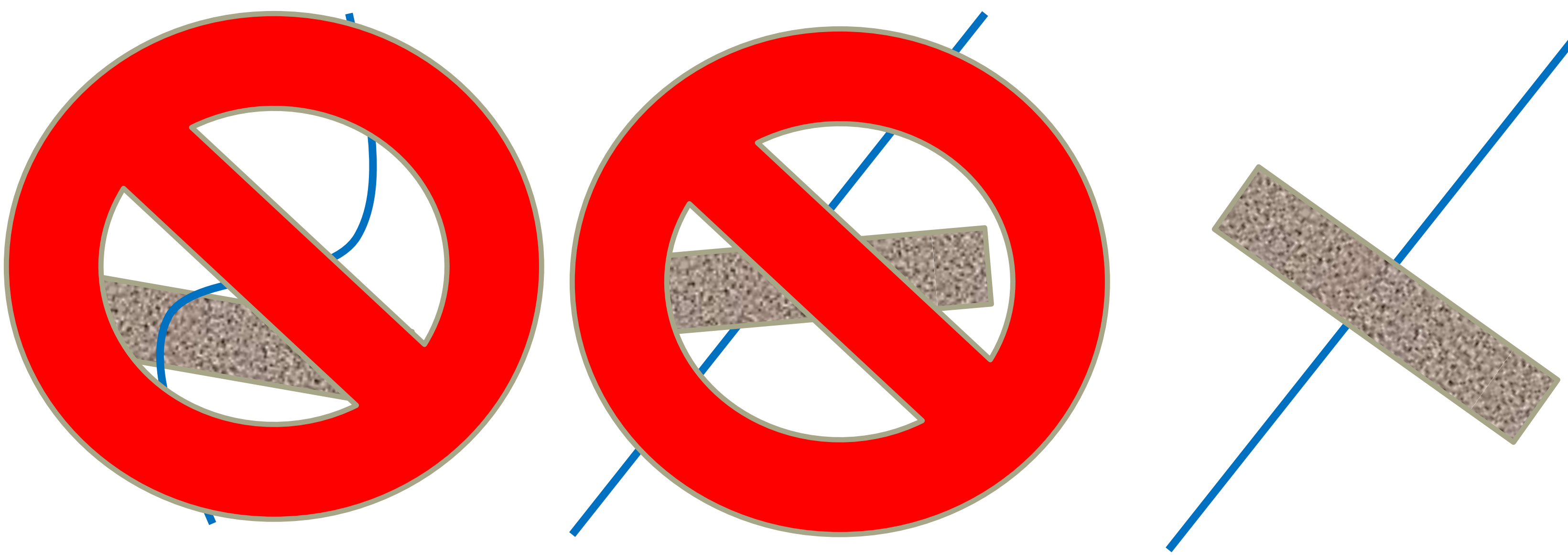
AVOID because of:

- Permitting/Environmental Compliance Issues
- Construction Issues
  - Equipment issues
  - Lack of suitable subgrade
  - Hydrostatic pressure under geotextile → “pumping”
  - Excessive amounts of fill required
- VA-578: “Avoid wetland areas.”

***Check for high water table during soil investigation

Stream Stability

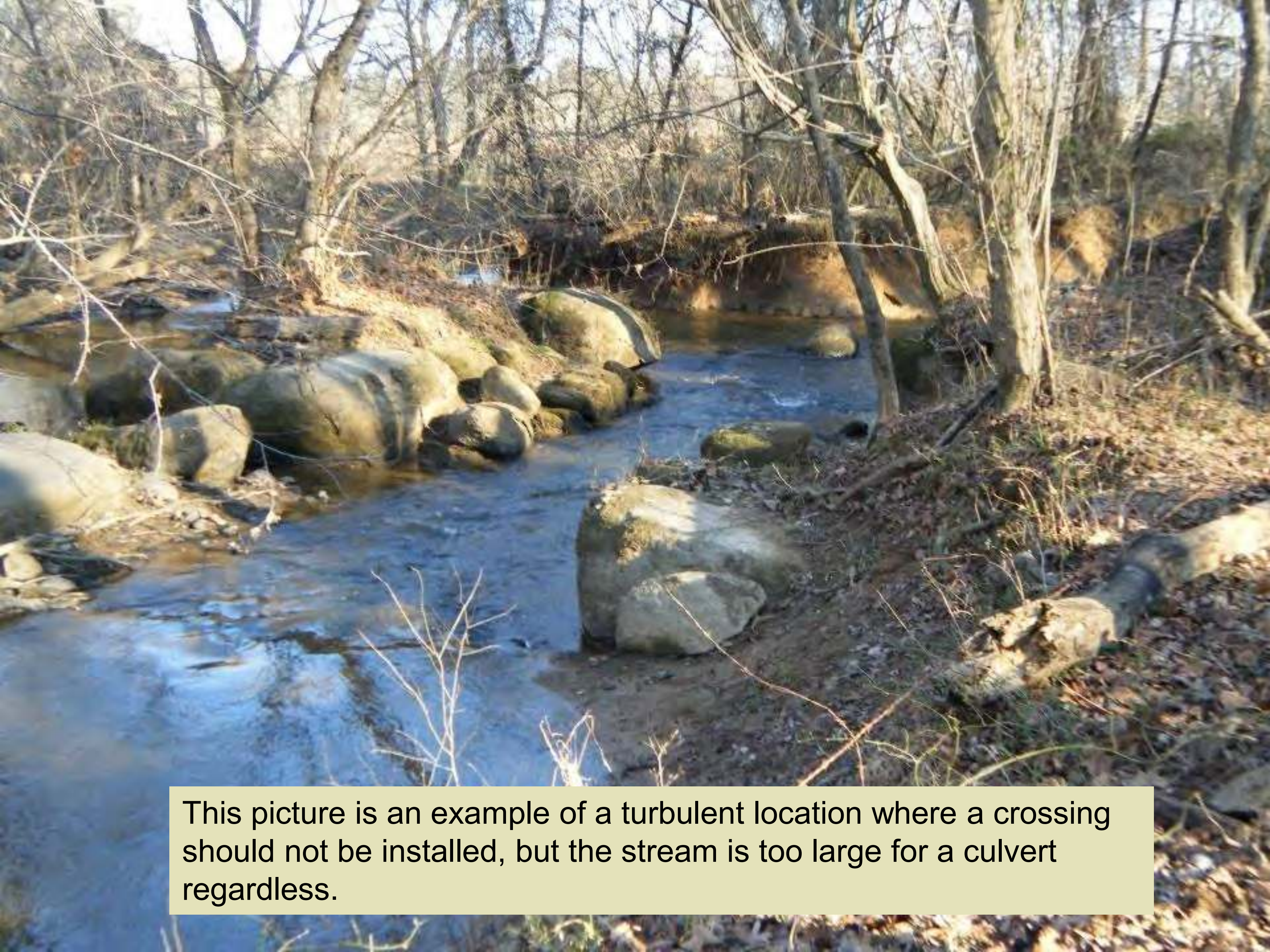
- Select a spot where the crossing will be perpendicular to the stream in a relatively straight stretch of the stream



Keep in mind that most culvert crossings will require a culvert that is 30-40ft. long!

Stream Stability

- Avoid turbulent areas
  - Immediately downstream of existing culverts (esp. roadway culverts)
  - Near large boulders
  - Rapid grade changes
- VA-578: “Do not place crossings where channel grade or alignment changes abruptly, excessive seepage or instability it evident, overfalls exist (evidence of incision and bed instability), where large tributaries enter the stream…”



This picture is an example of a turbulent location where a crossing should not be installed, but the stream is too large for a culvert regardless.

Stream Bottom

VA-578 requires: “At least one culvert pipe shall be placed with its entire length set six inches below the existing stream bottom”

Try to find a location where the culvert can be bedded easily.

Note: This location would be more conducive to a ford.

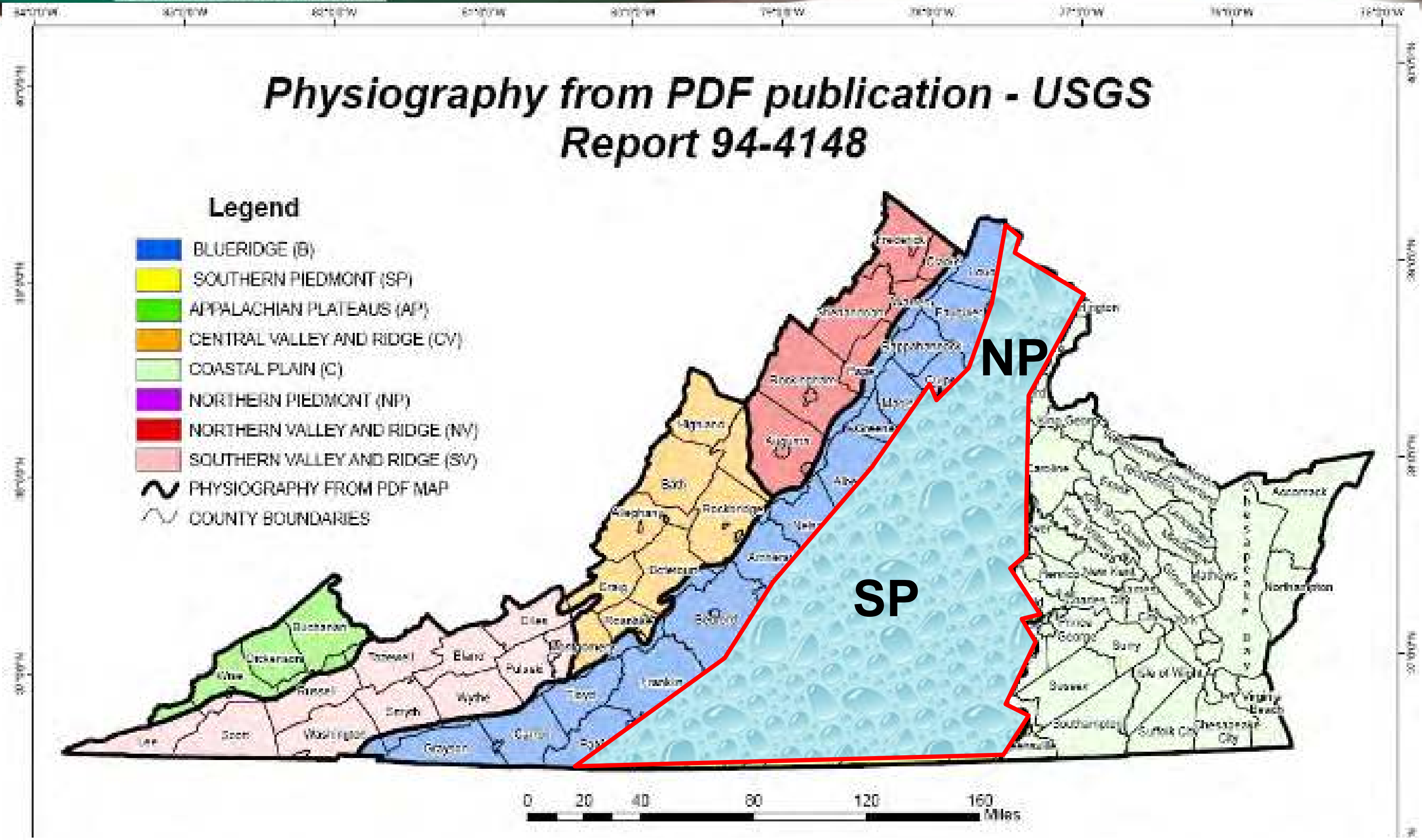
Watershed/Drainage Area

- Less DA *generally* means lower peak flow
- Must be less than 5 square miles to fall under 578 blanket permit (USACE, VMRC, DEQ, etc.)
- VA-578: “Do not place crossings…where large tributaries enter the stream…”
- VA-578: “Do not use culverts where large flows of sediment or large woody material are expected”
  - Wooded areas upstream have a lower CN and will contribute less runoff than other land uses, but the potential for debris to clog the culvert is much higher

Watershed/Drainage Area Cont'd

- Is the drainage area <50acres and agriculture/forestry is the dominant land use? VA-578 allows you to default to the following minimum pipe sizes:
  - Northern & Southern Piedmont: 30" *
  - All other regions: 24"

  *The calculated pipe discharge can be also used to size the culvert for drainage areas <50 acres, but the selected pipe shall be no smaller than 24"



Minimum Pipe Size (Default Pipe Size for Ag/Forestry Drainage Areas < 50ac.)

Northern Piedmont (NP) and Southern Piedmont (SP): 30”
All Other Regions: 24”

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Quiz

Question	Answer
A site in the Northern Valley & Ridge region has a 40-acre drainage area, including 20 acres of pasture and a 20-acre subdivision. Minimum pipe size?	24” minimum, but hydrologic & hydraulic calculations must be conducted since the land use is not predominantly ag/forestry.
A site in the Northern Piedmont has a 40-acre drainage area with a drainage area that is all pasture. Minimum pipe size?	30” minimum, unless calculations are conducted to show that a 24” will work.
For the previous example, hydrologic & hydraulic calculations are conducted and it is determined that a 18” culvert would pass the design flow. What size can be installed?	Minimum of 24”

Site Selection: Final Tips

- Walk as much of the stream as possible. You might find a decent site for a stream crossing, but there may be an even better site that you could miss if you don’t inventory the whole stream.
- All else being equal, select a site that is close to the potential borrow site.

Survey/Field Data Collection

Survey/Field Data Collection

- Soils Investigation
- Survey
- Manning’s “n” Recon
- Photographs
- Watershed Info

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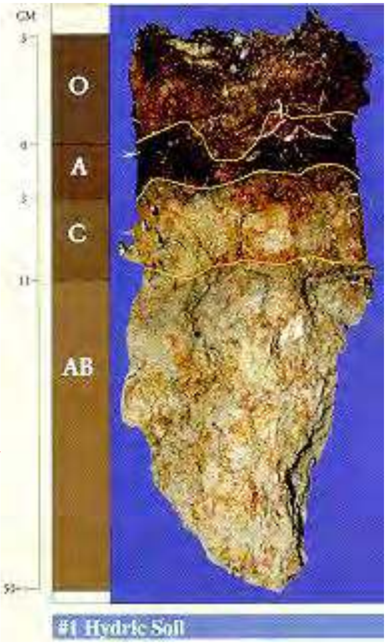
Soils Investigation

- Perform an on-site soils investigation at the crossing site
- Not *as* important for culverts as for ford crossings (less excavation for culverts), but still important!
- Do borings where cut may be needed for a spillway or to achieve final grade

Soils Investigation: What to Look For

- Layers that would affect construction:
  - Bedrock
  - Sand Lenses
  - Water Table
  - Mottling (evidence of hydric soils)
    - Typically orange/red/brown streaks/spots in gray soils



https://www.na.fs.fed.us/spfo/pubs/n_resource/wetlands/wetlands5_soils.htm

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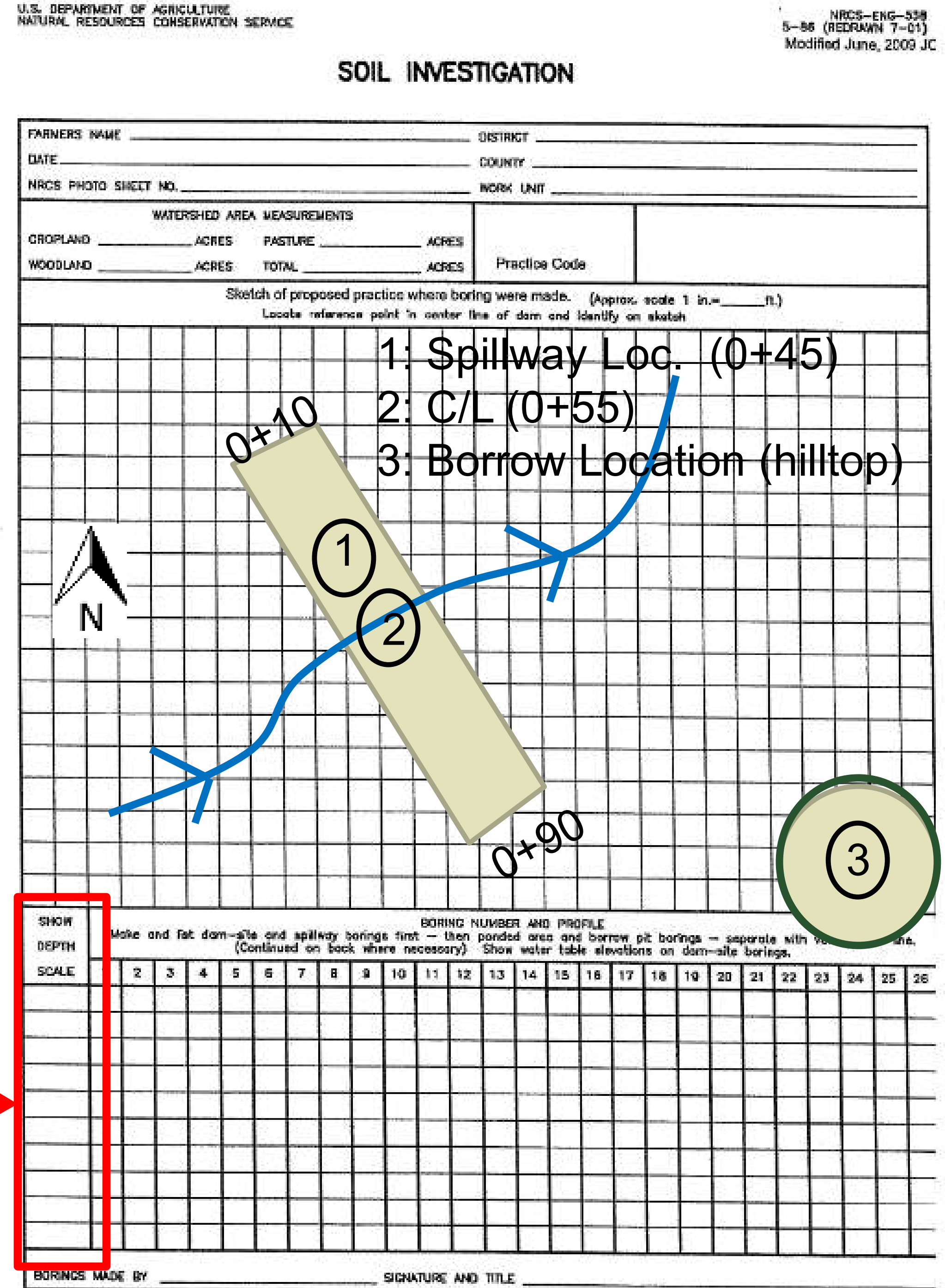
Pick locations where cut will occur:
For Fords: typically top of bank and beyond
For Culverts: typically streambed (6" embedment + 3-6" of bedding gravel = 12" total excavation) and 9" for surface layers; also where cut may be needed for a spillway

Also, do borings at your proposed borrow site to determine suitability and see how much borrow material is available!

Recommend 0.5ft increments (depth of bucket of soil auger)



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TYPES OF MATERIAL ENCOUNTERED IN BORINGS
(Use one of systems below)

UNIFIED CLASSIFICATION

GW – Well graded gravel; gravel, sand mix
GP – Poorly graded gravels
GM – Silty gravels; gravel-sand-silt mix
GC – Clayey gravels; gravel-sand-clay mix
SW – Well graded sands; sand-gravel mix
SP – Poorly graded sands
SM – Silty sand
SC – Clayey sands; sand-clay mixtures
ML – Silts; silty, v. fine sands; sandy or clayey silt
CL – Clays of low to medium plasticity
CH – Inorganic clays of high plasticity
MH – Elastic silts
OL – Organic silts and silty clays, low plasticity
OH – Organic clays, medium to high plasticity

USDA CLASSIFICATION

g – gravel
s – sand
vfs – very fine sand
sl – sandy loam
fsl – fine sandy loam
l – loam
gl – gravelly loam
si – silt
sil – silt loam
cl – clay loam
sicl – silty clay loam
scl – sandy clay loam
sic – silty clay
c – clay

1. Suitable material is available for practice. ☐ YES ☐ NO (Indicate where located on the sketch on reverse side)

REMARKS:

2. Explain hazards requiring special attention in design. (Seepage, spring, rock, etc.)

GENERAL REMARKS:

27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54

Borrow Areas

- Where will the fill material come from?
  - This is the material that will go on top of the culvert and form the base of the “road”
- Conduct soil borings in potential borrow areas to see how much material is available and to make sure it will be suitable
- Can use Web Soil Survey to identify potential borrow sites
  - Should hopefully be close to the crossing

Web Soil Survey for Borrow Areas

Soil Data Explorer

Suitabilities and Limitations for Use

Construction Materials

Roadfill Source

Description — Roadfill Source

Roadfill is soil material that is excavated in one place and used in road embankments in another place. The soils are rated as a source of roadfill for low embankments, generally less than 6 feet high and less exacting in design than higher embankments. The ratings are for the whole soil, from the surface to a depth of about 5 feet. It is assumed that soil layers will be mixed when the soil material is excavated and spread.

The soils are rated "good," "fair," or "poor" as potential sources of roadfill. The ratings are based on the amount of suitable material and on soil properties that affect the ease of excavation and the performance of the material after it is in place. The thickness of the suitable material is a major consideration. The ease of excavation is affected by large stones, depth to a water table, and slope. How well the soil performs in place after it has been compacted and drained is determined by its strength (as inferred from the AASHTO classification of the soil) and linear extensibility (shrink-swell potential). Normal compaction, minor processing, and other standard construction practices are assumed.

Numerical ratings between 0.00 and 0.99 are given after the specified features. These numbers indicate the degree to which the features limit the soils as sources of roadfill. The lower the number, the greater the limitation.

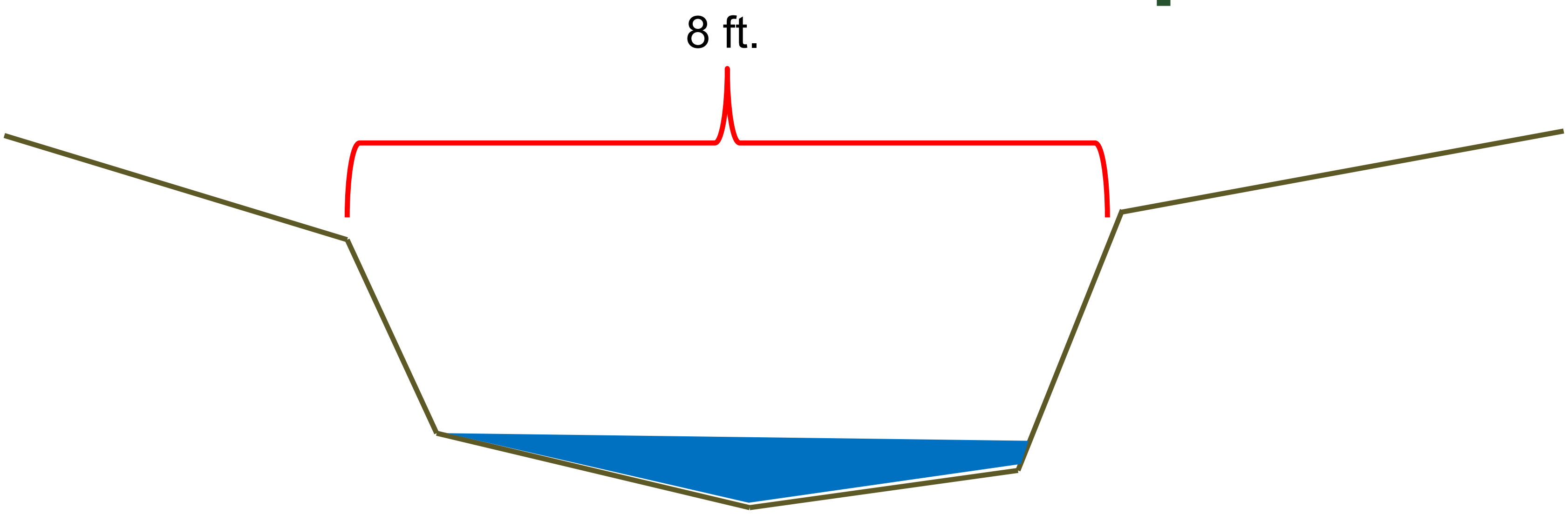
The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Survey Data

- Cross-section of stream along centerline of proposed crossing
  - Be sure to capture all low points beyond the “Top of Banks”; this will be needed for the headwater elevation to determine the culvert’s capacity
- “Natural” cross-section of stream if crossing site has been altered
  - “Natural” cross-section will be used for bankfull capacity calculations
- Upstream and downstream stream centerline points to calculate stream slope
  - Take shots in riffles, not in pools
  - DN-578: “collect points along a reach that extends at least 10 bankfull widths upstream and downstream of the crossing site”

“Bankfull Widths” Example



Bankfull Width: 8 ft.
10 Bankfull Widths: 8 ft. x 10 = 80 ft.
Find riffles for stream slope shots at least 80 ft. upstream and 80 ft. downstream

Survey Cross-Sections

- Capture enough elevation data to make an accurate representation on paper

- Take at least 7-points:

1. Enter Survey Data (ft):		
	Distance (ft)	Elevation (ft)
Cross Section:		
Left Floodplain		
Top Left Bank		
Toe Left Bank		
Center		
Toe Right Bank		
Top Right Bank		
Right Floodplain		

- Survey *at least* to the fence setbacks; recommend going farther to make sure you capture enough data, especially if there is a low point beyond (which will be needed for the "headwater")

Surveying Suggestion

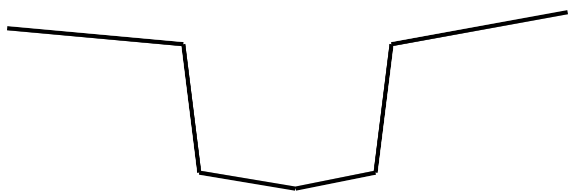
It is better to take too many survey shots in the field and not need a few than to get back to the office and realize that you should've taken a few more than you did!

Measuring the Survey Stations

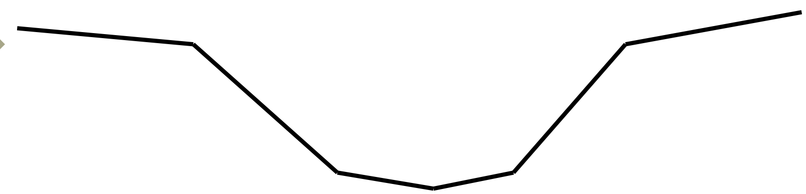
- The survey stations for the cross-sections need to be measured in such a way that they reflect *only* the horizontal distance.
- A measuring wheel is fine for relatively flat areas, but at the channel, use a measuring tape or lay the survey rod horizontally to measure the horizontal distance.

Using the measuring wheel to measure stations across the channel will result in a distorted representation on paper and will affect the bankfull flow calculations.

A channel that actually looks like this…



…will look more like this on paper if survey stations are measured with the wheel.



A tape (pulled taut) or rod across the channel will accurately measure horizontal distance.

“Bankfull”

- The “Bankfull flow” may be the design flow for the culvert (if the bankfull flow is less than the 2-yr, 24-hr storm peak discharge)
  - Lower top of bank elevation
  - “Bankfull flow is the discharge that fills a stream channel up to the elevation at which flow begins to spill onto the floodplain”
- Bankfull elevations are not always easy to determine
- When in doubt, take plenty of survey shots and take good notes

Bankfull Indicators

- Elev. of active floodplain
- Change in vegetation
- Tops of depositional bars
- Break in bank slope
- Change in bank material (from coarser to finer)
- Small inundation benches
- Staining on rocks
- Exposed root hairs

Survey Notes Sketch

- North
- TBM Location and Description
- Stream Flow Direction
- Centerline of Crossing with Direction of Stations
  - Typically survey from left to right looking downstream
- Location of “natural” cross-section (if needed)
- Existing fences and structures
- Note proposed crossing width (discuss with landowner)

Deciding on Crossing Width

- VA-578:
  - Multi-Use (Equipment+): No less than 12ft.
  - Livestock-Only: 8ft. to 30ft. wide
  - 16ft. wide will suffice for most equipment, but be sure to ask the producer

Design the “least-cost technically feasible” alternative.

