SCS
NATIONAL
ENGINEERING
HANDBOOK

SECTION 16

DRAINAGE OF AGRICULTURAL LAND

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

UNITED STATES DEPARTMENT OF AGRICULTURE

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NATIONAL ENGINEERING HANDBOOK

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PREFACE

This section of the National Engineering Handbook of the Soil Conservation Service has been developed as a guide for investigations, surveys, design, construction, and maintenance of facilities for agricultural drainage. It is intended primarily as a working handbook, and very little theory is included. References are given to research data and theoretical analyses where it is felt the user may wish additional information on a particular procedure or criteria.

The handbook is developed for use in all fifty states and the Carribean Area, so it is necessarily rather general in many respects. For use in a specific area it should be supplemented with data on soils, climate, topography, and land use data applicable to the area.

The Engineering Field Manual for Conservation Practices, USDA-SCS, includes a chapter on drainage which has some of the same information included in this handbook. It is developed primarily for work unit operations, and covers the drainage work performed in the work unit in more specific detail than does this section of the National Engineering Handbook.

In addition to the handbook and field manual, drainage standards and guides should be available in each state, area, and work unit where drainage of wet land is a needed practice. The drainage guide is the accumulative record of experiences of drainage engineers and other technicians in planning, installing, and evaluating the effectiveness of drainage systems. It provides a local guide for such criteria as depth and spacing of ditches and drains, drainage coefficients, and other standards based on soils, climate, topography, and land use. Drainage guides should supplement and be consistent with SCS standards developed at the National and state levels. The number of drainage guides needed in each state will depend on variations in drainage problems. A guide may cover an entire state, problem area, or work unit area.

Personnel working on planning and design of drainage improvements also should have access to textbooks, hydraulic handbooks and tables, hydrologic records, bulletins, and other data of value in planning and design of drainage works. The Corps of Engineers' Hydraulic Tables is especially helpful in channel design. King and Brater's Handbook of Hydraulics is used in the solution of many drainage design problems.

This section of the National Engineering Handbook has been developed over a period of sixteen years. Tentative drafts of two chapters were issued in September 1955. Most of the chapters have been revised many times since the first draft, and many of them have been in field use for several years. A large number of Soil Conservation Service employees have contributed to the development of the handbook by their review and suggestions.

Credit for the inception of the project and guidance in its growth through most of the development period is due to the late John G. Sutton. His knowledge of agricultural drainage and experience in drainage operations were invaluable in developing this handbook.

In addition to John Sutton, the following SCS drainage engineers have been the principal contributors to the project:

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INTRODUCTION

Definition of Agricultural Drainage

Agricultural drainage may be defined as the removal and disposal of excess water from agricultural land.

The sources of excess water may be precipitation, snowmelt, irrigation water, overland flow or underground seepage from adjacent areas, artesian flow from deep aquifers, floodwater from channels, or water applied for such special purposes as leaching salts from the soil or for temperature control.

Drainage systems are needed to supplement natural drainage in many areas. The amount of water to be removed by such systems depends, therefore, upon the relative effectiveness of the natural and the constructed drainage.

Agricultural drainage is divided into two broad classes: surface and subsurface. Some installations serve the dual purposes of surface and subsurface drainage.

Drainage in the United States

Drainage has made agricultural development possible on much of the most productive land in the United States. The 1959 Census of Agriculture shows that nearly 102 million acres in 39 states are contained in more than 8400 drainage enterprises with areas over 500 acres in size. Within these enterprises, drainage improvements have been made on about 92 million acres. It is estimated that about 39 million acres not covered in the census have been drained by individual landowners and in small group enterprises less than 500 acres in size (1).* Now approximately 130 million acres or about one-third of all cropland is drained artificially.

According to statistics compiled by the International Commission on Irrigation and Drainage for its 1965 Annual Bulletin, the area protected by drainage works in the United States is 40 million hectares (98.8 million acres) not including irrigated areas (2). This is slightly more than one-half of the total drainage (not including irrigated areas) reported by the 59 nations included in the tabulation. Data for China is not included.

