

The Basics of Agricultural Tile Drainage

Basic Engineering Principals 2

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**Date
Location**

ASABE Tile Drain Standards

Design Standard

ASAE EP480 MAR1998 (R2008)
Design of Subsurface Drains in Humid Areas



American Society of
Agricultural and Biological Engineers

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**ASAE EP480
MAR1998
(R2008)**

**Design of
subsurface
Drains in
Humid
Climates**

ASABE Tile Drain Standards

Construction Standard

ASAE EP481 FEB03
Construction of Subsurface Drains in Humid Areas



American Society of
Agricultural and Biological Engineers

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ASAE EP481 FEB03

Construction of subsurface Drains in Humid Areas

Drain Design Procedure

- I. Determine if and where an adequate outlet can be installed!
- II. Estimate hydraulic conductivity (K) based on soil type.
- III. Select drainage coefficient (D_c) based on crop and soil type.

Drain Design Procedure

IV. Select suitable depth for drains

- o Typical range 3 to 6 ft.
- o Cover greater than 2.5 ft
- o Depth / spacing balance to minimize cost

V. Determine spacing

- o Use soil textural table guidelines
- o Use iGrow Web-based calculator.

Drain Design Procedure

- VI. Size laterals and mains to accommodate the design flow.
- Maintain minimum velocity to clean pipe.
(0.5 ft / s - No silt; 1.4 ft / sec - w/silt)
 - Match pipe size to design flow.
(telescope the size of main as drained area increases)
 - Properly design outlet.

Design Challenges

- ✓ The design process results in a design for a 2 to 5 year event, controlling larger events too costly.
- ✓ Every soil will be different and crop type matters.
- ✓ Costs/benefits will vary from year to year.
- ✓ Climate trends are unpredictable.

Drain Tile Installation Equipment



Tractor Backhoe



Tile Plow



Chain Trencher



Wheel Trencher

Drain Tile Materials



Clay Tile (organic soils)



Concrete Tile (mineral soils)



Drain Pipe Materials

- Polyethylene Plastic -

Single wall corrugated



Dual wall (smooth wall)



Water enters the pipe through slots in wall

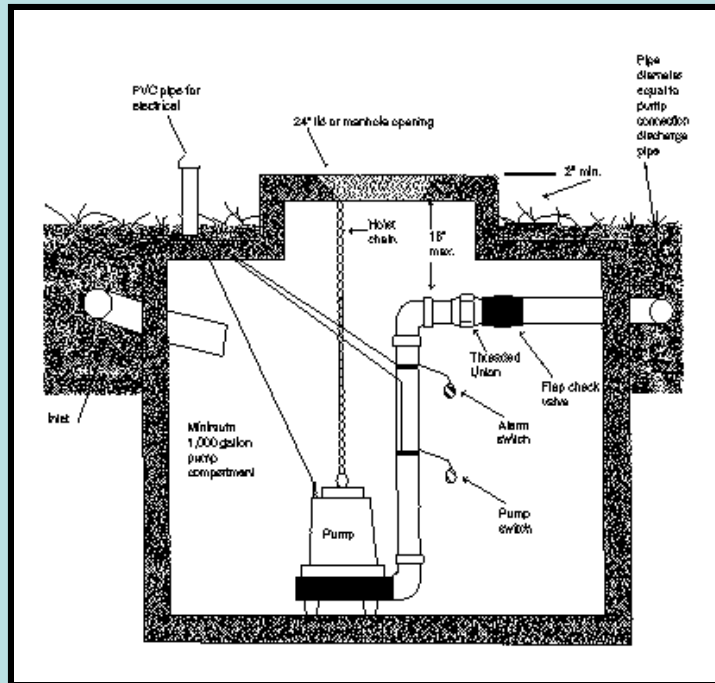
I. The Drain Outlet

- ✓ MUST have sufficient grade for gravity flow !
< set preliminary grade>
 - If not, a pump station will be necessary.
- ✓ Receiving water must have adequate capacity.
- ✓ Provide guards to keep animals out.



- ✓ Daylight outlet pipe
1 ft above base flow
in receiving channel

Drainage Pump Stations



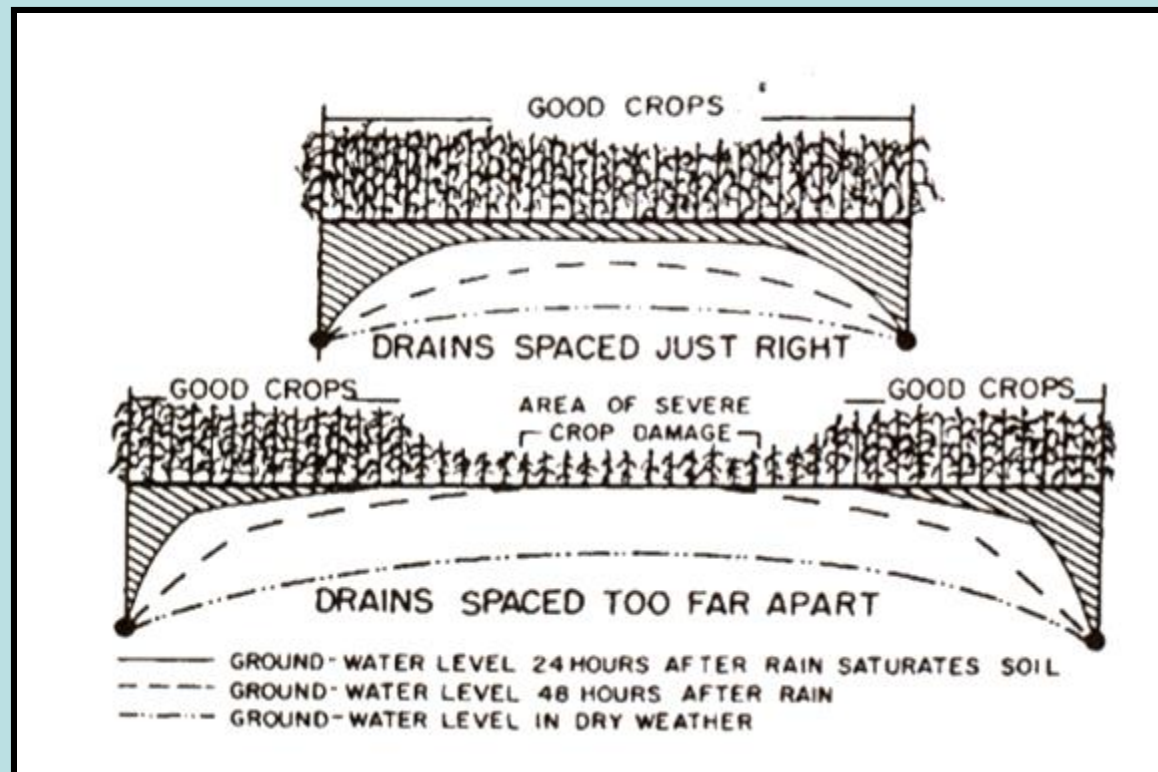
When you don't have the fall to use gravity

II. Determine K_{sat} for Soil

- ✓ Use web soil survey for site in question.
- ✓ Conduct site specific soil survey (test pit).
- ✓ Use values base on soil texture.
- ✓ Ask local experts (county staff, NRCS, drainage contractors).