Manning's "n" Recon

- Gather information about the channel to determine the Manning's "n" value when you get back to the office
- This value will be used to help determine the bankfull flow
- Print the following worksheet to take with you and circle values while you're in the field

- Page 40 of DN-578

(Stream Crossing Design Note)

- Keep in mind: total values for most Virginia streams will be between 0.035 and 0.075

Table 2. Factors Affecting Manning's *n* (based on the *Virginia Erosion and Sediment Control Handbook* and USGS WSP 2339).

n factor	Condition of Channel or Floodplain	n Value or Adjustment Factor	Description for Channels	Description for Floodplains
n_1 (Base Value: Material)	Earth	0.02		
	Rock	0.025		
	Fine gravel	0.024		
	Coarse gravel	0.028		
n_2 (Adjustment for Irregularity)	Smooth	0	Smoothest attainable for materials	Smoothest and flattest attainable for materials
	Minor	0.005	Good dredged channels; slightly eroded side slopes	Slightly irregular in shape with a few dips, rises, or sloughs.
	Moderate	0.010	Fair to poor dredged channels; moderately eroded side slopes	More rises, dips, sloughs, hummocks
	Severe	0.020	Badly sloughed banks of natural streams	Very irregular with many rises, dips, or sloughs. May have furrows perpendicular to flow.
n_3 (Adjustment for variation in cross section size and shape for channels)	Gradual	0	Gradual change	Not applicable to floodplains.
	Occasional	0.005	Large and small sections alternating occasionally	
	Frequent	0.010-0.015	Large and small sections alternating frequently	
n_4 (Adjustment for obstructions)	Negligible	0	Obstructions (debris, stumps, roots, boulders) occupy less than 5% of the cross-sectional area	Obstructions (debris, stumps, roots, boulders) occupy less than 5% of the cross-sectional area
	Minor	0.010-0.015	Obstructions occupy less than 15% of the cross-sectional area	Obstructions occupy less than 15% of the cross-sectional area
	Appreciable	0.020-0.030	Obstructions occupy 15%-50% of the cross-sectional area	Obstructions occupy 15%-50% of the cross-sectional area
	Severe	0.040-0.060	Obstructions occupy more than 50 % of the cross-sectional area	Obstructions occupy more than 50 % of the cross-sectional area
n_5 (Adjustment for vegetation)	Low	0.005-0.010	Dense turf grass or weeds with avg. depth of flow = 2 or more times the vegetation height. Tree switches with avg. depth of flow = 3 or more times the vegetation height.	Dense turf grass or weeds with avg. depth of flow = 2 or more times the vegetation height. Tree switches with avg. depth of flow = 3 or more times the vegetation height.
	Medium	0.010-0.020	Turf grasses with flow 1-2 times height of grass; stemmy grasses, tree seedlings with flow 2 to 3 times height of veg.; bushy growth, dormant season, no veg. along bottom, with R>2 ft.	Turf grasses with flow 1-2 times height of grass; stemmy grasses, tree seedlings with flow 2 to 3 times height of veg.; bushy growth, dormant season, no veg. along bottom.
	High	0.025-0.050	Turf grass with flow = height of grass; willows, cottonwoods in the dormant season with R = 2 to 4 ft.	Turf grass with flow = height of grass; willows, cottonwoods in the dormant season.
	Very High	0.050-0.100	Turf grass with very shallow flow; bushy willows; trees with full foliage and weeds with R = 10 to 12 ft.	Turf grass with very shallow flow; bushy willows; trees with full foliage and weeds.
n_6 (Adjustment for sinuosity)	Minor	0	Meander length/straight length = 1.0 to 1.2	Not applicable to floodplains.
	Appreciable	$0.15n_s$	Meander length/straight length = 1.2 to 1.5	
	Severe	$0.30n_s$	Meander length/straight length = 1.5 and greater	
	Where $n_s = n_1 + n_2 + n_3 + n_4 + n_5$			

Photographs

- Take pictures while you're surveying for the following uses:
  - If needed for T&E Review
    - Stream Crossing Location
    - Facing Upstream of Crossing
    - Facing Downstream of Crossing
    - Banks
    - Streambed
  - To help with Manning's "n" determinations
  - For "Before & After" purposes
  - To send to DCR or NRCS engineering staff if you have questions while designing

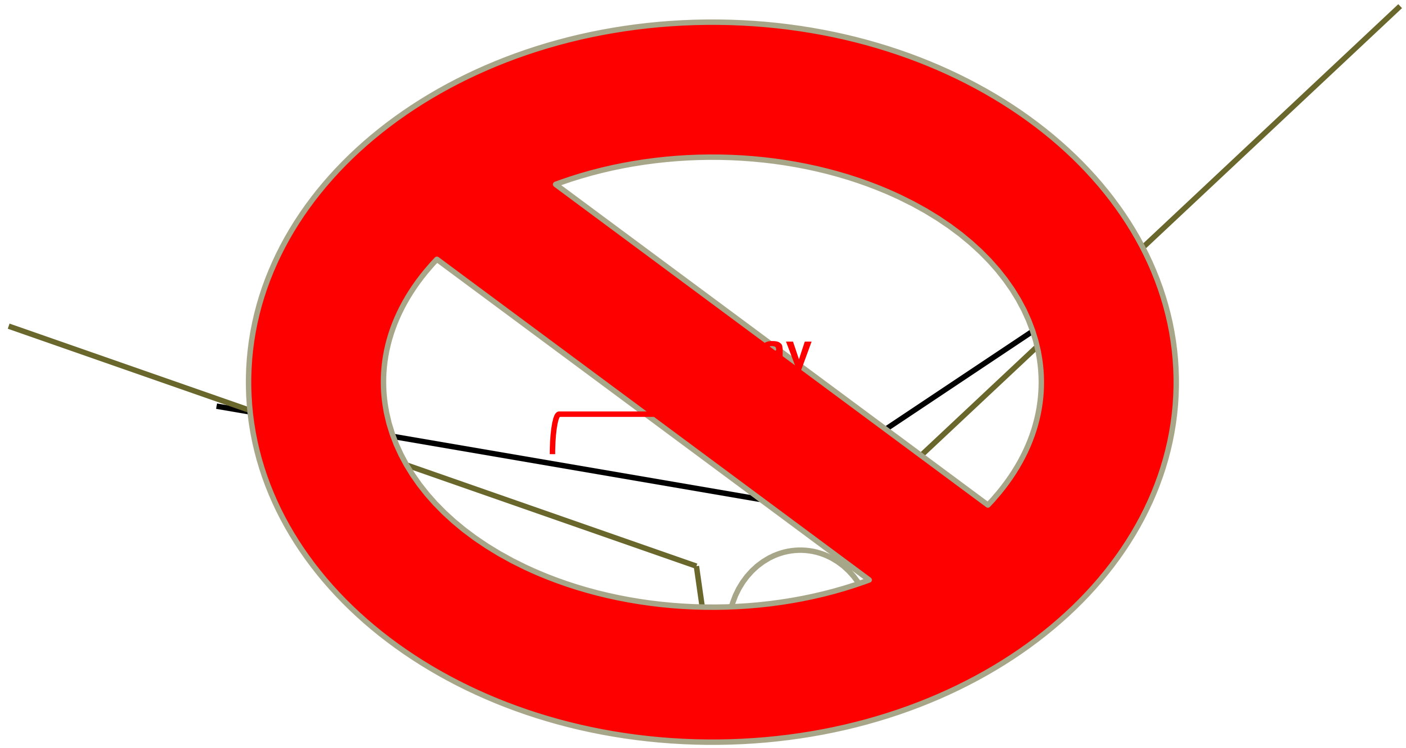

Before


After

Tips for Surveying/Data Collection

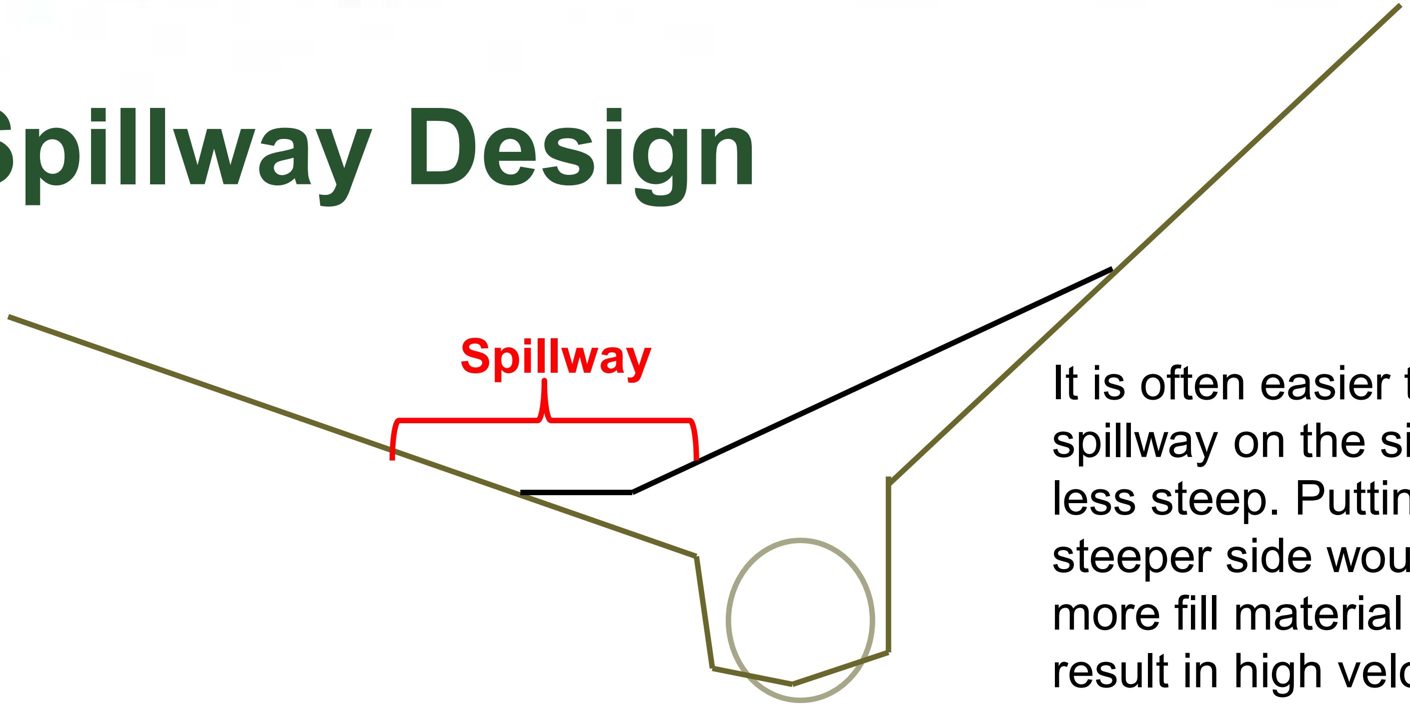
- Make sure to set benchmark on something that will not be removed during construction
  - Consider setting two benchmarks – one for the contractor, one that is farther downstream and not mentioned to the contractor
- Determine which side of the stream would be better for the emergency spillway (for out-of-bank flows)
  - VA-578: “Crossings shall be adequately protected so that out-of-bank flows safely bypass without damaging the structure or eroding the streambanks or the crossing fill.”
  - The fill over the culvert should NOT be the lowest point of the crossing
  - See following slides for examples

Spillway Design



This may seem like the easiest way to design the fill over the culvert, but in a high flow event (or if the culvert gets blocked) the water will spill over directly on top of the culvert and could wash the culvert out completely.

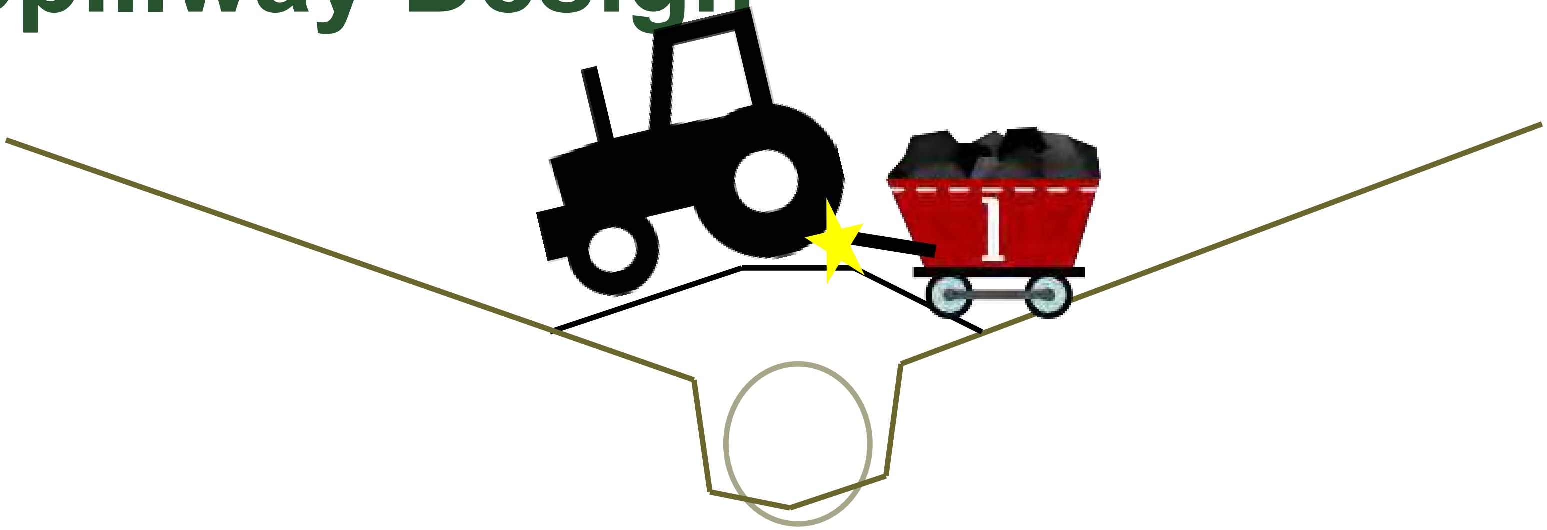
Spillway Design



It is often easier to put the spillway on the side that is less steep. Putting it on the steeper side would require more fill material and could result in high velocities on the discharge end of the spillway.

A better design would be to design the low point of the crossing to one (or both) sides of the culvert so that water flows around the culvert (ideally on natural ground, which is less likely to wash away than fill material). The culvert will be much less likely to wash out.

Spillway Design



If the slopes are approximately the same on either side,

(1) Can design spillways on both sides (which can cause problems for trailer access or vehicles with low ground clearance – more on this later), OR

(2) Can design one spillway on the side which will function better as a spillway

What factors make a good spillway?

(1) Natural ground with good grass vegetation, no existing erosion

(2) No or few trees or other obstacles (which can catch debris and dam up the spillway)

(3) Avoid excessive drop-offs

***Figure this out and take notes in the field!

Watershed Info

- You will need information on the watershed to size the culvert; some can’t be gathered accurately just from aerials or topo maps
  - Watershed Boundaries
    - E.g. Roads often follow drainage divides, but where do the ditches outlet?
  - Watershed Land Use
    - Pasture: What is the management? Continuous vs. Rotational Grazing
    - Woodland: Do the livestock have access, or are the woods protected?
    - Cropland: No-till vs. Conventional
- Become familiar with different “Cover Descriptions” in the “RCN” tab of EFH2

Design

Design

1) Design Flow/Hydrologic Calculations

   How much water does the culvert need to pass?

2) Sketch cross-section on Stream Crossing Design Sheets
3) Hydraulic Calculations
4) Finalize Design Drawings
5) Complete Design Packet

Iterative Process

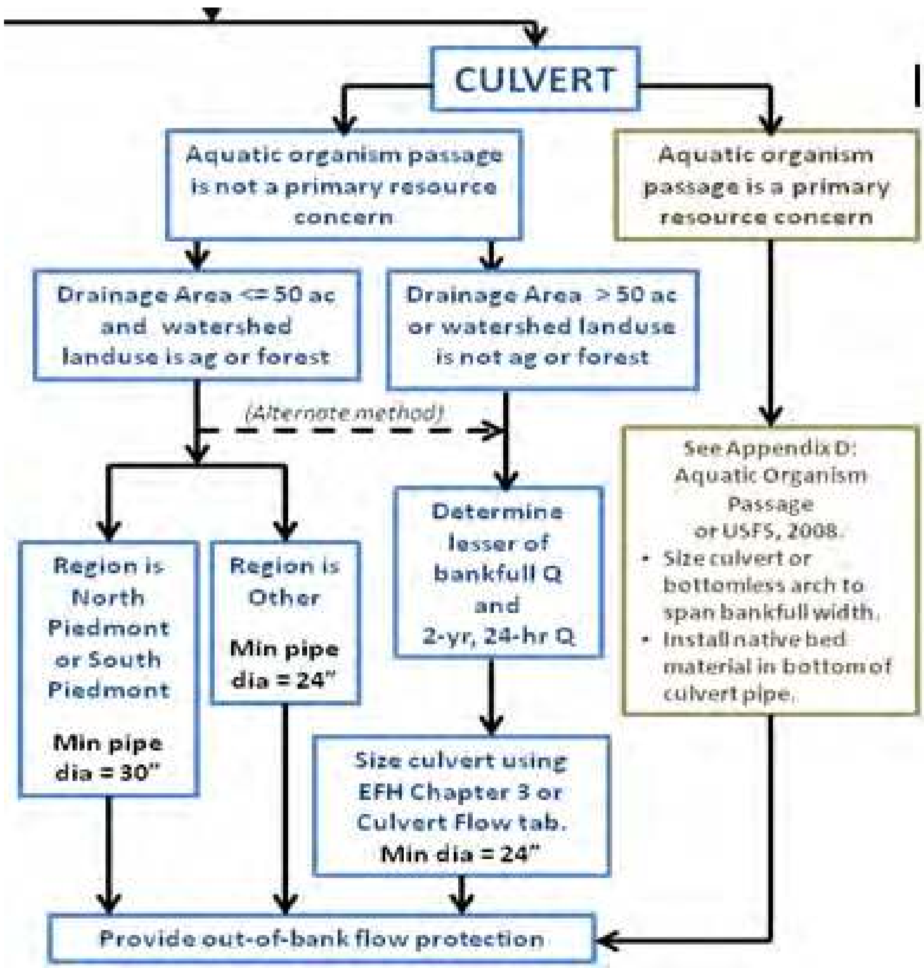
Hydrology vs. Hydraulics

- Hydrology: estimating the amount of water runoff based on the watershed
- Hydraulics: calculating the capacity of the culvert (how much water it can discharge)

The *hydrology* of the watershed will determine the necessary *hydraulic* capacity of the culvert.

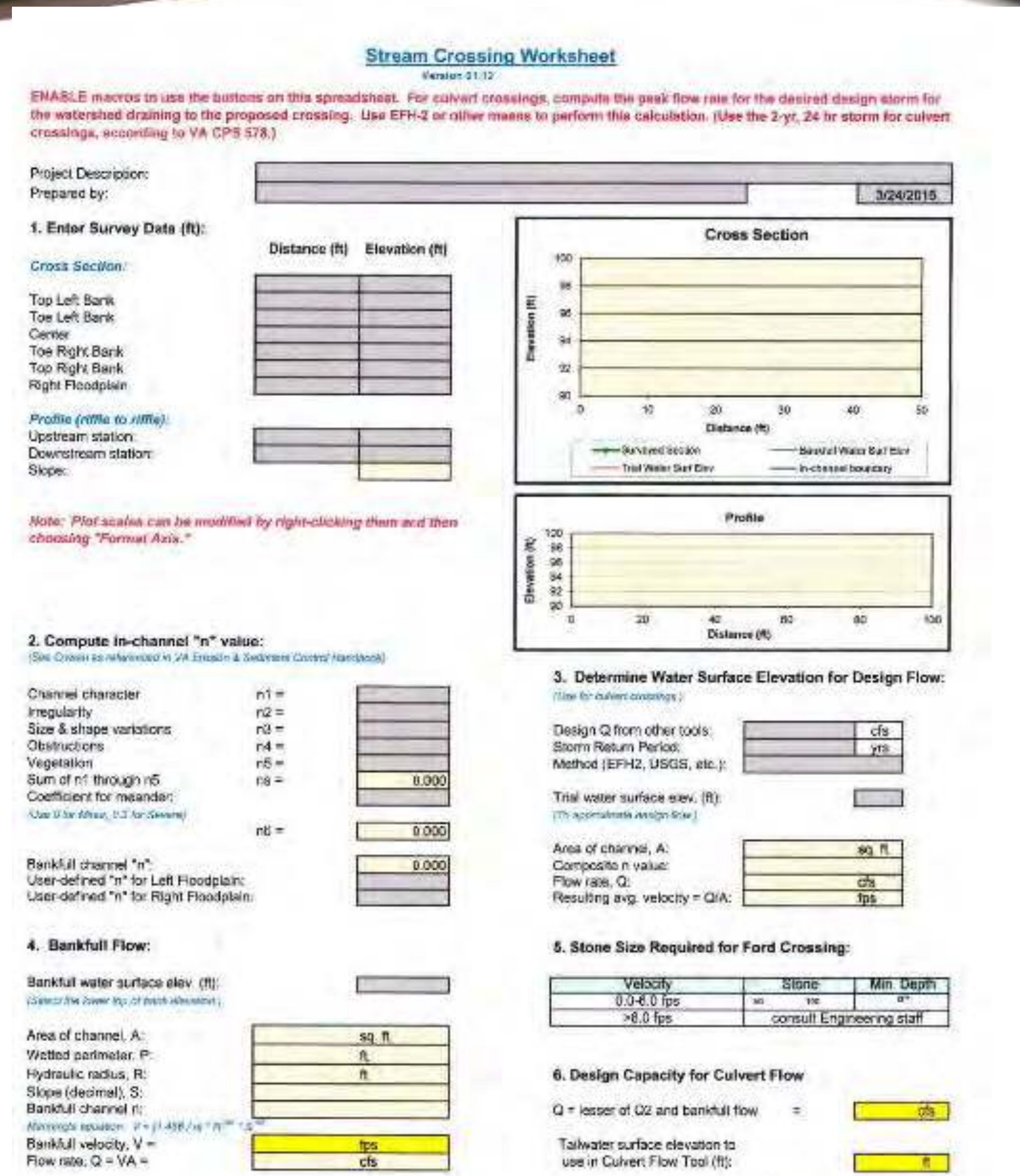
1) Design Flow/Hydrologic Calculations

- VA-578: "The design flow for culverts not associated with a road will be the 2-year, 24-hour storm peak discharge, or bankfull flow, whichever is less."
  - Bankfull Flow: "the discharge that fills a stream channel up to the elevation at which flow begins to spill onto the floodplain"



Bankfull Flow Calculations

- NRCS “Stream Crossing worksheet” makes bankfull flow calculations easy
- If your cross section does not follow the normal 7-point profile:
  - Calculate manually (see DN-578, pg.10 & 41-42)
  - Use another cross-section analyzer worksheet



Stream Crossing Worksheet

ENABLE macros to use the buttons on this spreadsheet. For culvert crossings, compute the peak flow rate for the desired design storm for the watershed draining to the proposed crossing. Use EFH-2 or other means to perform this calculation. (Use the 2-yr, 24 hr storm for culvert crossings, according to VA CPS 578.)

Project Description:
Prepared by: 3/24/2015

1. Enter Survey Data (ft):

	Distance (ft)	Elevation (ft)
Cross Section:		
Top Left Bank		
Toe Left Bank		
Center		
Toe Right Bank		
Top Right Bank		
Right Floodplain		
Profile (riffle to riffle):		
Upstream station		
Downstream station		
Slope:		

Note: Plot scales can be modified by right-clicking them and then choosing "Format Axis."

2. Compute in-channel "n" value:

Channel character	n1 =	
Irregularity	n2 =	
Size & shape variations	n3 =	
Obstructions	n4 =	
Vegetation	n5 =	
Sum of n1 through n5	n6 =	0.000
Coefficient for meander:		
	nt =	0.000
Bankfull channel "n":		0.000
User-defined "n" for Left Floodplain:		
User-defined "n" for Right Floodplain:		

3. Determine Water Surface Elevation for Design Flow:

Design Q from other tools:		cfs
Storm Return Period:		yrs
Method (EFH2, USGS, etc.):		
Trial water surface elev. (ft):		
Area of channel, A:		sq. ft
Composite n value:		
Flow rate, Q:		cfs
Resulting avg. velocity = Q/A:		fps

4. Bankfull Flow:

Bankfull water surface elev. (ft):		
Area of channel, A:		sq. ft
Wetted perimeter, P:		ft
Hydraulic radius, R:		ft
Slope (decimal), S:		
Bankfull channel n:		
Bankfull velocity, V =		fps
Flow rate, Q = VA =		cfs

5. Stone Size Required for Ford Crossing:

Velocity	Stone	Min. Depth
0.0-8.0 fps		
>8.0 fps	consult Engineering staff	

6. Design Capacity for Culvert Flow

Q = lesser of Q2 and bankfull flow	=	cfs
Tailwater surface elevation to use in Culvert Flow Tool (ft):		ft

Virginia Department of Conservation & Recreation

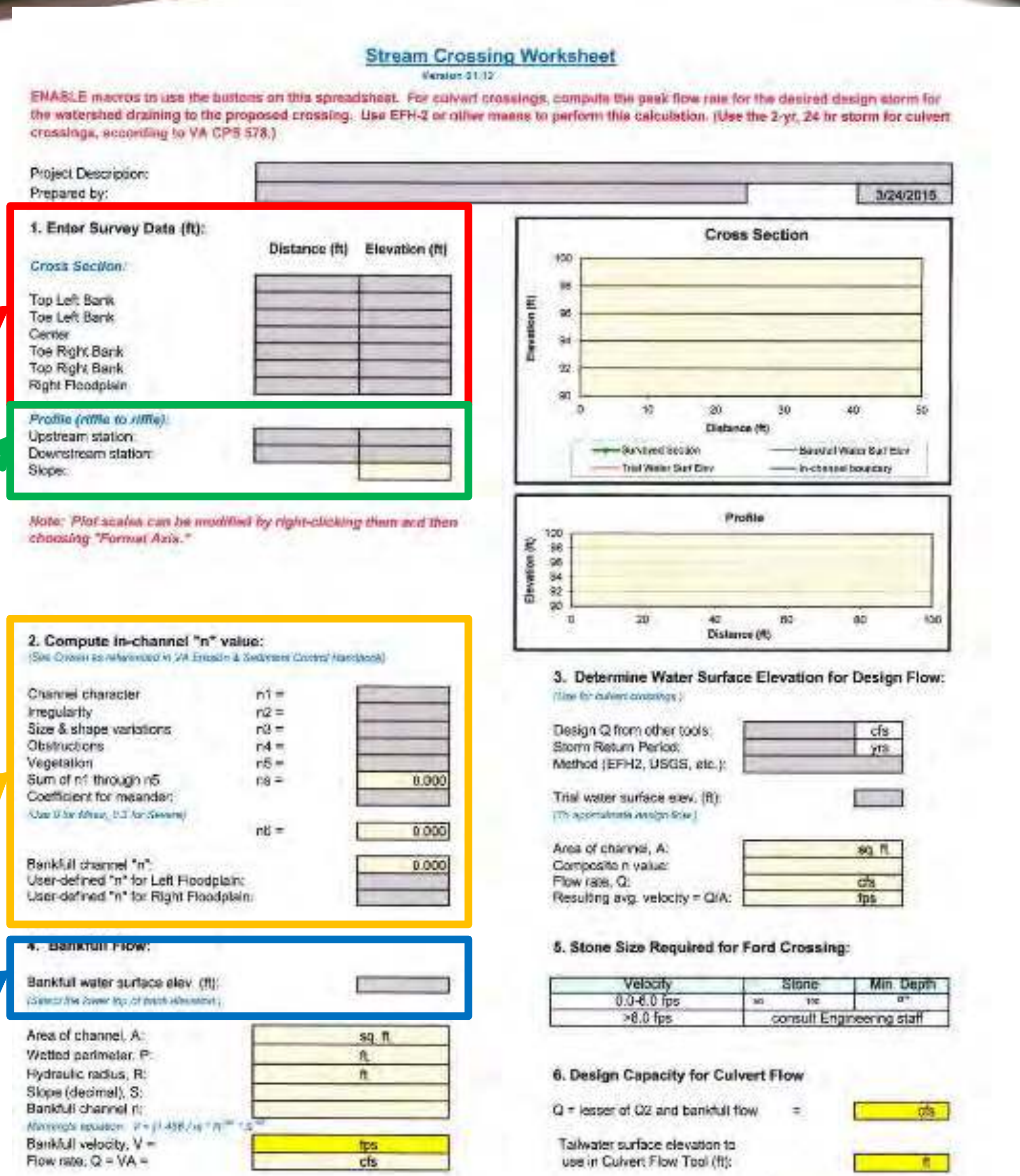
Bankfull Flow Calculations

Use the "natural" cross-section survey data

If upstream slope is significantly higher than the average slope, consider using the upstream slope for the calculation

(See following slide for Manning's "n" suggestions)

"Select the lower top of bank elevation"


Stream Crossing Worksheet

ENABLE macros to use the buttons on this spreadsheet. For culvert crossings, compute the peak flow rate for the desired design storm for the watershed draining to the proposed crossing. Use EFH-2 or other means to perform this calculation. (Use the 2-yr, 24 hr storm for culvert crossings, according to VA CPS 578.)

Project Description:
Prepared by: 3/24/2015

1. Enter Survey Data (ft):

Cross Section	Distance (ft)	Elevation (ft)
Top Left Bank		
Toe Left Bank		
Center		
Toe Right Bank		
Top Right Bank		
Right Floodplain		

Profile (riffle to riffle):
Upstream station:
Downstream station:
Slope:

Note: Plot scales can be modified by right-clicking them and then choosing "Format Axis."

Cross Section

Profile

2. Compute in-channel "n" value:

Channel character	n1 =	
Irregularity	n2 =	
Size & shape variations	n3 =	
Obstructions	n4 =	
Vegetation	n5 =	
Sum of n1 through n5	n6 =	0.000
Coefficient for meander:		
	nt =	0.000
Bankfull channel "n":		0.000
User-defined "n" for Left Floodplain:		
User-defined "n" for Right Floodplain:		

3. Determine Water Surface Elevation for Design Flow:

Design Q from other tools: cfs
Storm Return Period: yrs
Method (EFH2, USGS, etc.):

Trial water surface elev. (ft):

Area of channel, A: sq. ft
Composite n value:
Flow rate, Q: cfs
Resulting avg. velocity = Q/A: fps

4. Bankfull Flow:

Bankfull water surface elev. (ft):

Area of channel, A: sq. ft
Wetted perimeter, P: ft
Hydraulic radius, R: ft
Slope (decimal), S:
Bankfull channel n:
Bankfull velocity, V = fps
Flow rate, Q = VA = cfs

5. Stone Size Required for Ford Crossing:

Velocity	Stone	Min. Depth
0.0-8.0 fps		
>8.0 fps	consult Engineering staff	

6. Design Capacity for Culvert Flow

Q = lesser of Q2 and bankfull flow = cfs

Tailwater surface elevation to use in Culvert Flow Tool (ft): ft

Manning's "n" determination

2. Compute in-channel "n" value:
(See Cowan as referenced in VA Erosion & Sediment Control Handbook)

Channel character	n1 =	
Irregularity	n2 =	
Size & shape variations	n3 =	
Obstructions	n4 =	
Vegetation	n5 =	
Sum of n1 through n5	ns =	0.000
Coefficient for meander:		
(Use 0 for Minor, 0.3 for Severe)		
	n6 =	0.000
Bankfull channel "n":		0.000
User-defined "n" for Left Floodplain:		
User-defined "n" for Right Floodplain:		

- See DN-578, Pg. 40 for criteria for selecting these values
- Come up with one representative value for entire bankfull height
- Better to underestimate

<u>Higher "n"</u> → <u>More resistance in channel</u> → <u>Lower Velocity & Flow</u>

Overestimating "n" means the flow will be underestimated and the culvert may be undersized. THIS IS A DISSERVICE TO THE LANDOWNER who has to maintain the crossing.

For n5, Vegetation:

n_5 (Adjustment for vegetation)	Low	0.005-0.010	Dense turf grass or weeds with avg. depth of flow = 2 or more times the vegetation height. Tree switches with avg. depth of flow = 3 or more times the vegetation height.
	Medium	0.010-0.020	Turf grasses with flow 1-2 times height of grass; stemmy grasses, tree seedlings with flow 2 to 3 times height of veg.; bushy growth, dormant season, no veg. along bottom, with R>2 ft.
	High	0.025-0.050	Turf grass with flow = height of grass; willows, cottonwoods in the dormant season with R = 2 to 4 ft.
	Very High	0.050-0.100	Turf grass with very shallow flow; bushy willows; trees with full foliage and weeds with R = 10 to 12 ft.

- Many of the descriptions depend on the depth of flow.
  - E.g:
    - bankfull depth = 2ft.
    - Fescue-lined channel (H=8in.)
    - n5 = 0.005 – 0.010

Keep in mind that you are coming up with a composite for the **whole channel** at the bankfull elevation. If you have a wide channel with trees on the banks, do NOT use “Very High” for n5, because the bulk of the flowing water will not actually be impacted by the trees.

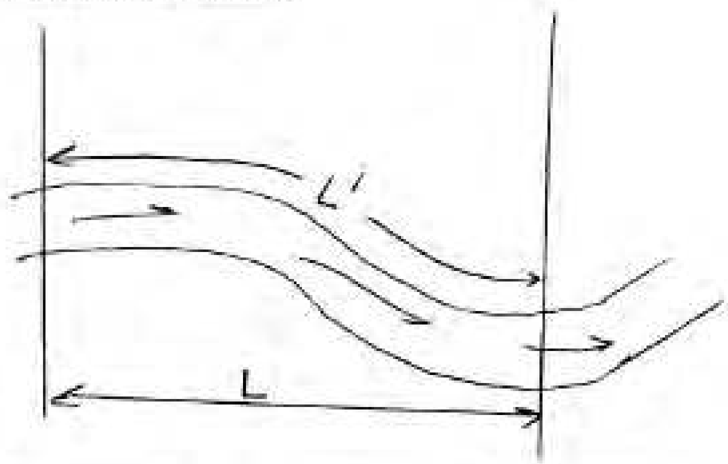
For n6, Coefficient of Meander:

TABLE 5-23

REDUCTION IN PERMISSIBLE VELOCITY BASED ON SINUOSITY

Sinuosity*	Percent Reduction in Permissible Velocity
Slight (1.0 to 1.2)	5%
Moderate (1.2 to 1.5)	13%
Very Sinuous (1.5 and greater)	22%

* Sinuosity - degree of curvature of channel.



Sinuosity = L'/L

After calculating the "n" value using the "Stream Crossing Worksheet", come back to this chart to see if your value falls within the general range for the stream type. If not, consider adjusting your values.

Manning's n for Channels (Chow, 1959).

