OREGON DEPARTMENT OF TRANSPORTATION

Highway Division

Geometronics Unit

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CONSTRUCTION SURVEYING MANUAL FOR CONTRACTORS

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This companion manual to Special Provision 00305 provides detailed information on performing construction survey work for highways, bridges, signs, signals, illumination and associated work.

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CHAPTER 1 - GENERAL INFORMATION

1.1 Scope - This work consists of all surveying activities necessary to control the many phases of work required to construct a Project to the lines and grades as shown, specified, or established.

Make all supporting computations and field notes required for control of the work and as necessary to establish the exact position, orientation, and elevation of the work from control stations, including furnishing and setting construction stakes and marks, reference marks, and additional control stations.

Plans, specifications and other data necessary to lay out the work will be available for inspection at the Project Manager's office.

1.2 Definitions:

Confidence Points - Random points measured in the field within the boundary of a digital terrain model (DTM), the purposes of which are to verify the accuracy of the DTM and to provide evidence just prior to construction that the DTM is a reasonable representation of the original ground for computation of volumes and pay quantities. Similarly, confidence points are used to verify that a constructed grade has been built according to the design DTM. Additional information is available from the Engineer.

Confidence point locations follow these guidelines:

- Randomly selected without regard for the location of DTM points or triangles
- Evenly distributed over the entire DTM area to be validated
- Proportionately distributed between confidence point classifications as applicable
- At a density sufficient to validate the surface, generally ten per instrument location as used in collecting DTM data or if not applicable, as in data collected photogrammetrically, 2% of DTM points

Control Network - An array of control stations either established by the Contractor or provided by the Agency.

Control Station - Any item identified in the Project records as having a position and elevation on the Project datum and intended to be used to control the many phases of the construction work.

Digital Terrain Model (DTM) - An electronic computer model of the shape of the ground.

Reference Stakes - Stakes set away from but with information relating back to the intended location and grade.

Slope Catch - The location where a design slope intersects the existing ground and where excavation or embankment work should begin to provide the intended earthwork.

Slope Staking - The process of using measurements and calculations in the field to determine the slope catch. Slope staking shall normally include setting stakes to mark the slope catch and setting a reference stake for every catch stake.

Stakes - Stakes, nails, marks, string lines, or other devices or mechanisms set or established for the purpose of indicating or controlling the location, orientation, or grade of any feature intended for construction, or for the purpose of limiting or influencing the construction work.

Staking - The act of placing stakes.

Survey Marker - Any survey monument, control station, or stake.

Survey Monument - Any natural or man-made item specified or identified in a property deed, boundary survey, government document, or other instrument of public record, when the purpose of said item is to mark or reference a property boundary, geographical location, elevation, or other position.

Surveyor - The individual designated by the Contractor and licensed in the state of Oregon as a Professional Land Surveyor and placed in "responsible charge" of the survey work as defined in ORS 672.002(6)(b).

Temporary Bench Mark (TBM) - A control station established for the purpose of providing vertical control for the Project. A TBM may or may not have an established horizontal position.

1.3 Mandatory Pre-Survey Conference - The prime Contractor, subcontractors, surveyor, survey crew leader, and all surveying personnel who are to be involved in the survey work shall meet with the Project Manager two weeks prior to beginning survey work. The purpose of this meeting will be to discuss methods and practices of accomplishing required survey work.

1.4 Review by the Engineer - The Engineer may periodically review the notes, calculations and layout work, including field locations, for compliance with these specifications. Survey work that does not meet the tolerances in Chapter 4.1 of this manual may be rejected, and the work redone at the Contractors expense to meet the tolerances.

Review by the Engineer does not constitute approval or acceptance of the work, nor does it relieve the Contractor of responsibility for performing work in conformance with the plans and specifications.

1.5 Agency Responsibilities:

- Provide copies of plans and specifications.
- Establish initial horizontal and vertical control stations in the proximity of the Project.

- Provide horizontal and vertical alignment data.
- Provide cross section finish grade elevations.
- Perform measurements and calculations for pay quantities.
- Perform final "as constructed" measurements.

1.6 Contractor Responsibilities - Perform or provide the following items of work:

- Make calculations, field notes and survey drawings for the layout and control of the work as are necessary to construct the Project as specified.
- Provide original or copies of notes, calculations and drawings as requested.
- Preserve survey monuments and control stations according to Chapter 6.2 of this manual and as governed by applicable law.
- Replace and augment control stations as necessary to control the Project.
- Establish additional control stations as necessary to control the Project.
- Set stakes to define construction centerline, centerline offsets, detour lines, or other lines necessary for control of the Project work.
- Set stakes to define the work, that may include but is not limited to the following:
    - Roadway location and grade.
    - Fences and gates.
    - Guardrail, barrier, barricades, and associated features.
    - Traffic delineators, reflectors, and guide devices.
    - Temporary and permanent pavement striping and pavement marking devices.
    - Temporary and permanent signing.*
    - Poles and footings, cabinets, junction boxes, sensors, and other features associated with illumination and signal facilities.*
    - Curbs, walks, stairs, walls, mailboxes, and other miscellaneous structures.*
    - Pipes, manholes, inlets, weirs, settlement basins and other drainage and water quality structures and facilities.*

      *This includes field verification of fit and functionality or as instructed by the Engineer.

    - Landscaping items.
    - Earthwork features including guardrail flares and mounds, berms, and mounds
    - Buildings and other structures and facilities.
    - Environmental impact mitigation features.

