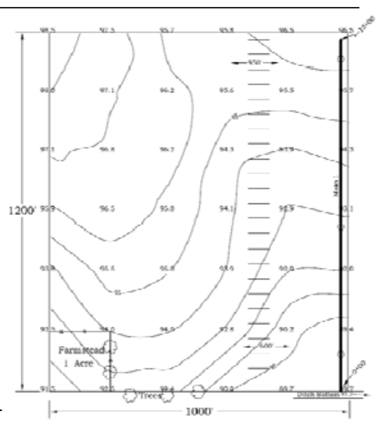
Surveys and Maps for Drainage Design

SURVEY TYPES

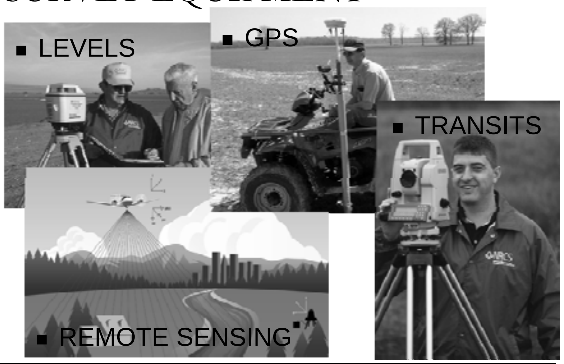
- <u>BENCH LEVEL</u> Survey
  Used to determine the elevation of a <u>point</u> (1-D)
- <u>PROFILE</u> Survey
  Used to determine the elevations of a <u>line</u> (2-D)
- <u>TOPOGRAPHIC</u> Survey
  Used to determine the elevations of a <u>surface</u> (3-D)

What is a Contour Map?

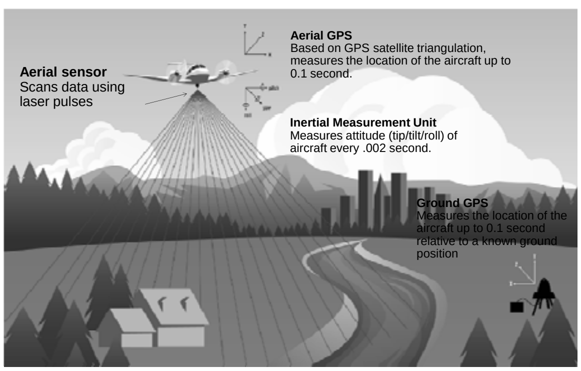
A contour line is a line that passes through a series of points having the same elevation.



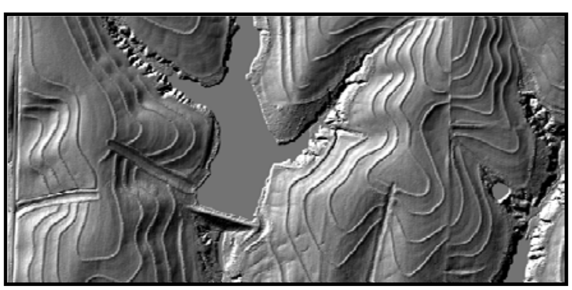
SURVEY EQUIPMENT



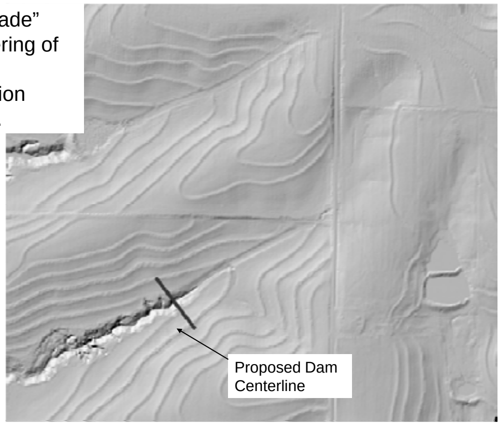
LiDAR: Light Detection and Ranging



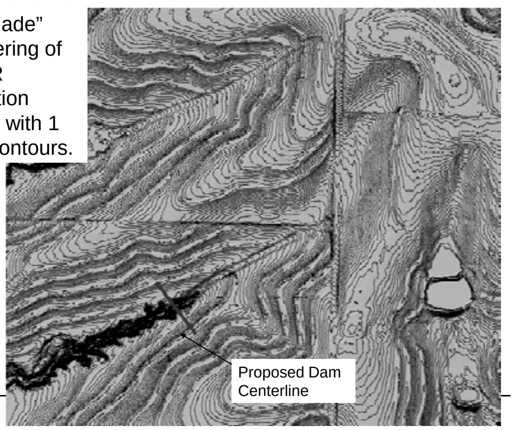
LiDAR Surface



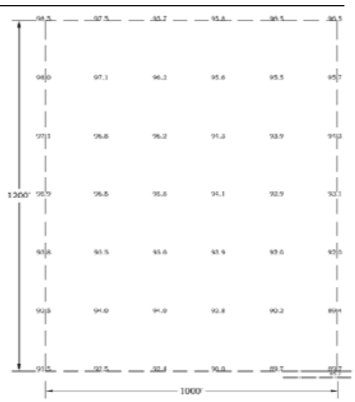
“Hillshade” Rendering of LiDAR Elevation Model.



“Hillshade” Rendering of LiDAR Elevation Model with 1 foot Contours.



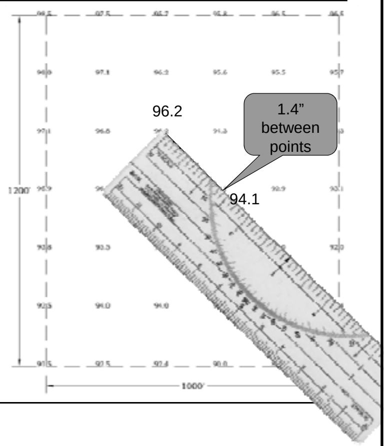
Making a Contour Map



The numbers in this map represent the elevations of survey points plotted to scale.

Making a Contour Map

Contours are made by interpolating between the survey points.

