OREGON
DEPARTMENT
OF
TRANSPORTATION

Geometronics
OREGON DEPARTMENT OF TRANSPORTATION

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SURVEY

POLICY AND PROCEDURE

MANUAL

14 August 2015

Inaugural Operational Release

The development of a Survey Policy and Procedure Manual has been a vision for many years. The content that follows is the product of that vision. This inaugural release of the operational copy, distributed 14 August 2015, is for full implementation. ODOT staff is expected to adhere to the procedures contained in this manual. Work orders for consultant surveyors are expected to reference this manual and require consultants to adhere also. We encourage each of you to become familiar with the material and utilize it to the extent practicable.

Please contact the Geometronics Unit with any comments or recommendations, particularly if you discover an error. The Geometronics Unit anticipates a need to continually track input that we learn about for revisions and to release an update periodically, perhaps as often as annually.

This version does NOT include Chapter 2 on construction. The need to harmonize this manual with the standard ODOT construction contract documents and procedures creates a more complex process and involves more participants than was necessary for the other chapters. We are still working toward releasing a construction supplement within the next few months.

The members of the Geometronics Unit anticipate that the community of land surveying professionals who provide surveying services to the agency will welcome the arrival of this manual. We hope that you will find value in it and that our clients will see improved consistency and perhaps a higher general quality in the products we deliver as a result of the guidance provided in its pages.

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Ron Singh, PLS

ODOT Chief of Surveys/Geometronics Manager

Table of Contents

Inaugural Operational Release i

Acknowledgement ii

Table of Contents iii

Forward xi

- **Intended Audience** xi
- **Intended Application** xi
- **Media Format** xi

Revision History xii

- **Review Copy** xii
- **Operational Copy** xii

Chapter 1 - Common Requirements 1

1.1 Introduction 1
1.11 Overview 1
1.12 Application 1
1.13 Scope 1
1.14 Authority 1
1.15 Typical Project 2
1.151 Description of Typical Project 2
1.152 Workflow of Typical Project 2

1.2 General Considerations 4
1.21 Overview 4
1.22 Safety 4
1.221 Survey Safety Manual 4
1.222 Responsibility for Safety 4
1.223 Safety Training 4
1.23 Laws and Regulations 4
1.231 Responsible Charge 5
1.232 Required Notifications 5
(A) County Surveyor (or multiple County Surveyors if appropriate) 5
(B) National Geodetic Survey (NGS) 5
(C) Geometronics Unit/ODOT Chief of Surveys 6
1.233 Freight Mobility and Emergency Vehicles 6

1.234 Right of Entry 7
1.235 Utility Notification 7
1.236 Environmental Concerns 8
1.237 FCC Regulations 8
1.24 Units of Measure 8
1.241 Established Units 8
1.242 Standard Units 9
1.243 Digital Scale Factor 9
1.244 Use of Stationing and Mile Points 9
1.25 General Accuracy Concepts 9
1.251 Accuracy Requirements 9
1.252 Accuracy Statements and Claims 9
1.253 Accuracy of Points 9
1.26 Control of the Survey Work 10
1.261 Scope and Schedule 10
1.262 Personnel 10
(A) Professional in responsible charge 10
(B) Survey field crew leader 11
1.263 Equipment 11
1.264 Processing Tools 11
1.265 Responsibility for Preservation of Markers and Monuments 11
1.266 Regulating Level of Effort 12

1.3 Equipment 13
1.31 Overview 13
1.32 Selection of Equipment 13
1.321 Level-of-Effort Considerations 13
1.322 Manufacturer Specifications 13
1.323 Terrestrial Equipment 13
1.324 Global Navigation Satellite System Equipment 14
1.33 Care and Maintenance 14
1.34 Periodic Assessments 15
1.341 Overview 15
1.342 Assessment Frequency 15
1.343 Assessment Documentation 15
1.344 Characteristics to Assess 16
(A) Support Equipment 16
(B) Leveling Equipment 16
(C) Total Station Equipment 16
(D) Global Navigation Satellite System Equipment 17

1.4 Standard Procedures 18
1.41 Overview 18
1.42 Guiding Principles 18
1.421 Error, Risk, Accuracy, and Precision 18
1.422 Procedures for Various Equipment 18
(A) Tripod Heights 18
(B) Bipods 19
1.43 Validation Procedures 19
1.431 Backsight/Elevation Checks 19
1.432 Global Navigation Satellite System Real-Time Kinematic Check Shots 19
1.433 Height Checks 20
1.434 Confidence Points 20
(A) Definition of Confidence Points 20
(B) Collection of Confidence Points 20

(C) Placement of Confidence Points 21
(D) Application 21
1.44 Equipment-Related Procedures 21
1.441 Leveling Procedures 21
1.442 Total Station Procedures 21
(A) Distance measurements 21
(B) Angle Measurements 22
1.443 Global Navigation Satellite System Kinematic Procedures 22
(A) Global Navigation Satellite System Kinematic Specifications 22
(B) RTK Localization (Site Calibration) 22

1.5 Monuments and Markers 24
1.51 Definitions 24
1.52 Monument Inscription Requirements 25

1.6 Products and Deliverables 26

1.7 Documentation 27
1.71 Record Identification 27
1.711 Purpose of the Work or Record 27
1.712 Official Project Name 27
1.713 Key Number 27
1.714 Highway and Route Identification 27
1.715 Personnel Involved 28
1.72 Project Journal 28
1.73 Equipment Testing and Calibration 28
1.74 Transmittal 28
1.75 Data Formats 28
1.76 Coordinate Lists 29
1.77 Common Content of Field Data and Notes 29
1.771 Character of “Original” Field Notes 29
1.772 Content and Format of Field Notes 30
1.773 Point Numbering 32
1.774 File Naming 33
1.775 Electronic Data Storage 34

1.8 References 36
1.81 ODOT Publications 36
1.811 Manuals 36
1.812 Forms 36
1.82 Outside Publications 36

1.9 Specific Activities &Tasks 37

Chapter 2 - Construction 38

Chapter 3 - Project Control 39

3.1 Introduction 39
3.11 Scope 39
3.12 “Project Control” Defined 39

3.2 General Considerations 40
3.21 Overview 40

3.211 Guiding Principles 40
3.212 Coordinate Systems 40
(A) Horizontal Datum 40
(B) Vertical Datum 41
(C) Geoid Model 42
(D) Mapping Projection 42
(E) Coordinate Units 43
3.22 Accuracy of Control Points 43

3.3 Equipment 44
3.31 Overview 44
3.32 Equipment Requirements 44

3.4 Standard Procedures 45
3.41 Sets of Angles 45
3.411 Distance measurements 45
3.412 Angle Measurements 45
3.413 Sweeping Multiple Sets of Points 45
3.42 Static GNSS Observations 47
3.43 Redundancy and Observation Sequences 48
3.431 Network Point 48
(A) Common criteria for any network point 48
(B) Horizontal Network Points 48
(C) Temporary Bench Mark 49
(D) Three-Dimensional Network Points 49
3.432 Linear Point 49
3.433 Controlled Strategic Point 49
(A) Double Tie 50
(B) Modified Double Tie 51
(C) Resection or Free Station 52
(D) Closing to Other Control 53
3.434 Strategic Point 53
3.435 Side Shot 56
3.44 Other Procedures 56

3.5 Monuments and Markers 57
3.51 Overview 57
3.511 Monuments Required 57
3.512 Permanence, Stability, and Survivability 57
3.52 Characteristics of Marks and Monuments 57
3.521 Characteristics of Horizontal Network Marks 57
3.522 Characteristics of Vertical Network Marks 58
3.53 Placement of Marks and Monuments 58
3.531 Placement of Horizontal Project Control 58
3.532 Placement of Vertical Project Control 58
3.54 Reference Requirements for Project Control Points 59

3.6 Products and Deliverables 60

3.7 Documentation 61

3.8 References 62
3.81 ODOT Publications 62
3.82 Outside Publications 62

3.9 Specific Activities &Tasks 63
3.91 Resetting Benchmarks 63

3.92 Establishing Project Control 63
3.921 Horizontal Project Control 64
(A) Universal Horizontal Project Control Procedures 64
(B) Traverse Procedures 64
(C) Horizontal Network Procedures 65
3.922 Vertical Project Control 66
(A) Vertical Control Required 66
(B) Trigonometric Leveling 66
(C) Universal Differential-Leveling Procedures 67
(D) Level Circuit Procedures 68
(E) Vertical Network 68
3.923 Three-Dimensional Project Control 69

Chapter 4 - Boundary 70

4.1 Introduction 70
4.11 Overview 70
4.12 Application 70

4.2 General Considerations 71
4.21 Guiding Principles 71
4.22 Boundary Surveying and Right of Way Functions 71
4.23 Accuracy of Boundary Points 71

4.3 Equipment 72
4.31 Boundary Field Work 72
4.32 Computer Aided Design (CAD) Maps 72

4.4 Standard Procedures 73
4.41 Boundary Monument Locations 73
4.42 Property Acquisition Process 73
4.43 Staking or Flagging Boundary Lines for Negotiations 73

4.5 Monuments and Markers 74

4.6 Products and Deliverables 75
4.61 Right-of-Way Maps 75
4.62 Right-of-Way Layout Design 75
4.63 Professional Seal 75
4.64 Recovery and Monumentation of Boundary Points 75

4.7 Documentation 76

4.8 References 77
4.81 Right of Way Engineering Manual 77
4.82 History of Highways 77
4.83 Control, Recovery and Retracement Surveys 77
4.84 Right Of Way Monumentation Surveys 77

4.9 Specific Activities &Tasks 78
4.91 Recovery, Retracement, and Resolution 78
4.911 Preparation Recovery of Boundary Point 78
4.912 Recovery of Boundary Evidence 78
4.913 Retracement and Resolution of the Boundary 78
4.92 Boundary Monumentation 78
4.921 Monumentation of Highway Right Of Way Boundaries 78

(A) Network Option ... 79
(B) Boundary Option ... 79
4.922 Monumentation of Quarries and Stockpile Sites ... 80
(A) ODOT Owned Sites ... 80
(B) ODOT Controlled Sites Bounded by Government and Private Land ... 80
(C) ODOT Controlled Sites Bounded Entirely By Government Land ... 80
(D) Monuments, Guard Posts, and Line Marking Standards ... 81
4.923 Monumentation of Other Properties ... 81

Chapter 5 - Topography ... 84

5.1 Introduction ... 84
5.11 Overview ... 84
5.12 Application ... 84
5.13 Scope ... 84

5.2 General Considerations ... 85
5.21 Overview ... 85
5.22 Guiding Principles ... 85
5.23 Selection of a Method ... 86
5.24 Selecting Features ... 86
5.25 Integrated Topographic Collection ... 86
5.26 Accuracy of Topography ... 86
5.261 Accuracy of Topographic Points ... 86
5.262 Positional Accuracy of Topographical Points ... 87
5.263 Allowance for Practical Limitations on Accuracy ... 87
5.264 High-Accuracy Zones ... 87
5.265 Delineation of Non-Standard Accuracy Areas ... 88

5.3 Equipment ... 89

5.4 Standard Procedures ... 90
5.41 Global Navigation Satellite System Kinematic Procedures ... 90
5.42 Purpose and Function of Topographic Data ... 90
5.43 Mapping and Modeling Original Ground ... 91
5.431 Objectives of Original Ground Basemap ... 91
5.432 Types of Original Ground Data ... 91
5.433 Spacing of Topographic Data Points ... 91
5.434 Elevation Data for Topographic Data Collection ... 92
5.435 Validation Features in Topographic Data Collection ... 92
5.436 Attributes of Original Ground Data ... 92
5.437 Original Ground Basemap ... 97
5.438 Original Ground iDTM ... 98
5.439 Drainage Study ... 98
5.44 Construction As-Built Maps ... 99
5.441 Construction Mapping Objectives ... 99
5.442 Construction Mapping Attribute Characteristics ... 100
5.45 Property Boundary ... 100
5.451 Property Boundary Topographic Data Objectives ... 100
5.452 Property Boundary Topographic Data Attribute Characteristics ... 100

5.5 Monuments and Markers ... 101

5.6 Products and Deliverables ... 102
5.61 Original Ground ... 102

5.611 Basemap 102
5.612 Confidence Point Analysis Report 103
5.62 Construction 103
5.63 Property Boundary 103
5.64 Geospatial Positioning 103

5.7 Documentation 104

5.8 References 105

5.9 Specific Activities &Tasks 106
5.91 Roadside Inventory 106
5.92 Data Collection 106
5.921 Overview 106
5.922 Terrain 107
5.923 Utilities 107
5.924 Hydraulics 108
5.925 Drainage 108
5.926 Environment & Archaeology 109
5.93 Detailed Basemap 109
5.94 Intelligent Digital Terrain Model 109
5.941 Building an Intelligent Digital Terrain Model 110
5.942 Deliverables: 110
5.943 Original Ground Confidence Point Analysis 110
(A) Observation Equipment 110
(B) Confidence Point Density 111
(C) Analysis Procedure 111
(D) Original Ground Confidence Point Tolerances Values 112
(E) Original Ground Confidence Point Acceptance Criteria 112
(F) Failing Results 113
(G) Confidence Point Documentation 113
(H) Confidence Point Deliverables 113

Indexes

Topical Index I-1

Index of Tables and Figures I-6

Apendixes

Glossary A-1

Acronyms and Abbreviations A-8

Reference Material A-9
ODOT Forms A-9
ODOT Publications A-9
External Publications A-10
Other Resources A-10

Checklists A-10
Project Kickoff A-100
Location Completion & Handoff A-11
Contractor Surveying Handoff A-11

Forms **A-11**
Technology Aids **A-11**

Forward

Intended Audience

The purpose of the ODOT Survey Policy and Procedure Manual is to provide specific instruction for land surveying and related activity either performed by or performed for the Oregon Department of Transportation, hereinafter called ODOT. The primary intended audience is the surveyor in responsible charge as described in Oregon Revised Statutes, hereinafter referred to as the Surveyor. However, the audience also includes anybody involved with department projects such as contract surveyors, consultants, and local agencies.

Intended Application

This manual addresses only ODOT-specific practices and requirements. It is not a training or how-to manual. ODOT assumes that the user of this manual already has a good knowledge and understanding of survey practices. Therefore, any subject matter broader than Agency practices, policies, and procedures is not included.

Media Format

ODOT developed the Survey Policy and Procedure Manual for digital distribution only: ODOT does not plan to distribute printed copies. As such:

- Page layouts and formatting for optimized on-screen viewing rather than the printed page.
- Reference material includes embedded links as appropriate.

The format and design support printing by the user:

- On standard letter-size paper
- With Header and Footer information and in some cases Chapter, Section, Subsection, and Topic headings that provide some context reference on each page.

Revision History

Review Copy

27 March 2015 – Original public draft

Operational Copy

14 August 2015 – Significant revisions throughout

Chapter 1 - Common Requirements

1.1 Introduction

1.11 Overview

This Chapter contains common agency requirements for all survey activities. The following Chapters provide specific direction for Construction, Project Control, Boundary, and Topography surveys.

1.12 Application

Apply these common policies and procedures except where specific direction dictates otherwise within the Section, Subsection, or Topic related to a particular activity or task.

1.13 Scope

All survey work or survey-related activity performed by ODOT or for ODOT by other entities is subject to the policies and procedures of this manual.

1.14 Authority

The Geometronics Unit developed the policies and procedures described in this manual under the authority of the ODOT Chief of Surveys. The Chief of Surveys has been delegated authority to establish such policies and procedures.

This manual has three fundamental purposes:

- ♦ Provide documentation of ODOT survey procedures.
- ♦ Maintain a certain quality of survey work performed.
- ♦ Regulate the level of effort expended.

The circumstances of some projects may prompt the surveyor to deviate from the standards. Concurrence by the ODOT Chief of Surveys is required for any deviation and for use of techniques and equipment not addressed in this manual. Request approval for any deviation using Form #734-2959 "SURVEY POLICY DEVIATION REQUEST". In addition, document within the project records any deviation along with the rationale for doing so.

1.15 Typical Project

While ODOT surveyors may be involved in a wide array of activities and are called upon to perform all sorts of survey and survey-related functions, some projects are more conventional than others. Below is a brief description of a typical project and the workflow associated with such a project.

1.151 Description of Typical Project

A typical project is originated and the prospectus drafted through the Statewide Transportation Improvement Plan (STIP) development process. It may be as simple as a turn lane or beacon light, or it may be as much a construction of a completely new highway. The most complex of projects is normally the reconstruction of an existing facility while continuing to support traffic flow. Ancillary activity away from the main project may involve a quarry site, environmental mitigation, or other location. These may be a part of a STIP project or unrelated to the STIP.

Ideally, the Region Surveyor is involved in the scoping of a STIP project early, before any work begins and while the Region is finalizing funding and budgeting. As part of this initial scoping, the surveyor may need to collect data for an inventory of roadside hazards in support of the roadway designer effort to address them. Such roadside hazards may have significant impact on the scope and budget of the project.

1.152 Workflow of Typical Project

Once the overall scope of the project is defined and funding is approved, the surveyor is one of the first to begin work on the project. Be sure to address right of entry matters. Depending on the scope of the project, the surveyor is obligated to provide or perform the following.

- Establish horizontal and vertical project control suitable to serve the duration of the project through construction and to the final monumentation of right of way
- Recover monuments, develop resolution of current/existing right of way, and record results with the county
- Complete topographical survey including the shape of the ground, the size and location of any streams or bodies of water, and all natural and manmade features.
- Design parcel boundaries for acquisition, develop descriptions of parcels, and affix PLS seal to descriptions
- Layout and mark proposed right of way in the field for negotiation purposes
- Execute a pre-construction survey
- Provide construction direction through stakes and ground markings or through data for automated machine guidance

- Measure constructed features for final payment and/or for periodic progress payments
- Document final “As-Built” features above, below, and on the ground
- Monument new right of way and record with the county placement of new monuments or replacement of disturbed monuments

1.2 General Considerations

1.21 Overview

This Section covers responsibility and control of the activity. It also addresses matters that pertain to most survey projects or tasks.

1.22 Safety

Protecting yourself and others is of paramount importance. Every activity has some risk associated with it, but no task is so important that safety is a second priority. Keep safety in the forefront at all times and stop work when it cannot be completed in a reasonably safe manner.

1.221 Survey Safety Manual

The Safety Subsection of this manual does not replace or supersede the ODOT Survey Safety Manual.

- ♦ Adhere to latest version of the Survey Safety Manual of ODOT available from the Geometronics Unit at http://www.oregon.gov/ODOT/HWY/GEOMETRONICS/docs/Survey_Safety_Manual.pdf
- ♦ Adhere to safety requirements of this manual as well.
- ♦ In the event of a conflict, the Survey Safety Manual governs.

1.222 Responsibility for Safety

Every person associated with a task or project has substantial responsibility for the safety and well-being of all workers and every member of the traveling public.

In addition to following the requirements of the ODOT Survey Safety Manual, check with the appropriate ODOT Safety Officer for other ODOT safety policies and OSHA/OrOSHA regulations that apply to your planned activity.

1.223 Safety Training

Ensure that new employees receive appropriate orientation training as soon as practicable after reporting for duty, typically within the first few days or the first week. Include in that training an introduction to this manual and the Survey Safety Manual.

1.23 Laws and Regulations

A diverse collection of legal and regulatory requirements affects Survey activity. The Surveyor and their representatives must be educated and diligent in adhering to the laws and regulations that govern their activities.

1.231 Responsible Charge

Perform all survey work defined in Oregon Revised Statutes (ORS) 672.005(1)(c) through 672.005(1)(f) and ORS 672.005(2) under the responsible charge of a Professional Land Surveyor registered in the state of Oregon. While ORS permits some types of survey work under the responsible charge of an Oregon registered Professional Engineer (PE), ODOT requires that an Oregon PLS take responsible charge of any activities covered in the above statutes.

1.232 Required Notifications

During any survey project, there is the potential for performing activities that require by statute or rule that the surveyor provide notification to various entities regarding potential disturbance or destruction of record monuments. This Topic provides a summary of those notifications. In addition to the notifications required in this Topic, comply with the requirements in Topic 4.912 "Recovery of Boundary Evidence". For additional or more detailed information on required notifications, consult the pertinent reference documents, contact the entity to be notified, or consult the Geometronics Unit.

(A) County Surveyor (or multiple County Surveyors if appropriate)

- ♦ Notify as required in Oregon Revised Statutes 209.250(9) of changes made or found to monuments and accessories of the Public Land Survey System.
- ♦ Notify as required in Oregon Revised Statutes 209.140 of monuments and accessories of the Public Land Survey System subject to potential disturbance by the proposed project.
  - Include monuments and accessories in the proximity of the project in addition to those in the likely or potential path of destruction.
  - Notify in writing with "Project Notification To County Surveyors" (ODOT Form 734-2298) http://www.oregon.gov/ODOT/HWY/Geometronics/docs/project_notification_to_county_surveyors.pdf
  - Follow the direction of the County Surveyor with regard to referencing, resetting, or other activity related to preserving the position including use of state forces, contract bid item, or separate contract.
  - Upon commencement of any field location surveys.
  - Again during the preconstruction survey.

(B) National Geodetic Survey (NGS)

- ♦ Reset of Bench Marks listed in the NGS Integrated Data Base: http://www.ngs.noaa.gov/cgi-bin/datasheet.prl
  - Notify ODOT Geometronics as early as practicable of need to reset the bench mark.
  - Reset the bench mark per instructions in the National Geodetic Survey "Bench Mark Reset Procedures": http://www.ngs.noaa.gov/PUBS_LIB/Benchmark_4_1_2011.pdf
  - Submit documentation of the completed bench mark reset to the NGS as required on Page 11 of the NGS "Bench Mark Reset Procedures"

- Send a copy of the documentation to the ODOT Geometronics Unit at the address on the front of this manual or by e-mail to odot.geometronics@odot.state.or.us.

♦ Recovery of Geodetic Survey Marks listed in the National Geodetic Survey Integrated Database: http://www.ngs.noaa.gov/cgi-bin/datasheet.prl

- File report of recovery the geodetic control by filing a recovery report using the NGS on-line tool at:
  http://www.ngs.noaa.gov/cgi-bin/recvy_entry_www.prl
- If mark is destroyed, send the recovered mark or a photo of the destroyed mark with recovery report.
- Send a copy of the recovery report to the ODOT Geometronics Unit at the address on the front of this manual or by e-mail to odot.geometronics@odot.state.or.us.

(C) Geometronics Unit/ODOT Chief of Surveys

♦ Reset of ODOT Bench Marks

- Notify ODOT Geometronics Unit as early as practicable of need to reset the bench mark.
- Reset the bench mark per instructions in the National Geodetic "Survey Bench Mark Reset Procedures".
- Submit documentation of the completed bench mark reset as required on Page 11 of the National Geodetic Survey "Bench Mark Reset Procedures" above, except send the required documentation to the ODOT Geometronics Unit at the address on the front of this manual or by e-mail to
  odot.geometronics@odot.state.or.us .

♦ Other Geodetic Mark Recoveries

- File report of recovery of other geodetic control survey marks using ODOT Form 734-2802:
  http://www.odot.state.or.us/forms/odot/highway734/2802.pdf
- Send completed form to ODOT Geometronics Unit at the address on the front of this manual or by e-mail to
  odot.geometronics@odot.state.or.us.

1.233 Freight Mobility and Emergency Vehicles

When organizing and executing a project, provide for mobility of the following vehicles.

♦ Have a plan and provide for immediate transit of any emergency vehicles through the work area without delay.

♦ Freight mobility is an important objective of ODOT. Do not restrict movements of freight vehicles in general or the passage of oversized vehicles without first coordinating with the ODOT Freight Mobility Coordinator or with the respective District Office. Additional information on freight mobility matters including the ODOT Mobility Procedures Manual and contact information for the Freight Mobility staff in the five Regions and in the Motor Carrier Transportation Division is available at:
http://www.oregon.gov/ODOT/MCT/Pages/mobility.aspx

1.234 Right of Entry

ODOT employees and agents have the right to enter onto private property for project work under Oregon Revised Statutes (ORS) 366.365 and ORS 35.220. However, ORS 672.047 regulates land surveyors, provides specific right of entry for Professional Land Surveyors, and places further requirements on them. Therefore, in order to enter upon private property for any survey activity, the persons so entering must comply with the provisions of ORS 672.047 regarding notice to the landowner and occupant, preventing damage, removing temporary markings, and providing a copy of any survey product.

The law allows either notice by first class mail or by personal notice to the landowner and occupant. Notice by first class mail must be mailed at least seven days prior to entry. Personal notice must be hand delivered to the landowner or occupant or it may be posted in a conspicuous place where the landowner or occupant may reasonably be expected to see the notice. ODOT has a door hanger to be used for personal notice. Even with notification by first class mail, it is good practice to provide personal notice when entering upon the land. Also provide personal notice if you or your representative have been absent from the project for an extended period of time or the original notification does not cover the new activity. Searching for monuments or making measurements to a monument that is on or adjacent to private property constitutes entry and obligates the surveyor to fulfill the notification requirement prior to beginning the work.

