SOUTH CAROLINA

DEPARTMENT OF TRANSPORTATION

PRECONSTRUCTION SURVEY MANUAL

2023

PRECONSTRUCTION SURVEYING PROCEDURES AND STANDARDS FOR ENGINEERING & DESIGN PROJECTS

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PREFACE

This Preconstruction Survey Manual is a guide to provide uniform mapping practices for the **South Carolina Department of Transportation (SCDOT)** and Consultant personnel conducting field surveys, terrestrial scanning, mobile scanning, and aerial mapping for SCDOT projects. The designer and surveyor should attempt to meet all specifications presented in this Manual. Many of these standards are intended to mirror the standards found in the **Standards of Practice Manual for Surveying in South Carolina** and **Chapter 5** of the **Federal Highway Administration's Project Development and Design Manual (Surveying and Mapping)**.

This manual presents most of the specifications normally required for mapping of SCDOT roadway projects; however, it is difficult to address all field conditions that the surveyor will encounter. Additional survey requirements are also referenced in the SCDOT Design Manual, which outlines certain procedures and special cases.

"While the instructions contained herein obviously do not cover all situations that may arise while making a survey, they should be of considerable help to the Chief of Party." (SCDOT, 1957).

All surveying must meet or exceed the standards set forth in the most current revision of the Standards of Practice Manual for Surveying in South Carolina.

Within this manual, SCDOT uses bold text for emphasis of specific words in quotes.

"A final remark bears on the relationship between the classification standards and measurement system specifications. Specifications are combinations of rules of thumb and studies of error propagation, based upon experience, of how to best achieve a desired level of quality. Unfortunately, there is no guarantee that a particular standard will be met if the associated specifications are followed." (Standards and Specifications for Geodetic Control Networks, 1984).

REVISIONS

March 1957	Revisions Unknown
August 2003	Entire Manual
October 2012	Entire Manual
June 2023	Entire Manual

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1.0 SAFETY

Land Surveyors and Survey crews perform their work in many hazardous environments. SCDOT promotes safe workplaces and recognizes the responsibility of safety for each individual. **The consultant is completely responsible for the safety procedures and the safety of its employees.** When working within SCDOT right-of-way, perform all survey work in compliance with the **Manual of Uniform Traffic Control Devices (MUTCD)** and the **SCDOT Work Zone Safety Manual**.

The **Occupational Safety and Health Administration (OSHA)** provides publications on their website, www.osha.gov.

The **South Carolina Occupational Safety and Health Administration** (SCOSHA) manages and regulates the OSHA operations in South Carolina. SCOSHA's website, www.scosha.llronline.com provides more information about state specific rules and regulations.

The **Federal Highway Administration's Project Development and Design Manual** (Code of Safe Surveying Practice) details safety procedures and practices.

For more information or questions pertaining to Workplace Safety, please contact the **SCDOT Occupational Safety and Health Office**.

2.0 AERIAL MAPPING

Aerial mapping uses various sensors to collect data remotely from an elevated (above ground level) platform. This data is then used to create final digital maps of the (3D) existing ground terrain surface and the (2D) planimetric features. These final digital maps are then provided to the transportation design engineers. The following sections are provided as general information, and can change for specific projects. Unless specified otherwise, aerial mapping must comply with applicable sections of the American Society for Photogrammetry and Remote Sensing publication **ASPRS Positional Accuracy Standards for Digital Geospatial Data (Edition 1, Version 1.0. - November, 2014)** and the **South Carolina Standards of Practice for Surveying** (S.C. Code Ann. Section 40-22-2, et seq.; 26 S.C. Code Ann. Regs. Chapter 49 (1991 as amended)).

ASPRS Positional Accuracy Standards for Digital Geospatial Data, Edition 1, Version 1.0, November, 2014: "The objective of the ASPRS Positional Accuracy Standards for Digital Geospatial Data is to replace the existing ASPRS Accuracy Standards for Large-Scale Maps (1990), and the ASPRS Guidelines, Vertical Accuracy Reporting for Lidar Data (2004) to better address current technologies. This standard includes positional accuracy standards for digital orthoimagery, digital planimetric data and digital elevation data. Accuracy classes, based on RMSE values, have been revised and upgraded from the 1990 standard to address the higher accuracies achievable with newer technologies. The standard also includes additional accuracy measures, such as orthoimagery seam lines, aerial triangulation accuracy, lidar relative swath-to-swath accuracy, recommended minimum Nominal Pulse Density (NPD), horizontal accuracy of elevation data, delineation of low confidence areas for vertical data, and the required number and spatial distribution of checkpoints based on project area."

Consultants are contracted by SCDOT to complete all aerial mapping projects. All aerial mapping must be under the direct supervision of and certified by a registered **South Carolina Professional Land Surveyor (lidar only)** or a registered **South Carolina Professional Photogrammetric Surveyor (imagery and lidar)**.

2.01 AERIAL PHOTOGRAMMETRY – GENERAL

Historically, SCDOT used aerial mapping methods on all interstate highways and high traffic volume highways to minimize traffic exposure of field survey crew personnel, avoid travel lane closures, and meet the project's schedule. Currently, SCDOT requires both aerial photogrammetry and aerial lidar on current aerial mapping projects.

Manual of Photogrammetry, 4th Ed., ASPRS (1980): "Photogrammetry is the art, science, and technology of obtaining reliable information about physical objects and the environment through processes of recording, measuring, and interpreting photographic images and patterns of electromagnetic radiant energy and other phenomena."

ASPRS Guidelines for Procurement of Geospatial Mapping Products and Services (2014): "Professional geospatial mapping services utilize Geomatics, photogrammetry, and related remote sensing technologies and/or GIS to produce geospatial mapping deliverables and information for which there is an expectation or representation of reliable spatial accuracy, thematic accuracy, or content."

South Carolina Code of Regulations Chapter 49 (Labor, Licensing and Regulation for Professional Engineers and Land Surveyors) Section 460-E (2012): "Airborne and spaceborne surveys are defined as the use of photogrammetry, LIDAR, IFSAR, or other similar measurement technologies for obtaining reliable information about physical objects and the environment, including terrain surface, through the process of recording, measuring, and interpreting images and patterns of electromagnetic radiant energy and other phenomena. This Rule establishes minimum allowable photogrammetric production procedures and standards for photogrammetric mapping and digital data production."

South Carolina Code of Laws (Professionals and Occupations) S.C. Code Ann. §40-22-20 (26-b) (2016): **"**A photogrammetric surveyor [SCPPS] determines the configuration or contour of the earth's surface or the position of fixed objects on the earth's surface by applying the principles of mathematics on remotely sensed data, such as photogrammetry."

Advantages of Aerial Photogrammetry as compared to conventional surveys

1. Photographs provide a dated permanent record of existing conditions.
2. Photographs give a detailed spatial perspective of ground features.
3. Ortho-rectified photographs can be used to measure 2D ground features.
4. Efficiency and costs savings as compared to traditional ground surveying methods.
5. Mapping in locations that are difficult or impossible to access from the ground.
6. Significantly reduces field crew exposure to high volume traffic highways.

Disadvantages of Aerial Photogrammetry as compared to conventional surveys

1. Seasonal conditions (vegetation, shadows, etc.) affect data acquisition and mapping.
2. Mapping of planimetric (2D) features is a function of image resolution.
3. Obscured areas, underground utilities, Right-of-Way boundaries, property boundaries, and small features cannot be mapped.
4. Digital imagery file sizes are very large requiring dedicated digital storage.

2.02 AERIAL LIDAR – GENERAL

SCDOT began using aerial lidar data for roadway design in **year (2012).** SCDOT requires a combination of both aerial photogrammetry and aerial lidar on current aerial mapping projects.

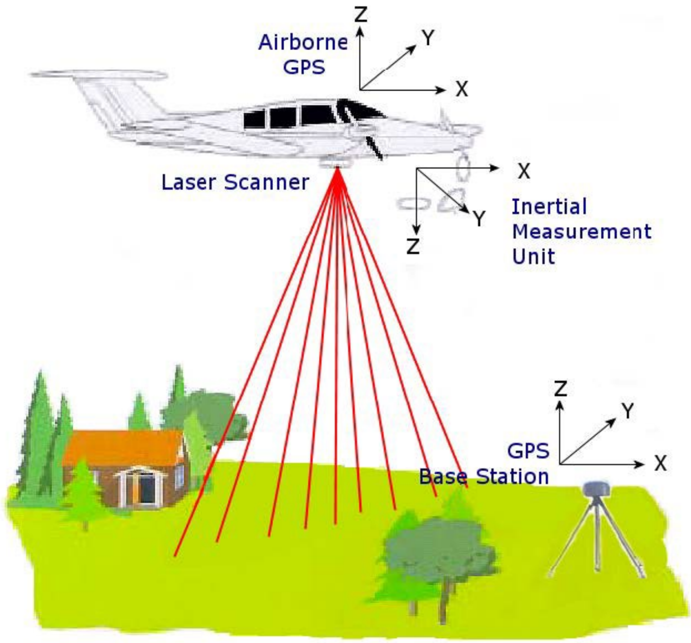


Figure 1 Example Aerial Lidar (FHWA, 2018)

"LiDAR is collected using a **laser that measures distance** to an object by emitting timed pulses and measuring the time between emission and reception of reflected pulses. The measured time interval is converted to a distance. Modern LiDAR sensors are capable of recording several returns per pulse. Multiple returns occur when the beam footprint strikes multiple targets before terminating. The sequence of returns from a single pulse, (For example, first, 2nd, 3rd, last or first and last), is also recorded along with an intensity value." (CDOT, 2015).

"**AGPS and IMU data are collected on board the aircraft during flight**. [AGPS and IMU data are also used during photogrammetric flights.] Base station information must be collected on the ground during the flight mission. These data provide the input necessary to provide initial geo-referencing. Swath-to-swath calibration is then performed to refine the relative accuracy of the resulting point cloud. To achieve high levels of accuracy and quality control, application of ground control is applied in the data calibration process. Elevation data is converted from ellipsoid to orthometric values, completing the process. " (CDOT, 2015).

"A **classification** process follows which identifies the type of return, (for example bare-earth, water, vegetation, structure, etc.). The classification process typically includes automated and a final manual editing process. The automated classification routines are best accomplished with highly sophisticated software that provide for user inputs that modify algorithms for different return densities and land cover types. A final manual editing process is necessary to assure the required quality level of the data point classification. The end result produces the coordinate (X, Y, and Z) position for each return, called a point cloud. Point clouds can be used to generate a DTM, DEM, vegetation clouds or may be used as a source from which to extract planimetric map features." (CDOT, 2015)

Advantages of Aerial Lidar as compared to conventional surveys

1. Lidar provides a dated permanent record of existing conditions.
2. Lidar point clouds are flexible mapping data with multiple post data acquisition uses.
3. Efficiency and cost savings compared to traditional ground surveying methods.
4. Mapping in locations that are difficult or impossible to access from the ground.
5. "LiDAR is more successful than photogrammetric methods at achieving ground returns in vegetated areas. As a rule, if any sky can be seen when looking straight up from ground level, some ground returns can be expected." (CDOT, 2015)
6. Significantly reduces field crew exposure to vehicles on high volume traffic interstates and highways.

Disadvantages of Aerial Lidar as compared to conventional surveys

1. Aerial lidar does not accurately determine depths of turbid non-shallow standing or flowing water. Outfall ditches, creeks, ponds, lakes, and rivers will need conventional field survey or sonar bathymetric mapping to accurately determine depth.
2. Dense ground cover can give false "bare earth" laser returns resulting in a less accurate ground terrain surface model.
3. "Depending on the density of the [point cloud] data set, without the aid of photogrammetry, identification of planimetric features can be difficult, (e.g. curb and gutter, hydrants, manholes, small road signs, etc.) Since it is an aerial view, size of culverts may be difficult if not at all possible along with any other feature that cannot be seen or measured from above." (CDOT, 2015)
4. Obscured areas, underground utilities, Right-of-way boundaries, property boundaries, and small features cannot be mapped.
5. Lidar data file sizes are very large requiring dedicated digital storage.
6. Feature details (type of material) can be difficult to interpret from aerial lidar data.

2.03 AERIAL MAPPING ACCURACY REQUIREMENTS

SCDOT uses the American Society for Photogrammetry and Remote Sensing (ASPRS) Root Mean Square Error (RMSEx,y,r) threshold horizontal accuracy classes for digital orthoimagery and aerial digital planimetric data. The ASPRS RMSEz threshold vertical accuracy classes (for non-vegitated surfaces) and the 95th Percentile vertical statistic (for vegetated surfaces) are used for the aerial digital elevation data.

The accuracy of the aerial lidar DTM mapping data over the bare earth paved roads should meet the **ASPRS Non-Vegetated Vertical Accuracy (NVA) class** of **0.10'** (or 3.05-cm). The ASPRS NVA vertical accuracy class is expressed as **RMSEz** over non-vegetated surfaces and should be met for all paved (non-vegetated) surfaces. A note must indicate mapping areas where the vertical error exceeds RMSEz 0.10' (or 3.05-cm) for paved (non-vegetated) surfaces. The accuracy of the lidar DTM data over the bare earth of vegetated ground surfaces should meet the **ASPRS Vegetated Vertical Accuracy (VVA) class** of **0.69'** (or 21.0-cm). The ASPRS VVA vertical accuracy class is expressed as the 95th Percentile error statistic over all vegetated surface types (short grass, weeds and crops, brush lands, and fully forested). A note must indicate mapping areas where the vertical error exceeds the 0.69' (or 21.0-cm) 95th Percentile error for vegetated surfaces. The horizontal accuracy for all un-obscured planimetric mapping should meet the **ASPRS horizontal (x,y) accuracy class** of **0.50'** (15.24-cm). The ASPRS horizontal accuracy class is expressed as **RMSExy** on un-obscured planimetric features. The RMSE (root mean square error) and/or 95% confidence level statistic as described in the **ASPRS Positional Accuracy Standards for Digital Geospatial Data, Edition 1, Version 1.0, November, 2014** is used by the SCDOT for field verification of the delivered mapping data.

A **specific project's** aerial mapping accuracy requirements could vary from those listed above, and should be used when developing the aerial mapping plan.

2.04 AERIAL GROUND CONTROL POINTS

The ground control **panel points** must be set to control the entire mapping area. The majority of the ground control panel points must be set on hard surfaces within the mapping area with the exception of locations where hard surfaces do not exist. A permanent marker must be placed at the surveyed location of the panel points: PK nail (hard surface) or rebar (non-hard surface). Where permissible, paint is recommended for ground control panel points set on hard surfaces. If thermoplastic pavement marking tape is used, then sufficient pavement preparation is recommended for good adhesion to the pavement surface.

Figure 2 Example Painted Panel (US Highway 76)

Photo identification points (PIDs) can be substituted for panel points provided the PIDs have a well-defined visible point in the aerial imagery and/or lidar data. PIDs examples include sidewalk intersections, concrete slab corners, existing paint marks on asphalt or other clearly visible features.

Figure 3 Example PIDs (US Highway 501)

The consultant is responsible for the **location, dimensions, material and configuration** of the aerial ground control panel points and PIDs which must achieve the project's accuracy specifications.

The horizontal (x,y) coordinates and vertical (z) elevation of all mapping ground control points must be tied to the **project's Primary and Main survey control**. The **vertical and horizontal accuracy** of the mapping ground control points must be sufficient to support the specified accuracy of the aerial mapping project. SCDOT recommends the **ASPRS Positional Accuracy Standards for Digital Geospatial Data, Edition 1, Version 1.0, November, 2014** when determining the vertical and horizontal accuracy of aerial mapping ground control points.

The consultant will determine the aerial **ground control point spacing** which must achieve the project accuracy with ground control panel points and/or PIDs not exceeding a **maximum** spacing of **1500'** when feasible.

2.05 AERIAL DATA ACQUISITION

2.05.01 RGB Vertical Aerial Imagery (Non-Oblique)

Depending on the project specifications, the consultant must design a flight layout that is suitable for either a **0.083'** (or 2.54-cm) or **0.25'** (or 7.62-cm) average spatial image resolution (pixel size) for the digital ortho-rectified photographs. (An ortho-rectified photograph is an aerial photograph of uniform scale which has been geometrically corrected (for terrain relief displacement, optical sensor distortions, and sensor orientation variables) to measure true distances of features within the photograph.)

"When producing digital orthoimagery, the Ground Sample Distance (GSD) as acquired by the sensor (and as computed at mean average terrain) should not be more than **95% of the final orthoimage pixel size**." (ASPRS Positional, 2014).

Orthophotos should be rectified using ground elevations which will result in any **elevated features** (tops of buildings, power lines, top of signs, etc.) being radially displaced from their true location.

RGB color imagery must be acquired with the sun angle being 30 degrees or higher above the horizon and skies free of haze, clouds, and smoke. **Optimal dates** for South Carolina (varies depending on location within state):

November 10th – 20th (leaf off) thru **December 4th – 15th** (sun angle >30°)

January 4th - 18th (sun angle >30°) thru **March 15th – 30th** (leaf on)

The imagery must be collected at a **minimum of 60% forward overlap - 30% side lap**, and must not contain any excessive **tip, tilt, crab or cloud cover**. (Tip and Tilt are the angular differences of the camera's optical axis and the vertical nadir point; Crab is the angular difference between direction of flight and the orthogonal orientation of the images.)

In areas where water bodies are under **tidal influence**, aerial photography must be acquired within a time not to vary by more than 2 hours from the time of low tide.

All **flight plans** must be designed and approved by a Certified Photogrammetrist prior to acquisition.

The RGB aerial imagery is typically acquired simultaneously with an industry standard **airborne position and orientation system (POS)** which uses both an inertial navigation system (INS) and a global navigation satellite system (GNSS). The POS and ground control contributes to accurate photo center positioning which assists in the aerial triangulation (AT) of the entire block of images. **It is understood the method of aerial triangulation is a professional decision**, and the statement above should not constrain the Photogrammetrist to use POS if use of ground control points and tie points offer a better solution for the final digital aerial triangulation.

The consultant must provide SCDOT a completed **Aerial Mapping Plan** prior to data acquisition (see appendix for Aerial Mapping Plan form).

2.05.02 Aerial Lidar

The consultant must acquire the airborne Light Detection and Ranging (lidar) scan data with an industry standard **Airborne Laser Scanner (ALS)** capable of achieving the project accuracy specifications.

The airborne lidar scanning data must be acquired simultaneously with an industry standard **airborne position and orientation system (POS)** which uses both an inertial navigation system (INS) and a global navigation satellite system (GNSS) while simultaneously collecting ground based GNSS data to be used for post processing. Unless specified for the project, the post processed airborne laser scan data must use the ground control panel points for transformation and/or verification of the point cloud transformation to the project's survey control datum.

"**Horizontal error** in [lidar] derived elevation data is largely a function of positional error as derived from the Global Navigation Satellite System (GNSS), attitude (angular orientation) error (as derived from the INS) and flying altitude; and can be estimated based on these parameters." (ASPRS Positional, 2014).

Positional Accuracy of the lidar data must be validated "prior to classification and development of derivative products from the point data, the absolute and relative vertical accuracy of the point data shall be verified" (USGS, 2019)

The **Intra-swath** precision (smooth surface precision) and the **Inter-swath** (overlap) consistency must be sufficient to eliminate gaps in coverage and achieve the project's specified mapping accuracy standards.

The ALS and flight plan must generate a minimum nominal point density of **15 points/m^2**.

The consultant must provide SCDOT a completed **Aerial Mapping Plan** prior to data acquisition (see appendix for Aerial Mapping Plan form).

2.06 AERIAL MAPPING DATA PROCESSING

Lidar flights must be calibrated to each other and to the ground control points.

A **lidar statistics report** showing delta "z" elevation residuals and ASPRS RMSEz must be produced to ensure the accuracy of the laser hits vs. ground control check panels and ground validation points.

If specified for individual projects, the consultant must use lidar processing software to classify all lidar data into a **bare earth model** and output other lidar classes.

The consultant must perform a rigorous **orthophoto rectification** of all imagery. The rectified orthophotos must have a constant scale and all ground features must be presented in their true locations without displacements due to terrain relief and camera orientation variables.

The consultant must provide a digitally ortho-rectified **mosaic(s)** of the project area in both a **TIF** and **SID** format.

2.07 DIGITAL AERIAL TRIANGULATION

Aerial Triangulation (AT) (or aerotriangulation) is "The process for the extension of horizontal and/or vertical control whereby the measurements of angles and/or distances on overlapping photographs are related into a spatial solution using the perspective principles of the photographs". (Manual of Photogrammetry, 4th Ed., ASPRS, 1980).

Analytical Aerial Triangulation (AT) methods and procedures must be used to extend and densify the ground control points, and establish the photo control required for photogrammetric map compilation. Analytical Aerial Triangulation uses mathematical equations (typically collinearity equations) to solve the unknown orientation variables (camera constants, measured photo coordinates, and ground coordinates). This mathematical solution relates the internal (photo) orientation to the external (ground) orientation enabling the calculation of ground object coordinates from photographs. (Elements of Photogrammetry with Application in GIS, Fourth Edition, 2014).

"Camera calibration establishes the **interior orientation parameters** for each lens cone of a metric camera, and aerial triangulation (AT) establishes the exterior orientation parameters for each photograph or digital image as well as absolute orientation of all stereo models to fit ground control." (USACE, 2015).

The consultant must precisely perform softcopy (digital image) analytical aerial triangulation using the surveyed ground control panel points for the **final exterior orientation transformation**.

The airborne position and orientation system (POS) data collected during the photography mission can be used to assist in positioning of the camera at the instant of image exposure, and treated as an additional observation to be "adjusted" in the course of the photogrammetric process. (Surdex, 2008).

Tie point matching must be performed on all image areas to best contribute to the strength and quality of the image block.

The consultant must follow accepted softcopy aerial triangulation procedures and utilize equipment that will achieve the aerial triangulation accuracy required to meet or exceed orthophoto accuracy standards.

SCDOT recommends the **ASPRS Positional Accuracy Standards for Digital Geospatial Data, Edition 1, Version 1.0, November, 2014** when determining the vertical and horizontal accuracy of aerial triangulation and INS-based sensor orientation of digital imagery. "For photogrammetric data sets, the aerial triangulation and/or INS-based direct orientation accuracies must be of higher accuracy than is needed for the final, derived products." (ASPRS Positional, 2014).

2.08 MAPPING AND DIGITAL TERRAIN MODELS

All mapping must be furnished by the consultant as **Planimetric (2D)** and **Digital Terrain Model (3D)** digital mapping files. Both the planimetric and digital terrain model features must be placed on separate, segregated CADD levels as specified by the SCDOT. Digital terrain model data must be submitted with spot elevations and break lines placed on separate CADD levels. Break lines representing the edge of pavement, curb and gutter, sidewalks or raised medians must be placed on a CADD level separate from all other break lines.

All **aerial ground control points and PIDs** must be shown with identification number in the final planimetric (2D) mapping file.

All digital files must be fully compatible with the **SCDOT's CADD software system**. (Refer to the latest SCDOT Roadway CADD Manual.)

For the State of South Carolina, the conversion from meters to feet is based on the **International Foot** (1 meter = 3.2808398950131 foot or 1 foot = 0.3048 meter).

The consultant must use the **SCDOT's CADD standard level scheme and cell library**. (Refer to the latest SCDOT Roadway CADD Manual.) The SCDOT CADD standard **base level scheme** for existing features is "**RD_EX_**". SCDOT adds to the base level scheme for specific **feature categories** (example for existing building line: RD_EX_**Bldg**). For aerial mapping projects, these standard feature categories can be expanded for better clarification (example: RD_EX_Bldg_**Canopy**). Labels can also be used for further clarification when mapping features.

Obscured Areas must be identified in the digital files with a closed polygon feature and labeled "Obscure Area".

2.09 AERIAL MAPPING ACCURACY SUMMARY

2.09.01 Aerial Planimetric and Aerial Lidar Mapping Accuracy

Horizontal Accuracy Class	Accuracy to Project Survey Control Network			Orthoimagery Mosaic Seamline Mismatch
	RMSEx and RMSEy	RMSEr	Horizontal Accuracy at 95% Confidence Level	
0.50’ (15.24cm)	**≤0.50’ (15.24cm)**	**≤0.71’ (21.64cm)**	**≤1.22’ (37.19cm)**	**≤1.0’ (30.48cm)**
X	≤X	≤1.414*X	≤2.448*X	≤2*X

Vertical Accuracy Class	Accuracy to Project Survey Control Network			Relative Accuracy (where applicable) (note 1)		
	RMSEz Non-Vegetated	NVA at 95% Confidence Level	VVA at 95th Percentile (note 2)	Within-Swath Hard Surface Repeatability (Max Diff)	Swath-to-Swath Non-Vegetated Terrain (RMSDz)	Swath-to-Swath Non-Vegetated Terrain (Max Diff)
0.10’ (3.05cm)	**≤0.10’ (3.05cm)**	**≤0.196’ (5.97cm)**	**≤0.69’ (21.03cm)**	**≤0.06’ (1.83cm) (note 3)**	**≤0.08’ (2.44cm) (note 4)**	**≤0.16’ (4.88cm) (note 5)**
X	≤X	≤1.96*X	≤0.69’	≤0.60*X	≤0.80*X	≤1.60*X

Note 1: “Relative accuracy assessment characterizes the internal geometric quality of an elevation data set without regard to surveyed ground control.” (ASPRS Positional, 2014).

Note 2: SCDOT uses a vertical VVA 95th percentile of 0.69’ derived from verification results of past aerial mapping projects by various Consultants. These Consultants used various sensors and mapping plans. Summary of verification results of varying surface types:
Non-mowed Short Grass: (12) projects (total sample size = 914 points) with a total % weighted average of the 95th percentile = 0.50’.
Tall Grass & brush: (7) projects (total sample size = 385 points) with a total % weighted average of the 95th percentile = 0.64’.
Wooded: (9) projects (total sample size = 547 points) with a total % weighted average of the 95th percentile = 0.94’.

Note 3: Within-swath relative accuracy (smooth surface repeatability) is associated with lidar elevation data. “Suitable test areas will have produced only single return lidar points and will not include abrupt changes in reflectivity (e.g., large paint stripes, shifts between black asphalt and white concrete, etc.), as these may induce elevation shifts that could skew the assessment.” (ASPRS Positional, 2014).

Note 4: Root-mean-square-difference (RMSDz) is calculated using the RMS differences between the overlapping lidar swaths because neither swath represents an independent source of higher accuracy. (ASPRS Positional, 2014).

Note 5: “Swath-to-swath relative accuracy is assessed by comparing the elevations of overlapping swaths. As with within-swath accuracy assessment, the comparisons are performed in areas producing only single return lidar points. Elevations are extracted at checkpoint locations from each of the overlapping swaths and computing the root-mean-square-difference (RMSDz) of the residuals. ” (ASPRS Positional, 2014).

2.09.02 Aerial Ground Control Point Accuracy for Aerial Triangulation and Lidar

Mapping Type	Mapping Horizontal Accuracy RMSEx RMSEy	Mapping Vertical Accuracy RMSEz(DEM)	Ground Control Horizontal Accuracy RMSEx RMSEy	Ground Control Vertical Accuracy RMSEz
Planimetric Data Only	**≤0.50’ (15.24cm)**	**N/A**	**≤0.125’ (3.81cm) RMSEx RMSEy ≈0.18’ (5.49cm) RMSEr Aerial Triangulation**	**≤0.25’ (7.62cm) Aerial Triangulation**
Planimetric and Elevation Data	**≤0.50’ (15.24cm)**	**≤0.10’ (3.05cm)**	**≤0.125’ (3.81cm) RMSEx RMSEy ≈0.18’ (5.49cm) RMSEr Aerial Triangulation**	**≤0.025’ (0.76cm) Lidar**
Planimetric Data Only	RMSEx(map) RMSEy(map)	N/A	≤1/4 * RMSEx(map) ≤1/4 * RMSEy(map) Aerial Triangulation	≤1/2 * RMSEx(map) ≤1/2 * RMSEy(map) Aerial Triangulation
Planimetric and Elevation Data	RMSEx(map) RMSEy(map)	RMSEz(DEM)	≤1/4 * RMSEx(map) ≤1/4 * RMSEy(map) Aerial Triangulation	≤1/4 * RMSEz(DEM) Lidar

General Note 1: Accuracies follow the specifications shown in ASPRS Positional Accuracy Standards for Digital Geospatial Data, Edition 1, Version 1.0, November, 2014.

General Note 2: Mapping Accuracy – Accuracy of project specified final delivered mapping products.

General Note 3: Planimetric Data Only - Accuracy of ground control designed for planimetric data (orthoimagery and/or digital planimetric map) production only.

General Note 4: Planimetric and Elevation Data - Accuracy of ground control designed for elevation data, or planimetric data and elevation data production.

General Note 5: The pixel size of the final digital orthoimagery is used to associate the horizontal accuracies shown, not the Ground Sample Distance (GSD) of the raw image.

Panel Point and/or PIDs Location, Type, and Spacing
The **consultant** is responsible for the **location, dimensions, material, and configuration** of the aerial ground control panel points and PIDs which must achieve the project's accuracy specifications.
The **consultant** will determine the aerial **ground control point spacing** which must achieve the project accuracy with ground control panel points and/or PIDs not exceeding a **maximum** spacing of **1500' when feasible**.

2.09.03 Aerial Triangulation Accuracy

Mapping Type	Mapping Horizontal Accuracy RMSEx RMSEy	Mapping Vertical Accuracy RMSEz(DEM)	Aerial Triangulation Horizontal Limits RMSEx RMSEy	Aerial Triangulation Vertical Limits RMSEz
Planimetric Data Only	**≤0.50' (15.24cm)**	**N/A**	**≤0.25' (7.62cm) RMSEx RMSEy ≈0.35' (10.67cm) RMSEr**	**≤0.50' (15.24cm)**
Planimetric and Elevation Data	**≤0.50' (15.24cm)**	**≤0.10' (3.05cm)**	**≤0.25' (7.62cm) ≈0.35' (10.67cm) RMSEr**	**≤0.05' (1.52cm)**
Planimetric Data Only	RMSEx(map) RMSEy(map)	N/A	≤1/2 * RMSEx(map) ≤1/2 * RMSEy(map)	≤ RMSEx(map) or RMSEy(map)
Planimetric and Elevation Data	RMSEx(map) RMSEy(map)	RMSEz(DEM)	≤1/2 * RMSEx(map) ≤1/2 * RMSEy(map)	≤1/2 * RMSEz(DEM)

General Note 1: "For INS-based direct orientation, image orientation angles quality shall be evaluated by comparing checkpoint coordinates read from the imagery (using stereo photogrammetric measurements or other appropriate method) to the coordinates of the checkpoint as determined from higher accuracy source data." (ASPRS Positional, 2014).

2.09.04 Aerial Imagery Specifications

Project specified **RGB 0.083'** (or 2.54-cm) <u>or</u> **RGB 0.25'** (or 7.62-cm) average spatial image resolution (pixel size) for the **digital ortho-rectified photographs**.
"When producing digital orthoimagery, the **Ground Sample Distance (GSD)** as acquired by the sensor (and as computed at mean average terrain) **should not be more than 95% of the final orthoimage pixel size**." (ASPRS Positional, 2014)
Optimal dates for South Carolina (varies depending on location within state): **November 10th – 20th (leaf off)** thru **December 4th – 15th (sun angle >30°)** **January 4th - 18th (sun angle >30°)** thru **March 15th – 30th (leaf on)**
The imagery must be collected at a **minimum of 60% forward overlap - 30% side lap**, and must not contain any excessive tip, tilt, crab or cloud cover.
In areas where water bodies are under **tidal influence**, aerial photography must be acquired within a **time not to vary by more than 2 hours from the time of low tide.**
The consultant must provide SCDOT a completed **Aerial Mapping Plan** prior to data acquisition

2.10 AERIAL MAPPING REPORT

The information below must be provided in the aerial mapping report:

Project Overview

1. Project ID, Road Number and County.
2. Consultant Company Name, Address and Phone Number.
3. Photogrammetrist for image and lidar (SCPPS license number) or Professional Land Surveyor for lidar only (SCPLS license number) in responsible charge of mapping project.
4. Length of project mapped in miles.

Acquisition

1. Camera
    a. Owner.
    b. Manufacturer.
    c. Model and Serial Number.
    d. CCD Element Size (um).
    e. Focal Length.
    f. Calibration Date.
    g. Platform (fixed wing, rotary, uav).
2. Lidar
    a. Owner.
    b. Manufacturer.
    c. Model and Serial Number.
    d. Platform (fixed wing, rotary, uav).
3. POS (GNSS-IMU system)
    a. Manufacturer.
    b. Model and Serial Number.
4. Average AGL (Image and lidar).
5. Total Flight Lines (Image and lidar).
6. Total Exposures.
7. Date(s) and weather conditions of Acquisition.

Final Aerial Triangulation (AT) results:

1. Software.
2. Number of Ground Control Points used in final adjustment.
3. Number of Check Points.
4. Statistics for Ground Control Points
    a. Maximum Delta, Minimum Delta RMSEx,y,z.
    b. Ground Control Point RMSEx.
    c. Ground Control Point RMSEy.
    d. Ground Control Point RMSEz.

Overall Adjustment Sigma (microns).

Lidar

1. Software.
2. Number of Ground Control Points.
3. Control Point list (Northing, Easting, Control Point z, z from lidar).
4. Statistics for Control Points
    a. Maximum and Minimum delta z (elevation difference) of control points.
    b. Delta z (elevation difference) for each control point.
    c. RMSEz and Accuracy at 95% confidence (RMSEz x 1.96) for project.
5. Lidar Point Density as collected (points/m^2).

Ortho-imagery

1. GSD of Raw Image.
2. Pixel size of final ortho-image.

Ground Control (panels, PIDs)

1. A description of the field survey methods used to establish the aerial ground control points.
2. Aerial ground control panel point/PIDs identification number.
3. Northing and Easting coordinate.
4. Elevation.
5. Point type description.
6. Project's Primary and Main survey control used to establish the Ground Control Points to include the project's horizontal and vertical datums.

Certification

A certificate, substantially in the following form, must be affixed to all maps or reports to include the seal and signature of the Photogrammetrist in responsible charge of the mapping project:

''I hereby state that to the best of my professional knowledge, information, and belief, that this Photogrammetric [or for Land Surveyor '*lidar only'] project was performed in accordance with the requirements of the Standards of Practice Manual for Surveying in South Carolina, and meets or exceeds the requirements as specified therein and meets or exceeds this project's accuracy specifications.''* (S.C. Code Ann. Section 40-22-2, et seq.; 26 S.C. Code Ann. Regs. Chapter 49 (1991 as amended)).

2.11 AERIAL MAPPING DELIVERABLES

Surveying and mapping consultants must deliver files to the SCDOT that are compatible with the latest SCDOT's CADD and Plan Development Process. SCDOT Roadway Projects are assigned Project ID Numbers. All files submitted by the consultant must be referenced to a Project ID. The types of files and naming conventions are listed below, and are examples of some of the files that might be requested by the SCDOT. **The examples shown below assume a Project ID number of "P012345"**.

An electronic copy of any digital data set delivered to the SCDOT must be retained in the permanent files of the licensee. The term "Bentley" as used in this manual refers to a native Bentley digital data format. Refer to the latest SCDOT Roadway CADD Manual for current format requirements.

12345 aerial report.pdf	**PDF format**, signed and sealed by licensee.
12345_aerial.txt	ASCII comma delineated file of **ground control points**.
r12345pp_aerial.dgn	**2D** Bentley file containing all **planimetric** mapping.
12345dtm_aerial.dgn	**3D** Bentley file with all **breaklines and spot elevations**.
12345dtm_aerial_bridge.dgn	**3D** Bentley file of **bridge deck**.
12345_aerial.tin	Digital Terrain Model (**bare earth**).
12345_aerial_bridge.tin	Digital Terrain Model (**bridge deck**).
12345_aerial_.las	**Bare Earth** LAS files (and other classifications if requested).
12345_aerial_bridge.las	**Bridge** LAS file.
12345_[image number].tif	TIF **orthophoto** images.
12345_[image number].tfw	Geographic world file.

<u>Compressed Image File(s)</u>

12345_[image number].sid or .ecw	SID or ECW compressed **orthophoto** images.
12345_[image number].sdw or .eww	Geographic world file.
12345_mosaic.sid or .ecw	SID or ECW **mosaic** image.
12345_mosaic.sdw or .eww	Geographic world file.

3.0 MOBILE LIDAR MAPPING

Mobile lidar mapping uses various sensors to collect data remotely from a ground based moving platform. This data is then used to create final digital maps of the existing (3D) pavement terrain surface and the roadway/roadside planimetric (2D) features. These final digital maps are then provided to the transportation design engineers. The following sections are provided as general information and can change for specific projects. Unless specified otherwise, the mobile lidar mapping must comply with applicable sections of the **ASPRS Positional Accuracy Standards for Digital Geospatial Data (Edition 1, Version 1.0. - November, 2014)** and the **NCHRP Report 748, Guidelines for the Use of Mobile LIDAR in Transportation Applications**.

Consultants are contracted by SCDOT to complete all mobile lidar mapping projects. All mobile lidar mapping must be under the direct supervision of and certified by a registered **South Carolina Professional Land Surveyor (lidar only)** or a registered **South Carolina Professional Photogrammetric Surveyor (imagery and lidar).**

3.01 MOBILE LIDAR – GENERAL

Historically, SCDOT began using mobile lidar mapping methods in **year (2017)** on interstate highways and high traffic volume highways to maximize field survey crew safety by limiting roadway traffic exposure, avoiding travel lane closures, and improving project delivery schedules.

"**Mobile LIDAR** uses laser scanning equipment mounted on vehicles in combination with global positioning systems (GPS) and inertial measurement units (IMU) to rapidly and safely capture large datasets necessary to create highly accurate, high resolution digital representations of roadways and their surroundings." (NCHRP, 2013).

"**Mobile lidar** and imagery systems typically use a single or dual laser sensor configuration for 3D point cloud collection, a single or dual GNSS receiver configuration for 4D positioning (x, y, z, and time), an inertial measurement unit (IMU), a distance measuring instrument (DMI) for movement compensation and positional tracking during GNSS gaps, and an array of cameras to capture images along the route which can be georeferenced to the point cloud data." (ESP, 2020).

"The [**mobile lidar**] collects laser measurement data continuously throughout each [mobile lidar] run. The position and orientation of the scanner(s) are determined using a combination of data from GNSS, an inertial measurement unit (IMU), and possibly other sensors, such as precise odometers [DMI]. An IMU uses a computer, motion sensors (accelerometers) and rotation sensors (gyroscopes) to continuously calculate and record the position, orientation, and velocity (direction and speed) of a moving object without the need for external reference. Within the [mobile lidar] the IMU is used to calculate change of XYZ position and orientation (roll, pitch and yaw) of the sensor array between GNSS observations, and during periods of reduced or no GNSS reception. By combining the laser range, scan angle, scanner position and orientation of the platform from GNSS and IMU data, highly accurate XYZ coordinates of the point scanned by each laser pulse can be calculated." (CALTRANS, 2011).

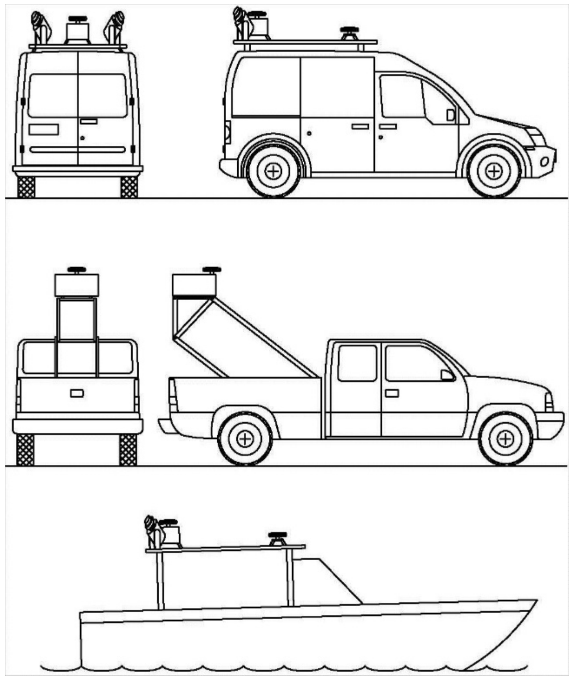


Figure 4 Scanning Platforms (CALTRANS, 2011)

Advantages of Mobile Lidar Mapping as compared to conventional surveys

1. Lidar provides a dated permanent record of existing conditions.
2. Lidar point clouds are flexible mapping data with multiple uses post data acquisition.
3. Provides a denser data set of highly accurate and precise x,y,z points compared to conventional survey methods.
4. Significantly reduces field crew exposure to vehicles on high volume traffic interstates and highways.
5. Increases the efficiency of large-scale high-accuracy mapping projects.
6. Efficiently collect overhead objects such as clearance.

Disadvantages of Mobile Lidar Mapping as compared to conventional surveys

1. Mobile lidar does not accurately determine depths of turbid non-shallow standing or flowing water. Outfall ditches, creeks, ponds, lakes, and rivers must use conventional field survey or sonar bathymetric mapping to accurately determine depth.
2. Dense ground cover can give false "bare earth" laser returns resulting in a less accurate ground terrain surface model.
3. Obscured areas, underground utilities, Right-of-way boundaries and property boundaries cannot be mapped.
4. Lidar data file sizes are very large requiring dedicated digital storage.
5. "High incidence angles result in poor intersection geometry and affect the range measurement precision" (MDPI ISSN 2072-4292, 2011). (See figure below). This incidence angle limits the lateral distance from the mobile lidar sensor for acquisition of reliable quality lidar bare earth data when transverse drive lines are not feasible.

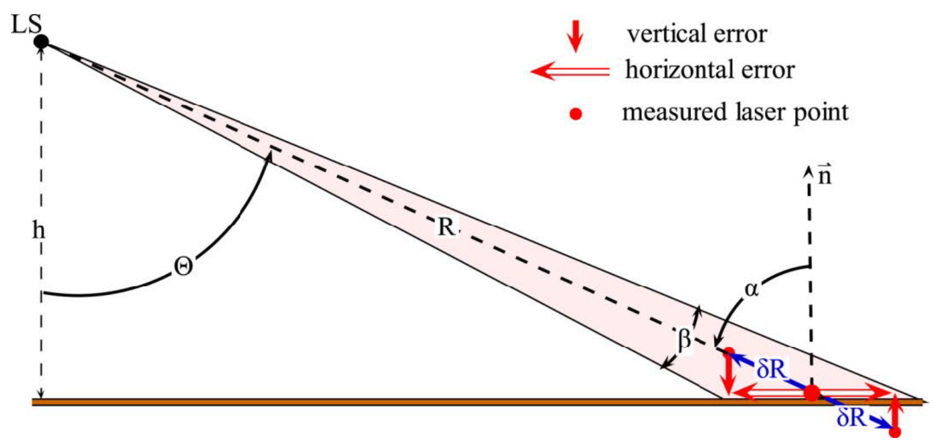


Figure 5 Incident Error (MDPI ISSN 2072-4292, 2011)

3.02 MOBILE LIDAR MAPPING ACCURACY REQUIREMENTS

SCDOT uses the American Society for Photogrammetry and Remote Sensing (ASPRS) Root Mean Square Error (RMSE) threshold accuracy classes for mobile lidar digital planimetric data and mobile lidar digital elevation data.

For paved (asphalt and concrete) surfaces the accuracy of the Mobile lidar DTM mapping data over the bare earth paved roads should meet the **ASPRS Non-Vegetated Accuracy (NVA) class** of either **0.025'** (or 0.76-cm) or **0.05'** (or 1.52-cm) depending of project specifications. The ASPRS NVA vertical accuracy class is expressed as **RMSEz** over non-vegetated surfaces and should be met for all paved (non-vegetated) surfaces. A note must indicate mapping areas where the vertical error exceeds RMSEz of either 0.025’ (or 0.76-cm) or 0.05’ (or 1.52-cm), depending on project specifications, for paved (non-vegetated) surfaces. The horizontal accuracy for all planimetric mapping should meet the **ASPRS horizontal (x,y) accuracy class** of **0.20’** (or 6.1-cm). The ASPRS horizontal accuracy class is expressed as **RMSExy** on un-obscured planimetric features. The RMSE (root mean square error) and/or 95% confidence level statistic as described in the **ASPRS Positional Accuracy Standards for Digital Geospatial Data, Edition 1, Version 1.0, November, 2014** is used by the SCDOT for field verification of the delivered mapping data.

A **specific project’s** mobile mapping accuracy requirements could vary from those listed above and should be used when developing the mobile mapping plan.

3.03 MOBILE LIDAR GROUND CONTROL POINTS

The **ground control panel points (targets)** must be set to control the entire mapping area. The majority of the ground control must be set on flat hard surfaces using adhesive traffic marking tape or liquid paint (glass beads recommended for greatest lidar reflectivity), with the exception of locations where hard surfaces do not exist. A permanent marker must be placed at the surveyed location of both the panel points and validation points: PK nail (hard surface) or rebar (non-hard surface).

If thermoplastic pavement marking tape is used, then sufficient pavement preparation is recommended for good adhesion to the pavement surface.

Figure 6 Example Mobile Lidar Ground Control Point

Photo identification points (PIDs) can be substituted for panel points provided the PIDs have a well-defined visible point in the lidar data, and consistencies in painting, material and pavement conditions.

SCDOT recommends a **maximum ground control panel point spacing** of approximately **1500** feet and a **maximum validation point spacing** of approximately **500** feet between panel points be used to achieve the project accuracy, with panel and validation points placed on both sides of the road. If deemed necessary for roads separated by a grass median or barrier wall, sufficient panel points, validation points and/or PIDs can be placed on the inside shoulder to meet the projects accuracy specifications. The consultant is responsible for the **location, dimensions, material and configuration** of the mobile lidar ground control panel points, validation points, and PIDs which must achieve the project's accuracy specifications.

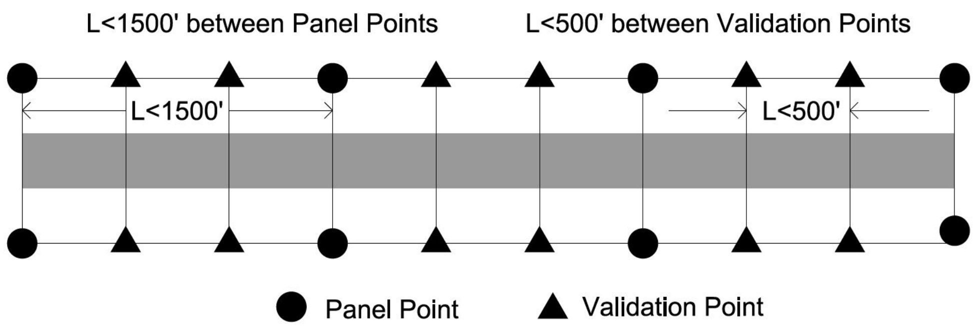


Figure 7 Maximum Panel Point and Validation Point Spacing

The horizontal (x,y) coordinates and vertical (z) elevation of all ground control points must be tied to the **project's Primary and Main survey control**. The **vertical and horizontal accuracy** of the ground control points must be sufficient to support the specified accuracy of the mobile mapping project.

SCDOT recommends the following guidelines derived from the **ASPRS Positional Accuracy Standards for Digital Geospatial Data, Edition 1, Version 1.0, November, 2014** for the accuracy of the panel points, validation points, and PIDs (see Mobile Mapping Summary Table).

3.04 MOBILE LIDAR DATA ACQUISITION

The mobile mapping plan must achieve a minimum of **20% side overlap** of multiple scan passes for point cloud consistency, elimination of gaps, and minimize shadowing.

The mobile lidar scan data must be acquired with an **industry standard Laser Scanner** capable of achieving the project accuracy specifications. The mobile mapping system should include a combination of orientation sensors to include a **Position and Orientation System (POS)** (which should include both an Inertial Measurement Unit (IMU) and a Global Navigation Survey System (GNSS)), ground control, and a **Digital Measurement Instrument (DMI)** when poor or no GNSS signal reception is anticipated.

SCDOT recommends the **GNSS base station(s)** occupy the project's Primary Survey Control network during the mobile lidar mapping session with baselines not exceeding **7 miles**.

Within drivable areas of the projects feature extraction mapping limits, the Mobile Lidar Mapping plan must generate a **minimum point density** of **100 points/m^2** on hard roadway features, and a point density for feature extraction outside the hard roadway features which achieve the project's specified mapping accuracies.

3.05 MOBILE LIDAR MAPPING DATA PROCESSING

The mobile lidar data should be **geo-referenced** using a combination of RTK GNSS or post processed kinematic (PPK) GNSS, Inertial Measurement Unit (IMU), localization to targets, and ground control points surveyed by accurate methods. Available high resolution static laser scan data can be used but is not intended as the primary method of geo-referencing.

If **digital imagery** is used for feature extraction, it must be georeferenced to the point cloud and the extraction methods must meet the final mapping accuracy requirements.

The Mobile Mapping Report must include a **statistics report** showing the delta x,y & z residuals and ASPRS RMSEx,y,z of the laser hits vs. ground control panels, and RMSEz for validation points.

If requested by SCDOT, the Consultant must use lidar processing software to **classify** all lidar data into bare earth and "clean" the remaining point cloud to exclude (vehicles, people, non-stationary objects, etc.). Additional classifications above the bare earth must be provided if requested for specific projects.

3.06 MOBILE LIDAR MAPPING AND DIGITAL TERRAIN MODELS

All visible **planimetric (2D) physical features** deemed to be significant that lie within the Feature Extraction Limits must be mapped and delivered in a native Bentley format using the latest SCDOT CADD standards with a mapping scale of **1"=50'** and typically include the following:

- Outside Edge of the paved shoulder as can be determined.
- Back of Curb, Curb Gutter line and Edge of Curb.
- Bottom edge of Concrete Islands.
- Edge of Sidewalks.
- Painted lines representing the travel lanes.

- Vertical physical features (example: signs, guardrails, etc.) within **10ft** of the edge of the paved shoulder of Interstates, U.S. and S.C. Highways, or within **Mapping Limits** of specific projects.
- Special projects can include Concrete Joints of roadway.

Figure 8 2D Planimetric Features

All **(3D) break lines** as defined by SCDOT and **(3D) features** deemed to be significant must be mapped using Digital Terrain Model (DTM) methods within the Feature Extraction Limits. The resulting mapped (3D) elements must be sufficient for the creation of a pavement bare earth DTM to meet the project accuracy requirements and typically include the following:

- 2.0-foot point grid on pavement surface from Edge of Paved Shoulder to Edge of Paved Shoulder (typical offset of 0.5 to 1.0 feet from extracted Edge of Paved Shoulder, and walls to avoid debris).
- Breaklines associated with visible Edge of Paved Shoulder, roadway crowns, and travel-way break lines, curbing, bottom edge of concrete islands, etc.
- Spot elevations for gaps in break lines, areas of unnoticeable break lines, and high/low points.

Figure 9 Interstate 3D Breakline Features

3D breakline features shown in the figures below are for **illustrative purposes** and these features should be specifically defined in the scope of work feature extraction task.

Figure 10 Interstate 3D Breakline along Reveal Line, Bottom of Reveal at Asphalt Paving, and Top of Wall

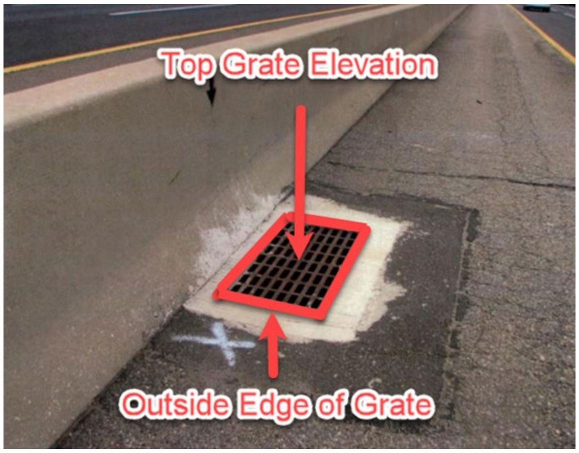


Figure 11 Interstate 3D Breakline along Outside of Grate and Top Center Grate Elevation

The Consultant must extract 2D and 3D features as defined below for **bridges**:

- Bridge Columns (2D shape).
- Bent Cap Centerline (2D line).
- Bridge clearance at lane lines, crown lines and minimum clearance points (3D line).
- Bridge clearance of attachments above all travel lane lines (3D line).
- Special projects could include bridge deck joints (2D) and detailed sub-structure elements (3D models).

Figure 12 Interstate 2D and 3D Features of overpass bridge

3.07 MOBILE LIDAR MAPPING ACCURACY SUMMARY

3.07.01 Mobile Lidar Mapping Accuracy

Horizontal Accuracy Class	Accuracy to Project Survey Control Network		
	RMSEx and RMSEy	RMSEr	Horizontal Accuracy at 95% Confidence Level
0.20’ (6.10cm)	**≤0.20’ (6.10cm)**	**≤0.28’ (8.53cm)**	**≤0.49’ (14.93cm)**
X	≤X	≤1.414*X	≤2.448*X

Vertical Accuracy Class	Accuracy to Project Survey Control Network			Relative Accuracy (where applicable) (note 1)		
	RMSEz Non-Vegetated	NVA at 95% Confidence Level	VVA at 95th Percentile	Within-Swath Hard Surface Repeatability (Max Diff)	Swath-to-Swath Non-Vegetated Terrain (RMSDz)	Swath-to-Swath Non-Vegetated Terrain (Max Diff)
0.05’ (1.52cm)	**≤0.05’ (1.52cm)**	**≤0.10’ (3.05cm)**	**≤0.50’ (15.24cm)**	**≤0.03’ (0.91cm) Note 2**	**≤0.04’ (1.22cm) Note 3**	**≤0.08’ (2.44cm) Note 4**
0.025’ (0.76cm)	**≤0.025’ (0.76cm)**	**≤0.05’ (1.52cm)**	**≤0.50’ (15.24cm)**	**≤0.015’ (0.46cm) (note 2)**	**≤0.02’ (0.61cm) (note 3)**	**≤0.04’ (1.22cm) (note 4)**
X	≤X	≤1.96*X	≤0.50’	≤0.60*X	≤0.80*X	≤1.60*X

Note 1: “Relative accuracy assessment characterizes the internal geometric quality of an elevation data set without regard to surveyed ground control.” (ASPRS Positional, 2014).

Note 2: Within-swath relative accuracy (smooth surface repeatability) is associated with lidar elevation data. “Suitable test areas will have produced only single return lidar points and will not include abrupt changes in reflectivity (e.g., large paint stripes, shifts between black asphalt and white concrete, etc.), as these may induce elevation shifts that could skew the assessment.” (ASPRS Positional, 2014).

Note 3: Root-mean-square-difference (RMSDz) is calculated using the RMS differences between the overlapping lidar swaths because neither swath represents an independent source of higher accuracy. (ASPRS Positional, 2014).

Note 4: “Swath-to-swath relative accuracy is assessed by comparing the elevations of overlapping swaths. As with within-swath accuracy assessment, the comparisons are performed in areas producing only single return lidar points. Elevations are extracted at checkpoint locations from each of the overlapping swaths and computing the root-mean-square-difference (RMSDz) of the residuals. ” (ASPRS Positional, 2014).

3.07.02 Mobile Lidar Mapping Ground Control Point (Target) Accuracy

Mapping Vertical Accuracy RMSEz(DEM)	Mapping Horizontal Accuracy RMSEx RMSEy	Ground Control Horizontal Accuracy RMSEx RMSEy	Ground Control Relative Vertical Accuracy
≤0.05’ (1.52cm)	**≤0.20’ (6.10cm)**	**≤0.10’ (3.05cm) RMSEx RMSEy ≈0.14’ (4.27cm) RMSEr**	**≤0.021’ (0.64cm) relative vertical accuracy between panel points with maximum spacing of 1500ft.**
≤0.025’ (0.76cm)	**≤0.20’ (6.10cm)**	**≤0.10’ (3.05cm) RMSEx RMSEy ≈0.14’ (4.27cm) RMSEr**	**≤0.016’ (0.49cm) relative vertical accuracy between panel points with maximum spacing of 1500ft.**

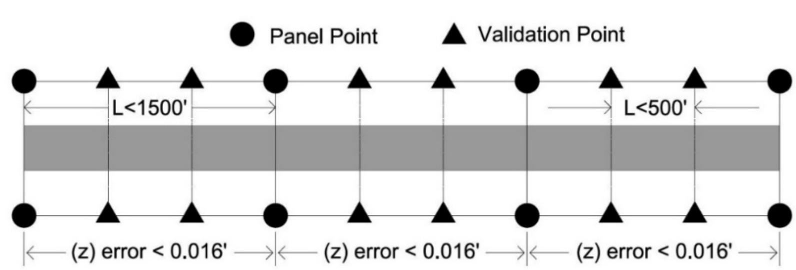


Figure 13 Example Relative Vertical Accuracy for Panel Points (Targets)

3.07.03 Mobile Lidar Mapping General

Minimum **20% Side Over Lap** of multiple scan passes.
Industry Standard Laser Scanner with POS, GNSS, and **DMI** when poor or no GNSS signal reception anticipated.
GNSS Base Station(s) **baselines not to exceed 7 miles.**
Minimum Point Density of **100 points/m2**.

3.08 MOBILE LIDAR MAPPING REPORT

The information below must be provided in the mobile mapping report:

Project Overview

1. Project ID, Road Number and County.
2. Consultant Company Name, Address and Phone Number.
3. Photogrammetrist for image and lidar (SCPPS license number) or Professional Land Surveyor for lidar only (SCPLS license number) in responsible charge of mapping project.
4. Length of project mapped in lane miles.
5. Anomalies encountered during the mobile mapping project.

Acquisition

1. Lidar
    a. Owner.
    b. Manufacturer.
    c. Model and Serial Number.
    d. Platform (car, van, truck, boat).
2. Camera
    a. Owner.
    b. Manufacturer.
    c. Model and Serial Number.
    d. CCD Element Size (um).
    e. Calibration Date.
3. POS (GNSS-IMU system)
    a. Manufacturer.
    b. Model and Serial Number.
4. Total mileage of lidar Drive Lines.
5. Date(s) of Acquisition.

Lidar

1. Processing, Registration, and Extraction Software.
2. Project survey control points used for Base Station setups and maximum baseline length.
3. Number of Ground Control Points (both panel points and validation points).
4. Statistics report of Ground Control Points as compared to localized point cloud:
    a. Maximum and Minimum delta z (elevation difference) of ground control points.

   b. Delta z (elevation difference) of each ground control point.
   c. RMSEz and ASPRS 95% Accuracy (RMSEz x 1.96) for all ground control points.
   d. Ground Control Point RMSEx.
   e. Ground Control Point RMSEy.
5. Lidar Point Density as collected (points/m^2).