Type of Channel and Description	Minimum	Normal	Maximum
Natural streams - minor streams (top width at floodstage < 100 ft)			
1. Main Channels			
a. clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. same as above, but more stones and weeds	0.030	0.035	0.040
c. clean, winding, some pools and shoals	0.033	0.040	0.045
d. same as above, but some weeds and stones	0.035	0.045	0.050
e. same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
f. same as "d" with more stones	0.045	0.050	0.060
g. sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
2. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages			
a. bottom: gravels, cobbles, and few boulders	0.030	0.040	0.050
b. bottom: cobbles with large boulders	0.040	0.050	0.070
3. Floodplains			
a. Pasture, no brush			
1.short grass	0.025	0.030	0.035
2. high grass	0.030	0.035	0.050
b. Cultivated areas			
1. no crop	0.020	0.030	0.040
2. mature row crops	0.025	0.035	0.045
3. mature field crops	0.030	0.040	0.050
c. Brush			
1. scattered brush, heavy weeds	0.035	0.050	0.070
2. light brush and trees, in winter	0.035	0.050	0.060
3. light brush and trees, in summer	0.040	0.060	0.080
4. medium to dense brush, in winter	0.045	0.070	0.110
5. medium to dense brush, in summer	0.070	0.100	0.160
d. Trees			
1. dense willows, summer, straight	0.110	0.150	0.200
2. cleared land with tree stumps, no sprouts	0.030	0.040	0.050
3. same as above, but with heavy growth of sprouts	0.050	0.060	0.080
4. heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.080	0.100	0.120
5. same as 4. with flood stage reaching branches	0.100	0.120	0.160

1) Design Flow/Hydrologic Calcs. Cont'd

- With the info we have entered into the "Stream Crossing Worksheet", the "bankfull flow" has been calculated
- Now we need to calculate the "2-year, 24-hour storm peak discharge"
  - USGS Regression Equations
  - EFH-2
  - Other Methods: Check with your DCR or NRCS Engineer

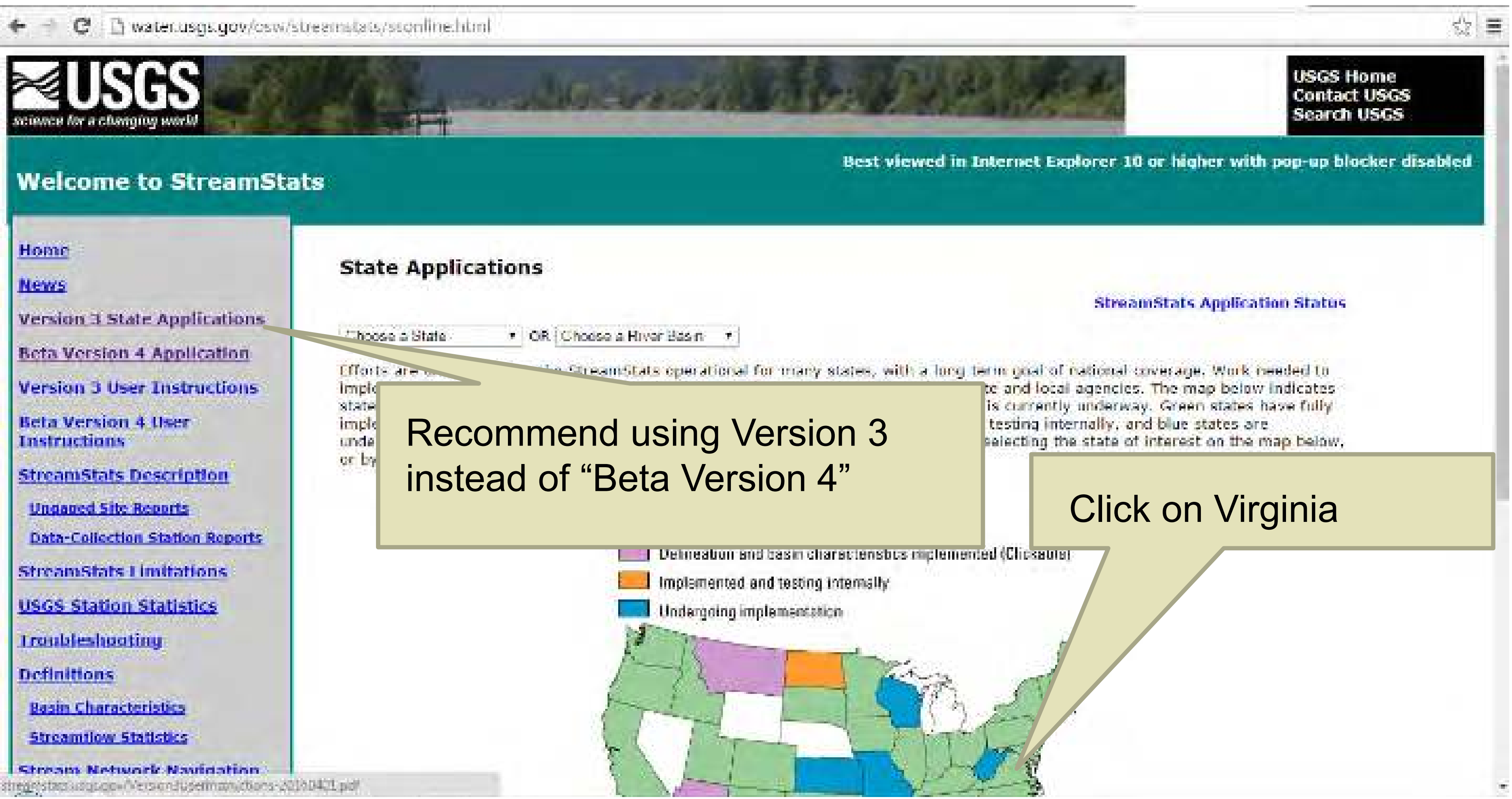
EFH-2 vs. USGS Regression Analysis

	EFH-2	USGS Regression Analysis
Description	Computer program based on Engineering Field Handbook Ch. 2	Spreadsheet or StreamStats web application
Inputs	Drainage Area, watershed length, avg. watershed slope, curve number (based on land use and hydrologic soil group)	Location, Drainage Area
Accuracy	Very good, site specific	Marginal (typically no better than ±22%)
Ease of Use	Fairly time-consuming	Very Easy and Quick

EFH-2 requires a little bit more work but will generally produce much more accurate results. The USGS method may provide a good starting point, but EFH-2 is preferred.

USGS StreamStats Web Application

- http://water.usgs.gov/osw/streamstats/



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Virginia

Beta version 4 has arrived!

Beta version 4 is now available for most states on a trial basis, and version 3 remains available. Beta version 4 provides a single user interface (at http://ssdev.cr.usgs.gov/streamstats/) for all states that are implemented, rather than separate applications for each state, as in versions 2 and 3, and the user interface is more user friendly than previous versions. Limited beta version 4 documentation can be accessed by clicking on the *Help* button in the user interface. Also, information for user-selected ungaged sites currently cannot be obtained for the Arkansas, Arizona, Georgia, Iowa, Indiana, North Carolina, Oregon, South Carolina, Tennessee, and Washington because of unique functionality for those states that is not yet implemented. Users are encouraged to provide comments and report bugs by use of the *Help* button on the interface. See the StreamStats home page for a description of the differences in capabilities between version 3 and beta version 4.

Please help us conserve our server system resources by closing the Interactive Map window when you are finished using it. Doing to will help ensure system availability for all users. Thank you. Please contact the StreamStats by email at support@streamstats.freshdesk.com if you have any questions.

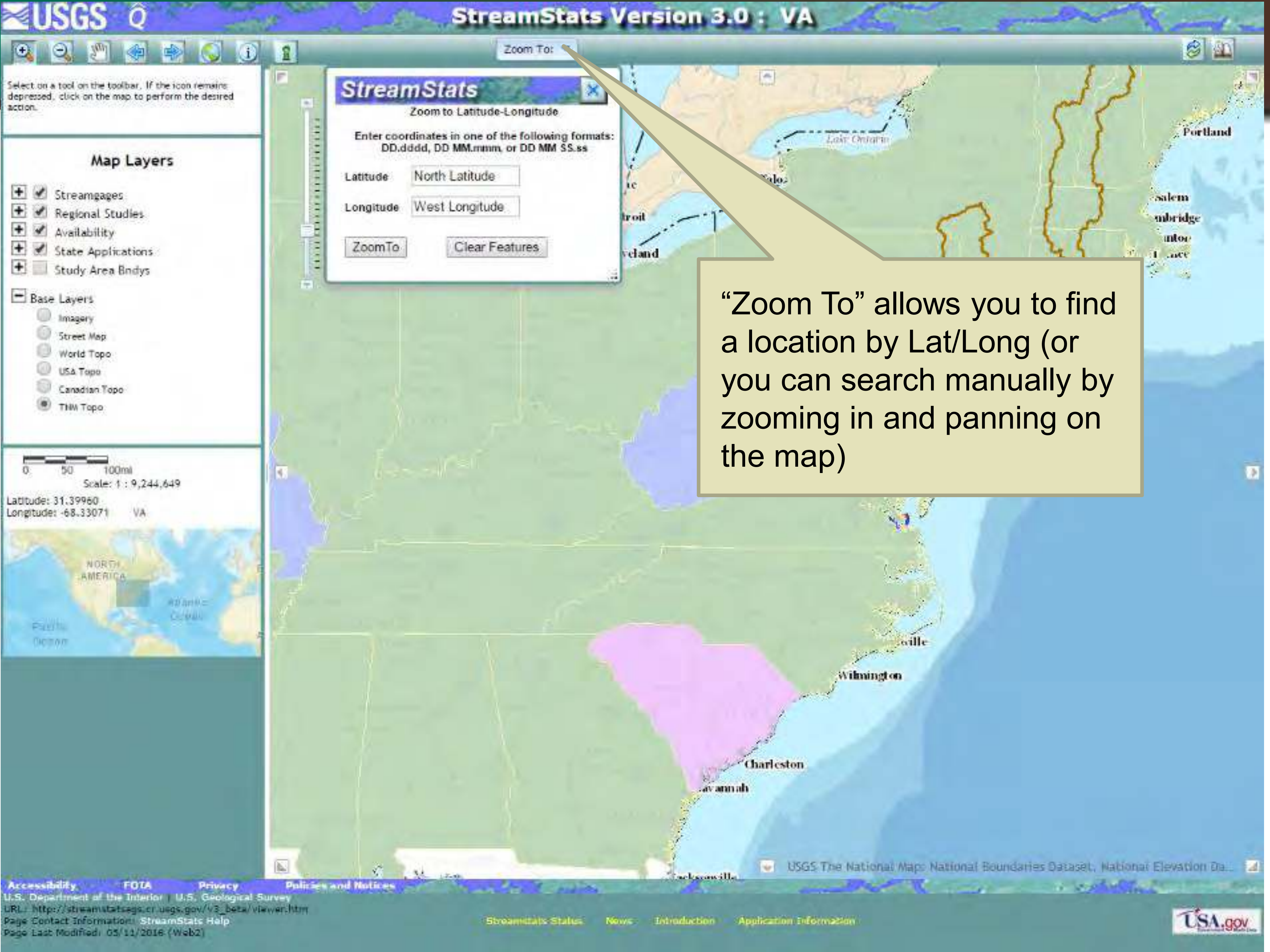
StreamStats for Virginia can be used to estimate the magnitude of peak flows for Virginia streams under rural, natural streamflow conditions at the 2-, 5-, 10-, 25-, 50-, 100-, and 200-year recurrence-intervals, and under urban conditions at the 1.005-, 1.01-, 1.05-, 1.11-, 1.25-, 1.49-, 2.0-, 2.3-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year recurrence intervals. StreamStats for Virginia may also be used to estimate the magnitude of low flows for Virginia streams under rural, natural streamflow conditi ... 2.5, 3.3, 5, 10, 20, 50, 100, and 200 year recurr ... for a variety of land cover, elevation, precipi ... shed delineations. The reports below present th ... ciated with the estimates, and describe ... racteristics used in the equations. Users should ... in estimates of streamflow statistics for ungaged si ...

Click on Interactive Map

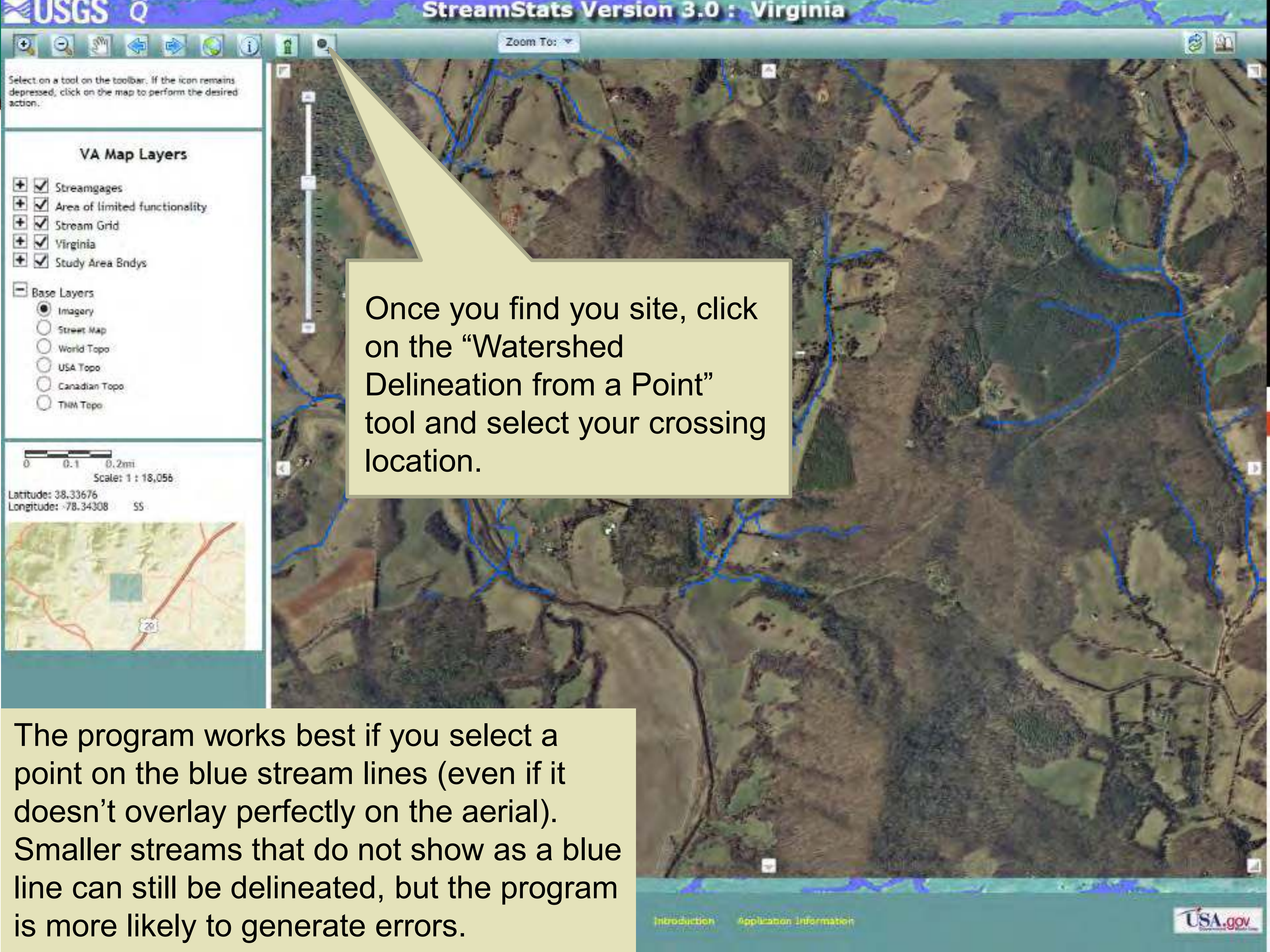
- Austin, S.H., Krstolic, J.L., ... ufe, 2011, Low-flow characteristics of Virginia streams: U.S. Geological Survey Scientific Investig ... 2011-5143, 122 p.
- Austin, S.H., Krstolic, J.L ... gand, Ute, 2011, Peak-flow characteristics of Virginia streams: U.S. Geological Survey Scientific Invest ... Report 2011-5144, 106 p.
- Austin, S.H., 2014, Me ... nd equations for estimating peak streamflow per square mile in Virginia's urban basins: U.S. Geologic ... vey Scientific Investigations Report 2014-5090, 25 p.

Interactive Map

NOTE: Virginia StreamStats operates in a unique manner when a delineated basin has drainage area that is in multiple hydrologic regions. Normally in these cases, StreamStats provides flow estimates using the equations for each hydrologic region and then produces final estimates that weight the estimates from each hydrologic region according to the

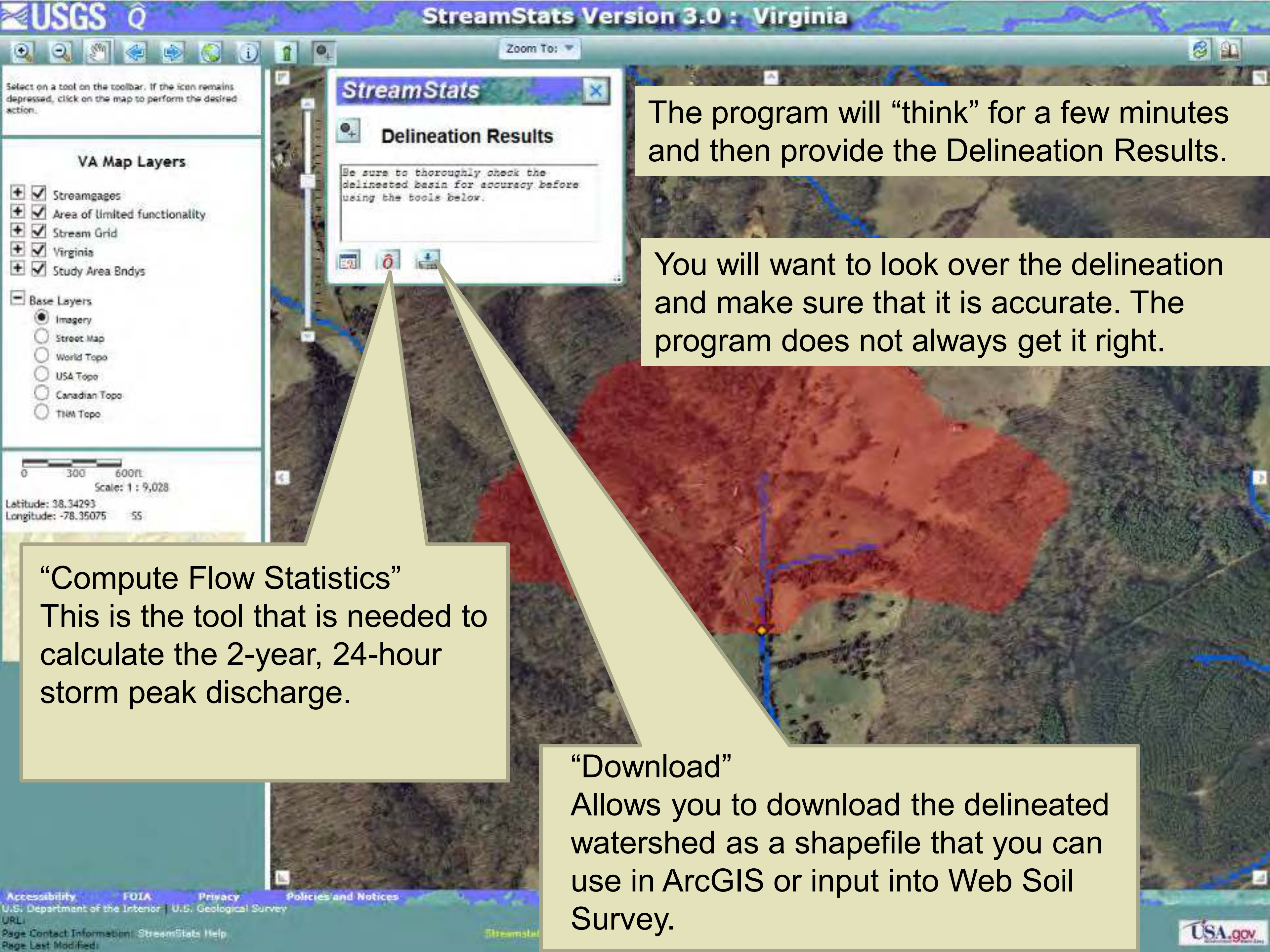


"Zoom To" allows you to find a location by Lat/Long (or you can search manually by zooming in and panning on the map)



Once you find you site, click on the "Watershed Delineation from a Point" tool and select your crossing location.

The program works best if you select a point on the blue stream lines (even if it doesn't overlay perfectly on the aerial). Smaller streams that do not show as a blue line can still be delineated, but the program is more likely to generate errors.



The program will “think” for a few minutes and then provide the Delineation Results.

You will want to look over the delineation and make sure that it is accurate. The program does not always get it right.

“Compute Flow Statistics”
This is the tool that is needed to calculate the 2-year, 24-hour storm peak discharge.

“Download”
Allows you to download the delineated watershed as a shapefile that you can use in ArcGIS or input into Web Soil Survey.

StreamStats Version 3.0

Flow Statistics Ungaged Site Report

Date: Wed Apr 6, 2016 12:41:18 PM GMT-4
Study Area: Virginia
NAD 1983 Latitude: 38.345 (38 20 42)
NAD 1983 Longitude: -78.3604 (-78 21 38)
Drainage Area: 0.17 mi2

Peak Flows Region Basin Characteristics

100% Blue Ridge 2011 5144 (0.17 mi2)

	Value	Regression Equation Valid Range	
		Min	Max
	0.17	0.06	7866

This is the 2-year, 24-hour storm peak discharge (38.1 cfs in this example). This will be compared to the bankfull flow.

...egion Basin Characteristics

	Value	Regression Equation Valid Range	
		Min	Max
Dr... ...ea (square miles)	0.17	0.09	7393

Peak Flows Region...

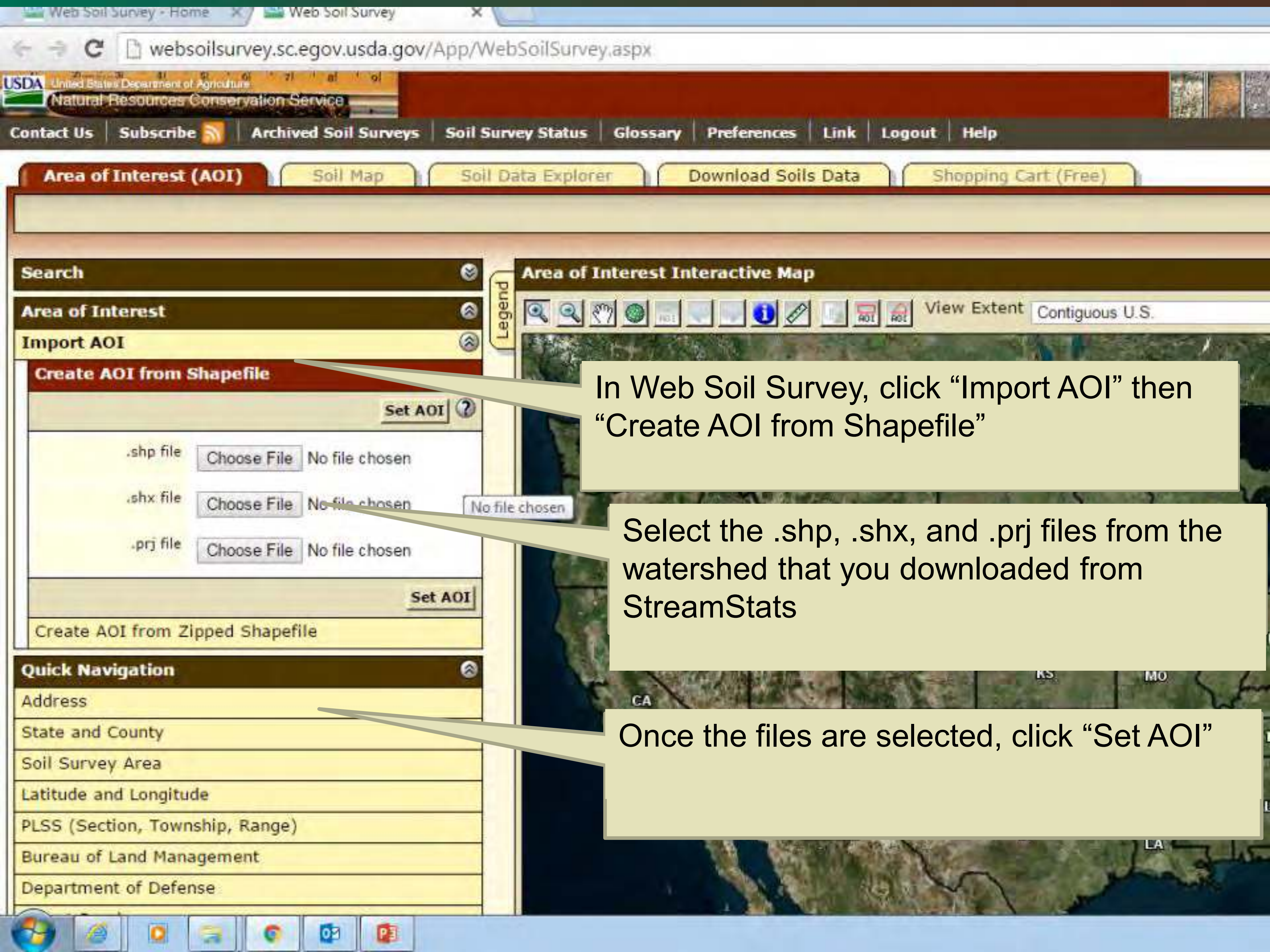
Statistic	...alue	Unit	Prediction Error (percen...
PK2	38.1	ft3/s	17
PK2 33...	46.3	ft3/s	18
PK5	94.6	ft3/s	20
PK10	155	ft3/s	24
PK25	256	ft3/s	29
PK50	360	ft3/s	32
PK100	534	ft3/s	30

Notice the error: **± 17%. It can be as high as 43% depending on your location.** Even 17% could be the difference between two culvert sizes. This is why EFH2 is generally preferable to this USGS method.

The “Download” tool is useful if you want to run EFH2. The watershed can be downloaded and brought into Web Soil Survey as the “Area of Interest” to determing the hydrologic soils groups of the soil types in the watershed.

Download a “Shapefile”

The shapefile will be downloaded in a .zip file.
Unzip the file and keep all the files that are titled “GlobalWatershed.xxx”.
Delete files that are title “GlobalWatershedPoint.xxx”

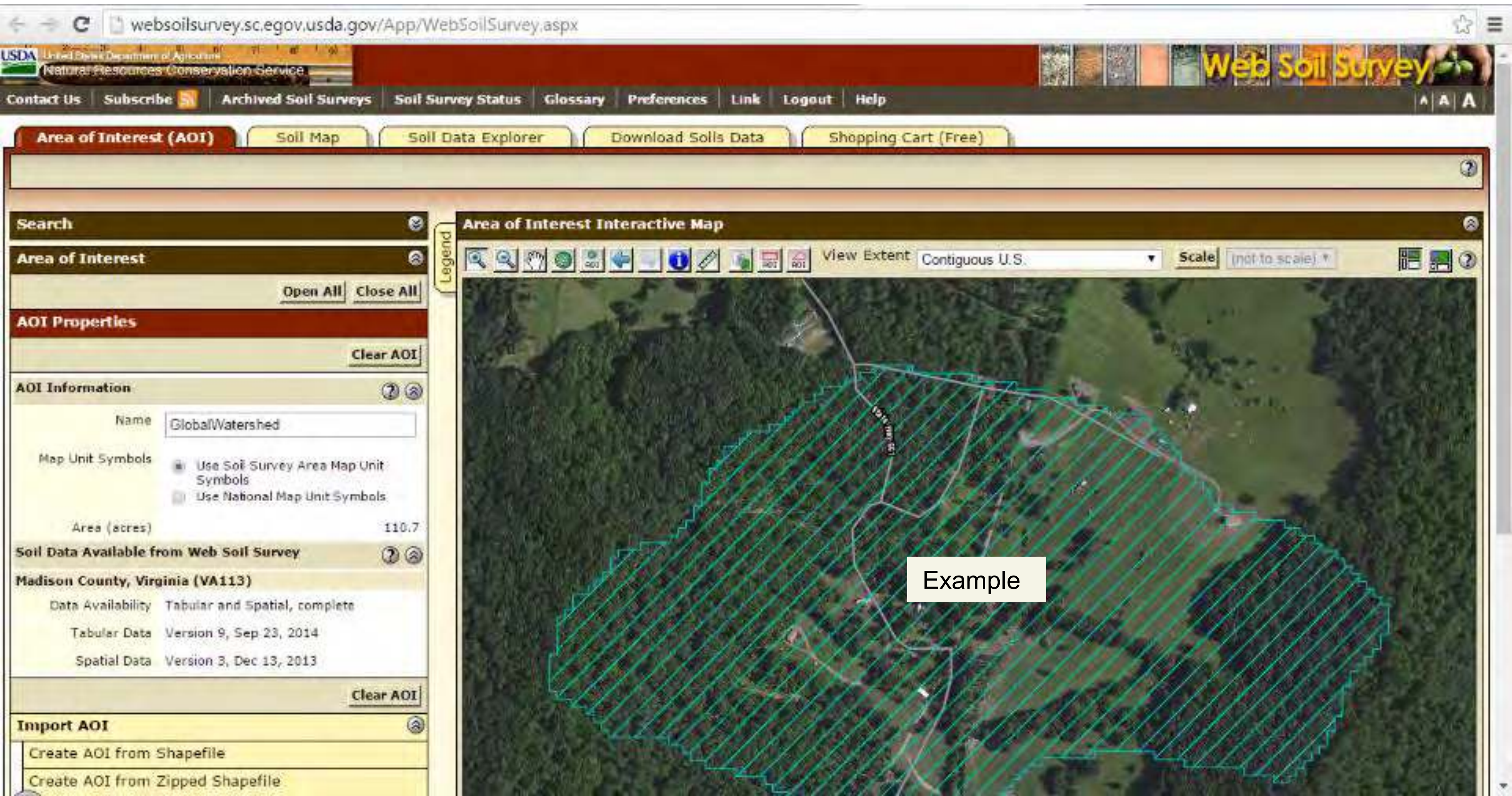


In Web Soil Survey, click “Import AOI” then “Create AOI from Shapefile”

Select the .shp, .shx, and .prj files from the watershed that you downloaded from StreamStats

Once the files are selected, click “Set AOI”

The watershed should become the AOI in Web Soil Survey:



For EFH2, you will need the "Hydrologic Soil Group" of the soil types in the watershed.

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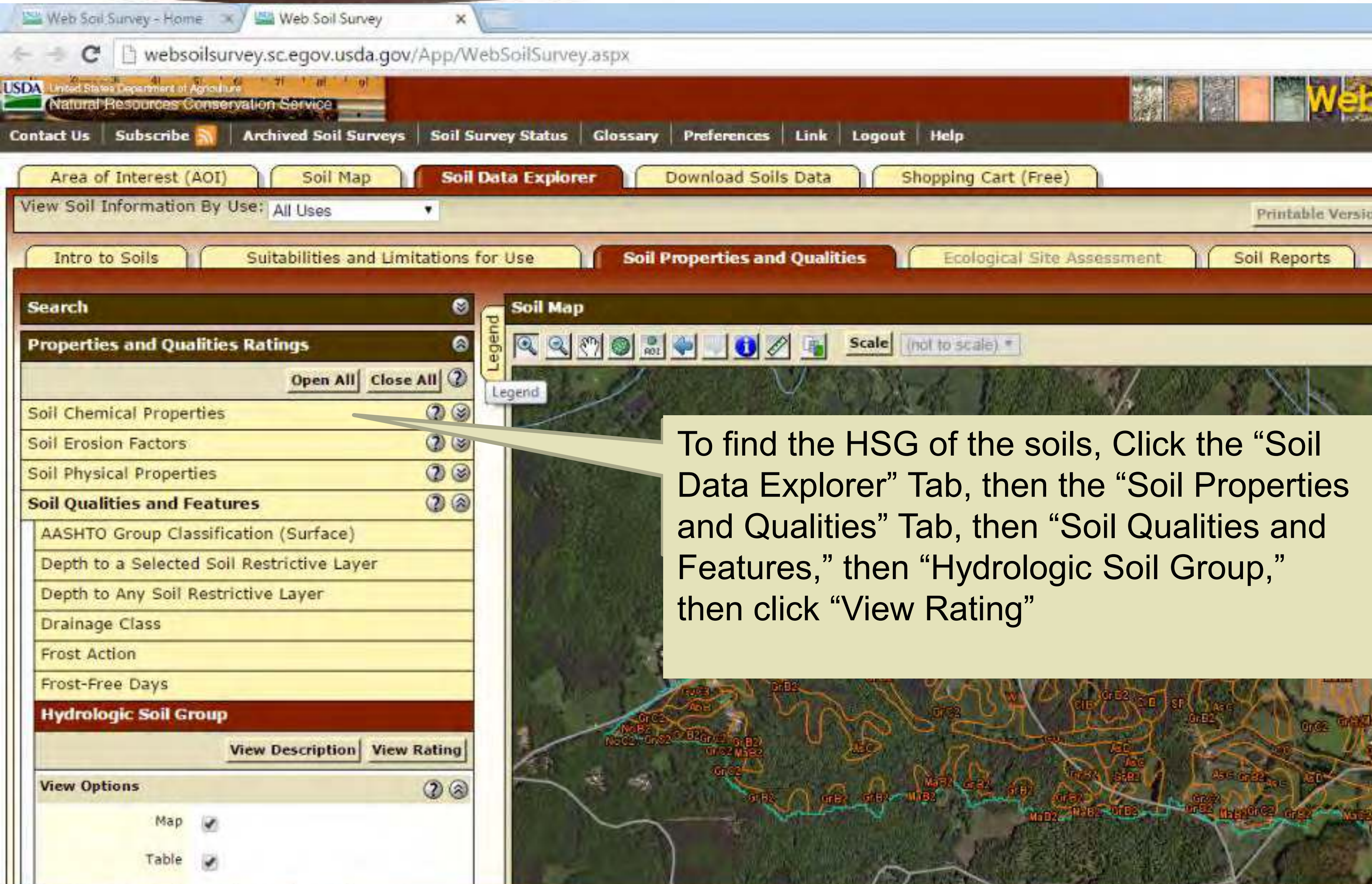

To find the HSG of the soils, Click the “Soil Data Explorer” Tab, then the “Soil Properties and Qualities” Tab, then “Soil Qualities and Features,” then “Hydrologic Soil Group,” then click “View Rating”

What are HSGs?

Description

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

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Hydrologic Soil Group— Summary by Map Unit XXX County, Virginia (VA113)				
Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
BeD	Brandywine loam, very deep, 15 to 25 percent slopes	A	3.3	3.0%
BeF	Brandywine loam, very deep, 25 to 45 percent slopes	A	3.6	3.2%
BnF	Brandywine stony loam, very deep, 25 to 50 percent slopes	A	11.2	10.1%
DkC2	Dyke loam, 7 to 15 percent slopes, eroded	B	5.1	4.6%
ElC2	Elioak fine sandy loam, 7 to 15 percent slopes, eroded	B	0.6	0.5%
EmD2	Elioak loam, 15 to 25 percent slopes, eroded	B	2.3	2.1%
EyC	Eubanks-Lloyd loams, 7 to 15 percent slopes	A	2.2	2.0%
EyC2	Eubanks-Lloyd loams, 7 to 15 percent slopes, eroded	A	10.0	9.1%
EyD2	Eubanks-Lloyd loams, 15 to 25 percent slopes, eroded	A	0.5	0.5%
GlC2	Glenelg loam, 5 to 15 percent slopes, eroded	B	0.6	0.5%
HaC	Hazel loam, 7 to 15 percent slopes	B	2.1	1.9%
HaD	Hazel loam, 15 to 25 percent slopes	B	18.4	16.6%
HaF	Hazel loam, 25 to 55 percent slopes	B	37.2	33.7%
LoD	Louisburg sandy loam, 15 to 25 percent slopes	A	3.0	2.7%
MvB	Meadowville loam, 2 to 7 percent slopes	A	10.5	9.5%
Totals for Area of Interest			110.7	100.0%

Results

HSG	Total Percentage
A	40.1
B	59.9
C	0
D	0

Add the “like” HSGs together to determine the total acreage of each HSG in the drainage area.

