



## TABLE OF CONTENTS

### Chapter 13: Drainage

#### **Section 13-1 Drainage Practice**

- 13-1-1 ..... Drainage Practice Background
  - 1.1 ..... Introduction
  - 1.2 ..... General
  - 1.3 ..... Basic Statewide Practice
  - 1.4 ..... Design Responsibility
  - 1.5 ..... Common Drainage Law
  - 1.6 ..... Statutory Drainage Law
  - Attachment 1.1 ..... Glossary of Terms
- 13-1-5 ..... Major Drainage Guidelines and Criteria
  - 5.1 ..... Definition
  - 5.2 ..... General Guidelines
  - 5.3 ..... Surface Data Collection
  - Attachment 5.1 ..... Drainage Data Requirements, Design Aids and Computer Software
  - Attachment 5.2 ..... Major Drainage Summary Sheet
- 13-1-10 ..... Documentation of Hydrologic/Hydraulic Design
  - 10.1 ..... Introduction
  - 10.2 ..... Bridge and Box Culvert Design
  - 10.3 ..... Stormwater Report Applicability
  - 10.4 ..... Design Documentation
  - 10.5 ..... Stormwater-Drainage-WQ Report Spreadsheet Instructions for Drainage Design
  - Attachment 10.1 ..... Stormwater-Drainage-WQ Report Spreadsheet: Drainage - Summary Worksheet
  - Attachment 10.2 ..... Stormwater-Drainage-WQ Report Spreadsheet: Drainage - Data Worksheet
- 13-1-15 ..... Culvert Material Selection Standard
  - 15.1 ..... Application
  - 15.2 ..... Selection Standard
  - 15.3 ..... Special Situations
  - 15.4 ..... Corrosion Concerns About Steel Culvert Pipe
  - 15.5 ..... Abrasion Concerns
  - 15.6 ..... Limited Clearance Installations
  - 15.7 ..... Culvert Selection Justification
  - 15.8 ..... Tied Joints
  - 15.9 ..... Height of Cover for Culvert Pipes
  - 15.10 ..... Roughness Coefficient for Culvert Pipe
  - Attachment 15.1 ..... Potential for Bacterial Corrosion of Zinc Galvanized Steel Culvert Pipe (Map)
- 13-1-17 ..... Storm Sewer Material Selection Standard
  - 17.1 ..... Application
  - 17.2 ..... Selection Standard
  - 17.3 ..... Approved Materials
  - 17.4 ..... Special Situations
  - 17.5 ..... High Groundwater and Buoyancy of Thermoplastic Pipe
  - 17.6 ..... Storm Sewer Pipe Connections
  - 17.7 ..... Height of Cover for Storm Sewer
  - 17.8 ..... Roughness Coefficient for Storm Sewer
- 13-1-20 ..... Large Drainage Conduit
  - 20.1 ..... Introduction
- 13-1-21 ..... Precast Box Culverts
  - 21.1 ..... Introduction
- 13-1-25 ..... Fill Height Tables

- 25.1.....Design Criteria
- 25.2.....Design Methods
- 25.3.....Cut Ends
- 25.4.....Multiple Structures
- 25.5.....Abrasive or Corrosive Conditions
- Attachment 25.1....Storm Sewer Fill Height Table for Concrete Pipe
- Attachment 25.2....Fill Height Table-Corrugated Steel, Aluminum, Polyethylene, Polypropylene and Reinforced Concrete Pipe, HS20 Loading, 2- 2/3in x 1/2in Corrugations
- Attachment 25.3....Fill Height Tables: Corrugated Steel Pipe, 3 in x 1in Corrugations; and Structural Plate Pipe, 6in x 2in Corrugations
- Attachment 25.4....Fill Height Tables: Corrugated Steel Pipe Arch, 2- 2/3in x 1/2in Corrugations; and Corrugated Steel Pipe Arch, 3in x 1in Corrugations
- Attachment 25.5....Fill Height Table, Structural Plate Pipe Arch, 6inx2in Corrugations
- Attachment 25.6....Fill Height Tables: Corrugated Aluminum Pipe, 3in x 1in Corrugations; and Aluminum Alloy Structural Plate Pipe, 9in x 2 1/2in Corrugations
- Attachment 25.7....Fill Height Table, Corrugated Aluminum Pipe Arch, 2 2/3in x 1/2in Corrugations
- Attachment 25.8....Fill Height Table, Aluminum Alloy Structural Plate Pipe Arch, 9in x 2- 1/2in Corrugations
- Attachment 25.9....Fill Height Table, Reinforced Concrete Arch and Elliptical Pipe (all sizes); and Dimensions for Reinforced Concrete Arch and Elliptical Pipe (English)
- 13-1-30.....Culvert Replacement and Analysis for Perpetuation and Rehabilitation Projects
  - 30.1.....Background
  - 30.2.....Applicability
  - 30.3.....Guidelines for Culvert Replacement on Perpetuation and Rehabilitation Projects
  - 30.4.....Culvert Materials on Perpetuation and Rehabilitation Projects
  - 30.5.....Culvert Extensions, Endwalls and Traversable Grates on Perpetuation and Rehabilitation Projects
  - 30.99.....Resources
  - Attachment 30.1....Guidelines for Determining a Rural Area
  - Attachment 30.2....Culvert Sizing Quick Check