Ground Control (panels, PIDs)

1. A description of field survey methods used to establish the mobile lidar ground control points.
2. Ground control identification number.
3. Northing and Easting coordinate.
4. Elevation.
5. Point type description.
6. Project's Primary and Main survey control used to establish the Ground Control Points to include the project's horizontal and vertical datums.

Certification

A certificate, substantially in the following form, must be affixed to all maps or reports to include the seal and signature of the Photogrammetrist (lidar and imagery) or Land Surveyor (lidar Only) in responsible charge of the mapping project:

''I hereby state that to the best of my professional knowledge, information, and belief, that this mobile mapping project was performed in accordance with the requirements of the Standards of Practice Manual for Surveying in South Carolina, and meets or exceeds the requirements as specified therein and meets or exceeds this project's accuracy specifications.'' (S.C. Code Ann. Section 40-22-2, et seq.; 26 S.C. Code Ann. Regs. Chapter 49 (1991 as amended)).

3.09 MOBILE LIDAR MAPPING DELIVERABLES

Surveying and mapping consultants must deliver files to the SCDOT that are compatible with the latest SCDOT's CADD and Plan Development Process. SCDOT Roadway Projects are assigned Project ID Numbers. All files submitted by the consultant must be referenced to a Project ID. The types of files and naming conventions are listed below and are examples of some of the files that might be requested by the SCDOT. **The examples shown assume a Project ID number of "P012345"**.

An electronic copy of any digital data set delivered to SCDOT must be retained in the permanent files of the licensee. The term "Bentley" as used in this manual refers to a native Bentley digital data format. Refer to the latest SCDOT Roadway CADD Manual for current format requirements.

12345 mobile report.pdf	**PDF format**, signed and sealed by licensee.
12345_mobile.txt	ASCII comma delineated file of **ground control points**.
r12345pp_mobile.dgn	**2D** Bentley file containing all **planimetric** mapping.
12345dtm_mobile.dgn	**3D** Bentley file bare earth **breaklines and spot elevations**.
12345dtm_mobile_bridge.dgn	**3D** Bentley file **bridge** features.
12345_mobile.tin	Digital Terrain Model (**bare earth**).
12345_mobile_bridge.tin	Digital Terrain Model (**bridge deck**).
12345_mobile.las	Localized and Validated LAS file(s).
12345_mobile_bridge.las	Bridge LAS file.
12345_mobile_tile.dgn	Lidar LAS file tile map (if requested).

4.0 PRECONSTRUCTION FIELD SURVEY GUIDELINES

A **South Carolina Licensed and Registered Land Surveyor** is required to be directly responsible for the proper execution and certification of the field surveying work. The scope of survey work is determined by the requirements for the design of the project, preparation of the right-of-way, and the detailed construction plans. The following field survey information is a supplement to other SCDOT requirements for the design and development of the project.

4.01 PRECONSTRUCTION SURVEY ELEMENTS

Project engineers must analyze highway design projects in depth to determine the appropriate level of surveying and mapping needed for the design of the proposed improvements depicted on the final Construction Plans. The type of facilities being planned for highway improvements should be considered when deciding the types of survey and mapping required to achieve the project objective. The following flow chart depicts the typical workflow for a preconstruction survey project:

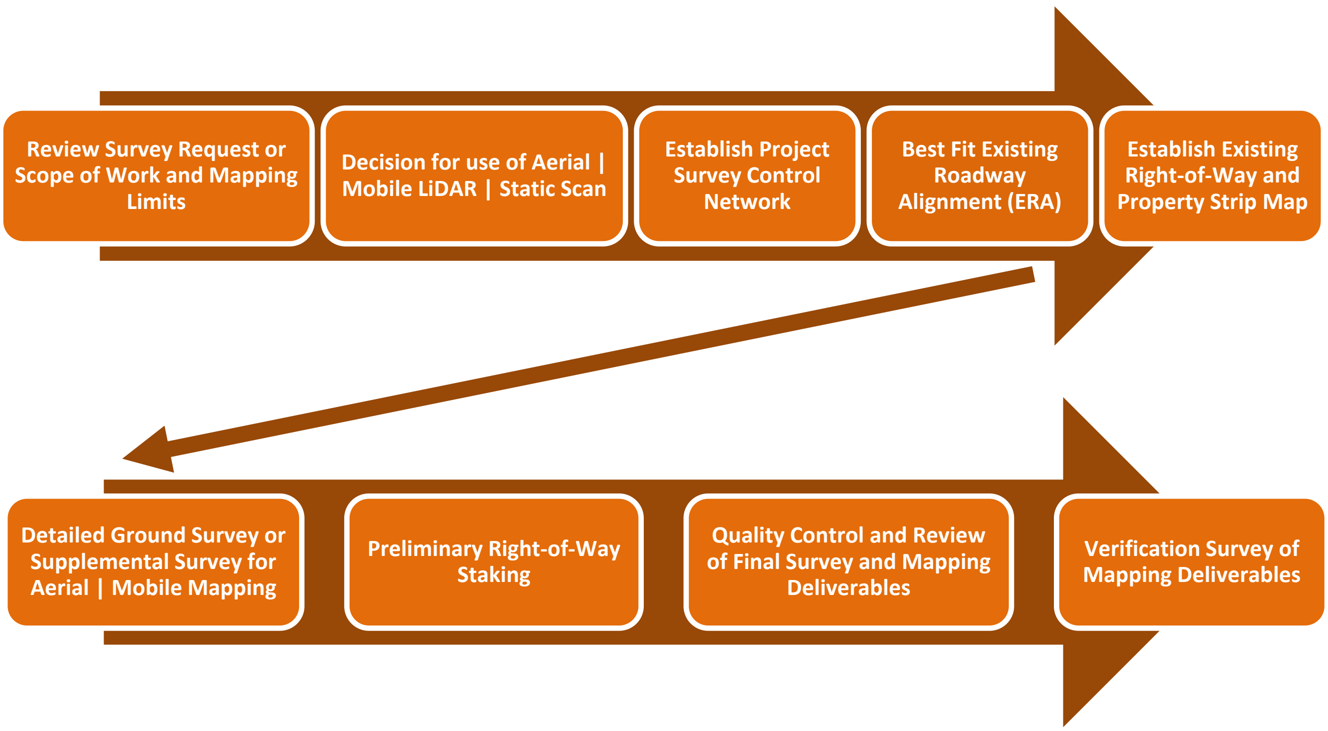


Figure 14 Preconstruction Survey Elements

The following is a list of survey tasks that are typically required for a roadway surveying and mapping project:

1. **Review Survey Request or Scope of Work and Mapping limits** - Determine the best surveying and mapping methods and verify the requested mapping limits.

2. **Public Notification** - No survey or mapping work will be performed on any property outside of the existing right-of-way without first providing a public notification.

3. **Aerial Mapping and Mobile Lidar** – Determine if aerial mapping and/or mobile lidar mapping is needed to (1) reduce the field crew exposure to vehicles on high volume traffic interstates/highways and (2) more efficiently and cost effectively complete the mapping.

4. **Project Survey Control** - Establish the survey control network.

5. **Best Fit Existing Roadway Alignment (ERA)** - An overall view of the project's existing roadway alignment which takes into account the irregularities of the constructed road while staying true to the intent of the roadway plans.

6. **Property and Right-of-Way Surveys** – Develop a property strip map and establish the existing right-of-way lines.

7. **Topographic Breakline Surveys and Pavement DTMs** - Locate the ground surface topography within the project limits and all roadway features (edge of pavement/concrete, travel lanes, breakpoints, crown, etc.).

8. **Drainage Surveys** - Outfall Ditches, Streams, Creeks, Rivers, Lakes, Ponds, Swamps, Marshes, and Tidal areas are surveyed in varying distances from the road centerline as directed in the requirements for hydraulic design studies and as directed by the Lead Hydraulic Engineer.

9. **Bridge surveys, Culvert surveys and Pipe Surveys**- Bridge Surveys must meet an accuracy necessary for hydrographic and bridge design. Major bridge rehabilitation will have more extensive survey requirements as directed by the Lead Structural Engineer.

10. **Railroad Surveys** - Identify specific elements along an existing railroad corridor.

11. **Planimetric Surveys** - Identify and locate cultural and natural topographic features (trees, buildings, sidewalks, etc.).

12. **Subsurface Utility Engineering (SUE)** - Surveys that identify the location of above and underground utility facilities and following the SCDOT SUE utility mapping standards.

13. **Environmental Surveys** - Surveys that identify specific locations and boundaries which impact roadway designs (archeological sites, historic sites, wetland, floodway, wildlife protected areas, etc.).

14. **Right-of-way Staking and Right-of-way Plat** - Temporary right-of-way staking will be directed by the SCDOT right-of-way agent for each project. The right-of-way plat must be based solely on information depicted on the final approved SCDOT construction plans for the project.

15. **QA-QC & Ground Tests** - Verification of topography and critical design locations.

4.02 REVIEW SURVEY REQUEST/SCOPE AND MAPPING LIMITS

The existing features within the **survey and mapping limits** must be analyzed to determine the required accuracy needed using the safest, most efficient and cost effective method of collecting the required survey and mapping data. The survey and mapping limits for the project can typically be determined using available mapping resources (online aerial imagery, county aerial photographs, USGS topographic maps, etc.), and existing roadway plans.

4.03 PUBLIC NOTIFICATION

No survey or mapping work is to be performed on property outside of the existing right-of-way without providing a public notification. The public notification will be in accordance with the requirements of the South Carolina Eminent Domain Procedure Act (S.C. Code Ann. Section 28-2-10, et seq.). S.C. Code Ann. Section 28-2-70(C) provides: "The condemnor shall have the authority, after reasonable notice to the landowner, to enter upon the real property in which an interest is proposed to be acquired for the purpose of making a survey, determining the location of proposed improvements, or making an appraisal. In the event a landowner refuses to allow entry, the circuit court may issue an ex parte order enforcing this section. A landowner shall have no cause of action for trespass arising out of the exercise of authority pursuant to this section." "Reasonable notice" would likely be by newspaper advertisment, letter and/or personal notification by the project's Program Manager to any landowner and occupant of any private property upon which a survey team expects or is reasonably likely to enter for surveying. Other means of notification are needed if the work to be performed will be in areas that may cause concerns for security to residents and property owners. An example landowner letter is provided in the appendix.

4.04 AERIAL MAPPING AND MOBILE LIDAR

The general requirements for aerial mapping and mobile lidar mapping are provided in this manual. Any mapping derived from aerial mapping and mobile lidar mapping could require supplementation by ground field surveying (conventional surveys) to ensure that the final compiled mapping will provide sufficient information, detail, and accuracy needed for the project's design and development.

4.05 PROJECT SURVEY CONTROL

The specifications for the horizontal and vertical project survey control are provided below. Many of these standards are intended to mirror the standards found in the **Standards of Practice Manual for Surveying in South Carolina** and **Chapter 5** of the **Federal Highway Administration's Project Development and Design Manual (Surveying and Mapping)**. These requirements may be modified if warranted by project conditions. The Preconstruction Surveys Manager or the Assistant Preconstruction Surveys Manager must approve any modifications.

The horizontal survey control consists of **Primary Survey Control (PSC)**, **Main Survey Control (MSC)**, and **Secondary Survey Control (SSC)**. Positional coordinates are typically established on the South Carolina State Plane Coordinate System's map projection. The **South Carolina State Plane Coordinate System** map projection used for the project should coincide with the datum(s) supporting the current National Spatial Reference System.

For certain projects, the surveyor might choose to **localize** the project control from the South Carolina State Plane Coordinate System (grid coordinates) to a local, ground distance based datum (ground) while maintaining the grid coordinate orientation (state plane grid North orientation). The intent of using a localized datum is to avoid the use of a Combined Scale Factor for measured distances.

If the project's horizontal coordinates are not referenced to the South Carolina State Plane Coordinate System or Localized, identify the **local coordinate system** used and its relationship to the National Spatial Reference System. The Preconstruction Surveys Manager or the Assistant Preconstruction Surveys Manager must approve the use of a local coordinate system for any SCDOT projects.

Horizontal coordinates must be in English units. The English unit in South Carolina is the international foot. (S.C. Code Ann. Section 40-22-2, et seq.; 26 S.C. Code Ann. Regs. Chapter 49 (1991 as amended)). The conversion from meters to **international foot** is (1 meter = 3.28083989501 foot or 1 foot = 0.3048 meter).

Elevations for benchmarks must be reference to the **North American Vertical Datum of 1988 (NAVD88)**. (Note: This vertical datum requirement will be reviewed and possibly changed to include the proposed new North American-Pacific Geopotential Datum of 2022 (NAPGD2022) when adopted by the National Geodetic Survey).

SCDOT uses three (3) types of survey accuracies for Project Survey Control:
(1) **Network Accuracy** – The accuracy of a point that represents the uncertainty of its coordinates with respect to the South Carolina State Plane Coordinate System (SCSPCS) at the 95% confidence level. The intent is to achieve a reasonable SCSPCS network accuracy for post construction repeatable points (e.g., property monuments found, right-of-way monumentation, etc.) that is balanced with the goals of SCDOT's primary mission (maintain and construct roads and bridges).
(2) **Local Accuracy** – The relative accuracy between project specific control points and represents the repeatability of measurements relative to other directly connected, adjacent control points at the 95% confidence level.
(3) **Unadjusted Ratio of Precision** - The Unadjusted Ratio of Precision is the calculated ratio of the unadjusted error of closure (numerator) to the total length of either a loop traverse, a link traverse, or a level circuit (denominator). "There is no simple correlation between relative closure accuracies [(Unadjusted Ratio of Precision)] and 95% radial positional accuracies; thus, determining a closure order based on a specified feature accuracy requirement is, at best, only an approximate process" (FGDC Part 4, 2002). "The most common way to express proportional accuracy is as the ratio between the overall length of a traverse and the misclosure of the closing course. This can be for a single measurement (i.e. 200 ft, +/- 0.01 ft is a precision ratio of 1:20,000), or for multiple measurements (such as the vertical accuracy expressed as closure times the square root of the traverse distance)." (CALTRANS, 2015).

4.05.01 PRIMARY SURVEY CONTROL (PSC)

Primary Survey Control coordinates are typically **"grid"** coordinates based on the South Carolina State Plane Coordinate System map projection and derived solely from **Global Navigation Satellite System (GNSS)** survey methods.

The Primary Survey Control is set flush to the ground and is a **⅝" Rebar (minimum 18"long) with Cap**. The cap is stamped with the Project Identification number (PID) and the Primary Survey Control Number (PSCN).

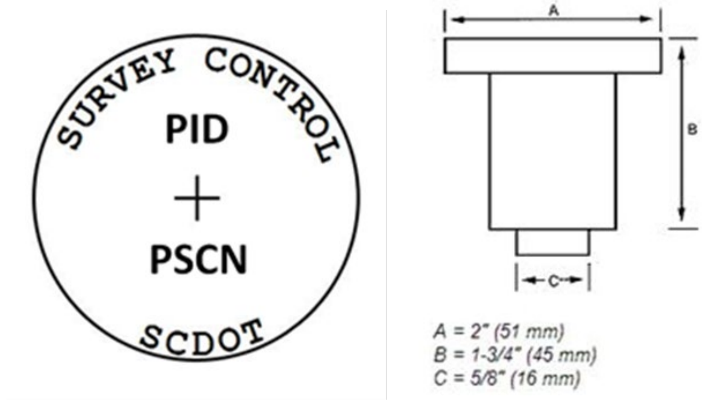


Figure 15 Primary Survey Control (PSC) Cap

All Primary Survey Control **azimuth pairs** are set at approximately **one mile intervals** along the project corridor. For projects less than **1.5 miles**, the PSC points are set in azimuth pairs at the beginning and end of the project limits. For projects less than **0.5 mile**, **one PSC azimuth pair** is set at either the beginning or end of the project limits. (Azimuth pair is defined as two inter-visible permanent markers set within the existing SCDOT right-of-way in areas of the project with a reasonable expectation of not being disturbed during the life of the project leading up to construction.)

The spacing between the Primary Survey Control Azimuth Pair points must be between **750 feet - 1450 feet.** Where the minimum spacing (750 feet) is not possible due to obstructions or project topography, the surveyor should measure a direct GPS vector between azimuth points and/or use a Terrestrial Total Station Survey (TTSS) method to establish the azimuth between the Azimuth Pair points with a minimum point spacing of 500 feet.

Figure 16 Primary Survey Control Layout

GNSS **Static**, GNSS **Post Processed Kinematic**, GNSS **Real Time Kinematic** (RTK), NGS GNSS **OPUS** and/or the GNSS **South Carolina Virtual Reference Station (SCVRS) Real Time Network (RTN)** can be used to establish 2D positional coordinates (Northing, Easting) for the project's Primary Survey Control. The surveyor is responsible for designing the GNSS survey method to meet the project's survey control network accuracy specification.

A **Terrestrial Total Station Survey (TTSS)** method can be used in areas of the project where a GNSS survey method cannot be used to establish all of the Primary Survey Control. In these areas of the project where a TTSS method is used, the TTSS traverse must begin and end on known points with both initial and closing azimuths (Primary Survey Control azimuth pair), and must have a minimum unadjusted ratio of precision of **1:25,000** or better.

Primary Survey Control must have a horizontal (Northing, Easting) **95% network accuracy of 0.07 feet** or better. (95% Network accuracy is defined as the accuracy of a project survey control point that represents the uncertainty of its coordinates with respect to the South Carolina State Plane Coordinate System at the 95% confidence level.)

The **Survey Control Data Sheet** must include all Primary Survey Control (PSC) points for the project and include the following information for each PSC point:

- Horizontal Datum.
- Northing and Easting to the nearest one hundredth of a foot (0.01).
- Station and Offset referenced to the road alignment or baseline.
- Elevation to the nearest hundredth of a foot (0.01).
- Description of the survey control point.

GNSS "tie points" to a published NGS horizontal control mark(s) or CORS station(s) must be included in the **survey report** with the intent of showing the network accuracy of the Primary Survey Control points.
Example description of GNSS tie points: TIE NGS [monument name].

4.05.02 MAIN SURVEY CONTROL (MSC)

Main Survey Control coordinates are typically **"grid"** coordinates based on the South Carolina State Plane Coordinate System.

The Main Survey Control is set flush to the ground and can be either a **⅝" Rebar or Spike (minimum 8" long)**. Longer rebar or spikes should be used in unstable or sandy soil.

The spacing between the Main Survey Control points must be between **500 feet - 1320 feet** and inter-visible with at least two other Main Survey Control points and/or Primary Survey Control point. The surveyor must obtain prior approval from the SCDOT Survey Manager when the minimum spacing (500 feet) cannot be achieved due to obstructions or project topography.

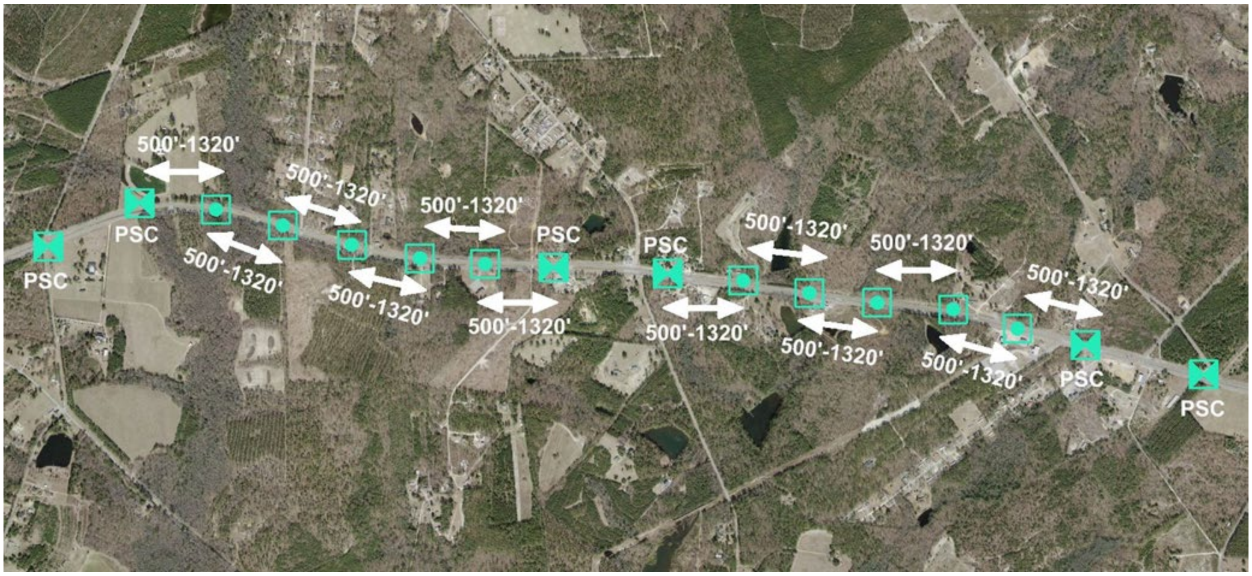


Figure 17 Main Survey Control Layout

A **Terrestrial Total Station Survey (TTSS)** traverse method is recommended to establish the Main Survey Control with a minimum unadjusted ratio of precision of **1:20,000** by beginning and ending on Primary Survey Control azimuth pair(s). A Terrestrial Total Station Survey (TTSS) survey and mapping system includes a total station survey instrument and an electronic data collecting system which uses prisms and prism poles to perform conventional survey methods of traverse, resection, topographic and planimetric mapping, and trigonometric leveling. If a **GNSS method** is used to establish the Main Survey Control, a direct GNSS vector is recommended between each Main Survey Control (MSC) point, with the final adjustment of the MSC GNSS vectors constrained to the Primary Survey Control network. The GNSS method is required to meet a minimum unadjusted ratio of precision of 1:20,000 between any two MSC points, or between a MSC point and a Primary Survey Control point.

The difference in the measured distance between individual Main Survey Control points and the published distance must not exceed **+/- 0.025 feet** at the minimum horizontal distance of **500 feet** (i.e. 500 feet, +/-0.025 feet is a precision ratio of 1:20,000).

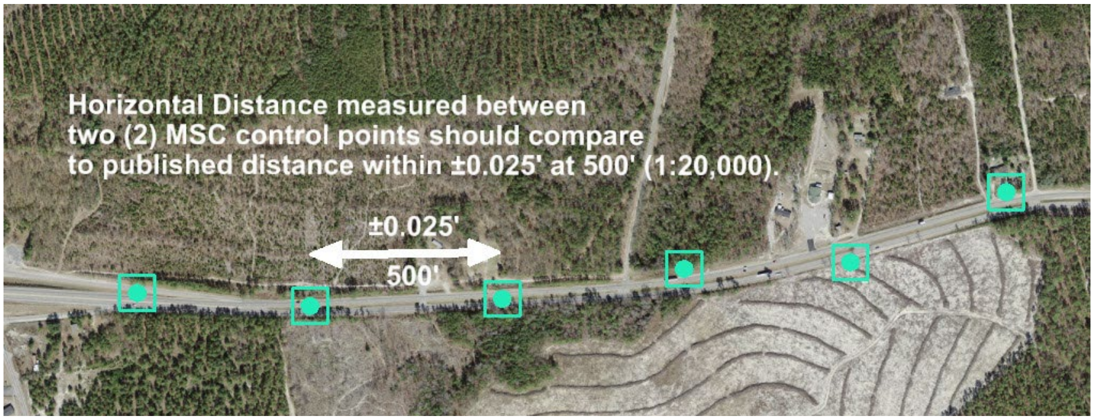


Figure 18 Horizontal Unadjusted Ratio of Precision

The **Survey Control Data Sheet** must include all Main Survey Control (MSC) points for the project and include the following information for each MSC point:

- Horizontal Datum.
- Northing and Easting to the nearest one hundredth of a foot (0.01).
- Station and Offset referenced to the road alignment or baseline.
- Elevation to the nearest hundredth of a foot (0.01).
- Description of the survey control point.

4.05.03 SECONDARY SURVEY CONTROL (SSC)

Secondary Survey Control coordinates are typically **grid** coordinates based on the South Carolina State Plane Coordinate System and typically derived from a **Terrestrial Total Station Survey (TTSS)** survey method.

Secondary Survey Control point coordinates and elevations are established by **traverse or resection** from Primary Survey Control (PSC) and/or Main Survey Control (MSC) points. If using **GNSS methods**, a "tie point(s)" to a PSC or MSC point(s) is required. A "tie point" is collected by occupying a point of known coordinates and elevation, and recording new coordinate and elevation values, giving a check to the project's established survey control datums.

Secondary Control points are considered **temporary work points** for the collection of field data, and are **not intended** to be included in either the final construction plans or the Survey Control Data Sheet.

Primary and Main survey control should be used to collect the field data before Secondary Survey Control is considered an option.

Example survey tasks for the use of Secondary Survey Control:

- Drainage surveys.
- Mapping of man-made features.
- Mapping of natural features.
- Topographic (bare earth).
- Utility surveys.
- Right-of-way staking.
- Property Line Surveys.

The Secondary Survey Control is set flush to the ground and made of a **ferrous material** (consisting of iron).

A **Terrestrial Total Station Survey (TTSS)** or **Global Navigation Satellite System (GNSS)** survey method can be used to establish the Secondary Survey Control. For a TTSS survey, a minimum unadjusted ratio of precision of **1:10,000** is required. For a GNSS survey, a **local accuracy** of **+/- 0.10 feet** is required.

The required local accuracy of the Secondary Survey Control (SSC) should be matched to the feature being mapped. (Example: Drainage surveys using SSC could possibly require a lower local accuracy as compared to SSC used for property line surveys.) The surveyor in charge of the project is responsible for determining the accuracy of the SSC which meets the project's mapping task.

4.05.04 VERTICAL CONTROL – PROJECT BENCHMARKS (BM)

The project's **Primary Survey Control points (PSC)**, **Main Survey Control points (MSC**), and **Project Benchmarks (BM)** must be referenced to either a published **National Spatial Reference System (NSRS) benchmark** or use an elevation(s) derived from **GNSS survey methods**.

A published National Spatial Reference System **"NGS" benchmark** that is within **1,000 feet** of the project limits must be used as the starting reference elevation for the project's vertical datum. Further elevation ties must be made to all recovered published NGS benchmarks within **1,000 feet** of the project limits. When additional NGS benchmarks are not available, GNSS methods can be used to verify the NGS published benchmark elevation for accuracy to the specified vertical datum. The project's surveyor should make a professional decision about the additional effort needed to increase the distance of differential level loop circuits to a published NSRS benchmark(s) used for determining the vertical datum of the project.

The **North American Vertical Datum of 1988 (NAVD 88)** must be used unless otherwise specified. Any elevation data that might be used from any previous project must be verified for accuracy and vertical datum. Historically, some SCDOT transportation projects have been referenced to the National Geodetic Vertical Datum of 1929 (NGVD29), or to an assumed datum.

Mean Sea Level is a term used by many to reference a vertical datum in the United States, but does "not mean sea level, the geoid, or any other equipotential surface. Therefore, it was renamed in 1973, the National Geodetic Vertical Datum on 1929." "*Mean sea level* was held fixed at the sites of 26 tide gauges, 21 in the United States and 5 in Canada. The datum is defined by the observed heights of mean sea level at the 26 tide gauges and by the set of elevations of all bench marks resulting from the adjustment. A total of 106,724 kilometers of leveling was involved, constituting 246 closed circuits and 25 circuits at sea level." (NGS Datums, 2020).

If a NGS benchmark is not within **1,000 feet** of the project limits, then **GNSS methods** can be used to establish the vertical datum for the project. "With the use of [GNSS], a Geoid model is necessary to produce orthometric heights or elevations. A Geoid model is [a] geo-potential surface that utilizes gravity for a given horizontal position that relates the ellipsoid to 'mean sea level'." (ARDOT, 2013).
When using GNSS methods, the surveyor should use the most current National Spatial Reference System **Geoid model** as published by the National Geodetic Survey and record a **"tie"** point(s) to a published NGS benchmark(s) or CORS station(s).

The project's benchmarks are set within the existing road right-of-way with a reasonable expectation of not being disturbed during the life of the project leading up to construction, and made of either/(or a combination of):

- **concrete monument with beveled cap** flush to the ground.
- **ferrous spike** (consisting of iron) driven above ground level into a **vertical object.**
- **ferrous spike** driven into **asphalt** of sufficient stability.
- **Scribed mark** in concrete of sufficient stability.

Once the vertical datum has been established, a **differential leveling method** or an equivalently accurate method must be used to determine the elevations for all Primary Survey Control points (PSC), Main Survey Control points (MSC), and Project Benchmarks (BM).

If project site conditions make a differential leveling method difficult or impractical, a **Trigonometric "Trig" leveling method** can be used following certain specifications. Refer to the appendix for acceptable Trig procedures.

Elevation benchmarks are established using the following criteria:

- **Projects shorter than 1.0 mile: One benchmark will be set within project limits** near the project alignment or baselines within the existing SCDOT right-of-way.
- **Projects longer than 1.0 mile: one benchmark will be set every 1.0 mile** near the project alignment or baselines within the existing SCDOT right-of-way.
- **Bridge projects**:
  - **Existing bridge span <100 feet: one benchmark** (near end of bridge).
  - **Existing bridge span >100 feet: two benchmarks (**one near each end of bridge).

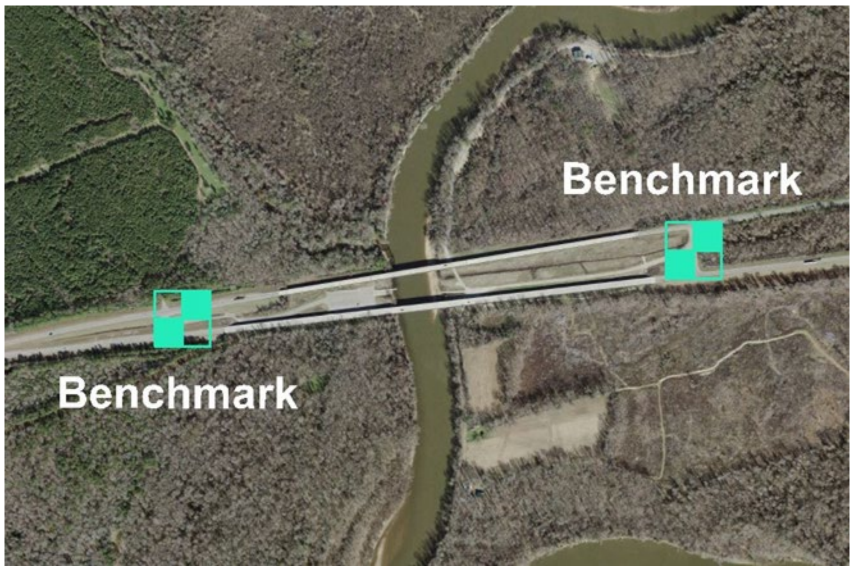


Figure 19 Benchmark Bridge >100' Layout

The **maximum allowable error of closure** for differential level surveys is 0.05 feet multiplied by the square root of the length of the level circuit in miles, **or as specified for specific projects**.

Standard Allowable Elevation (z) Error of Closure = 0.05 feet x √length of level circuit in miles.

(A **"level circuit"** is defined as a series of setups closing on the starting point, or a series of setups between two points of known elevations, in which the known elevations meet the project's specified elevation accuracy.)

The **Survey Control Data Sheet** must include all benchmarks for the project and include the following information for each benchmark:

- Vertical Datum.
- Approximate Northing and Easting to the nearest foot.
- Station and Offset referenced to the road alignment or baseline.

- Elevation to the nearest hundredth of a foot (0.01).
- Description of the benchmark.
- NSRS reference elevation used to establish the project's vertical datum:
    - All NGS benchmark(s) used in level circuit.
    - For a GNSS method, the "tie" point(s) to a published NGS benchmark(s) or CORS station(s).

4.05.05 PROJECT SURVEY CONTROL ADJUSTMENT

4.05.05.01 TERRESTRIAL TOTAL STATION SURVEY (TTSS) ADJUSTMENT

For typical linear transportation projects, a "**Link Traverse**" method is used to constrain the Main Survey Control (MSC) points to the beginning and ending Primary Survey Control (PSC) azimuth pairs. The link traverse method eliminates the effort needed to traverse back to the starting point, which also reduces additional terrestrial traverse error by using a GNSS method to establish accurate beginning and ending azimuth pairs at approximately one mile intervals.

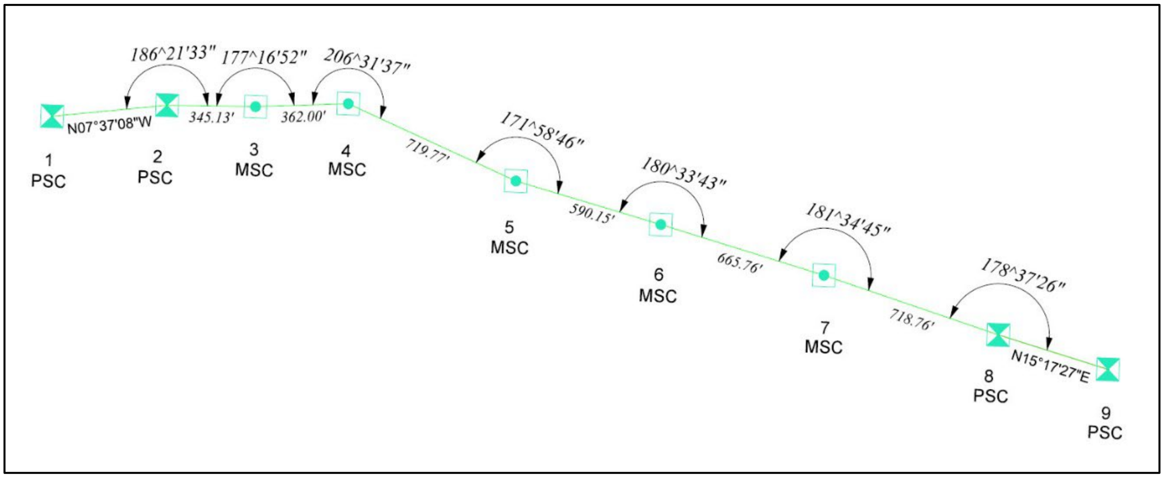


Figure 20 Example Link Traverse

In order to use the link traverse method, the Main Survey Control points should be adjusted to the Primary Survey Control azimuth pairs.

The appendix gives guidance on horizontal adjustment methods suitable for SCDOT transportation projects.

4.05.05.02 ELEVATION ADJUSTMENT

For typical linear transportation projects, a **"Level Link Circuit"** is used and the Main Survey Control (MSC) elevations are adjusted to the known elevations at each end of the level Link circuit.

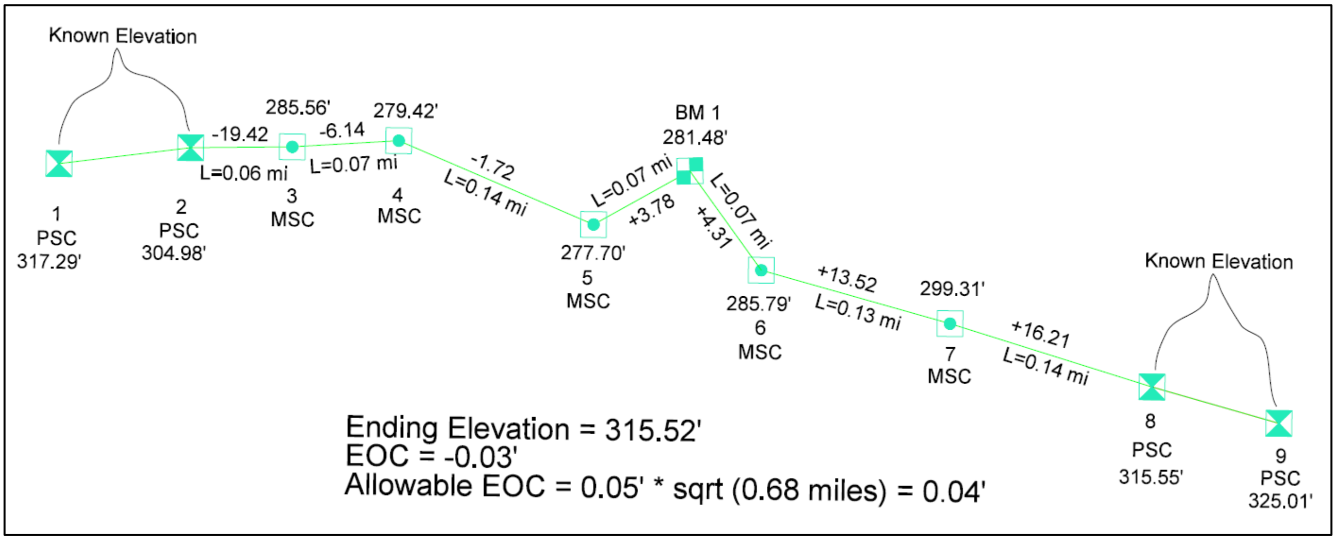


Figure 21 Example of Level Link Circuit

If using one benchmark of known elevation, then a **"Double-Run" level loop circuit** is used, which for linear transportation projects requires running levels back thru the Main Survey Control points and closing on the starting benchmark.

The appendix gives guidance on elevation adjustment methods suitable for SCDOT transportation projects.

4.05.06 PROJECT CONTROL ACCURACY SUMMARY

4.05.06.01 Project Control Horizontal and Vertical Accuracy

Point Type	Survey Method	95% Network Accuracy (Note 1)		Local Accuracy (Note 2)		Unadjusted Ratio of Precision (Note 3)	Point Spacing
		Horizontal	Vertical	Horizontal	Vertical		
PSC	GNSS	≤ 0.07’ (2.0cm)	N/A	≤ 0.025’ (Note 4)	≤ 0.02’ (Note 4)	(Note 5)	Between Azimuth Points (750’-1450’) Between Azimuth Pairs (≈1.0 mile) (Note 6)
MSC	TTSS or GNSS	N/A		≤ 0.025’ (Note 7)	≤ 0.02’ (Note 7)	≥ 1:20,000 (Note 8)	(500’ – 1320’)
SSC	TTSS or GNSS	N/A		≤ 0.10’ (Note 9)	≤0.05’ (Note 9)	≥ 1:10,000	N/A
BM	Differential or Trig Levels (note 10)	Project NSRS Reference Benchmark Elevation ≤ 0.15’ (Note 11)		≤ 1.0’	≤ 0.02’ (Note 12)	≤ 0.05’ * √miles	(Note 13)

Note 1: Network Accuracy is the accuracy of a point that represents the uncertainty of its coordinates with respect to the South Carolina State Plane Coordinate System (SCSPCS) at the 95% confidence level. The intent is to achieve a reasonable SCSPCS network accuracy for post construction repeatable points (property monuments found, right-of-way monuments set, etc.) that is balanced with the goals of SCDOT’s primary mission (maintain and construct roads and bridges).

Note 2: Local accuracy is the relative accuracy between project specific control points and represents the repeatability of measurements relative to other directly connected, adjacent control points at the 95% confidence level.

Note 3: Unadjusted Ratio of Precision is the calculated ratio of the unadjusted error of closure (numerator) to the total length of either a loop traverse, a link traverse, or a level circuit (denominator).

Note 4: The local horizontal accuracy of ≤0.025’ applies only to the relative accuracy between PSC and MSC points after the final MSC traverse adjustment. The expected local horizontal accuracy between PSC azimuth points is approximately ≤0.10’ (3.0cm). Local Vertical Accuracy of ≤0.02’ between PSC points is derived from the minimum point spacing of 750’ and is a function of (≤ 0.05’ * √miles) rounded to nearest hundredth of a foot.

Note 5: An Unadjusted Ratio of Precision of ≥ 1:25,000 is acceptable for establishing Primary Survey Control when using a TTSS method in areas of the project where a GNSS survey method is not feasible.

Note 6: For projects less than 1.5 miles, the PSC points are set in azimuth pairs at the beginning and end of the project limits. For projects less than 0.5 mile, one PSC azimuth pair is set at either the beginning or end of the project limits.

Note 7: Local Horizontal Accuracy of ≤0.025’ and Local Vertical Accuracy of ≤0.02’ is derived from a minimum point spacing of 500’. The Local Vertical Accuracy is a function of (≤ 0.05’ * √miles) rounded to nearest hundredth of a foot.

Note 8: The minimum Unadjusted Ratio of Precision for TTSS link traverse or loop traverse using PSC azimuth pair(s).

Note 9: The required local accuracy of the Secondary Survey Control (SSC) is matched to the feature being mapped with the surveyor in charge of the project determining the accuracy of the SSC which meets the project’s mapping task.

Note 10: See appendix for Trigonometric (“Trig”) Leveling guidance.

Note 11: One project NSRS reference benchmark will establish the vertical datum for the project to the listed 95% Network Accuracy. This NSRS reference benchmark is then used to determine elevations for all project PSC, MSC, and BM points.

Note 12: Local vertical accuracy relative to adjacent Primary Survey Control or Main Survey Control.

Note 13: Projects shorter than 1.0 mile: One benchmark will be set within project limits near the project alignment or baselines within the existing SCDOT right-of-way. Projects longer than 1.0 mile: one benchmark is set every 1.0 mile near the project alignment or baselines within the existing SCDOT right-of-way. Bridge projects: Existing bridge span <100 feet: one benchmark (near end of bridge), Existing bridge span >100 feet: two benchmarks (one near each end of bridge).

4.05.06.02 Project Control Monument Type

Point Type	Monument Material	Listed on Survey Control Data Sheet
Primary Survey Control (PSC)	5/8" Rebar (minimum 18"long) with Cap *(note1)*	Yes
Main Survey Control (MSC)	5/8" Rebar or Spike (minimum 8"long) *(note 1,2)*	Yes
Secondary Survey Control (SSC)	Ferrous Material *(note 1)*	No
Benchmark (BM)	Ferrous Spike in Vertical Object or Asphalt, Concrete Monument with Beveled Cap, or Scribe in concrete.	Yes

Note 1: If a rebar monument is not feasible due to site conditions, a ferrous spike in asphalt or scribe in concrete is acceptable.

Note 2: Longer rebar or spikes should be used in unstable or sandy soil.

4.05.07 THE SOUTH CAROLINA REAL TIME NETWORK

The **South Carolina Geodetic Survey** (SCGS) manages the statewide GNSS Real Time Network (RTN). A **Virtual Reference Station Network (VRS) GNSS survey** is "[a] geodetic survey that uses multiple dual frequency survey grade satellite receivers each collecting the same satellite data simultaneously. Base stations are operated by the SCGS [South Carolina Geodetic Survey] and data is streamed to the Rovers via the Internet and processed in real time to yield three dimensional vectors between the Base Stations and Rovers. VRS vectors solutions yield a "network check" solution and therefore will meet minimum standards without additional independent checks. **VRS surveys require an "independent check" by occupying a known geodetic control point in the National datum in the vicinity of the survey to verify the proper operation of the Rover**. An expected relative accuracy of 0.05 [feet] can be obtained dependent on the length of time of VRS observations, the quality of the receivers, PDOP of less than 3, a minimum of 5 GPS satellites and minimal multipath." (S.C. Code Ann. Section 40-22-2, et seq.; 26 S.C. Code Ann. Regs. Chapter 49 (1991 as amended)).

The **minimum** GNSS accuracy standards listed below are referenced from the South Carolina Code of Regulations Chapter 49 (Labor, Licensing and Regulation for Professional Engineers and Land Surveyors) Section 430-C (2012):

Type	Relative Accuracy (95%)	Maximum PDOP	Minimum # of Satellites	Site Calibration
Static GNSS	0.07'+1:50,000	5	4	N
Property Corner Positions (note 1)	0.07'+1:20,000	5	4	N
RTK GNSS	0.07'+1PPM distance from base	3	5	Y
VRS GNSS	**0.07'**	**3**	**5**	**N**

[General] Note 1: Property Corner Positions - "GNSS STATIC survey technique [...] [used] to establish SC State Plane Coordinates on property corners, the corners shall be positioned from the nearest two (2) first or second order horizontal control monuments in the National Geodetic Survey (NGS) data base. Property corners shall be positioned to a horizontal accuracy of at least 0.07' + 1/20,000 or 0.2 feet (whichever is smaller) with relation to the nearest NGS horizontal control monument." (S.C. Code Ann. Section 40-22-2, et seq.; 26 S.C. Code Ann. Regs. Chapter 49 (1991 as amended)).

4.05.08 SURVEY CONTROL DATA SHEET

SCDOT Preconstruction Design Memorandum No. 8 requires the development of a Survey Control Data Sheet by a South Carolina Professional Land Surveyor in responsible charge of each preconstruction survey project.

The intent of the Survey Control Data Sheet is:
1. Preserve information related to the location of property corner monuments found during the preconstruction field survey.
2. Clearly define the datums used to establish the project survey control.
3. Provide information which can be used to re-establish individual property corner monuments.
4. Provide project survey control coordinate and elevation information to be used during construction.

A SCDOT standard full sized plan sheet must be prepared showing the Horizontal and Vertical Datum Description, a tabulated list of (Primary Survey Control (PSC) points, Main Survey Control (MSC) points, Project Benchmarks (BM), and property monuments found), Date of Survey, and the surveyor's signature and seal.

4.05.08.01 DATUM DESCRIPTIONS

The horizontal coordinate system developed for each project must be described by a **DATUM DESCRIPTION**. The **DATUM DESCRIPTION** must be one of the following types:

- **GRID** State Plane Coordinate System
- **LOCALIZED** State Plane Coordinate System
- **ASSUMED** Coordinate System (see Note)

<u>**GRID State Plane Coordinate System**</u> datum description must be used for projects where the horizontal coordinate values are true Grid Coordinates. A Combined Scale Factor must be applied when measuring horizontal ground distance between these points. This **Datum Description** is as follows:

The GRID Coordinate System developed for this project is based on NAD83 (2011) South Carolina State Plane Coordinate System. A Combined Scale Factor (CSF) for each Survey Control Point must be computed and applied to horizontal ground distances. Elevations for this project are based on NAVD88 values for Bench Mark number ___ with an elevation of _____'

LOCALIZED State Plane Coordinate System datum description must be used for projects where the horizontal coordinate values have been scaled from grid to reflect ground coordinates. A single point is selected as the Localization Point for the Localized project which represents a true Grid State Plane Coordinate. The remaining control points are to be scaled to the ground from the Localization Point using the Combined Scale Factor. Scale factors are not applied when measuring horizontal ground distances. This **Datum Description** is as follows:

The LOCALIZED Coordinate System developed for this project is based on the NAD83 (2011) South Carolina State Plane Coordinate System used to establish the Localization Point. The Localization point is Primary Survey Control point number __ with a Northing of _________ and an Easting of __________. The Combined Scale Factor (CSF) (ground to grid) is ___________. Elevations for this project are based on NAVD88 for Bench Mark number __ with an elevation of ______'

ASSUMED Coordinate System datum description are used for projects that are not based on South Carolina State Plane Coordinate System and reads as follows:

This ASSUMED Coordinate System developed for this project is based on Primary Survey Control point number __ with a false northing of __________ and a false Easting of _______. Elevations for this project are based on NAVD88 for Bench Mark Number __ with an elevation of ______'.

-Or-

This ASSUMED Coordinate system developed for this project is based on Primary Survey Contorl point number __ with a false Northing of _______ and a false Easting of _______. Elevations for this project are based on ASSUMED for project Bench Mark number __ with an elevation of ______'.

Note: ASSUMED Coordinate Systems should only be used when extending or adding to an existing project that is not tied to the South Carolina State Plane Coordinate System. **Prior approval must be obtained from the SCDOT Preconstruction Survey Office before an ASSUMED Coordinate System is used.**

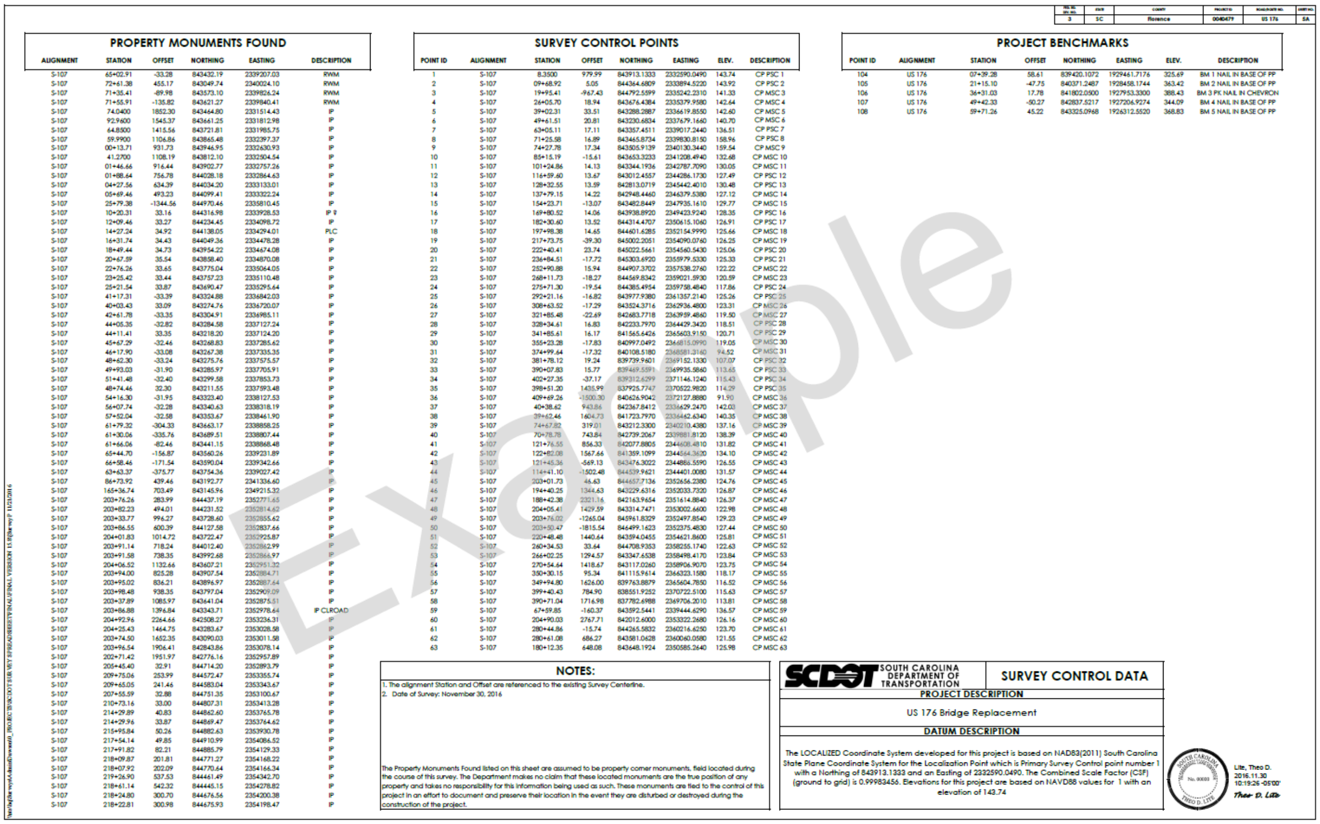


Figure 22 Example Survey Control Data Sheet

4.06 BEST FIT EXISTING ROADWAY ALIGNMENTS (ERA)

The SCDOT uses roadways and associated features, as constructed, to calculate the **Existing Roadway Alignment** (ERA). SCDOT's existing roadway plans, and possibly county/municipal roadway information, are required documents for constructing an ERA.

The SCDOT's method of creating the existing roadway alignment is a very rigorous process which can include 1000's of linear feet of existing roadway. For the existing roadway, the length of these alignments require the use of best fit solutions for tangent sections and the use of a degree-of-curve which best fits the original road plans at time of construction. This process results in an overall view of the project's existing roadway alignment which takes into account the irregularities of the constructed road while staying true to the intent of the roadway plans.

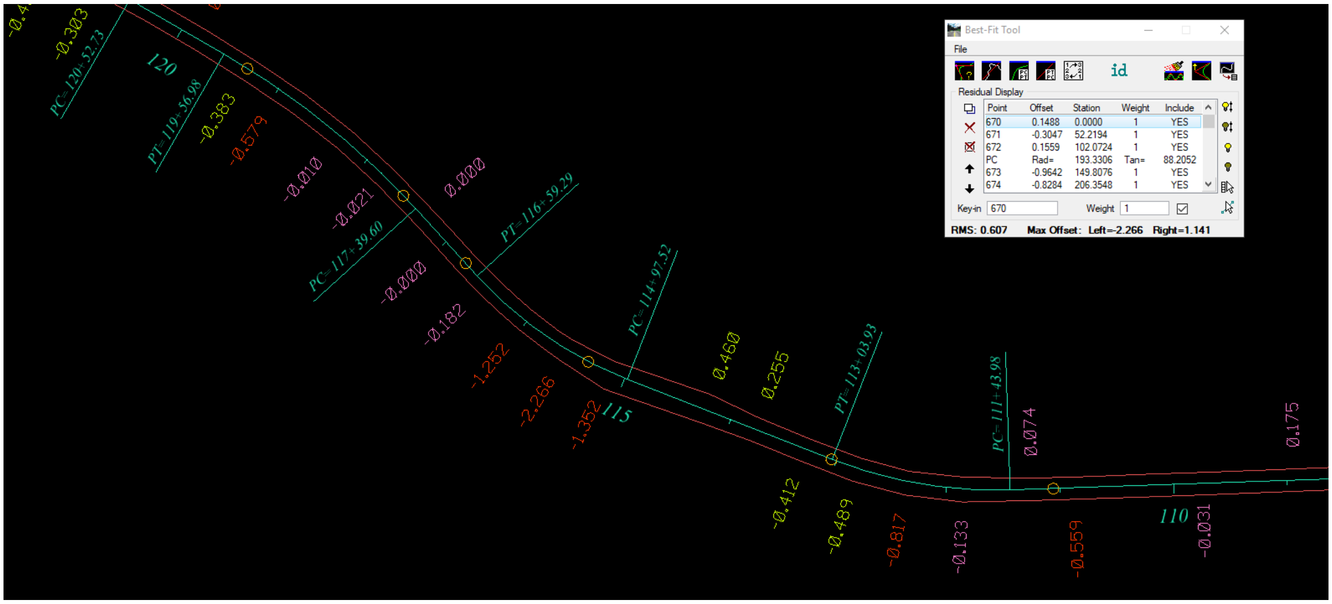


Figure 23 Example Best-Fit Tool used on S-164 (Gibbs Shoal Rd) ERA

4.07 PROPERTY AND RIGHT-OF-WAY SURVEYS

All surveying of existing SCDOT right-of-way must adhere to the standards, practices, and policies set forth in the Standards of Practice Manual for Surveying in South Carolina. Base mapping of existing Right-of-way, Easements, Property, and/or other real property rights must be developed to a sufficient level of accuracy to support due process for Right-of-way appraisal and acquisition.

4.07.01 RE-ESTABLISHING EXISTING RIGHT-OF-WAY

Re-establishing existing right-of-way involves technical and legal boundary principles. The purpose of this chapter is to provide the surveyor with terms and definitions of title documents which can be used for this re-establishment process and is not intended as an all-inclusive instructional manual for re-establishing existing right-of-way. The project surveyor in responsible charge must be knowledgeable in the appropriate laws and regulations related to re-establishing existing right-of-way.

“The land that a highway occupies is the right-of-way. It consists of the land owned by the operating agency or land that the operating agency has a right to use for roadway purposes. The rights required to support a roadway must include sufficient interest to provide for both the construction and continued maintenance of the facility.” (Wilson, 2013).

Right-of-way (or, “right of way”) as used herein means an easement, established by grant from a landowner (usually by way of a deed or marking on a recorded plat) or long usage (prescription), to pass along a specific route through property belonging to another. The plural of "right-of-way" is "rights-of-way". Right-of-way is often used colloquially to mean any land used by SCDOT for roads and related purposes; however, right-of-way more precisely means an easement as opposed to ownership of land in fee simple. SCDOT owns some property rights in fee simple and others by easement. An easement is, generally, a property right that gives its holder an interest in land owned by another. Where an easement exists, the easement is the dominant estate and the fee is the servient estate

In the absence of existing undisturbed right-of-way monuments, SCDOT considers the roadways and associated features, as constructed, the **primary controlling monuments** for reconstructing the existing road right-of-way.

Titles 28 and 57 of the South Carolina Code of Laws pertain to SCDOT rights-of-way:
South Carolina State Highway System (S.C. Code Ann. Section 57-5-10, et seq.)
South Carolina Eminent Domain Procedure Act (S.C. Code Ann. Section 28-2-10, et seq.)

The SCDOT existing right-of-way is typically referenced to the best fit **Existing Roadway Alignment (ERA)** and reconstructed from SCDOT roadway plans and deeds to right-of-way. It is important to review not only the current roadway plans, but also previous plans to better understand the history of any changes to a particular roadway's right-of-way.