As the basis for reporting data for the ICID survey is not the same as for the census, the figures given are not comparable, but when drained areas in irrigation projects and in small drainage projects (less than 500 acres in size) are included, the data reported compares favorably with the 130 million acres given above as the total area of agricultural drainage in the United States.

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*Numbers in parentheses refer to references listed on page 12.

Drainage on an individual farm is and always has been the responsibility of the landowner. Needed drainage works beyond the farm are usually obtained by landowners cooperating under state law or under an informal group arrangement. A state agency may provide drainage facilities when the need for drainage is widespread over the state. This is done under cooperative arrangements with the local political subdivision.

Federal government participation in drainage until the mid 1930's had been limited to minor research and technical assistance. Today federal assistance is provided as an integral part of a comprehensive land and water development program through individual projects of the Departments of Agriculture, Army, and Interior. Earlier drainage works, with some exceptions, were established under conditions of a pioneering agriculture by landowners and local artisans, largely piecemeal, on a trial-and-error basis, and along general principles handed down from generation to generation.

Current new facilities, and the improvement of old facilities, are now planned and installed on the basis of engineering designs applied to a coordinated system of surface and subsurface ditches and drains discharging in an adequate outlet; and whatever protecting dikes, diversion channels, gates and pumps may be required by site conditions for protection against overflow. Designs incorporate the latest knowledge and techniques of hydrology, hydraulics, geology and the soil sciences. Construction materials, methods and equipment are used to provide the most efficient and economical installations applicable to the sites. Design and construction are being modified and improved by continuing research findings of industry, state and federal governments.

Drainage in the Soil and Water Conservation Program

Soil Conservation Service assistance for drainage measures is provided primarily for increasing the efficiency of land use while conserving our land resource on farms and ranches. This is done by improving existing drainage systems or by constructing new systems.

Drainage permits better timing of seasonal cultivation, lowers the cost of cultivation, and improves seed germination. Drainage also may permit adjustment in land use on a farm or ranch, so the steeper land subject to erosion may be used for hay or pasture, and the flatter, drained land for cultivated crops.

In many irrigated areas of the West, the water table rises and causes increasing damage to land and crops. Harmful salts may accumulate and saline or alkaline conditions may develop where the water table is near the surface.

Drainage is a first step in the improvement of much of our wet land before other needed conservation practices can be applied successfully.

Drainage Enterprises

To assure adequate disposal of excess water from all parts of drainage systems, there must be uninterrupted flow from the point where the water starts through the disposal system to an adequate outlet. The outlet must be capable of handling the flow without it causing damages above or below the point of discharge. Improvements frequently are needed to a channel, beyond the point where the drainage system discharges, to obtain required capacity and to prevent flooding.

Frequently a channel providing the outlet for a drainage system, or systems, must be improved through land under several ownerships. In such cases it is necessary for the landowners to work together to accomplish their objective--improved drainage. Some type of organization of the landowners is usually needed.

Group organization for drainage improvement may be desirable for any one or all of the following reasons:

1. To obtain an adequate outlet for drainage from all lands in which the group is interested, and to permit coordinated planning.

2. To provide an organization to obtain the necessary financing, and the means for equitably distributing the costs of planning, constructing, and maintaining the needed improvements among all the benefited owners.

3. To provide the organization and leadership required to plan, construct, and maintain the needed improvements.

4. To obtain necessary rights-of-way for construction and maintenance operations.

Types of enterprises

State laws for forming drainage enterprises vary considerably, and the terminology in them is different in the several states. It is necessary for personnel engaged in drainage work to become familiar with applicable drainage laws and procedures for forming drainage enterprises. For the discussion here the following terms and their definitions will be used.