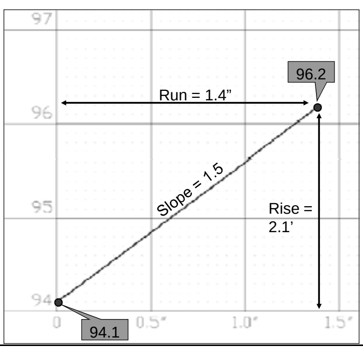


Making a Contour Map

Slope of line between the two survey points:

$$\text{Slope} = \frac{\text{Rise}}{\text{Run}}$$

$$\text{Slope} = \frac{96.2' - 94.1'}{1.4''} = 1.5$$



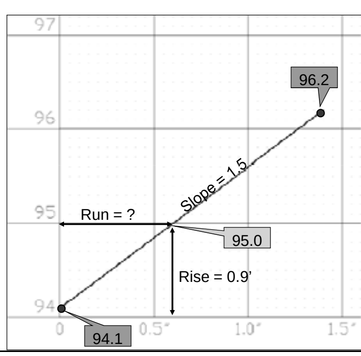
Making a Contour Map

With Slope and Rise known, we can solve for Run:

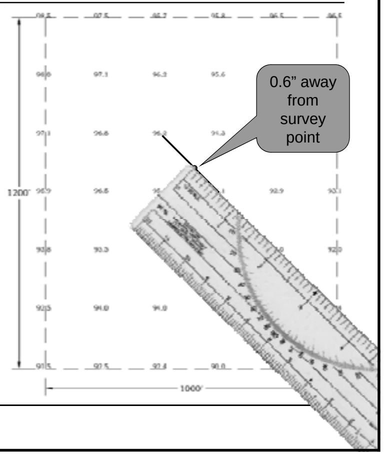
$$\text{Slope} = \frac{\text{Rise}}{\text{Run}}$$

$$\text{Run} = \frac{\text{Rise}}{\text{Slope}}$$

$$\text{Run} = \frac{95.0 - 94.1}{1.5} = 0.6''$$

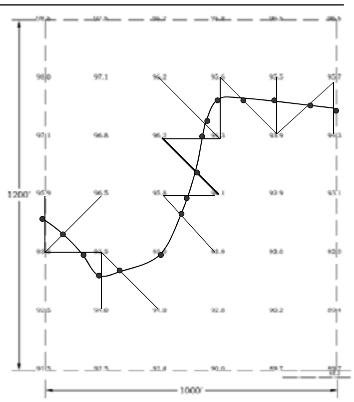


Making a Contour Map



Plot the point for Elevation 95.0 a distance of 0.6" from the survey point.

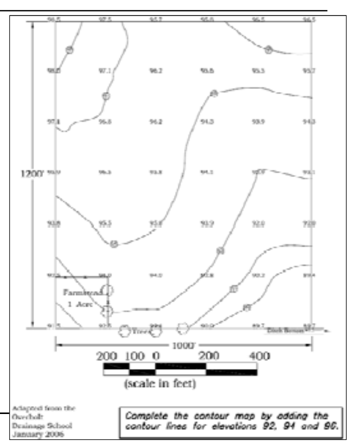
Making a Contour Map



Next, interpolate the rest of the Elevation 95.0 points.

Now, connect the points to make the 95.0 contour line.

Making a Contour Map

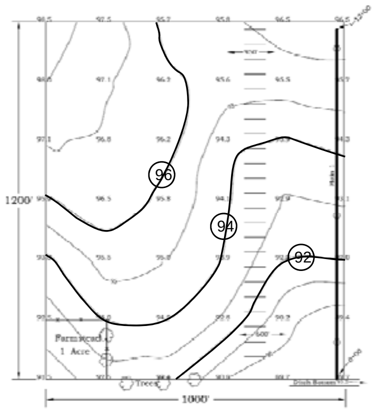


Now, it is your turn.

Start Problem #4

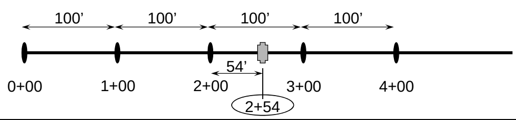
Complete the contour map by adding contour lines for elevations 92, 94 and 96.

Making a Contour Map



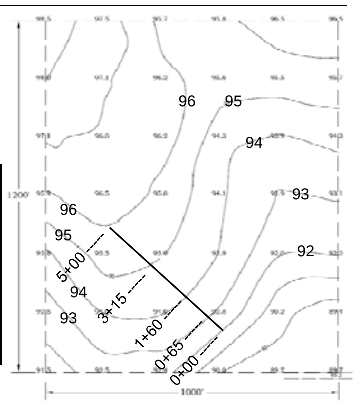
STATIONING A LINE

- Stationing (distance)
  - Points at multiples of 100 feet measured along a line: *0+00, 1+00, 2+00, 3+00, 4+00, . . .*
  - Example: A point that is 54 feet beyond Station 2+00 is identified as Station 2+54



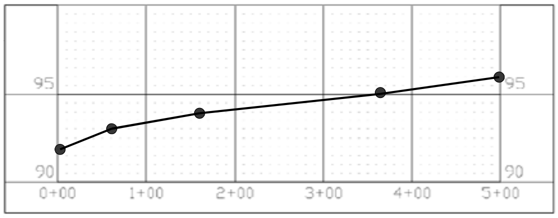
Profiling a Line from a Contour Map

Station	Elev.
0+00	92.0
0+65	93.0
1+60	94.0
3+65	95.0
5+00	96.0



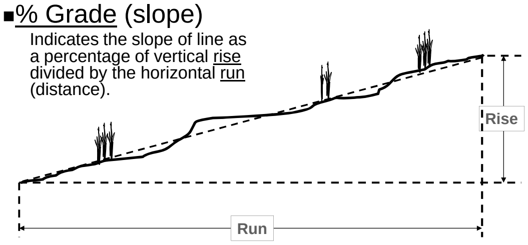
Profiling a Line from a Contour Map

Station	Elev.
0+00	92.0
0+65	93.0
1+60	94.0
3+65	95.0
5+00	96.0



PROFILES: % Grade

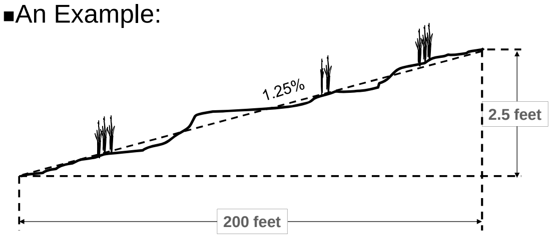
- % Grade (slope)
  Indicates the slope of line as a percentage of vertical rise divided by the horizontal run (distance).



$$\% \text{ Grade} = \frac{\text{Rise}}{\text{Run}} \times 100\%$$

PROFILES: % Grade

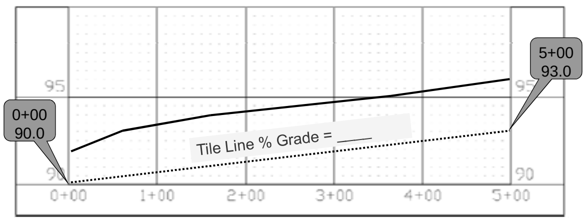
- An Example:



$$\% \text{ Grade} = \frac{2.5'}{200'} \times 100\% \quad = \quad 1.25\%$$

Computing % Grade

$$\text{Slope} = \frac{93.0' - 90.0'}{500'} \; x \; 100 = 0.6\%$$



NRCS Natural Resources Conservation Service

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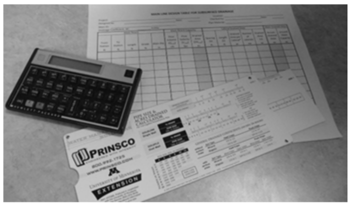
SUBSURFACE DRAIN DESIGN



Pipe Capacity

Marty Comstock, P.E.
Agricultural Engineer

Objectives

- At the end of this presentation you will be able to:
  - List the factors affecting pipe capacity
  - Determine the capacity of a drain pipe using a "slide rule" for a given Drainage Coefficient (DC)
  - Calculate the area drained with a given pipe

2

How many acres can a tile line drain?

