Subsurface Drainage System Design and Management for Crop Production and Environmental Considerations

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Situation

- Substantial demand for agricultural products that are dependent on row-crop production
- Increased concern and demand for clean water
- Subsurface drainage systems are essential for row-crop production in the cornbelt
- Use of subsurface drainage systems increases the export of nitrate-N to downstream water bodies





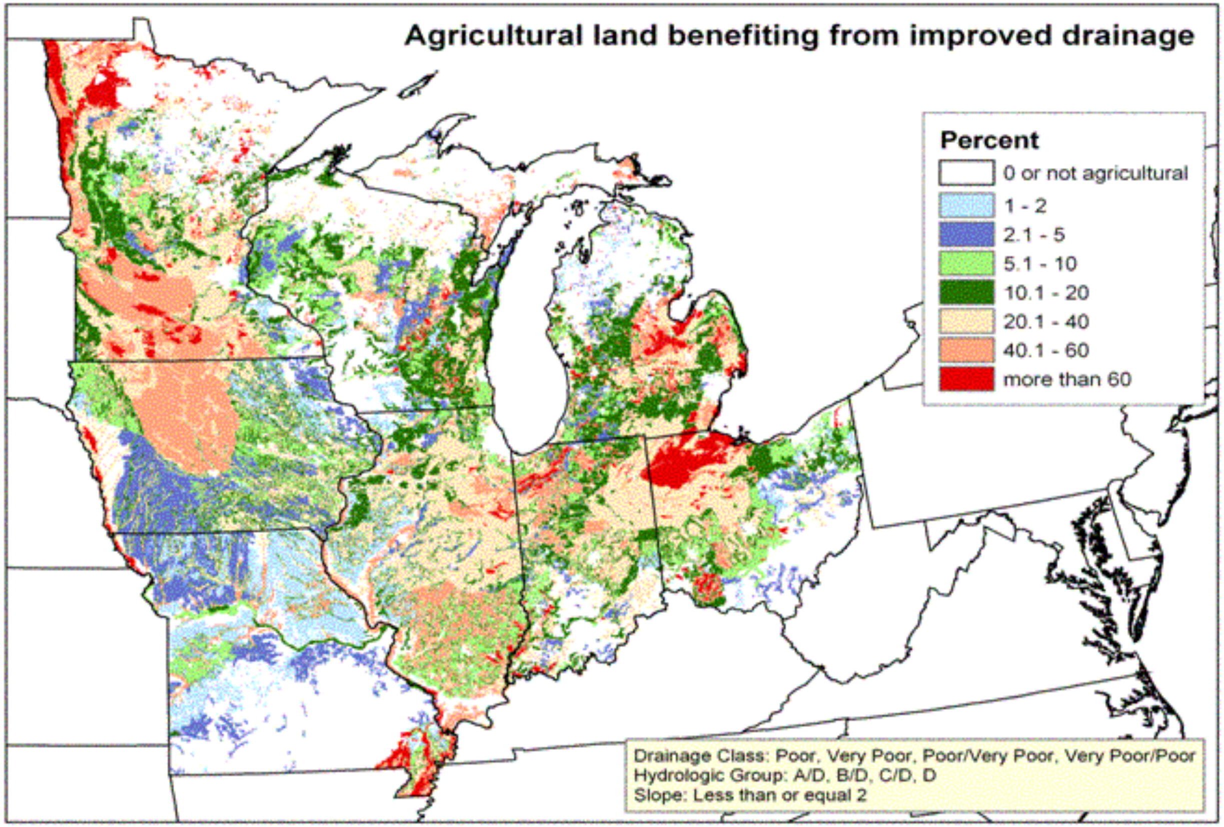
Goals of Drainage

- Primary goals of agricultural drainage in humid areas are to:
  - provide for site trafficability for timely planting and harvesting and to lower the water, and
  - lower the water content in the root zone to provide adequate aeration following excessive rainfall



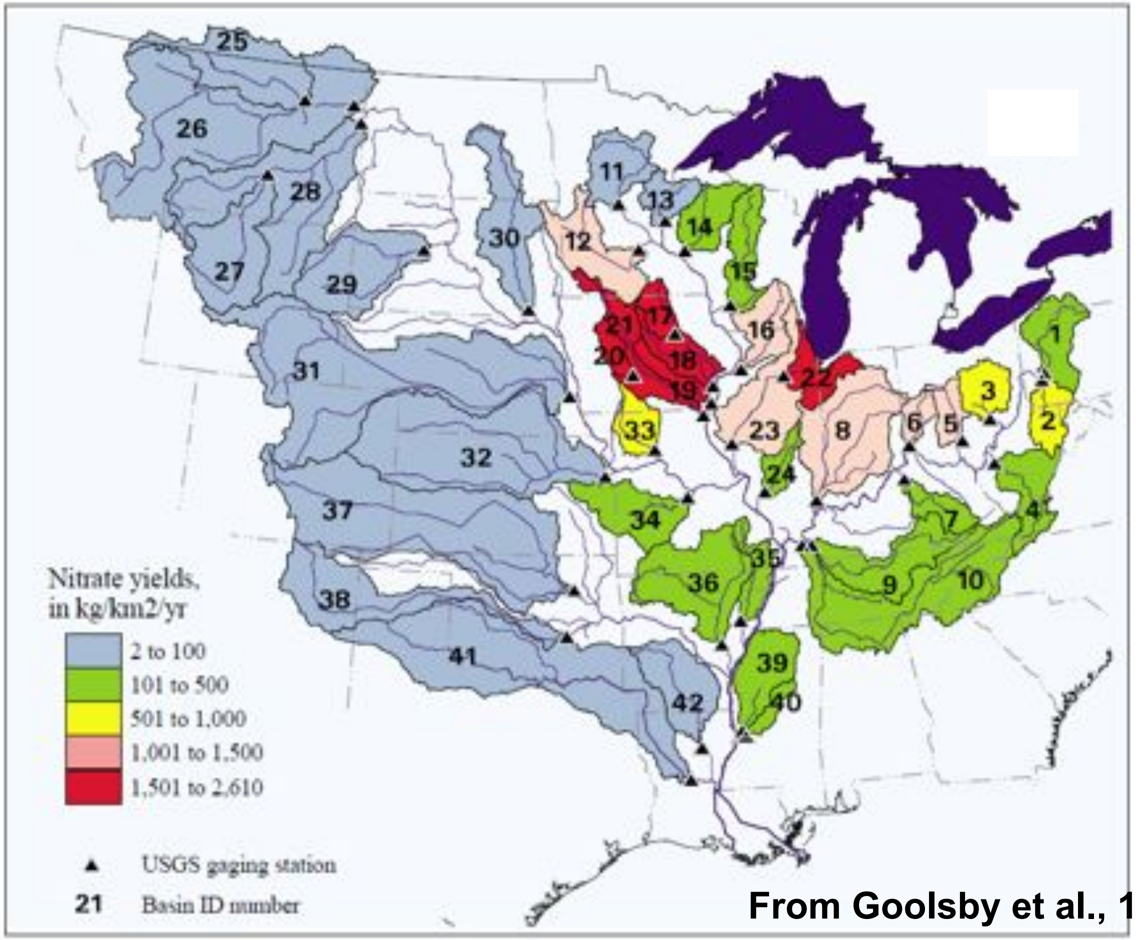


Estimated Extent of Drainage



Source: USDA-ARS National Laboratory for Agriculture and the Environment

Nitrate Export



From Goolsby et al., 1999

J.B. Crim Farm

Nov 15 ,1916 end of 54 inch block tile in northern Boone Co





Steps in the Installation of an Efficient Tile Drainage System.

Never undertake a job of tiling without the supervision of good drainage engineers.

A line of stakes set by the engineers for the guidance of the diggers.

Digging the second spading.

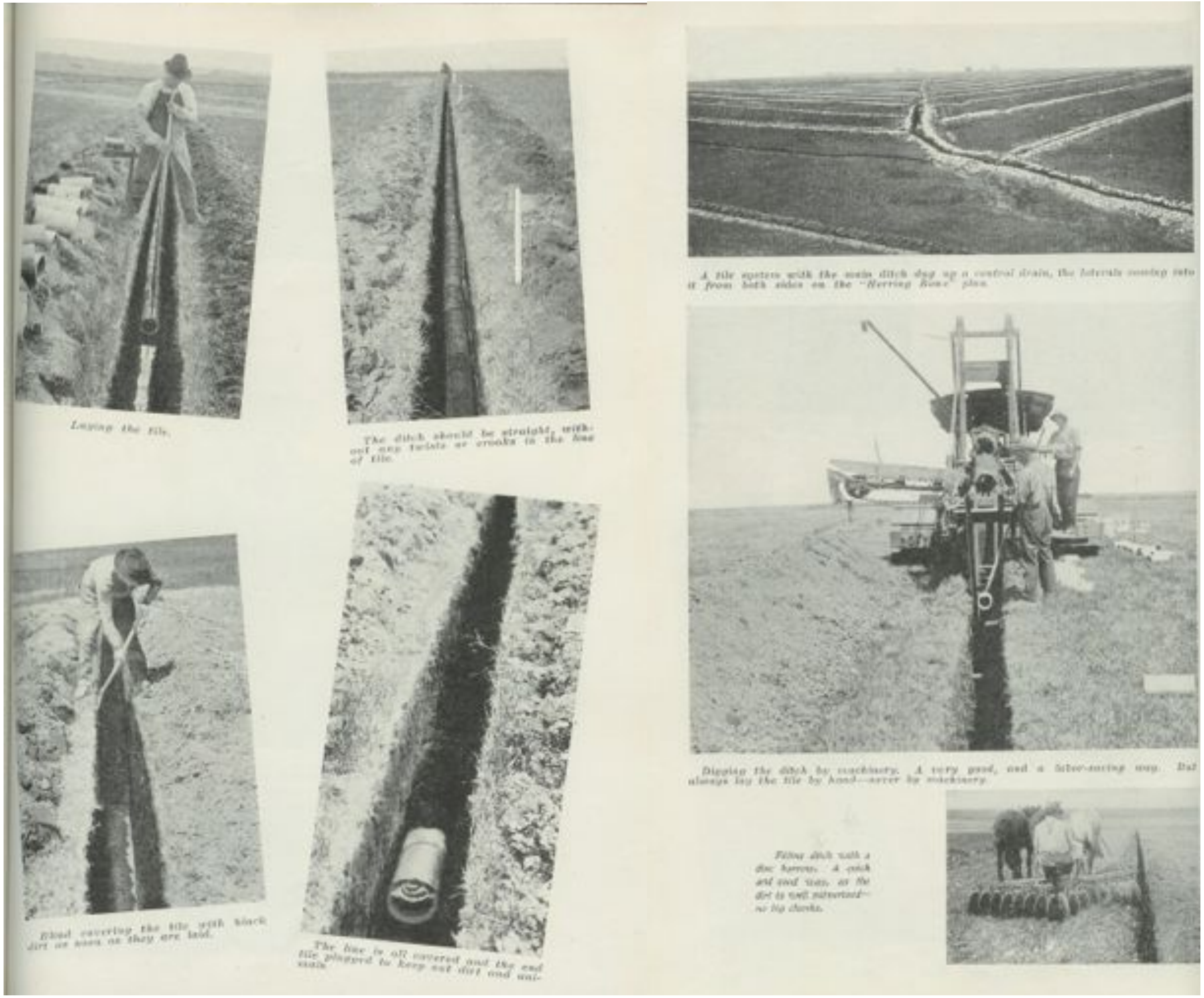
Digging the third spading to [illegible] the tile good and deep.

Digging the first spading true to a line.

Cleaning out after the first spading and throwing the fine, black dirt out by itself to one side of the ditch.

Cleaning and shaping the bottom ready to receive the tile.

Gouging the bottom of the ditch to insure it is the right depth and the fall is uniform.



Laying the tile.

The ditch should be straight, without any twists or crooks in the line of tile.

Blind covering the tile with black dirt as soon as they are laid.

The line is all covered and the end tile plugged to keep out dirt and water.