If at any time, the landowner does not allow you onto the property, then leave and discuss the matter with your manager and possibly the ODOT Chief of Surveys.

1.235 Utility Notification

Comply with the Oregon Utilities Coordinating Council (OUCC) and the Oregon Utility Notification Center (OUNC) current Standards Manual. The 2014 edition is available in the URL below.

http://digsafelyoregon.com/wp-content/uploads/public/Standards-Manual-July-2014.pdf

As cited in the Standards Manual, OAR 952-001-0010(7) defines "excavation" as " ...any operation in which earth, rock or other material on or below the ground is moved or otherwise displaced by any means... ". Some activities of a survey crew clearly are excavation. However, a literal interpretation would consider many of the routine and benign activities of a survey crew as excavation. Any “excavation” requires notifying OUNC and waiting for the marking of all underground utilities in the area before proceeding.

Forceful manual digging or utilization of any power excavation equipment clearly falls within the letter and spirit of the definition. Similarly, driving the typical iron rod into the ground as a survey monument is excavation, as is the setting of delineators and witness posts. However, the council has recognized certain survey activities as acceptable without the precautions required for excavation. Notify the Oregon Utility Notification Center and follow the guidelines for excavators at any time excavation exceeds the following.

- Activities such as the placement and setting of tripods, PK nails, lath, flags, and hubs where that activity moves or displaces earth, rock, or other materials up to a depth, as measured from the ground surface, that is no greater than 12 inches are not considered excavation.

- The work of exposing survey monuments may be conducted so long as the work is done in a non-invasive manner. Careful hand excavation while searching for survey monuments would not require notifying OUNC. Employ hand tools or other such non-invasive methods to locate the survey monument.

If in doubt, always contact the One Call Center and request utility locates for the area.

Additionally, OAR 952-001-0080 provides an avenue for obtaining locate marks for "Design Information". This is independent of any excavation activity. Make requests for design information to OUNC.

1.236 Environmental Concerns

State, local, and federal laws, rules, and regulations under the umbrella of "environmental protection" restrict activity that has the potential to harm any of a variety of resources. Violating environmental protections can result in either civil action or criminal prosecution or possibly both.

As a surveyor, do not attempt unaided to determine acceptable activities. Contact the Region Environmental Coordinator (REC) for advice regarding environmental protection restrictions that might affect scheduling or work methods and appropriate environmental precautions. Establish contact with a REC as early in the process as practicable. Notify the REC prior to any survey activity that extends beyond the paved portion of the roadway. Beyond that delineation, survey work may infringe on legal environmental protections.

Document in the project survey records the conversation with the REC and any related decisions.

1.237 FCC Regulations

Surveyors use radio transmissions to convey both voice and data. The Federal Communications Administration regulates such activity. Operate radio transmitters in accordance with governing laws and regulations.

NOTE: ODOT crews may contact the Geometronics Unit or the ODOT Communications Wireless Group regarding licensing, output power, frequency range, and other matters.

1.24 Units of Measure

1.241 Established Units

Work in the established system of United States customary units of measure for all survey work unless one or more of the following conditions exists.

- ODOT has determined to use other units for a specific project.
- Construction plans are provided in some other units.
- ODOT has adopted a policy to use some other units in all survey and engineering activity.

1.242 Standard Units

Measure and record all data for survey work in standard units and to a standard precision. Use the following standard units and precision. Follow variations in precision where defined elsewhere in this manual.

	Unit	Definition	Precision
Length	SI Foot	1 = 0.3048 meter	0.01
Angles	Degrees, Minutes, & Seconds	360 Degrees = 1 Circle 60 Minutes = 1 Degree 60 Seconds = 1 Minute	00-00-00 (DD-MM-SS)

Table 1A - Standard Units

1.243 Digital Scale Factor

Create digital products with a scale of 1:1 where distances in digital products are equal to actual measured distances.

1.244 Use of Stationing and Mile Points

When employing engineers stationing and/or mile points, conform to the information on "STATIONING" provided in Section 11.3.2.4 of the 2012 ODOT Highway Design Manual or any successor. http://www.oregon.gov/ODOT/HWY/ENGSERVICES/pages/hwy_manuals.aspx

1.25 General Accuracy Concepts

All accuracy requirements are local accuracy relative to project control. Values derived from procedural requirements such as differences between double occupations and splits between direct versus inverted observations may have tolerances defined in this manual, but do not represent the required accuracy of a point.

1.251 Accuracy Requirements

Unless explicitly defined otherwise, all requirements within this manual for accuracy of equipment, positions, or data are at the 95% confidence level.

1.252 Accuracy Statements and Claims

Express all statements of accuracy at the 95% confidence level.

1.253 Accuracy of Points

Determine point locations according to the accuracy requirements in the relevant Chapters of this manual.

1.26 Control of the Survey Work

This manual provides instruction specifically to the Oregon Professional Land Surveyor in responsible charge, and indirectly through that individual to all personnel working under that responsible charge. As the Surveyor in responsible charge, you are responsible for the control of the work performed under your charge.

1.261 Scope and Schedule

Develop and maintain a plan for accomplishing the scope of the work within the schedule required.

- ♦ Begin survey work only after funding approval.
- ♦ Review the legal considerations in Subsection 1.23 “Laws and Regulations” of this manual.
- ♦ Consult with the client (designer, project manager, etc.)
- ♦ For Statewide Transportation Improvement Plan projects, study the Project Prospectus.
- ♦ For construction projects, study the plans and specifications

1.262 Personnel

All personnel are to maintain a professional and courteous demeanor. Additionally, personnel engaged in survey work shall have certain minimum qualifications and are responsible for certain aspects of the work.

(A) As the professional in responsible charge

- ♦ You must:
  - Maintain current registration as a Professional Land Surveyor with OSBEELS (the Oregon State Board of Examiners for Engineering and Land Surveying)
  - Have professional competence in the areas of activity expected on the project (boundary, mapping, construction, bridges, etc.)
- ♦ You are responsible for the following:
  - Maintaining familiarity with the site conditions and progress of the project
  - Becoming familiar with the scope, objective, plans, contracts, specifications, and other documents applicable to the project
  - Using appropriate equipment and methods
  - Testing and calibration of equipment
  - Determining notes and documentation required for types of survey task
  - Determining the accuracy required for each survey task
  - Maintaining close communication with the project leader, designer, project inspector, project manager, other survey crews, and other parties involved with the Project

- Performing all work using individuals with the technical qualifications and necessary skill to accomplish the tasks in a professional and competent manner
- Notifying the appropriate persons of conflicts and changes that may be necessary due to utilities, match point variations, design revisions, or other variables.

(B) Assure that the survey field crew leader

- ♦ Has the following qualifications
  - Technical competence conducting field work in the areas of activity expected on the project (GNSS, vertical control, boundary, mapping, construction, bridges, etc.)
  - The necessary safety training to minimize risk to the crew, other workers, and the public
- ♦ Takes responsibility for:
  - Becoming familiar with the scope, objective, plans, contracts, specifications, and other documents applicable to the project
  - Keeping close communication with the Professional Land Surveyor

1.263 Equipment

Use only equipment that:

- ♦ Conforms to the specifications of this manual.
- ♦ Is in good repair.
- ♦ Has been serviced on a reasonable interval.
- ♦ Is in proper adjustment and appropriately calibrated as further described in Subsection 1.33.
- ♦ Has not been damaged or experienced potential damage.

1.264 Processing Tools

For ODOT staff, process survey data using only software, services, or tools provided by the Geometronics Unit or explicitly approved by the ODOT Chief of Surveys. This limitation does not apply to contractors, consultants, or other outside entities unless so directed.

1.265 Responsibility for Preservation of Markers and Monuments

In addition to the circumstances listed in Topic 1.232 under “Required Notifications”, make every reasonable effort to preserve any survey mark of record with any entity. Examples include:

- ♦ Property markers on file with the respective county surveyor
- ♦ Public Land Survey and Donation Land Claim corners
- ♦ Highway and road centerline, right-of-way markers, recorded or not
- ♦ Bench marks in the National Geodetic Survey Integrated Database

- Bench marks on record with ODOT
- Survey marks bearing inscriptions from any public agency

Where statutory obligations exist, comply with those statutes. Where ownership or location of record is clear, contact that agency. Otherwise, contact the ODOT Geometronics Unit office or the ODOT Chief of Surveys.

1.266 Regulating Level of Effort

Make a determination in cooperation with the client (designer, project manager, etc.) regarding the level of effort appropriate for each task. Balance accuracy, precision, and detail against conserving valuable ODOT resources. Do not expend unnecessary resources simply with the purpose of playing it safe.

1.3 Equipment

1.31 Overview

This Section covers common equipment requirements for all types of activity addressed in this manual. Specific requirements may be added or revised elsewhere.

Govern selection and use of equipment as outlined below. Check, adjust, and calibrate equipment as appropriate and document the process according to this Section and any additional requirements covered elsewhere in this manual pertaining to specific activities.

1.32 Selection of Equipment

Select equipment based on the factors in this Subsection.

1.321 Level-of-Effort Considerations

Control the level of effort required for a task by first selecting the tool and procedure capable of achieving the required results with minimal investment of time and resources.

1.322 Manufacturer Specifications

Select equipment capable of compliance with the accuracy requirements defined for the various tasks and activities throughout this manual. Evaluate the intended accuracy of equipment based on the manufactures specifications and the following criteria.

1.323 Terrestrial Equipment

Terrestrial Equipment is comprised of the tools used in the traditional surveying to measure precise elevation differences, precise angles, and/or precise distances. Certain activities may require criteria that are more stringent than the minimums listed in this Topic.

Use only survey-grade Terrestrial equipment that is:

- ♦ Components designed to be used together
  - Electronic Distance Meter and mount
  - Target
  - Prism
  - Height measurements device
  - Plumbing pole
- ♦ Differential Leveling Equipment
  - Optical or digital levels equipped with a compensator

- Leveling systems with a combined manufacturer's stated accuracy of 0.005 ft. (2 mm) standard deviation or better for 1 km double run

♦ Total Stations

- Equipped with single-axis or dual-axis compensators
- With a manufacturer's stated angular accuracy of 5 seconds or better
- With a manufacturer's stated distance accuracy of 2 mm +/- 2 ppm or better

1.324 Global Navigation Satellite System Equipment

Use only survey-grade Global Navigation Satellite System receivers with the following characteristics for survey activities:

♦ Minimum of dual-frequency

♦ Manufacturer's stated horizontal Real-Time Kinematic and Post-Processed Kinematic accuracy of 10 mm + 1 ppm or better

♦ Manufacturer's stated horizontal static accuracy of 5 mm + 1 ppm or better

1.33 Care and Maintenance

As the surveyor in responsible charge, assure that equipment is used and transported in a way that does not place at risk reliable results that are adequate for the requirements of this manual and the intended task. In the interest of such assurance, assure that the equipment is cared for as a minimum to include the following characteristics.

♦ Wipe off with a soft cloth and then air dry all equipment used in rain or other wet conditions. Do not subject equipment to heat.

♦ Use bipods only when attended by a crew member who is monitoring it for movement and who is poised to attend it in a moment's notice. Do not use bipods as unattended backsights or foresights.

♦ Transport equipment in padded or otherwise protective containers equal to or superior to the factory packaging.

♦ Service equipment according to manufacturer's guidelines

♦ Take equipment out of service immediately upon any incident that poses the potential to damage the equipment or to degrade the measurements or other data. Return the equipment to service only after appropriate repairs have been made and the equipment has been assessed for proper function as described in Subsection 1.34 "Periodic Assessments".

1.34 Periodic Assessments

1.341 Overview

As the surveyor in responsible charge, periodically assess all equipment before use and periodically thereafter. Assure that equipment is in serviceable condition, is performing to manufacture's specifications, and that it provides reliable results adequate for the requirements of this manual and the intended task. Complete the following procedures as appropriate.

- ♦ Inspect the condition of each component.
- ♦ Test according to ODOT policy, industry standards, or manufacture's instruction.
- ♦ Calibrate digital corrections where available and retest.
- ♦ Adjust physical/mechanical settings where appropriate and retest.
- ♦ Establish the appropriate corrections to apply later to the collected measurements.

1.342 Assessment Frequency

Inspect and test all equipment on a periodic basis adequate to assure proper operation and accurate results. Test no less frequently than specified below. Test more often as appropriate based on activity. Adjust, calibrate, repair, or replace the equipment as appropriate when the testing reveals attributes that are outside of requirements defined in this manual. Assess the equipment based on the following events.

- ♦ Following any service or repair
- ♦ Following any incident with potential for damage
- ♦ Assess prior to any critical survey work
- ♦ Assess at least quarter annually
- ♦ Before using any unfamiliar equipment

1.343 Assessment Documentation

Keep records of equipment assessments. Note satisfactory as well as problematic findings. Include any corrective actions and reassessments. Maintain the records in the project file or an equipment file. Include each of the following as appropriate.

- ♦ Date
- ♦ Reason from the "Frequency " list above
- ♦ Equipment identification
- ♦ Assessment results – Use Form #734-2332 for E.D.M. Accuracy Test
- ♦ Any resulting actions

1.344 Characteristics to Assess

(A) Support Equipment

For all equipment used to support instrumentation or targets, assess the following.

- Tripod integrity (stable and secure legs, joints, clamps, and feet, etc.)
- Integrity of plumbing poles (stable and secure joints, clamps, and feet, etc.)
- Circular levels (accurate on tribrachs, poles, and rods, etc.)
- Optical plummet devices (plumb when leveled)

(B) Leveling Equipment

For differential leveling, assess the following.

- Level integrity (mates well with tripod, footscrews well-fitting, etc.)
- Integrity of rods (stable and secure joints, clamps, and feet, etc.)
- Circular level (accurate on instrument and rods)
- Compensator (rebounds appropriately after turning footscrew)
- Two-Peg Test (produces results adequate for intended work)

(C) Total Station Equipment

For equipment designed to turn angles/or measure distances or both, assess the following

- Base integrity (mates well with tripod, footscrews well-fitting, etc.)
- Circular level (accurate)
- Compensator (rebounds appropriately after turning footscrew)
- Horizontal collimation (produces results adequate for intended work)
- Vertical index error (produces results adequate for intended work)
- Standing axis error (produces results adequate for intended work)
- Tilting axis error (produces results adequate for intended work)
- Collimation (line-of-sight, Electronic Distance Meter beam, digital target sighting system all properly aligned)
- Electronic Distance Meter Measurements (On an National Geodetic Survey Calibration Baseline) (Conduct after adjustment of any other components)

NOTE: The fundamental test on the baseline is the slope distance from the Electronic Distance Meter to the prism. Form #734-2332 addresses this specific assessment. However, the base line is also a great place to validate certain results computed inside the total station, such as zenith angle, elevation difference, and horizontal distance since published values for each of these are available from the data sheet

(D) Global Navigation Satellite System Equipment

For equipment designed to acquire a position from satellites, assess the following

- Antenna mount integrity (mates well with tripod, footscrews well-fitting, etc.)
- Circular level (accurate)

1.4 Standard Procedures

1.41 Overview

This Section covers standard procedures that apply to all types of activity addressed in this manual. Specific requirements may be added or revised elsewhere.

Follow these procedures for all survey activity unless otherwise directed under the Chapters covering:

- ♦ Chapter 2 - Construction
- ♦ Chapter 3 - Project Control
- ♦ Chapter 4 - Boundary
- ♦ Chapter 5 - Topography

1.42 Guiding Principles

For all survey work and related activity, there are universal principles that constrain the decisions. This Subsection summarized some of those principles and standard actions to address them.

1.421 Error, Risk, Accuracy, and Precision

Balance the potential for error with the appropriate level of risk for the task performed. Then select a procedure consistent with that level of risk. Resist investing excessive resources in an effort to avoid acceptable levels of risk.

Precision requirements are dependent on the task performed. Follow the direction applicable for specific tasks.

Govern the precision on any given measurement by the current task and the required product. Determine precision requirements from the portions of the manual that describe each task.

1.422 Procedures for Various Equipment

This Subsection addresses equipment procedures independent of the type of work you are performing. Follow the portions of the manual that address more specific tasks and activities, but use this as the foundation for all observations.

(A) Tripod Heights

Except when leveling, measure instrument height at the start of each occupation and record the measurement.

(B) Bipods

The manufacturers of bipods design them for stabilizing the plumbing pole only while being held in place by survey personnel. Do not leave a plumbing pole on a point supported by a bipod alone. Similarly do not leave a plumbing pole supported by a bipod-style tripod. If a target or antenna is to occupy a point unattended, set up a standard wooden survey tripod.

1.43 Validation Procedures

1.431 Backsight/Elevation Checks

Validate every observation series made with a total station by including a known reference point at the beginning of the series and again at the end of the series.

- Begin and end sets of angles on the same point to provide validation that the instrument has remained stable throughout the observation process. Begin on a known point if one is available. Begin with a direct reading to this point. Follow that with direct observations and inverted observations to all other points, known and unknown. If a second set is required, include those additional observations in the process, together with the corresponding additional observations to the starting point. End with an inverted reading on the original point. For allowable observation sequences, see the Topic 3.413 “Sweeping Multiple Sets of Points” in Standard Procedures for Project Control.
- Begin each series of side-shots by observing a known point. Include both horizontal position and elevation in the validation. End each series of side-shots by observing a known point, either the same original point or not. Check into separate additional points as available. For sequences extending over an hour, check in periodically to some known point to verify that the instrument setup has not been compromised. Record all check shots.

1.432 Global Navigation Satellite System Real-Time Kinematic Check Shots

Validate every observation series made with Global Navigation Satellite System Real-Time Kinematic procedures by including a Check Shot on known control at the beginning of the series and again at the end of the series.

- Begin and end Global Navigation Satellite System Real-Time Kinematic sessions on a known Controlled Strategy Point or better. Stake out to that known point and verify the position to within the criteria of Table 3F “Specifications for Double Tie points” for maximum horizontal/vertical differences. Record and document the procedure and results.
- Take Check Shots representative of the location and procedure of the intervening activity. Take check shots in the vicinity of the intended work. Use the same configuration in equipment and technology as intended for the work.
- Check into separate additional points as available. For sequences extending over an hour, check in periodically to some known point to verify that the receiver configuration has not been compromised. Record all check shots.
- Name the point with the original control point number and provide a suffix of “CHK”.

1.433 Height Checks

Validate correct instrument heights (HI) with Global Navigation Satellite Systems or a total station to minimize the potential for an error in height:

- Measure the height of tripod-mounted equipment as required in Topic 1.422(A).
- Verify by independent measurement the graduations on a variable height pole.
- Verify proper and secure operation of the height-locking mechanism.

1.434 Confidence Points

(A) Definition of Confidence Points

Confidence Points are collected within the boundary of a Digital Terrain Model, the purpose of which are:

- To verify the accuracy of the Digital Terrain Model.
- To provide a level of confidence to the design team who will rely on this original ground model as a base for the design.
- To provide evidence just prior to construction that the original ground Digital Terrain Model is a reasonable representation of the original ground for computation of volumes and pay quantities.
- To verify that a surface is constructed accurately to the design.
- Any other application that fits the concept of confidence points described in this Topic.

Confidence Points do not test the accuracy of the specific measurements used to create the Digital Terrain Model. Procedures described in the other Topics of this Subsection address validation of the modeling collection process:

Use Confidence Points to test the Digital Terrain Model for adequate and properly placed points and lines or that a constructed surface matches the design.

(B) Collection of Confidence Points

Collect Confidence Points as follows.

- Collect Confidence Points with a Total Station.
- Ideally, collect Confidence Point data independent of the Digital Terrain Model data collection. This may be done prior to or after the Digital Terrain Model data collection.
- If an independent survey is impractical, it is acceptable to collect Confidence Point data at the same time as the Digital Terrain Model data. Be especially certain in this situation to validate observations with backsight checks and elevation checks or RTK check shots.
- Apply the same procedure for Confidence Point data collection as that used for the Digital Terrain Model.
- Apply the proper point attribute for the type of Confidence Point measured.

- Do not exceed maximum measurement distances defined for the collection of Digital Terrain Model data.

(C) Placement of Confidence Points

Collect Confidence Points to fulfil the following objectives.

- Represent all surface types and according to the distribution of the various types of surfaces depicted by the Digital Terrain Model.
- Randomly distributed throughout the Digital Terrain Model to provide a good sampling of the overall model.
- At a density as required for the specific application addressed in later Chapters.

(D) Application

The following aspects of Confidence Points are variable depending on application. They are addressed along with the requirements for each application.

- Error Tolerances and Acceptance Standards
- Number (density) of Confidence Points
- Confidence Point Types or Names
- Computation and Analysis

1.44 Equipment-Related Procedures

1.441 Leveling Procedures

Perform leveling work in accord with the procedures in Chapter 3 - Project Control.

1.442 Total Station Procedures

(A) Distance measurements

- Include distance measurements with all observations unless impractical.
- Compensate for exact prism offset by inputting the correction value into the instrument.
- Utilize alternate prism assemblies (not specifically designed for the system) only on non-control measurements, after considering the effect on measurements and making corrections if appropriate.
- Compensate for corrections to atmospheric conditions by inputting the correction value into the instrument.

(B) Angle Measurements

Refer to Subsection 3.41 for details on measuring angles for control observations. When collecting Side Shots, measure in direct face a single value for each component: horizontal circle, vertical circle, and slope distance

1.443 Global Navigation Satellite System Kinematic Procedures

(A) Global Navigation Satellite System Kinematic Specifications

Kinematic surveying is commonly used for topographic data collection and the general requirements are therefore covered in Chapter 5 under Subsection 5.41 "Global Navigation Satellite System Kinematic Procedures".

(B) RTK Localization (Site Calibration)

Localization of Real-Time Kinematic positioning, sometimes referred to as "Site Calibration", is the process of establishing parameters whereby positions can be reported by the receiver in a coordinate system that is not otherwise mathematically related to the native coordinate system of the satellite navigation system. The concept is to determine the rotation in space, the scaling factor, and the offset from the origin that best translates the system coordinates to the local coordinates of the project. Software handles the math involved in establishing localization parameters. However, the user is responsible to provide suitable input and to check the resultant output for conformance to the intended purpose.

Chapter 5 under Subsection 5.41 "Global Navigation Satellite

This manual does not address the use of localization for rough positioning while engaged in activities such as monument searches, network design, or asset inventory. Apply sound and defensible judgment in developing parameters for such use.

Localization in the context addressed here is applicable when used for any of the activities covered in this manual for which survey grade equipment is required and Real-Time Kinematic surveying is allowed. Covered activities include setting stakes or marks, constructing any feature, setting RTK. control points, tying boundary features, setting right-of-way monuments, and collecting topographical data.

Apply localization of real-time positons to horizontal positions, vertical, or both as appropriate. Use a localization of the Real-Time Kinematic coordinate system for the following purposes:

- To match a prior survey in which a systematic error is apparent
- To match a project coordinate system in the horizontal or vertical that cannot be met by simply assigning a coordinate system as described in Topic 3.212

Avoid establishing an LDP in the following situations.

- The project is on the OCRS or some other standard coordinate system
- As the initial coordinate system for a project
- The localization would not serve the entire project area.
- A LDP already exists for the project

To establish localization parameters onto a project control coordinate system, adhere to the following criteria.

- Build horizontal localization parameters on a minimum of four horizontal control points that surround the project to the extent practicable.
- Build vertical localization parameters on a minimum of four vertical control points (optimally permanent or temporarily bench marks) that surround the project to the extent practicable.
- Reject any localization point with horizontal residuals greater than 0.10 ft. (30 mm)
- Reject any localization point with vertical residuals greater than 0.15 ft. (45 mm)
- Verify the resulting LDP by using RTK to tie into the points that were used for the localization plus an additional point that was not used, then check residuals on these points.

When utilizing localizations for survey tasks, adhere to the following:.

- Check the equipment setup on a routine basis.
- Check into control after establishing the parameters and before utilizing the localization.
- Check in to at least one control point start of daily activity.
- Check in again at any time that the control station changes, either by moving a local base station or by switching to a different continuous real-time station.
- Validate LDP parameters by collecting and recording a position on a known point and verifying that residuals are within tolerance
- Avoid surveying outside the bounds of the localization, as doing so will likely introduce an increase in error .

1.5 Monuments and Markers

Various locations in this manual define monument and markers for a variety of purposes. This Section addresses common parameters for setting survey monuments and other markers on ODOT projects. For information on monuments for specific tasks, see Section 5 “Monuments and Markers” of the respective Chapters.