That depends. . . .

- What is the diameter of the pipe?
- What kind of pipe is it?
- What slope is it installed on?
- How much water needs to be drained?
- How fast does the water need to be drained?

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Pipe Capacity - Hydraulics

$$Q = V \times A$$

- **Q** = Capacity or volume flow rate
  cubic feet per second (cfs)
- **V** = Velocity
  feet per second (fps)
- **A** = Cross-sectional area
  square feet (sf)

4

Pipe Velocity - Hydraulics

V = Velocity, feet per second (fps)

Manning's Equation:

$$V = 1.486 \div n \times r^{0.667} \times s^{0.5}$$

n = Pipe Roughness Coefficient
r = Pipe Hydraulic Radius (feet) = A ÷ P
A = Area, P = Wetted Perimeter
s = Pipe Slope (feet per feet)

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Roughness Coefficient

n = Roughness coefficient (unitless)

- A higher value indicates a rougher surface than a lower value
- Examples:

Corrugated Plastic Tubing (4"-8")	n = 0.015
Corrugated Plastic Tubing (10"-15")	n = 0.017
Smooth Wall (Plastic)	n = 0.010
Clay Tile	n = 0.013
Corrugated Metal Pipe	n = 0.025

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Corrugated Plastic Pipe
n = 0.017 (10" - 15")

Smooth Wall PE Pipe
n = 0.012

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Slope

S = Slope or hydraulic gradient (feet per feet)

S = Rise ÷ Run

- Example: 0.8 feet rise in 400 feet run
  - Slope = 0.8 ÷ 400 = 0.002 ft/ft or <u>0.20%</u>
- Example: 2.9 ft. rise in 825 ft. run
  - Slope = 2.9 ÷ 825 = 0.00352 ft/ft or <u>0.35%</u>

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Pipe Area - Hydraulics

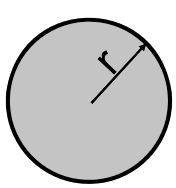
A = Cross-sectional area

Area of a Circle:

$A = \pi \times r^2$

π = Pi = 3.14

r = Radius



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Pipe Capacity - Hydraulics

Manning's Equation for a pipe:

$$Q = 0.000614 \div n \times d_i^{2.67} \times s^{0.5}$$

n = Roughness coefficient

d_i = Inside pipe diameter (inches)

s = Slope (feet per feet)

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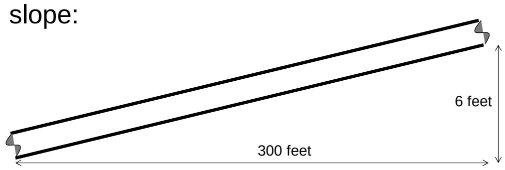
Slope, s

Given 6 inch diameter corrugated plastic tile with 6 feet of fall in 300 feet of length, find the slope:



Slope = rise÷run = 6 ft ÷ 300 ft = 0.02 ft/ft = 2%

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Capacity, Q

Given 6 inch diameter corrugated plastic tile with a 2% slope; calculate the capacity when the pipe is flowing full:

$$Q = 0.000614 \div n \times d_i^{2.67} \times s^{0.5}$$

$$Q = 0.000614 \div .015 \times 6^{2.67} \times 0.02^{0.5}$$

$Q = \underline{0.7}$ cubic feet per second (cfs)

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Velocity, V

Given 6 inch diameter corrugated plastic tile with a 2% slope; calculate the velocity when the pipe is flowing full:

$$Q = V \times A$$

$$V = Q \div A$$

$$A = \pi \times r^2 = 3.14 \times (3/12)^2 = 0.20 \text{ sf}$$

$$V = 0.7 \text{ cfs} \div 0.20 \text{ sf} = \underline{3.5 \text{ fps}}$$

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Maximum Velocity by Soil Texture

- Velocities in excess of the allowable may induce erosion of soil material into the tile line.

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Maximum Velocity by Soil Texture

Soil Texture	Velocity ft/s
Sand and Sandy loam	3.5
Silt and silt loam	5.0
Silt clay loam	6.0
Clay and clay loam	7.0
Coarse sand or gravel	9.0

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Min. Velocity and Grade

- If sedimentation is not a problem – Min. velocity is 0.5 ft/sec.
- If sedimentation is a hazard – Min. velocity is 1.4 ft/sec.

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How to determine capacity

- Hand Calculations
- Slide Rules
- Computer spreadsheet
- Computer programs

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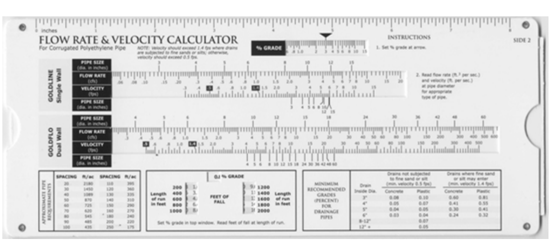
Industry Slide Rules



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Computer Spreadsheet

Available on MLICA website:

http://www.mlica.org/2013_drainage_workshop.htm

Available from other sources – industry, etc.

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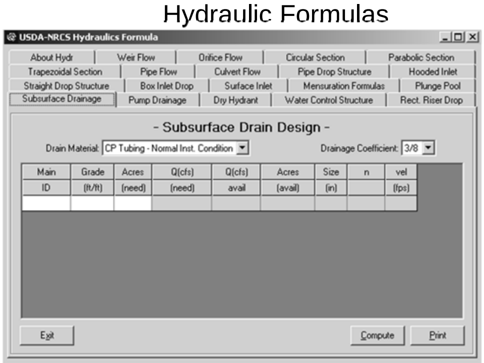
NRCS Engineering Program
Hydraulic Formulas



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Review of Factors Affecting Capacity

We need the following data to calculate pipe flow rate with our tools:

