Agricultural Tile Drainage:
Function and Value

John Panuska PhD, PE

Natural Resources Extension Specialist
Biological Systems Engineering Department
UW Madison

Overview

Agricultural Tile Drainage: Function and Value

How do agricultural tile drain systems work ?

Regional patterns for tile drainage.

One way to look at tile drain system value.

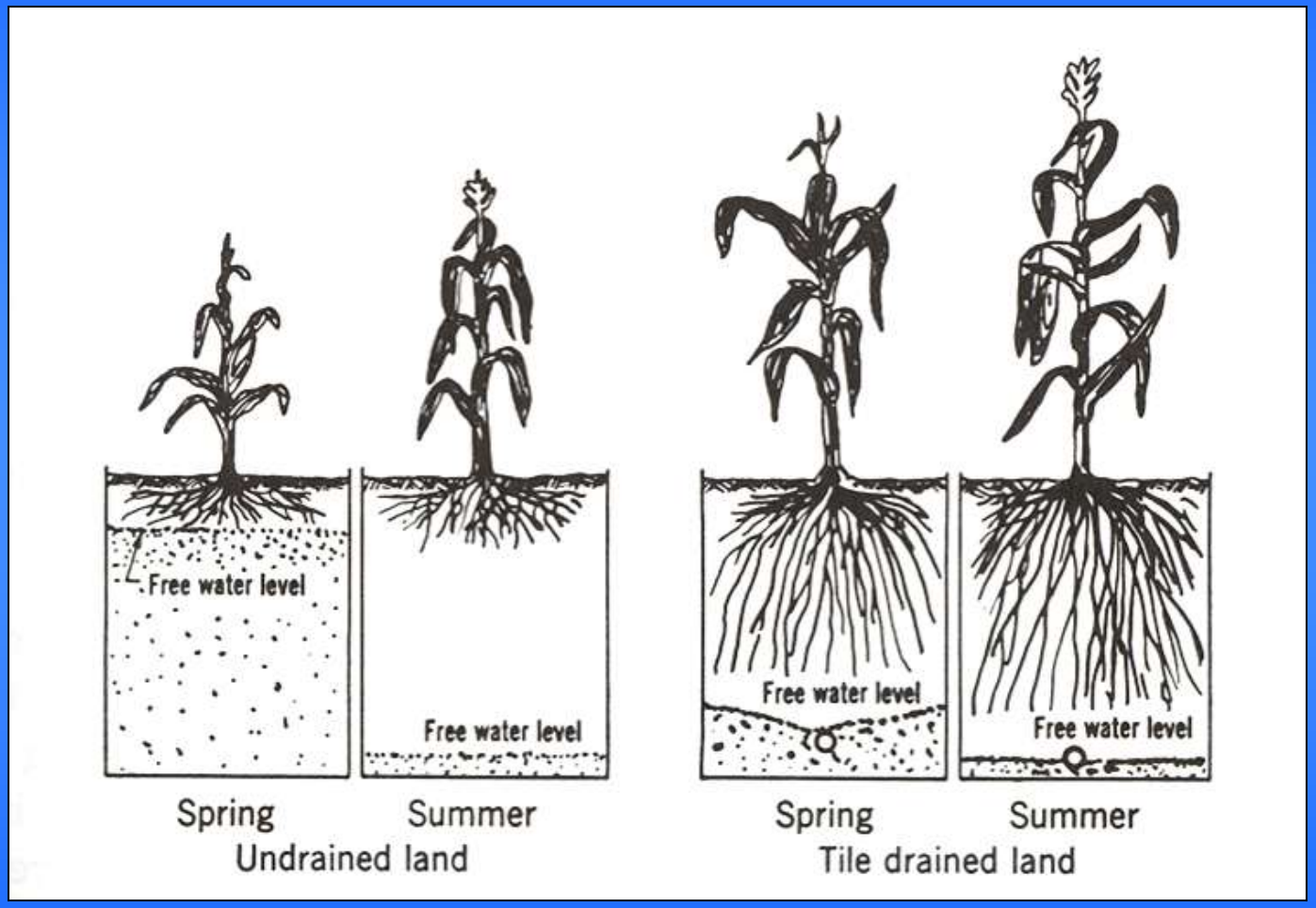
System Design Objectives

Maintain water table at proper level for healthiest plant growth.