III. Proper Lateral Depth and Spacing

Drain spacing, water table depth and crop response



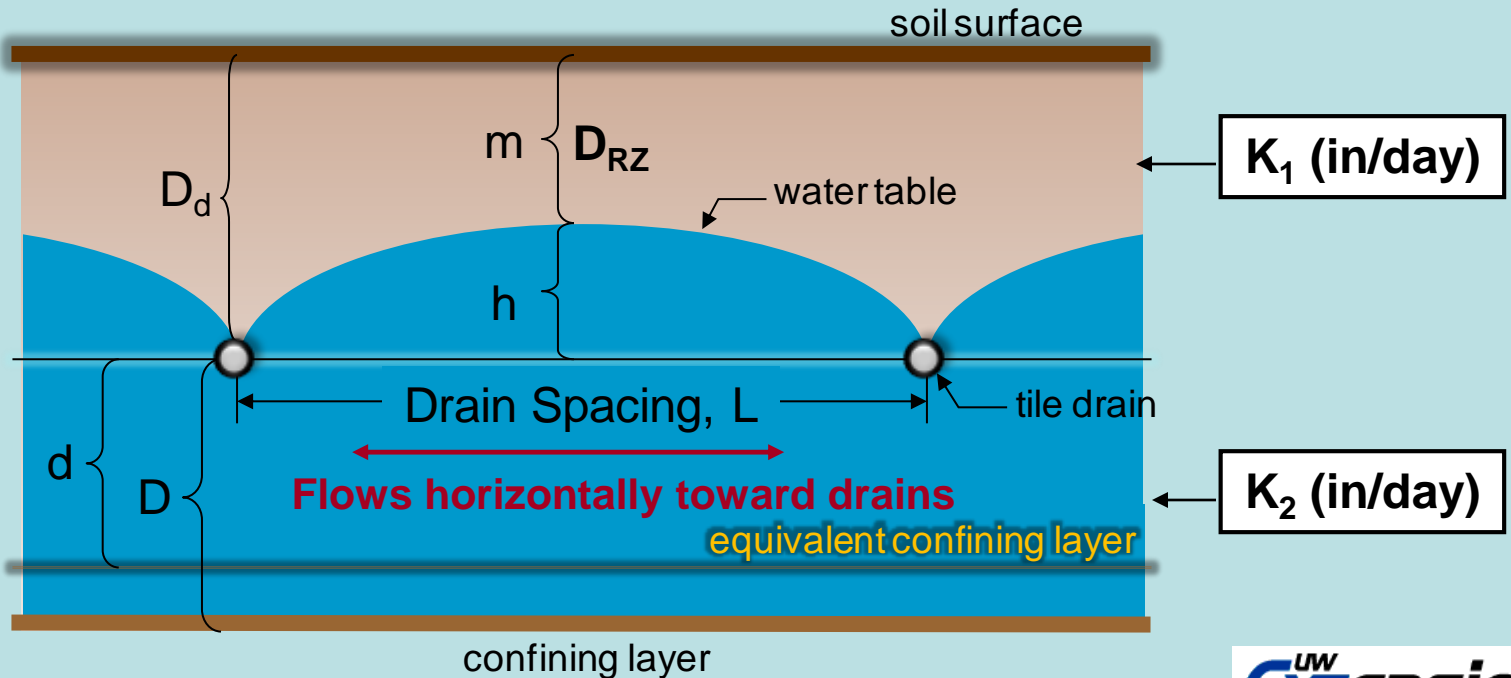
Drain depth and spacing integrate the water removal rate (D_c) and soil permeability (K)



Drain Depth / Spacing - Equation

$$DC = \frac{(8 * K_2 * d * h)}{L^2} + \frac{(4 * K_1 * h^2)}{L^2}$$

Hooghoudt Equation, 1940



Determination of Soil K

USDA United States Department of Agriculture
Natural Resources Conservation Service

Web Soil Survey

Home About Soils Help Contact Us

You are here: Web Soil Survey Home

Search
Enter Keywords: **Go**
All NRCS Sites

Browse by Subject

- Soils Home
- National Cooperative Soil Survey (NCSS)
- Archived Soil Surveys
- Status Maps
- Official Soil Series Descriptions (OSSD)
- Soil Series Extent Mapping Tool
- Geospatial Data Gateway
- eX-GIS
- National Soil Characterization Data
- Soil Health
- Soil Geography

The simple yet powerful way to access and use soil data.

START WSS

Welcome to Web Soil Survey (WSS)

Web Soil Survey (WSS) provides soil data and information produced by the National Cooperative Soil Survey. It is operated by the USDA Natural Resources Conservation Service (NRCS) and provides access to the largest natural resource information system in the world. NRCS has soil maps and data available online for more than 95 percent of the nation's counties and anticipates having 100 percent in the near future. The site is updated and maintained online as the single authoritative source of soil survey information.

Soil surveys can be used for general farm, local, and wider area planning. Onsite investigation is needed in some cases, such as soil quality assessments and certain conservation and engineering applications. For more detailed information, contact your local [USDA Service Center](#) or your [NRCS State Soil Scientist](#).

Four Basic Steps

- 1 Define...**
Area of Interest (AOI) Use the Area of Interest tab to define your area of interest.

Click to view larger image.
- 2 View...**

I Want To...

- Start Web Soil Survey (WSS)
- Know the requirements for running Web Soil Survey — will Web Soil Survey work in my web browser?
- Know the Web Soil Survey hours of operation
- Find what areas of the U.S. have soil data
- Find information by topic
- Know how to hyperlink from other documents to Web Soil Survey
- Know the SSURGO data structure

Announcements/Events

- Web Soil Survey 3.2 has been released! [View description of new features and fixes.](#)
- Web Soil Survey Release History
- Sign up for e-mail updates via [GovDelivery](#)

I Want Help With...

- Getting Started With Web Soil Survey
- How to use Web Soil Survey
- How to use Web Soil Survey Online Help
- Known Problems and Workarounds
- Frequently Asked Questions
- Citing Web Soil Survey as a source of soils data

The WSS can calculate a depth weighted K value

Tables — Saturated Hydraulic Conductivity (Ksat) — Summary By Map Unit

Summary by Map Unit — Brown County, Wisconsin (W1009)

Map unit symbol	Map unit name	Rating (micrometers per second)	Acres in AOI	Percent of AOI
KhB2	Kewaunee silt loam, 2 to 6 percent slopes, eroded	2.0931	0.1	86.6%
McA	Manawa silty clay loam, 0 to 3 percent slopes	1.1856	0.0	13.4%
Totals for Area of Interest			0.1	100.0%

Description — Saturated Hydraulic Conductivity (Ksat)

Saturated hydraulic conductivity (Ksat) refers to the ease with which pores in a saturated soil transmit water. The estimates are expressed in terms of micrometers per second. They are based on soil characteristics observed in the field, particularly structure, porosity, and texture. Saturated hydraulic conductivity is considered in the design of soil drainage systems and septic tank absorption fields.

For each soil layer, this attribute is actually recorded as three separate values in the database. A low value and a high value indicate the range of this attribute for the soil component. A "representative" value indicates the expected value of this attribute for the component. For this soil property, only the representative value is used.

The numeric Ksat values have been grouped according to standard Ksat class limits.

