STATE OF NEVADA
DEPARTMENT OF TRANSPORTATION
CONSTRUCTION DIVISION

CONSTRUCTION SURVEY MANUAL
NOVEMBER 2017

THE GREAT SEAL OF THE STATE OF NEVADA

NEVADA DOT
SAFE AND CONNECTED
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## Glossary
ABOUT THIS MANUAL

The purpose of this document is to provide general guidance and standards for surveying, including data setup, preliminary field work, construction staking and documentation of survey information for various NDOT projects. It is to also serve as a guide for local public agencies, service providers and others, both within and outside of NDOT, who are responsible for project survey.

This manual is divided into the following chapters:

1. Introduction
2. Analysis of Contract Plans
3. Data Setup
4. Preliminary Fieldwork
5. Robotic Total Station
6. Global Positioning System (GPS)
7. Construction Stakeout
8. Equipment

This manual should be easily read and understood by anyone with a fundamental understanding of NDOT's construction process. In conjunction with related documentation and supplemental training, this manual will serve as a framework for administering NDOT contracts.

The Construction Survey Manual does not address every phase, process or event throughout the surveying process in detail, nor will it replace good engineering judgment. References to documents and/or related resources are provided throughout this manual where necessary or applicable.

CONVENTIONS USED IN THIS MANUAL

References in this manual include the following:

- “The Department”: the Nevada Department of Transportation (NDOT).
- “Project”: The lifecycle of an NDOT project up until it is advertised.
- “Contract”: The lifecycle of an NDOT project upon advertisement.
- “Total Station”: Refers to any of the robotic systems used for the purposes of construction survey (e.g. Trimble, Leica, Topcon, Sokia)
- “Data Collector”: refers to the field data collection and storage device (e.g., Trimble TSCE, TSCxx, Leica CS15 etc.).
- “Standard Specifications”: NDOT’s Standard Specifications for Road and Bridge Construction. (This includes “Special Provisions”, unless otherwise stated.)
- “Standard Plans”: NDOT’s Standard Plans for Road and Bridge Construction.
- “Project plans”: Plans, as defined in Subsection 101.03, “(Terms and Conditions) Definitions”, of the Standard Specifications, specific to the contract/project.
1 INTRODUCTION

- “Special Provisions”: Specifications specific to the contract/project.

The order of precedence of contract documents is:

1. Supplemental Notices
2. Special Provisions
3. Contract Plans
4. Standard Specifications
5. Standard Plans

When discrepancies and/or contradictions exist within the above referenced documents occur, always follow the order of precedence to determine the governing documents. Guidelines when working with Standard Specifications, Standard Plans, Project Plans and/or Special Provisions include:

- Changes to Standard Specifications in between published editions are made as Pull Sheets. When a Pull Sheet is implemented, it is included in a project’s Special Provisions. (This incorporation of change in contract documents is a reason why Special Provisions take precedence over Standard Specifications.)
- Changes to Standard Plans are made as Special Details. When Special Details are implemented, they will be included in the Project Plans. (This incorporation of change in contract documents is a reason why Project Plans take precedence over Standard Plans.)
- Changes to contract documents after a project is advertised but before the bid is opened are provided in a Supplemental Notice.

UPDATES, REVISIONS TO THIS MANUAL

The Construction Division is responsible for maintaining an updated Construction Survey Manual. The Construction Division will revise and/or issue updates as needed. Users can request a revision to the guide in writing to the Construction Division at ndotconstruction@dot.nv.gov. The Construction Division will review the request and take appropriate action. Between revisions/updates, the Construction Division may issue interim Construction Division policy memorandums that would be incorporated into the next revision.

DISTRIBUTION OF THIS MANUAL

ANALYSIS OF CONTRACT PLANS
OVERVIEW

NOTE: Refer to “Conventions Used in this Manual”, in Chapter 1, for terminology used in this chapter and/or the order of precedence of contract documentation.

- This chapter is an outline of the analysis of contract plans as it relates to the identification of standard procedures from the Location Division at the Nevada Department of Transportation. Many of the citations within this chapter have been directly referenced from the Location Division’s Special Instructions for Location Consultants. The Location Division publishes this manual for the benefit of contractors wishing to provide consulting services for the Department, but it also serves as a guide for survey standards Department wide.

UNITS OF MEASUREMENT

Currently, the U.S. Survey Foot is the recognized unit of measurement at the Nevada Department of Transportation for all survey work, with sub units of tenths and hundredths of a foot. In years past, contracts may have been designed in meters as well, with sub units of millimeters. Current contracts that are to tie to legacy surveys in metric must also be in metric.

ACCURACY

Accuracy for construction stakeout surveys should adhere to the standards set forth in the Special Instructions for Location Consultants. The specific applicable reference in the manual is titled, “Minimum Engineering Survey Standards”. An excerpt from that section concerning Positional Tolerance is shown in Table 1.

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<th>VERTICAL (+/-)</th>
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<td>Structural Concrete</td>
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MONUMENT IDENTIFICATION

Survey Monuments at the Nevada Department of Transportation are to be set or located prior to construction by a Location Division Survey. These monuments may vary in character and location due to the type and age of the particular monument.
The specific location of each control point is identified by coordinates. NDOT uses three types of coordinate systems:

1. **Geodetic:** A coordinate system based on the shape of the earth being approximately a sphere, with coordinates being in latitudes and longitudes (39-15-5.10626, -119-58-24.50336)

2. **Universal Transverse Mercator (UTM):** A coordinate system based on the shape of the earth being approximately a cylinder, with coordinates measured in meters (4348892.17, 243412.25)

3. **State Plane Coordinate System:** A coordinate system similar to the UTM, modified to reduce errors due to the curvature of the earth, with coordinates measured in feet (14765156.56, 2231013.09)

Federal law prohibits the willful damage or destruction of monuments established by federal government agencies. The following federal agencies have placed markers throughout the state to establish vertical and horizontal controls for future surveys:

- U.S. General Land Office (Bureau of Land Management) (USGLO)
- U.S. Bureau of Land management (BLM)
- United States Geological Survey (USGS)
- United States Coast and Geodetic Surveys (USC & GS)
- National Geodetic Survey (NGS)

Figure 2-1: Construction Control Feno Monument
For a complete list of potential monument types that may be encountered in the field, refer to the *Special Instructions for Location Consultants* under the sub-heading of “Instructions for Setting and Stamping of Control Monuments”.