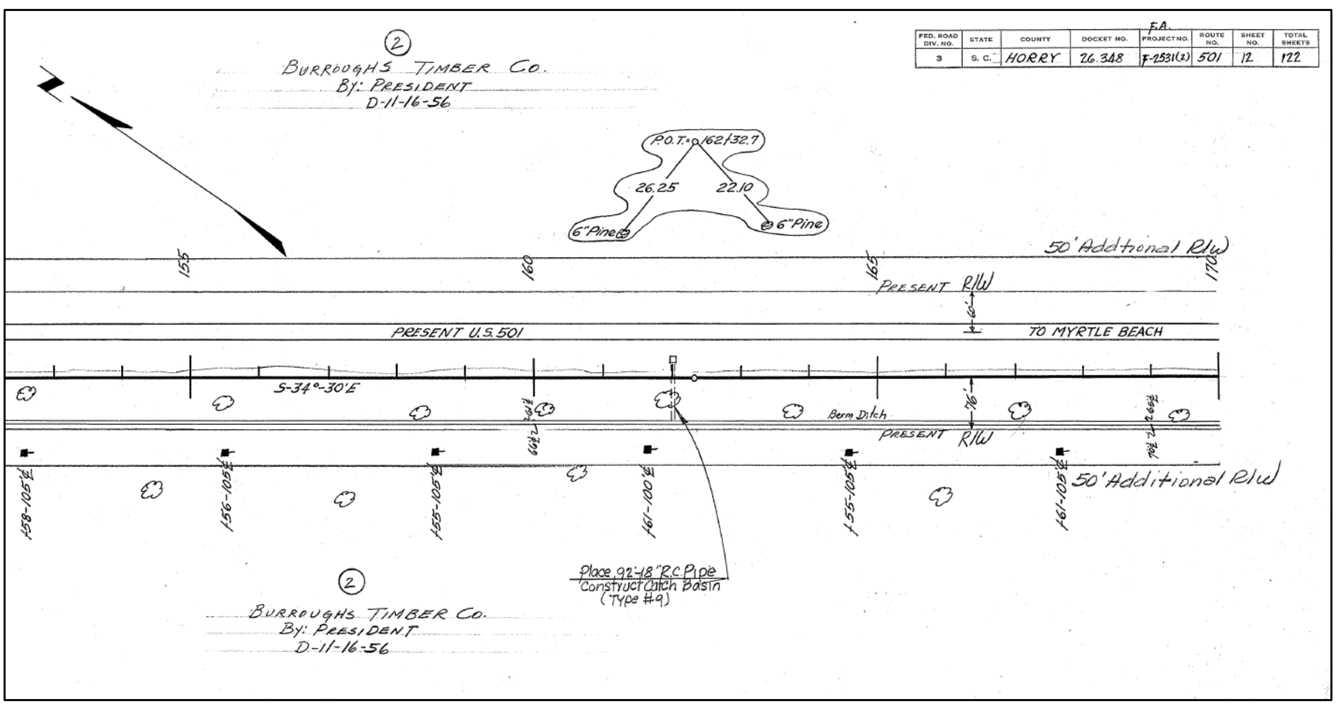


Figure 24 Example Existing and Proposed New Right-of-way (1956)

SCDOT property interests include:

- **Fee Simple** - complete ownership of, and all rights in, the land. This is the ownership interest typical of homeowners.
- **Written Easement** a/k/a "right of way" - a partial interest in property owned by another with the right to preempt the fee owner for a particular purpose. This is the ownership interest typical of modern utilities.
- **Dedicated Right-of-way** - These easements are established by plat, deed, land description, or for use as a public road by city ordinance, resolution or letter. The landowner then makes a dedication of the easement and the governing authorities formally accept the dedication.
- **Permission** – A permission or license is not an ownership interest but only a temporary right given by a landowner for a particular purpose and a limited time. These usually allow a right of entry to the property to perform some minor construction work, such as connecting a driveway to a driveway entrance. <u>Permission documents are not used to re-establish right-of-way</u> and are not recorded in county registers of deeds offices.
- **Condemnation** - The prescribed statutory process by which land or an interest in land - such as an easement - is acquired for a public works project from landowners unwilling to sell.
- **Prescriptive Easement** a/k/a "right of way" - public use and maintenance over time establishes the right of the public to use land, but there is no recorded writing. There is instead dedication by a landowner and acceptance by the governing authorities through maintenance of the road easement.
- **Special Provisions** - Special provisions outline work as defined within a document to be performed on property of the grantor outside of the right-of-way.

All of these property interests can be obtained by gift, negotiation and purchase, long established use by the public and public maintenance, or by condemnation.

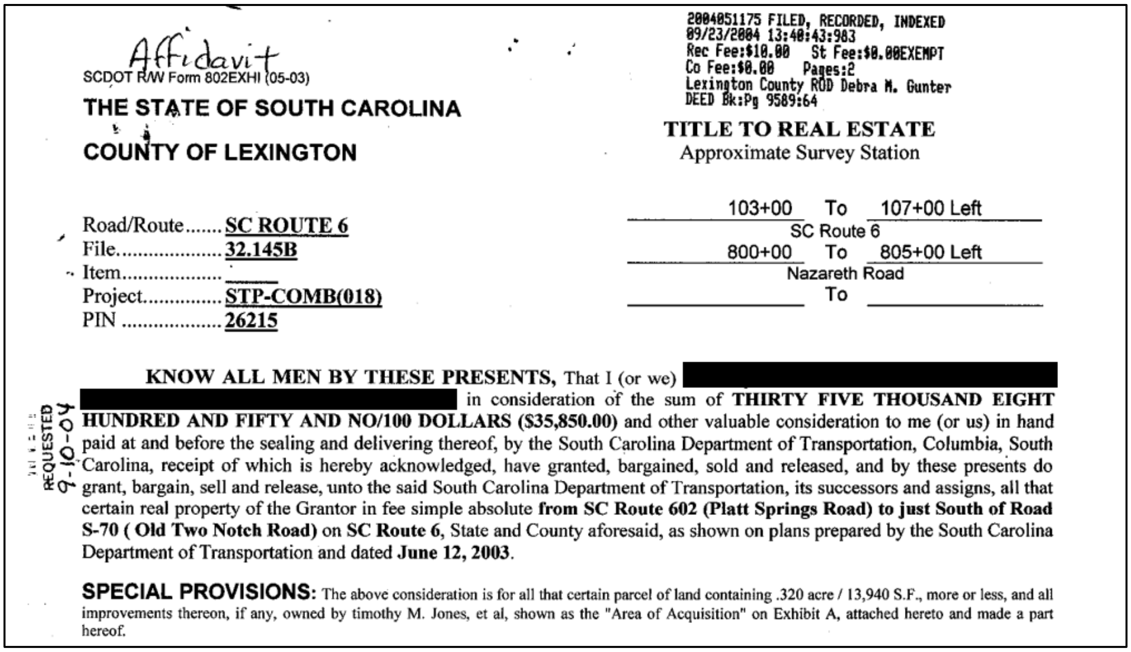
Prior to **April 1, 1988**, by statute, SCDOT maintained title documents in the fireproof vault of the Right-of-Way Office at SCDOT Headquarters. As of April 1, 1988, these instruments are now recorded in county courthouses with the Clerks of Court (or the Register of Deeds Office, if the county has one).
NOTE: Thorough research typically requires review of the documents in the SCDOT Right-of-Way Office vault.

<u>**Fee Simple**</u>

A fee simple interest as it relates to the roadway means the landowner or government owns the title interest in the property defined by the extents of the roadway, and holds a recorded title to real estate (deed).

“An Absolute or fee-simple estate is one in which the owner is entitled to the entire property, with unconditional power of disposition during one’s life, and descending to one’s heirs and legal representatives upon one’s death intestate.” (Black's Law Dictionary with Pronunciations, 1990).

The exhibit and highway plan reference number are listed in the deed which are used to reconstruct the right-of-way.



Affidavit
SCDOT R/W Form 802EXHI (05-03)

2004051175 FILED, RECORDED, INDEXED
09/23/2004 13:40:43:983
Rec Fee:$10.00 St Fee:$0.00EXEMPT
Co Fee:$0.00 Pages:2
Lexington County ROD Debra M. Gunter
DEED Bk:Pg 9589:64

THE STATE OF SOUTH CAROLINA

COUNTY OF LEXINGTON

TITLE TO REAL ESTATE
Approximate Survey Station

Road/Route....... SC ROUTE 6
File.................. 32.145B
Item..................
Project.............. STP-COMB(018)
PIN 26215

103+00 To 107+00 Left
SC Route 6
800+00 To 805+00 Left
Nazareth Road
To

REQUESTED 9-10-04

KNOW ALL MEN BY THESE PRESENTS, That I (or we) [redacted] in consideration of the sum of **THIRTY FIVE THOUSAND EIGHT HUNDRED AND FIFTY AND NO/100 DOLLARS ($35,850.00)** and other valuable consideration to me (or us) in hand paid at and before the sealing and delivering thereof, by the South Carolina Department of Transportation, Columbia, South Carolina, receipt of which is hereby acknowledged, have granted, bargained, sold and released, and by these presents do grant, bargain, sell and release, unto the said South Carolina Department of Transportation, its successors and assigns, all that certain real property of the Grantor in fee simple absolute **from SC Route 602 (Platt Springs Road) to just South of Road S-70 (Old Two Notch Road)** on **SC Route 6**, State and County aforesaid, as shown on plans prepared by the South Carolina Department of Transportation and dated **June 12, 2003**.

SPECIAL PROVISIONS: The above consideration is for all that certain parcel of land containing .320 acre / 13,940 S.F., more or less, and all improvements thereon, if any, owned by timothy M. Jones, et al, shown as the "Area of Acquisition" on Exhibit A, attached hereto and made a part hereof.

Figure 25 Example Fee Simple Title to Real Estate (2004)

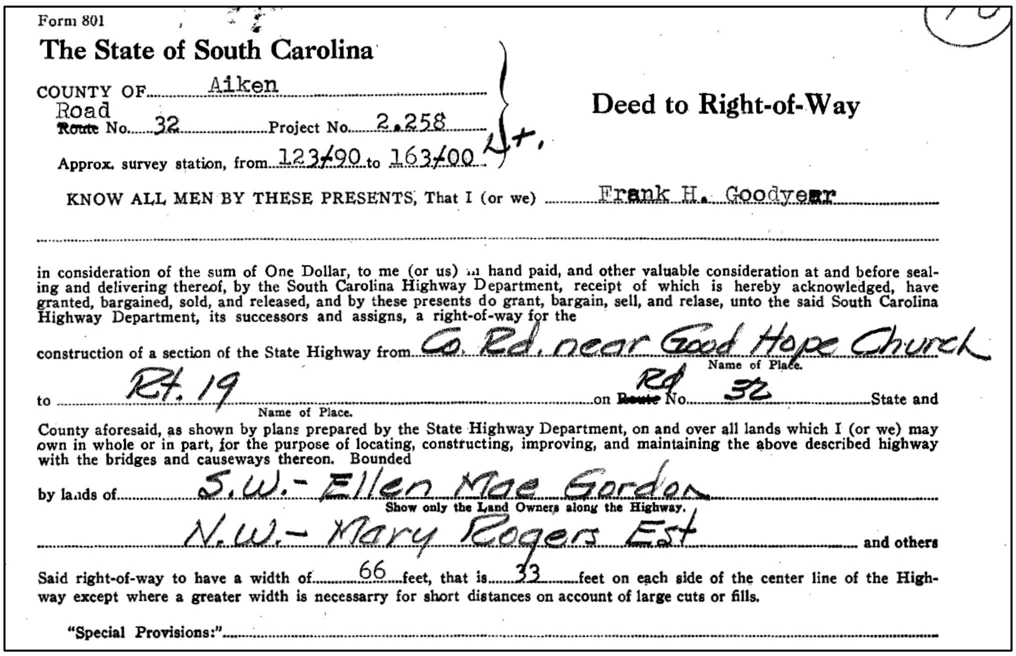
Easement

An easement is a right to use the real property of another for a specific purpose. There are written easements and prescriptive easements. Highway easements preempt the landowner’s ability to use the right-of-way for any use that conflicts with highway purposes. The oldest easements are generally prescriptive and are supplemented by written easements in more recent times.

“Some characteristics of the ultimate result of an easement, such as pavement in the case of a road, for instance, may be visible, but the easement itself cannot be seen. Many would look at these characteristics and conclude that that is the easement, when in reality, it is the *result of the easement* or *evidence of the location* of the easement.” (Wilson, 2013).

Early roads usually belonged to the landowners whose land the roads traversed. As populations grew and communities developed, these roads became more important for the transportation of goods to and from the coast. As traffic increased on main roads and maintenance became more expensive, many landowners asked the government to take over the roads. These roads were not actually deeded to the government (there was no paper record), but by the landowner dedicating these to public use and by the government accepting these by taking over maintenance, the roads themselves became prescriptive easements covering that area of the road and area necessary for the road (for drainage and lateral support, usually). If the land was used or maintained for the road, the prescriptive easement applied. In other cases, developers laid out a town or subdivision (example: Columbia and Camden) and sold the lots between the streets, then dedicated the streets to the local government. With growth and modernization, subsequent easements were often obtained by purchase or condemnation.

The highway plan reference number used to reconstruct the right-of-way is listed in the deed.



Form 801

The State of South Carolina

COUNTY OF Aiken

~~Route~~ Road No. 32 Project No. 2,258

Approx. survey station, from 123+90 to 163+00

Deed to Right-of-Way

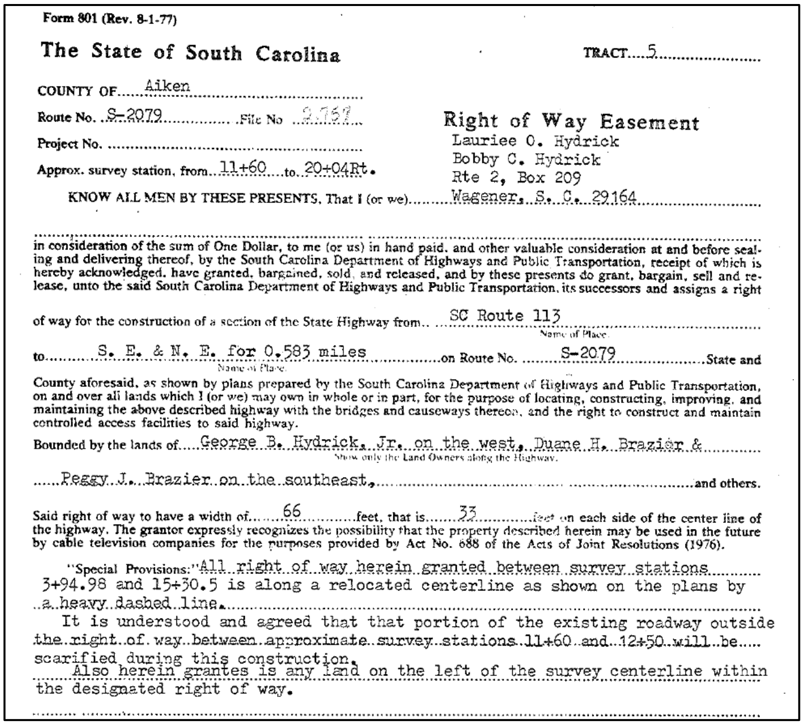
KNOW ALL MEN BY THESE PRESENTS, That I (or we) Frank H. Goodyear

in consideration of the sum of One Dollar, to me (or us) in hand paid, and other valuable consideration at and before sealing and delivering thereof, by the South Carolina Highway Department, receipt of which is hereby acknowledged, have granted, bargained, sold, and released, and by these presents do grant, bargain, sell, and relase, unto the said South Carolina Highway Department, its successors and assigns, a right-of-way for the construction of a section of the State Highway from Co. Rd. near Good Hope Church (Name of Place.) to Rt. 19 (Name of Place.) on ~~Route~~ Rd No. 32 State and County aforesaid, as shown by plans prepared by the State Highway Department, on and over all lands which I (or we) may own in whole or in part, for the purpose of locating, constructing, improving, and maintaining the above described highway with the bridges and causeways thereon. Bounded by lands of S.W. - Ellen Mae Gordon (Show only the Land Owners along the Highway.) N.W. - Mary Rogers Est and others

Said right-of-way to have a width of 66 feet, that is 33 feet on each side of the center line of the Highway except where a greater width is necessarry for short distances on account of large cuts or fills.

"Special Provisions:"

Figure 26 Example Easement (Deed to Right-of-way) (1948)



Form 801 (Rev. 8-1-77)

The State of South Carolina

TRACT 5

COUNTY OF Aiken

Route No. S-2079 File No 2,757

Project No.

Approx. survey station, from 11+60 to 20+04Rt.

Right of Way Easement

Lauriee O. Hydrick
Bobby C. Hydrick
Rte 2, Box 209

KNOW ALL MEN BY THESE PRESENTS, That I (or we) Wagener, S. C. 29164

in consideration of the sum of One Dollar, to me (or us) in hand paid, and other valuable consideration at and before sealing and delivering thereof, by the South Carolina Department of Highways and Public Transportation, receipt of which is hereby acknowledged, have granted, bargained, sold, and released, and by these presents do grant, bargain, sell and release, unto the said South Carolina Department of Highways and Public Transportation, its successors and assigns a right of way for the construction of a section of the State Highway from SC Route 113 (Name of Place) to S. E. & N. E. for 0.583 miles (Name of Place) on Route No. S-2079 State and County aforesaid, as shown by plans prepared by the South Carolina Department of Highways and Public Transportation, on and over all lands which I (or we) may own in whole or in part, for the purpose of locating, constructing, improving, and maintaining the above described highway with the bridges and causeways thereon, and the right to construct and maintain controlled access facilities to said highway.

Bounded by the lands of George B. Hydrick, Jr. on the west, Duane H. Brazier & Peggy J. Brazier on the southeast, and others. (Show only the Land Owners along the Highway.)

Said right of way to have a width of 66 feet, that is 33 feet on each side of the center line of the highway. The grantor expressly recognizes the possibility that the property described herein may be used in the future by cable television companies for the purposes provided by Act No. 688 of the Acts of Joint Resolutions (1976).

"Special Provisions:" All right of way herein granted between survey stations 3+94.98 and 15+30.5 is along a relocated centerline as shown on the plans by a heavy dashed line.

It is understood and agreed that that portion of the existing roadway outside the right of way between approximate survey stations 11+60 and 12+50 will be scarified during this construction.

Also herein grantes is any land on the left of the survey centerline within the designated right of way.

Figure 27 Example Easement (Right-of-way Easement) (1985)

Permission (*not used to re-establish right-of-way*)

SCDOT sometimes obtains a signed agreement (permission) with a property owner to enter the landowner's property for a limited time to perform work on their land for the purpose of roadway construction and/or maintenance. In other states, these have been supplanted by temporary easements. A Permission document signed by a landowner without consideration is typically used for outfall ditches, driveway connections and sloping rights during road construction. The permission agreement "grants to the Department the right to do the work outlined in the Special Provisions with the understanding that this work is to be done on property of the grantor outside of the right of way. By signing this instrument, the ***landowner does not convey any right of way*** for the purposes of this construction. This permission is valid only for construction and does not grant the Department permission to reenter the property to maintain the work unless this is specifically stated in the Special Provisions." (SCDOT Acquistion Manual, 2019).

SCDOT R/W Form 803 (05-03)

THE STATE OF SOUTH CAROLINA

COUNTY OF LEXINGTON

PERMISSION FOR:

CONTRUCT DRIVE
NPDES

Road/Route	**SC ROUTE 6**
File	**32.145B**
Item	
Project	**STP-COMB(018)**
PIN	**26215**

KNOW ALL MEN BY THESE PRESENTS, That I (or we) **Dan H. Lockhorn and Theresa L Langford, 1557 South Lake Drive, Lexington SC 29073** in consideration of the sum of One Dollar ($1.00), to me (or us) in hand paid, and other valuable consideration at and before the sealing and delivering hereof, do hereby grant to the South Carolina Department of Transportation permission to do the work as outlined below, with the understanding that this work is to be done on property of the grantor outside of the right of way, it being fully understood and agreed that no right of way is being granted to the Department for the purpose of this construction. Further, permission is granted to perform construction beyond the right of way such as grading and other work necessary to adjust the grade of driveways to conform to the proposed roadway improvements as shown on the plans for the construction of this project.

SPECIAL PROVISIONS:

Also.it is understood and agreed that a drive entrance will be constructed to tie in with existing drive on the property of the grantor, by the SCDOT, it contractors or assigns, in accordance with the Access and Roadside Management Standards Manual, during construction of this project.

[Also] Herein granted is permission to use heavy equipment for clearing, placement, maintenance, and access for the purpose of construction of a silt fence for NPDES (National Pollutant Discharge Elimination System) to extend beyond the right of way right of SC Route 6, between approximate survey stations 43+00 and 43+95 as shown on the plans for this project with the understanding no additional property is granted for the permission, in accordance with Department standards.

Figure 28 Example Permission Document

Dedicated Right-of-way

Dedicated right-of-way is typically an exception to using a best fit Existing Roadway Alignment (ERA) when retracing existing right-of-way. Dedicated right-of-way may be a prescriptive easement or property set aside by deed, plat, or city letter for use as a public road. Typically these documents (plat, deed, land description, or city ordinance, resolution or letter) can be used to reconstruct the existing dedicated rights-of-way.

Note that merely marking the dedication on recorded plats does NOT automatically constitute acceptance. See S. C. Code Ann. § 6-29-1170.

Dedication of real property is *"[t]he appropriation of land, or an easement therein, by the owner, for the use of the public, and accepted for such use by or on behalf of the public."* (Black's Law Dictionary with Pronunciations, 1990).

"Only the owner of a fee simple interest can make a dedication. To prove a dedication of land to the public, the party claiming dedication must show that a person who owned the land intended to dedicate it to a public use and that the dedication was accepted by the public. The owner's intention to dedicate must be manifested in a positive and unmistakable manner. A dedication need not be made by deed or other writing, but may be effectually made by acts or declarations. Intent to dedicate may also be implied from long public use of the land to which the owner acquiesces. Nevertheless, dedication is an exceptional mode of passing an interest in land, and the proof of dedication must be strict, cogent, and convincing. The acts proved must not be consistent with any construction other than that of a dedication."
Hoogenboom v. City of Beaufort, 315 S.C. 306, 316, 433 S.E.2d 875, 883 (Ct. App. 1992) (cert denied, 317 S.C. 12, 451 S.E.2d 393, 1994) (citations omitted).

"In some cases where the [highway] Department can occupy the dedication that has been set and recorded in the courthouses, it is best to have an entire subdivision plat providing the dedicated width for an entire roadway. When a sub-division plat is unavailable, individual plats may be utilized to verify dedication through the individual properties. Where no sub-division plat is available and the survey party or the Agent is able to locate individual property plats and identify iron pins marking the property corners, these may be accepted as providing a dedication for the road." (SCDOT Acquistion Manual, 2019).

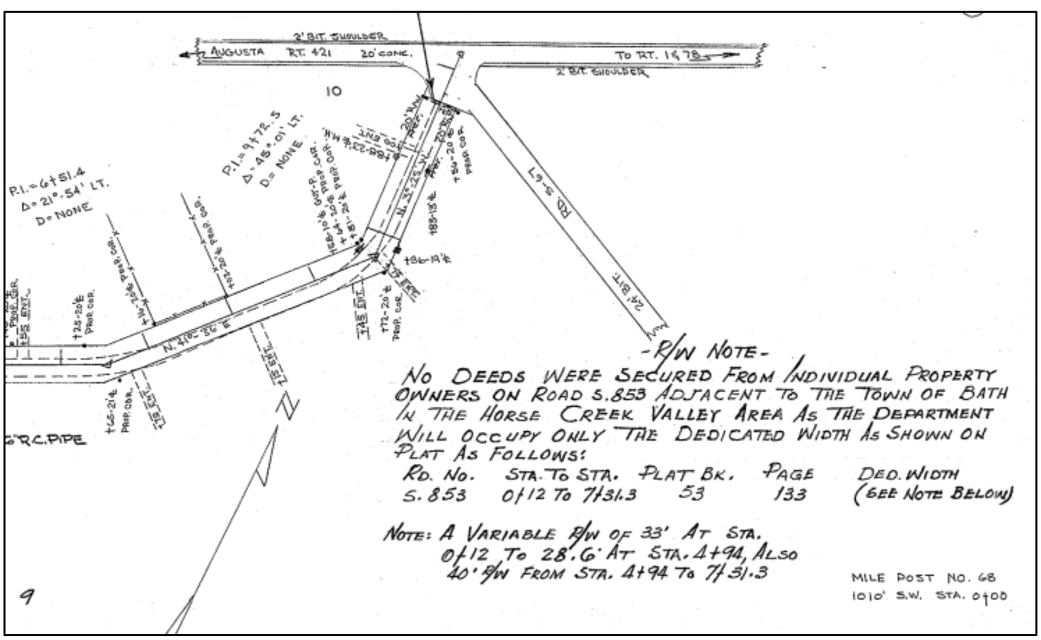


Figure 29 Example Dedicated Right-of-way by Plat

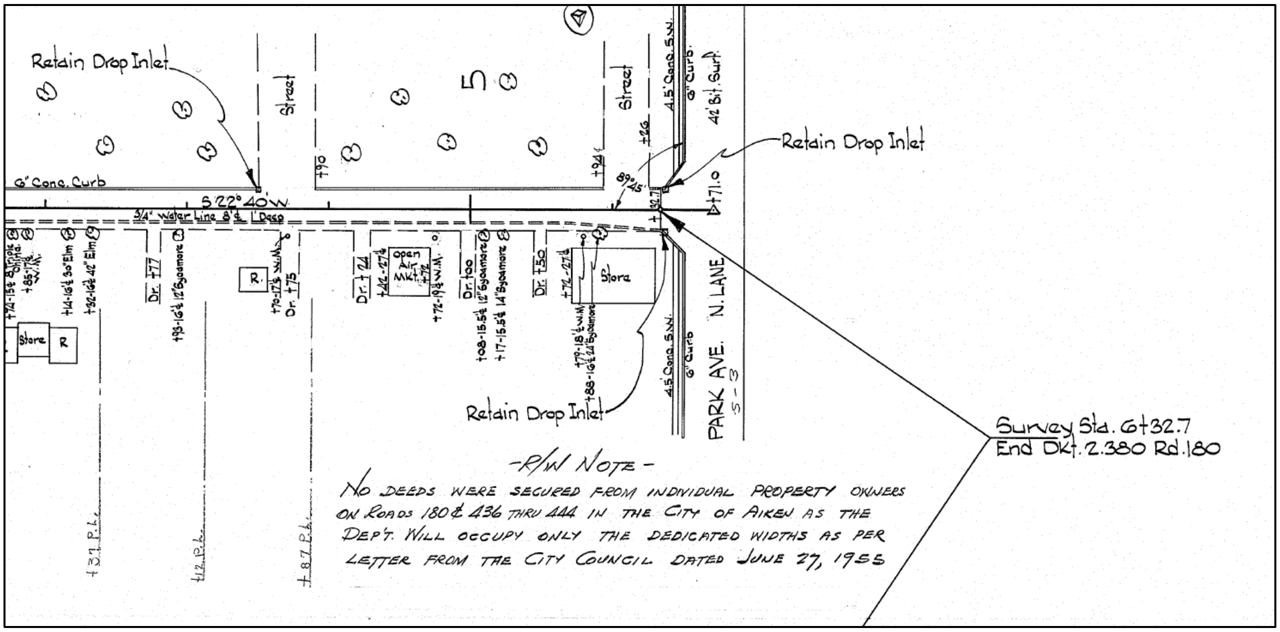


Figure 30 Example City of Aiken Prescriptive Easements

Mr. S. N. Pearman
State Highway Engineer
State Highway Department
Columbia, South Carolina

Re: Docket 2.380 - Roads 180 & 436 thru 444 - Aiken County

Dear Mr. Pearman:

With reference to the improvement on behalf of the City of Aiken, I wish to verify the widths of said streets as shown by map of the City of Aiken, said widths being as follows:

Road 180: Along Fairfield St. 150 feet from Richland Ave. to Park Ave.
Road 436: Along Fauburg St. 90 feet from Richland Ave. to Hayne Ave.
(Now S-176) — Road 437: Along Abbeville Ave. 150 feet from Pendleton St. to Laurens St.
(Now S-128) — Road 438: Along Pendleton St. 150 feet from Barnwell Ave. to Edgefield Ave.
Road 439: Along Dolan Rd. 50 feet from Whiskey Rd. (Sta. 17+00), westerly for approximately 0.3 mile (Sta. 0+00).
Road 440: Along ~~Power House~~ Rd. 50 feet from S. Boundary Ave. to Magnolia Dr.
Road 441: Along Kershaw St. 150 feet from Richland Ave. to Hampton Ave.
(Now S-367) — Road 442: Along Marion St. 150 feet from Colleton Ave. to S. Boundary Ave.
Road 443: Along Colleton Ave. (South Lane) 150 feet from Union St. to Charleston St. Also along Colleton Ave. (North Lane) 150 feet from Union St. to Marion St.
(Now S-177) — Road 444: Along Barnwell Ave. 150 feet from Vaucluse Rd. to Morgan St.

This letter is written by authority of resolution of the City Council adopted on this date.

Yours very truly,

CITY OF AIKEN

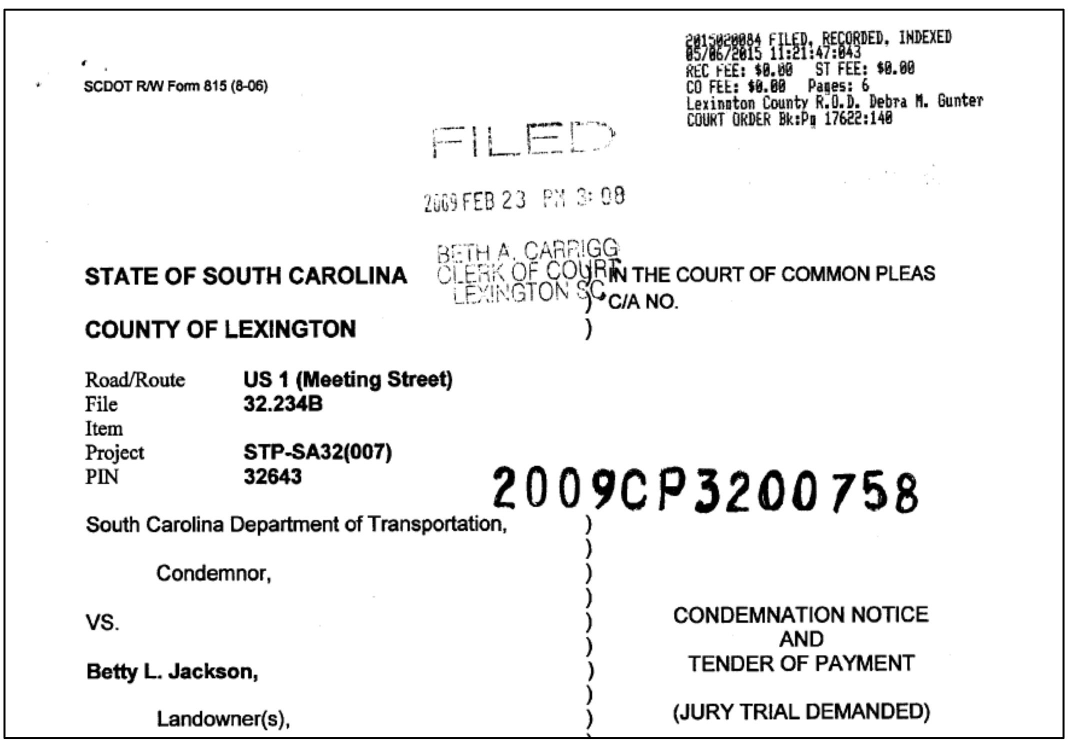
Charles McJones
Mayor

Figure 31 Example City of Aiken vouching to State Highway department (SCDOT's predecessor agency) that the City of Aiken has prescriptive easements, either written (by deed or plat) or non-written (established by long public maintenance) for these roads which the City wants taken in to the State Highway System.

Condemnation

Condemnation is simply the prescribed statutory process by which land or an interest in land – such as an easement -- is acquired for a public works project from landowners unwilling to sell. The process proceeds through the courts to ensure landowners have notice of the acquisition, a fair and just opportunity to appear and contest the acquisition or the amount of compensation, and an appeal process if they perceive that they were treated unfairly at any point. The procedure is codified in Title 28, The South Carolina Eminent Domain Procedure Act (S.C. Code Ann. Section 28-2-10, et seq.)

"Until 1924, securing a right-of-way was a local problem, one county authorities had to take care of, even if they were acting on behalf of the [highway] Department. Then with the passage that year of "pay-as-you-go," [highway] Department officials were given condemnation powers formerly exercised at the local level, and in 1925 lawmakers stipulated that the [highway] Commission (or any three members) could acquire "right-of-way, material for the construction of highways, sand, rock, clay, and other material." They also established methods for settling disputes with landowners and for awarding compensation and gave survey crews the right to go onto any land prior to condemnation proceedings." (Moore, 1987).



SCDOT R/W Form 815 (8-06)

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REC FEE: $0.00 ST FEE: $0.00
CO FEE: $0.00 Pages: 6
Lexington County R.O.D. Debra M. Gunter
COURT ORDER Bk:Pg 17622:140

FILED

2009 FEB 23 PM 3:08

BETH A. CARRIGG
CLERK OF COURT
LEXINGTON SC

STATE OF SOUTH CAROLINA) IN THE COURT OF COMMON PLEAS
) C/A NO.
COUNTY OF LEXINGTON)

Road/Route **US 1 (Meeting Street)**
File **32.234B**
Item
Project **STP-SA32(007)**
PIN **32643**

2009CP3200758

South Carolina Department of Transportation,

Condemnor,

VS.

Betty L. Jackson,

Landowner(s),

CONDEMNATION NOTICE
AND
TENDER OF PAYMENT

(JURY TRIAL DEMANDED)

Williams, Sr., recorded August 14, 2007, in Deed Book 12246, Page 212 in the Office of the Clerk of Court of Lexington County.

3. **South Carolina Tax Commission, n/k/a Department of Revenue, is made a party in this action as "Other Condemnee(s)" by virtue of its claims of interest in that certain State Tax Lien in the amount of $2, 010.66 filed January 2, 2008, in Deed Book 12581, Page 303, in the RMC Office for Lexington County.**

4. The following is a description of the real property subject to this action and a description of the interest sought to be acquired in and to the property by the Condemnor:

> **All that parcel or strip of land, in fee simple, containing 0.004 acre/185 square feet, more or less, and all improvements thereon, if any, owned by Betty L. Jackson, shown as the "Area of Acquisition" on Exhibit A, attached hereto and made a part hereof, between approximate survey stations 79+00 and 80+00 right of US Route 1 (Meeting Street), and between approximate survey stations 93+00 and 94+00 right of Road S-370.**
>
> **Tax Map Number: 004657-12-007**

5. The SCDOT is vested with the power of eminent domain pursuant to Section 57-5-320 and Section 28-2-60, Code of Laws of South Carolina, 1976, as amended.

Figure 32 Example Condemnation

Prescriptive Easements

Prescriptive easements typically exist when a roadway easement was not specifically granted, but was established by government maintenance of the roadway over a period of time at the request of a landowner and with the acquiescence of the landowner's successors. Some examples of what SCDOT maintains are: **Ditch to Ditch**, **Edge of Pavement**, **Back of Curb**, **Back of Guardrail**, and **Outfall Ditches**. The best source of information for these prescriptive easements can be found at **SCDOT's district maintenance offices**. Note, however, that the use of vegetation control measures (herbicide spraying, mowing, trimming) means that maintenance is often actually several feet beyond the strict "Edge of Pavement, Back of Curb, Back of Guardrail" description.

"For secondary roads the additions to the State Highway System must be reviewed to determine whether the road was taken into the system under the **Beltline Act** or the Construction Act. If the road was taken in under the Beltline Act and no improvements have been made to the road since it was taken into the system, then the agent must refer the person inquiring to the county maintenance office. In such cases, the Department claims as right of way by prescription of what it maintains (e.g. ditch to ditch, edge of pavement, back of sidewalk to back of sidewalk)." (SCDOT Acquistion Manual, 2019).

"There is no legislative act specifically entitled "the Beltline Act." The term seems loosely to refer to a series of legislative acts between 1924 and 1952 by which the General Assembly directed the Department to take over and maintain certain roads previously maintained by the counties." (SCDOT, Synopsis of Commission Actions, 2018).

Special Provisions

Special provisions outline work as defined within a document to be performed on property of the grantor outside of the right-of-way. Special previsions can be found in right-of-way documents (example: title to real estate, easement, or permission).

"In the course of [right-of-way] acquisition over the years, the [highway] Department has found it useful to develop a listing of acceptable Special Provisions to be included on right of way instruments. [...] This list is a compilation of standardized provisions that are commonly used by the Department for both Narrative and Exhibit provisions." (SCDOT Acquistion Manual, 2019).

SPECIAL PROVISIONS: Also herein granted are two triangular areas as follows: A 20 X 25 foot triangular area left of approximate survey station 0+20, and a 20 X 20 foot triangular area right of approximate survey station 0+20, both at the intersection of Road S-851 and Road S-926. All property herein granted is more particularly shown on the plans for this project.

SPECIAL PROVISIONS: The right of way herein granted is for an outfall ditch right of approximate survey station 6+50, said ditch right of way being 10 feet on the left and 10 feet on the right side of the ditch centerline and extending to Road S-662 as shown on the plans for this project. The right of way herein granted is along a relocated centerline as shown on the plans by a dashed line between approximate survey stations 5+66.97 and 9+01.0. All property herein granted is more particularly shown on the plans for this project. Right of way herein granted is subject to plans being revised.

Figure 33 Example Special Provisions

4.07.02 DEPICTING PRIVATE PROPERTY

A thorough search of public records is required to obtain deeds and plats for private properties that will be affected by the road improvement project. These plats and deeds are used to create a **property strip map** along the road corridor. Instruments for easements and other right-of-way that are part of the public record must also be reviewed and identified on the property strip map. Where ground conditions indicate the existence of easements or other right-of-way, research must be made to identify the easement or other right-of-way. Again, remember that the SCDOT Right-of-Way Office vault is a resource to be consulted for older right-of-way documents.

The reconnaissance and field survey of **property monuments** must be performed within the project limits to facilitate the mapping of the properties from the deed and/or plat information of record. The property monuments that are found must be tied into the project's horizontal survey control network.

A survey of the entire boundary for each individual property is not typically performed on SCDOT highway projects. Instead, the property lines immediately adjacent to SCDOT right-of-way are typically developed by utilizing the position of found property monuments, the property boundary information in deeds and plats, ground evidence of ownership lines, information from property owners, and sources of information for right-of-way and easement lines. SCDOT considers this a partial property survey which does not constitute a full boundary survey of each individual property.

Property owner information delivered to the design engineer must include the following information:

- Owner Name(s).
- Deed Book and Page Reference.
- Plat Book and Page Reference.
- Tax Map Reference.
- Total Acreage per records.

Digital copies of all documents collected and submitted to the SCDOT must be compiled and organized by SCDOT tract number, to include:

- Deeds and other documents related to properties.
- Plats and Maps.

4.08 TOPOGRAPHIC (DTM) SURVEYS

Within the pre-determined survey corridor, 3D topographical data must be collected for all DTM breaklines, natural and cultural (man-made) features, and ground survey data. All measurements along longitudinal features or breaklines are taken at regular intervals, not to exceed 50 feet on curves or 100 feet on tangents unless additional data is needed to accurately depict existing conditions.

4.08.01 EXISTING ROADWAY SURVEYS / PAVEMENT DTMS

All SCDOT Safety recommendations should be followed when collecting survey data on existing roadway and when on SCDOT right-of-way.

Existing paved roadway surfaces are surveyed using break-lines with surveyed points located on a cross section at predetermined station intervals. Generally most roadways cross-sections include edge of pavements and crown points. Depending on the existing roadway conditions, number of lanes, etc., more topographic points will be collected. The distance between each located pavement shot of roadway features should not exceed 100 feet on tangents and 50 feet in curves.

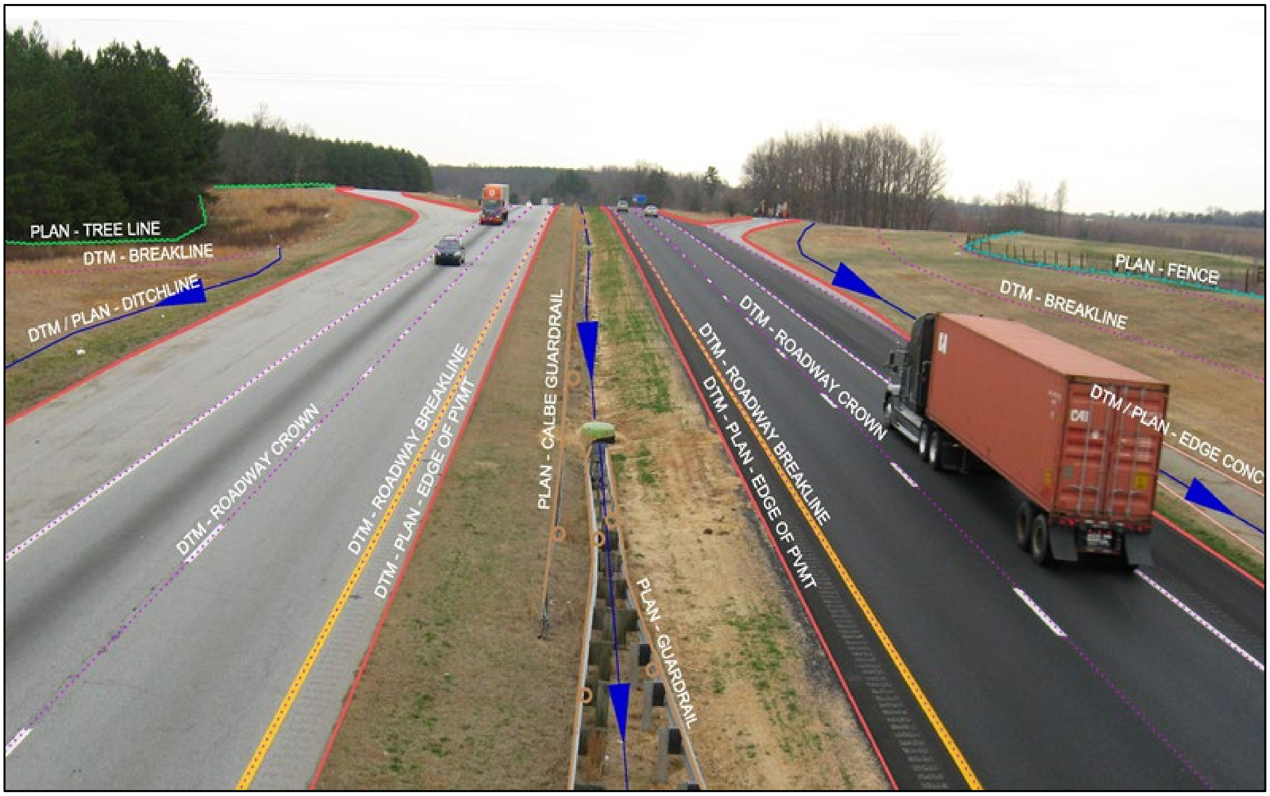


Figure 34 Highway Survey Example

For projects using aerial mapping, it is required to replace the existing edge of pavement DTM break-lines with ground surveys or mobile mapping, and delete the aerial mapping edge of pavement DTM break-lines. The edge of pavement could be retained if collected by aerial mapping at low altitudes which meets project accuracy requirements.

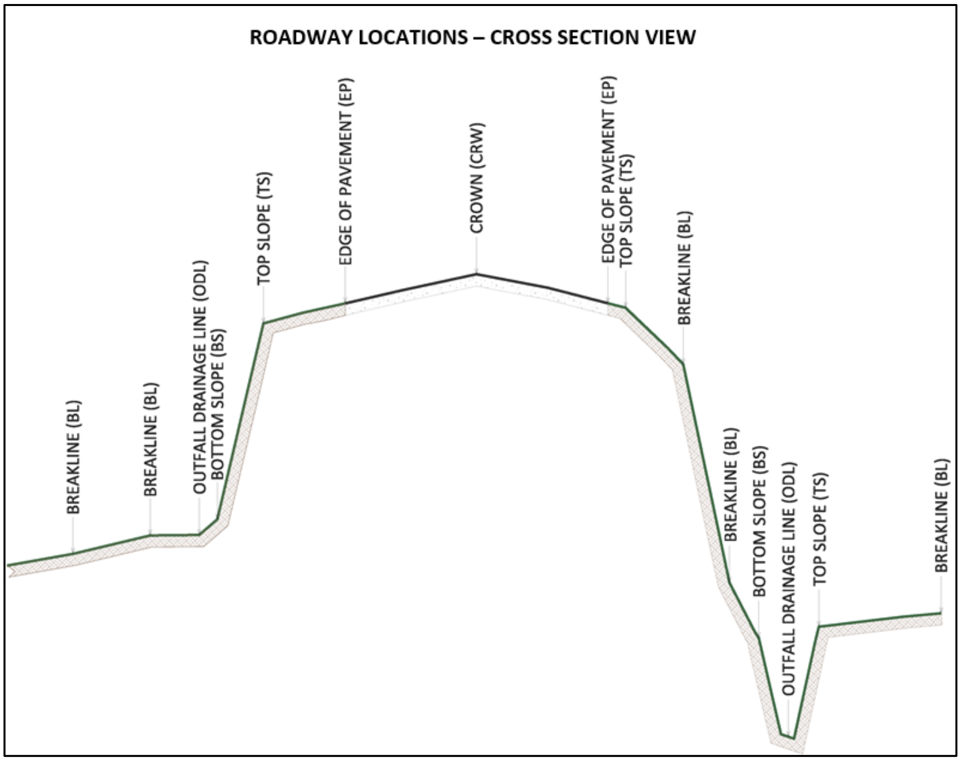


Figure 35 Roadway Survey Detail – Cross Section

4.09 DRAINAGE SURVEYS

Outfall Ditches, Streams, Creeks, Rivers, Swamps, Lakes, Ponds, Marshes, and Tidal areas are surveyed in varying distances from the road centerline **as directed in the requirements for hydraulic design studies** and **as directed by the Lead Hydraulic Engineer**.

General guidelines for locating and collecting hydraulic cross section survey data:
Outfall Ditch: Minimum **300 feet** up and down-stream as measured from the end of the drainage structure (e.g., pipe, culvert), with cross-section intervals no greater than 100 feet.
Stream, Creek, and River: Minimum **500 feet** up and down-stream as measured from the end of the drainage structure (e.g., pipe, culvert, bridge), with cross-section intervals no greater than 100 feet.
Lakes, Ponds, Swamp, **Marsh, and Tidal area**: Contact the Lead Hydraulic Engineer for mapping specifications.

“**Ditches** are engineered channels, such as roadside ditches in cut sections, toe-of-slope ditches, and interceptor ditches placed at the top of cut slopes.” (FHWA, 2018).

Figure 36 Example of Outfall Ditch Flowline

"Stream. A general term for a body of flowing water. In hydrology the term is generally applied to the water flowing in a natural channel as distinct from a canal." (USGS, Water Resources of the United States, 2022).

Figure 37 Example of Fresh Water Stream

Figure 38 Example of Tidal Creek

"A **river** forms from water moving from a higher elevation to a lower elevation, all due to gravity. […] Flowing water finds its way downhill initially as small **creeks**. As small creeks flow downhill they merge to form larger **streams** and rivers. Rivers eventually end up flowing into the oceans. […]" (USGS, Rivers, Streams, and Creeks, 2022).

Figure 39 Example of Gervais Street bridge over Congaree River

“Many **swamps** in South Carolina have no recognizable channel but carry flows requiring a bridge. The lack of channel is due to flat slopes and thick vegetation on the floodplains. A scour hole resembling a channel, at first glance, will usually form at a bridge site in a swamp. But a more detailed investigation will reveal that the scour hole will only extend roughly 100 feet upstream and 200–300 feet downstream from the bridge.” (SCDOT Hydraulic Design, 2000).

Lakes are normally much deeper than ponds and have a larger surface area. **Ponds** are shallow enough to allow sunlight to reach the bottom, whereas sunlight cannot reach the bottom of all areas of a lake.

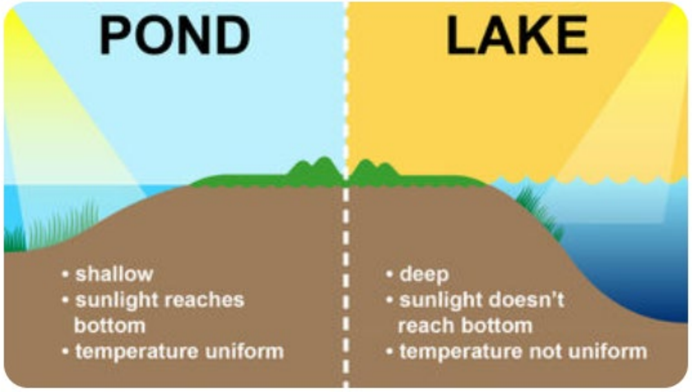


Figure 40 Example of Difference between Pond and Lake

4.09.01 OUTFALL DITCHES, STREAMS & CREEKS LESS THAN 3 FEET WIDE

Provide two (2) Top of Bank breaklines along the top outside edge of the drainage feature and any other breaklines between the center of the drainage feature and the Top of Bank. Provide the center breakline of the drainage feature along the deepest section of the feature.

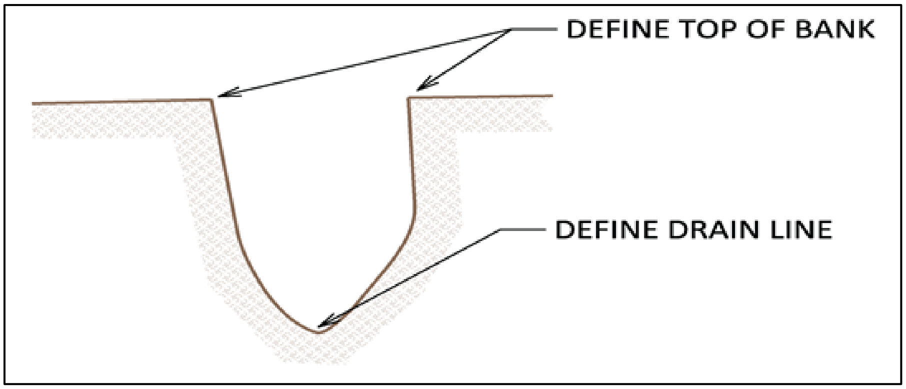


Figure 41 Example Outfall Drainage Survey Detail – Cross Section

Figure 42 Example Outfall Ditch Survey

4.09.02 OUTFALL DITCHES, STREAMS, & CREEKS MORE THAN 3 FEET WIDE

Provide two (2) Top of Bank breaklines along the top outside edge of the drainage feature and any other breaklines between the toe or bottom of the drainage feature and the Top of Bank. Provide two drain breaklines along the toe or bottom of the feature.

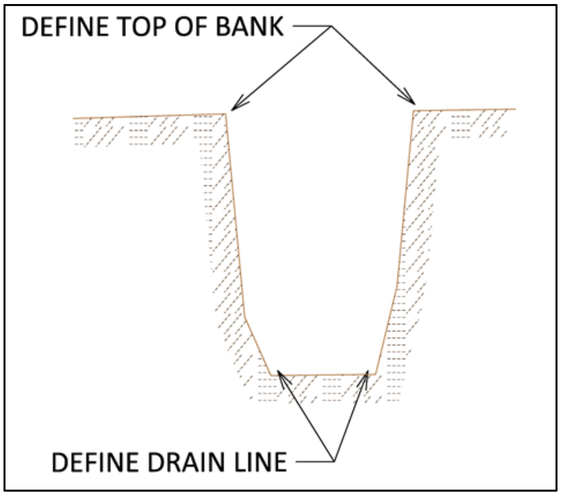


Figure 43 Example Outfall Drainage Survey Detail – Cross Section

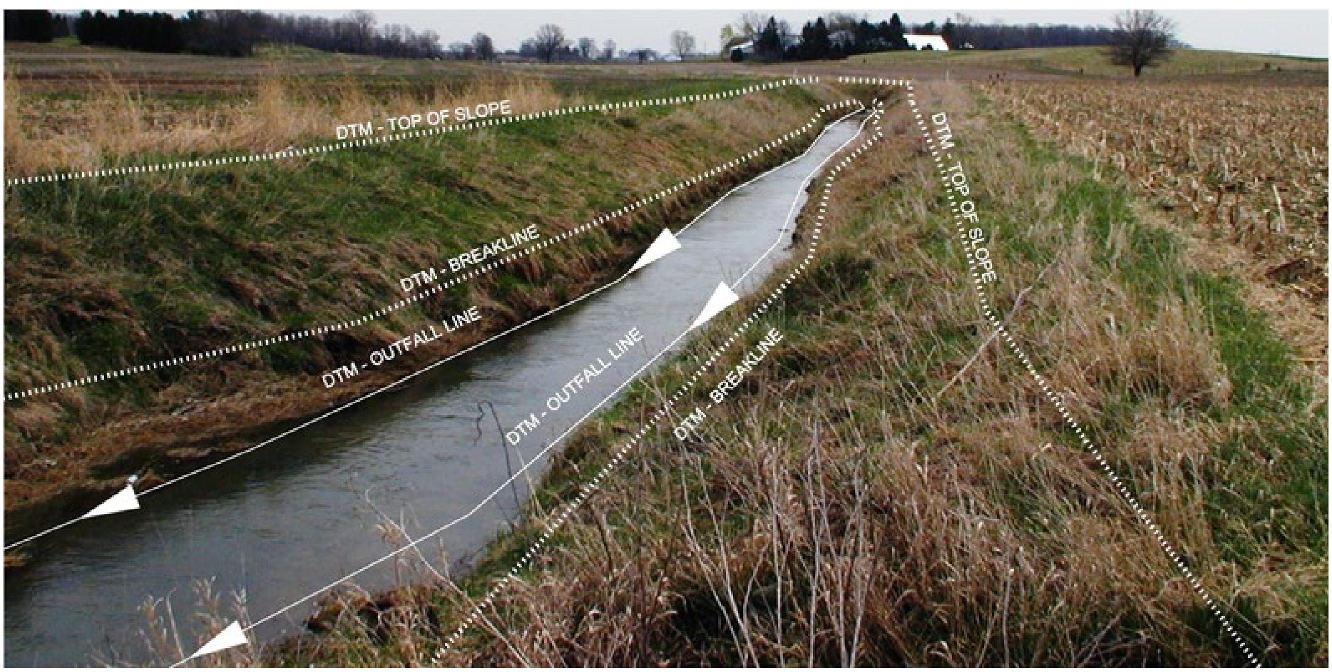


Figure 44 Example Outfall Ditch Survey

4.09.03 RIVERS, LAKES, and PONDS

Bathymetric surveys use sonar based equipment when water depth of rivers, lakes, ponds, and other large bodies of water prohibits the mapping of underwater channel cross sections using traditional survey methods.

“The term "**bathymetry**" originally referred to the ocean's depth relative to sea level, although it has come to mean “submarine topography,” or the depths and shapes of underwater terrain. In the same way that topographic maps represent the three-dimensional features (or relief) of overland terrain, bathymetric maps illustrate the land that lies underwater.” (NOAA, What is bathymetry?, 2022).

SCDOT provides no directive or guideline for bathymetric surveys using sonar based equipment. All surveying procedures and methods are required to meet or exceed the provisions found in the Standards of Practice Manual for Surveying in South Carolina. The SCDOT may request proof of professional competency and/or a special certification for large Hydrographic or Bathymetric surveys. Contact the Lead Hydraulic Engineer for project bathymetric specifications.

4.09.04 ESTABLISHING DRAINAGE FEATURE ALIGNMENTS

Reference alignments are calculated for drainage features. These alignments are created and calculated as follows:

- Alignment stationing will begin downstream and run upstream.
- Alignments consist of Non-Tangent lines with Points of Intersection.
- Points of Intersection are calculated in the center of and at major bends in the ditches.
- Extend the Tangent closest to the interesting roadway alignment.
- Alignments are named OFL01, OFL02, etc.

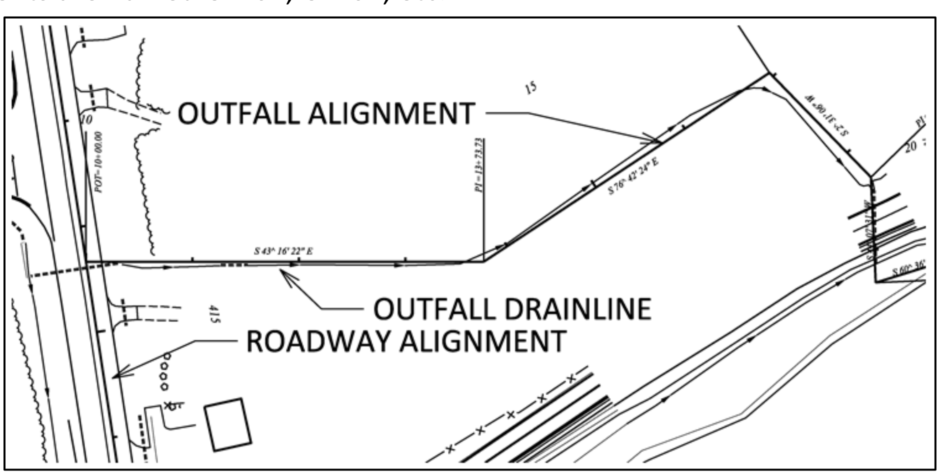


Figure 45 Example Outfall Drainage Alignment

4.10 BRIDGE, CULVERT, and PIPE SURVEYS

4.10.01 BRIDGE SURVEYS

Bridge Surveys must be performed to provide both accurate bridge planimetry (2D) with appurtenance, and DTM (3D) information for hydrographic and bridge design. Bridge survey data is dependent upon the structure type and anticipated type of work. Projects involving bridge work include new, replacement and rehabilitation. Major rehabilitation such as bridge widening, deck replacement or major reconfiguration of the bridge will have different and more extensive survey requirements. The Lead Structural Engineer should direct the survey crew in what bridge data is to be field surveyed and mapped.

An **existing bridge** survey will include the following:
Typical features required on bridges:

- Bent cap (bearing seat) elevations and bent cap centerline.
- Planimetric (2D) location of concrete columns or piles (older bridges may have wooden piles).
- Low chord of bridge girder.
- Abutments (e.g., endwalls, wingwalls, etc).
- Utilities attached to bridge.

Other optional project specific features as directed by the Lead Structural Engineer:

- Bridge joints.
- Vertical clearance at crown of pavement and all painted travel lanes for overpass bridges.
- Raised sidewalks, multi-use paths, raised medians, median barriers, parapet wall, etc.

Additional items required for any **bridge that spans a water course**, such as:
Typical features required on bridges over a water course:

- Observed water elevation on date of survey.
- Historical high water mark.
- Elevation on top of parapet wall.
- Abutment toe.

Other features as directed by the Lead Hydraulic Engineer:

- Flood Way & 100 year Flood (Floodplain) location.