1. Drainage enterprise--a project, by an organization or a group, to make drainage improvements within certain defined boundaries. All of the following types of organizations are included:

2. Legal organization--an organization established in accordance with state laws to provide the means to carry on drainage work on lands within certain boundaries. Such legal organization has the power to tax and to condemn land for rights-of-way. Legal organizations include drainage districts, water control and improvement districts, levee districts, conservation and reclamation districts, and agencies for county and township ditches and drains. The term "drainage district," as used here, denotes any legal organization as already described.

3. Voluntary or cooperative groups--an unincorporated drainage enterprise where the entire membership is voluntary. There are two types:

    a. Drainage association--a formal organization of landowners or operators to do drainage work within a certain defined area--without the powers of taxation or condemnation, but with contractual and purchasing powers.

    b. Informal drainage group--a group of two or more landowners or operators, who have mutually agreed to work together on drainage improvements within a certain defined area without the powers of taxation or condemnation.

Characteristics of enterprises

The differences in the types of organization for drainage enterprises are in the degree of organization and in the powers they have. Generally the informal group will be adequate for small enterprises. As the enterprise increases in size and number of landowners or operators, the organization to handle financing, procurement of easements, construction and maintenance needs to have its powers increased and its responsibilities clarified. Various factors enter into selecting the best type of organization. To furnish the best advice, the engineer should know the characteristics of each type.

Drainage districts

Laws governing drainage districts vary between states. They are specific, however, and must be followed exactly. A digest of the laws pertaining to drainage and drainage districts currently applicable in the state is a valuable working tool. In most states drainage districts have the following advantageous characteristics:

1. They can handle all kinds of drainage work.

2. A group of commissioners is elected or appointed. These commissioners have authority to operate and maintain the district.

3. Drainage districts are provided with means for financing large enterprises. They have the power to tax and usually they may sell bonds on approval of the landowners in the district or the court. Taxes may be levied to finance new construction or to improve or maintain existing works.

4. Districts have the authority to acquire rights-of-way for drainage work. This includes the power of condemnation.

5. Drainage districts can hire employees and purchase equipment and supplies to carry on drainage activities.

Some disadvantages of drainage districts for handling drainage work which could be handled by drainage associations are:

1. Often several months are required to organize.

2. Many drainage districts have high overhead costs.

Certain drainage districts organized in the past have experienced financial difficulties and have failed to maintain their improvements. Hence, in many areas, landowners and operators are reluctant to organize even though some type of legal organization to obtain rights-of-way, to equitably finance the work and to maintain works of improvement is essential where sizeable group drainage facilities are needed.

Drainage associations

These associations have been most successful where they did not include too large a working group, usually of not more than 15 members. The association is unincorporated and voluntary for all members. It operates under articles of association and elected officers.

Unless restricted by state laws concerning the size of groups which may organize associations, the drainage association may be given official status

by the recording of the articles of association in the office of the county or parish clerk. If the number of farmers is insufficient to meet requirements for such organization under state law, the association may be formed as outlined but the recording of the articles of association with the county clerk would not be possible.

Advantages of drainage associations are:

1. The organization is simple and may be accomplished quickly.

2. An elected official is available to do business for the association.

3. An organization is provided to carry out continued maintenance.

4. Means are provided to distribute costs, collect money (through voluntary subscription only), and make contracts.

Some disadvantages are:

1. There are no provisions for taxation or condemnation for rights-of-way. Rights-of-way may be obtained through negotiation only.

2. Death or serious injury to an association employee may impose a large financial liability. If the association hires employees, it should obtain compensation insurance for such contingencies.

Informal groups

Small groups, usually less than half-a-dozen farmers, are held together only through agreement and are financed by voluntary contribution.

There is no formal organization. In dealing with the group it is necessary to get the members together, or carry the proposition to each member separately, unless a member has been duly elected by the group as their leader.

Advantages of the informal group are:

1. Simplicity of formation--no organization is necessary. The group is formed merely by each member signing a group agreement.