- Remove and dispose of all flagging, lath, stakes and other temporary staking material after the Project is completed.
- For bridge work, supply survey drawings depicting the location and elevations of the elements of substructure and superstructure and place stakes for features including but not limited to the following:

  Substructure:

  - Piling
  - Footings
  - Columns, walls, and abutments
  - Pile caps and cross beams
  - Bearing pads or devices

  Superstructure:

  - Horizontal alignment and deck edges
  - Soffit grades
  - Seismic restraints
  - Wing walls and retaining walls
  - Bridge end panels
  - Deck elevations
  - Railings
  - Deck drains and other bridge drainage facilities

- Set reference stakes and elevations in the vicinity of the structure work, as are necessary for the Engineer to check the layout. This may include establishment of a control network.

1.7 Survey Methods - Survey procedures shall be appropriate for the equipment being used and be according to current Agency practices.

New survey procedures that are not according to current Agency practices shall be submitted to the Engineer for review 21 days prior to conducting the work. The surveyor may be required to demonstrate the capabilities, accuracy, and reliability of the intended procedure. The Engineer will evaluate the procedure and intended application and provide approval or rejection within 21 days. Work may proceed immediately upon approval of procedures by the Engineer.

Test and adjust survey equipment according to Agency's procedures and maintain records of test results and submit copies to the Engineer upon request. Information on Agency test procedures may be obtained from the Engineer.

1.8 Survey Work Records - Contractor's survey personnel shall maintain a Project daily record of work performed by the survey crew. The daily record shall contain the date, crew names, type and location of work, and work accomplished. Upon request, furnish a copy of diary entries to the Engineer. Furnish a final copy of the diary when the Project is complete.

Contractor's survey personnel shall make all field notes and calculations in a manner consistent with current Agency practices and on forms provided or approved by the Engineer. Computations, survey notes and other records necessary to accomplish the work shall be neat, legible and complete. Furnish copies of computations, notes and other records when requested by the Engineer.

When a Project affects any permanent change to vertical clearances within the traveled way, complete and submit a Standard Vertical Clearance form (Form No. 734-2614) within 30 days of the change to the vertical clearance.

When a Project temporarily restricts any vertical clearances, complete and submit a Standard Vertical Clearance form (Form No. 734-2614) 28 days before the restriction takes effect.

For bridges, furnish all computations, layout notes, and drawings of the structure to the Engineer for review 7 Calendar Days before beginning construction.

Upon completion of construction staking and prior to final acceptance of the Contract, furnish to the Engineer, computations, survey notes, Project records and other data used to accomplish the work. Include an itemized list of the data.

All data and original documentation associated with the Project will become the property of the Agency.

1.9 Communication With the Surveyor - The Engineer has the right to communicate directly with the surveyor.

CHAPTER 2 - ELECTRONIC DATA

2.1 General - The Engineer will not be responsible for any data translations. Compressed data provided by the Engineer or the Contractor will be in a "self-expanding executable" format. The method of exchange of electronic data will be mutually agreed upon at the pre-survey conference.

2.1.1 Data Formats Provided by the Engineer:

- **CAD (graphics) Files** - Microstation Design File (.DGN) format.
- **Horizontal Control Coordinates** - ASCII Coordinate File format.
- **Elevations** - ASCII Elevation File format.
- **Horizontal Alignments** - Bentley Systems, Inc. ASCII Horizontal Alignment format.
- **Vertical Alignments** - Bentley Systems, Inc. Vertical Alignment format.
- **DTM Data** - Bentley Systems, Inc. DTM or Microstation Design File (.DGN) format.
- **Cross Section Data** - Cross Section or Station, Offset and Elevation (SOE) File format.

2.1.2 Data Formats Provided by the Contractor:

- **DTM Data** - Bentley Systems, Inc. DTM or Microstation Design File (.DGN) format.
- **CAD (graphics) Files** - Microstation Design File (.DGN) format.
- **"As Staked" Coordinate Data** - ASCII Coordinate File format.
- **Confidence Points** - ASCII Coordinate File format.
- **Vertical Control Point Elevations** - ASCII Elevation File format.
- **Coordinates of Miscellaneous Survey Points Set** - ASCII Coordinate File format.

2.1.3 Data Format Details - Data exchanged between the Agency and the Contractor will be in the following formats as referred to in this Chapter:

2.1.3.1 ASCII Coordinate File Format:

Point ID Northing Easting Elevation Feature Description

- Point IDs are alphanumeric up to 8 characters long.
- Coordinates/Elevations are decimal numbers in the units required by the Project.
- Feature names are up to 8 character alphanumeric codes.
- Descriptions may be up to 27 characters and may contain any combination of printable ASCII characters.

- Columns may be separated by spaces or commas.
- Name all ASCII coordinate files with an extension of .CRD.

Example: 105 216473.675 576231.905 102.562 SET_NTW 1/2 inch iron rod

2.1.3.2 ASCII Elevation File Format:

Point ID Elevation Description

- Point IDs are alphanumeric up to 8 characters long.
- Elevations are decimal numbers in the units required by the Project.
- Descriptions may be up to 27 characters and may contain any combination of printable ASCII characters.
- Columns may be separated by spaces or commas.
- Name all ASCII elevation files with an extension of .ELV.

Example: 425 542.768 TBM12, n.w. bolt on lum.

