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Learning by Doing:

Planning and Designing a Saturated Buffer

Presented by:

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www.il.nrcs.usda.gov

Illinois Sustainable Ag Partnership – June 19, 2019

United States Department of Agriculture

Agenda

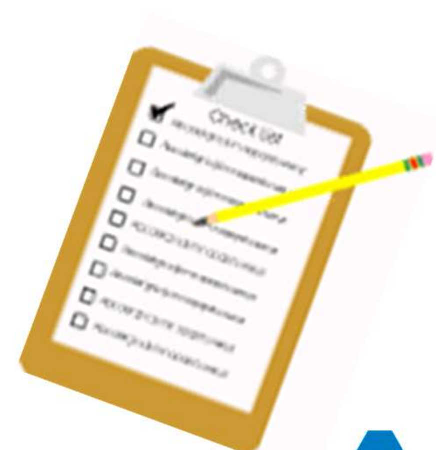
- Planning and site evaluation
  - *What to ask the landowner*
  - *What to look for when visiting the site*
- Preliminary design

Planning and Site Evaluation

- Sometimes called “Inventory & Evaluation” or I&E
- Is the site appropriate for a saturated buffer?
  - If not, is there a better site nearby?
  - Or is there a more suitable conservation drainage practice?
- Plan maps and quantity estimates so client can make planning decisions
  - Client preferences
  - Preliminary design alternative(s)

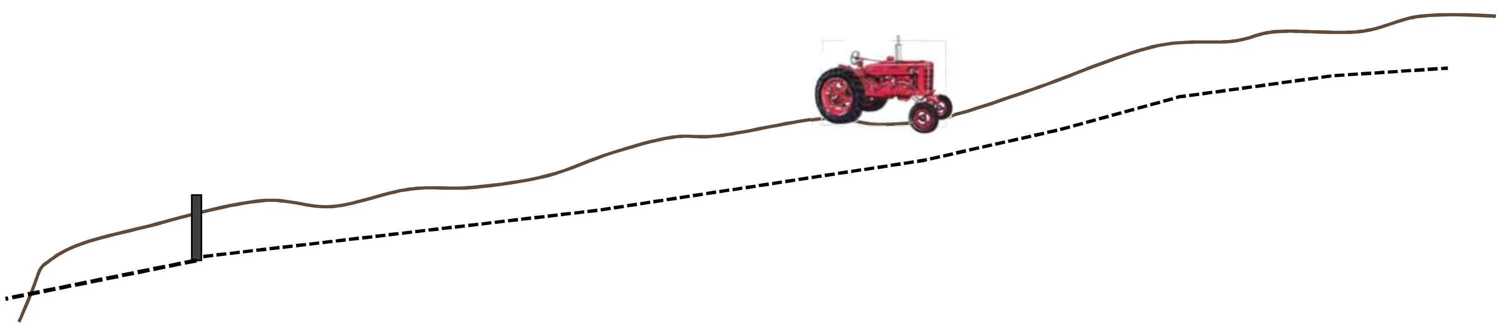
Saturated Buffer I&E info needed – basic

- ID info (county and client name, legal description/location)
- Is the land currently under a conservation program?
- Preferences of the client
  - Active or passive management?
  - Open to doing DWM as well?
- What crops are grown (including any cover crops)?
- Will the site be used for monitoring/research?



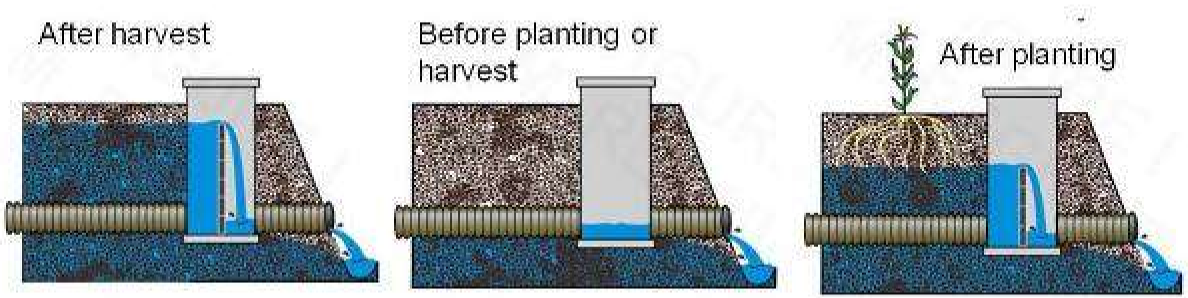
Set it and forget it?

- If topography allows, set saturated buffer lower in elevation so it can operate year round without affecting field trafficability.



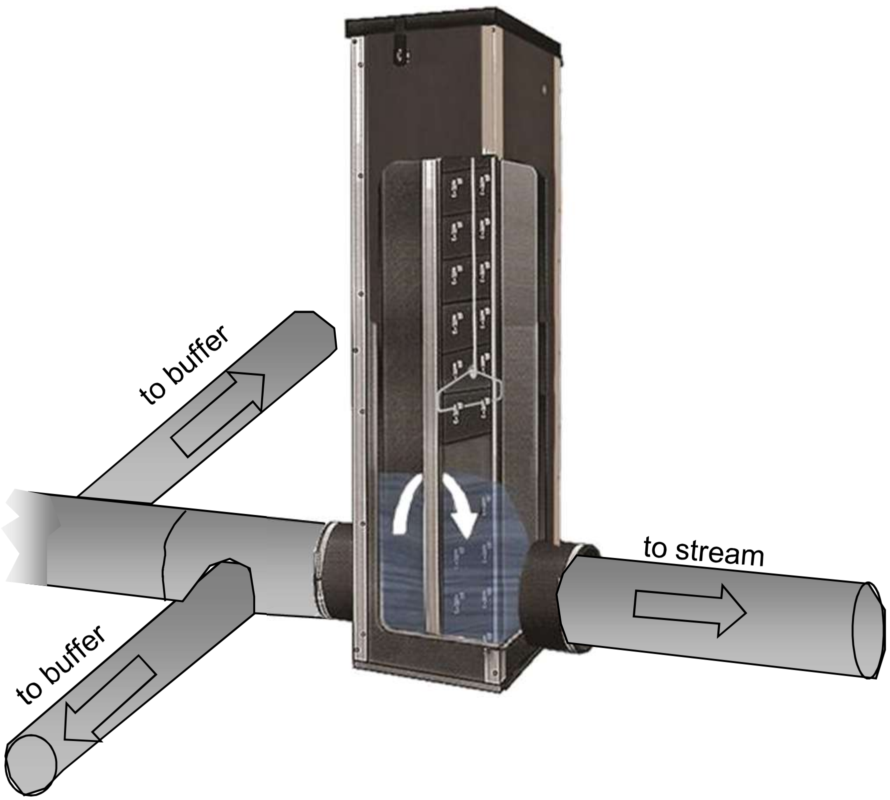
What is DWM?

- Drainage Water Management (CPS 554)
- If the site is relatively flat, some measure of DWM will likely be required.
- *May be able to hold back water and nutrients for crop production.*

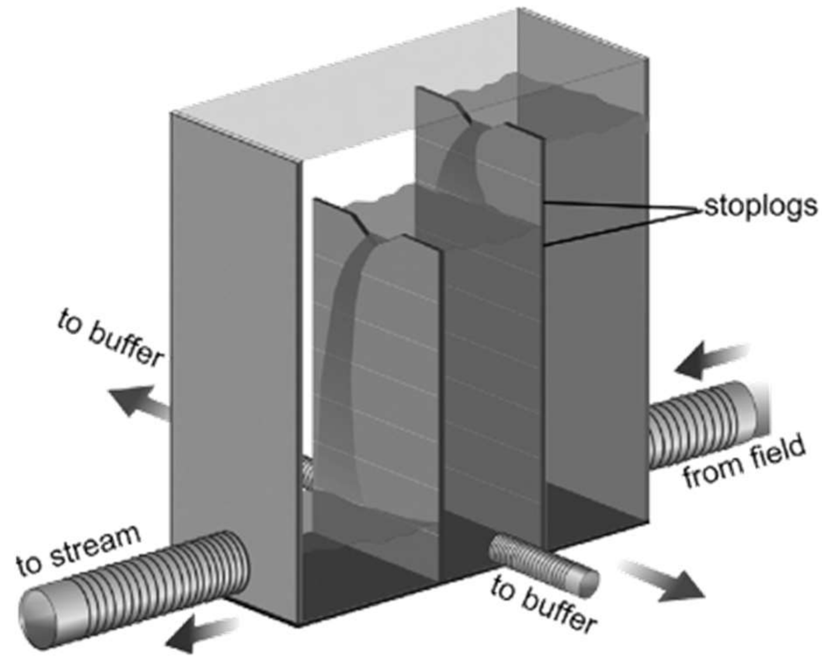


Structure type depends on monitoring

Basic structure



Monitoring structure



Saturated Buffer I&E info needed - maps

- Aerial, with property boundaries, location of proposed practice
- Topography/soils with drainage area delineated (LiDAR preferred)
- Tile *(or at least tile diameter and material, depth, grade, location, surface intakes)*