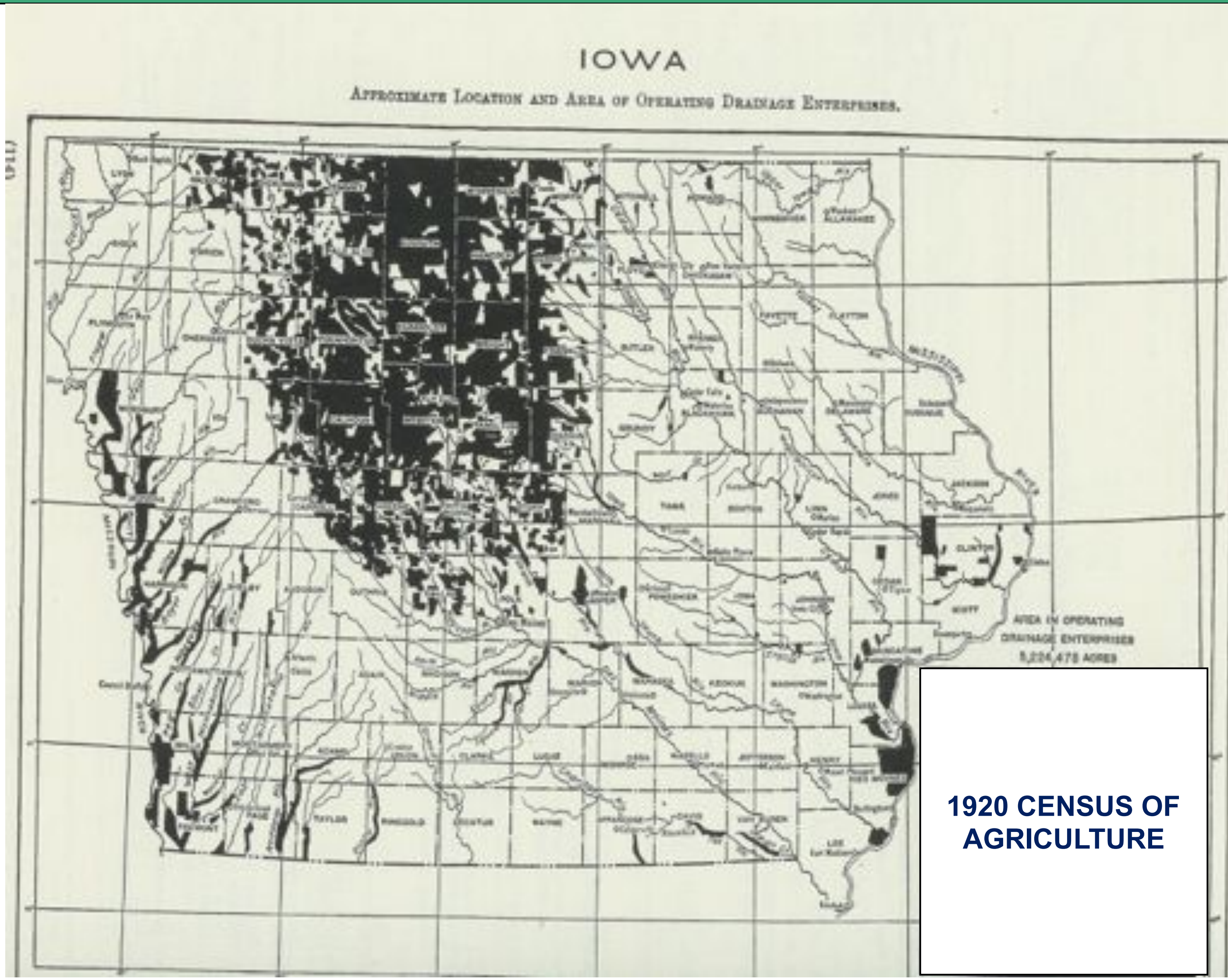
A tile system with the main ditch dug up a central drain, the laterals coming into it from both sides on the "Herring Bone" plan.

Digging the ditch by machinery. A very good, and a labor-saving way. But always lay the tile by hand—never by machinery.

Filling ditch with a disc harrow. A quick and good way, as the dirt is well pulverized—no big chunks.



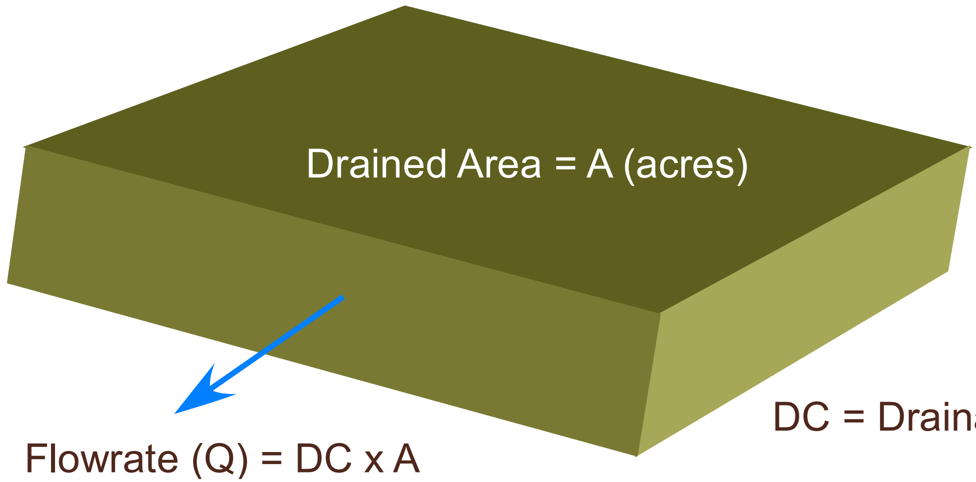




1920 CENSUS OF AGRICULTURE

Drainage Coefficient and Drainage Intensity

- Drainage coefficient –how much water can exit the system in a unit of time – sizing of pipe
- Drainage intensity – how much water can get to the drainage system in a unit of time - spacing of the drainage system
- What controls outflow from the system? – Depends on system design



DC = Drainage Coefficient

Drainage Coefficient – Amount of water that can be removed in a 24 hour period

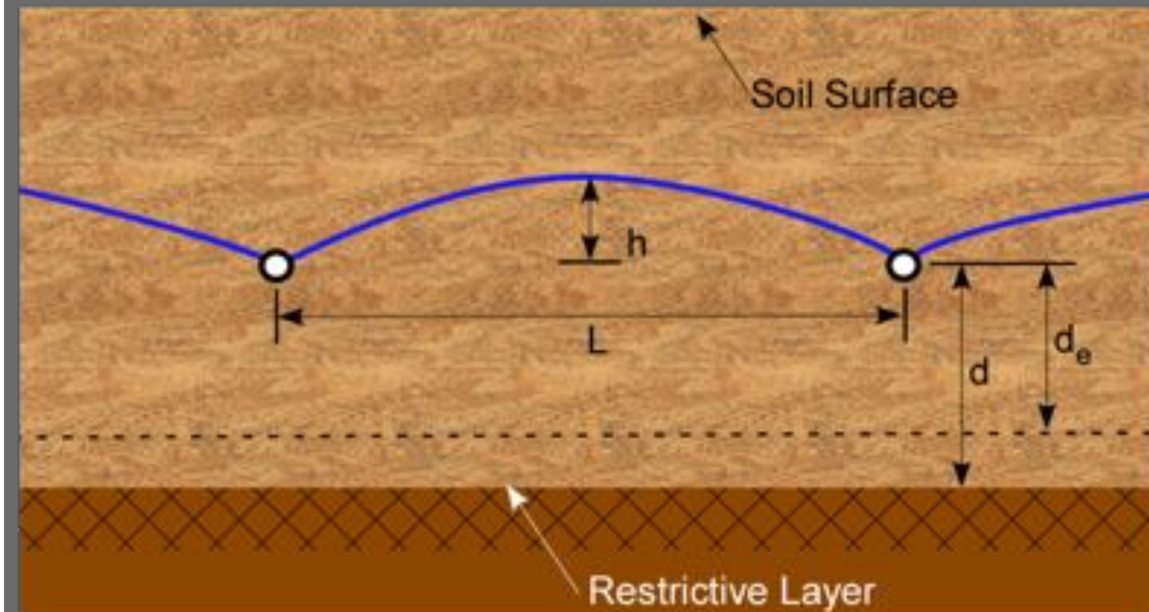
Recommended Drainage Coefficients (NRCS Field Handbook)

	Inches to be removed in 24 hours	
Soil Type	Field crops	Truck crops
Mineral	3/8 to 1/2	1/2 to 3/4
Organic	1/2 to 3/4	3/4 to 1.5





Drainage Intensity



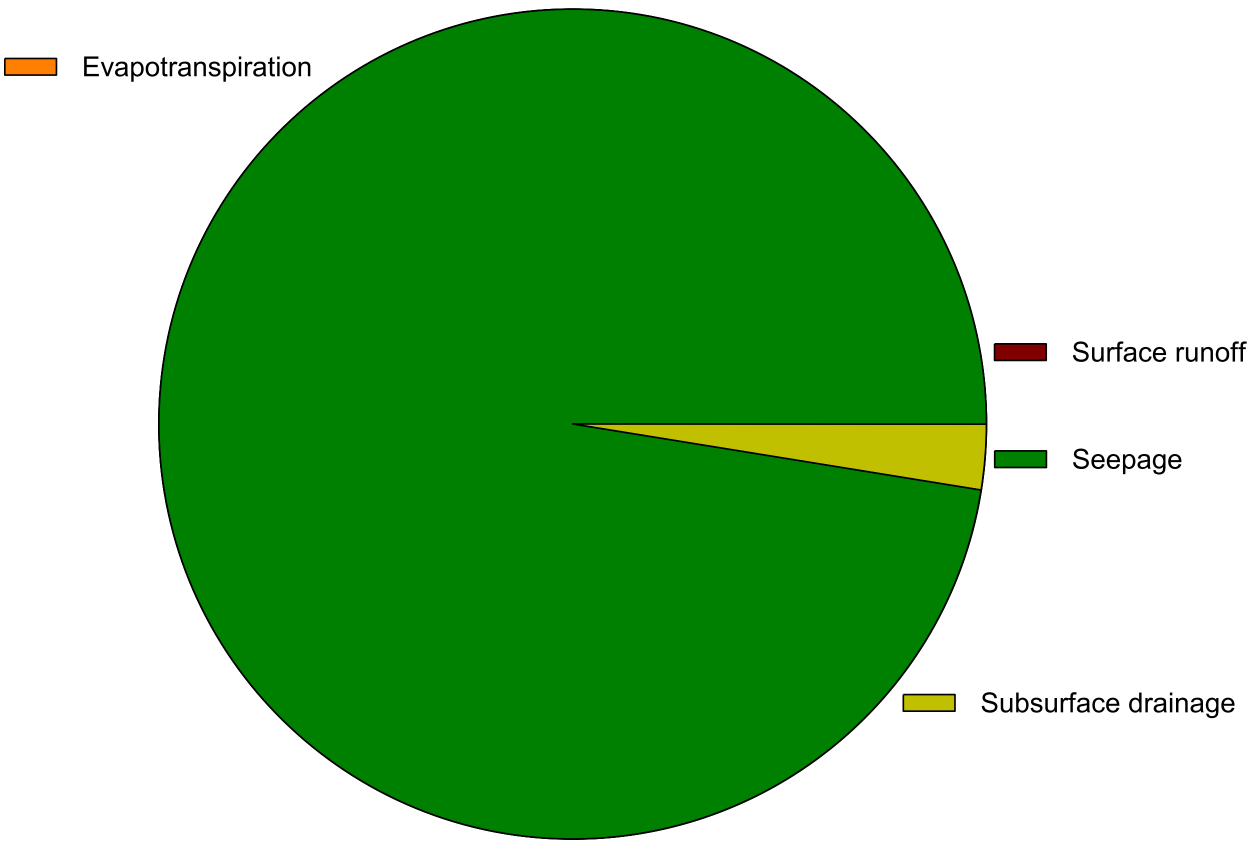
Steady-State Drainage Design

Hooghoudt Equation

$$DI=4K_e D(2\,d_e+D)/L^2$$

- L = spacing between laterals (ft)
- K_e = hydraulic conductivity (ft/day)
- h = water table height above laterals (ft)
- DI = drainage intensity (ft/day)
- d_e = equivalent depth of impermeable layer below pipe drain center (ft)

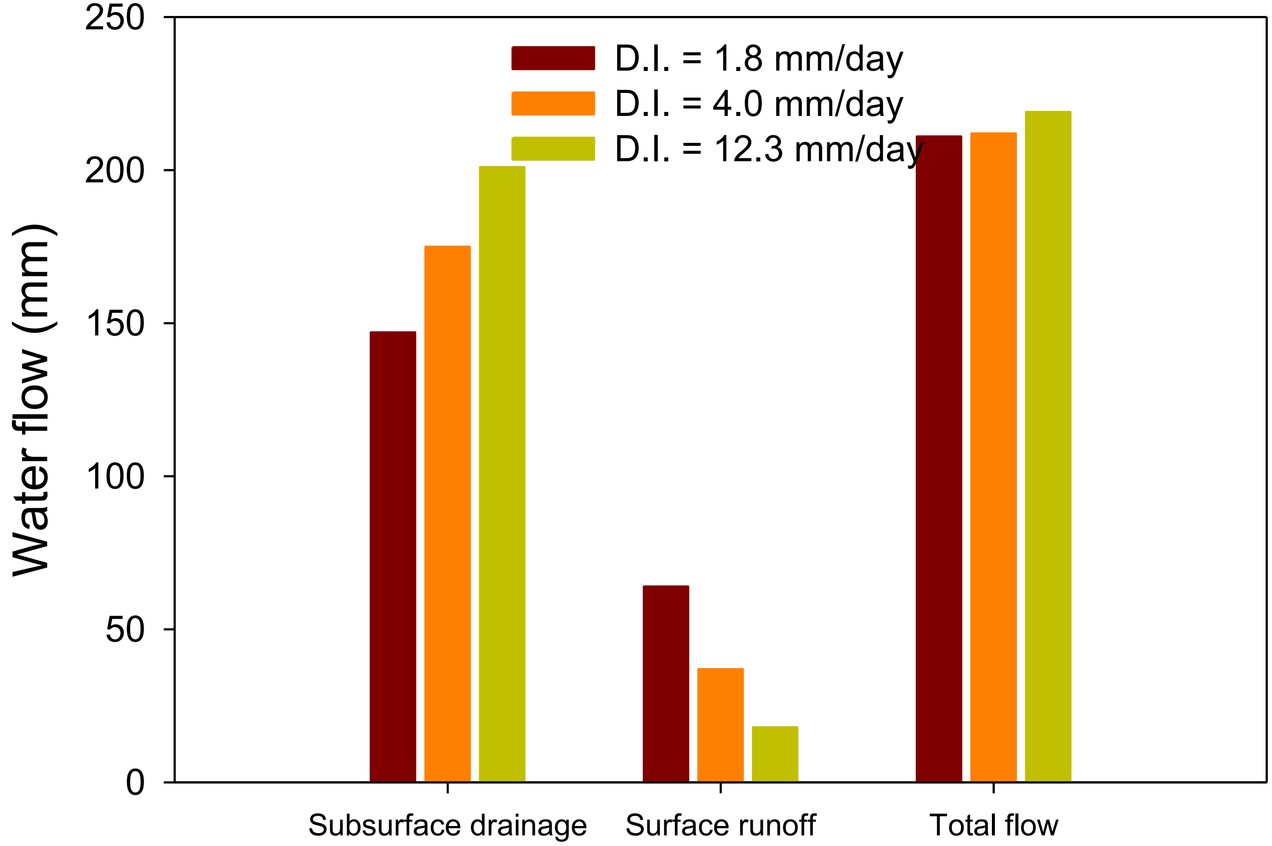
Annual Water Balance (31 in. of Precipitation)



