Section 9-1 Introduction

9-1-1 General
  1.1 Originator
  1.2 General

9-1-5 Description of Surveys
  5.1 Engineering Surveys
  5.2 Control Surveys
  5.3 Primary Control Surveys
  5.4 Secondary Control Surveys
  5.5 Alignment Surveys
  5.6 Photogrammetric Surveys
  5.7 Right-of-Way Surveys

9-1-10 Automation Links to Surveys

9-1-15 Need for Accuracy

Section 9-5 Policies

9-5-1 Preservation of Survey Monuments
  1.1 General
  1.2 Definitions
  1.3 Types of Monuments Typically Found along WisDOT Projects
  1.4 Geodetic Survey Control Station Replacement Procedure
  1.5 Procedure to Perpetuate USPLSS and/or Land Parcel Boundary Monuments

9-5-3 Monument Perpetuation Document
  3.1 Monument Perpetuation Document Procedure
  3.2 Monument Perpetuation Document Examples

Attachment 3.1 Edited Transportation Project Plat Example
Attachment 3.2 Table Option with Maps Example
Attachment 3.3 Table Option without Maps Example

9-5-5 Right-of-Way Monumentation

9-5-10 Standard Geodetic References

9-5-15 Requests for Photogrammetric Products and Services
  15.1 Procedure
  15.2 Resources

Attachment 5.1 Right-of-Way Monumentation Policy

Section 9-10 Public Relations

9-10-1 Public Contacts
  1.1 Informational Letter
  1.2 Notification of Local Officials
  1.3 Property Owner Contacts
  1.4 Published Notices and Press Releases
  1.5 Public Contacts

9-10-5 Entry and Operations on Private Land
  5.1 Entry on Private Land
  5.2 Right of Entry Process
  5.3 Entry on Indian Land
  5.4 Entry on Public Land
  5.5 Entry on Utility Right-of-Way
  5.6 Entry on Railroad Right-of-Way
  5.7 Operations on Private Land
  5.8 Operations on Public Land

9-10-6 Surveys or Inspections on Railroad Right-of-Way
  6.1 Right of Entry
  6.2 Entry Process
  6.3 Working on Railroad Right-of-Way
<table>
<thead>
<tr>
<th>Section 9-20 Spatial Reference Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>9-20-1 General</td>
</tr>
<tr>
<td>9-20-5 The Public Land Survey System</td>
</tr>
<tr>
<td>9-20-10 The National Spatial Reference System (NSRS)</td>
</tr>
<tr>
<td>9-20-15 Horizontal Datums</td>
</tr>
<tr>
<td>9-20-20 Vertical Datums</td>
</tr>
<tr>
<td>9-20-25 Coordinate Systems</td>
</tr>
<tr>
<td>9-20-30 Coordinate Transformation</td>
</tr>
<tr>
<td>9-20-35 Combination Factor Selection</td>
</tr>
<tr>
<td>9-20-40 Grid/Ground Coordinate Conversions</td>
</tr>
</tbody>
</table>
Section 9-25 Monumentation

9-25-1 Perpetuation of Landmarks
   1.1 Corners To Be Recovered And Perpetuated
   1.2 Landmark Perpetuation

9-25-5 Control Monumentation
   5.1 Horizontal Control
   5.2 Vertical Control
   5.3 Three-Dimensional Control
   5.4 Alignment Surveys

9-25-6 Right of Way Monumentation
   6.1 Monument Location and Type
   6.2 Right-of-Way Marker Post
   6.3 Coordinates
   6.4 Positioning Requirements
   6.5 Documentation
   6.6 Minor Acquisition

9-25-10 Engineering Survey Monuments
   10.1 Type 1 Monument
   10.2 Type 2 Monument
   10.3 Type 3 Monument
   10.4 Type 4 Monument

