USDA Natural Resources Conservation Service
National Employee Development Center

Module 108

Drainage Hydrology

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Engineering
Hydrology Training Series

Module 108—Drainage Hydrology

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Natural Resources Conservation Service
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Preface

This module consists of a study guide which contains in-depth discussions about drainage hydrology, drainage removal, and peak discharge using appropriate hydrology procedures.

Proceed through this module at your own pace. Be sure you completely understand each section before moving on. If you have questions or need help, please request assistance from your supervisor. If your supervisor cannot clear up your problems, he/she will contact the state-appointed resource person. The resource person is familiar with the material and should be able to answer any questions you may have.

Be sure to write out your answers to the included activities. This will help to reinforce your learning. After completing each activity, compare your answers with the included solution.

Acknowledgment

The design and development of this training module is the result of a concerted effort by practicing engineers in the Natural Resources Conservation Service. The contributions from many technical and procedural reviews have helped make this module one that will provide needed hydrology and hydraulic skills to NRCS employees.

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Module Description

Overview

This module presents the method for determining drainage coefficients and their associated use in computation of drainage removal rate capacities. Alternate methods for determining instantaneous peak discharges are presented.

Objectives

Upon completion of this module, the participant will be able to:

- Describe the background needed to understand drainage hydrology.
- Compute design drainage removal and peak discharge rates using appropriate hydrology procedures.
- Perform at ASK Level 3 (perform with Supervision).

Prerequisites

Modules 102—Precipitation; 103—Runoff Concepts; 104—Runoff Curve Number Computations; 105—Runoff Computations; 151—EFM-2 Microcomputer Program; or their equivalent.

References

Chapters 2, 14. *Engineering Field Manual.*

Section l6, Drainage, *National Engineering Handbook of Conservation Practices*, Surface Drainage, Field Ditch (607) and Main or Lateral (608).

Stephens, John C., and Mills, M.C. (1965). *Using the Cypress Creek Formulas to Establish Run-off Rates in the Southern Coastal Plains and Adjacent Flatwoods Land Resource Area.* U.S. Department of Agriculture, ARS-41-95.

Duration

Participant should take as long as necessary to complete this module. Training time for this module is approximately two hours.

Eligibility

This module is intended for all NRCS personnel who calculate or analyze drainage capacities.

Method of Completion

This module is self-study, but the state or NTC should select a resource person to answer any questions that the participant's supervisor cannot handle.

Module 108—Drainage Hydrology

Introduction

Drainage is the removal and disposal of excess water. Two separate principles are involved in drainage work. These are surface and subsurface drainage. Surface drainage will be covered in this module. The module is applicable to field office operations. The applicable practice standards are from National Handbook of Conservation Practices (NHCP) 607 (Surface Drainage, Field Ditch) and 608 (Surface Drainage, Main or Lateral).

Participants completing this module will be able to follow appropriate procedures to determine and analyze design discharge capacity for drainage systems; to compute drainage removal discharge rates and determine instantaneous peak rates in flatlands. An understanding of design hydrology is needed for all applications where drainage capacity is to be computed or analyzed. The module is oriented toward the computation and analysis of hydrology needs for evaluation or design of drainage improvements. Determination of capacity is one of several technical skills necessary for the planning, design, and construction of drainage systems. Other needed skills include open channel hydraulics, layout (surveying), and construction inspection.

In the past, NRCS has been active in providing assistance for drainage. Concerns over loss of remaining wetlands, water quality issues and environmental quality has increased the need for technical proficiency for drainage activities. Future needs for hydrologic analysis for environmental concerns associated with drainage systems may exceed needs for capacity determinations for damage reductions.

Background

Principles of agricultural drainage—general

The purpose of surface drainage on agricultural land is to:

- Prevent water from ponding on land or in drains crossed by farm equipment.
- Prevent damages to crops by removing excess water in a timely manner.
- Prevent excess erosion in surface drains.

Drainage generally implies improvements associated with land lacking sufficient slope to cause water to flow to an outlet. This condition is found in irregular surfaces of glaciated land, above constrictions of alluvial floodplains, or above dams.

Drainage is also used in combination with irrigation systems to recover or remove excess water. In arid climates, salinity control must be considered in drainage operations. Another concept in surface drainage design is to provide an outlet for subsurface drainage systems.

Although agricultural drainage is a practice that has become restricted by policy and law, removal of excess water is still required. Excess water is generally a result of excess precipitation. Surface drains are needed to provide the capacity to remove excess ponding or flooding without excessive erosion so that agricultural crop production can be maintained or improved.

Visual evidence of inadequate drainage

Observations such as surface wetness, lack of vegetation, undesirable vegetation in agricultural operations, crop stands of irregular color or growth, variation in soil color, and salt deposits on the ground indicate inadequate drainages. Each of these items indicate a drainage problem. The amount of agricultural drainage needs vary considerably. Variations are dependent on climate, geology, topography, soils, crops and farming methods. Improvement needs should be determined for each particular site.

Factors Affecting Drainage

Site topography, geology, soils, or man-made obstructions may retard water movement and cause poor drainage. Another factor includes low capacity channels on the site or adjacent to the area.

Site factors may exist separately or in a combination of the following:

- Lack of a natural drainageway or other depression to serve as an outlet. These conditions are typically associated with the glaciated and Coastal Plains area where natural drainage systems are still in the process of development.

- Lack of sufficient land slope to let water flow to its outlet. Such sites are typical of glaciated land, above constrictions and natural barriers of valley flow plains, or above dams.

- Soil layers of low permeability that restrict downward movement of water trapped in surface depressions or in the soil profile. These layers may occur within the plant root zone. These are soils having a heavy subsoil, rock formation, or compact layer (hardpan).

- Man-made obstructions which obstruct or limit the flow of water. Examples include roads, dikes, bridges, culverts, fence rows, and dams.

- Outlet conditions which hold the water surface above ground. These conditions include high lake stages, pond stages, or tidewater elevations.

- Natural surface barriers which cause local concentrations of water.

- Subsurface drainage problems in irrigated areas due to deep percolation losses from irrigation and seepage losses from the supply system. Most soil in arid areas contain some salts in varying concentrations. High water table conditions caused by deep percolations from irrigation tend to concentrate salt accumulations in the root zone. Much of the subsurface drainage work in arid regions is for salinity control.

There is no danger of overdrainage of most soils with poor internal drainage. Close spacing of drains on soils in poor physical condition aids in the establishment and growth of vegetation needed for soil conditioning even though this intensity of drainage may not be needed on the same soil in good physical condition. The removal of free water in the soil eliminates moisture in excess of that held by capillary action. Drainage does not remove the capillary water used by growing plants. The depth of the drains controls the height of the water table. If the water table is too low in soils with a low capillary "pull", moisture may not move upward into the root zone. This is a desirable condition in irrigated saline, saline-alkali, and alkali soils.