Any monuments pertinent to a contract will be listed in the contract plans’ project control sheet, referred to as the Location Control (LC) sheet (refer to Figure 2-2 through Figure 2-9). The project control sheet is prepared by the Geodesy Section of the Location Division. These control sheets are generally completed when the design is 30 percent complete, and they are typically included in the 90 percent complete plans.

When control sheets are not available, the construction survey crew must use the original roadway reference monuments previously set by construction. If the crew cannot find the original survey monuments, the Resident Engineer may request that the Location Division establish control. Contact the Location Division’s Geodesy Section for any questions concerning project control.
Figure 2-2: Project Control Sheet Sample (1 of 8)
### CONSTRUCTION CONTROL

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**Note:** Figures and data provided are illustrative and do not reflect the actual project control sheet sample. This example is intended to demonstrate the format and content typical for such sheets in the State of Nevada's construction projects. Actual sheets may vary in detail and data accuracy. Always consult the official documents for precise information. This table is a simplified representation and may not cover all the necessary columns or data points required for a complete project control sheet.
Figure 2-4: Project Control Sheet Sample (3 of 8)
Figure 2-6: Project Control Sheet Sample (5 of 8)
Figure 2-7: Project Control Sheet Sample (6 of 8)

State of Nevada Department of Transportation Construction Division
Construction Survey Manual
November 2017
Figure 2-8: Project Control Sheet Sample (7 of 8)
Figure 2-9: Project Control Sheet Sample (8 of 8)
Data input for project control is critical in today’s age of GPS Surveying. Most information needed to set up a new contract can be found on the Location Information System or “LoIS” as mentioned previously. The information contained in this database can be queried either by map or by attributes. The attributes can be queried by Point Name, LPN Name, UTM Coordinates/Radius, Lat-Long/Radius and PLSS Sections. LoIS is a valuable resource, because it provides essential information concerning a monument's Ground and Grid coordinates, Ortho and Ellipsoidal Elevations, Horizontal and Vertical Datum, State Plane Zone, Units, Area Combination Factor and descriptions and pictures of the monument. Questions concerning LoIS and its contents should be directed to the Geodesy Section of the Location Division.
NOTE: Refer to “Conventions Used in this Manual”, in Chapter 1, for terminology used in this chapter and/or the order of precedence of contract documentation.

The modern Total Station, in advance of theodolites, chain measurements and the sizable labor required to make use of both tools, offers a new standard with servo-driven laser-measuring robotic tools that automate data collection and reduce the labor requirements to a single operator. Combined with Global Positioning Satellite (GPS), the Robotic Total Station completes a dynamic approach to construction survey. That twofold approach allows the surveyor some flexibility and convenient transitions between two methods of survey, all the while maintaining dependable accuracy.

The Total Station lacks the sophistication of GPS, in consideration of the complex computations for terrestrial solutions from orbiting satellites, but delivers efficient results with accuracy that is solely dependent on the equipment condition and user input. Simply put, the equipment will yield varying results based on the preparatory effort of the operator.

In this chapter, the user will find reference to essential quick-start routines that hasten the startup time of the Total Station and reduce prospective operational errors. The limited routines in this manual do not represent the entire arsenal of techniques offered by the Total Station. Therefore, the user is encouraged to explore their manufacturer’s operating manuals and collector help screens to realize the full potential of these instruments.

For Desktop Software-Project Design Input: The central computer (office or notebook) is the hub for importing and exporting design data, or project data built from contract plans, into the data collector, which the surveyor then uses to stake or measure information in the field.

Monuments are typically taken from the contract plans under referenced datum, then researched in the NDOT Location Information System (LoIS) LPN files, and verified in the field.

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<td>V Datum = NAVD 88</td>
</tr>
<tr>
<td>-115-8-34.85322</td>
<td>Conv = 0-15-35.8</td>
<td>H Datum = NAD 83/94</td>
</tr>
<tr>
<td>UTM - 11 = 4005708.09</td>
<td>Hf = 0.99982786</td>
<td>Zone = East(2701)</td>
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<tr>
<td>666989.67</td>
<td>Sf = 0.999823013</td>
<td>Units = Feet</td>
</tr>
<tr>
<td>State Plane = 26769083.37</td>
<td>Area CF = 0.999823013</td>
<td>Date = 6/26/2006</td>
</tr>
<tr>
<td>kl = 0.99991931</td>
<td>H-Acc = 0.05</td>
<td>LPN 997</td>
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<tr>
<td>hf = 0.99990854</td>
<td>H-Rel = GA</td>
<td>V-Acc = 0.1</td>
</tr>
<tr>
<td>Ground</td>
<td>Ortho Elev</td>
<td>V-Rel = GP</td>
</tr>
<tr>
<td>26772821.32</td>
<td>786245.18</td>
<td></td>
</tr>
</tbody>
</table>

NOTE: The typical LoIS monument description contains the information above. The essential data is the Geodetic coordinates, Ground coordinates, and Ortho and “Ellp” (Ellipsoidal) elevations. The V&H Datum references obviously need to fit the project datum. The user is encouraged to explore these LPN folders and seek the “help” sections for further explanations.