Disadvantages of the informal group are:

1. Working with an unorganized group is often difficult, especially as it concerns financing of unforeseeable things.

2. No organization is available to carry out future maintenance.

3. Acquisition of rights-of-way is often a problem since they can be obtained only through voluntary agreement.

Procedure for enterprises

General

All drainage jobs have certain similarities, and all enterprises must pass through certain stages of development. As the size and complexity of the job increases, the steps of development need to be more detailed and more clearly defined. The larger and more complex jobs will require more elaborate

engineering treatment. All enterprises require an engineering appraisal of the problem, presenting this appraisal to the owners, obtaining a decision of the owners as to course of action, making more detailed engineering surveys, preparing plans, and supervision of construction.

Some drainage enterprises, from a technical viewpoint, could be handled by either a drainage association or a drainage district. Others could be worked by an informal group or a drainage association. To determine which method is preferable for specific conditions, the procedure for development will be discussed for the three types of enterprises concurrently. In using the following information the policies of the Soil Conservation Service and the laws of the state should be followed closely.

Soil Conservation Service assistance to groups prior to organization

Assistance of SCS to a group enterprise provided in accordance with SCS policies, as covered in other communications, may take many forms. It may consist of advice as to courses of action and assistance with conservation planning; or it may consist of a complete engineering job for the improvements, and assistance with conservation planning. The guide for this assistance is contained in current policy statements of the Administrator. The form of the request from the group to the soil conservation district for assistance will be much the same as that for any request. For unorganized groups, signatures of at least two-thirds of the membership should be obtained.

Reconnaissance. - If the group of landowners has retained an engineer, he should be present during a reconnaissance of the proposed project, preliminary survey, meetings of the group, design surveys, planning works of improvement, and construction. After receiving an approved request for assistance, a reconnaissance of the project should be made for use in making recommendations to the group as to the feasibility of the project and the best type of organization. Chapter 2 of this handbook contains information on making the reconnaissance.

Preliminary information. - After the reconnaissance has been made the engineer should report to the group on his findings. He should make this report to the group and not to individuals. The report should be written, but is probably more effective if presented orally. The following points should be covered:

1. The areas within the limits of the proposed enterprise which need drainage.

2. Condition and adequacy of channels below the outlet to receive drainage runoff.

3. Flood, siltation, and erosion hazards.

4. Land capabilities.

5. Other drainage programs which may affect the enterprise.

6. Drainage facilities needed.

7. Discussion of costs and benefits. (This will be very general and based on experience with other drainage programs on the same type of land.)

8. Maintenance required and its probable annual cost.

9. Opinion as to physical and economic feasibility.

10. Recommendation as to type of organization needed to accomplish the job.

Completion of plans for organization. - Following the Service's report on the reconnaissance of the project, the group will have questions and will need to have free discussion of all aspects of the job. Perhaps a lawyer will need to be consulted. It may be necessary for the engineer to examine an alternate proposal. The group should obtain all the information it needs to make a decision or to determine its course of action. The SCS representative should make sure that members of the group understand their responsibilities.

Organization of enterprises

Legal enterprises. - The steps in the organization of a drainage district are prescribed by law and vary between states. Usually the reconnaissance provides sufficient engineering information on which to base a recommendation for the organization. The engineer should study the laws in his state to make sure all essential information is obtained and requirements of timing are complied with.

Drainage associations. - A drainage association can be organized simply by a vote of the members to adopt some simple articles of association. This may be accomplished at the meeting where the report on the reconnaissance by the engineer is presented.

Informal groups. - The formation of informal groups should follow the same procedure as that in the organization of a drainage association. The only differences would be to eliminate the adoption of articles of association and formal election of officers. If the group deemed it desirable, a leader could be elected to represent the group.

Operations after organization

The procedure to be followed after the organization of a legal enterprise is prescribed by law and must be followed.

Further contacts between SCS and the drainage association should be made with the man designated by the association, usually the president.

In the informal group it will be necessary to continue working with all the members of the group. Care should be taken to avoid working with only one individual in an informal group unless he is the designated leader for the group.