There is a possibility of overdraining some extremely sandy soils and some peat and muck area. These soils have a particular depth of water table that is best for plant growth, which should be considered in designing the drainage system.

Benefits of agricultural drainage

Removal of free water promotes soil bacterial action essential for the manufacture of plant food by allowing air to enter the soil. The roots of plants, as well as soil bacteria, must have oxygen. Drainage accomplishes this by providing air space through the soil. Rainfall water passing downward through the soil carries out carbon dioxide and permits fresh air to be drawn in. Thus, drainage provides needed soil aeration.

Surface drainage removes ponded water quickly, thereby allowing the remaining gravitational water to move through the soil.

The removal of free water by drainage allows soil to warm up quickly because more heat is required to raise the temperature of wet soil. Soil warmth promotes bacterial activity which increases the release of plant food and the growth of plants. Soils that warm up sooner in the spring can be planted earlier. Better germination conditions for seed are provided.

The removal of ground water improves the conditions for plant-root growth. For example, if free water is removed only from the top foot of soil, crop roots will feed in this confined area; but if free water is removed from the top 3 feet, this entire depth of soil is available as a root zone from which plants can obtain nutrients and moisture.

Environmental Concerns

NRCS Policy on wetland protection

Key point

The first question to ask about any drainage work being considered is, "Should it be undertaken at all?"

Concerns have been brought about by the loss of wetlands and the quality of remaining wetlands due to vast drainage undertakings in this country. There are laws and policies outlining restraints on development of additional drainage works or improvements to existing drainages. Numerous changes have occurred regarding wetland regulation in recent years. No doubt more changes will take place in future years. A complete coverage of wetland policy is outside the scope of this module. However, this concern should not be overlooked. Applicable policy must be acknowledged when undertaking drainage projects. Involvement in drainage activities necessitates keeping current on wetland protection policy and restrictions involving work in or adjacent to wetland areas.

Key point

The next question to address when drainage work is being considered is, "Are wetlands involved?"

This question implies that wetlands must be defined and an understanding of wetland delineation be known before proceeding. One of the provisions of the Food Security Act (FSA) of 1985 dealt with wetland conservation, often referred to as "swampbuster." Under this program, USDA farm programs are not eligible to any farmer who converts a wetland after December 23, 1985 to produce an agricultural commodity.

Wetlands are generally defined as areas of soil that, under natural conditions, are saturated or covered with water most of the year (hydric soils) and support mostly water-loving plants (hydrophytic). One widely accepted interpretation of this definition under FSA is that agricultural fields (or open areas) meeting certain hydrologic conditions would be considered wetlands (commonly called "farmed" wetlands). Under FSA, a national effort was made to delineate wetlands, especially "farmed" wetlands, for implementation of FSA. Therefore, a delineation of wetlands should be available in each field office.

Downstream hydrologic affects

Considerations must be given to the downstream impacts in terms of both quantity and quality of water associated with planned drainage measures. One special concern is that the measure not increase downstream water surface stages or add additional volumes of water to areas where drainage systems are inadequate. Other considerations associated with quantity and quality follow.

Quantity:

- Effects on the water budget components, especially relationships between runoff and infiltration.
- The effect of changes in the water table on the rooting depth for anticipated land uses.
- Effect on groundwater recharge.

Quality:

- Downstream effects of erosion and yields of sediment and sediment-attached substances.
- Effects on the salinity of the soil in the drained field.
- Effects on the loadings of dissolved substances downstream.
- Potential changes in downstream water temperature.
- Effects on wetlands or other water-related wildlife habitat.
- Effects on the visual quality of downstream water courses.

Activity 1

At this time, complete Activity 1 in your Study Guide to review the material just completed. When you have completed the Activity, compare your answers with the solutions provided. When you are satisfied that you understand the material, continue with the Study Guide text.

Activity 1

1. What is the purpose of drainage?

2. What factors cause poor drainage?

3. Name three cases where drainage should not be considered unless additional measures are undertaken.

   a.

   b.

   c.

Design Drainage Removal And Peak Discharge Rates

Regional discharge capacity

Degree of drainage

Drainage capacity for surface ditches should be determined from soil permeability, land use, degree of protection desired, and climatological area. In humid areas, drainage needs arise from excess precipitation. In arid or semi-arid areas, need for drainage arises principally from irrigation tailwater releases.

Crops differ in their tolerance to excess water in both amount and time. Either the water itself may be injurious to the plant or the saturation of the root zone results in an oxygen deficiency and accumulation of toxic gases. Complete saturation of roots for extended periods may not cause serious damage if it occurs during dormant periods of plant growth or if flow from drainage is sufficient to allow for oxygenation of the root zone. The designer needs to recognize differences in crop requirements by selecting an appropriate degree or intensity of drainage. Drainage requirements are based on maximum duration and frequency of surface ponding, the maximum height of the water table, and the minimum rate at which the water table must be lowered. Local drainage guides indicate the drainage criteria required for various crop-soil combinations.

Drainage coefficients

Much empirical information has provided a basis for drainage design. This information has accumulated over years of experience in drainage work. Experience from other sites may need to be adapted to local use. This may be helpful where no local guides exist.

In order to give proper consideration to the characteristics of precipitation and runoff, drainage coefficients have been developed. For surface drainage, this coefficient is usually expressed as a curve. The removal rate per unit of area varies according to the size of the drainage area. This variation is such that removal rate per unit area decreases with increasing drainage area.

In many areas of the country, the value of the coefficient for use in the general formula for surface drainage, $Q = CM^{5/6}$, has been determined by many years of experience. Values which are related to the kind of protection needed by different types of agriculture and kinds of crops have been determined for specific climate areas. This experience has provided valuable information and should continue to be used. Figure 5-1 in NEH-16 (see figure 1) indicates the area where these drainage coefficients, which are shown in figures 2 and 3, are applicable.