Keep soil voids free of excess water, which permits air flow and allows important biological processes to take place in soil.

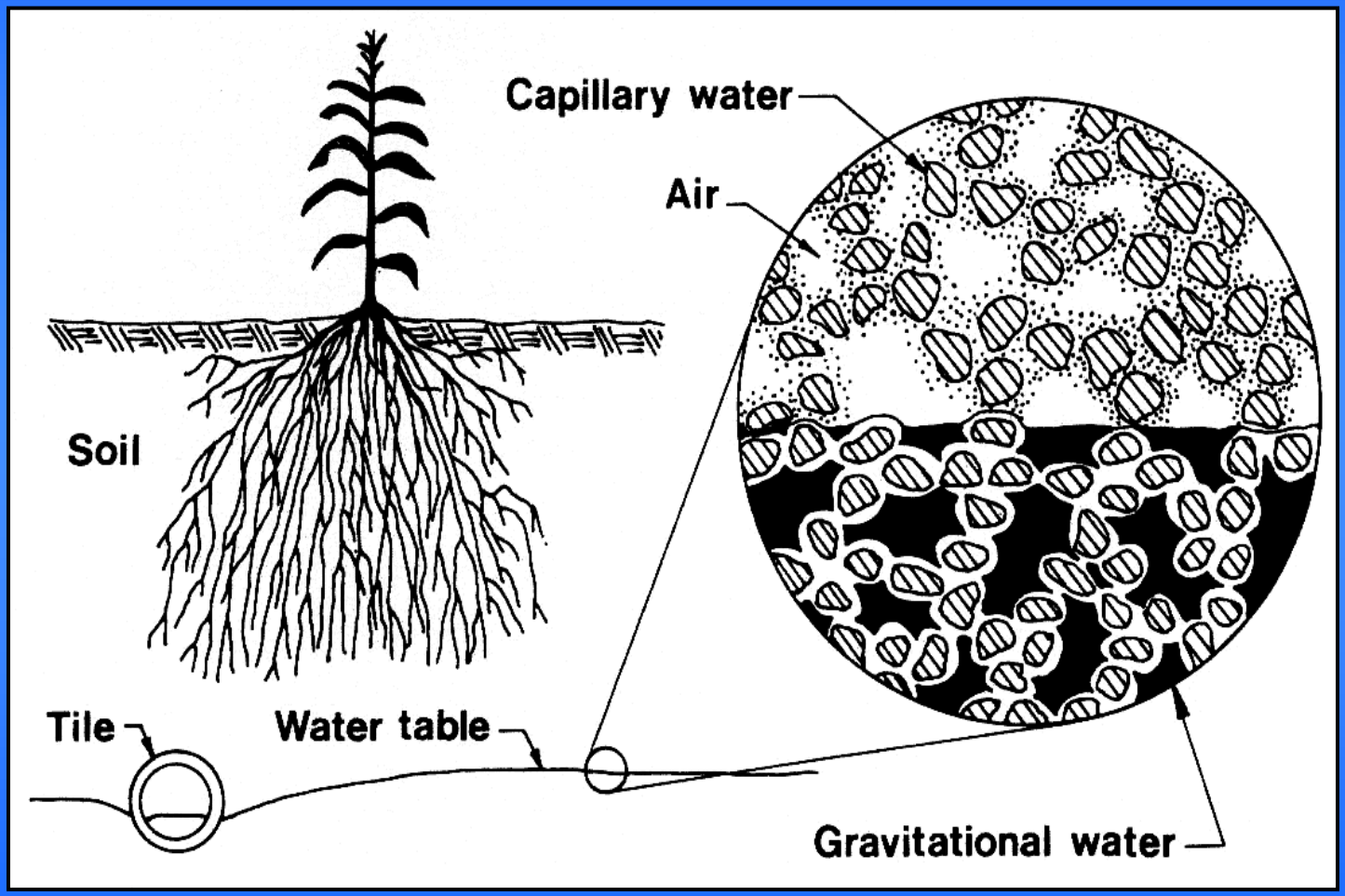
Minimize inefficient equipment operation caused by wet areas.