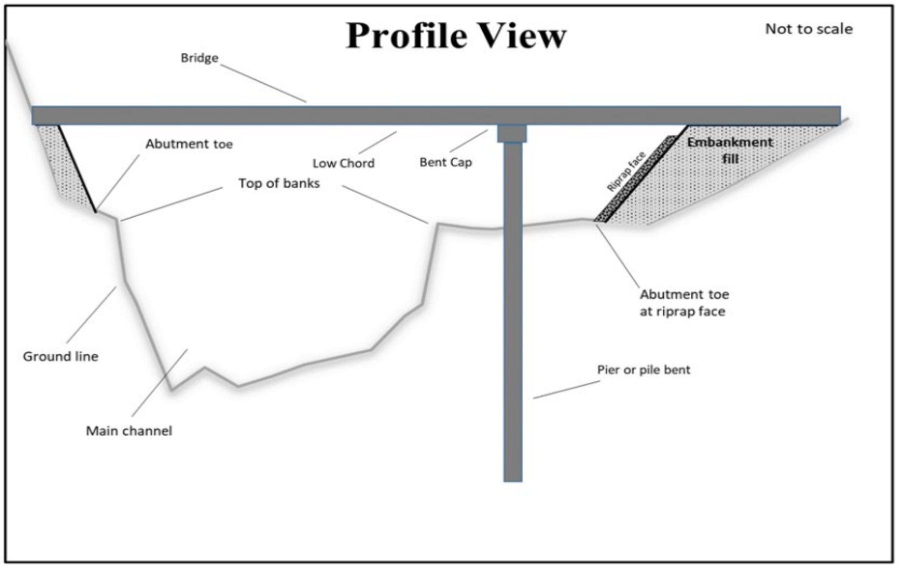


Figure 46 Abutment Toe Profile View

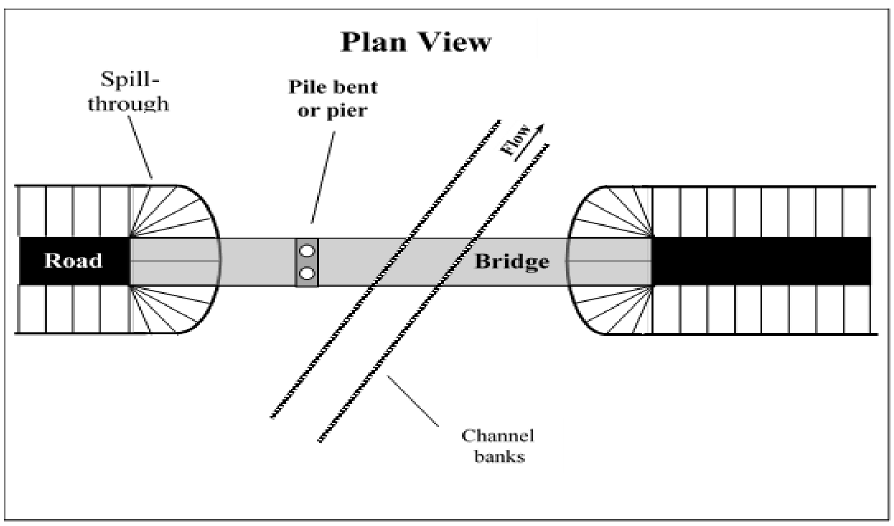


Figure 47 Spill-Through Abutment Toe Plan View

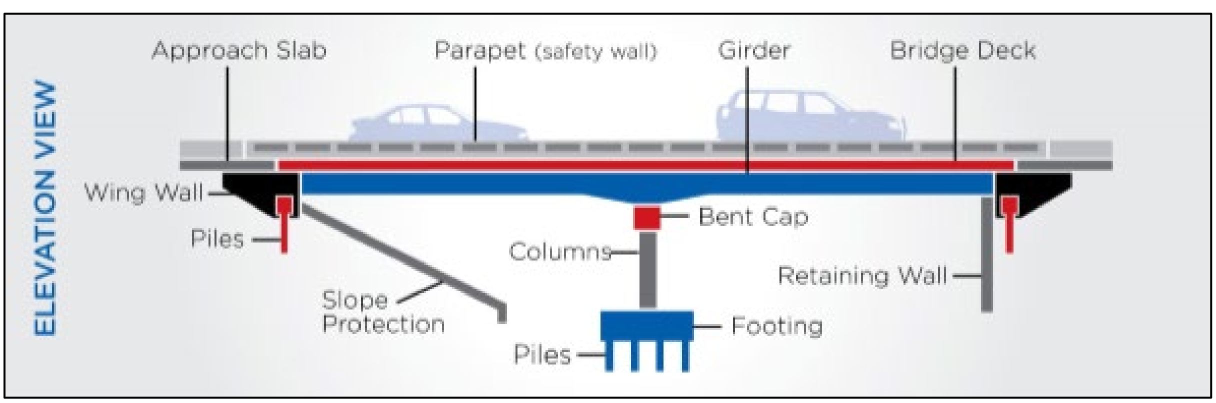


Figure 48 Typical Bridge Features over Roadway

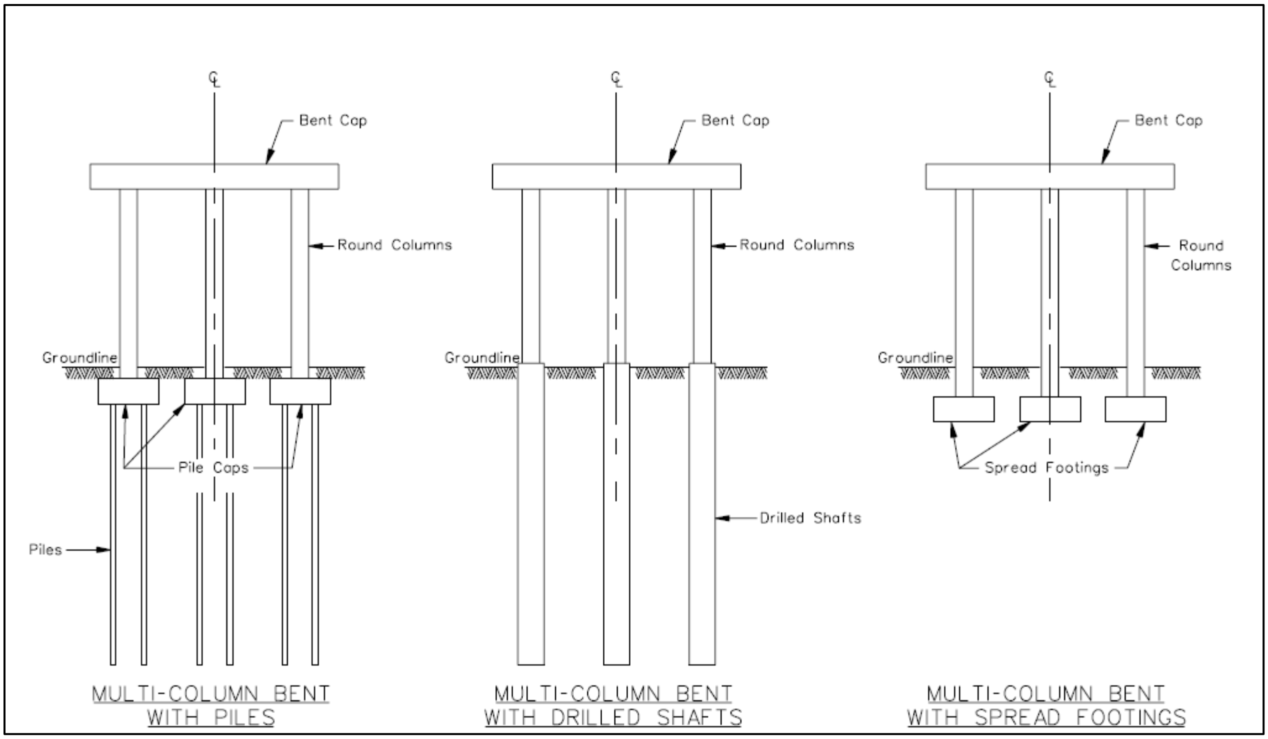


Figure 49 SCDOT Bridge Design Manual (2006)

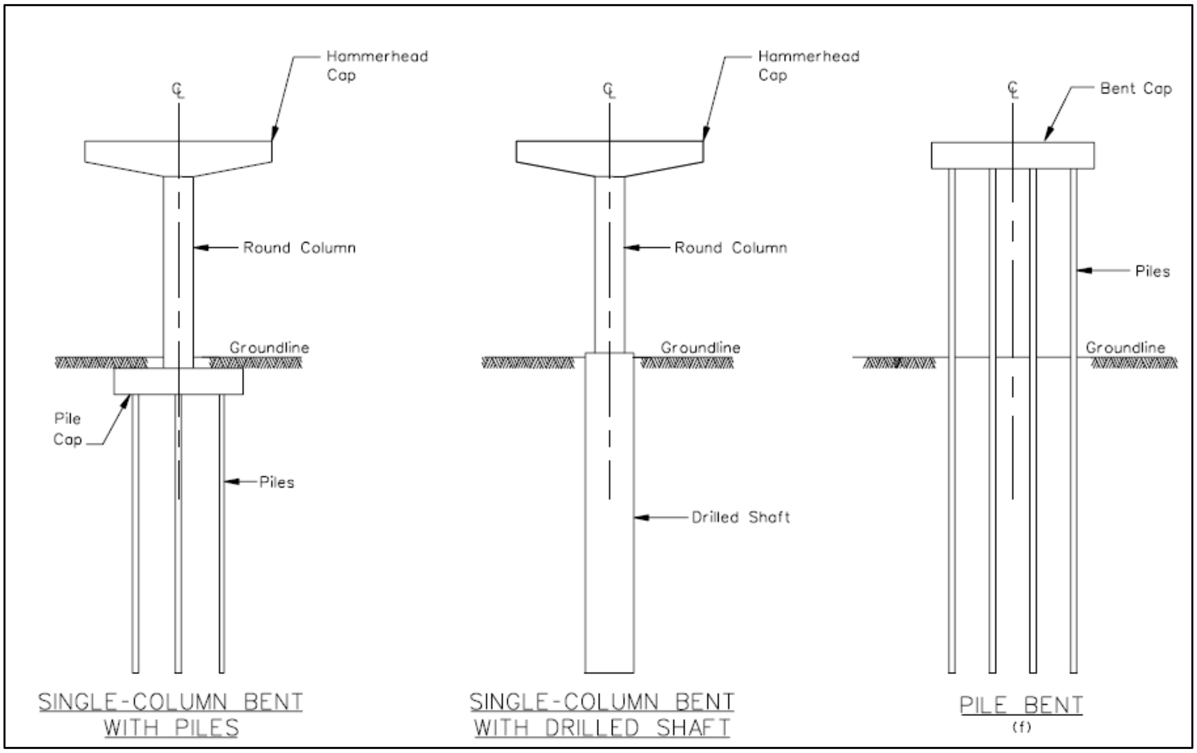


Figure 50 SCDOT Bridge Design Manual (2006)

Locate outside top center of **bent cap** at both ends to define centerline of entire bent cap. Ensure elevation is true for top of bent cap.

Figure 51 Bridge Bent Cap (bearing seat) Survey Locations

Bridges should be located by four corners for a tangent structure. For curved structures, outline the structure sufficiently to show the location in a plan view.

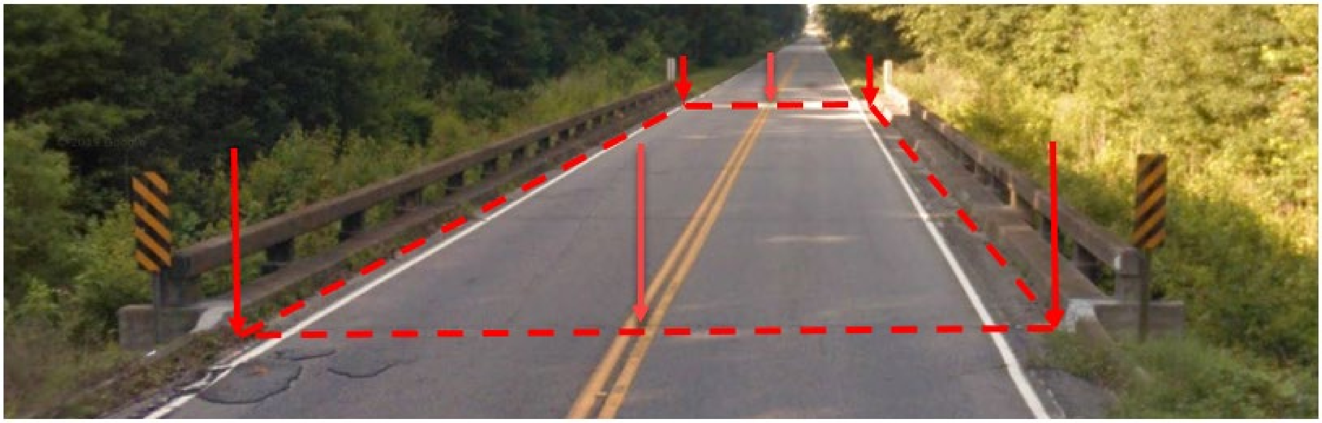


Figure 52 Concrete Bridge Deck Survey Locations

Figure 53 Wooden Bridge Deck Survey Locations

4.10.02 WATER ELEVATIONS BELOW BRIDGE

For the **observed water level** locate a single point at edge of water body near bridge and include date in description. This point will be used primarily by the bridge design engineer to calculate the grade for top of drill shaft to be used during construction.

Figure 54 Observed Water Level

For the **historical high water mark** of both non-tidal waters and tidal waters, locate point at high water mark closest to road centerline and include date in description. SCDOT distinguishes a "historical high water mark" as different from a jurisdictional "Ordinary High Water" line as defined by the U.S. Army Corps of Engineers (USACE High Water Mark, 2005). SCDOT follows the USGS publication "Identifying and Preserving High-Water Mark Data" (USGS, 2016) for field evidence of the "historical high water mark" such as: mud lines, seed lines, debris lines, ice rings, cut lines, wash lines, and debris snags. Reference the USGS publication for additional detail.

Figure 55 Wash Line (USGS, 2016)

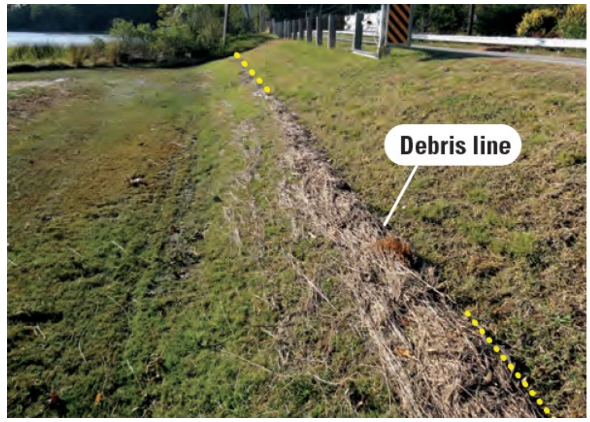


Figure 56 Example Debris Line (USGS, 2016)

Figure 57 Seed Line (USGS, 2016)

Figure 58 Cut Line (USGS, 2016)

Figure 59 Mud Line (USGS, 2016)

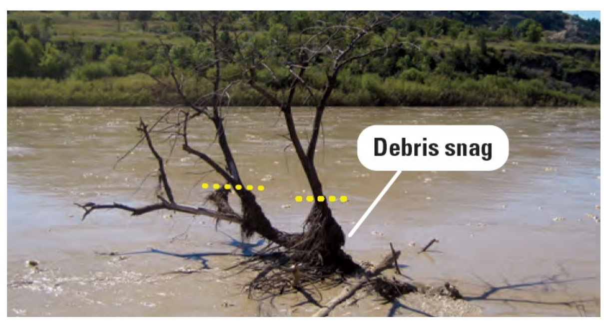


Figure 60 Debris Snag (USGS, 2016)

4.10.03 BRIDGE HYDRAULIC CROSS SECTIONS

Bridges which cross streams, creeks, rivers, lakes, ponds, swamps, marshes, and tidal areas are surveyed in varying distances from the road centerline **as directed in the requirements for hydraulic design studies** and **as directed by the Lead Hydraulic Engineer**.

General guidelines for locating and collecting bridge hydraulic cross section survey data:
Stream, Creek, and River: Minimum **500 feet** up and down-stream as measured from the end or the face of the proposed or existing bridge structure, with cross-section intervals no greater than 100 feet.
Lakes, Ponds, Swamps, Marsh, and Tidal area: Contact the Lead Hydraulic Engineer for mapping specifications.

Include cross-section data at the proposed or existing bridge face or end locations (both upstream and downstream). Cross section data points must include the following:

- Top of stream / river banks.
- Toe or bottom of stream / river banks.
- Thalweg (lowest point) of stream / river.
- Spill-through abutment toe.

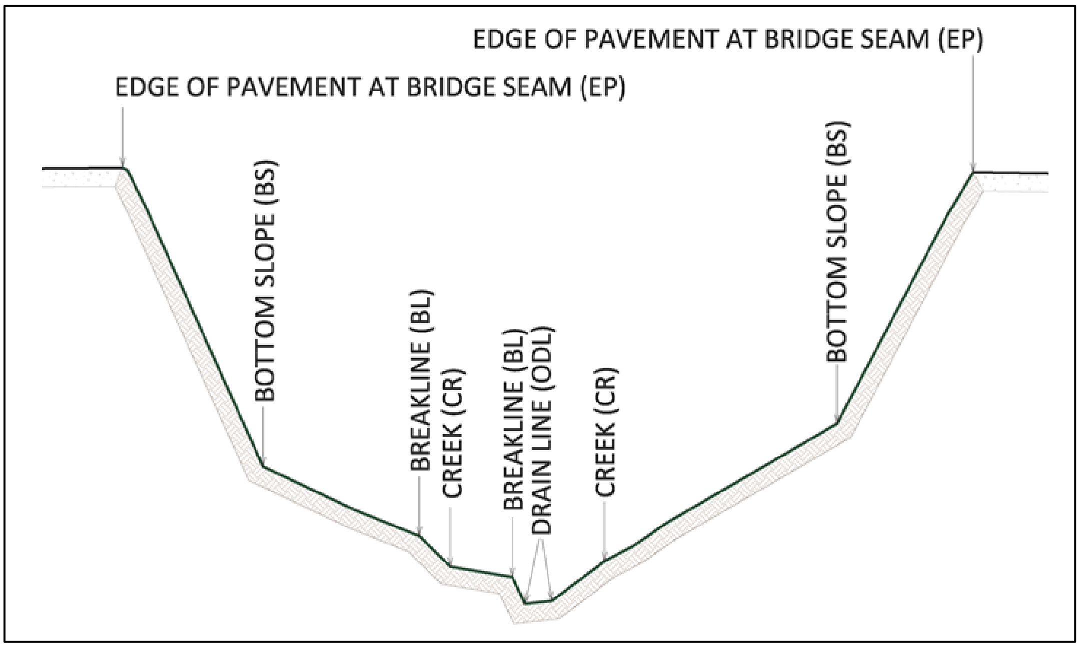


Figure 61 Bridge DTM Survey – Cross Section View

4.10.04 CULVERT SURVEYS

Survey the 2D location of culverts by locating the inside face of the inlet and outlet sections. If the culvert has Wingwalls or Headwalls, survey them by locating the top front of beginning and end. If the culvert has a concrete apron, locate the outside edges. DTM shots are required at the culvert locations, apron locations, and behind the wing walls. Include a culvert sketch (see box culvert sketch form in appendix).

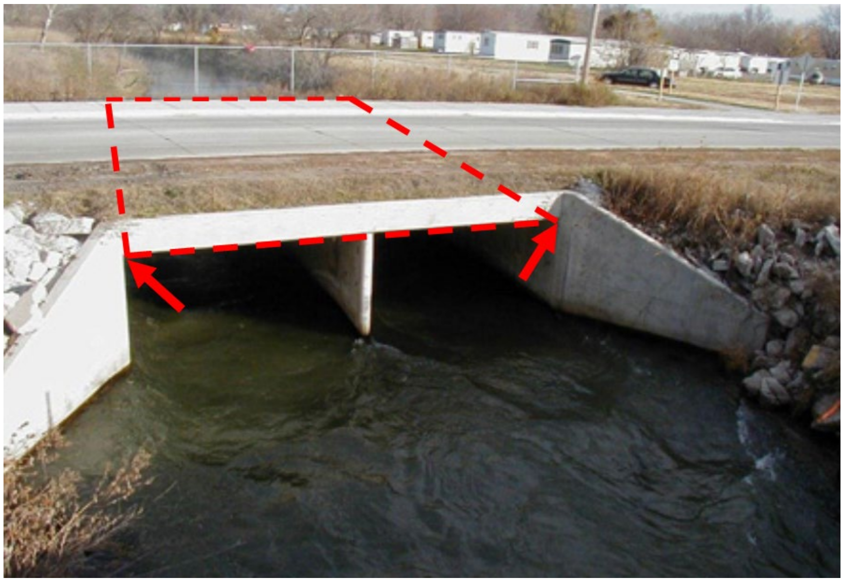


Figure 62 Planimetric (2D) location of culvert

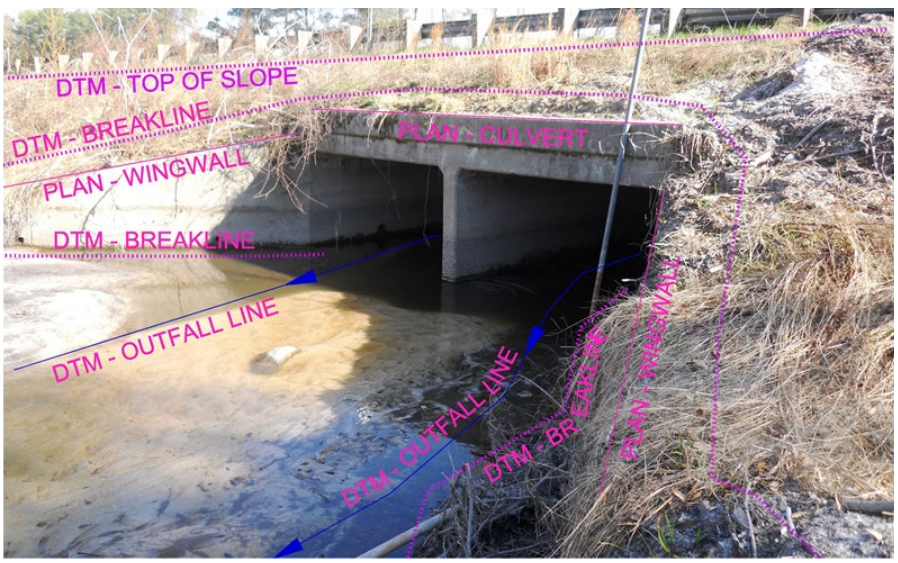


Figure 63 Culvert Survey Example

4.10.05 DRAINAGE PIPES

A drainage pipe is a hollow cylinder that conveys flow from one point to another. A pipe may be used by itself or as part of a storm sewer system.

Locate storm sewer pipes with the following information:

- Pipe size.
- Pipe Material.
- Invert Elevation.

Figure 64 Example Storm Sewer Pipe

4.10.06 HEADWALLS AND WINGWALLS

Locate headwalls at top front corner closest to ditch and include width of wall. Locate wingwalls at top inside corner closest to the ditch and include width of wall. Locate pipe invert flow line with pipe type and size.

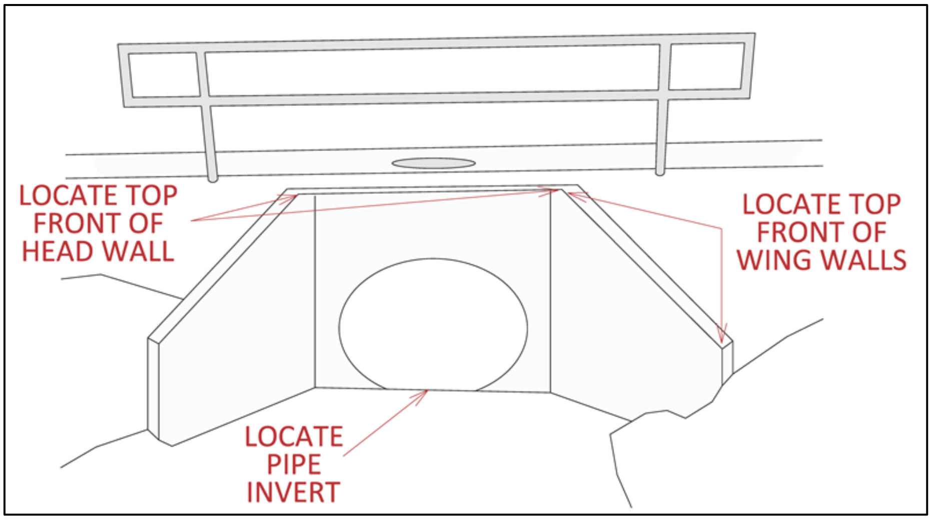


Figure 65 Headwall and Wingwall

4.10.07 INLET STRUCTURES

Curb Inlets are generally located with a minimal amount of shots depicting the following information:

- Center Top of Structure with structure code and description of type or size.
- Curb Flow Line Elevation Shot.
- Outline of structure if needed for clarity.
- Inlet structure Pipe Flow Line elevations with size and type.

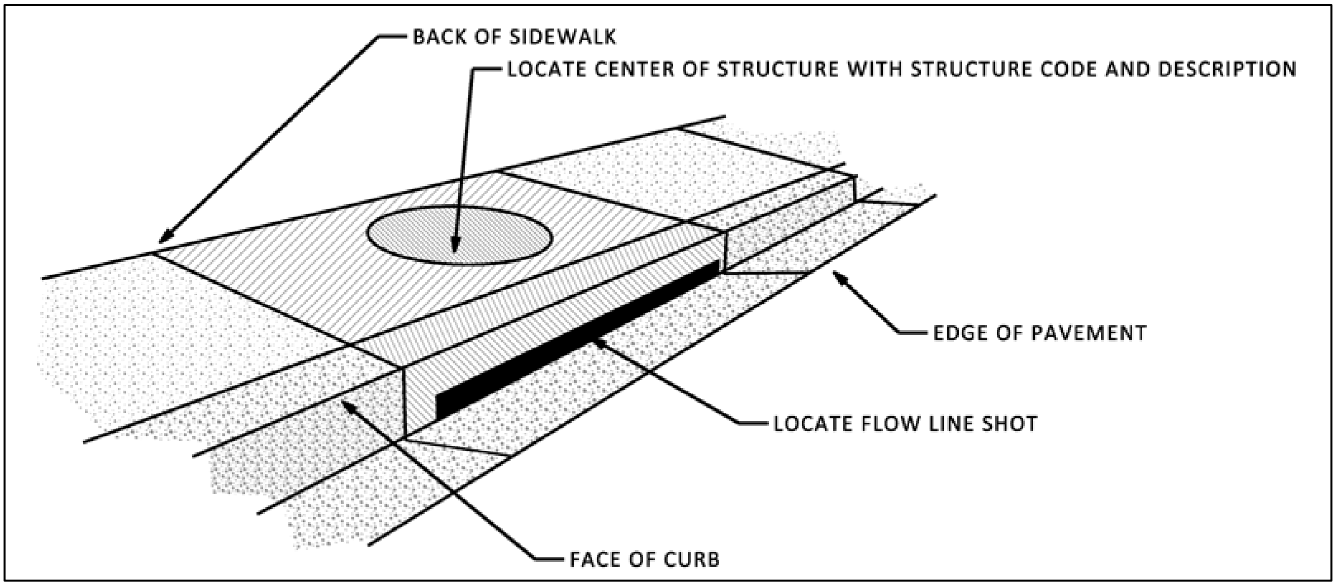


Figure 66 Typical Curb Inlet Locations

Drop inlets are located depicting the following information:

- Center Top of Structure with structure code and description of type or size.
- Center Top Elevation Shot.
- Grates larger than 3'x3' should be located by corners.
- Locate concrete aprons with Concrete codes.
- Inlet structure Pipe Flow Line elevations with size and type.

4.11 RAILROAD SURVEYS

When projects require land acquisition or Right-of-Entry from a Railroad Company, the following railroad survey information for plan development is required, unless directed otherwise by the SCDOT Railroad Projects Manager:

- Location of all railroad appurtenances.
- Existing drainage structures and flow patterns.
- Railroad right-of-way.
- Location of the nearest railroad milepost marker.
- Railroad alignments must be stationed using railroad VAL map stationing, unless other railroad documents are provided showing railroad stationing.

If a project involves a **parallel encroachment but road improvements do not cross the railroad right-of-way**, include the following information in the survey:

- Distance to tracks (all measurements are referenced from the centerline of the tracks).
- Cross sections from the project to mainline tracks with ground line & top of rail elevations.
- Topography to the mainline tracks.
- All drainage structures and channels on both sides of the mainline tracks with elevations of flow line and top of structures.
- Nearest railroad right-of-way line to road project.

When the **SCDOT right-of-way crosses or the road is within 25' of crossing a railroad right-of-way** (within the project limits), the field survey must include:

- The centerline of the railroad must be located a minimum of **200 feet** left and right of the crossing roadway survey centerline with appropriate topography, drainage structures and cross section data within the railroad right-of-way, to include top of rail elevations.

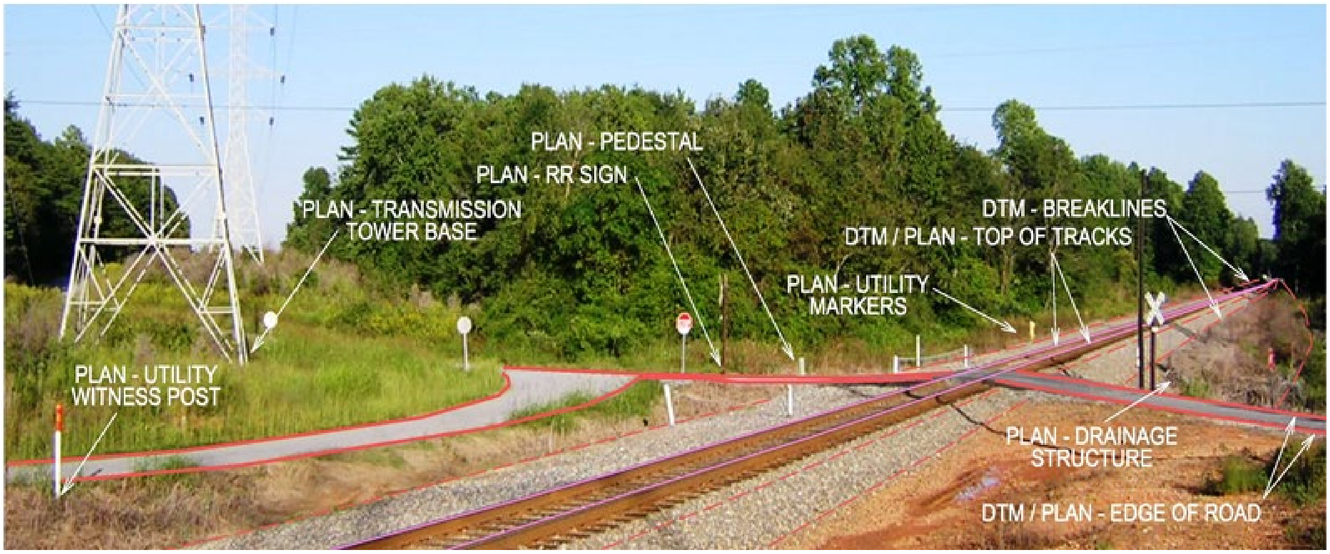


Figure 67 Railroad Survey Example

4.12 PLANIMETRIC SURVEYS

All cultural (man-made) and natural features pertinent to the roadway project must be located and mapped. These items include, but are not limited to the following:

- Roadways, curb and gutter, paved areas.
- Sidewalks, trails.
- Buildings, canopies, decks, steps.
- Signs, mailboxes, columns, flag poles.
- Historical or majestic trees, ornamental trees, wooded area boundaries, shrubs.
- Fences, walls, guard rails.
- Streams, rivers, lakes, marshes, ponds, swamps, and tidal areas.
- Utility poles, telephone pedestals, meter boxes.

All planimetric features should include descriptions of its material, type, species, size, condition, etc. On projects where aerial survey is used, it is necessary to classify the planimetric features shown in the mapping (building type, tree species and sizes).

4.13 SUBSURFACE UTILITY ENGINEERING SURVEYS

The standard survey practice of accurately mapping the location and elevation of all above ground utilities is required for most projects. For other projects, where the location of underground utilities is considered critical to the design process, Subsurface Utility Engineering (SUE) services is used.

SUE is a method for identifying the location of subsurface utilities at various levels of quality. Each quality level is defined by the thoroughness, accuracy and methods used in gathering the subsurface utility information.

Refer to the latest SCDOT SUE CADD Manual for CAD drafting standards and the latest SCDOT Utilities Accommodation Manual for additional SCDOT SUE standards.

4.14 ENVIROMENTAL SURVEYS

Environmental areas (wetlands, protected species habitats, etc.) are located as directed by the environmental engineer. Make note of delineation information and collection methodology.

Figure 68 Example of Surveyed Jurisdictional Wetlands showing flag numbers (e.g., WF-001)

4.14.01 FLOODPLAIN SURVEYS

If a floodplain survey is requested by the Lead Hydraulic Engineer, the SCDOT requires all floodplain crossings meet the Federal Emergency Management Agency (FEMA) regulation requirements (SCDOT Hydraulic Design, 2000).

"Field surveying for floodplain mapping is uniquely different from topographic design surveys in that the data collected is not necessarily intended to describe a continuous DTM surface. Survey cross-sections are typically requested by hydraulic engineering in selected locations so as to depict the volumetric capacity of the flood valley. The following guidelines identify some of the typical requirements for floodplain mapping surveys:

- Cross-section data must include full width of the flood valley.
- Cross-section survey points are required at significant breaks in the ground line. The highest density of survey points will probably lie in the flow channels. Floodplain data points should emphasize the general slope of the plain and its width. […].
- Aerial photographs of the road and any adjacent rivers are often the best way to provide a complete depiction of the floodplain valley. […] In some instances, a controlled aerial survey may prove more economical in getting flood plain survey data, particularly when aerial photogrammetry is being conducted as part of the roadway design. Consult with hydraulic engineering specialists in these instances to determine the limits of coverage desired." (FHWA, 2018).

SCDOT requires the flood plain mapping elevations meet the FEMA vertical accuracy for the highest level of flood risk: RMSEz = 0.41' (12.5cm). (FEMA, 2019)

The figure below depicts the methodology used by FEMA for their Flood Hazard Mapping Program. Points labeled "G" represent gradient breaks where there is a significant change in the slope of the terrain.

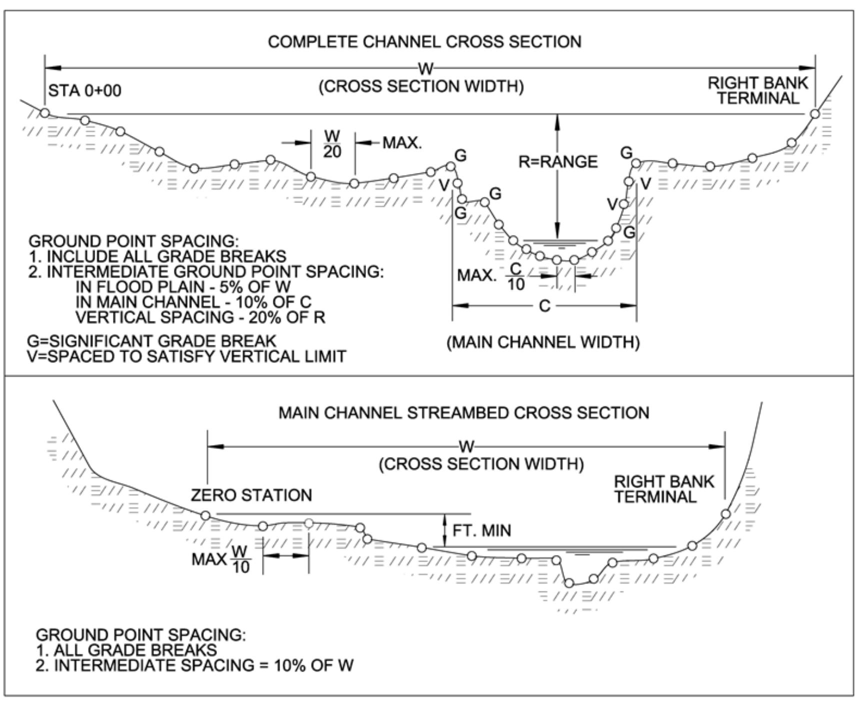


Figure 69 "Examples of cross section ground point spacing" (Maune, 2003)

4.14.02 WETLAND AREAS

Wetland surveys are generally the surveyed location of an environmental engineer's flagged delineation of wetland (jurisdictional) areas. Locate flags noting the flag color and design and the flag number. Make note of wetlands located by other methods (soils, vegetation, etc.)

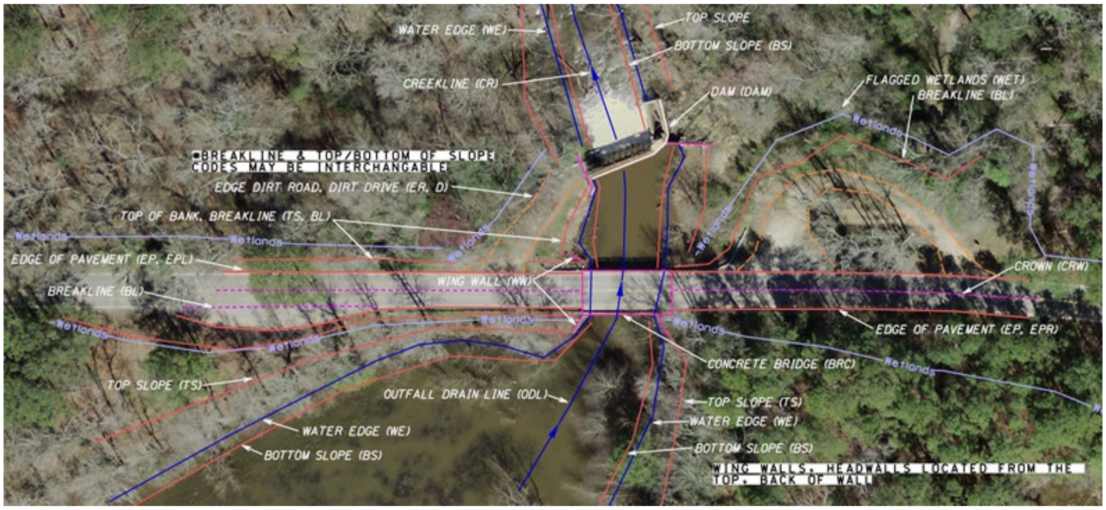


Figure 70 Wetland area example on bridge survey

4.15 RIGHT-OF-WAY STAKING and RIGHT-OF-WAY PLAT

During right-of-way acquisition, staking is typically performed when the SCDOT is affecting property outside of the existing right-of-way. These stakes will show both existing and proposed right-of-way, helping the right-of-way agent clearly show the impact to the land owner.

The right-of-way plat is typically performed at the end of a road construction project and memorializes the newly acquired right-of-way.

4.15.01 RIGHT-OF-WAY STAKING

Temporary right-of-way staking will be directed by the SCDOT right-of-way agent for each project. Right-of-way break points including POTs, PCs, PTs, transition right-of-way points, and right-of-way along extended tangents are staked on 100' stations, with curves staked at 50 foot stations.

Right-of-way stake material and labeling specifications:

- 36" x 2" x ¾" wooden stake.
- Highly visible florescent flagging.

- Alignment side (road side) of stake must show right-of-way width:
  - **New** right-of-way example: “**NEW 50’ RW**”.
  - **Present** right-of-way example: “**PRES 33’ RW**”.
  - **Transitional** right-of-way example: “**TRANS RW**”.
- Property side of stake must show road alignment station (example: “10+00”).

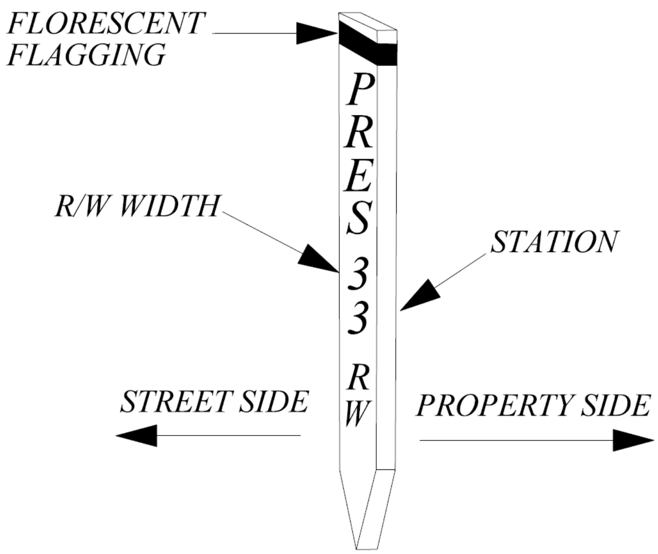


Figure 71 Example Right-of-Way Stake

4.15.02 RIGHT-OF-WAY PLAT

The SCDOT right-of-way plat is completed as a bid item during highway construction projects. This plat must be based solely on information depicted on the final approved SCDOT construction plans for the project. This plat must meet the South Carolina Standards of Practice for Surveying insofar as to document and **monument the new right-of-way** for future property retracement surveys, while also depicting the present right-of-way for reference with annotation only (no monuments).

The right-of-way monument material specification and spacing must follow the **SCDOT Standard Drawing No. 809-105-00** and the **SCDOT Standard Specifications for Highway Construction** (latest version). Right-of-way monuments must not be placed at points common to side property lines and/or corners. **In the event that the plan reflects a break in the right-of-way along a side property line, the right-of-way monument must not be set without the side property line being retraced and established by way of survey.** The South Carolina Professional Land Surveyor must prepare a plat documenting the location of all right-of-way monuments set, and reference the station and offset of these new right-of-way monuments to the plan centerline. The plat must show the entire project corridor (and any new right-of-way areas) as an enclosed strip of land to include the mainline and all side roads as defined by the construction limits depicted on the project’s construction plans.

The right-of-way plat **must be recorded in the Registers of Deeds (ROD) office** of the county or counties in which the project resides and a copy of the recorded plat must be submitted to the SCDOT Resident Construction Engineer (RCE) to be included in the highway as-built plans.

In addition to the Standards of Practice Manual for Surveying in South Carolina requirements for a General Boundary Survey (Section 49-460-A), SCDOT requires the following information:

1. Plat must be titled "Right-of-Way Plat Prepared for SOUTH CAROLINA DEPARTMENT OF TRANSPORTATION".
2. Road name and number.
3. SCDOT Project ID Number.
4. Existing and Proposed Alignments showing stationing and curve data.
5. All station and offset labels must be referenced to the Relocation alignment if different from the Survey centerline alignment.
6. Tie Equality of Original Survey centerline and Relocation centerline.
7. Labeling of Present and New right-of-way widths.
8. Station and Offset of Transitional Right-of-way referenced to Relocation centerline.
9. Bearing, Distance, and Curve data must be labeled for both the Relocation centerline and Survey centerline.
10. Acreage of New Right-of-way.
11. Labeling of State Plane Coordinate for a minimum of one identifiable point on right-of-way which can be related to the relocation centerline.
12. Reference to the final approved SCDOT construction plans used to create right-of-way plat.

When a right-of-way marker location is inaccessible and cannot be set, a witness or reference marker shall be set on the right-of-way line with the station and offset noted on the right-of-way plat.

Below is an example Right-of-way plat and excerpts for clarity showing the minimum required information.

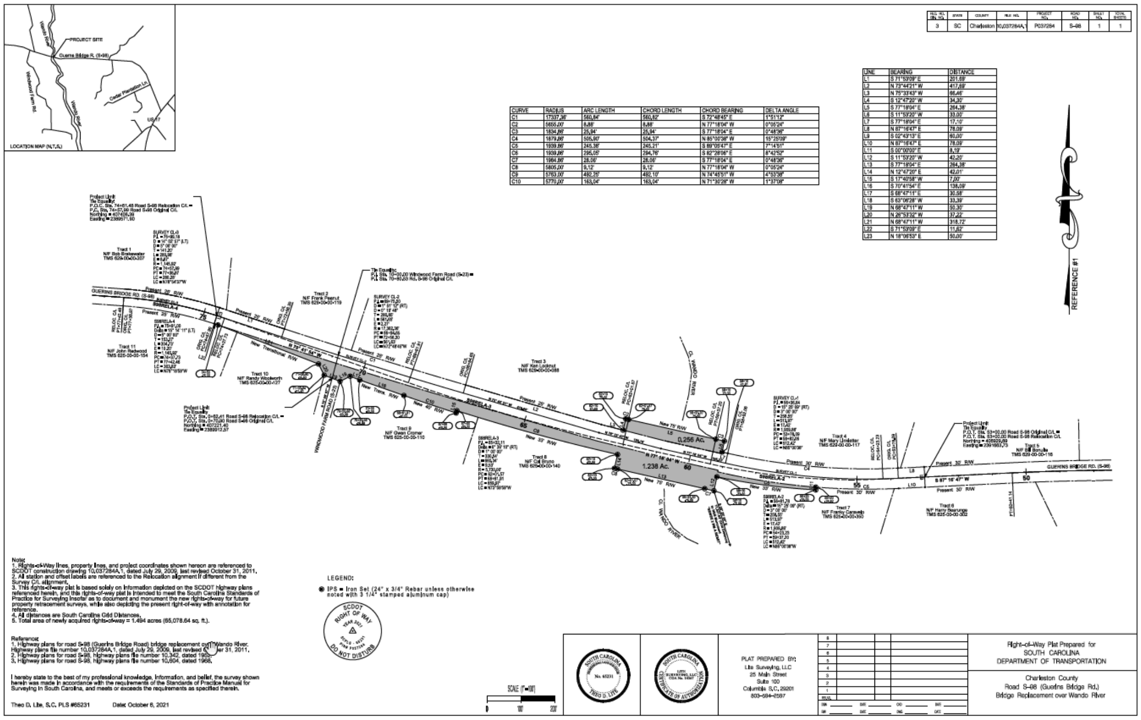


Figure 72 Example Right-of-way Plat

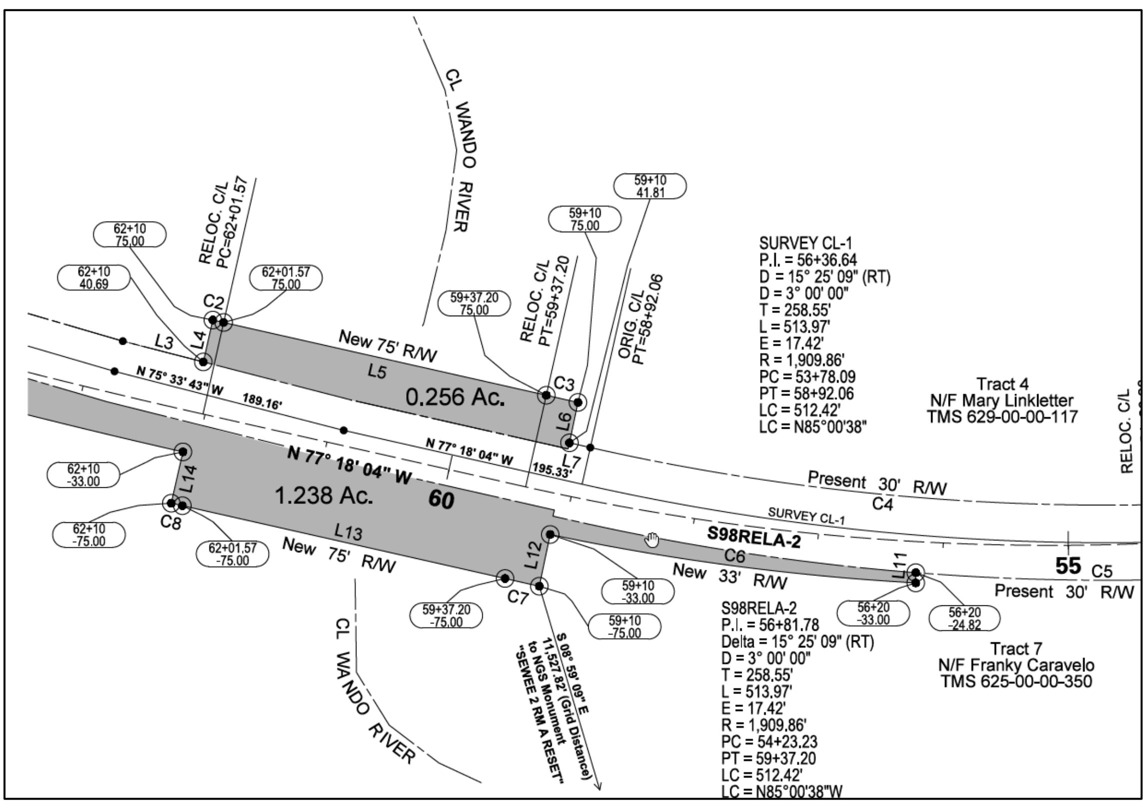


Figure 73 Example Right-of-way Plat Excerpt

Note:
1. Rights-of-Way lines, property lines, and project coordinates shown hereon are referenced to SCDOT construction drawing 10.037284A.1, dated July 29, 2009, last revised October 31, 2011.
2. All station and offset labels are referenced to the Relocation alignment if different from the Survey C/L alignment.
3. This rights-of-way plat is based solely on information depicted on the SCDOT highway plans referenced herein, and this rights-of-way plat is intended to meet the South Carolina Standards of Practice for Surveying insofar as to document and monument the new rights-of-way for future property retracement surveys, while also depicting the present right-of-way with annotation for reference.
4. All distances are South Carolina Grid Distances.
5. Total area of newly acquired rights-of-way = 1.494 acres (65,078.64 sq. ft.).

Reference:
1. Highway plans for road S-98 (Guerins Bridge Road) bridge replacement over Wando River. Highway plans file number 10.037284A.1, dated July 29, 2009, last revised October 31, 2011.
2. Highway plans for road S-98, highway plans file number 10.342, dated 1952.
3. Highway plans for road S-98, highway plans file number 10.604, dated 1968.

I hereby state to the best of my professional knowledge, information, and belief, the survey shown herein was made in accordance with the requirements of the Standards of Practice Manual for Surveying in South Carolina, and meets or exceeds the requirements as specified therein.

Theo D. Lite, S.C. PLS #65231 Date: October 6, 2021

Figure 74 Example Right-of-way Plat Excerpt

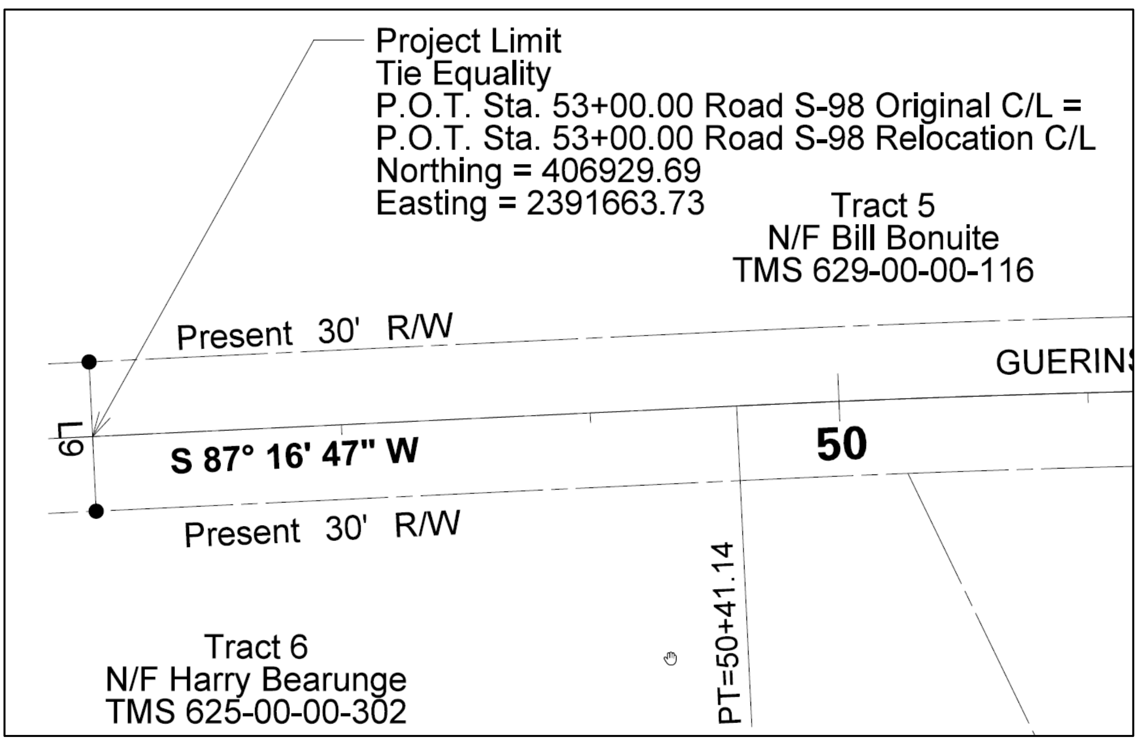


Figure 75 Example Right-of-way Plat Excerpt

Right–of–Way Plat Prepared for
SOUTH CAROLINA
DEPARTMENT OF TRANSPORTATION

Charleston County
Road S–98 (Guerins Bridge Rd.)
Bridge Replacement over Wando River

Figure 76 Example Right-of-way Plat Excerpt

FED. RD. DIV. NO.	STATE	COUNTY	FILE NO.	PROJECT NO.	ROAD NO.	SHEET NO.	TOTAL SHEETS
3	SC	Charleston	10.037284A.1	P037284	S–98	1	1

Figure 77 Example Right-of-way Plat Excerpt

LEGEND:

⦿ IPS = Iron Set (24" x 3/4" Rebar unless otherwise noted with 3 1/4" stamped aluminum cap)

Figure 78 Example Right-of-Way Plat Excerpt

4.16 QA-QC & GROUND TESTS

Throughout the roadway design process, verification of topography and critical design locations may be necessary to guarantee conformity of the roadway design to field conditions, and insure critical areas and “tie-in” points reflect a sufficient level of accuracy for constructability. Some items that may be subject to testing include, but are not limited, to the following:

- Relocation Alignment tie-in points.
- New Alignment tie-in points.
- Designed outfall structure points.
- Proposed easements or utility location.

- Construction limits, slope stakes.
- Verification of project survey control prior to construction.
- Environmental areas as determined by others.

4.17 FIELD SURVEY FILE DELIVERABLES

Surveying and mapping consultants must deliver files to the SCDOT that are compatible with the latest SCDOT's CADD and Plan Development Process. SCDOT Roadway Projects are assigned Project ID Numbers. All files submitted by the consultant must be referenced to a Project ID. The types of files and naming conventions are listed below, and are examples of files typically requested by the SCDOT. **The examples shown below assume a Project ID number of "P012345"**.

An electronic copy of any digital data delivered to the SCDOT must be retained in the permanent files of the licensee. The term "Bentley" as used in this manual refers to a native Bentley digital data format. Refer to the latest SCDOT Roadway CADD Manual for current format requirements.

12345.xlsx	Project Report Spreadsheet (optional for consultants).
12345deed.pdf	Digital copy of all courthouse Deeds, Plats and Property Ownership records.
12345pp.dgn	Planimetric survey data (2D) in Native Bentley format.
12345dtm.dgn	Topographic Breakline data (3D) in Native Bentley format.
345.gpk	Best Fit Existing Road Alignment (ERA) described in a Geopak .gpk file format.
12345prop.dgn	Property Strip Map and Existing Road Right-of-way in Native Bentley Format.
12345.tin	Digital Terrain Model in Native Bentley format.
12345.new	ASCII file containing the final survey point data.
12345_SCDS.pdf	Survey Control Data Sheet listing property monuments and survey control data.

Note: Any additional surveys submitted for the same project will follow the same naming convention but will add an a, b, c, etc. Example: for the first additional survey the file name will be 123456a.new, the second additional survey will be 123456b.new etc.

5.0 DATA COLLECTION FEATURE CODES & PROCEDURES

5.01 GENERAL OVERVIEW

This section of the manual has been developed as a guide to provide uniform feature coding for the collection of field data when performing design surveys. **It is intended to be used by SCDOT survey crews** but could aid others.

The following information in this section of the manual is NOT a standard or specification for consultant contracts and is for information only for consultants.

A **feature** as defined within this section of the manual is any man-made or natural object located within the project limits such as pavement, bridges, pipes, ditches or streams, etc. The **feature code** is a combination of alphanumeric characters which help to abbreviate the full feature description.

Example: **AC** - **Air Conditioner Unit**

Features will be classified as either **POINT**, a feature whose position can be defined by a single measurement (survey shot), or **LINE (CHAIN),** which is a feature shown by a string (series) of connected points. The codes used in the description for electronic data submitted to the SCDOT headquarters office must be identical to the codes described herein for the CADD system to recognize the applicable features. Except for the use of numbers for multiple line features, no other alphanumeric characters should be used with the primary feature code unless it is separated from the code by a *space*.

Example: **AGT propane** or **EPL1**

Any additional description needed for the survey point can be placed after the feature code provided a delimiter (space) is used for separation. This will include such information as size and type of a pipe, size and type of a tree, height and type of a fence, etc. Unless otherwise noted, sizes are assumed to be in inches.

Examples: **IP 1in Pipe** = Iron Pin Found 1in diameter Pipe **BM nail 20 Pine** = BM nail in 20in Pine

Occasionally, a feature is not represented within the standard Feature Code list. Two codes have been reserved for this situation. **MSP (Miscellaneous Point)** and **MSL (Miscellaneous Line)** are feature codes which can be used with an additional description.

Examples: **MSP rivet** or **MSL ramp**

5.02 SOFTWARE SYSTEM

The SCDOT Preconstruction Survey Department uses a combination of software systems for processing field survey data. The following is a flow chart showing the software associated with each step in the process, from the collection of field data to the final delivery to the SCDOT Design Groups.