The Survey software typically has a “Points Management” function that allows the user to insert northing, easting, and elevation data. Those points, when entered as such, usually display on the software’s main screen, where “view” functions render point labeling for easier screen identification. To reduce entry errors, the use of the “cut and paste” entry method is highly suggested in comparison to the tedious keypad entry.
In concern of GPS points for calibrations, LoIS Longitude and Latitude (Geodetic) data can be copied and pasted with minor alterations to the Longitude and Latitude, where in LoIS they display as: Latitude: 36-10-54.38842, but enter as 36.105438842 and Longitude: -115-8-34.85322 but enter as 115.083485322 (note the 8 in the longitude minutes are entered “08” when less than 10).

- Road Alignment and Vertical Profile: The software typically allows for horizontal and vertical alignment.
- Information input, where either electronic design files are imported into the routine or the user manually inputs alignment data from the contract plans.
- Typical Section Template Data: The vertical profile information adds the dimensional aspect of a surface relative to the planned or existing roadway. Using the contract plans, cross sectional templates are built using subgrade depth, cross slope, shoulder cuts or fills, shoulder width, ditch elevation, and back slope data. With this information in the data collector, the surveyor will have instantaneous cut or fill information and the preparatory slope staking effort is minimal.
- Surface Datum: Surface data for the contract is obtained by two main methods. First, the contract may have design information derived from aerial mapping which contains accuracy to within .3 to .4 ft. The second method is by cross section, where the survey crew performs a preliminary grid collection of elevations within the roadway limits.
- Stakeout Data Input: Once all roadway alignment information and design surface data has been input into the desktop software, the data then must be downloaded to the data collector for field staking and compilation.
- Drainage Stakeout Data: Alignment, culvert dimensions, and flow line elevation data in the contract plans can build a drainage model that, when staked, yields accurate quantities of drainage excavation.
- Special Survey Data: Geographical Information Systems (GIS) data can be merged into survey data, where satellite imagery can be overlaid to show a road alignment in its actual environment.

**NOTE:** Refer to your equipment manufacturer's owner's manual for actual input methods. Software compatibility issues may require additional research and updates for accurate data management.

### DATA COLLECTOR SETUP

The specifics of the data collector setup vary by manufacturer and model. Refer to Appendix A – Data File Management for the file/folder structure for survey data.

- **Connectivity:** The typical method of connecting the data collector and the central system includes USB/ USB mini-B, Bluetooth, and Wi-Fi. The user will need to ascertain the most effective way to transfer files within the environment provided.

- **Memory and File Considerations:**
  - Memory of late is readily available, but the user should consider collector capacity in heavy staking and collection conditions.
  - Roadway sections, as in the plans, need different file associations. Slope staking, drainage items, aggregate base section staking (redheads and blue-tops), curb-and-gutter, asphalt, PCCP, electrical items, and even permanent striping all need file names that isolate daily stakeouts and collection.

- On-board data collector operating systems typically allow for temporary contract information storage. Your collector file system centers on the limits of the operating software, the survey standards for data storage, and ultimate compatibility for differing users.

- **Download Daily Stakeout:** The central computer being the hub for contract data manipulation is the starting point for the surveyor's workload. To prevent recovery issues, the tasks for the day should be downloaded and uploaded accordingly for minimal memory usage.
DATA SETUP

- Collection of Data: Feature codes and terrain strategies lend to the methodology the user employs into data collection (e.g., a cross-section of a road may involve original ground, curb and gutter, utility accesses, and asphalt. The user may want to survey one component at a time, and thus reduce constant and error-prone toggling of feature code selections). Refer to file:\datsrv1\017Public\FeatureCodeLibraries\SUE for more information.

- Backup, Protection, and Uploading Data to Desktop: The user is cautioned that all electronic devices are prone to catastrophic failure and that a backup system should be in place for daily protection of data files.

TOTAL STATION CONFIGURATION

The electronic manipulation of any survey equipment starts with the data collector. The Total Station is configured by the data collector through specific setup routines that reside in the collector's software. Permanent survey style settings such as model type, communication frequencies, laser specifications, prism specifications, and instrument properties are typical data collector inputs. Setup information regarding atmospheric conditions, setup point coordinates, backsight coordinates, instrument height, and prism height are data collector settings made upon the onsite initialization of the instrument.

A significant instrument setting is the Direct Reflex (prismless) configuration that involves reflected laser measurements to any surface that has sufficient characteristics of reflection. The resulting rectangular coordinates can be used to model the surface irregularities. In this situation, the operator is controlling the survey solely through the data collector and without a need to leave the instrument. (Refer to “Surface Scan”, in Appendix B for the Data Collector and instrument Direct Reflex settings.)

The operating manuals and help screens will always be the definitive source for the information regarding the configuration of the Total Station.

TOTAL STATION SETUP

The Total Station will be used in a variety of setup situations. In order to ensure efficient results, some key elements such as the tripod used, the power sources, and cable connections need to be addressed.

Tripod - Out of the case, the immediate requirements for the Total Station center on the platform that the instrument will be mounted. A sturdy tripod is an essential piece for the operation of the equipment, where fluctuations in the leveling of the instrument will be problematic. Most instruments will cease operation, shutdown the instrument, and require a re-initialization if the leveling is out of balance.

Power. A typical Total Station lists a multitude of battery requirements for their equipment, such as the instrument, the prism pole, the radio, and for any long-range transistorized prisms. Most manufacturers offer a variety of ways to power the instrument by means of close proximity connections to a vehicle or by batteries in remote areas away from road access. Recharging of remote power sources can be completed either in the vehicle or in the field office. Strict adherence to the manufacturer's requirements will yield the most usage out of these expensive batteries. It is recommended that backup batteries be on hand for all equipment and for any unforeseen remote operations.

Connections. Manufacturers are compelled to realize profit through accessories. The cables required to connect a Total Station to various components represents a myriad of specificity. Seldom do the data cables of one manufacturer fit the data ports of another. With that added uniqueness, having connection problems in remote terrain is not a pleasant experience for anyone. The protection of these specialized cables is paramount, as replacement cables, due to their specialty, carry robust pricing.