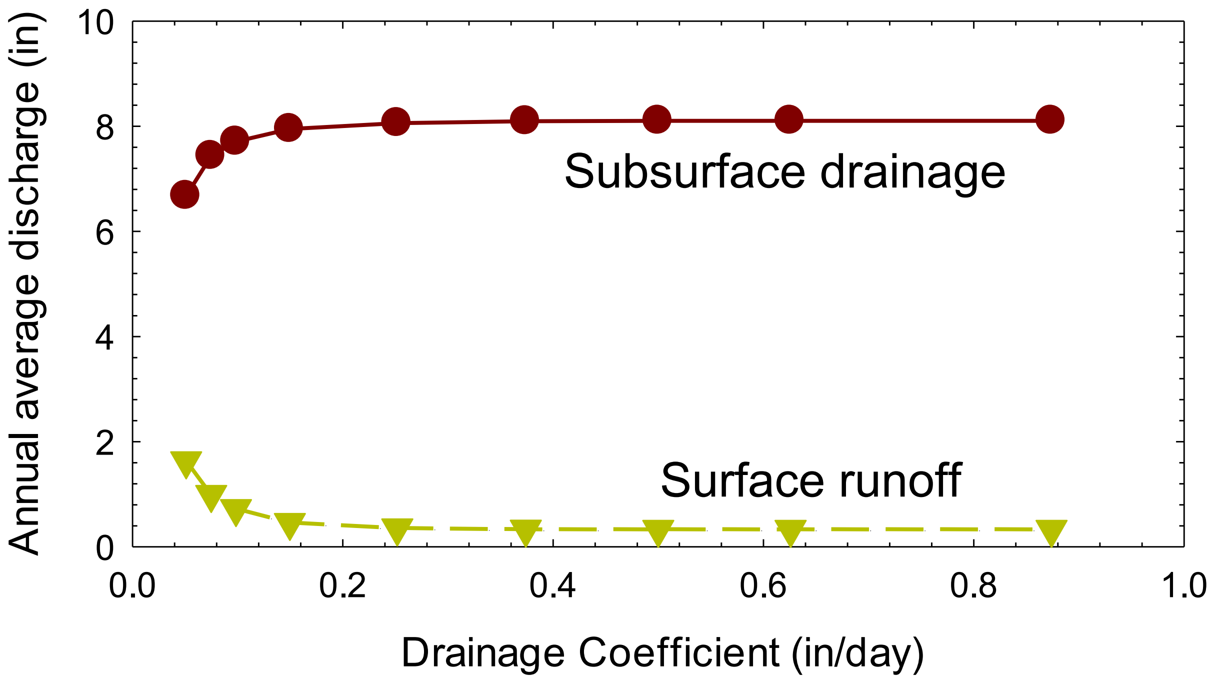




Impacts of Drainage Intensity – Annual Flow



Impacts of Drainage Coefficient–Annual Flow



Planning an Ag Drainage System

- Follow local, state, and federal regulations
- Gather soil information
- Outlet location and size
- Downstream limitations
- Is the new drainage system economical?





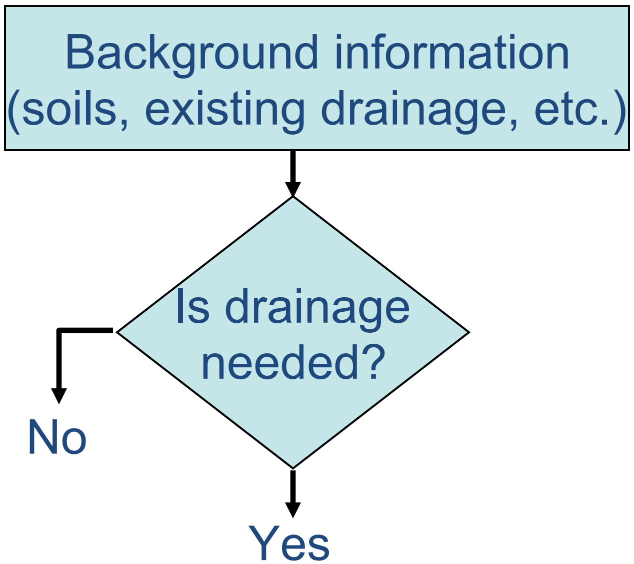
Soil Assessment

- Soil types and location
- Seasonal high water tables – are there indicates of high water table conditions
- Soil texture
- Sources
  - County soil surveys
  - State Drainage Guides
  - Local expertise or other tiling contractors





Design Flowchart



(Table 2-2. continued)

Soil name	Natural soil drainage[1]	Tile spacing, ft.[2]	
		36" depth	48" depth
Calco	Poor	65-85	80-110
Calcousta	Very poor	80-90	90-110
Caleb	Moderately well		
Calmar	Moderately well to well		
Camden	Well		
Caneek	Somewhat poor to poor	70-90	90-110
Canisteo	Poor	70-80	90-100





Design Flowchart

Background information (soils, existing drainage, etc.)

Is drainage needed?

No

Is there an outlet?

No

Area to be drained

Determine Drainage Coefficient





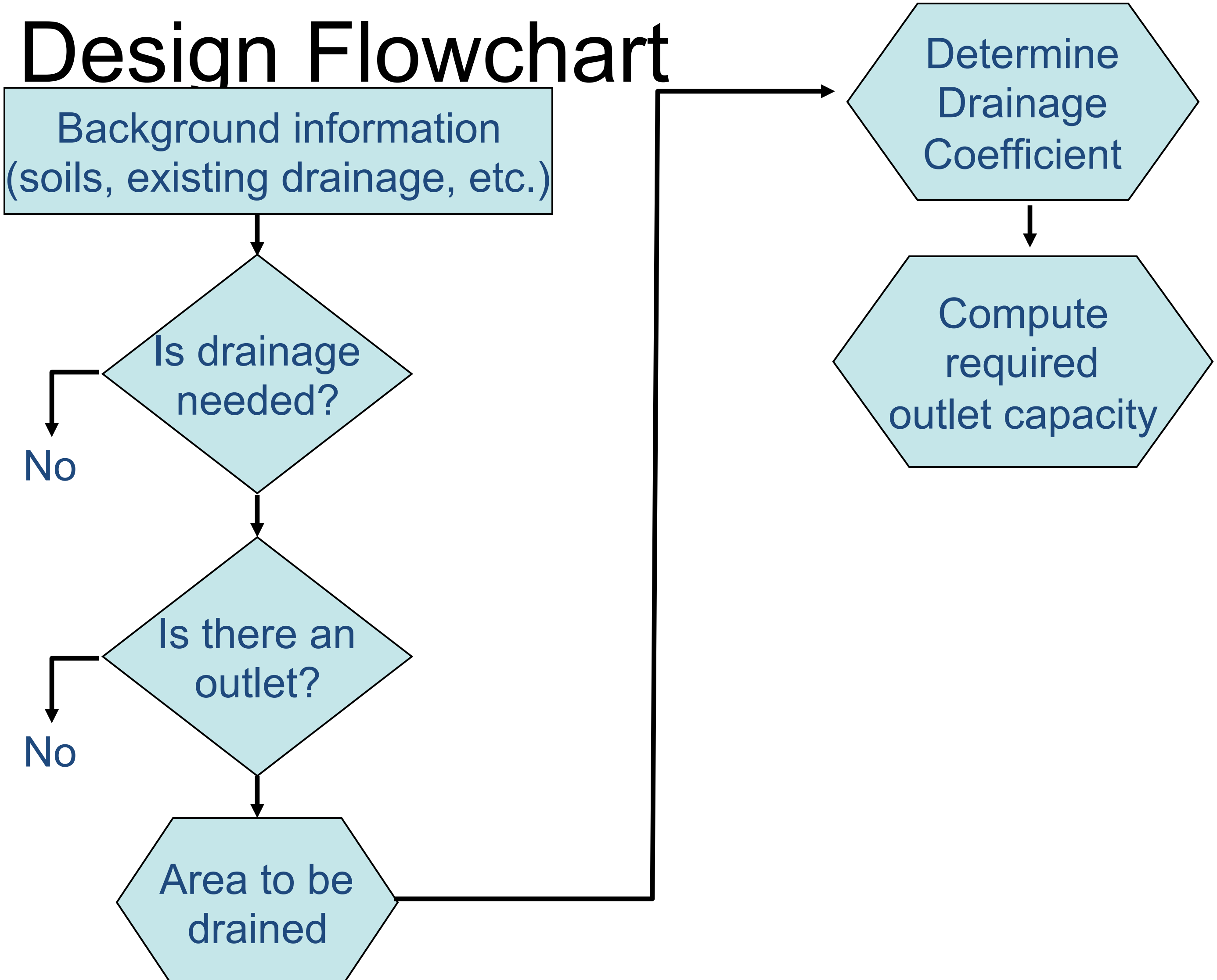
Situations that may call for greater drainage coefficient

- High value crops
- Crops have low tolerance for wetness
- Topography is flat so there is little surface drainage
- Large amounts of surface residue
- Poor surface drainage
- Crop ET is low
- Planting and harvest times are critical