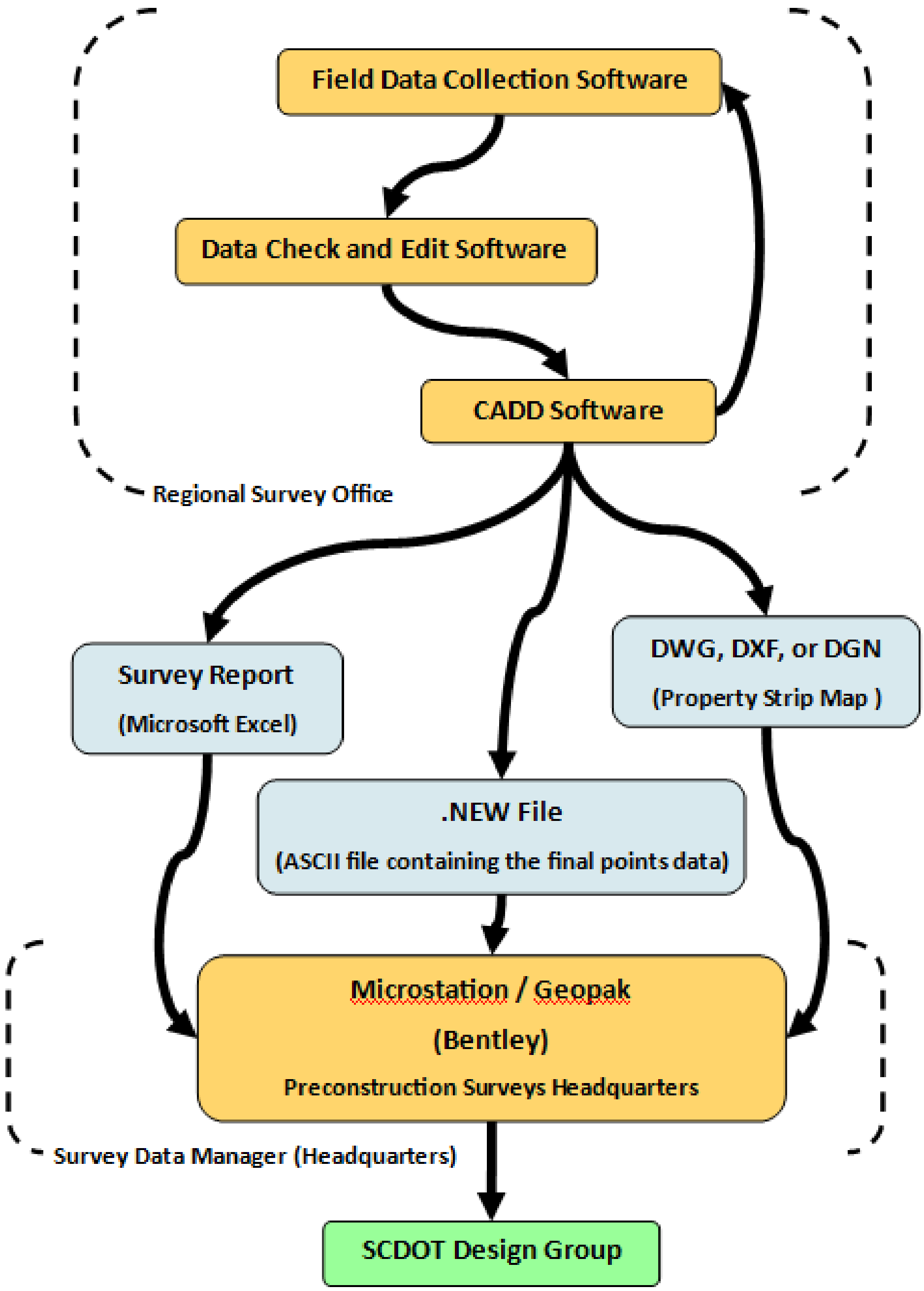


Figure 79 SCDOT Survey Data Flowchart

5.03 SURVEY MANAGER DATABASE (SMD)

The SCDOT Design Groups use **Bentley** products as its Computer-Aided Design and Drafting (CADD) software. Within this CADD environment, Bentley uses the **Survey Manager Database (SMD)** file to control which graphical elements are associated with specific **Survey Feature Codes** as well as how these elements are displayed. The SMD file can control:

- Point Attributes - Cells (Symbols).
- Linear Attributes – Linestyles.
- Symbology (Levels/Layers, Colors, Line Weight).
- If the collected field survey point will be used to develop the Digital Terrain Model (DTM Inclusion).
- Labels (Point Number, Elevation, Description).

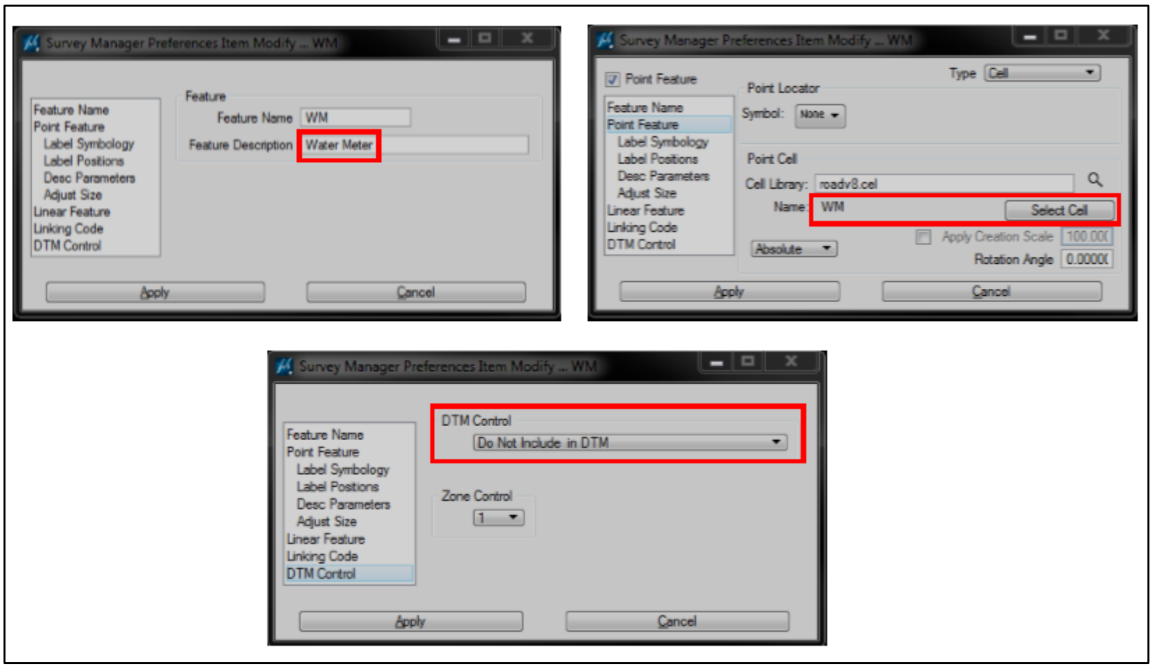


Figure 80 Example of SMD file (Water Meter)

WM - Water Meter

Point = Yes

Line = No

DTM Inclusion = No

Located on the center of the top cover with single point.

Example: Point Description = WM

Figure 81 Example of Feature Code description.

5.04 LINKING CODES

The **Bentley** software is also used for **automatic line work** creation in the CADD environment. This is accomplished by using special **"Linking Codes"** in combination with the standard **Feature Codes**. In the figure below, a side road was surveyed and linking codes were used to create lines automatically. In this example, points (3097-3098, 3101-3102, 3105, 3112, 3121-3122 and 3124) were coded to create the edge of pavement left (EPL1). Point 3097 begins the line "EPL1A" and point 3124 ends the line "EPL1B". The point numbers are not required to be sequential (3097,3098,3099,3100) but are required to be coded such that the beginning point number starting the line is followed by an ***increasing series*** of point numbers up to the final ending point.

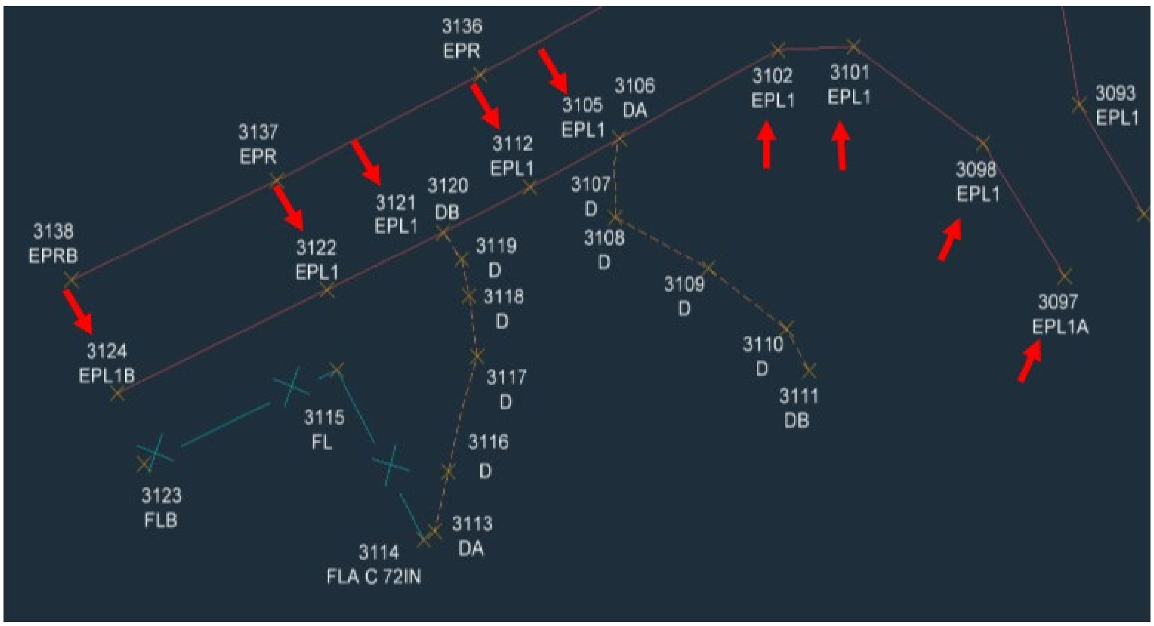


Figure 82 Example of automatic line work using Linking Codes.

The primary **Feature Code** can be expanded for multiple lines being coded for line work simultaneously using the same base feature code. This is accomplished by adding additional numbers 1 thru 9 to the base feature code.

Example: **EPL**, **EPL1**, **EPL2** up to **EPL9**

The **Linking Codes** currently in use are **"A"** for **begin line** and **"B"** for **end line** within the survey software used in the Regional Survey Office.

Example: **EPLA** (begin line) and **EPLB** (end line)

When the **.NEW** file is delivered to Headquarters, the **"A"** and **"B"** are converted to **"+"** (begin line) and **"-"** (end line) for the automated line work within the **Bentley** software.

5.05 PLANIMETRIC (2D) and BREAKLINE (3D) POINT RANGES

Each SCDOT Preconstruction Survey field office provides a single point data file in an ASCII format to the Headquarters Survey Data Manager which contains a combination of both Planimetric (2D) and "Breakline" (3D) point data. Each file has the following naming convention: **40479.new**

Project ID Number

File extension unique to SCDOT

```
* Begin Section: Controls
*
* Control Points
   1, 772122.41880,1981639.38710,   209.72000,CP 1 5/8 REBAR W/DISC
   2, 772348.68085,1982016.58716,   203.27000,CP 2 5/8 REBAR W/DISC
   3, 772844.96183,1982039.14554,   191.80000,CP 3 5/8in REBAR
* S-32-609 (Julius Felder St.)
   4, 772330.00237,1982064.78171,   202.82000,PI 10+00.00
   5, 772637.86342,1982064.27656,   196.36000,PC 13+07.86
   6, 772690.00205,1982064.19101,     0.00000,PI 13+60.00
   7, 772739.85196,1982048.91257,   193.85000,PT 14+11.38
   8, 772637.28914,1981714.27703,     0.00000,RP 1 S-609
   9, 773015.80207,1981964.33692,   189.28000,POT 17+00.00
* Bench Marks
  10, 772353.40580,1982090.70020,   202.04000,BM 1 PP 529076
  11, 773495.34450,1981905.01180,   190.76000,BM 2 PP C9022
* End Section: Controls
*
* Begin Section: Topography
*
 1000, 772260.21730,1981888.18780,   206.80940,IP 3/4in PIPE
 1001, 772294.40060,1981980.16500,   204.64920,IP 1 1/2in PIPE
 1002, 772304.98050,1982079.40380,   203.07980,IP 1 1/2in PIPE
 1011, 772298.16980,1981955.02120,   204.65990,EPRA
 1012, 772323.48370,1981947.01370,   204.83720,SWLA CONC
 1013, 772328.17800,1981945.44750,   204.92460,SWL1A CONC
 1014, 772336.72940,1981942.07410,   204.35120,FLA C 60in
 1015, 772344.12310,1981940.04770,   204.29350,SWRA ASPH
*
* End Section: Topography
*
* Begin Section: Cross Sections
*
20000, 772298.16980,1981955.02120,   204.65990,EPRA
20001, 772300.64100,1981954.10540,   204.41570,BLA
20002, 772311.00180,1981951.07390,   204.50110,CRWA
20003, 772320.10070,1981947.95420,   204.45310,BL1A
20004, 772323.48370,1981947.01370,   204.83720,SWLA CONC
20005, 772328.17800,1981945.44750,   204.92460,SWL1A CONC
20006, 772332.62280,1981943.69940,   204.37400,BS1A
20007, 772344.12310,1981940.04770,   204.29350,SWRA ASPHALT
```

Figure 83 Example of .NEW file

Within each ".NEW" file, point number ranges are used to designate point groups:

- **Control** Points: **1-999** (Survey Control, Benchmarks and Road Alignment).
- **Planimetric (Topo)** Points: **1000-19,999** (2D points).
- **Breakline** Points: **20,000-89,999** (3D points).
- **Non Essential** Points: **90,000-100,000** (Calculated Points).

For most projects, survey points will have correct elevations and a single survey point can be used in both point ranges and included in both the final 2D and 3D CADD drawing.

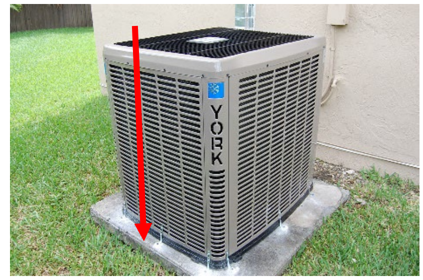
The Survey Data Manager will process the .NEW file with the understanding that the field office personnel have created the Planimetric and Breakline point ranges to accurately depict the existing conditions of the project. The Codes contained in this manual are to be used at the discretion of the surveyor in regards to their use in the final 2D and 3D point ranges. The description of each points "DTM Inclusion" is a guideline or suggestion but is not intended to restrict the use of any code being included in the 3D point range.

5.06 FEATURE CODES

AC	Air Conditioner Unit	Point	ETB	Electric Transformer	Point
AGT	Above Ground Tank	Line	F	Flower Bed	Line
B	Building	Line	FH	Fire Hydrant	Point
BDL	Berm Ditch Left	Line	FL	Fence Left Other	Line
BDR	Berm Ditch Right	Line	FLAG	Flag Pole	Point
BL	BreakLine	Line	FLT	Flood - Ground Light	Point
BM	Bench Mark	Point	FOL	Fiber Optic Cable	Line
BRC	Bridge - Concrete (or Steel)	Line	FR	Fence Right Other	Line
BRW	Bridge - Wood	Line	GEO	Geodetic Marker	Point
BS	Bottom of Slope	Line	GL	Gas Line	Line
BSW	Back Edge of Sidewalk	Line	GLT	Gas Line Test Point	Point
C	Column	Point	GM	Gas Meter	Point
CAP	Cap for Underground Tank	Point	GP	Guy Pole	Point
CBN	Catch Basin	Point	GPI	Gas Pump Island	Line
CEM	Cemetery	Line	GR	Guard Rail	Line
CFL	Curb Face Left	Line	GRV	Grave	Line
CFR	Curb Face Right	Line	GV	Gas Valve	Point
CL	Center Line	Point	GVT	Gas Vent	Point
CLP	CL Road Profile Spot Shot	Point	GW	Guy Wire	Point
CMT	Concrete Monument	Point	H	Hedge Row	Line
CNP	Canopy - Overhang	Line	HW	Head Wall	Line
CP	Control Point	Point	IP	Iron Pin / Property Corner	Point
CPD	Concrete Pad	Line	IRV	Irrigation Valve	Point
CRL	Creek Left	Line	JB	Junction Box	Point
CRR	Creek Right	Line	LP	Light Pole	Point
CRW	Crown of Road	Line	MAR	Marsh Line	Line
CVL	Culvert	Line	MBX	Mailbox Commercial	Point
D	Drive Dirt	Line	MCL	Miscellaneous Curb Left	Line
DAM	Dam	Line	MCR	Miscellaneous Curb Right	Line
DC	Driveway Concrete Edge	Line	MDC	Median - Concrete	Line
DF	Drain Field	Line	MHD	Man Hole Drainage	Point
DI	Drop Inlet	Point	MHE	Man Hole Electric	Point
DP	Driveway Asphalt Edge	Line	MHG	Man Hole Gas	Point
DTL	Ditch Left	Line	MHS	Man Hole Sewer	Point
DTR	Ditch Right	Line	MHT	Man Hole Telephone	Point
EBC	Existing Bent Cap	Line	MHU	Man Hole Utility	Point
EBO	Existing Bent Column	Point	MHW	Man Hole Water	Point
EP	Edge Of Pavement	Line	MP	Meter Pole - Service	Point
EPL	Edge Of Pavement Left	Line	MSL	Miscellaneous Line	Line
EPP	Electrical Pedestal	Point	MSP	Miscellaneous Point	Point
EPR	Edge Of Pavement Right	Line	ODL	Outfall Ditch Flow Line	Line
ERL	Edge Of Dirt Road Left	Line	ODW	Observed Date Water	Point
ERR	Edge Of Dirt Road Right	Line	OH	Overhead Electric	Line

OHT	Overhead Telephone	Line	SWL	Sidewalk Left of C/L	Line
OT	Orchard Tree	Point	SWP	Swamp Line	Line
OTL	Orchard Tree Line Left	Line	SWR	Sidewalk Right of C/L	Line
OTR	Orchard Tree Line Right	Line	T	Tree	Point
OUT	Outlet Residential Power	Point	TB	Telephone Booth	Point
P	Pipe Existing Storm	Line	TBX	Telephone Box	Point
PC	Point of Curve	Point	TC	Top of Curb	Line
PCC	Point of Compound Curve	Point	TCW	Tower Communication	Point
PI	Point of Intersection	Point	TFJ	Traffic Signal Box	Point
PL	Property Line Evidence	Line	TG	Telegraph Pole	Point
PLC	Point Calculated	Point	TIE	Tie to Control Point	Point
PLT	Planter	Line	TL	Tree Line Left	Line
POC	Point on Curve	Point	TP	Telephone Pole	Point
POST	Point on Sub Tangent	Point	TPP	Telephone Pedestal	Point
POT	Point on Tangent	Point	TR	Tree Line Right	Line
PP	Power Pole	Point	TS	Top of Slope or Shoulder	Line
PRC	Point of Reverse Curve	Point	TSP	Traffic Signal Pole	Point
PSC	Primary Survey Control	Point	TVP	TV Cable Pedestal	Point
PT	Point of Tangency	Point	TW	Tower Outline - Utility	Line
RDP	Retention Pond - Top Bank	Line	UGC	Underground Cable	Line
RP	Radius Point of Curve	Point	UGT	Underground Tank	Point
RR	Railroad Track	Line	UT	Underground Telephone	Line
RRM	Railroad Mile Post	Point	UTV	Underground TV	Line
RRS	Railroad Signal	Point	VAC	Vacuum Commercial	Point
RRT	Railroad Trestle	Line	VGL	Valley Gutter - Left	Line
RRX	Railroad Crossing Arm	Point	VGR	Valley Gutter - Right	Line
RSB	Railroad Signal Box	Point	VOID	Ignore Point	Point
RWE	Right-of-way Line Existing	Line	W	Wall	Line
RWM	Right-of-way Monument	Point	WE	Water Edge	Line
S	Shrub	Point	WEL	Well	Point
SAR	Sewer Air Release Valve	Point	WET	Wet Lands	Line
SAT	Satellite Dish	Point	WH	Water High Mark	Line
SL	Shrub Line	Line	WL	Water Line	Line
SN	Sign	Line	WLK	Walkways - Trail not conc	Line
SP	Sign Post	Point	WM	Water Meter	Point
SPG	Spigot - Water	Point	WMW	Water Monitoring Well	Point
SPK	Sprinkler - Water	Point	WT	Wall Top	Line
SPR	Spring	Point	WTS	Witness Post Utility	Point
SS	Sanitary Sewer	Line	WV	Water Valve	Point
SSC	Sanitary Sewer Cleanout	Point	WW	Wing Wall	Line
SSV	Sanitary Sewer Valve	Point	X	Spot Shot	Point
STP	Steps	Line			
SW	Sidewalk to the Road	Line			

AC Air Conditioner Unit



Point = Yes
Line = No
DTM Inclusion = No

Located at closest point to survey centerline with single point or point opposite building.

Example: Point Description = AC

AGT Above Ground Storage Tank

Point = No
Line = Yes
DTM Inclusion = No

Locate outside four corners of tank with description.

Example: Point Description = AGT Gasoline

B Building

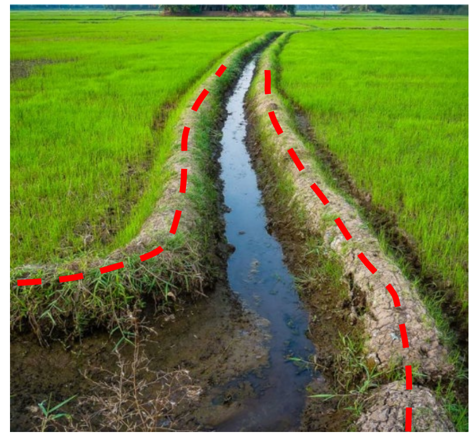
Point = No
Line = Yes
DTM Inclusion = No

Locate the outside corners of the building footprint. If only (2) or (3) building corners are accessible, then building dimensions can be used to define the entire building footprint.

Abbreviations for building types:

BU	(business)
CRC	(church)
G	(garage)
HT	(house trailer)
R	(residence)
SCH	(school)
SH	(shed)
STO	(storage)

Example: Point Description = B R



BDL Berm Ditch Left

Point = No
Line = Yes
DTM Inclusion = Yes

Locate the top edge of berm ditch left of the road centerline. If the berm ditch should cross the centerline of the road, continue with same code to finish line.

Example: Point Description = BDL

BDR Berm Ditch Right

Point = No
Line = Yes
DTM Inclusion = Yes

Locate the top edge of berm ditch right of the road centerline.
If the berm ditch should cross the centerline of the road, continue with same code to finish line.

Example: Point Description = BDR

BL Break Line

Point = No
Line = Yes
DTM Inclusion = Yes

Miscellaneous break line is used to define a contour break where other supplied codes will not adequately describe the feature.

Example: Point Description = BL

BM Bench Mark

Point = Yes
Line = No
DTM Inclusion = No

Locate project bench mark for horizontal position only with description. Elevations derived from approved methods. The bench mark will be set out of the assumed construction zone.

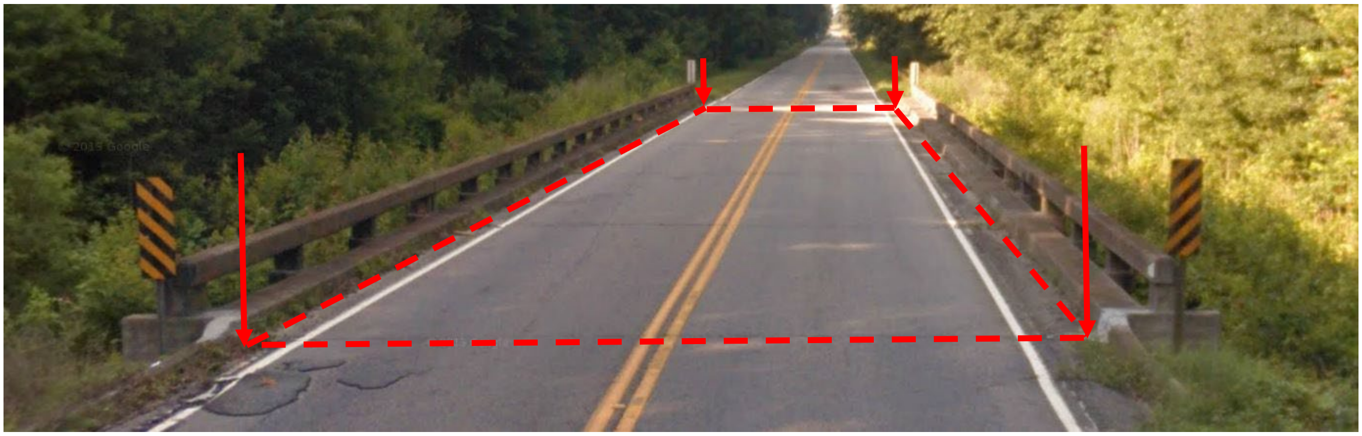
Example: Point Description = BM 1 Spike 12inPine

BRC Bridge Concrete (or Steel)

Point = No
Line = Yes
DTM Inclusion = No

Locate four (4) points which accurately define the bridge deck.
Typically located in the flowline created by the parapet (safety wall).
Ensure elevation is true for bridge deck locations.

Example: Point Description = BRC



BRW Bridge Wood

Point = No
Line = Yes
DTM Inclusion = No

Locate four (4) outside corners of bridge deck.

Example: Point Description = BRW

BS Bottom of Slope

Point = No
Line = Yes
DTM Inclusion = Yes

Locate a series of points along the bottom (toe) of slope.

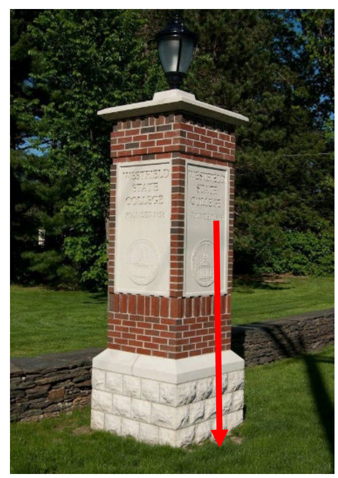
Example: Point Description = BS

BSW Back Edge of Sidewalk

Point = No
Line = Yes
DTM Inclusion = Yes

Locate a series of points along the back edge of sidewalk.

Example: Point Description = BSW



C Column

Point = Yes
Line = No
DTM Inclusion = No

Locate the center of the column closest to the road centerline.
Additional description should give dimensions and type of material.

Example: Point Description = C 24X24 BR

CAP Cap for Underground Tank

Point = Yes
Line = No
DTM Inclusion = No

Locate center of fill cap.

Example: Point Description = CAP diesel

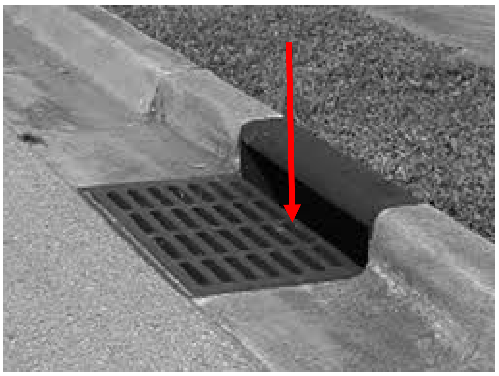
CBN Catch Basin

Point = Yes
Line = No
DTM Inclusion = No

Locate catch basin with one point as depicted in figures with description.

Additional points can be located using “CPD” (Concrete Pad - Slab) to define outside edges if necessary.

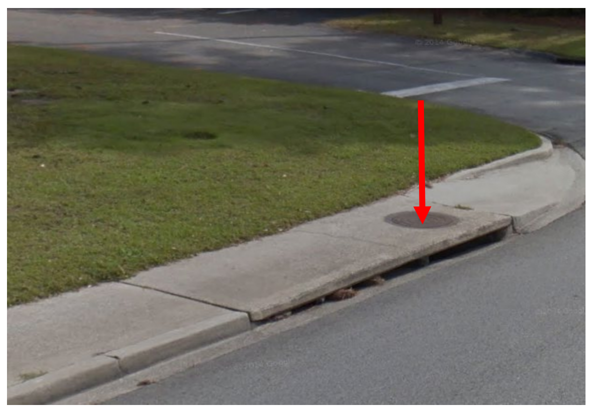
Example: Point Description = CBN 9 48x48



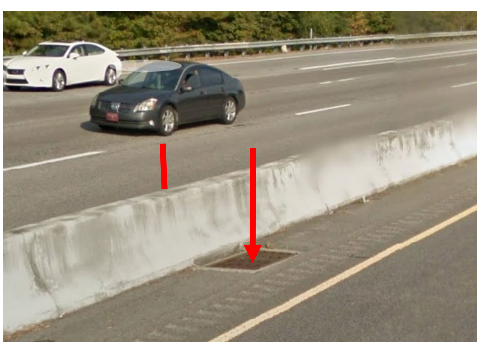
SCDOT Type 1 Catch Basin

SCDOT Type 16 Catch Basin

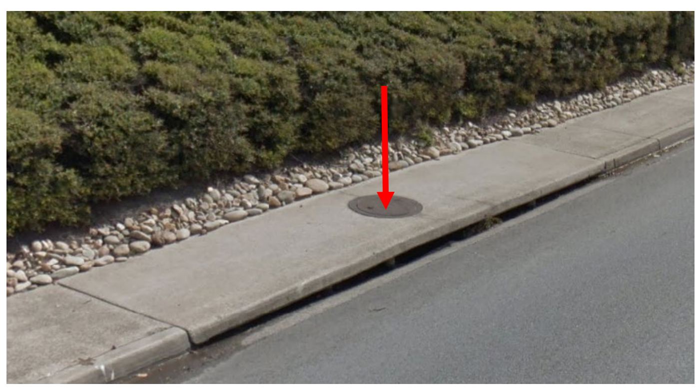
SCDOT Type 9 Catch Basin



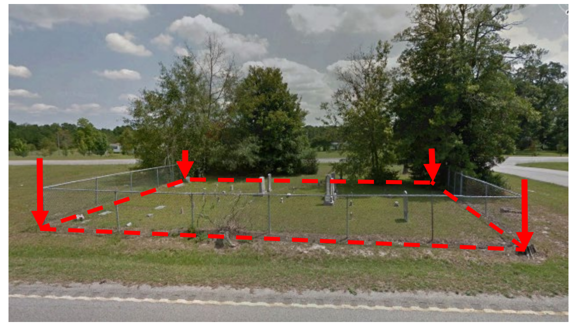
SCDOT Type 17 Catch Basin



SCDOT Type 15 Catch Basin



SCDOT Type 18 Catch Basin

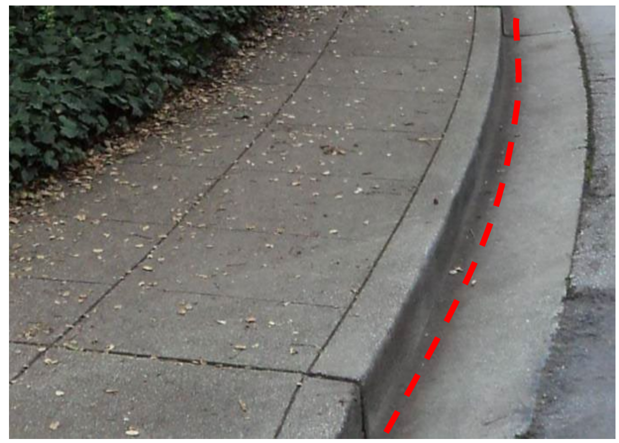


CEM Cemetery

Point = No
Line = Yes
DTM Inclusion = No

Locate a sufficient number of points to define outside edge of cemetery.

Example: Point Description = CEM



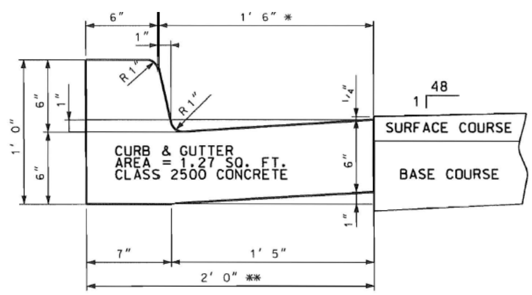
CFL Curb Face Left

Point = No
Line = Yes
DTM Inclusion = Yes

Locate a series of points along face of curb in the gutter along the left side of the survey centerline. CFL to be used for standard curb and gutter. Use feature code "MCL" for all other types of curb. Use an additional description with the first location to describe as18 inch or 24 inch curb width.

Example: Point Description = CFLA 18

CFR Curb Face Right



Point = No
Line = Yes
DTM Inclusion = Yes

Locate a series of points along face of curb in the gutter along the right side of the survey centerline. CFR to be used for standard curb and gutter. Use feature code "MCR" for all other types of curb. Use an additional description with the first location to describe as18 inch or 24 inch curb width.

Example: Point Description = CFRA 24

CL Center Line

Point = Yes
Line = No
DTM Inclusion = No

Locate points along existing centerline as needed. To be used at the discretion of the surveyor for use during alignment calculations or other purposes associated with defining the existing centerline.

Example: Point Description = CL

CLP Centerline Road Profile Spot Shot

Point = Yes
Line = No
DTM Inclusion = Yes

Locate points along the road centerline profile. CLP points are to be used to supplement x-sections as needed.

Example: Point Description = CLP

CMT Concrete Monument

Point = Yes
Line = No
DTM Inclusion = No

Locate at the center of the monument or at the point considered to be the boundary point.

Example: Point Description = CMT 3X3

CNP Canopy / Overhang of Building

Point = No
Line = Yes
DTM Inclusion = No

Locate corners of canopy facing road.

Example: Point Description = CNP

CP Control Point

Point = Yes
Line = No
DTM Inclusion = No

This code is used for project control and may be derived from terrestrial or GPS observations. Refer to the SCDOT Preconstruction Survey Manual for a more detailed description and methods used to establish the Project Control Points (CP).

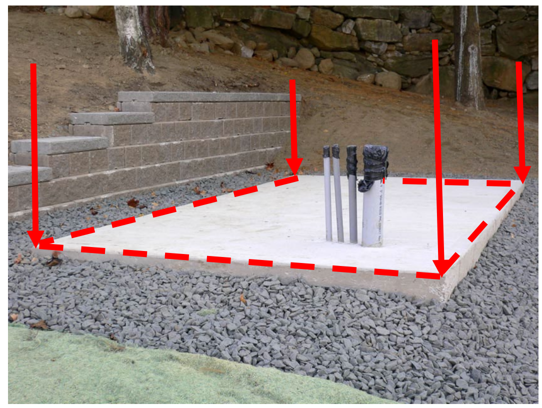
Example: Point Description = CP 8in Spike

CPD Concrete Pad / Slab

Point = No
Line = Yes
DTM Inclusion = No (unless pad is flush with existing grade).

Locate a minimum of (3) points to define concrete pad.

Example: Point Description = CPD



CRL Creek Left

Point = No
Line = Yes
DTM Inclusion = Yes

Locate the left top bank of creek facing downstream.

Example: Point Description = CRL

CRR Creek Right

Point = No
Line = Yes
DTM Inclusion = Yes

Locate the right top bank of creek facing downstream.

Example: Point Description = CRR

CRW Crown

Point = No
Line = Yes
DTM Inclusion = Yes

Locate points along centerline of road representing high point or crown of the road separating the travel lanes.

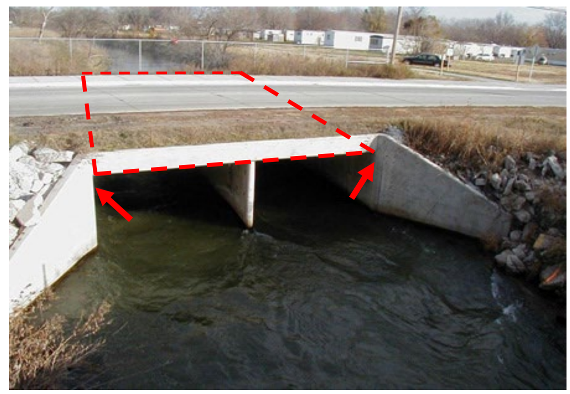
Example: Point Description = CRW

CVL Culvert

Point = No
Line = Yes
DTM Inclusion = No

Locate inside four (4) corners of culvert. Include box culvert sketch on standard SCDOT form.

Example: Point Description = CVL



D Drive Dirt

Point = No
Line = Yes
DTM Inclusion = Yes

Locate points along the edge of dirt drive.

Example: Point Description = D

DAM Dam

Point = No
Line = Yes
DTM Inclusion = Yes

Locate inside top edge of dam closest to impounded water.

Example: Point Description = DAM

DC **Drive Concrete Paved**

Point = No
Line = Yes
DTM Inclusion = Yes

Locate points along the edge of concrete drive.

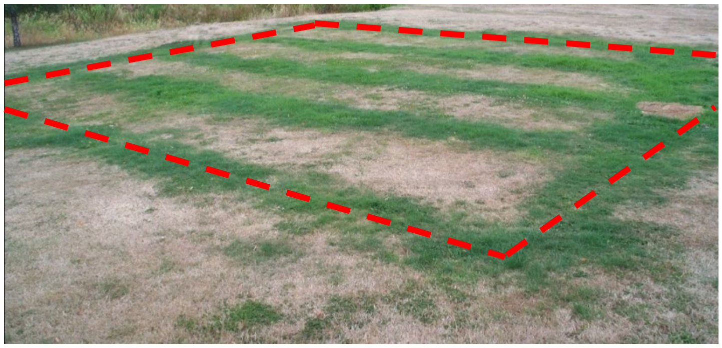
Example: Point Description = DC

DF **Drain Field**

Point = No
Line = Yes
DTM Inclusion = Yes

Underground drain fields are located at the approximate ends. Typically the drain field will only be identified by surface vegetation patterns or surface clean-out structures.

Example: Point Description = DF

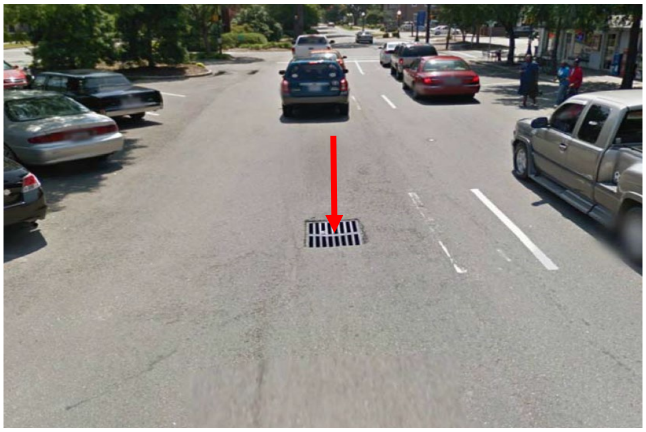


DI **Drop Inlet**

Point = Yes
Line = No
DTM Inclusion = No

Locate top center of structure with description of size.

Example: Point Description = DI 36X36



DP **Drive Paved Asphalt**

Point = No
Line = Yes
DTM Inclusion = Yes

Locate points along the edge of paved asphalt driveway.

Example: Point Description = DP

DTL Ditch Left

Point = No
Line = Yes
DTM Inclusion = Yes

Locate top edge of ditch on left side of road.

Example: Point Description = DTL

DTR Ditch Right

Point = No
Line = Yes
DTM Inclusion = Yes

Locate top edge of ditch on right side of road.

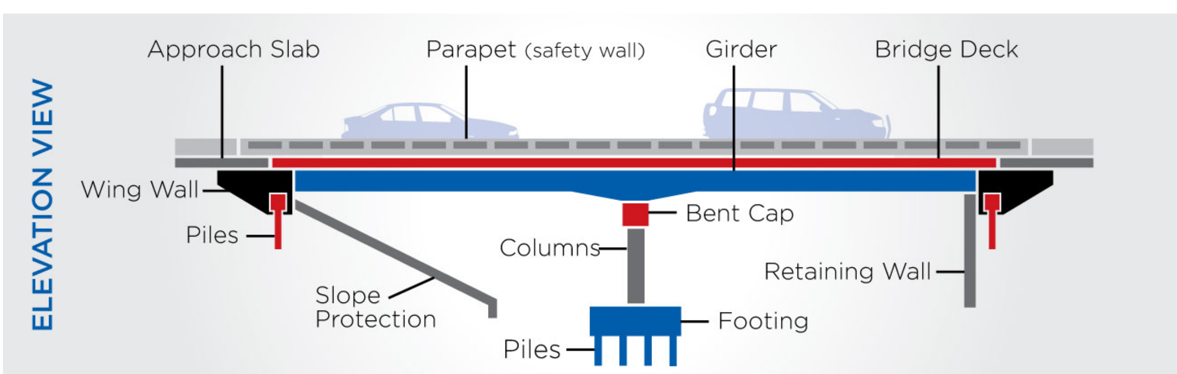
Example: Point Description = DTR

EBC Existing Bent Cap

Point = No
Line = Yes
DTM Inclusion = No

Locate outside center of bent cap at both ends to define centerline of entire bent cap. Ensure elevation is true for top of bent cap.

Example: Point Description = EBC



EBO Existing Bent Column

Point = Yes
Line = No
DTM Inclusion = No

Locate center of column closest to road centerline.
Describe type of Bent Column (Concrete, Steel, Wood).

Example: Point Description = EBO Concrete

EP Edge Of Pavement

Point = No
Line = Yes
DTM Inclusion = Yes

Locate points along the edge of pavement. Used for additional pavement location.

Example: Point Description = EP

EPL Edge of Pavement Left

Point = No
Line = Yes
DTM Inclusion = Yes

Locate edge of pavement on left side of road.

Example: Point Description = EPL

EPP Electrical Pedestal

Point = Yes
Line = No
DTM Inclusion = No

Locate at point closest to the road centerline.

EPR Edge of Pavement Right

Point = No
Line = Yes
DTM Inclusion = Yes

Locate edge of pavement on right side of road.

Example: Point Description = EPR

ERL Edge of Dirt Road Left

Point = No
Line = Yes
DTM Inclusion = Yes

Locate edge of dirt road on left side.

Example: Point Description = ERL

ERR Edge of Dirt Road Right

Point = No
Line = Yes
DTM Inclusion = Yes

Locate edge of dirt road on right side.

Example: Point Description = ERR

ETB Electric Transformer\Box\Marker

Point = Yes
Line = No
DTM Inclusion = No

Locate center of box closest to road centerline and describe size of box.

Example: Point Description = ETB 3X4

F Flower Bed

Point = No
Line = Yes
DTM Inclusion = No

Locate outline of flower bed

Example: Point Description = F

FH Fire Hydrant

Point = Yes
Line = No
DTM Inclusion = No

Locate at closest point to road centerline.

Example: Point Description = FH

FL Fence Left

Point = No
Line = Yes
DTM Inclusion = No

Locate series of points along fence. First point to begin fence should include description.
Examples of Fence Descriptions:

1. Barbed Wire (BW)	5. Split Rail (SR)
2. Chainlink (C)	6. Vinyl (V)
3. Hog Wire (HW)	7. Wood (W)
4. Lattice (L)	8. Wrought Iron (I)

Example: Point Description = FL 48inwire

FLAG Flag Pole

Point = Yes
Line = No
DTM Inclusion = No

Locate center of pole closest to road centerline.

Example: Point Description = FLAG

FLT Flood / Ground Light

Point = Yes
Line = No
DTM Inclusion = No

Locate center of ground light.

Example: Point Description = FLT

FOL Fiber Optic Cable

Point = No
Line = Yes
DTM Inclusion = No

Locate a sufficient number of paint marks or flags to map location of underground fiber optic line.

Example: Point Description = FOL

FR Fence Right

Point = No
Line = Yes
DTM Inclusion = No

Locate series of points along fence.
First point to begin fence should include description.
Examples of Fence Descriptions:

1. Barbed Wire	5. Split Rail
2. Chainlink	6. Vinyl
3. Hog Wire	7. Wood
4. Lattice	8. Wrought Iron

Example: Point Description = FL 48in wire

GEO Geodetic Marker

Point = Yes
Line = No
DTM Inclusion = No

Locate center mark of survey disk.

Example: Point Description = GEO J32 1965

GL Gas Line

Point = No
Line = Yes
DTM Inclusion = No

Locate a sufficient number of paint marks or flags to map location of underground gas line.

Example: Point Description = GL

GLT Gas Line Test Point

Point = Yes
Line = No
DTM Inclusion = No

Locate center of test station cap.

Example: Point Description = GLT

GM Gas Meter

Point = Yes
Line = No
DTM Inclusion = No

Locate center of gas meter closest to road centerline.

Example: Point Description = GM

GP Guy Pole

Point = Yes
Line = No
DTM Inclusion = No

Locate center of guy pole at the point closest to road centerline. Include Pole Number and Utility Owner if available.

Example: Point Description = GP SCEG 17540

GPI Gas Pump Island

Point = No
Line = Yes
DTM Inclusion = Yes

Locate 3 or 4 corners of the island. Location is at bottom edge of island.

Example: Point Description = GPI

GR Guard Rail

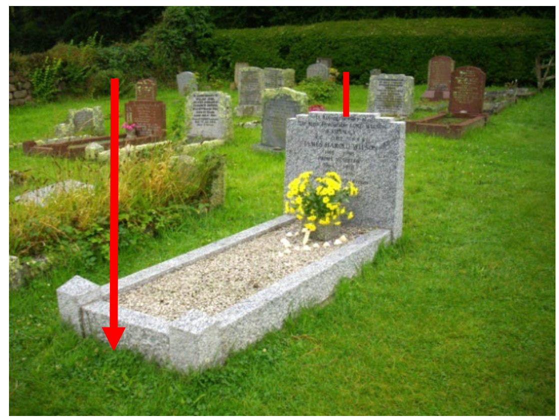
Point = No
Line = Yes
DTM Inclusion = No

Locate along edge of the guard rail closets to road centerline

Examples of Guard Rail Descriptions:

1. Cable
2. Metal
3. Wood

Example: Point Description = GR metal



GRV Grave

Point = No
Line = Yes
DTM Inclusion = No

Locate both ends of the center of grave.

Example: Point Description = GRV

GV Gas Valve

Point = Yes
Line = No
DTM Inclusion = No

Locate center of gas valve.

Example: Point Description = GV

GVT Gas Vent

Point = Yes
Line = No
DTM Inclusion = No

Locate center of gas vent closest to road centerline with vent number.

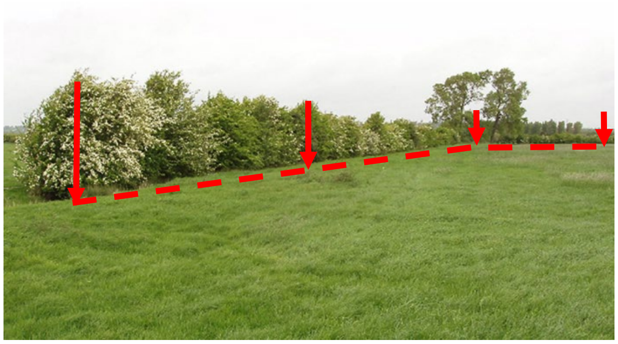
Example: Point Description = GVT 13B

GW **Guy Wire**

Point = Yes
Line = No
DTM Inclusion = No

Locate at point where guy wire anchor enters ground.

Example: Point Description = GW



H **Hedge Row**

Point = No
Line = Yes
DTM Inclusion = No

Locate a series of points along edge of hedge row closest to the centerline of road.

Example: Point Description = H

HW **Head Wall**

Point = No
Line = Yes
DTM Inclusion = No

Locate top front corner of headwall closest to ditch with width.

Example: Point Description = HW 4in

IP Iron Pin / Property Corner

Point = Yes
Line = No
DTM Inclusion = No

Locate property pin / corner with description.

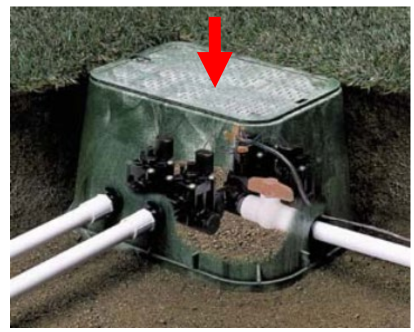
Example: Point Description = IP 1in pipe with cap

IRV Irrigation Valve

Point = Yes
Line = No
DTM Inclusion = No

Locate center of irrigation valve box.

Example: Point Description = IRV

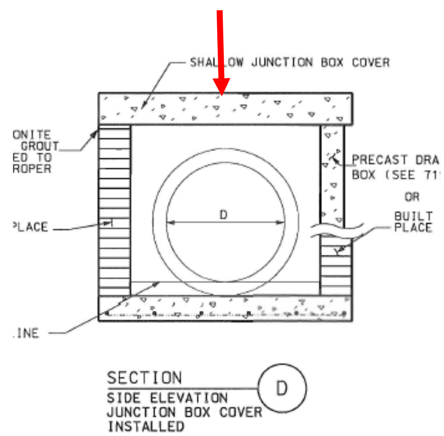


JB Junction Box

Point = Yes
Line = No
DTM Inclusion = No

Locate center of junction box.

Example: Point Description = JB

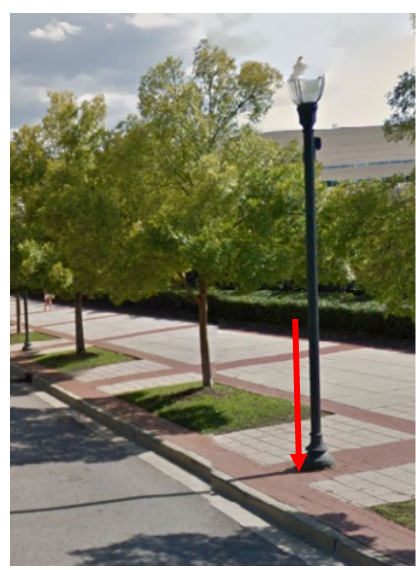


LP Light Pole

Point = Yes
Line = No
DTM Inclusion = No

Locate center of light pole edge closest to road centerline.

Example: Point Description = LP ornamental



MAR Marsh Line

Point = No
Line = Yes
DTM Inclusion = No

Locate a sufficient number of points to define the edge of marsh.

Example: Point Description = MAR

MBX Mailbox Commercial

Point = No
Line = Yes
DTM Inclusion = No

Locate the center of both ends of the mail box.

Example: Point Description = MBX

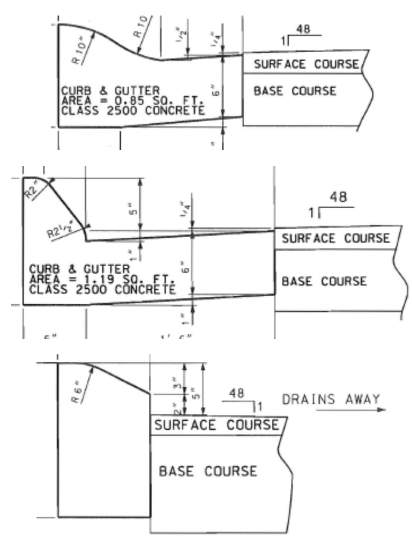
MCL Miscellaneous Curb Left

Point = No
Line = Line
DTM Inclusion = Yes

Located a series of points on the left side of road along the gutter line of curb with description. This feature code is used for non-standard curb.

Example: Point Description = MCL OGEE

MCR Miscellaneous Curb Right



Point = No
Line = Line
DTM Inclusion = Yes

Located a series of points on the right side of road along the gutter line of curb with description. This feature code is used for non-standard curb. Sketch should be provided to define shape of curb.

Example: Point Description = MCL OGEE

MDC Median - Concrete

Point = No
Line = Yes
DTM Inclusion = Yes

Locate bottom and/or top perimeter of median to include key transition points.

Example: Point Description = MDC

MHD Man Hole Drainage

Point = Yes
Line = No
DTM Inclusion = No

Locate center of drainage manhole.

Example: Point Description = MHD

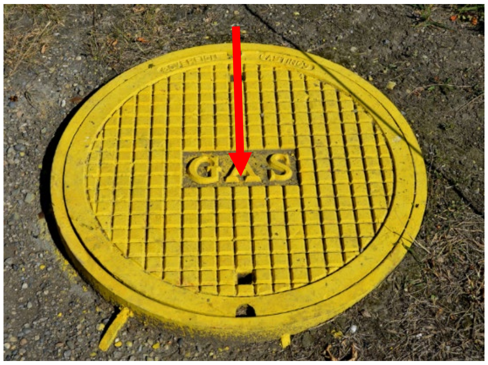
MHE Man Hole Electric

Point = Yes
Line = No
DTM Inclusion = No

Locate center of electric manhole.

Example: Point Description = MHE

MHG Man Hole Gas



Point = Yes
Line = No
DTM Inclusion = No

Locate center of gas manhole.

Example: Point Description = MHG

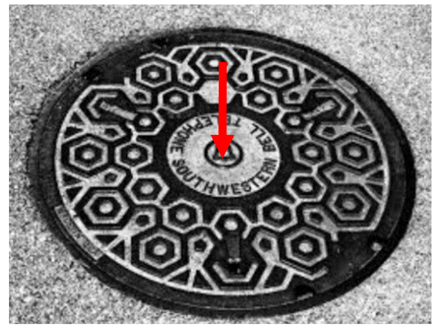
MHS Man Hole Sewer

Point = Yes
Line = No
DTM Inclusion = No

Locate center of sewer manhole.

Example: Point Description = MHS

MHT Man Hole Telephone



Point = Yes
Line = No
DTM Inclusion = No

Locate center of telephone manhole.

Example: Point Description = MHT

MHU Man Hole Utility

Point = Yes
Line = No
DTM Inclusion = No

Locate center of manhole. This feature code is used to locate an unknown utility.

Example: Point Description = MHU

MHW Man Hole Water

Point = Yes
Line = No
DTM Inclusion = No

Locate center of water manhole.

Example: Point Description = MHW

MP Meter / Service Pole

Point = Yes
Line = No
DTM Inclusion = No

Locate center of meter pole closest to road centerline.

Example: Point Description = MP

MSL Miscellaneous Line

Point = No
Line = Yes
DTM Inclusion = No

Locate a sufficient number of points to define the miscellaneous line. Include description of feature.

Example: Point Description = MSL brick

MSP Miscellaneous Point

Point = Yes
Line = No
DTM Inclusion = No

Locate center of object closest to road centerline with description.

Example: Point Description = MSP Giant Rooster

ODL Outfall Ditch - Flow Line

Point = No
Line = Yes
DTM Inclusion = Yes

Locate a sufficient number of points along deepest section to define the flow line of ditch.

Example: Point Description = ODL

ODW Observed Date Water

Point = Yes
Line = No
DTM Inclusion = No

Locate a single point at edge of water body near bridge and include date in description. This code will be used primarily by the bridge design engineer to calculate the grade for top of drill shaft to be used during construction. (*Reference: SCDOT Bridge Design Memorandum - DM0111 March 7, 2011*)

Example: Point Description = ODW 1-14-19

OH Overhead Electric

Point = No
Line = Yes
DTM Inclusion = No

Locate point beneath overhead electric line. Used to define direction of overhead electric line.

Example: Point Description = OH

OHT Overhead Telephone

Point = No
Line = Yes
DTM Inclusion = No

Locate point beneath overhead telephone line. Used to define direction of overhead telephone line.

Example: Point Description = OHT

OT Orchard Tree

Point = Yes
Line = No
DTM Inclusion = No

Locate center of tree closest to road centerline with description.

Example: Point Description = OT apple

OTL Orchard Tree Line Left

Point = Yes
Line = No
DTM Inclusion = No

Locate on the left side of road a sufficient number of points closest to road centerline to define tree line with description.

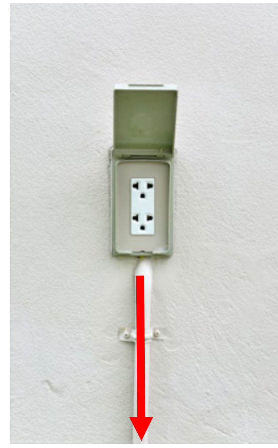
Example: Point Description = OTL apple

OTR Orchard Tree Line Right

Point = Yes
Line = No
DTM Inclusion = No

Locate on the right side of road a sufficient number of points closest to road centerline to define tree line with description.

Example: Point Description = OTR apple



OUT Residential Power Outlet

Point = Yes
Line = No
DTM Inclusion = No

Locate at point closest to the road centerline.

Example: Point Description = OUT

P Pipe Existing Storm

Point = No
Line = Yes
DTM Inclusion = Yes

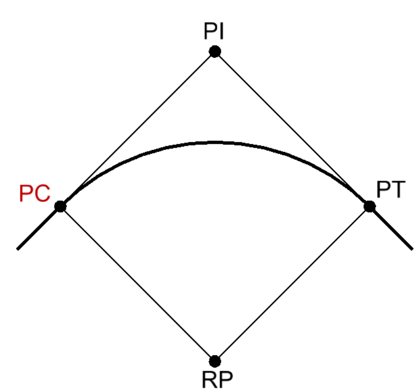
Locate center bottom (flow line) of each end of pipe with description.

Example: Point Description = P 18RC

*The following abbreviated descriptions can be used:
AF (Asphalt Fiber)
CM (Corrugated Metal)
CI (Cast Iron)
CPP (Corrugated Plastic Pipe)
PVC (Polyvinyl Chloride)
RC (Reinforced Concrete)
TC (Terra Cotta)

*If flow line of pipe (invert elevation) cannot be located, the description "NFL" (No Flow Line) will be added to the feature code.

Example: Point Description = P 18RC NFL



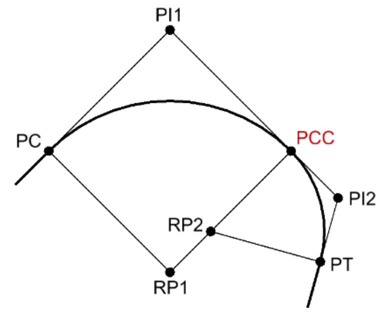
PC Point of Curve

Point = Yes
Line = No
DTM Inclusion = No

Typically used to describe a calculated point derived from final alignment calculations.

Example: Point Description = PC 10+00

PCC Point of Compound Curve

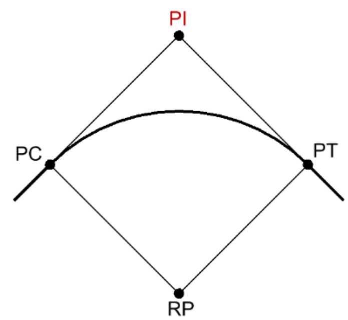


Point = Yes
Line = No
DTM Inclusion = No

Typically used to describe a calculated point derived from final alignment calculations.

Example: Point Description = PCC 12+50

PI Point of Intersection



Point = Yes
Line = No
DTM Inclusion = No

Typically used to describe a calculated point derived from final alignment calculations.

Example: Point Description = PI 14+50

PL Property Line Evidence

Point = No
Line = Yes
DTM Inclusion = No

Used for the location of field evidence of possible property lines. This field evidence is to be used with documents (plats, deeds, etc.) when developing property maps.

Example: Point Description = PL fence

PLC Calculated Point

Point = Yes
Line = No
DTM Inclusion = No

Used to develop calculated points for field location and/or final map creation
Example: Point Description = PLC

PLT Planter

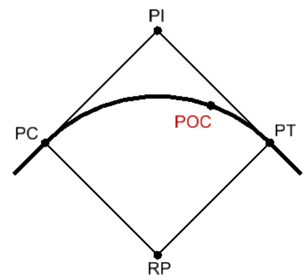
Point = No
Line = Yes
DTM Inclusion = No

Locate sufficient number of points to define planter.

Example: Point Description = PLT

POC Point On Curve

Point = Yes
Line = No
DTM Inclusion = No

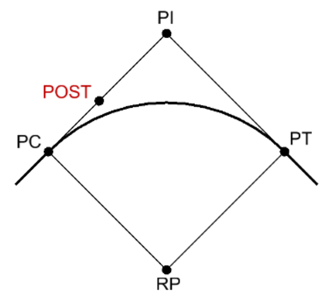


Typically used to describe a calculated point derived from final alignment calculations.