Rating Options — Saturated Hydraulic Conductivity (Ksat)

Units of Measure: micrometers per second

Aggregation Method: Dominant Component

Component Percent Cutoff: None Specified

Tie-break Rule: Fastest

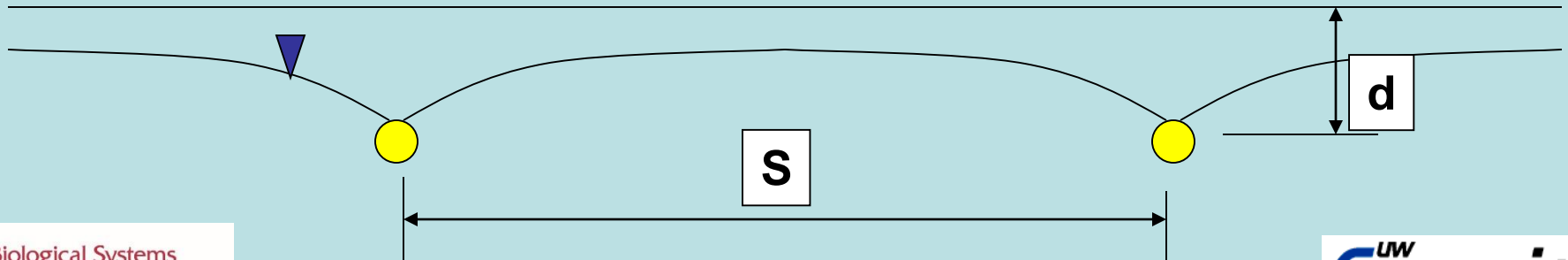
Interpret Nulls as Zero: No

Layer Options (Horizon Aggregation Method): All Layers (Weighted Average)

<https://websoilsurvey.sc.egov.usda.gov/>

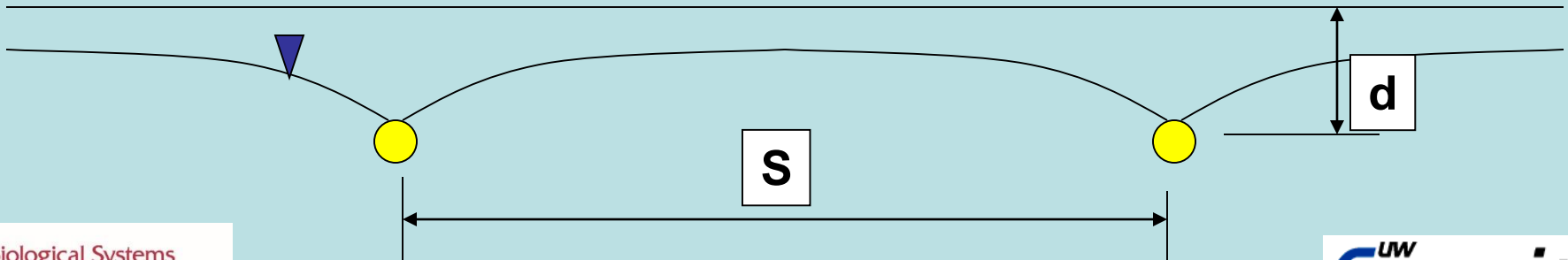
Lateral Depth and Spacing

The goal is to maintain as consistent a Dc value across the field as possible.



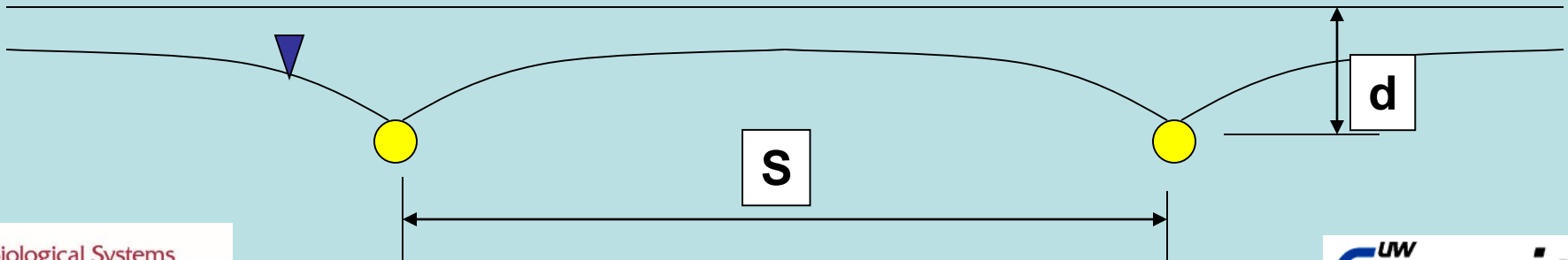
Lateral Depth and Spacing

- ✓ A relationship exists between depth and spacing of drains.
- ✓ For soils of uniform permeability, the deeper the drains, the wider the spacing (within limits).
- ✓ Higher permeability soils can have greater spacing
- ✓ Need to provide adequate root depth above the saturated zone.



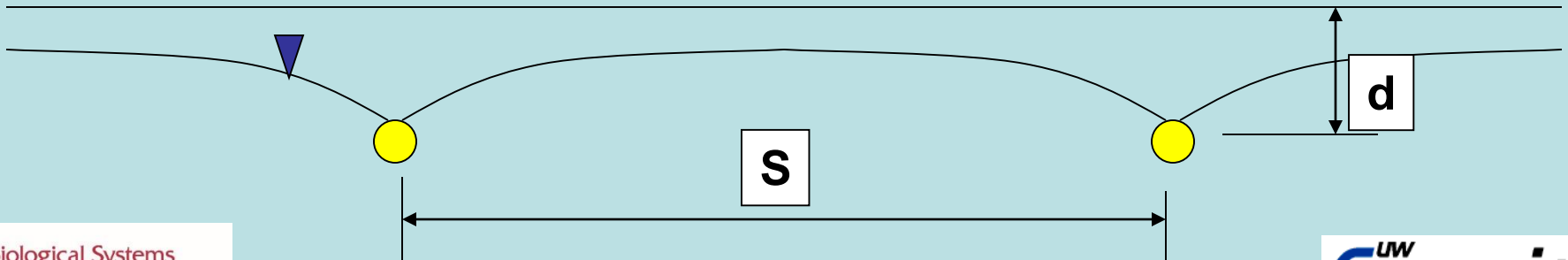
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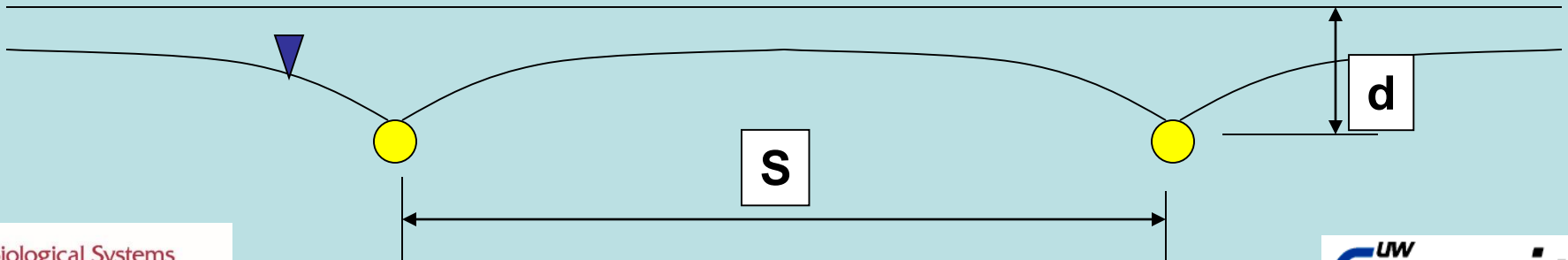
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Lateral Depth and Spacing