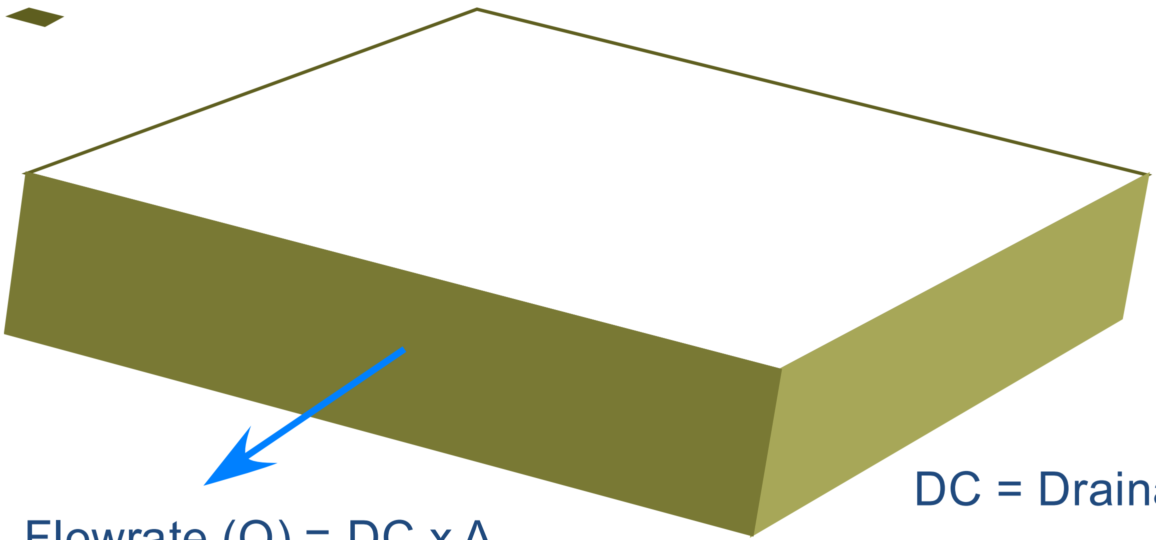
Design Flowchart







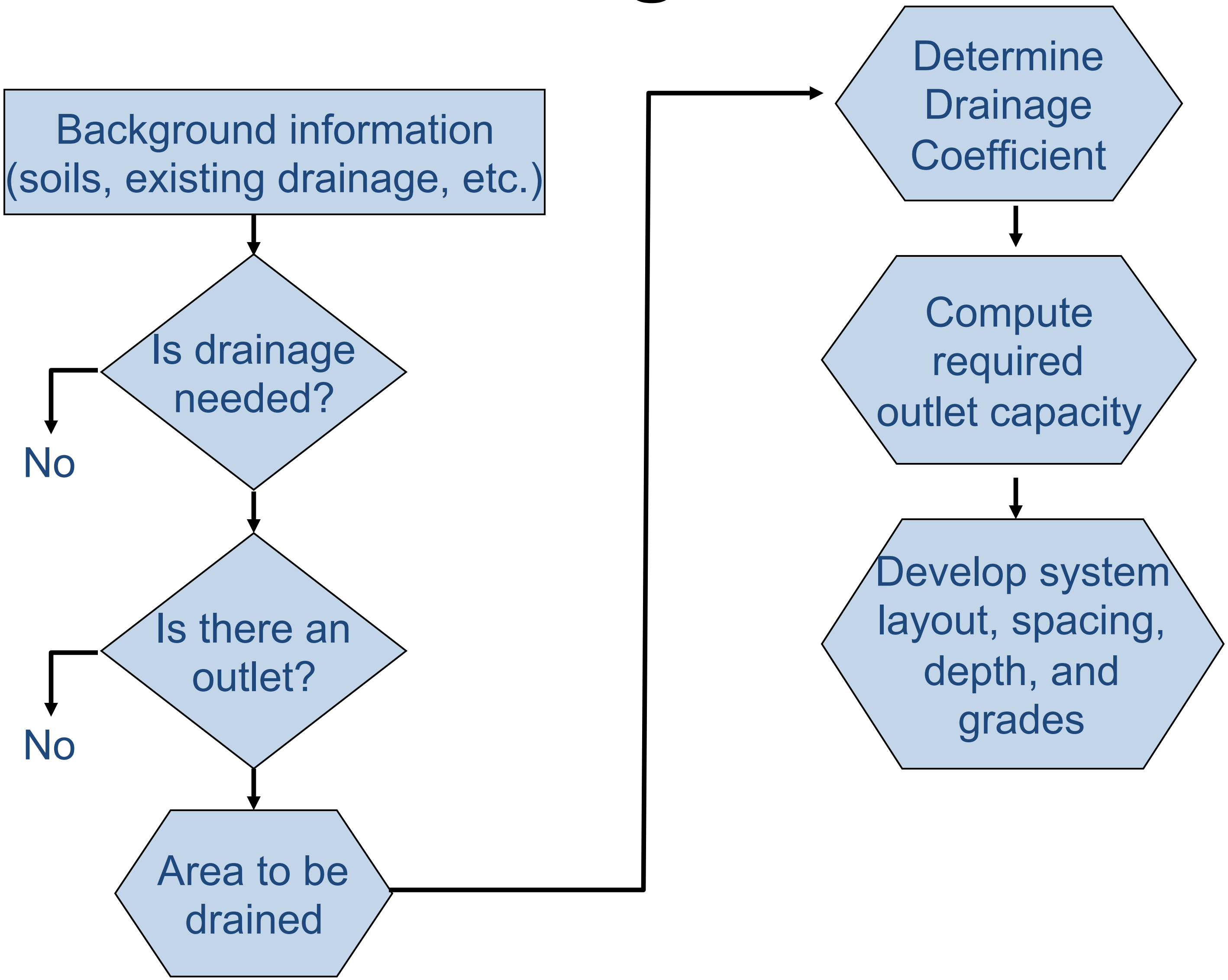
Required Drainage Capacity



DC = Drainage Coefficient

Flowrate (Q) = DC x A

Design Flowchart



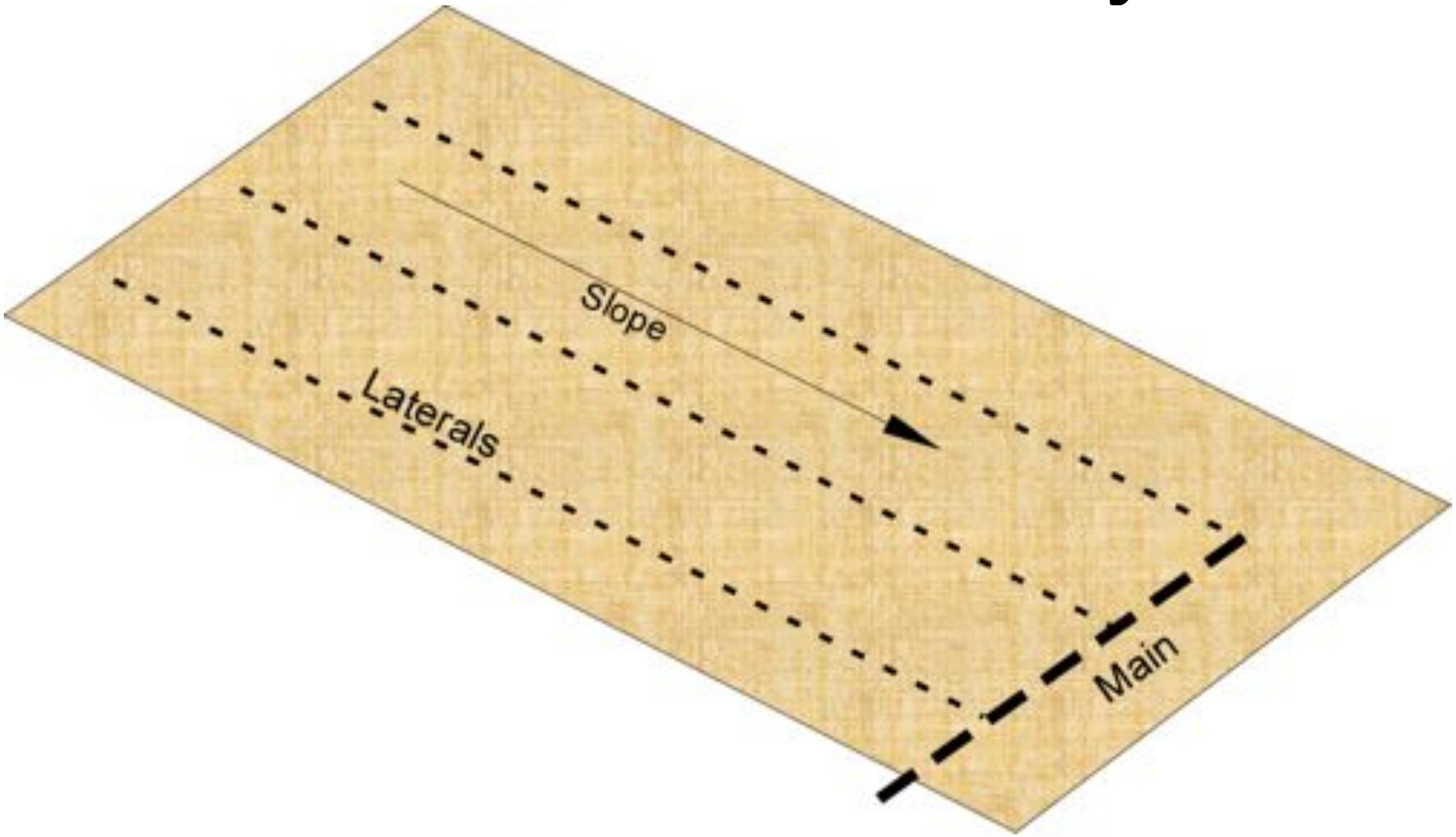
Layout

- Layout determines uniformity of drainage
- Should start with **contour (topo) map** of field