**Section 13-5 Field Work**

- 13-5-1.....Introduction
  - 1.1.....Introduction
- 13-5-5.....Survey Data
  - 5.1.....Drainage Cross Section for Small Culverts
  - 5.2.....Drainage Surveys for Large Culverts and Bridges
  - 5.3.....Preliminary Field Review
  - 5.4.....Changes in Existing Flow Conditions
  - 5.5.....Tail-Water Controls
  - 5.6.....Final Field Review

**Section 13-10 Hydrology**

- 13-10-1.....Design Criteria
  - 1.1.....Introduction
  - 1.2.....Flood Frequency
  - 1.3.....Design Frequency
  - 1.4.....Freeboard Considerations
  - 1.5.....Use and Design of Overflow Sections
  - 1.6.....Probability of Flood Occurrence
  - 1.7.....Future Development Effects
  - 1.8.....Hydraulic Information on Plans
  - Attachment 1.1.....Flood Design Frequency Selection Chart
  - Attachment 1.2.....Probability of Flood Occurrence (Table)
  - Attachment 1.3.....Probability of Flood Damage Before Payment of 25-Year Mortgage
- 13-10-5.....Methods of Determining Peak Runoff
  - 5.1.....Design Discharge
  - 5.2.....Discharge Frequency Graph
  - 5.3.....Rational Method
  - 5.4.....Urban Hydrology for Small Watersheds (TR-55)

[5.5.....USGS Flood Frequency Equations for Wisconsin](#)  
[5.6.....Gaging Station Data](#)  
[5.7.....Log Pearson Type III Distribution](#)  
[5.8.....Transferring Gaged Discharges](#)  
[5.9.....Comparison of Similar Drainage Basin at Gaged Sites](#)  
[5.10.... Published Watershed Studies](#)  
[5.11.... Field Review Notes, Interviews, and Historical Data](#)  
[5.12.... References](#)  
[Attachment 5.1.....Area Limits for Peak Discharge Methods](#)  
[Attachment 5.2.....Runoff Coefficients \(C\), Rational Formula, and Runoff Coefficients for Specific Land Uses](#)  
[Attachment 5.3.....Time of Concentration of Small Drainage Basins \(Nomograph\)](#)  
[Attachment 5.4.....Rainfall Intensity-Duration-Frequency Curves](#)  
[Attachment 5.5.....Contour Map for Example Problem](#)  
[Attachment 5.6.....Runoff Curve Numbers for NRCS TR-55 Method](#)  
[Attachment 5.7.....TR-55 Graphical Discharge Method \(Example\)](#)  
[Attachment 5.8.....Discharge Frequency Graph \(Example\)](#)  
[13-10-10.....Hydrograph Development and Routing](#)  
     [10.1.....Development](#)  
     [10.2.....Procedure](#)  
     [10.3.....NRCS Triangular and Curvilinear Dimensionless Unit Hydrograph Methods](#)  
     [10.4.....Routing](#)  
     [10.5.....Detention Pond Example](#)  
     [10.6.....References](#)  
[Attachment 10.1....Basic Watershed Data Work Sheet](#)  
[Attachment 10.2....Hydrograph Development Work Sheet](#)  
[Attachment 10.3....Sample Hydrograph](#)  
[Attachment 10.4....Headwater Depth Nomograph](#)  
[Attachment 10.5....Depth-Outflow Graph \(example\)](#)  
[Attachment 10.6....Storage Indicator Curve Work Sheet](#)  
[Attachment 10.7....Storage-Indicator Curve \(example\)](#)  
[Attachment 10.8....Stage-Storage Curve \(example\)](#)  
[Attachment 10.9....Hydrograph Data Work Sheet](#)  
[Attachment 10.10..Hydrograph \(Example\)](#)  
[Attachment 10.11..Example Problem Illustration](#)

