ORGANIZATION OF SUBJECT MATTER

AND DEVELOPMENT OF AN OUTLINE FOR TEACHING A COURSE IN

SOIL AND WATER CONSERVATION

by

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B. S. in Agricultural Engineering
Iowa State College
1938

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A MAJOR THESIS

Submitted to the

Department of Agricultural Engineering
Virginia Polytechnic Institute
Blacksburg, Virginia

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In Partial Fulfillment of the Requirements

For the Degree of

MASTER OF SCIENCE

in

AGRICULTURAL ENGINEERING

September

1939

APPROVED

Course Adviser

APPROVED

Dean of Agriculture
ACKNOWLEDGEMENT

The author wishes to express his appreciation to Professor P. B. Potter of the Agricultural Engineering Department for his guidance and inspiration in the conduct of this study.

He is also indebted to the following men of the Agricultural Engineering Department who freely gave of their time and advice: Professor C. E. Seitz, Head of the Department, Professor S. H. Byrne, Course Adviser, Professor J. W. Sjogren, and Mr. U. F. Earp.

Sincere thanks are extended to and of the Experiment Station, and to Dr. T. B. Hutcheson, Head of the Agronomy Department, for their helpful suggestions.

Melvin E. Blessing
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Organization of Subject Matter and Development of an Outline for
Teaching a Course in Soil and Water Conservation

INTRODUCTION

Since this broad subject is now neither organized nor outlined, there is a particular need for a definite outline of material for teaching this course at Virginia Polytechnic Institute. The proposed outline, by eliminating overlapping subject matter, and by making use of the great abundance of experimental data and written material, will make it possible to give students a broad understanding of the fundamentals of the course in the short time allotted. This arrangement will also eliminate the necessity for students to purchase text books covering all the divisions, which is undesirable from an economic standpoint even if satisfactory texts were available. For the above reasons there is an urgent need to have in the department an up-to-date outline for the use of any instructor teaching the course.

The purpose of this outline is to enable the Agricultural Engineering Department to offer an improved course in Soil and Water Conservation. In order to promote more efficient teaching, it seems desirable to combine the subjects of Soil Erosion, Drainage, Flood Control, and Irrigation in one course. The flexible nature of the outline method of presentation permits the inclusion of up-to-date material and will facilitate future revision.

The organization and development of material is, therefore, taken up as a thesis subject in the hope that a real contribution may be made to the work of the department, as well as to any instructor desiring to install a course of this kind.
OBJECTIVES

Considering the above statements, this problem has been planned with the following objects in mind:

1. To assemble all available material on soil and water conservation, select that which is usable, and organize the same into logical divisions.

2. To develop an outline of the material that will promote more efficient teaching and facilitate the study of the subject.

3. To compile a bibliography of all selected references as well as a representative list of problems covering the entire subject.
PROCEDURE

Preliminary Review: The preliminary work of this study consisted of a survey of all available material on the subject. The agricultural branch of the Virginia Tech library, the Agricultural Engineering Departmental library, the personal libraries of Mr. J. H. Hillard, Professor J. W. Sjogren, and of the author, along with the numerous publications of the U.S.D.A., the Soil Conservation Service, and other governmental agencies, all were fruitful sources of information.

A review was made of several bibliographies containing over 10,000 references on the subject. These proved convenient in locating information on a particular topic. The U.S.D.A. Miscellaneous Publication 312, a "Bibliography on Soil Erosion and Soil and Water Conservation", which included short abstracts of four thousand three hundred eighty eight articles was particularly useful.

Organization of Subject Matter: After assembling and selecting the material, it was organized into logical divisions. Since the source, as outlined, consists of a combination of Erosion Control, Drainage, Irrigation, and certain pertinent minor subjects, it seemed practical to organize the outline into four divisions, namely: General, Drainage, Erosion Control, and Irrigation. The General section was placed first in order to introduce subjects such as Hydraulics and Soils which are more or less common to the other divisions. Also, certain subjects like Flood Control and Agricultural Law, which of necessity have to be minimized in this condensed course, and which were not sufficiently important to make up a major section alone, were placed in the General section. The other three major divisions were arranged alphabetically, placing Irrigation
last. It is suggested that, if class time is limited, it would be better
to omit the subject matter on Irrigation than on any other major topic,
because irrigation is of lesser importance in this particular section of
the country. Since the last topic would generally be stressed least,
irrigation was placed last in the series. Due to the importance of
Erosion Control as a current, national issue, it was given special emphasis.
The abundant material in the outline should facilitate a rather comprehensive
treatment of this subject. The above organization proved the most conven-
ient and usable of several tentative plans.

Lessons: The four major divisions were divided into suitable sub-
topics to be used as lesson headings. The particular sequence of lessons
was chosen so as to introduce fundamental subjects first. For example,
"Fundamentals of Soil Science" precedes the lesson on "Rainfall and Runoff".
This arrangement permits the teaching of properties of soils before explain-
ing the action of the soil when exposed to rainfall.

In outlining any lesson, an attempt was made to cover the important
phases of the topic regardless of the length of the lesson; consequently,
some of the lessons are rather long for one assignment. It is suggested
that the instructor assign part of a lesson for the student's class prepar-
ation and cover the remainder of the lesson in his lecture. Another
possibility is to lecture on the high points of the entire lesson, and
require the students to study the details from references.

Since this is an outline and not a textbook, subject matter
details are purposely omitted. The lesson outlines are double spaced
for better appearance and to furnish space for the insertion of notes.
One or more references are listed at the beginning of each lesson. These references were chosen because they seemed to cover the subject most adequately. For convenience in finding a reference, the card index number is included with each one.

Filing System: The original plan was to file all the cards alphabetically by author. Then the plan of arranging material entirely by topic was tried. A combination of the two plans seems to make the material most accessible. The lessons were arranged in alphabetical order by subjects; then the references under each lesson were arranged alphabetically by author. Cards of the card index system were made out in the standard form used by most libraries.

Problems: The introduction of appropriate problems was made one of the major objectives of this outline for two main reasons. First, the Agricultural Engineering graduate must be prepared to solve practical problems. Second, the problem method is considered an effective means of presenting the subject matter.

In order to be most effective, problems must be introduced at the opportune time. Therefore, at the end of each lesson, references are made to problems that have a particular bearing on the topics covered. The problems are of a type that will emphasize the importance of engineering fundamentals and give the student a worthwhile use of preparatory subjects such as trigonometry, the calculus, and hydraulics.

Many of the problems are modifications of those found in reference texts. Other problems and questions are of the type given in recent Civil Service examinations.
**Special References:** For convenience in looking up subject matter, the material directly referred to in the lessons was listed in the Special Reference section. The method of choosing these references is explained under "Lessons."

**Selected Bibliography:** One of the most difficult problems of this study was to include in the bibliography the best articles from among the thousands that have been written. An attempt was made to select material by authors of known repute. U.S.D.A. Technical and Farmer's Bulletins were found to be very accurate and practically indispensable to this outline. Many college and experiment station publications proved valuable. The articles chosen from the Agricultural Engineering Journal were listed in chronological order under each of the four major divisions of the subject. These articles form a separate section of the bibliography, and are not included in the card index system. It did not seem feasible to make up cards for over three hundred articles obtained from the Agricultural Engineering Journal. In order to limit the number of articles from the Journal and, at the same time, include those of most importance, most of these articles were selected from the Journals published since 1930.