Beyond the elements mentioned above, Total Stations are delicate optical equipment that will always need periodic recalibration. These recalibrations are best handled through a local manufacturer's repair center. Internal batteries often need changing as well. The repair center is the best source for the restoration needs of your individual equipment, as warranties can be voided if the user attempts an unauthorized repair.
The following list is a basic approach to general instrument setup in the field:

- Set and rough-level the tripod
- Mount and bubble-level the instrument (or tri-bracket)
- Rough center the instrument over the control point (plumb bob)
- Connect power to the instrument
- Connect the data collector and initialize the instrument
- While in sync with the collector, fine-level and then re-center the instrument
- Set the local atmospheric conditions (temperature, barometric pressure, etc.)
- Initialize the station setup
- Initialize a robotic survey
- Disconnect the data collector
- Reconnect the data collector to the prism pole mounted radio
- Establish remote radio communications with the instrument radio
- Begin the survey under robotic conditions
- Open a project file in the collector and stake points or accumulate data as needed

### TOTAL STATION ROBOTIC SURVEYS

During stakeout, the robotic operation of the Total Station is controlled remotely via radio communications to the instrument from the prism pole-mounted data collector. Line of sight obstructions and long distant operations will affect the distance measuring and reception abilities of the communication equipment. The surveyor needs to assess his operating environment and plan for obstructions accordingly. The plan of attack may include the setting of additional construction control to avoid obstructions and reduce extensive distances between the prism and instrument.

The operator is reminded that Total Stations are not fool proof and when operating at great distances in robotic mode, the instrument can lose track of the prism target. Electronic “long-range” prisms help in target relocks by signaling their location when the telescope is within a few degrees of the target. Another search feature allows the operator to engage the instrument into a predefined scan to relocate a lost target. If all else fails, the operator can have the instrument return to the previously staked point for relock or have the instrument turn a certain angle to relock.

During robotic operations, the data collector provides basic audible and symbolic instructions that readily indicate direction and walking distance to reach the intended stakeout point. The typical data collector has several icons of significance during a remote operation. The operating manuals and help screens will always be the definitive source for the information on these collector screens.
CHAPTER FOUR

PRELIMINARY FIELDWORK

4
OVERVIEW

The following chapter is an outline of preliminary fieldwork as it relates to the identification of project control and construction limits. The Location Division at the Nevada Department of Transportation is responsible for the location and determination of project control prior to construction. Many of the citations within this chapter have been directly referenced from the Location Division’s Special Instructions for Location Consultants. The Location Division publishes this manual for the benefit of contractors wishing to provide consulting services for the Department, but it also serves as a guide for survey standards Department wide.

Monuments encountered within any NDOT contracts are required to be perpetuated in accordance with Transportation Policy (TP) 1-9-3.

FIELD ASSESSMENT OF IN-PLACE ERRORS

A preliminary jobsite visit and exploratory field survey should be conducted prior to the start of construction. This includes a cursory review of any plans or data received to verify that existing features and facilities are correctly depicted. Any errors found in the field should be reported to the Resident Engineer and the Designer of Record to avoid impacts to the contract’s schedule and budget.

FIELD IDENTIFICATION OF MONUMENTS IN LoIS

Information concerning the type and character of specific project control can be found in the Survey Monument Web Map of LoIS.

The database, maintained by the Geodesy Section in the Location Division, contains pertinent information regarding controlling attributes for a particular monument. The type of information that can be found in LoIS is described in Chapter 2 under “Monument Identification” and “Data Input-LoIS File Research”.

Field identification of monuments in LoIS requires an understanding of the point types that are used for control and their character. This information can be found in the Special Instructions for Location Consultants in the Survey Section. The various types of monuments used are shown in Table 4-1.

<table>
<thead>
<tr>
<th>TABLE 4-1: MONUMENT TYPES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BASIC</strong></td>
</tr>
<tr>
<td>Wooden Hub</td>
</tr>
<tr>
<td>Washer Disc</td>
</tr>
<tr>
<td>Rebar Marker</td>
</tr>
<tr>
<td>Feno Monument</td>
</tr>
<tr>
<td>Concrete Marker</td>
</tr>
</tbody>
</table>

Additional attention must be paid to the point types and their naming convention in order to properly reference the specific monument in LoIS. An example of the naming convention typically found on NDOT control is shown below:

EXAMPLE: LPN1012, first station point number, section corner
Designation = 1012001L

- Numbers 1, 2, 3 and 4 designate the Location Project Number (LPN) assigned by NDOT
Based on survey standards, various point types have been established with differing degrees of control reliability. The letter designations appear on the monument at the end of the point number to differentiate the type of monument found in the field. The list of available point types used is shown below.

**POINT TYPES**

- A = Traverse point
- X = Permanent basic control point
- M = Construction control point
- K = Construction control point / no spirit level elevations
- L = Section corner (PLSS)
- H = Highway reference monument
- S = Local street monument
- P = Property corner
- Z = Fixed NGS control (X, Y, & Z)
- B = Boundary Control Point
- R = Railroad or Reset

For further identification, LoIS contains a field which often includes pictures of the monument in question. You can access this image by clicking on the “View Monument” icon in the LoIS control report for the specific monument. (See Figure 4-1 through Figure 4-9.)
Figure 4-1: A-Traverse Point

Figure 4-2: X-Permanent Basic Control Point
Figure 4-3: M-Construction Control Feno Monument

Figure 4-4: K-Construction Control Point / No Spirit Level Elevations
Figure 4-5: L-Section Corner (PLSS)

Figure 4-6: H-Highway Reference Monument
Figure 4-7: S- Local Street Monument

Figure 4-8: P-Property Corner
Horizontal control and vertical datum information pertinent to a contract will be listed in the contract plans project control sheet, referred to as the “LC” sheet. The project control sheet is prepared by the Geodesy Section of the Location Division. This portion of the contract plans contains valuable metadata concerning specific control for the contract. This includes the control located by station and offset, Horizontal datum, Vertical datum and the area combined ground to grid factor. Any monuments found in the field not included in the project control sheet should be examined by the Location Division prior to use to verify its compatibility with the established control network for the contract.

