MICHIGAN TRAINING MODULE

GRASSED WATERWAY AND DIVERSION PLANNING, DESIGN, AND CONSTRUCTION

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PREFACE

This module has been written to provide basic planning, design, and construction training for grassed waterways and diversions. This module is designed to be used for training of new employees. It may be used as a working reference by others.

The module is to be used as a self-study tool. It is expected that assistance to the student from experienced designers will be provided as needed. The training should take place under the direction an experienced planner/designer. The exercises will be more meaningful if they are completed for a “real” diversion or grassed waterway project.

The prerequisites for this module are:

Basic Engineering Surveys for Conservation Practices
Hydrology Training Series Modules 101 through 106

References for this module are:

Conservation Practice Standards:
- 342, Critical Area Planting
- 362, Diversions
- 412, Grassed Waterway
- 468, Lined Waterway or Outlet
- 620, Underground outlet

Engineering Field Handbook (EFH), Chapters 2, 3, 6, 7, 9, and 14
Ohio Engineering Programs Curve Numbers and Peaks
Ohio Engineering Programs Waterway Design Module
Microsoft Exel Waterway design Worksheet

For more information, read Stability Design of Grass-Lined Open Channels, Agricultural Handbook Number 467.

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CONTENTS

INSTRUCTIONS

At the end of each section, there are questions to be answered. The questions are designed to give you feedback on your ability to accomplish the module objectives. Discuss your answers with the trainer assigned to you.

If you have difficulty in a specific area, please contact your facilitator (module leader).

You will need a calculator, drafting paper, computer with Ohio Programs and the waterway Exel Spreadsheet.

Contents of package: 1 Study Guide

OBJECTIVE

This module is intended to provide the student with a basic understanding of grassed waterway and diversion planning, design and construction. After completion of this module, the student should be able to plan and design simple grassed waterways or diversions with assistance and supervision.

INTRODUCTION

Grassed waterways are natural or constructed channels down slopes. They are shaped or graded to required dimensions, including suitable vegetation for stable conveyance of runoff. The primary purposes of grassed waterways constructed in Michigan are; to reduce gully erosion, and to provide safe outlets for diversions.

Diversions are stable channels constructed across slopes. The primary purposes of diversions constructed in Michigan are; to divert water from farmsteads, animal waste systems and other improvements, and to divert water from areas subject to erosion. This training module covers only grass lined diversions, and consequently, does not cover armored diversions.

Grassed waterways and diversions are two of the most commonly used conservation practices. Though they appear to be simple in design, there are complex facets to the planning, design, and construction of these practices. Considerations of watershed characteristics, channel slopes, soils, outlets, and vegetation type and density are needed for every waterway and diversion.

SECTION 1 – PLANNING

General

When planning for a conservation practice, it is essential that the problem be defined before a solution can be considered. This may seem obvious, but sometimes the landowner has decided on a solution before the problem has been well defined. This can lead the conservationist into planning and designing what the landowner thinks they want instead of the best solution for the problem.

When planning a grassed waterway or diversion, a stable outlet is always required, and should be a taken into consideration during planning. Other important considerations include:

1. The ability of the soil to maintain a vigorous vegetative cover.
2. The ability of the landowner to maintain the vegetative cover.
3. Land ownership in any areas water will be detained or redirected.
4. Traffic patterns for livestock and equipment. (Vegetated waterways and diversions should not be used as livestock travel ways or roadways, but safe crossing of the waterway or diversion should be planned.)
5. Will subsurface (tile) drainage be required to provide unsaturated soil conditions for vegetation growth?
6. Soil erosion rate from the watershed, and the potential for sedimentation.
7. Locations of utilities, especially where deep cuts are planned.
8. How will the waterway or diversion fit the landscape. (Planning flatter fill or cut slopes can help the diversion or waterway blend into the environment as well as make mowing and other maintenance easier.)

Grassed Waterways

Grassed waterways alone or in combination with other practices are among the tools that are available to treat ephemeral gully and gully erosion problems. In choosing an alternative for control of gully erosion, you and the landuser will both need to know the advantages and disadvantages of the alternatives. Some of the advantages and disadvantages to the grassed waterways, diversions and alternative common erosion control practices are listed below.