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Case Study

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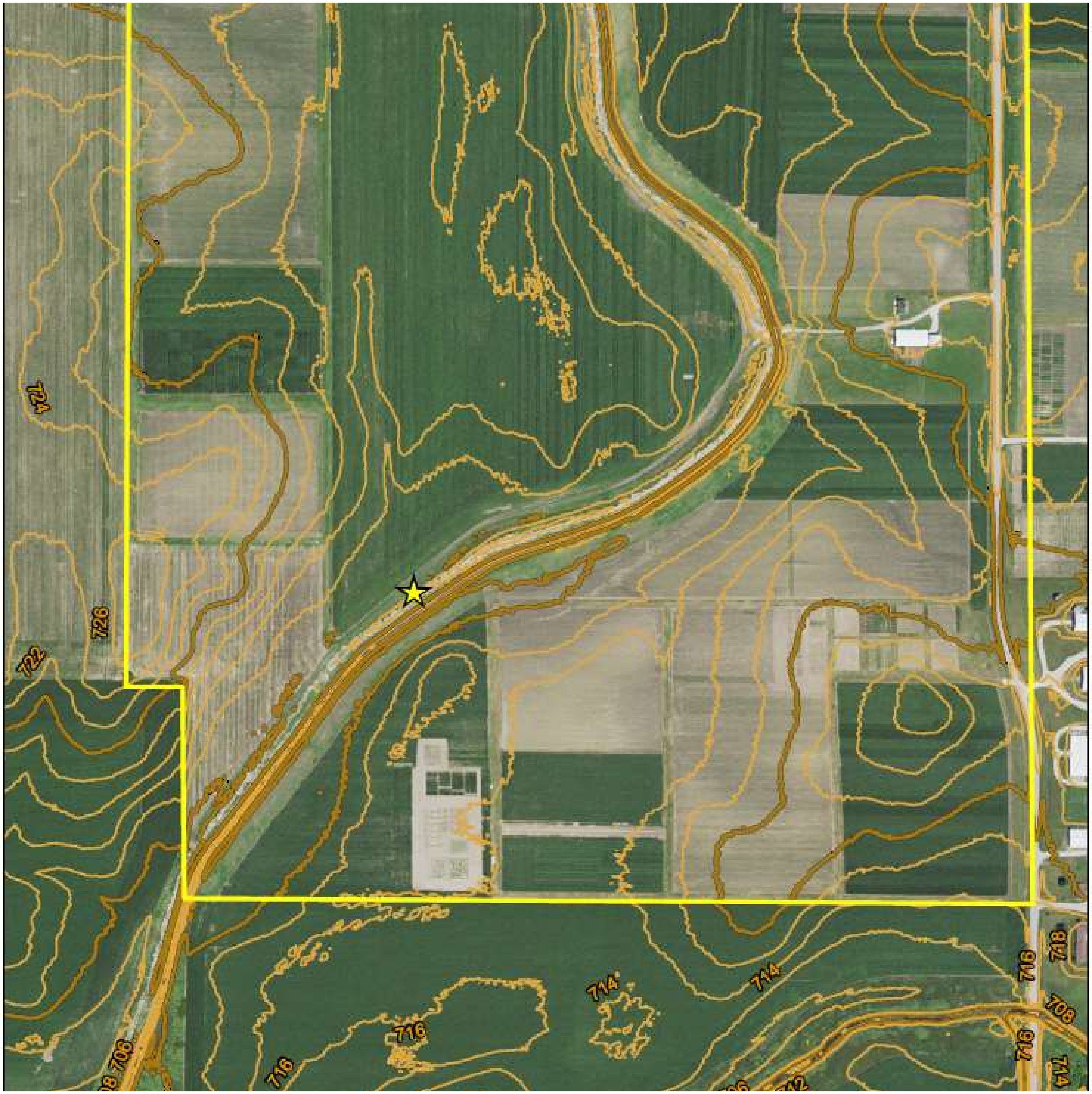

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Natura

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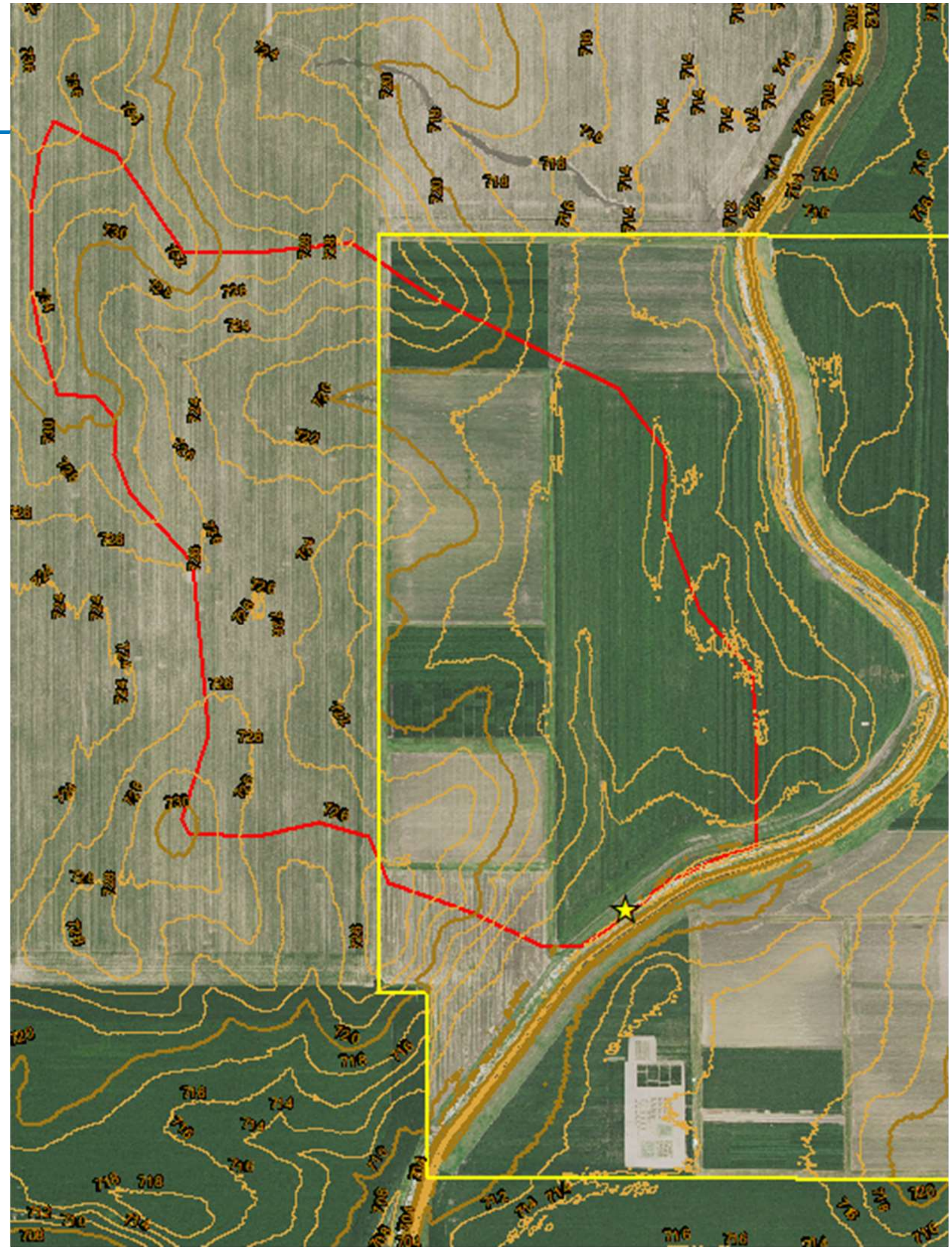
Surface Drainage Area



Preplanning - Soil

- Presence of Organic Matter
- Capable of holding a water table
  - Poorly or somewhat poorly drained
  - Absence of sandy or gravelly layers?
- Hydraulic properties
  - Ksat
  - Drainable porosity

Soil Physical Properties
- Bulk Density, One-Third Bar
- Organic Matter
- Saturated Hydraulic Conductivity (Ksat)
- Water Content, One-Third Bar

Soil Qualities and Features
- Drainage Class

Prepare for the site specific geologic investigation

http://websoilsurvey.sc.egov.usda.gov

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Do the soils on this site look feasible for a saturated buffer?

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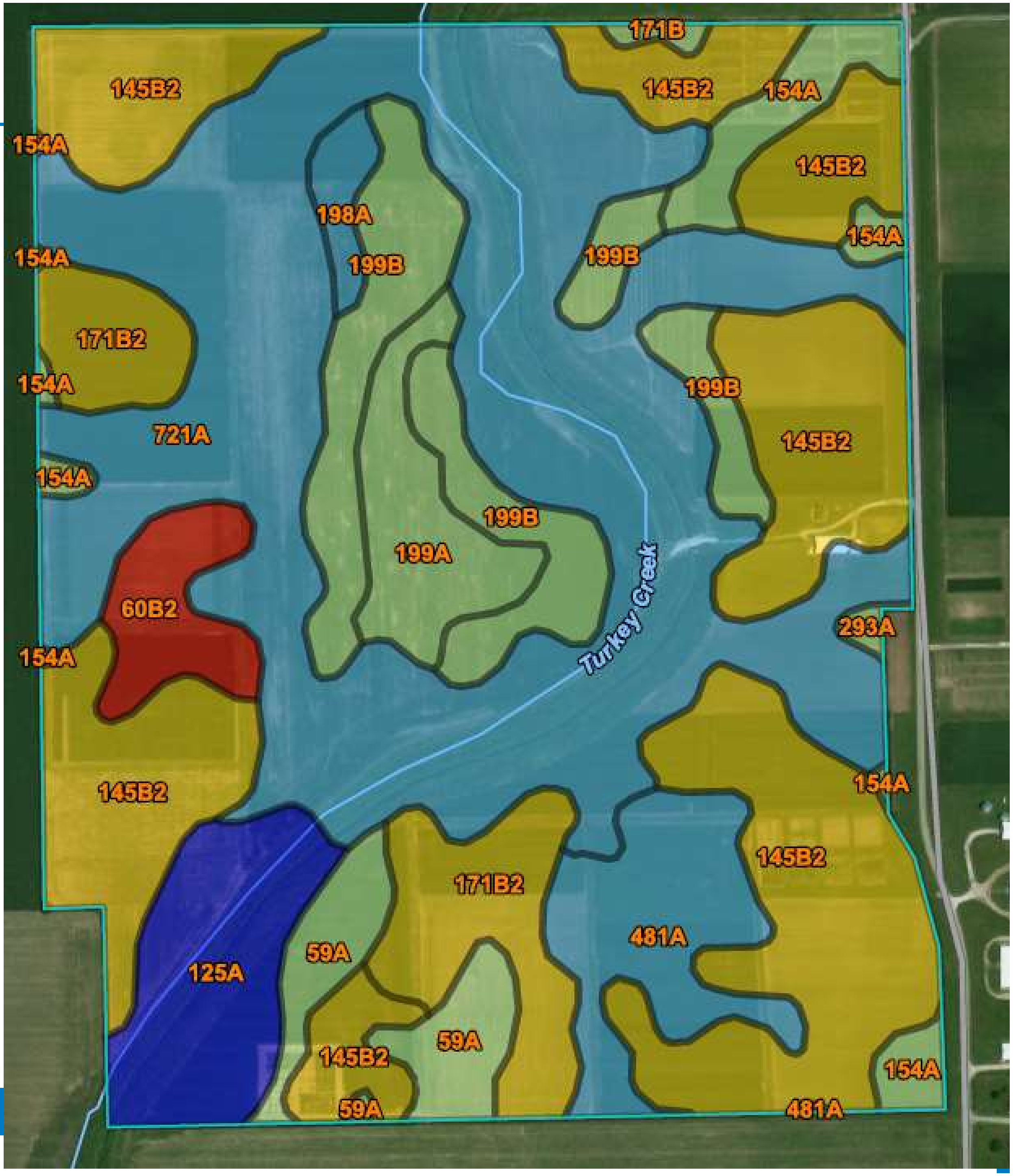
Organic Matter (top 30”)