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

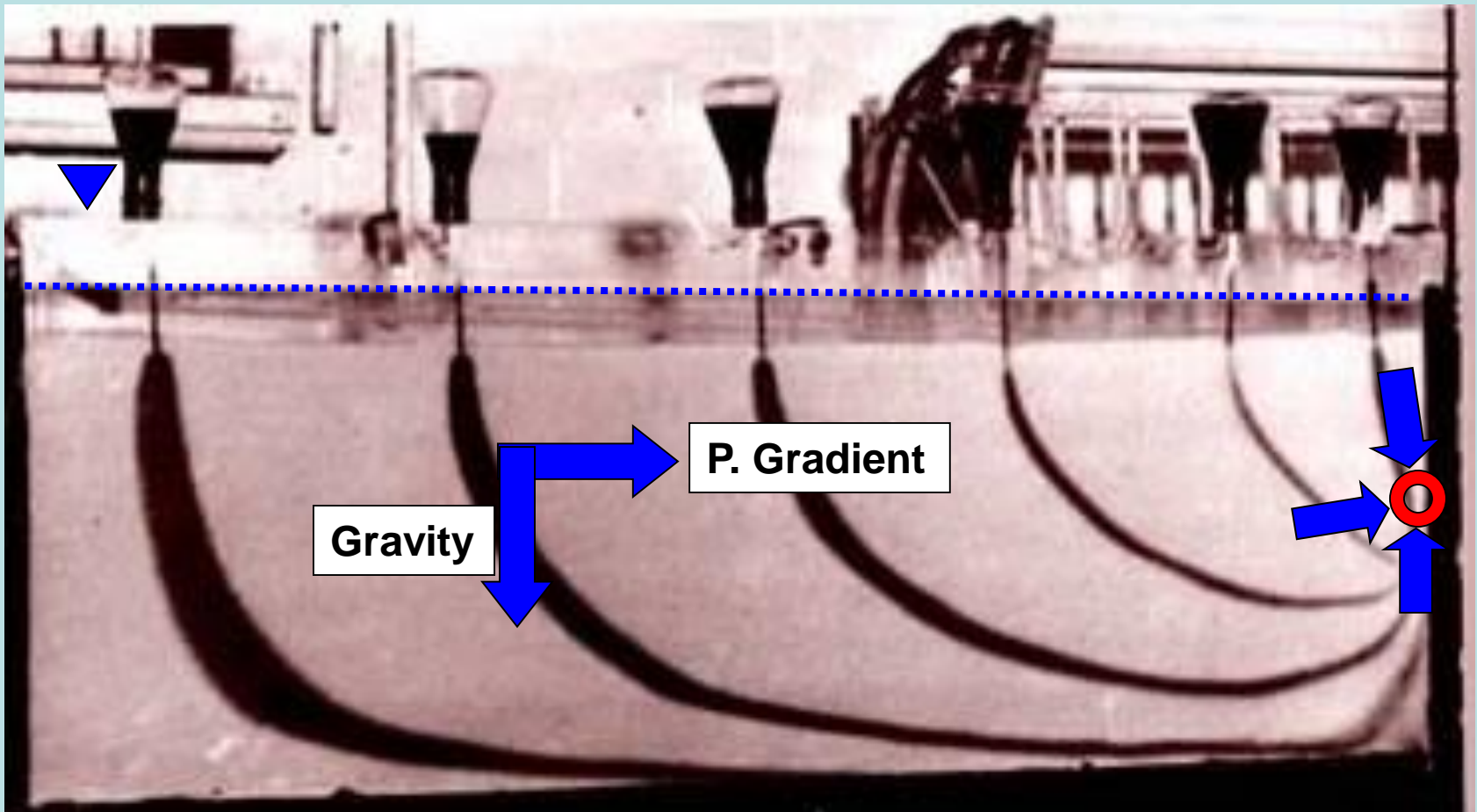
Typical drain depth range = 3 to 6 ft.

Typical spacing = 30 to 100 ft.

Depth / spacing balance to minimize cost.

Minimum cover greater than 2.5 ft.

Drain Water Flow Patterns



From Gary Sands – U of MN

Drain Depth / Spacing - Table

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

Soil Texture	Hyd. Cond (in/hr)	Spacing (Ft)	Depth (Ft)
Clay	0.02 - 0.04	10 - 20	3.0 - 3.6
Clay Loam	0.04 - 0.20	16 - 33	3.0 - 3.6
Loam	0.02 - 0.79	33 - 82	3.6 - 4.0
Fine sandy loam	0.79 - 2.6	82 - 164	4.0 - 4.6
Sandy loam	2.6 - 5.1	164 - 230	3.6 - 5.0
Peat and Muck	5.1 - 9.8	230 - 330	3.6 - 5.0

Source: Soil & Water Conservation Engineering 5th Ed., 2006

Depth / Spacing - Calculator



Drainage Calculators

Utilize these calculators to address common drainage questions. Additional information is available on [iGrow](#)

Pipe Size -> Area Drained

Area Drained by Pipe Sizes

Avg. Hydraulic Conductivity

Drain Spacing

Drainage Coefficient

Grade -> Fall

Fall -> Grade

Min. Grade Needed

Hydraulic Conductivity Converter

Max. Lateral Length

Length -> Lateral Sizing

Max. Laterals on Main

Area Drained -> Pipe Size

Pump Size

Subirrigation Spacing


Sump Storage

Visit [iGrow.org](#) for the latest information from SDSU Extension. This tool was developed in collaboration with [University of Minnesota Extension](#)

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<http://www.igrowdrainage.org/>

Depth / Spacing - Example



A Service of SDSU Extension

Drainage Calculators

Pipe Size -> Area Drained

Area Drained by Pipe Sizes

Avg. Hydraulic Conductivity

Drain Spacing

Drainage Coefficient

Grade -> Fall

Fall -> Grade

Min. Grade Needed

Hydraulic Conductivity Converter

Max. Lateral Length

Length -> Lateral Sizing

Max. Laterals on Main

Area Drained -> Pipe Size

DRAIN SPACING

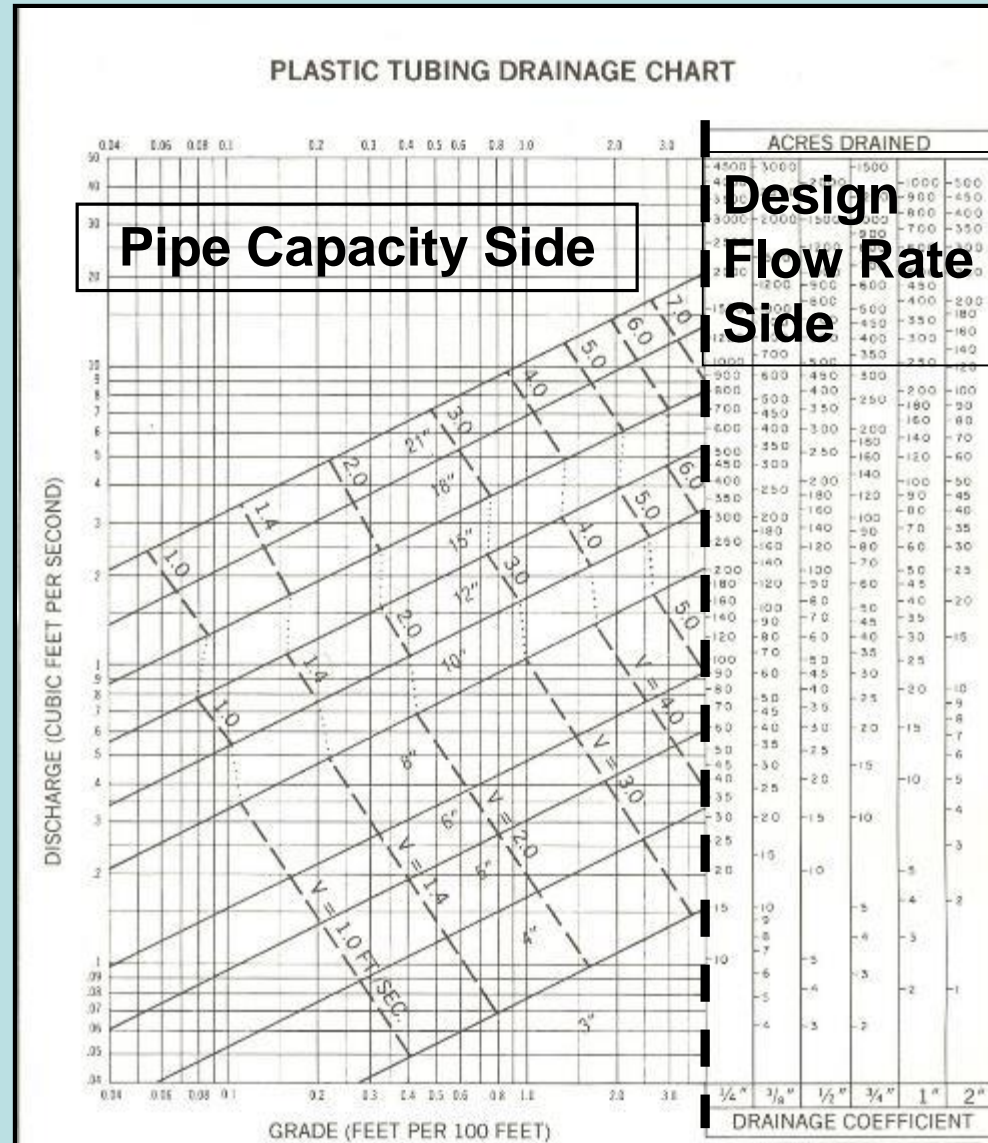
Drainage Coefficient	<input type="text" value="0.5"/>	in./day
Calculate		
Tile Diameter	<input type="text" value="4"/>	in
Tile Depth	<input type="text" value="4"/>	ft
Depth to Restrictive Layer	<input type="text" value="8"/>	ft
Minimum Water Table Depth	<input type="text" value="2"/>	ft
Hydraulic Conductivity Units	<input type="text" value="in / hour"/>	
Hydraulic Conductivity Value	<input type="text" value="1.0"/>	
<input type="button" value="CALCULATE"/>		