Grassed waterway:

Advantages:

Inexpensive initial cost
Reduces quantity of sediment and nutrients from reaching surface waters
Aesthetically pleasing
Improved wildlife habitat

Disadvantages:

Larger failure rate during establishment than for other alternatives
May use significant cropland area (Effect may be reduced by use of waterway for hay production)

Water and Sediment Control Basins:

Advantages:

Reduces amount of sediment and attached nutrients reaching surface waters
Less loss of cropland than other alternatives
Can assist in reducing flood flows

Disadvantages:

High cost
Does not reduce sheet and rill erosion

Terraces:

Advantages:

Reduces amount of sediment and attached nutrients reaching surface waters
Reduces sheet and rill erosion in cropland
Can modify the land to be more farmable
Less loss of cropland than other alternatives
Flattens slope where steep backslope terraces are used
Retains runoff for moisture conservation
Can assist in reducing flood flows

Disadvantages:

High cost
Not well adapted to much of the topography in Michigan

Diversions

Unlike waterways, there are few alternatives where a vegetated diversion meets the landusers objectives. The principal alternative is a structural diversion constructed of underground pipe, concrete, riprap, or other “hard” material.

QUESTIONS (About the project assigned to you)

A. For grassed waterway projects:

1. What type of erosion is being controlled by the planned waterway?

2. How will the outlet be stabilized, or is it already stable?

3. Are the soils erosive or erosion resistant?

4. Does the waterway fit the landscape?

B. For diversion projects:

1. What is being protected by the diversion?

2. How will the outlet be stabilized, or is it already stable?

3. Are the soils erosive or erosion resistant?

4. Does the diversion fit the landscape?

5. Does the diversion redirect water to another watercourse where the water previously did not flow? If so, does it enter another property in a place different from the existing flow channel?

SECTION 2 – SURVEYING (No questions section)

Adequate Information needs to be collected to determine slope and length of the waterway or diversion. Consider the alternatives that might be chosen during the design process to provide a safe outlet for the waterway or diversion when determining survey needs. The completion of the Basic Engineering Surveys Training Module should have provided you with the basic surveying knowledge to survey for a grassed waterway or diversion. The guidance shown below for the number of rod readings should be taken as just that - guidance. There are no “rules” about frequency of rod readings or cross-sections, except that the detail of survey required needs to represent the topography adequately for design of the practice.

The survey for a grassed waterway or diversion should include the following:

Soil Boring - Soil boring(s) need to be made to determine if the soils in the waterway or diversion as easily eroded or erosion resistant. Borings may be used to verify soil survey classifications. Description of the soil requirements for determining erosion resistant and easily eroded soils is located under Soil Considerations in section 3 of this module. This is done through obtaining and field classifying soil materials from the boring. Several borings may be needed and samples classified where soils are not similar through the waterway profile. Field classification of soils in not covered in this module. Field classification is covered in the Engineering Field Handbook, Chapter 4, or you may contact your area engineer or area soil scientist for assistance.

Benchmark – A benchmark is necessary to tie the construction layout to the design survey. Place the benchmark where it will not be disturbed by tillage, construction activities or livestock.

Profile – A profile of the waterway or diversion through the outlet is required for all waterways. This information is required to allow the designer to determine a slope for velocity calculations and be able to minimize cuts and fills for the waterway or diversion construction. For waterways or diversions with a length of 1000 feet or less, profiles should be made with rod readings taken at grade changes or a maximum of 100 feet apart. Longer waterways may allow for rod readings up to 200 feet apart.

Cross-sections – A cross-section of a waterway or diversion is surveyed to allow the designer to determine the most efficient fit of the designed waterway or diversion to the topography, considering peak discharge, outlet, amount of earthwork and subsurface drainage requirements. Cross-sections of the waterway channel area should be taken at obvious changes in cross-section or a maximum of 300 feet apart. Sometimes cross-sections are needed as close as 50 feet apart where there is very steep ground or rugged terrain. Each cross-section should be taken perpendicular to the centerline of the waterway. If possible, the survey should extend in elevation at least 1 foot above the potential edges of the waterway. A cross section is required for most outlet structure designs. Outlet structures may need survey adequate to design an emergency spillway.

Layout Sketch – Each set of waterway or diversion survey notes should have a layout sketch showing the location of the waterway or diversion and an approximate centerline along with pertinent landmarks adequate to locate the waterway in the field. The benchmark should also be shown on the sketch.