2.1.3.3 Cross Section or Station, Offset and Elevation (SOE) File Format:

Station Offset Elevation Pen Up (Pen Down)

- The station values should be in ascending order.
- For each station, the offsets should be in ascending order from left to right.
- The pen up (pen down) column distinguishes one cross section from the next.
- The first point in each cross section should have a value of 1 in the pen column.
- The final point in each cross section should have a value of 2 in the pen column.
- All intermediate cross section points should have a value of 0 in the pen column.
- Name all cross section data files with an extension of .SOE.

Example:

Station	Offset	Elevation	Pen Up (Pen Down)
656+82	- 86.94	855.04	1
656+82	- 34.80	881.44	0
656+82	- 8.00	882.59	0
656+82	0.00	882.69	0
656+82	12.00	882.57	0
656+82	41.50	682.87	0
656+82	82.84	856.32	2

2.1.3.4 Bentley Systems, Inc. ASCII Horizontal Alignment Format:

Records beginning with an "*" are ignored.
The record beginning with "{" defines the format.
Name all ASCII Horizontal Alignment files with an extension of .HAL.

Example:

```
* BENTLEY SYSTEMS, INC. HORIZONTAL ALIGNMENT TO ASCII
*
* Alignment name: EP
* Alignment description: Default
* Alignment style: Rdwy_Edge_Asph_E
* Input Factor: 1.00000000
*
```

{ TYPE	STATION	RADIUS	X_CRD	Y_CRD	DIRECTION	SPI_LENGTH
LIN	0.00	0.00	7544794.26	526252.58	S 56°28'17.3" W	0.00
LIN	32.67	0.00	7544767.02	526234.53	S 52°26'03.8" W	0.00
LIN	68.27	0.00	7544738.80	526212.82	S 52°44'16.7" W	0.00
LIN	105.44	0.00	7544709.22	526190.32	S 52°10'25.3" W	0.00
LIN	142.63	0.00	7544679.85	526167.52	S 52°14'42.7" W	0.00
LIN	174.51	0.00	7544654.64	526147.99	S 52°43'36.1" W	0.00
LIN	205.47	0.00	7544630.00	526129.24	S 52°50'34.1" W	0.00
LIN	237.22	0.00	7544604.70	526110.07	S 52°59'10.8" W	0.00
LIN	272.76	0.00	7544576.32	526088.67	S 52°05'50.7" W	0.00
LIN	305.68	0.00	7544550.34	526068.45	S 52°25'05.5" W	0.00
LIN	340.50	0.00	7544522.75	526047.21	S 52°33'06.9" W	0.00
LIN	375.61	0.00	7544494.88	526025.86	S 52°03'29.1" W	0.00
LIN	399.86	0.00	7544475.76	526010.96	S 52°03'29.1" W	0.00

2.1.3.5 Bentley Systems, Inc. ASCII Vertical Alignment Format:

Records beginning with an "*" are ignored.
The record beginning with "{" defines the format.
Name all ASCII Vertical Alignment files with an extension of .VAL.

Example:

```
* BENTLEY SYSTEMS, INC. VERTICAL ALIGNMENT TO ASCII
*
* Alignment name: EP
* Alignment description:
* Alignment style: Rdwy_Edge_Asph_E
* Input Factor: 1.00000000
*
```

{ TYPE	STATION	ELEVATION	SLOPE	VC_LENGTH
LIN	0.00	107.78	- 0.0	0.00
LIN	32.67	107.75	0.0	0.00
LIN	68.27	107.77	- 0.0	0.00
LIN	105.44	107.64	0.0	0.00
LIN	142.63	107.66	0.0	0.00
LIN	174.51	108.06	0.0	0.00
LIN	205.47	108.26	0.0	0.00
LIN	237.22	108.58	0.0	0.00
LIN	272.76	109.00	0.0	0.00
LIN	305.68	109.21	-0.0	0.00
LIN	340.50	109.19	0.0	0.00
LIN	375.61	109.41	0.0	0.00
LIN	399.86	109.78	0.0	0.00

2.1.3.6 Microstation Design File Format:

Bentley Systems, Inc. proprietary format.

CHAPTER 3 - MATERIALS, EQUIPMENT, AND LABOR

3.1 Materials - Furnish all materials including supplies, clothing, and incidentals required to accomplish the work. Use materials of good quality and suitable for the purpose intended. Stakes, hubs, and guinnies are to be of sufficient length to provide a solid set in the ground. Mark the stakes in such a way as to remain legible for the intended duration. Provide and use safety equipment required by State and federal regulations.

3.2 Survey Equipment - Furnish survey equipment required to accomplish the work that meets the following requirements:

- Components designed to work together.
- Suitable for the purpose intended.
- Capable of achieving specified tolerances.
- In good operating condition.
- Maintained to meet manufacturers specifications.
- Kept in proper adjustment throughout the duration of the Project.

Submit documentation on survey equipment that is new to the industry, to the Engineer for review 21 days prior to its use. The Engineer will evaluate the equipment and intended application and provide approval or rejection within 21 days. Equipment may be used immediately upon approval by the Engineer.

3.3 Personnel - Provide technically qualified personnel capable of performing required tasks in a timely and accurate manner. Perform work under the direction and review of the Surveyor.