**CONSTRUCTION LIMITS**

Construction limits can be verified through the contract plans for a particular contract. Additionally, project limits can also be loaded to the data collectors from Inroads or as a text file. Construction limits are not always the same as the Right of Way limits for a contract. Right of Way limits should always be determined prior to construction to avoid potential trespass onto adjacent property.

**NOTE:** Determination of legal boundaries must be performed by the Location Division or a licensed and authorized Land Surveyor in the State of Nevada.
Figure 4-10: Right-of-Way Fencing
OVERVIEW

If necessity is the mother of invention, then the invention of the Total Station robotic instrument truly fits the requirements of the necessity. This powerful engineering tool performs the work of a five-man survey crew, is twice as accurate, and reduces tedious errors in time-consuming data collection. Unlike Global Positioning Satellite (GPS), the equipment offers pinpoint precision in severe environmental conditions, where satellite radio crosstalk interference and overhead obstructions commonly renders a GPS useless.

The instrument is based on older theodolite technology that was eventually enhanced by laser or electronic distance measurement (EDM) and internal motor driven components that made remote operation possible through local radio control. That remote operation allows the instrument operator the luxury of hands on survey, where a physical presence at the point of stakeout had always been desired.

Figure 5-1: Trimble 5600 Robotic Total Station

The advances in distance measurement capabilities have led the surveyor to the world of “Prismless Survey”, where the instrument can now perform measurements from afar and out of the hazards of heavy traffic conditions. Prismless survey is a great tool for surface scans, where the extremities of an existing surface are input through the data collector software, and the instrument takes robotic observations in a grid pattern. Those collected observations can be used to create 3D surface models.

LIMITATIONS

The limitations of the Total Station are based on the manufacturer's model specifications and the geographical nature of the intended survey location.

Manufacturers build differing features into their equipment, where degree of accuracy, distance measuring, robotic controls, communication features, convenience features, telescopic options, durability, and battery life are options the user needs to consider prior to the final purchase. The daily needs, future needs, and equipment upgrade capabilities to meet those needs are all parameters the consumer should consider prior to committing to one piece of equipment.
Geographical limitations, such as physical obstructions, will limit the user's production. A construction survey conducted in rugged well-vegetated terrain will force tedious breakdowns and setups of the equipment to remain clear of obstructions. Telescopic limitations in this type of terrain and the effects of heat shimmer make long observations difficult.

The Total Station also has minor measurement limitations, where the distance between the prism target and instrument, prism configurations, temperature, common foliage, weather conditions, and prism characteristics all effect measurement characteristics. Long-range prisms have expanded the length of observation capabilities. The overall range is determined by the manufacturer's specifications, where the Trimble 5600 and a single long-range prism yields distances to 16,400 ft maximum.

Power options in relation to the locations of the planned instrument setup are another concern. In rural areas, where the user's vehicle is nearby, DC connections can power the equipment from a simple cigarette lighter or alligator clips to the vehicle battery. In remote areas, portable rechargeable power packs or gel batteries are transported to the setup site and the day's survey production is based on that collective stored power.

The time of day is typically not a problem for a Total Station. Many models come with illumination features that allow nighttime usage. The data collectors are backlit as well, so the surveyor can operate twenty-four hours a day if the power is available.

**ESTABLISH LOCALIZED CONSTRUCTION CONTROL**

In relation to geographical limitations, the establishment of localized construction control can aid greatly in the reduction of numerous equipment movements.

The Total Station has the edge over GPS in elevation precision, so the surveyor will want construction control in the areas of ditch work, culvert pipe, reinforced concrete boxes, traffic signals, curbs, valley-gutters, stockpiles, and any area of redundant surveys. The prudent surveyor performs a reconnaissance of these areas of construction and physically walks the contract to assess where the Total Station setups will yield the most productive shots.

To maintain accurate coordinates and elevations, the surveyor most likely will field-calculate and traverse in these points from project monuments. Their locations will be in areas of extreme activity, so protection is a priority and is enhanced through conspicuous delineation by means of bold colored ribbons and brightly painted lath. The preferred location for these points is near existing utility poles or in areas designated as "Not to be Disturbed".

Time saving efforts, made early in the contract, will help avoid the ever-wandering contractor's penchant to mysteriously find and destroy your construction control points.

All data collected can be uploaded and processed in the respective office software for further distribution to field personnel, the contractor, various engineering factions, or Engineer of Record.

**LOCALIZED DRAINAGE CONTROL**

As previously mentioned, the presence of control near drainage construction provides the surveyor a reference to quickly check initial offset stakeout points, flow line grade, drainage excavation quantities, elevations of existing connection sections for tie-in, potential utility conflicts, and as-built conditions. The Total Station is an invaluable tool for these areas of need. All data collected can be uploaded and processed in the respective office software for further distribution to field personnel, the contractor, various engineering factions, or Engineer of Record.
MISCELLANEOUS CONSTRUCTION CONTROL

This topic essentially reminds the surveyor that rare circumstances may dictate the need for control outside the normal lines of stationing and elevation references. Items like existing utility locations, where manhole covers, valve covers, and junction boxes may be in need of relocation after construction and paving operations. Control may be simple ties to undisturbed curb and gutter or extensive coordinate references topographically depicted in a 3D model.

Either process involves a preliminary or detailed walk of the roadway, with thorough identification or inventory of the facilities (utilities) in place. The Total Station can be setup in intersections, and with robotics, the remote operator can be physically at the utility and enter feature codes (description) data accordingly. Refer to file:\datsrv1\017Public\FeatureCodeLibraries\SUE for more information.

