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 Traverseable 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)
### FDM Chapter 13 Table of Contents

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
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 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
   35.1 Background Information
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)
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
FDM Chapter 13 Table of Contents

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