**Special Library:** The indexed material on file is, in reality, a small library on Soil and Water Conservation. The instructor who has charge of this library is urged to add new material whenever possible and thus make it more complete and keep it up-to-date. It is felt that this library is a real contribution to the Department and to the Soil and Water Conservation course.
LESION TOPICS

I. General Topics

1. Fundamentals of Soil Science
2. Rainfall and Runoff
3. Measurement of Water
4. Open Ditches—Design, Location, Construction, and Maintenance
5. Dams
6. Explosives and Their Use
7. Clearing Land
8. Flood Control
9. Flood Control
10. Useful Principles of Law

II. Drainage

11. Subsurface Drainage; Location and Design of Tile Drains
12. Design and Cost of Tile Drains
13. Tile—Selection, Installation, and Accessories
14. Special Methods of Drainage; Tile-Trenching Machinery
15. Drainage of Irrigated Lands
16. Drainage Districts

III. Erosion Control

17. Introduction
18. Factors Affecting Rate of Erosion
19. Methods of Control
20. Terrace Design
21. Terrace Location; Principles and Practices
22. Terrace Construction Methods and Machinery
23. Terrace Construction Costs and Maintenance
LESSON TOPICS cont'd.

24. Terrace Outlets: Control of Collies

25. Check Dams and Soil Saving Dams

26. Special Uses of Vegetation

27. Wind Erosion

IV. Irrigation

28. Fundamental Principles of Irrigation

29. Spray Irrigation

30. Sprinkling and Porous Hose Methods of Irrigation

31. Federal Irrigation Projects

32. Federal Irrigation Projects
SOIL AND WATER CONSERVATION OUTLINE

GENERAL SECTION
Lesson 1

FUNDAMENTALS OF SOIL SCIENCE

Reference: Soils and Men

A. Soil and Society, pp. 865-866
   1. Soil and Landscape
   2. Agricultural Techniques
   3. Race and Soil
   4. Changes in society
   5. Movement of the people
   6. Development of soil science
   7. Future development

B. Physical Nature of the Soil, pp. 887-896
   1. Soil profile
   2. Solid, liquid, and gaseous components of the soil
   3. Color, texture, and structure

C. Water Relations of the Soils
   1. Movement of soil water
   2. Forms of soil water
   3. Field capacity
   4. Wilting coefficient
   5. Relative volumes of soil material, air, and water
   6. Storage and conservation of available water
      a. Amount of capillary rise
      b. Muleh theory
   7. Soil moisture losses
      a. Runoff
Lesson 1 cont'd.

b. Evaporation
c. Transpiration
d. Percolation

8. Plasticity

9. Effect of soil chemical properties upon soil water

D. General Chemistry of the Soil, pp. 911-915

1. Elements of soil chemistry
   a. Silicon compounds
   b. Ten essential elements
   c. Important minor elements
   d. Soil colloids
   e. Base exchange
   f. Soil acidity—pH
   g. Soil solution

E. Soil Organic Matter and Soil Humus, pp. 929-939

1. Composition of organic matter and humus

2. Mineralization

3. Accumulation of organic matter and humus

4. Factors governing content and nature of soil humus
   a. Original quality
   b. Rate of decomposition
   c. Humus under different types of formation
      (1) Grasslands
      (2) Forests
      (3) Deserts

5. Distribution of humus in the soil

6. Soil organic matter and soil productivity
Lesson 2

RAINFALL AND RUNOFF


A. Precipitation

1. Relation of intensity, area, and duration

2. Relation of magnitude and intensity to frequency of recurrence

3. Critical rate for runoff

B. Annual Precipitation

C. Factors Affecting Runoff

1. Rainfall characteristics

Rainfall intensities

2. Watershed characteristics governing the amount and rate of runoff

a. Type

b. Erosive condition

c. Physical nature of the soil

d. Degree and length of slope

e. Distribution and kind of vegetal cover

f. Size and shape of drainage area

g. Existence of channels

3. Time of concentration

D. Rational runoff formula

1. \( r = CIA \)

2. Values of \( C \)

E. Runoff in Terrace Channels—Reductions in value of \( C \) for terraced watersheds
Lesson 2 cont'd.


- Sources of Moisture for precipitation in the United States
  1. Effect of soil conservation practices on return of rainfall to the ocean
  2. Aerometeograph
  3. Continental evaporation and precipitation
  4. North American air masses and their source regions
  5. The cycle of air masses
  6. The hydrologic cycle
  7. Atmospheric moisture and precipitation
     a. Rainfall and absolute amount of moisture
     b. Local rainfall from local supply of moisture
     c. Variability of rainfall
  8. Calculation of depth of water in atmosphere
  9. Atmospheric moisture relations
     a. Sources of atmospheric moisture
     b. Air-mass invasions
  10. Summary

Problems: 1, 2, 3, 4, and 5
Lesson 3

MEASUREMENT OF WATER

Reference: Kringold: Runoff from Small Drainage Basins (R-4 v. II) pp. 18-31

A. Measuring Runoff—Details of Instrumentation and Procedure

1. Selection of sites and establishment of studies

2. Instrumentation and methods used in securing the data

Runoff hydrographs

3. Precipitation records

4. Permanent characteristics of the drainage basins

5. Variable conditions of the drainage basins

6. Computation and dissemination of data

Reference: Kulp: Farm Water Measurement (Meas. 5) pp. 1-22

B. Water Measurement

1. Units used for measuring rate of flow

2. Standard conditions for weirs

3. Construction and setting of weirs

4. Weir scales or gages

5. Operation of weirs

6. Advantages and disadvantages of weirs

7. Types of measuring devices

   a. Rectangular weir

   b. Cipolletti weir

   c. 90° triangular weir

   d. Suppressed weir

   e. Submerged orifice

   f. Parshall measuring flume (Venturi flume)
Lesson 3 cont'd.

Reference: King and Wisler: *Hydraulics*

G. Flow of water in open channels, pp. 176-191

1. Description and definition of open channels
2. Wetted perimeter and hydraulic radius
3. Function and distribution of velocities
4. Energy contained in water in an open channel
5. Continuity of flow in open channels
6. Loss of head
7. Hydraulic gradient or water surface
8. Loss of head due to friction in open channels
9. Chezy formula
10. Kutter formula
11. Manning formula
12. Comparison of Manning and Kutter formulas
13. Cross-section of greatest efficiency, pp. 198-200 (Par. 125)
14. Backwater, pp. 204-206 (Par. 128)

Problems: 6, 13
Lesson 4

OPEN DITCHES: DESIGN, LOCATION, CONSTRUCTION, AND MAINTENANCE

Reference: Ayres and Seates: Land Drainage and Reclamation

A. Design, pp. 118-124

1. Velocity of flow
2. Discharge
3. Number of acres ditch will drain
4. Side slopes
5. Selecting velocity for open ditches
6. Desirable cross-section
7. Determining the size of ditch for a given area
8. Depth of water in ditches

B. Location and Construction, pp. 126-140

1. Reconnaissance survey
2. Preliminary survey
3. Location of open ditches
4. Laying out curves for open ditches
5. Construction methods and machinery
   a. Digging ditches by hand
   b. Digging ditches with scrapers
   c. Drags as ditches
   d. Road graders as ditches
   e. Elevating graders as ditches
   f. Dredges
      (1) Floating-dipper dredge
      (2) Land dredge
      (3) Hydraulic dredge
Lesson 4 cont'd.