	<= 0.70
	> 0.70 and <= 1.49
	> 1.49 and <= 2.47
	> 2.47 and <= 3.26
	> 3.26 and <= 3.79
	Not rated or not available



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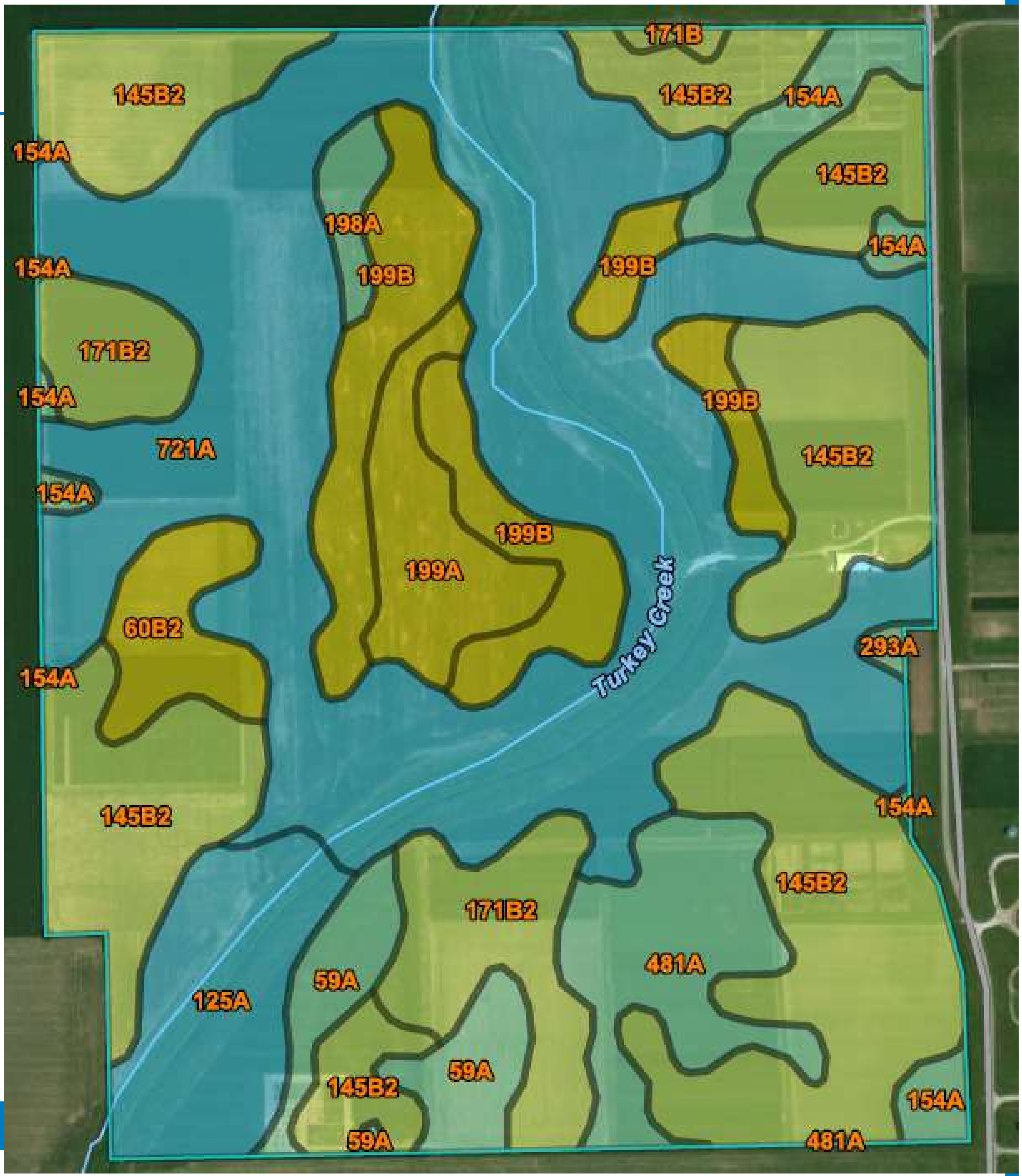
Drainage Class
Excessively drained
Somewhat excessively drained
Well drained
Moderately well drained
Somewhat poorly drained
Poorly drained
Very poorly drained
Subaqueous



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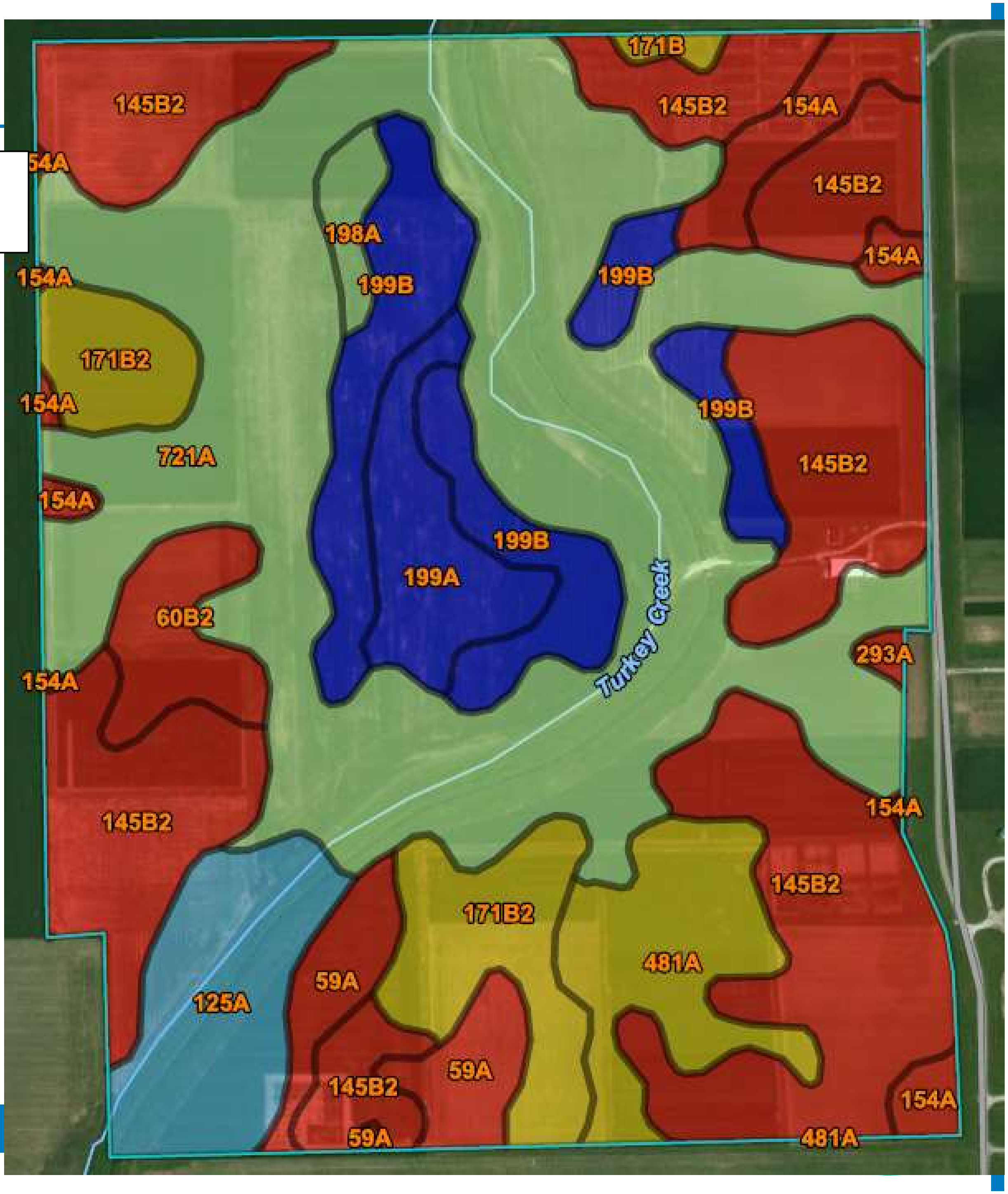
Saturated Hydraulic Conductivity (µm per second)

red	<= 6.5381
yellow	> 6.5381 and <= 8.0483
light green	> 8.0483 and <= 10.1485
light blue	> 10.1485 and <= 13.5588
blue	> 13.5588 and <= 16.8937



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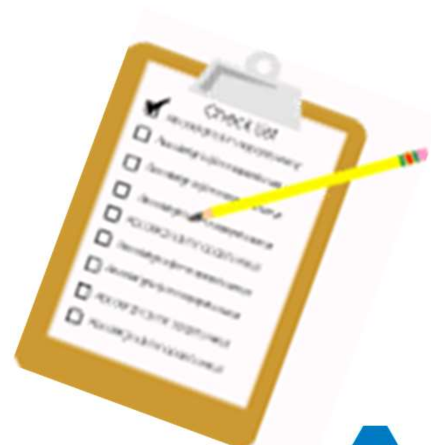
Tile Map

- "Sorry, we don't have one for this site."
- What we do know:
  - Location of outlet to ditch is shown on the map
  - Tile is 8" diameter corrugated plastic
  - No surface intakes

Saturated Buffer I&E info needed – site conditions

- Vegetation on site (photos?)
- Crops/ proximity
- Elevations (baseflow, crop, proposed buffer site, etc)
- Info about the tile outlet
- Receiving channel/ area (bank stability)
- Geologic investigation
- Any abandoned tile we need to be aware of?