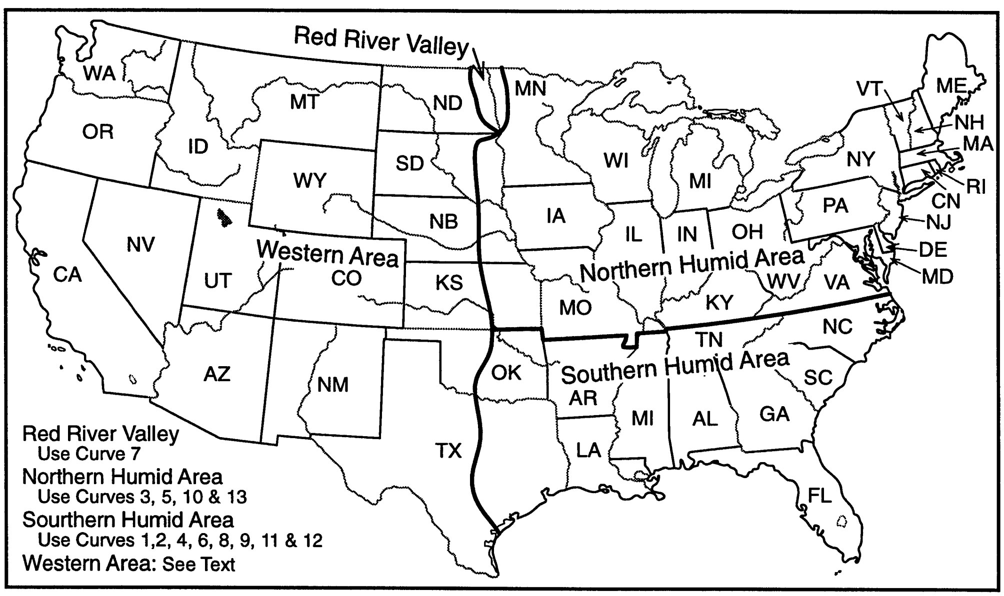

Figure 1. Key map showing drainage coefficients for use in drainage design.

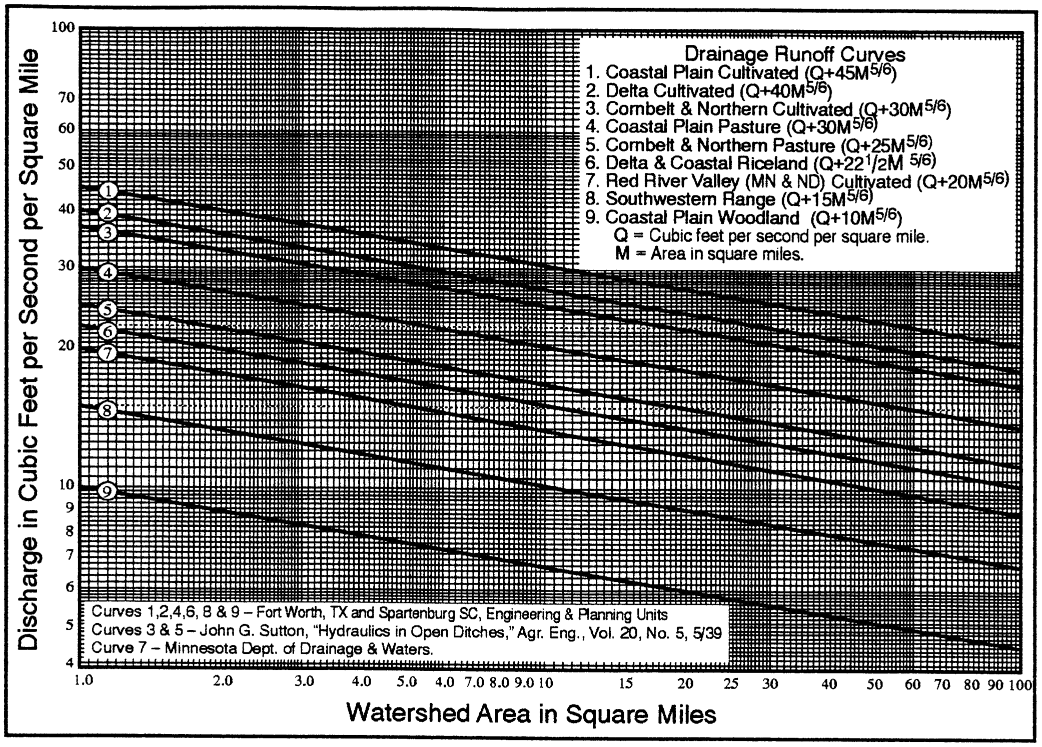

Figure 2. Drainage runoff curves.

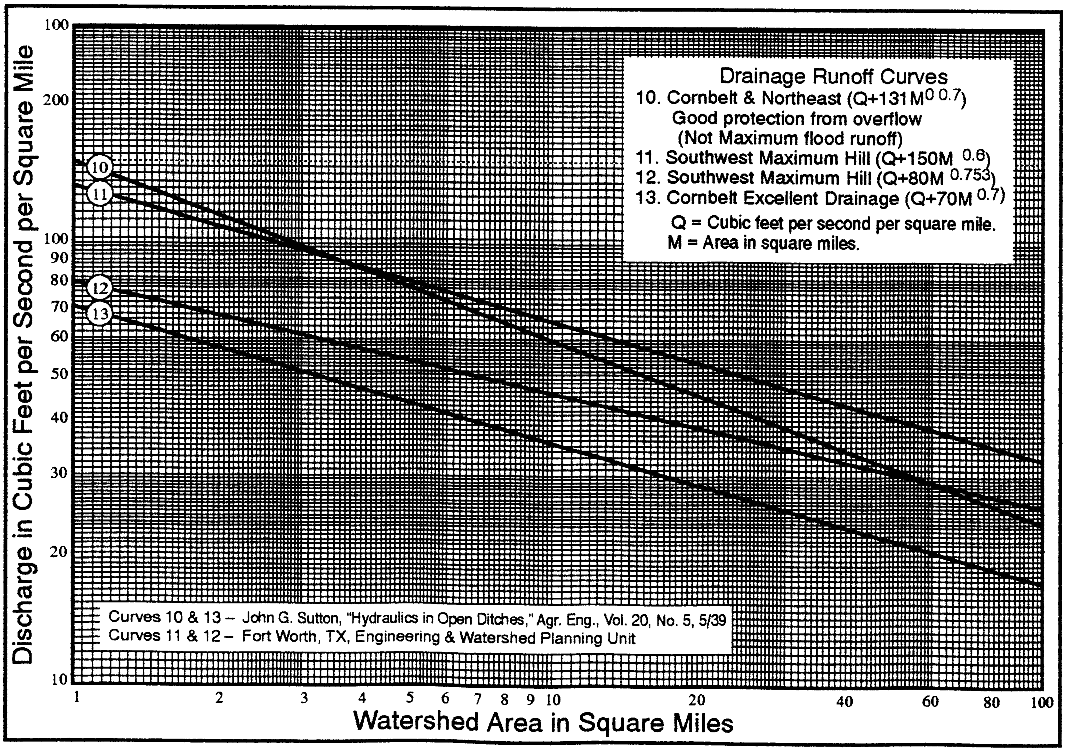

Figure 3. Drainage runoff curves.

In cases where a drainage coefficient is needed in the area west of the north-south dividing line, it should be:

1. based on the characteristics of the watershed and crops to be grown, and
2. somewhat lower than the coefficients in use for similar conditions to the east of the north-south line.