1.51 Definitions

The following is a partial list of monument nomenclature and the terms used in this manual

CSP – Controlled Strategic Point

Deep shanked aluminum caps with plastic insert– More durable and identifiable option to the RPC and YPC

H&T – a wooden hub driven firmly into the ground flush with the surface and with a tack implanted flush in the exposed end of the hub

Mini Copper Disc - Berntsen “BP2” as shown in Figure 1B or similar item
http://www.berntsen.com/Surveying/Concrete-Survey-Markers/BP-Series-Markers-for-Concrete/ctl/ViewProduct/mid/585/ItemID/405

Figure 1B – Berntsen “BP2”

PK nail – Parker-Kalon brand masonry nail, Mag Nail, Screw, or similar (describe what is actually set.)

R&C – a 5/8-in. (16-mm) diameter rebar or iron rod 30 in. (77 cm) long that is driven into the ground (typically flush with the ground surface or below) and fitted with a metal or plastic cap

RPC – R&C with a red plastic cap inscribed “ODOT” or “ODOT CONTROL” and used as the standard monument for project control except when other factors suggest otherwise

Set IR - a R&C meeting the requirements in Oregon Revised Statutes placed at the location indicated

YPC – R&C with a yellow plastic cap inscribed “ODOT”, “ODOT R/W”, or similar and used as the standard monument for right of way monumentation

1.52 Monument Inscription Requirements

When setting monuments for ODOT control or ODOT boundary, set only monuments bearing ODOT identification. Do not set monuments bearing company names or logos or inscribed with any PLS license number.

When serving as an employee of ODOT, set only monuments bearing ODOT identification on all monuments requiring inscriptions. Never set monuments bearing any PLS license number, other inscription, or logo.

1.6 Products and Deliverables

Various locations in this manual define products and deliverables. Section 6 on “Products and Deliverables” in each Chapter is designed to address requirements for products and deliverables associated with that Chapter. Section 9 of each Chapter is designed to address Specific Activities and Tasks and includes with each activity or task a list of deliverables associated with that specific activity or task.

In addition to the specific requirement in Section 6 of each Chapter, each applicable record specified under Section 7 of each Chapter becomes a deliverable upon completion of the project. The requirement to create, maintain, or keep any record indicates that it is a deliverable, whether specifically listed as such or not.

1.7 Documentation

All documentation required by this manual becomes the property of ODOT at the time of creation of the record.

Every record created in the course of a survey project, whether electronic, paper, or otherwise, becomes a part of the project documentation. Avoid scratch notes. Create every record as nearly to the time and place of the event as practicable. Manage and maintain all project documentation and records in a consistent and meaningful manner and in conformance with this Section.

With all records related to survey activity, include the following information as pertinent.

1.71 Record Identification

Every record created in the course of a survey project should have adequate identification to allow future readers to determine easily the relevance of the document to their interests. Such identification may even become a matter of legal significance in the event of litigation or contract disputes.

Certain documents such as property descriptions and items prepared specifically as court exhibits will likely have such content inherently. In some instances, those in authority may choose deliberately to omit such content for appearance, legal, or other functional reasons. Otherwise, provide future readers with information that enables them to easily recognize the applicable project and the role of the record.

1.711 Purpose of the Work or Record

Provide a statement of purpose on the title page of field notes, in the subject line or opening paragraph of correspondence, in the narrative portion of the record, or other conspicuous location.

1.712 Official Project Name

Always use the official ODOT Project name in all documentation

1.713 Key Number

For Statewide Transportation Improvement Plan projects, include the Key Number in all project records and correspondence.

1.714 Highway and Route Identification

Include the ODOT Highway Name and ODOT Highway Number and any associated Interstate Route, United States Route, or Oregon Route numbers in all project records and correspondence.

1.715 Personnel Involved

Include with every record the name of the individual who originated the record. In the case of data collected by a field crew, include the name of each field crewmember and their respective duties as further detailed in Topic 1.772 “Content and Format of Field Notes”.

1.72 Project Journal

For each project that results in survey documentation, create and maintain a project journal tracking the purpose, timeline, and progress of the project. Begin with those items listed in Subsection 1.71 “Record Identification” and then add to the journal as appropriate. Record events, decisions, and activities that define the progress of the survey project. Include with each event the date and associated persons.

1.73 Equipment Testing and Calibration

For all testing and calibration of equipment required in this manual, document the process including results, append recent records to an ongoing file for the specific equipment, and include a copy in the records of any relevant project.

1.74 Transmittal

Include with every record transmitted between work units internal or external to ODOT a letter of transmittal that describes the following as a minimum.

- Sender name and title
- Intended recipient name and title
- Project identification listed in Subsection 1.71 “Record Identification”
- Purpose of the transmittal
- Any intended response or action by the recipient

1.75 Data Formats

Store, share, and transmit data in a consistent and unambiguous format according to the following priority.

1. Software native files – utilize this option unless meeting the criteria for a lower priority format.
2. LandXML - when sharing between software packages with incompatible native formats including sharing with external entities where use of ODOT standard software is not required by contract or other agreement.

3. Text file of coordinates or other exchange format as suitable - when LandXML is not practicable, parties of the exchange agree on an expedient format, and no specified format or software is required by contract or other agreement. When creating a text file of any format, include a header portion that contains all of the pertinent items in Subsection 1.71 “Record Identification”. In addition, list pertinent characteristics such as coordinate system described in Topic 3.212, accuracy (when applicable), source, etc. Furthermore, clearly label data types such as a header for each column in a coordinate list identifying the contents of each column. In the case of a more elaborate format, describe a sample line or otherwise define the contents. Do not put the reader in a position to speculate on how to interpret the data. Include this metadata for documentation even if it must be deleted from the file before importing into the destination software.

1.76 Coordinate Lists

Throughout this manual, Geometronics has attempted to follow certain formats as listed below with regard to coordinate annotations. Label and interpret coordinates consistent with this list unless clearly labelled otherwise or it is apparent that an existing file does not conform.

- X, Y, Z – Always refers to Earth Centered Earth Fixed and **never** to northing and easting on a projection grid
- Latitude, Longitude – Refers to geodetic position in arc units
- Height – Refers to height above the ellipsoid (typically associated with Latitude and Longitude)
- N, E – Refers to Northing and Easting on the projection grid (or local grid)
- Elevation - Refers to elevation above vertical datum (typically considered equivalent to “Orthometric Height” and typically associated with Northing and Easting)

1.77 Common Content of Field Data and Notes

Provide notes for all field survey activity either hand-written, electronically recorded, or a combination of both.

1.771 Character of “Original” Field Notes

Collect original field notes as follows for all survey work.

- Collect hand-written Survey Field Notes in pencil.
- Make any corrections by drawing a line through the erroneous data without obscuring it and add the replacement data adjacent to it.
- Record hand-written notes on appropriate official ODOT form and of paper type suitable for the conditions (bond or Write-in-the-Rain).
- Collect all field notes in the field, at the time, and at the scene. Do not record information at a later time from memory or transcribe from scratch notes. In the event that scratch notes

are collected for any reason, those are the original field notes. Properly label such notes and preserve them with the project records.

- ♦ For electronically collected measurement data;
  - Consider original field notes to be the combination of the original electronically collected data and supporting field notes.
  - When hand-written notes are collected, supply one complete set of hand-written notes with each digital data file. Label the notes with the computer file name.
- ♦ Include as supplemental any data that is available such as rubbings, photographs, or videos. Reference supplemental data to the field notes.

1.772 Content and Format of Field Notes

Provide the following with each set of Field Notes:

- ♦ Title page on form #734-2135A "ELECTRONIC DATA TITLE SHEET" for electronic data including Global Navigation Satellite System observations. Include on the title page: The form is available from the ODOT storeroom.
  - Complete project name or activity and purpose
  - Highway name
  - County name
  - Project identification number (Key #, contract #, etc.)
  - Electronic data file name if applicable
  - Point numbers or range covered by this set of notes if applicable
  - Brief description of work covered by this set of notes
  - Date range of activity recorded
  - Equipment number or serial number
  - Full first and last name of all crew members
- ♦ Include in the headers of each subsequent page relevant data for that page, including the information as indicated on form #734-2135R, whether that form is used or not:
  - Date of work
  - Names or initials of crew. Initials are adequate provided that they match the names on the title page and that the initials are not ambiguous, as in Bob Schaefer and Bill Smith.
  - Annotation of crew member roles (instrument operator, note keeper, and rod person for total station or for leveling)
  - Page numbers in book format with even-numbered pages on the left and odd-numbered pages on the right. Begin with Page 1 on the title page. Include the back page and any blank pages.
  - Total number of pages in this set of notes

  - Project name or activity purpose. Abbreviate the project name if necessary, but maintain the essence of the name. Informal communication may use “SRB” when referring to the “Snake River Bridge Deck Repair” project or similarly “PM-E” for the “US-20: Pioneer Mountain – Eddyville Section”. However, avoid abbreviating to a cryptic level on field notes.
  - Electronic data file name if applicable
  - Brief weather statement
- ♦ Include additional pages as needed for:
  - Special notes
  - Legend for symbols and abbreviations
  - Other useful data such as an overall schematic of an entire control network
- ♦ In addition to data related to the particular task, note on each page specific data including:
  - New instrument set-up location and details
  - Instrument/target/antenna height for all control points
- ♦ Field Notes specific to task:

  Field note and data requirements for specific tasks and activities are addressed in the particular Topics along with that subject matter.

1.773 Point Numbering

Use the following point number ranges for collecting field data

Item	Starting Number	Ending Number
Geodetic Points (Not related to a project)	Alpha-Numeric	
Horizontal Control Network Points	1	499
Strategic Points	500	799
Controlled Strategic Points	800	999
Found Monuments	1,000	2,999
Temporary Easements	3,000	3,999
Permanent Easements	4,000	4,999
Set Monuments	5,000	6,999
Calculated Points	6,000	6,999
Photo Pre-Marks with GNSS Elevations	7,000	7,999
Photo Pre-Marks with Differential Elevations	8,000	8,999
Differential Leveling Turn Points	9,000	9,999
Miscellaneous Points for Construction	10,000	14,999
Reserved for Future Use	15,000	49,999
Topographic Features	50,000	None

NOTE: Prior to 2003, 3000 – 4999 signified aerial photo control points

Table 1C - Point Numbering Convention

1.774 File Naming

Name electronic field data collection files consistent with current ODOT conventions.

Survey Task or Activity	File Name Format
Original Ground Mapping (Topography)	xxxxxTyy.zzz
Horizontal Control (Networks)	xxxxxNyy.zzz
Construction Mapping (Topography)	xxxxxCyy.zzz
Levels (Elevations)	xxxxxLyy.zzz
Monument Ties	xxxxxMyy.zzz
Where xxxxx = five-digit project key number yy = two-digit serial number 01 through 99 zzz = three-character extension	

Table 1D - File Naming Convention

1.775 Electronic Data Storage

Organize, store, and archive all survey data consistent with current ODOT conventions. Assure that data is stored in a location where a system or process is in place that routinely creates backup copies of the data. For ODOT staff, this is a designated crew file server. Do not maintain unique data on an individual workstation where data is not backed up. Contact the Computer Support Desk or the Geometronics Unit for guidance on where to store data.

- ♦ Naming convention – Do not use spaces in names of folders or files as they cause problems with some systems and software. RunWordsTogetherAndCapitalizeTheFirstLetterOfEachWordForReadability.
- ♦ Active Data – Use the following folder structure under the project number.

NOTE: Survey personnel may continue to us the historical structure until the Geometronics Unit or EAST (the ODOT Engineering Automation Support Team) releases an automation tool designed to support the folder structure described here.

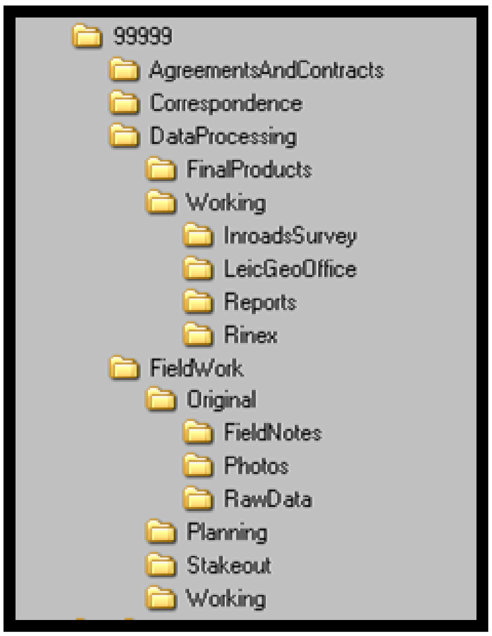

Figure 1E - Electronic Data Folder Structure

* Proprietary names permitted within certain folders - See descriptions below.

- \99999\AgreementsAndContracts
  Create subfolders for any client and for each data supplier (Region, Tech Services, consultant, etc.) and for each solicitation. Store all work orders, scope documents, and such in the appropriate folder.
- \99999\Correspondence
  Store all formal or meaningful correspondence in this folder and important e-mail messages in a subfolder.

- \99999\DataProcessing\
  Store all data subsequent to the field work in this folder and subfolders of it.
  - \99999\DataProcessing\FinalProducts
    At the point when a data processing product is completed, move it to the FinalProducts folder and write-protect it.
  - \99999\DataProcessing\Working
    Store all work in progress including input files, computations, adjustments, engineering drawings, and output data in this folder. Store source data such as mapping from other entities, RINEX data from Continuous GPS Station or, National Geodetic Survey Continuously Operating Reference Station, and so forth in appropriate subfolders. If desired, create subfolders with appropriate names for software-specific data.
- \99999\FieldWork\
  Store all data collected or used in the field in this folder.
  - \99999\FieldWork\Original
    Write-protect and store unedited raw files, electronics copies of field notes, photos taken to supplement the survey data, and any other related data in the Original folder or into appropriately labeled sub folders.
  - \99999\FieldWork\Planning
    Store mission-planning data, research maps and documents, electronic copies of prior field notes, and other records used in planning the survey in the Planning folder or into appropriately labeled subfolders.
  - \99999\FieldWork\Stakeout
    Store all data prepared for construction stake-out, setting right-of-way or boundary markers, or other data for placing points at planned locations in the field into this folder or into appropriately labeled subfolders.
  - \99999\FieldWork\Working
    Store all changing data including edited raw files, computations, adjustments, and output data in this folder or into appropriately labeled subfolders.

♦ Archiving Survey Data

When all survey aspects of a project are completed or when major milestones are achieved, archive survey data according to the current engineering data archiving practices of the ODOT Engineering Applications Support Team.

1.8 References

Below is a partial list of reference items.

1.81 ODOT Publications

1.811 Manuals

Survey Safety Manual
http://www.oregon.gov/ODOT/HWY/GEOMETRONICS/docs/Survey_Safety_Manual.pdf

ODOT GNSS Guidelines
http://www.oregon.gov/ODOT/HWY/GEOMETRONICS/docs/GNSS_guidelines.pdf

Highway Design Manual
http://www.oregon.gov/odot/hwy/engservices/pages/hwy_manuals.aspx#2012_English_Manual

ODOT Construction Manual
http://www.oregon.gov/ODOT/HWY/CONSTRUCTION/CM.shtml

1.812 Forms

ODOT forms for field notes are available in a variety of layouts. Some are mentioned throughout this manual. Any field note form with a form number is available through either the ODOT storeroom or the Geometronics office. Contact the Geometronics Unit if you encounter challenges locating any form.

Survey Policy Deviation Request

Project Notification to County Surveyors Form 734-2298

ODOT Survey mark Report Form 734-2802 and is on the internet at:
http://www.odot.state.or.us/forms/odot/highway734/2802fil_survey-mark.pdf

1.82 Outside Publications

National Geodetic Survey User Guidelines for Single Base Real-Time GNSS Positioning
http://www.ngs.noaa.gov/PUBS_LIB/NGSRealTimeUserGuidelines.v1.1.pdf

National Geodetic Survey Calibration Baselines
http://www.ngs.noaa.gov/CBLINES/calibration.html

1.9 Specific Activities &Tasks

There are no specific tasks associated with the generalized content of Chapter 1. See the respective Chapters for specific activities and tasks associated with the content of that Chapter.

Chapter 2 - Construction

This Chapter is currently in development and will be added to the manual in late 2015

Chapter 3 - Project Control

3.1 Introduction

3.11 Scope

This Chapter describes localized control surveying related to projects involving any combination of Boundary, Topographic, and/or Construction survey tasks. Follow these survey control procedures for preliminary engineering, construction activity, and other purposes related to a project.

This manual does not address control survey work for the purpose of expanding, densifying, or otherwise enhancing references to the NSRS (National Spatial Reference System), establishing new benchmarks, or other statewide or large area survey control. Such work is under the direction of the ODOT Chief of Surveys. If called upon for such work, follow the direction from that person and consider this manual as supplemental.

3.12 "Project Control" Defined

As applied in this Chapter addressing "Project Control", a Project is any of the following:

- Any project listed in the STIP (Statewide Transportation Improvement Plan)
- Survey activity for the purpose of aiding in construction or positioning of an item
- Survey activity for the purpose of locating, establishing, or relocating any boundary line or right-of-way line
- Survey activity for the purpose of collecting topographic data including remote sensing applications

3.2 General Considerations

3.21 Overview

This Section addresses the general considerations in establishing project control.

3.211 Guiding Principles

- Establish project control that will endure for the life of the project.
- Establish project control that is safe and effective to use.
- Strive to provide for future needs of the project such as monumentation by network.
- Strive to provide for future Real-Time Kinematic positioning on the project by dispersing control points throughout the project for check shots as required in Topic 1.432 "Global Navigation Satellite System Real Time Kinematic Check Shots".
- Apply a least squares adjustment to both horizontal and vertical network observations whenever practicable.
- Incorporate redundancy at each permanent project control point whenever practicable.

3.212 Coordinate Systems

Initiate projects on an approved coordinate system that includes the following:

- A horizontal datum and epoch (adjustment) with associated reference ellipsoid
- A vertical datum and epoch (adjustment)
- A geoid separation model (when using Global Navigation Satellite System to derive orthometric heights)
- A mapping projection
- Specified units

(A) Horizontal Datum

Initiate projects on the most current horizontal datum/epoch of the National Spatial Reference System (NSRS) or the Oregon Real-time GPS Network.

Access the current horizontal datum/epoch of the National Spatial Reference System in the following priority:

1. Using static GNSS, establish a minimum of two project control points by tying to a minimum of two active control stations of the National Geodetic Survey’s Continuously Operating Reference Station system and/or the Oregon Real-time GPS Network. (Figure 3A “Project Control Tied to Active Geodetic Control”) Directly measure the baselines between the project control points that are tied to the NSRS in order to ensure their relative accuracy meets the required position error budget of the constrained least squares adjustment for the project.

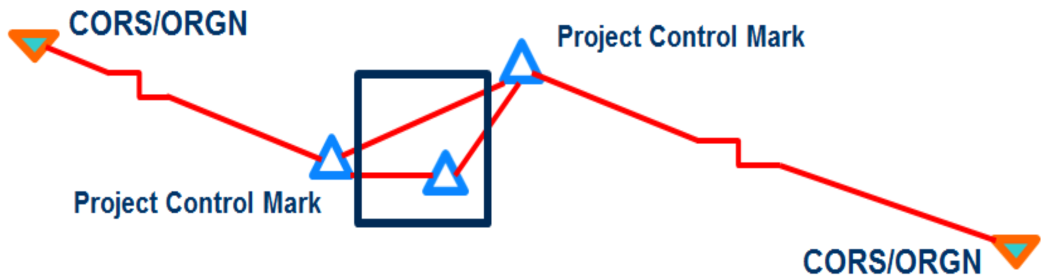

Figure 3A – Project Control Tied to Active Geodetic Control

2. Using static GNSS, establish a minimum of two project control by tying to a minimum of two passive control stations near the project that have published coordinates in the National Geodetic Survey Integrated Database. (Figure 3B “Project Control Tied to Passive Geodetic Control”) Directly measure the baselines between the project control points that are tied to the NSRS in order to ensure their relative accuracy meets the overall position error budget of the constrained least squares adjustment for the project.

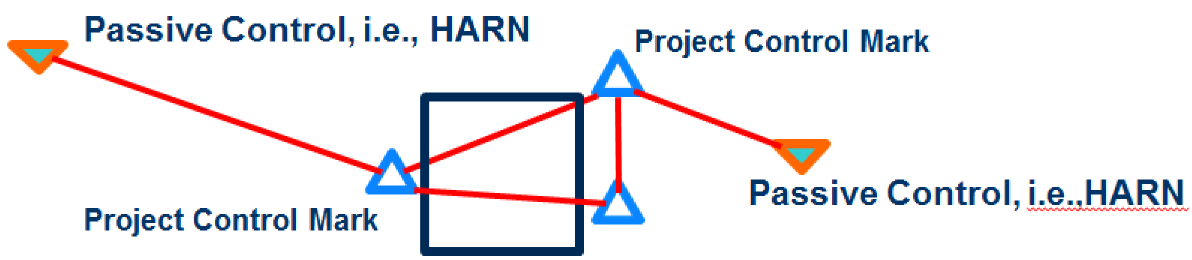

Figure 3B – Project Control Tied to Passive Geodetic Control

3. If it is impracticable to access the current NSRS horizontal datum/epoch using the above two methods, apply for a Survey Deviation to use a different method to access the current NSRS horizontal datum/epoch, or to use a different datum/epoch for the project.

(B) Vertical Datum

Initiate projects on the current vertical datum/epoch of the National Spatial Reference System.

Access the current vertical datum/epoch of the National Spatial Reference System in the following priority:

1. Differentially level between the project and two or more bench marks with published coordinates in the National Geodetic Survey Integrated Data Base referenced to the most current vertical datum/epoch of the National Spatial Reference System (NSRS). Validate that the record elevations match within standard ODOT leveling acceptance criteria described in Topics 3.922(D) “Level Circuit Procedures” or 3.922(E) “Vertical networks”. In the event

that the validation effort does not meet the criteria, incorporate additional bench marks until two validate each other.

2. Differentially level between the project and a single bench mark that has published coordinates in the National Geodetic Survey Integrated Data Base referenced to the most current vertical datum/epoch of the NSRS. Verify the elevation of the bench mark by comparing to Continuous GPS Stations using static Global Navigation Satellite Systems and applying the appropriate geoid separation to a GNSS-derived ellipsoid height on the mark that has an accuracy of 0.06 ft. (2 cm) at the 95% confidence level. The GNSS-derived orthometric height must be within 0.3 ft. (10 cm) of the published elevation for the mark.
3. Establish GNSS-derived orthometric elevations from Continuous GPS Station on two or more marks on the project by applying the appropriate geoid separation to a GNSS-derived ellipsoid height on each point that is accurate to 0.06 ft. (2 cm) at the 95% confidence level. Run levels between the marks to verify accuracy. Validate that the elevations match within standard ODOT leveling acceptance criteria.
4. If it is impracticable to access the current NSRS vertical datum/epoch using the above three methods, apply for a Survey Deviation to use a different method to access the current NSRS vertical datum or use a difference datum/epoch for the project.

Having established the project vertical basis, document the process, findings, decisions, and marks held. When establishing project elevations of different value than record on non-validated bench marks, clearly and prominently document that situation in the project **control narrative, and include modified values in TBM (Temporary Bench Mark) list and** project control data.

(C) Geoid Model

When using Global Navigation Satellite System to derive project elevations, ensure the geoid separation model used is compatible with the datum/epoch and reference ellipsoid used for the project. For example, the Geoid12A model must be used to calculate orthometric heights from NAD 83 (2011) epoch 2010.00 ellipsoid heights.

(D) Mapping Projection

Initiate projects using a mapping projection selected in the following priority.

1. The Oregon Coordinate Reference System (OCRS) zone in which the project is located.
2. If an OCRS zone other than the zone where the project is located is more suitable, apply for a Survey Deviation to use the more suitable zone.
3. If no OCRS zone covers the area in which the project is located, use North American Datum of 1983 (NAD 83) Oregon State Plane coordinates scaled to a Local Datum Plane at a mean project elevation.

NOTE: The OCRS projections and the NAD 83 Oregon State Plane projections are both defined in relationship to the North American Datum of 1983 and its Geodetic Reference System of 1980 (GRS80) reference ellipsoid. When the National Spatial Reference System is updated to a different horizontal datum other than NAD 83, the parameters for the OCRS projections and Oregon State Plane projections will be redefined to be referenced to the new datum and reference ellipsoid.

(E) Coordinate Units

Specify the units used for the coordinates of the project. See Subsection 1.24 “Units of Measure” for specific details about the units required for ODOT projects.

3.22 Accuracy of Control Points

Determine point locations for project control within the error tolerances in the following absolute accuracy table.