SECTION 3 – DESIGN

Several elements of design for grassed waterways and diversions are listed and described below. The steps for designing a waterway or diversion are stated in chapter 7 under "Steps in the design of a Waterway". Along with this information it is good practice to learn from local experience in the designs. Some areas have especially erosive soils or particular seed mixes that are easily available. Finally, to provide consistently successful designs, the designer needs to understand the science behind the design elements.

Soil Considerations

The erosion resistance, infiltration rate, permeability, fertility, and groundwater depth all affect the success of a waterway/diversion project. The erosion resistance is discussed in the next paragraph. The other factors affect the potential growth of the vegetation.

The design method used in Chapter 7 defines erosion resistant soils as those having a plasticity index of 10 to 40. These soils classify as CL, CH, SC, and GC in the unified classification system. All soils that do not meet the above criteria are classified as erosive soils. If soil survey classifications are verified by the soil borings, Soils 5 descriptions may be used for design. Soil classification is not part of this training module. For information on the Unified Soil Classification System, consult your EFH, Chapter 4 and/or your area engineer. A comparison of USDA and Unified classification systems is provided in Figure 4-7 of Chapter 4 of the EFH. (Hint. Clays are generally erosion resistant. Silts and sands are generally erosive.)

Peak Discharge

The minimum design discharge for the waterway or diversion is shown in each conservation practice standard. The normal design discharge for waterways and diversions is the peak discharge from the 10 year frequency 24 hour storm. Where the waterway slope is flatter than 1%, the standard allows a design for 50% of design peak flow in the waterway channel. Where a grassed waterway or diversion is designed as part of a comprehensive nutrient management plan, a 25 year frequency, 24 hour duration storm design is required. Note the limitations for use of EFH-2 methods in section 6 on page 2-7.

The peak discharge calculation is made using Engineering Field Handbook – Chapter 2 methods. The Ohio Engineering Programs use this method. Completion of Hydrology Training Series Modules 101 through 106 and 151 should provide the student with the training required to complete the peak discharge calculation.

Open Channel Flow

To learn how to calculate water flow in channels, read about Manning's Equation on pages EFH 3-39 through 3-42. Work the open channel problems on pages 3-47 through 3-49. It is important to understand these concepts so you can make appropriate assumptions in the design of grassed waterways and diversions.

The student should read EFH – Chapter 7, Pages 7-7, velocities, and MI7-14.3. This information, taken in conjunction with Exhibit 7.1 on page 7-17 helps the student understand how to determine “retardance” values for grassed waterways and diversion design. Note that Manning’s “n” changes for the same channel depending on not only density and height of vegetation (retardance), but with the depth of flow as well.

Channel shape, whether parabolic or trapezoidal is mostly a function of local custom or contractor preference. Either shape will work, so in most cases, the determining factor in choosing a waterway/diversion channel shape will be local contractor experience/preference.

A basic assumption for waterways and diversions is laminar or straight line, flow. Where waterways become more complex, such as, when branches are added together forming a larger waterway or waterway slope needs to change due to topography, you need to plan for a smooth transition. A “rule of thumb is to change the width of the waterway no more than 1 foot for each 5 feet of length. This allows the flow to follow the edges of the waterway smoothly. Where changes in grade, or cross-section are abrupt, care should be taken to match flow depths of the upstream and downstream portions of the waterway in order to avoid turbulence and subsequent erosion.

Stability

Designs for grassed waterways and diversions are based on a “permissible velocity” approach. Permissible velocities are shown on page 7-7 and in Exhibit 7-3 on page 7-19 of EFH, Chapter 7. The permissible velocity is calculated for the when the vegetation has the least retardance after establishment. Normally “D” for Michigan.

To reduce sedimentation in waterways/diversions, a minimum velocity of 1.5 feet per second at the design should be used. This is not stated in the reference material or in the standards, but is a widely accepted “rule of thumb”.

Capacity

Designs for grassed waterways and diversions are also based on a “capacity” approach. Since waterway vegetation height and density is different throughout the practice life, the capacity to transmit water through is required to be adequate in conditions where retardance is highest. Normally Retardance “C” or “B” for Michigan.