EFH-2

EFH2 Limitations

- Watershed is accurately represented by a single runoff curve number between 40 and 98.
- Watershed area is between 1 and 2,000 acres.
- Watershed length is between 200 and 26,000 feet.
- Average watershed slope is between 0.5 and 64%.
- No valley or reservoir routing is required.
- Urban land use within the watershed does not exceed 10%.

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EFH2 Inputs

Input	Units	Description
Drainage Area	Acres	Area draining to proposed culvert location
Curve Number	-	EFH-2 has a curve number calculating tab – you input the breakdown of area by HSG and land use
Watershed Length	Feet	Length of longest flow path from watershed boundary to outlet (culvert location)
Watershed Slope	Percent	Average slope of WATERSHED – NOT slope of flow path
Rainfall Information	-	Electronic files available by county, OR get pinpoint accurate data from NOAA PFDS

This is different from most other hydrologic methods and is the most commonly seen problem in EFH2 calculations

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
BeD	Brandywine loam, very deep, 15 to 25 percent slopes	A	3.3	3.0%
BeF	Brandywine loam, very deep, 25 to 45 percent slopes	A	3.6	3.2%
BnF	Brandywine stony loam, very deep, 25 to 50 percent slopes	A	11.2	10.1%
DkC2	Dyke loam, 7 to 15 percent slopes, eroded	B	5.1	4.6%
ElC2	Elioak fine sandy loam, 7 to 15 percent slopes, eroded	B	0.6	0.5%
EmD2	Elioak loam, 15 to 25 percent slopes, eroded	B	2.3	2.1%
EyC	Eubanks-Lloyd loams, 7 to 15 percent slopes	A	2.2	2.0%
EyC2	Eubanks-Lloyd loams, 7 to 15 percent slopes, eroded	A	10.0	9.1%
EyD2	Eubanks-Lloyd loams, 15 to 25 percent slopes, eroded	A	0.5	0.5%
GlC2	Glenelg loam, 5 to 15 percent slopes, eroded	B	0.6	0.5%
HaC	Hazel loam, 7 to 15 percent slopes	B	2.1	1.9%
HaD	Hazel loam, 15 to 25 percent slopes	B	18.4	16.6%
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LoD	Louisburg sandy loam, 15 to 25 percent slopes	A	3.0	2.7%
MvB	Meadowville loam, 2 to 7 percent slopes	A	10.5	9.5%
Totals for Area of Interest			**110.7**	**100.0%**

Average Watershed Slope

Average watershed slope

The average watershed slope (Y) is the slope of the land and not the watercourse. It can be determined from soil survey data or topographic maps. Hillside slopes can be measured with a hand level, Locke level, or clinometer in the direction of overland flow. Average watershed slope is an average of individual land slope measuremdnts.

The soils report can also be used to estimate the average "Watershed Slope" for EFH2.

Calculate a weighted average of the slope of the soil types in the watershed.

Watershed Slope

(A) Slope Range of Soil Type	(B) Avg. Slope of Soil Type	(C) Total Percentage of Area	(D) Decimal Percentage	(E) Weighted Slope
2-7%	5%	9.5	0.095	0.48
7-15%	11%	16.1	0.161	1.77
5-15%	10%	0.5	0.005	0.05
15-25%	20%	26.9	0.269	5.38
25-55%	40%	33.7	0.337	13.5
25-45%	35%	3.2	0.032	1.12
25-50%	38%	10.1	0.101	3.84
			Total: **(Average Slope):**	**26.1**

Column B: Average the slope range in Column A
Column C: Add together the "Percent of AOI" of all of the soil types with this slope range
Column D: Column C/100
Column E: Multiply Columns B and D

Curve Number Calculation

COVER DESCRIPTION		Percent (CN)			
		Hydrologic Soil Group			
		A	B	C	D
OTHER AGRICULTURAL LANDS					
Pasture, grassland or range	poor	16.04(68)	23.96(79)	-	-
Woods	fair	24.06(36)	35.94(60)	-	-
Total Area (by Hydrologic Soil Group)		40.1	59.9		
TOTAL DRAINAGE AREA: 100 Percent		WEIGHTED CURVE NUMBER: 60			

Consider:

-The 2-yr storm is most likely to happen during summer months (thunderstorm), so it may be conservative to consider land cover conditions expected during summer.

-If cropland, consider early July when straw is baled, or April/May for full tillage corn

-If pasture, consider the “summer slump” of cool-season forages

-Think about management tendencies of the landowner.

-If you know of imminent land development, go ahead and factor it in to your calculation.

Rainfall Information

- More accurate (site-specific) precipitation data can be obtained from NOAA at: http://hdsc.nws.noaa.gov/hdsc/pfds/index.html

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

PDS-based precipitation frequency estimates with 90% confidence intervals (i

Duration	Average recurrence interval (years)							
	1	2	5	10	25	50	100	2
5-min	0.343 (0.310–0.378)	0.410 (0.372–0.454)	0.485 (0.438–0.536)	0.549 (0.496–0.606)	0.622 (0.557–0.685)	0.679 (0.606–0.747)	0.735 (0.651–0.808)	0. (0.69
10-min	0.546 (0.494–0.604)	0.654 (0.593–0.723)	0.774 (0.700–0.856)	0.872 (0.786–0.963)	0.986 (0.884–1.09)	1.08 (0.960–1.19)	1.16 (1.03–1.28)	1 (1.05
15-min	0.680 (0.616–0.752)	0.819 (0.742–0.906)	0.975 (0.881–1.08)	1.10 (0.991–1.22)	1.24 (1.12–1.37)	1.36 (1.21–1.49)	1.46 (1.30–1.61)	1 (1.37
30-min	0.929 (0.840–1.03)	1.13 (1.02–1.25)	1.38 (1.25–1.52)	1.58 (1.43–1.75)	1.83 (1.64–2.02)	2.03 (1.81–2.23)	2.22 (1.97–2.44)	2 (2.12
60-min	1.16 (1.05–1.28)	1.41 (1.28–1.56)	1.76 (1.59–1.95)	2.06 (1.85–2.27)	2.43 (2.18–2.68)	2.74 (2.44–3.01)	3.05 (2.70–3.36)	3 (2.96
2-hr	1.38 (1.24–1.54)	1.68 (1.50–1.87)	2.11 (1.89–2.35)	2.48 (2.22–2.77)	2.97 (2.64–3.31)	3.38 (2.98–3.77)	3.81 (3.34–4.23)	4 (3.70
3-hr	1.51 (1.35–1.70)	1.83 (1.63–2.07)	2.30 (2.04–2.60)	2.70 (2.39–3.05)	3.23 (2.84–3.64)	3.69 (3.22–4.14)	4.16 (3.61–4.67)	4 (4.01
6-hr	1.92 (1.71–2.18)	2.32 (2.06–2.64)	2.89 (2.55–3.28)	3.40 (3.00–3.86)	4.09 (3.58–4.63)	4.70 (4.08–5.32)	5.34 (4.58–6.05)	6 (5.12
12-hr	2.40 (2.13–2.73)	2.89 (2.57–3.30)	3.61 (3.20–4.11)	4.27 (3.76–4.85)	5.19 (4.54–5.89)	6.02 (5.20–6.82)	6.92 (5.91–7.83)	7 (6.67
24-hr	2.95 (2.65–3.31)	3.57 (3.21–4.01)	4.55 (4.08–5.10)	5.37 (4.80–6.02)	6.58 (5.85–7.36)	7.62 (6.72–8.50)	8.76 (7.67–9.76)	1 (8.65

- Enter the lat. & long. for the site and it will give you the rainfall amounts for different storm events
- Can be entered manually into EFH2

Client: Example
County: State: VA
Practice: Culvert Crossing
Calculated By: RC Date: 4/6/2016
Checked By: __________ Date: __________

Drainage Area:	132	Acres	(user entered value)
Curve Number:	60		(provided from RCN Calculator)
Watershed Length:	2158	Feet	
Watershed Slope:	26.3	Percent	
Time of Concentration:	0.33	Hours	(calculated value)
Rainfall Type:	II		

Storm Number	1	2	3	4	5	6	7
Frequency (yrs)	1	2	5	10	25	50	100
24-Hr rainfall (in)	2.90	3.50	4.40	5.30	6.50	7.50	8.60
Ia/P Ratio	00.46	00.38	00.30	00.25	00.21	00.18	00.16
Used	00.46	00.38	00.30	00.25	00.21	00.18	00.16
Runoff (in)	.30	.53	.97	1.48	2.26	2.96	3.79
(ac-ft)	03.30	05.83	10.67	16.28	24.86	32.56	41.69
Unit Peak Discharge (cfs/acre/in)	00.544	00.715	00.849	00.892	00.928	00.950	00.968
Peak Discharge (cfs)	21	50	108	174	276	371	484

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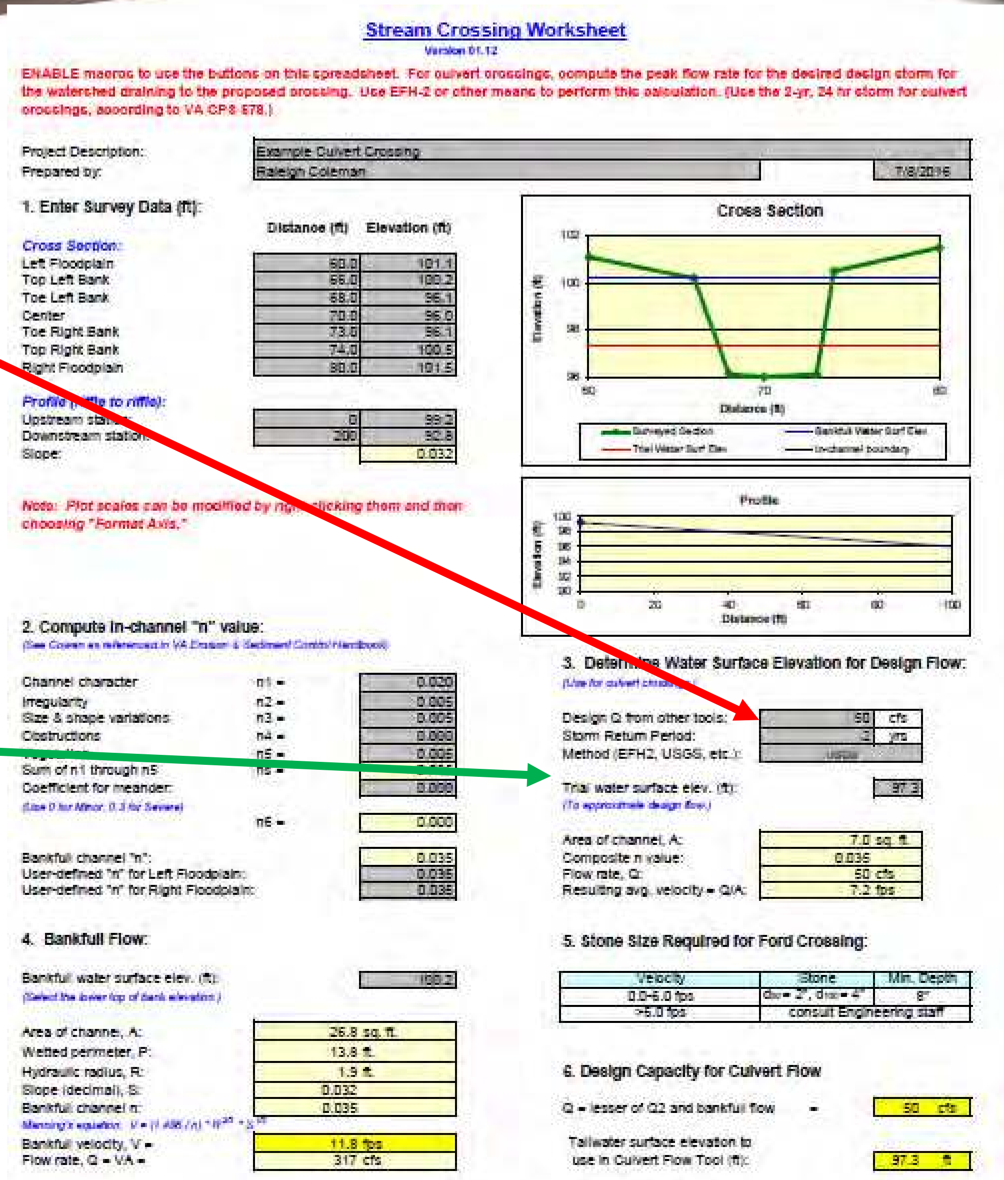
- After you have calculated the 2-yr, 24-hr discharge using the USGS method or EFH-2, plug these values back into the "Stream Crossing Worksheet."
- The worksheet will pick the lesser of the two (bankfull flow vs. "design Q from other tools") as the design capacity for the culvert
- Enter trial elevations in the "Trial water surface elevation" box until the flow rate is approximately the same as the value you entered in the "Design Q" box above.
  - This will be used for your tailwater depth in the "Culvert Flow Tool."



Now that we know the capacity that the culvert must pass, we can start to design the culvert and perform hydraulic calculations.

Culverts 101

Culvert Materials

VA-578: Acceptable culvert materials include concrete, corrugated metal, corrugated plastic, new or used high quality steel, and any others materials that meet the requirements of VA NRCS CPS *Structure for Water Control (Code 587).*

- Double-wall High Density Polyethylene (HDPE)
  - Construction Spec. VA-745 Plastic Pipe
- Corrugated Metal Pipe (CMP)
  - Construction Spec. VA-751 Corrugated Metal Pipe
- Reinforced Concrete Pipe (RCP)
  - Construction Spec. VA-757 Concrete Pipe

Advantages/Disadvantages of Culvert Types

	Advantages	Disadvantages
HDPE	Easy to install (lightweight), long lifespan (chemically inert), low Manning's n = high conveyance	Buoyancy problems (lightweight); easily crushed if not backfilled properly; difficult to couple pipes together
RCP	Less likely to experience buoyancy problems; long lifespan; moderate Manning's n	Difficult to install (heavy)
CMP	Relatively easy to install	Short lifespan (corrosion); highest Manning's n = lowest conveyance

Deciding on Culvert Material

- Web Soil Survey has features for "Corrosion of Concrete" and "Corrosion of Steel"
- Soil Data Explorer → Suitabilities and Limitations for Use → Building Site Development → Corrosion of Concrete/Corrosion of Steel

You don’t necessarily need to specify the culvert material in the design unless you have a specific reason. You can simply specify the length and diameter and include the construction specs. for all three types.

*Be sure to run hydraulic calculations for the *highest* Manning’s “n” of any of the options that you specify (typically CMP).

Calculating the Hydraulic Capacity of Culverts

How much flow will the culvert carry?

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Culvert Hydraulic Capacity

- Depends on whether the culvert is under *inlet control* or *outlet control*
- Do these factors matter in inlet vs. outlet control?

Factor	Inlet Control	Outlet Control
Slope	Yes	Yes
Roughness of Culvert	Yes	Yes
Diameter of Culvert	Yes	Yes
Inlet Shape	Yes	Yes
Headwater	Yes	Yes
Tailwater	NO	Yes
Length of Culvert	NO	Yes

Inlet vs. Outlet Control

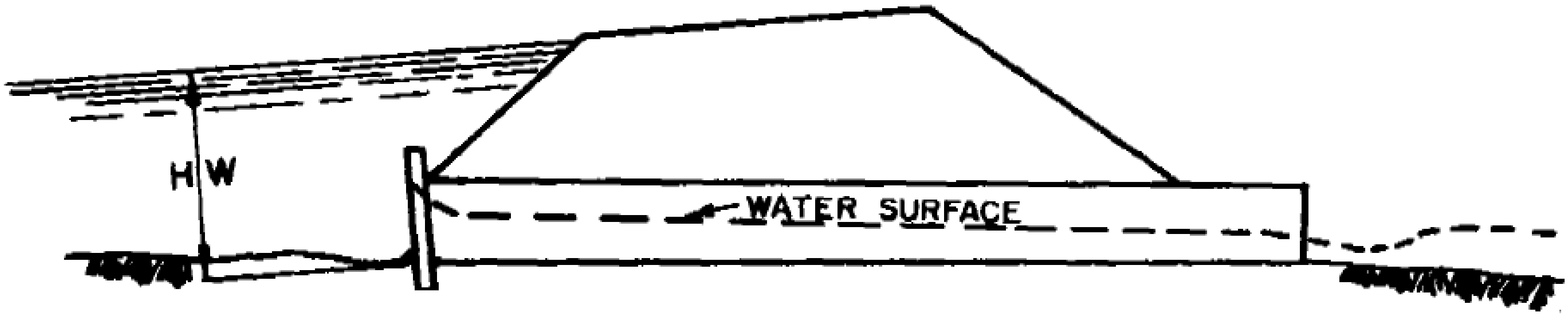


Figure 3-7 Culverts with inlet control

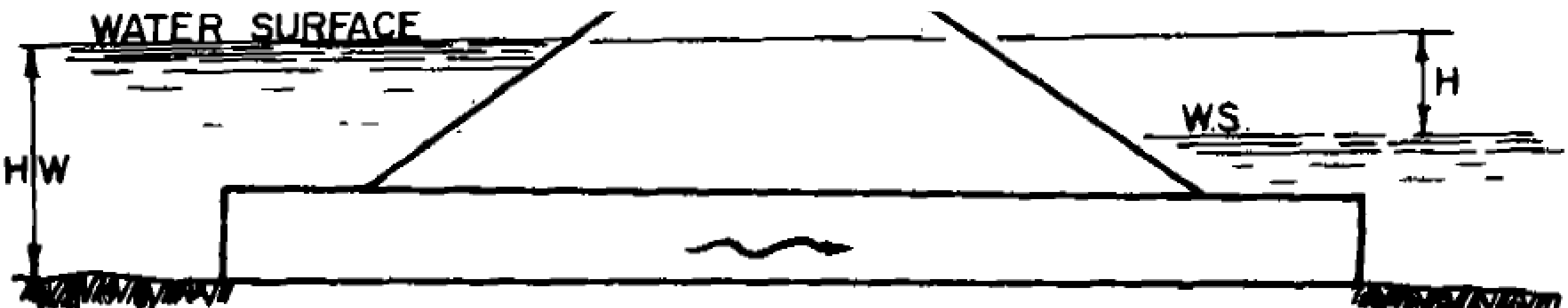
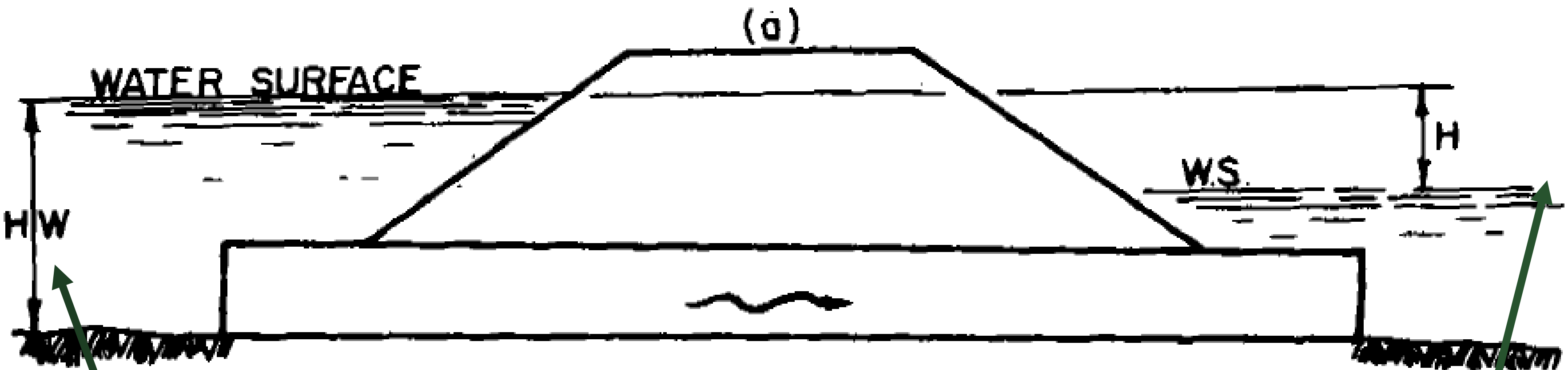


Figure 3-8 Culverts with outlet control

Headwater and Tailwater



- **Headwater**: Maximum elevation that water can "stack" at the inlet before it starts to flow over or around the culvert
- **Tailwater:** Depth of water at the outlet

Headwater

- The headwater elevation will be unique for each site
- Should be the low point in the “spillway” that will be created for the culvert
- Determine once you plot the stream crossing profile (see example, to follow)

Tailwater

- See the “Stream Crossing Worksheet”

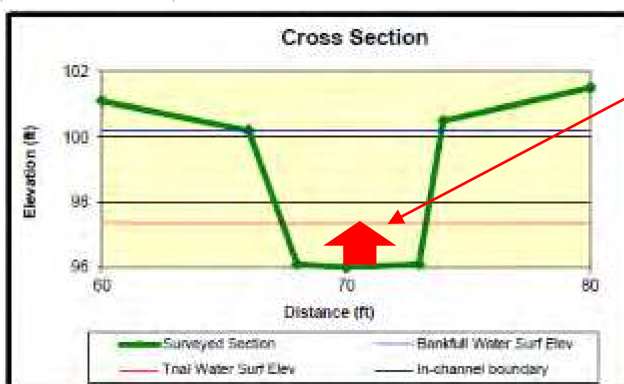
6. Design Capacity for Culvert Flow		
Q = lesser of Q2 and bankfull flow =	50	cfs
Tailwater surface elevation to use in Culvert Flow Tool (ft):	97.3	ft

1. Enter Survey Data (ft):	Distance (ft)	Elevation (ft)
Cross Section:		
Left Floodplain	60.0	101.1
Top Left Bank	66.0	100.2
Toe Left Bank	68.0	96.1
Center	70.0	96.0
Toe Right Bank	73.0	96.1
Top Right Bank	74.0	100.5
Right Floodplain	80.0	101.5

The water for this site will be flowing at elevation 97.3ft. during the design flow.

This means that the water will be flowing 1.3ft. deep in the channel.

Tailwater Elevation:	97.3 ft.
Stream Bottom:	-96.0 ft.
Tailwater Depth:	1.3 ft.



- Most culverts in Virginia will be under inlet control if there is sufficient grade in the stream.
- You can begin by assuming Inlet Control to size the culvert; then later use the “NRCS Hydraulics” program to determine if the culvert is actually under inlet or outlet control.

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Sizing the Culvert

- Start with “HW/D” nomograph – page 3-92 in EFH Ch. 3
- This nomograph is for CMP under inlet control
  - CMP will provide conservative flow estimates since it has the highest roughness
  - Inlet control will be confirmed later.

3-92

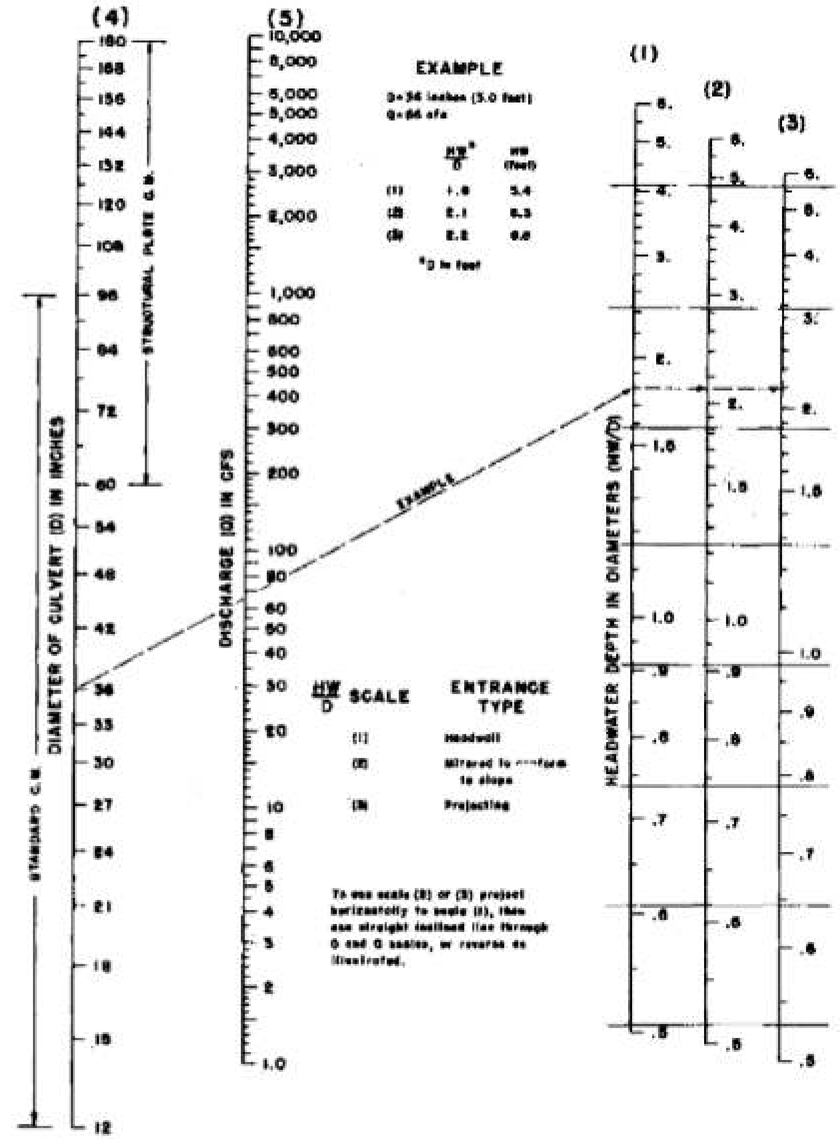


Exhibit 3-10 Headwater depth for CM pipe culverts with inlet control (Ref. Hyd. Eng. Cir. No. 5, USBPR, 1965)

Using the HW/D Nomograph

Three variables:

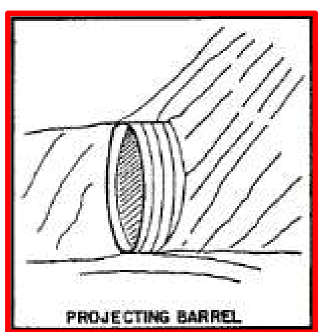
Culvert Diameter

Discharge in CFS

HW/D (for 3 entrance conditions)

→ Use Column (3) for Projecting

If 2 variables are known, the 3rd can be determined



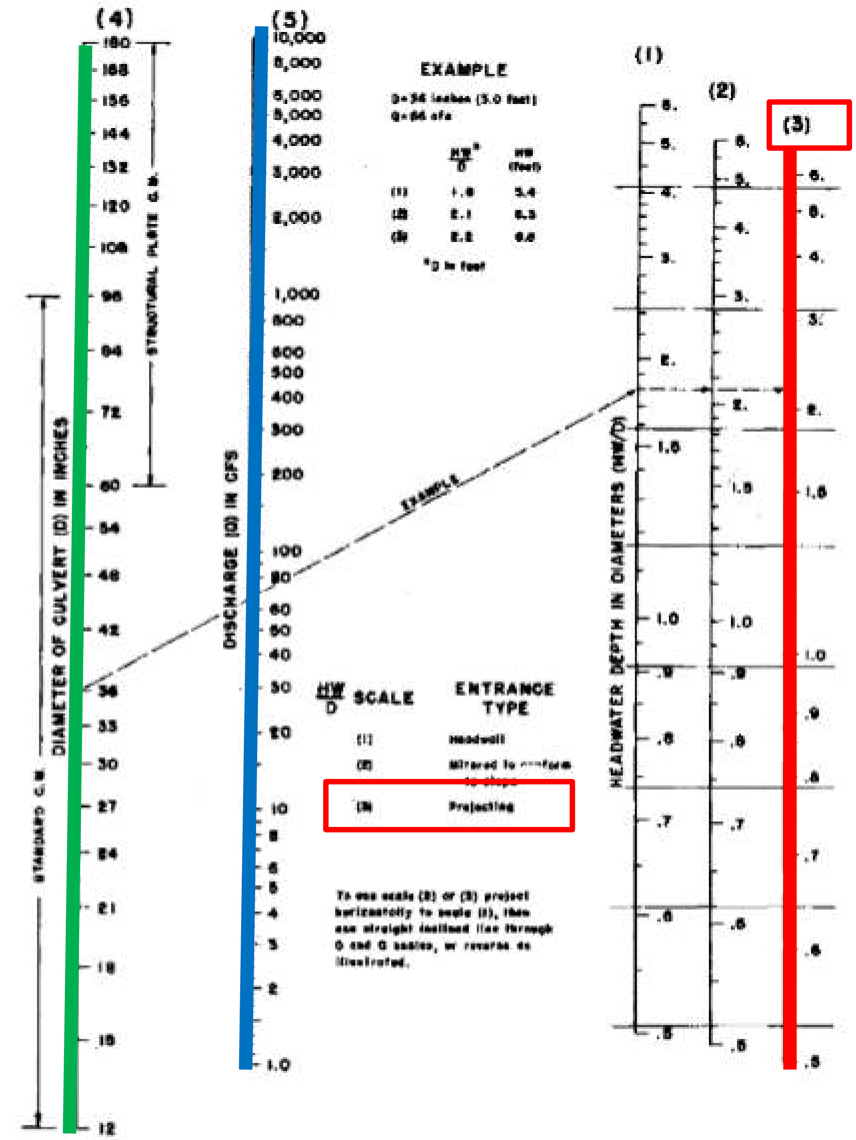
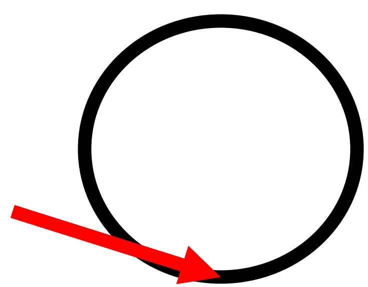


Exhibit 3-10 Headwater depth for CM pipe culverts with inlet control (Ref. Hyd. Eng. Cir. No. 5, USBPR, 1965)

What is “HW/D”?

- HW = Headwater Elevation, in feet above the culvert invert
- D = Culvert Diameter, in feet
- “Headwater depth in diameters”



“HW” = (105’-100’) = 5’

“D” = 36” → 3’

HW/D = 5/3 = **1.67**

*Note: this is a “Stand-alone” example and does not relate to the example featured in the remainder of the presentation.

HW/D : Where to start?

- We don’t know the culvert diameter yet (that’s what we’re trying to find)
- Typically safe to assume a HW/D of at least 1 (meaning water will at least be able to pool up to the top of the culvert)

Example

- Assume HW/D ≥ 1
  - Draw horizontal line to Column 1
- Design Flow: 50cfs
  - Draw line through 50cfs to Column 4
- For this example, a 42” culvert will be too small, unless we can increase the headwater. Proceed with 48” culvert for now. We will need to adjust for the 6” countersink later (see slide 152).

Typically start with a culvert diameter that will fit nicely into your channel.