	Horizontal	Vertical
Horizontal Network Points	0.03 ft. (10 mm)	N/A
Vertical Points (TBM)	N/A	0.03 ft. (10 mm)
3D Network Points	0.03 ft. (10 mm)	0.03 ft. (10 mm)
Controlled Strategic Points	0.06 ft. (20 mm)	0.06 ft. (20 mm)
Strategic Points	0.06 ft. (20 mm)	0.06 ft. (20 mm)

Table 3C - Accuracy of Control Points

3.3 Equipment

3.31 Overview

This Section covers equipment requirements for establishing project control.

3.32 Equipment Requirements

Use only equipment that fulfils the requirements in Subsection 1.32 “Selection of Equipment”. Additional requirements are addressed along with associated procedures in Section 9 of this Chapter. Assure that assessment of all equipment is complete and up to date as required in Subsection 1.34 “Periodic Assessments”.

3.4 Standard Procedures

3.41 Sets of Angles

3.411 Distance measurements

♦ When turning sets of angles, measure distances in both direct and reverse unless the equipment is not compatible with inverted distances. Do not measure distances in the inverted face with instruments that are not configured for that purpose.

3.412 Angle Measurements

When measuring angles for accurate and precise applications using a total station, use the table below to determine the required number of sets

Application	Number of Sets
Networks	2
Traverses	2
Strategic Points	1
Double Ties	1

Table 3D - Sets of Angles

3.413 Sweeping Multiple Sets of Points

♦ Tying multiple points with Sets from a single location is used in:

- Networking
- Tying property monuments
- Establishing two or more strategic points

♦ Use either conventional or non-conventional observation sequences:

- Conventional Sequence– direct-face on all points followed by inverted-face on the same points in reverse order. For a second set, simply repeat the first.

  When using tripods, the number of points that can be observed in a conventional sequence is limited by the number of tripods available. Observing more than one "foresight" requires that multiple targets remain stationary for the entire sequence or that a crew member visit each point multiple times.

- Non-conventional sequence - Any sequence that deviates from the conventional sequence but still includes both a direct-face and a inverted-face observation on each point and that begins and ends on the same point as required in Topic 1.431 “Backsight/Elevation Checks”. For a second set, simply repeat a direct and reverse observation to each point in any order following the same criteria as in the first set.

  Non-conventional sequences are never explicitly required by policy, but when properly utilized, can save time and effort with no sacrifice of survey quality.

  Example #1: When making ties to one or more monuments or other points that are difficult to access, a survey crew member need only visit each point once, collecting all the required observations during that single visit before returning or moving on to the next point. The instrument need not be returned to observe the “backsight” or starting point at any time during that visit provided that the “backsight” or starting point is observed at some time both before and after the observations to each of the other points.

  Example #2: When making ties to many monuments or other points that are visible from a single instrument location, a survey crew member can use limited equipment to observe unlimited points in the same set of angles. One (or more) person shuffles tripods or moves a plumbing pole (depending on accuracy needs) from one location to another while the instrument operator makes the required observations to each point in rapid succession. The observation time on each point is not prolonged by turning to any other points. This allows the target to remain in place for a comparatively short time and then be available to move to another point. As in Example #1 and all applications of non-conventional sequences, the entire observation sequence must conclude on the same point it began.

3.42 Static GNSS Observations

Unless specifically modified for activities covered elsewhere in the manual, the following tables govern application of static Global Navigation Satellite System activities.

Static observations using a Global Navigation Satellite System receiver are the preferred method for many control survey activities. Static observations are also valid for non-control survey activities. Adhere to the requirements of the Table 3E "Summary of GNSS Static Specifications" located below when employing static observations for any purpose.

Equipment	
Minimum number of receivers	2
Antenna Support Setup	Tripod
Field Procedures	
Minimum satellite elevation mask in degrees above horizontal	10
Epoch interval in seconds of time for observations	5
Minimum time in minutes between starts of observations on any one station	45
Minimum number of observed satellites	4
Maximum GDOP/PDOP value during station observations	8/6
Minimum observation time in minutes for baselines less than 5 km *	20
Minimum observation time in minutes for baselines 5 to 10 km *	30
Minimum observation time in minutes for baselines 10 to 15 km *	45
Minimum observation time in minutes for baselines 15 to 30 km *	60
Minimum observation time in minutes for baselines greater than 30 km *	120

* Recommended times - Additional time may be required to resolve integers.

Table 3E – Summary of GNSS Static Specifications

3.43 Redundancy and Observation Sequences

This Subsection addresses observation sequences independent of the type of work you are performing. Follow the portions of the manual that address more specific tasks and activities, but use this as the foundation for all observations.

3.431 Network Point

A network point is a control point that has greater redundancy than that created in a traverse or level circuit. Networking with least-squares adjustment is the ODOT-preferred method for locating and verifying the location of any point or mark where the objective is either superior accuracy or enhanced confidence (or both). This Chapter on Project Control addresses networking for control points. However, it may be desirable at times to establish one or more network points for other purposes.

A network point has three characteristics that distinguish it from all lesser types of points. Firstly, the data used to establish the position includes a level of redundancy that is beyond the capabilities of traditional adjustment processes such as compass rule or linear proportioning of discrepancies. This increased redundancy provides the basis for comprehensive error trapping and analysis, as well as statistical analysis of error regions which defines a level of confidence in the final position. Secondly, a least squares adjustment is required to provide a best fit to this additional level of redundancy. Thirdly, the added effort of redundant observations and associated adjustment justifies establishing a substantial monument that will be usable for an extended period into the future.

Below are the common criteria for a networked point regardless of the purpose.

(A) Common criteria for any network point

Include one (or more) redundant observation to every point in the network that is beyond the observations included in a linear point. To meet this requirement of redundancy, it must be possible to remove any observation from the computations and have enough data remaining to compute, prove, and adjust the point. A traditional linear point as described in this Subsection lacks the level of redundancy required for a network point.

(B) Horizontal Network Points

- ♦ Use only tripods for the following setups:
  - Total Station
  - Target and/or prism
  - Global Navigation Satellite System Antenna
- ♦ Acceptable observations include
  - 2 sets of angles with a Total Station
  - Static Global Navigation Satellite Systems baselines

(C) Temporary Bench Mark

A temporary bench mark (TBM) is a fixed point that is either natural or manmade and serves as part of the vertical framework for a project. It is set to be vertically stable where no part of it is moveable or adjustable. The elevation on a TBM is established through differential leveling. This class of vertical control is not to be confused with a permanent bench mark whose elevation is known with respect to a reference datum and from which other elevations can be established.

(D) Three-Dimensional Network Points

Three-dimensional network points must meet all the requirements of horizontal network points and must carry valid elevations. They do not necessarily maintain the characteristics of a TBM.

3.432 Linear Point

A linear point is a control point that is part of a linear survey, specifically a traverse or level circuit. Use linear points only when compelling circumstances make a vertical, horizontal, or three-dimensional network impractical. Procedures for traverses and leveling circuits are addressed elsewhere in this Chapter on Project Control.

3.433 Controlled Strategic Point

A “Controlled Strategic Point” is a strategic point that has been verified by a double tie or has been closed back to one or more existing control points to minimize the potential for a blunder in its location. A Controlled Strategic Point can be used for all the purposes of a strategic point plus for establishing other control and boundary locations.

First, establish the point as strategic point. Then verify it before depending on it for establishing other control or boundary positions. Verify the location by one of the following methods. Each method is detailed more extensively in the narrative that follows.

- ♦ A (full) Double Tie
- ♦ A Modified Double Tie
- ♦ Resection or Free Station
- ♦ Closing to different control

Regardless of the method selected, accept only control points that have been verified by reproducing check positions within the criteria of Table 3F “Specifications for Double Tie points” for maximum horizontal/vertical differences. Record and document the procedure and results that elevate a Strategic Point to that of “Controlled”.

The following are procedures for creating a controlled strategic point using various methods and types of equipment. See Table 3G “Summary of Strategic Point Specifications” for a summary of requirements.

(A) Double Tie

A Double Tie establishes and validates a position on a Controlled Strategic Point utilizing two independent ties to the new position. Ideally, the two ties do not make use of any common control points nor common observation corridors. The procedure guards against misidentified control points at instrument, backsight, or reference locations. It also traps for setup errors at any of those locations as well as any measurement errors.

When establishing a location using the Double Tie method; first tie the point from one set of control points and then tie again with observations from a different point. Accept any result that produces two positions that are within the criteria in Table 3F "Specifications for Double Tie points".

Terrestrial Equipment

When using terrestrial equipment to create a Controlled Strategic Point with a double-tie, follow the identical procedure of a Strategic Point and then add a separate set of measurements from a different instrument location. This may involve simply trading places between the instrument and backsight. For the most robust validation, make the second observation from a distinct pair of control points.

Global Navigation Satellite System Equipment

When using Global Navigation Satellite System equipment to create a Controlled Strategic Point with the double-tie method, follow the basic procedure for a Strategic Point and then add a separate position from a reference/base station on a separate control point and at a time separation as defined in Table 3F "Specifications for Double Tie points".

Positions based on a real-time network fulfill the objective of different control, as there is no opportunity for misidentification of reference points. Additionally, using a Real-Time Network eliminates the potential for setup error at the base. However, the Check Shot in Table 3F "Specifications for Double Tie points" is required when using a Real-Time Network to validate the settings in the Global Navigation Satellite System receiver and the output from the receiver.

Check Shot Required Before and After Other Work *	Yes
Occupation time in Epochs	60
Minimum time in minutes between observations	30
Maximum GDOP value during station observations	8
Maximum PDOP value during station observations	6
Rover satellite mask in degrees above horizontal	15
Maximum horizontal difference in ft. (m) between occupations	0.07 (0.020)
Maximum vertical difference in ft. (m) between occupations	0.09 (0.025)

* See description in the Topic on "Side Shot"

Table 3F - Specifications for Double Tie Points

(B) Modified Double Tie

A Modified Double Tie is similar to a Double Tie except that it employs a less-robust check between control points from which the new position is established. The procedure guards against misidentified control points at instrument, backsight, or reference locations. However, it may not identify setup errors at all of those locations nor reveal certain measurement errors. Accept any result that produces two positions that are within the criteria in Table 3F "Specifications for Double Tie Points".

Reserve the Modified Double Tie for establishing the location of boundary markers and only in situations where the use of a full double tie is not practical. Examples of acceptable uses of a Modified Double Tie include:

- ♦ Property corners that are readily visible through only one viewing corridor or only from a single vantage point.
- ♦ Situations that would require setting an additional control point exclusively for the purpose of creating a second tie to a small number of property boundary markers.
- ♦ When creating ties to property corners using Global Navigation Satellite System Real-Time Kinematic with only a single base receiver.

Terrestrial Equipment

When using terrestrial equipment to create a Controlled Strategic Point using a Modified Double-Tie, first tie the point twice from the same control point, from the initial backsight and finally a second time using a separate backsight. Verify the two measured positions on the new point as determined from both backsights and assure that they are within the criteria.

Alternately, observe both backsights and the new point in a set of angles and distances to all points. Evaluate the fit through a least squares adjustment or other suitable analysis tool. This method supports setting of multiple Controlled Strategic Points in one procedure by simply including both backsights and all foresights in the sets.

Global Navigation Satellite System Equipment

When using Global Navigation Satellite System equipment to create a Controlled Strategic Point using a Modified Double-Tie, follow the basic procedure to that of a Strategic Point. The required Check Shots in Table 3F "Specifications for Double Tie points" are critical to the integrity of a Modified Double Tie made using Global Navigation Satellite System and is the feature that elevates the point from a Strategic Point to a **Controlled** Strategic point.

(C) Resection or Free Station

A Resection or Free Station is a procedure for determining the position of a point by observations taken from the unknown point to points of known position rather than the other way around. If any observations are made to that point from a known point and incorporated into solving for the location of that unknown point, then it is not simply a resection or free station point but is considered some other description of control such as a network point depending on the overall procedure employed to determine the location.

In the purest sense, a resection involves only the observation of horizontal angles or directions to known control points along with possibly vertical angles. The position and possible elevation is then determined using a form of triangulation. Modern survey equipment allows for easy inclusion of distances and therefore renders a pure resection largely obsolete. However, ODOT does not preclude the use of such a procedure provided that adequate redundancies and other requirements for the task are satisfied.

The addition of one or more distances into the solution may be referred to as "Free Station" and typically produces a more robust solution. "Free Station" can also suggest a similar process where the measured angles are not related to any particular orientation, such as plumb. This process has been employed by some laser scanning systems at ODOT and elsewhere.

In some instances, either term may be adopted by software developers for proprietary use and have slight variations in meaning based on use within the software. For the purposes of this manual, "resection" and "free station" are synonymous. Both involve determining an instrument location by occupying that location with a total station. The use of the latter term is favored, as it suggests a more liberal collection of potential observations.

Terrestrial Equipment

When using terrestrial equipment to establish a Controlled Strategic Point with a free station method, occupy the point and observe directions and distances to three or more known control points. Strive to surround the new point with the existing tied control and avoid situations where the tied control are all within 30 degrees of horizontal angle from each other.

Where practicable, incorporate both angles and distances to each point into the solution. In the event that any directions or distances are not collected, include observations to additional known control points such that the overall level of redundancy is equivalent to the base requirement.

Once the new position is determined, verify the measured positions to all foresights against control data. Accept any result where the data fits all positions within the criteria in Table 3F "Specifications for Double Tie points". Single component observations (direction only or distance only) must produce a line or arc that passes within the stated tolerance of the point. Alternately, accept any result where the observation residuals all are within the listed tolerances.

Global Navigation Satellite System Equipment

The concept of a free station is a total station technique and is not applicable to GNSS surveying.

(D) Closing to Other Control

Closing to other control directly checks the point against two or more existing control stations. This characteristic is absent in the Modified Double Tie method. The procedure of closing to other control guards against misidentified control points at the instrument, backsight, or reference locations. However, the observation and analysis of closing to other control may be more complex than a full Double Tie and therefore avoided.

Depending on the survey tools used for the observations and the analysis employed, a new check position may be generated for various combinations of the points in the closing sequence. Compute new positions for one or more existing control points by tying them from the Controlled Strategic Point. Accept any result that reproduces all positions within the criteria in Table 3F “Specifications for Double Tie points”.

Terrestrial Equipment

When using terrestrial equipment to measure a Controlled Strategic Point with a Close to Other Control method, first tie the point as a Strategic Point, then occupy the new point, backsight the previous instrument location (or some other known control point), and tie one or more separate known control points. For the most robust validation, include control points beyond the original pair from which the point was set. Verify the measured positions to all check foresights against control data.

Global Navigation Satellite System Equipment

When using Global Navigation Satellite System equipment to create a Controlled Strategic Point with a Close to Other Control method; first, follow the basic procedure of a Strategic Point ,then occupy the new point with the base, and finally tie one or more known control positions and verify that the results match within the criteria.

3.434 Strategic Point

A “Strategic Point” is set for the purpose of providing an instrument for mapping, terrain modeling, or other non-control work. Other acceptable uses of Strategic Point control includes ties of photogrammetric targets (pre-marks) and scanner or LiDAR control points. Observing a Strategic Point does not require ties from multiple control points.

Accept any result that produces two positions that are within the criteria of Table 3F “Specifications for Double Tie points” ‘Specifications for Double Tie points”. Accept either position, or if checking process results in a third position by averaging or some similar combining of the measurements, use any of the three potential positions.

Typically measure a Strategic Point only from a Controlled Strategic (or better) control point. In some instances, it may be acceptable to set a Strategic Point from another Strategic Point. Limit use of such a point to collection of small pockets of topographical data. In the event that a third-generation Strategic Point is needed, elevate the points to that of a Controlled Strategic Point or develop additional control based on the requirements of this Chapter. Do not establish any control from a second-generation Strategic Point.

Terrestrial Equipment

When using terrestrial equipment to establish a Strategic Point by measuring angles and distances, turn one complete set of angles and distances from a single backsight.

Global Navigation Satellite System Equipment

When using Global Navigation Satellite System equipment to establish a Strategic Point by observing baselines, collect two positions on the new point following the requirements of Table 3F “Specifications for Double Tie points” “Specifications for Double Tie points”. The second position observed after the required time has passed is essential in eliminating the potential of an inaccurate position caused by interference with or corruption of the satellite signals during a single occupation.

The Check Shot listed in Table 3F “Specifications for Double Tie points” is not essential for a Strategic Point. However, a check shot is always a good practice while collecting Real-Time Kinematic data and doing so during this process will elevate the procedure to that of a Modified Double Tie and elevate the new point to a **Controlled** Strategic Point suitable to making ties to boundary points. See the next Topic for more information.

	Strategic Point	Modified Double Tie	Double Tie	Closing
Universal Requirements				
Tie Required To/From a Second Control Point	N	N	Y	Y
Allowable uses				
Topo, mapping, non-critical construction staking	Y	Y	Y	Y
All above plus locating boundary points	N	Y	Y	Y
All above plus setting control and for critical construction staking	N	N	Y	Y
Total Station				
Number of Instrument Locations	1	1	2	2
Total Number of Existing Control Points Required	2	3	>1	>1
Number of Backsights	1	2	2	N/A
Number of Sets of Angles to Each Point	1	1	1	1
Number of known points sighted from each instrument location	1	2	1	1
GNSS Single-Base Correctors				
Second Position Required After Time Separation	Y	Y	Y	Y
Number of Base Locations	1	1	2	2
Total Number of Existing Control Points Required	1	2	2	>1
“Check Shot” Required	N	Y	N	Y
GNSS Network Correctors				
Second Position Required After Time Separation	Y	Y	Y	Y
Number of Base Locations	N/A	N/A	N/A	N/A
Total Number of Existing Control Points Required	1	2	2	>1
“Check Shot” Required	N	Y	N/A	Y

* Not Applicable if using a permanent base such as a ORGN station

Table 3G - Summary of Strategic Point Specifications

3.435 Side Shot

A side shot is an observation that consists of a single set of data and has no redundancy. A side shot with a total station includes a solitary distance measurement combined with a solitary reading of each the horizontal and vertical angles. A side shot with a level includes a solitary foresight observation from a particular instrument location. A side shot using GNSS consist of a collecting a single position (typically from one or a very small number of epochs, but addition of more epochs only does not elevate it above a side shot),

Use side shots or topo shots for collection of bulk data where minor errors are not detrimental to the data. Side shots are acceptable for bulk staking of construction points. Collect side shots when the context within the other points will identify an error. If not identified, the error will not degrade overall data to an unacceptable degree.

However, do not use side shots from Global Navigation Satellite System for setting stakes to control major structure points, final grade stakes, or pavement elevations. Also, do not use side shots from Global Navigation Satellite System for collecting existing topography of items considered a “hard surface” as defined for confidence points in original-ground modeling.

Use side shots for collection of topographical features and measuring cross-sections and profiles.

The following are parameters for creating a topo point or side shot using various types of equipment.

- Leveling - Take a single rod reading and record using the most expedient process available.
- Terrestrial Equipment - Measure and record single values for vertical circle, horizontal circle, and slope distance.
- Global Navigation Satellite System Kinematic – Collect one epoch. Collect more than one epoch only if doing so simplifies the use of specific software or otherwise enhances efficiency. Collect and record a check shot on a known point before and after other work to verify that the setup is correct and has not been compromised during use.
- Scanning - By nature, all scan data are side shots.
- Photogrammetry - By default, all photogrammetry data are side shots unless specifically designed and reported otherwise.

3.44 Other Procedures

All other procedures related to Project Control are covered in Section 9 of this Chapter.

3.5 Monuments and Markers

3.51 Overview

The usefulness of project control points can extend over considerable time and through quite variable conditions with exposure to a numerous hazards. Set project control point markers and monuments with the capability to maintain position and identity for many years.

When establishing a horizontal project control point, choose a point that complies with the following concepts.

- ♦ Located in a safe location for equipment and personnel
- ♦ Horizontally stable for the duration of the survey and throughout all weather conditions
- ♦ Has a clearly identifiable center point
- ♦ Meets all of the requirements for future applications such as R/W monumentation by network

3.511 Monuments Required

Include identifiable marks and monuments on the ground for all project control.

3.512 Permanence, Stability, and Survivability

Set markers and monuments for the purpose of project control such that they will endure the effects of time and elements at the specific location for a period of time greater than the expected project length. Consider the impacts of traffic, agricultural activity, commercial development, vandalism, and the anticipated effects of the project throughout its duration. Consider the effects of nature such as frost heave, erosion, and animal life. Also, consider the effects imposed by humans such as traffic, development, vandalism, and such.

3.52 Characteristics of Marks and Monuments

Listed below are the characteristics for different types of project control points.

3.521 Characteristics of Horizontal Network Marks

- ♦ May include Network Option points
- ♦ May include any vertical project control point that meets other requirements
- ♦ Minimum of three per project
- ♦ Acceptable types (see Subsection 1.51 for definitions.)
    - R&C

- Mini Brass Cap
- PK nail
  - Not more than 10% of the network
  - Not adjacent to one another

3.522 Characteristics of Vertical Network Marks

- ♦ Meets all of the requirements for turn points in Topic 3.922(C) "Universal Differential-Leveling Procedures"
- ♦ May include any horizontal project control point that meets temporary bench mark requirements
- ♦ Do not use iron rods or rebar fitted with a cap or any other appurtenance that could detach, move, or become loose.
- ♦ Free from movable and removable parts.

NOTE: Do not use features such as the valve on top of a fire hydrant that will or may change position. Do not use plastic or metal survey caps set on iron rods or rebar that may shift position or separate from the iron.

3.53 Placement of Marks and Monuments

3.531 Placement of Horizontal Project Control

Determine horizontal control point locations and density according the following guidelines

- ♦ 1500 ft. (450 m) or less between monuments
- ♦ Within 750 ft. (225 m) of any location for work on the project
- ♦ Intervisible with two or more other monuments somewhere within the network, but not necessarily the points within the maximum spacing distance

  If the intent is to exercise the network option for monumentation in lieu of replacing recorded survey monuments that are removed destroyed or disturbed as the result of the construction or reconstruction of a public road, govern placement of monumentation according to the requirements of ORS 209.155.

NOTE: Nothing in the requirements for monument spacing is intended to restrict observation distances, mandate a tie between specific points in the network, or supersede statutory obligations.

3.532 Placement of Vertical Project Control

Determine vertical control point (temporary bench mark) locations according the following guidelines

- ♦ Must have at least 1 per project or 1 per mile, evenly distributed

- Must have 1 placed each side of any major crossing where a structure is required.

3.54 Reference Requirements for Project Control Points

There are no standard reference requirements for project control points that are not specifically used in the Network Option for monumentation. Nevertheless, use typical survey stakes, colored flagging, and paint markings to facilitate locating and identifying marks.

3.6 Products and Deliverables

Section 9 of this Chapter is designed to address specific control survey activities and tasks and includes with each activity or task a list of deliverables associated with that specific activity or task. This Section contains requirements for products and deliverables associated with control survey activity.

The products and deliverables are the following

- ♦ Durable and identifiable points on the ground
- ♦ Adjusted coordinate values in one, two, or three dimensions as appropriate for each point.
- ♦ All required items in Section 1.7 “Documentation”
- ♦ At the conclusion of each project, send original project control field notes to the Geometronics Unit for cataloging and permanent storage

3.7 Documentation

In addition to those items of documentation addressed in Chapter 1, provide the following for each project in which network control points are established. For any point that is worthy of including in a network, provide the information below as it relates to that point.

- ♦ Project or network journal
- ♦ Project or network narrative describing
  - Network purpose
- Definition of the coordinate system components described in Subsection 3.212
  - Geographical extent
  - Summary of procedure
  - Issues encountered
  - Solutions to issues
  - Any decisions
  - Rationale for decisions
- ♦ Field notes describing
  - The sequence of the observations
  - The vicinity sketch of each control point
  - Start and stop times for static Global Navigation Satellite System observations
  - Record of required procedures such as height measurements
- ♦ Description of each marker adequate to locate and positively identify it
- ♦ Network diagram illustrating geometry and redundancy
- ♦ Project control sheet for inclusion in construction plans
- ♦ Least squares adjustment reports
  - Minimally constrained showing acceptable results
  - Fully constrained showing acceptable results

3.8 References

Below is a partial list of reference items.

3.81 ODOT Publications

3.82 Outside Publications

National Geodetic Survey Geodetic Leveling
http://www.ngs.noaa.gov/PUBS_LIB/Geodeticleveling_nos_3.pdf

Bench Mark Resets
http://www.ngs.noaa.gov/PUBS_LIB/Benchmark_4_1_2011.pdf

3.9 Specific Activities &Tasks

3.91 Resetting Benchmarks

Follow the instruction in the Bench Mark Reset Procedures published by the National Geodetic Survey available at http://www.ngs.noaa.gov/PUBS_LIB/Benchmark_4_1_2011.pdf modified as follows.

- Direct any effort seeking assistance or advice to the ODOT Geometronics Unit as listed on the face of this document.
- Submit documentation and destroyed marks to the ODOT Geometronics Unit at the address listed on the face of this document.