The Surveyor is responsible for:

- Maintaining registration as a Professional Land Surveyor in the State of Oregon.
- Performing or validating requirements for procedures and testing of equipment.
- Maintaining familiarity with the site conditions and progress of the Project.
- Becoming familiar with the plans and specifications.
- Determining notes and documentation required for types of survey work.
- Determining the accuracy required for each survey stake.
- Using appropriate equipment and methods.
- Keeping close communication with the Project inspector(s), Project Manager, and Agency survey crews working on the Project.
- Being familiar with the varying construction survey requirements of each aspect of the Project, including the various bridge construction techniques when applicable.

- Notifying the Project inspector of conflicts and changes necessary due to utilities, match point variations, design revisions, or other variables.

The survey crew leader is responsible for:

- Becoming familiar with the plans and specifications.
- Keeping close communication with the Project inspector(s), Project Manager, and Agency survey crews working on the Project.
- Notifying the Project inspector of conflicts and changes necessary due to utilities, match point variations, design revisions, or other variables.

CHAPTER 4 - CONSTRUCTION STAKING

4.1 Construction Staking Tolerances - Set stakes or other devices at an adequate frequency and within the following tolerances:

Item	Horizontal	Vertical
Box Culverts	+/- 0.10 ft.	+/- 0.05 ft.
Bridge Substructures	+/- 0.03 ft.	+/- 0.03 ft.
Bridge Superstructures	+/- 0.02 ft.	+/- 0.02 ft.
Clearing and Grubbing Stakes	+/- 1.00 ft.	n/a
Construction Centerline Control Points	+/- 0.05 ft.	n/a
Construction Centerline Station Points	+/- 0.10 ft.	n/a
Curbs, Walks, and Bike Paths	+/- 0.03 ft.	+/- 0.02 ft.
Grade Stakes - Roadway Subgrade	+/- 0.20 ft.	+/- 0.05 ft.
Grade Stakes - Top of Rock	+/- 0.20 ft.	+/- 0.03 ft.
Grade Stakes - Roadway Finish	+/- 0.10 ft.	+/- 0.02 ft.
Manholes, Inlets, and Culverts	+/- 0.10 ft.	+/- 0.03 ft.
PCC Pavement	+/- 0.10 ft.	+/- 0.02 ft.
Slope Stakes and References	+/- 0.30 ft.	+/- 0.10 ft.
Traffic Markings	+/- 0.20 ft.	n/a
Walls - Retaining, MSE, Sound, etc.	+/- 0.10 ft.	+/- 0.05 ft.
Wetland Mitigation Control Stakes	+/- 0.20 ft.	+/- 0.20 ft.
Luminaire and Signal Poles (incl. ftgs.)	+/- 0.20 ft.	+/- 0.03 ft.

Miscellaneous items not listed above will have a horizontal and vertical tolerance of 0.20 foot, unless otherwise directed. Features that are to be constructed flush to another surface should take on the same tolerance as that surface.

Tolerances for special circumstances will be discussed at the pre-survey meeting.

These staking tolerances are not cumulative to the construction tolerances identified for the appropriate items in which construction tolerances are required.

4.2 Slope Stakes and References - When slope staking is performed by the Contractor, set slope stakes and references on both sides of centerline at 50 foot stations and at terrain breaks and changes in the typical section. Establish slope stakes in the field as the actual point of intersection of the design roadway slope with the existing ground line. Direct staking of the theoretical (computer generated) slope stake catch point requires prior approval of the Engineer.

Set slope stake references farther out from centerline than the actual catch point. Include all reference point and slope stake information on the reference stakes.

If an automated slope staking routine is intended to be used, the system shall be able to perform the proper superelevation, lane transitions, and benching, as well as duplicate other details in the design surface. The system shall record field modifications made to the final catch slopes. Any modifications shall be recorded and provided to the Engineer.

Record the actual as staked (three dimensional) position of the slope and reference stakes. Prepare field notes showing slope stake and reference information, and provide to the Engineer.

Measure and record confidence points upon completion of the roadbed side slopes and ditches. Location and spacing of these confidence points shall be such that they provide a reasonable record of the constructed roadbed side slopes and ditches and placed at a nominal rate of one confidence point for every 2,000 square feet of roadbed side slopes and ditches.

4.3 Clearing Limits - When clearing limits are to be established by the Contractor, set clearing limit stakes according to the Oregon Standard Specifications for Construction, Section 00320. Space clearing limit stakes at intervals not greater than 50 feet or as directed.

4.4 Grade Stakes - Set grade stakes or other control for grade elevation and horizontal alignment. Set grade stakes at each grade break line. Set additional points at intervals, as necessary, not to exceed the width of the grading equipment, or as approved by the Engineer. Set these rows at 50 foot stations or as required in special situations, as in road connections and other areas where conditions require tighter spacing of grade stakes to assure grade and alignment.

Measure and record confidence points upon completion of the subgrade and each course and prior to the placement of the next course. Location and spacing of these confidence points shall be such that they provide a reasonable record of the grade as constructed and placed at a nominal rate of one confidence point for every 1,000 square feet of grade.

Provide confidence point data in the form of an ASCII Coordinate File Format to the Engineer for analysis. The Engineer may request additional confidence points if quantity, distribution, or placement does not meet the stated criteria in this Chapter and in the confidence point location guidelines in Chapter 1.2 of this manual. The Engineer may choose to collect additional confidence points using Agency personnel.

The Engineer will evaluate the grade using any combination of industry-standard techniques and the standard Agency confidence point analysis procedure. The confidence point analysis will use the tolerance value defined in Chapter 4.1 of this manual for the particular course, and will be deemed unacceptable if any points are outside of these tolerances.