3-92

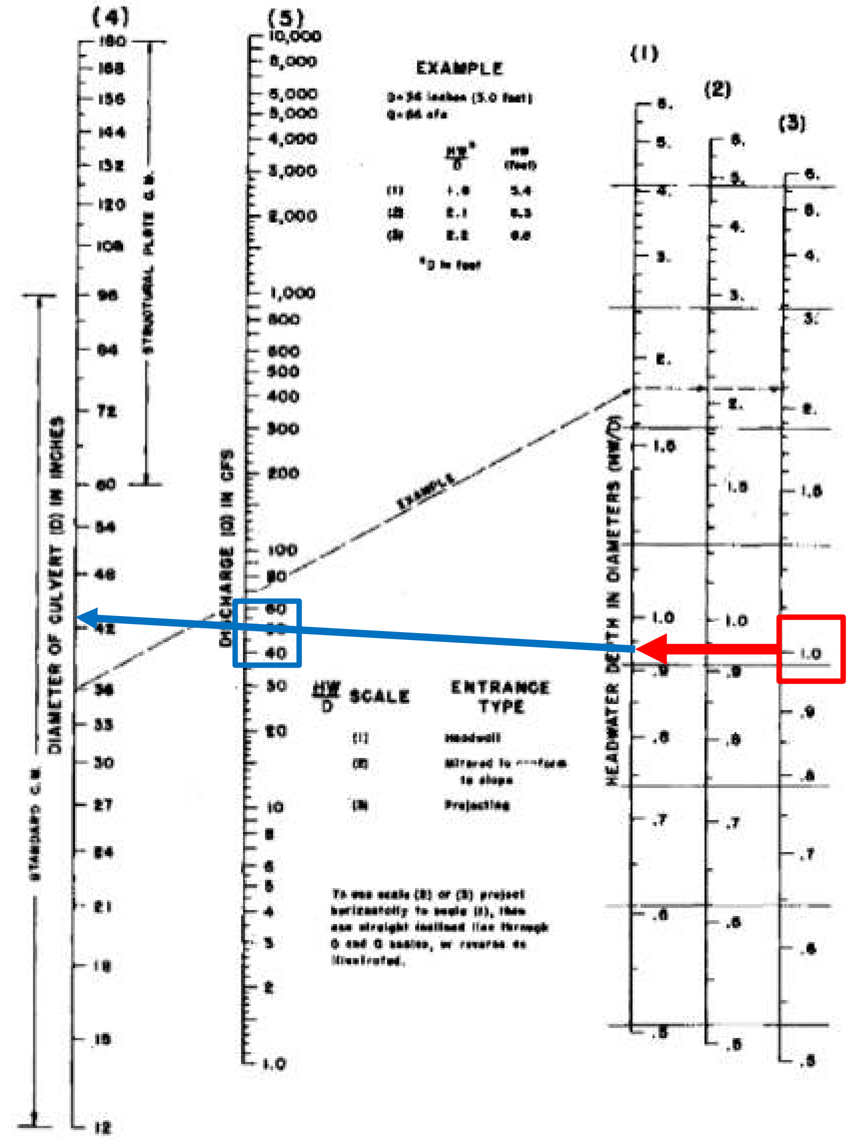


Exhibit 3-10 Headwater depth for CM pipe culverts with inlet control (Ref. Hyd. Eng. Cir. No. 5, USBPR, 1965)

Plot on SC Design Sheets

Plot the proposed crossing centerline profile here. (There is no need to plot the "natural" cross-section in the design.)

Connect survey points with a dashed line for the existing grade.

1" = 10' (horizontal) and 1" = 2' (vertical) typically works well for stream crossings.

Start the vertical elevation at least 1' below the bottom of the stream (so that you can show the culvert 6" below stream bottom and 6" of bedding material).

Stream Crossing Profile

Scale:

Horizontal 1"=

Vertical 1"=

Stream Crossing Design Notes

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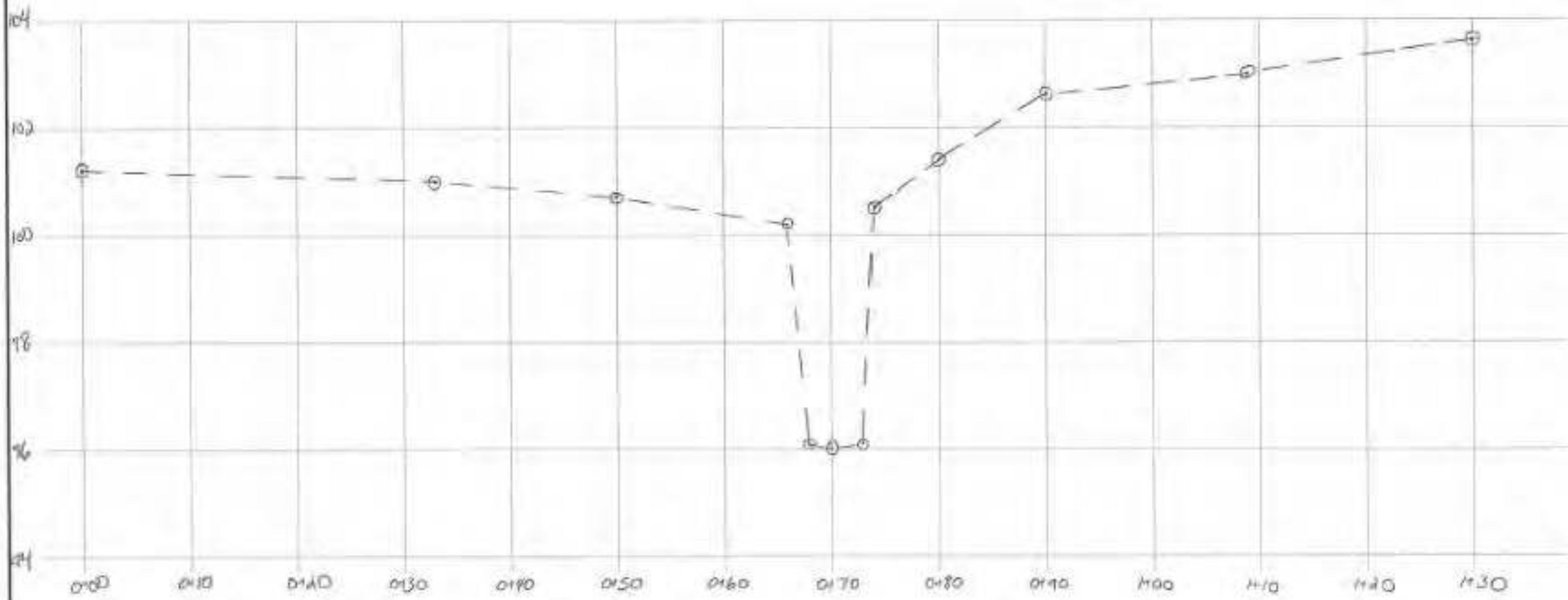


Stream Crossing Profile
(On centerline of crossing)

Scale:
Horizontal 1"= 10' Vertical 1"= 2'

Stream Crossing Design Notes

1. The slope of the approaches (ramps) shall be 6:1 or flatter. (8:1 is recommended)
2. If livestock will have access to the side slopes, then the side slopes shall be armored. If fencing will restrict livestock access, the side slopes may be seeded. Grade side slopes to 3:1 or flatter if they are to be seeded. Grade side slopes to 2:1 if they are to be armored. Armoring shall consist of 6 inches of VDOT #1 (2" to 4") stone over geotextile.
3. If necessary to provide a solid bottom at the crossing, the existing streambed shall be excavated to the depth of the selected Typical Stone Layer (on Sheet 2). Any stone placed to harden the channel bottom must be installed below the existing natural grade of the stream.
4. If no stone is needed to harden the stream bottom, then the stone on the ramps shall be placed so that the ramps blend naturally into the streambed. A 2'x2' rock key may be placed at the end of each ramp to provide toe protection. Do not place any stone that will obstruct the natural flow path of the stream.
5. Excavated material shall be spread outside of the floodplain.
6. Geotextile shall meet the Class I requirements for nonwoven geotextile in Virginia Construction Specification VA-795 Geotextiles. Class II may be used with engineers approval.
7. Seed all disturbed areas according to the Attachment to Virginia Construction Specification VA-706, Seeding.

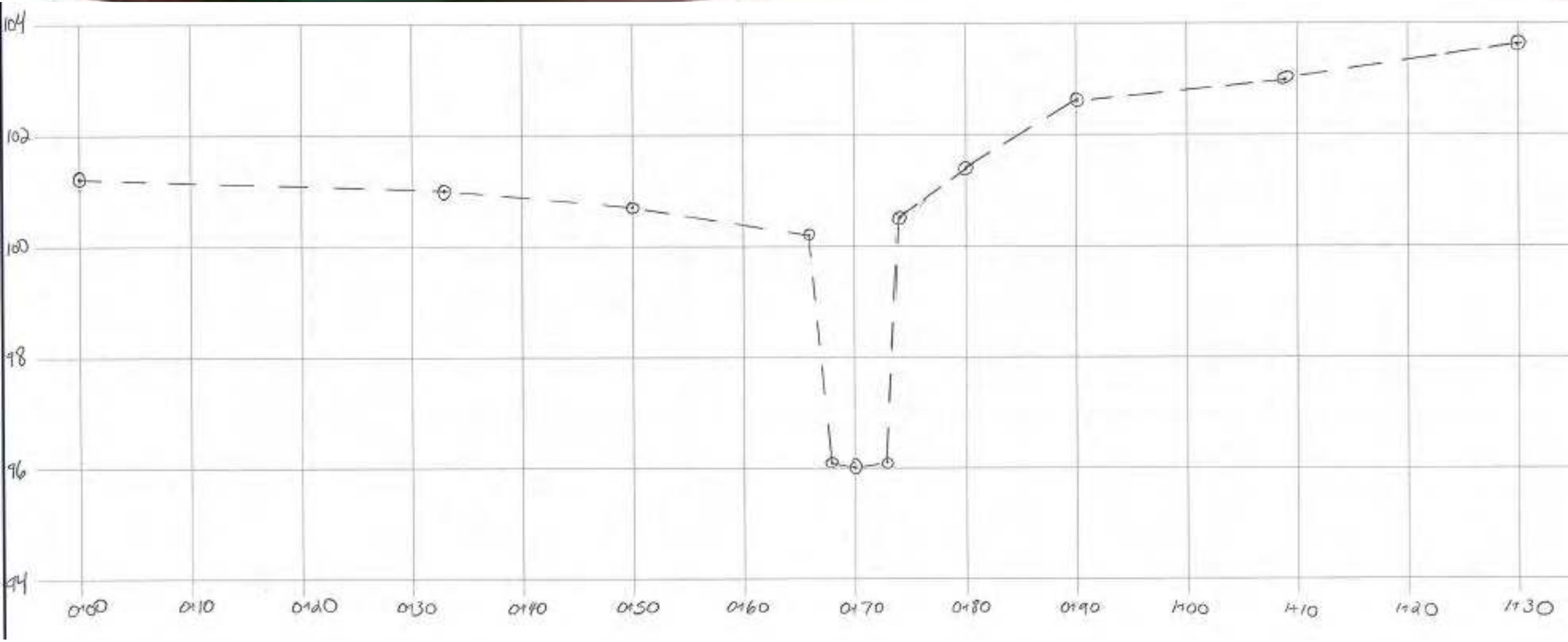
Stream Crossing Detail
Example Culvert Crossing

DCR

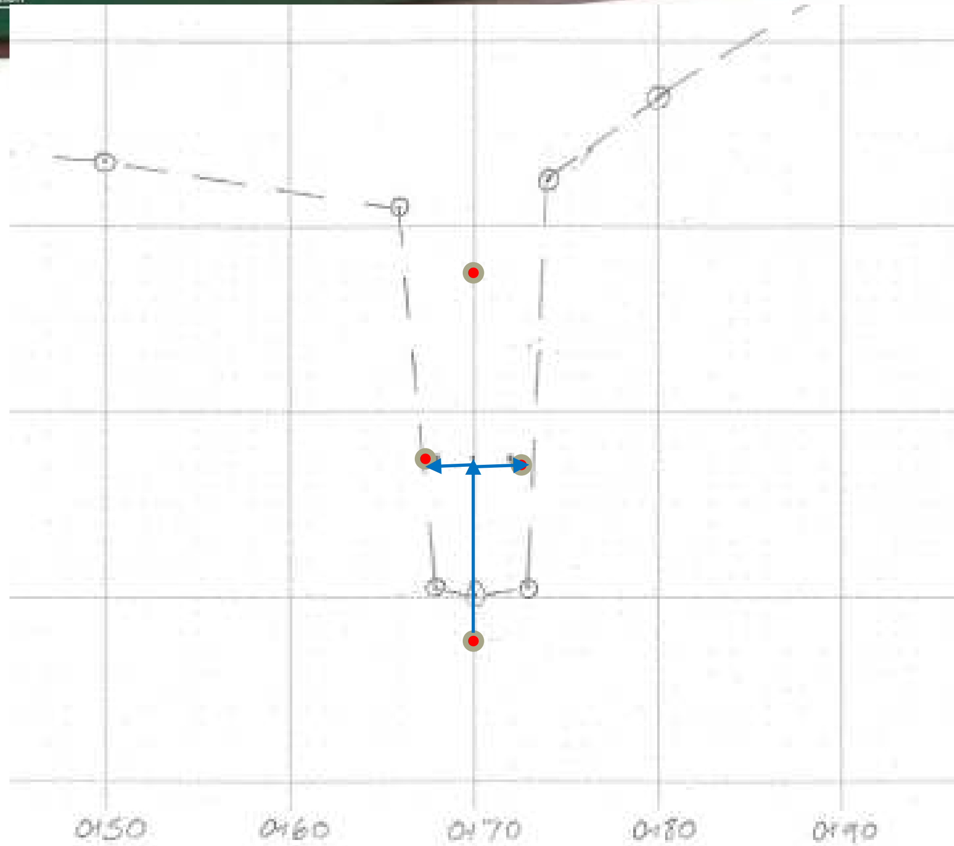
This drawing adapted from NRCS Standard Drawing VA-SD-801 v2.1.1

Drawing Name

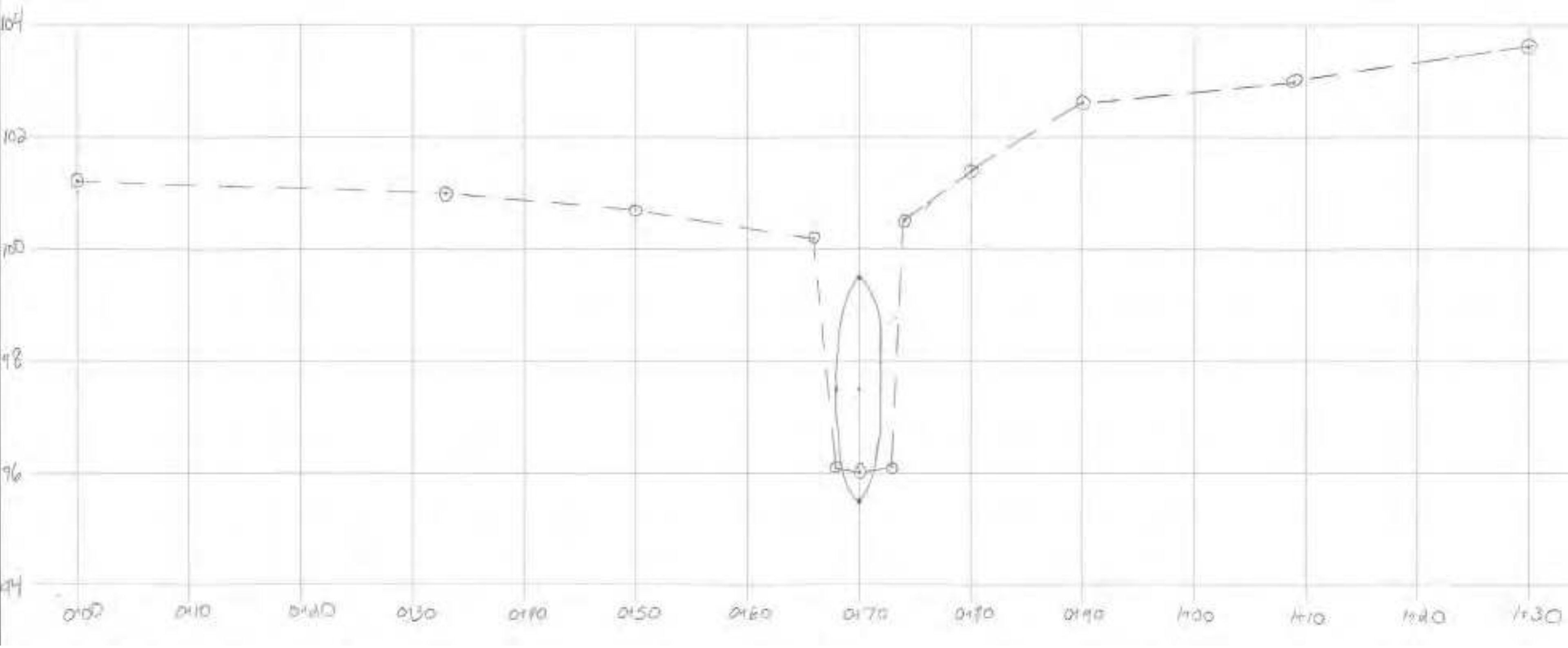
Sheet of



1. Plot the points from the survey.
2. Connect the points with a dashed line. Dashed lines represent existing grades. Final grades (if different than existing grades) will be shown with solid lines.



3. Start to draw the culvert based on your preliminary HW/D results. This can be tricky because the horizontal and vertical scales are different.
   a. Draw a point 6” below the centerline of the channel. This will be the culvert invert.
   b. Draw a point the culvert’s diameter above the first point. This will represent the top of the culvert. In this case, the diameter is 48”, so the point will be drawn 4’ above the invert.
   c. From the vertical center of the culvert, draw a point half of the diameter in either direction. These points will represent the sides of the culvert.



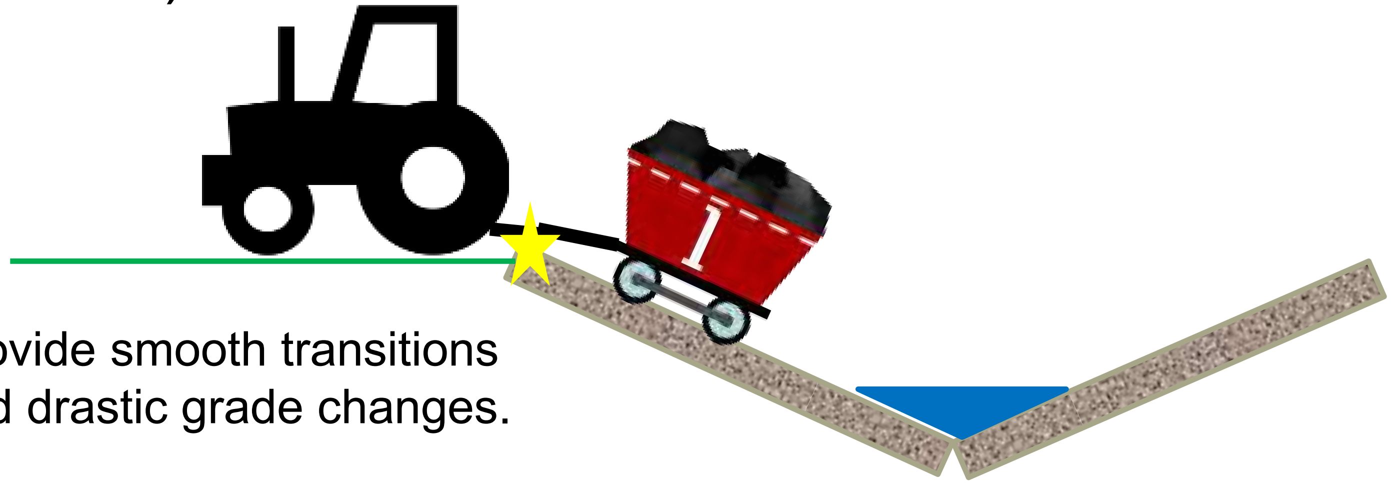
4. Connect the dots to illustrate the culvert.

Drawing the Earthfill

- The final grade you choose will depend on the planned use and existing site conditions (slopes and soil investigation)
- VA-578: “Make the approaches stable, with gradual ascent and descent grades which are not steeper than 6 horizontal to 1 vertical (6:1).”
- 8:1 is recommended for crossings that will also serve vehicles and tractors

Determine Ramp Slope/Final Grades

- Beware of problems that can occur if there is a drastic grade change at the point of daylight (if excavating to achieve a 6:1) or at the crest of fill material.

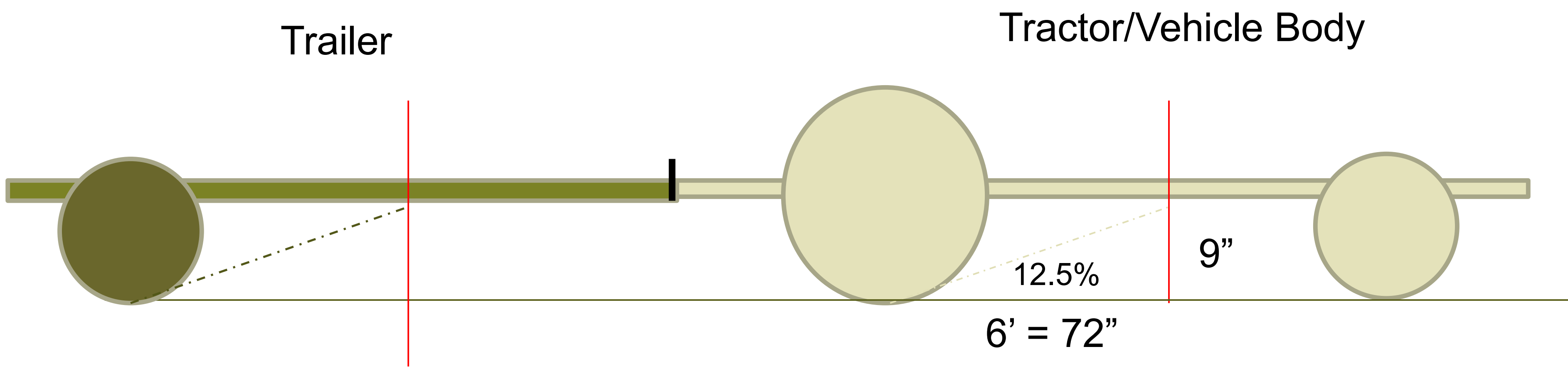


Try to provide smooth transitions and avoid drastic grade changes.

- VA-578: “Configure the crossing approaches (gradient and curves) to properly accommodate the lenngth and turning radii of vehicles using the crossing.”

Determining Max. Gradient Change without Bottoming Out

(at top of ramps)



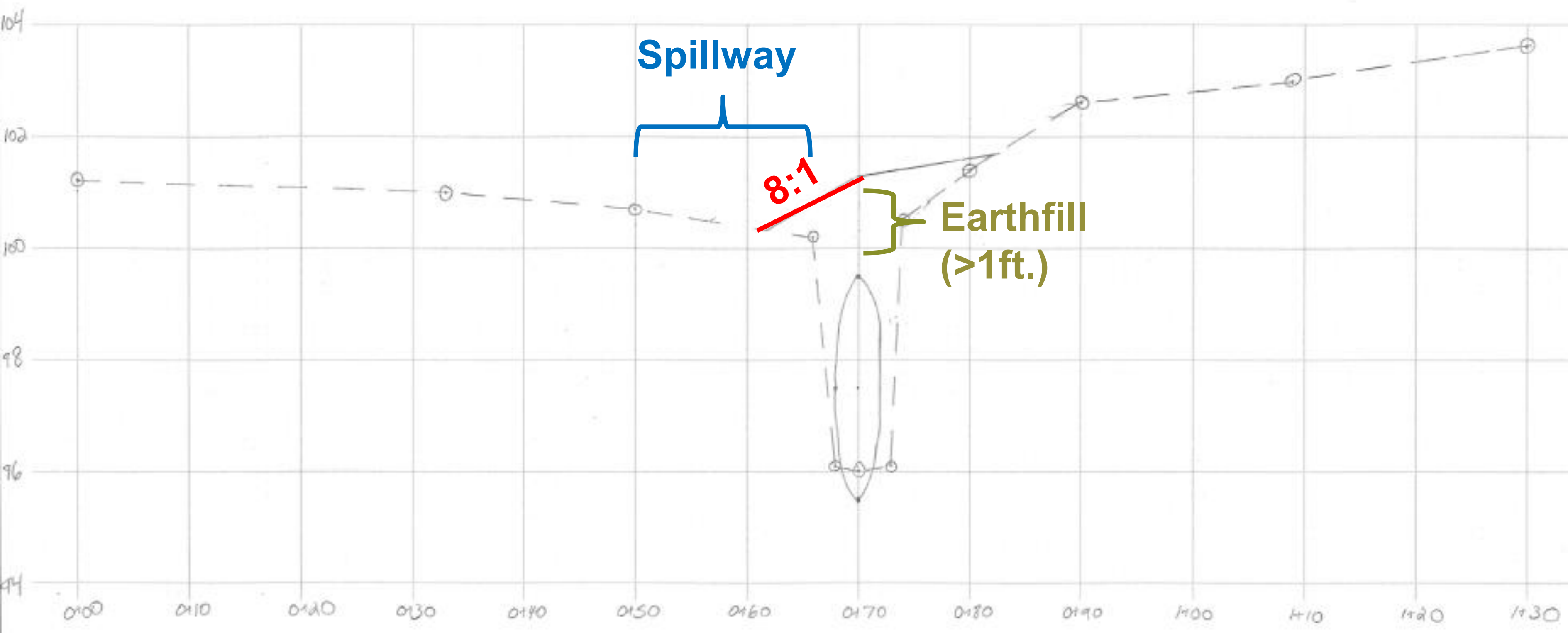
1. Find mid-point of vehicle or mid-point of trailer (i.e. halfway between axles for tractor or axle & hitch for trailer)
2. Measure height of lowest point at midpoint
3. Calculate slope by comparing the halfway length to the chassis height. This is the maximum grade change that could occur without bottoming out when going over break point at top of ramp.

Ex: 9”/72” = 0.125 = 12.5% = 8:1 → Max. Grade Change at top of ramp can be 8:1 or 12.5%

*NOTE: This is generally a *conservative* approach for trailers because of extra clearance provided by the tongue.

Slide adapted from one provided by Keith Burgess, Monacan SWCD

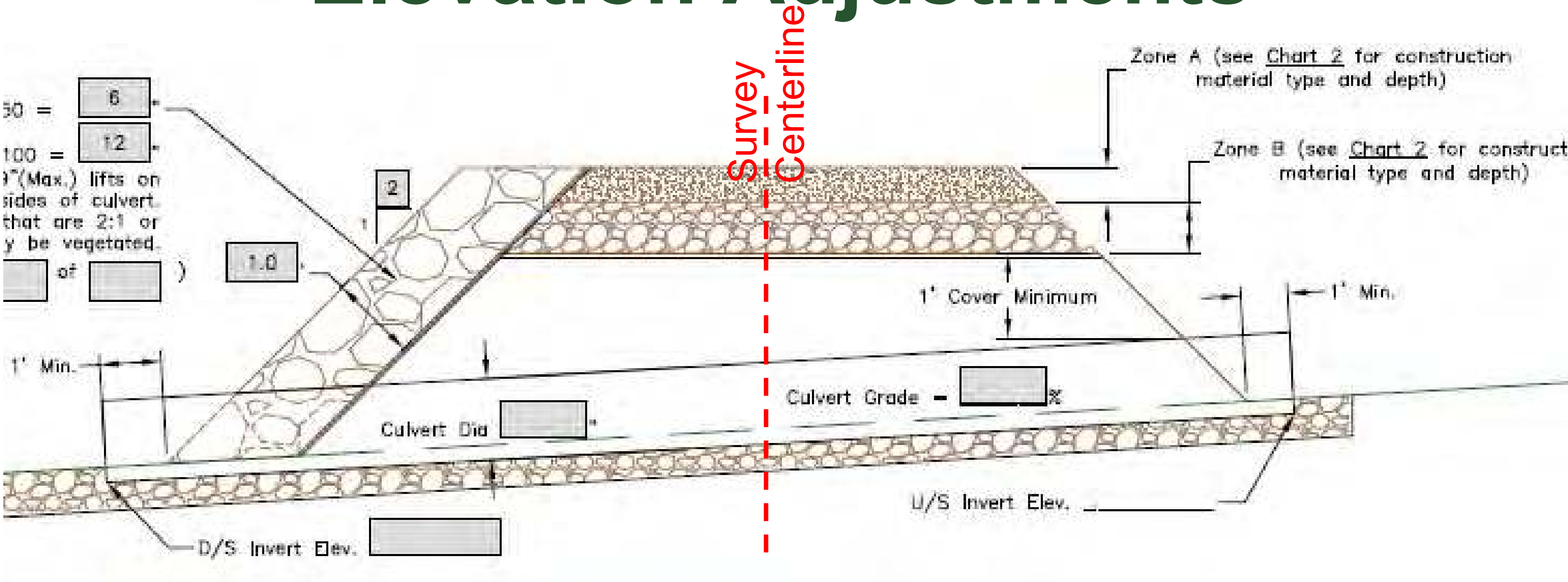
Here’s a landowner-installed culvert that shows the problem with hard angles on the crossing surface. Most vehicles will bottom out on this crossing.



5. Show the earthfill over the culvert. A minimum of 1' of earthfill is required. Make sure to keep all grades 6:1 or flatter (8:1 or flatter is recommended). Also try to avoid showing hard angles in lines, which will create points where vehicles can bottom out or trailer necks can drag. (These earthfill lines create strange angles at the moment, but once the stone layers are added, it will make sense.

More than one foot of earthfill is shown on this centerline profile because…

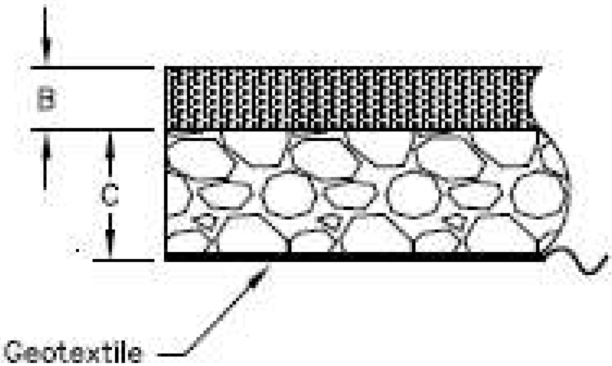
Elevation Adjustments



- The survey that was conducted was for the centerline of the crossing. If the top of the crossing is level and the culvert is installed at the grade of the stream, then more than 1ft. of fill will be needed at the centerline of the crossing to ensure 1ft. of fill at the upstream edge of the crossing.
- You'll also need to do math to determine the upstream invert, downstream invert, and tailwater depth because of this same principle.

Stone Layers

For All Streams Flowing 6fps or Less



The stone layers are identical to those for ford crossings because the culvert is only sized for the 2-yr or bankfull flow and will likely be overtopped fairly frequently.

For Streams Flowing 6fps or Less		
Layer	Material Type	Layer Depth
B	VDOT #57 or #357	3”
C	VDOT #1	6” Minimum (8” Recommended)

Recommend avoiding “clean” or “washed” stone; specifying a “well-graded” stone will aid in packing/ aggregation and result in a better crossing.

*May be capped with optional 2” of Crusher Run/VDOT #21A

Sizes of Open-Graded Coarse Aggregates

Va. Size No.	% Passing Sieve Openings														
	4 in.	3 1/2 in.	3 in.	2 1/2 in.	2 in.	1 1/2 in.	1 in.	3/4 in.	1/2 in.	3/8 in.	No. 4	No. 8	No. 16	No. 50	No. 100
1	Min 100	90–100		25–60		Max. 15		Max. 5							
2			Min. 100	95–100	35–70	Max. 15		Max. 5							
3				Min. 100	90–100	35–70	0–15		Max. 5						
357				Min. 100	90–100		35–70		10–30		Max. 5				
57						Min. 100	95–100		25–60		Max. 10	Max. 8			
78								Min. 100	90–100	40–75	5–25	Max. 10	Max. 5		

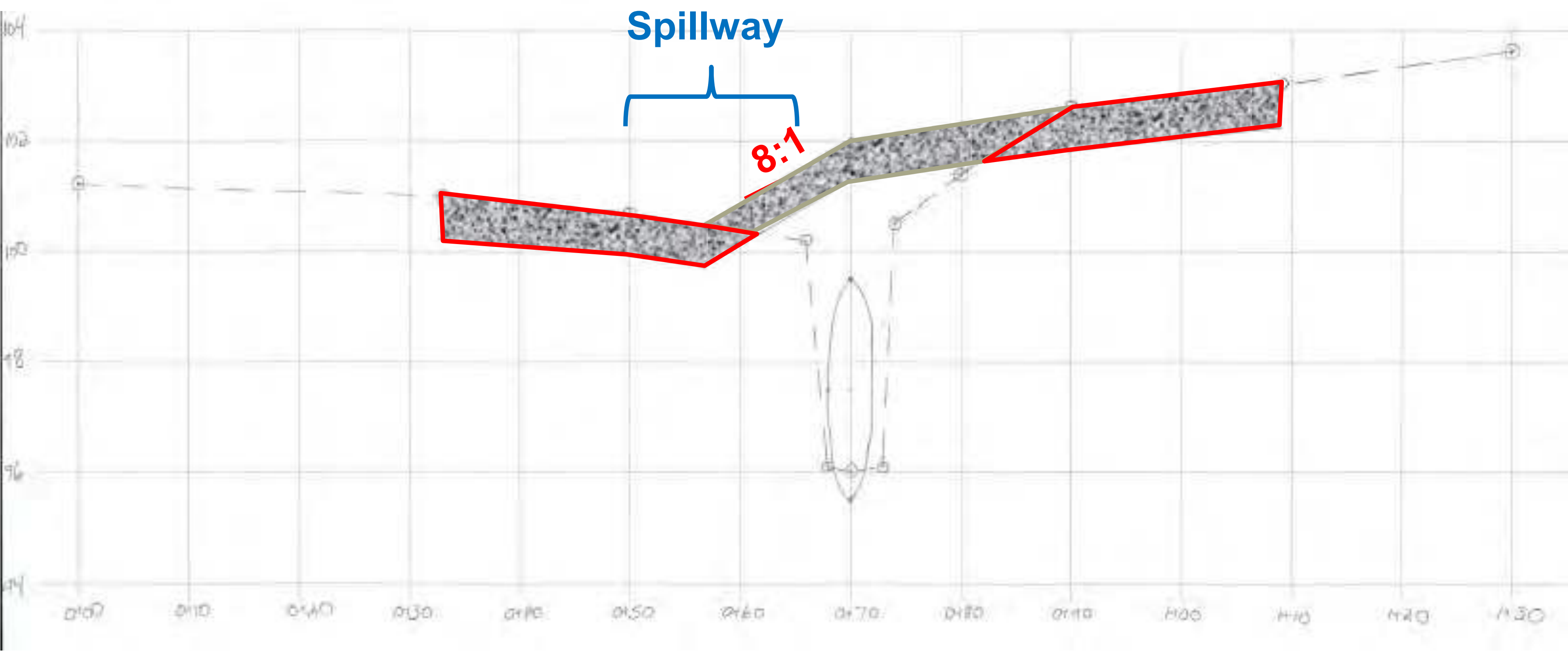
* From VDOT Road and Bridge Specifications, 2007

Due to variations in sizing from one quarry to another, refer to chart above for proper stone sizing when ordering stone.