Q&A: Any sites we should avoid?

- Subsurface drainage system must have NO surface inlets
- Soils need to be able to hold a water table and have enough organic matter
- Bank/channel must be stable
- Avoid locations where restrictive layer is significantly above channel flowline *(unless you can show bank stability)*

Q&A: Any sites we should avoid?

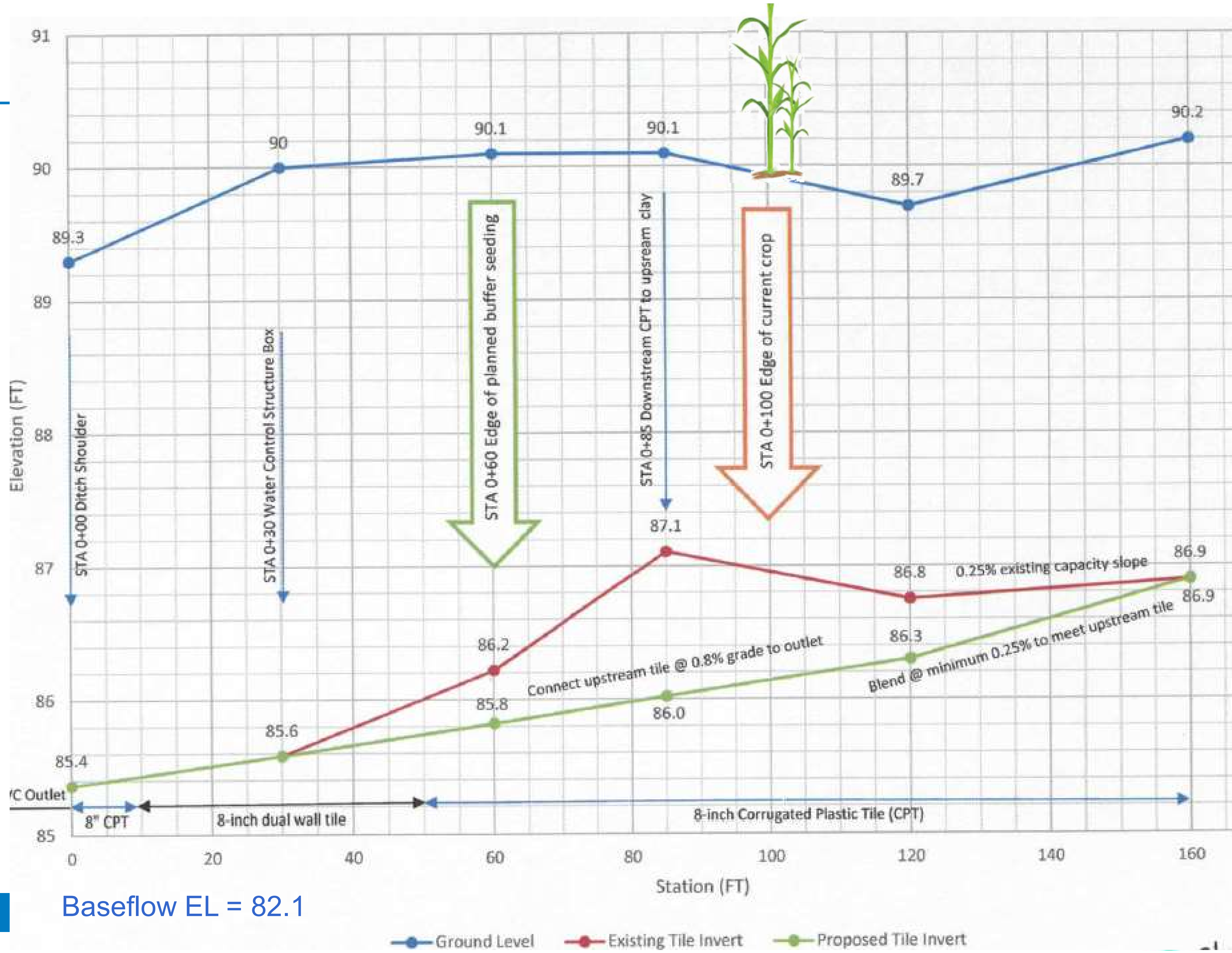
- Minimize flooding from receiving channel
- Avoid flooding the crops! (and neighbors)
- Avoid locations within drip line of trees (to reduce root plugging)

Vegetation: corn and soybeans.
No cover crops.
Cropped area 100’ back from ditch bank.

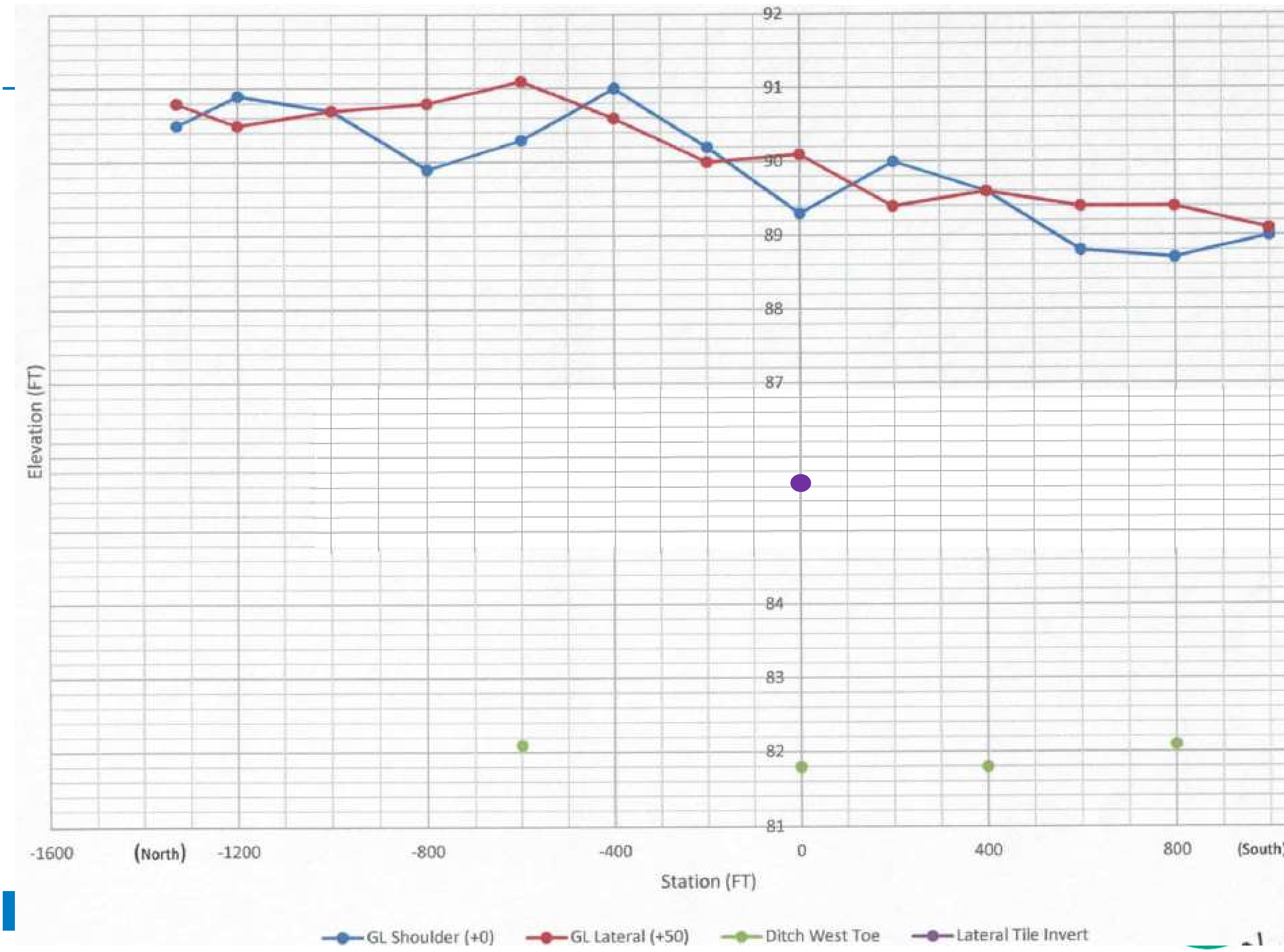
Critical elevations

- Elevations of:
  - Crop field edge
  - Ground surface at proposed distribution line and any low spots along that line
  - Tile depth near proposed distribution line
  - Tile outlet flowline
  - Baseflow in ditch
- Get survey data (or save for design phase)
- Control elevation

What is this?