- Size of pipe, diameter
- Roughness Coefficient, n, or type of pipe
- Slope, s

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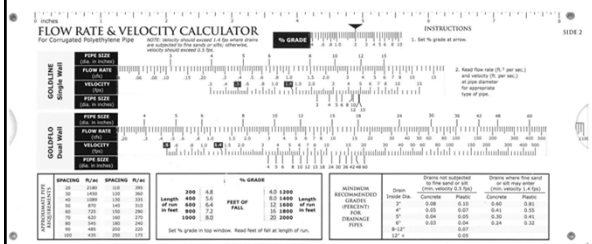
Using the Slide Rule



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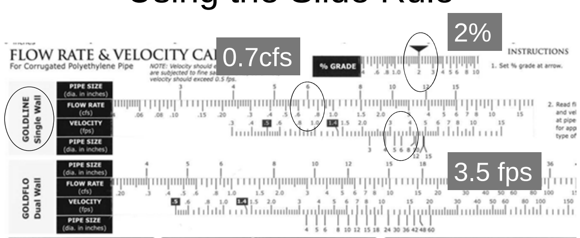
Using the Slide Rule



Given 6 inch diameter corrugated plastic tile with a 2% slope calculate the capacity when the pipe if flowing full:

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Examples – Pipe capacity

Using the slide rule, find Q and v

- Assume all pipes flowing full

- 6” CPT, 0.3% grade,
- 15” CPT, 0.15% grade;
- 24” dual wall, 0.05% grade;
- 4” CPT, 3% grade

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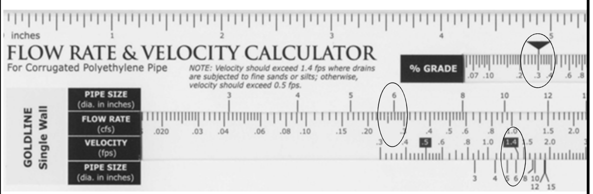
Examples – Pipe capacity

Using Slide Rule, find Q and v

- Assume all pipes flowing full

Example 1: 6" CPT, 0.3% grade

➢ From Slide Rule: Q = 0.265 cfs, V = 1.35 fps



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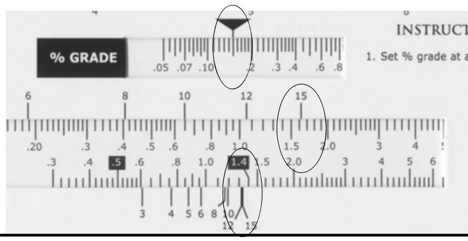
Examples – Pipe capacity

Using Slide Rule, find Q and v

- Assume all pipes flowing full

Example 2: 15" CPT, 0.15% grade

➢ From Slide Rule: Q = 1.61 cfs V = 1.35 fps



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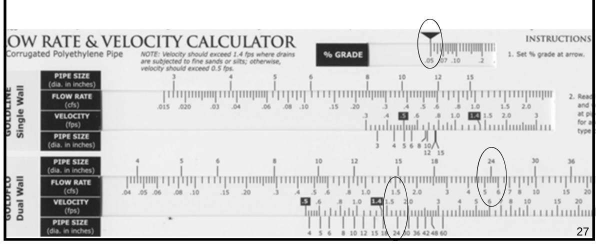
Examples – Pipe capacity

Using Slide Rule, find Q and v

- Assume all pipes flowing full

Example 3: 24" Dual Wall, 0.05% grade

➢ From Slide Rule: Q = 5.4 cfs V = 1.72 fps



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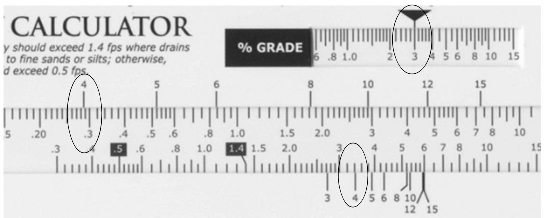
Examples – Pipe capacity

Using Slide Rule, find Q and v

- Assume all pipes flowing full

Example 4: 4” CPT, 3% grade; normal installation

➢ From Slide Rule: Q = 0.285 cfs V = 3.4 fps



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How many acres can a tile line drain?

That depends. . . .

➢What is the diameter of the pipe?

➢What kind of pipe is it?

➢What slope is it installed on?

➢How much water needs to be drained?

➢How fast does the water need to be drained?

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Drainage Coefficient

➢ How much water?
- Depth of water over a given area (inches)

➢ How fast?
- 24 hours

This is the Drainage Coefficient (D.C.)

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Drainage Coefficient

Ref: *Missouri* NRCS Subsurface Drain Standard 606

SOIL	FIELD CROPS	TRUCK CROPS
Mineral	⅜” to ½”	½” to ¾”
Organic	½” to ¾”	¾” to 1½”

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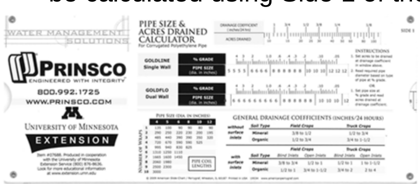
Sizing Tile for an Area

- Given
  - the drainage coefficient (DC),
  - the acres being drained, (DA) and
  - the slope of the tile (s),

  The size of tile needed to drain the area can be calculated using Side 1 of the slide rule.



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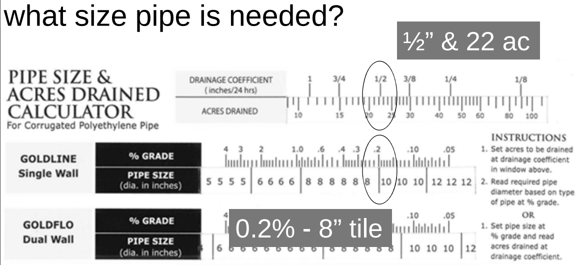
Sizing Tile for an Area

Given a DC of ½ inch/day, a DA of 22 acres and a tile grade of 0.2%;
what size pipe is needed?



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Examples

- DC = 0.375 (3/8) in/day, DA = 8 ac, Slope = 1%
  - Required tile size = ?
- DC = 0.375 (3/8) in/day, DA = 45 ac, Slope = 0.5%
  - Required tile size = ?
- DC = 0.5 (1/2) in/day, DA = 63 ac, Slope = 0.3%
  - Required tile size = ?