**Section 13-15 Hydraulic Design of Culverts**

[13-15-1.....Economic Analysis](#)  
     [1.1.....Introduction](#)  
[13-15-5.....Design Criteria](#)  
     [5.1.....Introduction](#)  
     [5.2.....Culvert Location](#)  
     [5.3.....Structure Size Selection](#)  
     [5.4.....Allowable Headwater](#)  
     [5.5.....Design Freeboard and Headwater-to-Depth Ratio](#)  
     [5.6.....Inlet Treatments](#)  
     [5.7.....Improved Inlets](#)  
     [5.8.....End Protection](#)  
     [5.9.....Type, Shape, and Roughness of Culvert](#)  
     [5.10.....Design Tail Water](#)  
     [5.11.....Allowable Velocity](#)  
     [5.12.....Depth of Flow](#)  
     [5.13.....Check Discharges](#)  
     [5.14.....References](#)  
[Attachment 5.1.....Entrance Loss Coefficients \(Ke\) for Culverts](#)  
[13-15-10.....Culvert Hydraulics](#)  
     [10.1.....Introduction](#)  
     [10.2.....Available Design Aids](#)

- 10.3.....Inlet-Outlet Control
- 10.4.....Discharge Velocity
- 10.5.....Improved Inlets
- 10.6.....Culvert Performance Curve
- 10.7.....References
- Attachment 10.1....Energy Losses Through a Conduit (schematic)
- Attachment 10.2....Inlet and Outlet Control Problem Sample Work Sheets
- Attachment 10.3....Culvert Hydraulic Performance Curves (examples)
- 13-15-15 .....Special Hydraulics
  - 15.1.....Introduction
  - 15.2.....Drainage Disposal by Pumping
  - 15.3.....Siphons and Sag Culverts
  - 15.4.....Type of Conduit

**Section 13-20 Hydraulic Design of Bridges**

- 13-20-1 .....Design Methods
  - 1.1.....Definition
  - 1.2.....Type of Flow
  - 1.3.....Methods
  - 1.4.....Additional Literature
- Attachment 1.1.....Types of Flow Encountered at Bridges

**Section 13-25 Storm Sewer Design**

- 13-25-1 .....Introduction
  - 1.1.....Introduction
  - Attachment 1.1.....Storm Sewer Design Flow Chart
- 13-25-5 .....Basic Drainage Area Information
  - 5.1.....Basic Information Needs
- 13-25-10 .....Field Drainage Information
  - 10.1.....Field Information Needs
- 13-25-15 .....Preliminary Layout of System
  - 15.1.....Background Information
  - 15.2.....Inlet Locations
  - 15.3.....Conduit Location
  - 15.4.....Standards for Storm Drain Pipe
  - 15.5.....Manholes
  - 15.6.....Outfalls
- 13-25-20 .....Design Discharge
  - 20.1.....Design Discharge Information
- 13-25-25 .....Gutter Design
  - 25.1.....Capacity
  - 25.2.....Gutter Types
  - 25.3.....Longitudinal Slopes
  - Attachment 25.1....Gutter Design Nomograph
  - Attachment 25.2....Gutter Design Example
- 13-25-30 .....Hydraulic Design of Inlets
  - 30.1.....Inlet Types
  - 30.2.....Allowable Inlet Capacities
  - 30.3.....Capacities of Gate Inlets and Combination Inlets on a Continuous Grade
  - 30.4.....Capacity of Gate Inlets in a Sag
  - 30.5.....Capacity of Curb Openings in a Sag
  - 30.6.....Spacing of Inlets on a Continuous Grade
  - 30.7.....Literature on Inlet Design
  - 30.8.....References
  - Attachment 30.1....Reduction Factors for Inlets
  - Attachment 30.2....Performance Curves for Slotted CMP Surface Drains
- 13-25-35 .....Hydraulic Design of Storm Sewers
  - 35.1.....Background Information