Drainage Design Objectives



Improve Root Development

Drainable Water

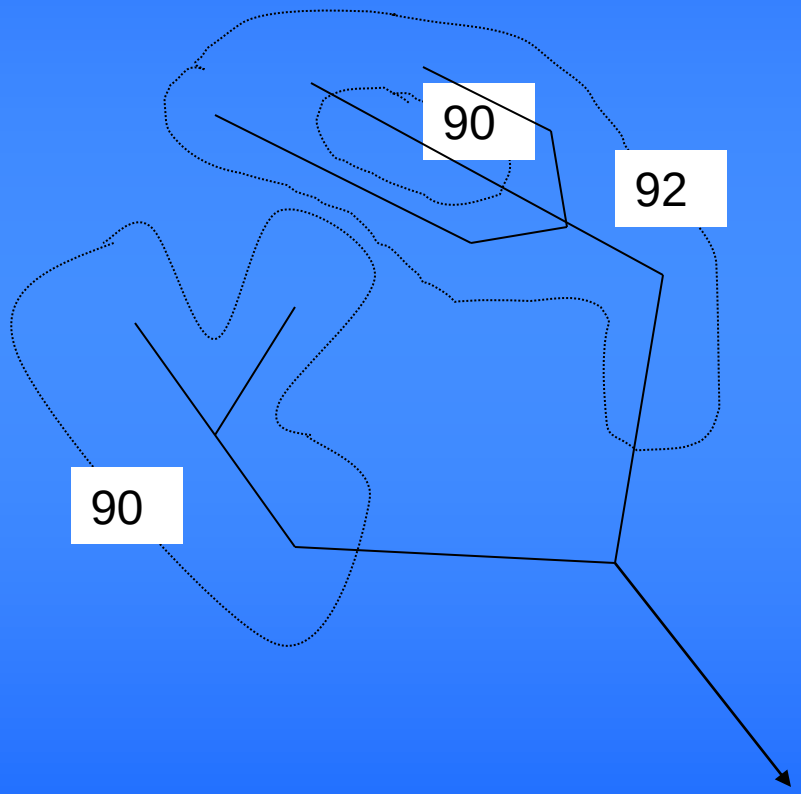


Tile Patterns

- Natural or Random -

Follow natural depressions.

Used frequently in "pot hole" landscapes to drain isolated depressions.