Drainage coefficients for subsurface drainage are usually expressed as a certain quantity of water removal from the drainage area per day. This may be expressed as inches per day from the watershed, or cubic feet per second per square mile. For large areas the rate may decrease. Where the need for both surface and subsurface drainage exists in a watershed, consideration must be given to the requirements of each in computing the design capacity for the ditch which serves as the common outlet.

In irrigated areas where subsurface flow is continuous and generally uniform for extended periods, it should be considered as a base flow in computing the required capacity of the outlet ditch. In those areas where subsurface flow is the result of precipitation and is intermittent, the usual case in NRCS drainage work, the required capacity of the outlet ditch will be governed by the surface drainage flow. After a rainstorm the surface flow usually passes its peak before subsurface flow begins. In both situations the minimum depth of the outlet ditch will be determined by its required depth for subsurface drainage of its watershed. Any open ditch in an area subject to rainstorms will periodically be subjected to runoff from storms of abnormally high intensity. The type of agriculture and other improvements in the flood plain will determine the feasibility of constructing the ditch to the size required to carry the runoff from these abnormally large rainstorms within banks. Decisions are made on an evaluation of damages which would result from overbank flow and the cost of improvements which would prevent it.

Effect of outlet capacity on selection of drainage improvement

In selecting criteria for design of drainage improvements, due consideration must be given to the capacity of the outlet into which the drainage ditches must empty. In determining the adequacy of outlets, the following basic requirements should be met.

- The capacity of the outlet should be such that the discharge from the project watershed, after the installation of proposed improvements, will not result in stage increases that will cause significant damages below the termination of the project ditch.

- The capacity of the outlet should be such that the design flow from its watershed can be discharged into it at an elevation equal to or less than that of the termination of the hydraulic gradeline used for design of the project ditch.

- The design flow from the watershed above the outlet should be determined in the same manner as the design discharge from the project.

- The probability of installing additional ditches in other watersheds which are served by the same outlet should be considered. Current national objectives make this a low probability.

- Where the outlet is a channel installed by the Corps of Engineers or other federal or state agency, the capacity of the project ditch will be governed by the capacity of the outlet. Criteria for design of the project ditch should be comparable to that of the outlet in such cases.

- Where subsurface drainage is needed, the depth of the outlet needs to be such that subsurface drains may discharge freely into mains and laterals at normal low water flow.

Design drainage discharge procedures

Cypress Creek Formula

Key point

The capacity of surface drainage for flatland is usually determined by the general formula
$Q = CM^{5/6}$

- Q= required capacity of ditch in cfs.
- C= a coefficient related to the characteristics of the watershed and the magnitude of the storm against which the watershed is to be protected (cfs/sq. mi.)
- M= drainage area in square miles

The Cypress Creek Formula applies to areas where the natural land slopes are about one percent or less. The formula may be used for minor portions of steeper land in a watershed which is predominantly flatland. This is an important formula for drainage design or analysis. Design flow from uplands in the watershed should be computed by procedures covered in Section 4, Hydrology, NEH, or from applicable hill land drainage curves. The design flow from the watershed can then be determined by adding to computed upland flow the flow of flatland increments computed from drainage curves.

Stephens and Mills Method to Compute Drainage Coefficients

In some areas, agricultural changes or improvements are being made which indicate the need for a more precise determination of runoff than that provided by use of the applicable drainage coefficient. In other situations there may be a need to develop a coefficient which is adapted to the specific needs in a particular watershed and the experience with similar conditions is not adequate to indicate the best coefficient to use.

Where this is the case, the coefficient "C" for the surface drainage formula may be determined by the following procedure, which is a combination of the recommendations of Stephens and Mills and the NRCS curve number procedures for determining runoff rates.

Values of coefficient "C" for the flatland portion of the watershed may be determined from the relationship

$$C = 16.39 + 14.75\, R_e$$

Where "R_e" is the rainfall excess in inches. See figure 5-4, NEH 16 (figure 4), for solution of the above equation. "R_e" should be determined in accordance with NRCS runoff curve number procedures. Runoff can then be related to rainfall frequency values. In determining "R_e" for flatland watersheds the following factors should be considered:

- Water accumulation to shallow depths on flatland during intense or extended periods of rainfall is not necessarily damaging. Such accumulations should extend to relatively short periods of time. It is not feasible to contain all runoff within ditchbanks on flatland except for extremely low intensity and short duration storms. The level of protection on flatland refers to the duration and frequency of storms against which protection is afforded, to the extent that flooding to the depth and duration which will cause significant crop loss will not occur. Drainage formulas, with coefficients ranging from 15 to 50, generally provide this kind of protection against storms of recurrence frequency of once in 2 to 5 years, depending on the kind of crop.