RESULTS

Drain Spacing	49	ft
---------------	----	----

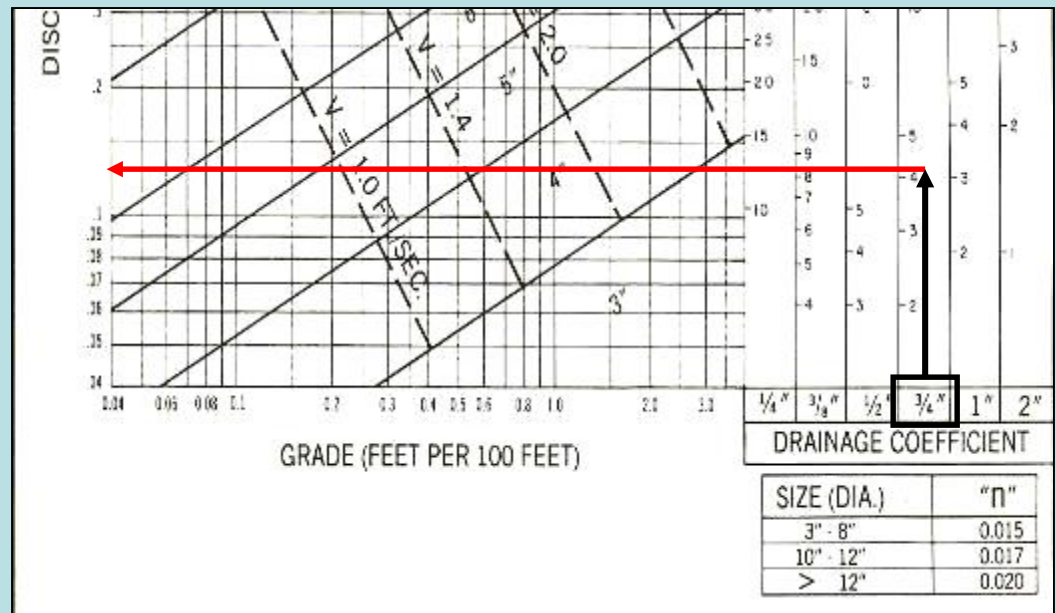
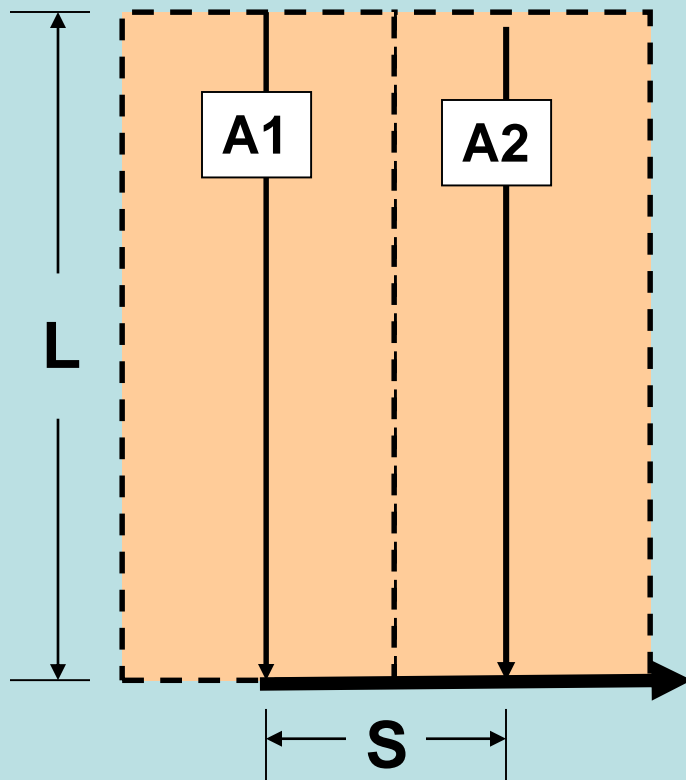
Engineering Design Aids

- Tubing Drainage Chart -



Flow into laterals

Area drained = $L \times S$; $L = 1,500$ ft; $S = 61$ ft;
 $A_T = (1,500 \times 122) / 43,560 = 4.2$ ac; $D_c = \frac{3}{4}$ in.



0.14 cubic feet / second = 63 gpm

VI. Sizing Laterals and Mains

$$D_c \text{ (in/day)} \times \text{Area (ac)} = \text{Flow rate (ac} \cdot \text{in/day)}$$

$$(\text{ac} \cdot \text{in/day}) / 23.8 = \text{Flow rate (ft}^3\text{/sec)}$$

Manning's equation for gravity pipe flow

$$\text{Pipe capacity (cfs)} = \frac{0.4631}{n} \times D^{2.667} \times S^{1/2}$$

D = pipe diameter (ft) and S = pipe slope (ft/ft)

n = .009 smooth interior pipe
.015 3" to 8" sizes
.017 9" to 12"
.020 > 12"