g. Dragline excavator

h. Ditching with dynamite

6. Ditch berms and waste banks

A. Maintenance, pp. 141-156

1. Introduction

2. Prevention of siltation

3. Soil washing

4. Diversion ditches

5. Settling basins

6. Control of silt by flooding

7. Caving banks

8. Restoration methods---clean-out work

9. Enlarging outlets

10. Tributary inlets

11. Control of vegetation

12. Care of spoil banks

13. Bridges

14. Maintenance

Reference: Boulder Dam, folder (Dams 3)

D. All-American Canal---America's greatest irrigation ditch

Problems: 14, 19
Lesson 5

DAMS AND RESERVOIRS

Reference: Bureau of Reclamation; Boulder Dam (Dams 3)

A. Boulder Dam

1. History
2. Statistics—what you will want to know
3. How Boulder Dam works
4. Achievements
5. Lake Mead
6. Domestic water
7. Irrigation
8. River flow
9. Plan of repayment

Reference: Bureau of Reclamation; Grand Coulee Dam (Dams 4)

B. Grand Coulee and the Columbia Basin

1. Type and size
2. Comparative size
3. Columbia River storage basin
4. Power and irrigation
5. Power plant
6. Pumping on the Columbia Basin project
7. Balancing reservoir in the Grand Coulee
8. Lands to be irrigated

C. Details of Construction of the Grand Coulee Dam (Dams 5)
Lesson 5 cont'd.


D. Reservoirs for farm use

1. Use of farm reservoirs
2. Water supply
3. Choosing the site
4. Legal requirements
5. Earth dams
6. Protection of earth embankments
7. Rock fill dams
8. Concrete dams
9. Outlet and inlet structures
10. Spillways
11. Reservoir losses
12. Prevention of silting (Dams 5, additional reference)
13. Maintenance

Note: Check Dams and Soil Saving Dams are included under Gully Control

Problems: 20, 24
Lesson 6

EXPLOSIVES

Reference: Ayres and Sevates—Land Drainage and Reclamation, pp. 202-232
Powder Co. Manual

A. Explosives and their Use

1. Introduction
2. Kinds of explosives
3. Action of explosives
4. Strength of explosives
5. Explosives and water
6. Firing explosives
7. Where to use different kinds of explosives
8. Hauling explosives
9. Storing explosives
10. Using explosives
11. Frozen explosives
12. Explosive accessories
13. Blasting caps
14. Dampproof fuses
15. Cap crimper
16. Electric blasting caps
17. Blasting machines
   a. Leading wire
   b. Connecting wire
   c. Galvanometer and rheostat
18. Tools for agricultural blasting
Lesson 6 cont'd.

19. Priming with cap and fuse
   a. Attaching blasting cap to fuse
   b. Priming cartridges in side

20. Priming with electric blasting caps

21. Loading

22. Tamping

23. Firing by electricity

24. Handling misfires

25. Blasting stumps
   a. Taprooted stumps
   b. Semi-taprooted stumps
   c. Large lateral rooted stumps

26. Methods of blasting boulders
   a. Block holing
   b. Snake holing
   c. Mud capping
   d. Seam blasting

27. Table of charges for blasting boulders

28. Blasting ditches

29. Propagation method of blasting

30. Electrical method of blasting
Lesson 7
CLEARING LAND

References: Ayres and Moscato, Land Drainage and Reclamation, pp. 255-275.

A. Clearing Land of Brush
1. Introduction
2. Economic consideration
3. First step in preparation
4. Grazing
5. Missouri method of grazing
6. Advantages of grazing
7. Cutting and burning
8. Salvaging firewood
9. Southern method
10. Fire hazards
11. Economic advantage of burning
12. Effects of fire on fertility
13. North Carolina method
14. Mississippi method
15. Western methods
16. Eastern methods
17. Plows and plowing
   a. Kinds of plows and tractor
   b. Wisconsin plow
   c. Minnesota practice
   d. Handling palmetto
   e. Large plows
   f. Advantages and disadvantages of plowing
Lesson 7, cont'd.

B. Clearing Land of Stumps

1. Advantages and disadvantages of grubbing

2. Burning
   a. Power augers
   b. Powder splitting
   c. Burning roots
   d. Char-pitting
   e. Synekt burner
   f. Hood burner
   g. Washington stump burning machine
   h. Conclusions as to burning

3. Pulling
   a. Low power pullers
   b. Twisting device
   c. whip
   d. Wattle puller
   e. Requisites of a good stump puller
   f. Hand pullers
   g. Horsepower pullers
   h. Tractor attachment
   i. Large machines
   j. Advantages and disadvantages of pullers

4. Decay of stumps

5. Use of poison

6. Disposal of the stump

7. Selection of the most appropriate method of clearing land
Lesson 8

FLOOD CONTROL

Reference: Soils and Men, pp. 109-110

A. Effect of soil erosion on floods, navigation water, power development, and water conservation

1. Possible relation between soil erosion and floods

2. Relation between erodibility and runoff
   a. Yancey River in Mississippi
   b. Appalachian Region near Asheville, N. C.
   c. Cooper Basin, Texas
   d. Verdugo and Maines Canyons in Los Angeles County, California
   e. Santa Clara Valley of California
   f. Tyler, Texas
   g. Bethany, Missouri
   h. Zanesville, Ohio
   i. Guthrie, Oklahoma

3. Relative importance of denudation as compared to other causes of floods

4. Effect of a combination of frozen ground, melting snow, and concentrated rainfall

5. Comparison of old and new flood deposits

6. Sedimentation and its effect on navigability of streams

7. Sedimentation of reservoirs
   a. New River in Virginia
   b. Lake Vase in Brazos River in Texas
   c. Lake Taneycomo on White River in Missouri
   d. Lake Decatur on Sangamon River in Illinois
   e. Elephant Butte Reservoir on Rio Grande River in New Mexico
Lesson 8 Cont'd

8. Predicted average life of reservoirs

9. Effect of increased runoff on ground water supply
Lesson 9

FLOOD CONTROL


B. Protection of Land from Flood Waters

1. General topographic conditions
2. General plan of flood protection by levees
3. General flood control plan
   a. Levee system
   b. System of overflow weirs or spillways
   c. Channel improvement
   d. Detention reservoirs
4. Flood control plan for the Sacramento River
5. Flood control plan for the Mississippi River
6. Levee protection for topographic units
7. Location, spacing, and height of levees
8. Alignment of levees
9. Levee cross-sections and dimensions
10. Freeboard, berm, banquette
11. Side slopes and crown width of levees
12. Preparation of levee foundation
13. Borrow pits
14. Shrinkage of material and settlement of levees
15. Protection of water-side slope of levees
16. Interior drainage
   a. General plan
   b. Storage in drainage system

Problems: 25 and 26
Lesson 10

USEFUL PRINCIPLES OF LAW

Reference: Ayres and Soates: Land Drainage and Reclamation

A. Useful Principles of Law, pp. 190-201.

1. What the waters of the farm comprise
2. Bodies of water
3. Watersources
4. Navigable streams
5. Pleatable streams
6. What is meant by riparian
7. Riparian rights
8. Riparian duty to refrain from polluting the stream
9. Riparian right to access and wharfs
10. Surface waters defined
11. Disposal of surface water
12. Restrictions on the disposition of surface waters
13. Underground and percolating waters
14. Ice
15. Liabilities for casualties
16. Essential features of drainage contracts
   a. Material changes
   b. Engineer's authority
   c. Agreement
   d. Representation
   e. Consideration
   f. Assignment
   g. Interpretation of contracts
Lesson 10 cont'd.