3.92 Establishing Project Control

Follow these procedures for establishing or enhancing project control.

Continuous GPS Station

Constrain project control to a continuously operating Global Positioning System Station (cGPS) only when the station meets one or more of the following.

- The PLS in responsible charge of control survey is also in responsible charge of the operation of the cGPS.
- The National Geodetic Survey operates the station as part of the national Continuously Operating Reference Station site and publishes a current position for the Continuously Operating Reference Station.
- The cGPS is part of The Oregon Real-Time GPS Network.

OPUS

Accept results of the National Geodetic Survey “Online Positioning User Service” (OPUS) tools OPUS-Static and OPUS-Projects to compute control positions only if they fulfill all requirements for the task, including redundancy, network geometry, adjustment, and documentation. Do not use OPUS-Rapid Static for ODOT survey projects.

Real-Time Kinematic/Real-Time Network

Real-Time Global Navigation Satellite System positioning does not fulfill the requirements for network project control.

3.921 Horizontal Project Control

Follow these procedures for establishing or enhancing horizontal project control.

(A) Universal Horizontal Project Control Procedures

Follow these procedures for all horizontal project control activity whether linear or as a network.

Field Work

- ♦ Perform horizontal project control activity using properly tested, adjusted, and calibrated Terrestrial Equipment or Global Navigation Satellite System Equipment
- ♦ Use a standard wooden survey tripod for each occupation of a point with a target, instrument, or antenna
- ♦ Provide an independent setup for each target, instrument, or antenna use.

(B) Traverse Procedures

NOTE: Modern measurement tools and computing capabilities render traverses inappropriate in most cases. Create a horizontal project control network unless compelling circumstances suggest otherwise. Upon reaching the decision to perform traversing, submit the required deviation request to the ODOT Chief of Surveys and then follow the procedure below.

Traverse Field Work

In addition to the requirements above for universal horizontal project control procedures, follow these additional requirements when conducting linear traversing.

- ♦ Submit a SURVEY POLICY DEVIATION REQUEST form and secure concurrence before deciding on a traverse.
- ♦ Always close a traverse.
- ♦ When referencing these marks during future horizontal work, establish positions on all points from either the outbound leg or from the return leg. Do not establish positions on some marks from the outbound and others from the return side. This is to avoid propagating the discrepancy between the two, which a compass rule adjustment does not address.

Traverse Adjustment and Acceptance

Apply a Compass Rule adjustment and evaluate closure as follows.

- Evaluate acceptance of observed data based on calculated misclosures of:
    1. No greater than two arc seconds × $\sqrt{\mathbf{N}}$ of angular misclosure where **N =** the number of instrument occupations
    2. Linear misclosure of no less than one part in 20,000 after evenly distributing an acceptable angular misclosure

- Apply a proportional adjustment to the position of each point.

(C) Horizontal Network Procedures

Horizontal Network Field Work

In addition to the requirements above for universal horizontal project control procedures, follow these additional requirements when constructing a horizontal network.

- Connect network points with angle sets or Global Navigation Satellite System static baselines.
- Exclude Global Navigation Satellite System dependent baselines from all networks
- Typically, connect each network point to three adjacent network points or control marks as necessary to achieve the redundancy described in the Topic 3.431 "Network Point". In some situations, it may be appropriate to tie to more or less than three points for a portion of the network. For example, ties to additional points may be advantageous near a highway intersection or interchange where the network diverges. Similarly, it may be appropriate to employ a series of linear points similar to a traverse as a part of the network when connecting to a critical point located in deep forest. Be prepared to explain any variation from the target of three.
- Do not create or include hinge points.
- Select monument locations as detailed in Subsection 3.531 "Placement of Horizontal Project Control"

NOTE: Nothing in the requirements for monument spacing is intended to restrict observation distances.

Horizontal Network Adjustment and Acceptance

Unconstrained Adjustment

Apply an unconstrained or minimally-constrained least squares adjustment and evaluate acceptance of network measurements based on the following maximum values:

- 0.015 ft. (4.5 mm) plus 1 ppm of the baseline length on any X, Y, or Z residual. Some software may only report these residuals in latitude, longitude, and height. If so, apply the limits of .012 ft. (3.5 mm) plus 1 ppm of the baseline length to each of the latitude and longitude and 0.018 ft. (5.5 mm) to the height.

NOTE: The proportional component of the allowance is 0.001 ft. in 1000 ft. (1 mm in 1 km) and is therefore insignificant for typical ODOT network distances. Nevertheless, it may become significant in the event of an observation extending longer than 1000 ft. (300 m). As an example, 0.106 ft. for a 20-mile baseline (30 mm for a 30-km baseline).

- 3 arc-seconds on 2/3 of angular residuals as computed in a minimally-constrained adjustment
- 9 arc-seconds on any angular residual as computed in a minimally-constrained adjustment
- 0.015 ft. (5 mm) plus 2 ppm on 2/3 of distance residuals as computed in a minimally-constrained adjustment

- 0.045 ft. (15 mm) plus 6 ppm on any distance residual as computed in a minimally-constrained adjustment

NOTE: The proportional component of the distance allowance is 0.002 ft. in 1000 ft. (0.6 mm in 300 m) and is therefore trivial for typical ODOT network distances. Nevertheless, it may be significant for some measurements, especially those that significantly exceed 1000 ft. (300 m)

Constrained Adjustment

Apply a fully-contained least squares adjustment and accept positions based on the following maximum values:

- 0.100-ft. (30-mm) 95% confidence region on any point in the network

NOTE: Evaluate for undetected errors related to any point that exceeds 0.050 ft. (15 mm) 95% confidence region.

NOTE: Consider fixed points to have no error for purposes of evaluating the 95% confidence regions of the adjusted points.

For adjustments of GNSS baselines, evaluate acceptance of network measurements by examining GNSS baseline results in the least squares adjustment report for quality indicators such as residuals, RMS values, ambiguities fixed, percent of observations used to determine whether the baseline is acceptable to meet the overall position error budget of the constrained adjustment

3.922 Vertical Project Control

(A) Vertical Control Required

Establish vertical control in the form of temporary bench marks for all projects. Consider horizontal control monuments as vertical control only when both of the following are true:

- The mark itself conforms to the requirements in this manual for vertical project control (temporary bench mark) monuments
- The procedures used to establish the elevation conform to the requirements in this manual for establishing temporary bench marks for vertical project control

Follow these procedures for establishing or enhancing vertical project control.

(B) Trigonometric Leveling

Do not use trigonometric leveling for alone for project vertical control. In the event that a situation suggests trigonometric leveling is the only method needed, secure the required deviation approval from the ODOT Chief of Surveys, use appropriate equipment as defined below, and follow the procedure stipulated in the deviation approval.

- Perform trigonometric leveling using Terrestrial Equipment as defined in the Glossary and that has been properly tested, adjusted, and calibrated.

(C) Universal Differential-Leveling Procedures

NOTE: With some modifications, the ODOT procedure for differential leveling follows those for Third Order leveling in 1984 Federal Geodetic Control Committee Standards and Specification for Geodetic Control Networks (http://www.ngs.noaa.gov/FGCS/tech_pub/1984-stds-specs-geodetic-control-networks.pdf). It also draws from the supplement FGCS Specifications and Procedures to Incorporate Electronic Digital/Bar-Code Leveling Systems. (http://www.ngs.noaa.gov/FGCS/tech_pub/Fgcsvert.v41.specs.pdf)

However, Section 3.5 of the 1984 Federal Geodetic Control Committee publication requires several procedures that are not mandatory for typical ODOT leveling activity. ODOT only requires those procedures included in this manual.

Follow these procedures for all differential-leveling activity whether linear or as a network.

- Perform differential leveling using Terrestrial Equipment as defined in the Glossary and that has been properly tested, adjusted, and calibrated.
- Limit observation distance to 300 ft. (90 m).
- Balance distances from each setup to within 30 ft. (10 m).
- Balance foresight and backsight distances on each run between durable marks to within 30 ft. (10 m).
- When leveling with two rods, Leapfrog rods such that only one rod occupies each turn point.
- When establishing a turning point, choose a point that complies with the following concepts.
  - Located in a safe location for equipment and personnel
  - Vertically stable for the duration of the survey
  - Has a distinct high point

NOTE: The ODOT Geometronics office has turning pins and turtles available for loan to internal ODOT staff on an as-needed basis.

- When establishing a Temporary Bench Mark, choose a point that complies with applicable portions of Section 3.5.

NOTE: When faced with transferring elevations over long distances or unfavorable routes such as across a large body of water, consult with the Geometronics Unit.

(D) Level Circuit Procedures

NOTE: Modern measurement tools and computing capabilities render linear leveling inappropriate in most cases.

Establish TBMs unless compelling circumstances suggest otherwise. Upon reaching the decision to perform linear leveling, secure the required deviation approval from the ODOT Chief of Surveys and then follow the procedure below.

Level Circuit Field Work

In addition to the requirements above for all leveling activity, follow these additional requirements when conducting linear leveling.

- Establish an intermediate elevation mark as required in Topic 3.532 "Placement of Vertical Project Control". If not setting TBM points on a particular task, set a durable turn point at the same interval. Return to these to troubleshoot in the event of a blunder.
- Turn through each intermediate elevation mark, whether a TBM or durable turn point, for potential blunder recovery.
- Always close linear leveling.

NOTE: When referencing marks during future vertical work that were established using linear procedures, establish elevations on all new points from either the outbound run or from the return run, not some points from the outbound and others from the return. This is to avoid propagating the discrepancy between the two, which prorating of error does not address.

Leveling Circuit Adjustment and Acceptance

- Evaluate acceptance of established elevations based on a calculated misclosure no greater than:
  - 0.05 ft. × √**D** miles (12 mm × √**D** km) between bench marks where D represents the distance of the leveling run
  - 0.03 ft. × √**L** miles (8 mm × √**L** km) for a closed loop where L represents the distance of the loop
- Apply a linear adjustment to each run or loop.

(E) Vertical Network

Vertical NetworkField Work

In addition to the requirements above for all leveling activity, follow these additional requirements when constructing a vertical network.

- Establish a TBM . Connect temporary bench marks with differential leveling procedures utilizing turn points as needed.
- Connect temporary bench mark to three or more adjacent project vertical control network points (temporary bench marks) or bench marks.

Vertical Network Adjustment and Acceptance

- Apply an unconstrained or minimally-constrained least squares adjustment and evaluate acceptance of network measurements based on the following maximum values:
  - 0.0010 ft. (0.3 mm) on any elevation difference residual between turn points
- Apply a fully-constrained least squares adjustment and evaluate acceptance of established elevations based on the following maximum values:
  - 0.020 ft. (6.0 mm) 95% confidence range on the elevation of any point (temporary bench mark)

NOTE: The 95% confidence range requirement does not apply to turn points or other unpublished points in the network.

NOTE: Consider fixed points to have no error for purposes of evaluating the 95% confidence range of the adjusted points.

3.923 Three-Dimensional Project Control

There are times when the surveyor may select one point to serve as both horizontal control and vertical control. However, some common practices for establishment of horizontal control points would fail to meet the requirements for a vertical control point (temporary bench mark). Likewise, a vertical control point (temporary bench mark) may not meet the requirements for a Control Network Point. Nevertheless, when a monument meets all of the requirements for a Horizontal Network Point, the horizontal position has been established following the Horizontal Network Procedures, and the elevation has been established following the Differential Leveling Procedures, the surveyor may use the monument for Three-Dimensional Project Control.

Chapter 4 - Boundary

4.1 Introduction

4.11 Overview

This Chapter addresses ODOT procedures for survey work related to property boundary and right-of-way matters. Included are recovery and retracement of existing markers and boundaries, descriptions of property for transfer of ownership or rights, and establishment of monuments and creating record surveys for new or reestablished boundary lines and monuments.

4.12 Application

Apply these policies and procedures for all survey activity that involves property boundary and right-of-way matters. Give preference to this Chapter with regard to that subject matter in the event of any conflicts with other Chapters. Where this Chapter is silent or incomplete regarding a particular subject, follow the direction provided in the other Chapters. For example, to establish survey project control as part of a boundary survey when establishment of said project control is beyond any specific instruction in this Chapter, follow the instructions in the Chapter on Project Control.

4.2 General Considerations

4.21 Guiding Principles

Use these guiding principles to govern boundary survey work

- Comply with applicable laws
- Establish and maintain physical markers delineating ODOT ownership
- Create a record of survey and enter into the public record.

4.22 Boundary Surveying and Right of Way Functions

The phases of right of way and other boundary surveying work are:

- Recovery, Retracement and Resolution
- Monumentation

Perform right of way and other boundary surveying under the direction and control of a registered Oregon Professional Land Surveyor. Prepare and submit when required:

- Control, Recovery and Retracement Survey to county for filing.
- Monumentation Survey to county for filing.

For survey filing map standards refer to the Control Recovery and Retracement Surveys document and the Right of Way Monumentation Surveys document.

NOTE: Preparation of legal descriptions and drawings for the acquisition of right of way for ODOT projects, though a part of surveying, is a Right of Way process. For standards, practices and procedures of right of way drawings and writing legal descriptions, refer to the Right of Way Engineering Manual.

4.23 Accuracy of Boundary Points

Determine point locations for property boundaries within the error tolerances in following accuracy table

	Horizontal	Vertical
All Boundary Points	0.06 ft. (20 mm)	N/A

Table 4A - Accuracy of Boundary Points

4.3 Equipment

4.31 Boundary Field Work

Use only equipment that fulfils the requirements in Subsection 1.32 “Selection of Equipment”. Assure that assessment of all equipment is complete and up to date as required in Subsection 1.34 “Periodic Assessments”.

4.32 Computer Aided Design (CAD) Maps

Produce Right of Way and other boundary maps consistent with the current ODOT symbology, conventions, and file formats.

4.4 Standard Procedures

4.41 Boundary Monument Locations

Acceptable methods for tying or setting monuments are:

- Incorporate as a project control point within project control network
- Tie from project control (CSP or better) using any of the methods described in Topic 1.433 Controlled Strategic Point:
  - Full Double Tie
  - Modified Double Tie
  - Resection or Free Station
  - Closing to different control

4.42 Property Acquisition Process

Right of Way and other boundary maps in ODOT follow a highly structured process. Follow the Right Of Way Engineering Manual when creating descriptions and maps associated with transferring ownership of real property to or from ODOT.

4.43 Staking or Flagging Boundary Lines for Negotiations

(For Future Development)

4.5 Monuments and Markers

Requirements for Monuments and Markers are covered in Section 9 along with the respective procedures.

4.6 Products and Deliverables

Section 9 of this Chapter is designed to address specific boundary survey activities and tasks and includes with each activity or task a list of deliverables associated with that specific activity or task. This Section contains requirements for products and deliverables associated with boundary survey activity.

4.61 Right-of-Way Maps

Prepare right of way drawings, legal descriptions and other related documents per the Right of Way Engineering Manual.

4.62 Right-of-Way Layout Design

Refer to the Right of Way Engineering Manual for ODOT preferences and conventions used when laying out right of way.

4.63 Professional Seal

Sign and stamp with the seal of the registrant all legal descriptions per Right of Way Engineering Manual and in conformance with Oregon Revised Statutes 672.025 and Oregon Administrative Rule 820-010-0621.

4.64 Recovery and Monumentation of Boundary Points

For survey filing map standards refer to the Control Recovery and Retracement Surveys document and the Right of Way Monumentation Surveys document.

4.7 Documentation

Documentation for boundary work includes the items in Section 1.7 on common documentation requirements for all survey work and the deliverables required in Section 1.6.

4.8 References

4.81 Right of Way Engineering Manual

http://www.oregon.gov/ODOT/HWY/GEOMETRONICS/row_eng/rw_manual/rw_eng_manual.pdf

4.82 History of Highways

ftp://ftp.odot.state.or.us/web_docs/HSHO.pdf

4.83 Control, Recovery and Retracement Surveys

http://www.oregon.gov/ODOT/HWY/GEOMETRONICS/docs/control_recovery_and_retracement_surveys.pdf

4.84 Right Of Way Monumentation Surveys

http://www.oregon.gov/ODOT/HWY/GEOMETRONICS/docs/right_of_way_monumentation_surveys.pdf

4.9 Specific Activities &Tasks

4.91 Recovery, Retracement, and Resolution

4.911 Preparation Recovery of Boundary Point

Before beginning boundary work:

- Develop project control in accordance with ODOT's Horizontal Control procedures as outlined in Chapter 3 – Project Control.
- Research pertinent records that define the project area and develop a list of monuments for searching.

4.912 Recovery of Boundary Evidence

- Locate and tie sufficient evidence to define the right-of-way.
- Locate and tie sufficient evidence to define specifically required property boundaries.
- Locate and tie all monuments of record subject to destruction or disturbance per Oregon Revised Statutes 209.155.
- Tie the property corners defining the back property line of each private lot only when they are required in any of the cases above.
- Tie monuments as described in Subsection 4.41 on Boundary Monument Locations.
- Locate and tie a minimum of one corner monument as described in Oregon Revised Statutes 209.250(3)(d).

4.913 Retracement and Resolution of the Boundary

- Use the monuments and boundary evidence found and observed during the recovery stage to confirm or re-compute the geometry of the existing right-of-way centerline and right-of-way boundary lines.
- Develop Control, Recovery, and Retracement Surveys and file with County Surveyor prior to commencement of construction to comply with Oregon Revised Statutes 209.155. The map shall comply with Oregon Revised Statutes 209.250. Refer to Control, Recovery and Retracement Surveys standards documents.

4.92 Boundary Monumentation

4.921 Monumentation of Highway Right Of Way Boundaries

Delineate the newly defined right of way by either of two methods required by Oregon Revised Statutes 209.155(2) and as outlined below.

(A) Network Option

Establish a permanent survey control network that references the right of way center line and the right of way boundary.

- Include in this network at least two monuments from part of the original control network used to locate the monuments during the location survey.
- For the remainder of the network control points use R&C stabilized horizontally and vertically, and fitted with a 1-1/2" brass cap.
- Do not exceed 1500 feet for the distance between monuments.

NOTE: The network option cannot be used to reference monuments removed, disturbed, or destroyed and which are lying outside the newly defined right of way. Replace these monuments as required by Oregon Revised Statutes 209.150 and 209.155.

Place a salmon or orange colored composite fiberglass post or steel guard post with a 6" x 18" white aluminum paddle within the right of way facing the roadway centerline and one foot behind the monument. For monuments that lie adjacent to and one foot or less from the right of way line place the orange colored composite fiberglass post or steel guard post with a 6" x 18" white aluminum paddle facing the roadway centerline and one foot ahead on stationing of the monument.

The composite fiberglass guard post or steel guard post with paddle shall be marked "Survey Marker". (See Figure 4B "Monuments, Guard Posts, and Line Marking Standards")

Develop a Right Of Way Monumentation map and file with the County Surveyor.

- Identify on the map the final horizontal control network, the new right of way centerline, and the new right of way boundary.
- File this map within 180 days of completion of construction.
- Comply with Oregon Revised Statutes 209.250 for this map.
- The date of Second Notification constitutes the effective date of completion of construction.

(B) Boundary Option

Monument, or reference with monuments, all right-of-way centerline control points and monument the right of way boundary at all angle points, points of curve, points of tangency, and at least every 1000 feet on long curves and tangents.

- A minimum of two reference monuments shall be set to reference each centerline control point.
- The boundary monuments shall be set at all the points of change in the actual right-of-way boundary regardless of its relationship to the centerline control points.

The monuments set shall be YPC. Consultants contracted by ODOT, and monumenting ODOT boundaries shall use ODOT YPC in lieu of caps with their PLS number.

Place a white composite fiberglass or steel guard post with a 6” x 18” white aluminum paddle facing the roadway centerline and within the highway right of way adjacent to each reference monument 1 foot (0.3 meter) in from the right of way and 1 foot (0.3 meter) ahead on line.

The composite fiberglass guard post or steel guard post with paddle shall be marked “Boundary”. (See Figure 4-B “Monuments, Guard Posts, and Line Marking Standards”)

Leave the horizontal control network in place even after the right-of-way monumentation is complete.

Develop a Right-of-Way Monumentation map and file with the County Surveyor.

- On this map, identify the final horizontal control network, the new right-of-way centerline, and the new right-of-way boundary.
- File this map within 180 days of completion of construction.
- Comply with Oregon Revised Statutes 209.250 for this map.
- The date of Second Notification constitutes the effective date of completion of construction.

4.922 Monumentation of Quarries and Stockpile Sites

Delineate the boundaries of ODOT quarries and stockpile sites as follows:

(A) ODOT Owned Sites

Monument all corners of the property and mark the boundary lines. (See Monuments, Guard Posts, and Line Marking Standards)

Develop a Boundary Monumentation map in compliance with Oregon Revised Statutes 209.250 and file with the County Surveyor.

(B) ODOT Controlled Sites Bounded by Government and Private Land

Monument all corners of quarry or stockpile sites lying within Federal or State Government land but bounded on one or more sides by private land and mark the boundary lines. (See Monuments, Guard Posts, and Line Marking Standards)

Develop a Boundary Monumentation map in compliance with Oregon Revised Statutes 209.250 and file with the County Surveyor.

(C) ODOT Controlled Sites Bounded Entirely By Government Land

Permanent corner monuments are optional on quarry or stockpile sites held by easement and lying within and bounded entirely by Federal or State Government land.

Mark the calculated corner locations and easement lines. (See Monuments, Guard Posts, and Line Marking Standards) The easement boundary may be determined by the use of the Bureau of Land Management's Geographic Coordinate Database Section (GCDB) coordinates if approved by the controlling state or federal agency.

(D) Monuments, Guard Posts, and Line Marking Standards

All boundary monuments set on quarry and stockpile sites shall be YPC. Consultants contracted by ODOT, and monumenting ODOT boundaries shall use YPC in lieu of caps with their PLS number.

In addition to the corner monuments, each corner shall be referenced with a flat composite fiberglass guard post or a steel guard post with 6" x 18" aluminum paddle within the property adjacent to the monument and one foot in from the boundary line. The composite fiberglass posts or the paddles shall be white in color and marked "BOUNDARY". (See Figure 4B"Monuments, Guard Posts, and Line Marking Standards")

The boundary lines of all quarry and stockpile sites shall be marked with white fiberglass fence posts wrapped with two-inch red reflective tape bands. (See Figure 4B "Monuments, Guard Posts, and Line Marking Standards")

The markers will be placed intervisible along the line with a minimum spacing of 200 feet, a maximum spacing of 500 feet and shall extend approximately five feet above the ground. The markers shall be placed within the quarry property no more than one foot from the line. For non-ODOT owned quarry and stockpile sites where permanent corner monuments will not be set, reference the calculated corner locations as set forth above.

If a property line between a quarry or stockpile site and the adjoining property is marked by an existing fence, or a boundary line is along a road or natural feature such as a river, then the line need not be marked as stated above. The feature marking the line shall be clearly identified on any survey filed or map submitted.

The intent of this marking standard is to place the line markers so as to be intervisible and clearly mark the boundary line. In some areas, a shorter spacing than 200 feet may be necessary. In other areas, a greater spacing than 500 feet may be allowed. Heavy brush may require a greater height above the ground and longer posts be used. Use discretion and coordinate with Region Geologists for any major variation of this standard.

If requested by Region Geologists to mark excavation areas, stockpiles, setbacks and buffers within a quarry boundary, the markings shall be in compliance with Oregon Administrative Rule 632-030-0015(2b). Markers used must be approved by the Oregon Department of Geology and Mineral Industries (DOGAMI), set to be clearly visible and of no more than 200 foot spacing on center.

4.923 Monumentation of Other Properties

Properties other than highway right of way, quarry and stockpile sites shall be surveyed and boundary maps prepared in compliance with Oregon Revised Statutes 209.250 and filed with the County Surveyor.