The Engineer will evaluate the grade and provide acceptance or rejection before the end of the first business day following receipt of the confidence point data. Do not begin placement of the next course until the Engineer has accepted the grade and approval is given to proceed.

4.5 Walls - Set stakes or other devices to control the location and elevation of walls, including retaining walls, geotextile walls, wing walls, sound walls and other walls as specified. Provide horizontal and vertical control for elements of wall(s) including but not limited to footings, leveling pads, batter slope and direction, and top elevation. Stake drainage facilities, electrical conduits, water pipes and other items shown or identified that are to be integrated into the construction of the wall(s).

4.6 Pipes and Culverts - Stake pipes and culverts to fit field conditions. Their location may be different from the plans. Perform the following:

- Determine the roadbed slope catch points at the inlet and outlet of pipes and culverts.
- Set reference point offsets to pipes and culverts. Record information necessary to determine structure length and end treatments.
- Stake ditches or grade to make pipes and culverts functional.
- Complete a Culvert Data Sheet (Form 734-3247) according to Agency standards.
- Submit a copy of the field notes to the Engineer by the next working day following completion of the staking work.

4.7 Box Culverts - Set stakes or other devices to control the location and elevation of box culverts as specified. Provide horizontal and vertical control for elements of the box culvert(s) including but not limited to footings, side walls, wing walls, weirs, fish ladders, aprons and top elevation. Stake other drainage facilities, electrical conduits, water pipes, and other items shown or identified that are to be integrated into the construction of the box culvert(s). Stake ditches to make the box culvert(s) functional.

4.8 Manholes and Inlets - Determine the location of manholes, inlets, siphon boxes, slope protectors, and other similar structures. This may require an approved field adjustment to the planned location in order to avoid obstacles or assure placement at the low point. Determine the elevation of the center of the grate.

Set a stake referencing the center of the structure. Set a guard stake with the following information written on it:

- Type of structure
- Centerline station
- Centerline offset
- Reference distance
- Cut or fill to top of structure
- Center of structure elevation

Establish a reference line to control the alignment of the structure. Record data on the Culvert Data Sheet (Form 734-3247) containing staking information for the outlet pipe from the specific drainage structure.

4.9 Stockpile Sites - Perform the work necessary for the initial layout and measurement of the stockpile site by one of the following methods:

4.9.1 Cross Section Method - Establish a reference baseline, site limits, and clearing limits. Survey and record original ground cross sections prior to placement of stockpile material. Take cross-sections at maximum 25 foot intervals, grade breaks in the existing ground, and at locations anticipated to be grade breaks in the completed stockpiled. Survey and record final cross sections after completion of the stockpile. Take cross sections at all previous locations plus any additional locations necessary to accurately reflect size and shape of stockpile.

4.9.2 Digital Terrain Model (DTM) Method - Establish instrument control stations, site limits, and clearing limits. Survey and record original ground measurements. Use the proper placement of breaklines and regular terrain points. Record a minimum of 10 confidence points. Verify instrument setup by recording elevation and backsight checks.

Survey and record the final surface measurements. Use the proper placement of breaklines and regular terrain points. Record a minimum of 10 confidence points. Verify instrument setup by recording elevation and backsight checks.

CHAPTER 5 - HORIZONTAL AND VERTICAL CONTROL AND LAYOUT

5.1 Horizontal Control - Establish horizontal control stations using Theodolite/EDM network or static GPS techniques. Least squares adjustments shall be applied to either method. The use of traverses will be permitted only if approved by the Engineer.

Preserve all Agency provided and Contractor established horizontal control stations for the life of the Project. If the horizontal control network cannot be preserved in its original position during construction or if the Agency provided control stations are not of adequate quantity or location, establish a secondary horizontal control network using the original control as a basis. This secondary control network may then be used by the Contractor to layout all construction items and may be used by the Agency for right-of-way monumentation and for other purposes.

5.1.1 General Specifications - Horizontal control networks shall conform to these general requirements in addition to Theodolite/EDM or GPS specifications to follow.

5.1.1.1 Equipment:

- Use tripods for all occupations with Theodolite, target, or GPS antenna.
- Test all components and adjust according to manufacturer specifications.

5.1.1.2 Procedures:

- Include in field notes a detailed point description and vicinity sketch for each control station and survey monument established or used.
- Perform a minimally and fully constrained Least Squares adjustment.
- The line used for the basis of bearing shall be greater than 1,000 feet unless approved by the Engineer.
- Prior to using 2 points for the basis of bearing, perform an analysis to verify that the points are actually those indicated in the record.
- Control station monuments shall conform to the requirements of the Agency "Right-of-Way Monumentation Policy" available from the Engineer.
- If available, include at least three existing control stations in establishing any control network.
- Establish a point identifier for each control point within the range of 1 - 399. Alphanumeric point identifiers up to eight characters may be used. Inscribe the point identifier on the monument.

5.1.1.3 Acceptance Standards - A least squares adjustment shall be accepted base on the following criteria for all specified tolerances:

- Two-thirds of all values shall be within the total tolerance.
- 100% of all values shall be within 3 times the total tolerance.
- Tolerance for confidence regions at the 95% level is 0.05 feet + 50 ppm based on the shortest distance to the nearest unadjusted control station.

5.1.1.4 Data Requirements:

- Field notes containing a detailed point description and vicinity sketch for each control station and survey monument established or used.
- Minimally and fully constrained least squares adjustment reports.