h. Principles of construction
i. Subchanges and agreements
j. Discharge of contracts

17. Specifications

18. Where contract blanks may be obtained

Reference: Soils and Men. pp. 296-318

B. The Soil and the Law

1. Our federal system—powers and limitations

2. State soil conservation districts laws
   a. State or Nation
   b. Due process and the police power
   c. Due process and public purpose
   d. Delegation of legislative power

3. The Agricultural Adjustment Program
   a. The general spending power
   b. The decision in United States v. Butler

4. The Agricultural Conservation Plan

5. The Agricultural Adjustment Act of 1938

6. Present trends and needs
   a. The judge and the constitution
   b. Need of constitutional amendment
SOIL AND WATER CONSERVATION OUTLINE

DRAINAGE SECTION
Lesson 11

SUBSURFACE DRAINAGE: LOCATION AND DESIGN OF TILE DRAINS

Reference: Ayres and Stretch: Land Drainage and Reclamation

A. Subsurface Drainage, pp. 320-329

1. Definition of subsurface drainage
2. Methods used in subsurface drainage
   a. Natural
   b. Surface ditches
   c. Use of poles and stones
   d. Use of tile
3. Benefits of subsurface drainage
4. Benefits dependent on adequate surface drainage
5. Soil-water characteristics
   a. Ground-water table
   b. Shape of ground-water table
   c. Velocity of surface water
   d. Velocity of underground water

B. Location of Tile Drains, pp. 330-341

1. Tile-drainage terms
2. Methods of survey
3. Locating tile with the topographical map of the field
4. Staking out drains
5. Obtaining grades
6. Systems of tile drains
   a. Natural system
   b. Cutoff system
   c. Elkington system
   d. Herringbone system
Lesson 11 Cont'd.

e. Gridiron system
f. Double main system
g. Grouping system
h. Across-the-slope system

7. Selection and design of the system
8. Theory of spacing and depth of tile drains
9. Spacing for tile drains
10. Depth of the drains
11. Grade for tile drains

Problems: 27, 30
Lesson 12

DESIGN OF TILE DRAINAGE: ESTIMATION OF COST

Reference: Ayres and Seates: Land Drainage and Reclamation

A. Design of Tile Drains, pp. 342-351
1. Flow of water in tile drains
2. Factors governing discharge
3. Velocity formulas
   a. \( V = \frac{1.852}{S^{1/2}} \)
   b. \( Q = aV \) and \( A = Q/A \)
4. Use of tile size chart
5. Selection of drainage coefficient for tile
6. Size of laterals
7. Size of mains and sub mains
8. Sample drainage report

B. Estimating Cost of Tile Drainage
1. Preliminary estimate of cost
2. Bill of materials
3. Estimating cost
   a. Cost of tile
   b. Cost of hauling
   c. Cost of installing tile
      (1) Common method of estimating installation cost
      (2) Man-hour basis
   d. Cost of accessories
   e. Cost of engineering and supervision

Problems: 26, 38
Lesson 13

TILE: SELECTION, INSTALLATION, AND ACCESSORIES

Reference: Ayres and Sessions: Land Drainage and Reclamation

A. Selection of Tile, pp. 352-353

1. Essentials of good drain tile
2. Regular tile
3. Dense tile
4. Strength and soundness
5. Kinds of tile
   a. Clay tile
   b. Concrete tile
6. Concrete v. clay tile

B. Installation of tile, pp. 359-374

1. Methods of establishing grade
   a. Water method
   b. Sighting method
   c. Line-and-gage method
   d. Line-and-rod method
2. Digging the ditch
   a. Machine ditching
   b. Hand ditching
3. Laying tile
4. Checking grade
5. Backfilling
6. Specifications for laying tile drains

C. Drain-tile accessories, pp. 375-382

1. Outlet construction
   a. Protection against caving banks
   b. Protection against small animals
Lesson 13 cont'd.

e. Protection against backwater
d. Protection against tramping by stock
e. Protection against freezing and thawing

2. Surface inlets

3. Silt basins

Problems: 34, 35
Lesson 14

SPECIAL METHODS OF DRAINAGE: TILE-TRENCHING MACHINERY

Reference: Ayres and others: Land Drainage and Reclamation

A. Special Methods of Drainage, pp. 393-399

1. Vertical drainage
2. Trench ditches
3. Draining cellars
4. Draining barnyards
5. Draining roads
6. Drainage as an antimalarial measure
7. Drainage of pest and muck marshes


B. Tile-Trenching Machinery

1. Requisites of a good machine
2. General classes of trenching machines
   a. Plows
   b. Wheel excavators
   c. Endless-chain excavators
   d. Scraper excavators
4. Cost of trenching machinery
5. Selecting a trenching machine

Problem: 31
Lesson 15

DRAINAGE OF IRRIGATED FARMS

Reference: U.S.D.A. Farmer's Bul. 800, (p-4a): The Drainage of Irrigated Farms

A. Drainage and Irrigation, pp. 1-50.

1. Need for drainage of irrigated lands
2. Beneficial results of draining irrigated lands
3. Subsurface investigations
4. Required depth of drains
5. Spacing and location of drains
6. Types of drains
7. Sizes of drains
8. Construction methods
9. Devices
   a. Bulkheads and outfalls
   b. Manholes
   c. Observation wells
   d. Angle boxes
   e. Surface inlets and flushing wells
   f. Flumes
   g. Relief wells
10. Costs
11. Alkali reclamation
12. Maintenance

Problems: 32, 36, 37
Lesson 16

DRAINAGE DISTRICTS

Reference: Ayres and Scoates: Land Drainage and Reclamation

A. Drainage Districts, pp. 170-189

1. Purpose of drainage districts

2. Fundamental principles of drainage districts

3. Procedure in organizing a drainage district

4. The preliminary report

5. The hearings

6. Establishment of district

7. Estimation of benefits

8. Basis for estimate of benefits
   a. Elevation and classification of land
   b. Proximity to main drain
   c. Distance to natural outlet
   d. Thoroughness of drainage
   e. Soil fertility

9. Records of estimates

10. Assessment of lands in accordance with benefits received
    a. Arbitrary assessment
    b. Uniform cost per acre and ad valorem assessments
    c. Assessment on basis of increased land values
    d. Assessment by classification
    e. Assessment on basis of 100
    f. Assessment on percentage basis

11. Benefits to railroads, highways, town lots, etc.
12. Appraisal of damages
   a. Damages to land
   b. Damages to highways and railroads
13. Estimating the cost of drainage districts
14. The assessment roll
15. Levy of drainage tax
16. Financing of drainage districts

Problems: 29, 33
SOIL AND WATER CONSERVATION OUTLINE

EROSION CONTROL SECTION
Lesson 17

SOIL EROSION - INTRODUCTION

Reference: Ayres, Soil Erosion and Its Control

A. Introduction, pp. 1-19

1. Significance of erosion
   a. Old-world object lessons
   b. Extent of erosion in the U.S.A.

2. Erosion inventory in the U.S.A.

3. Benefits of erosion control

4. Justifiable annual expenditure

5. Types of erosion
   a. Water erosion
      (1) Sheet erosion
      (2) Incipient or finger gullying
      (3) Gully erosion
      (4) Stream erosion
   b. Wind erosion - wave action

6. Combating agencies

Reference: Soils and Men, pp. 84-103.