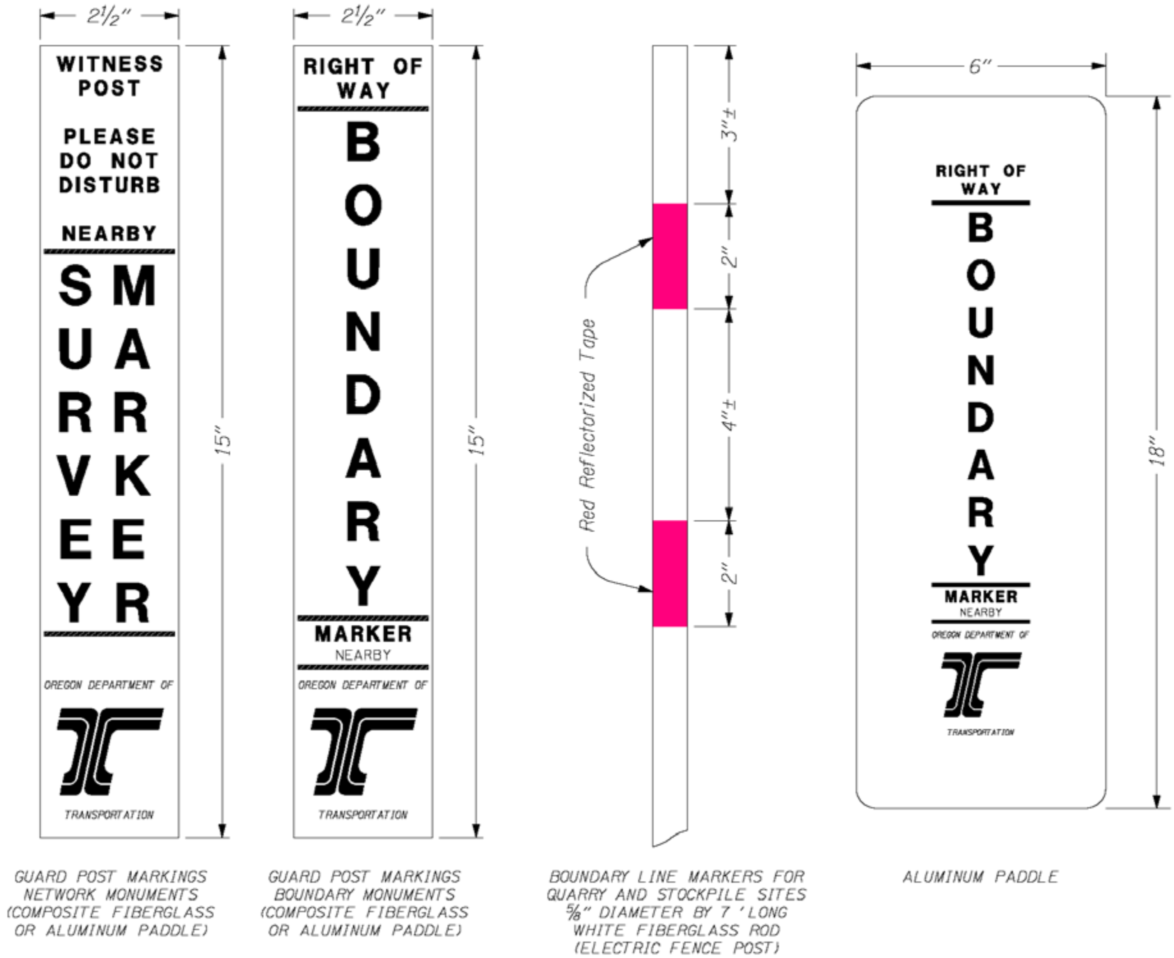

Figure 4B - Monuments, Guard Posts, and Line Marking Standards

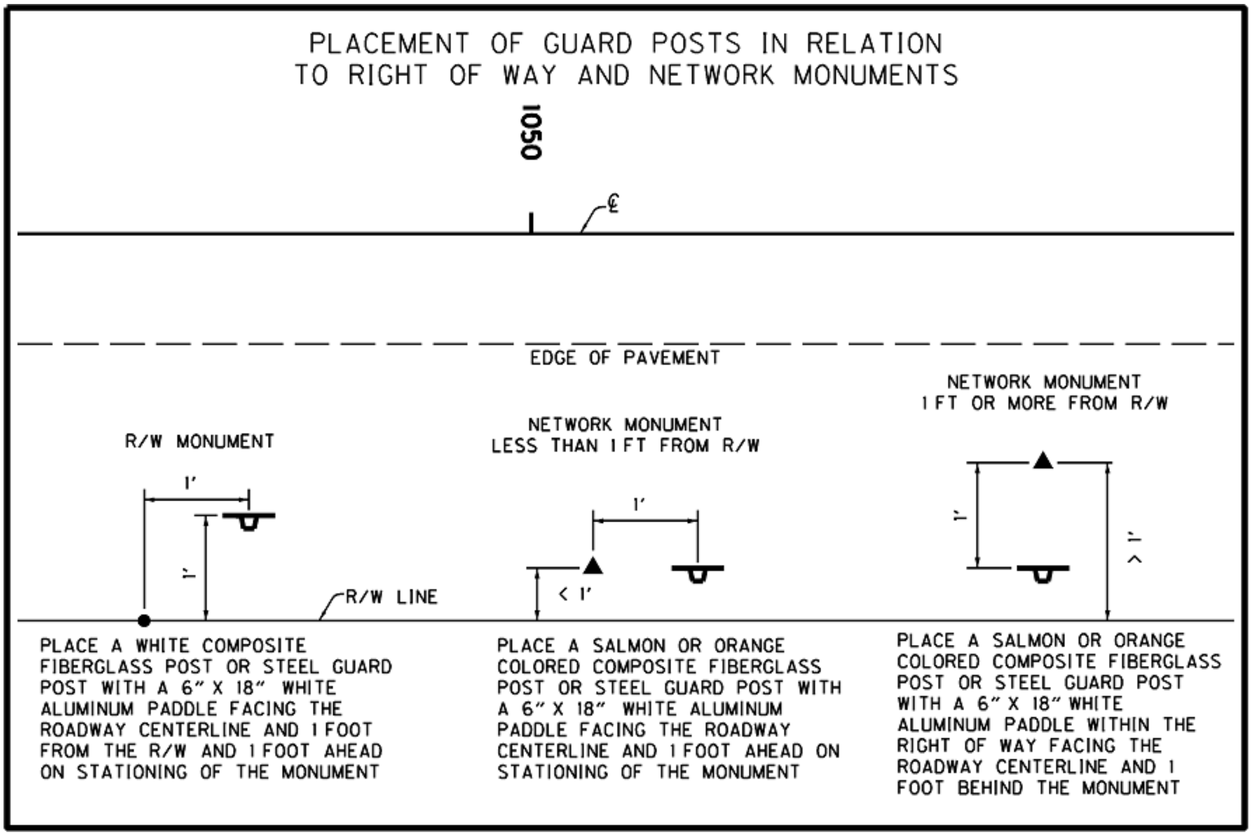

Figure 4C – Placement of Guard Posts

Chapter 5 - Topography

5.1 Introduction

5.11 Overview

This Chapter addresses the specific activities associated with collection of topographic features and the creation of products representing that data, including determination of linear, area, or volumetric quantities for design or payment purposes. Use it as specific supplement to the common provisions in Chapter 1.

5.12 Application

Apply these policies and procedures for all survey activity that involves collection of spatial data related to location, size, orientation, or any other physical attribute of manmade or natural features.

5.13 Scope

This Chapter focuses primarily on electronic data collection. ODOT does not prohibit methods that are more rudimentary. However, their use has become largely obsolete. Make a decision to revert to manual measurements and/or paper notes only after considering the cost and benefit. Once reaching that decision, follow a process designed to be efficient and to deliver the proper product. Document the decision in the project records.

Data collection typically occurs in support of one or more on the following activities.

- Planning and reconnaissance
- Design and construction of a project
- Asset management

5.2 General Considerations

5.21 Overview

ODOT collects topographic data for a wide variety of purposes and with an equally wide variety of requirements. Those purposes can include the following and others.

- ♦ Reconnaissance for concept evaluation
- ♦ The foundational data for a design
- ♦ Asset inventory
- ♦ Land ownership and occupational matters
- ♦ Payment of contract work, either final or partial progress

Assure that persons involved understand their role, the purpose of the data collected, and the associated requirements. That may include the following and others.

- ♦ Accuracy and precision constraints
- ♦ Attribute information
- ♦ Timelines, particularly contractual obligations
- ♦ Potential conflict of interest (for example, a construction contractor is normally prohibited from measurement activities that affect payment for that contract.)

5.22 Guiding Principles

- ♦ Consistency - data accuracy, detail, and symbology is independent of the source of the data. Choose the correct collection tool(s) to deliver the required product.
- ♦ The surveyor is the owner of all data collected under their direction but the look, feel, and format of deliverables is under the control of others such as the ODOT CADD Standards Committee.
- ♦ Collect valid elevations with all topographic points.
  - Collect elevations on survey markers on top of the monument.
  - Collect elevations on top of items where the top is integral to the design effort such as retaining walls and bridge deck components.
  - Collect elevations at ground level (unless indicated otherwise) for all features that contact the ground, do not meet either of the two criteria above, and extend into the air such as trees, poles and risers, buildings, walls, fence, barrier and guardrail, and mailboxes.
  - Collect elevation at the lowest extreme of the feature for features that do not contact the ground, including such items as building eaves, sign faces, bridge soffits, and overhead utilities.

- In the event that there is a deliberate effort to collect an elevation other than as described above, communicate as overtly as practical that the elevation is nonstandard and the intent.
- In the event that collecting an elevation as described above is not practicable, remove the elevation, set it to -9999, or otherwise render it obviously invalid.

5.23 Selection of a Method

Select a tool and method for collecting topographic data that meets the needs of the project.

5.24 Selecting Features

Determine what features to collect based on the scope of that project.

5.25 Integrated Topographic Collection

For the purpose of efficiency, collect data simultaneously for use in creating basemaps and creating digital terrain models.

5.26 Accuracy of Topography

5.261 Accuracy of Topographic Points

Determine locations of topographic features within the error tolerances in the following accuracy table. Accuracy of Topographic Points is required at a nominal level as further detailed in this Chapter.

	Horizontal	Vertical
All Topographic Points	0.10 ft. (30 mm)	0.10 ft. (30 mm)

Table 5A - Accuracy of Topographic Points

5.262 Positional Accuracy of Topographical Points

There is only one Positional Accuracy Specification for all topographical points. This applies to both the horizontal and vertical position. It is an indication of how good any individual measurement is and should not be confused with Confidence Point Specifications. Measure all points within **the values in Table 5A "Accuracy of Topographic Points"** relative to the project control points. To achieve the standard accuracy with a Total Station, take shots no farther than **+/-** 800 ft. (250 m) from the instrument under most conditions.

5.263 Allowance for Practical Limitations on Accuracy

Some easing of the above accuracy requirements may be appropriate in some areas. Employ the practice of using reflectors mounted on leveling rods and other such approximate techniques only when the situation meets ALL of the conditions below.

- The terrain qualifies as "Natural" or "Rugged" as described in the topographic confidence point criteria in Table 5E "Original Ground Confidence Points Tolerances".
- The area is heavily vegetated or otherwise occupied with objects obstructing line of sight to most of the area and obstructing line of sight to the sky for Global Navigation Satellite System observations.
- The project leader, designer, and other clients concur that the result will serve the project adequately and such concurrence is documented in the project records.
- The area is included in the confidence point analysis and the results in the area so modelled do not compare unfavorably with the result for the overall model.
- Any basemap or other product created in such manner shows the area clearly delineated on the basemap or other product as described in Topic 5.264 Delineation of Non-Standard Accuracy Areas and that the associated narrative and project records describe the process.

5.264 High-Accuracy Zones

Certain areas of some projects justify additional time, effort, and expense to achieve a high level of accuracy and/or detail in the topographical data beyond that justifiable for the entirety of a typical digital terrain model. The designer, project leader, or project team must clearly identify and delineate these high-accuracy zones and accept additional expenditures in order for the surveyor to deliver them.

The deliverable for a high-accuracy zone may be no more elaborate than a digital terrain model with a higher density of data points. It may be a digital terrain model with more precise positions on the data points. It may be a combination of both. Alternatively, it may be a completely different product such as a collection of profile lines in three dimensions or a series of cross-sections.

The requesting party has the obligation to define the objective of elevated accuracy and the geographical extent of the zone. The surveyor has the responsibility to develop a plan to meet those objectives and an associated estimate of cost and timeline. Part of the plan includes a validation procedure and a report of the results.

5.265 Delineation of Non-Standard Accuracy Areas

Delineate all portions of the mapping and modeling data that purposefully varies from the standard in Table 5A “Accuracy of Topographic Points”. Delineate both lower accuracy areas as described in Topic 5.263 Allowance for Practical Limitations on Accuracy as well as higher accuracy areas as described in Topic 5.264 High-Accuracy Zones.

Delineate non-standard accuracy areas in both graphic products and non-graphical files. Delineated visually and label appropriately within a CADD file or any relevant graphic depiction of the project any areas where the mapping detail or accuracy is greater or lesser than the standard in Table 5A “Accuracy of Topographic Points”. Delineate such areas within a non-graphic file such as a DTM or TIN file by use of separate files and/or use of triangulation control lines such that the model of one accuracy indicates a void in areas of different accuracy.

5.3 Equipment

Use only equipment that fulfils the requirements in Subsection 1.32 “Selection of Equipment”. Assure that assessment of all equipment is complete and up to date as required in Subsection 1.34 “Periodic Assessments”.

5.4 Standard Procedures

5.41 Global Navigation Satellite System Kinematic Procedures

Kinematic surveying is principally appropriate for topographical mapping and similar activities where bulk data is collected and precision is not paramount. Follow these guideless for Kinematic data collection.

	Single Base	Multi-base
Base Station		
Antenna support	Tripod*	Not Applicable
Satellite mask above horizontal	10 Degrees*	Not Applicable
Rover		
Satellite mask above horizontal	15 Degrees	
Maximum Distance to Base	6 mi. (10 km)	22 mi. (35 km)
Observe 3D Check Point	Yes	
Maximum GDOP/PDOP	8/6	
Epoch Interval	1 Second	
Single Point Horizontal/Vertical Position Quality**	0.03 ft. (1 cm)/0.07 ft. (2 cm)	
Localization		
Minimum number of horizontal localization points	3***	
Minimum number of vertical localization points	1	
Optimal number of horizontal localization points	4***	
Optimal number of vertical localization points	4***	

* Not Applicable if using a permanent base such as a ORGN station
** As reported by the GPS equipment RTK quality value – May vary between manufacturers
*** Optimal placement of multiple points for both horizontal and vertical localization is equally distributed radially and outside the intended work area. Horizontal and vertical localization may use common points.

Table 5B - Summary of GNSS RTK Specifications

5.42 Purpose and Function of Topographic Data

Survey personnel collect topographic data for a variety of purposes and functions. While there are some variations from one application to another, the concepts are similar. The following Subsections cover topographical data collection for:

- ♦ Subsection 5.43 Original Ground
- ♦ Subsection 5.44 Constructed As-Built Maps
- ♦ Subsection 5.45 Property Boundary

5.43 Mapping and Modeling Original Ground

Engineering projects in development are the dominant application of topographic data collection in ODOT

5.431 Objectives of Original Ground Basemap

In a typical original ground survey, several objectives rely on the topographic survey:

- ♦ Design of the project to accomplish the solution identified
- ♦ Providing the basis for the engineers estimate for constructing the project
- ♦ Identifying and minimizing impacts on adjoiners
- ♦ Identifying and quantifying right-of-way acquisition demands

5.432 Types of Original Ground Data

In a typical original ground survey, there are at least three kinds of data collected. There is some integration of the three, but the purposes are distinct. Assure that the data collected meets the objectives of each. The three kinds of data include:

- ♦ Terrain Data – must adequately depict the shape of the ground and may be devoid of attribute data except terrain attributes. Represent the shape of the ground accurately in areas defined by various shapes including radial curves with small radii.
- ♦ Feature Data – identifies attributes of natural and manmade linear and point features above, below, or on the surface of the ground. Represent curved lines as such and not as a series of straight lines or chords. Feature data may or may not influence the representation of the terrain
- ♦ Property Boundary Data – Includes features that indicate lines of occupation. This is distinct from boundary monuments covered in the chapter on boundary. However, they may be merged in an effort to identify ownership lines.

5.433 Spacing of Topographic Data Points

Take shots at standard spacing of 50 ft. (15 m) intervals or less without regard to lines or points. Shot spacing must be close enough together that vertical separation between the ground and the triangle representing it should not exceed the Confidence Point Tolerance for that surface.

Collect data for non-breakline linear features only at horizontal changes. However, collect the horizontal location of any line such that it is within 0.30 ft. (0.10 m) of the feature it represents. Some exceptions to this may be appropriate on extremely rugged terrain.

5.434 Elevation Data for Topographic Data Collection

Measure and record the elevation on each feature according to Table 5 "Original Ground Data Feature Mapping Characteristics" in Subsection 5.41. Measure the elevation of each feature according to the following:.

- ♦ If a feature contacts the ground, measure the elevation at the point of contact.
- ♦ If a feature does not contact the ground, measure the elevation along the bottom edge of the feature.

Record the elevation on each point in one of the following manners.

- ♦ Record an elevation that represents the earth surface at that location and identify the point for inclusion in the Digital Terrain Model.
- ♦ Record an elevation that does not represent the earth surface at that location but rather represents the dominant concern at that location such as the flow line of a manhole. Identify the point for exclusion from the Digital Terrain Model.
- ♦ Record a point that has no valid elevation. This may occur consistently for certain features. More commonly, indicate an invalid elevation occasionally such as when horizontally locating at an undetermined height above the ground a power pole with an inaccessible base. Remove invalid elevation and set to null or modify to -9999.

5.435 Validation Features in Topographic Data Collection

Follow the relevant common procedures on validation in Subsection 1.43. Include validation data in working files. Validation features that have significant value in the process but do not appear on the final products include:

- ♦ Back sight Checks
- ♦ Elevation Checks
- ♦ Confidence Points

5.436 Attributes of Original Ground Data

Table 5C "Original Ground Data Feature Mapping Characteristics" that occupies the following pages provides specific information on common features mapped by various means and how to treat the elevation data in the resulting terrain model. There are two types of features.

- ♦ Point features: Items represented by a single symbol on the map and positioned in the model at a specific single location on the project.
- ♦ Line or linear features: Items represented on the map by a line drawn through a series of points and positioned in the model over some area of the project

Within these two types, handle the data with one of these methods during the terrain modeling process.

- ♦ Non-triangulated: A feature, either point to line, that is on, above, or below that surface and that has no influence on the shape of the terrain surface defined in the triangulated irregular network

- Contourable: A feature where the points are loaded into the terrain surface as terrain points ("Random Features" in Bentley InRoads) from which the software then generates vertices for the triangulated irregular network
- Breakline: A line feature in which the points are used as terrain points and in addition has constraining characteristics on the triangulated irregular network by prohibiting any triangles from crossing that feature.

The ODOT configuration supports the user selecting the method on certain features. Otherwise, vary the method from default only for defensible purpose. The table indicates the default handling of modeling characteristics for each feature. Plain Font indicates a "non-triangulated" feature. *Italicized Font* indicates a "triangulated" feature. **Bold Font** indicates a breakline feature. ***Bold Italic Font*** indicates that the method is selectable by the user.

Table 5C – Original Ground Data Feature Mapping Characteristics

Non-Triangulated features in Plain *Triangulated features in Italic*

Breakline features in Bold ***User controllable features in Bold***

Feature	Type	Position	Notes
Arrow	Point	Tie at tip of arrow	Tie at split for Lt. and Rt. combined arrow
Barrier	***Line***	***Perimeter***	***Tie the base of each exposed face***
Bench Mark	Point	Center or Center Punch	Add record elevation
Billboard	Line	Bottom edge of sign	
Bollard	Point	Base of object at Center	
Box Culvert	Collect the 3D linear positions at the inverts (inlet and outlet) of the box culvert. Collect any other features associated with the box culvert such as wing walls and aprons.		
Bridge	Collect the 3D linear positions on top of and at the outside edge of the bridge structure. If the edge of the bridge is visible (e.g. an expansion joint) where it crosses the road, continue collecting this line feature across the road.		
Bridge Bent	***Collect the 3D linear positions of the bent centerline. These centerline positions are collected, if possible, at ground level at the base of the bent and at the top of the bent, but, if this is not possible, collect the positions for the bent centerline from above, on the bridge deck.***		
Bridge Soffit	Collect the 3D linear positions of the bottom (low part of the underside) of the bridge soffit at each end of the span and at the higher edge of each lane or shoulder, at leading and trailing sides of the bridge.		
Brush Line	Line	Perimeter	
Building Eave	Line	Bottom Edge of Eave	
Building Wall	**Line**	**Face of Wall**	**Add a breakline at base of wall**
Canal, Top Edge	**Line**	**Perimeter**	

Table 5C – Original Ground Data Feature Mapping Characteristics

Non-Triangulated features in Plain *Triangulated features in Italic*

Breakline features in Bold ***User controllable features in Bold***

Feature	Type	Position	Notes
Cattle Guard	Line	Perimeter of metal structure	Also tie controlling concrete match lines
Confidence Points	Point		Place strategically for surface check
Concrete, Edge	**Line**	**Perimeter**	
Crosswalk	Line	Perimeter	
Crown	***Line***	***Centerline***	
Curb	***Line***	***Top Back of curb***	
Ditch Bottom	**Line**	**Centerline**	
Drain-field	Line	Perimeter	
Fence/Gate	**Line**	**Perimeter**	
Fence –non-breakline	Line	Perimeter	
Fire Hydrant	Point	Center	
Found Monument	Point	Center or Center Punch	
Fuel Fill Cap	Point	Center	
Fuel Tank	Line	Perimeter	
Fuel Tank (Locates)	Line	Centerline	
Gas Pump	Point	Center	
Gas Valve, Riser, or Vent Pipe	Point	Center	
Gas Vault	**Line**	**Perimeter**	
Generic Breakline	**Line**		
Generic Line	Line		
Generic Point	Point		
Gravel, Edge	***Line***	***Perimeter***	
Guardrail	***Line***	***Face of rail***	
Gutter	***Line***	***Flow-line***	***Also defines curb alignment***
Guy Wire	Line		Tie terminus of wire and Pole
Guy Wire Anchor	Point		Tie where anchor enters the ground
Handrail	Line	Perimeter	
Headgate	Point	Center	
Hedge	Line	Perimeter	
Inlet	Point	Top Center of grate	
Irrigated Field, Edge	**Line**	**Perimeter**	
Junction Box	Point	Center	
Landscaping/ Lawn	**Line**	**Perimeter**	
Luminaire	Point	Center of lamp	Tie Pole with separate shot
Mailbox	Point	Center	Tie at base of post

Table 5C – Original Ground Data Feature Mapping Characteristics

Non-Triangulated features in Plain *Triangulated features in Italic*

Breakline features in Bold ***User controllable features in Bold***

Feature	Type	Position	Notes
Manhole	Point	Center of Lid	
Monitoring Well	Point	Center	
Monument Box	Point	Center of lid	
Overhead Utility Line	Line	Center of Line	Tie from the ground or using reflectorless
Pavement, Edge	**Line**	**Perimeter**	
Pipe	All pipes, except arch pipes: Collect the 3D linear positions at the inverts (inlet and outlet) of the pipe. If both ends of the pipe are not available, collect data for the found, accessible end, and estimate & collect a 3D position for the pipe direction. Data should also be collected where the pipe is visible and an accompanying height change recorded, if necessary, to reduce data to the correct invert elevation. Note dimensions, condition, and any other important characteristics of pipe, as per the ‘Survey Field Note Standards’ document. Note if the 3D position is collected for direction only.		
Pipes (Arch)	Collect the 3D linear position at the inverts (inlet and outlet) of the pipe. If the pipe is buried, note that the elevation is at the top of the streambed material (as you may not be permitted to dig, or disturb, the streambed). If both ends of the pipe are not available, collect data for the found, accessible end, and estimate & collect a 3D position for the pipe direction. Data should also be collected where the pipe is visible and an accompanying height change recorded, if necessary, to reduce data to the correct invert elevation. Note the dimensions. You will need both the height and the width, as different manufacturers make different pipe configurations. The height is the interior rise. If the invert of the pipe is buried, note that the interior height is from the top of the pipe to the top of the streambed material. The width is the interior span and is measured at the widest part of the interior of the pipe. Note the condition, and any other important characteristics of the pipe such as end treatments. Note if the 3D position is collected for direction only.		
Pole	Point	Center of Pole	
Power Vault, Edge	**Line**	**Perimeter**	
Public Phone	Point	Center of Mount	
Railroad Ballast, Edge	**Line**	**Perimeter**	
Railroad Track	Line	Center of Tracks	Distance split between the rails.
Random Fill Line	**Line**	**Perimeter**	

Table 5C – Original Ground Data Feature Mapping Characteristics

Non-Triangulated features in Plain *Triangulated features in Italic*

Breakline features in Bold ***User controllable features in Bold***

Feature	Type	Position	Notes
Retention Pond, Edge	**Line**	**Perimeter**	
Rip Rap, Edge	**Line**	**Perimeter**	
Satellite Dish	Point	Center of Mount	
Septic Tank	*Line*	*Perimeter*	
Sewer Clean Out	Point	Center of Lid	
Sign Face	Line	Bottom Edge	
Sign on 1 Post	Point	Center, base of post	
Sign Posts on multi post sign	Point	Center, base of post	
Signal Control Cabinet	Point	Center of Cabinet	
Signal Loop Detector	Point	Center of Detector	
Signal Head	Point	Center of Head	Point can be taken directly beneath
Signal Mast Arm	Line	Center of Mast	
Slide Scarp	**Line**	**Perimeter**	
Slope Tube	Point	Center, base	
Solar Panel	Point	Center, base	
Sound Berm, Edge	**Line**	**Toe of berm**	
Spring, Water	Point	Center	
Sprinkler Head	Point	Center of head	
Sprinkler, Pivot	Point	Center of head	
Stop Bar	Line	Center of stripe	
Stream Cross-Section	Line		90 Degrees to Thalweg
Stream Thalweg	**Line**	**Center of Thalweg**	
Stream	Line	Top of water at Thalweg	
Sump	Point	Center of Sump	
Telephone Riser	Point	Center, base	
Telephone Vault, Edge	**Line**	**Perimeter**	
Temporary Bench Mark	Point	Center or Center punch	
Terrain Breakline	**Line**		**Shots at grade breaks**
Terrain Point	*Point*		*Spot elevations*
Test Bore Hole	Point	Center of Hole	Taken at ground elevation
Tree Line	Line	Perimeter	

Table 5C – Original Ground Data Feature Mapping Characteristics

Non-Triangulated features in Plain *Triangulated features in Italic*

Breakline features in Bold ***User controllable features in Bold***

Feature	Type	Position	Notes
Tree, Deciduous or Coniferous	Collect point on all ornamental trees and collect any natural growing, unplanted, individual trees equal to, or greater than, 6 in. (15 cm) in diameter at breast height, within the project limits. If the trees are in a grove or forest, collect the tree line.		
Underground Utility Line	Line	Center of fixture	
Utility Locate Marks	Line	Center of Marks	
Utility Pothole	Point	Top center of fixture	Elevation should reflect actual elevation of the fixture
Walk, Edge of	**Line**	**Perimeter**	
Wall, sound, retaining, etc.	**Line**	**Base of Wall at face**	
Water Meter	Point	Center of Lid	
Water Pipe, Exposed	Line	Top, Center of Pipe	
Water Pump	Point	Center of pump	
Water Stand Pipe	Point	Center, base of pipe	
Water Valve	Point	Center of lid	
Water, Edge of	**Line**	**Perimeter**	
Well, water	Point	Center, base of well	
Wetland, Edge	Line	Perimeter	
Stripe: No Passing	***Line***	***between stripe***	***Typically "Double Yellow"***
Stripe Skip No Pass	***Line***	***Center of Skip stripe***	***Left or Right depends on direction shot***
Stripe: Skip or Solid	***Line***	***Center of stripe***	***All skip & solid lines the same except feature code***
Yard Light	Point	Center of light	

5.437 Original Ground Basemap

Once the data is collected, show the features on a basemap. Follow these guidelines and see Subsection 5.61 "Original Ground" for further information on basemaps.