Example: Point Description = POC 45+50

POST Point On Sub Tangent

Point = Yes
Line = No
DTM Inclusion = No

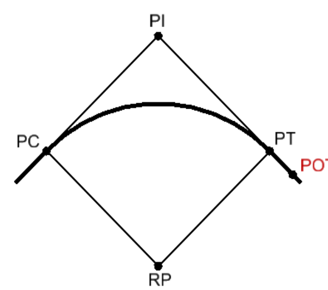


Typically used to describe a calculated point derived from final alignment calculations

Example: Point Description = POST 28+50

POT Point On Tangent

Point = Yes
Line = No
DTM Inclusion = No



Typically used to describe a calculated point derived from final alignment calculations.

Example: Point Description = POT 18+50

PP Power Pole

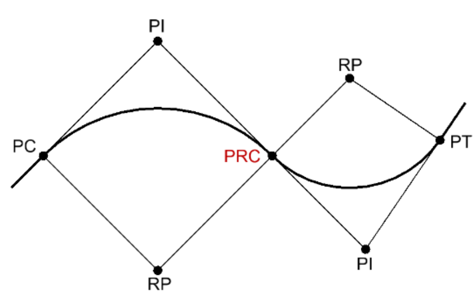
Point = Yes
Line = No
DTM Inclusion = No

Locate center of power pole closest to road centerline of road with owner and pole number.

Example: Point Description = PP SCEG #123456

PRC Point of Reverse Curve

Point = Yes
Line = No
DTM Inclusion = No



Typically used to describe a calculated point derived from final alignment calculations.

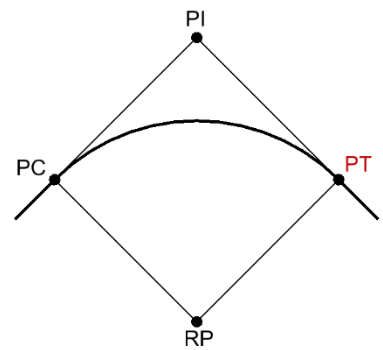
Example: Point Description = PRC 52+25

PSC Primary Survey Control
Point = Yes
Line = No
DTM Inclusion = No

This code is used for the projects Primary Survey Control and is derived solely from GPS observations. In addition to the feature code (PSC), include a description of the type of monument set. Refer to the SCDOT Preconstruction Survey Manual for a more detailed description of methods used to establish the PSC.

Example: Point Description = PSC rb/cap

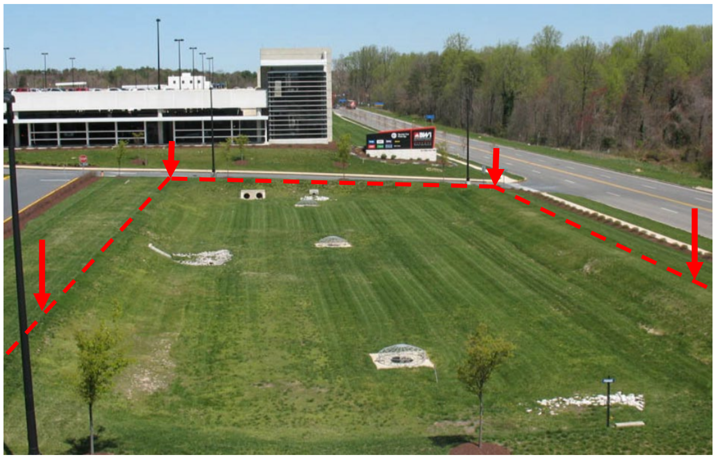
PT Point of Tangency
Point = Yes
Line = No
DTM Inclusion = No



Typically used to describe a calculated point derived from final alignment calculations.

Example: Point Description = PT 19+75

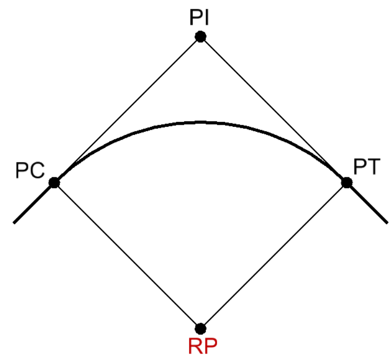
RDP Retention/Detention Pond
Point = No
Line = Yes
DTM Inclusion = Yes



Locate sufficient number of points to define inside top edge of pond.

Example: Point Description = RDP

RP Radius Point of Curve
Point = Yes
Line = No
DTM Inclusion = No



Typically used to describe a calculated point derived from final alignment calculations.

Example: Point Description = RP

RR Railroad Track

Point = No
Line = Yes
DTM Inclusion = Yes

Locate sufficient number of points to define top of rail.

Example: Point Description = RR

RRM Railroad Mile Post

Point = Yes
Line = No
DTM Inclusion = No

Locate center of railroad mile post marker with number.

Example: Point Description = RRM 678

RRS Railroad Signal

Point = Yes
Line = No
DTM Inclusion = No

Locate center of railroad signal closest to road centerline.

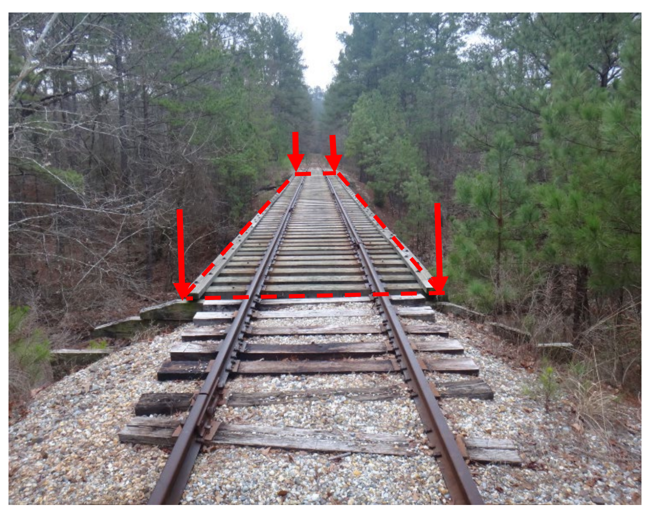
Example: Point Description = RRS

RRT Railroad Trestle

Point = No
Line = Yes
DTM Inclusion = No

Generally (4) points located at outside edge of railroad trestle with description.

Example: Point Description = RRT wood

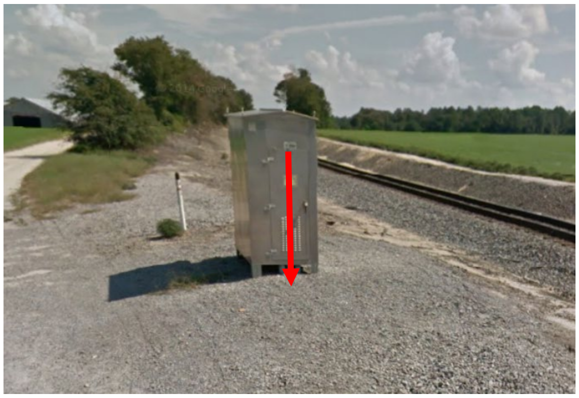


RRX Railroad Crossing Arm

Point = Yes
Line = No
DTM Inclusion = No

Locate center of railroad crossing arm closest to road centerline.

Example: Point Description = RRX



RSB Railroad Signal Box

Point = Yes
Line = No
DTM Inclusion = No

Locate center of box closest to road centerline.

Example: Point Description = RSB

RWE Right-of-way Line Existing

Point = No
Line = Yes
DTM Inclusion = No

Used to develop calculated points for existing right-of-way.

Example: Point Description = RWE

RWM Right-of-way Monument

Point = Yes
Line = No
DTM Inclusion = No

Locate center of right-of-way monument with description.

Example: Point Description = RWM concrete

S **Shrub**

Point = Yes
Line = No
DTM Inclusion = No

Locate center of shrub closest to centerline of road.

Example: Point Description = S

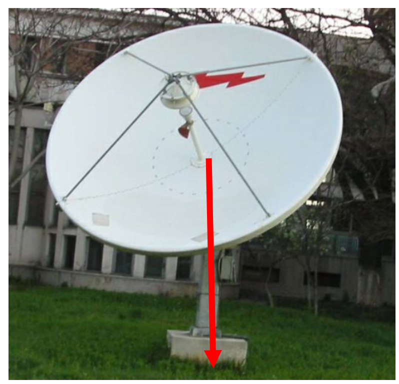
SAR **Sewer Air Release Valve**

Point = Yes
Line = No
DTM Inclusion = No

Locate center of sewer air release valve manhole lid.

Example: Point Description = SAR

SAT **Satellite Dish**



Point = Yes
Line = No
DTM Inclusion = No

Locate center of satellite dish closest to center of road.

Example: Point Description = SAT

SL **Shrub Line**

Point = No
Line = Yes
DTM Inclusion = No

Locate a series of points along edge of shrub line closest to the centerline of road.

Example: Point Description = SL

SN Sign

Point = No
Line = Yes
DTM Inclusion = No

Locate end of sign at center and describe width and type.

Example: Point Description = SN 6 wood

SP Sign Post

Point = Yes
Line = No
DTM Inclusion = No

Locate center of sign post closest to road centerline and describe.

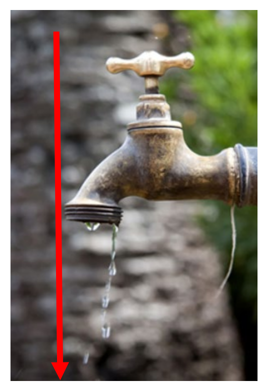
Example: Point Description = SP Billboard

SPG Water Spigot

Point = Yes
Line = No
DTM Inclusion = No

Locate center of water spigot closest to road centerline.

Example: Point Description = SPG



SPK Water Sprinkler

Point = Yes
Line = No
DTM Inclusion = No

Locate center of water sprinkler.

Example: Point Description = SPK

SPR Spring
Point = Yes
Line = No
DTM Inclusion = No

Locate center of spring at edge of opening.

Example: Point Description = SPR

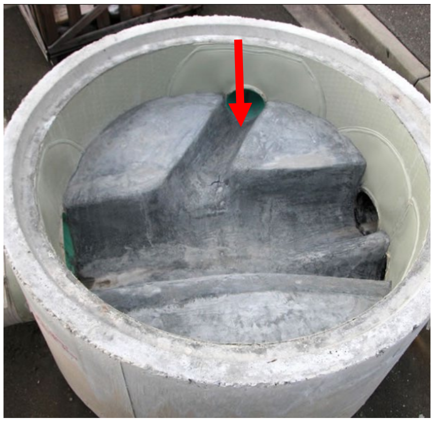
SS Sanitary Sewer
Point = No
Line = Yes
DTM Inclusion = No

Locate sanitary sewer line with description.

Example: Point Description = SS 6in PVC

*If flow line of pipe (invert elevation) cannot be located, the description "NFL" (No Flow Line) will be added to the feature code.

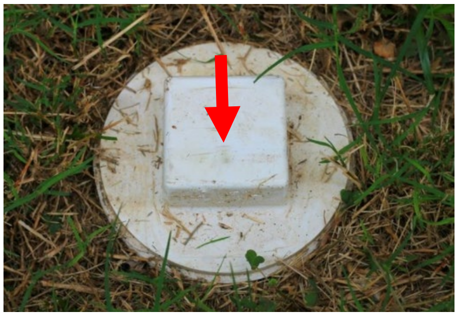
Example: Point Description = SS NFL



SSC Sanitary Sewer Cleanout
Point = Yes
Line = No
DTM Inclusion = No

Locate center of sewer cleanout cap.

Example: Point Description = SSC



SSV Sanitary Sewer Valve
Point = Yes
Line = No
DTM Inclusion = No

Locate center of sewer valve.

Example: Point Description = SSV

STP Steps

Point = No
Line = Yes
DTM Inclusion = No

Locate outside corners of steps.

Example: Point Description = STP Concrete

SW Sidewalk to the Road

Point = No
Line = Yes
DTM Inclusion = Yes

Locate both edges of sidewalk with description. The type of material if other than concrete will be defined by an additional description.

Example: Point Description = SW

SWL Sidewalk Left of C/L

Point = No
Line = Yes
DTM Inclusion = Yes

Locate edge of sidewalk left of the road centerline with description and width. The type of material if other than 54 inch (4.5ft) concrete will be defined by an additional description.

Example: Point Description = SWL

SWP Swamp Line

Point = No
Line = Yes
DTM Inclusion = No

Locate edge of swamp.

Example: Point Description = SWP

SWR Sidewalk Right of C/L

Point = No
Line = Yes
DTM Inclusion = Yes

Locate edge of sidewalk right of the road centerline with description and width. The type of material if other than 54 inch (4.5ft) concrete will be defined by an additional description.

Example: Point Description = SWR

T Tree

Point = Yes
Line = No
DTM Inclusion = No

Locate center of tree closest to road centerline and describe.

Example: Point Description = TR 52 n pine

TB Telephone Booth

Point = Yes
Line = No
DTM Inclusion = No

Locate center of telephone booth closest to road centerline.

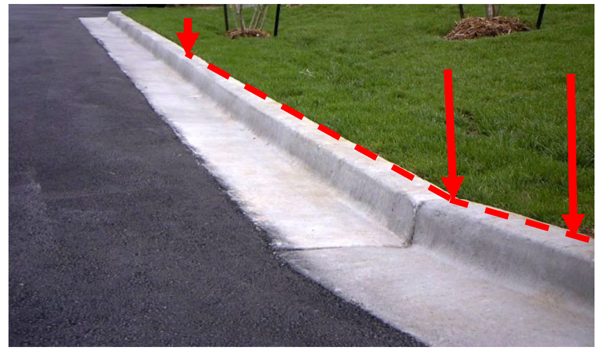
Example: Point Description = TB

TBX Telephone Box

Point = Yes
Line = No
DTM Inclusion = No

Locate center of telephone box closest to road centerline with description.

Example: Point Description = TBX 3x1 SB metal



TC Top of Curb

Point = No
Line = Yes
DTM Inclusion = Yes

Locate the top back of curb.

Example: Point Description = TC

TCW Communication Tower

Point = Yes
Line = No
DTM Inclusion = No

Locate center of tower closest to road centerline and describe.

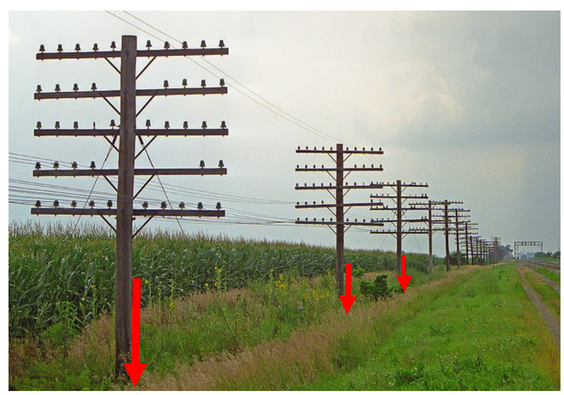
Example: Point Description = TCW metal cell

TFJ Traffic Signal Box

Point = Yes
Line = No
DTM Inclusion = No

Locate center of signal box closest to road centerline and describe.

Example: Point Description = TFJ 48x24



TG Telegraph Pole

Point = Yes
Line = No
DTM Inclusion = No

Locate center of pole closest to road centerline with owner and pole number.

Example: Point Description = TG abandoned wood

TIE Tie Point

Point = Yes
Line = No
DTM Inclusion = No

Used to record check shot when staking out existing survey control.

Example: Point Description = TIE CP1

TL **Tree Line Left**

Point = No
Line = Yes
DTM Inclusion = No

Locate a series of points along tree line left of road centerline.

Example: Point Description = TL

TP **Telephone Pole**

Point = Yes
Line = No
DTM Inclusion = No

Locate center of pole closest to road centerline with owner and pole number.

Example: Point Description = TP ATT 123456

TPP **Telephone Pedestal**

Point = Yes
Line = No
DTM Inclusion = No

Locate center of pedestal closest to road centerline with owner and number.

Example: Point Description = TPP SB 31B1

TR **Tree Line Right**

Point = No
Line = Yes
DTM Inclusion = No

Locate a series of points along tree line right of road centerline.

Example: Point Description = TR

TS Top of Slope or Shoulder Break

Point = No
Line = Yes
DTM Inclusion = Yes

Locate sufficient number of points to define top of slope.

Example: Point Description = TS

TSP Signal Pole

Point = Yes
Line = No
DTM Inclusion = No

Locate center of signal pole closest to road centerline with owner and pole number.

Example: Point Description = TSP SCDOT 123456

TVP Cable TV Pedestal

Point = Yes
Line = No
DTM Inclusion = No

Locate center of cable box closest to road centerline with owner and size.

Example: Point Description = TVP TWC 24x36

TW Power Line \ Utility Tower

Point = No
Line = Yes
DTM Inclusion = No

Locate outside four corners of tower with owner and tower number.

Example: Point Description = TW SCE&G 123456

UGC Underground Cable

Point = No
Line = Yes
DTM Inclusion = No

Locate a sufficient number of paint marks or flags to map location of underground cable line with description of utility.

Example: Point Description = UGC electric

UGT Underground Tank

Point = Yes
Line = No
DTM Inclusion = No

Locate center of approximate underground tank with description.

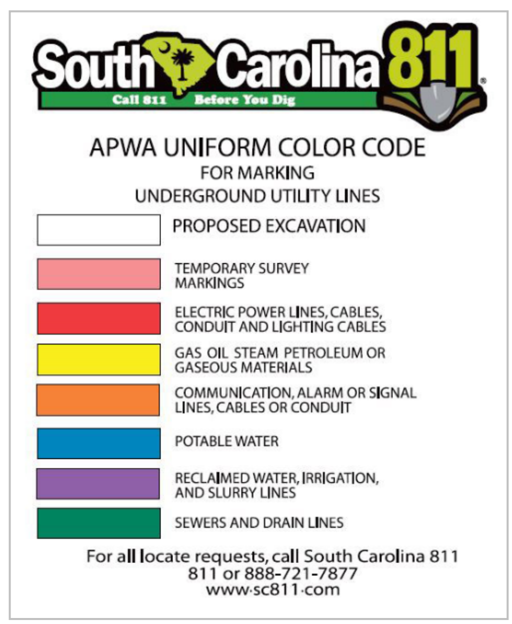
Example: Point Description = UGT gas

UT Underground Telephone

Point = No
Line = Yes
DTM Inclusion = No

Locate a sufficient number of paint marks or flags to map location of underground telephone line.

Example: Point Description = UT



UTV Underground TV

Point = No
Line = Yes
DTM Inclusion = No

Locate a sufficient number of paint marks or flags to map location of underground television line.

Example: Point Description = UTV

VAC Commercial Vacuum

Point = Yes
Line = No
DTM Inclusion = No

Locate center of vacuum closest to road centerline.

Example: Point Description = VAC

VGL Valley Gutter - Left

Point = No
Line = Yes
DTM Inclusion = Yes

Locate a series of points to accurately define flow line of valley gutter left of road centerline. Include description of width and paving material. Note any changes in width with additional point descriptions.

Example: Point Description = VGL 24 asph

VGR Valley Gutter - Right

Point = No
Line = Yes
DTM Inclusion = Yes

Locate a series of points to accurately define flow line of valley gutter right of road centerline. Include description of width and paving material. Note any changes in width with additional point descriptions.

Example: Point Description = VGR 24 asph

VOID Ignore Point

Point = Yes
Line = No
DTM Inclusion = No

Code used for points to be excluded from final submitted data files.

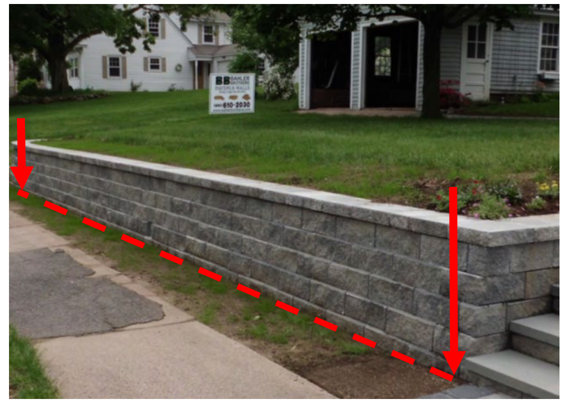
Example: Point Description = VOID

W **Wall**

Point = No
Line = Yes
DTM Inclusion = Yes

Locate series of points along bottom of wall with description of material and/or height.

Example: Point Description = W 36 mse block

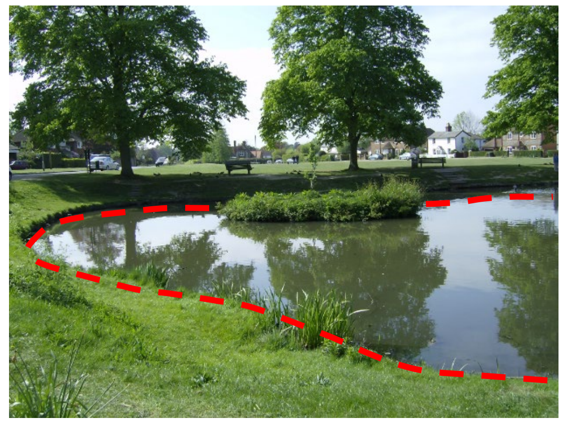


WE **Water Edge**

Point = No
Line = Yes
DTM Inclusion = No

Locate series of points along edge of water body.

Example: Point Description = WE pond



WEL **Well**

Point = Yes
Line = No
DTM Inclusion = No

Locate center of well at ground level closest to road centerline with description.

Example: Point Description = WEL house

WET **Wetlands**

Point = No
Line = Yes
DTM Inclusion = No

Locate series of wetland id points with description.
Typically wetland id points are flagging tape tied to vegetation above ground level with an id point number.

Example: Point Description = WET A1

WH Water High Mark

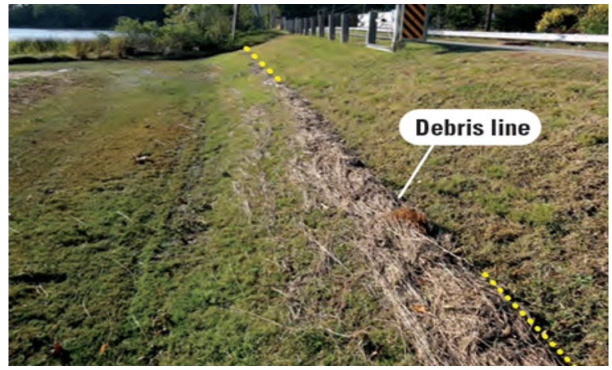
Point = Yes
Line = No
DTM Inclusion = No

Locate point at historical high water mark closest To road centerline and include date in description. This code can be used for both non-tidal waters and tidal waters.

Example: Point Description = WH OHW 1-12-16

Example: Point Description = WH MHW 1-12-16

Abbreviations:
Non-Tidal *Historical High Water Mark (**OHW**)*
Tidal *Historical High Water Mark (**MHW**)*



SCDOT follows the USGS publication "Identifying and Preserving High-Water Mark Data" (USGS, 2016) for field evidence of the "historical high water mark" such as: mud lines, seed lines, debris lines, ice rings, cut lines, wash lines, and debris snags. Reference the USGS publication for additional detail.

WL Water Line

Point = No
Line = Yes
DTM Inclusion = No

Locate a sufficient number of paint marks or flags to map location of underground water line.

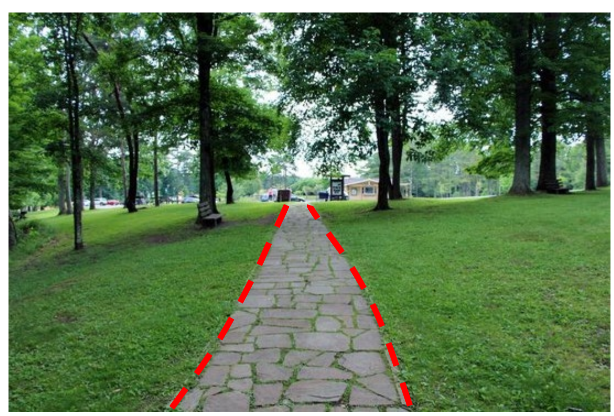
Example: Point Description = WL

WLK Walkways / Trail (non concrete)

Point = No
Line = Yes
DTM Inclusion = Yes

Locate series of points to define the walkway or trail with description.

Example: Point Description = WLK stone



WM Water Meter

Point = Yes
Line = No
DTM Inclusion = No

Located center of water meter cover.

Example: Point Description = WM

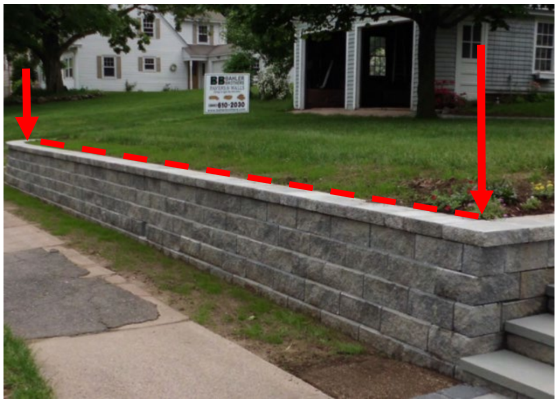
WMW Water Monitoring Well

Point = Yes
Line = No
DTM Inclusion = No

Locate center of monitoring well cover with number.

Example: Point Description = WMW 45

WT Wall Top



Point = No
Line = Yes
DTM Inclusion = Yes

Locate series of points along top back of wall with description of material. This code is not necessary if wall is being used as fence.

Example: Point Description = W mse block



WTS Utility Witness Post

Point = Yes
Line = No
DTM Inclusion = No

Locate center of witness post closest to road centerline with description.

Example: Point Description = WTS gas MP6590

WV **Water Valve**

Point = Yes
Line = No
DTM Inclusion = No

Locate center of water valve.

Example: Point Description = WV

WW **Wing Wall**

Point = No
Line = Yes
DTM Inclusion = No

Locate top inside corner of wing wall closest to ditch with width.

Example: Point Description = WW 6 conc

X **Spot Shot**

Point = Yes
Line = No
DTM Inclusion = Yes

Code used to locate spot shot for ground elevation.

Example: Point Description = X

BRIDGES (ALL)	
BRIDGE CONCRETE	BRC
BRIDGE WOOD	BRW
EXISTING BENT CAP	EBC
EXISTING BENT COLUMN	EBO
GUARDRAIL	GR
BUILDING APPURTENANCES	
AIR CONDITIONING UNIT	AC
ABOVE GROUND TANK	AGT
BUILDING	B
COLUMNS	C
FILL CAP FOR U/G TANK	CAP
CEMETERY	CEM
CANOPY / OVERHANG	CNP
DRAIN FIELD	DF
FLAG POLE	FLAG
FLOOD / GROUND LIGHT	FLT
GAS PUMP ISLAND	GPI
GRAVE	GRV
IRRIGATION VALVE	IRV
MAILBOX COMMERCIAL	MBX
MAILBOX	MBX
RESIDENTIAL POWER OUTLET	OUT
PLANTER	PLT
SATELLITE DISH	SAT
SIGN	SN
SIGN POST	SP
WATER SPIGOT	SPG
SPRINKLER	SPK
STEPS	STP
COMMERCIAL VACUUM	VAC
WELL	WEL
WALKS / TRAIL (NON CONC)	WLK
CONCRETE	
BACK EDGE OF SIDEWALK	BSW
FACE OF CURB	CFL, CFR
CONCRETE PAD / SLAB	CPD
CONCRETE DRIVEWAY	DC
MISCELLANEOUS CURB	MCL, MCR
MEDIAN CONCRETE	MDC
SIDEWALK TO THE ROAD	SW
SIDEWALK	SWL, SWR
TOP OF CURB	TC
WALL	W
WALL TOP	WT

DRIVEWAYS - NON CONCRETE	
DIRT DRIVE	D
ASPHALT DRIVE	DP
DTM / BREAKLINES	
BREAKLINE	BL
BOTTOM/TOE SLOPE	BS
CENTERLINE ROAD PROFILE	CLP
CROWN OF ROADWAY	CRW
TOP SLOPE / SHOULER BREAK	TS
SPOT ELEVATION	X
ENVIRONMENTAL AREAS	
WETLANDS	WET
FENCE	
FENCE	FL, FR
HYDROLOGY	
BERM DITCH (TOP)	BDL, BDR
CREEK (TOP OF BANK)	CRL, CRR
DAM	DAM
DITCH (TOP OF BANK)	DTL, DTR
MARSH LINE	MAR
OUTFALL DITCH - FLOW LINE	ODL
OBSERVED DATE WATER	ODW
SPRING	SPR
SWAMP LINE	SWP
WATER EDGE	WE
WATER HIGH MARK	WH
WATER MONITOR WELL	WMW
MISCELLANEOUS	
MISCELLANEOUS LINE	MSL
MISCELLANEOUS POINT	MSP
IGNORE POINT	VOID
R-W / PROP / ESMTS	
CENTER LINE OF ROAD	CL
CONCETE MONUMENT	CMT
IRON PIN/PROPERTY CORNER	IP
PROPERTY LINE EVIDENCE	PL
CALCULATED POINT	PLC
RIGHT OF WAY LINE EXISTING	RWE
RIGHT OF WAY MONUMENT	RWM
PAVEMENTS	
EDGE OF PAVEMENT	EPL, EPR
EDGE OF DIRT ROAD	ERL, ERR
VALLEY GUTTER	VGL, VGR

NON-SUE UTILITIES	
ELECTRICAL PEDESTAL	EPP
ELECTRIC TRANS BOX	ETB
FIRE HYDRANT	FH
FIBER OPTIC LINE U/G	FOL
GAS LINES	GL
GAS LINE TEST POINT	GLT
GAS METER	GM
GUY POLE	GP
GAS VALVE	GV
GAS VENT	GVT
GUY WIRE	GW
LIGHT POLE	LP
ELECTRIC MAN HOLE	MHE
GAS MAN HOLE	MHG
SANITARY SEWER MANHOLE	MHS
TELEPHONE MAN HOLE	MHT
UTILITY MAN HOLE	MHU
WATER MAN HOLE	MHW
METER / SERVICE POLE	MP
OVERHEAD ELECTRIC	OH
OVERHEAD TELEPHONE	OHT
POWER POLE	PP
SEWER AIR RELEASE VALVE	SAR
SEWER LINE	SS
SANITARY SEWER CLEANOUT	SSC
SANITARY SEWER VALVE	SSV
TELEPHONE BOOTH	TB
TELEPHONE BOX	TBX
COMMUNICATION TOWER	TCW
COMMUNICATION TOWER	TCW
TRAFFIC SIGNAL BOX	TFJ
TELEGRAPH POLE	TG
TELEPHONE POLE	TP
TELEPHONE PEDESTAL	TPP
TRAFFIC SIGNAL POLE	TSP
TV PEDESTAL	TVP
POWER LINE / UTILITY TOWER	TW
UTILITY CABLE U/G	UGC
TANK U/G	UGT
TELEPHONE U/G	UT
TV U/G	UTV
WATER LINE U/G	WL
WATER METER	WM
UTILILITY WITNESS POST	WTS
WATER VALVE	WV

RAIL ROAD TRACKS	
RAILROAD TRACK	RR
SIGNAL BOX	RSB
MILE POST	RRM
SIGNAL	RRS
TRESTLE	RRT
CROSSING ARM	RRX
STORM SEWER	
CATCH BASIN	CBN
DROP INLET	DI
JUNCTION BOX	JB
DRAINAGE MAN HOLE	MHD
PIPE EXISTING STORM	P
RETENTION/DETENTION POND	RDP
CULVERT	CVL
HEAD WALL	HW
WING WALL	WW
SURVEY CONTROL	
BENCHMARK	BM
CONTROL POINT	CP
GEODECTIC MONUMENT	GEO
PRIMARY SURVEY CONTROL	PSC
TIE POINT	TIE
VEGETATION	
TREE	T
SHRUB	S
SHRUB LINE	SL
HEDGE ROW	H
TREE LINE	TL, TR
FLOWER BED	F
ORCHARD TREE LINE	OTL, OTR
ORCHARD TREE	OT
ALIGNMENT	
POINT OF CURVE	PC
POINT OF COMPOUND CURVE	PCC
POINT OF INTERSECTION	PI
POINT OF CURVE	POC
POINT ON SUB TANGENT	POST
POINT OF TANGENCY	POT
POINT OF REVERSE CURVE	PRC
RADIUS POINT OF CURVE	RP
LINKING CODES	
START LINE	A
END LINE	B

AIR CONDITIONING UNIT	AC
ABOVE GROUND TANK	AGT
BUILDING	B
BERM DITCH (TOP)	BDL, BDR
BREAKLINE	BL
BENCHMARK	BM
BRIDGE CONCRETE	BRC
BRIDGE WOOD	BRW
BOTTOM/TOE SLOPE	BS
BACK EDGE OF SIDEWALK	BSW
COLUMNS	C
CAP FOR U/G TANK	CAP
CATCH BASIN	CBN
CEMETERY	CEM
FACE OF CURB	CFL, CFR
CENTER LINE OF ROAD	CL
CENTERLINE ROAD PROFILE	CLP
CONCETE MONUMENT	CMT
CANOPY / OVERHANG	CNP
CONTROL POINT	CP
CONCRETE PAD / SLAB	CPD
CREEK (TOP OF BANK)	CRL, CRR
CROWN OF ROADWAY	CRW
CULVERT	CVL
DIRT DRIVE	D
DAM	DAM
CONCRETE DRIVEWAY	DC
DRAIN FIELD	DF
DRAIN FIELD	DF
DROP INLET	DI
ASPHALT DRIVE	DP
DITCH (TOP OF BANK)	DTL, DTR
EXISTING BENT CAP	EBC
EXISTING BENT COLUMN	EBO
EDGE OF PAVEMENT	EPL, EPR
ELECTRICAL PEDESTAL	EPP
EDGE OF DIRT ROAD	ERL, ERR
ELECTRIC TRANS BOX	ETB
FLOWER BED	F
FIRE HYDRANT	FH
FENCE	FL, FR
FLAG POLE	FLAG
FLOOD / GROUND LIGHT	FLT
FIBER OPTIC LINE U/G	FOL
GEODECTIC MONUMENT	GEO

GAS LINES	GL
GAS LINE TEST POINT	GLT
GAS METER	GM
GUY POLE	GP
GAS PUMP ISLAND	GPI
GUARDRAIL	GR
GRAVE	GRV
GAS VALVE	GV
GAS VENT	GVT
GUY WIRE	GW
HEDGE ROW	H
HEAD WALL	HW
IRON PIN/PROPERTY CORNER	IP
IRRIGATION VALVE	IRV
JUNCTION BOX	JB
LIGHT POLE	LP
MARSH LINE	MAR
MAILBOX COMMERCIAL	MBX
MAILBOX	MBX
MISCELLANEOUS CURB	MCL, MCR
MEDIAN CONCRETE	MDC
MAN HOLE DRAINAGE	MHD
MAN HOLE ELECTRIC	MHE
MAN HOLE GAS	MHG
MANHOLE SANITARY SEWER	MHS
MAN HOLE TELEPHONE	MHT
MAN HOLE UTILITY	MHU
MAN HOLE WATER	MHW
METER / SERVICE POLE	MP
MISCELLANEOUS LINE	MSL
MISCELLANEOUS POINT	MSP
OUTFALL DITCH - FLOW LINE	ODL
OBSERVED DATE WATER	ODW
OVERHEAD ELECTRIC	OH
OVERHEAD TELEPHONE	OHT
ORCHARD TREE	OT
ORCHARD TREE LINE	OTL, OTR
RESIDENTIAL POWER OUTLET	OUT
PIPE EXISTING STORM	P
POINT OF CURVE	PC
POINT OF COMPOUND CURVE	PCC
POINT OF INTERSECTION	PI
PROPERTY LINE EVIDENCE	PL
CALCULATED POINT	PLC
PLANTER	PLT

POINT OF CURVE	POC
POINT ON SUB TANGENT	POST
POINT OF TANGENCY	POT
POWER POLE	PP
POINT OF REVERSE CURVE	PRC
PRIMARY SURVEY CONTROL	PSC
RETENTION/DETENTION POND	RDP
RADIUS POINT OF CURVE	RP
RAILROAD TRACK	RR
RAIL ROAD MILE POST	RRM
RAIL ROAD SIGNAL	RRS
RAIL ROAD TRESTLE	RRT
RAIL ROAD CROSSING ARM	RRX
RAIL ROAD SIGNAL BOX	RSB
RIGHT OF WAY LINE EXISTING	RWE
RIGHT OF WAY MONUMENT	RWM
SHRUB	S
SEWER AIR RELEASE VALVE	SAR
SATELLITE DISH	SAT
SHRUB LINE	SL
SIGN	SN
SIGN POST	SP
WATER SPIGOT	SPG
SPRINKLER	SPK
SPRING	SPR
SEWER LINE	SS
SANITARY SEWER CLEANOUT	SSC
SANITARY SEWER VALVE	SSV
STEPS	STP
SIDEWALK TO THE ROAD	SW
SIDEWALK	SWL, SWR
SWAMP LINE	SWP
TREE	T
TELEPHONE BOOTH	TB
TELEPHONE BOX	TBX
TOP OF CURB	TC
COMMUNICATION TOWER	TCW
COMMUNICATION TOWER	TCW
TRAFFIC SIGNAL BOX	TFJ
TELEGRAPH POLE	TG
TIE POINT	TIE
TREE LINE	TL, TR
TELEPHONE POLE	TP
TELEPHONE PEDESTAL	TPP
TOP SLOPE / SHOULER BREAK	TS

TRAFFIC SIGNAL POLE	TSP
TV PEDESTAL	TVP
POWER LINE / UTILITY TOWER	TW
UTILITY CABLE U/G	UGC
TANK U/G	UGT
TELEPHONE U/G	UT
TV U/G	UTV
COMMERCIAL VACUUM	VAC
VALLEY GUTTER	VGL, VGR
IGNORE POINT	VOID
WALL	W
WATER EDGE	WE
WELL	WEL
WETLANDS	WET
WATER HIGH MARK	WH
WATER LINE U/G	WL
WALKS / TRAIL (NON CONC)	WLK
WATER METER	WM
WATER MONITOR WELL	WMW
WALL TOP	WT
UTILILITY WITNESS POST	WTS
WATER VALVE	WV
WING WALL	WW
START LINE	A
END LINE	B

5.07 SUGGESTED DTM INCLUSION

AC	Air Conditioner Unit		ETB	Electric Transformer	
AGT	Above Ground Tank		F	Flower Bed	
B	Building		FH	Fire Hydrant	
BDL	**Berm Ditch Left**	**DTM**	FL	Fence Left Other	
BDR	**Berm Ditch Right**	**DTM**	FLAG	Flag Pole	
BL	**BreakLine**	**DTM**	FLT	Flood - Ground Light	
BM	Bench Mark		FOL	Fiber Optic Cable	
BRC	Bridge - Concrete (or Steel)		FR	Fence Right Other	
BRW	Bridge - Wood		GEO	Geodetic Marker	
BS	**Bottom of Slope**	**DTM**	GL	Gas Line	
BSW	**Back Edge of Sidewalk**	**DTM**	GLT	Gas Line Test Point	
C	Column		GM	Gas Meter	
CAP	Cap for Underground Tank		GP	Guy Pole	
CBN	Catch Basin		**GPI**	**Gas Pump Island**	**DTM**
CEM	Cemetery		GR	Guard Rail	
CFL	**Curb Face Left**	**DTM**	GRV	Grave	
CFR	**Curb Face Right**	**DTM**	GV	Gas Valve	
CL	**Center Line**	**DTM**	GVT	Gas Vent	
CLP	**CL Road Profile Spot Shot**	**DTM**	GW	Guy Wire	
CMT	Concrete Monument		H	Hedge Row	
CNP	Canopy - Overhang		HW	Head Wall	
CP	Control Point		IP	Iron Pin / Property Corner	
CPD	**Concrete Pad (if at grade)**	**DTM**	IRV	Irrigation Valve	
CRL	**Creek Left**	**DTM**	JB	Junction Box	
CRR	**Creek Right**	**DTM**	LP	Light Pole	
CRW	**Crown of Road**	**DTM**	**MAR**	**Marsh Line**	**DTM**
CVL	Culvert		MBX	Mailbox Commercial	
D	**Drive Dirt**	**DTM**	**MCL**	**Miscellaneous Curb Left**	**DTM**
DAM	**Dam**	**DTM**	**MCR**	**Miscellaneous Curb Right**	**DTM**
DC	**Driveway Concrete Edge**	**DTM**	**MDC**	**Median - Concrete**	**DTM**
DF	**Drain Field**	**DTM**	MHD	Man Hole Drainage	
DI	Drop Inlet		MHE	Man Hole Electric	
DP	**Driveway Asphalt Edge**	**DTM**	MHG	Man Hole Gas	
DTL	**Ditch Left**	**DTM**	MHS	Man Hole Sewer	
DTR	**Ditch Right**	**DTM**	MHT	Man Hole Telephone	
EBC	Existing Bent Cap		MHU	Man Hole Utility	
EBO	Existing Bent Column		MHW	Man Hole Water	
EP	**Edge Of Pavement**	**DTM**	MP	Meter Pole - Service	
EPL	**Edge Of Pavement Left**	**DTM**	**MSL**	**Miscellaneous Line**	**DTM**
EPP	Electrical Pedestal		**MSP**	**Miscellaneous Point**	**DTM**
EPR	**Edge Of Pavement Right**	**DTM**	**ODL**	**Outfall Ditch Flow Line**	**DTM**
ERL	**Edge Of Dirt Road Left**	**DTM**	ODW	Observed Date Water	
ERR	**Edge Of Dirt Road Right**	**DTM**	OH	Overhead Electric	

OHT	Overhead Telephone		**SWL**	**Sidewalk Left of C/L**	**DTM**
OT	Orchard Tree		**SWP**	**Swamp Line**	**DTM**
OTL	Orchard Tree Line Left		**SWR**	**Sidewalk Right of C/L**	**DTM**
OTR	Orchard Tree Line Right		T	Tree	
OUT	Outlet Residential Power		TB	Telephone Booth	
P	**Pipe Existing Storm**	**DTM**	TBX	Telephone Box	
PC	Point of Curve		**TC**	**Top of Curb**	**DTM**
PCC	Point of Compound Curve		TCW	Tower Communication	
PI	Point of Intersection		TFJ	Traffic Signal Box	
PL	Property Line Evidence		TG	Telegraph Pole	
PLC	Point Calculated		TIE	Tie to Control Point	
PLT	Planter		TL	Tree Line Left	
POC	Point on Curve		TP	Telephone Pole	
POST	Point on Sub Tangent		TPP	Telephone Pedestal	
POT	Point on Tangent		TR	Tree Line Right	
PP	Power Pole		**TS**	**Top of Slope or Shoulder**	**DTM**
PRC	Point of Reverse Curve		TSP	Traffic Signal Pole	
PSC	Primary Survey Control		TVP	TV Cable Pedestal	
PT	Point of Tangency		TW	Tower Outline - Utility	
RDP	**Retention Pond - Top Bank**	**DTM**	UGC	Underground Cable	
RP	Radius Point of Curve		UGT	Underground Tank	
RR	**Railroad Track**	**DTM**	UT	Underground Telephone	
RRM	Railroad Mile Post		UTV	Underground TV	
RRS	Railroad Signal		VAC	Vacuum Commercial	
RRT	Railroad Trestle		**VGL**	**Valley Gutter - Left**	**DTM**
RRX	Railroad Crossing Arm		**VGR**	**Valley Gutter - Right**	**DTM**
RSB	Railroad Signal Box		VOID	Ignore Point	
RWE	Right-of-way Line Existing		**W**	**Wall**	**DTM**
RWM	Right-of-way Monument		**WE**	**Water Edge**	**DTM**
S	Shrub		WEL	Well	
SAR	Sewer Air Release Valve		WET	Wet Lands	
SAT	Satellite Dish		WH	Water High Mark	
SL	Shrub Line		WL	Water Line	
SN	Sign		**WLK**	**Walkways - Trail not conc**	**DTM**
SP	Sign Post		WM	Water Meter	
SPG	Spigot - Water		WMW	Water Monitoring Well	
SPK	Sprinkler - Water		**WT**	**Wall Top**	**DTM**
SPR	Spring		WTS	Witness Post Utility	
SS	Sanitary Sewer		WV	Water Valve	
SSC	Sanitary Sewer Cleanout		WW	Wing Wall	
SSV	Sanitary Sewer Valve		**X**	**Spot Shot**	**DTM**
STP	Steps				
SW	**Sidewalk to the Road**	**DTM**			

APPENDIX A – AERIAL MAPPING PLAN FORM

Project Identification Number: ____________________
Project Name: _____________________________________
Project County: ___________________________________

Project Accuracy Requirements: Vertical ______feet Horizontal ______feet

No. of Exposures: _________ No. of Ground Control Points (Panels): _______
Mapping Scale: ___________ Panel Point Spacing (1500' maximum): ________feet
Photo Scale: ___________ Lidar Point Density: ______________pts/m^2

No. of Flight Lines: Imagery _________ Lidar _________
Approximate Project Length: ________miles
Approximate Project Area: __________acres

Aircraft: ____
Sensor (Manufacturer): Digital Camera ____
Lidar ____

Average Flight Altitude (AGL): Imagery __________feet Lidar ____________feet

Estimated Aircraft Mobilization Time: ________________hours

Brief Description of Aerial Mapping Plan: ____
____
____
____
____
____
____
____
____

APPENDIX B – PROJECT CONTROL POINT VERIFICATION FORM

LAND SURVEYOR'S STAMP

PROJECT ID:
DATE:
Phone # :

Attach the Contract Plans Survey Control Drawings to this form

SCDOT PROJECT SURVEY CONTROL VERIFICATION FORM

✓ Complete and submit via e-mail to RCE

1. **Review the Survey Control Drawings, and identify all horizontal and vertical control that were <u>unrecovered</u> in the field.**

- IF ALL HORIZONTAL AND VERTICAL POINTS WERE RECOVERED INTACT, CHECK BOX ☐

OR

- IF ANY POINTS WERE UNRECOVERED, COMPLETE TABLE BELOW

UNRECOVERED POINTS	
HORIZONTAL	VERTICAL

2. Attach a report (ascii file) documenting the verified Northing, Easting, and Elevation of existing control points in a format shown below.

Survey Method used to check the existing control points (check any that apply)
☐ Automatic Level, ☐ Total Station, ☐ GPS

Point	Measured			Plan – Measured Value			Description
	Northing	Easting	Elevation	Northing	Easting	Elevation	

3. Are additional control points and/or bench marks to be set?

☐ No ☐ Yes

Attach a report documenting Northing, Easting, and Elevation of all additional control points

How will the additional control be established?

Survey Method (check any that apply)
☐ Automatic Level, ☐ Total Station, ☐ GPS

4. Datum(s)

Vertical Datum: __________ Horizontal Datum: __________ Combined Factor: ____________________

5. GPS Network

- Will the SCVRS Network be utilized? ☐ Yes ☐ No
- Is a "site calibration used to "localize" to the existing control points? ☐ Yes ☐ No
  If "Yes", please email the localization file to the RCE.

APPENDIX C – NSSDA REPORTING ACCURACY STATISTICS

The RMSE (root mean square error) and/or 95% confidence level statistic as described in the **ASPRS Positional Accuracy Standards for Digital Geospatial Data, Edition 1, Version 1.0, November, 2014** is used by the SCDOT for field verification of mapping data. “The National Standard for Spatial Data Accuracy (NSSDA) documents the equations for computation of RMSEx, RMSEy, RMSEr and RMSEz, as well as horizontal (radial) and vertical accuracies at the 95% confidence levels, Accuracyr and Accuracyz, respectively. These statistics assume that errors approximate a normal error distribution and that the mean error is small relative to the target accuracy.” (ASPRS Positional, 2014).

“Example on the NSSDA Accuracy Computations:

For the purposes of demonstration, suppose you have five checkpoints to verify the final horizontal and vertical accuracy for a data set (normally a minimum of 20 points would be needed). Table D.1 provides the map-derived coordinates and the surveyed coordinated for the five points. The table also shows the computed accuracy and other necessary statistics. In this abbreviated example, the data are intended to meet a horizontal accuracy class with a maximum RMSEx and RMSEy of 15 cm and the 10 cm vertical accuracy class.

Computation of Mean Errors in x/y/z:

$$\bar{x} = \frac{1}{(n)} \sum_{i=1}^{n} x_i$$

where:

x_i is the i^{th} error in the specified direction

n is the number of checkpoints tested,

i is an integer ranging from 1 to n.

Mean error in Easting:

$$\bar{x} = \frac{-0.140 - 0.100 + 0.017 - 0.07 + 0.130}{5} = -0.033m$$

Mean error in Northing:

$$\bar{y} = \frac{-0.070 - 0.100 - 0.017 + 0.150 + 0.120}{5} = -0.006m$$

Mean error in Elevation:

$$\bar{z} = \frac{-0.007 + 0.010 + 0.102 - 0.100 + 0.087}{5} = -0.087m$$

Computation of Sample Standard Deviation:

$$s_x = \sqrt{\frac{1}{(n-1)}\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

where:

x_i is the i^{th} error in the specified direction,

$\bar{x}$ is the mean error in the specified direction,

n is the number of checkpoints tested,

i is an integer ranging from 1 to n.

Example Sample Standard Deviation in Elevation:

Sample Standard Deviation in Easting:

$$s_x = \sqrt{\frac{(-0.140-(-0.033))^2 + (-0.100-(-0.033))^2 + (0.017-(-0.033))^2 + (-0.070-(-0.033))^2 + (0.130-(-0.033))^2}{(5-1)}}$$
$$= 0.108\,\text{m}$$

Sample Standard Deviation in Northing:

$$s_y = \sqrt{\frac{(-0.070-0.006)^2 + (-0.100-0.006)^2 + (-0.070-0.006)^2 + (0.150-0.006)^2 + (0.120-0.006)^2}{(5-1)}}$$
$$= 0.119\,\text{m}$$

Sample Standard Deviation in Elevation:

$$s_z = \sqrt{\frac{(-0.071-0.006)^2 + (0.010-0.006)^2 + (0.102-0.006)^2 + (-0.100-0.006)^2 + (0.087-0.006)^2}{(5-1)}}$$
$$= 0.091\,\text{m}$$

Table D.1 NSSDA Accuracy Statistics for Example Data Set with 3D Coordinates

Point ID	Map-derived values			Survey Check Point Values			Residuals (Errors)		
	Easting (E)	Northing (N)	Elevation (H)	Easting (E)	Northing (N)	Elevation (H)	Δx Easting (E)	Δy Northing (N)	Δz Elevation (H)
	meters	meters	meters	meters	meters	meters	meters	meters	meters
GCP1	359584.394	5142449.934	477.127	359584.534	5142450.004	477.198	–0.140	–0.070	–0.071
GCP2	359872.190	5147939.180	412.406	359872.290	5147939.280	412.396	–0.100	–0.100	0.010
GCP3	395893.089	5136979.824	487.292	359893.072	5136979.894	487.190	0.017	–0.070	0.102
GCP4	359927.194	5151084.129	393.591	359927.264	5151083.979	393.691	–0.070	0.150	–0.100
GCP5	372737.074	5151675.999	451.305	372736.944	5151675.879	451.218	0.130	0.120	0.087
Number of check points							**5**	**5**	**5**
Mean Error (m)							**–0.033**	**0.006**	**0.006**
Standard Deviation (m)							**0.108**	**0.119**	**0.006**
RMSE (m)							**0.102**	**0.106**	**0.081**
RMSEr (m)							**0.147**	**=SQRT(RMSE$_X^2$ + RMSE$_Y^2$)**	
NSSDA Horizontal Accuracy$_r$ (ACCr) at 95% Confidence Level							**0.255**	**=RMSEr × 1.7308**	
NSSDA Vertical Accuracy$_z$ (ACCz) at 95% Confidence Level							**0.160**	**=RMSEz × 1.9600**	

Computation of Root Mean Squares Error:

$$RMSE_x = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_{i(map)} - x_{i(surveyed)})^2}$$

where:

$x_{i(map)}$ is the coordinate in the specified direction of the i^{th} check-point in the data set,

$x_{i(surveyed)}$ is the coordinate in the specified direction of the i^{th} check-point in the independent source of higher accuracy,

n is the number of checkpoints tested,

i is an integer ranging from 1 to n.

$$RMSE_x = \sqrt{\frac{(-0.140)^2 + (-0.100)^2 + (0.017)^2 + (-0.070)^2 + (0.130)^2}{5}} = 0.102\text{m}$$

$$RMSE_y = \sqrt{\frac{(-0.070)^2 + (-0.100)^2 + (-0.070)^2 + (0.150)^2 + (0.120)^2}{5}} = 0.107\text{m}$$

$$RMSE_z = \sqrt{\frac{(-0.071)^2 + (0.010)^2 + (0.102)^2 + (-0.100)^2 + (0.087)^2}{5}} = 0.081\text{m}$$

$$RMSE_r = \sqrt{RMSE_x^{\,2} + RMSE_y^{\,2}}$$

Computation of NSSDA Accuracy at 95% Confidence Level:

(Note: There are no significant systematic biases in the measurements. The mean errors are all smaller than 25% of the specified RMSE in Northing, Easting, and Elevation.)

Positional Horizontal Accuracy at 95% Confidence Level =

$$2.4477\left(\frac{RMSE_r}{1.4142}\right) = 1.7308\left(RMSE_r\right) = 1.7308\left(0.148\right) = \mathbf{0.255m}$$

Vertical Accuracy at 95% Confidence Level =

$$1.9600(RMSE_z) = 1.9600(0.081) = \mathbf{0.160\ m} =$$

$$\sqrt{\left(\left(0.102^2\right) + \left(0.107^2\right)\right)} = 0.148m$$

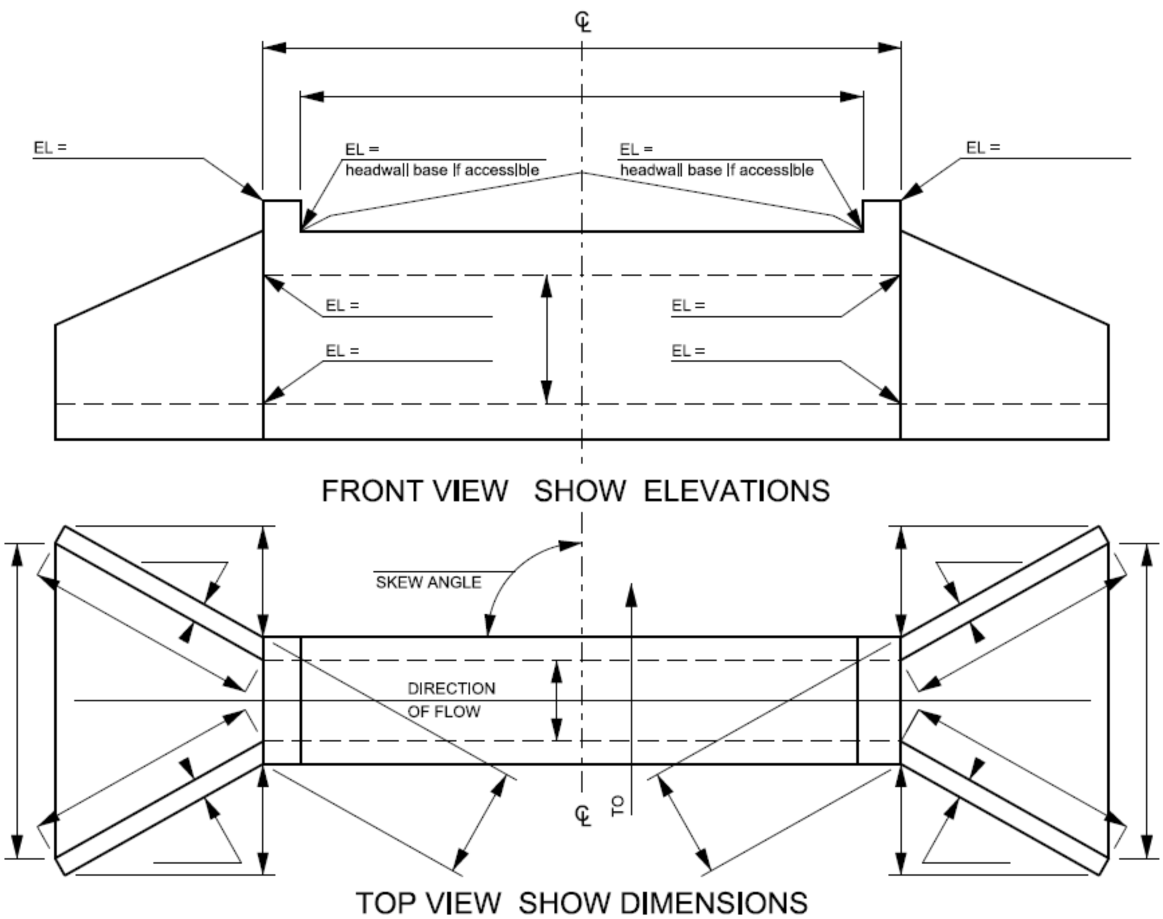
" (ASPRS Positional, 2014).