B. The Problem: The Nation as a Whole

1. The nature and extent of soil losses
   a. Nature of soil losses
   b. Changes in physical condition
Lesson 17 cont'd.

c. Losses of plant nutrients
   (1) Through cropping
   (2) Through leaching
   (3) Through erosion

d. Significance of various losses

e. Erosion reconnaissance survey

f. Land suitable for cultivation

2. Effect of soil losses on crop yields
   a. Influence of improved cultural techniques
   b. Evidence from old field experiments
   c. Effects of erosion on crop yields

Problem 52
Lesson 18

FACTORS AFFECTING RATE OF EROSION

Reference: Ayres, Soil Erosion and Its Control

A. Factors Affecting Rate of Erosion, pp. 20-38

1. Effect of rainfall on runoff
2. Effect of land slope on runoff
3. Effect of soil variables
   a. Soil tests
      (1) Moisture equivalent
      (2) Colloid content
      (3) Dispersion ratio
4. Effect of vegetation
   a. Forests
   b. Grass cover crops and cultivation
5. Effect of frost action
6. Miscellaneous factors: \( E = f(GSTV) \)

Reference: Agricultural Education, Vol. 13, no. 7 and 8, (Slopes-1)

B. The significance of Land Slopes, pp. 100-130

1. The relation of degree of slope to erosion losses
2. The relation of length of slope to erosion losses
3. The relation of slope to soil conservation practices
4. The relation of slope to land uses
5. The relation of slope to cropping systems
6. The relation of slope to tillage practices

Problems: 44, 45
Lesson 19

SEASON CONTROL METHODS

Reference: Ayres; Soil Erosion and Its Control

A. Methods of Control, pp. 39-62

1. Use of vegetation
2. Crop rotation
3. Contour farming
4. Basin listing
5. Use of explosives
6. Chisel cultivation
7. Strip cropping
   a. Width of strips
   b. Permanent contour markers
   c. Protection of gullies
   d. Strip cropping with terraces
   e. Strip cropping to facilitate terracing
   f. Width and arrangement of strips
   g. Advantages of strip cropping
   h. Disadvantages of strip cropping
8. Permanent pastures
   a. Grass lands
   b. Contour ridging
9. Forests and woodlots
10. Use of terraces
11. Correlation of methods

Problems: 49, 53
Lesson 20

TERRACE DESIGN

Reference: Farmer's Bulletin 1789; (Terr. 10) Terracing

1. Terracing for Soil and Water Conservation, pp. 1-32
   1. Introduction
   2. Terracing in an erosion control program
      a. Terracing and agronomic control measures
      b. Terracing experiments at the soil and water conservation experiment stations
   3. Hydraulics of terrace design
      a. Surface slope
      b. Rate of runoff
      c. Velocities in terrace channels
   4. Types of terraces
      a. Drainage type
      b. Absorptive type
      c. Fence type

Reference: Ayres: Soil Erosion and Its Control

5. Terrace Design, pp. 100-119
   1. Terrace types
   2. Design principles
   3. Terrace spacing
   4. Terrace grades
      a. Level terraces
      b. Graded terraces
      c. Special gradient tables
Lesson 20 cont'd.

5. Length of terraces

6. Terrace cross sections
   a. Capacity formula
   b. Shape of channel
   c. Depth of flow
   d. Dimensions of cross section

Problems: 47, 48, 50, 51
- 45 -

Lesson 21

TERRACE LOCATION: PRINCIPLES AND PRACTICES

Reference: Ayres: Soil Erosion and Its Control

A. Terrace location - Principles and Practices

1. Economics of terracing, pp. 120-124

2. Application of level to terrace layout, pp. 131-134

Reference: Farmer's Bulletin 1789, (Terr. 10)

B. Terracing for Soil and Water Conservation, pp. 22-33

1. Planning the terrace system
   a. General considerations
   b. Terracing and soil types
   c. Terracing and cultural practices
      (1) Tillage equipment and terrace design
      (2) Cropping practices and terrace design

2. Terrace specifications
   a. Limiting land slopes
   b. Spacings
   c. Lengths
   d. Cross sections

3. Terrace staking, realignment, and marking
   a. Preliminary staking
   b. Realignment of terrace lines
   c. Marking terrace lines

Problem: 54
Lesson 22

TERRACE CONSTRUCTION METHODS AND MACHINERY

Reference: Ayres: Soil Erosion and Its Control

A. Methods and Machinery, pp. 155-164

1. When to terrace

2. Construction methods

   a. Making pilot cut

   b. Direction earth should be moved

   c. Preliminary preparation

   d. Construction details

3. Construction equipment

   a. Terracing plows

   b. Steel V-drag

   c. Light terracing graders

   d. Four wheel graders

   e. Special terracing graders

   f. Heavy elevating graders

   g. Light elevating grader

   h. Multiple disk plow

   i. Whirlwind rotary terracer

4. Completion and checking of terrace grades

   Specifications for use in checking construction of terraces

Problems: 40, 41
Lesson 25

TERRACE CONSTRUCTION COSTS AND MAINTENANCE

Reference: Ayres: Soil Erosion and Its Control, pp. 165-186

A. Cost of Terracing

1. Variable factors
2. Effect of variation in implements and power
3. Whirlwind rotary terracer
4. Light elevating grader terracer
5. Two-wheel blade graders
6. Heavy equipment
7. Miscellaneous equipment
8. Form for cost data

B. Terrace cultivation and maintenance

1. Plowing terraced land
2. Row crops and terraces
   a. Contour farming with terraces
   b. Crop stripping with terraces
   c. Key terrace farming
   d. Straight-row farming
3. Farming terraced land - Farmer's Bulletin 1789
   (Terr. 18), pp. 56-59
Lesson 24

TERRACEOUTLETS: CONTROL OF GULLIES


A. Terrace Outlets, pp. 187-201

1. Location
2. Natural outlets
3. Constructed outlets
4. Channel design
5. Vegetative control
6. Suitable vegetative species
7. Establishing vegetation
8. Outlet structures

B. Control of Gullies, pp. 202-216

1. Terminology
2. Treatment of small gullies
3. Principles governing the use of check dams
   a. Notch capacity required
   b. Height of check dams
   c. Spacing of check dams
   d. Other design factors
4. Overfall protection
   a. Use of brush
   b. Flumes
   c. Paved channel
   d. Watertight structures
   e. Diversion ditches

Problem: 43
Lesson 25

CHECK DAMS AND SOIL-SAVING DAMS


A. Temporary and Semi-permanent Check Dams, pp. 217-234

1. Brush dams
   a. Single-post row; longitudinal brush
   b. Double-post row; crosswise brush
   c. Pole type

2. Roven-wire dams
   a. V-type
   b. Suspended-net type
   c. Fixed-basker type

3. Cost comparison of wire and brush dams

4. Semi-permanent check dams
   a. Loose-rock dams
   b. Log dams
   c. Flank check dams

B. Permanent or Soil-Saving Dams, pp. 235-272

1. rubble masonry dams

2. Concrete dams; design

3. Earth dams
   a. Location
   b. side-spillway dams
   c. drop-inlet dams

4. Pondage fill

5. Storage dams

6. Drop inlets on existing culverts

Problem: 42
A. The Use of Vegetation in Erosion Control, pp. 273-302

1. Gully control

   a. Trees in gully control
      
      (1) Advisability of tree planting
      (2) Check dams for gully planting
      (3) Sloping gully banks
      (4) Tree planting
      (5) Tree species

   b. Shrubs in gully control

   c. Vines in gully control
      
      (1) Rudaw
      (2) Wild honeysuckle
      (3) Himalaya blackberry

   d. Grasses in gully control

2. Stream bank protection

   a. Forms of bank cutting

   b. Remedies for bank cutting
      
      (1) Inclined tree planting
      (2) Retards
      (3) Woods system

   e. River bank protection

3. Eroded material in the lower Mississippi River
Lesson 26 cont'd.

Reference: U.S.D.A., Farmer's Bulletin No. 1760 (Veg. 22)