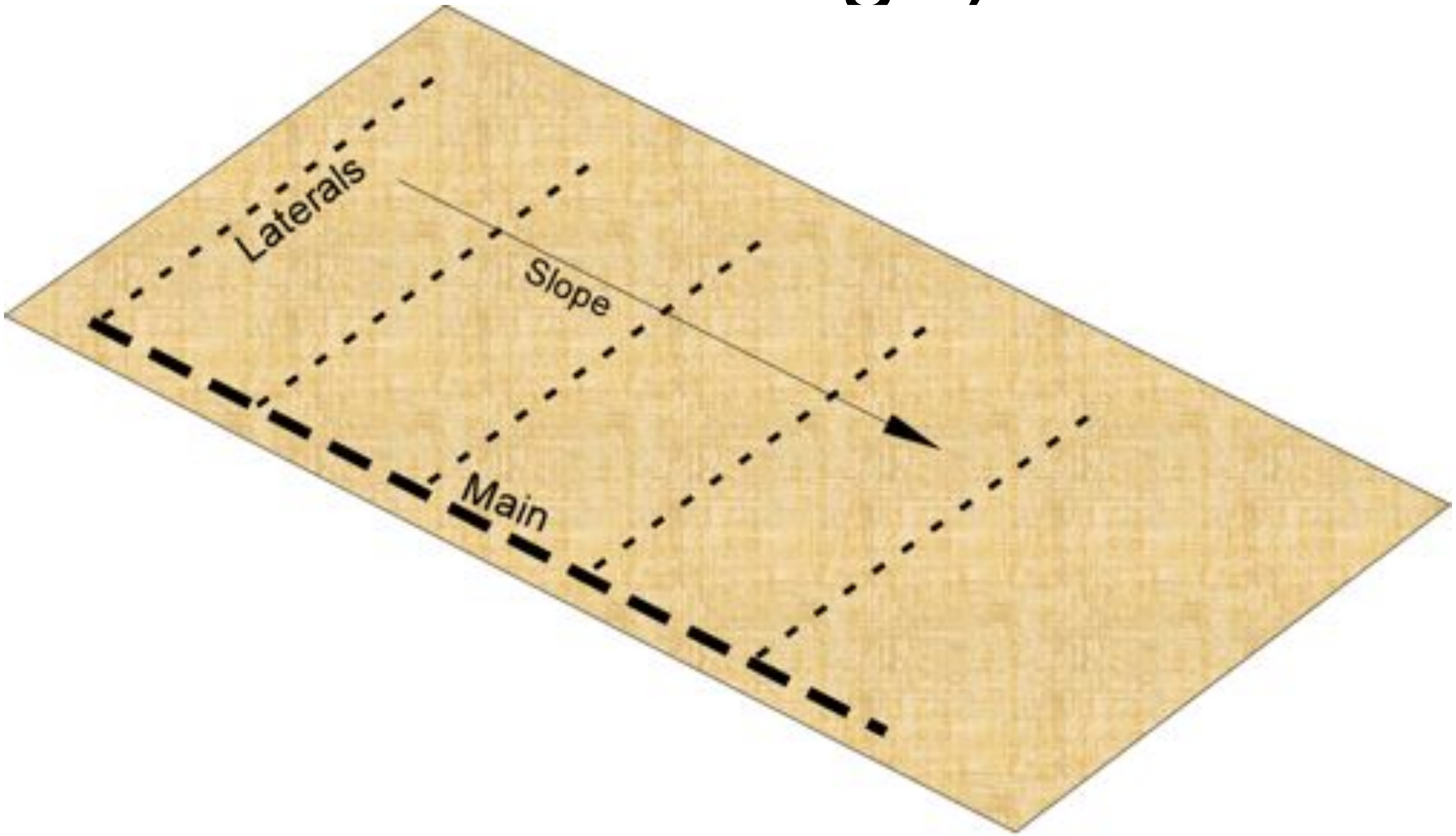




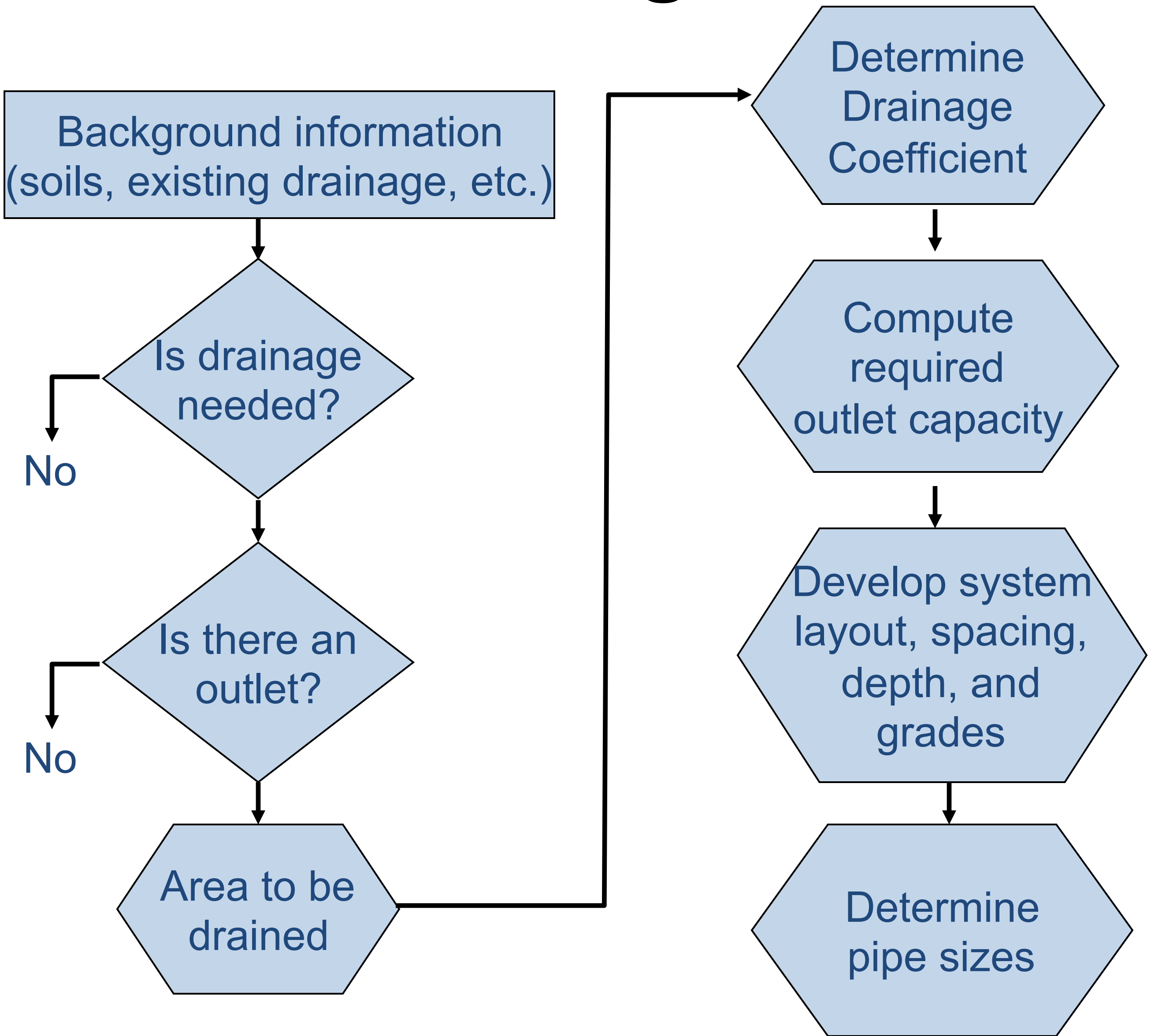
Conventional Tile Layout

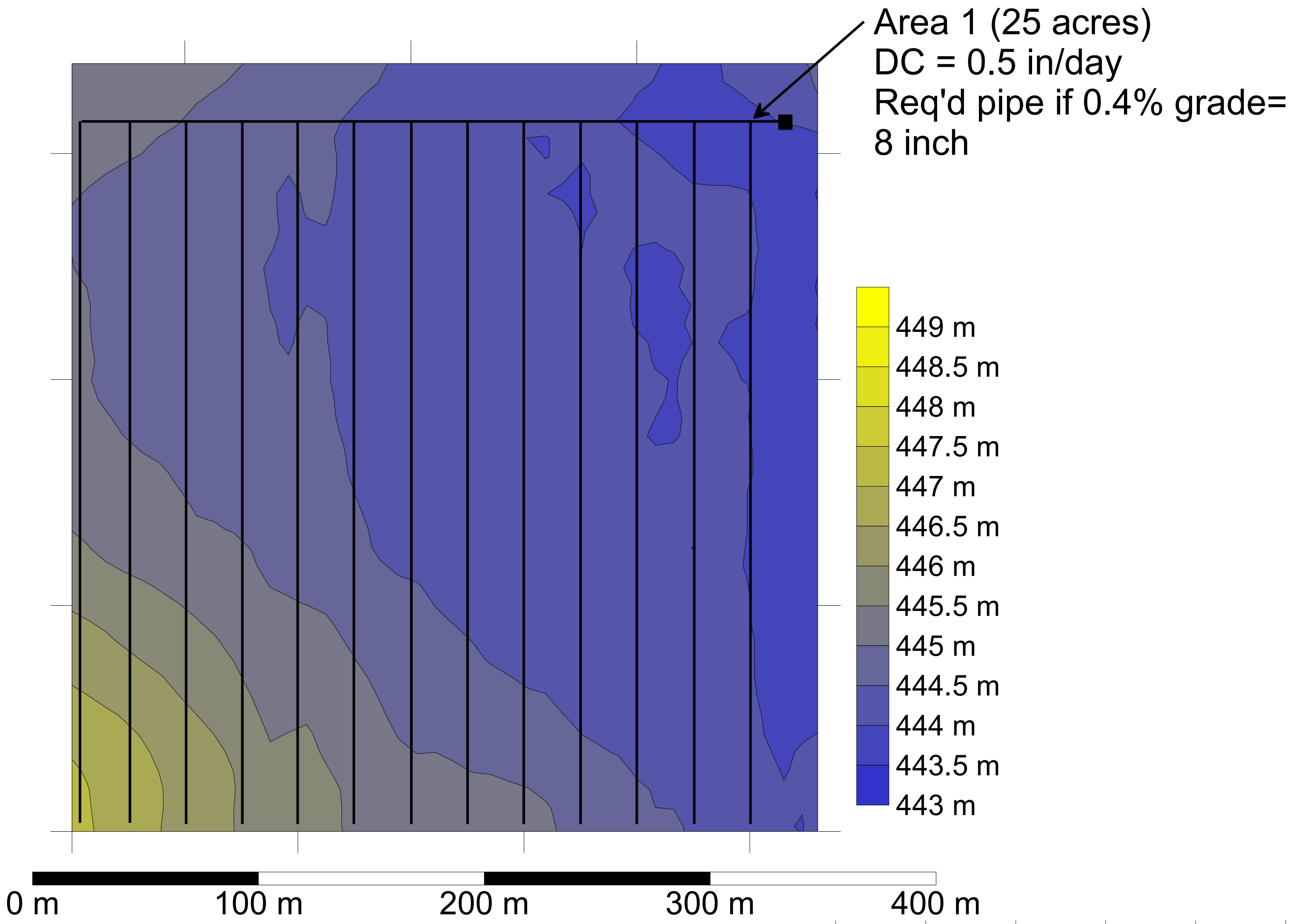


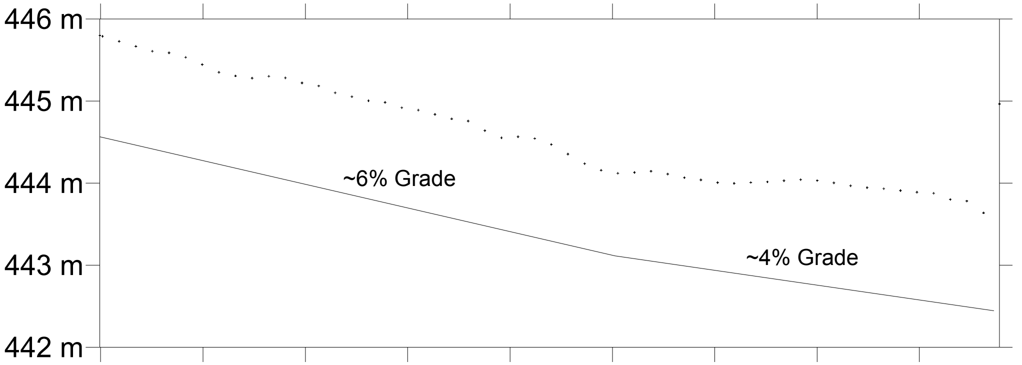
Layout on Contour (more uniform drainage)