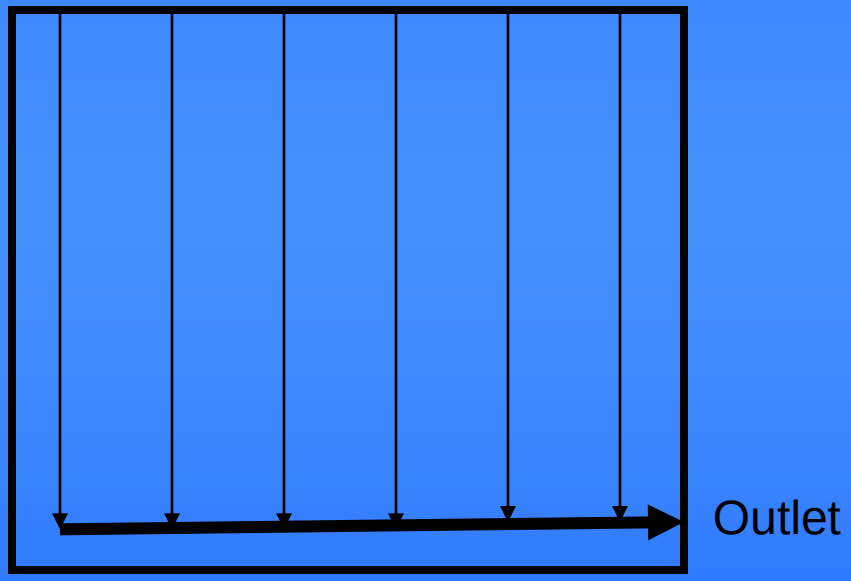


Tile Pattern
- Gridiron -

Drainage of level areas, uniform slopes

and soils w/ wide-spread wet areas.

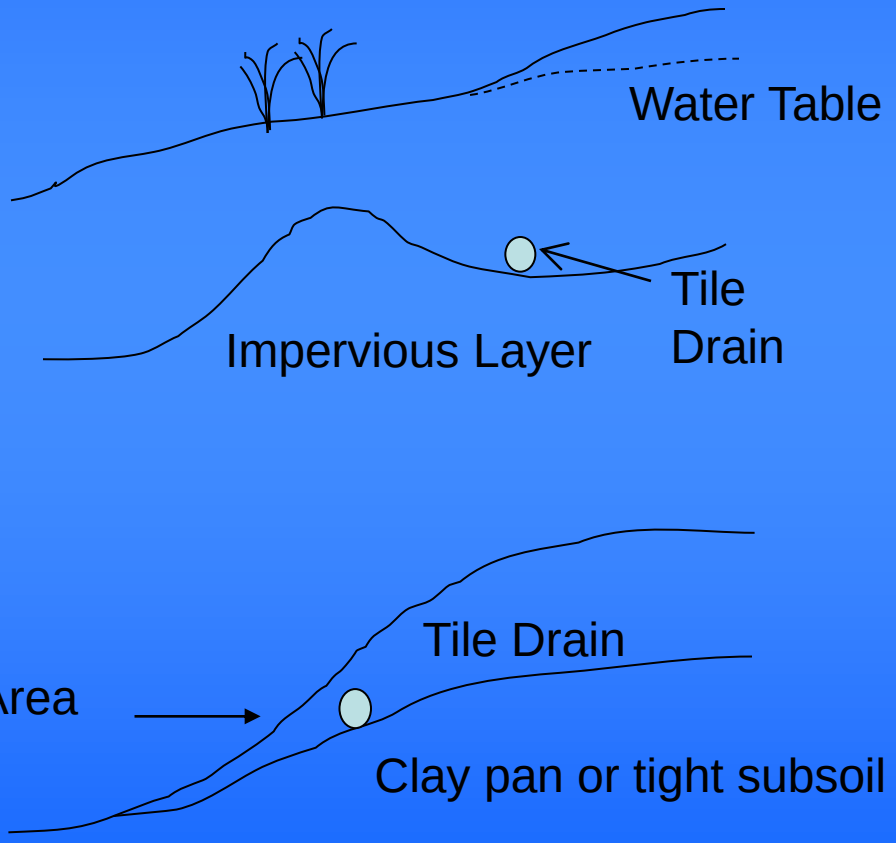
One main or sub-main serves as many laterals as possible



Tile Pattern
- Cutoff or Interceptor -

Sloping water table creates wetted area.

Used to intercept shallow lateral flow.