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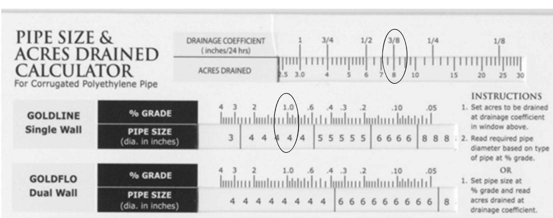
Example 1

- D.C.=0.375 (3/8) in/day, A = 8 ac, Slope = 1%
  - Required tile size = ?
- From Slide Rule: Tile Size = 4”



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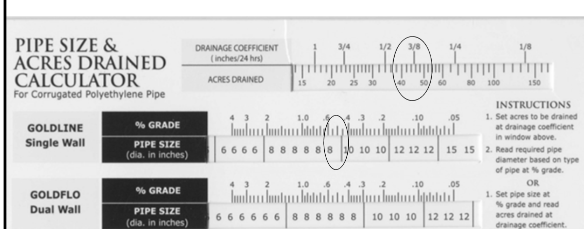
Example 2

- D.C.=0.375 (3/8) in., A = 45 ac, Slope = 0.5%
  - From Slide Rule, Tile Size = 8”



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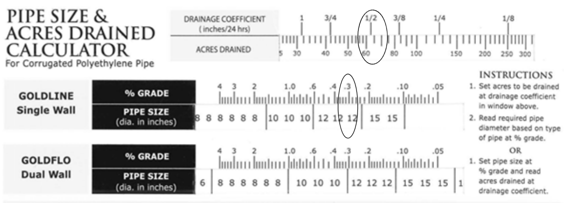
Example 3

- D.C.= 0.5 (1/2) in., A = 63 ac, Slope = 0.3%
  - From Slide Rule, Tile Size = 12”



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Review

- Factors affecting pipe capacity
- Use the slide rule to compute the capacity of various drain pipes
- Use the slide rule to calculated the area drained with a given pipe

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Any Questions?

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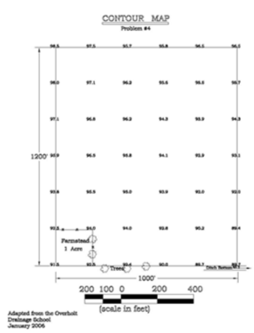
SUBSURFACE DRAIN DESIGN

QUIZ

Selecting pipe size

- Given:
  - DA = 82 Acres
  - 0.15% grade
  - DC = 3/8 in/day
  - CPT
- Determine:

1. Size of CPT (single wall) needed.
2. Flow capacity of pipe.
3. Flow velocity of pipe.



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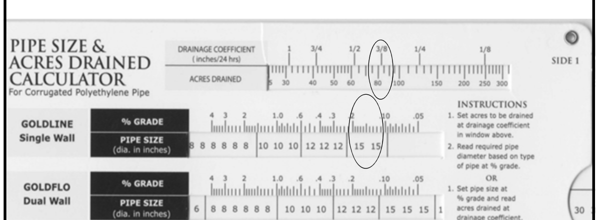
1. Size of CPT (single wall) needed?

- On Side 1, set the 3/8” D.C. to 82 acres
- Read the pipe size for a grade of 0.15%

- <u>Use 15” CPT</u>



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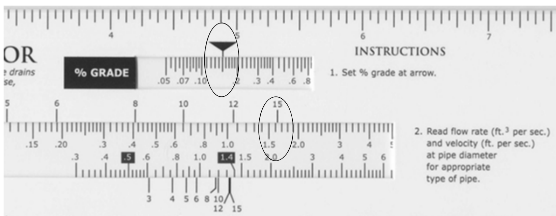
2. What capacity will the 15” CPT carry?

- On side 2, set the grade at 0.15%
- Read the flow rate for 15” CPT,
- <u>Q = 1.62 cfs</u>



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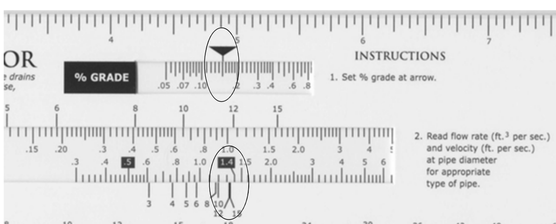
3. What is the velocity of the 15” CPT?

- On side 2, set the grade at 0.15%
- Read the flow rate for 15” CPT,
- <u>V = 1.35 fps</u>



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Selecting pipe size

- Extra Credit:

  What grade is required to achieve the necessary flow rate (1.62 cfs) with a 12” CPT?

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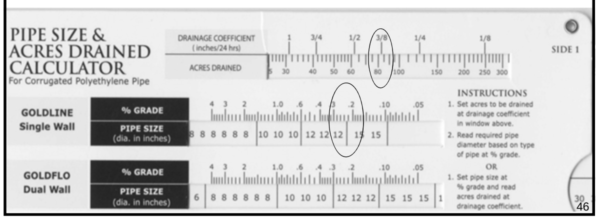
What grade is required for a 12" CPT?

- On Side 1, set the 3/8" D.C. to 82 acres
- Read the grade for the division line between 12" and 15" CPT.
- <u>0.23 % is the minimum grade for a 12" CPT</u>



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Class Problem 1

- Now that you are experienced,
- Work Problem 1

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Class Problems 2 & 3

- Work Problems 2 & 3

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United States Department of Agriculture

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LATERAL LINE DESIGN

NRCS

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Objectives

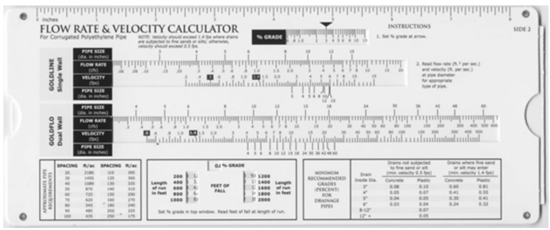
- At the end of this presentation you will be able to:
  - Determine the amount of area that can be drained by a lateral.
  - Determine the maximum lateral length for a given spacing and DC.

Lateral Capacity - Hydraulics

Same hydraulics principals used for designing the Main.

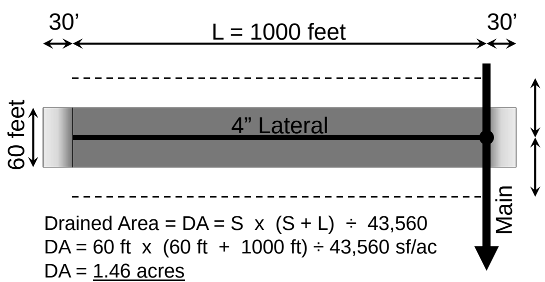
Slope, diameter & pipe roughness

Slide Rule



Example – Lateral capacity

How much area can be drained by a single 4” diameter CTP lateral 1000 feet long spaced 60 feet apart?



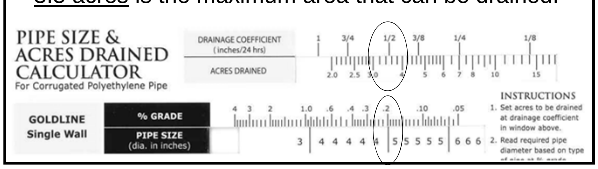
Drained Area = DA = S x (S + L) ÷ 43,560
DA = 60 ft x (60 ft + 1000 ft) ÷ 43,560 sf/ac
DA = 1.46 acres

Example – Lateral capacity

If the grade of the lateral is 0.2 % and the DC is ½”/day, what is the maximum area that a 4” CPT lateral can drain?