Stone Sizing Schedule

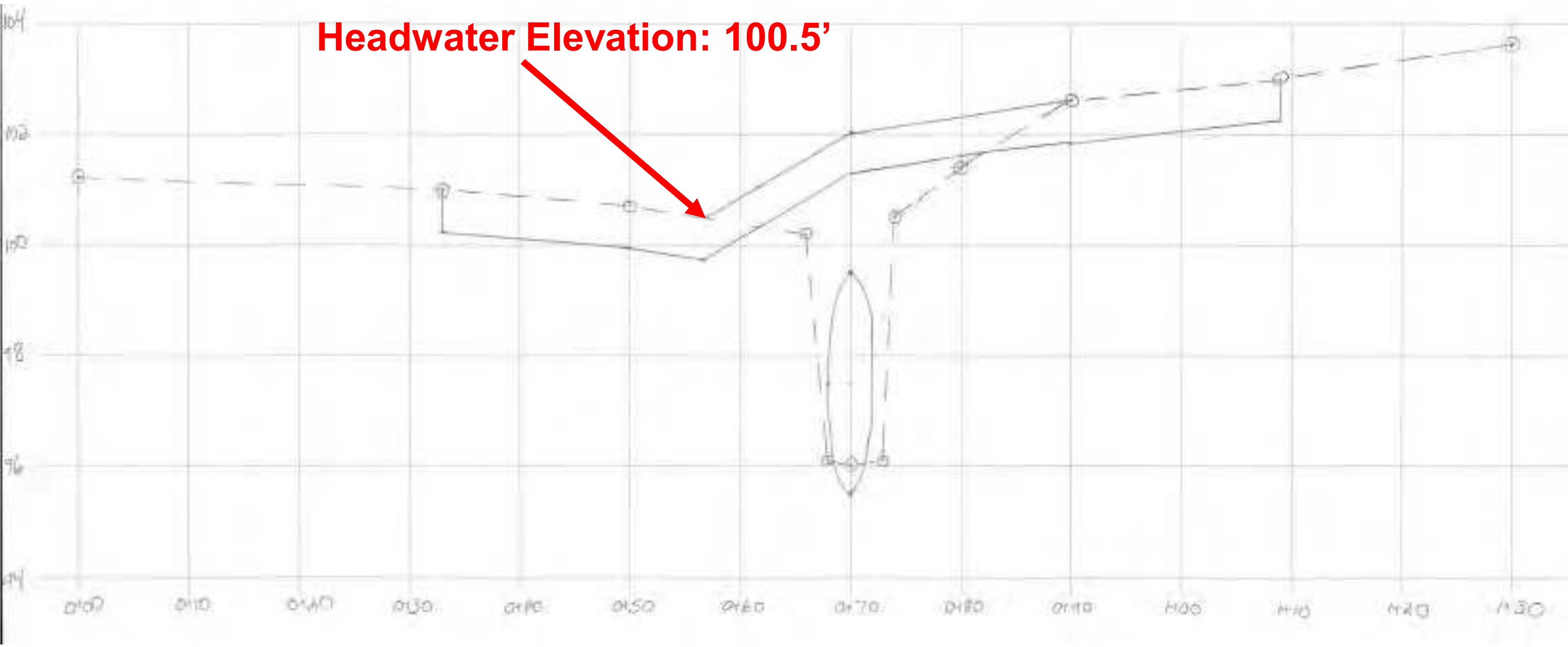
NRCS

The VDOT classifications may vary slightly from quarry to quarry across the state. To make sure that the contractor acquires the right size stone, you can specify the gradation more specifically using the chart above from the VDOT Road and Bridge Specifications.



6. Show the stone layers. Surface stone should be 9” total (6” of VDOT#1 and 3” of VDOT#57 or #357, the same as for ford crossings).
Except for the stone on top of the earthfill, the stone should be installed “at-grade” to help keep it in place. This will require 9” of excavation. Extra topsoil not needed to restabilize the site can be disposed of at the borrow site if appropriate.

Now the headwater elevation and culvert length can be determined, followed by the invert elevations at the inlet and outlet of the culvert!



This is the maximum elevation that the water can pool before it starts to flow over or around the culvert.

Culvert Length Calculation

$$L_{min} = W + 2S_h(F + D) + 2$$

where: L_{min} = minimum pipe length
W = width of the crossing
S_h = side slope horizontal units per vertical unit (a 2:1 side slope means 2 horizontal units per vertical unit. S_h for a 2:1 side slope = 2)
F = fill height above pipe (1' minimum)
D = diameter of pipe – 0.5' for countersink

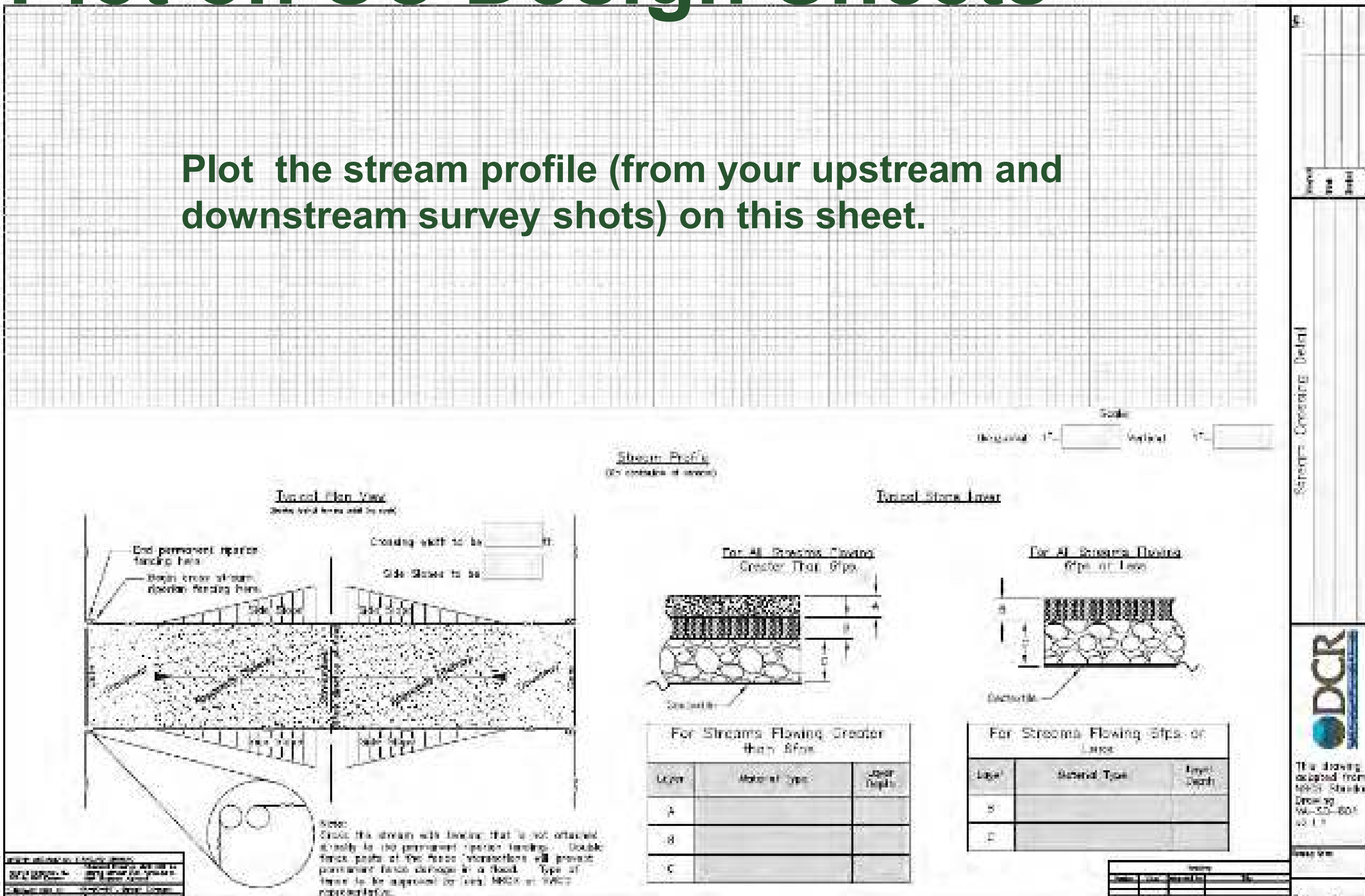
W = 12
S_h = 2
F = ~1.25' earth + 9" stone = 2
D = 4 – 0.5 = 3.5

L_{min} = 12 + 2(2)(2+3.5) + 2 = 36ft.

***We'll also be adding a 1ft. thick layer of riprap on the upstream and downstream sides of this crossing, so we'll add 2ft. for a total culvert length of 38ft. Knowing that most culverts come in lengths of 10 or 20ft., we'll assume that the contractor will use **40ft.** of culvert.

Plot on SC Design Sheets

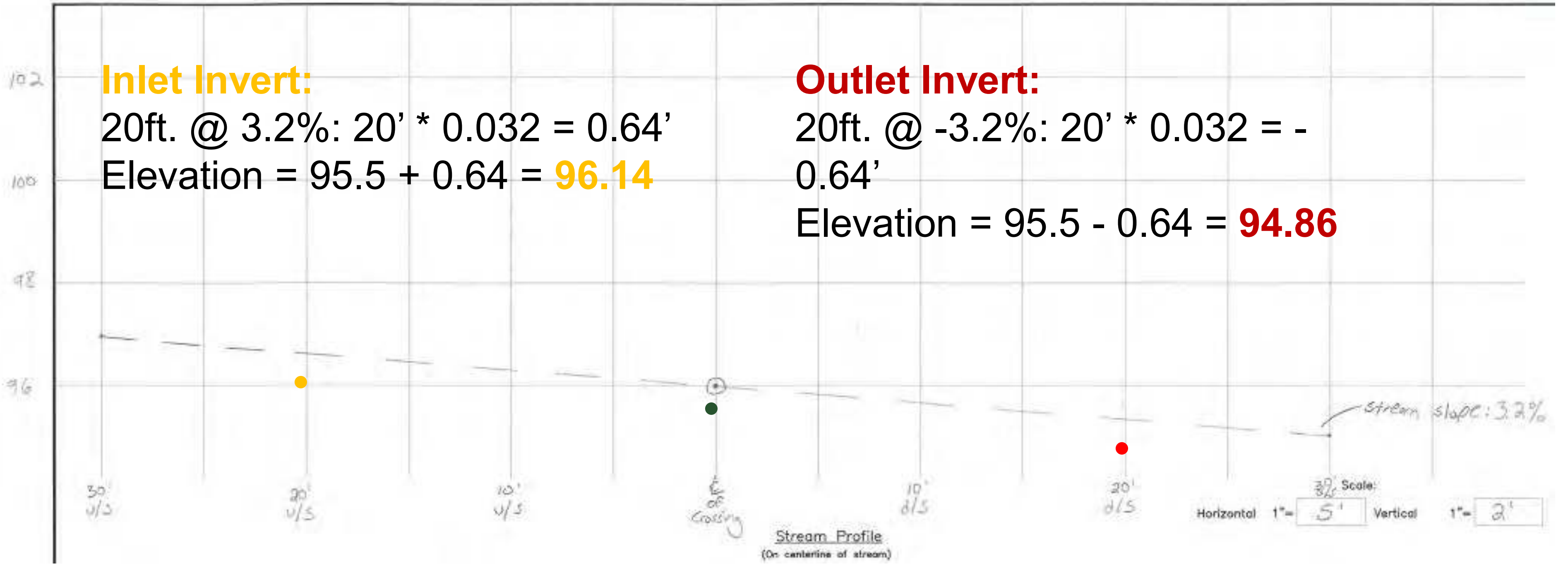
Plot the stream profile (from your upstream and downstream survey shots) on this sheet.



Virginia Department of Conservation & Recreation

Inlet Invert:
20ft. @ 3.2%: 20’ * 0.032 = 0.64’
Elevation = 95.5 + 0.64 = **96.14**

Outlet Invert:
20ft. @ -3.2%: 20’ * 0.032 = -0.64’
Elevation = 95.5 - 0.64 = **94.86**

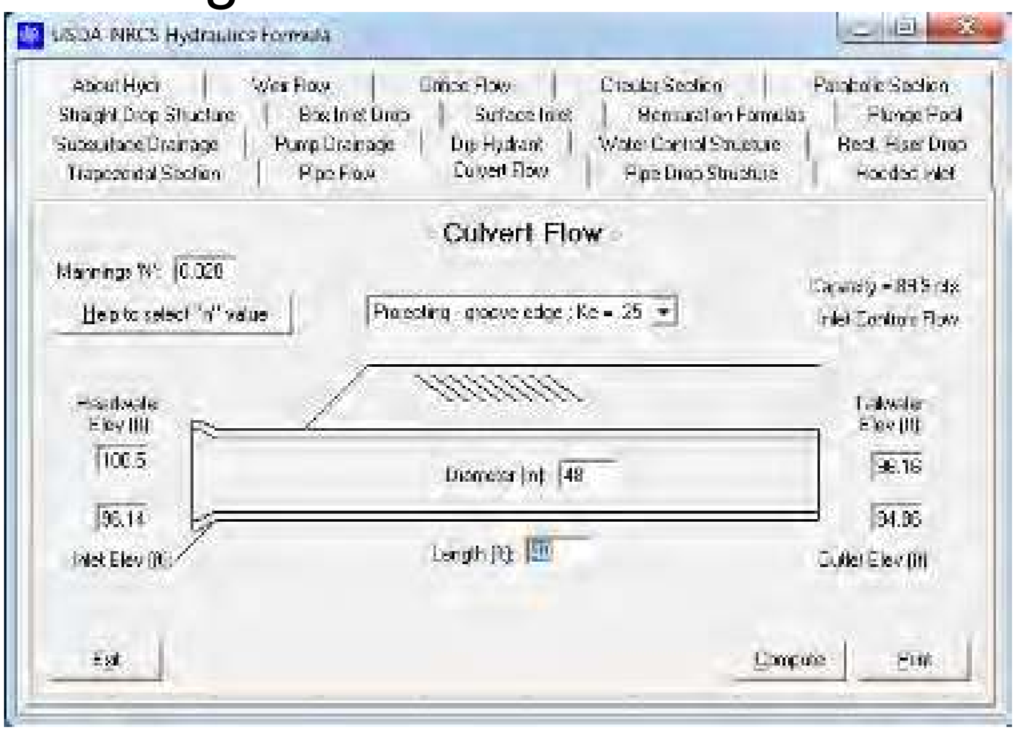


7. Plot the stream grade. In order to show the culvert with enough detail to be meaningful, you may not be able to use a scale that shows the upstream and downstream survey points. Just show a representative line for the stream slope. **From your “Centerline of Crossing” Survey Point, you know that the middle of the culvert will be at elevation 96.0’- 0.5’ (6” countersink) = 95.5’.**

8. Calculate the invert elevations for the inlet and outlet of the culvert. With 40’ of culvert length, the inlet will be 40/2 = 20’ upstream, and the outlet will be 20’ downstream.

NRCS Hydraulics Formula – Culvert Flow Tab

Now that we have the critical elevations, check to make sure that this culvert will work before we complete the design.

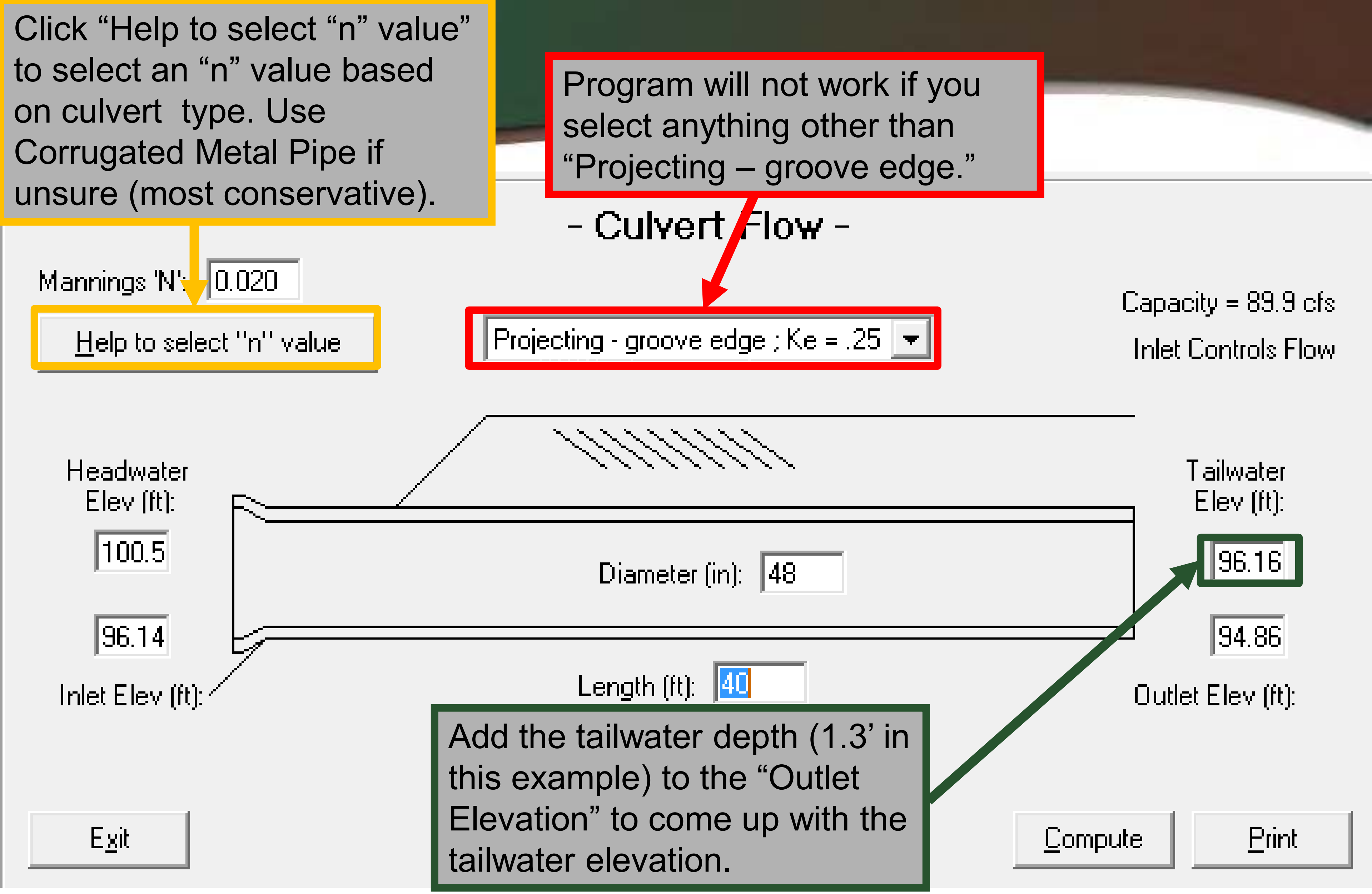


Advantages over Nomograph:

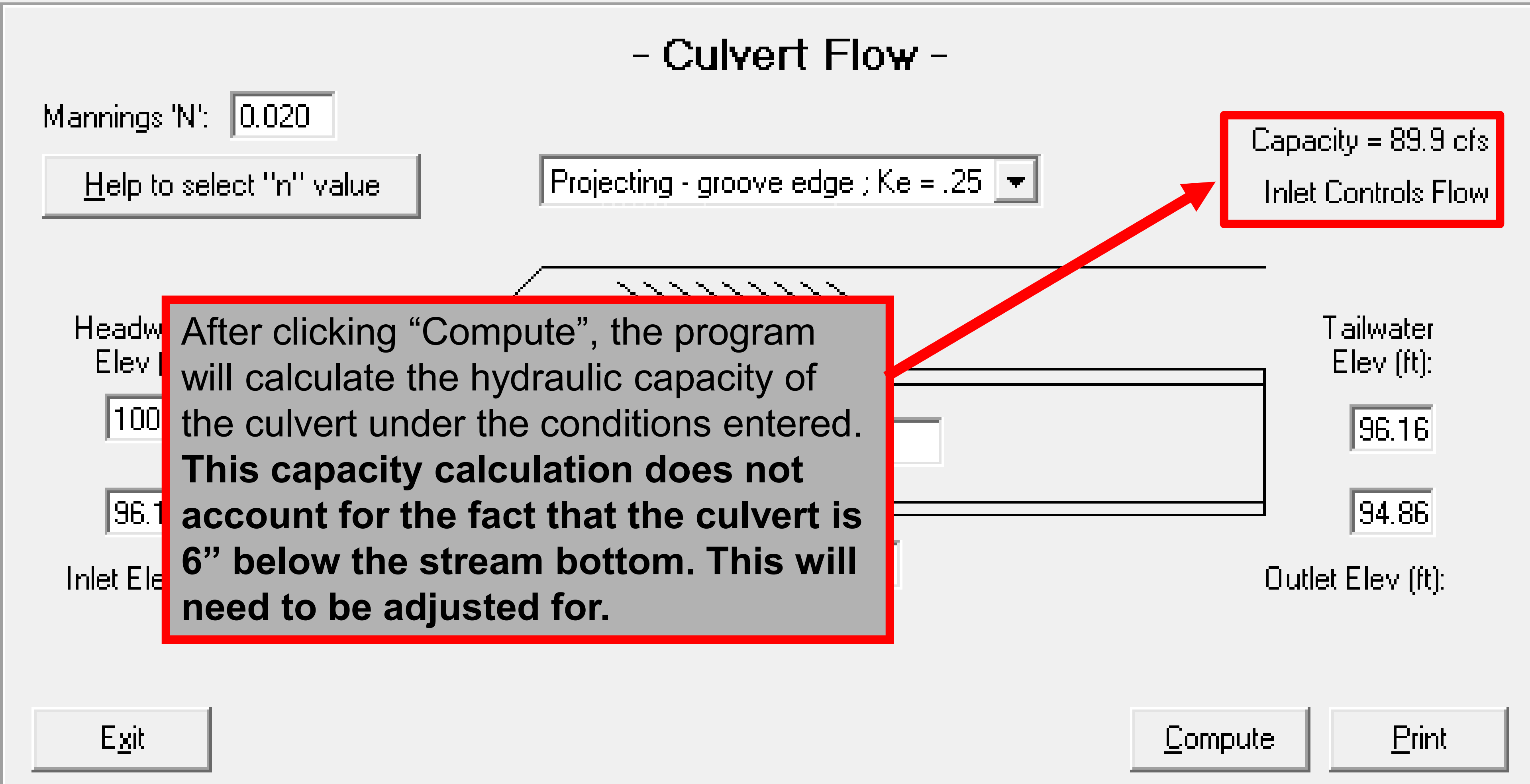
-More precise

-Determines Inlet vs. Outlet Control

-Variety of Manning's "n" Values



- This program typically does not work if the headwater elevation does not completely submerge the culvert entrance. You’ll have to rely on the nomograph in that instance.



- This program typically does not work if the headwater elevation does not completely submerge the culvert entrance. You'll have to rely on the nomograph in that instance.

Natural Resources Conservation Service
United States Department of Agriculture

Culvert Evaluation

Participant: Example

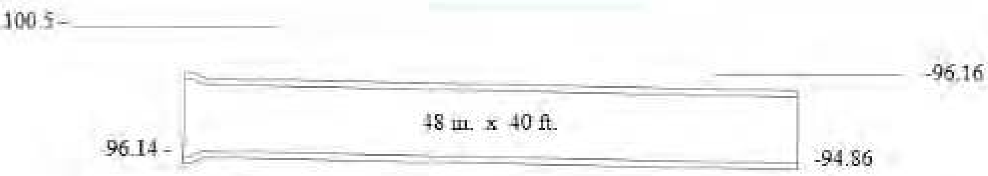
Location:

County: County, Virginia

Designer: Raleigh Coleman | Checker: ____________
Date: 07/07/2016 | Date: ____________

Hydraulics Formula, Version 2.2.1

Culvert Crossing



'n' value: 0.020
Length: 40 ft.
Diameter: 48 in.
Projecting - groove edge ; Ke = .25

Capacity = 89.9 cfs

Inlet Controls Flow

Elevation of Headwater: 100.5
Elevation of Inlet: 96.14
Elevation of Tailwater: 96.16
Elevation of Outlet: 94.86

Countersink Adjustment

Countersunk Pipe Capacity = Correction Factor * Calculated Capacity

Example: = 0.92 * 89.9cfs = **82.7 cfs**

Pipe Diameter	Multiply pipe capacity by:
24”	0.80
30”	0.86
36”	0.89
42”	0.91
48”	0.92
>48”	N/A

After adjusting for the countersink, compare the adjusted capacity to the design flow requirement.

Is the culvert capable of carrying the required design flow (2-yr, 24-hr peak discharge or bankfull flow, whichever is less)? 82.7cfs > 50cfs

If NO: Increase pipe diameter, increase headwater if possible by raising fill

If YES: Proceed with design.

If YES, but excessively: Consider redesign with a smaller culvert to minimize cost, but take into account conditions of the site (culvert smaller than channel can cause erosive velocities at outlet)

- VA-578: Design culverts with sufficient capacity to convey the design flow and transported material without appreciably altering the stream flow characteristics.

Other Design Considerations

- Buoyancy
- Bedding Materials
- Outlet Protection
- Side Slope Protection

Virginia Department of Conservation & Recreation

Buoyancy

VA-578: “Design culverts in a manner that is consistent with sound engineering principles”

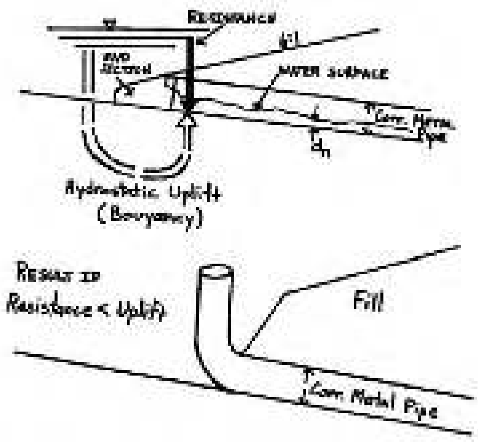


Figure 8-12. Hydrostatic Uplift Forces and Effects on Pipe

If Resistance < Hydrostatic Uplift:

Increase weight on end of pipe by adding concrete endwall or concrete anchor blocks.

8.3.6.1 Buoyancy Protection

When water is displaced by embankment material or by a culvert, a buoyant or upward force exists. If the buoyant force is greater than the weight of the object displacing the water, flotation will occur. Pipe flotation (or hydrostatic uplift) can be a problem where the following conditions exist:

- Lightweight pipe is used (i.e., corrugated metal or plastic)
- Pipe is on a steep grade (usually inlet control)
- There is little or no weight on the end of the pipe (i.e., flat embankment slopes, minimal cover and/or no endwalls)
- High headwater depths (HW/D> 1.0)

From VDOT Drainage Manual, Chapter 8

If you have a culvert where buoyancy may be an issue, contact DCR engineering staff or NRCS Area Engineer for assistance.

Culvert Failure via Buoyancy

A headwall can be constructed to prevent buoyancy problems.

HDPE is especially prone to buoyancy problems.

Bedding Materials

- Typically VDOT#57 is sufficient
- Purpose:
  - Uniformly distribute forces on the culvert to keep if from crushing
  - Make it easy to position the culvert during construction

DCR

Virginia Department of Conservation & Recreation

Bedding Materials

Table 5-2
Classes of Embedment and Backfill Materials

ASTM D2321[A] Class	Description	ASTM D2487 Notation	ASTM D2487 Description	AASHTO M43 Notation	AASHTO M145 Notation	ASTM D2321[A] Percentage Passing Sieve Sizes 1 ½ in (40mm)	3/8" (9.5mm)	No. 4 (4.75mm)	No. 200 (0.075mm)	Atterberg Limits LL	PI	Coefficients Cu	Cc
[illegible]	Crushed rock, angular	N/A	[illegible]	[illegible]	N/A	[illegible]	[illegible]	[illegible]	[illegible]	Non-Plastic		N/A	
I	Clean, coarse grained soils	GW	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
		GP	[illegible]	[illegible]								[illegible]	[illegible]
		SW	[illegible]					[illegible]				[illegible]	[illegible]
		SP	[illegible]									[illegible]	[illegible]
	[illegible]	[illegible]	Sands and gravels which are borderline between clean and with fines	N/A		[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	
II	Coarse grained soils with fines	GM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	N/A	
		GC	[illegible]								[illegible]		
		SM	[illegible]					[illegible]			[illegible]		
		SC	[illegible]								[illegible]		
	[illegible]	ML	[illegible]					[illegible]	[illegible]	[illegible]	[illegible]		
		CL	[illegible]						[illegible]		[illegible]		
III	[illegible]	ML	[illegible]	N/A	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	N/A	
		CL	[illegible]	N/A							[illegible]		
IV	[illegible]	MH	[illegible]	N/A	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	N/A	
		CH	[illegible]	N/A							[illegible]		
V	[illegible]	OL	[illegible]	N/A	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	N/A	
		OH	[illegible]	N/A						[illegible]	[illegible]		
		PT	[illegible]	N/A									

Notes:

A) Refer to ASTM D2321 for more complete soil descriptions.
B) Class I materials allow for a broader range of fines than previous versions of D2321. When specifying class I material for infiltration systems, the engineering shall include a requirement for an acceptable level of fines.
C) All particle faces shall be fractured.
D) Assumes less than 25% passes the 3/8" sieve.
E) Class IV materials require a geotechnical evaluation prior to use and should only be used as backfill under the guidance of a qualified engineer.
F) Uniform fine sands (SP) with more than 50% passing a 100 sieve behave like silts and should be treated as Class III soils if allowed.
G) Class V materials shall not be permitted as bedding and backfill material.

This chart is shown for informational purposes only and is not intended to be a recommendation of a specific manufacturer.

Outlet Protection

<u>Erosive Culvert Exit Velocities</u>

A culvert, because of its hydraulic characteristics, increases the velocity of flow over that in the adjacent channel. High velocities may be damaging just downstream from the culvert outlet and the erosion potential at this point should be considered in culvert design. In many cases it is necessary to riprap the channel for a short distance downstream of the culvert exit.