- Display asymmetrical lines in the proper orientation.
- Orient point symbols as appropriate.
- Label features that do not have unique symbols.

5.438 Original Ground iDTM

Once the data is collected, create an intelligent DTM as described in Topic 5.941 "Building an Intelligent Digital Terrain Model".

- Include all features in the IDTM.
- Define triangulation attributes according to ODOT standards for mass point, blearkline, boundary, and do-not-triangulate.
- Validate the shape of the original ground as depicted in the iDTM by completing a Confidence point Analysis as described in Topic 1.434 "Confidence Points" and Topic 5.943 "Original Ground Confidence Point Analysis" .

5.439 Drainage Study

Some projects need to have a drainage study completed as a part of the original ground topography survey. A drainage study is a thorough examination and documentation of existing drainage features and their function. Coordinate with the hydraulics engineer or the project leader to determine the need for and extent of a drainage study.

The study does not typically include culverts under the roadway that are not connected at either end. Similar information may be needed for culverts, but this is not generally thought of as part of the drainage study. A drainage study does include information on all manholes, catch basins, inlet structures, junction boxes, and pipes that are part of a system with the role of routing rainwater runoff from the ground surface to a functional discharge location.

Typically, any drainage system planned for removal, replacement, or abandonment will not be the subject of a drainage study. In contrast, any system planned for revision, expansion, or as the discharge for a new system will be candidates for a drainage study. A study may possibly be performed on a system for which no modification are planned in the case where the capacity of the system is in question or if modifications planned on the surface of the ground are expected to increase the runoff into the system.

A functional discharge location is the point where the drainage system empties into a much larger flow such that the capacity is no longer restricted. Likely functional discharge locations would be into a body of water such as a ditch, creek, lake, or river. In some cases, the functional discharge location may be at a merger with significantly larger drainage system where the runoff volume in the subject system becomes trivial in the larger system. For example, an 18-inch pipe discharging into a 96-inch pipe will have minimal impact on the function of the larger pipe.

The study typically includes performing the following activities in the field.

CAUTION: Aspects of the drainage study may subject persons to hazards not common to survey tasks. Potential risks include vertical falls, working over water, and confined space entry.

- Measure and record elevations at every flow transition and access point.
  - Inflow and outflow end of every pipe
  - Rim and flow line elevations, orientation and configuration of every manhole

  - Grate and flow line elevations, size and configuration of grate of every catch basin and inlet

- ♦ Create schematic of pipes connecting drainage structures.
  - Determine incoming route and size of any drainage facility entering into the project.
  - Determine connectivity, size, gradient, and condition of pipes.
  - Determine the eventual discharge location back to the ground surface including discharge situation (river, creek, field, etc.) with the route, size or capacity, and mechanism of travel to the discharge.
- ♦ Determination of flow routes will require varying levels of complexity. The process fundamentally requires introducing an agent at one end of a pipe and investigating where that agent emerges. Below are some common agents or tools of different sophistication.
  - Ambient light, flashlights, strobes, and sunlight off a mirror
  - Noise generated by portable air horns, battery powered piezo alarm, or pounding on grates and covers with a hammer
  - Biodegradable dye or foam introduced into the flow of water at the uphill end
  - Operation of a sewer inspection camera

5.44 Construction As-Built Maps

5.441 Construction Mapping Objectives

In a typical construction project, there are at least three reasons for topographic data collection. The methodology is similar with the three methods aside from the timing and level of effort. All three depend on an accurate and verified Original Ground Survey:

- ♦ Final Payment Re-Measure Survey – A Final Payment Re-Measure Survey is identical in essential details to the original ground survey. This survey determines payment quantities to the construction contractor at the conclusion of the contract. In addition, a topographical survey may determine quantities for payment of any feature paid by physical measurement, whether by length, area, or volume.
- ♦ Progress Payment Re-Measure Survey – A Progress Payment Re-Measure Survey is similar to the Final Payment Re-Measure Survey. This survey determines payment quantities to the construction contractor at one or more intervals in the progress of the project. The quantities are measured for progress estimates only, and do not control ultimate payment values therefore, the survey can be less detailed. The determination of level of effort is the responsibility of the construction project manager for the project. Payment quantities may be for items paid by length, area, or volume.
- ♦ As-Constructed Survey – The distinguishing factor of the As-Constructed Survey is that it shows significant detail of each feature as it was constructed. Features that are underground or otherwise not easily accessible are mapped and modeled during the construction process before access is compromised.

5.442 Construction Mapping Attribute Characteristics

Use the same attributes and features as in an original ground survey.

5.45 Property Boundary

Topographic data may or may not be a part of a boundary or right-of-way survey.

5.451 Property Boundary Topographic Data Objectives

In a typical boundary related project or right of way survey, there are at least three reasons for collection of topographic data: Evidence of occupation affecting potential ownership matters

- ♦ Evaluation of possible encroachments
- ♦ Contextual information on map products

5.452 Property Boundary Topographic Data Attribute Characteristics

Use the same attributes and features in an original ground survey

5.5 Monuments and Markers

There are no specific monument requirements for the collection of topographic features. Establish any control point in conformance with Chapters 1 and 3.

5.6 Products and Deliverables

This Section contains requirements for products and deliverables associated with topographic survey data collection.

5.61 Original Ground

5.611 Basemap

In depicting original ground, the primary deliverable is and has been a basemap. An original ground basemap consists of the following:

- ♦ A Computer Aided Design graphics file groomed according to the ODOT Computer Aided Design Drafting Standards.
    - Orient directional symbols consistently with the represented feature.
    - Annotate on the CADD, associated DTM file, or other suitable format such information as:
        - ▪ Size, material, and legend of signs.
        - ▪ Ownership and identification numbers from utility poles and risers.
- ♦ A digital terrain model
    - In the form of a Topological Triangle Network file
    - Contains all the attributes including those that are beyond what is necessary to create a Triangle Irregular Network file
    - Includes all the features including those that are not a part of a pure Triangle Irregular Network
    - Contains all the features and attributes of each item mapped
- ♦ All in the version of Bentley Systems in use at ODOT at the time the work begun.

The following defines a basemap independent of technology:

A basemap is a coordinate correct, three-dimensional representation of topographic features (natural and man-made), project control (if desired), location of underground utilities, as-built drawings, and drainage studies as they exist in the field. A basemap also contains supporting information about topographic features. Computer aided design graphics for the basemap are dictated by the current ODOT Menu Standards, Contract Plans Development Guide and this document. Currently, “ODOT Basemaps Standards” dictate that basemaps must be “stand-alone”. A stand-alone basemap must contain all the necessary information without having to refer elsewhere for that information.

Adhere to the following principals when developing a basemap.

- ♦ These standards shall not be dependent on the source of the data. It should not be necessary to know the source of the data to determine the accuracy or completeness of the data – all the data should be collected to meet the same minimum level of precision. Choose the correct tool(s) to deliver the required level of precision.

- Contourable point and line features have valid northing, easting, and elevation positions that are used to create a digital terrain model. These features accurately represent the surface at that point. The purpose of a digital terrain model is to create an accurate representation of any given surface.
- Display all basemap features according to the drafting standards as portrayed in the ODOT Menu.
- When an unusual situation is encountered in the field, collect the data in some logical manner and note any unique qualities of the feature and/or collection method.
- Collecting more data than is required is not cost effective. It is vitally important that surveyors be aware of the project scope and/or be in direct communication with the designer or customer.

5.612 Confidence Point Analysis Report

Provide a confidence analysis with passing results. Provide the report based on the analysis described under the Topic of “Confidence Point Test” in Subsection 5.95 “Confidence Point Analysis”.

5.62 Construction

Topographic surveying in a construction environment provides the basis for payment for a certain quantity of a contract work item at a bid price. To accomplish this, develop a payment document from the survey data. Develop the payment document in conformance with the direction from the contract administrator. This document becomes a part of the contract record.

5.63 Property Boundary

When collecting data exclusively for boundary work, the surveyor in responsible charge of the boundary work dictates the deliverable. However, the delivery of mapping data to the boundary surveyor is coincidental to the design deliverable. No additional product is typically necessary.

5.64 Geospatial Positioning

This manual does not define standard deliverables for Asset Management and GIS-type products. Negotiate deliverables with the asset manager.

5.7 Documentation

(For Future Development)

5.8 References

(For Future Development)

5.9 Specific Activities &Tasks

The Roadway Design Unit and other supporting units for design of a project determine the design needs. Contact the Region Tech Center Survey, Roadway, and other Units for help in determining needs for a project as applicable for the project.

Collect the existing topographic features and create an Intelligent Digital Terrain Model as discussed in Subsection 5.95 "Data Collection".

Collect topographic data of man-made and/or natural features using a variety of ODOT-approved methods. These methods include but are not limited to collecting the data using:

- Terrestrial (total station)
- Global Navigation Satellite System
- 3-D Laser Scanning
- Station and offset
- By mile point

Conform all data collected to file naming and coding formats that are in current use by ODOT. ODOT will provide examples of the current formats. Data collection methods and new survey technology not specifically mentioned here must have prior approval by ODOT's Geometronics Unit before use.

5.91 Roadside Inventory

Collect all data in the roadside inventory as negotiated with the survey client. A Roadside Inventory is typically performed for pavement preservation projects. Full topographic and Intelligent Digital Terrain Model projects usually need only the sign inventory sheet completed. Conform the roadside inventory to ODOT standards as defined in the highway design manual.

5.92 Data Collection

5.921 Overview

Contact Region Tech Center Survey and Roadway Units for the project layout of design.

Collect pertinent topographic features, man-made or natural, within the limits of the project described in the survey scope documents. Associate three-dimensional coordinates with the tied topographic features. Collect these tied features using ODOT coding formats and accepted methods (terrestrial, Global Navigation Satellite Systems, and 3-D Laser Scanning).

- Deliverables include:
  - The original notes taken in the field and one electronic copy, in Adobe Portable Document Format (PDF), of the original field notes.

- Coordinate file containing the following information:
  - Point number
  - Northing
  - Easting
  - Elevation
  - Alpha feature code
- A Bentley MicroStation DGN file containing all the tied topographic features and conforming to ODOT conventions.
- An Intelligent Digital Terrain Model containing all the tied topographic features and conforming to ODOT conventions.

5.922 Terrain

Locate and map the terrain features. Collect the topographical data to create points and break lines in adequate quantity and in proper placement to represent accurately the surface of the ground.

5.923 Utilities

Locate and map the project utilities for all safety, modernization, bridge and signal projects to provide surface evidence of features above and below ground for inclusion in the Intelligent Digital Terrain Model or other mapping.

♦ Field Utility Survey

Collect utility information beyond the ends of the topographic survey area such that direction of path and distance to next connected feature is included.

Record in the field notes the utility ownership when describing the line data points. Record all visible utility identifications in the field notes. Such numbers shown on power and/or telephone poles, vault tags, telephone pedestals (aka risers), cabinets, meters, fences or screened enclosures for gas regulators, and sanitary sewer pump stations for example.

Measure and record all utility facility structures (e.g. concrete pads, top slab of vaults, pump station housing, barrier screens or fenced enclosures). Make a request to the utility owner to pull the cover whenever a manhole is found locked or bolted.

Tie in the field all utility features including, but not limited to underground and overhead power lines, underground and overhead telephone lines, poles, risers, underground and overhead cable television lines, underground gas lines and underground water lines. Measure vertically the lowest wires that cross street or road intersections and calculate a true elevation of those wires.

- Utility Mapping

  Place all surveyed utility facilities, both overhead and underground, in the mapping file with the standard ODOT symbology controlled by current ODOT Computer Aided Design configuration files.

  Locate and separately tie all footings for power transmission poles and towers. Make ties to adjacent towers. Draft utility features in accord with current ODOT drafting standards.

- Deliverables include:
  - The original notes taken in the field and one electronic copy, in Adobe Portable Document Format (PDF), of the original field notes.
  - Coordinate file containing the following information:
    - Point number
    - Northing
    - Easting
    - Elevation
    - Alpha feature code
  - An Intelligent Digital Terrain Model or a basemap containing all the tied utility features and conforming to Agencies file naming conventions.

5.924 Hydraulics

Consult with the Region Tech Center Hydraulics' Unit Designer to determine the need and extent of the Hydraulic study.

For all bridge projects and for some large culvert projects collect all the hydraulic, bridge and culvert information requested by hydraulic engineer in accordance with the ODOT Hydraulics Manual on streams and rivers that pass under or are parallel to any highways in the area.

Refer to the Hydraulics manual for products and deliverables.

5.925 Drainage

Consult with the Roadway Designer to determine the need and extent of the drainage study.

Accomplish a Drainage Study for all modernization, safety, and signal projects.

Tie all drainage features that are in the ODOT Hydraulics Manual. Provide sketches of drainage facilities. Show orientation of pipes and manhole cone; elevation of manhole lid, and inverts.

- Deliverables include:
  - The original notes taken in the field and one electronic copy, in Adobe Portable Document Format (PDF), of the original field notes.

- Coordinate file containing the following information:
  - Point number
  - Northing
  - Easting
  - Elevation
  - Alpha feature code
- A basemap or an Intelligent Digital Terrain Model containing all the tied drainage features and conforming to Agencies file naming conventions.

5.926 Environment & Archaeology

Locate any environmental and/or archaeology sites to the extent and need determined by the Region Environmental Coordinator. Survey Environmental & Archaeological Features for all modernization, intersection safety, and signal projects.

- ♦ Deliverables:
  - The original notes taken in the field and one electronic copy of the original field notes, in Adobe Portable Document Format (PDF).
  - Coordinate file containing the following information: Point number, Northing, Easting, Elevation, and alpha feature code.
  - A MicroStation design file (*.dgn) or Intelligent Digital Terrain Model containing all the tied drainage features and conforming to Agencies file naming conventions.

5.93 Detailed Basemap

Take all applicable topographic data collected in Utilities Features, Hydraulics Features, Drainage Features, Environmental & Archaeological Features, and create a detailed basemap file. A detailed basemap has all features drafted to ODOT Criteria. ODOT will provide this standard.

- ♦ Deliverables:
  - Detailed Base Map in MicroStation design file (*.dgn)

5.94 Intelligent Digital Terrain Model

The Bentley systems engineering software that is currently the standard tool set in ODOT creates a digital terrain model that Bentley refers to as “intelligent”. At a very simplistic level, “Intelligent” indicates that the model contains more types of data than basic terrain data necessary to construct a triangulated irregular network and that it manages that data in support of other functions.

Within ODOT, reference to an Intelligent DTM (also referred to as an Intelligent Digital Terrain Model) carries even more meaning. Create an Intelligent Digital Terrain Model within the Bentley file format, but also include within that file adequate information to benefit from the capabilities of the format.

- Include within the Intelligent Digital Terrain Model file all mapped features including those features that do not influence the shape of the triangulated irregular network.
- Include settings to control how InRoads should treat each item during the creation of the triangulated irregular network.
- Include a feature name that can be associated with symbology MicroStation.
- Include in the provided fields thorough descriptive text such as point identifier, tree dimensions, pipe size, pole numbers, and so forth.

A properly created intelligent digital terrain model contains all of the information collected in the field and contained within the field data-collection file and the accompanying field notes.

5.941 Building an Intelligent Digital Terrain Model

Create a three (3) dimensional intelligent digital terrain surface using all of the topographical data collected within the mapping area.

Create the Intelligent Digital Terrain Model that meets ODOT criteria for surface triangulation. Collect confidence points in the field and generate a confidence point report. Meet ODOT Criteria for the topographical data and confidence points. Generate 0.2-ft. (5-cm) minor contours and 1-ft. (25-cm) major contours throughout the Intelligent Digital Terrain Model for a QC analysis of the surface.

Limit Intelligent Digital Terrain Model shots to a 50-foot (20-meter) spacing to show the terrain. Gather topographic data using techniques consistent with the construction of an Intelligent Digital Terrain Model. Use a combination of survey data at break lines, features, and spot locations to develop the Intelligent Digital Terrain Model for use by ODOT for design. Leave any utility ties out of the model.

5.942 Deliverables:

- InRoads DTM file that is compatible with ODOT's current version of InRoads
- Confidence Point report in Adobe Portable Document Format (PDF)

5.943 Original Ground Confidence Point Analysis

Conduct a confidence point analysis as described in Topic 1.434 "Confidence Points" and supplemented in this Subsection

(A) Observation Equipment

Use survey grade theodolite to observe Confidence Points.

(B) Confidence Point Density

Locate Confidence Points at a density sufficient to validate the surface. Confidence Point locations are:

- At a density of:
  - Roughly ten per total station location as used in collecting Digital Terrain Modeling data.
  - Ten Confidence Points for each roughly 1500-ft. (500-m) strip.
  - Ten Confidence Points within any roughly 800-ft. (250-m) radius.
- Randomly selected without regard for the location of Digital Terrain Model points or triangles.
- Evenly distributed over the entire Digital Terrain Model area to be validated.
- Proportionately distributed between Confidence Point types as applicable.

(C) Analysis Procedure

Conduct a Confidence Point analysis using the current ODOT analysis tool or approved alternate. Generate a report showing the test results that include a status for each point indicating whether the Digital Terrain Model is within tolerance at that location, outside of tolerance, or exceeds that value by three-times. Plot the locations of Confidence Point by type and result to support visual analysis of the results.

Investigate all Confidence Points that exceed the tolerance. Examine the area surrounding each failing Confidence Point and try to resolve the failure even if it passes the “three-times” test. Employ techniques such as drawing tight contours, rotating the view, and conducting a drive-through or fly-through. Overlay the feature mapping with the triangles and look for features such as ditch bottoms, edges of pavement, and roadway crowns that are not properly represented by the triangles. Try to identify triangulation errors such as triangles crossing breaks in grade or extending across areas not intended for modeling.

There is a multitude of causes for exceeding the tolerance. Table 5D "Confidence Point Errors" below shows some of them along with potential means to locate and identify a standard remedy.

Problem	Identification	Remedy
A blunder in the Confidence Point position	Field Verification	Re-observe Confidence point
A blunder in the data used to create the DTM	Field Verification	Re-observe DTM data in the vicinity
Instrument or backsight blunder	As the first two above, but the error will impact all observations relying on that data	
A blunder in the triangulation process (for example, a breakline crossing a ditch)	Contours and spikes	Modify constraints and re-triangulate DTM
Inappropriately placed Confidence Point (for example, on bridge not modelled)	Viewed in map view	Delete or ignore Confidence Point and document with reasoning in analysis report

Table 5D - Confidence Point Errors

Look for patterns such as a distinct area with increased density of failures or repeating pockets of failing points. Look for any systematic error that these may be suggesting.

(D) Original Ground Confidence Point Tolerances Values

Type	Surface Represented	Feet	Millimeters
Surfaced	Paved or Concrete Surface	+/- 0.10	+/- 30
Graded	Machine Graded & Compacted Surface	+/- 0.3	+/- 100
Natural	Irregular Natural Ground	+/- 0.6	+/- 200
Rugged	Extremely Rugged & Rock Surface	+/- 1.5	+/- 500

Table 5E – Original Ground Confidence Point Tolerances

(E) Original Ground Confidence Point Acceptance Criteria

- Two-thirds of all errors fall within the Confidence Point error tolerances.
- All of the errors fall within three times said tolerances.

(F) Failing Results

Remedy or justify every three-times failure and accept up to one-third of the Confidence Points exceeding the respective tolerance values. Each Digital Terrain Model used for detail design or for earthwork payment must have a passing Confidence Point analysis.

(G) Confidence Point Documentation

Keep a record of all original Confidence Point observations. a well as a record of the final Confidence Point analysis report showing the test results. Include an explanation for accepting three-times failures.

(H) Confidence Point Deliverables

Provide the following information for a topographic mapping survey:

- Intelligent Digital Terrain Model (current version of Bentley InRoads .dtm file) containing all the tied topographic features.
- Confidence Point report on the Intelligent Digital Terrain Model in Adobe Portable Document Format (PDF).
- Original notes taken in the field and one electronic copy in Adobe Portable Document Format (PDF), of the original field notes.
- Coordinate file containing the following information: Point number, Northing, Easting, Elevation.