Using Side 2 of the slide rule:

- Set the division line between the 4” and 5” tile size on the 0.2% Grade mark.
- Read the Acres Drained for a DC of ½”/day
- 3.5 acres is the maximum area that can be drained.

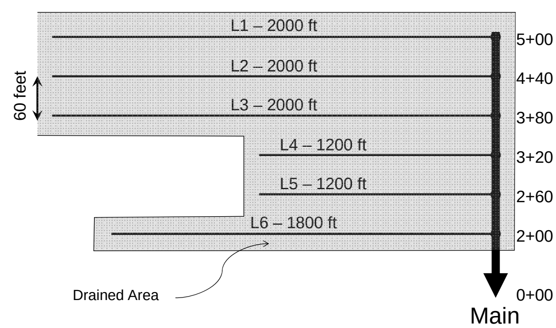


Lateral Capacity Chart

MAXIUM LATERAL LENGTH USING 4" DIAMETER CORRAGATED PLASTIC TILE

% Grade (4" CPT)	DC ("/day)	AREA (acre)	LATERAL SPACING (feet) 20	30	40	50	60	70	80	90	100	% Grade (4" CPT)
0.05	3/8	2.35	5,110	3,410	2,550	2,040	1,700	1,460	1,270	1,130	1,020	0.05
	1/2	1.75	3,810	2,540	1,900	1,520	1,270	1,080	950	840	760	
0.1	3/8	3.35	7,290	4,860	3,640	2,910	2,430	2,080	1,820	1,620	1,450	0.1
	1/2	2.50	5,440	3,630	2,720	2,170	1,810	1,550	1,360	1,210	1,080	
0.2	3/8	4.75	10,340	6,890	5,170	4,130	3,440	2,950	2,580	2,290	2,060	0.2
	1/2	3.55	7,730	5,150	3,860	3,090	2,570	2,200	1,930	1,710	1,540	
0.3	3/8	5.80	12,630	8,420	6,310	5,050	4,210	3,600	3,150	2,800	2,520	0.3
	1/2	4.35	9,470	6,310	4,730	3,780	3,150	2,700	2,360	2,100	1,890	
0.4	3/8	6.65	14,480	9,650	7,240	5,790	4,820	4,130	3,620	3,210	2,890	0.4
	1/2	5.00	10,890	7,260	5,440	4,350	3,630	3,110	2,720	2,420	2,170	
0.5	3/8	7.50	16,330	10,890	8,160	6,530	5,440	4,660	4,080	3,630	3,260	0.5
	1/2	5.60	12,190	8,130	6,090	4,870	4,060	3,480	3,040	2,710	2,430	
0.6	3/8	8.10	17,640	11,760	8,820	7,050	5,880	5,040	4,410	3,920	3,520	0.6
	1/2	6.10	13,280	8,850	6,640	5,310	4,420	3,790	3,320	2,950	2,650	

Groups of Laterals



DESIGN TABLE FOR SUBSURFACE DRAINAGE

Project: Example   Location:

Designed by: Date: Checked by: Date:

Drainage Coefficient, DC: 0.5 in/day   Lateral Diameter: 4 inch   ver 1/10/2013

Lateral Design									
Main Connect Station ft	Lateral ID or Group ID ID	Number of Laterals in Group ea	Grade %	Spacing (S) ft	Lateral Length (L) ft	Drained Length (S+L) ft	Drained Area per Lateral* ac	Drained Area per Group ac	Accum. Drained Area ac
5+00	L1	1		60	2,000	2,060	2.84	2.84	2.84
4+40	L2	1		60	2,000	2,060	2.84	2.84	5.67
3+80	L3	1		60	2,000	2,060	2.84	2.84	8.51
3+20	L4	1		60	1,200	1,260	1.74	1.74	10.25
2+60	L5	1		60	1,200	1,260	1.74	1.74	11.98
2+00	L6	1		60	1,800	1,860	2.56	2.56	14.55

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3+80	L1-L3	3		60	2,000	2,060	2.84	8.51	8.51
2+60	L4-L5	2		60	1,200	1,260	1.74	3.47	11.98
2+00	L6	1		60	1,800	1,860	2.56	2.56	14.55

Groups of Laterals

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3+80	L1-L3	3		60	2,000	2,060	2.84	8.51	8.51
2+60	L4-L5	2		60	1,200	1,260	1.74	3.47	11.98
2+00	L6	1		60	1,800	1,860	2.56	2.56	14.55

Main ID: Example Pipe Material: CPT-Single Wall

Main Design									
Main Reach					Main Reach Capacity			Drained Area	
From Station ft	To Station ft	Length ft	Grade %	Main Dia. in	Maximum Flow Volume (Q_{max}) cfs	Maximum Flow Velocity (V_{max}) fps	Maximum Drained Area (DA_{max}) ac	Lateral Accum. Drained Area ac	Unused Main Capacity ac
5+00	3+80	120	0.50	5	0.21	1.55	10.1	8.51	1.55
3+80	0+00	380	0.50	6	0.34	1.75	16.4	14.55	1.81

NRCS Natural Resources Conservation Service

United States Department of Agriculture

Gravity Outlets in Drainage Systems

Roger C. Moe and Carroll J. W. Drablos

All drainage systems require outlets that have adequate capacity, depth, and stability to meet design requirements. If the outlet is inadequate, the value of the entire drainage system can be greatly reduced.

Adequacy of Outlets

An outlet channel must be able to carry flow from the particular drainage system being designed as well as from the entire drainage area. When the outlet carries flow from subsurface drains, it should be deep enough that subsurface drains can be discharged into it above normal low water flow.

Installing new channels or improving existing ones usually increases peak discharges downstream from the end of the point that has been improved. Be careful to prevent increased stages downstream from creating significant damage. The channel must be stable when there is flow at design capacity. If your drainage area exceeds 1 square mile, consult USDA Soil Conservation Service (SCS) Technical Release No. 25, "Design of Open Channels." This publication describes how to evaluate channel stability.

Required Capacities

The criteria for drainage design are based on the fact that crops can tolerate a limited amount of flooding but must not be flooded for long periods, usually no longer than 24 to 48 hours. The term "drainage coefficient" denotes the depth in inches of water that a drainage system can remove from its entire watershed in 24 hours. The drainage coefficient may range from 3/8 inch for normal subsurface drainage to more than 2 inches for surface drainage of truck crops grown on muck soils. For more details on designing outlets to protect land from overflow and on various levels of drainage for agricultural crops, consult "Drainage of Agricultural Land" (Section 16 of the SCS *National Engineering Handbook*) and the *Engineering Field Manual*.