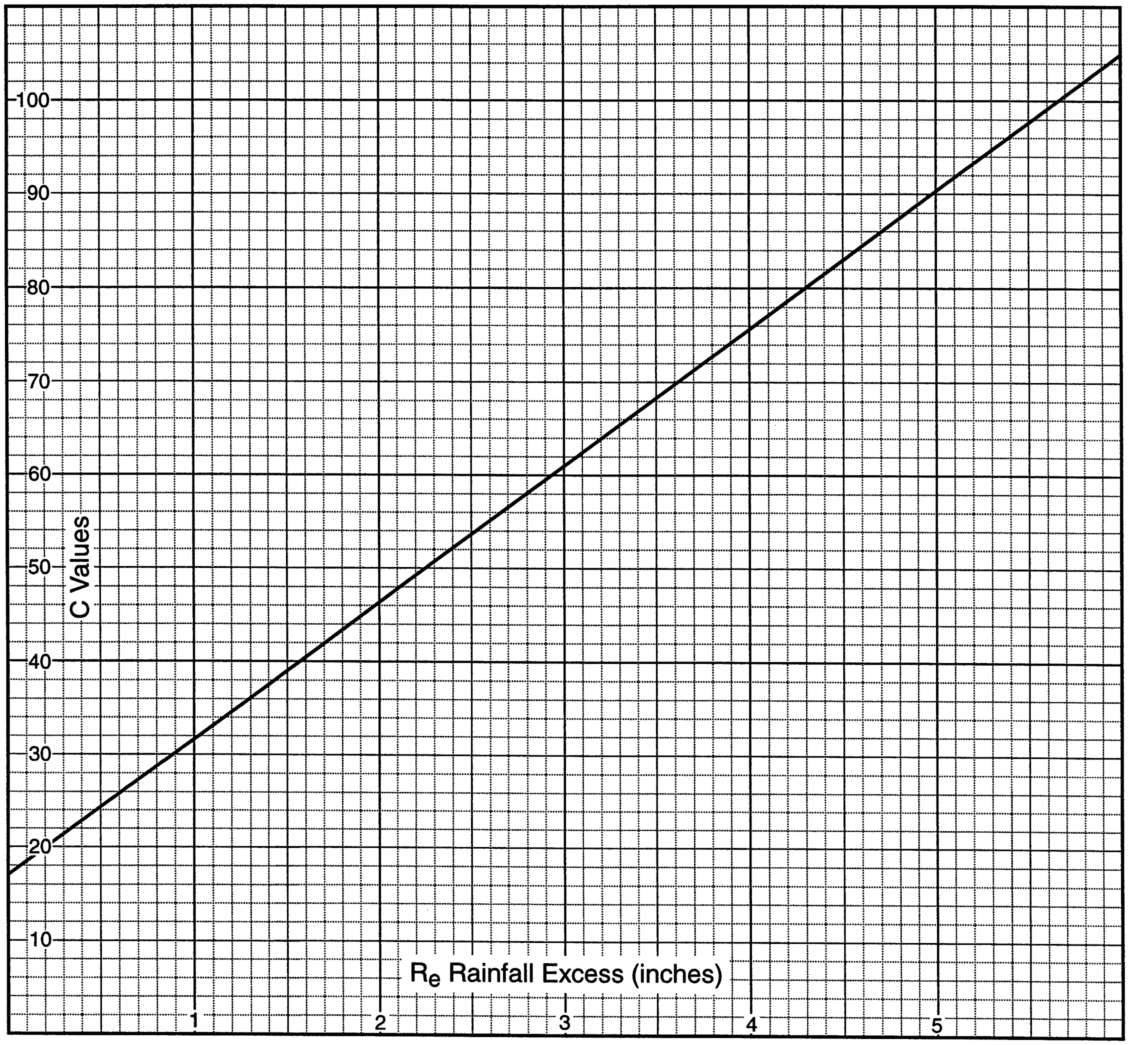

Figure 4. Determination of coefficient, C, in the drainage formula $Q=CM^{5/6}$.

- In determining the degree of protection to be provided, topography and soils need to be investigated. Land which is a foot or two higher receives a much greater degree of protection than land at general field level on which the channel design is based. Lands at the lowest elevations adjoining channels frequently are classed as "heavy" soils and are best suited to pasture or water-tolerant crops. Often the "lighter" soils, best suited for row crops, lie slightly higher in elevation. This is usually true of land built up by stream overflow. In such situations, channels designed on drainage curves with coefficients in the range of 15 to 30 may provide adequate protection for the lower lying lands in a watershed and also provide a much greater degree of protection for lands which are a foot or two higher than the design hydraulic gradeline. In complex watersheds or drainage systems, flood routing may be needed to determine the required channel size.

- A common understanding of "24-hour removal" is that the rainfall excess from a particular storm is removed from the watershed within 24 hours after the cessation of rain. Use of the Stephen Mills Method to relate drainage coefficients to corresponding rainfall excess is restricted to areas where the 24-hour event can be determined.

- Within a particular watershed there may be sloping upland, flat bottom land, forest land, highly developed general cropland, or even some urban land. The characteristics of each distinct type of land and land use within the watershed determines the coefficient to be used in design of improvements on that parcel of land and in computing the drainage flow from it. In order to comply with one of the principles of the surface drainage formula, that the rate of removal per unit of area varies according to the size of the drainage area, it is necessary to maintain the same relation of total flow to total area as the formula specifies. This can be done within tolerable limits by determining the acreage of one type of land which, by use of its proper coefficient, will produce the same flow as a different acreage of another type of land using its proper coefficient. Then, as the addition of flow proceeds downstream in a watershed, each subsequent determination is based on the addition of area as well as water. Additional explanation of the concept of equivalent drainage is given in EFM, figure 14-13.

Computing Ditch Sizes at Junctions Using 20-40 Rules

Drainage runoff is determined by the applicable drainage curves. Runoff is determined above and below the outlet of contributing ditches and streams, at points of change in the channel slope, at culverts and bridges, and at the outlet. It is general practice to begin the runoff calculations at the upper end of the ditch and proceed downstream. To determine desired discharge below the junction of contributing drainage areas, or watersheds, there are three empirical procedures termed the "20-40" rule which should be used in computing required capacities for a ditch below a junction with a lateral.

For large drainage areas, the application of the procedures may have considerable effect on the ditch design. On small areas the change in required ditch capacity may be so slight that the procedures need not be applied. Experience in applying the "20-40" rule will guide the designer in its use.

Case 1

Where the tributary area of one of the ditches is from 40 to 50 percent of the total area, the required capacity of the channel below the junction shall be determined by adding the required design capacities of the ditches above the junction. This is based upon the assumption that the flows from two watersheds of about the same size may reach the junction about the same time and therefore the ditch capacity below the junction should be the sum, of the two flows. This rule should be used in all cases for areas less than 300 acres.

Case 2

Where the watershed area of a lateral is less than 20 percent of the total watershed area immediately below the junction, the design capacity of the ditch below the junction shall be determined from the drainage curve for the total watershed area below the junction. This is used where a ditch draining a small area joins a ditch draining a much larger area.

Case 3

Where the watershed area of a lateral is in the range of from 20 to 40 percent of the total watershed area, the discharge shall be proportioned from the smaller discharge at 20 percent to the larger discharge at 40 percent. In this range, the discharges should be computed by both methods (the sum of capacities for the two individual watersheds and the capacity based on total watershed area) and the difference in cfs obtained. Then, the design discharge for the channel below the junction should be obtained by interpolation. This is a combination of rules 1 and 2.

See example 1 for an application of the "20-40" rule.

Example 1—20-40 Rule

Assume that a lateral draining 3,200 acres joins an outlet draining 10,200 acres above the junction with 13,400 acres watershed area below the junction. A curve developed from the formula $Q = 45\ M^{5/6}$ is to be used to calculate runoff. Since the watershed area of the lateral is between 20 and 40 percent of the total watershed, the flow will be computed as follows:

Step 1

Runoff from 3,200 acres	170 cfs
Runoff from 10,200 acres	460 cfs
Total discharge from the two watersheds	630 cfs

Step 2

Runoff from total watershed 13,400 acres	580 cfs

Step 3

Subtract step 2 from step 1	50 cfs

Step 4

Percent of small watershed (3,200 acres) of total watershed

(13,400 acres) is $\frac{3200}{13400} \times 100 = 23.8\%$

Step 5

Difference between 23.8 and 20 = 3.8

Step 6

$$\frac{3.8}{20} \times 100 = 19\%$$

Step 7

From step 3, 50 x 19% = 9.5

Step 8

Add 580, from step 2, and 9.5, from step 7 589

This is the final interpolated discharge from this watershed below this junction.