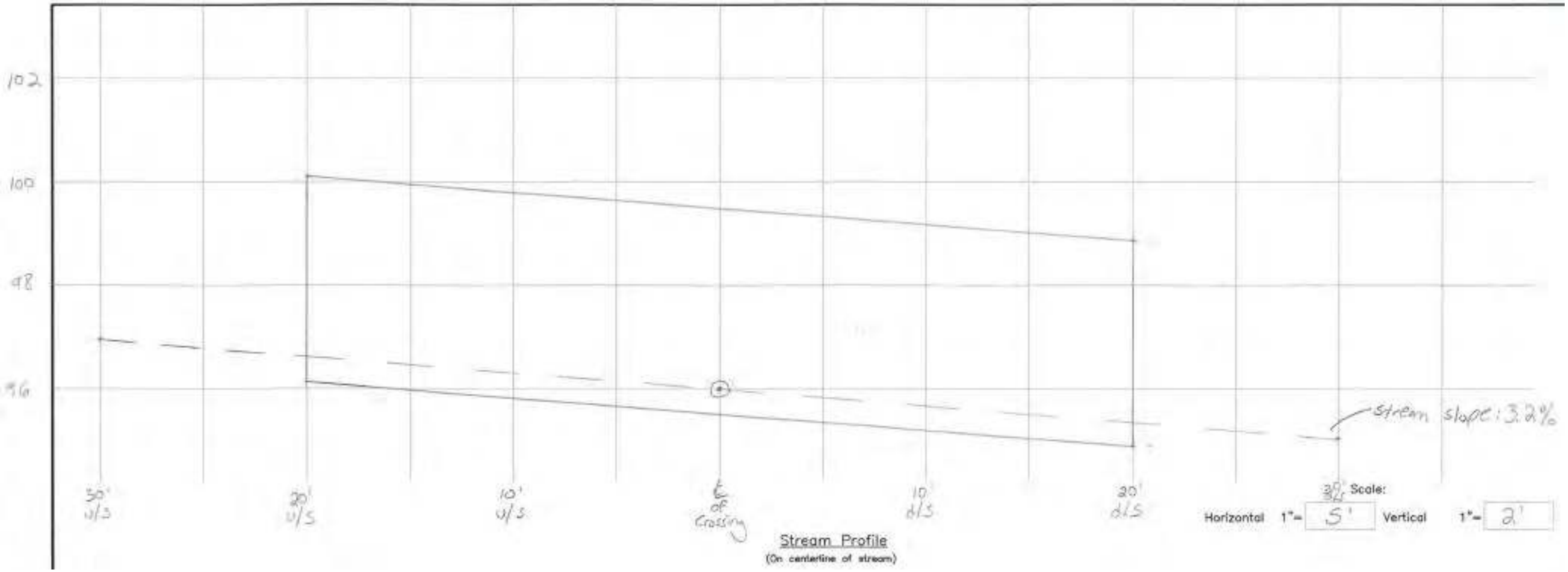
- Typically not needed in defined channels because the natural stream substrate will be 6” deep in the culvert and the culvert is at the same grade as the stream
- If placing a culvert in a swale with no defined channel, outlet protection should be considered to prevent erosion and channelization at the outlet

Side Slope Protection

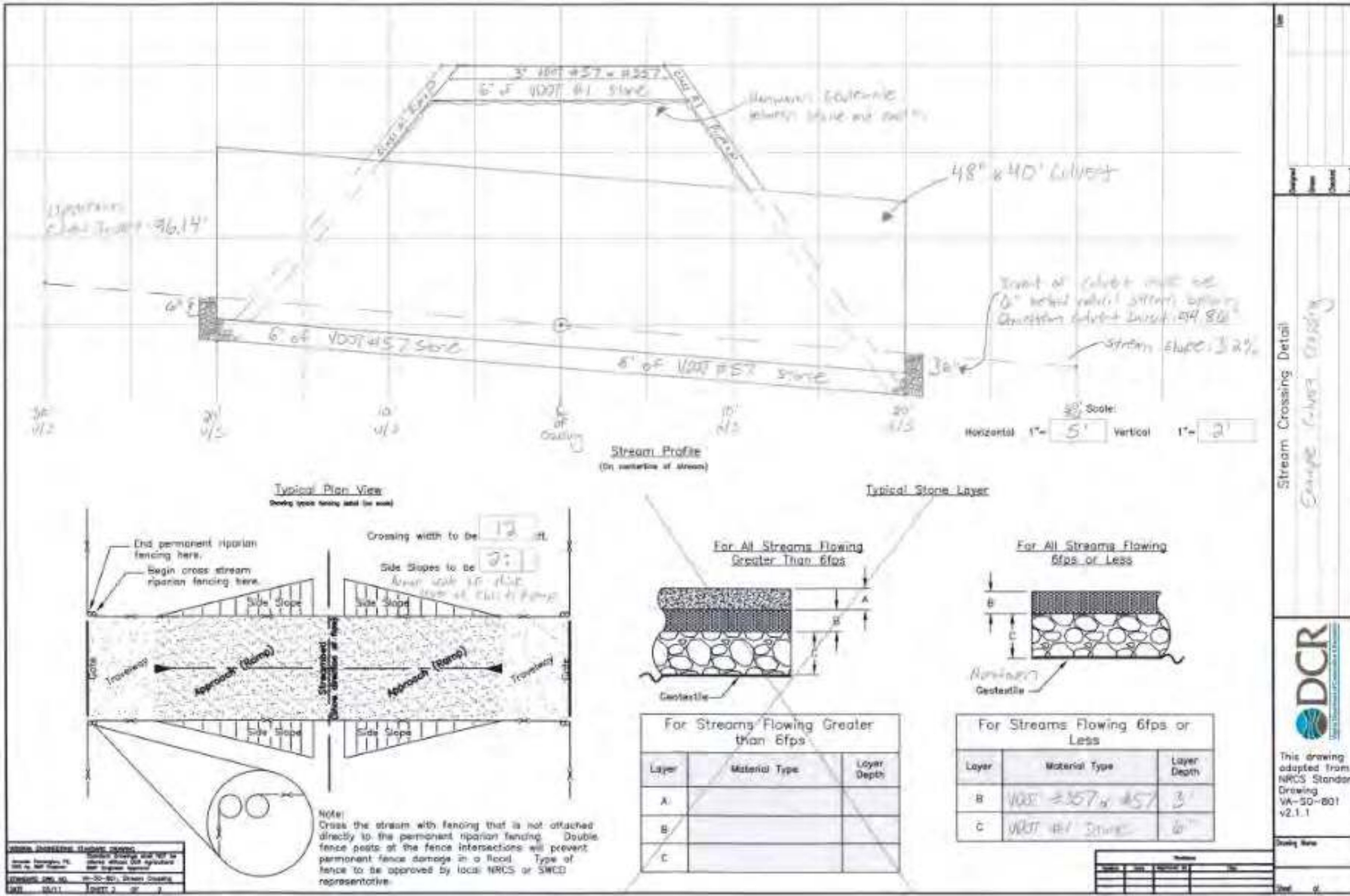
- VA-578: “Crossings shall be adequately protected so that out-of-bank flows safely bypass without damaging the structure of eroding the streambanks or crossing fill.”
- Typically: 1ft. thick layer of angular Class AI Riprap if 2:1 side slopes (especially on downstream side of crossing)
- Field stone may be used; if not angular, may use a concrete slurry (~2000psi) to lock it together

Contractor must keep cement out of stream

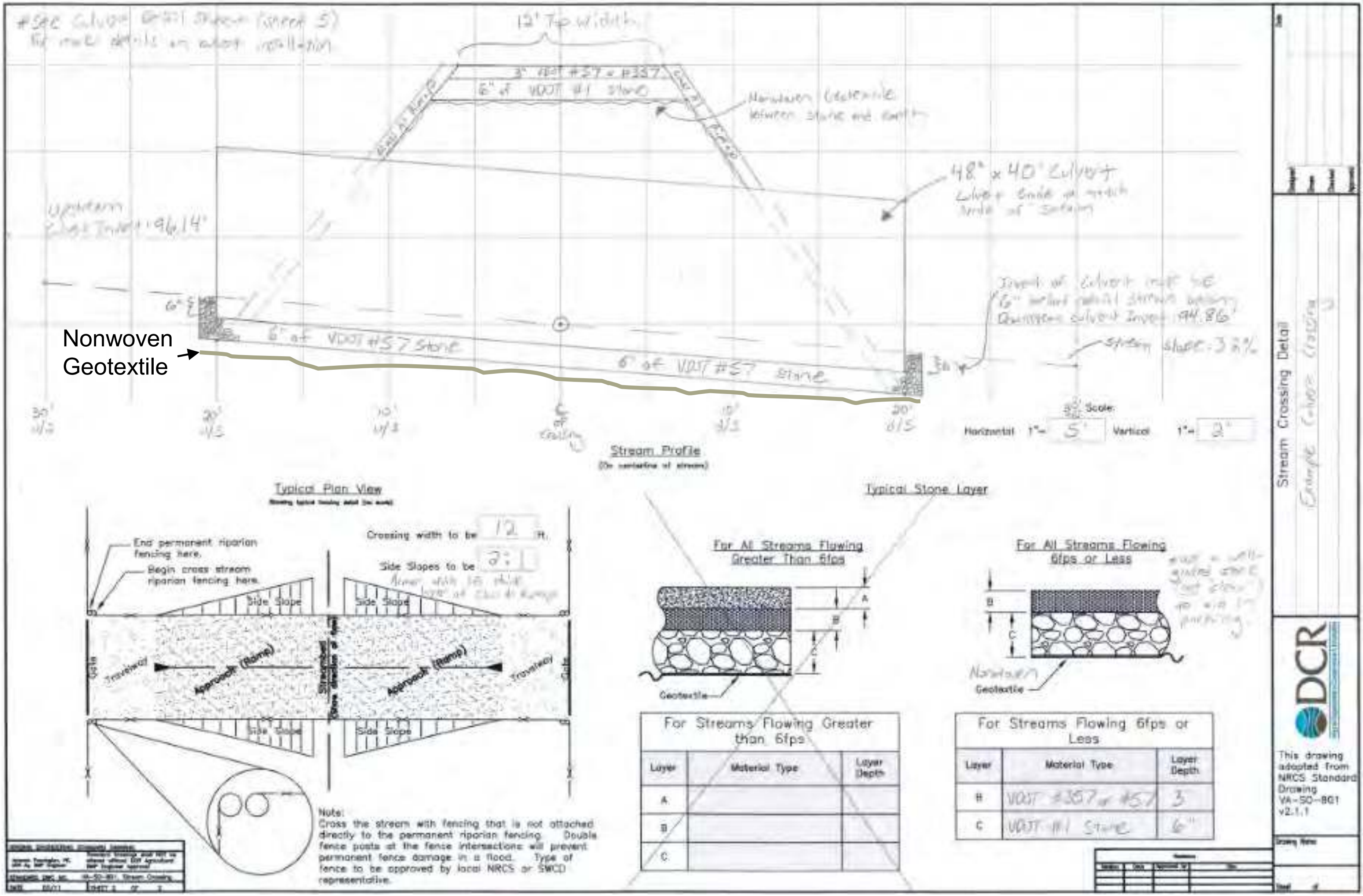
Finishing the Design Drawings


102
100
98
96
30' u/s
20' u/s
10' u/s
℄ of Crossing
10' d/s
20' d/s
30' d/s
stream slope: 3.2%
Scale:
Horizontal 1"= 5'
Vertical 1"= 2'
Stream Profile
(On centerline of stream)

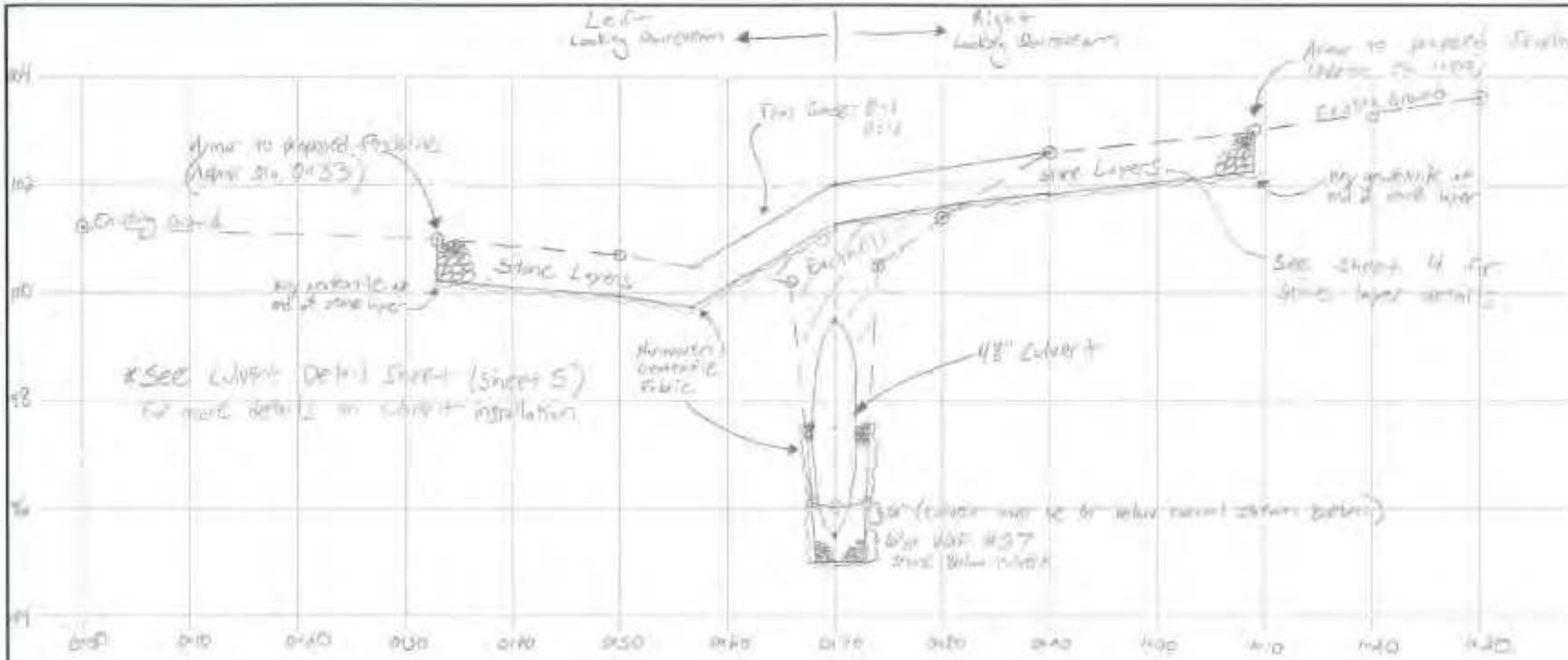
Virginia Department of Conservation & Recreation



Virginia Department of Conservation & Recreation



Virginia Department of Conservation & Recreation



Stream Crossing Profile
(On centerline of crossing)

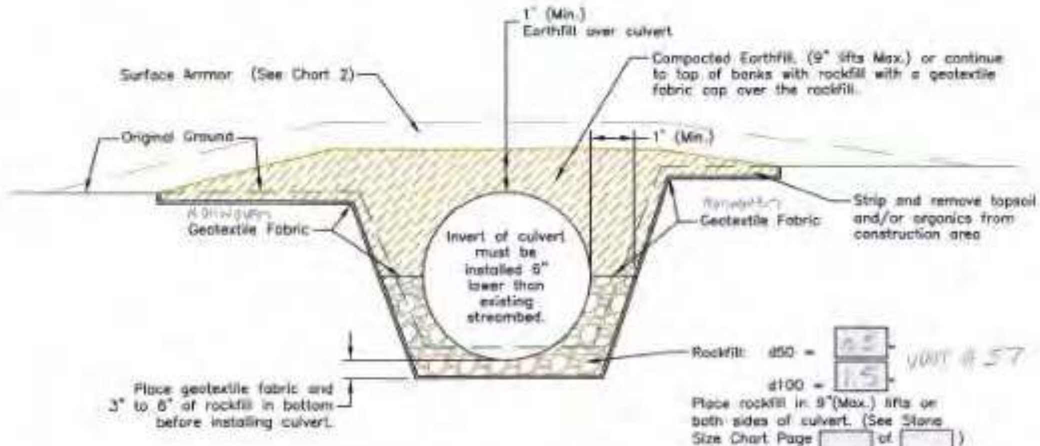
Scale:
Horizontal 1"= 10' Vertical 1"= 2'

Stream Crossing Design Notes

1. The slope of the approaches (ramps) shall be 6:1 or flatter. (8:1 is recommended)
2. If livestock will have access to the side slopes, then the side slopes shall be armored. If fencing will restrict livestock access, the side slopes may be seeded. Grade side slopes to 3:1 or flatter if they are to be seeded. Grade side slopes to 2:1 if they are to be armored. Armoring shall consist of 6 inches of VDOT #1 (2" to 4") stone over geotextile.
3. If necessary to provide a solid bottom at the crossing, the existing streambed shall be excavated to the depth of the selected Typical Stone Layer (on Sheet 2). Any stone placed to harden the channel bottom must be installed below the existing natural grade of the stream.
4. If no stone is needed to harden the stream bottom, then the stone on the ramps shall be placed so that the ramps blend naturally into the streambed. A 2'x2' rock key may be placed at the end of each ramp to provide toe protection. Do not place any stone that will obstruct the natural flow path of the stream.
5. Excavated material shall be spread outside of the floodplain.
6. Geotextile shall meet the Class I requirements for nonwoven geotextile in Virginia Construction Specification VA-795 Geotextiles. Class II may be used with engineers approval.
7. Seed all disturbed areas according to the Attachment to Virginia Construction Specification VA-706 Seeding.

Stream Crossing Detail
Example Culvert Crossing

This drawing adapted from NRCS Standard Drawing VA-SD-801 v2.1.1



Single–Culvert Crossing Section Detail
Not to Scale

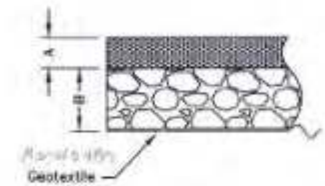
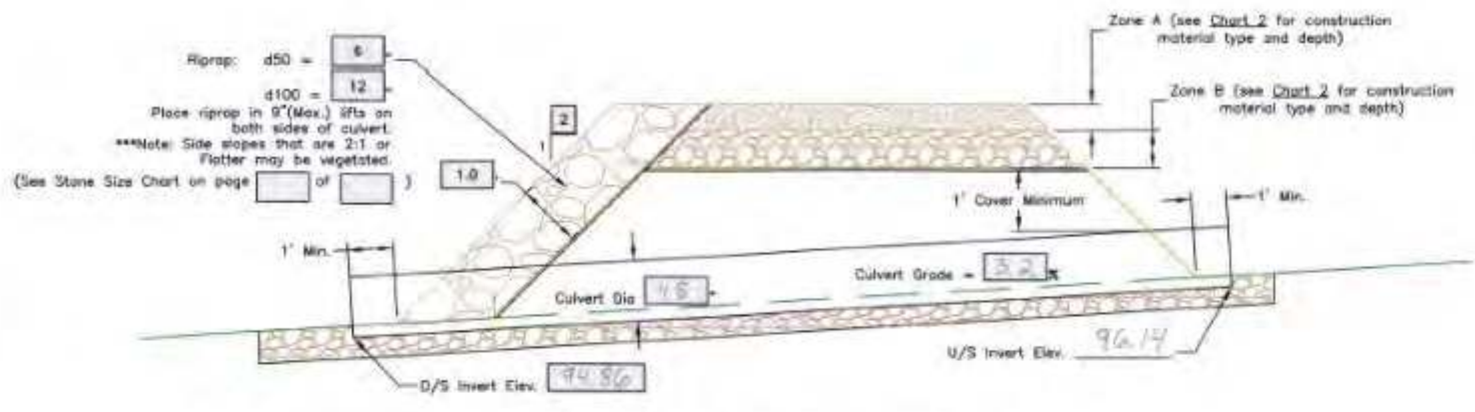


Chart 2 — Culvert Crossing Materials		
Zone	Construction Material	Depth of Material (inches)
A	VDOT # 57	3"
B	VDOT # 1	6"

(See Stone Size Chart on page [ ] of [ ])



Culvert Crossing Profile Detail
Not to Scale

Project Name Example culvert crossing
Landowner
County Virginia
Tract#

NRCS
Natural Resources Conservation Service
United States Department of Agriculture

File Name
Drawing Name

Complete the Design Packet

Stream Crossing Design Components:

- Sheet 1: Cover Sheet
- Sheet 2: Plan View
- Sheet 3: Stream Crossing Detail Pt. 1: Stream Crossing Profile
- Sheet 4: Stream Crossing Detail Pt. 2: Stream Profile
- Sheet 5: Culvert Detail Sheet (if sufficient detail cannot be conveyed on the Stream Crossing Detail Sheets)
- Attachments:
  - NRCS Practice Standard (VA-578 Stream Crossing)
  - NRCS Construction Specifications
  - NRCS Practice Operation & Maintenance Agreement (VA-578 Stream Crossing)
  - Survey Notes
  - Calculations (e.g. material quantity calculations, stream crossing worksheet)

Design Attachments: Construction Specifications

Spec. #	Title	When to Include?
VA-705	Pollution Control	Anytime ground disturbance involved
VA-706	Seeding	Anytime ground disturbance involved
VA-707	Site Preparation	Always include for stream crossings
VA-708	Salvaging & Spreading Topsoil	Include if topsoil will need to be stripped. May not be necessary for existing crossing sites.
VA-711	Removal of Water	If working in live surface water
VA-721	Excavation	Always include for stream crossing
VA-723	Earthfill	For earthfill above culvert pipe
VA-727	Diversions	Include if diversions are planned to divert upland surface runoff away from crossing
VA-731	Concrete Construction	If a headwall will be poured or slurry used to stabilize riprap
VA-745	Plastic Pipe	If the culvert will be plastic
VA-751	Corrugated Metal Pipe	If the culvert will be corrugated metal
VA-757	Concrete Pipe	If the culvert will be concrete
VA-761	Loose Rock Riprap	If riprap will be used to stabilize fill slopes
VA-795	Geotextile	Covers geotextile under stone

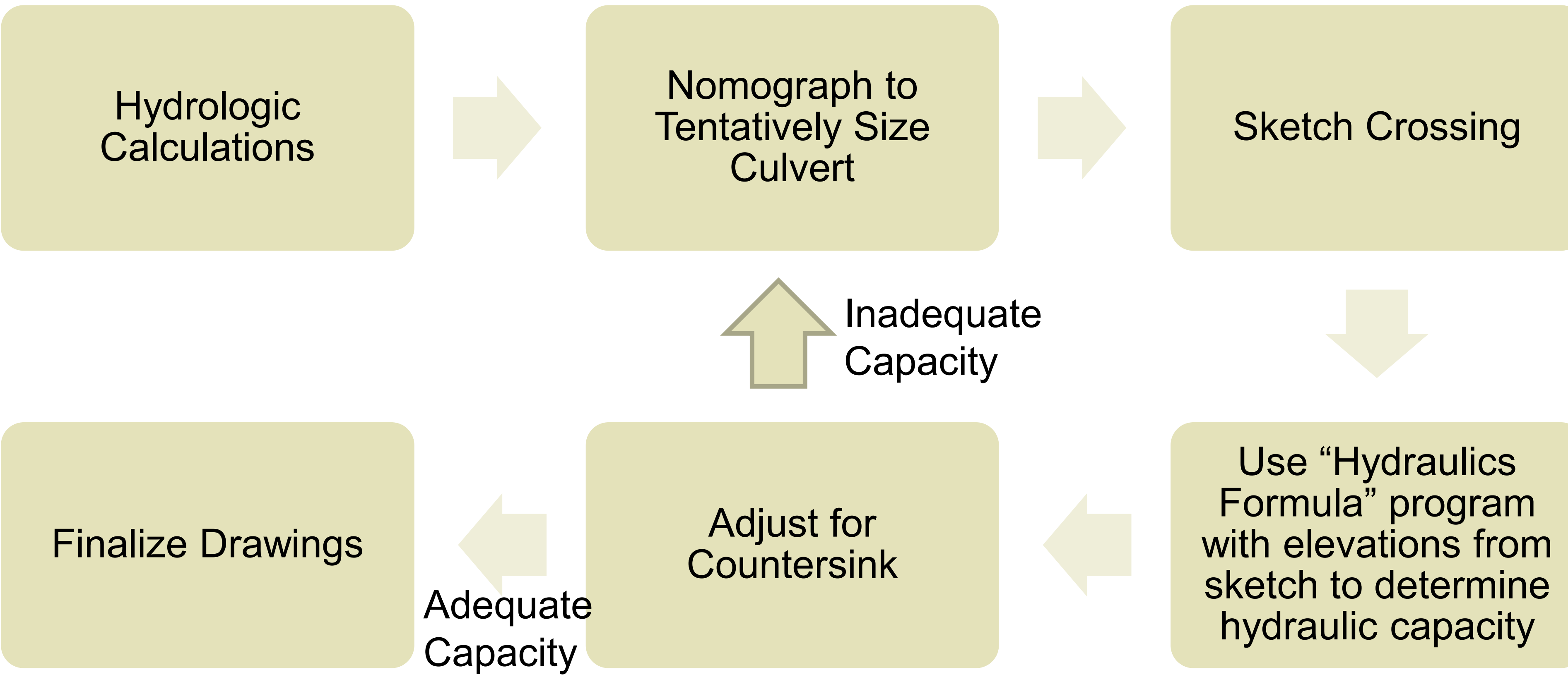
Availability

- DCR Design Sheets must be used for projects designed by SWCD staff.
- Sheets are available online in .pdf and .dwg (for AutoCAD) formats at:

  http://www.dcr.virginia.gov/soil-and-water/district-engineering-services

- NRCS Stds. and Specs. are available on the eFOTG, section IV

Review: General Design Process



Design Data

See complete list of “Design Data” in the VA-578 CPS.

DESIGN DATA

1. Completed Environmental Evaluation and subsequent requirements.
2. Soils investigation.
3. Survey and plot data: profile, cross-sections, topography, as needed.
   a. Survey and plot profile along centerline of stream (distance should be sufficient to determine channel slope).
   b. Survey and plot the existing cross-section perpendicular to the flow, extending beyond the ends of the planned ramps to ensure adequate representation of the designed cross section. Include typical cross sections as needed.
4. Design computations, including purpose of practice and references used.
   a. Sketch of area to indicate stream meandering and limits of stream protection, if needed.
   b. Determine drainage area, land use, and, if applicable, design flows and design velocities.
   c. For ramp crossings, design ramp to best fit the section and meet the design criteria. For culvert crossings, show culvert design calculations.
   d. Add construction sequence to include stream channel diversion, dewatering, and sediment control measures, as needed.
   e. Document landowner/VDGIF contact concerning the proposed stream crossing. Record date, contact person, and outcome of site visit, if one occurred.
5. Plan view of site with existing and planned features, showing dimensions, distances, etc. Include such items as: utilities; fencing; crossing width and length; ramp slopes and side slopes; culvert material, diameter, and length.
6. Standard Cover Sheet (VA-SO-100) including crossing location map.
7. Materials and quantities needed. Identify borrow material and/or spoil area, as needed. Specify thickness, gradation, quantities and type of rock or stone. Specify type, dimensions, and anchoring requirements of geotextile. Specify thickness, compressive strength, reinforcement, and other special requirements for concrete, if used.
8. Vegetation and/or ground cover requirements.
9. Identification of needed Erosion & Sediment Control measures.
10. Supplemental practices required.
11. Virginia Conservation Practice Specifications (700 Series).
12. Operation and Maintenance Plan

Note: Regulatory agencies may request spot checks of stream crossings to ensure permit conditions are being followed.

CHECK DATA

1. As-built surveys.
   a. Cross-section of completed crossing.
   b. Profile of stream channel to show crossing and stream are on a uniform grade.
2. As-built plans including dimensions, types and quantities of materials installed, and variations from design. Include justification for variations.
3. Locations of appurtenant practices.
4. Adequacy of vegetation and/or ground cover.
5. Complete as-built section of Cover Sheet.

OPERATION AND MAINTENANCE

Develop an operation and maintenance plan and implement it for the life of the practice.

Include the following items in the operation and maintenance plan, as a minimum:

Inspect the stream crossing, appurtenances, and associated fence after each major storm event and make repairs if needed.

- Remove any accumulation of organic material, woody material, or excess sediment.
- Replace surfacing stone used for livestock crossing as needed.

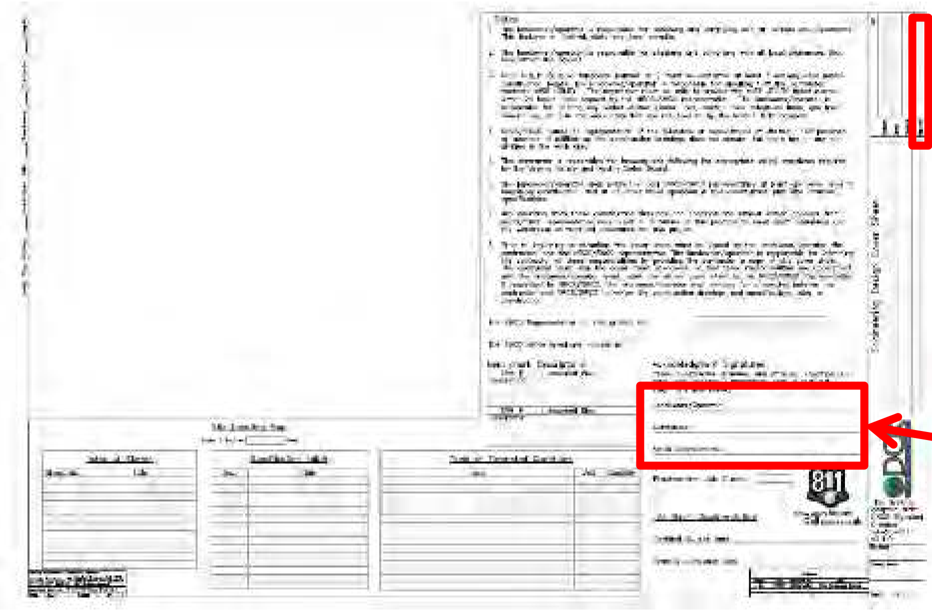
Construction

General Steps in Construction

1) Pre-Construction Conference
2) Excavation
3) Bedding the Culvert
4) Earthfill
5) Armoring (Geotextile + Stone)
6) Fencing
7) Seeding

1. Pre-Construction Meeting

- A pre-construction meeting and good oversight will prevent many construction issues from happening.



Must be "Approved" by someone with appropriate "Design" EJAA before issued for construction

Make sure to get "Acknowledgement Signatures" from all parties at pre-con meeting

- Ideally: Meet on-site, stake the corners of the proposed crossing and go over the cut/fill depths at different points along the profile

Things to stress at Pre-Con Meeting/ Things that contractors tend to "forget":

- Deliverables/Inspections
- NON-woven geotextile
- KEY ends of geotextile
- MAX slopes
- Stone gradations
- Culvert must be embedded 6" into streambed
- Removal of cut material outside of floodplain
- Construction Specs.
- Seed all disturbed areas

2. Excavation/Site Prep.

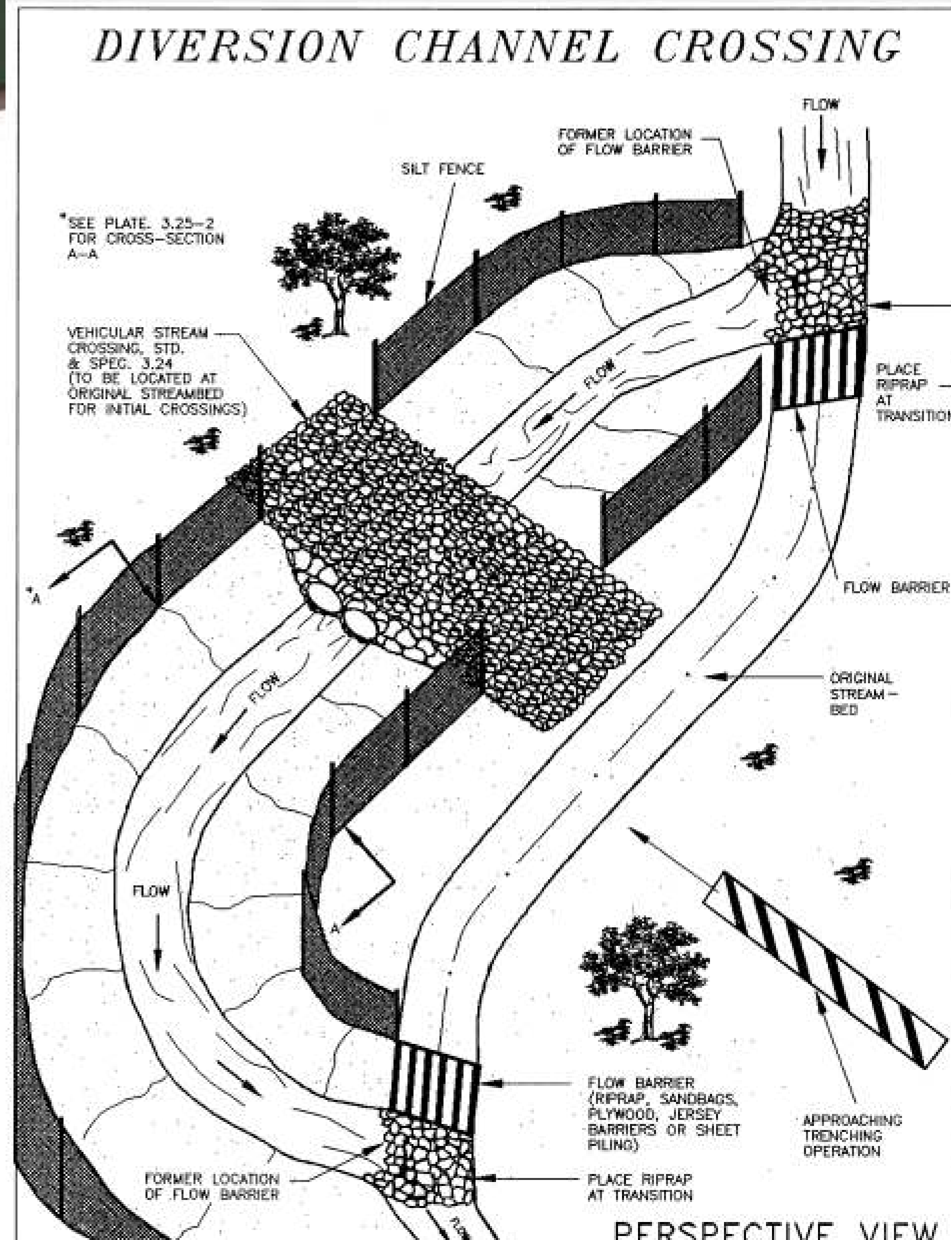
- Remove organic material from crossing area, dig to sufficient depth in streambed (approx. 12” deep: 6” for bedding material, 6” for culvert countersink)
- VA-757: “The trench or foundation width on which the pipe will be laid will be at least two times the pipe diameter, or the pipe diameter plus two feet whichever is greater.”