Hydraulic Design and Construction

After determining the required channel capacities, you should design a channel that is large enough to convey the desired flow without exceeding a predetermined water-surface elevation and to permit velocities that are neither erosive nor so slow as to cause large amounts of sediment to be deposited. The following sections describe some basic hydraulic concepts necessary to accomplish these purposes.

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Water-Surface Elevation—Hydraulic Gradient

The hydraulic gradient represents the surface of the water when the ditch is operating at the design flow. The design of the hydraulic gradient for drainage ditches should be determined from control points. These should include significant low areas served by the ditch, any tributary ditches, and the outlet. The hydraulic gradient is drawn through or below as many control points as possible based on their importance. It should be based on a careful study of the profile of the natural ground surface, critical elevations established by surveys, and channel obstructions such as culverts and bridges.

If control point elevations are estimated rather than computed from survey data, the hydraulic gradeline should be no less than:

1. 1.0 foot below fields that will receive normal drainage from ditches draining more than 1 square mile
2. 0.5 foot for ditches draining 40 to 640 acres
3. 0.3 foot for ditches draining less than 40 acres

For lands to be used only for such water-tolerant crops as trees and grasses, these requirements may be modified, and the hydraulic gradeline may be set at ground level. These guidelines do not apply to channels where the flow is contained by dikes.

Permissible Velocities

Velocities must be high enough to prevent siltation but low enough to avoid erosion. Table 1 lists the maximum allowable velocities for small drainage areas of 1 square mile or less. Avoid velocities less than 1.5 feet per second. Low velocities cause siltation and increase the potential for growth of mosses and weeds, which can reduce channel cross section.

Table 1. Maximum Allowable Velocities for Given Soil Textures

Soil texture	Velocity (feet per second)
Sand or sandy loam	2.5
Silt loam	3.0
Sandy clay loam	3.5
Clay loam	4.0
Stiff clay	5.0
Fine gravel, cobbles, or graded loam to cobbles	5.0
Graded mixture silt to cobbles	5.5
Coarse gravel, shales, hardpans	6.0

Roughness Coefficient

The coefficient "n" must take into account not just roughness, but vegetation, meanders, obstructions, and anything else that may affect channel flow. For the designs within the scope of this paper, a value of n = 0.04 is commonly used for aged condition, and many design tables are based on this value. However, you should also base the value on retarding influences that will exist after the channel has aged and try to take into account the amount of maintenance you expect to be done. The Soil Conservation Service's *National Engineering Handbook*, Section 5, "Hydraulics," (Supplement B) provides a detailed procedure for estimating "n" values. Generally, "n" tends to decrease as the hydraulic radius increases. Table 2 provides recommended values for "n" based on the hydraulic radius of the channel. These values can be used in solving the Manning Formula for mains and laterals with good alignment.

Table 2. Value of Roughness Coefficient

Hydraulic radius	"n"
less than 2.5	0.040 to 0.045
2.5 to 4.0	0.035 to 0.040
4.1 to 5.0	0.030 to 0.035
more than 5.0	0.025 to 0.030

Channel Depth

Open ditches that serve as outlets for closed drains should be designed so that the normal water surface is at or below the invert of the outlet end of the closed drain. The clearance between a subsurface drain invert and the ditch bottom should be at least 1 foot for ditches that fill with sediment at a normal rate. Lower values can be used where there are unusual site conditions. The normal water surface is defined as the elevation of the usual low flow during the growing season.

Cross Section

In the design of the outlet the cross section should be set below the hydraulic grade line. It should meet the combined requirements of capacity, limiting velocity, depth, side slopes, and bottom width, and if necessary it should allow for initial sedimentation. The side slopes should be stable, meet maintenance requirements, and be designed according to site conditions. They should be no steeper than 2:1 for silt, 1 1/2:2 for clay and other heavy soils, and 1:1 for sands, peat, and muck.

Construction equipment and maintenance requirements determine the bottom width, which should be established to fit site conditions. If you will have to cross ditches in performing farming operations, you will want to keep this in mind when deciding the proper bottom width and side slopes.

Location

Where possible locate outlet channels near or parallel to field boundaries or property lines so as not to interfere with cropping patterns. However, it will often be desirable to follow natural drainage courses to minimize excavation.

Channel Alignment

We recommend that you lay out open channels in straight lines and gentle curves. Table 3 shows recommended minimum radii of curvature without bank protection. Bank protection should be provided if changes in alignment sharper than those listed are necessary.

Table 3. Minimum Radii of Curvature Without Bank Protection

Width of ditch top (feet)	Fall (feet per mile)	Minimum radius of curvature (feet)	Approximate degree of curve
Small ditches	Under 3	300	19
(less than 15)	3 to 6	400	14
Medium size ditches	Under 3	500	11
(15 to 35)	3 to 6	600	10
Large ditches	Under 3	600	10
(greater than 35)	3 to 6	800	7

Berms and Spoil Banks

Excavated soil may either be deposited in adjacent low areas or placed in spoil banks along the channel. If you put the soil in spoil banks, you must leave a berm or flat area adjacent to the channel bank to allow for roadways and maintenance equipment. Berms will also prevent excavated material from rolling back into the channel and will lessen sloughing of banks by reducing heavy loads. Berms should be at least 10 feet wide; they should be 15 feet wide along channels over 8 feet deep (Figure 1). Spoil banks should have stable side slopes, and provision must be made so that water is channeled through the spoil and into the ditch without causing serious erosion.

In cropland areas it is often desirable to spread the spoil. Spreading may begin at or near the channel bank, or a berm may be left as described above. If spreading begins at the channel bank, it should be carried upward at a slope not steeper than 3 feet horizontal to 1 foot vertical to a depth not exceeding 3 feet. From the point of maximum depth, the spoil should be graded to slope away from the channel at a slope not steeper than 4 to 1 and preferably 8 to 1 if the spoil is to be farmed (Figure 2).

Structural Protection

Ideally, surface water should enter the channel only through lateral ditches graded to the bottom of the channel or over or through stabilizing structures such as chutes, drop spillways, or conduits with proper inlets. These structures may be located at the entrances of lateral channels, at the heads of ditches, or along the channel at selected intervals to serve as outlets for individual drainage systems.

Maintenance

Proper maintenance of a drainage system prolongs its life and reduces operating costs. Maintenance must be taken into account in any drainage system design. As part of your maintenance program you should control vegetation by mowing, pasturing, or chemicals, remove sediment bars as they form, remove sediment that has accumulated over several years, repair structures, and do any other work that is necessary to maintain the original effectiveness of the system.

Seeding ditch banks to form a permanent cover will in many cases prolong the life of many ditches by helping to stabilize the banks and reduce infestation by weeds. Brush and weeds reduce the velocity of water flowing through the ditch and thereby reduce its drainage capacity. Short-stemmed grasses are preferred since they provide a smooth surface for water. The grass may need mowing occasionally. Brush and weeds should be controlled by chemical sprays. Chemicals should be used with care.