MATERIAL PIT CROSS SECTIONS

Prior to the start of the contract, the survey crew typically accesses the material pit of intent and performs a cross section for a model of existing pit conditions. The pit model is based off construction control from the roadway monuments, section corner monuments, or a surveyor placed take-off point with an assumed elevation and coordinates. The problem with the latter control is the data lacks a true reference to existing topography.

Once a protected control point is established, the Total Station can be set to use either remote or scan shots. The surface scan feature is a valuable tool in pit assessment conditions. (Refer to “Surface Scan”, in Appendix B, for more information.) The surveyor cross sections the pit for a 3D model and after material production is ceased, the surveyor can re-cross section the identical grid patterns and compare the original surface to the excavated surface. The office software can create an instantaneous report that represents a comprehensive volumetric account of quantities used.

The scanning feature is also a great tool for stockpile assessment. Accuracy is dependent on the shape of the material piles, and the contractor should be made aware that uniformity in his stockpile would aid in any payment resolution.
CHAPTER SIX

GLOBAL POSITIONING SYSTEM (GPS)
Global Positioning System (GPS) is a tool that the construction industry has adopted from the United States Military. It is a constellation of at least 24 satellites that provide accurate position coordinates. GPS uses satellites and computers to compute positions anywhere on the Earth.

There are three main segments to the GPS. The first being space. This medium encompasses a minimum of 24 satellites that orbit the earth every 12 hours at an altitude of about 12,551 miles. The second segment is control. There is a master station located at Schriever Air Force Base in Colorado Springs, Colorado. Each satellite passes over one of four monitoring stations twice a day. The master station calculates corrections and synchronizes the atomic clocks aboard the satellites. The third and final segment is the user. The user is, simply put, anyone who has a GPS receiver and can access the signal.

GPS survey methods include, but are not limited to:

- Static GPS surveys
- Fast-static GPS surveys
- Real-Time GPS surveys (RTK)
- Post-Processed kinematic GPS surveys

The type of GPS survey used mostly for construction is Real-Time GPS survey (RTK). RTK is similar to a Total Station radial survey. RTK surveys measure the baselines from the reference station to the roving receivers point. A radio at the reference station broadcasts the position of the reference point to the rovers, and the system processes the baselines in “Real Time” allowing for project coordinate information to be gathered and analyzed during the actual field survey. RTK surveying provides centimeter-level precision without post-processing. There are three types of survey methods in RTK surveys: topo points, continuous surveys, and stakeouts. Topo points are short (usually 3-15 second) occupations, e.g., over a sample site or survey marker. Continuous survey mode allows ongoing data collection at a specified logging interval, e.g., every 5 seconds, or a specified distance interval, e.g., 1 meter. Continuous mode is used for mapping. Stakeout mode allows navigation to predetermined coordinates.

The following are some of the items that will affect the accuracy of a GPS survey:

- **Satellite Geometry.** A minimum of four satellites are required to survey with GPS. A minimum of five satellites is recommended. The configuration of the visible satellites the receiver is able to track in relation to each other will make a significant difference in the data that is being collected. Satellite geometry is expressed as a numeric value known as Dilution of Precision (DOP). Good satellite geometry will have small DOP values while poor satellite geometry will have large DOP values. As a guideline, DOP values of six or lower are required for NDOT GPS surveys. The ideal satellite geometry is one which has the visible satellites distributed throughout the sky. Good satellite geometry will yield a higher precision. Satellite geometry factors that must be considered when planning a GPS survey are:
  - Number of satellites available.
  - Minimum elevation angle above the horizon (elevation mask).
  - Obstructions limiting satellite visibility.
  - Position Dilution of Precision (PDOP).
  - Vertical Dilution of Precision (VDOP).
  - Horizontal Dilution of Precision (HDOP).
  - Geometric Dilution of Precision (GDOP).
Weather Conditions. Generally, weather conditions do not affect GPS surveying; however, the following conditions must be considered when planning a GPS survey:

- GPS observations should never be conducted during an electrical storm.
- Significant changes in weather or unusual weather conditions should be noted either in the field notes, data collector, or receiver.
- Horizontal and vertical GPS observations can at times be affected by severe snow, hail and rain storms. Therefore, high accurate GPS surveys should not be conducted during these periods.
- Sunspots or magnetic storms can affect GPS observations; care needs to be taken to avoid GPS surveying during these periods.

Elevation Mask Angle. Nearly all GPS receivers, inexpensive or expensive, have a “Mask Angle” setting. This means that the receiver can be set to ignore any satellite signals that come from below a user-definable angle above the horizon, or “mask” them out. The most typical mask angle is usually somewhere between 10 and 15 degrees. The drawback here is that setting the mask angle too high might exclude satellites needed to acquire the necessary minimum of four. It’s a trade-off. Are you so desperate for a position at that exact time that you're willing to accept a degraded signal? It does happen. In that case, the mask angle could be set to maybe 5 degrees, or even to zero if there’s a clear view of the horizon, such as at sea, and simply accept a degraded signal and possibly (probably) a poorer accuracy as a result. In most cases, it’s better to keep the mask angle at that upper end of around 15 to (at most) 20 degrees and just wait for a sufficient number of satellites to become available above the mask.

Now that the full GPS constellation is complete, there will rarely be times with too few satellites sufficiently high in the sky to get a good position. Another potential source of error is receiver noise, or electronic noise produced by the receiver itself that interferes with the very weak incoming signal. While this error is highly variable among receiver brands, most have some kind of internal filtering designed to minimize the problem some better than others. Elevation mask also helps to minimize the atmospheric noise in the data. Satellites that are high in the sky will have less atmospheric noise than satellites low in the sky and very close to the observer’s horizon. By having an elevation mask set, the noise in the GPS satellite signal is kept to a minimum.