8. The Use of Bluegrass sod in the Control of Erosion

1. Securing bluegrass stands
2. Sodding
3. Use of sod in bags
4. Stabilizing gully banks with bluegrass sod
5. Sod check dams
6. Sod headers
7. Seeding and sodding terrace outlets
8. Grassed waterways
9. Maintenance of bluegrass sod

Problem: 46
A. Preventing Soil Blowing on the Southern Great Plains

1. The area and the problem

2. Implements useful in preventing soil blowing
   a. One-way disk
   b. Field or duckfoot cultivator
   c. Rotary rod weeder
   d. Lister
   e. Spring-tooth harrow
   f. Packer
   g. Sugar-beet cultivator
   h. Chisel
   i. Road scarifier
   j. Other implements or devices

3. Winter wheat farming practices
   a. Preparing the soil for planting
   b. Seeding wheat
   c. Cultivation after seeding
   d. Abandonment of winter wheat
   e. Fallow for winter wheat

4. Cultivation for row crops
   a. Handling sorghums and cotton to prevent soil blowing
   b. Handling beans and cowpeas to prevent soil blowing

5. Strip cropping
6. Shelterbelts
7. Rangelessing
SOIL AND WATER CONSERVATION OUTLINE

IRRIGATION SECTION
Lesson 28

FUNDAMENTAL PRINCIPLES OF IRRIGATION


A. Fundamental Principles of Irrigation, pp. 1-36

1. Selecting land for an irrigated farm
   a. Climate and crops
   b. Surface features
   c. Soil conditions

2. Water supplies and water rights
   a. Natural streams
   b. Large canals
   c. Reservoirs and pumping plants

3. Supplementary irrigation—definition

4. Measuring water—units
   a. Capacities of farm ditches
   b. Capacities of flumes
   c. Capacities of pipes

5. Constructing farm ditches
   a. Velocity and discharge tables
   b. Forms
   c. Grades
   d. Locations
   e. Laying out ditches
   f. Crossing depressions
   g. Controlling weeds along ditch banks
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Lesson 28 cont'd.

6. Preparing land for irrigation
   a. Using a topographic map
   b. Removing native vegetation
   c. Surface grading
   d. Preparing land for standard methods of irrigation
      (1) Flooding from field laterals
      (2) Furrow irrigation
      (3) Check irrigation (Basin method)
      (4) Border irrigation
   e. Preparing land for garden irrigation

7. Irrigating different crops
   a. Alfalfa
   b. Grain
   c. Potatoes
   d. Fruit trees
   e. Pastures
   f. Small fruits and vegetables

8. Reducing wastage of water

9. Maintaining the proper percentage of soil moisture

10. Importance of drainage of irrigated lands

Problems: 60, 61, 64, 65
Lesson 29
SPRAY IRRIGATION


1. Purpose of Irrigation in the Eastern States

2. Kinds of Irrigation

3. Types of Spray-irrigation systems
   a. Overhead pipe system
   b. Circular-spray system

4. Water supplies
   a. Common sources of supply
   b. Quantity and quality of water required

5. Planning a spray-irrigation system
   a. Choosing the water supply
   b. Laying out the piping system
   c. Quality of pipe and fittings
   d. Supports for the nozzle lines
   e. Pumping for spray irrigation
   f. Kinds of pumps
   g. Size of pump required
   h. Measurement of pressure or head on the pump
   i. Engines and motors

6. Installing the system
   a. Procuring the water
   b. A screen for surface water
   c. Setting the pump and engine
   d. Suction pipe and priming
Lesson 29 cont'd.

e. Laying the mains and setting the uprights

f. Assembling the nozzle lines

7. Cost of spray irrigation---Itemized bill of materials

8. A typical small spray-irrigation system

Alternate plans

9. Operation and upkeep

10. Profits from spray irrigation

Problems: 55, 56, 57, 58, 63
Lesson 30

SPRINKLING AND POROUS HOSE METHODS OF IRRIGATION: WATER APPLICATION EFFICIENCIES

Reference: Agricultural Engineering Journal

A. Irrigation by sprinkling, V. 18, no. 12, pp. 535-538

1. Objectives of Investigations
2. Description of portable sprinkler systems
3. Distribution of water from sprinklers
4. Type of sprinkler pattern for most uniform distribution
5. Evaporation losses
6. Friction losses in sprinkler pipe

B. Development of the porous hose method of irrigation in Michigan V. 15, no. 8, pp. 262-263

1. Brief description of method
2. Use of variable weight hose
3. Method of moving the hose
4. Cost of applying water

C. Water Application Efficiencies, V. 20, no. 2, pp. 55-56

1. Definition of--"Water Application Efficiency"
2. Factors influencing efficiency
3. Measuring water application efficiencies
4. Measurements made at the experiment stations
   a. California studies
   b. Utah studies
5. Utility of the concept "Water application Efficiencies"

Problems: 59, 62, 66
Lesson 31

FEDERAL IRRIGATION PROJECTS

Reference: U.S. Dept. of Interior Publication (I-9)

A. Projects, pp. 1-19

1. The Reclamation Act and its achievements
   a. Need for reclamation
   b. Results on existing projects

2. Engineering works
   a. Tunnels and siphons
   b. Dams
     (1) Stony Gorge Dam
     (2) Black Canyon Dam
     (3) American Falls Dam
     (4) Gibson Dam
     (5) Owyhee Dam
     (6) Shoshone Dam
     (7) Boulder Dam

3. Financing construction

4. Project costs and public notices

5. Repayment of construction cost

6. Warren Act lands

7. Operation and maintenance

8. How to acquire land

9. Opportunities for settlers
   a. Use of interest free capital
   b. Variety of climatic and soil conditions
Lesson 31 cont'd.

e. Capital required

d. Cost of developing raw land

e. Available farms

10. Hints to settlers
Federal Irrigation Projects

Reference: U.S. Dept. of Interior; Publication (I-9)

A. Projects, pp. 24-83

1. Arizona, Salt River Project
2. Arizona-California, Yuma Project
3. California, Orland Project
4. Colorado River, Boulder Canyon Project
5. Colorado, Grand Valley Project
6. Colorado, Uncompahgre Project
7. Idaho, Boise Project
8. Idaho, King Hill Project
9. Idaho, Minidoka Project
10. Montana, Huntley Project
11. Montana, Milk River Project
12. Montana, Sun River Project
13. Montana-North Dakota, Lower Yellowstone Project
14. Nebraska-Wyoming, North Platte Project
15. Nevada, Nevada Project
16. New Mexico, Carlsbad Project
17. New Mexico-Texas, Rio Grande Project
18. Oregon, Umatilla Project
19. Oregon, Vale Project
20. Oregon-California, Klamath Project
21. Oregon-Idaho, Owyhee Project
22. South Dakota, Belle Fourche Project
Lesson 32 cont'd.