Pipe Capacity

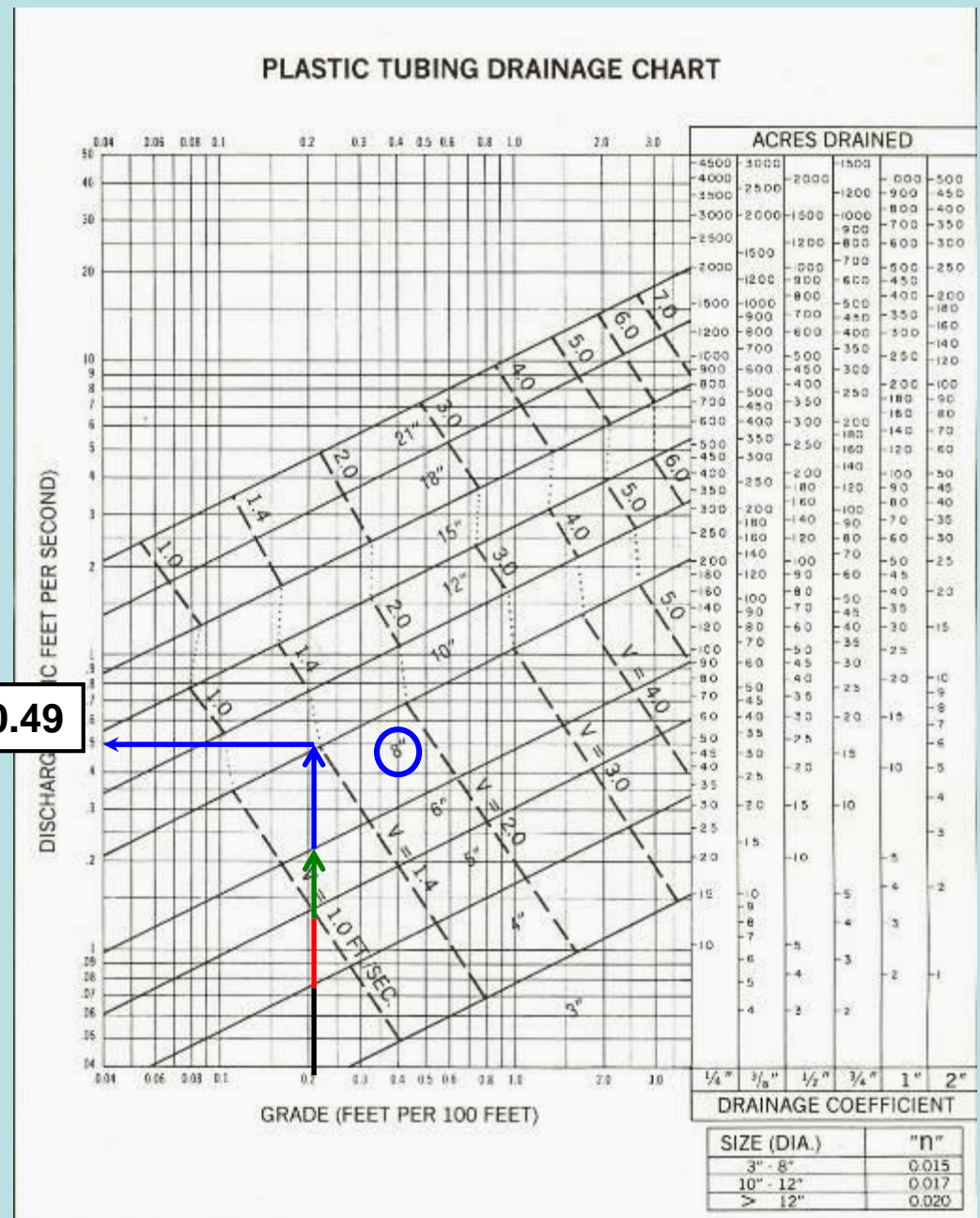
Read pipe flow capacity for pipe size from the scale on the left.

See your drainage design chart.

Full flow capacity of a 8 in diameter pipe @ 0.22 %

= 0.49 cfs
= 220 gpm

cfs x 448.83 = gpm



Example Problem

For $D_c = 1/2$ in / day

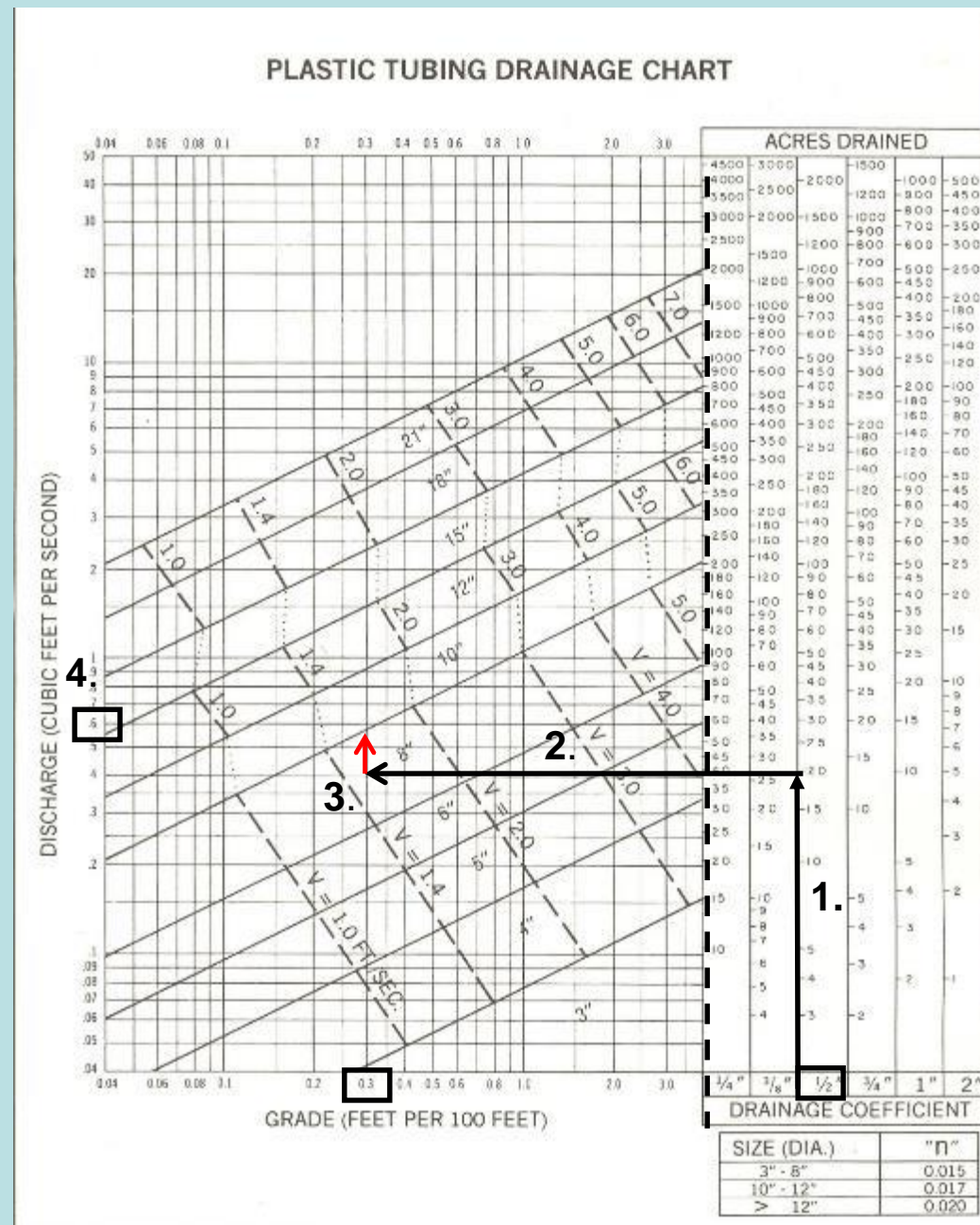
Area = 20 ac

Pipe Slope = 0.30%
= 0.0030 ft/ft


Requires:

Pipe needs to carry 0.42 cfs
(use next highest standard
size) of 8 in diameter which has
full flow capacity of 0.57 cfs & V
~ 1.6 ft /sec.

Use across different scales
to telescope the pipe size



Area / Pipe Size - Example

**Drainage Calculators**

Pipe Size -> Area Drained

Area Drained by Pipe Sizes

Avg. Hydraulic Conductivity

Drain Spacing

Drainage Coefficient

Grade -> Fall

Fall -> Grade

Min. Grade Needed

Hydraulic Conductivity Converter

AREA DRAINED -> PIPE SIZE

Drainage Coefficient

Calculate

0.5

in./day

Drained Area

20

Acres

Pipe Grade

Calculate

0.3

%

Pipe Material

Single Wall Plastic

CALCULATE

RESULTS

Flow Rate (full pipe)

0.4201

cfs

Flow Velocity (full pipe)