Multi-Path Errors. Another potential, though relatively minor, source of signal error is Multi-Path. Multi-Path is simply the reception of a reflected satellite signal. With multi-path reception, the receiver collects both the direct signal from the satellite and a fractionally delayed signal that has bounced off of some nearby reflective surface then reached the receiver. This is the same kind of thing seen in television “ghosts.” The problem is that the path of the signal that has reflected off some surface is longer than the direct line to the satellite. This can “confuse” some lower-end receivers resulting in an incorrect range measurement and, consequently, an incorrect position. Most receivers have some way of “seeing” and comparing the correct and incorrect incoming signal. Since the reflected multi-path signal has traveled a longer path, it will arrive at a fraction of a second later, and a fraction weaker than the direct signal. By recognizing that there are two signals one right after another, and that one is slightly weaker than the other, the receiver can reject the later, weaker signal, minimizing the problem. This ability is referred to as the receiver’s multi-path rejection capability.

Dilution of Precision (DOP). The DOP is a measure of the geometry of the visible satellite. The ideal orientation of four or more satellites would be to have them equally spaced all around the receiver, including one above and one below. Because we’re taking our position from only one side of the Earth, that’s really not possible since that part of space is blocked by the planet itself. The next best orientation is to have one satellite directly above and the other three evenly spaced around the receiver and elevated to about 25 to 30 degrees (to help minimize atmospheric refraction). This would result in a very good DOP value. If all the satellites are clustered together, it would result in a poor DOP value and your readings could be suspect. A low numeric DOP value represents a good satellite configuration, whereas a higher value represents a poor satellite configuration. The DOP at any given moment will change with time as the satellites move along their orbits. When the satellites are widely spaced, the overlap area of the two zones of possible satellite range error is relatively small. The diagram below on the left illustrates a pair of widely spaced satellites which would result in a good or low DOP value. The diagram on the right in Figure 6-1 illustrates poor satellite geometry resulting in poor or high DOP.
A DOP value of less than 2 is considered excellent—about as good as it gets, but it doesn’t happen often, usually requiring a clear view of the sky all the way to the horizon. DOP values of 2 to 3 are considered very good. DOP values of 4 or below are frequently specified when equipment accuracy capabilities are given. DOP values of 4 to 5 are considered fairly good and would normally be acceptable for all but the highest levels of survey precision requirements. A DOP value of 6 would be acceptable only in low precision conditions, such as in coarse positioning and navigation. Position data should not be recorded when the DOP value exceeds 6.

It’s important to carefully consider where the data is to be collected. Is the area of interest on Main Street of a large city? If so, the receiver is likely to be surrounded by tall buildings that restrict satellite visibility resulting in poor DOPs, since the only satellites that the receiver can see will be nearly straight up. That is, provided it’s even possible to see enough satellites to get a position at all. In addition, the glass-sided structures all around the receiver act as nearly perfect multi-path reflectors. It’s possible that, because of the efficiency of the buildings to reflect the incoming satellite signal, the receiver’s multi-path rejection capability may actually be overloaded. These are very difficult problems to overcome, particularly in dense urban areas with many tall buildings. And the problems aren’t just in the cities. Even out in the country with wide open spaces there are conditions to be considered. Close proximity to high-power lines is a problem. The electromagnetic radiation surrounding the lines can interfere with the satellite signal, contributing an error that is nearly impossible to compensate for or model. Forests with dense canopy cover can obscure the sky and interfere with the incoming satellite signal. The problem is even worse if the vegetation is wet, since the liquid water itself can also interfere with the signal.

- **Human Error.** The greatest contributor to error in GPS measurement is human error. Care must be taken while performing any GPS survey to keep human error to a minimum by proper procedures, redundant checks, repeat measurements and GPS observation log reports. The following are some common examples of human error:
  - Misreading antenna height measurements
  - Transposing numbers entered electronically
  - Rushing observations
  - Poor centering and leveling over points
  - Observing the wrong survey point (for example, observing a reference mark instead of the actual mark itself)
  - Incorrect equipment configuration settings
EQUIPMENT

NDOT is currently using GPS equipment from various manufacturers such as Leica and Trimble and also various generations of old and new. Therefore, you will need to refer to the operating manuals on the actual setup and operation of your equipment.

RECEIVERS

RTK surveys utilize two or more receivers. One is used as a reference or base station over a control monument. The other receiver or (rover) is moved from point to point collecting data. Additional receivers can be employed to achieve better productivity.

BASE RADIO

A radio or cellular link between the receiver and the rover is required. Some receivers utilize an internal radio while others need an external base radio to transmit to the rovers. The rover has a built-in radio to receive data from the base. Most external base radios include an antenna that mounts on a standard tripod and are powered by its own battery. The rover units have a small whip antenna and do not require an external power source.

DATA COLLECTOR

The Data Collector is needed for running the rover receiver. The Data Collector gives control over the survey and records data. It communicates with the rover by either cable or by Bluetooth. Most Data Collectors work exclusively on their manufacturer’s equipment and will not communicate with other brands. Most Data Collectors have an internal battery. Each manufacturer has its own menu’s and procedures. Therefore, the operator’s manual must be referenced.
SOFTWARE
Each manufacturer has its own version of software for downloading data from the Data Collector and receiver. Data can then be manipulated from your personal computer and transferred back to the Data Collector for stakeout.

MISCELLANEOUS
Observe the following recommendations and precautions:

- Use a fixed height rod for both the base and the rover to eliminate height of instrument mistakes.
- Use bi-pod leg attachments when performing calibration shots.
- Check “fish eye” level bubbles frequently for plumb.
- Always take caution when winding up cords as they have glass encasements inside that if kinked will break and malfunction.

BATTERIES AND BATTERY CHARGERS
Supply the electricity required to run GPS equipment. Plan ahead to keep your batteries in the best condition and fully charged. Each supplier that delivers your GPS units include chargers that correspond with that equipment. Do not mix and match chargers and/or cables not meant for each particular unit. The life of the batteries can be affected by temperature. During very cold conditions, place hand warmers or other suitable devices inside the base/radio case. Keep rover batteries in a heated truck or in an inside pocket to keep them warm until needed. Conversely, when surveying in very hot conditions, keep the equipment off the direct surface of the ground by using a blanket and make sure to keep the equipment shaded as much as possible. It may be necessary to adjust your surveying times to reflect the coolest possible times.