5.1.2 Theodolite/EDM Networks:

5.1.2.1 Equipment:

- Use Theodolites with a maximum angular standard of error no greater than +/- 6 seconds.
- Use EDMs with a maximum distance standard error no greater than +/- 0.02 feet +/- 5 ppm.
- All components shall be of compatible accuracy and designed to be used together.

5.1.2.2 Field Procedures:

- Include distance measurements with all observations unless impractical.
- Have at least one redundant observation for every point in the network.
- Triangulation, trilateration, and resection methods are acceptable.

5.1.2.3 Acceptance Tolerances:

- Tolerance for angle residuals is +/- 3 seconds.
- Tolerance for distance residuals is +/- 0.02 feet +/- 2 ppm.

5.1.2.4 Data Requirements - Provide the following to the Engineer for each network or circuit established:

- **Raw Data Files** - These are electronic data files containing original measurements produced by the Theodolite (total station). The file shall contain:
  - Observation data for each measurement, including:
    - point identifier
    - direction, plate reading, or horizontal angle

- vertical or zenith angle
- slope distance

- Supplemental measurement data, including:

  - distance units recorded
  - angular units recorded
  - curvature and refraction correction applied
  - atmospheric correction applied
  - prism correction applied

- Codes or instructions to the processing software on how to process the data.
- Atmospheric conditions at the time of the survey.
- Angular and distance units recorded, and whether the distance has been corrected for curvature and refraction and atmospheric conditions.

- **Set Reduction Report** - This report summarizes the reduction of the angle sets and mean distances.

- **Least Squares Adjustment Reports** - These reports contain details of the least squares adjustment, including a list of all angular and distance residuals, confidence region values at a 95% confidence level, and final adjusted coordinates.

5.1.3 GPS Networks:

5.1.3.1 Equipment:

- GPS receivers shall be dual frequency geodetic receivers with a manufacturer specified accuracy of +/- 0.02 feet +/- 1 ppm or better.
- All components shall be of compatible accuracy and designed to be used together.

5.1.3.2 Field Procedures:

- Ensure that satellite geometry during the field observation phase is sufficient to produce accurate results. The geometric dilution of precision (GDOP) shall not be greater than 8.
- The number of healthy satellites being observed at any time shall be four or more.
- The elevation mask shall be not less than 15 degrees.
- Horizontal survey measurements, once completed, shall form a closed figure, and shall be connected to at least two existing horizontal control stations.

- Network shall be comprised entirely of independent baselines.
- Adjacent stations shall have direct connections.
- Every station shall be connected to two or more stations.
- Receiver documentation shall be followed for observation times and epoch intervals.
- Each control station shall be occupied no less than twice, of which two occupations shall be separated from each other by time. Separation shall be measured start-time to start-time. Separation shall be 90 minutes or more from initial occupation and 90 minutes or more from any 12 hour multiple thereafter for 30 days. Additional occupations beyond two are not subject to time restrictions.
- Back-to-back occupations of 90 minutes or more shall be separated by off leveling and re-setting the tripod and rotation of the tribrach or leveling equipment by 120 degrees or more.
- Stations closer together than 1,500 feet shall be connected with terrestrial observations.
- Inter-visible stations closer together than 3,000 feet shall be connected with terrestrial observations.

5.1.3.3 Acceptance Tolerances:

- Tolerance for linear residuals in latitude, longitude, and elevation is +/- 0.05 feet.

5.1.3.4 Data Requirements - Provide the following to the Engineer for each network established:

- **Receiver Independent Exchange (RINEX) Data Files** - These are industry-standard non-proprietary electronic data files containing original data collected by the receiver. The provided files shall contain all data supported by both the RINEX file format and the equipment and software employed in the survey. Files provided shall include as a minimum:
  - GPS observation data file
  - GPS navigation message file
- **Observation Log Sheet** - This log includes, for each observation, start and stop times, and antenna height including measurement procedure.
- **Least Squares Adjustment Reports** - These reports contain details of the least squares adjustment, including a list of all latitude, longitude, and height residuals, confidence region values at a 95% confidence level, and final adjusted coordinates.

5.1.4 Traverses:

5.1.4.1 Equipment:

- Identical to requirements for Theodolite/EDM networks.

5.1.4.2 Field Procedures:

- Include distance measurements with all observations unless impractical.
- Close both traverse for angle and distance.

5.1.4.3 Acceptance Standards:

Closure shall be a minimum of 1:20,000 after angular adjustment and prior to coordinate adjustment.

5.1.4.4 Data Requirements - Provide the following to the Engineer for each traverse established:

- **Adjustment Report** - This report contains details of the traverse adjustment, including adjusted coordinates.

- **Other Reports** - All data required for Theodolite/EDM networks except least squares adjustment report.

5.2 Vertical Control - Establish vertical control stations using differential leveling and third order or better equipment and techniques. The development of vertical control by techniques other than differential leveling must be approved by the Engineer. A least squares adjustment shall be applied to each network of acceptable level circuits.

The Agency provided and Contractor established vertical control stations shall be preserved for the life of the Project. If the vertical control network cannot be preserved in its original position during construction or if the Agency provided control stations are not of adequate quantity or location, establish a secondary vertical control network using the original control as a basis. This secondary control network would then be used to layout all construction items and may be used by the Agency for other purposes.