1.45

fps

Required pipe size is

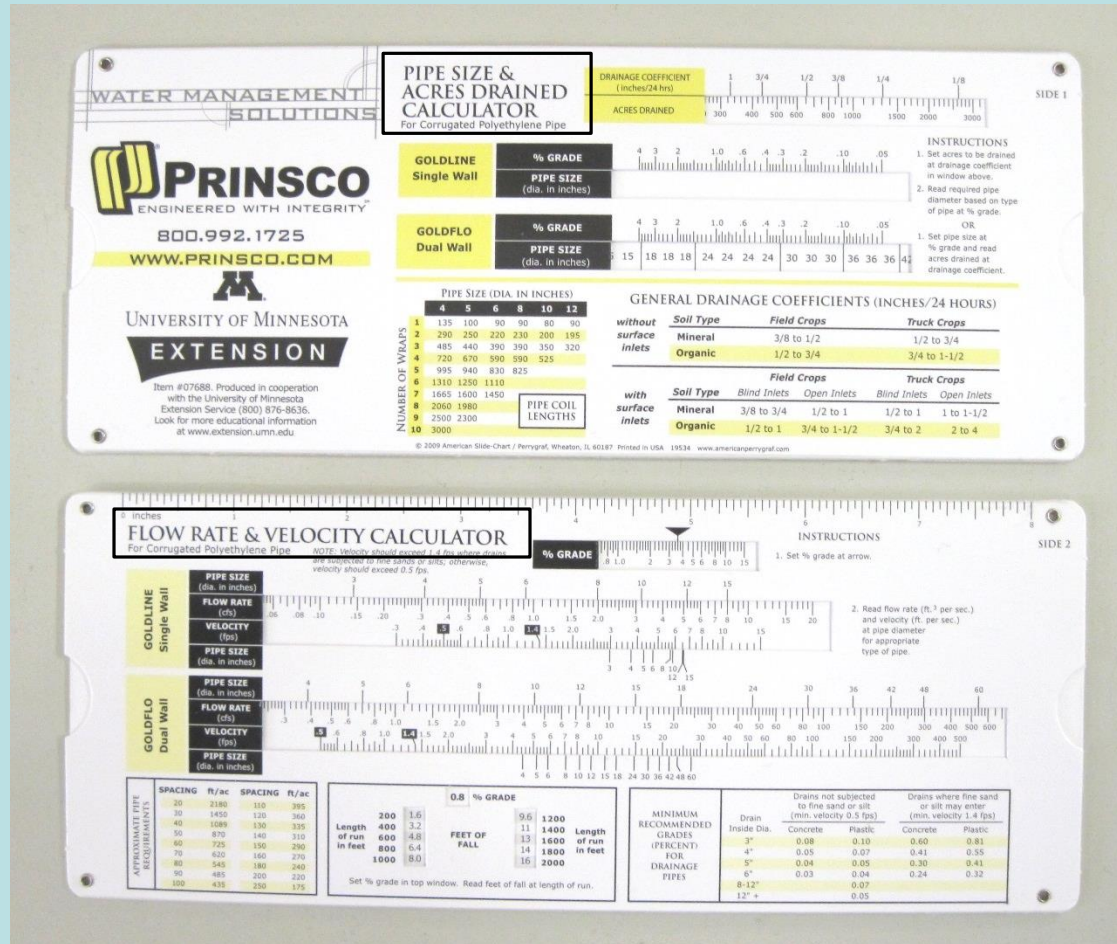
7.3

inches

CLEAR ALL FIELDS

Note the non-standard pipe diameter. Select 8" diameter.

Slide Rule Design Tool



Drainage Resources

fyi.uwex.edu/drainage/

University of Wisconsin-Extension

Cooperative Extension

Search ...



Tile Drainage Resources

Cooperative Extension

UW Extension
University of Wisconsin-Extension

[Home](#) [Trainings & Workshops](#) [University & Agency Links](#) [Video Resources](#) [Web Resources](#)

This site is designed to provide farmers, conservationists, and agronomists with a variety of information and resources related to agricultural tile drainage.

Workshops

Understanding Agricultural Drainage Mapping Tile Drainage Systems Controlled or Managed Drainage Systems Research Update – What we've learned from WI Farms Drainage District Overview Enabling no-till yields to increase with earthworms, drainage Corps Regulatory Process

PAGES

[Trainings & Workshops](#)

[University & Agency Links](#)

[Video Resources](#)

[Web Resources](#)

UW DISCOVERY FARMS

[UW Discovery Farms](#)

Drainage Resources

Learningstore.uwex.edu

Tile Drainage in Wisconsin: Understanding and Locating Tile Drainage Systems

FACT SHEET NO. 1 UWEX

Subsurface drainage is used for agricultural, residential and industrial purposes to remove excess water from poorly drained land. An important feature statewide, drainage enhances Wisconsin agricultural systems, especially in years with high precipitation. Drainage systems improve timeliness of field operations, enhance growing conditions for crop production, increase crop yields on poorly drained soils and reduce yield variability. In addition to agronomic benefits, subsurface drainage can improve soil quality by decreasing soil erosion and compaction.

To maintain agricultural productivity and protect water quality, producers, consultants and agency personnel must understand tile drainage, locate drainage systems and properly maintain them.

The purpose of this publication is to:

- ✓ provide information on tile drainage systems throughout Wisconsin and
- ✓ describe methods to locate tile drains in the field.

"Once the tiles are located, producers or consultants should develop accurate maps and keep copies (both electronic and paper) in a secure file system. Modifications to existing systems or the installation of new tiles should also be identified. Your local Land Conservation Departments should be able to provide copies of aerial photos or base maps."



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Tile Drainage in Wisconsin: Maintaining Tile Drainage Systems

FACT SHEET NO. 2 UWEX

Tile drains play an important role in Wisconsin's agricultural production systems. Drains alleviate saturated soil conditions, maintaining optimal root zone moisture for plant growth. Saturated soils can kill or damage crops by depriving roots of oxygen. Saturated soils also delay field access and can increase soil compaction if fields are worked. Water-logged soils can cause denitrification, the process where soil bacteria convert nitrate to nitrogen gas, thereby decreasing available nitrogen for plants. Regular maintenance of tile drains is an important management practice to ensure agricultural productivity on tile-drained land in Wisconsin.

The purpose of this publication is to:

- ✓ provide information on inspecting and maintaining tile drainage systems and
- ✓ present issues to consider when modifying existing tiles or installing new drains

"Tile drainage systems should be inspected annually, preferably at peak flow times that typically occur during spring melt and after heavy rainfall events."



Figure 1: The subject with a rodent guard

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UW Extension Soil Conservation, UW-Madison
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Research Coordinator, UW Extension Service
Joe Papp
DNR Staff, DNR

Tile Drainage in Wisconsin: Managing Tile-Drained Landscapes to Prevent Nutrient Loss

FACT SHEET NO. 3 UWEX

Subsurface drainage of agricultural land has the ability to improve yields and reduce surface runoff and erosion losses. However, with a reduction in surface runoff, more water infiltrates the soil and percolates through the soil profile. This is of particular importance to farmers, as this water can also transport essential plant nutrients, specifically nitrogen and phosphorus, out of the root zone. Once nutrients reach the tile drain, they have a direct conduit to surface waters.

Tile-drained agricultural land must be well-managed to reduce the loss of nutrients to surface waters. Nutrient management practices must be carefully followed to minimize the risk of nutrient loss and to maximize fertilizer use efficiency. Additional considerations need to be taken with manure applications on tile-drained land to both minimize nutrient loss and prevent manure entry into tile drains.

The purpose of this publication is to:

- ✓ provide information on nutrient management concerns in tile-drained agricultural landscapes, and
- ✓ present management and treatment practices to reduce the loss of nutrients from tile systems to surface water.

"Proper management of crop nutrients on tile-drained landscapes is the key to reducing nutrient loss and maximizing nitrogen use efficiency."