Baseflow EL = 82.1



Elevation (FT)
92
91
90
89
88
87
84
83
82
81
-1600
(North)
-1200
-800
-400
0
400
800
(South)
Station (FT)
GL Shoulder (+0)
GL Lateral (+50)
Ditch West Toe
Lateral Tile Invert

Geologic/ Soil Investigation

- Possible to hold a water table
- At least 1.2% organic matter in top 2.5 feet
- Abandoned pipes or tile?
- Depth to restrictive layer
- Hydraulic conductivity (or save for design phase)

Log of test hole

NRCS-ENG-533
REV.11/03

HOLE / East

U.S. DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE

LOG OF TEST HOLES

Watershed: Turkey Creek
Location: Sec. T. R.
Logged by:
Date: 5/24/18
Drilling Equipment:

Project:
Hole No. ① East
Owner:
State: ILLINOIS
County: McLean
Notes:
Location of Holes:

Hole Depth From (In ~~Feet~~)	Hole Depth To (In ~~Feet~~)	DESCRIPTION OF MATERIAL	USCS	Samples No.	Type	From Feet	To Feet	Fines %	Sand %	Gravel %	Moist. %
0	19	Mixed colors - material from dredged ditch									
19	33	Black alluvial material High om	CL								
33	38	Black material High om	CL								
38	51	Black with gray material Hydric soil	CL								
51	59	Gray with black material	CL								
59	64	Gray material with krotovinas	CL								
64	69	Gray gravelly sand with red oxides	SC								
69	90+ (7.5ft)	Black alluvium w/ gray mottles	CL								
		* Water present									

Notes:
Depth of 38-51 has gray colors indicating (hydric soil conditions and) indicates seasonal water table.

Depth of 64-69 contains porous sand with red iron oxides. Indicates lateral water flow, with dissolved oxygen content


Stream bedload is sand.

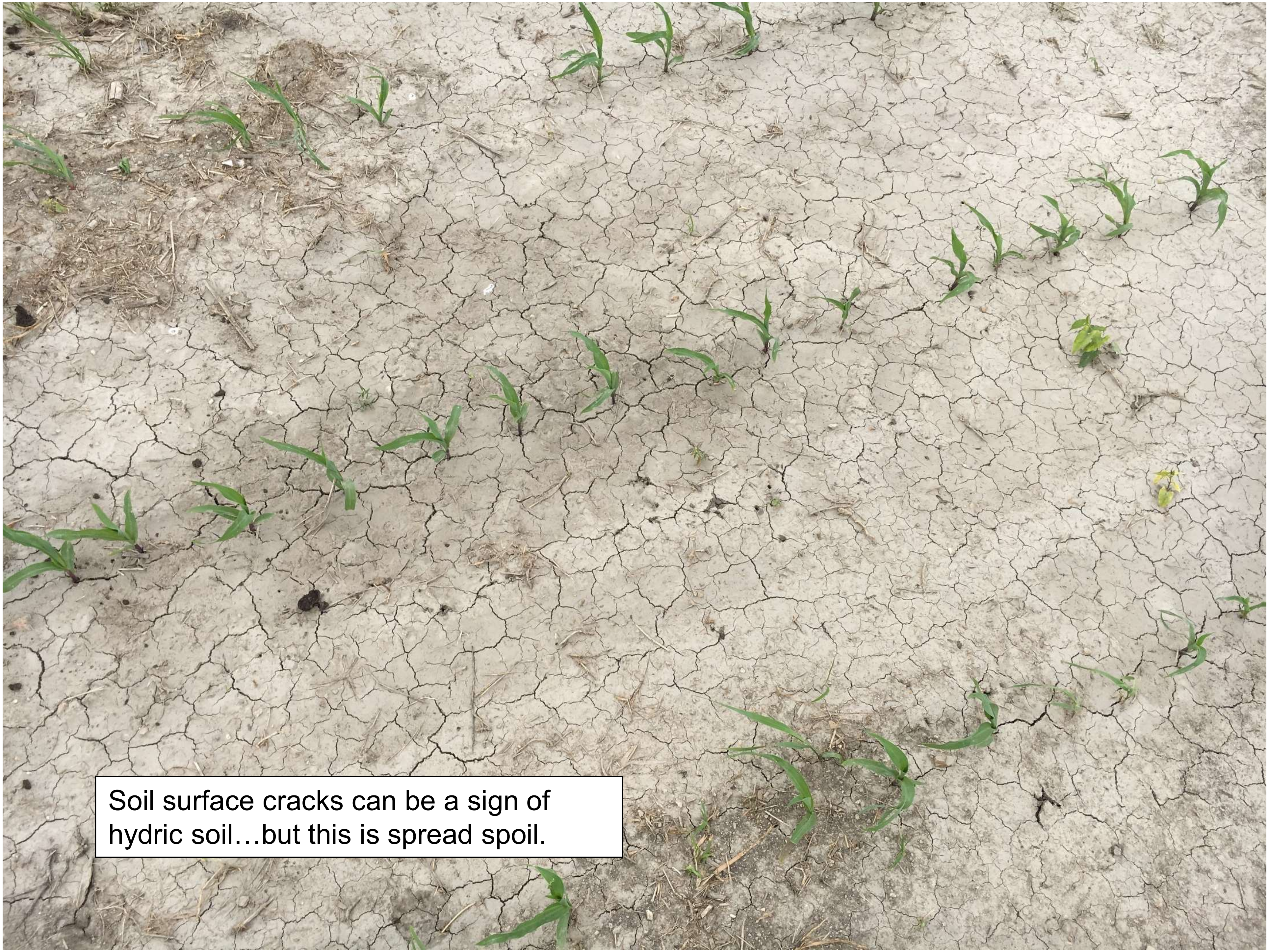
Spoil spread out from recent ditch dredging includes sand, silt, cobbles.

30” deep soil sample using tile spade shows black, high carbon layers.

At the bank, red mottled sandy material is showing, although the material ribbons.

Along ditch bank about 1’ above base flow is saturated, shows some red mottles above that location.

Tile probe brings up water droplets from 36” depth.



Soil surface cracks can be a sign of hydric soil…but this is spread spoil.


Looking downstream, are these banks stable?
Proposed saturated buffer

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Piece of 8" clay tile found in the ditch adjacent to tile outlet. Any other tile present?

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Help the Land

Ready for preliminary design?

- Is the site appropriate for a saturated buffer?
  - If not, is there a better site nearby?
  - Or is there a more suitable conservation drainage practice?

Determining Drainage System Capacity

1. Mainline configuration (*tile size, type, grade* → capacity of outlet main)
2. Drainage Coefficient (Q = DC *inches/day* x acres drained)
   - With tile map (known drained area)
   - Without tile map (estimated drained area)
3. Modeling
   - Library of DRAINMOD runs for typical soil textures
   - Site specific modeling

Drainage System Capacity – Option 1

- Mainline configuration
  - Tile size and diameter
  - Tile grade
  - Roughness coefficient

$$Q = \frac{1.486}{n} A\, R^{\frac{2}{3}} S^{\frac{1}{2}}$$

- Tends to be conservative

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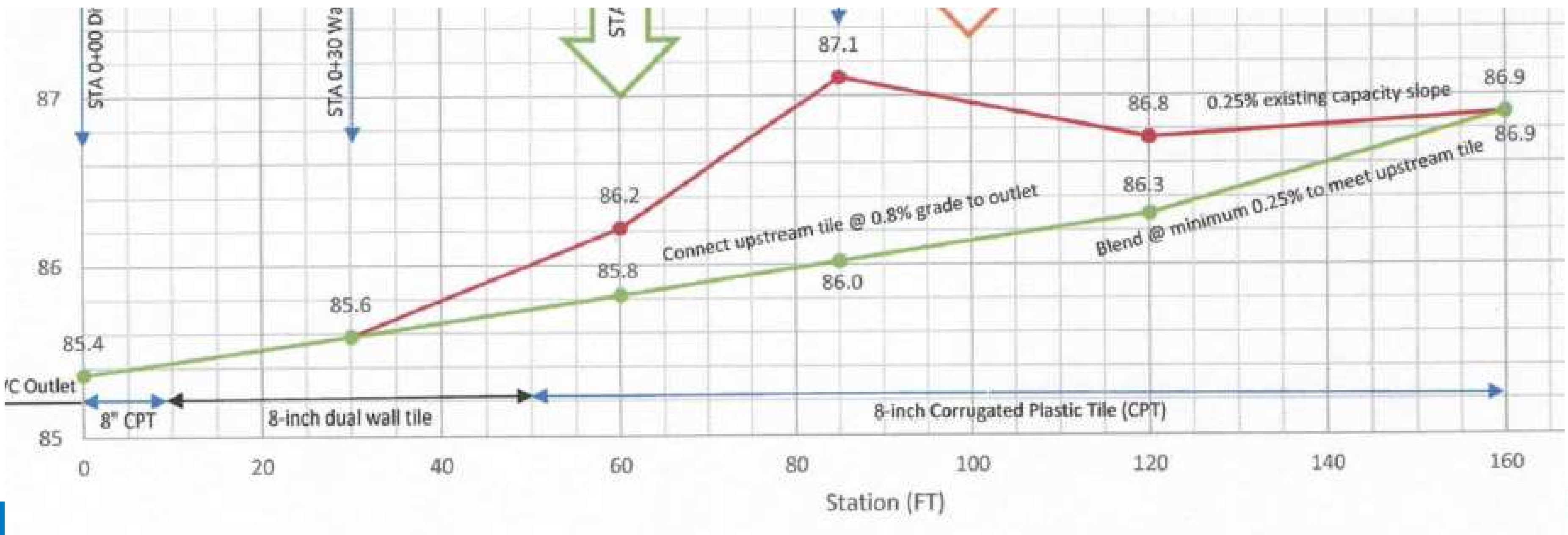
Case Study

- Spreadsheet calculator needs to know:
  - Tile size = _________ inch
  - Tile grade = __________%