5.2.1 Field Procedures:

- Use a compensated (or "automatic") optical level or compensated digital level.
- Use precise non-adjustable rod(s) unless otherwise directed. Do not use "Lenker" or self-computing rods.
- Use a rod level with each rod.

- Include a minimum of two published bench marks in each circuit unless otherwise directed.
- If the circuit between benches does not close within the tolerance stated below, close circuit back to the starting point.
- If the use of one benchmark is approved, close circuit back to the starting point.
- Select turning points that are firm, solid objects with a defined high point. Set a nail, spike, or stake if no existing items are acceptable. Turning plates with a weight of not less than 4.5 pounds may be used.
- Balance backsight and foresight distances to within 30 feet on each setup and to within 30 feet on the entire circuit.
- Make a record of the rod reading(s) and the observation distance on each sighting
- Set TBM's near significant construction items (bridges, intersections, and other locations where elevations will be needed) and not more than 1,000 feet apart throughout the Project.
- Select TBM monuments that are firm, solid objects with a defined high point, not likely to be moved by human or natural influences, readily identifiable, and out of the path of construction. Do not use fire hydrants, guardrails, highway signs, or nails or spikes in utility poles or fence posts.
- Include detailed point descriptions and vicinity sketch in field notes.
- Take field notes when recording measurements electronically. Include data and information not electronically measured and recorded.
- Apply a vertical least squares adjustment to allowable errors. The use of proportional distribution of error may be used if approved by the Engineer.

5.2.2 Acceptance Standards - Each leveling circuit shall be accepted based on the "point-to-point" or "closed-loop" limits described below. A single least squares adjustment shall be applied to the observations in the leveling circuits meeting the acceptance standards

- Accept point to point circuit based on the following. Error of closure shall be no greater than:

  $$\text{Allowable Error} = 0.05\ \text{ft.}\sqrt{D}$$

  D = Shortest level line distance in miles

- If a closed loop, the error of closure shall be no greater than:

  $$\text{Allowable Error} = 0.035\ \text{ft.}\sqrt{E}$$

  E = Perimeter of level loop in miles

5.2.3 Data Requirements - Provide the following to the Engineer for each network or circuit established:

- **Raw Data** - These are hand written field notes or hand written field notes accompanied by electronic data files containing original measurements produced by the level. The file shall contain:
  - Data for each measurement, including a:
    - point identifier (within a range of 400 - 499 and also inscribed on the monument)
    - rod reading
    - observation distance
  - Supplemental measurement data, including:
    - distance units recorded
    - curvature and refraction correction applied
- **Level Computation Report** - This report contains the computation of unadjusted elevations, observation distance imbalances, computer allowable error, and closure error.
- **Level Adjustment Report** - This report contains the adjustment details, including residual values, adjusted elevations and standard errors.
- **ASCII Elevation Data File**

5.3 Bridges - Set stakes, nails, or other devices to control the location and elevation of the various parts of bridges and progressive phases of construction. Provide horizontal and vertical control for all elements of bridge construction. Stake drainage facilities, electrical conduits, water and sewer pipes, pedestrian and bicycle facilities, traffic signal and sign supports, illumination devices, and other items shown or identified that are to be integrated into the construction of the bridge.

Identify marks or provide field notes or reports to the Engineer. Such provision of information shall be adequate for the Engineer to review the location and elevation of the mark for the intended purpose prior to incorporating material that is based on the mark.

5.3.1 Bridge Survey Control Stations - Use the smallest number of original Project control stations as is practical for establishing positions and reference points for bridge construction on one bridge. Use of multiple control stations will increase the probability of incorporating error into the construction. Use control stations that are as closely related mathematically as practical. The Contractor may establish additional control stations as necessary to complete

the survey work. Additional control stations shall be established in such a manner as to provide the accuracy needed to meet the tolerances in Chapter 4.1 of this manual.

Original Project control stations shall be used only after the following evaluation is completed for each bridge:

- Supply a list of original Project horizontal and vertical control stations intended by the Contractor to be used in establishing positions on a given bridge.
- Measure relative positions of original Project horizontal control stations intended to be used.
- Measure elevation differences between original Project vertical control stations intended to be used.
- Supply horizontal and vertical measurement data to the Engineer.
- Compare measured values with those computed from original horizontal network coordinates and vertical network elevations.
- Any discrepancy of concern to either the Contractor or the Engineer will be resolved before that combination of control stations is used.

5.3.2 Layout Marks and Reference Points:

5.3.2.1 Substructure - Stake, reference, or otherwise identify locations, orientations, and elevations necessary for placement of substructure components, including but not limited to cofferdams, pilings (including batter), drilled shafts, footings, columns, abutments, caps, cross beams, bearing devices, temporary supports or falsework, and excavations and embankments associated with any of the above.

Verify and document the locations, elevations and spatial relationships with adjacent substructure components. On bridges where prefabricated beams will be used, measure and document span lengths between bearing devices at each beam location as soon as practical. Supply a copy of such documentation to the Engineer for review before the next stage of construction.

Compute the final elevations after studying the plans, specifications, and shop drawings. Adjust the grades as needed to compensate for camber of prefabricated beams, chording of beams across the low side of superelevations, width of flat beams on superelevated surfaces, and any other factor resulting from design or construction methods.

5.3.2.2 Superstructure - Stake, reference or otherwise identify locations, orientations, and elevations necessary for placement of superstructure components including but not limited to beams, girders, diaphragms, earthquake restraints, deck, rails, structure mounted traffic control and illumination devices, and concrete forms, temporary supports and falsework associated with any of the above.