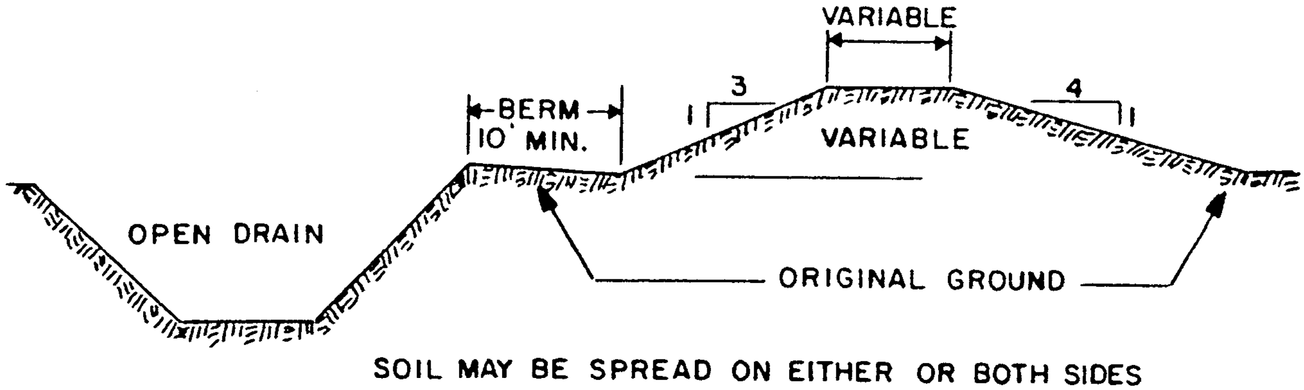

Figure 1. Open ditch spoil bank spreading (with berm).

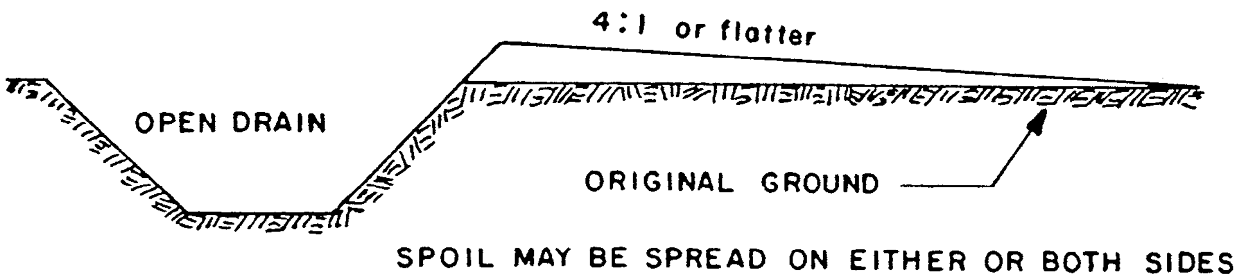

Figure 2. Open ditch spoil bank spreading (no berm).

Aquatic weeds should be kept out of the ditch bottoms because they delay drainage by reducing the rate of flow and causing sediment to deposit. Whether you can use herbicides to control weeds depends on what the water is used for downstream. Where herbicides cannot be used, burning the bottom of a dry ditch and raking up the refuse will provide some control.

We strongly recommend that you inspect your drainage system annually and develop a systematic maintenance program. Here are some of the major considerations in working out a plan for maintenance:

Past history of maintenance. Try to gather information on past maintenance efforts in your area if there have been any. Use maintenance methods that have been successful in the past as guides in developing your own maintenance plans.

Economics of maintenance. A maintenance program must be effective to be economical. If ditches are overgrown with brush and small trees, they may have only one-half to two-thirds of the designed capacity. Land that is poorly drained produces poor crops. Further, poor drainage can keep you from reaching the cost/benefit ratio you calculate to justify your drainage system. Maintenance must be carried out effectively for the drainage system to operate as planned.

Mowing. At most locations in humid areas mowing effectively controls brush and encourages grass on ditchbanks, travelways, and spoil disposal areas. Rotary mowers mounted on booms extending from tractors can safely handle 1 1/2:1 side slopes. Highway-type mowers on which the blade can be raised or dropped by 45 degrees are generally well adapted to ditch maintenance work. For mowing with standard farm equipment, a 4:1 or flatter side slope is preferable.

Pasturing. Controlled pasturing is one of the most economical and effective methods of maintaining ditches. In some locations pasturing is not practical because of the type of farming that is done on land adjoining the ditches. Pasturing should be controlled to keep cattle off ditchbanks during freezing and thawing, and wet weather. Hogs should be kept out of ditches. A good pasture arrangement usually includes carefully placed gates and fences with water gates across ditches.

Burning undesirable vegetation. In some locations controlled burning in the winter is a good way to remove dead weeds, tall grass, and small brush. This type of maintenance should be limited to channels through open areas and must comply with local antipollution regulations.

Chemical control of vegetation. Chemicals have controlled undesirable vegetative growth very effectively. In applying chemicals, be careful to keep them from drifting and causing damage. Information on the appropriate chemicals can usually be obtained from local dealers. The major chemical companies supply information on the use of specific products. Be sure you have the most up-to-date information available, including information on new herbicides, and follow carefully federal, state, and local laws and regulations governing the use of chemicals. Keep aquatic weeds out of ditch bottoms because they delay drainage by reducing flow rates and causing sediment deposits. These weeds can be controlled by herbicides, but whether you can apply herbicides depends on the downstream uses of the water and your legal liability. Be sure to investigate the legal aspects of the situation before using herbicides. Remove sediment deposits and accumulations of debris from outlet ditches to maintain their design capacity.

Farming adjacent to open ditches. When landowners perform their farming operations too close to the ditch bank, they increase the chances that soil will be deposited in the channel. Further, the heavy equipment operating adjacent to the ditch can cause sloughing of the side slopes.

Erosion control structures. Make an inventory of all structures associated with the open ditch. Inspect each structure annually and make repairs immediately where needed. Be sure to check (1) obstructions and/or washes in and around each structure, (2) water movement (leakage) in and around outlet tile and drop structures, (3) evidence of deterioration of structures, (4) submerging of tile outlets.

Culverts and Bridges

In designing culverts and bridges, determine carefully the weight of the field and highway vehicles that will use them. These structures should be designed to facilitate ditch maintenance around the abutments, and the openings must be large enough so as not to reduce ditch flow capacity. Where bridges are not feasible, fords with suitable ramp slopes should be constructed for machinery and livestock. See Section 16, "Drainage of Agricultural Land," in the SCS *National Engineering Handbook* for details on the design and installation of culverts and bridges for open ditches.