- 35.2.....Design Aids
- 35.3.....Conduit Design - Full Flow
- 35.4.....Pressure Flow
- 35.5.....Energy and Hydraulic Grade Lines (EGL and HGL)
- 35.6.....Hydraulic Standards for Storm Drain Pipe
- 35.7.....References
- Attachment 35.1....Manning Roughness Coefficients
- Attachment 35.2....Graphic Solution of the Manning Equation
- Attachment 35.3....Hydraulic Elements of a Circular Section
- Attachment 35.4....Capacity and Velocity Diagram for Circular Corrugated Pipe Flowing Full ( $n = 0.024$ )
- Attachment 35.5....Capacity and Velocity Diagram for Circular Concrete Pipe Flowing Full ( $n = 0.013$ )
- Attachment 35.6....Sewer Bend Loss Coefficients
- Attachment 35.7....Loss Coefficients for Miter Bends
- 13-25-40 .....Design Procedure: Full and Partially Full Flow
  - 40.1.....Background Information
  - 40.2.....Procedure
  - Attachment 40.1....Work Sheet for Storm Sewer Design
  - Attachment 40.2....Full and Partially Full Sewer Design Problem
- 13-25-45 .....Design Procedure: Surcharged Full Flow
  - 45.1.....Background Information
  - 45.2.....Procedure
  - Attachment 45.1....Energy and Hydraulic Grade Lines for a Properly and Improperly Designed Storm Sewer
  - Attachment 45.2....Work Sheet for Storm Sewer Design
  - Attachment 45.3....Example Work Sheet for Sewer Design Problem

### **Section 13-30 Channels and Road Ditches**

- 13-30-1 .....Channel Types and Characteristics
  - 1.1.....Channel Types
  - 1.2.....Roadside Ditches
  - 1.3.....Median Ditches
  - 1.4.....Toe of Slope and Intercepting Embankments
- 13-30-5 .....Channel Characteristics
  - 5.1.....Introduction
  - 5.2.....Vertical Alignment
  - 5.3.....Horizontal Alignment
  - 5.4.....Roughness Factors
  - 5.5.....Channel Geometry
  - 5.6.....Natural Channels
- 13-30-10 .....Hydraulic Design of Open Channels
  - 10.1.....Introduction
  - 10.2.....Types of Flow
  - 10.3.....Uniform Flow
  - 10.4.....Manning's Roughness Coefficient
  - 10.5.....Shear Stress
  - 10.6.....Design Parameters
  - 10.7.....General Design Procedures
  - 10.8.....References
- 13-30-15 .....Grass Lined Channels
  - 15.1.....Introduction
  - 15.2.....Grass Lining Properties
  - 15.3.....Manning's Roughness
  - 15.4.....Permissible Shear Stress
  - 15.5.....Grass Cover Factor
  - 15.6.....Permissible Soil Shear Stress
  - 15.7.....Grass Lined Channel Design Example
  - 15.8.....References
  - Attachment 15.1....Grass Lined Channel Design Example (Using HEC-15)

- [Attachment 15.2](#).....Grass Lined Channel Design WisDOT Spreadsheet Worksheet
- [Attachment 15.3](#).....Grass Lined Channel Design Example (Using WisDOT Spreadsheet)
- [13-30-25](#) .....Rock Riprap Lined Channels
  - [25.1](#).....Introduction
  - [25.2](#).....Analysis of Slopes Less than or Equal to 20 Percent
  - [25.3](#).....Manning's Roughness (for Rock Riprap Lined Channels)
  - [25.4](#).....Permissible Shear Stress
  - [25.5](#).....Rock Riprap Design Procedure
  - [25.6](#).....Design Example (Using Equations): Riprap Channel (Mild Slope)
  - [25.7](#).....Example Riprap Lined Design for Channel Slopes  $\leq 20\%$  Using the WisDOT Spreadsheet
  - [25.8](#).....Additional Design Considerations
  - [25.9](#).....References
- [Attachment 25.1](#).....Design Example (Using Equations): Riprap Channel (Mild Slope)
- [Attachment 25.2](#).....Riprap Channel (Mild Slope) WisDOT Spreadsheet Worksheet
- [Attachment 25.3](#)... Instructions and Example for Riprap Lined Design for Channel Slopes  $\leq 20\%$  Using the WisDOT Spreadsheet
- [Attachment 25.4](#).....Angle of Repose of Riprap in Terms of Mean Size and Shape of Stone
- [Attachment 25.5](#).....Map of Areas in Wisconsin where Rounded Riprap is Predominantly Available
- [13-30-30](#) .....Rock Riprap Lined Chutes
  - [30.1](#).....Introduction
  - [30.2](#).....Steep Slope Analysis
  - [30.3](#).....Rock Chute Design Spreadsheet
  - [30.4](#).....References
- [Attachment 30.1](#).....Rock Chute Design Data Spreadsheet and Design Example
- [Attachment 30.2](#).....Rock Chute Design - Plan Sheet
- [Attachment 30.3](#).....Rock Chute Design- Construction Detail