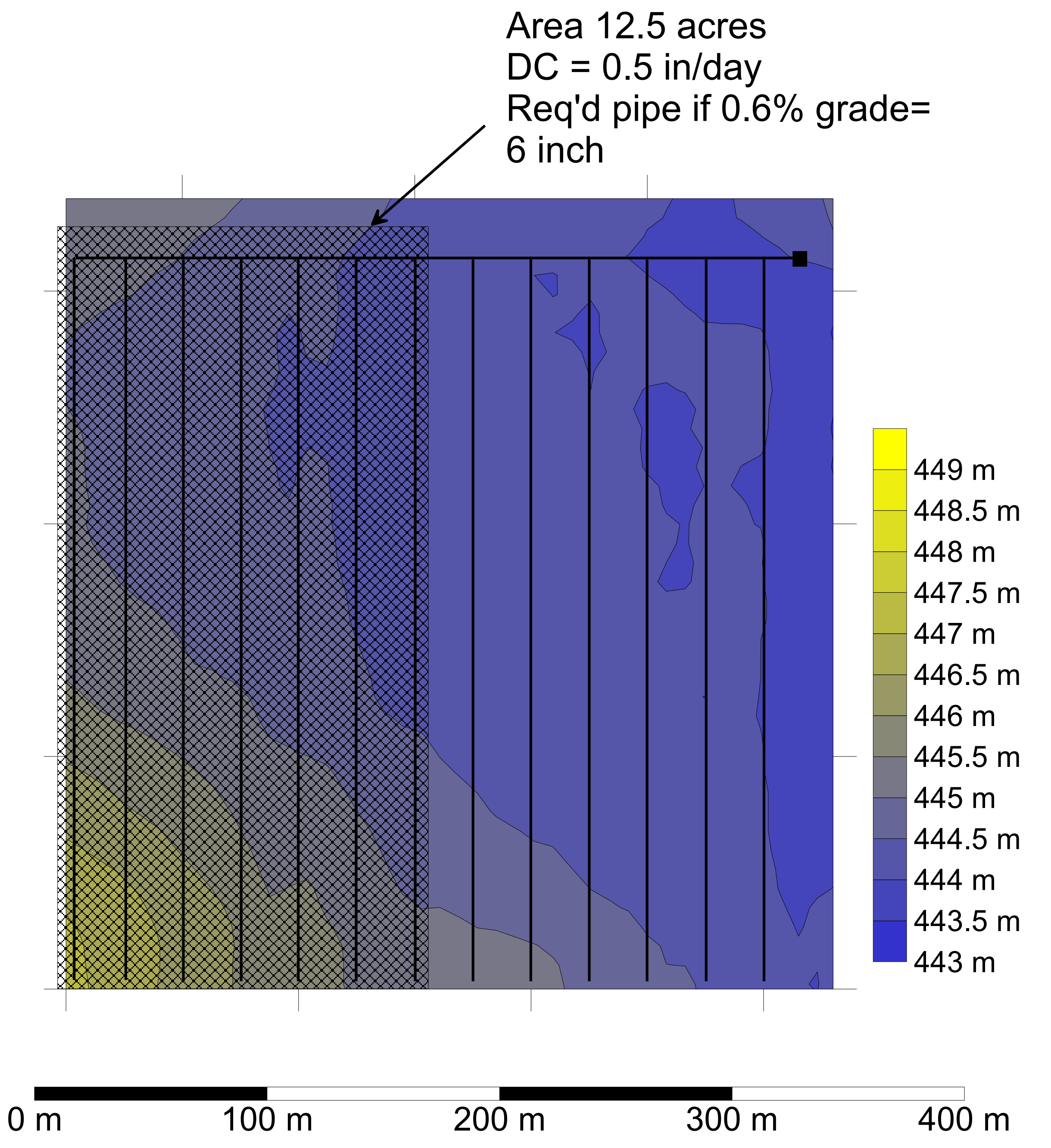


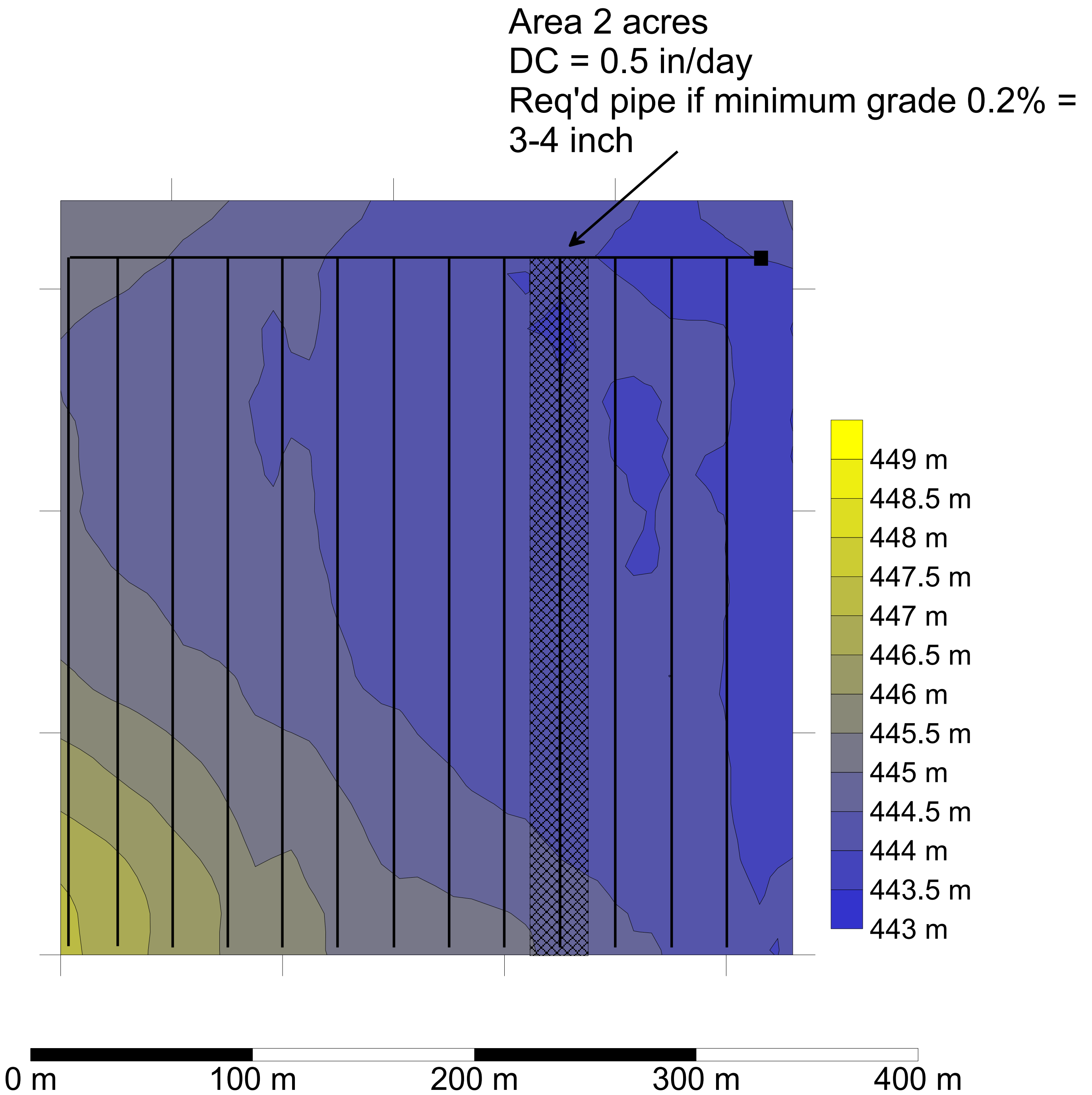
Design Flowchart



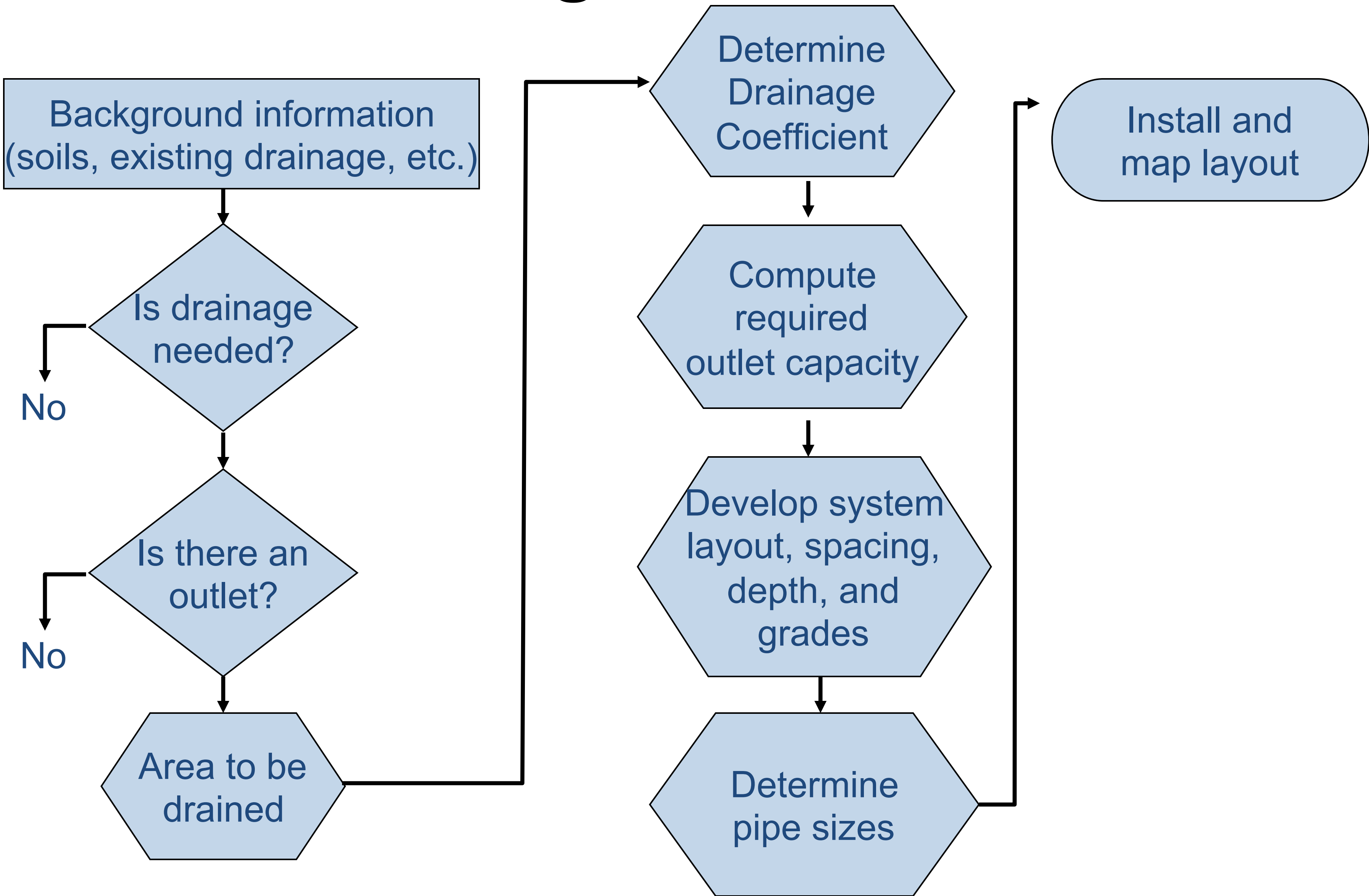

Area 1 (25 acres)
DC = 0.5 in/day
Req'd pipe if 0.4% grade=
8 inch
449 m
448.5 m
448 m
447.5 m
447 m
446.5 m
446 m
445.5 m
445 m
444.5 m
444 m
443.5 m
443 m
0 m
100 m
200 m
300 m
400 m


446 m
445 m
444 m
443 m
442 m
~6% Grade
~4% Grade


Area 12.5 acres
DC = 0.5 in/day
Req'd pipe if 0.6% grade=
6 inch
449 m
448.5 m
448 m
447.5 m
447 m
446.5 m
446 m
445.5 m
445 m
444.5 m
444 m
443.5 m
443 m
0 m
100 m
200 m
300 m
400 m


Area 2 acres
DC = 0.5 in/day
Req'd pipe if minimum grade 0.2% =
3-4 inch
449 m
448.5 m
448 m
447.5 m
447 m
446.5 m
446 m
445.5 m
445 m
444.5 m
444 m
443.5 m
443 m
0 m
100 m
200 m
300 m
400 m

Design Flowchart



Drain Spacing

- Spacing determines drainage intensity
- Important for uniformity of drainage
- Use regional guides, computations for soil conditions, experience
- Perform soil test to assess in-situ conditions

(Table 2-2. continued)

Soil name	Natural soil drainage[1]	Tile spacing, ft.[3] 36" depth	Tile spacing, ft.[3] 48" depth
Calco	Poor	65-85	80-110
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Canisteo	Poor	70-80	90-100





Drainage Design and Management

- How does drain spacing or drainage outlet capacity influence crop production?
- Can we design and/or manage our systems to optimize crop production while minimizing environmental impacts?





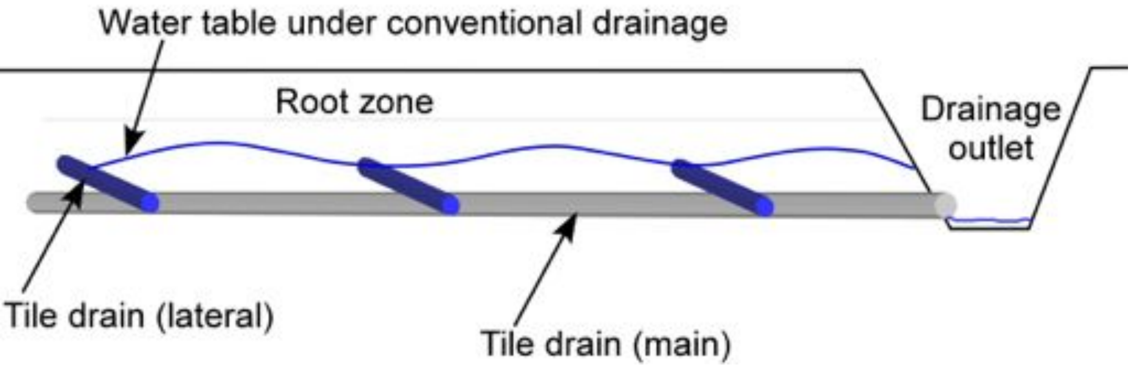
Drainage Water Management

- Objectives
  - Conserve soil water, increase yields, reduce losses of nutrients and other pollutants via drainage (specifically nitrate-nitrogen)
- Concept
  - Water that would drain out of the soil profile under conventional drainage is conserved and available to supply evapotranspiration requirements of the crop

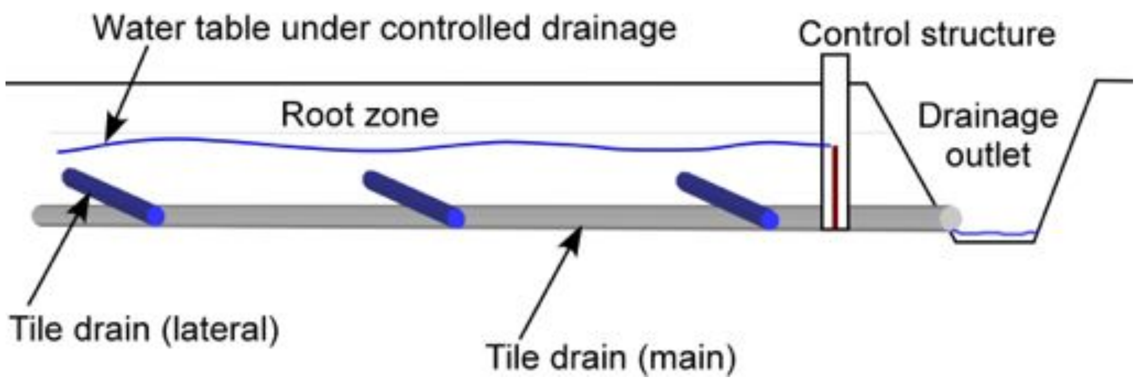




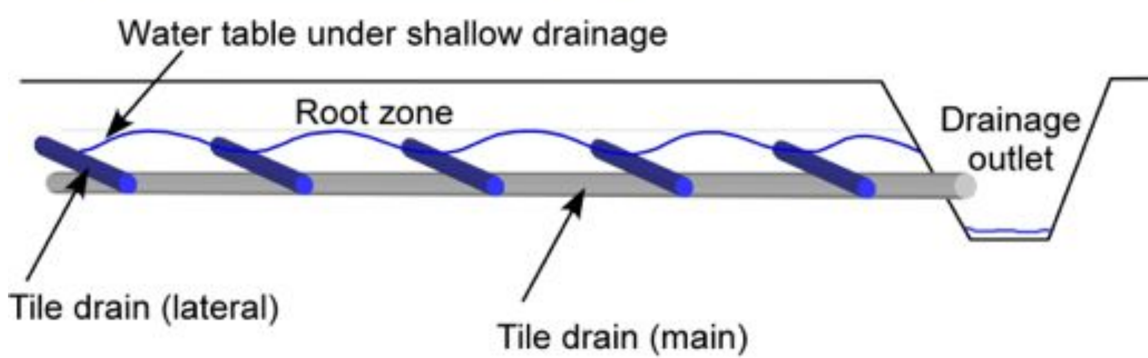
Conventional Drainage



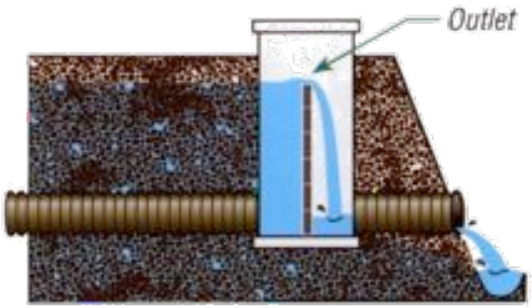
Controlled Drainage



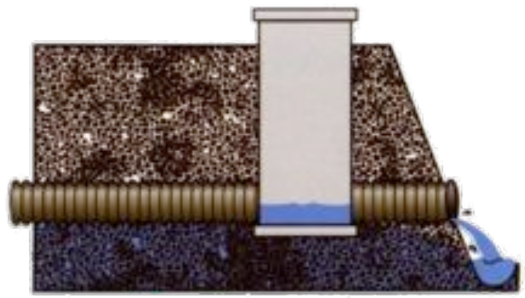
Shallow Drainage



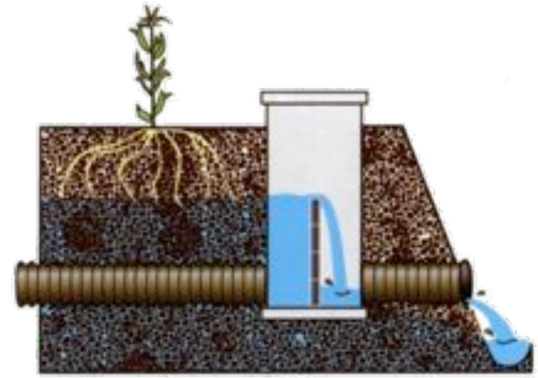
Drainage Water Management



The outlet is raised after harvest to reduce nitrate delivery during winter.

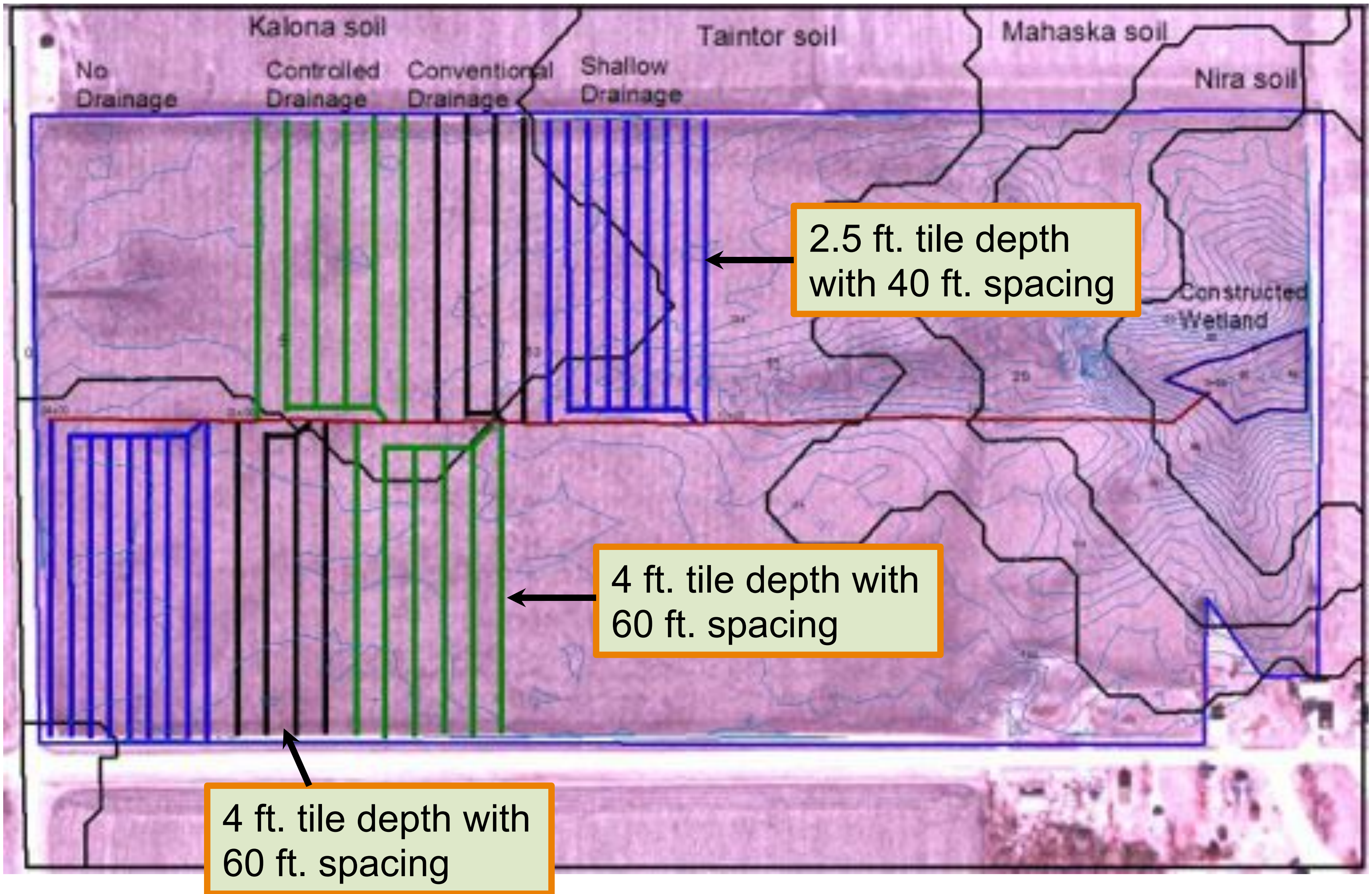


The outlet is lowered a few weeks before planting and harvest to allow the field to drain more fully.