Activity 2

At this time, complete Activity 2 in your Study Guide or review material just covered. When you have finished, compare your answers with the solutions provided. When you are satisfied that you understand the material, continue with the Study Guide text.

Activity 2

1. Using the Cypress Creek formula for computing discharge capacity for drainage desired based on removal rate using a drainage coefficient:

   a. Define each variable in the formula and give the English units.

   b. Determine drainage capacity of an outlet channel for a 1280 acre cultivated Delta field using drainage curves.

   c. Determine drainage capacity for a 320 acre field drain at the same site.

2. State four conditions where the outlet capacity influences the selection of drainage design.

3. Determine the rainfall excess (R_e) for a watershed with a drainage coefficient (C) of 40.

4. For the following watershed, determine the required capacity below the junction to the two drainage channels. The needed drainage coefficient has been determined to be C=45.

   Given: Watershed drainage areas:

Main	=	500 ac's
Lateral	=	400 ac's (tributary)
Total	=	900 ac's at junction

5. You have been asked for design assistance for a drainage improvement on a 1000 acre site. The existing capacity of the surface drain has been determined to be 60 cfs (capacity below the established hydraulic gradeline). The outlet for this particular site has a drainage coefficient C=35. What is your recommendation?

Peak Discharge by Frequency

Relationship between removal rate and instantaneous peak discharge

Drainage design capacity based on removal rate is unlike most other types of design capacity, which are based on instantaneous peak discharge. Where normal agricultural drainage capacity determination are needed, the concept of removal rate is appropriate. Design of channel improvements in "flatland" areas to provide a desired level of protection to residences and other high damageable property should be based on instantaneous peak discharge.

Peak discharge methods for flatlands

Where instantaneous peak discharge computation is needed, numerous procedures are available. These include:

- EFM-2, TR-55, or TR-20 using rainfall distributions, Types II or III, modified for flatlands.
- Magnitude and frequency from regionalized data developed by U.S. Geological Survey for specific flatland areas.
- Relationships developed between instantaneous peak versus maximum 24-hour average flows (fig. 5). An example of this relationship has been developed from ARS 41-95, USDA, by Stephens and Mills.

Caution should be taken in the application of these methods. For instance, if regionalized data is used, care should be taken to make proper adjustments for urbanization, if applicable. Where possible, experience should be relied upon to determine the most appropriate procedure. Generally, procedures which have been closely verified with observed events are considered reliable.

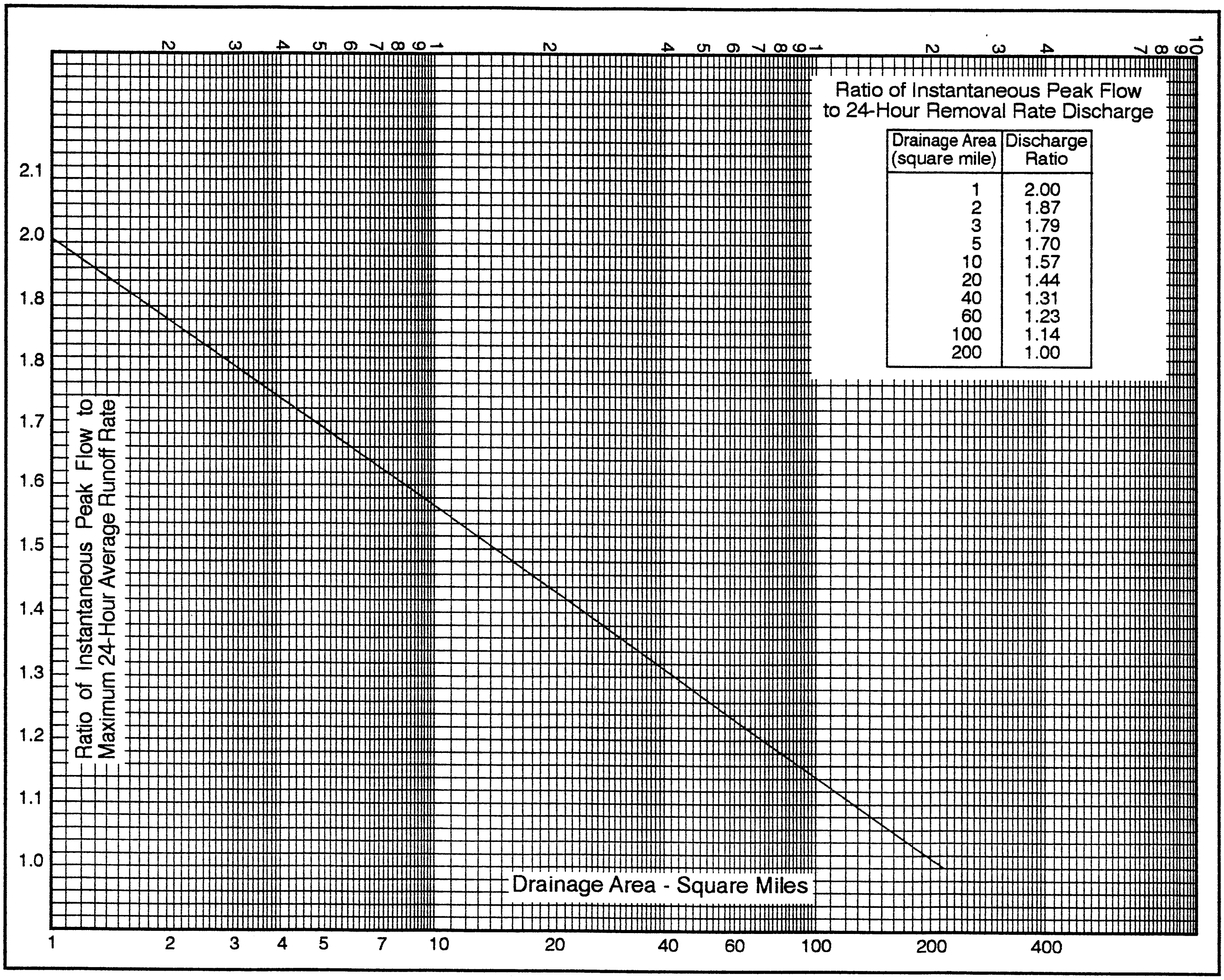

Figure 5. Relation between ratio of instantaneous peak flow to 24-hour removal rate discharge and drainage area for flatland areas. (From ARS 41-95, USDA by Stephens & Mills)

Examples—Determinations of peak discharge for flatlands

Example 1

To demonstrate the use of various procedures to determine peak discharge, a watershed with the following characteristics is used: Watershed land slope = 0.6% Runoff curve number = 80 Drainage coefficient C = 50 Total drainage area = 1210 ac's (1.89 sq. mi.) Location of watershed is northeast Louisiana in the Mississippi River alluvial floodplain, commonly called the Delta. Determine the instantaneous peak discharge for the 2 year, 24-hour, frequency event. The rainfall for this event at this location is determined from EFM-2 as 4.5 inches.