Ordinarily after the drainage enterprise is organized, more specific information is needed for further planning. The Soil Conservation Service probably will be called on to provide information similar to that developed in a preliminary survey--see Chapter 2. For very small groups this may be abbreviated but for the larger drainage associations and legal enterprises a full survey and report ordinarily will be justified. Progress reports at critical stages may be advisable so the group can make timely decisions.

The report should be presented orally to the full group. This will set the stage for discussion, decisions on proposed alterations in the plan, time schedules for further action, and financing arrangements.

Further work with a drainage association on design, construction, and maintenance can be handled with the person who has been designated by the association to handle its affairs.

Work with an informal group will need to be taken care of with the group as a whole.

Maintenance of the facility

One of the principal reasons for forming drainage enterprises is to provide for future maintenance of the drainage facilities.

A drainage district is ordinarily better qualified to handle maintenance than the drainage association or informal group. This is because it is a continuing organization and it has the authority to levy taxes for maintenance purposes.

Regardless of the size of the drainage system or type of organization, provisions for maintenance must be made to insure success of the enterprise. The maintenance program should be discussed during the organizational meetings and methods decided on. The design of the system will be based on methods of maintenance to be used.

A maintenance manual should be developed for the enterprise. The manual should describe the items of maintenance likely to be needed, how the maintenance will be accomplished and assign responsibilities. Dates should be set for maintenance inspections of the drainage system at least once each year. Personnel to assist in the inspections should be specified.

Individual farm drainage

Benefits from group enterprises do not accrue to the farmers involved until they have taken advantage of their newly constructed group facilities by draining their land into them. They should be encouraged to install their on-farm ditches and drains as soon as possible after the group facilities are constructed. This is necessary for success of the enterprise.

Drainage System Terms

The following terms, which apply to drainage systems and their various parts, are defined to provide Service personnel with a uniform understanding of their meaning as used in engineering standards and handbooks.

Reporting

This list includes drainage terms which are listed as SCS progress reporting items, but there is a breakdown of some of the reportable items into two or more items. For example, all of the following would be reported as Code 480 - Drainage Main or Lateral:

Stream - when improved as a part of a drainage system by construction to a designed size and grade.

Ditch -

Main Ditch -

Lateral, sublateral, farm lateral, field lateral -

The following would be reported as Code 606 - Drain:

Main Drain -
Submain Drain -
Relief Drain -
Interceptor Drain -

Definitions

Surface drainage
The removal of excess water from the soil surface.

Subsurface drainage
The removal of excess water from below the soil surface.

Stream
A natural waterway. Includes small rivers, creeks, bayous, arroyos, runs, etc., which form part of a drainage system. Improvements may be required but location remains essentially unchanged. Streams should be identified by name or number.

Ditch
An open waterway excavated in the earth to collect and/or convey drainage water. A ditch may carry flow from both surface and subsurface drainage.

Channel
That part of a stream or ditch where the flow of water is carried.

Drain
A conduit, such as tile, pipe, or tubing, installed beneath the ground surface and which collects and/or conveys drainage water.

The outlet
The terminal point of the drainage system, ditch, or drain under consideration.

Vertical drain
A well, pipe, pit, or bore into porous, underground, strata into which drainage water can be discharged. This is also called a drainage well.

Evaporation pond
A pond, with impervious bottom, for storage and evaporation of low quality drainage effluent.

The disposal system
That part of a drainage system which receives water from the collection system and conveys it to an outlet.

Main ditch. - The principal ditch--improved or constructed--serving one or more drainage systems. Main ditches should be identified by name or number.

Lateral. - A major ditch in a drainage system, identified by name or number. A lateral is the link between the main ditch and sublaterals or farm laterals.

Sublateral. - An important branch ditch, tributary to a lateral, and identified by name or number. When needed, it is the link between a lateral and farm laterals.

Farm lateral. - A principal drainage ditch serving only one farm or a major portion of one farm. It is the link between field laterals and the ditch which usually serves a group of farms.

Field lateral. - The disposal ditch serving those fields adjacent to it on one farm. It is the link between the farm lateral and the collection system.