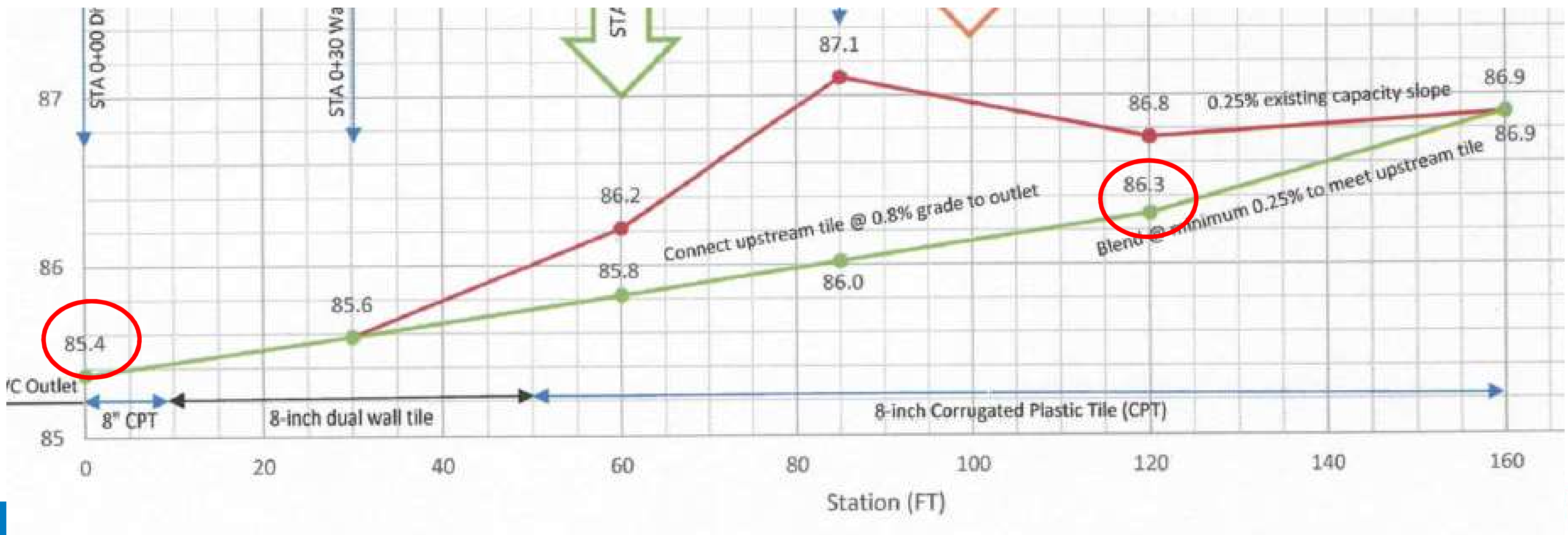


Case Study

- Tile size = ___8____ inch
- Tile grade = (86.3 – 85.4)ft / 120 ft = 0.0075 (or 0.75%)

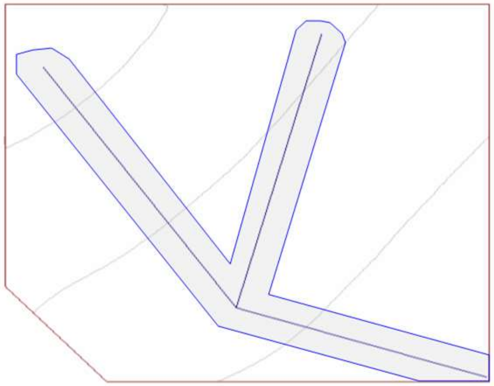
Determine System Capacity:

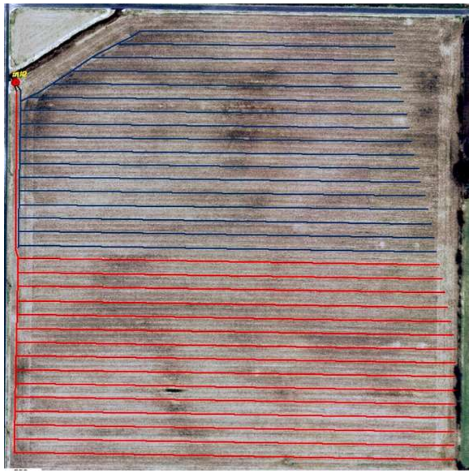
Option 1 - Mainline Configuration	
Mainline tile size (in)	8
Mainline tile grade (%)	0.75
Mainline tile material	CPT
	Manning's 'n' = 0.016
Peak velocity in mainline given size and grade	*2.44 ft/sec*
Peak flow from mainline size and grade	*0.853 cfs*



Drainage System Capacity – Option 2

- Drainage Coefficient method
  - **With tile map** – determine acres drained by the system
    - Find the drain spacing for the soil type and estimated depth, from the state Drainage Guide, and divide in half (**½S**)
    - Delineate drained acres by drawing a line around the tile system, **½S** on each side of the tile.
  - Then multiply drainage coefficient times drained acres *(with units conversions)*





Option 2 - Example

Given:

Random tile system 3,075 ft long including lateral. Harpster soil: tile spacing for 48” depth 80-90 ft. Typical Illinois drainage coefficient = 3/8” per day.

Find drainage system capacity: *first, find area drained*

Area drained, ft^2 = *length* x *spacing*

Area drained =

Option 2 - Example

Given:

Random tile system 3,075 ft long including lateral. Harpster soil: tile spacing for 48" depth 80-90 ft. Typical Illinois drainage coefficient = 3/8" per day.

Find drainage system capacity:

first, find area drained

Area drained, ft^2 = *length* x *spacing*

Area drained = (85)(3075) = 261,375 sq.ft. *(= 6.0 acres)*

Option 2 - Example

Given:

Random tile system 3,075 ft long including lateral. Harpster soil: tile spacing for 48" depth 80-90 ft. Typical Illinois drainage coefficient = 3/8" per day. Remember our drained area calculation just now.

Calculations: *now find capacity of tile – let the spreadsheet do it!*

Capacity of tile Q, cfs = *coeff.* x *area*

(Convert inches to ft; days to seconds. Keep area in square feet.)

Option 2 - Drainage Coefficient	
Drainage area of tile system (ac)	6
Drainage coefficient (inches/day)	0.375
Capacity of drainage system	*0.095 cfs*

Capacity of tile $Q = \left(\frac{DC}{24\ x\ 3600\ x\ 12}\right)(DA)$

What if there is no tile map?

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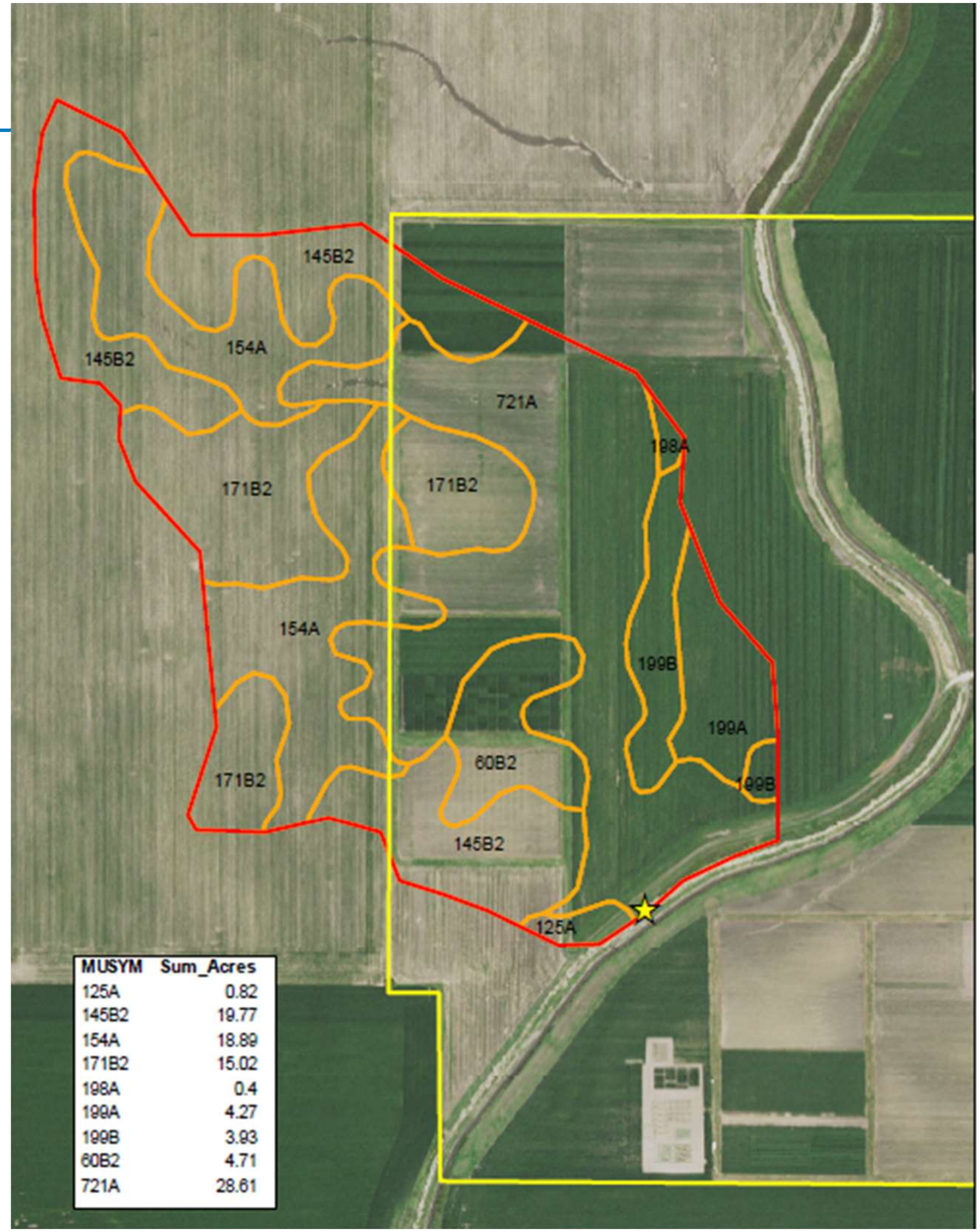
Drainage Area Soils

Total approx. 96.4 acres



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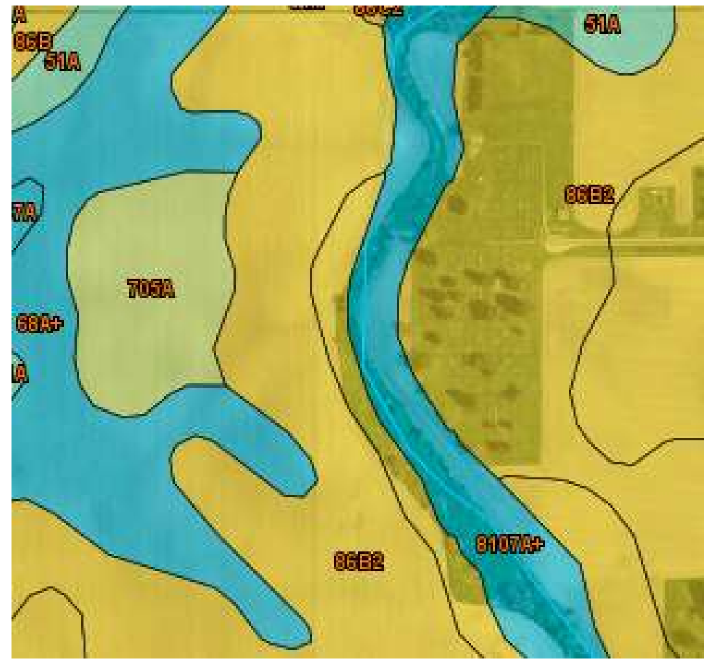
Acres Drained by Tile – Option 2, Method 2

- If you can't get a map of the tile system, delineate the entire watershed for surface flow to the tile outlet.
- Acres Drained = all of the watershed acres with poorly or very poorly drained soil, and half of the acres with somewhat poorly drained.
- Use Web Soil Survey to determine the soils in the watershed, and how many acres of each.