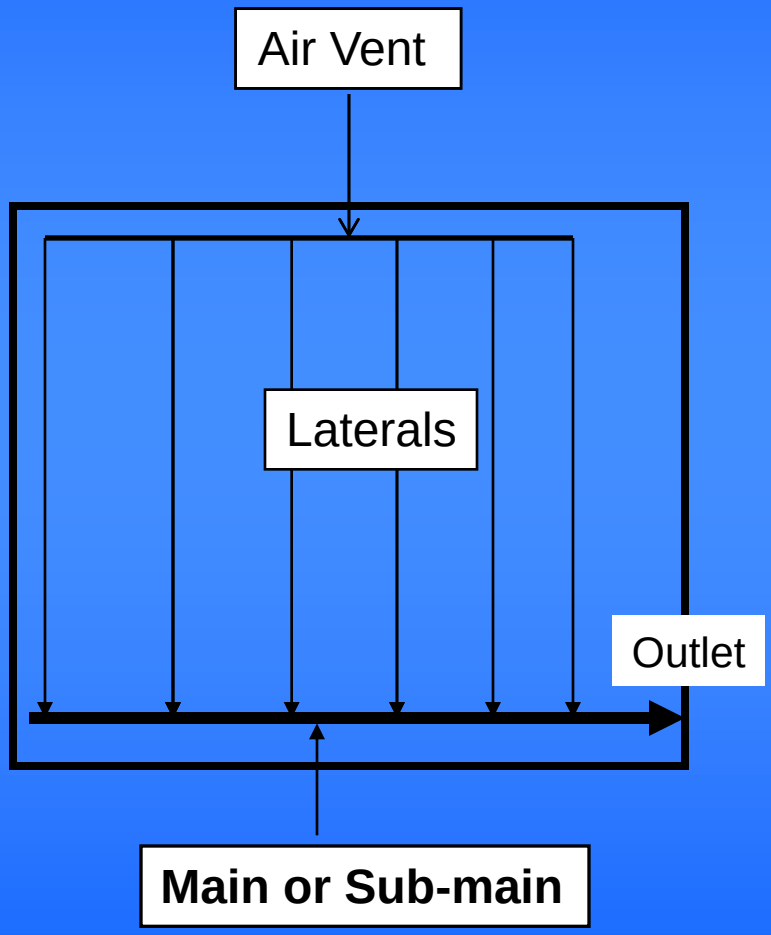
Tile System Components

Laterals are the initial collectors.

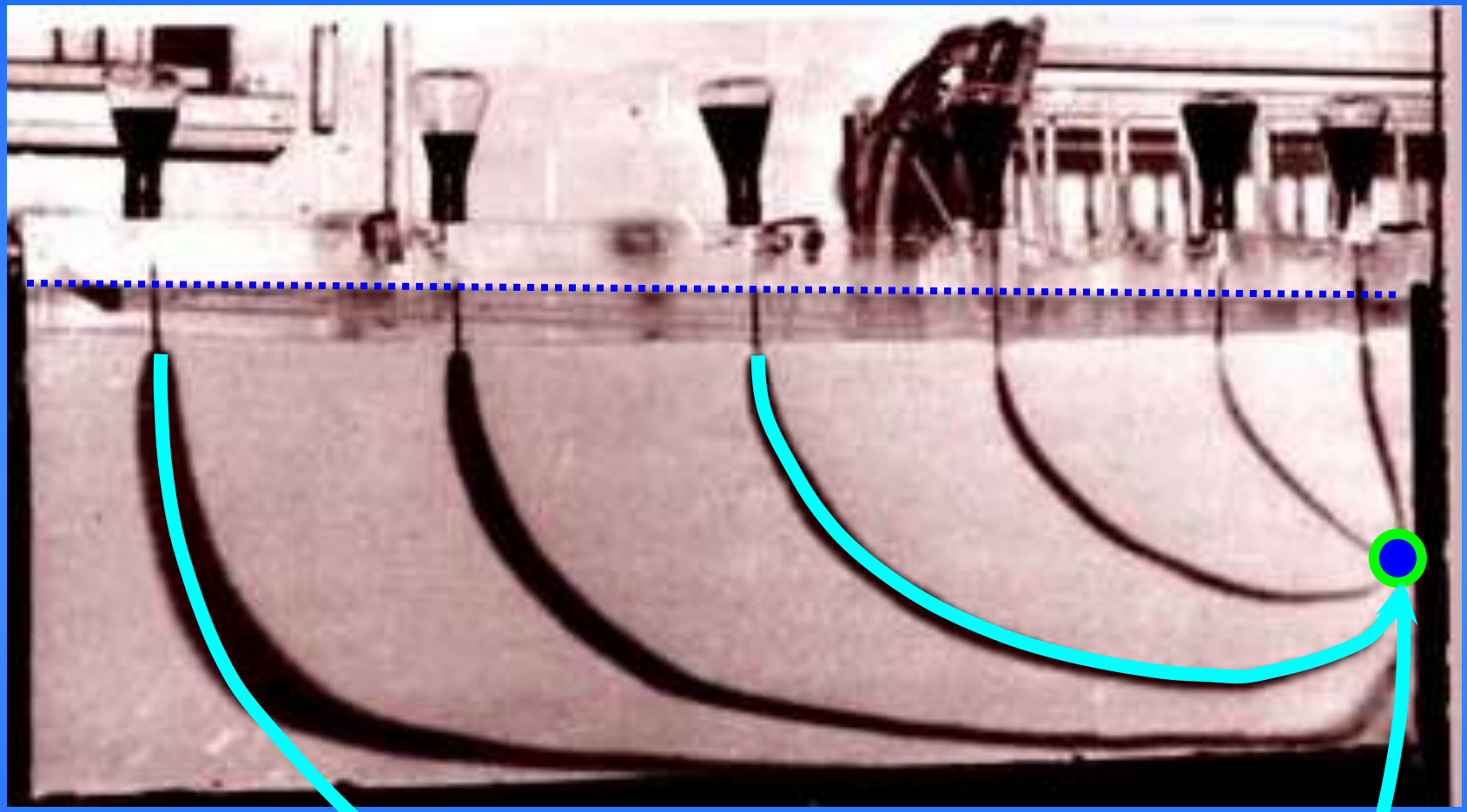
Sub-main or collector-main collect from laterals.