23. Utah, Salt Lake Basin Project
24. Utah, Strawberry Valley Project
25. Washington, Okanogan Project
26. Washington, Yakima Project
27. Wyoming, Riverton Project
28. Wyoming, Shoshone Project
PROBLEMS
General Problems

1. How many foot pounds of energy will be dissipated by one acre inch of water running down a hill 50' high?

2. A farm located near Blacksburg, Virginia, consists of 30 A. hilly pasture and 20 A. rolling cultivated land. The soil is a sandy loam. Find the largest runoff to be expected once in ten years.

3. Find the composite coefficient of imperviousness for a watershed containing 10 A. rolling cultivated land, 15 A. hilly pasture, 5 A. hilly timber, and 5 A. rolling timber.

4. Find the depth of a seven foot notch for a check dam to take care of the runoff from 30 A. Coefficient of imperviousness 0.50, rainfall of 0.5" in five minutes is expected once in ten years. Use weir formula \( c = 3.59L^{3/2} \).

5. Determine the maximum expected runoff from a 25 A. cultivated field near Athens, Georgia, having an average slope of 3% and a runoff coefficient, \( C = 0.50 \). The path of the water from the most remote point to the outlet traverses 75' across a 4% slope over an open cultivated field, 1000' of terrace channel, and 1200' down a vegetated channel on an 8% grade. The velocity of the water from remote point to outlet respectively is 4, 1, and 9 f.p.s.

6. If the head of water above an orifice is \( H \) feet, give the formula for the velocity of its jet.

7. Water flowing over a rectangular weir is proportional to what one of the following: \( h^{1/2} \), \( h^{3/2} \), \( h^2 \), \( h^{5/2} \), \( h^{1/2} \).

8. If a water company wishes an accurate continuous record of the quantity of water flowing in a main canal in which only a small difference in elevation can be allowed at the measuring device, which of the following devices should be used: (submerged weir, circular orifice, Parshall flume, V-notch weir, Cipolletti weir)?

9. The discharge over a 90° triangular notch weir with complete contraction is 2.49 c.f.s. If \( C = 2.45 \), \( R^2 = 2.45 \), determine the head in feet.

10. A semi-circular canal, \( 6' \) in diameter has a slope of 1/1000. \( V = 60(RS)^{1/2} \), Determine the discharge.

11. Find the discharge from a 10° circular orifice where the head is 16'.

12. What is the hydraulic gradient of a flowing stream?

13. Backwater-

Given: Earthen canal with trapezoidal cross-section, side slope 1 1/2 horizontal to 1 vertical, bottom width 20', water flowing 5' deep in original channel, uniform grade 1/2000, coefficient of roughness \( n = 0.03 \), a dam raises the water level 2' at the dam site.

Wanted: Construct the backwater curve by finding the elevation of the water surface at each 1000' upstream.

Suggested method: Continuous approximation using the Chezy or Manning formula.
14. A ditch has side slopes of 4:3 and is three feet deep, coefficient of roughness, n = 0.05, S = 0.0002 ft per ft. What bottom width will make the capacity 26 c.f.s.?

15. A certain irrigation canal is designed to carry 122.5 c.f.s. at a velocity of 2.5. f.p.s. What is the most economical bottom width and depth for each of the following slopes?
   a. 1/2 horizontal to 1 vertical
   b. 1 1/2 horizontal to 1 vertical
   c. 2 1/2 horizontal to 1 vertical

16. A tract of land three miles square must be drained by a ditch which has a fall of 1 1/2' per mile. The drainage coefficient is one inch in 24 hours. The soil is sandy. Design the ditch.

17. A ditch discharges 15 c.f.s. and drains an area of 4.5 square miles. What is the drainage coefficient?

18. The drainage coefficient of an area of eight square miles is 3/8". What is the discharge of the ditch draining this area?

19. Design a ditch to carry water from a drainage area of 560 acres. The runoff is one inch in 24 hours. C = 40, depth of tile outlet three feet.

20. A gate 5' x 5' is built into a dam with its upper edge, the long side, six feet below the surface of the water. Find the total pressure on the gate.

21. Vessel A with outward sloping sides is filled with water to a height of two feet. Vessel B with the same area on the bottom, but with inward sloping sides is filled with water one foot deep. Find the relative pressure on the bottoms of the two vessels. All sides are inclined 60° from the horizontal.

22. What is the principal cause of loss of water in an open, concrete lined reservoir?

23. An earth dam in a mountainous country should always be provided with which one of the following; flashboard, spillway, fish ladder, narrow crest, surge tank?

24. A gravity type concrete dam has a triangular cross-section, with the upstream face vertical, is 50' high, 20' wide at the base. The foundation is bed rock. Find the maximum pressure on the down-stream toe and compare with the safe bearing power of the concrete.

25. Design the most feasible type of protection for a sand-boat five feet in diameter, located 40' behind a 10' levee.

26. A motor pumps water at the rate of 5 c.f.s. from a drainage ditch, over a 40' levee into a river. The efficiency of the pump is 80%, of the motor 90%. Find the input in H. P.
Drainage Problems

27. What will be the runoff in cubic feet per second from an area of 300 acres, where the runoff or drainage coefficient is 3/8" in 24 hours?

28. What size tile is needed to take care of a runoff of ten cubic feet per second if the grade on which it is laid is 0.3 feet per 100 feet? 

\[ V = 153 \frac{r^2}{3} \frac{g}{1/2} \]

29. The water removed by drainage is ______. (hygroscopic, capillary, hydrostatic)

30. Upon what does the spacing of tile drains depend?

31. Find the diameter of the main required to carry the water that will drain from a 300 A. field, when 3/8" of water must be drained off every 24 hours and the velocity of the water in the main is 2.35 f.p.s. and the slope of the main is 1.5%.

32. What type of pump is used almost universally in drainage work?

33. Each acre in a 40 A. tract is 50% benefited with respect to nearness to outlet, 60% with respect to fertility, 90% with respect to elevation or thoroughness of drainage and 70% with respect to nearness to main drain. What is the total number of acre units of benefit received by the tract?

34. How many acres would a tile 10" in diameter, with a grade of 0.4% drain if the drainage coefficient is 1/2"?

35. Laterals are placed 80' apart in the field; they have a fall of 0.3%; they are 1,500' long. If the drainage coefficient is 3/8", what size tile would you use for the laterals?

36. How many acres will a 12" tile drain with a fall of 0.12% and with a drainage coefficient of 1/2"?

37. How many acres will a 40" tile drain with a fall of 0.2% with a drainage coefficient of 3/8"? How many square miles?

38. A farmer lives 6 miles from a station on a railroad and wishes to have the following tiles put in 5' deep by a contractor, with an engineer to superintend the work. Compile an estimate of the cost.

<table>
<thead>
<tr>
<th>Type of Tile</th>
<th>Length in Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>4&quot; tile</td>
<td>12,500</td>
</tr>
<tr>
<td>5&quot; tile</td>
<td>6,000</td>
</tr>
<tr>
<td>6&quot; tile</td>
<td>800</td>
</tr>
<tr>
<td>8&quot; tile</td>
<td>800</td>
</tr>
<tr>
<td>10&quot; tile</td>
<td>950</td>
</tr>
</tbody>
</table>

Three outlets will need to be constructed at a cost of $6.50 each.

40. A 20 A. Virginia field with an average slope of 8% is to be terraced.
   a. What type terrace and what vertical interval would you use?
   b. Draw a diagram showing the different slopes that should be used
      along a channel 600' long.

41. Design a terrace outlet channel for the field of the previous problem;
   n = 0.04; s = 0.017; maximum velocity five feet per second. Protect
   from the largest rainfall to be expected once in ten years.