Example 2

Determine the peak discharge using the computer procedure for EFM-2 or TR-55 (graphical). Enter appropriate watershed data, then select the DMV rainfall distribution. The DMV applies to the Type II storm region. This distribution is adjusted to include hydrograph affects from flatland watersheds. You may need assistance from your module facilitator (resource person) if computation is needed for a flatland in a Type III rainfall distribution area. This procedure is not presently available for Type I and IA rainfall distribution areas (western California, Oregon, and Washington). See figure 6, for TR-55 output for the Type III region.

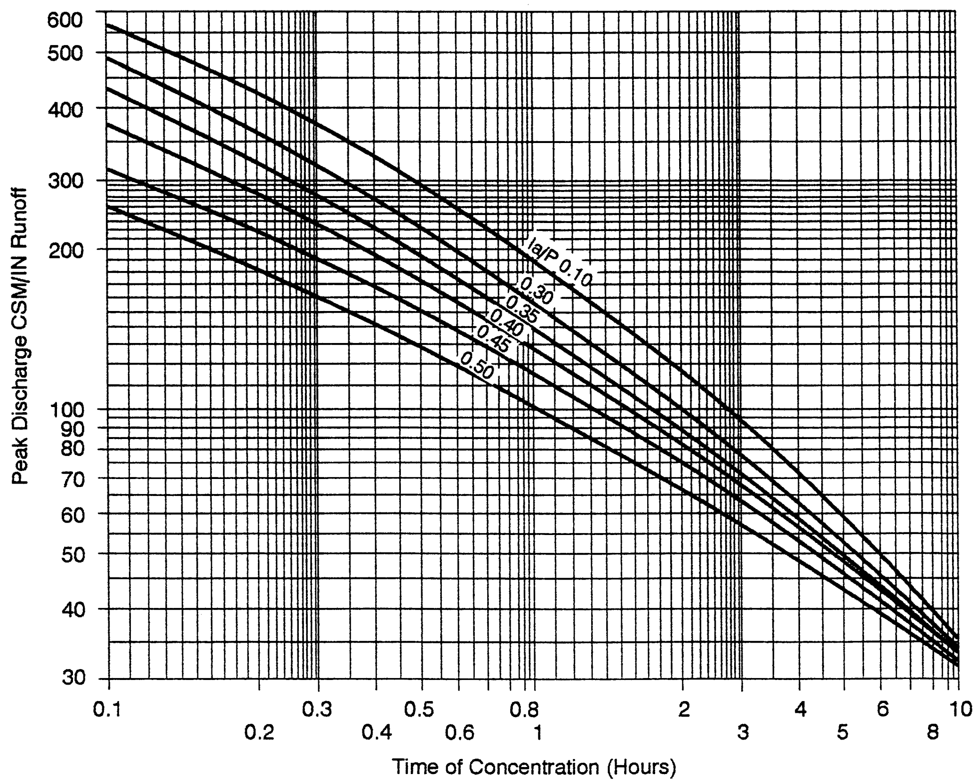

Figure 6. Peak discharge, SCS Type III using DMV.

Example 3

To determine the peak discharge using the relationship between instantaneous peak versus maximum 24-hour average flows, refer to NEH-16, figure 5-1 (figure 1). First, determine the 24-hour average runoff rate.

Given: $C = 50$

$Q = CM^{5/6}$

$Q = 50(1.89)^{5/6}$

$Q = 85$ cfs

From NEH-16, figure 5-1 (figure 1), Drainage Area = 1.89 sq. mi.: Peak rate = 1.88;

Peak rate = (1.88)(85) = 160 cfs (24-Hr. Removal Rate)

When using this method to obtain a peak flow value, be sure to use the Stephens and Mills relationship to relate removal rate to 24-hour frequency. This is done by determining the "R_e" (runoff) value for the appropriate "C" drainage coefficient value and using the curve numbers method to relate to frequency of rainfall excess. Refer to NEH-16, figure 5-4 (figure 4) for C of 50 and read R_e as 2.3 inches. Note runoff from EFM-2 procedure for this rainfall event is close (2.46 inches).

Example 4

The use of regionalized data developed for flatlands is a convenient method to determine peak flow values. Since this is a regionalized method and is developed from actual streamflow records, its use can provide excellent results if applied to comparable watershed areas. Some expertise is needed in selecting and applying the appropriate regionalized procedure. Reports are available for various locations throughout the nation and are in different stages of development. Your module facilitator (resource person) can give additional information about this method as well as site specific availability.

Notice the difference in the peak values obtained by the different methods. Numerous explanations can be given for the variation. In this particular case, a longer time of concentration would give a lesser peak discharge from the NRCS computation method. With a time of concentration in the range of nine (9) hours the peak would more closely match the one computed from the removal rate ratio method. In this case, hydraulic computations could be used to define the time of concentration computation.

Activity 3

At this time, complete Activity 3 in your Study Guide to review material just covered. When you have finished, compare your answers with the solution provided. When you are satisfied that you understand the material, continue with the Study Guide text.

Activity 3

1. Name three different techniques for providing an instantaneous peak discharge for flatlands.

   a. ______________________________

   ____

   b. ______________________________

   ____

   c. ______________________________

   ____

2. The removal rate for a watershed has been determined to be 50 cfs. The drainage area of the site is 1000 acres.

   a. What is peak flow?

   b. What is the removal rate of excess rainfall (R_e) in inches?

Summary

Completion of this module should have given you an understanding of drainage hydrology. You should be able to describe how to determine or analyze capacities of small drainage ditches or channels. You should be able to work with small watersheds. As you learn and apply various methods for computing peak discharges and drainage removal rates, you will want to compare results. You will have a better understanding of where to get additional information or help should you obtain unexpected results. Above all, remember to use only computation methods that have been approved for use in your Field Office or Area.

You should be aware of environmental concerns related to drainage activity. Wetland protection is a sensitive national issue which may also be reflected at the state and local level. You should know to consider downstream impacts on water quality and gravity.

Retain this Study Guide as a reference until you are satisfied that you have successfully mastered all the methods covered. It will provide an easy review at any time if you should encounter a problem.

If you have had problems understanding the module or if you would like to take additional, related modules, contact your supervisor.

When you are satisfied that you have completed this module, remove the Certification of Completion sheet (last page of the Study Guide), fill it out, and give it to your supervisor to submit, through channels, to your Training Officer.