Mains collect from sub-mains and collector-mains.

Must have a good outlet !



Water Entry into Laterals



From Gary Sands – U of MN

Lateral Depth and Spacing

Varies with soil permeability, crop and soil management practices, kind of crop, extent of surface drainage.

- Typical drain depth range = 3 to 6 ft.
- Typical spacing = 30 to 100 ft.
- Depth / spacing balance to minimize cost.
- Minimum cover greater than 2.5 ft.

Depth / Spacing - Calculator

Water table position is a function of . . . . .

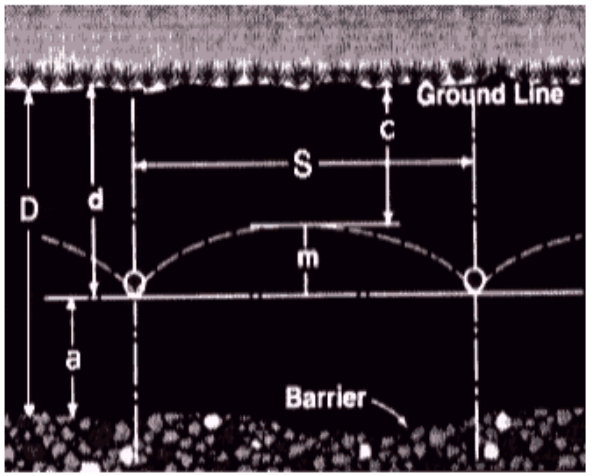
Lateral depth and spacing.

Soil hydraulic conductivity.

Impervious layer depth.

Desired drainage rate.