Sedimentation

A determination of sedimentation potential in the waterway needs to be made for each grassed waterway or diversion designed. The student needs to evaluate the potential for erosion of the contributing watershed. Calculating erosion rates and delivery ratios are not covered here. Before the waterway is constructed, the contributing watershed should be adequately treated for sheet and rill erosion. Where sheet and rill erosion are not able to be treated due to land ownership situations, the waterway may be built deeper assuming sediment deposition, or a sediment basin could be installed at the upstream end of the waterway.

Subsurface Drainage

Subsurface drainage may be required to establish and maintain vegetation in the waterway or diversion channel. Subsurface drainage should be designed using Part II of Chapter 14 of the EFH. The drain tubing should be placed near the edges or one edge in the case of a small waterway. The drain should not, under any circumstance, be located in the center of the waterway because settlement of the drain trench may cause a failure of the waterway.

Finding an adequate outlet is frequently the most difficult part of a subsurface drain design. Drainage cannot occur without an adequate outlet. A drop structure is frequently built to provide an outlet that allows drainage tubing to be installed below frost depth. Another alternative where the is not a good location for a subsurface drain outlet is to install a rock center to assist in drainage.

In some waterways, a sustained surface flow may need to be diverted from the waterway. The water can be diverted into surface inlets and through underground outlets that handle the base flow. You need to review standard 620, Underground Outlet if you will be diverting water underground.

Seeding and Mulching

Seeding and mulching should be completed in accordance with the Critical Area Planting Practice Standard, 342.

Channel Lining

This module does not cover lined channels. Rock centers are covered on Page 7-10 of EFH-7.

Design Programs
This module does use the computer design programs as part of the training process. The student is encouraged to use the programs to examine the relationships between:

1. Velocity and Grade
2. Velocity and Depth of Flow
3. Velocity and Retardance Value/”n” Value

Understanding these relationships will assist the designer in understanding the factors that have the greatest effect on flow capacity and velocity.

QUESTIONS

1. On grassed channels with a grade of 0.5%, does the capacity or velocity control the design?

2. What is the normal minimum velocity of water flow for waterway or diversion design, and why is there a minimum?

3. Which has a greater influence on flow velocities in shallow (<1 foot) flow depth: slope or retardance or flow depth? Use a computer design program to compare for several different situations and state a conclusion.

4. What are common seeding mixtures used in the county where you work?

SECTION 4 – CONSTRUCTION INSPECTION AND FINAL CHECKOUT

Inspection and final checkout of diversions and waterways includes preconstruction meeting, staking, checking grades and cross sections and as-built drawings.

These activities should be undertaken with an experienced inspector.

The survey portions of this are covered in the survey training module.

It is wise to build waterways when the weather will cooperate and provide ideal rainfall and temperatures for the establishment of the vegetation. If we knew when that was, 100% of properly designed waterways and diversions would be successes. As a consequence of having imperfect weather, intense rain will sometimes erode a newly constructed waterway. Sometimes it won't rain and the seeding fails. The only way to significantly reduce the chances of a erosion from an intense storm before establishment of vegetation is to temporarily divert water from the channel until establishment of the vegetation is complete.

Other practices that may help a waterway in become established include the use of mulch netting, erosion control fabrics, or straw bale dikes. All these practices include an increased cost. Is the result worth the cost? It depends on many factors.

QUESTIONS

1. What is the normal procedure in your county for limiting the potential for failure of waterways or diversions? Mulch with netting the center – or some other method?

SECTION 5 – MAINTENANCE REQUIREMENTS (No questions in this section)

Maintenance, from the designer's perspective, for the waterways and diversions should be addressed in an operation and maintenance plan. Examples of these plans are attached to this training document and are available on the Michigan NRCS web site.

Waterways and diversions may fail due to improper maintenance:

1) Through deposition of sediment because of lack of mowing and lack of appropriate erosion control in the watershed above

2) Through erosion of the channel due to loss of vegetation or use of the waterway as a roadway.

Avoiding these problems needs to be emphasized to the landowner.

Waterways and diversions also have the potential to fail without fault of the maintenance:

1) Through runoff in excess of design storm.

2) Through drought killing the grass.

All engineering practices may fail because we are designing based on economics for the practice. Failures of waterways and small diversions rarely are life threatening, therefore, a small rate of failure is acceptable as long as the failures are due to unusual circumstances instead of human error.