FACILITIES DEVELOPMENT MANUAL



Wisconsin Department of Transportation

TABLE OF CONTENTS

Chapter 13: Drainage

Section 13-1 Drainage Practice

13-1-1Drainage Practice Background

- <u>1.1</u>.....Introduction
- <u>1.2</u>.....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

<u>10.2</u>.....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

<u>13-1-15</u>......Culvert Material Selection Standard

- ______<u>15.1</u>.....Application
 - 15.2.....Selection Standard
 - <u>15.3</u>.....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)

<u>13-1-17</u>......Storm Sewer Material Selection Standard

- <u>17.1</u>.....Application
 - 17.2.....Selection Standard
 - 17.3.....Approved Materials
 - 17.4.....Special Situations
 - <u>17.5</u>.....High Groundwater and Buoyancy of Thermoplastic Pipe
 - <u>17.6</u>.....Storm Sewer Pipe Connections
 - 17.7.....Height of Cover for Storm Sewer
 - 17.8Roughness Coefficient for Storm Sewer
- 13-1-20 Large Drainage Conduit
 - 20.1.....Introduction
- <u>13-1-21</u>......Precast Box Culverts
 - 21.1....Introduction
- <u>13-1-25</u>......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 1inCorrugations; and Structural Plate Pipe, 6 in x 2 in Corrugations
- <u>Attachment 25.4</u>....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
- <u>Attachment 25.6</u>....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
- <u>Attachment 25.9</u>....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
 - <u>30.5</u>.....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
- 13-5-5Survey 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

<u>13-10-1</u>.....Design Criteria

- 1.1....Introduction
- 1.2.....Flood Frequency
- 1.3.....Design Frequency
- <u>1.4</u>.....Freeboard Considerations
- 1.5.....Use and Design of Overflow Sections
- 1.6.....Probability of Flood Occurrence
- <u>1.7</u>.....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 Pewarson 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
 - <u>10.4</u>.....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
 - <u>Attachment 10.7</u>....Storage-Indicator Curve (example)
 - <u>Attachment 10.8</u>....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
- 13-15-5Design 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

- <u>10.1</u>.....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

<u>13-20-1</u>......Design Methods <u>1.1</u>.....Definition <u>1.2</u>.....Type of Flow <u>1.3</u>.....Methods <u>1.4</u>.....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 Grate Inlets and Combination Inlets on a Continuous Grade 30.4.....Capacity of Grate 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

<u>35.1</u>.....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
- <u>13-30-5</u>......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
- <u>10.6</u>.....Design Parameters
- 10.7.....General Design Procedures
- 10.8.....References
- <u>13-30-15</u>.....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

- <u>Attachment 15.3</u>....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 ≤ 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
 - <u>Attachment 25.3</u>... Instructions and Example for Riprap Lined Design for Channel Slopes ≤ 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
- <u>13-30-30</u>.....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
- <u>13-35-5</u>......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
 - <u>Attachment 5.2</u>.....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
 - <u>1.6</u>.....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

<u>13-45-1</u> Background
<u>1.1</u> Introduction <u>1.2</u> Design Responsibility and Coordination <u>1.3</u> 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
5.8Access
5.9Traffic
<u>13-45-10</u> Culvert Rehabilitation by Sliplining 10.1Introduction
<u>10.2</u> Types of Sliplining
10.3Sliplining Materials
10.4Slipliner Design Considerations
Attachment 10.1Culvert Liner Hydraulic Check
13-45-15 Other Culvert Repair and Rehabilitation Practices
<u>15.1</u> Introduction <u>15.2</u> Invert Paving
<u>15.3</u> Cured in Place Pipe Liner (CIPP) 15.4Centrifugally Cast and Spray-on Liners
<u>15.5</u> Pre and Post Installation Inspection of Cured in Place Pipe Liners (CIPP), Cast, and Spray-on Liners
<u>15.6</u> Design Requirements for Cured in Place Pipe Liners (CIPP), Cast, and Spray-on Liners <u>15.7</u> 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
20.1Introduction
20.2Environmental Considerations
20.3Geotechnical Considerations
20.4Trenchless Construction Methods

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