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UW-Madison

Drainage Resources

www.extension.umn.edu/agriculture/water/



The screenshot shows the University of Minnesota Extension website's 'Agricultural Drainage' page. The header features the University of Minnesota Extension logo and a search bar. The navigation menu includes Agriculture, Community, Environment, Family, Food, Garden, Youth, and About. The main content area is titled 'Agricultural Drainage' and includes a large image of a green field with a drainage ditch. Below the image, text describes the University of Minnesota Extension agricultural drainage team's mission. A list of links includes 'About the Agricultural Drainage program', 'Drainage program team', 'Extension publications', and 'Recent presentations'. A sidebar on the right lists various resources: 'Drainage calculators', 'Drainage industry', 'Drainage law', 'Economics', 'Gulf hypoxia', 'History', 'Science and drainage', 'Technical, planning, and design', 'Water quality and environment', and 'Reports'. Below the sidebar, there are two featured articles: '2015 Drainage Design Workshops' and 'Two-stage drainage ditches can be a win-win'. The bottom of the page includes a link to a CNN.com article about conservation drainage in Minnesota.

UNIVERSITY OF MINNESOTA | EXTENSION

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Agricultural Drainage

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- Technical, planning, and design
- Water quality and environment
- Reports

The University of Minnesota Extension agricultural drainage team brings University research to producers and industry professionals to improve water management practices.

- About the Agricultural Drainage program
- Drainage program team
- Extension publications
- Recent presentations

2015 Drainage Design Workshops

The Drainage Design Workshops are a collaborative between Minnesota, North Dakota, and South Dakota. This year's workshops will be Feb. 17 – 18 in Sioux Falls, SD, Feb. 24 – 25 in St. Cloud, MN, and March 10 – 11 in Grand Forks, ND. Find more information on the workshops here (293 K PDF). Attendees can register here. Anyone wishing to attend as a vendor in our trade show area can register here.

Two-stage drainage ditches can be a win-win

Reduce cropland nutrient losses and ditch repair costs by modifying traditional drainage ditches.

Conservation drainage in Minnesota: CNN.com article

Minnesota farmer battles Gulf 'dead zone'

See the UWEX drainage site for other web sites

Pipe Size and Grades

- ✓ Desirable minimum working grade is 0.2 %
- ✓ Typical minimum pipe size is 3" - 4" in humid regions and 5" - 6" for organic soils.
- ✓ Minimum grade sufficient to maintain 0.5 ft /sec (1.4 ft / sec with sand and silt in flow).

Pipe Size and Grades

- Design Boundary Conditions -

✓ Very high velocities can cause “sink holes” when soil is actually pulled into the tile line.

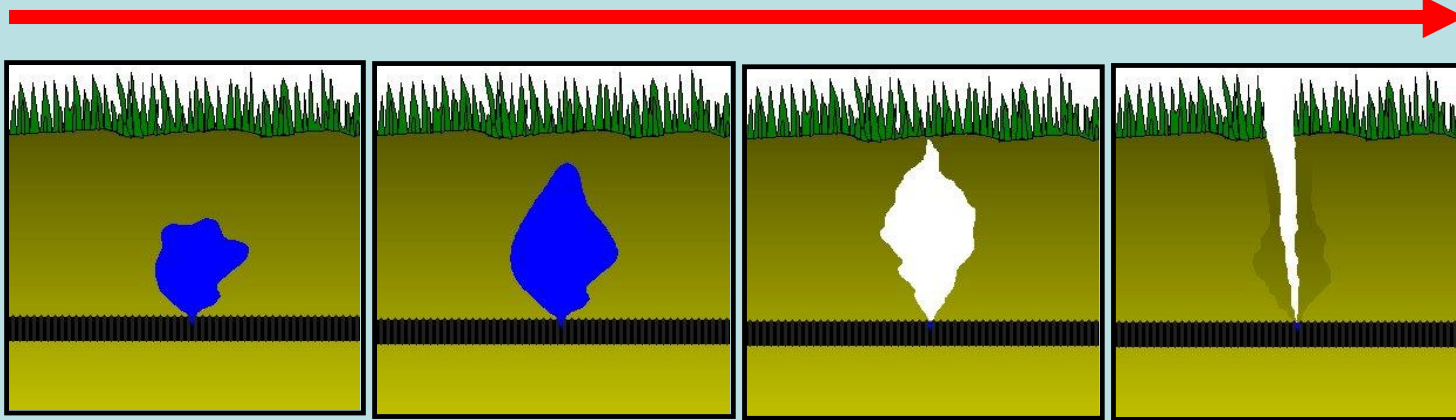
✓ “Blowouts” can occur when lines become pressurized.

Soil Texture	Max. Velocity ft/sec
Sand & sandy loam	3.5
Silt & silt Loam	5.0
Silty clay loam	6.0
Clay & Clay loam	7.0
Course sand or gravel	9.0

✓ Watch out for steep-to-flat grade changes and overloading mains Blowouts !

Tile Line Blowouts

Time



During storm event



After storm event

Sub-surface Water Management

- ✓ Reduces the total water export.
- ✓ Annual nitrate load reductions ~ 15 to 75%.
- ✓ There are still a number of unknowns about performance, research is on-going.
- ✓ Requires on-going management.

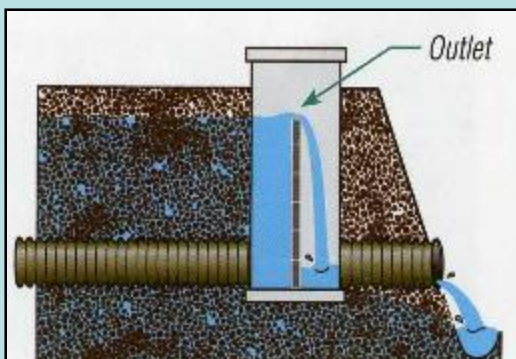


Figure 1. The outlet is raised after harvest to reduce nitrate delivery.

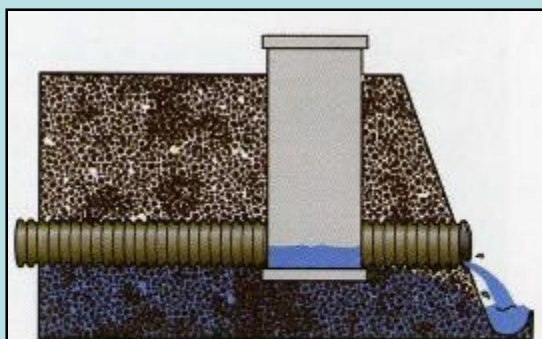


Figure 2. The outlet is lowered a few weeks before planting and harvest to allow the field to drain more fully.

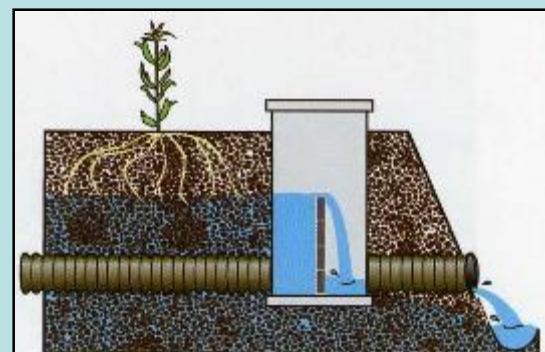


Figure 3. The outlet is raised after planting to potentially store water for crops.

Source: Drainage Water Management for the Midwest, Purdue Extension Service, <http://www.ces.purdue.edu/new>

Maintenance Issues

- Iron Ochre -

- ✓ Iron ochre is a red, yellow or tan gelatinous material adhering to drain wall openings or forms outside of buried tiles

- ✓ Ochre is a filamentous bacterial slime composed of organic masses and iron oxides.



Maintenance Issues

- Iron Ochre -

- ✓ Iron ochre formation is most common in sandy and organic muck soils (Ford and Harmon, 1993) or alternating wet and dry soils, such as those under irrigation.
- ✓ Bacterial growth supported by soluble (ferrous) iron in groundwater.
- ✓ On-going maintenance is the only economical option for controlling iron ochre formation.



Drainage System Cost

- Approximate ! -

Drainage system installation costs can vary ***significantly*** based on terrain, soils, outlet availability, etc.

Rough Range

~ \$1,000 - 1,500 / ac

QUESTIONS ? ? ?