Soil Qualities and Features

- AASHTO Group Classification (Surface)
- Depth to a Selected Soil Restrictive Layer
- Depth to Any Soil Restrictive Layer
- Drainage Class

http://websoilsurvey.sc.egov.usda.gov

Option 2 – Case study with no tile map

Given:

Typical Illinois drainage coefficient = 3/8" per day

Soils in watershed:

MUSYM	Sum_Acres
125A	0.82
145B2	19.77
154A	18.89
171B2	15.02
198A	0.4
199A	4.27
199B	3.93
60B2	4.71
721A	28.61

Find drained area and drainage system capacity:

first, find area drained

Drained Area =

Option 2 – Case study with no tile map

Map Unit	Soil Name	Acres	Drainage Class
125A	Selma	0.82	Somewhat poorly drained
145B2	Saybrook	19.77	Moderately well drained
154A	Flanagan	18.89	Somewhat poorly drained
171B2	Catlin	15.02	Moderately well drained
198A	Elburn	0.4	Somewhat poorly drained
199A	Plano	4.27	Well drained
199B	Plano	3.93	Well drained
60B2	La Rose	4.71	Well drained
721A	Drummer and Elpaso	28.61	Poorly drained

Find drained area and drainage system capacity:

first, find area drained

Drained Area = .5 (0.82 + 18.89 + 0.4) + 28.61 = 38.7 acres

Option 2 – Case study with no tile map

Given: *Typical Illinois drainage coefficient = 3/8” per day*

Remember our drained area calculation just now.

Calculations: *now find capacity of tile (let the spreadsheet do it)*

Capacity of tile $Q = \left(\frac{DC}{24\ x\ 3600\ x\ 12}\right)(DA\ in\ acres\ x\ 43{,}560)$

Option 2 - Drainage Coefficient	
Drainage area of tile system (ac)	38.7
Drainage coefficient (inches/day)	0.375
Capacity of drainage system	*0.610 cfs*

Design Flow

5% of Drainage System Capacity…figured whichever way you determine is appropriate

EXAMPLE:

Given: *Drainage system capacity = 0.61 cfs*

Calculation:

Design flow = .05 x 0.61 = 0.031 cfs

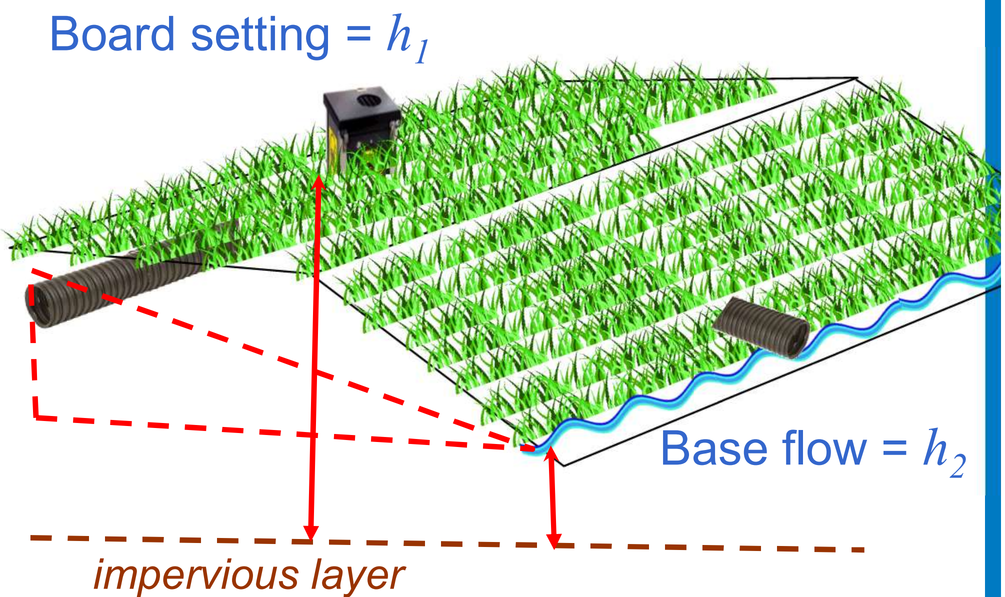

QUESTIONS
?

How to achieve the design flow?

- Unit flow per foot of "leach" pipe

$$q = \frac{K_{sat}}{2\,L}(h_1^2 - h_2^2)$$

- Impervious layer closer to surface means less unit flow
- Maintain water table within 12" of ground surface @ distribution pipe



The spreadsheet will help with this calculation.
Longer distribution pipe means more flow.

Saturated Hydraulic Conductivity

- Web Soil Survey?
- Guelph Permeameter
- Other methods

Soil saturated hydraulic conductivity, K_{sat} *(μm/sec)* | 9.17

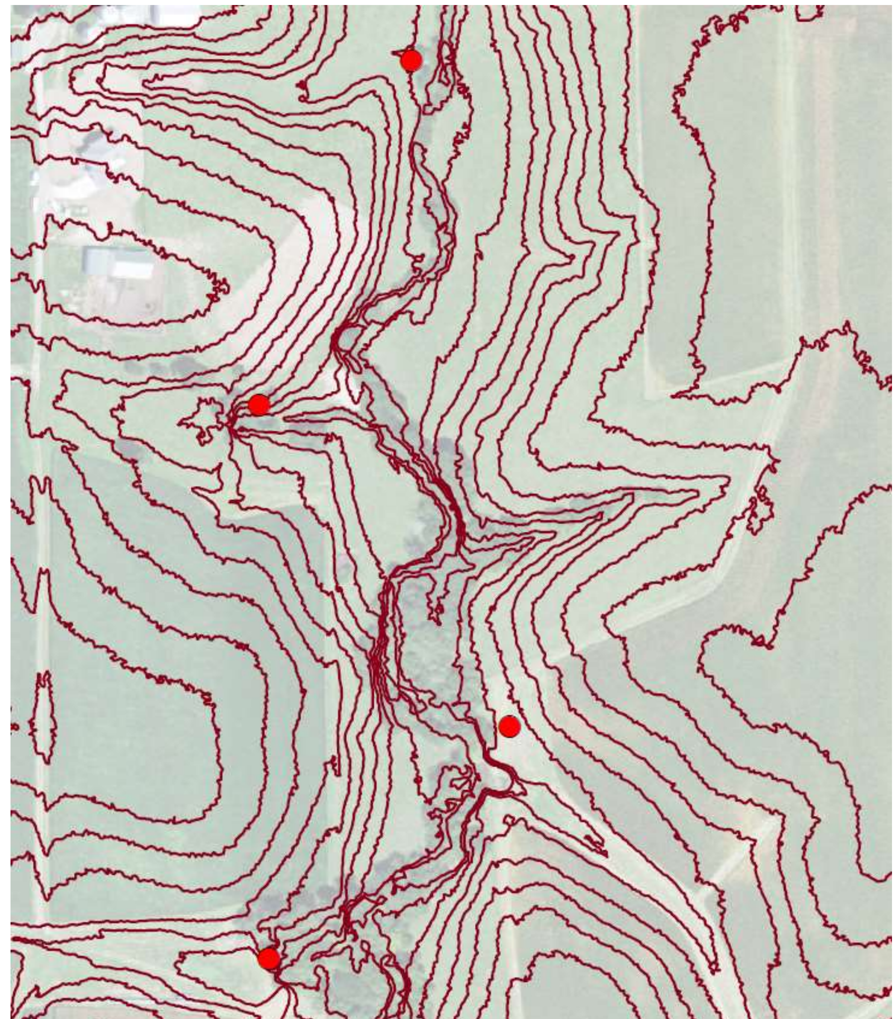
0.11 ft/hr

Complex topography can be a barrier

- Divide the analysis into reaches
  - Similar distance from stream

    (± 10%~?)
  - Similar change in elevation from distribution pipe to stream

    (± 1.5 ft)
- Consider a different conservation drainage alternative



SATURATED BUFFER DESIGN

USDA- Natural Resources Conservation Service

Illinois NRCS Version 2.1 - 4/10/2017

Project Name	EXAMPLE	**Designed by:**		**Date:**	
Site Location		**Checked by:**		**Date:**	
County					

Determine System Capacity:

Option 1 - Mainline Configuration

Mainline tile size (in)	8
Mainline tile grade (%)	0.75
Mainline tile material	CPT
	Manning's 'n' = 0.016
Peak velocity in mainline given size and grade	2.44 ft/sec
Peak flow from mainline size and grade	0.853 cfs
Minimum Design Capacity: (5% of Option 1, 2, or 3; whichever is lower)	0.030 cfs
Selected Design Capacity	0.031 cfs