The outlet is raised after planting to potentially store water for crops.

Crawfordsville

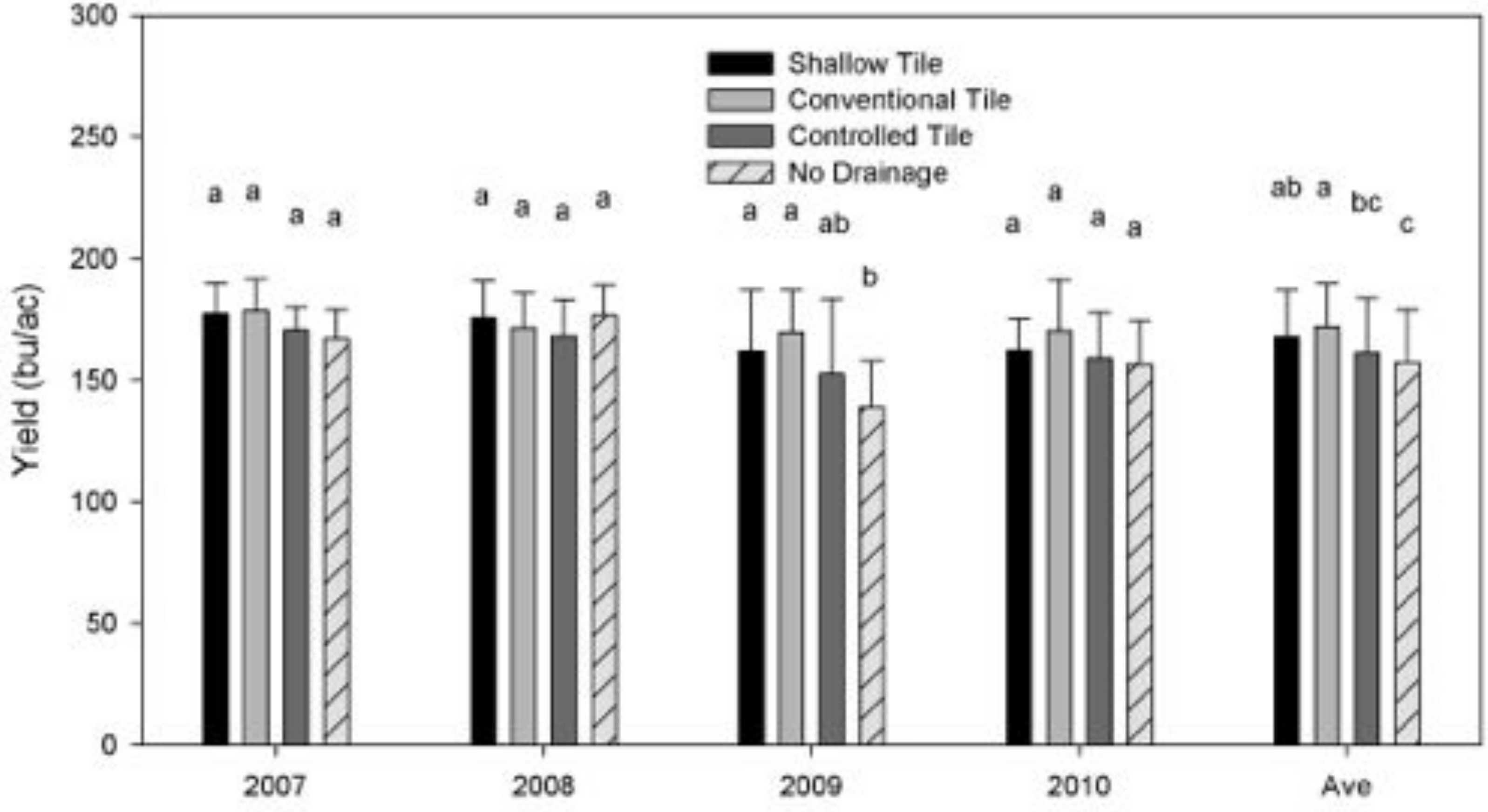


Annual Drainage

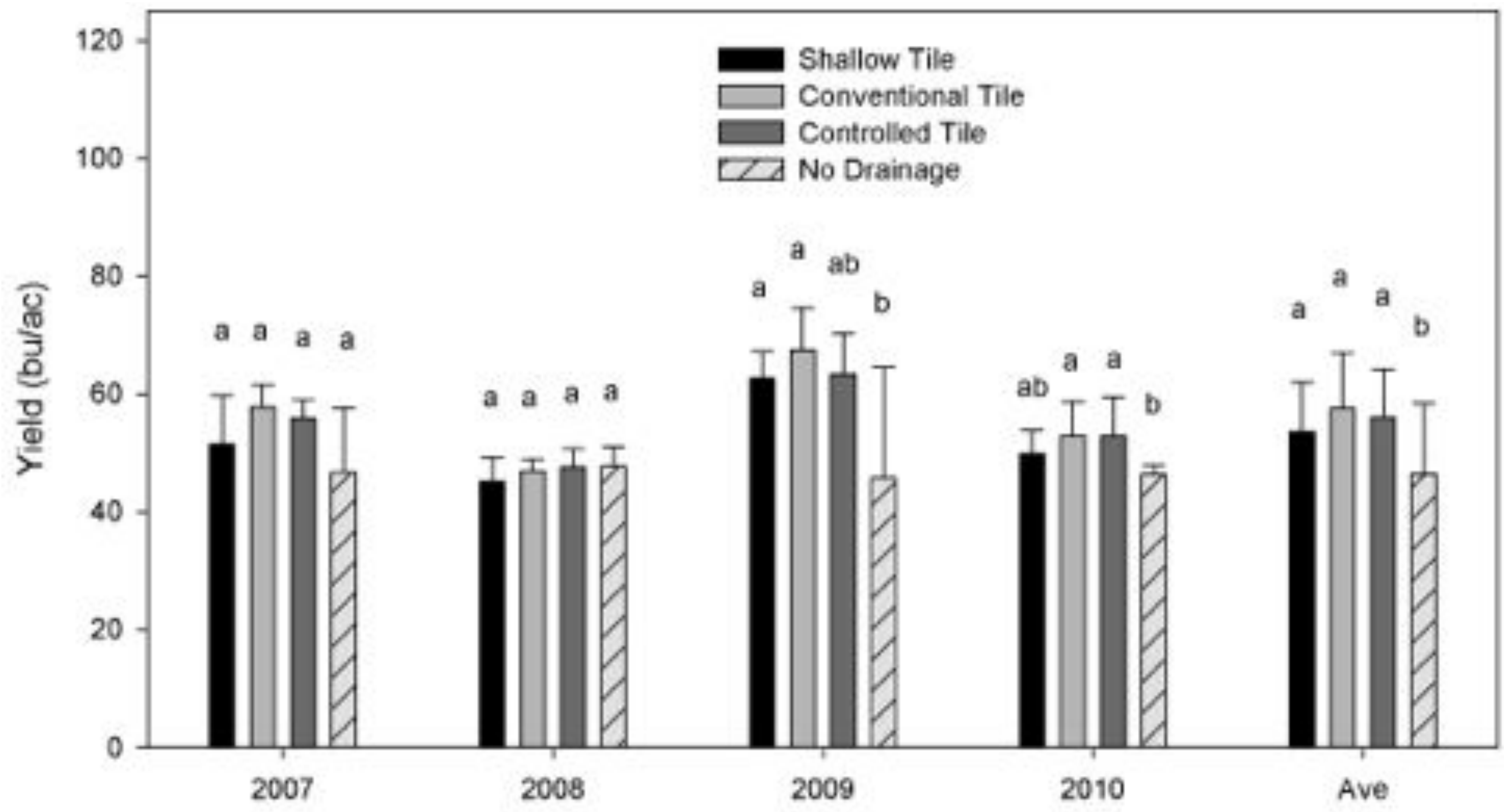
	Drainage (in)			
Treatment	2007	2008	2009	3-Yr Avg.
Conventional	10.12a	12.1a	15.0a	12.4a
Drainage Water Management	7.05a	9.13ab	9.72a	8.66b
Shallow	7.16a	5.63b	9.13a	7.28b
% Reduction Conv vs. DWM	30	24	35	30
% Reduction Conv vs. Shallow	29	53	39	41

Means within years or for the 3-yr average with a different letter are significantly different (p=0.05).

Corn Yield


300
250
200
150
100
50
0
Yield (bu/ac)
Shallow Tile
Conventional Tile
Controlled Tile
No Drainage
a a a a
a a a a
a a ab b
a a a a
ab a bc c
2007
2008
2009
2010
Ave

Soybean Yield



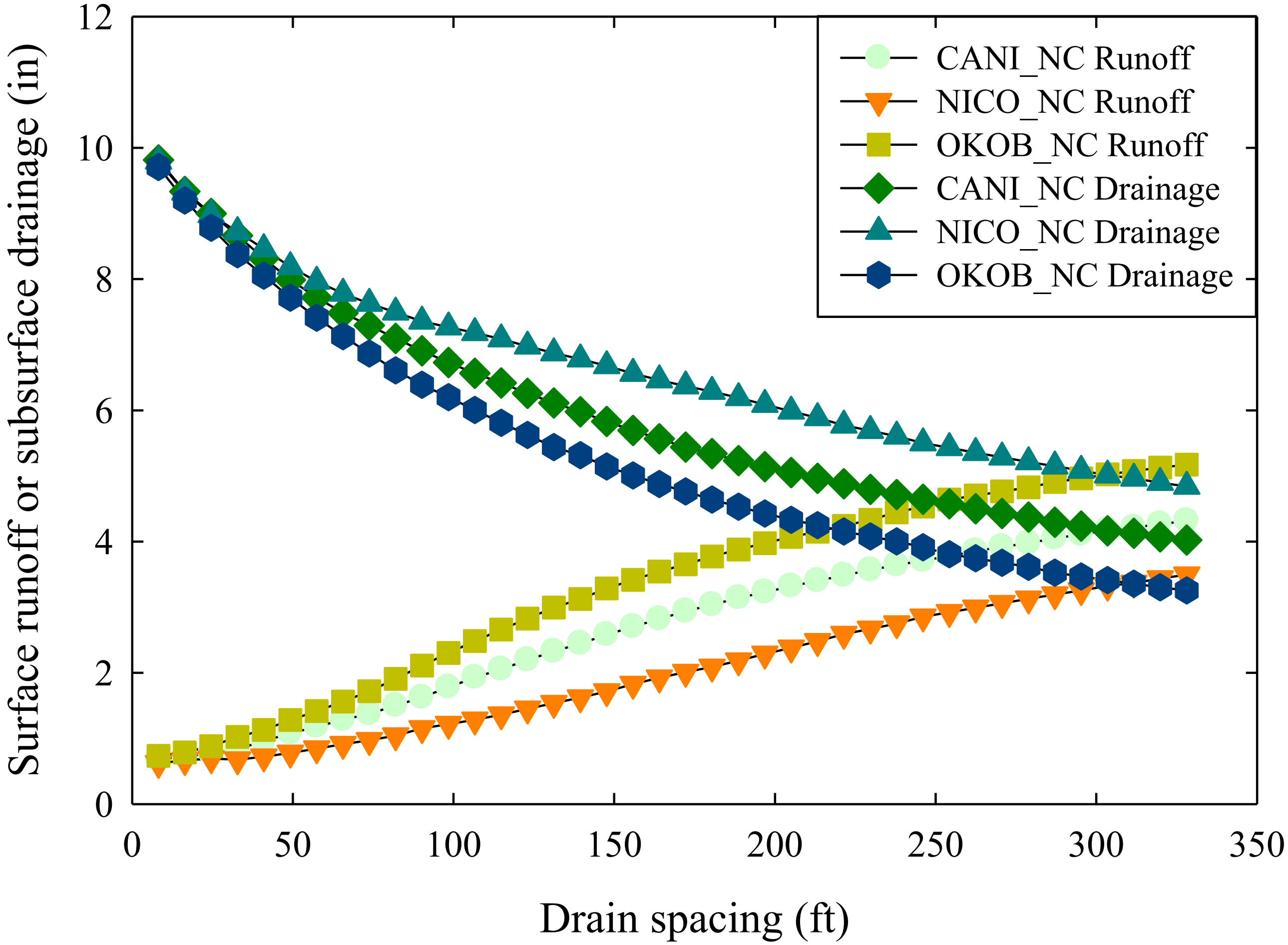
Simulations of Response to Subsurface Drainage

- Can't afford field investigations on many soils, over many years, and for many drainage spacings.
  - So, use a model that can represent major components of the systems (water flow and crop response to water stress – drought and excess water stress)
- DRAINMOD