Hooghoudt Equation



Example tile drainage system

Local references using this equation also exist

Input Parameters

c = 2.5 ft		D = 10 ft	
q = 0.37 in/day	☐ Calculate q		
d = 4 ft	○ Ditch (any size)		
◉ Tile	○ Drain tube		
D_t = 4 in		n = N/A in	
K_1 = .51 in/h	☐ Calculate K_1 N/A		
K_2 = .51 in/h	☐ Calculate K_2 N/A		

Intermediary Results

a = 6 ft		d_e = 2.0473445 ft	
m = 1.5 ft		r_e = 0.0167 ft	
v = N/A in			

Final Results

S = 33 ft		L_e = 16.5 ft	

Compute | Reset | Help | About

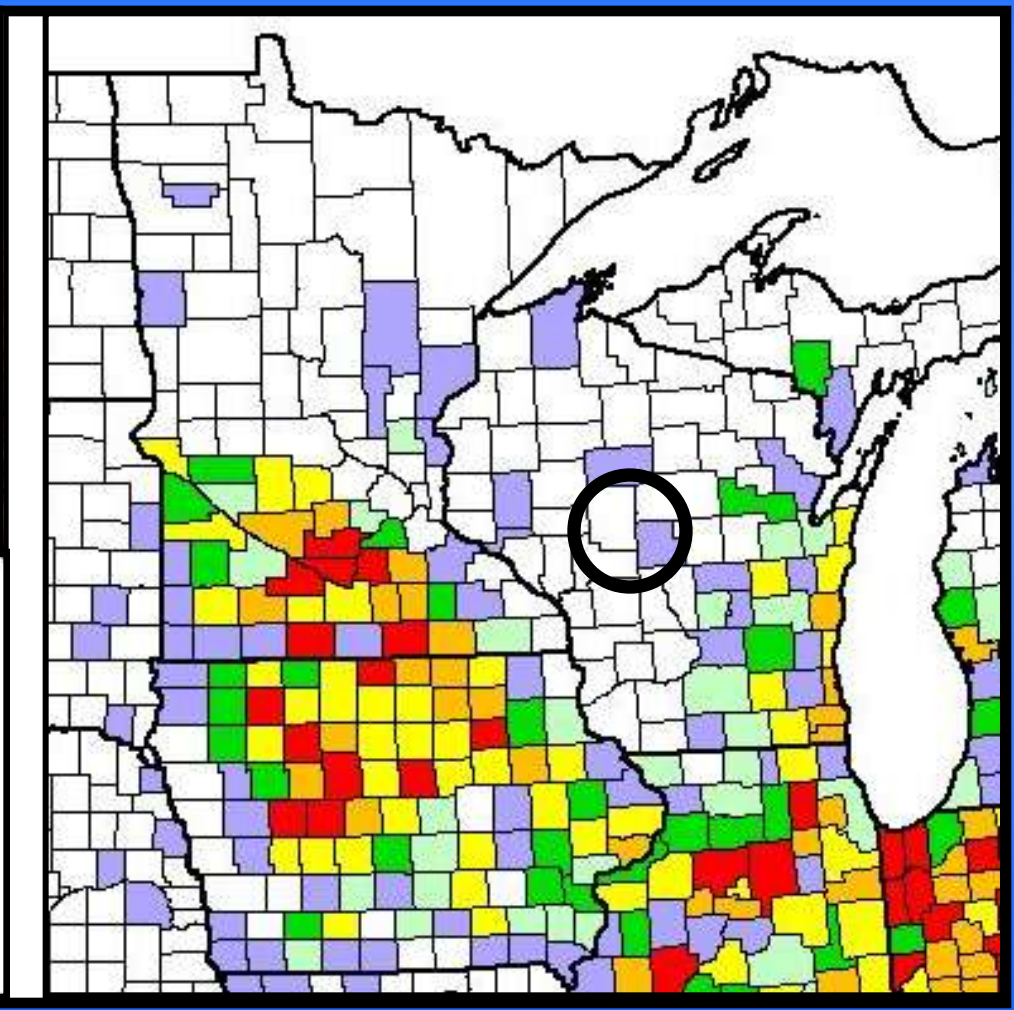
www.wli.nrcs.usda.gov/technical/web_tool/Ellipse_java.html

Regional Tiling Patterns

Percent of Harvest Acres using Sub-Surface Drainage

0	
0 - 5	20.1 - 40
5.1 - 10	40.1 - 60
10.1 - 20	60.1 - 100

Source: 1992 NRI; 1992 Census of Agriculture



Regional Tiling Patterns

Specifically, for the Marshfield, WI area.