Indexes

Topical Index

Topic **Page**

Accuracy...9, 18
  Claims...9
  Requirements...13, 14, 88-89
  Table of...43, 72, 87

Angle measurements ...
  Sets ...45
  Non-conventional sequences...46
  Units ...9, 22

Application (of the ODOT Survey Policy and Procedure Manual)...1

As Built ...3, 92, 100

Authority ...1

Backsight/Elevation Checks...19

Baseline Check...15

Basemap ...92, 98, 103, 110

Boundary Surveys ...71
  Boundary Option...80
  Descriptions and Drawings...2, 71, 72, 74, 76
  Recovery, Retracement and Resolution ...71, 72, 76, 79
  Maps, filing ...72, 79, 80, 81, 82
  Monumentation ...3, 24, 71, 72, 76, 79-84
  Monument Ties...33, 74, 76, 79
  Network Option...59, 80
  Other properties (not highways, stockpiles, or quarries)...82
  Quarries and Stockpiles...81-82
  References ...60, 80-82
  Retracement and Resolution...2, 72, 79
  Stamping and Sealing...2, 76
  Survey Filing Map Standards...72, 76, 79
  Topography ...2, 57, 85-114

Topic **Page**

Confidence Points 20, 93
- Analysis 88, 104, 111-112
- Application 21, 88
- Collection 20, 57
- Definition 20
- Errors 112-114
- Original Ground 88
- Placement 21, 92, 112
- Procedure 111-112
- Tolerance 8, 113
- Types 113

Control
- Bench Mark Resets 5-6, 64
- Constrained Adjustment 40, 41, 62, 66-67, 70
- cGPS/CORS 64
- Coordinate Systems 40
- Differential Leveling 16, 32, 41-42, 49, 59, 68-69
- Horizontal Network 32-33, 40, 43, 45, 48, 58-59, 66-67
- Level Circuit 41-42, 48, 49, 69
- OPUS 64
- Project Control 39-70
- References 60, 80-82
- RTK/RTN 20, 22-23, 91
- Three Dimensional Project Control 49
- Traverse 45, 49, 65-66
- Trigonometric Leveling 67
- Unconstrained Adjustment 66, 70
- Vertical datum 29, 40, 41-42, 49
- Vertical Network 40, 43, 49, 59, 69-70

Data
- Electronic 29 35
- Folder Structure 34
- Formats 28
- Processing 11

Datums 29, 40-43, 49

Distance measurements 21

Emergency Vehicles 6

Environmental 8

Equipment
- Terrestrial 13
- Compatible Components 13
- GNSS 14
- Manufacturer Specifications 13
- Selection 13

Topic **Page**

File
- Naming 33
- Folders 3
- Archiving 35

Forms 36

Free Station 32

Freight Mobility 6

GNSS
- Procedures 47, 56, 91
- Specifications 14, 47, 56, 91

HI Checks 20

Laws 4-8

Level of Effort 1, 12, 13

Leveling
- Equipment 13-14, 16
- Procedures 21, 41-42, 57, 59, 68-70
- Testing 16
- Trigonometric 67

Localization (Site Calibration) 22-23

Mapping Scale 9

Marks
- Control Marks 58
- Recovery 6, 71, 72, 76, 79
- Preservation 5, 11, 80
- Boundary 75, 79-83

Measurements
- Distance 21
- Angle 22
- Recovery 76

Mile Points 9

Monumentation
- Project Monumentation 3, 24, 71, 72, 76, 79-84
- Monument Ties 33, 74, 76, 79

Monuments .... See “Marks”

Notifications 5-6

Observation Sequences 19, 45-46

Point
- Numbering Convention 32

Preservation of Survey Markers 5, 11, 80

Topic **Page**

Prism
- Offset 21
- Alternate 21

Professional Land Surveyor ....
- Control of the Survey Work 10
- Oregon Registration 5, 10

Project
- Control 39
- Defined 2, 39
- Name 27
- Typical 2
- Workflow 2

Radio Transmissions 8

Records
- Field Data 29-35
- Field Notes 30-31
- File Naming 33
- Narrative 42, 62
- Point Numbering 32
- Required Information 27
- Transmittal 28

Recovery of Bench Marks 6

Redundancy 48

Right of Entry 7

Resection 32

Right of Way
- Acquisition 74
- Descriptions 2, 71, 72, 74, 76

Roadside Inventory 107

Safety 4
- Safety Manual 4
- Training 4

Scope of the Survey Policy and Procedure Manual 1

Stationing 9

Stockpile Sites
- Boundary 81

Topic	Page

Topography
As Constructed 100
Attribute Information 93-98
Basemap 87, 88, 92, 98, 103
Boundary Survey Application 101, 104
Confidence Points 111-114
Construction Application 100, 104
Traingulation attributes 94
Elevation Data 93
Features 93-98
Remeasure 100
Roadside Inventory 107
Spacing of Data 92
Types of Topography 92
Validation 93

Total Station
Procedures 21

Units of Measure 8-9

Utility Notification 7-8

Validation Procedures 19-21
Backsight/Elevation Checks 19
Confidence Points 20-21
HI Checks 20

Index of Tables and Figures

Table/Figure	Table/Figure #	Topic	Page
Standard Units	Table 1A	1.242	9
Berntsen “BP2” Marker	Figure 1B	1.51	24
Point Numbering Convention	Table 1C	1.773	32
File Naming Convention	Table 1D	1.774	33
Electronic Data Folder Structure	Figure 1E	1.775	34
Project Control Tied to Active Geodetic Control	Figure 3A	3.212	41
Project Control Tied to Passive Geodetic Control	Figure 3B	3.212	41
Accuracy of Control Points	Table 3C	3. 22	43
Sets of Angles	Table 3D	3.41	45
Summary of GNSS Static Specifications	Table 3E	3.42	46
Specifications for Double Tie points	Table 3F	3.433	50
Summary of Strategic Point Specifications	Table 3G	3.433	55
Accuracy of Boundary Points	Table 4A	4.23	70
Monuments, Guard Posts, and Line Marking Standards	Figure 4B	4.92	81
Placement of Guard Posts	Figure 4C	4.92	82
Accuracy of Topographic Points	Table 5A	5.26	85
Summary of GNSS RTK Specifications	Table 5B	4.51	89
Original Ground Data Feature Mapping Characteristics	Table 5C	5.436	91
Confidence Points Errors	Table 5D	5.953	109
Original Ground Confidence Points Tolerances	Table 5E	5.954	110

Appendices

Glossary

95% Confidence Level - A concept in statistical analysis, that quantitative expression of uncertainty wherein 95% of all samples statistically fall within the stated error, or customarily considered the area of uncertainty that includes the answer 95% of the time

ASCII file – A computer text file containing information coded according to the ASCII character set. See ASCII in Abbreviations and the definition for Text File

Automatic Level - An optical level equipped with *compensator*

Bench Mark or **Benchmark -** (see http://www.merriam-webster.com/dictionary/benchmark) and http://searchcio-midmarket.techtarget.com/definition/benchmark

Check Shot – A position measured with Real-Time Kinematic on a previously known control point for the purpose of verifying the receiver configuration and other variables in the positioning process. The term may also refer to a control point established specifically for the above purpose.

Compensator - A gravity-seeking device whose purpose is to compensate for any minor leveling inaccuracy in a survey instrument by adjusting either the line-of-sight or the resultant reading to a more correct position or value

Confidence Level - A concept in statistical analysis, the confidence level is that quantitative expression of uncertainty wherein some defined portion of all samples statistically fall, or in other words customarily considered the area of uncertainty that includes the answer a certain percentage of the time

Confidence Point Analysis - The process developed by the Oregon DOT for evaluating the suitability of a digital terrain model based on Confidence Points

Confidence Point - A random point collected arbitrarily in the field for the purpose of validating the relationship between the actual ground and a computer model of the ground

Continuous GPS Station - A continuously operating Global Positioning System station that is not a part of the National Geodetic Survey Continuously Operating Reference Station (CORS) system abbreviate cGPS to differentiate from the National Geodetic Survey CORS

Continuous Operating Reference Station - A continuously operating Global Navigation Satellite Systems station, especially one that is part of the National Geodetic Survey Continuously Operating Reference Station system abbreviate CORS

Cultural Resource - Archaeological, paleontological, and historical site or artifact

District Office - Any of the 14 (historically 16) administrative maintenance districts within ODOT They are numbered 1, 2B, 2C, 3 through 5, and 7 through 14. (2 was divided at one point into A, B, & C then A and 6 were later consolidated with adjoiners.) Each District covers a geographical portion of the state highway system. The District is functionally considered the owner of the highway and has control over matters such as access control, lane closures, and oversize loads. http://www.oregon.gov/ODOT/TD/TDATA/Pages/gis/odotmaps.aspx#ODOT_District_Maps

Dual Compensation - The characteristic of having two *compensators* or otherwise being compensated in both the longitudinal and transverse planes

Earth Centered Earth Fixed - A three-dimensional Cartesian coordinate system used for Global Navigation Satellite System positioning wherein the origin is located at the center of the Earth's mass including atmosphere and oceans, and oriented such that the z-axis exits the earth at the conventional terrestrial north pole, the x-axis passes through the equator at the prime meridian, and the y-axis forms a right-handed coordinate system with the other axes.

EDM Calibration Baseline - Any of a series of precisely measured groups of monuments established by the National Geodetic Survey or possibly other entities for the express purpose of testing distance-measuring equipment against a variety of know distances. National Geodetic Survey EDM calibration baselines can be located from information at http://www.ngs.noaa.gov/CBLINES/calibration.html.

Electronically Collected Data - Numeric measurements or descriptive information recorded through an electronic or electro-mechanical devise and written directly to computer memory without human interpretation, entry, or transcription.

English units - A somewhat erroneous label for traditional measurement units in use in the United States which are more correctly and properly referred to as US customary units

Hand Written Field Notes - Original documentation taken in the field at the time and place of the observation that includes all measurements plus supplemental data such as descriptive information, images, witness feature details, and so forth

Fly Line - A series of observations beginning at a known or assumed position and from which new positions are established without the assurance of closing to known positions and evaluating for errors. A fly line is not considered a good survey practice.

Non-conventional sequences - A procedure for expediting the process of tying multiple survey points with sets of angles by allowing observations in the most convenient or expedient sequence as determined in the field rather than following a predetermined observation sequence. A non-conventional sequences typically consists of collecting all observations to a given point at once before moving to the next point as opposed to revisiting each point for each sweep of the set (also see Topic 3.413 "Sweeping Multiple Sets of Points")

Global Navigation Satellite Systems - A title adopted by the United Nations referring to the combined systems including the United States operated NAVSTAR system commonly referred to as "GPS"

Global Positioning System - The full verbiage for the common term "GPS", it typically refers to NAVSTAR, the satellite-based positioning and navigation system developed by the United States Department of Defense

GNSS Base Station - The Global Navigation Satellite System receiver occupying a now position and providing corrector data for a receiver occupying unknown positions

Hard Conversion - The conversion of a quantity from one unit or system of units to another simply by applying a factor. See Soft Conversion for an explanation of the difference.

Horizontal Axis Index - (To Be Developed)

Independent Occupation - Establishment on or over a survey marker of a survey measurement system where any setup errors from the previous occupation are not systematically carried forward to the following occupation. An independent occupation requires completely reestablishing the position of the survey system following one set of observations and before commencing with a subsequent set of observations. All elements of establishing the position of the equipment must be disrupted from any previous occupational position and reestablished over the point afresh including planting tripod feet, plumbing the device by the leveling indicator, centering the plummeting device over point, measuring the height above the marker, and pointing the device. Forced Centering is prohibited when an Independent Occupation is called for.

Intelligent Digital Terrain Model - A Bentley digital terrain model that incorporates features such as centerlines, pavement edges or any topological feature into the surface model.

Jobsite Hazard Assessment - A specific inspection of a worksite to identify potential job hazards or the documentation of such an inspection

Key Number - STIP projects are assigned a unique identification number early in the project development process. This number is properly called the project Key Number.

Limits Indicator - Any device or mechanism whether physical or electronic which is intended to indicate acceptable limits for any value or to provide relative guidance in determining optimal settings. Examples are etch marks on glass leveling vials, Out-of-Acceptable-Range alarms on electronics instruments, or mechanical stops that prevent movement beyond a certain point.

Linear Point - Any control point along a linear control survey such as a traverse or level circuit where any allowable error is evenly distributed along the linear survey as contrasted with a network point which is associated with more generous redundancy that supports more comprehensive error identification and more robust positional accuracy analysis.

Local Accuracy – The uncertainty of the coordinates of a point relative to other control points in the project. From http://www.ngs.noaa.gov/PUBS_LIB/NGS-58.html "The local accuracy of a control point is a value expressed in centimeters that represents the uncertainty in the coordinates of the control point relative to the coordinates of the other directly connected, adjacent control points at the 95-percent confidence level. The reported local accuracy is an approximate average of the individual local accuracy values between this control point and other observed control points used to establish the coordinates of the control point."

Localization - Use of software/firmware to performs a rotation, translation, and scale transformation from the WGS 84 datum to a local coordinate system as defined by physical monuments.

Metric System of Measures - The system of measures used throughout the world based on the meter and also sometimes referred to as the International System or SI

Monument - Any object whether natural or manmade which has been either called for or placed with the intent of perpetuating a position, location, or elevation

Monumentation - The act of placing one or more Monuments to delineate or reference locations of significance such as a property boundary or roadway centerline

Multipath - Interference caused by reflected Global Navigation Satellite System signals arriving at the receiver, typically as a result of nearby structures or reflective surfaces. The reflected signal is delayed causing an apparent longer distance to the satellite. Usually the noise effect on the Real Time positioning is a few centimeters unless it causes an incorrect ambiguity resolution, which might result in decimeters of error.

Natural Resource - Biological or environmental sites or entities, particularly those legally protected such as listed species and habitat.

Navigation System Using Timing And Ranging - The full formal name for the United States satellite navigation system, typically shortened to "NAVSTAR" or simply replaced with the common term "GPS"

Nominal - ": 3

a: existing or being something in name or form only <nominal head of his party>

b: of, being, or **relating to a designated** or theoretical **size** that may vary from the actual : approximate <the pipe's nominal size>"

http://www.merriam-webster.com/dictionary/nominal

Observables - Any condition that can be observed (measured, evaluated, determined) in the process of collecting data, typically applied to Global Navigation Satellite System observations and the many qualities of the signal that can be evaluated for benefit

ODOT Chief of Surveys - The Registered Professional Land Surveyor with the responsibility for establishing and managing policy and procedures regarding ODOT survey activity, as of March 2014 Ron Singh.

ODOT - The Oregon Department of Transportation except where specifically stated otherwise or where clearly indicated otherwise by the context

Oregon Real-Time GPS Network - See www.TheORGN.net

Oregon Revised Statutes - the codified body of statutory law governing the U.S. state of Oregon (http://en.wikipedia.org/wiki/Oregon_Revised_Statutes)

Oregon Transportation Commission - A five-member group, the highest authority within the Oregon Department of Transportation (ODOT), each member appointed by the Governor of Oregon, and who together as a commission provide policy and planning direction for the agency

Peg Test - See Two-Peg Test

Personal Protective Equipment - Any item intended for use by a person to protect themselves from harm, specifically those items addressed by safety regulations.

Project Manager - That person responsible for managing a project under contract, administering the contract, and supervising personnel involved in quality control, documentation, and payment. References to the Project Manager may include the Project Manager's representative such as a project inspector when acting on behalf of the Project Manager. For the purposes of the ODOT Survey Policy and Procedure Manual, the Project Manager may be an ODOT employee, a local agency employee, a contractor or consultant, or any agent of ODOT charged with administration of the construction contract.

Real-Time Kinematic - The process and equipment for establishing differential Global Navigation Satellite System corrections immediately while occupying a point

Real-Time Network - A network of base stations and associated equipment and procedures to enable improved real-time differential Global Navigation Satellite System corrections based on multiple base stations

Redundant (observation, measurement, or other such data) – "Duplicated or added as a precaution against failure or error" (www.thefreedictionary.com), any measurement or observed data is redundant if it is beyond the minimum required to calculate a position on a point. Redundant data provides a basis for detecting errors, improving precision, validating a position, quantifying uncertainty, and distributing an acceptable magnitude of inaccuracy.

Region - Where the context supports or when used as proper noun, Region refers to one of the five numbered administrative Region offices with jurisdiction over a geographical portion of the Oregon state highway system. The Region typically handles many functions such as engineering, geology, environmental issues, as well as surveying. The Region office numbers and locations are as follows: 1 = Portland, 2 = Salem, 3 = Roseburg, 4 = Bend, and 5 = La Grande. The link below provides a map of the Regions
http://www.oregon.gov/ODOT/TD/TDATA/gis/docs/REGIONMAPS/RegionMap.pdf

Responsible Charge - Defined in Oregon Revised Statutes 672.002(9)

Reversion - The process of checking a piece of equipment by reversing a measurement and comparing the results such as "pegging" a level, "doubling" an angle, or any similar process. See Page 179 of David & Foote Sixth Edition

Set (of angles and/or distances) - A reading to each of the foresight and backsight on both horizontal and vertical circles in each face of the total station and typically includes a distance in each face.

Site Calibration - See Localization

Soft Conversion - The process of determining by policy an appropriate equivalent value for a specific item in another unit or system of units rather than simply applying a factor, which may result in unwieldy or otherwise undesirable values. For example, the hard (mathematical) conversion of a 12-foot travel lane is 3.6576 meters. Rounding to various precisions results in 3.658, 3.66, and 3.7 meters. By contrast, ODOT could make on a policy decision to soft-converting standard lane widths to 3.6 meters, 3.5 meters, or 4 meters.

Standard Deviation - A concept in statistical analysis quantifying the spread of results in a sample of data sometimes used to express the accuracy of measurements or measurement equipment and representing about 67% confidence level (see 95% confidence level)

Statewide Transportation Improvement Plan (STIP) - The document officially adopted by the Oregon Transportation Commission and which guides ODOT in allocating resources toward particular transportation improvement projects

Strategic Point - A “Strategic Point” is a point set for the purpose of providing an instrument location for mapping, terrain modeling, or other non-control work.

Temporary Bench Mark - Often abbreviated TBM a Temporary Bench Mark is a survey mark established for the purposes of providing a local reference elevation for a limited time period, typically the duration of a project. See also “Vertical Network Point”.

Terrestrial (Equipment or Methods) - For the purposes of the ODOT Survey Policy and Procedure Manual, the term refers to any survey-grade equipment designed for or any survey-grade procedure whereby an individual or team makes discrete measurements to a point in space through observing any combination of vertical, horizontal, or slope distance or the horizontal angle or horizontal plate reading or the vertical angle or zenith angle. Terrestrial Methods includes differential leveling. Use of technological devices to measure any or all of those components does not intrinsically remove it from the realm of Terrestrial Methods. Common tools for such observations are survey chains, steel or invar tape measures, differential leveling equipment, mechanical transits, optical reading theodolites, electronic theodolites, EDMs, and total stations. The term herein distinguishes Terrestrial Methods from space-based or aerial equipment such as Global Navigation Satellite Systems, airborne LiDAR, and aerial photogrammetry and from other indiscriminate collection of data such as 3-D laser scanning and terrestrial photogrammetry, either mobile or static. Terrestrial also does not include rudimentary tools such as compasses and cloth tape measures.

Text File - A file using ASCII characters without any formatting such as bold, underline, italics, margin settings, or other qualities other than the characters themselves. It may include such non-displaying/non-printing control characters as tab and new-line, but these will be interpreted according to the viewing software and settings.

Two-Peg Test - Any of several variations of a procedure for verifying the accuracy of an optical or digital level. The test quantifies the error in the line-of-sight by exaggerating and observing any variation from perpendicular to gravity. A procedure for conducting the Two-Peg Test can be found in any comprehensive survey text such as *Davis and Foote*. It is also included in the user manual for some levels, particularly those equipped with programs or automated procedures for performing the test.

United States Customary Units - Traditional measurement units in use in the United States (Inch, foot, mile) which are based on historical units developed in England and sometimes somewhat erroneously referred to as English units, either description mainly applied to distinguish them from SI (the metric system). United States Code Title 15 Chapter 6 on "Weights, Measures, and Standard Time" variably refers to them as "customary measurement units", "customary weights and measures", "customary units", and "traditional systems of weights and measures". The system is never formally named, never capitalized within, and never defined. The foot and inch are both used repeatedly to define other units such as wire gauges and barrel sizes. Chapter 6 of Title 15 never refers to them as "English" units.

Vertical Index - The graduation system or scale for determining the location around the vertical circle of a theodolite telescope or the zero point of that scale

Vertical Network Point - A survey control point with a known and stable elevation similar to a TBM but with network redundancy and adjusted by vertical least squares

Zero Baseline - A specific test for proper function of Global Navigation Satellite Systems receiver systems

Acronyms and Abbreviations

ASCII - American Standard Code for Information Interchange

BPA – Bonneville Power Administration

cm - centimeter in the metric system

CAD - Computer Aided Design

cGPS - Continuous GPS Station (Use of this acronym has evolved in the United States to refer to continuously operating GPS stations that are not part of the National Geodetic Survey national Continuously Operating Reference Stations)

CORS - Continuously Operating Reference Station (Use of this acronym in the United States has evolved to refer only to continuously operating GPS stations that are part of the NGS's National CORS.)

DTM - Digital Terrain Model

dm - decimeter in the metric system

EDM - Electronic Distance Meter

ECEF - Earth Centered Earth Fixed

FGCC - Federal Geodetic Control Committee

ft. - foot in US customary units

GNSS - Global Navigation Satellite Systems

GPS - Global Positioning System

iDTM - Intelligent Digital Terrain Model

in. - Inch in US customary units

JHA - Jobsite Hazard Assessment

km – kilometer in the metric system

m - meter in the metric system

mi. - Mile in US customary units

mm - millimeter in the metric system

N/A or **n/a -** Not applicable or Not available

NAD 83 – North American Datum of 1983

NAVD 83 – North American Vertical Datum of 1988

NAVSTAR - Navigation Satellite Timing And Ranging system (The full formal name for the United States global satellite navigation system that is commonly referred to as GPS.)

NGS - National Geodetic Survey

NSRS - National Spatial Reference System

ORGN - Oregon Real-Time GPS Network (www.TheORGN.net)

OrOSHA - Oregon Occupational Safety and Health Division (the state version of OSHA)

ORS - Oregon Revised Statutes

OSHA - United States Occupational Safety and Health Administration

OTC - Oregon Transportation Commission

PPE - Personal Protective Equipment

PPK - Post-Processed Kinematic

ppm - parts per million

RTK - Real-Time Kinematic

RTN - Real-Time Network

SI - Metric System of Measures (from French: Système international)

STIP - Statewide Transportation Improvement Plan

TBM - Temporary Bench Mark

USACE - United States Army Corps of Engineers

USC&GS - United States Coast and Geodetic Survey (a forerunner of the current National Geodetic Survey)

USGS - United States Geological Survey

WGS84 - World Geodetic System 1984

Reference Material

ODOT Forms

Project Notification to County Surveyors Form 734-2298
http://www.odot.state.or.us/forms/odot/highway734/2298.pdf

ODOT Survey mark Report Form 734-2802:
http://www.odot.state.or.us/forms/odot/highway734/2802fil_survey-mark.pdf

ODOT Publications

Survey Safety Manual
http://www.oregon.gov/ODOT/HWY/GEOMETRONICS/docs/survey_safety_manual_07-09.pdf

Right of Way Engineering Manual
http://www.oregon.gov/ODOT/HWY/GEOMETRONICS/ROW_Eng/RW_Manual/RW_Eng_Manual.pdf

Monumentation Standards
http://www.oregon.gov/ODOT/HWY/GEOMETRONICS/docs/odot_rw_monumentation_policy.pdf

History of State Highways in Oregon
ftp://ftp.odot.state.or.us/web_docs/HSHO.pdf

Highway Design Manual
http://transnet.odot.state.or.us/hwy/OPLStndSpecs/Shared%20Documents/HDM%20Re-Write%202011/2012%20HDM%20-%20FINAL/PDF/2012%20Chapter%2011%20Roadside%20Inventory,%20Design%20Process,%20Survey%20and%20Right-of-Way.pdf

ODOT Construction Manual
http://www.oregon.gov/ODOT/HWY/CONSTRUCTION/CM.shtml

External Publications

Oregon Utility Notification Center (OUNC) current Standards Manual
http://digsafelyoregon.com/wp-content/uploads/public/Standards-Manual-July-2014.pdf

National Geodetic Survey Calibration Baselines
http://www.ngs.noaa.gov/CBLINES/calibration.html

FGCC Standards and Specification for Geodetic Control Networks
http://www.ngs.noaa.gov/FGCS/tech_pub/1984-stds-specs-geodetic-control-networks.pdf

National Geodetic Survey User Guidelines for Single Base Real Time GNSS Positioning
http://www.ngs.noaa.gov/PUBS_LIB/NGSRealTimeUserGuidelines.v1.1.pdf

NGS Bench Mark Reset Procedures
http://www.ngs.noaa.gov/PUBS_LIB/Benchmark_4_1_2011.pdf

National Geodetic Survey Geodetic Leveling
http://www.ngs.noaa.gov/PUBS_LIB/Geodeticleveling_nos_3.pdf

FGCS Specifications and Procedures to Incorporate Electronic Digital/Bar Code Leveling Systems
http://www.ngs.noaa.gov/FGCS/tech_pub/Fgcsvert.v41.specs.pdf

Guidelines for Establishing GPS-Derived Ellipsoid Heights
http://www.ngs.noaa.gov/PUBS_LIB/NGS-58.html

Other Resources

National Geodetic Survey Integrated Database
http://www.ngs.noaa.gov/cgi-bin/datasheet.prl

Oregon Survey Laws & Administrative Rules
http://www.oregon.gov/ODOT/HWY/GEOMETRONICS/pages/survey_law.aspx

Checklists

Project Kickoff

- Project Prospectus
- Approved Expenditure Account or Fully executed Contract

Location Completion & Handoff

- Transmittal Letter
- Finish Products - Basemap, Terrain Model, Control and Recovery Surveys
- Feld notes, Project Narrative, Project Journals
- Original Ground Terrain Model
- Original Ground Terrain Model and Confidence Point Analysis Report.

Contractor Surveying Handoff

- Contract Documents - Plans, Specifications, Special Provisions
- Digital Design - Alignments, Profiles, Surfaces (in LandXML)

Forms

The following forms may be helpful or required in carrying out various tasks addressed in the body of the manual.

- E.D.M. Accuracy Test form
- Photogrammetry Review Checklist

Technology Aids

The following technology tools may be helpful in carrying out various tasks addressed in the body of the manual.

- Calibrations Baseline Calculations spreadsheet
- Project Creation Tool for building electronic folder structure.
- OCRS Projection files
- LDP computations Spreadsheet
- Field equipment files – feature catalogues, projection files
- MicroStation files – seed files, configuration, MDL programs
- Link to EAST Archiving
  http://highway.odot.state.or.us/tad/iseast/archives/