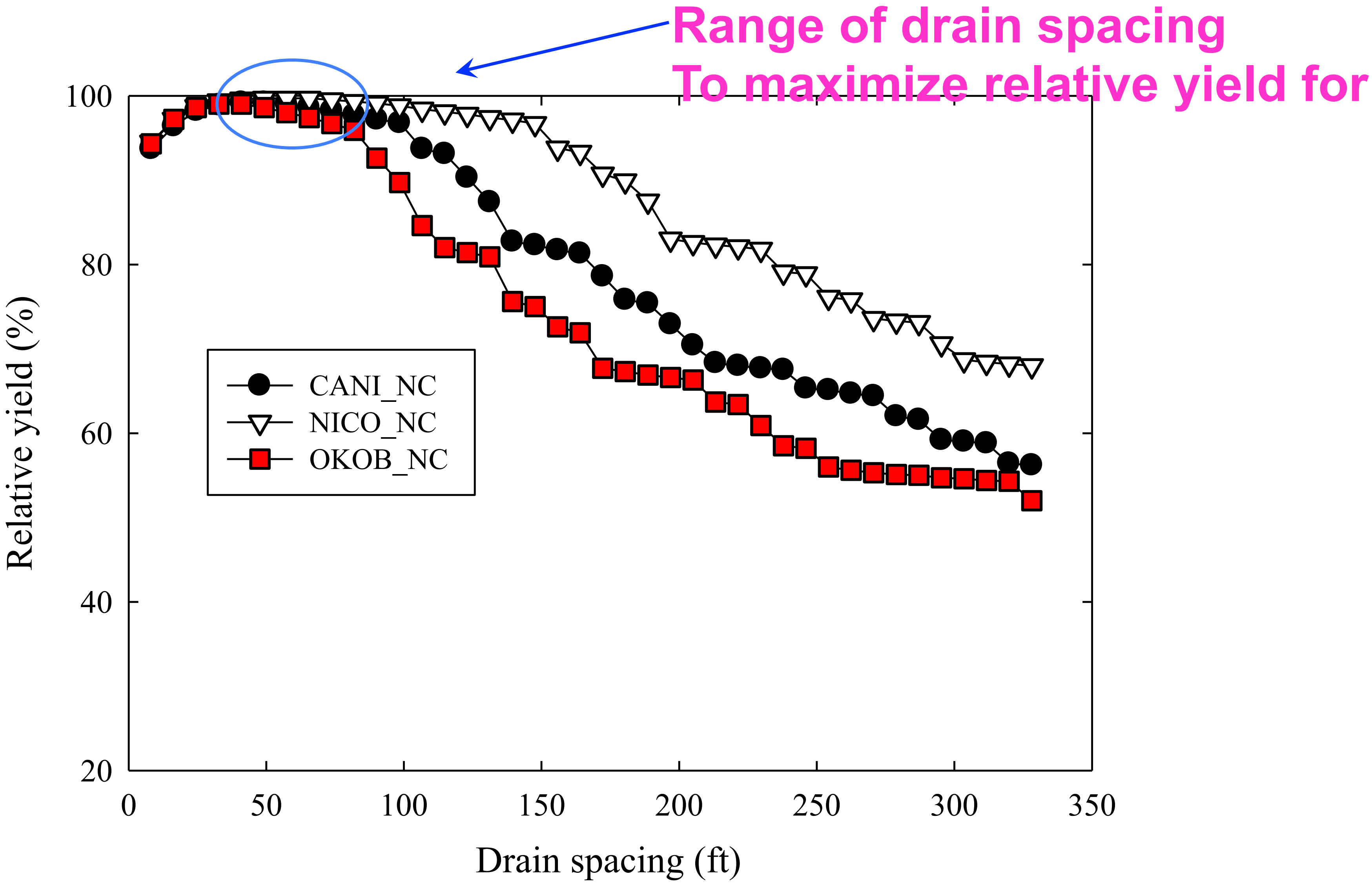
Effects of Drain Spacing on Drainage and Surface Runoff – North-Central Iowa



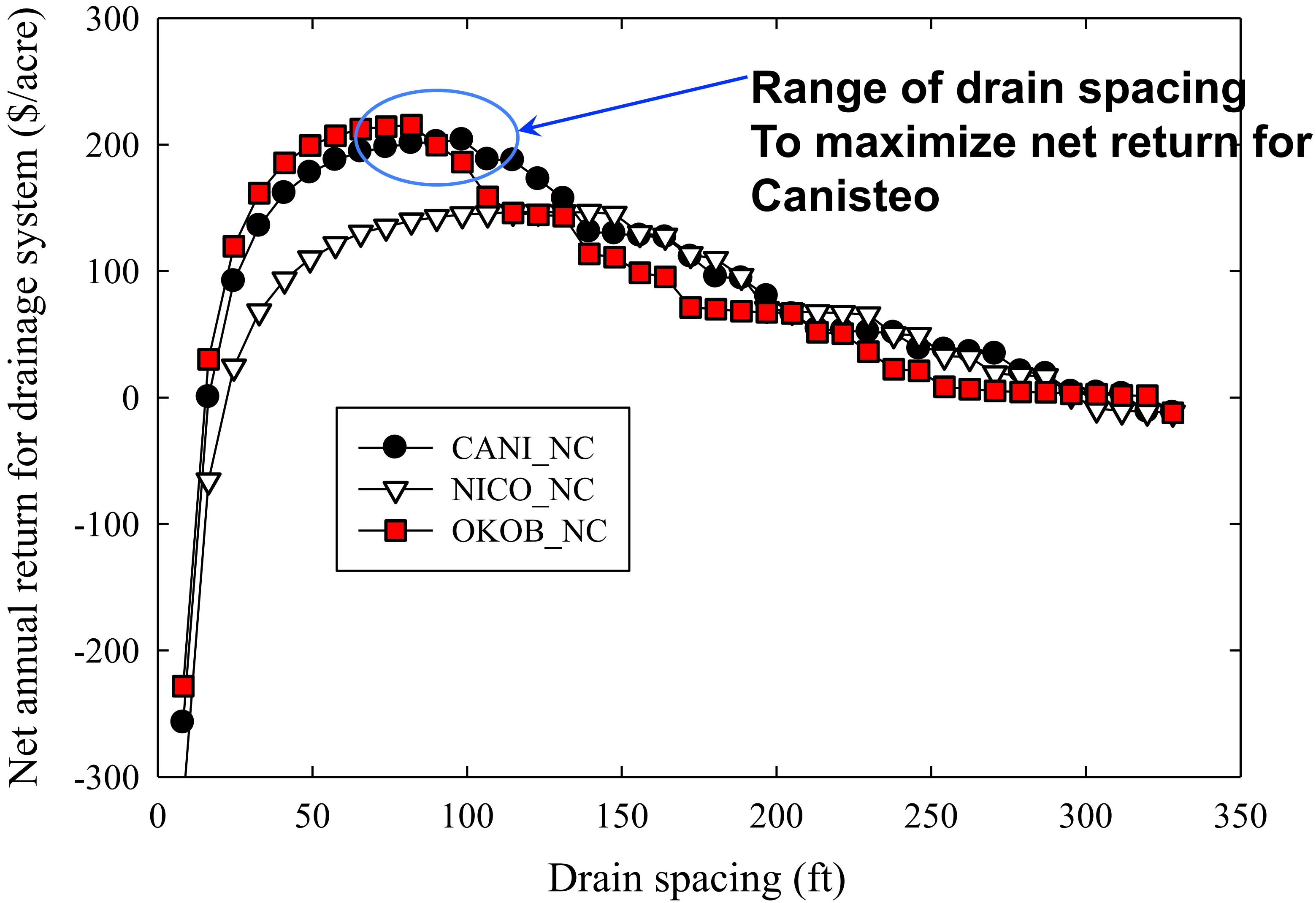




Effects of Drain Spacing on Relative Corn Yield – North-Central Iowa



Effects of Drain Spacing on Net Annual Return – North-Central Iowa



Range of drain spacing to maximize crop production and net annual return

Region	Soil series	Range of drain spacing (ft.) to maximize	
		Crop production	Net annual return
North East	CLYDE	40-60	60-80
	CLYDE-FLOYD COMPLEX	40-60	65-85
	TRIPOLI	40-60	45-65
North Central	NICOLLET	55-75	115-135
	CANISTEO	40-60	80-100
	OKOBOJI	25-45	70-90
Central	NICOLLET	55-75	115-135
	CANISTEO	45-65	80-100
	HARPS	30-50	55-75
South East	TAINTOR	45-65	45-65
	HAIG	40-60	60-80

Approximate annual drainage when maximizing crop production and net annual return

Region	Soil series	Drainage (in) when maximizing Crop production	Drainage (in) when maximizing Net annual return	% reduction in drainage for net return design
North East	CLYDE	10.2	9	**12**
	CLYDE-FLOYD COMPLEX	10.1	8.7	**14**
	TRIPOLI	9.8	9.3	**5**
North Central	NICOLLET	7.8	6.6	**15**
	CANISTEO	8	6.9	**14**
	OKOBOJI	8.5	6.6	**22**
Central	NICOLLET	8.4	7.3	**13**
	CANISTEO	8.1	7.2	**11**
	HARPS	8.9	7.5	**16**
South East	TAINTOR	9.3	8.8	**5**
	HAIG	9.4	8.2	**13**
	CLARINDA	10	8.2	**18**





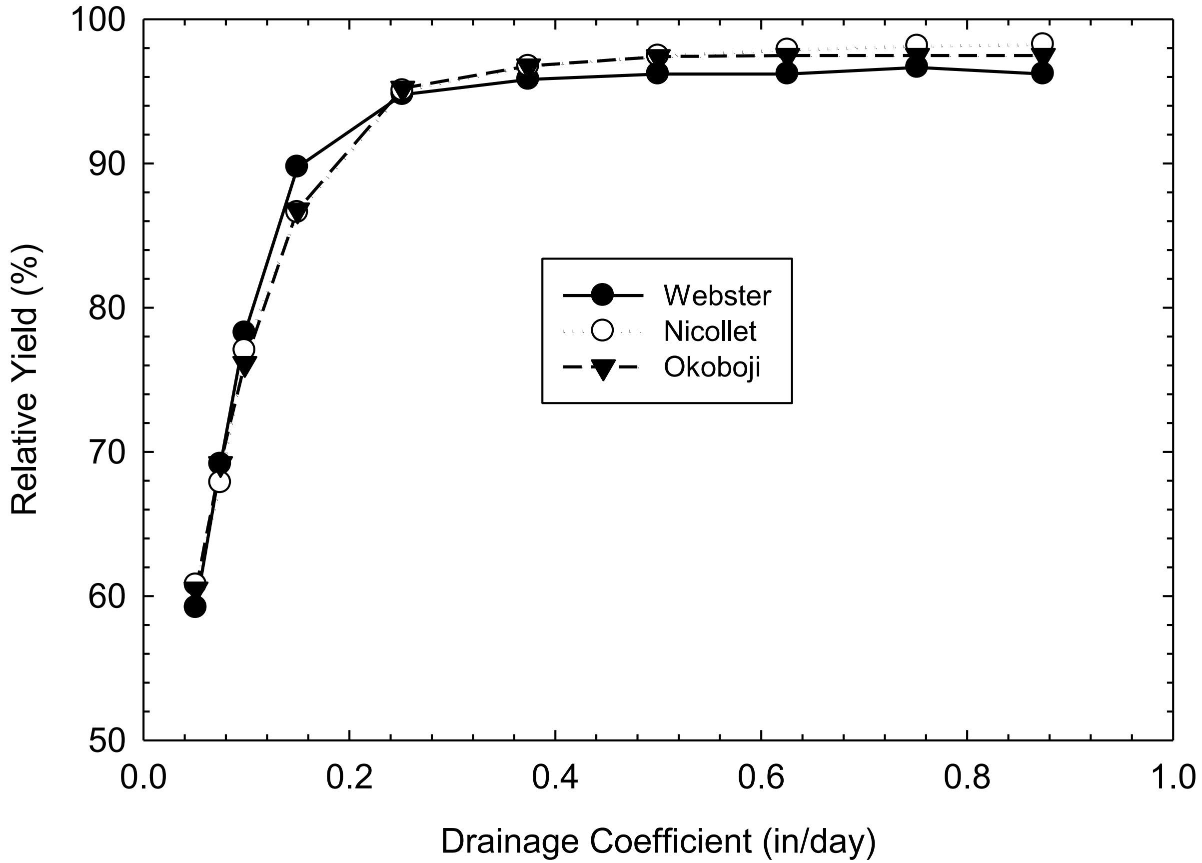
Drain Capacity

- Study in 1980's investigated drainage in the Des Moines River Basin
- Drain capacity of many drainage district mains evaluated
- Example:
  - Calhoun County
    - Avg. drainage coefficient of 38 mains was 0.18 in/day
    - Range in drainage coefficient from 0.05 to 0.44 in/day





How much do Under Designed Systems Impact Yield?



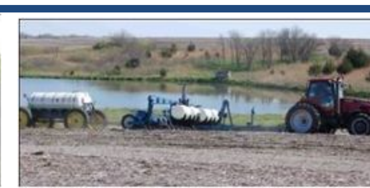



Example Yield Increases

Calhoun

District Size (acres)	Outlet Capacity (in/day)	Relative Yield	Inc in Rel. Yield if 0.5 in/day coefficient
1860	0.22	94	2
1025	0.18	92	4
1920	0.1	79	17
1600	0.09	76	21
2000	0.05	56	41
1920	0.13	86	10
1760	0.11	82	15
1120	0.44	97	0
1120	0.24	95	2
960	0.27	96	1
400	0.25	95	1




Summary

- Drainage is important for crop production
- Drainage design and management can be used to optimize crop production and minimize environmental impacts





Discussion

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