A *Diversion Channel* may be utilized to allow "work in the dry".

Virginia Erosion and Sediment Control Handbook

STD & SPEC 3.25

UTILITY STREAM CROSSING



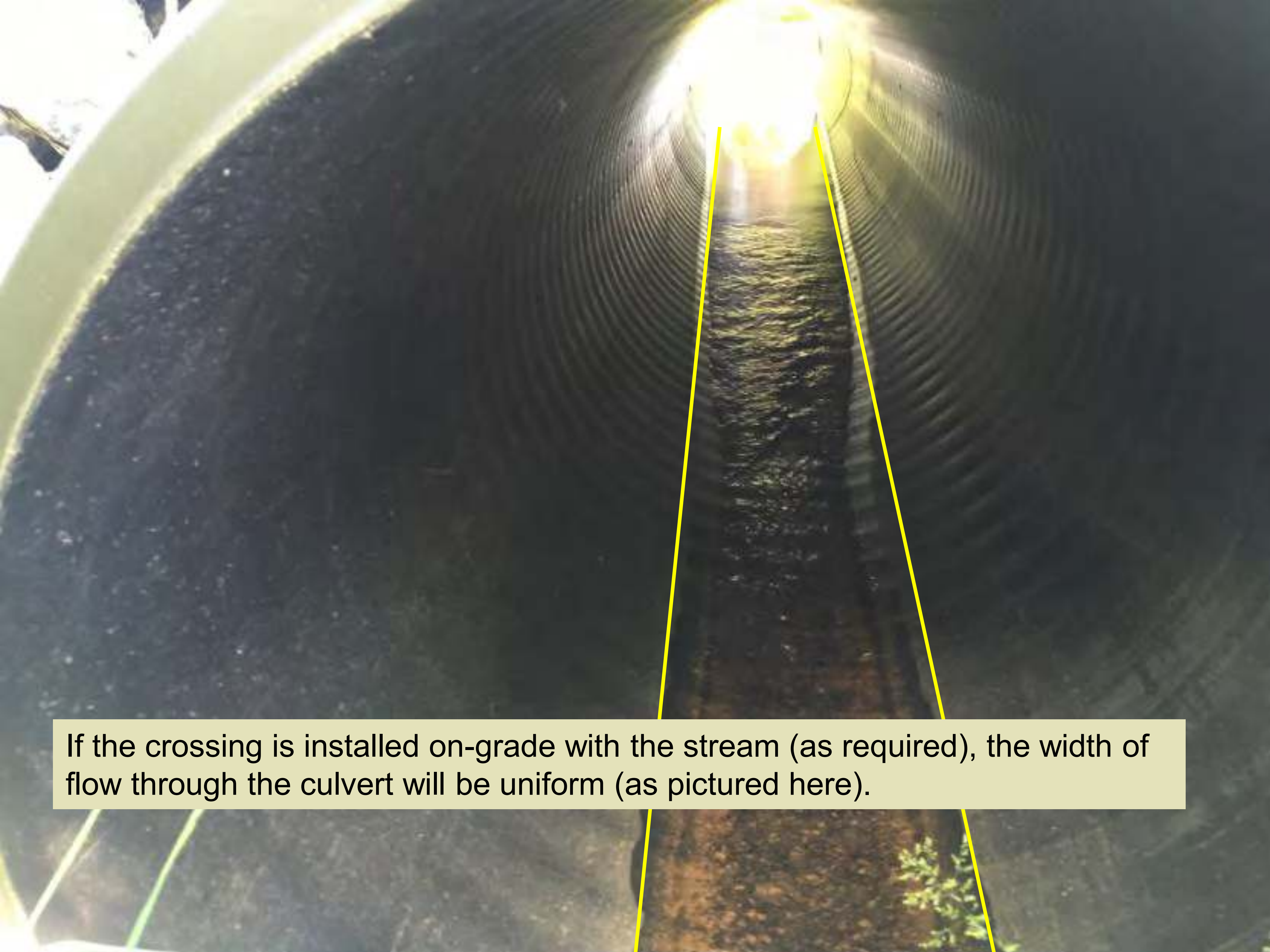
3. Bedding the Culvert

- See VA-745, VA-751, and VA-757 for bedding and coupling requirements.

***It is usually necessary to use survey equipment to make sure that the culvert is bedded at the proper elevation since the streambed has been excavated.

Excavation/Site Prep: Construction Spec. Highlights

- VA-745: “Bell-holes will be made in the bedding under bells or couplings and other fittings…”
- VA-751: Field welding or corrugated galvanized iron or steel pipe is not permitted. The pipe sections will be joined with fabricator-supplied bands meeting the specified joint requirements.



If the crossing is installed on-grade with the stream (as required), the width of flow through the culvert will be uniform (as pictured here).

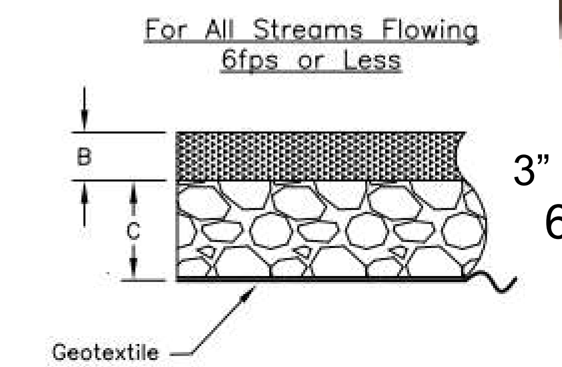
4. Earthfill

- Follow VA-723 Earthfill.

Construction Spec. Highlights

- VA-745: “The pipe will be held down during backfilling to the top of the pipe to prevent its being lifted from its original placement.”
- VA-751: “Unless otherwise specified, backfill over and around the pipe will be brought up uniformly on all sides and will extend a minimum of 2 feet over the pipe before earth moving equipment is allowed over the pipe.”
- VA-723: “Earthfill materials adjacent to *structures* will be placed and spread in layers not exceeding *4* inches in thickness before compaction”

5. Armoring

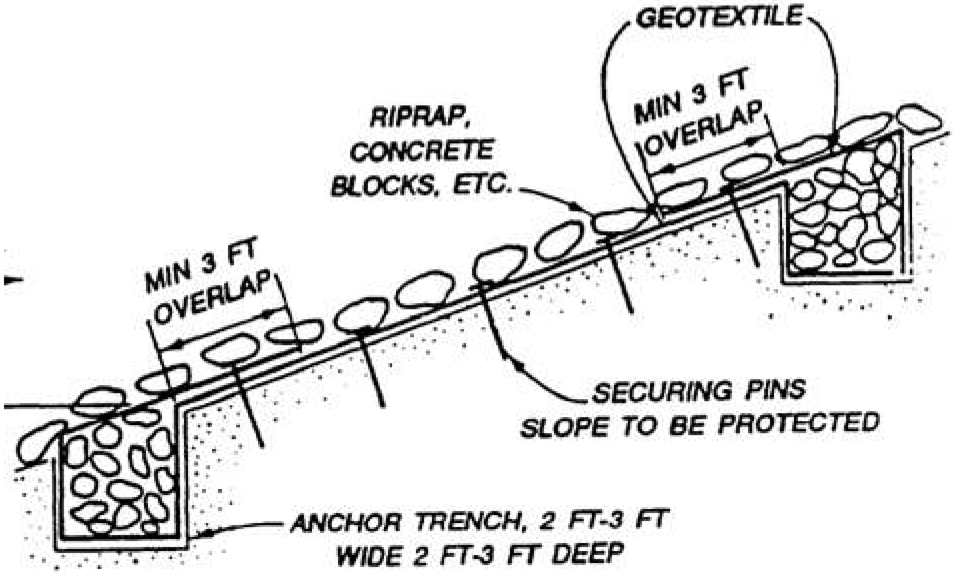


3” VDOT #57/#357
6” VDOT#1

- Lay Nonwoven Geotextile
  - Under entire length and width of stone layer
  - Key in at all ends
- Base Stone
- Surface Stone

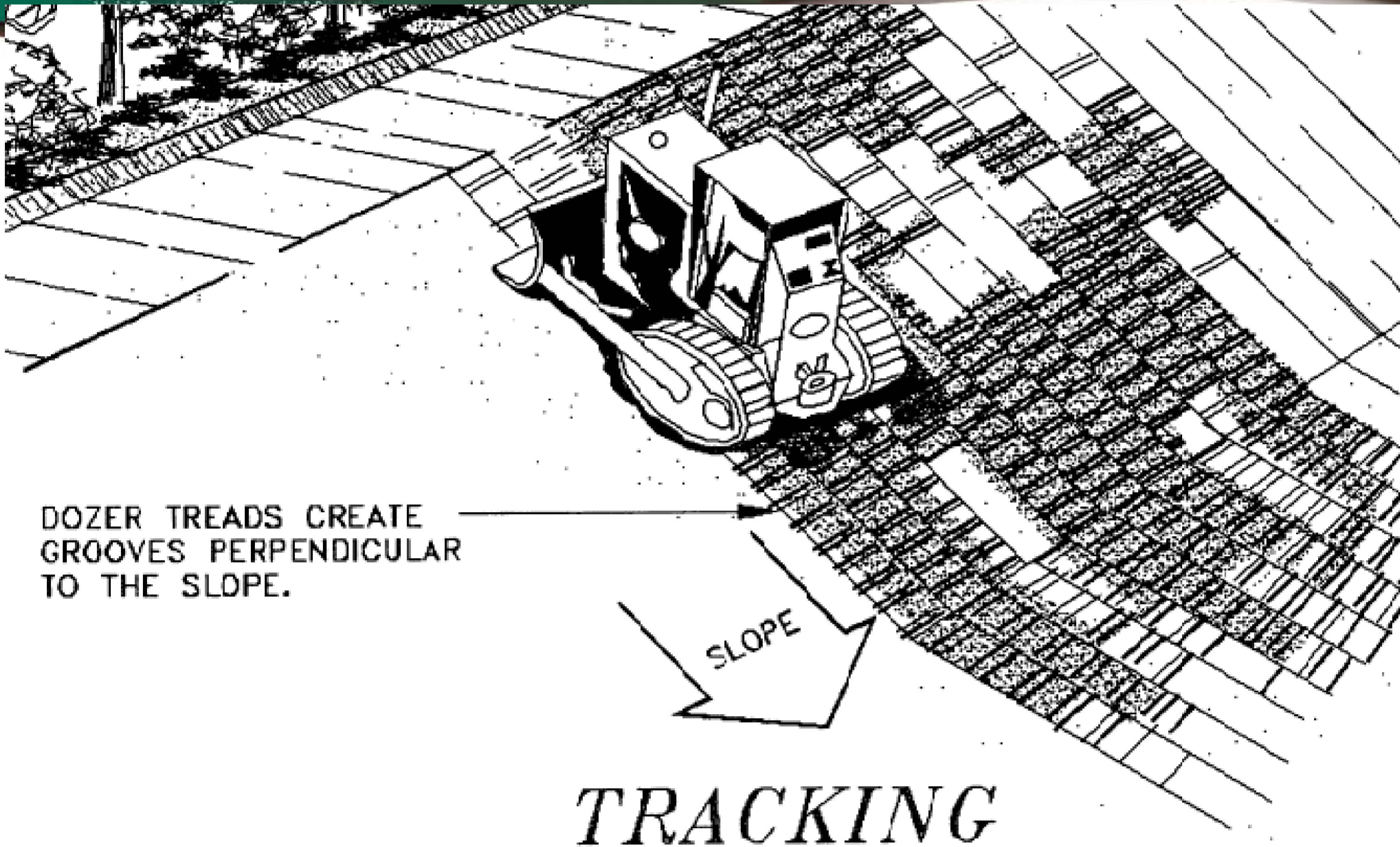
***May require a “Grade Check” prior to allowing contractor to place stone

Army TM 5-818-8 Key Detail:



Compacting Surface Stone Layer:

- VA-795: “Gravel…will be compacted with vibratory rollers **EXCEPT** on animal trails or stream crossings.”
- VA-795: “…moderate to heavy static rollers (steel drum or rubber tired) will be used. Fine-grained backfill will be compacted with sheepsfoot or rubber tired rollers.”



No matter what method of compaction is used, a well graded stone will pack better than a “clean” stone.

6. Fencing

- Proper fence selection and installation is an important part of crossing success
- Improper fencing can cause the crossing to fail
- If separate contractors will be hired for fencing and stream crossings, provide stream crossing design to fencer
- There should be no space between the stone and the fence.

Installing fencing *after* the stone is placed:

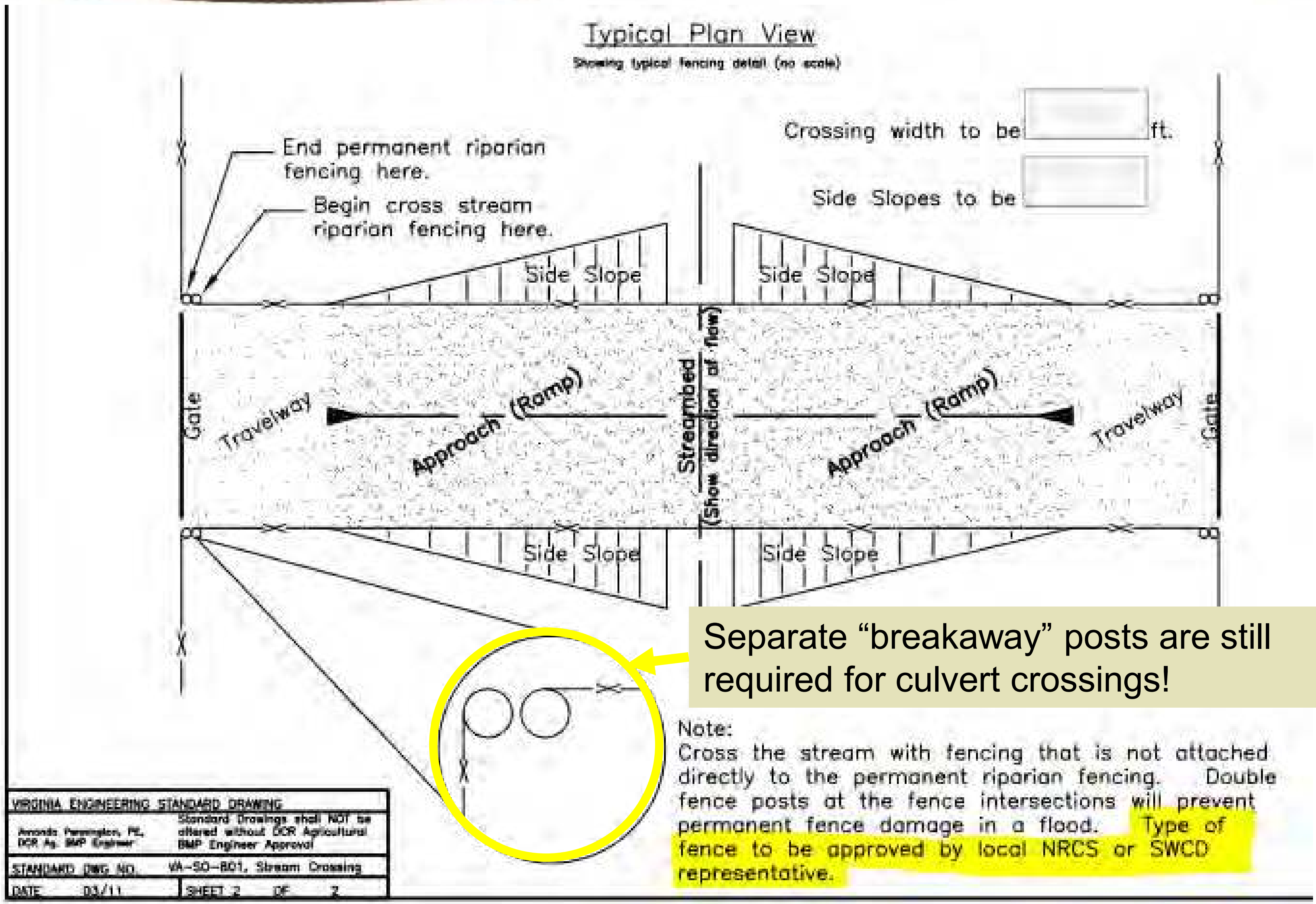
- Keeps the fence out of the way during grading
- Allows fenceposts to be installed immediately adjacent to gravel (so there is no gap between the fenceposts and the stone)
  - If given the choice, cattle will choose to walk on soft ground next to the stone instead of the stone.

For Crossing Fencing:

HT Smooth > Barbed > Woven

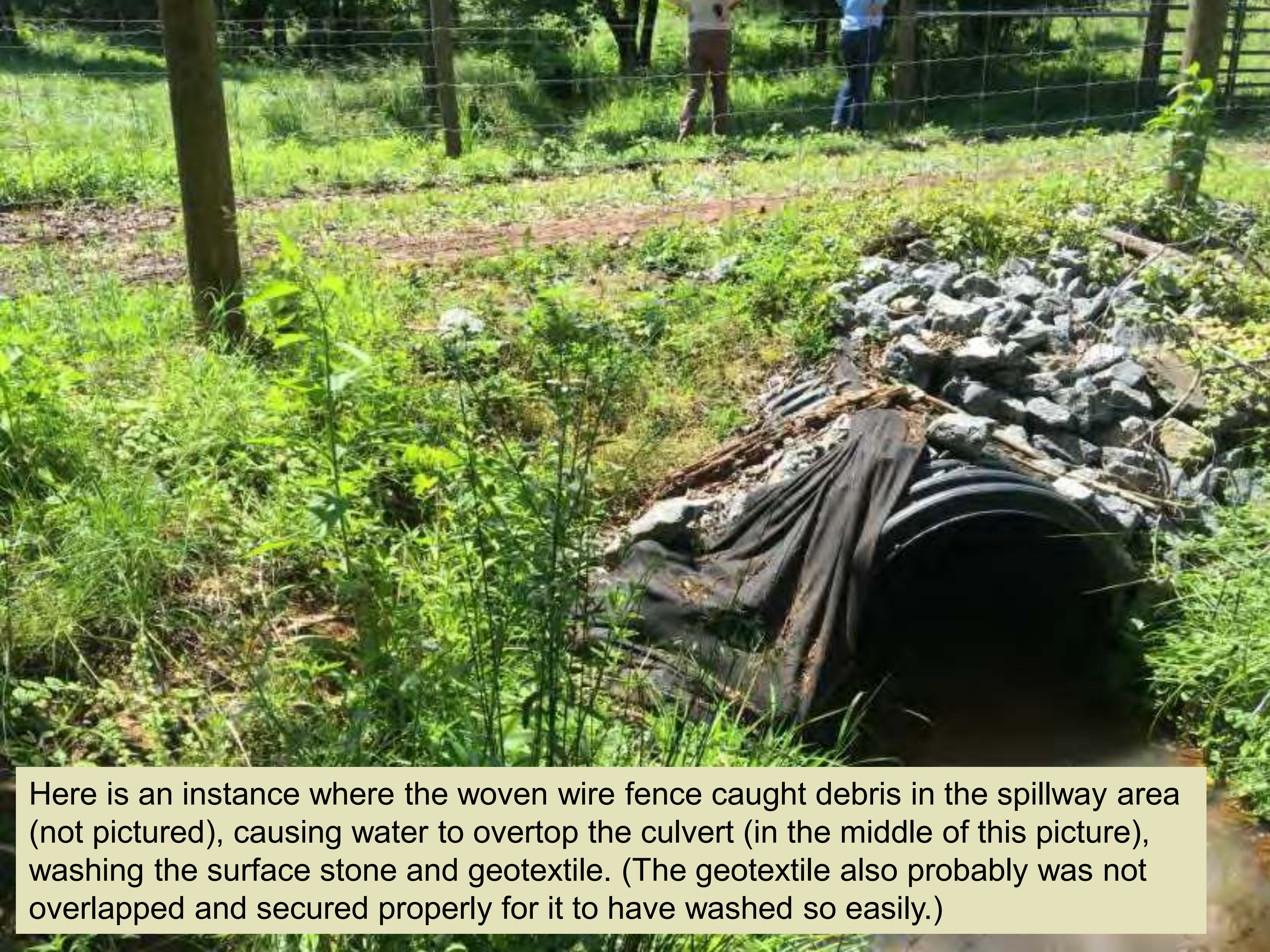
High-tensile smooth wire is the easiest to repair and is less likely to catch debris.

Virginia Department of Conservation & Recreation



Separate “breakaway” posts are still required for culvert crossings!

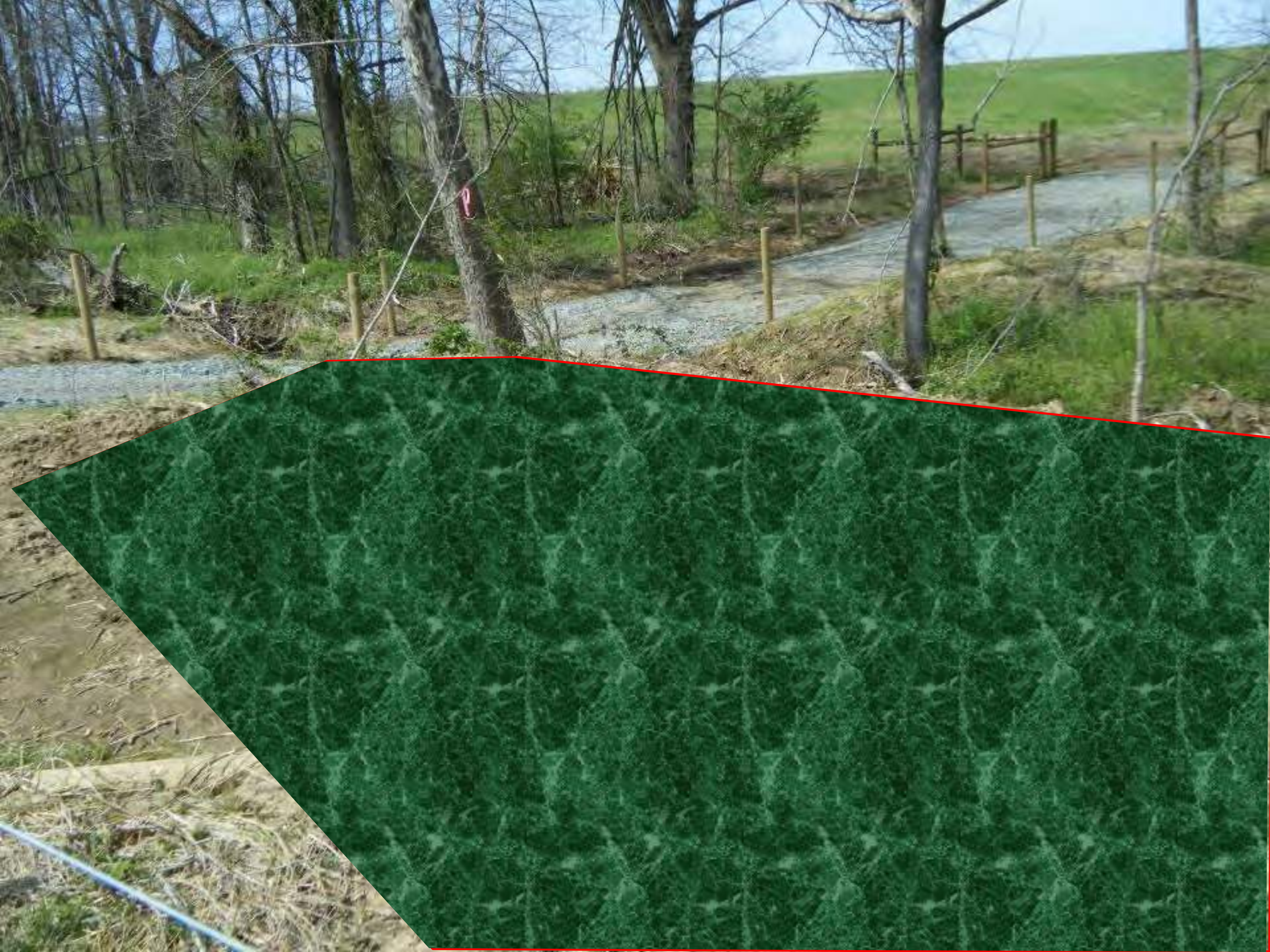

05/12/2014



Here is an instance where the woven wire fence caught debris in the spillway area (not pictured), causing water to overtop the culvert (in the middle of this picture), washing the surface stone and geotextile. (The geotextile also probably was not overlapped and secured properly for it to have washed so easily.)

7. Seeding

- Seed all disturbed area according to NRCS Construction Spec. VA-706
- “Plant all areas to be vegetated as soon as practical after construction.” (VA-578)
- “All excavated material must be placed in upland sites and not in any streams/floodplains or wetlands.” (VA-578)



As-Built/Certification

As-Built/Certification

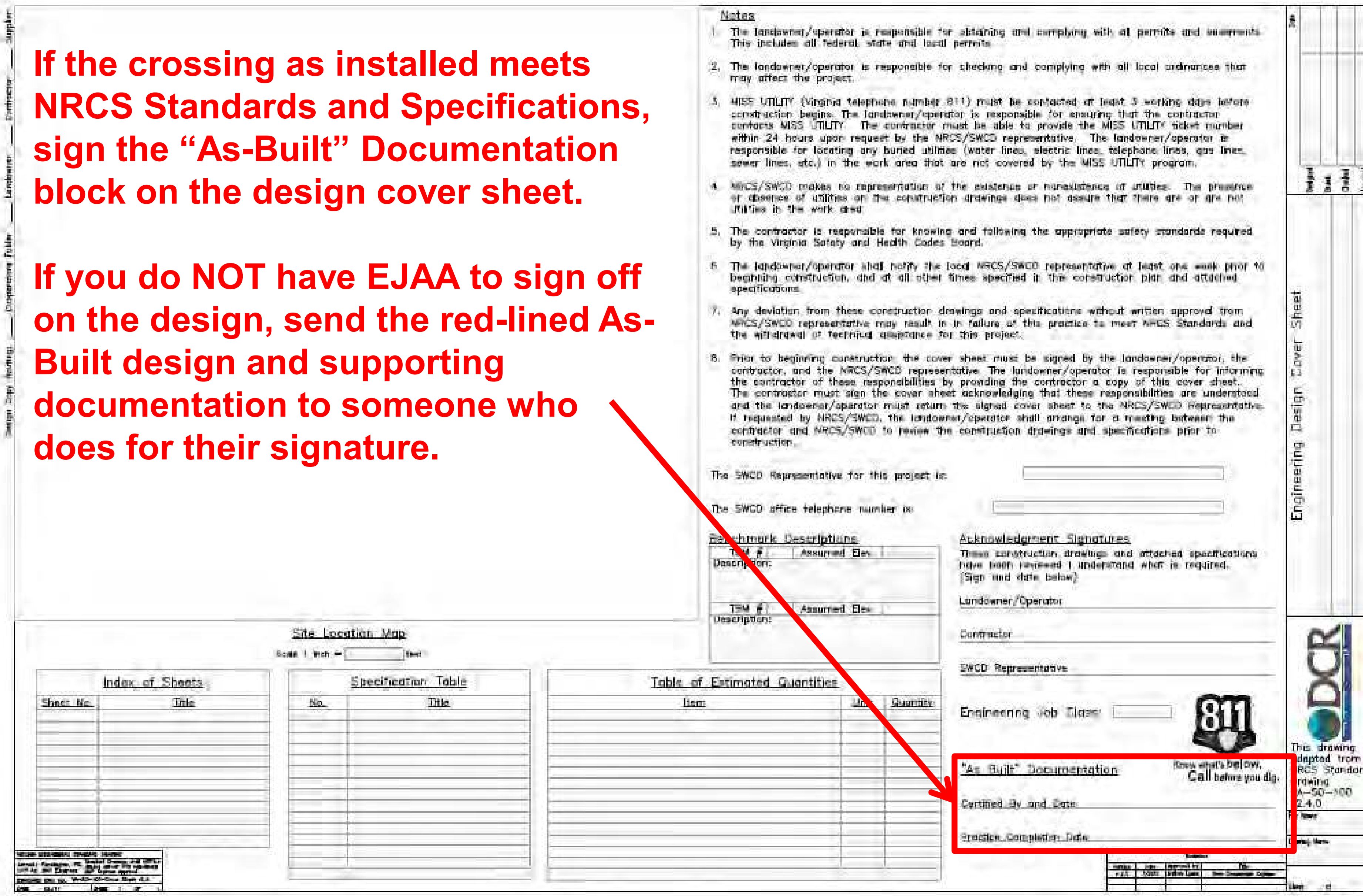
- Complete the checkout:
  - As-Built Survey
    - (If initial survey stakes have been removed, run the survey and use stream center-line as reference)
    - Survey all critical points from your design (culvert invert at inlet and outlet, centerline profile of crossing, measure slope of side slopes)
    - Be sure to survey enough to determine the ACTUAL headwater elevation. If the fill differs from the original design, the headwater may have changed, which could reduce the capacity of the culvert below the design requirements!
  - Measurements:
    - Length, Width, Depth of Stone Layers
    - Length, Diameter, Type of Culvert
  - Document Gradation of Stone and Presence of Nonwoven Geotextile
  - Make sure crossing as installed meets stds. and specs.
  - Take photographs for case file

As-Built/Certification Continued

- Complete the "As-Built" Drawings:
  - Plot the As-Built Survey in red on the original "Stream Crossing Profile" Sheet
    - The stream centerline can often be used to standardize the stations with the original survey
  - Verify that the final grades are satisfactory: Did they achieve the grades that were specified?
  - Document Measurements of Stone Layers
  - Document Gradation of Stone and Presence of Nonwoven Geotextile

If the crossing as installed meets NRCS Standards and Specifications, sign the “As-Built” Documentation block on the design cover sheet.

If you do NOT have EJAA to sign off on the design, send the red-lined As-Built design and supporting documentation to someone who does for their signature.



Hardening Existing Culverts

- Occasionally the “least cost technically feasible alternative” may be to harden an existing culvert
- Many will call this a “Trail and Walkway” (CPS 575)
  - VA-575: “Where a trail/walkway crosses a stream, use Virginia NRCS CPS *Stream Crossing”*
- Perform hydrologic and hydraulic calcs on culvert to make sure it passes the same design flow requirements for culvert stream crossings.

Existing Culvert Example

This culvert appears to have more than 10 years of “life” left in it. It may be appropriate to harden the surface.

It is embedded more than 6”. In order to adjust the hydraulic capacity, use the NRCS “EmbeddedPipes” Excel file and change the embedded depth from 6” to whatever it may actually be.

Existing Culvert Example

Hardening the surface would clearly address a resource concern.

Existing Culvert Example

A pond immediately downstream of the culvert creates a “backwater” condition that may actually make this culvert flow under “outlet control”. While surveying, survey the top of the dam elevation and use this as the “Tailwater Elevation”.

Surveying an Existing Culvert

- Collect the following data if surveying an existing culvert (in order to have enough data to determine if the existing culvert is sufficient to just armor the surface):
  - Centerline of Crossing
  - Upstream Top of Culvert (invert to be determined by subtracting diameter)
  - Downstream Top of Culvert (invert to be determined by subtracting diameter)
  - Streambed at Entrance
  - Streambed at Outlet
  - Existing Crossing Width
  - Existing Culvert Diameter
  - Existing Culvert Length
  - Stream Slope
  - Stream Cross-Section immediately upstream or downstream of culvert (in case it is not sufficient and needs to be replaced)
  - Natural Stream Cross-Section
  - If there happens to be a pond downstream: Top of dam and Low point in spillway

For More Information:

- Virginia NRCS Engineering Design Note 578 (DN-578) Stream Crossing (Available on eFOTG, Section IV)
- Design Guide MD#5, Culvert Stream Crossings Construction Details and Specifications
- NRCS Engineering Field Handbook Chapter 3 – Hydraulics
- NRCS Engineering Field Handbook Chapter 2 – Estimating Runoff
- VDOT Drainage Manual, Chapter 8

Questions?

Contact Information

DCR-DSWC Engineering Staff:

Amanda Pennington, P.E.
District Engineering Services Manager
804-786-0113
Amanda.pennington@dcr.virginia.gov

Raleigh Coleman
Ag BMP Engineering Specialist
540-270-0039
Raleigh.coleman@dcr.virginia.gov