Section 9-30 Real Time Kinematic (RTK) Surveys

9-30-1 Introduction
   1.1 Overview

9-30-5 RTK Application Categories and Their Uses

9-30-10 General Scheme of RTK Survey Data Collection

9-30-15 RTK Surveying Guidelines
   15.1 Table of RTK Surveying Guidelines
   15.2 Discussion of Items in Table

Section 9-35 Horizontal Control - Traverse

9-35-1 When Used

9-35-5 Classification, Standards and Specifications
   5.1 Reasons for Classification, Standards and Specifications
   5.2 Classification
   5.3 Standards and Specifications

9-35-10 Horizontal Control Data Base
   10.1 The National Geodetic Reference System: NAD 27

9-35-15 Field Reconnaissance
   15.1 Recovery of Horizontal Control Stations
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>15.2</td>
<td>Horizontal Control Survey Configuration</td>
</tr>
<tr>
<td>15.3</td>
<td>Field Sketches</td>
</tr>
<tr>
<td>9-35-20</td>
<td>Field Procedures - Distance Measurement</td>
</tr>
<tr>
<td>20.1</td>
<td>Electronic Distance Measurements</td>
</tr>
<tr>
<td>20.2</td>
<td>Principle of Measurement</td>
</tr>
<tr>
<td>20.3</td>
<td>Sources of Error</td>
</tr>
<tr>
<td>20.4</td>
<td>Prisms</td>
</tr>
<tr>
<td>20.5</td>
<td>EDM Operation</td>
</tr>
<tr>
<td>20.6</td>
<td>Data Collection</td>
</tr>
<tr>
<td>20.7</td>
<td>Taping</td>
</tr>
<tr>
<td>9-35-25</td>
<td>Field Procedures - Angle Measurement</td>
</tr>
<tr>
<td>25.1</td>
<td>Total Stations</td>
</tr>
<tr>
<td>25.2</td>
<td>Horizontal Angles</td>
</tr>
<tr>
<td>25.3</td>
<td>Vertical/Zenith Angles</td>
</tr>
<tr>
<td>25.4</td>
<td>Instrument Orientation</td>
</tr>
<tr>
<td>25.5</td>
<td>Horizontal Orientation</td>
</tr>
<tr>
<td>25.6</td>
<td>Vertical Orientation</td>
</tr>
<tr>
<td>25.7</td>
<td>Data Collection</td>
</tr>
<tr>
<td>9-35-30</td>
<td>Computations</td>
</tr>
<tr>
<td>30.1</td>
<td>Horizontal and Vertical Angle Reduction</td>
</tr>
<tr>
<td>30.2</td>
<td>Horizontal and Vertical Distance Reduction</td>
</tr>
<tr>
<td>30.3</td>
<td>Curvature and Refraction</td>
</tr>
<tr>
<td>30.4</td>
<td>Methods for Traverse Adjustment</td>
</tr>
<tr>
<td>30.5</td>
<td>Accuracy Evaluations</td>
</tr>
<tr>
<td>9-35-35</td>
<td>Monumentation Required</td>
</tr>
<tr>
<td>Attachment 5.1</td>
<td>Recommended Minimum Classification Requirements</td>
</tr>
<tr>
<td>Attachment 5.2</td>
<td>Standards and Specifications for Horizontal Control</td>
</tr>
<tr>
<td>Attachment 10.1</td>
<td>Sample Data Sheet for Typical Horizontal Control Station</td>
</tr>
<tr>
<td>Section 9-40</td>
<td>Vertical Control</td>
</tr>
<tr>
<td>9-40-1</td>
<td>When Used</td>
</tr>
<tr>
<td>9-40-5</td>
<td>Classification, Standards and Specifications</td>
</tr>
<tr>
<td>5.1</td>
<td>Reasons for Classification, Standards and Specifications</td>
</tr>
<tr>
<td>5.2</td>
<td>Classification</td>
</tr>
<tr>
<td>5.3</td>
<td>Standards and Specifications</td>
</tr>
<tr>
<td>9-40-10</td>
<td>Vertical Control Data Base</td>
</tr>
<tr>
<td>10.1</td>
<td>First-Order (Primary Network)</td>
</tr>
<tr>
<td>10.2</td>
<td>Second-Order (Secondary Network)</td>
</tr>
<tr>
<td>10.3</td>
<td>Third-Order (Local Vertical Control)</td>
</tr>
<tr>
<td>10.4</td>
<td>Project Order (Project Specific Vertical Control)</td>
</tr>
<tr>
<td>9-40-15</td>
<td>Field Reconnaissance</td>
</tr>
<tr>
<td>9-40-20</td>
<td>Field Procedures</td>
</tr>
<tr>
<td>20.1</td>
<td>Single Run Double Simultaneous Leveling</td>
</tr>
<tr>
<td>20.2</td>
<td>Double Run Leveling</td>
</tr>
<tr>
<td>20.3</td>
<td>Three Wire Leveling</td>
</tr>
<tr>
<td>20.4</td>
<td>Single Wire Leveling</td>
</tr>
<tr>
<td>20.5</td>
<td>Reciprocal Leveling</td>
</tr>
<tr>
<td>20.6</td>
<td>Trigonometric Leveling</td>
</tr>
<tr>
<td>20.7</td>
<td>Digital Leveling</td>
</tr>
<tr>
<td>20.8</td>
<td>Curvature and Refraction</td>
</tr>
<tr>
<td>20.9</td>
<td>Peg Test</td>
</tr>
<tr>
<td>20.10</td>
<td>Data Collection</td>
</tr>
<tr>
<td>9-40-25</td>
<td>Computations</td>
</tr>
<tr>
<td>25.1</td>
<td>Single-Wire Adjustment</td>
</tr>
<tr>
<td>25.2</td>
<td>Three-Wire Adjustment</td>
</tr>
<tr>
<td>25.3</td>
<td>Least Squares Adjustments</td>
</tr>
<tr>
<td>25.4</td>
<td>Accuracy Evaluations</td>
</tr>
</tbody>
</table>
Section 9-43 Planning and Scheduling