Main drain. - The principal subsurface drain which conducts drainage water from collection drains (see "The Collection System" below) and submain drains to the outlet. The drainage water may be excess surface water collected through surface inlets by the tributary drains and the main drain; or excess ground water collected by subsurface flow into the tributary drains and the main drain.

Submain drain. - A branch drain off the main drain into which collection drains or surface inlets flow.

The collection system - surface drainage
That part of a drainage system which collects excess surface water.

Field ditch. - A graded ditch for collecting excess water within a field. Water may enter it through crop rows or row ditches or by sheet flow over field surfaces.

Furrow. - Crop furrows are small channels developed in the preparation of cropland or in cultivating the crop.

Row ditch. - A small plow or shovel ditch cut each crop season across crop rows at low places to collect water and carry it into a field ditch or field lateral. These are often called annual, quarter, header ditches, etc.

The collection system - subsurface drainage
A system of ditches or drains located to collect excess ground water.

Relief ditch or drain. - A ditch or drain located at the depth and spacing required for control of the water table where the principal source of ground water is from the overlying land and the water table is relatively flat. These are usually drains.

Interceptor ditch or drain. - A ditch or drain located across the flow of ground water and installed to intercept subsurface flow.

Relief well. - A shallow well, which carries water under hydrostatic pressure, upward from a subsurface layer into a ditch or drain.

Pumped well drain. - A well sunk into an aquifer from which water is pumped to lower the prevailing water table.

Mole drain. - An underground conduit formed by pulling a bullet-shaped cylinder through the soil. A mole drain may discharge into either a ditch or drain.

Land forming
The process of changing the surface of the land to facilitate the movement of surface water over a field or a part of a field.

Land grading. - The shaping of the land surface by cutting, filling, and smoothing to planned grades. The primary purpose is to improve land drainage by establishing continuous grades so that runoff will flow over the surface without ponding. In some locations, this practice is called precision grading or land shaping.

Rough grading. - The shaping of the land surface according to judgment "by eye" or by limited use of engineering surveys. This operation may be the first step in land grading.

Land smoothing. - Shaping the land surface to eliminate minor differences in elevation and to smooth out depressions without changing the general contours of the land. The depth of cut in this operation is generally small and limited by the kind of equipment used. Land smoothing is also the finishing operation in land grading.

Land bedding. - Plowing, blading, or otherwise elevating the surface of flatland into a series of broad, low ridges, separated by shallow, parallel dead furrows or field ditches. Also known as "crowning" or "ridging" in some localities.

Land leveling. - The shaping of the ground surface by grading and smoothing to a planned grade and to specifications required to permit the uniform distribution of irrigation water. Land leveling operations improve drainage. In some cases improved drainage may be the initial objective of land leveling and the application of irrigation water a delayed objective.

The diversion system
A ditch system, ditch, or dike which diverts water away from a lower-lying area or prevents water from flooding land.

Diversion ditch. - A graded channel constructed across the land slope to intercept and divert water to a suitable outlet. Its capacity may be enlarged by shaping the spoil into a continuous dike on one or both sides of the ditch.

Dike. - An embankment constructed of earth or other suitable materials to protect land against overflow from streams, lakes, and tidal influences; also to protect flat land areas from diffused surface waters.

Floodway. - A channel, usually bounded by dikes, used to carry flood flows. The dikes confine the flood flow to a small portion of the flood plain.

Water control system
A drainage system designed to regulate inflow and/or outflow of water.

Water control facility. - A ditch, drain, dike, dam, or pump, alone or in combination, and with or without auxiliary water control structures, designed to regulate the flow of water from, through, or to an area for the purpose of controlling the elevation of water.

Structure for water control. - A structure in an irrigation or drainage system for water management that conveys water, controls the direction or rate of flow, or maintains a desired water surface elevation in a natural or artificial channel. Also includes any structure for managing water levels for wildlife or other purposes.

Pumping plant for water control. - A pumping facility installed for removing excess surface or ground water from lowlands, or for pumping from wells, ponds, streams, and other sources.

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