Most land drainage work done prior to 1970, so from a historical perspective per Dr. Leonard Massie . . .

- ✓ Fine silt soils would have filled tiles.
- ✓ Want 3 - 4 ft of aerated (drained) soil depth, flat terrain made outlet establishment difficult.

Regional Tiling Patterns

Land owners not interested in cooperation with each other.

SCS did not provide support and there were no tile contractors in the area.

The area had dairy and a not cash grain production focus at the time.

Drainage Value Estimation

There is no standardized method for tile drain benefit analysis.

There is a method commonly used in WI by drainage districts to assess benefits that is a reasonable approach.

This method was developed by Dr. Leonard Massey, UW-Madison BSE and John Prunuske, and has been in use for ~ 30 years.

Drainage Value Estimation

Benefits are determined for potential corn yields using the best available farming practices, susceptibility of the land to flooding and groundwater depth.

Corn is used because it is the common commodity familiar to most producers and data are readily available.

Benefits and therefore all calculations are assumed to be **long term**.

Drainage Value Estimation

(Base Benefit) x

(Yield Factor) x

(Groundwater Factor) x

(Flood Frequency Factor) =

Benefit / ac for each soil type.

Drainage Value Estimation

I. Calculation of Base Benefit

A. Gross Return ($/ac) =
Corn Price ($/Bu) x Best Yielding Soil in Group (Bu/ac)

B. Net Return ($/ac) =
Gross Return ($/ac) - Production Cost ($/ac)

C. Annual Increase ($/ac) = 4/5[#] x Net Return

- Benefit realized on average 4 out of 5 years.

Drainage Value Estimation

I. Calculation of Base Benefit (cont)

D. Long Term Return on Investment (using an interest rate of 12%)

Annual increase / 0.12 = **Base Benefit**

II. Yield, Groundwater & Flooding Factors

(Values between 0 - 1)

A. Yield Factor =

Yield from best yielding soil in group (Bu/ac) / Yield for a specific soil (Bu/ac)

Drainage Value Estimation

Adjustment Factors

Depth to GW (ft)	Factor
0	1.0
1	0.95
2	0.90
2.5	0.875
3	0.85
3.5	0.825
4	0.80
5	0.75
6	0.70

Flood Frequency & Duration	Factor
Frequent - Long	0.95
Frequent - Brief	0.90
Occasional - Brief	0.85
Rare	0.80
None	0.75

(Values based on best professional judgement of the authors).

Note that factors decrease as water impact increases.

EXAMPLE

Corn Price:	$4.00	/ bushel
Max. Yield:	160	bushels / acre
Gross Return:	$640.00	/ acre
Production Cost:	$448.00	/ acre (PEPS 2009)
Net Return:	$192.00	/ acre
Annual Increase:	$153.60	/ acre
Long Term Return on Investment:	12.00%	/ year
Base Benefit:	$1,280.00	/ acre

Benefit = Base ($1,280.00) x YF(80/160) = **0.5** x GW
@ 0 ft = **1.0** x FL (Freq. Brief) = **0.90** => $576.00/ac

Typical Tile Installation Cost ~ $800/ac

Production Cost and Yield Data

Production Cost Data - USDA

http://www.ers.usda.gov/Data/CostsAndReturns/testpick.hm#recent

Production Cost Data - UW Agronomy (PEPS)

http://corn.agronomy.wisc.edu/PEPS/

Crop Yield by Soils Unit - NRCS Soils Data Mart

http://soildatamart.nrcs.usda.gov/

Acknowledgement

Leonard Massie, Professor Emeritus

Biological Systems Engineering Department, UW - Madison

Dan Prunuske, PE

DesignTech Engineering, Beaver Dam, WI