Option 2 - Drainage Coefficient

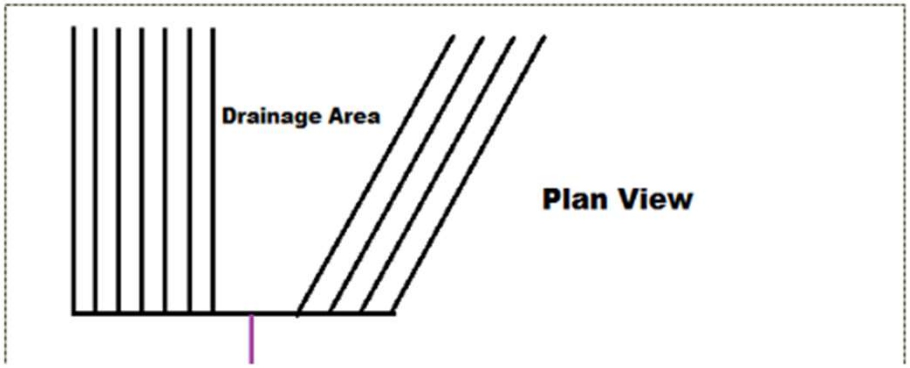
Drainage area of tile system (ac)	38.7
Drainage coefficient (inches/day)	0.375
Capacity of drainage system	0.610 cfs

Option 3 - Saturated Buffer system flow rate (Based on DRAINMOD Model or other source)

Describe Value Used and source	

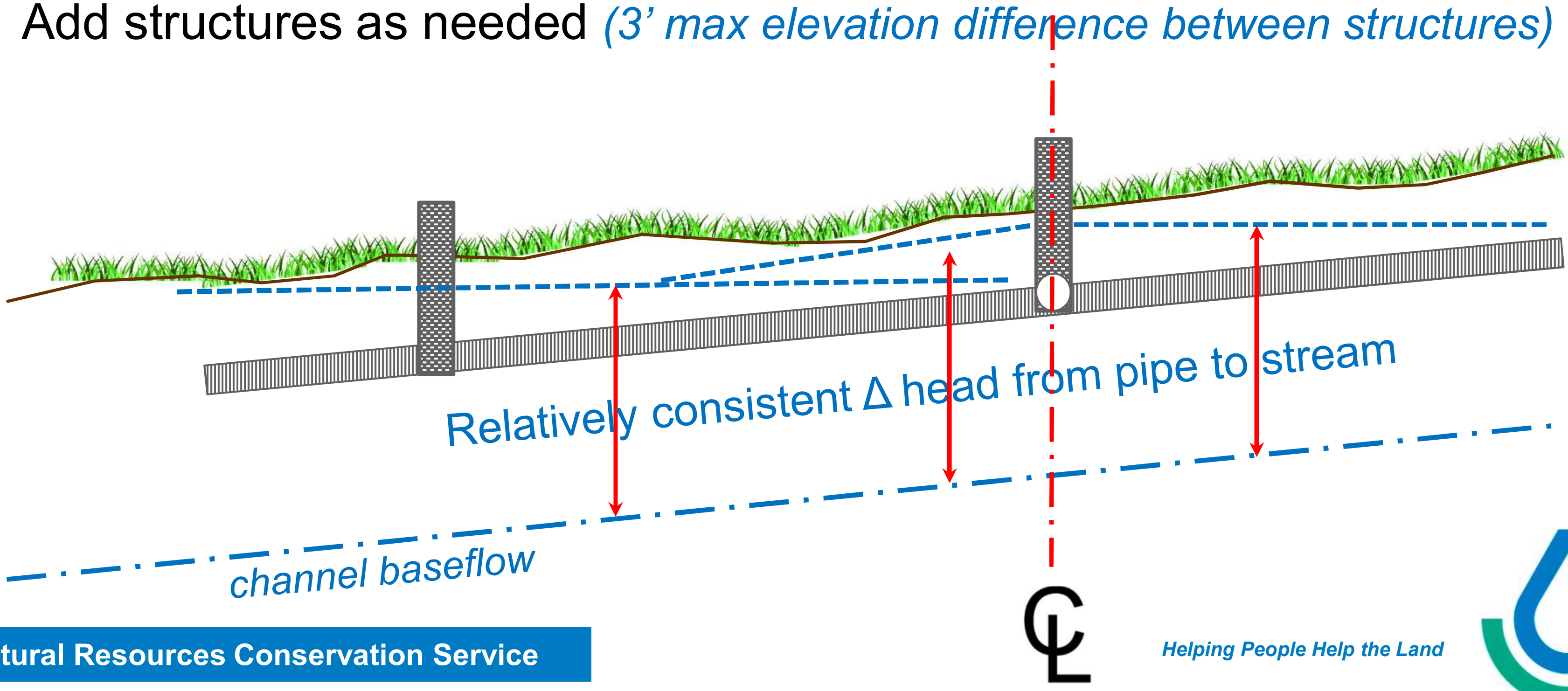
Size Distribution Pipe:

Distribution pipe min. grade (%)	0.10
Design distribution pipe diameter *(in)*	6 in
Distance from dist. pipe to outlet channel, L *(ft)*	40.0
Ground surface elevation at WCS *(ft)*	90.0
Depth of impervious layer *(ft)*	8.5
Design water control weir elevation *(ft)*	89.0
Baseflow water elevation in ditch or outlet *(ft)*	82.1



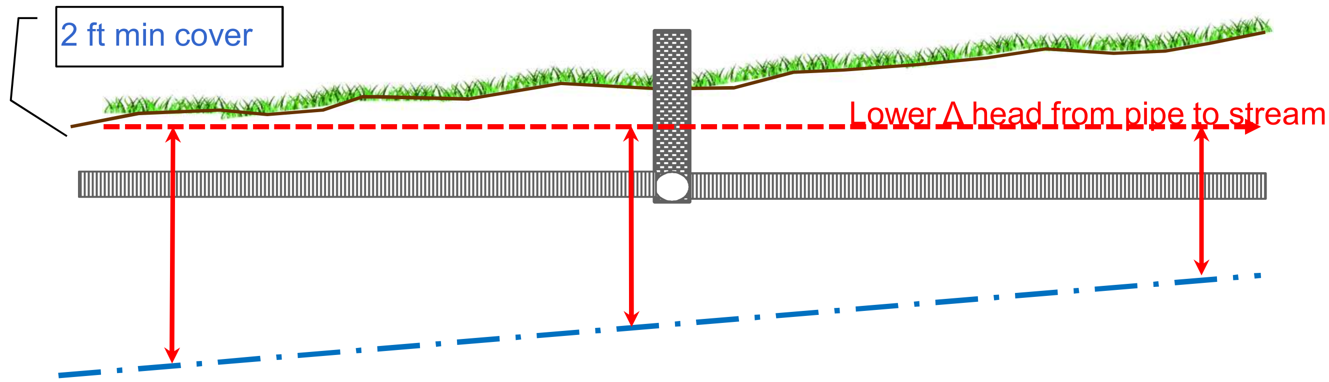
Criteria - Distribution Pipe

- Meet criteria for CPS 606 – Subsurface Drain
- Target is flow uniformity
- We analyze this 3-D problem in 2-D *(at the main water control structure*)
- Add structures as needed *(3' max elevation difference between structures)*

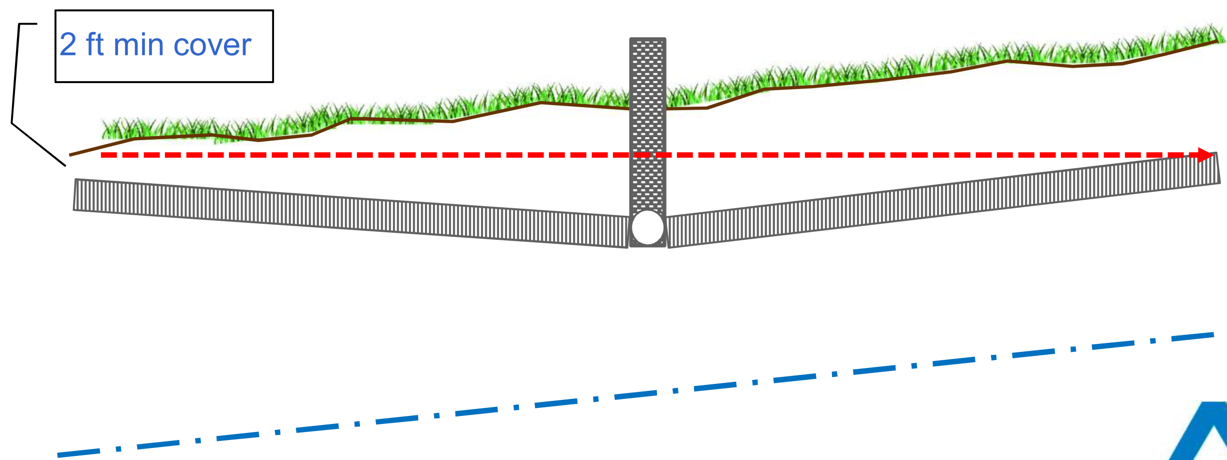


Other Distribution Pipe Layout Options

- Level



- Drain to structure

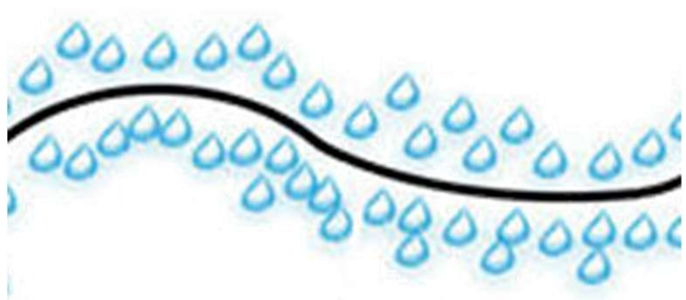


Sizing the Distribution Pipe Diameter

- The limitation needs to be flow through the soil, not flow through the pipe.

Think of it as a manifold with much larger potential input than output.

- IL standard drawings show 6” distribution pipe. This should be adequate for most situations.




QUESTIONS
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