Test

Circle T for true or F for false

1. T or F Drainage is the removal and disposal of excess water.

2. T or F Drainage generally implies improvements associated with land lacking sufficient slope to cause water to flow to an outlet.

3. T or F Surface wetness is a visual indication of inadequate drainage.

4. T or F Analysis of outlet conditions are a waste of time because they do not have anything to do with surface drainage.

5. T or F NRCS has no interest or policy concerning wetland protection.

6. T or F A field where agricultural crops are grown, or are attempted to be grown cannot be called a wetland because it does not have hydrophytic vegetation.

7. T or F Potential changes in downstream stages are of no concern.

Circle the best answer

8. The Cypress Creek formula can be written as:

   a. $Q = CM^{5/6}$

   b. $Q = CM0^{.835}$

   c. a or b

9. A 100 acre field drain sized for a C of 45 should have a capacity in cfs of:

   a. 2,086

   b. 7

   c. 10

10. A “C” value of 45 implies about what runoff rate (in inches):

    a. 4.5

    b. 2

    c. 1

    d. 3

Activity Solutions

Activity 1

1. What is the purpose of drainage?

   The purpose of drainage is the removal and disposal of excess water.

2. What factors cause poor drainage?

   a. *Lack of natural drainageway*

   b. *Lack of sufficient land slope to let water flow to outlet*

   c. *Low soil permeability*

   d. *Man made distructions*

   e. *Poor outlet conditions*

   f. *Natural surface barriers*

3. Name three cases where drainage should not be considered unless additional measures are undertaken.

   a. *Easily erodible soils.*

   b. *Sensitive wetlands may be affected by removal of excess water.*

   c. *Downstream water quality will be impaired.*

Activity 2

1. Using the Cypress Creek formula for computing discharge capacity for drainage design based on removal rate using a drainage coefficient.

   a. Define each variable in the formula and give the English units.

   $Q = CM^{5/6}$
   Q = Discharge (cfs)
   C = Drainage coefficient (cfs/sq. mi.)
   M = Drainage area (sq. mi.)

   b. Determine drainage capacity of an outlet channel for a 1280 acre cultivated Delta field using drainage curves.

   From figure 4 , Curve No.2, watershed area of 2 sq. mi., read discharge of 36 cfs/sq. mi.

   36 cfs/sq. mi. x 2 sq. mi. = 72 cfs

   A more straight forward approach would be to solve the Cypress Creek formula using the C value in the figure instead of reading the unit discharge. Following this approach:

   $Q = 40M^{5/6} = 40(2)^{5/6} = 71$ *cfs*

   c. Determine drainage capacity for a 320 acre field drain at the same site.

   For areas less than one sq. mi., solve the formula given in NEH-16, figure 5-4 (figure 4) for the area of interest.

   $Q = 40M^{5/6} = 40(0.5)^{5/6} = 22$ *cfs*

2. State four conditions where the outlet capacity influences the selection of drainage design.

   a. *Drainage improvement would increase downstream damages.*

   b. *Capacity at the outlet must take the discharge from the project ditch at or below an elevation equal to the design hydraulic gradeline.*

   c. *Drainage coefficient criteria for design of project ditch should be comparable to that of the outlet.*

   d. *Subsurface drainage outlets should be above normal low water flow.*

3. Determine the rainfall excess (R_e) for a watershed with a drainage coefficient (C) of 40.

   Using the Stephen and Mills method:

   $$C = 16.39 + 14.75R_e$$

   $$R_e = \frac{(40) - 16.39}{14.75} = 1.6''$$

   Or reference NEH-16, figure 5.4 (figure 4):

   For $C = 40$, *read* $R_e = 1.6''$

4. For the following watershed, determine the required capacity below the junction to the two drainage channels. The needed drainage coefficient has been determined to be C=45.

   Watershed Drainage Areas
   Main = 500 ac
   Lateral = 400 ac (or trib.)
   Total 900 ac (at jct.)

   Application is for the use of the 20-40 rule. First determine percentage the lateral is to the total drainage area.

   400ac - 900ac = 0.44 or 44 percent

   Since the lateral is between 40 and 50 percent of the total drainage area, Case 1 applies.

   For Case 1, the required capacity is the sum of capacity of each drainage area.

Watershed	*Areas (M)*		*Capacity (Q)*
	ac	*sq. mi.*	*cfs*
Main	*500*	*0.78*	*37*
Lateral	*400*	*0.62*	*30*
Total	*900*	*1.40*	*67*

   $Q = CM^{5/6}$, C = 45 (given), so

   $Q = 45(M)^{5/6}$ where M is in sq. mi.

   Required capacity below the junction is 67 cfs.

5. You have been asked for design assistance for a drainage improvement on a 1000 acre site. The existing capacity of the surface drain has been determined to be 60 cfs (capacity below the established hydraulic gradeline). The outlet for this particular site has a drainage coefficient C = 35. What is your recommendation?

   First determine "C" of the existing drain.

   $Q = CM^{5/6}$, $c = Q/M^{5/6}$

   $C = 60/(1000/640)^{5/6} = 41$

   Recommendation is that improvement of the existing capacity will not effectively increase surface drainage because the existing removal rate capacity at the site exceeds the capacity of the outlet channel.

Activity 3

1. Name three different techniques for providing an instantaneous peak discharge for flatlands.

   a. *NRCS procedures for peak discharge determinations using a rainfall distribution adjusted for flatlands.*

   b. *Relationship between instantaneous peak versus 24-hour removal rate (Stephens and Mills)*

   c. *Regionalized flow methods, most of which are developed and outlined in reports by U.S. Geological Survey.*

2. The removal rate for a watershed has been determined to be 50 cfs. The drainage area of the site is 1000 acres.

   a. What is the peak flow?

   Use NEH-16, figure 5-1 (figure l)

   Drainage area = 1000ac/(640 sq. ac/sq. mi.) = 1.56 sq.mi.

   Ratio = 1.92

   Peak flow = 1.92 x 50 = 96 cfs

   b. What is the removal rate of excess rainfall (R_e) in inches?

   Determine "C" from available information, then use NEH-16, Figure 5-4 (figure 4)

   $Q = CM^{5/6}$, $C = Q/M^{5/6} = 50/(1.56)^{5/6} = 35$

   From figure 4, read $R_e = 1.2$ *inches*

Hydrology Training Series
Module 108—Drainage Hydrology

Certificate of Completion

This is to certify that

____

has completed Hydrology Training Series
Module 108—Drainage Hydrology
on ________________ and should be credited with three hours of training.

Signed ________________________ ________________________
Supervisor/Trainer Participant

Completion of Hydrology Training Series
Module 108—Drainage Hydrology
is acknowledged and documented in the above-named employee's record.

Signed ________________________ Date ________________
Training Officer

United States Department of Agriculture, Natural Resources Conservation Service