APPENDIX D – CULVERT SKETCH

BOX CULVERT SKETCH

PIN ___________ COUNTY ____________________ ROUTE ____________ LOCATION ______________
SIZE ____________ VERTICAL REFERENCE POINT______________ ELEVATION _____________
FOUNDATION ___________INTERIOR WALL THICKNESS _____________ APRON - YES ____ NO ____
BOTTOM SLAB - YES ____ NO ____ IF NONE GIVE FOOTING SIZE _____________
COMMENTS ____

*IF NO BOTTOM SLAB PROVIDE FOOTING SKETCH ON REVERSE SIDE
*IF CULVERT HAS A DIFFERENT SHAPE OTHER THAN SHOWN HEREON PROVIDE SKETCH AND INCLUDE ALL DIMENSIONS AND ELEVATIONS
*IF SKEWED STATE WHETHER LEFT AND RIGHT OFFSET DIMENSIONS ARE ALONG SKEW ANGLE OR PERPENDICULAR TO ROADWAY CENTERLINE,



APPENDIX E – COMMON CURB & GUTTER TYPES

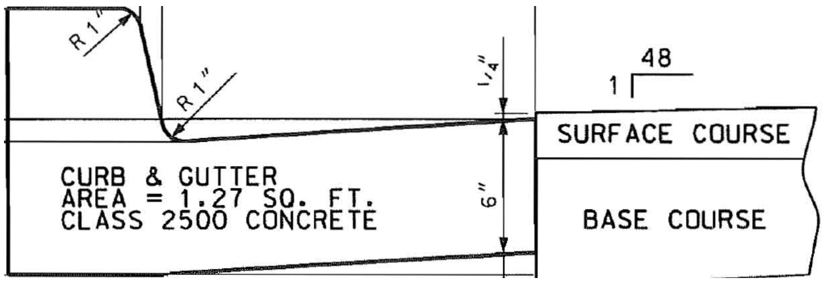


Figure 84 Vertical Face Curb

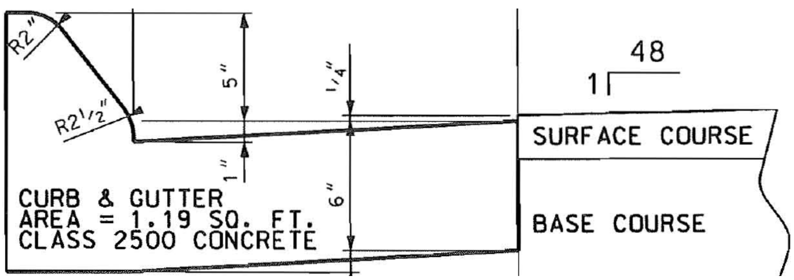


Figure 85 Mountable Curb

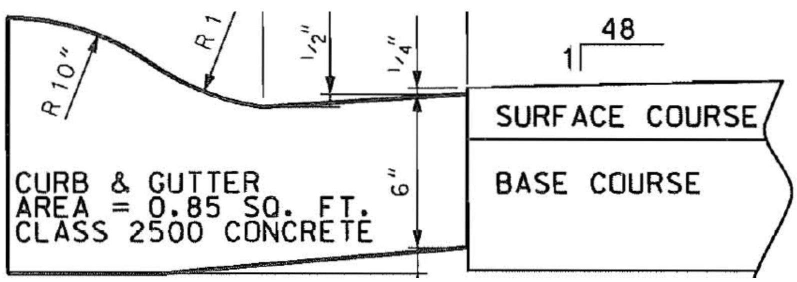


Figure 86 OGEE Curb

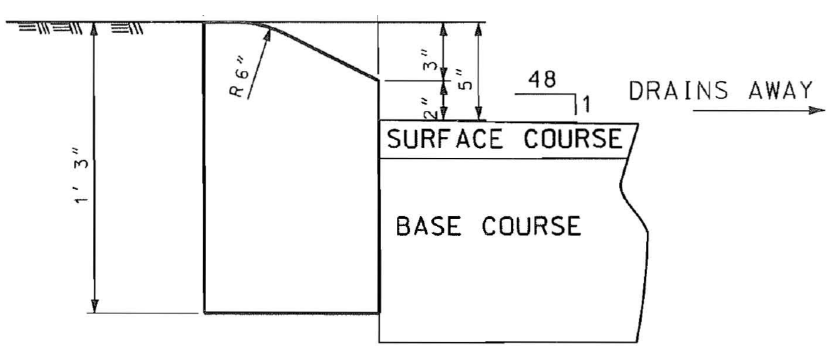


Figure 87 Median Island Curb

APPENDIX F – EXAMPLE LAND OWNER LETTER

Universal Real Estate Developers
Attention: Steven M. Smith
100 Elm Street
Columbia, SC 29200

Re: Elm Street Improvement Project (P012345), Richland County

Dear Mr. Smith,

The South Carolina Department of Transportation (SCDOT) has retained the services of a surveying and mapping consultant, Surveying, Inc. (Project Team) to conduct surveying and mapping services to prepare for the above referenced Project. The Project Team, usually no more than five people, will need to access your property at 100 Elm Street in Columbia to perform field work between 8:00 AM and 5:00 PM on various weekdays during the months of April 2021 thru August 2021. This field work will involve traditional surveying techniques and the placing of temporary reference points (Survey Control points) in the form of wooden stakes, colored tape and spray-painted ground markings. The purpose of this work is to gather precise information for the Project's design engineers. The Project Team may need to trim some ground vegetation in order to field survey the ground elevations and surface features on your property. They will try not to interfere with your use of the property and will cooperate with you to avoid doing so.
Please do not remove any stakes, tape or markings that the Project Team may place.

Field personnel will be required to wear safety vests, carry personal identification and have a copy of this letter to identify them as Project Team members. Unfortunately, field personnel will not be able to provide any definite information or answers to questions about the Project beyond what is in this letter. They will only be performing surveying and mapping, not construction or demolition.

We appreciate your patience, cooperation and understanding while these Project Team members are present and surveying on your property. If you have any questions or concerns about the Project or the surveying, please contact me in my Columbia Office at 803-737-1234 or by email at isonbd@scdot.org.

Sincerely,

Bud Ison, S.C. P.L.S.
SCDOT On-Call Services Manager

ec: Warren Buffet, SCDOT Survey Manager

APPENDIX G – PROJECT SURVEY CONTROL ADJUSTMENT

G.1 Terrestrial Total Station Survey (TTSS) Adjustment

A Least Squares method is preferred for terrestrial traverse adjustments, but is required for multiple terrestrial traverse loops interconnecting to form a network.

In the absence of a Least Squares method, the terrestrial traverse can be adjusted using the following steps in order as listed below:

Step 1: Traverse Misclosure (Unadjusted Ratio of Precision).

Step 2: Angle Adjustment.

Step 3: Compass (Bowditch) Rule Adjustment.

Step 4: Review Adjustment Results.

Step 1: Traverse Misclosure

The misclosure of the loop or link traverse should be calculated prior to any adjustments for compliance to the project's unadjusted ratio of precision requirements.

Step 2: Angle Adjustment

Applying equal angle corrections to each measured angle assumes error is the same at each instrument station. Unlike the **traditional loop traverse angle adjustment**, the sum of interior angles cannot be used as the angular closure check for a Link Traverse.

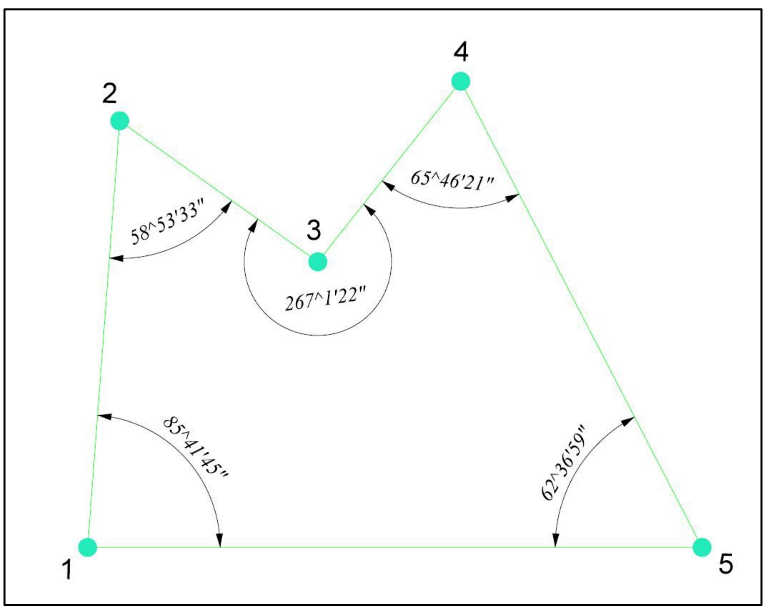


Figure 88 Example Loop Traverse Interior Angles

Loop Traverse Angle Closure Check:

∑ (interior angles) = (n-2) * 180° = (5-2) * 180° = 3 * 180° = **540°**

Point 1	85°41’45”
Point 2	58°53’33”
Point 3	267°01’22”
Point 4	65°46’21”
Point 5	62°36’59”
Sum:	**540°**00’00”

A **Link traverse angle adjustment** uses the angular difference between the ending calculated azimuth (or bearing) of the traverse determined from the beginning Primary Survey Control azimuth points, and the published azimuth (or bearing) between the two ending Primary Survey Control azimuth points.

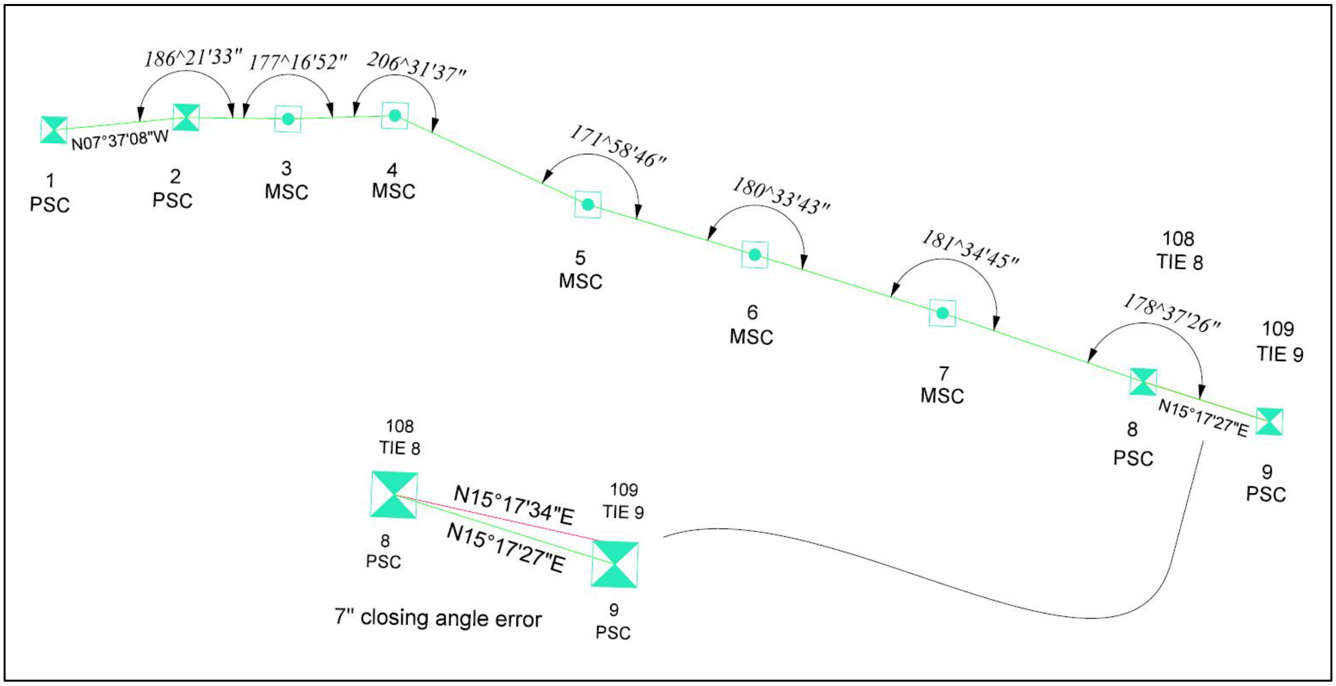


Figure 89 Example Link Traverse Closing Angular Error

Angular misclosure = N15°17’27”E - N15°17’34”E = **-** 0°00’07”

Correction per angle = **-**00°00’07” / 7angles = -00°00’01”/angle

Line	Raw Angle	Correction	Adjusted Angle
1-2-3	186°21’33”	-00°00’01”	186°21’32”
2-3-4	177°16’52”	-00°00’01”	177°16’51”
2-4-5	206°31’37”	-00°00’01”	206°31’36”
4-5-6	171°58’46”	-00°00’01”	171°58’45”
5-6-7	180°33’43”	-00°00’01”	180°33’42”

6-7-8 181°34'45" -00°00'01" 181°34'44"
7-8-9 178°37'26" -00°00'01" 178°37'25"

Step 3: Compass (Bowditch) Rule Adjustment

A Compass Rule adjustment proportionally distributes the linear Error of Closure (EOC) to each traverse point between the Primary Survey Control azimuth pairs and assumes all angles and distances within a traverse were measured with equal precision. Using the Compass Rule adjustment with a **Link traverse**, the error of closure is the sum total of the Latitude error (Lat_{error}) and Departure error (Dep_{error}) of the traverse as calculated from the beginning traverse point (point number 2 in figure below) and the ending traverse point (point number 8 in figure below). The Lat_{error} and Dep_{error} is then distributed proportionally to the traverse distances of the Main Survey Control points.

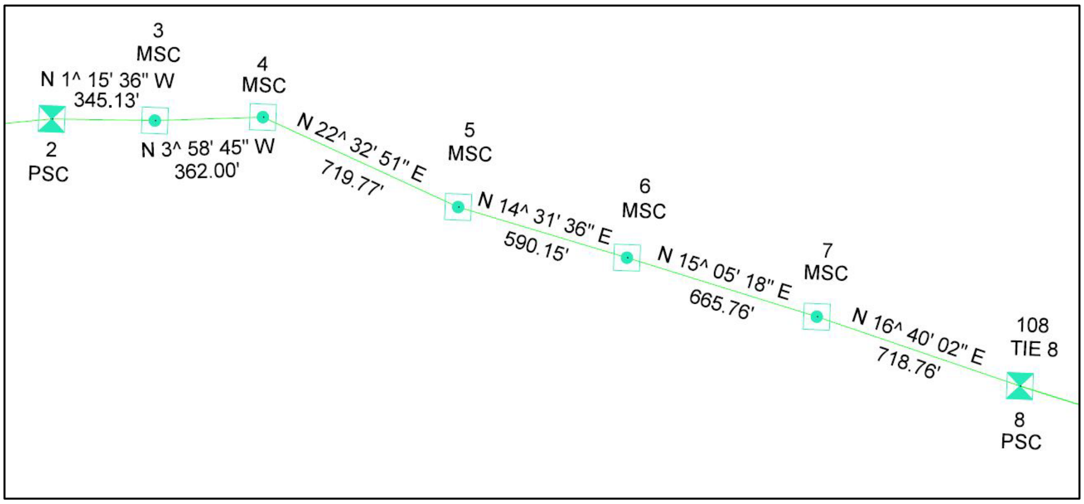


Figure 90 Example Link Traverse Beginning and Ending on Primary Survey Control Points

Point	Bearing	Length	Departure (Easting) East (+)	Departure (Easting) West (-)	Latitude (Northing) North (+)	Latitude (Northing) South (-)	Adjusted Departure	Adjusted Latitude	Coordinates Easting	Coordinates Northing	
2 (PSC)									**1846317.78**	**637433.13**	Start
	N1°15'36"W	345.13		-7.589	345.047		-7.570	345.036			
3									1846310.21	637778.17	
	N3°58'45"W	362.00		-25.121	361.127		-25.101	361.115			
4									1846285.11	638139.28	
	N22°32'51"E	719.77	275.995		664.752		276.034	664.729			
5									1846561.14	638804.01	
	N14°31'36"E	590.15	148.028		571.283		148.060	571.264			
6									1846709.20	639375.27	
	N15°05'18"E	665.76	173.303		642.808		173.339	642.786			
7									1846882.54	640018.06	
	N16°40'02"E	718.76	206.149		688.563		206.188	688.540			
108 (TIE 8)									1847088.73	640706.60	
8 (PSC)									**1847088.73**	**640706.60**	End
	Sum (∑)	3401.57	770.765		3273.580		770.95	3273.47			

ΔEasting $_{End\text{-}Start}$	770.95
ΔNorthing $_{End\text{-}Start}$	3273.47

Lat$_{\mathbf{error}}$ = $\sum Lat_{sum}$ - $\Delta N_{End\text{-}Start}$ = 3273.580' - 3273.470' = **-0.110'**

Dep$_{\mathbf{error}}$ = $\sum Dep_{sum}$ - $\Delta E_{End\text{-}Start}$ = 770.765' - 770.950' = **-0.185'**

Angle Adjusted Relative Precision = **√(-0.18'**)^2 + (**-0.11'**)^2 = **1:16,000**

Compass Rule Adjustment

Latitude Correction = [-Lat$_{error}$ / total distance] * Length$_{A\text{-}B}$

Departure Correction = [-Dep$_{error}$ / total distance] * Length$_{A\text{-}B}$

Example for (2-3)

Adjustment in Latitude $_{2\text{-}3}$ = *345.047'* + [-(-0.110') / 3401.57'] * *345.13'* = **345.036'**

Adjustment in Departure $_{2\text{-}3}$ = *-7.589'* + [-(-0.185') / 3401.57'] * *345.13'* = **-7.570'**

Figure 91 Example Compass Rule Adjustment of a Link Traverse

Step 4: Review Adjustment Results

After the final adjustments are complete, compare the unadjusted and adjusted points for possible resurvey or field verifications. In the example below, it would be advisable to recheck the field distance between point number 7 (MSC adjusted) and point number 8 (PSC fixed position).

	Unadjusted Distance	Adjusted Distance	Adjusted - Unadjusted Distance
2			
	345.13	345.12	-0.01
3			
	362.00	361.99	-0.01
4			
	719.77	719.76	-0.01
5			
	590.15	590.14	-0.01
6			
	665.76	665.75	-0.01
7			
	718.71	718.75	0.04
8			

Figure 92 Example of Unadjusted vs. Adjusted distances

G.2 Differential Level Adjustment

A Least Squares method is preferred for differential level circuit adjustments, but is required for multiple level loop circuits interconnecting to form a network.

In the absence of a Least Squares method, the differential level elevations can be adjusted using the following method:

Step 1: Review Datum Benchmark(s).

Step 2: Level Misclosure (EOC).

Step 3: Equal Distribution or Proportional Adjustment.

Step 4: Review Adjustment Results.

Step 1: Review Datum Benchmark(s)

Review the National Spatial Reference System (NSRS) network elevation accuracy of project benchmark(s) used for establishing the projects vertical datum. The National Geodetic Survey (NGS) has ended maintenance of passive benchmarks (physical ground monuments), which should cause the surveyor to examine and question any large elevation misclosures between published NGS passive benchmarks.

Step 2: Level Misclosure

The misclosure of the level loop or level link circuit should be calculated prior to any adjustments for compliance to the project's elevation precision requirement.

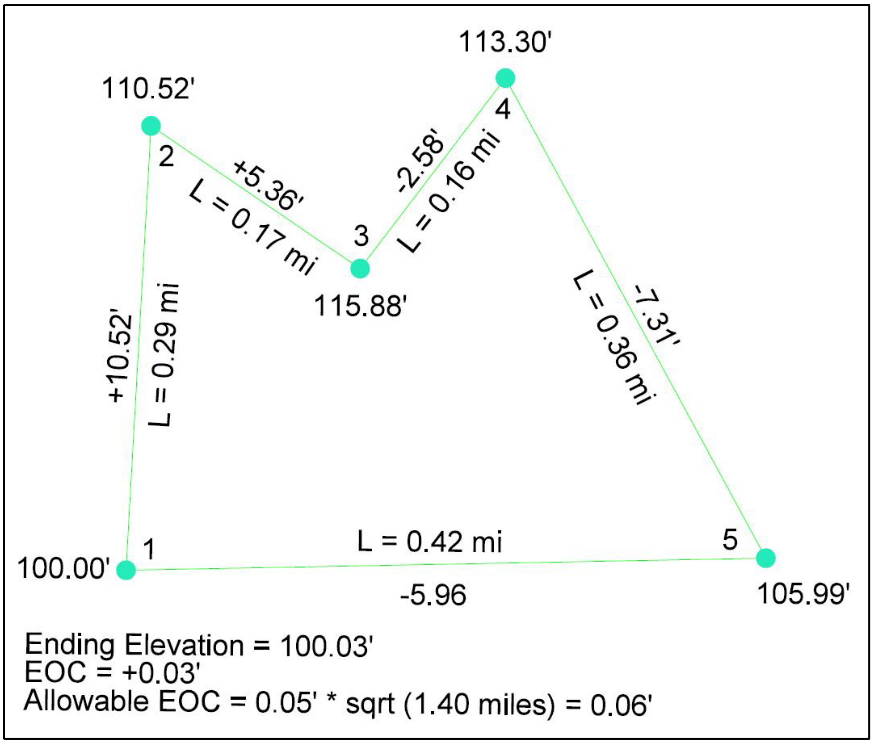


Figure 93 Example of Level Loop Circuit

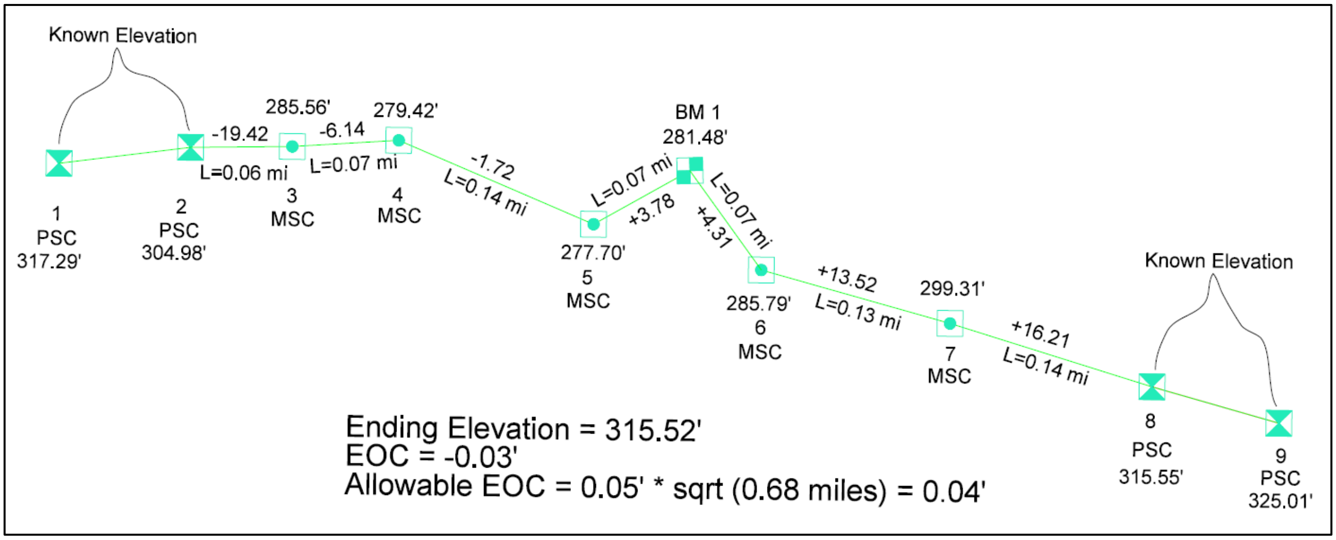


Figure 94 Example of Level Link Circuit

Step 3: Equal Distribution or Proportional Adjustment

Since route (linear) surveys typically involve a level link circuit (beginning and ending on separate benchmarks along a linear path), an equal distribution or proportional adjustment of the level link elevation misclosure can be used for SCDOT projects.

Many textbooks describe the details of the differential leveling method, but a few important topics on **leveling error** are listed below for reference before discussing the adjustment methods.

2-Peg Test

Perform a "2-peg test" of the self-leveling (automatic) or digital level before beginning the survey project. Perform a 2-peg test at the beginning of each day before continuing the previous day's levels. Follow the level manufactures guidelines for the 2-Peg test setup. Example shown below.

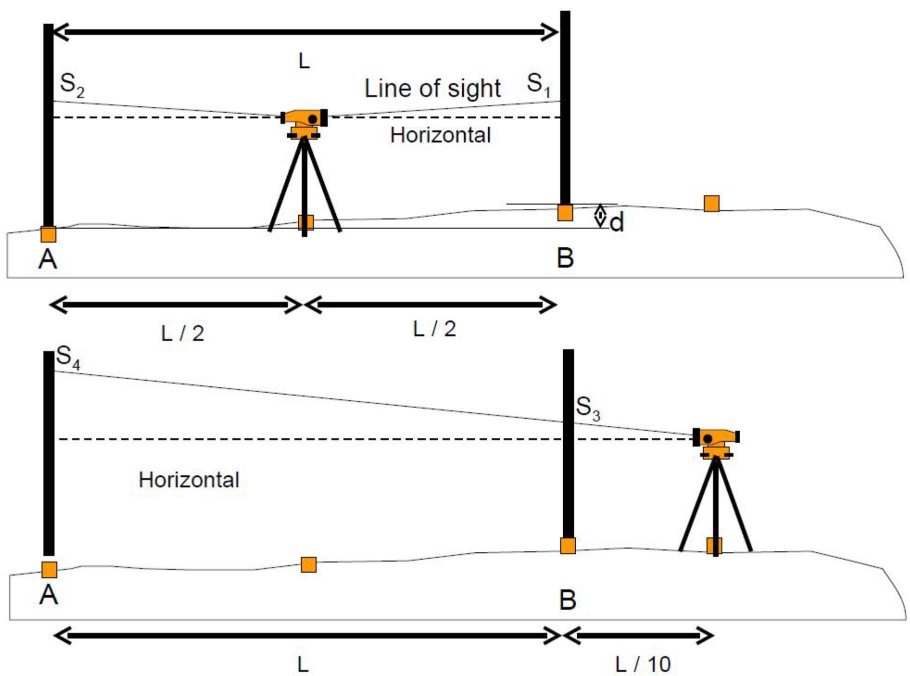


Figure 95 Example 2-Peg Test Setup (sudeshnairs.webs.com)

Collimation error $= (S_1 - S_2) - (S_3 - S_4) / L$

(L should be approximately 60' on flat ground)

Collimation error is typically express as **mm/m** or as a **vertical angle (α)**.

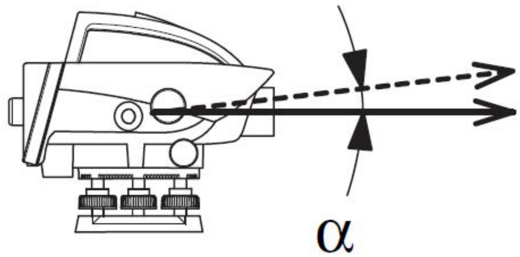


Figure 96 Example of Collimation vertical angle error (α) (WYDOT, 2016)

Acceptable Collimation error **specifications**:
Uren & Price (*Surveying for Engineers, 2010*): ± 1mm per 20m (≈0.003' per 60').
Wimpey: ± 4mm per 50 m (≈0.005' per 60').
National Geodetic Survey:

Second Order Class 2 (≈0.03' * √mile): ± 0.05mm per 1m **(≈0.003' per 60')** or **(α ≈ 10.3")**.

Third Order (0.05' * √mile): ± 0.10mm per 1m **(≈0.006' per 60')** or **(α ≈ 20.6").**

A self-leveling (automatic) or digital level's **collimation error** is the result of the level line of sight (LoS) not being perpendicular with the level's vertical axis, assuming the vertical axis of the level is correctly adjusted and coincides with a plumb line (gravity). If the collimation error exceeds the instrument specifications then the level needs adjustment before use.

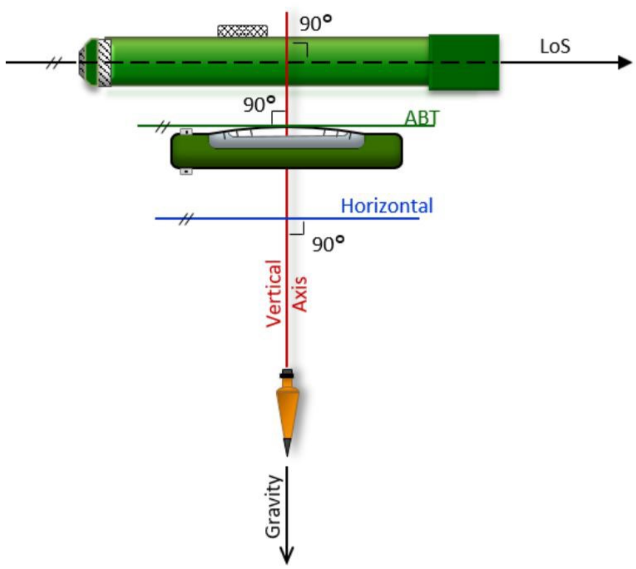


Figure 97 Vertical Axis of Level (jerrymahun.com)

Balance Foresight and Backsight Distances

Balancing the foresight (FS) and backsight (BS) distances of each level setup can help minimize the effects of instrument collimation error, and the combined effects of the Earth's curvature and atmospheric refraction.

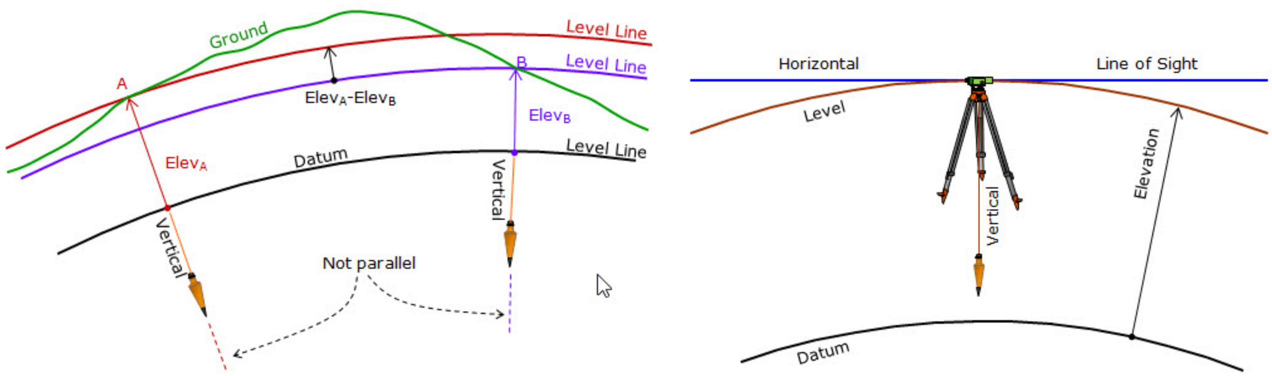


Figure 98 Level Line (jerrymahun.com)

A **level line** is perpendicular to the direction of gravity, which creates a curved line on the surface of the Earth. The level surface is a curved surface, which acts as a datum for vertical distances.

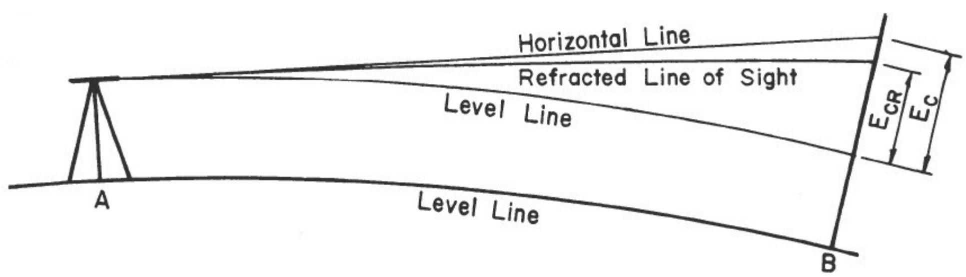


Figure 99 Earth Curvature and Atmospheric Refraction of Level Line (Buckner, 1991)

E_C (curvature of earth effect on horizontal line of sight) = $0.024 * F^2$

E_{CR} (combined curvature of earth and atmospheric refraction correction = **$0.0206 * F^2$** <u>or</u> **$0.574 * M^2$**

F = distance of AB in 1000's of feet

M = distance of AB in miles

In Figure above, the Earth's curvature can be visualized as following the curved level line (i.e., the combined effects of many equipotential gravity surfaces). Not correcting for Earth's curvature over long distances will result in incorrect elevations related to the true equipotential (gravity) surface.

Maintaining equal backsight and foresight distances can minimize these errors.

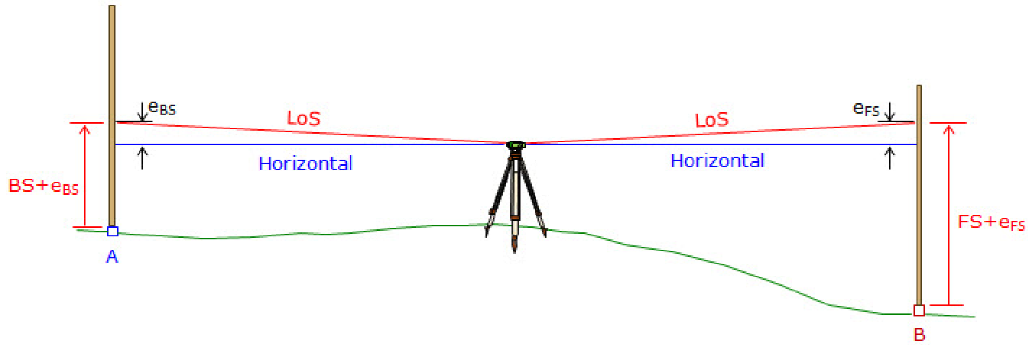


Figure 100 Minimizing Error by Balancing Backsight and Foresight (jerrymahun.com)

The algebraic sign of the backsight (+) and foresight (-) readings will include the sum of the collimation, earth's curvature and atmospheric refraction errors. These errors for the backsight (e_{BS}) and foresight (e_{FS}) will be approximately equal ($e_{BS} \approx e_{FS}$) if the backsight and foresight distances are approximately equal.

$$Elev_B = Elev_A + (BS+e_{BS}) - (FS + e_{FS})$$
$$Elev_B = Elev_A + BS + e_{BS} - FS - e_{FS}$$
$$Elev_B = Elev_A + BS - FS + \mathbf{(e_{BS} - e_{FS})}$$
$$Elev_B = Elev_A + BS - FS$$

National Geodetic Survey maximum allowable distances:
Second Order Class 2 (**≈0.03' * √mile**):
maximum ΔBS-FS distance per setup = 10m (**≈33'**) | maximum sight length (½AB) = 70m (**≈230'**).
Third Order (**0.05' * √mile**):
maximum ΔBS-FS distance per setup = 10m (**≈33'**) | maximum sight length(½AB) = 90m (**≈295'**).
(Δ = difference)

Rod Bubble

Verify rod bubble is in adjustment. If a rod bubble is not used then slowly wave (rock) the rod away and toward the level operator to give the true reading of a plumb level rod. The rod should only be rocked on a single pivot point at the bottom center of the rod. The level operator should record the lowest reading on the rod.

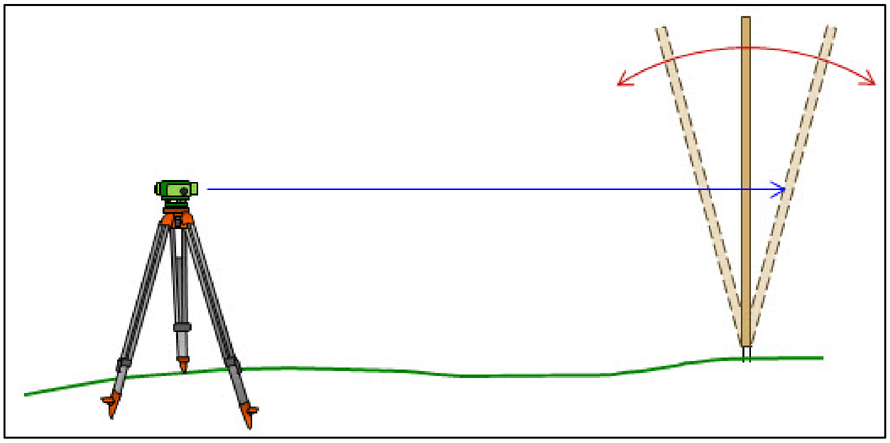


Figure 101 Minimizing Rod Plumb Error by "Rocking" (jerrymahun.com)

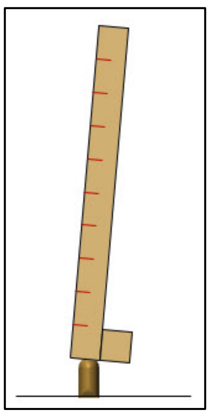


Figure 102 Rod pivot point (jerrymahun.com)

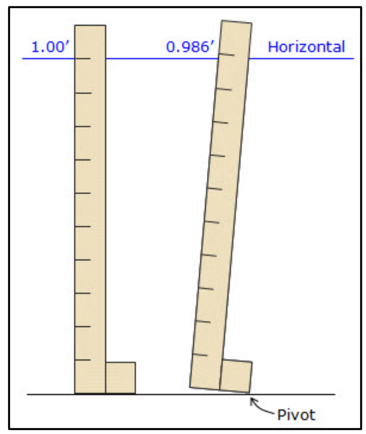


Figure 103 Rod rocking error (jerrymahun.com)

G.2.1 Equal Distribution Adjustment

An equal distribution of level circuit elevation errors assumes all errors are positive or negative, and distributes elevation errors equally among raw elevations based on the cumulative number of leveled points (MSC, BM, temporary turning point, etc.) starting from the first leveled point in the level circuit. In the example below the elevation error of closure = -0.03' and will be distributed over five (5) Main Survey Control points and one (1) Benchmark. Take note there is one temporary turning point between MSC4 and MSC5, which is included in the cumulative number of leveled points leading up to MSC5.

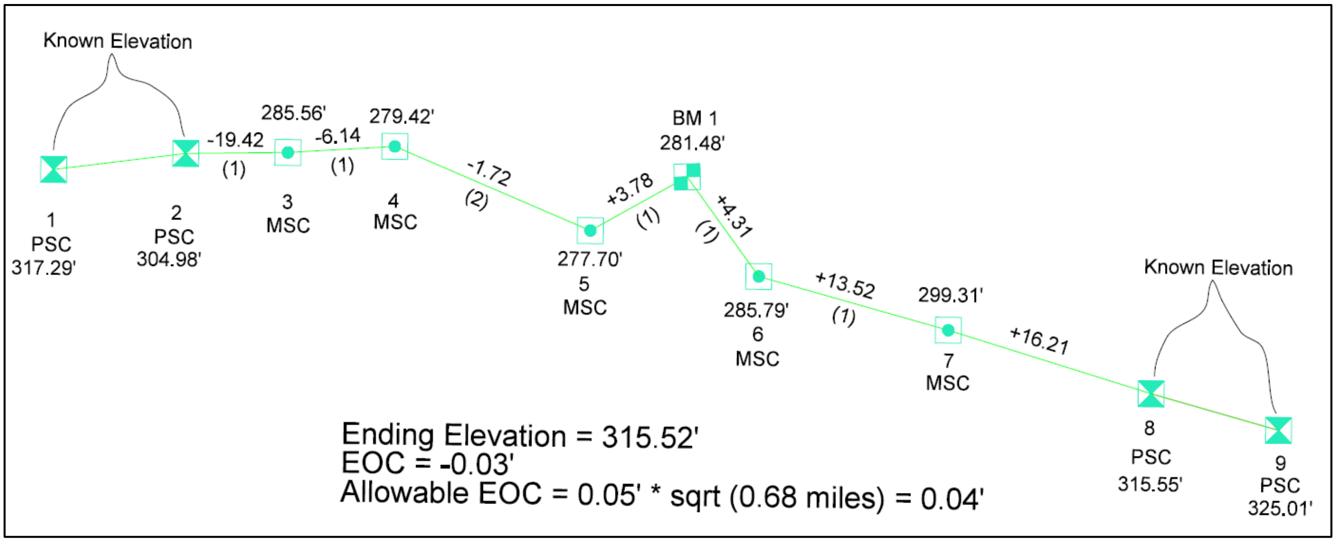


Figure 104 Example Equal Distribution Adjustment

$$\textit{Adjusted Elev}_{point} = \textit{Elev}_{point} + \sum n * [\pm EOC / (\#\ of\ total\ leveled\ points)]$$

∑n = cumulative number of leveled points (MSC, BM, temporary turning point, etc.) up to and including the adjusted level point.

$AdjElev_3$ = 285.56’ + 1 * [+0.03’ / 6 (points)] = **285.565’**

$AdjElev_4$ = 279.42’ + 2 * [+0.03’ / 6 (points)] = **279.430’**

$AdjElev_5$ = 277.70’ + 4 * [+0.03’ / 6 (points)] = **277.720’**

$AdjElev_{BM1}$ = 281.48’ + 5 * [+0.03’ / 6 (points)] = **281.505’**

$AdjElev_6$ = 285.79’ + 6 * [+0.03’ / 6 (points)] = **285.820’**

$AdjElev_7$ = 299.31’ + 7 * [+0.03’ / 6 (points)] = **299.345’**

G.2.2 Proportional Distribution Adjustment

If the distances are known between the survey control points and benchmark(s), then a proportional distribution of the elevation errors can be performed. A proportional distribution of level circuit elevation errors assumes all errors are positive or negative, and distributes elevation errors proportionally by distance to the raw elevations.

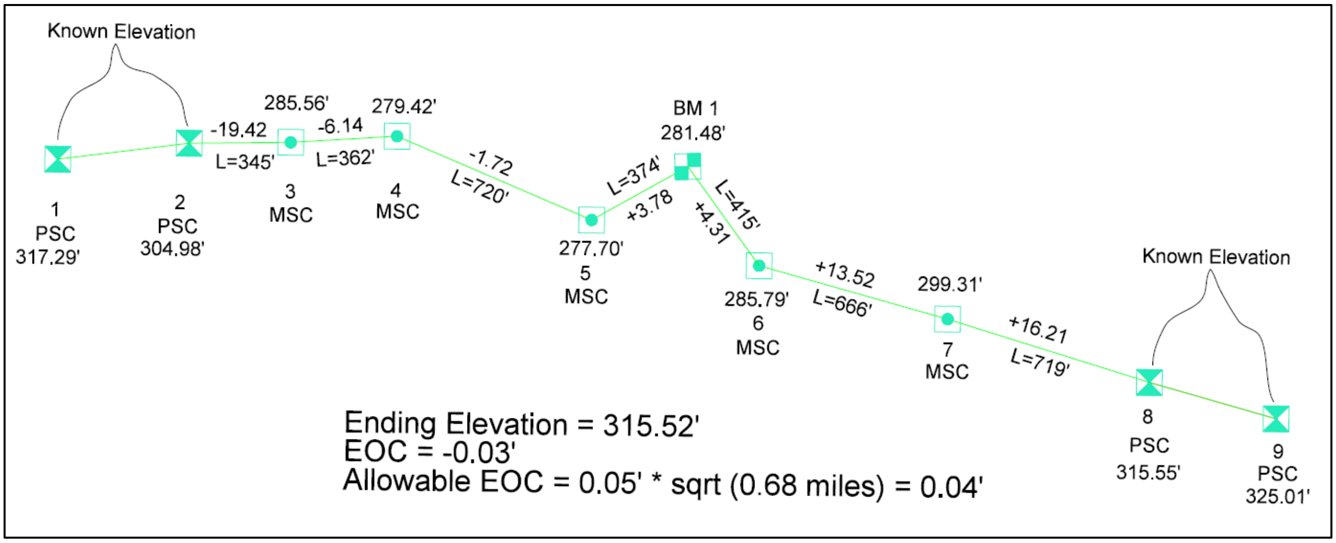


Figure 105 Example Proportional Distribution Adjustment

$$Adjusted\ Elev_{point} = Elev_{point} + \sum d * [\pm EOC / (total\ level\ run\ distance)]$$

∑d = cumulative distance between leveled points starting at beginning benchmark

$AdjElev_3$ = 285.56’ + 345’ * [+0.03’ / 3601’] = **285.563’**

$AdjElev_4$ = 279.42’ + 707’ * [+0.03’ / 3601’] = **279.426’**

$AdjElev_5$ = 277.70’ + 1427’ * [+0.03’ / 3601’] = **277.712’**

$AdjElev_{BM1}$ = 281.48’ + 1801’ * [+0.03’ / 3601] = **281.495’**

$AdjElev_6$ = 285.79’ + 2216’ * [+0.03’ / 3601’] = **285.808’**

$AdjElev_7$ = 299.31’ + 2882‘ * [+0.03’ / 3601’] = **299.334’**

Step 4: Review Adjustment Results

After the final adjustments are complete, compare the unadjusted and adjusted elevations for possible resurvey or field verifications. In the examples below, the differences between the adjusted point number 7 elevation and the closing benchmark elevation gives an acceptable delta (difference).

Example check of **Equal** Distribution Adjustment:

Adjustment Check: $AdjElev_7$ (299.345’) + $FS_{7\text{-}8}$ (16.21) – PSC 8 (315.55) = **Δ+0.005’**

Example check of **Proportional** Distribution Adjustment:

Adjustment Check: $AdjElev_7$ (299.334’) + $FS_{7\text{-}8}$ (16.21) – PSC 8 (315.55) = **Δ-0.006’**

G.2.3 SCDOT Recommended (note 1) Second Order Class II Differential Leveling Specifications

SCDOT Second Order Class II Operation/Specification	Compensator-Level Three-Wire Observation	Electronic/Digital Bar Code Level
Difference in length between fore and back sites, not to exceed per setup	16 feet	16 feet
Cumulative difference in length between fore and back sights, not to exceed per level loop or level link circuit	33 feet	33 feet
Maximum sight lengths	230 feet	230 feet
Minimum ground clearance of sight line (i.e. minimum rod reading)	1.6 feet	1.6 feet
Maximum level link circuit misclosure	0.03’√miles	0.03’√miles
Maximum level loop circuit misclosure	0.03’√miles	0.03’√miles
Difference between top and bottom interval not to exceed	.20 of rod unit	N/A
Collimation (Two-Peg) Test	Daily (not to exceed 0.003 feet) (Note x)	Daily
Minimum number of readings. (Use repeat measure option for each observation)	N/A	3

Note 1: These recommended specifications are for guidance only and SCDOT does not guarantee following this guidance will result in expected results listed. Methods and specifications used to attain a specified accuracy and precision are the sole responsibility of the signing/sealing licensed professional.

G.2.4 SCDOT Recommended (note 1) Third Order Differential Leveling Specifications

SCDOT Third Order Operation/Specification	Compensator-Level Three-Wire Observation	Compensator-Level Single-Wire Observation	Electronic/Digital Bar Code Level
Difference in length between fore and back sites, not to exceed per setup	33 feet	33 feet	33 feet
Cumulative difference in length between fore and back sights, not to exceed per level loop or level link circuit	33 feet	33 feet	33 feet
Maximum sight lengths	300 feet	300 feet	300 feet
Minimum ground clearance of sight line (i.e. minimum rod reading)	1.6 feet	1.6 feet	1.6 feet
Maximum level link circuit misclosure	0.05’√miles	0.05’√miles	0.05’√miles
Maximum level loop circuit misclosure	0.05’√miles	0.05’√miles	0.05’√miles
Difference between top and bottom interval not to exceed	.30 of rod unit	N/A	N/A
Collimation (Two-Peg) Test	Daily (not to exceed 0.006 feet) (Note x)	Daily	Daily
Minimum number of readings. (Use repeat measure option for each observation)	N/A	N/A	3 (Note x)

Note 1: These recommended specifications are for guidance only and SCDOT does not guarantee following this guidance will result in expected results listed. Methods and specifications used to attain a specified accuracy and precision are the sole responsibility of the signing/sealing licensed professional.

APPENDIX H – TRIGONOMETRIC "Trig" LEVELING

Trigonometric "Trig" leveling is a method for transferring elevations using trigonometric equations with the measured zenith angle "Z" and slope distance "S". Modern EDM total stations can internally calculate and display the vertical distance "V" using these trigonometric equations and the measured zenith angle and slope distance.

H.1 Instrument on Point

"**Instrument on Point**" trig level method is used for side shots measured from a single survey control point for collecting mapping data elevations.

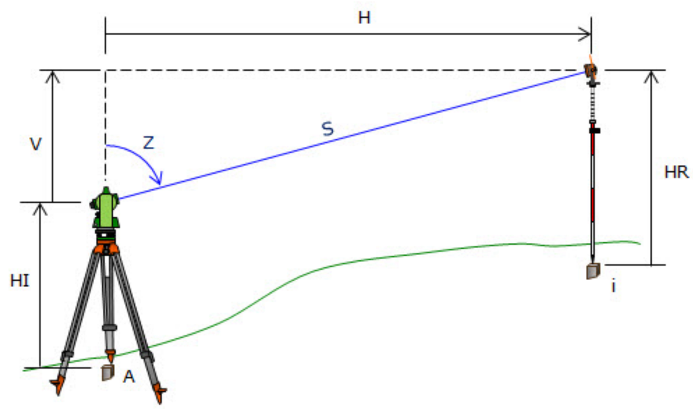


Figure 106 Instrument on Point - instrument is setup on known elevation point (jerrymahun.com)

$$Elev_i = Elev_A + HI + (S * \cos z) - HR$$

$Elev_i$ = Elevation of point i
$Elev_A$ = Elevation of point A
HI = measured height from instrument index point to $Point_A$
*(S * cos z) = V = vertical distance from instrument index point to prism nodal point*
S = slope distance measured by instrument EDM
z = zenith angle
HR = measured height of rod from bottom of rod to prism nodal point

Trigonometric leveling involves measurements of single quantities (e.g., Height of Instrument, EDM distance, etc.) each of which has its own individual random errors. "How the errors accumulate, cancel, decrease, or otherwise behave through the process of computing the final value *indirectly* is termed *propagation of random errors*. To be able to compute random errors in indirect measurements for all but the simplest situations, the student should have a general knowledge of differential calculus and be able to evaluate partial derivatives. Those without such background will, however, be able to apply the several general formulas to be derived. These emerge as simple algebraic formulas after application of the general formula for propagation of random errors" (Buckner, 1991).

Errors associated with an **Instrument on Point** leveling method are:

1. **Incorrect instrument height** (HI) due to misreading scale and/or inability to measure the true plumb height to the instrument's index point.

   Example below shows an HI = 5.35' as measured to the instrument's index mark. When using an instrument width of 0.6', the correct HI = 5.34' giving an **HI error = +0.01'**.

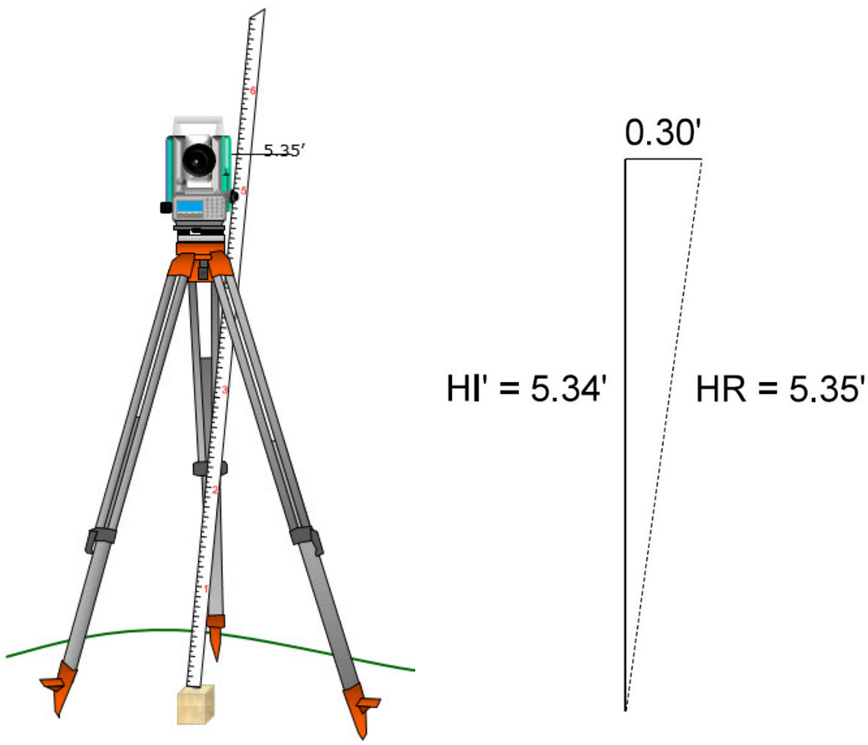


Figure 107 Incorrect Instrument Height (jerrymahun.com)

2. **Incorrect rod height** (HR) can be typically **±0.01'**.

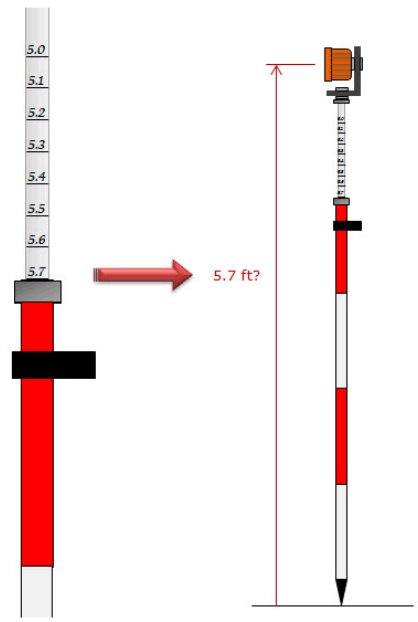


Figure 108 Incorrect Rod Height (jerrymahun.com)

3. **Vertical index error** is a function of the side shot **distance.**

e_i *(Vertical Index Error) = S * sin (½ * a)*

S = slope distance

a = Index angle error(a)

Example: 500' * sin (½ * 0°0'10") = **±0.01'**

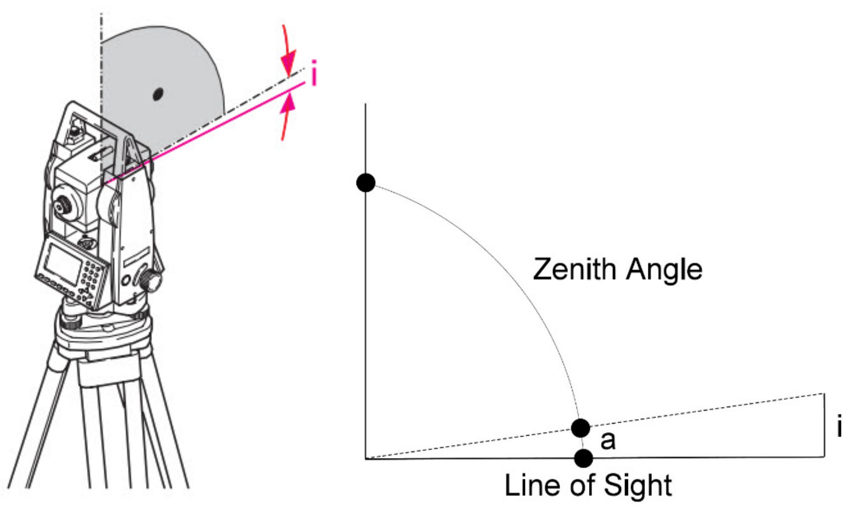


Figure 109 Vertical Index Error (Leica Geosystems)

4. **Curvature of the Earth and Atmospheric Refraction error (E_{CR})** is typically small at short distances.
   E_{CR} = **0.0206 * F^2**
   F = distance in 1,000s of feet.
   Example: E_{cr} = 0.0206 * $(0.5)^2$ = **±0.005'** @ 500' side shot.

5. Manufacture's **EDM distance error** combines a constant error (±mm) plus a proportional error based on the distance measured (ppm, or parts per million).
   Example Manufacture's EDM accuracy specification: 2mm + 2ppm
   Constant EDM error (±mm) = ±2mm × $\frac{1.0'}{304.8mm}$ = ±0.007'.
   Proportional EDM error (ppm) at 500' = $2 \times \frac{500'}{1{,}000{,}000}$ = 0.001'
   Manufactures EDM specified error = ±0.007' + 0.001' = **±0.008'** @ 500'

6. **Temperature and atmospheric pressure EDM error ≈ 0** if using instrument correction settings.

7. **Instrument angular accuracy** can add to the uncertainty of trig vertical distances. Multiple sets can improve the angular precision of an instrument.

Angular uncertainty[1] of the total station, in arc-seconds	Linear error for the foresight distance, in plus or minus feet		
	200 feet	500 feet	1,000 feet
30	0.0290	0.0726	0.1452
20	0.0193	0.0484	0.0967
10	0.0097	0.0241	0.0483
5	0.0048	0.012	0.024
1	0.0009	0.0023	0.0046
0.5	0.0004	0.0011	0.0022
0.1	0.0001	0.0001	0.0003

Figure 110 Instrument Angular Uncertainty and Vertical Error (USGS, 2020)

The **uncertainty** of the trig vertical distance for a side shot can be estimated using the general formula of **random error propagation**. The general formula is an estimated random error propagation by a Pythagorean-type approach, which recognizes the independence of each error of the measurement. (Buckner, 1991).

ε_{VD} (Uncertainty of Vertical Distance) = $\sqrt{e_{HI}^2 + e_{HR}^2 + e_i^2 + e_{CR}^2 + e_{\alpha d}^2}$

ε_{VD} (Example: **S=500'**, **z=90°00'00"**) = **±0.02'**.

e = uncertainty

e_{HI} = measured height of instrument = ±0.01'

e_{HR} = measured height of rod = ±0.01'

e_i = vertical index error = ±0.01' @ 500'

e_{CR} = Earth's curvature and atmospheric refraction = ±0.005' @ 500'

$e_{\alpha d}$ = combined error of distance and pointing error = $\sqrt{(S*\sin z)^2 * e_z^2 + (\cos z)^2 * e_{EDM}^2}$ = ±0.005'

S = slope distance

z = zenith angle

e_z = 90% pointing error in angle (@1.6449σ) = $\frac{\pm 1.9"}{\sqrt{1 reading}}$ = ±1.9" (±0.0000092115 radians)

e_{EDM} = EDM error @ 500' = ±0.008'

Zenith Angle Range (50° - 130°)	Instrument on Point Uncertainty in Trig Vertical Distance with Propagated Random Error (ε_{VD})			
	±0.015	±0.016	±0.02	±0.026
	100'	250'	500'	750'
	Slope Distance (feet)			

Assumptions: e_{HI}=±0.01', e_{HR}=±0.01', e_i=±10", e_{CR}=included, e_z±1.9", ε_{EDM}=2mm+2ppm, single zenith angle (1 reading), survey equipment has been properly calibrated to eliminate systematic errors, no mistakes.

****CAUTION**: The uncertainty of measured vertical distance values in the table above assume ideal conditions which is unlikely during a normal survey. These uncertainty values are listed only to demonstrate the minimum error when following proper procedures under ideal conditions.

Figure 111 Instrument on Point method Trig Vertical Distance Uncertainty

H.2 Remote Elevation

"**Remote Elevation**" method is used to remotely transfer an elevation from a known point to another point using the trigonometric leveling method. SCDOT uses this method for establishing elevations for main survey control when project site conditions make a differential leveling method difficult or impractical. "If the instrument is halfway between the two points, the curvature and refraction effects cancel regardless of the elevation differences among the three points." (Buckner, 1991).

Some of the **trig errors** discussed in the "Instrument on Point" leveling method apply to the "Remote Elevation" method:

1. **Incorrect rod height error** (e_{HR}) ≈ **0** if **one fixed rod** is used for both the backsight and foresight.
2. **Vertical index error** (e_i) ≈ **0** when using a direct and reverse zenith angle for multiple sets.
3. **Curvature of the Earth and Atmospheric Refraction error** (E_{CR}) ≈ **0** if the distance between the backsight and foresight are balanced. (Buckner, 1991).
4. **EDM distance error** (e_{EDM}) is a function of the manufacturers EDM constant error + ppm.