9-43-1 Minimum Data Requirements
   1.1 Reconstruction, Reconditioning, or Expansion Project
   1.2 Pavement Replacement Project
   1.3 Resurfacing Project
   1.4 Bridge Replacement or Bridge Rehabilitation Project
   1.5 References

9-43-5 Survey Time Frame
   Attachment 1.1 Surveying Operations to Meet Minimum Data Requirements

Section 9-45 Geospatial Projects

9-45-1 General
9-45-5 Aerial Imagery Products
   5.1 Vertical Aerial Imagery
   5.2 Digital Aerial Mosaic
   5.3 Digital Geo-Referenced Imagery
   5.4 Oblique Aerial Imagery

9-45-10 Aerial Photogrammetry Products
   10.1 Digital Terrain Model (DTM)
   10.2 Planimetric Map
   10.3 Expedient Planimetric Map
   10.4 Extensions to DTM and Mapping Products
   10.5 Digital Ortho Imagery

9-45-15 Aerial Photogrammetry Work Flow
9-45-20 LiDAR Products
   20.1 Scanner Types
   20.2 Ground Control and Targeting
   20.3 Accuracy Requirements
   20.4 How to Request a LiDAR Project
   20.5 Deliverables
   20.6 Limitations
   20.7 Factors to Consider when Selecting LiDAR for a Project
   20.8 Conclusion

9-45-25 LiDAR Work Flow
9-45-30 Unmanned Aircraft Systems (a.k.a. UAS, UA, UAV, Drones)
9-45-35 Ground Control
   35.1 Target Document
   35.2 Surveying Photogrammetry and LiDAR Targets