42. Determine the size of culvert and riser to use in a soil saving dam
   to operate under a head of 20'. The watershed is rolling and comprises
   100 A; 30 A. cultivated, 30 A. pasture, and 40 A. timber. A sodded
   depression exists around one end of the dam, which can be used as an
   auxiliary spillway. This depression is about 6' wide and will carry
   a flow of one foot in depth before the water will begin to flow over
   the dam. Use the largest rainfall intensity that will occur once in
   50 years. Duration of rainfall equals time of concentration of the
   watershed.

43. A terrace channel in central Iowa drains 6.5 A.; length 2000'; bottom
   width 3'; depth 1.15'; slope 0.33%; side slope 2.67-1; coefficient of
   imperviousness 0.45. What is the maximum discharge and how often will
   the channel overflow?

44. Find the velocity of flow in a channel with a cross section of 8.5
   sq. ft. and a discharge of 12.75 c.f.s.

45. If the channel in the above problem is a terrace 1620' long, located
   on land with a slope of 6%, what is the time of concentration?

46. Which one of the following crops is most effective in soil erosion:
   soy beans, tobacco, corn, alfalfa, cotton?

47. What is the maximum fall per 100' recommended for terraces?

48. The success of a system of terraces is largely dependent upon ________.

49. Where are contour furrows used most effectively?

50. What is the maximum length for a terrace draining in one direction?

51. Which terraces should be constructed first in the field?

52. What is the use of a lysimeter?

53. What is the maximum rate of runoff not likely to be exceeded more than
    once in ten years for an area of 25 A. of hilly agricultural land near
    Knoxville, Tenn.? From a reconnaissance survey, the tract has been
    classified as 10 A. of hilly cultivated land, 9 A. of hilly pasture,
    and 6 A. of hilly timber. A fairly well defined channel leads from
    the upper reaches of the watershed to the point of exit, a distance by
    channel of 1200'. The slope of the channel is 5% and the velocity of
    the water flowing in the channel is estimated at 300 f.p.m., making
    the time of concentration about four minutes.
54. Compare the capacities of two terrace channels on a grade of 0.5%.
    One is 3' deep with a bottom width of 2' and a top width of 8'. The other is 1' deep, 12' wide at the bottom, and 26' wide at the top.
    In general, which shape channel is preferable?

55. The indicated remedy for accumulated alkalinity in irrigated soil is

56. What determines the useful water storage capacity of a given field for a specific crop?

57. What structure is used to carry irrigation water across a stream bed in which, at times, the water is at approximately the same level as the irrigation water?

58. Piped water under pressure is always necessary for which of the following: furrow irrigation, check irrigation, sub-surface irrigation, sprinkling irrigation, flood irrigation?

59. What power is required to pump water at the rate of 16 c.f.s. against a head of 11' for 30 hours? The efficiency of the system is 62.5%.

60. What method of irrigation makes most economical use of water?

61. What method of irrigation should be used for wheat on rolling ground?

62. A canal delivers 2.2 second feet of water to a 24 A. field continuously for 11 hours. If the water were uniformly distributed over the field, what depth of irrigation in inches was applied?

63. For successful sub-irrigation one needs:
    a. light topsoil underlain by light subsoil
    b. light topsoil underlain by heavy subsoil
    c. heavy topsoil underlain by light subsoil
    d. heavy topsoil underlain by heavy subsoil
    e. light topsoil underlain by gravel subsoil

64. An irrigator desires to lift a stream of 500 g.p.m. a vertical height of 40'. If he purchases an electric motor of 90% efficiency and a pump of 60% efficiency, how many kilowatts of electricity will the electric motor use while pumping? How many horsepower?

65. A fruit grower is entitled to a stream of 50 Utah miner's inches for orchard irrigation. How many hours will it take him to apply 4 acre-inches per acre to a 10 acre orchard? (50 Utah miner's inches = 50 c.f.s.)

66. Consider an alfalfa tract prepared for irrigation by the border strip method. Assume that the soil is a loam having a permeability to water of 2' per 24 hour day. The border strips have a mean width of 66' and a length of 560'. If the irrigator turns a stream of 0.5 c.f.s. into each strip, how far will the water advance before it is all absorbed?
RECOMMENDATIONS FOR USING THE OUTLINE

This outline, including the accompanying bibliography and problems, is intended for use as a course of study by both the instructor and students in soil and water conservation classes. It is recommended that mimeographed copies of this outline be made up for class use. This will make it possible for each student to procure a copy of all the lesson outlines, including both problem assignments and references. The use of the outlines will save much class time that otherwise would be used for dictating references and problems. If possible, a sufficient number of copies of the special references will be kept on file, to provide each student with a copy. Copies of references listed in the selected bibliography are intended, primarily, for the use of the instructor, who should have them conveniently located for reference and for filing additional material.

The course was outlined in 32 lessons, nine of which deal with the subject of drainage which is now taught in another course in the Department. The complete outline will require, at least, a three-hour course, not including a laboratory, to cover the material. It is intended that, if the drainage section is omitted, the remaining material may be presented in a two-hour course. It is further suggested that, if class time is limited, it might be better to omit some subject matter on Irrigation than on any other major topic, because irrigation is of lesser importance in this particular section of the country. The very important subject of erosion control should receive special emphasis, and more time than any other one subject in the outline. Since many of the lessons are rather long for one assignment, the instructor might assign part of a lesson for the student’s class preparation and cover the remainder of the lesson in his lecture. The author believes that all of the material outlined is essential to the course, and whenever possible, all of it should be included.
After using this outline, the instructor may find that certain topics are stressed too much or too little. Also, problems that have been assigned to certain lessons might fit in better elsewhere. If notes concerning possible improvements are inserted in the outline, it will facilitate future revision.
CONCLUSIONS

It is believed that in addition to completing the proposed study of assembling, organizing, and outlining this course, that two other very important objectives have been achieved. The outline includes material that places special emphasis on the relation of engineering to agronomy, as well as a study of costs and economic feasibility. A combination of agronomic and engineering practices is known to be indispensable to the soil and water Conservation program. For instance, terracing is very ineffective without vegetative control and proper crop rotations. It is a purpose of this course to teach the Agricultural Engineer to specify when special structures are not needed, as well as to recommend their use when they are necessary. Another objective of this course is to give the student a proper concept of the economic problems involved. The cost of terracing a field may amount to more than the value of the terraced land. Also, the student should be made to realize that the government conservation program is needed for experimental and educational purposes, but if private capital and enterprise were used to construct such control measures, it would in many cases prove an impractical investment. It is the engineer's duty to understand these phases of the problem and to determine when control measures are economically feasible and practical.

This study made it necessary to select and condense the best technical material from an almost unlimited amount of literature of varying quality. The author has broadened his outlook on the subject by inspecting Soil and Water Conservation works in the Pacific Northwest, in the Great Plains area, and in the Southeastern States. He believes the outline is sufficiently comprehensive to cover all the most important phases of
the subject. After teaching this course for a term previous to making
this study, the author fully realized that the course needed organizing,
and has put forth much effort to work up a practical and usable outline.
Although others might arrange this outline differently, use other refer-
ences, and change the general set-up, it is believed that this is a rela-
tively unbiased presentation. The element of personal prejudice has been
eliminated as far as possible by consultation with those who have had
much experience in soil and water Conservation through teaching or research
work. It is thought that this outline will prove very helpful and well
adapted to its intended use.
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