Stake alignment of structure as needed at each stage of construction. Stake alignment of poured-in-place items at 10 foot stations or as established by the Engineer. Stake alignment for the following items as needed to maintain the horizontal tolerance defined in Chapter 4.1 of this manual :

- Outside edge of girder(s).
- Face(s) or centerline(s) of internal girders or stem walls.
- Edge of deck.
- Alignment of grade breaks.
- Pedestrian and bicycle facilities.
- Rails and railings.

Stake grades at each stage of construction. Stake grade of poured-in-place items at 10 foot stations, or as established by the Engineer. Apply corrections to design grades based on the dynamics of the evolving structure. Corrections that may be required depend upon the design of the bridge and the construction methods employed. Provide correction values to the Engineer at least 15 working days prior to incorporating into the structure. The following list is examples of possible corrections:

- Design camber (upward adjustment to compensate for anticipated deflection).
- Structural deflection (deflection of the bridge under its own increasing weight).
- Post tensioning lift (upward movement of the bridge under post tensioning forces).
- Structural shifting (dynamics of the bridge under eccentric loading).
- Falsework deflection (deflection of falsework beams under increasing weight).
- Falsework crush (compression of falsework supports under increasing weight).
- Form crush (compression of forms under increasing weight).
- Equipment deflection (deflection of deck finishing machine or deck rails).
- Other adjustments to staked value to achieve the design grade.

5.3.3 Bridge Deck Grades - Set stakes or other devices to control the deck grade elevations. The exact process will depend upon the type of deck and the equipment being used.

5.3.3.1 Portland Cement Concrete Deck - The surveyor and survey crew leader shall attend the first of the two deck pre-placement conferences, described in the Oregon Standard Specifications for Construction, subsection 00540.02(a), required for each deck placement.

Control of a PCC deck may involve significant work with the deck placement crew to establish control for a deck finishing machine. Rails for supporting the deck finishing machine are generally set up on either side of the deck. Each rail is held up by adjustable

supports every 5 feet. Adjust the rail at each support to the desired grade while the rail is supporting the weight of the finishing machine. Corrections may need to be applied as listed in Chapter 5.3.2.2 of this manual.

5.3.3.2 Asphaltic Concrete Deck - Control of an AC deck will not generally involve as many variables as PCC. An AC deck serves as a wearing surface, but not a structural component. Asphaltic concrete will frequently be used as filler to create the desired superelevations when flat beams form the superstructure. Stake control of the finish grade like any asphalt finish grade. Under some circumstances, design camber and structural deflection may need to be considered.

5.4 Pavements - Set stakes or other control devices to control the location and elevation of asphalt and PCC pavement as shown. Provide surveying or survey-related activity necessary to control grade, thickness, and smoothness as required.

5.5 Signs, Signals, Illumination and Fabricated Items - Determine the exact location and their relative location to roadway and bridge features as appropriate such as edge of pavement, curbs, islands, sidewalks, sidewalk ramps, lane lines, bridge columns, bridge decks, and other existing features for the following items:

- Posts and poles including foundations.
- Cabinets.
- Junction boxes.
- Detectors.
- Other similar sign, signal, and illumination appurtenances.
- New Fabricated Items.

Provide the following documentation to the Engineer before submitting working drawings:

- Field verified length of poles, posts, mast arms, and tenon locations.
- Field verified orientation of triangular bases for poles.
- Field verified measurements of all existing features including orientation and relationship to all other new appurtenances and new fabricated items.
- Plan, elevation, and side views.
- Identification of all obstacles.

Field adjustment to the planned location may be required in order to avoid obstacles and to ensure its placement in a functional location. Do not submit working drawings until the Engineer returns the field verified documents. The Engineer will return field verified documents within 21 calendar days after receipt of the documents.

Set a stake referencing the center of the item. Set a guard stake with the following information written on it:

- Description of item (by plan number if applicable).
- Centerline station.
- Centerline offset distance.
- Cut or fill from reference point (and what point the cut or fill is to).
- Intended elevation.

If the orientation of the item is significant and is not clear, establish a reference line for the skew of the item.

Have bridge layout and roadway layout features staked, including referencing, no more than seven calendar days before submitting field verification documents.

CHAPTER 6 – TEMPORARY PROTECTION, PRESERVATION, AND MONUMENTATION

6.1 Temporary Protection and Direction of Traffic - Provide work zone signing according to ODOT's "Oregon Temporary Traffic Control Handbook for Operations of 3 Days or Less".

Provide temporary roll-up signs and sign supports meeting the requirements of the Oregon Standard Specifications for Construction, subsection 00225.11. Provide flaggers and flagger equipment meeting the requirements of the Oregon Standard Specifications for Construction, Section 00225.

6.2 Preservation of Survey Markers:

(a) Project Control Points Established by the Engineer - Maintain, relocate or replace existing survey monuments, control points, and stakes, as determined by the Engineer. Perform the work to produce the same level of accuracy as the original monument(s) in a timely manner, and at no additional cost to the Agency.

(b) Monuments of Record - Preserve survey monuments according to the Oregon Standard Specifications for Construction, subsection 00170.82(c), ORS 209.140, and ORS 209.150. If such monuments are to be disturbed or destroyed, comply with requirements of these ORS at no additional cost to the Agency.

6.3 Project Monumentation - The Contractor will not be responsible for performing right-of-way monumentation.