9-45-40 Computation, Documentation and Distribution
   40.1 Computation
   40.2 Naming Standards
   40.3 Documentation and Distribution of Ground Control
   Attachment 1.1 Geospatial Products
   Attachment 5.1 Aerial Imagery Product Examples
   Attachment 10.1 Geospatial Product Examples
   Attachment 15.1 Aerial Photogrammetry Work Flow Diagram
   Attachment 35.1 Geospatial Targeting Guidelines
   Attachment 40.1 Naming Standards for WSI Files
   Attachment 40.2 Naming Standards for Folders and Files on the LiDAR Server
   Attachment 40.3 Wisconsin County Coordinate System Numbers and Abbreviations
   Attachment 40.4 Sample WSI Files for Ground Control and Map Check Data

Section 9-50 Alignments - Reference Line with Stationing

9-50-1 When Used
9-50-5 Standards and Specifications
5.1 ........ Alignment Surveys
5.2 ........ Reference Line With Stationing

9-50-10 ...... Field and Office Reconnaissance
10.1 ...... Establishing Existing Alignments
10.2 ...... References

9-50-15 ...... Field Procedures
15.1 ...... Establishing Existing Alignments
15.2 ...... New Alignments

9-50-20 ...... Alignment Computation
20.1 ...... Field-Surveyed Alignments
20.2 ...... Alignments Established by Design Computation
20.3 ...... Elements Common to All Alignments
20.4 ...... Data Storage

9-50-25 ...... Monumentation Required
Attachment 20.1 ...... Adjustment of Intermediate POT

Section 9-55 Drainage Structure Surveys

9-55-1 ...... Introduction
1.1 ...... When Used
1.2 ...... Data Collected
1.3 ...... Standards and Specifications
1.4 ...... Coordination

9-55-5 ...... Field Procedures
5.1 ...... Horizontal Alignment
5.2 ...... Topography
5.3 ...... Profile
5.4 ...... Cross Sections/DTMs
5.5 ...... Existing Structure Information

9-55-10 ...... Computations

9-55-15 ...... Monumentation Required
Attachment 5.1 ...... Horizontal Alignment at Drainage Structure
Attachment 5.2 ...... Flood Plain Section at Drainage Structure
Attachment 5.3 ...... Waterway Opening at Drainage Structure

Section 9-60 Structure Surveys

9-60-1 ...... Introduction
1.1 ...... When Used
1.2 ...... Standards and Specifications
1.3 ...... References

9-60-5 ...... Field Procedures
5.1 ...... Separation Structure Survey
5.2 ...... Rehabilitation Structure Survey

9-60-10 ...... Monumentation Required
10.1 ...... Separation Structure Survey
10.2 ...... Rehabilitation Structure Survey
Attachment 5.1 ...... Survey Data for Structure Rehabilitation Project
Attachment 5.2 ...... Structure Terminology Diagram

Section 9-65 Cross Sections/Digital Terrain Models (DTMs)

9-65-1 ...... Introduction
1.1 ...... When Used
1.2 ...... Standards and Specifications

9-65-5 ...... Field Procedures
5.1 ...... Cross Sections
5.2 ...... Digital Terrain Models (DTMs)
5.3 ...... Computations

9-65-10 ...... Monumentation Required

Section 9-70 Topography
9-70-1 Introduction
   1.1 When Used
   1.2 Standards and Specifications
   1.3 Other References

9-70-5 Field Procedures
   5.1 Computations
   5.2 Field Notes

9-70-10 Data Destination, Formats, etc.

Section 9-75 Right-of-Way
9-75-1 Introduction
   1.1 When Used
   1.2 Standards and Specifications

9-75-5 Field Procedures
   5.1 Methods
   5.2 Monumentation
   5.3 Computations

Section 9-80 Survey Mathematics
9-80-5 Survey Mathematics
   Attachment 5.1 Curve Formulas
   Attachment 5.2 Trigonometric Formulas
   Attachment 5.3 Cosine Law - Oblique Triangle
   Attachment 5.4 Coordinate Geometry