### **Section 13-35 Erosion and Water Pollution Control**

- [13-35-1](#) .....Special Hydraulic Structures
  - [1.1](#).....Introduction
  - [1.2](#).....Flow Control Gates
  - [1.3](#).....Debris Control Structures
  - [1.4](#).....Detention Basin
  - [1.5](#).....Temporary Sediment Structures
- [13-35-5](#) .....Energy Dissipaters
  - [5.1](#).....Introduction
  - [5.2](#).....Riprap Blanket
  - [5.3](#).....Lined Channel Expansions
  - [5.4](#).....Outlet Expansion
  - [5.5](#).....Literature on Energy Dissipaters
- [Attachment 5.1](#).....Dissipater Limitations
- [Attachment 5.2](#).....Recommended Configuration of Riprap Blanket Subject to Maximum and Minimum Tail Waters
- [Attachment 5.3](#).....Culver Outlet Erosion Protection, Lined Channel Expansions
- [Attachment 5.4](#).....Example Problem, Lined Channel Expansion Design
- [Attachment 5.5](#)..... Typical Outlet Expansion Diagram
- [Attachment 5.6](#).....Length Requirements for Expanded Pipes

### **Section 13-40 Subgrade Drainage**

- [13-40-1](#) .....Underdrains
  - [1.1](#).....Introduction
  - [1.2](#).....Descriptions
  - [1.3](#).....Design Criteria
  - [1.4](#).....Underdrain Conduit Installations
  - [1.5](#).....Material Considerations
  - [1.6](#).....Geotextile Fabric
  - [1.7](#).....Selection of Type
  - [1.8](#).....Construction

Attachment 1.1.....Subdrains

Attachment 1.2.....Suggested Depth and Spacing of Underdrains for Various Soil Types

**Section 13-45 Culvert and Storm Sewer Rehabilitation and Replacement**

13-45-1 .....Background

1.1.....Introduction

1.2.....Design Responsibility and Coordination

1.3.....Definitions

13-45-5 .....Design Considerations

5.1.....Introduction

5.2.....Evaluation

5.3.....Hydraulics

5.4.....Structural Condition

5.5.....Cleaning and Verification of Clearance

5.6.....Environmental

5.7.....Safety

5.8.....Access

5.9.....Traffic

13-45-10 .....Culvert Rehabilitation by Sliplining

10.1.....Introduction

10.2.....Types of Sliplining

10.3.....Sliplining Materials

10.4.....Slipliner Design Considerations

Attachment 10.1.... Culvert Liner Hydraulic Check

13-45-15 .....Other Culvert Repair and Rehabilitation Practices

15.1.....Introduction

15.2.....Invert Paving

15.3.....Cured in Place Pipe Liner (CIPP)

15.4.....Centrifugally Cast and Spray-on Liners

15.5.....Pre and Post Installation Inspection of Cured in Place Pipe Liners (CIPP), Cast, and Spray-on Liners

15.6.....Design Requirements for Cured in Place Pipe Liners (CIPP), Cast, and Spray-on Liners

15.7.....Cost Considerations for Cured in Place Pipe Liners (CIPP), Cast, and Spray-on Liners

13-45-20 .....Trenchless Installation of New or Replacement Culvert Pipe and Storm Sewer

20.1.....Introduction

20.2.....Environmental Considerations

20.3.....Geotechnical Considerations

20.4.....Trenchless Construction Methods

13-45-99 .....Resources and References

99.1.....Resources

99.2.....References