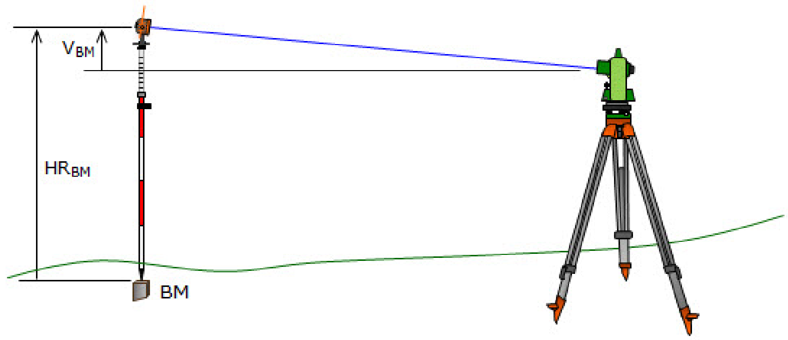


Figure 112 Remote Elevation - instrument elevation from known benchmark (jerrymahun.com)

$$\textbf{Elev}_{\textbf{instrument}} \textbf{ (assuming single fixed-height rod)} = \textbf{Elev}_{\textbf{BM}} + \textbf{HR}_{\textbf{BM}} - \textbf{(S * cos z)}$$

$Elev_{instrument}$ = Elevation of instrument optical center (index point)
$Elev_{BM}$ = Elevation of benchmark
HR_{BM} = measured height of rod from bottom of road to nodal point of prism
*(S * cos z) = V_{BM} = vertical distance referenced at benchmark*
z = zenith angle
S = slope distance measured by instrument EDM

For the table below, the uncertainty (error) in the trig vertical distance is for one direction only (e.g., backsight).

	Remote Elevation Uncertainty in Trig Vertical Distance with Propagated Random Error ($\mathcal{E}_{VD}$)			
Zenith Angle Range (50° - 130°)	90° ±0.001’ 50° or 130° ±0.004'	90° ±0.002’ 50° or 130° ±0.005'	90° ±0.004’ 50° or 130° ±0.006'	90° ±0.006’ 50° or 130° ±0.007'
	100'	250'	500'	750'
	Slope Distance (feet)			

Assumptions: e_{HI}=0', e_{HR}=0', e_i=±2", e_{CR}=0, ez=±1.9", e_{EDM}=2mm+2ppm, Direct & Reverse zenith angle sets = 1 (2 readings), Automatic Prism Locking Robotic Total Station and **Nodal Point Prism** (see definition below), survey equipment has been calibrated to eliminate systematic errors, no mistakes.

****CAUTION**: The uncertainty of measured vertical distance values in the table above assume ideal conditions which is unlikely during a normal survey. These uncertainty values are listed only to demonstrate the minimum error when following proper procedures under ideal conditions.

Figure 113 Remote Elevation method Trig Vertical Distance Uncertainty

H.3 Expected Vertical Error in Trig Level Circuit

Using the values in the **remote elevation** table above and the formula for *error in a series* (or *law of compensation*), the expected level circuit error of closure can be estimated.

Expected Vertical Error for Trig Level Circuit = $\pm\, \varepsilon_{VD}\, \sqrt{2N}$

ε_{VD} = Uncertainty in Trig Vertical Distance at each setup

N = Number of Trig Setups

2 = Two Vertical Distance readings per setup

Example: $\varepsilon_{VD} = \pm 0.006'$ with 8 Trig Setups.

Expected Vertical Error for Trig Level Circuit = $\pm 0.006' \sqrt{2 \times 8} = \pm 0.024'$.

****CAUTION**: The estimated expected vertical error for a trig level circuit in the example above assumes ideal conditions, which is unlikely during a normal survey. This example is only to demonstrate the expected error when following proper procedures under ideal conditions.

H.4 Nodal Point Prism

A **nodal point prism** is a corner cube prism (retroreflectors) used with electronic distance measuring (EDM) instruments where the optical, mechanical and electrical center of the prism is directly concentric with the plumb line. Every surveying prism has a nodal point but due to misalignment of the prism holder and an incorrect nodal offset correction, the nodal point can move in relation to the instrument line of sight.

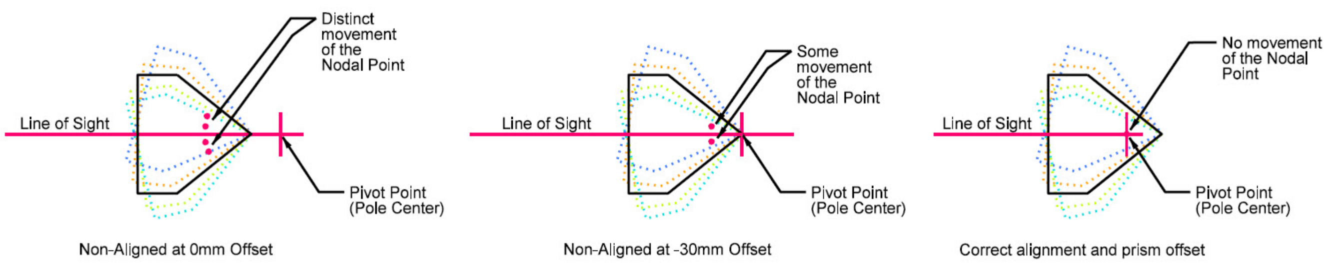


Figure 114 Nodal Point Prism Pivot Points (SCDOT reproduced SECO figure)

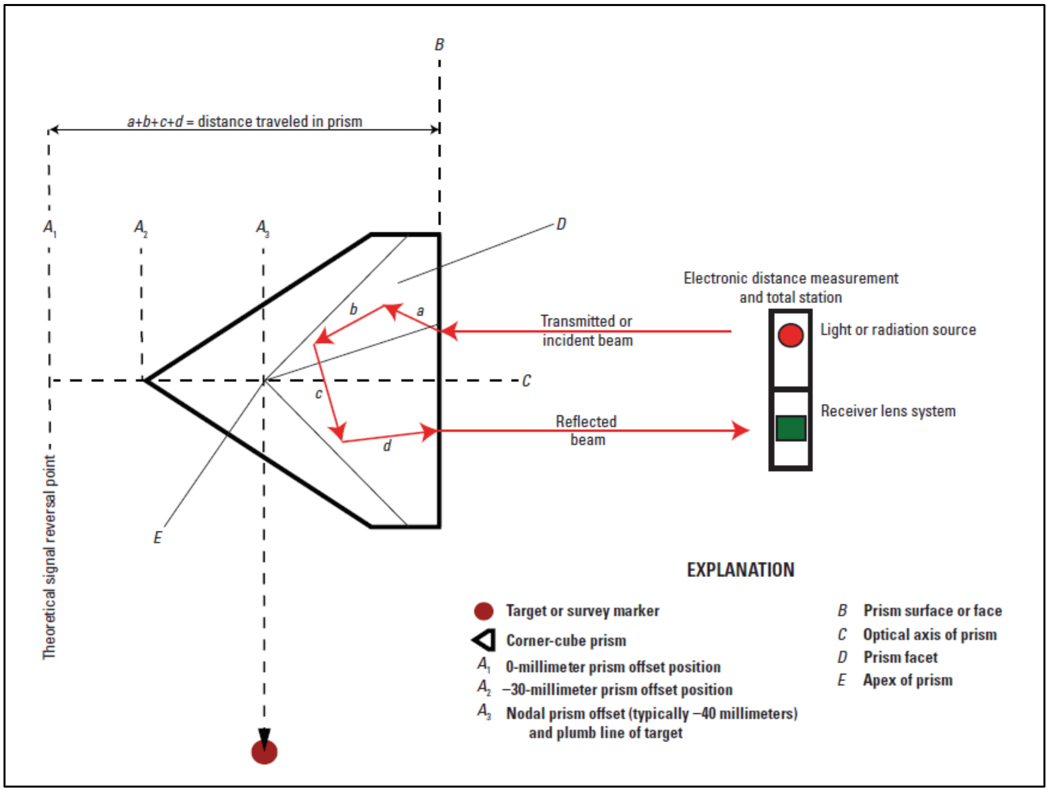


Figure 115 Component Parts of a Corner-Cube Prism (USGS, 2020)

APPENDIX I – SCDOT FIELD SURVEY CHECK LIST

Public Notification

____The project's Program Manager has provide "reasonable notice" (by way of local public notice and/or letters) to landowners prior to any field survey.

_____The project's On-Call Contract Manager has provided a signed Field Survey Personnel letter.

Survey Mapping Limits

_____Survey mapping limits (pdf and/or Google KMZ).

Project Survey Control

____Primary/Main Survey Control and Benchmarks per SCDOT Preconstruction Survey Manual specifications.

Best Fit Roadway Alignment (ERA)

____ERA established using (1) the roadway and associated features as constructed (2) SCDOT's existing roadway plans, and possibly county/municipal roadway information.

____SCDOT plans library, and if needed request individual R/W deeds from SCDOT R/W Department.

Courthouse Research

____Search public records for Property Owner Information (Owner Name, Tax Map reference number).

____Search public records for plats and deeds used to create a property strip map.

Property Monuments Field Survey

____Reconnaissance and field survey of property monuments.

A survey of the entire boundary for each individual property is not typically performed on SCDOT highway projects. Instead, the property lines immediately adjacent to SCDOT right-of-way are typically developed by utilizing the position of found property monuments, the property boundary information in deeds and plats, ground evidence of ownership lines, information from property owners, and sources of information for right-of-way and easement lines. SCDOT considers this a partial property survey which does not constitute a full boundary survey of each individual property.

Present Right-of-way and Property Strip Map

____Draft present right-of-way lines (or notes describing r/w).

____Draft property strip map.

Planimetric features (2D)

____All cultural (man-made) and natural features pertinent to the roadway project must be located and mapped.

(Examples below are not all inclusive and other features could exist on project)

____Roadways, curb and gutter, paved areas.

____Sidewalks, trails.

____Buildings, canopies, decks, steps.

____Signs, mailboxes, columns, flag poles.

____Stately trees, ornamental trees, wooded area boundaries, shrubs.

____Fences, walls, guard rails.

____Streams, rivers, lakes, marshes.

____Utility poles, telephone pedestals, meter boxes.

Breakline Features (3D)

____Sufficient topographic break-line (3D) data collected at a maximum of 100-foot intervals on tangents and 50-foot intervals on curves along the roadway corridors, which is used to accurately develop the Digital Terrain Model for the project.

(Examples below are not all inclusive and other features could exist on project)

____Roadway break-lines (edge-of-pavement, crown).
____Curb and gutter.
____Sidewalks.
____Top and Bottom slope break-lines.
____Concrete features (pads, medians).
____Driveways.
____Stream, Creek, River, Outfall Ditch, Lakes, Retention/Detention ponds.
____Top of Railroad Tracks.
____Walls.

Drainage Surveys

____Outfall Ditches, Streams, Creeks, Rivers, Lakes, Ponds, Marshes, and Tidal areas are surveyed in varying distances from the road centerline as directed in the requirements for hydraulic design studies and as directed by the Lead Hydraulic Engineer.
____Drainage Feature alignment.

*Outfall Ditch: Typically surveyed **300 feet** up and down-stream as measured from the end of the drainage structure (e.g., pipe, culvert), with cross-section intervals no greater than 100 feet.*

*Stream, Creek, and River: Typically surveyed **500 feet** up and down-stream as measured from the end of the drainage structure (e.g., pipe, culvert, bridge), with cross-section intervals no greater than 100 feet.*

Bridge Structures

____Bridge Surveys must be performed to provide both accurate bridge planimetry (2D) with appurtenance, and DTM (3D) information for hydrographic and bridge design.

Typical features required on bridges:
____Bent cap (bearing seat) elevations and bent cap centerline.
____Planimetric (2D) location of concrete columns or piles (older bridges may have wooden piles).
____Low cord of bridge girder.
____Abutments (e.g., endwalls, wingwalls, etc).
____Utilities attached to bridge.
Other optional project specific features as directed by the Lead Structural Engineer:
____Bridge joints.
____Vertical clearance at crown of pavement and all painted travel lanes for overpass bridges.
____Raised sidewalks, multi-use paths, raised medians, median barriers, parapet wall, etc.

Additional items required for any bridge that spans a water course:
Typical features required on bridges over a water course:
____Observed water elevation on date of survey.
____Historical high water mark.
____Elevation on top of parapet wall.
____Abutment Toe.
Other features as directed by the Lead Hydraulic Engineer:
____Flood Way & 100 year Flood (Floodplain) location.

Major rehabilitation such as bridge widening, deck replacement or major reconfiguration of the bridge will have different and more extensive survey requirements to be requested by Lead Structural Engineer.

Storm Drainage Structures
____Culverts.
____Drainage Pipes.
____Headwalls and Wingwalls.
____Inlet Structures.

Gravity Sanitary Sewer Manholes
____Rim and invert elevations determined at each manhole with flow lines depicted as running straight between manhole structures at ASCE38-22 Quality Level D (QLD) unless record information or site conditions indicate otherwise.

Wetland Boundaries
____Wetland surveys are generally the surveyed location of an environmental engineer's flagged delineation of wetland (jurisdictional) areas.

New and Existing R/W staking
____Temporary right-of-way staking will be directed by the SCDOT right-of-way agent for each project. Right-of-way break points including POTs, PCs, PTs, transition right-of-way points, and right-of-way along extended tangents are staked on 100' stations, with curves staked at 50 foot stations.

Geotechnical Bore Holes
____Field survey the horizontal location of Geotechnical Bore Holes including a ground elevation at each bore hole.

Traffic Control
____Maintain appropriate advance warning signage for traffic control purposes at all times when working within or near the existing traffic areas.

Rail Road Surveys
The following railroad survey information is <u>required</u>, unless direct otherwise by the SCDOT Railroad Projects Manager:
____Location of all railroad appurtenances.
____Existing drainage structures and flow patterns.
____Railroad right-of-way.
____Location of the nearest railroad milepost marker.
____Railroad alignments must be stationed using railroad VAL map stationing, unless other railroad documents are provided showing railroad stationing.

If a project involves a <u>parallel encroachment</u> on the railroad right-of-way, include the following information in the survey:
____Distance to tracks (all measurements are referenced from the centerline of the tracks).
____Cross sections from the project to mainline tracks with ground line & top of rail elevations.
____Topography to the mainline tracks.
____Drainage structures/channels both sides of tracks with elevations of flow line/top of structures.

____Nearest railroad right-of-way line to road project.

When the SCDOT right-of-way crosses or is within 25' of a railroad right-of-way within the project limits, the field survey must include:

____The centerline of the railroad must be located a minimum of 200 feet left and right of the roadway survey centerline with appropriate topography, drainage structures and cross section data within the railroad right-of-way, to include top of rail elevations.

Deliverables

____One (1) digital copy of Planimetric survey data (2D) in Microstation format.
____One (1) digital copy of ERA described in a Geopak .gpk file.
____One (1) digital copy of Topographic Breakline data (3D) in Microstation format.
____One (1) digital copy of Digital Terrain Model in Bentley format (.tin).
____One (1) digital copy of all courthouse Deeds, Plats and Property Ownership records.
____One (1) digital copy of signed and sealed Wetland Exhibit survey.
____One (1) digital copy of signed and sealed Survey Control Data sheet(s).

Files must be delivered in a format that is compatible with the latest SCDOT's CADD and Plan Development Process. SCDOT Roadway Projects are assigned Project ID Numbers. All files must be referenced to a Project ID. The types of files and naming conventions are listed below, and are examples of some of the files that might be requested by the SCDOT design engineer. The examples shown below assume a Project ID number of "P012345".

An electronic copy of any digital data delivered to the SCDOT must be retained in the permanent files of the licensee. The term "Bentley" as used in this manual refers to a native Bentley digital data format.

12345pp.dgn	Planimetric survey data (2D) in Native Bentley format.
345.gpk	ERA described in a Geopak file.
12345dtm.dgn	Topographic Breakline data (3D) in Native Bentley format.
12345.tin	Digital Terrain Model in Native Bentley format.
12345deed.pdf	Digital copy of all courthouse Deeds, Plats and Property Ownership records.
12345.new	ASCII file containing the final survey point data (Pt#, N, E, Elev, Desc).
12345_SCDS.pdf	Survey Control Data Sheet listing property monuments and survey control data.

NOTES

REFERENCES

ARDOT. (2013). In *Arkansas DOT Survey Manual.*

ASPRS. (2009). In *ASPRS Guidelines for Procurement of Professional Aerial Imagery, Photogrammetry, Lidar and Related Remote Sensor-based Geospatial Mapping Services.*

ASPRS. (2018). In *ASPRS Guidelines on Geometric Inter-Swath Accuracy and Quality of LiDAR Data.*

ASPRS Positional. (2014). In *ASPRS Positional Accuracy Standards for Digital Geospatial Data.*

ASPRS Procurement. (2014). In *ASPRS Guidelines for Procurement of Geospatial Mapping Products and Services.*

Black's Law Dictionary with Pronunciations. (1990). In Black, Nolan, Nolan-Haley, Connolly, Hicks, & Alibrandi, *Black's Law Dictionary with Pronunciations.*

British Columbia. (1998). In *Province of British Columbia, Ministry of Sustainable Resource management, Specifications for Aerial Triangulation.*

Buckner. (1991). In *Surveying Measurements and their Analysis.*

CALTRANS. (2011). In *California DOT Survey Manual.*

CALTRANS. (2015). In *California DOT Survey Manual.*

CDOT. (2015). In *Colorado DOT Survey Manual.*

Elements of Photogrammetry with Application in GIS, Fourth Edition. (2014). In Wolf, DeWitt, & Wilkinson, *Elements of Photogrammetry with Application in GIS, Fourth Edition.*

EngineerSupply. (2022, May 27). *Total Stations*. Retrieved from EngineerSupply: https://www.engineersupply.com/total-stations.aspx

FEMA, F. E. (2019). *FEMA Policy Standards for Flood Risk Analysis and MappingFEMA Policy #FP 204-078-1 (Rev 10).*

FGDC Part 3. (1998). In *FGDC-STD-007.3 Geospatial Positioning Accuracy Standards, Part 3: National Standard for Spatial Data Accuracy.*

FGDC Part 4. (2002). In *FGDC-STD-007.4-2002 Geospatial Positioning Accuracy Standards.*

FHWA. (2018). In *Federal Lands Highway Project Development and Design Manual.*

Ghilani. (2010). In C. D. Ghilani, *Adjustment Computations Spatial Data Analysis Fifth Edition.*

Glen, S. (2021, March 10). *Mean Error: Definition*. Retrieved from Statistics How To: https://www.statisticshowto.com/mean-error/

Henning, W. (2014). *User Guidelines for Single Base Real Time GNSS Positioning.* National Geodetic Survey.

How Things Work: Parts Per Million (PPM). (2004, February). *Professional Surveyor Magazine*.

Kemmerline Jr., T. (1953). What Constitutes Intent to Dedicate in South Carolina. *South Carolina Law Review*, Article 9.

Maune, D. F. (2003). *FEMA's Mapping and Surveying Guidlines and Specifications ASPRS Fall 2003.*

McFee, C. (2020, October 27). *An Introduction to CCD Operation*. Retrieved from Mullard Space Science Laboratory: https://www.mssl.ucl.ac.uk/www_detector/ccdgroup/optheory/ccdoperation.html#basics

MDPI ISSN 2072-4292. (2011). In Bitenc, Lindenbergh, Khoshelham, & Waarden, *Evaluation of a LIDAR Land-Based Mobile Mapping System.*

Moore, J. H. (1987). *The South Carolina Highway Department 1917-1987.* Columbia: University of South Carolina.

National Society of Professional Surveyors. (2002). In *Positional Accuracy Definitions and Procedures.*

NCDOT. (2014). In *North Carolina DOT Terrestrial Mobile LiDAR (Scanning) Guidlines.*

NCHRP. (2013). In *NCHRP Report 748, Guidelines for the Use of Mobile LIDAR in Transportation Applications.*

NGS. (2020). *State Plane Coordinate System (SPCS).* Retrieved from National Geodetic Survey: https://www.ngs.noaa.gov/SPCS/index.shtml

NGS Datums. (2020). Retrieved from National Geodetic Survey: https://www.ngs.noaa.gov/datums/faq.shtml

NOAA. (2020, August 6). *Space Weather Prediction Center*. Retrieved from NOAA: https://www.swpc.noaa.gov/

NOAA. (2021, March 8). *What is the National Spatial Reference System*. Retrieved from National Oceanic and Atmospheric Administration: https://oceanservice.noaa.gov/facts/nsrs.html

NOAA. (2022). *What is bathymetry?* Retrieved from https://oceanservice.noaa.gov/facts/bathymetry.html

NSPS. (2002). In *National Society of Professional Surveyors Postional Accuracy Definitions and Procedures.*

PennState Department of Geography. (2020). Retrieved from PennState Department of Geography: https://www.geog.psu.edu/

Resource Guide. (2022). Retrieved from Minnesota Shoreland Management: https://www.shorelandmanagement.org

S.C. Code Ann. Section 40-22-2, et seq.; 26 S.C. Code Ann. Regs. Chapter 49 (1991 as amended). (n.d.).

SC Code 40. (2016). In *South Carolina Code of Law Title 40 Chapter 20.*

SCDOT. (1957). In *Manual of Instructions for Survey Parties, South Carolina State Highway Department.*

SCDOT. (2018). *Synopsis of Commission Actions.* Columbia: SCDOT.

SCDOT Acquistion Manual. (2019). In SCDOT, *SCDOT Acquistion Manual.*

SCDOT Hydraulic Design. (2000). In *South Carolina Department of Transportation Requirements for Hydraulic Design Studies.*

SCDOT Safety Manual. (2017). In *South Carolina Department of Transportation Employee Safety Manual.*

SCDOT Technical Note 10. (2020). In *Bridge Load Rating & Evaluation Engineering Services - S-239-19 Technical Note 10.*

Standards and Specifications for Geodetic Control Networks. (1984). Federal Geodetic Control Committee.

Surdex. (2008). *Fully Analytical Aerial Triangulation Report.* Kanawha County, WV: Surdex Corporation.

UDOT. (2017). In *Utah Department of Transportation Survey & Geomatics Standards.*

USACE. (1993). In *USACE Principles of Photogrammetry.*

USACE. (2015). In *USACE EM 1110-1-1000, Photogrammetric and LiDAR Mapping.*

USACE High Water Mark. (2005). In *US Army Corps of Engineers Non-Tidal High Water Mark Regulatory Guidance Letter No. 05-05.*

USGS. (2016). In *Identifying and Preserving High-Water Mark Data.*

USGS. (2019). In *USGS Lidar Base Specifications version 2.1.*

USGS. (2020). In *Procedures and Best Practices for Trigonometric Leveling in the U.S. Geological Survey.*

USGS. (2022). *Rivers, Streams, and Creeks*. Retrieved from https://www.usgs.gov/special-topics/water-science-school/science/rivers-streams-and-creeks

USGS. (2022). *Water Resources of the United States*. Retrieved from https://water.usgs.gov/glossaries.html

Wilson, D. (2013). *Easements Relating to Land Surveying and Title Examination.*

Witter v. Harvey, 12 S.C.L. 67, 1 McCord 67 (1821). (n.d.).

WYDOT. (2016). In *Wyoming Department of Transportation Survey Manual.*

SYMBOLS, ABBREVIATED TERMS, AND NOTATIONS

2D	Two Dimensional (x,y).
3D	Three Dimensional (x,y,z).
AGPS	Airborne Global Positioning System.
ASCII	American Standard Code for Information Interchange.
AGL	Above Ground Level.
ALS	Airborne Laser Scanner.
ASPRS	American Society for Photogrammetry and Remote Sensing.
AT	Aerial Triangulation.
CADD	Computer Aided Design and Drafting.
CALTRANS	California Department of Transportation.
CCD	Charge Couple Device.
CDOT	Colorado Department of Transportation.
DEM	Digital Elevation Model (see definition).
DGN	File name extension for native Bentley file format.
DMI	Distance Measuring Instrument.
DSM	Digital Surface Model (see definition).
DTM	Digital Terrain Model (see definition).
E57	Standardized Point Cloud File Format (ASTM E57).
ECW	Enhanced Compression Wavelet (proprietary compressed image file).
EWW	World file for geo-referencing the ECW image file.
FAA	Federal Aviation Administration.
FGDC	Federal Geographic Data Committee.
FLH	Federal Land Highways.
GIS	Geographic Information System.
GNSS	Global Navigation Satellite System (GPS, GLONASS, Galileo, BeiDou).
GPS	Global Positioning System (United States satellites).
GSD	Ground Sampling Distance (ground distance between two consecutive pixel centers).
IFSAR	Interferometric Synthetic Aperture Radar.
INS	Inertial Navigation System.
IMU	Inertial Measurement Unit.
LAS	Industry standard Lidar point cloud file format based on the file name extension.
Lidar	Light Detection and Ranging.
NAD	North American Datum.
NAVD	North American Vertical Datum.
NCDOT	North Carolina Department of Transportation.

NCHRP	National Cooperative Highway Research Program.
NSRS	National Spatial Reference System
NSSDA	National Standard for Spatial Data Accuracy.
OPUS	Online Positioning User Service
PIDs	Photo Identification points.
PK	A thick-shank nail which can be set in asphalt, concrete or other hard material.
POS	Position and Orientation System (GNSS and IMU).
RGB	Red, Green, Blue, used in reference to parts of the visible light spectrum.
RMSE	Root Mean Square Error (estimate of positional accuracy by FGDC-STD-007.3-1998).
RMSEz	Root Mean Square Error “z” refers to elevation.
RMSEx,y	Root Mean Square Error “x,y” refers to the individual coordinates.
RMSEr	Root Mean Square Error “r” refers to a radial distance (x & y combined).
RTN	Real Time Network (GNSS)
SID	Multiresolution Seamless Image Database.
SDW	World file for geo-referencing the SID image file.
TIF	Tagged Image File Format (also abbreviated to TIFF).
TIN	Triangular Irregular Network (see definition).
TXT	ASCII Plain Text File format.
UAS	Unmanned Aerial System.
UAV	Unmanned Aerial Vehicle.
USACE	United States Army Corp of Engineers.
USGS	United States Geologic Survey.
VRN	Virtual Reference Station Network (GNSS)
x,y	Horizontal Coordinates.
z	Elevation.

TERMS AND DEFINITIONS

95% Confidence Level – Lidar mapping data "accuracy reported at the 95% confidence level means that 95% of the positions in the data set will have an error with respect to true ground position that are equal to or smaller than the reported accuracy value." (ASPRS Positional, 2014). ASPRS approximates the Non-vegetated Vertical Accuracy at the 95% confidence level in non-vegetated terrain (NVA) by multiplying the accuracy value of the Vertical Accuracy Class (or RMSEz) by 1.9600. This calculation includes survey checkpoints located in traditional open terrain (bare soil, sand, rocks, and short grass) and urban terrain (asphalt and concrete surfaces). The NVA, based on an RMSEz multiplier, should be used only in non-vegetated terrain where elevation errors typically follow a normal error distribution. RMSEz- based statistics should not be used to estimate vertical accuracy in vegetated terrain or where elevation errors often do not follow a normal distribution." (ASPRS Positional, 2014).

"Most standards in use today are specified at the 95 percent confidence level. This means that if we have a measured distance of 1000 feet with stated reliability of plus or minus 0.10 feet at 95 percent confidence level we can be confident that a measurement of that line will be between 999.90 feet and 1000.10 feet 95 out of 100 times." (NSPS, 2002).

Absolute Accuracy – "Absolute accuracy is the closeness of an estimated, measured, or computed value to a standard, accepted, or true value of a particular quantity. In mapping, a statement of absolute accuracy is made with respect to a datum, which is, in fact, also an adjustment of many measurements and has some inherent error. The statement of absolute accuracy is made with respect to this reference surface, assuming it is the true value." (PennState Department of Geography, 2020).

Accuracy – "The closeness of an estimated value (for example, measured or computed) to a standard or accepted (true) value of a particular quantity. Not to be confused with precision." (ASPRS Positional, 2014).

Aerial Mapping Plan – A written process of performing the aerial mapping which includes the industry standard photogrammetric methods, procedures and equipment needed to complete the final delivered mapping data within the projects specified accuracies.

Bare Earth Model – "Digital elevation data of the terrain free from vegetation, buildings, and other man-made structures. Elevations of the ground." (USGS, 2019).

Base Station – A GNSS receiver located over a known point or geodetic control monument.

Bentley - The term "Bentley" as used in this manual refers to a native Bentley digital data format.

Boresight Calibration (Remote Sensors) – "[T]he process of determining the differences in the rotations of the sensor (such as camera) rotational axes and the rotational axes of the Inertial Measurement Unit (IMU), which is usually bolted to the camera body. The IMU (link is external) is a device that contains gyros and accelerometers used in photogrammetry and lidar to sense and measure sensors rotations and accelerations. In photogrammetry where the IMU is used on an imaging camera, the boresight parameters are determined by flying over a well controlled site (site with accurate ground controls) and then conducting aerial triangulation on the resulted imagery." (PennState Department of Geography, 2020).

Bridge – "A structure, including supports, erected over a depression or an obstruction such as water, a highway, or a railway; having a track or passageway for carrying traffic or other moving loads; and having an opening measured along the centerline of the roadway of more than 20 feet between undercopings of abutments or spring lines of arches or extreme ends of openings for multiple boxes. It may also contain multiple pipes, where the clear distance between openings is less than half of the smaller contiguous opening; see Culvert. Any bridge meeting this definition needs to be inspected or load rated per the National Bridge Inspection Standards (NBIS)." (SCDOT Technical Note 10, 2020).

Calibration (Remote Sensors) – "A system calibration corrects for manufacturing errors (e.g. lever arm offsets, orientations) and produces a set of parameters that remain constant as long as the hardware is not modified or disturbed. (The frequency of recalibration depends on the desired system accuracy and capabilities and is typically done by the manufacturer)." (NCHRP, 2013).

Charge Couple Device (CCD) – "a highly sensitive photon detector. The CCD is divided up into a large number of light-sensitive small areas (known as pixels) which can be used to build up an image of the scene of interest. A photon of light which falls within the area defined by one of the pixels will be converted into one (or more) electrons and the number of electrons collected will be directly proportional to the intensity of the scene at each pixel. When the CCD is clocked out, the number of electrons in each pixel are measured and the scene can be reconstructed." (Mullard Space Science Laboratory, Chris McFee).

Confidence Level – " The percentage of points within a data set that are estimated to meet the stated accuracy; e.g., accuracy reported at the 95% confidence level means that 95% of the positions in the data set will have an error with respect to true ground position that are equal to or smaller than the reported accuracy value." (ASPRS Positional, 2014).

Confined Space – "1) Limited or restrictive means of entry or exit (for example, tanks, vessels, silos, storage bins, hoppers, vaults and pits are spaces that may have limited means of entry). 2) Is large enough and so configured that an employee can bodily enter and perform assigned work. 3) Is not designed for continuous employee occupancy.

Other examples of confined or enclosed spaces include, but are not limited to: boilers, ventilation or exhaust ducts, degreasers, furnaces, lift stations, pits, pumping stations, sewers, storm drains and cross line pipes, pipelines, tanks, tunnels, utility vaults, vats, wells, and open top spaces more than four (4) feet in depth such as trenches, tubs, catch basins and manholes.

Storm drains and cross line pipes large enough to walk into, with clear visibility end to end and good ventilation are generally not classified as a confined space. However, other factors such as internal combustion engines used in the area could create a confined space condition. Small storm drains and cross line pipes that require the entrant to bend over or crawl to enter should be treated as a confined space. Employees should use good judgment in making the determination as to whether an area is a confined space. If unsure, treat the area as a confined space." (SCDOT Safety Manual, 2017).

Culvert – "[…] Culverts are usually covered with embankment and are composed of structural material around their entire perimeter. Culverts shall only carry water. A culvert is considered a bridge and needs to be inspected and load rated per the NBIS if any of the following conditions are met. Whether a culvert has a floor or not does not matter when determining if a culvert is considered a bridge or not.

- The culvert has a hydraulic opening greater than 20 feet as measured along the center of the roadway.
- A grouping of culverts with a total length greater than 20 feet as measured along the roadway centerline, and where the clear distance between openings is less than half the smaller contiguous opening." (SCDOT Technical Note 10, 2020).

Datum – "A geodetic datum is an abstract coordinate system with a reference surface (such as sea level) that serves to provide known locations to begin surveys and create maps." (NGS Datums, 2020).

Digital Elevation Model (DEM) – "generic term for digital topographic and bathymetric data in all its various forms….implies x,y coordinates and z-values of the bare-earth terrain void of vegetation and man-made features" "A [DEM] is a specific raster data format once widely used by the USGS. DEMs are a sampled array of elevations for a number of ground positions at regularly spaced intervals." (McFee, 2020).

Digital Measurement Instrument (DMI) – An aftermarket vehicle sensor which determines distance traveled. "The distance computation involves the pulse count and calibration number, both of which are critical to the accuracy of the measurement. The calibration number is previously computed by traveling a precisely marked distance, and calculating the calibration number based off the distance traveled and pulse count." (Mycrodynamics). "A DMI is an encoder, normally placed on one of the wheels of the [mobile mapping] vehicle. The DMI measures tire rotation, which indirectly gives an estimate of distance traveled. A DMI is used in some [mobile mapping] systems and serves to supplement GNSS and IMU data with additional relative positioning information. The DMI is also incorporated into the Kalman filtering scheme to provide forward velocity information for calculating the trajectory. The DMI may also be used as the primary triggering device for image capture points based on the distance
moved along the ground surface." (NCHRP, 2013).

Digital Surface Model (DSM) – "Similar to DEMs except that they may depict the elevations of the top surfaces of buildings, trees, towers, and other features elevated above the bare-earth." (USGS, 2019).

Digital Terrain Model (DTM) – "As used in the United States, a 'DTM' is a vector dataset composed of 3D breaklines and regularly spaced 3D mass points, typically created through stereo photogrammetry, that characterize the shape of the bare-earth terrain. Breaklines more precisely delineate linear features whose shape and location would otherwise be lost. A DTM is not a surface model and its component elements are discrete and not continuous; a TIN or DEM surface must be derived from the DTM. Surfaces derived from DTMs can represent distinctive terrain features much better than those generated solely from gridded elevation measurements. A lidar point dataset combined with ancillary breaklines is also considered a DTM." (USGS, 2019).

Drive Line (Mobile Lidar) – One trajectory (pass or path) of collected lidar data which typically follows existing roadway travel lanes.

EDM (Distance Measuring Instrument) – A device that uses infra red or laser light to accurately measure distance by measuring the time of flight of the light.

Feature Extraction Limits – The area within the remote sensing data set to be used for Planimetric (2D) and Digital Terrain Model (3D) feature extraction.

Flight Line - A single pass of the collection [platform] over the target area. (USGS, 2019).

Geometric Correction – "A geometric correction or adjustment is done to correct for errors in the GNSS and IMU positioning information by adjusting the scan data to [project] control or between adjacent passes. This correction would be applied uniquely for each project. Not the same as a calibration." (NCHRP, 2013).

Global Navigation Satellite System (GNSS) – "Any satellite system which can be used to determine a precise location on the surface of the Earth. The US system is known as NAVSTAR Global Positioning System (GPS). The Russian system is known as the Global'naya Navigatsionnaya Sputnikovaya Sistema or GLONASS. The European Space Agency system is known as GALILEO." (S.C. Code Ann. Section 40-22-2, et seq.; 26 S.C. Code Ann. Regs. Chapter 49 (1991 as amended)).

Grid Coordinates – "A plane-rectangular coordinate system is by definition a flat surface. Geodetic positions on the curved surface of the Earth must be "projected" to their corresponding plane coordinate positions. Projecting the curved surface onto a plane requires some form of deformation. Imagine the stretching and tearing necessary to flatten a piece of orange peel. The orange peel cannot be flattened without deformation of the surface. Similarly, the surface of the earth cannot be represented on a flat plane surface without distortion. A long narrow strip of an orange peel can be flattened with a minimum of distortion. If coordinate systems are limited to long narrow strips a minimum of mapping error results. In [South Carolina] the Lambert Conformal map projection is used to transform the geodetic positions of latitude and longitude into the "N" (Northing) and "E" (Easting) coordinates of the [South Carolina State Plane Coordinate System]." (UDOT, 2017).

Ground Coordinates - Distances measured on the surface of the Earth (not on a mathematical projection) at right angles to each other in a rectangular system having two base lines at right angles to each other. Ground distances are not scaled (scale factor is exactly 1).

Ground Sample Distance (GSD) – "The linear dimension of a sample pixel's footprint on the ground. Within this document GSD is used when referring to the collection GSD of the raw image, assuming near-vertical imagery. The actual GSD of each pixel is not uniform throughout the raw image and varies significantly with terrain height and other factors. Within this document, GSD is assumed to be the value computed using the calibrated camera focal length and camera height above average horizontal terrain." (ASPRS Positional, 2014).

Horizontal Accuracy – "The horizontal (radial) component of the positional accuracy of a data set with respect to a horizontal datum, at a specified confidence level." (ASPRS Positional, 2014).

Image Resolution – “The smallest unit a sensor can detect or the smallest unit an orthoimage depicts. The degree of fineness to which a measurement can be made.” (ASPRS Positional, 2014).

Inertial Measurement Unit (IMU) – “The IMU performs two key functions. First, it provides orientation or attitude information (i.e., the roll, pitch and heading of the vehicle). Second, it assists in position estimation, particularly when GNSS quality degrades. The GNSS typically reports positioning information at rates of 1–10 Hz (i.e., one to ten measurements per second), whereas the IMU typically reports orientation information at a rate of 100–2000 Hz. The denser sampling by the IMU becomes increasingly important as the speed of the vehicle increases. Consider, for example, a vehicle traveling at 60 MPH (97 km/h), which travels 88 ft. (27 m) in 1 second. As GNSS positioning degrades, the IMU will begin to manage more of the positioning/orientation information using a filtering scheme (e.g., a Kalman filter), which optimally combines all measurements of vehicle motion to minimize geolocation errors. Depending on the accuracy of the IMU (i.e., the drift rate), the IMU may maintain accurate point cloud georeferencing without the aid of GNSS positioning over extended periods of time.” (NCHRP, 2013).

Inertial navigation System (INS) – “A self-contained navigation system, comprised of several subsystems: IMU, navigation computer, power supply, interface, etc. Uses measured accelerations and rotations to estimate velocity, position and orientation. An unaided INS loses accuracy over time, due to gyro drift.” (ASPRS Positional, 2014).

Level Circuit - A “level circuit” is defined as a series of setups closing on the starting point, or a series of setups between two points of known elevations, in which the known elevations meet the project’s specified elevation accuracy.

Lever Arm – In a mobile lidar system, a lever arm is the difference in origin (origin difference vector) of the laser scanner frame and the body frame of the IMU.

Lidar - “Light detection and Ranging is an active optical remote sensing technology which measures the return properties of scattered light to determine range, direction and other information of a distant line-of-site object.” (NCDOT, 2014).

Link Traverse – A traverse (or level circuit) method used to constrain the Main Survey Control (MSC) points to the beginning and ending Primary Survey Control (PSC) azimuth pairs and/or Project Benchmarks.

Local Accuracy – “The uncertainty in the coordinates of points with respect to coordinates of other directly connected, adjacent points at the 95% confidence level.” (ASPRS Positional, 2014). “Local accuracy is the relative accuracy between local [project specific] control points and represents the repeatability of measurements relative to other directly connected, adjacent control points at the 95-percent confidence level.” (CALTRANS, 2015).

Localization - The term “localization” as used in this manual is also referred to as “Site Calibration”, “Transformation”, or other terms depending on the surveyor’s software, and is the mathematical process used to relate points from one datum to another different datum.

Map Projection – "A map projection is a mathematical transformation of latitudes and longitudes on the surface of a sphere or ellipsoid representing the Earth to grid coordinates (northing, easting or y, x values) on a plane." (NGS, 2020).

Mean Error – "The average positional error in a set of values for one dimension (x, y, or z); obtained by adding all errors in a single dimension together and then dividing by the total number of errors for that dimension." (ASPRS Positional, 2014). "The mean error is an informal term that usually refers to the average of all the errors in a set. An "error" in this context is an uncertainty in a measurement, or the difference between the measured value and true/correct value. The more formal term for error is measurement error, also called observational error." (Glen, 2021).

Mean Sea Level – "Mean Sea Level" is a term used by many to reference to a vertical datum in the United States but does "not mean sea level, the geoid, or any other equipotential surface. Therefore, it was renamed in 1973, the National Geodetic Vertical Datum on 1929." "*Mean sea level* was held fixed at the sites of 26 tide gauges, 21 in the United States and 5 in Canada. The datum is defined by the observed heights of mean sea level at the 26 tide gauges and by the set of elevations of all bench marks resulting from the adjustment. A total of 106,724 kilometers of leveling was involved, constituting 246 closed circuits and 25 circuits at sea level." (NGS Datums, 2020).

Multipath – "Multipath is an erroneous GNSS distance measurement between a GNSS satellite and either the Rover or Base. The multipath signal results from the receiver using a signal that has been reflected off a structure or water surface on its way to the receiver. The resulting measurement of distance from the satellite to the receiver is longer." (S.C. Code Ann. Section 40-22-2, et seq.; 26 S.C. Code Ann. Regs. Chapter 49 (1991 as amended)).

National Spatial Reference System (NSRS) – "a consistent coordinate system that defines latitude, longitude, height, scale, gravity, and orientation throughout the United States." (NOAA, What is the National Spatial Reference System, 2021). The NRSR is defined and managed by NOAA's National Geodetic Survey.

Network Accuracy - The accuracy of a point that represents the uncertainty of its coordinates with respect to the South Carolina State Plane Coordinate System (SCSPCS) at the 95% confidence level. The intent is to achieve a reasonable SCSPCS network accuracy for post construction repeatable points (property monuments found, right-of-way monumentation, etc.) that is balanced with the goals of SCDOT's primary mission (Maintain and Construct roads and bridges).

Nominal Point Density (NPD) – "NPD is a ratio of the number of points to the area in which they are contained, and is typically expressed as pulses per square meter (ppsm or pts/m2)." (USACE, 2015).

Nominal Point Spacing (NPS) – "NPS is a linear measure of the typical distance between points and is most often expressed in meters." (USACE, 2015).

Non-Vegetated Vertical Accuracy (NVA) – "The vertical accuracy at the 95% confidence level in non-vegetated open terrain, where errors should approximate a normal distribution." (ASPRS Positional, 2014). The ASPRS NVA vertical accuracy <u>class</u> is expressed as RMSEz over non-vegetated surfaces.

Online Positioning User Service (OPUS) – An online (internet) service which computes geodetic coordinates of an unknown location using GNSS data at the unknown location in combination with Continuously Operating Reference Stations (CORS) GNSS data at known locations.

Panel Point – An artificial object of predetermined shape and size placed on the bare earth surface which is identifiable in the remotely sensed data and is typically used during the photogrammetric image and/or lidar point cloud processing.

Parts Per Million (ppm) – "A part per million simply means a fraction of 1/1,000,000. [For example] an error or variance or uncertainty of 20 PPM is 20/1,000,000 = 1/50,000." "Parts per million can be used to express the likely error in a measurement as in an instrument specification e.g., 2mm + 3ppm for an EDM, or as a resulting error in a measurement or a survey, based on a comparison with another measurement, or a value taken as definite, or even the mean of a group of measurements of the same quantity." (How Things Work: Parts Per Million (PPM), 2004).

Pass Points (photogrammetry) – "A point whose horizontal and/or vertical position is determined from photographs/images by photogrammetric methods and is intended for use as a control point in the relative orientation of adjoining photographs/images in the same flight line. An image point that appears in the overlap area of photos in the same strip of aerial photography are said to "pass" control from one photograph to the next in a single flight line. Pass points often fall within the triple-overlap areas when the aerial photography has a forward overlap of at least 60%, meaning that some points on the ground appear on three consecutive aerial photographs, adding strength to the aerotriangulation process. With softcopy photogrammetry, pass points are commonly identified through automated image correlation." (USACE, 2015).

Percentile – "A measure used in statistics indicating the value below which a given percentage of observations in a group of observations fall. For example, the 95th percentile is the value (or score) below which 95 percent of the observations may be found. For accuracy testing, percentile calculations are based on the absolute values of the errors, as it is the magnitude of the errors, not the sign that is of concern." (ASPRS Positional, 2014).

Pipe - A hollow cylinder that conveys flow from one point to another. A pipe may be used by itself or as part of a storm sewer system.

Pixel Resolution or Pixel Size – "As used within this document, pixel size is the ground size of a pixel in a digital orthoimage, after all rectifications and resampling procedures." (ASPRS Positional, 2014).

Planimetric Map – A map that displays only the x,y locations (2D) of features and represents only horizontal distances.

Point Cloud – "One of the fundamental types of geospatial data (others being vector and raster), a point cloud is a large set of 3D points, typically from a lidar collection." (USGS, 2019). "A relatively precise group of three dimensional point data collected by a laser scanner from a single observation session. A point cloud may be merged with other point clouds to form a larger composite point cloud." (NCDOT, 2014).

Position Dilution of Precision (PDOP) – “A numerical measure of the predicted accuracy of a geodetic position determined from GNSS satellites. The term represents the goodness of the geometry of the satellites with respect to the receiver location. A PDOP of 3 or less will generally insure accuracy of the highest survey quality. A PDOP of 5 or less is generally acceptable for most surveying and mapping projects where the distance between Rover and the nearest Base station is less than 10KM.” (S.C. Code Ann. Section 40-22-2, et seq.; 26 S.C. Code Ann. Regs. Chapter 49 (1991 as amended)). Dilution of precidsion (DOP) “is the ratio of the positioning accuracy to the measurement accuracy. $PDOP^2 = HDOP^2 + VDOP^2$.” (Henning, 2014).

Positional Accuracy – “The accuracy of the position of features, including horizontal and vertical positions, with respect to horizontal and vertical datums.” (ASPRS, 2018).

Precision (repeatability) – “The closeness with which measurements agree with each other, even though they may all contain a systematic bias.” (ASPRS Positional, 2014). “Precision is a statistical measure of the tendency for independent, repeated measurements of a value to produce the same result. A measurement can be highly repeatable, therefore very precise, but inaccurate if the measuring instrument is not calibrated correctly. The same error would be repeated precisely in every measurement, but none of the measurements would be accurate.” (PennState Department of Geography, 2020).

Professional Services – “those services that require specialized knowledge and skill; require independent judgment; and have an expectation of ethical conduct and professional expertise such that the resulting services will be consistent with the best interests of the client and public.” (ASPRS Procurement, 2014).

Project Survey Control Network (PSCN) – The Project Survey Control Network (PSCN) consists of the Primary Survey Control, Main Survey Control and Project Benchmarks. The PSCN is typically referenced to the NSRS, with all subsequent surveying and mapping data referenced to the PSCN.

Random Error – Related to surveying and mapping, “[r]andom errors follow laws of probability and compensation. That is, large errors rarely occur, small errors are more likely than large ones, and there is an equal opportunity for positive errors to occur as negative ones. And, since the latter is true, they tend to cancel or compensate. Note, that they only *tend to* cancel.” (Buckner, 1991). “[E]rrors that remain after all mistakes and systematic errors have been removed from the observed values. In general, they are the result of human and instrument imperfections. They are generally small and are as likely to be negative as to be positive. They usually do not follow any physical law and therefore must be dealt with according to the mathematical laws of probability.” (Ghilani, 2010).

Real Time Kinematic (RTK) – “A geodetic survey that uses multiple survey grade satellite receivers each collecting the same satellite data simultaneously. At least one Base receiver must be on a known geodetic control station and is capable of transmitting satellite data in real time to other Rover receivers. The data is processed by the Rovers in real time to yield three dimensional vectors between the Base and Rover stations. RTK vectors solutions yield a “no check” solution and therefore by themselves do not meet minimum standards without additional independent checks." (S.C. Code Ann. Section 40-22-2, et seq.; 26 S.C. Code Ann. Regs. Chapter 49 (1991 as amended)).

Registration (Lidar) - "The process of determining and applying to two or more datasets the transformations that locate each dataset in a common coordinate system so that the datasets are aligned relative to each other. (ASTM)" (NCHRP, 2013).

Relative Accuracy – "Relative accuracy is an evaluation of the amount of error in determining the location of one point or feature with respect to another. For example, the difference in elevation between two points on the earth's surface may be measured very accurately, but the stated elevations of both points with respect to the reference datum could contain a large error. In this case, the relative accuracy of the point elevations is high, but the absolute accuracy is low." (PennState Department of Geography, 2020).

Relative Positional Accuracy – "Relative Positional Accuracy is a value expressed in feet that represents the uncertainty of the location of any point in a survey relative to any other point in the same survey at the 95 percent confidence level. Therefore it is also the accuracy of the distance between all points on the same survey. Relative Positional Accuracy may be tested by comparing the relative location of points in a survey as measured by an independent survey of higher accuracy. The comparison should include the measurement of both distances and directions. Relative Positional Accuracy may also be tested by the results from a minimally constrained, correctly weighted least squares adjustment of the survey data. Note that sufficient redundancy in the survey measurements is required, if accuracy is to be tested this way, so as to make the application of the least squares adjustment a valid process." (National Society of Professional Surveyors, 2002).

Remote Sensing – "the process of gathering and processing information about an object without direct physical contact." (ASPRS, 2009).

Resection – A method of determining a location of one unknown point in relation to two or more known points using a total station to measure angles and distances.

Right-of-Way – As used within this manual means an easement, established by grant from a landowner (usually by way of a deed or marking on a recorded plat) or long usage (prescription), to pass along a specific route through property belonging to another. The plural of "right of way" is "rights of way". Right-of-way is often used colloquially to mean any land used by SCDOT for roads and related purposes; however, right-of-way more precisely means an easement as opposed to ownership of land in fee simple. SCDOT owns some property rights in fee simple and others by easement. An easement is, generally, a property right that gives its holder an interest in land owned by another. Where an easement exists, the easement is the dominant estate and the fee is the servient estate.

Root Mean Square Error (RMSE) – "The square root of the average of the set of squared differences between data set coordinate values and coordinate values from an independent source of higher accuracy for identical points." "Horizontal accuracy is to be assessed using root-mean-square-error (RMSE) statistics in the horizontal plane, i.e., RMSEx, RMSEy and RMSEr. Vertical accuracy is to be assessed in the z dimension only." (ASPRS Positional, 2014).

Rover - A GNSS receiver located over an unknown survey point whose coordinates are to be determined or checked against known geodetic control.

Sigma Naught – "Sigma naught is the degree of deviation from an assumed a priori accuracy. In block adjustment normally the a priory weight of 1 is assumed as a priori weight for the photogrammetric observations, thus sigma naught is the accuracy of the photogrammetric measurements." (British Columbia, 1998).

Spot Elevations – "Reported elevations of high, low and other prominent points. The precise location is generally denoted by a small 'x' and is thereby accompanied by the reported value of the elevation." (AerialSphere, 2020).

Standard Deviation – "A measure of spread or dispersion of a sample of errors around the sample mean error. It is a measure of precision, rather than accuracy; the standard deviation does not account for uncorrected systematic errors." (ASPRS Positional, 2014).

South Carolina State Plane Coordinate System – "The official coordinate system for surveying purposes in South Carolina is the South Carolina State Plane Coordinate System, single zone Lambert Polyconic Projection designated by the National Geodetic Survey as Zone 3900. For the purpose of the South Carolina State Plane Coordinate System, the foot is the International Foot with one inch being exactly 2.54 centimeters. To convert metric coordinates to the international feet multiply by 3.280839895." (S.C. Code Ann. Section 40-22-2, et seq.; 26 S.C. Code Ann. Regs. Chapter 49 (1991 as amended)).

Static GNSS Survey – "A geodetic survey that uses multiple survey grade satellite receivers each collecting the same satellite data simultaneously. At least one satellite receiver must be on a known geodetic control station. The data is post-processed to yield three dimensional vectors between the known and unknown control stations. Static vectors solutions yield a "no check" solution and therefore by themselves do not meet minimum standards without additional independent checks." (S.C. Code Ann. Section 40-22-2, et seq.; 26 S.C. Code Ann. Regs. Chapter 49 (1991 as amended)).

Stereo Models – Overlapping successive photographs along a flight line which have at least 55% forward overlap and at least 20% side overlap. (USACE, 2015).

Survey Control Data Sheet - An SCDOT standard full sized plan sheet showing the Horizontal and Vertical Datum Description, a tabulated list of (Primary Survey Control (PSC) points, Main Survey Control (MSC) points, Project Benchmarks (PBM), and property monuments found), Date of Survey, and the surveyor's signature and seal.

Swath – "The data resulting from a single flightline of collection." (USGS, 2019).

Swath-to-Swath – "For lidar and IFSAR collections, relative accuracy between swaths (swath-to-swath) in overlap areas is a measure of the quality of the system calibration/bore-sighting and airborne GNSS trajectories. Swath-to-swath relative accuracy is assessed by comparing the elevations of overlapping swaths. As with within-swath accuracy assessment, the comparisons are performed in areas producing only single return lidar points. Elevations are extracted at checkpoint locations from each of the overlapping swaths and computing the root-mean-square-difference (RMSDz) of the residuals. Because neither swath represents an independent source of higher accuracy, as used in RMSEz calculations, the comparison is made using the RMS differences rather than RMS errors." (ASPRS Positional, 2014).

Terrestrial Total Station Survey (TTSS) – A survey and mapping system that includes a total station survey instrument and an electronic data collecting system which uses prisms and prism poles to perform conventional survey methods of traverse, resection, topographic and planimetric mapping, and trigonometric leveling.

Tie Point (photogrammetry) – "Image points that appear in the sidelap area of photos in overlapping strips of aerial photography, used to "tie" adjoining strips together. When the aerial photography is flown with 60% forward overlap, and when tie points are measured at the top and bottom corners of each image with adjoining strips, tie point images will appear on 4-6 images, adding extra strength to the aerotriangulation process." (USACE, 2015).

Tie Point (Terrestrial or GNSS surveys) - A "tie point" is typically used to record the position of an existing project control point by occupying a point of know coordinates and elevation, and recording new coordinate and elevation values, giving a check to the project's established datums.

Triangular Irregular Network – A three dimensional (3D) surface model derived from irregularly spaced points and break line features which create a triangular mesh, with the vertices of these triangles representing the field surveyed elevations.

Total Station – "[A]n optical surveying instrument that uses electronics to calculate angles and distances. It combines the functions of a theodolite with that of a transit level and electronic distance meter (EDM). […] Total stations measure distance by using a modulated infrared carrier signal, which is generated by a small solid-state emitter inside the instrument's optical path. This beam is reflected off a prism or an object that the user wants to survey, while the modulated pattern of the returning signal is read and interpreted by a computer inside the instrument." (EngineerSupply, 2022).

Traverse – "A *traverse* is a series of connected lines whose lengths and directions are known. Traverses must start and end on points whose position is known in order to have a geometric checks of the field work." (Buckner, 1991).

Triangulated Irregular Network (TIN) – "A vector data structure that partitions geographic space into contiguous, nonoverlapping triangles. In lidar, the vertices of each triangle are lidar points with x, y, and z values." (USGS, 2019).

Unadjusted Ratio of Precision – The Unadjusted Ratio of Precision is the calculated ratio of the unadjusted error of closure (numerator) to the total length of either a loop traverse, a link traverse, or a level circuit (denominator). "The accuracy of …surveys may be evaluated, classified, and reported based on closure ratios for the horizontal point or vertical elevation difference, as obtained in the field when points are redundantly occupied". (FGDC Part 4, 2002). "The most common way to express proportional accuracy is as the ratio between the overall length of a traverse and the misclosure of the closing course. This can be for a single measurement (i.e. 200 ft, +/- 0.01 ft is a precision ratio of 1:20,000), or for multiple measurements (such as the vertical accuracy expressed as closure times the square root of the traverse distance)." (CALTRANS, 2015). "There is no simple correlation between relative closure ratio accuracies and 95% radial positional accuracies; thus, determining a closure order based on a specified feature accuracy requirement is, at best, only an approximation." (CALTRANS, 2015). "Assuming that there are no mistakes and that systematic errors are compensated, […] an *error of closure* represent[s] an accumulation of random errors." (Buckner, 1991).

Uncertainty (of measurement) – "[A] parameter that characterizes the dispersion of measured values, or the range in which the "true" value most likely lies. It can also be defined as an estimate of the limits of the error in a measurement (where "error" is defined as the difference between the theoretically-unknowable "true" value of a parameter and its measured value).Standard uncertainty refers to uncertainty expressed as a standard deviation." (ASPRS Positional, 2014).

Validation Point – "a surveyed point used to verify or validate the accuracy of the processed data (point cloud, DTM surface, etc.). If this point is then used as a control point to adjust the data, additional validation points should be established in the local area to verify the readjustment. These points are set pre-determined spacing". (NCDOT, 2014).

Vegitated Vertical Accuracy (VVA) – "An estimate of the vertical accuracy, based on the 95th percentile, in vegetated terrain where errors do not necessarily approximate a normal distribution." "VVA consolidates the NDEP's vegetated land cover categories (weeds and crops, brush lands, and fully forested [. . .])." (ASPRS Positional, 2014).

Virtual Reference Network System (VRS) GNSS Survey – "A geodetic survey that uses multiple dual frequency survey grade satellite receivers each collecting the same satellite data simultaneously. Base stations are operated by the SCGS and data is streamed to the Rovers via the Internet and processed in real time to yield three dimensional vectors between the Base Stations and Rovers. VRS vectors solutions yield a "network check" solution and therefore will meet minimum standards without additional independent checks. VRS surveys require an "independent check" by occupying a known geodetic control point in the National datum in the vicinity of the survey to verify the proper operation of the Rover." (S.C. Code Ann. Section 40-22-2, et seq.; 26 S.C. Code Ann. Regs. Chapter 49 (1991 as amended)).

Within-Swath – "For lidar collections, within-swath relative accuracy is a measure of the repeatability of the system when detecting flat, hard surfaces. Within-swath relative accuracy also indicates the internal stability of the instrument. Within-swath accuracy is evaluated against single swath data by differencing two raster elevation surfaces generated from the minimum and maximum point elevations in each cell (pixel), taken over small test areas of relatively flat, hard surfaces. The raster cell size should be twice the NPS of the lidar data." (ASPRS Positional, 2014).

UAS (unmanned aerial system) – An aircraft piloted by remote control or onboard computers which can carry mapping sensors, GNSS and INS. Other terms used are UAV (unmanned aerial vehicle) or drone.

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