There is one other issue with batteries that might need to be mentioned. This is the slow deterioration that occurs over time. When battery life declines by half, get rid of the batteries and replace them with new ones. The lost time and maneuvering in the field to keep changing batteries is not cost effective.

EQUIPMENT MAINTENANCE
At the beginning of any survey and at least every 6 months, all survey equipment should be checked and adjusted if needed. Checks and adjustments shall include but are not limited the following:

- Tripods - nuts and bolts are tight, no loose or broken legs, tripod head is tight, flat, and not damaged.
- Fixed Height Tripods - level bubbles are in adjustment, rod is not bent or damaged, height of rod is correct as reportedly measured, and legs are secure.
- Rods - level bubbles are in adjustment, rod is not bent or damaged, height of rod is correct as reportedly measured, and adjustable rod height clamps are secure.
- Tribrachs - optical plummets are in adjustment, level bubble is in adjustment, no loose legs, no loose or missing screws, bottom head is flat and not damaged.
- Cables - no cuts, breaks, pinch marks or damage.
- Receivers - no cracks or visible signs damage.
- Receiver Antennas - if equipped with a ground plane, it is not bent or warped, no cracks or visible signs of damage.

Follow the manufacturer’s recommendations on the care and storage of your equipment. Store the equipment in a secure area and do not store the equipment in a wet case.
PROCEDURES

Proper planning is an important step in an RTK survey. The first step in beginning a survey is to locate control monuments in your project area. These can be found in the contract plans project control sheets (refer to “Monument Identification”, in Chapter 2, for more information). Use at least six to eight control points for a site calibration (the minimum is three for horizontal and four for vertical). Place the calibration points around the perimeter of the job site. Do not survey outside of the area enclosed by the calibration points as the calibration is not valid beyond this perimeter.

There are times of the day when the number of satellites available will vary. The positions of the satellites at various times of the day are also a factor. Planning your work around these times greatly increases productivity and the quality of your results. The selection of the base station sites will also affect the success of the RTK observations. The base should be situated in a location that minimizes obstructions. A problem at the base will affect all rovers. In general, a clear view of the sky above 15 degrees is desired. At least five healthy satellites must be observed and the PDOP shall not exceed six during any GPS survey observations.

Consider the following when choosing a site:

- Sites should be free of vertical obstructions blocking the horizon such as buildings, overhangs, terrain, trees, fences, utility poles, overhead lines, or any other visible obstructions. Non-obstructed skies 15 degrees above the horizon are best.
- Sites should not be located close to radio transmitters including cellular phone equipment, because they may disrupt satellite signal reception.
- Sites close to large flat surfaces such as signs, fences, glass, or utility boxes should be avoided.
- If feasible, sites should not be disturbed by future construction activities and should be outside the design construction limits and top of cuts for the contract.

PREPARING THE DATA COLLECTOR

- Set up the data collector for an RTK survey. The methods will vary depending on the manufacturer. Therefore, the operator’s manual should be referenced. Trimble uses a feature called a “survey style” which is a template of settings for different types of surveys. Each style contains dozens of settings for receivers, base and rover radios, etc.
- A feature code library should be loaded into the data collector. (Refer to file:\datsrv\1017Public\FeatureCodeLibraries\SUE for more information.)
- Set up a job on the data collector.
- Enter the names, coordinates and ortho elevations of the control points that were selected. When naming points, use different names for Grid and WGS-84 coordinates with grid being keyed in from the project control sheets and WGS-84 from 3-minute field observations. For example, a point named 997117 S use 997117 S for grid coordinates and G997117 S for WGS-84 coordinates.

BASE STATION SET-UP

To set up the base station for RTK survey:

1. Select a location over a control point where there is a clear and unobstructed view of the sky and preferably this location is higher than the area to be surveyed.
2. Set the GPS receiver antenna over the control point and face it to the north. GPS antennas should be set up over the points using fixed-height antenna tripods. When using standard tripods with a tribrach, the antenna slope-height will be measured multiple times (per manufacturer’s directions) and the average recorded.

![Base Station Setup Diagram]

- $H = \text{True height of fixed height tripod rod}$
- $S = \text{Slant height field measurement}$
- $C = \text{Distance for addition of ground plane}$
- $R = \text{Radius from antenna phase center to edge of ground plane}$
- $\text{BGP} = \text{Bottom of ground plane (or antenna)}$

3. Attach the GPS antenna cable to the GPS antenna and then into the GPS receiver. (In some units, the receiver is built into the antenna. Therefore, this step is unnecessary).

4. Attach the data cable to the receiver.

5. Attach the battery to the base receiver.

6. Set up a tripod and place the radio antenna on it approximately 20 feet away from your GPS antenna.

7. Plug the radio antenna cable into the antenna port on the Trimmark 3 or other radio.

8. Attach the power cable to the external radio battery and plug the other end into the radio.

9. Plug one end of the radio cable into the base receiver and then the other into the radio.

10. Turn on the receiver.

To start a Trimble base receiver:

1. Start a file in your data collector by selecting Files from the main menu. Select New Job. Name your job and then tap coordinate system. Four choices will come up. For this time, select no projection/no datum. The screen will change and make sure the coordinates are selected Ground. Enter in the project height (can be found on the LPN sheet) and select Use Geoid Model. Select the proper geoid model and hit Store. Make sure your feature code library is selected (refer to file:\datsrv1\017Public\FeatureCodeLibraries\SUE for more information) and that US survey feet is entered in the units category. Enter in the LPN number and your name and hit Accept.

2. Connect the data collector to the data cable already attached to the Trimble base receiver and select Survey. Then select the appropriate RTK survey style. Then select START BASE RECEIVER.
3. It will ask for a point number. Key in the point name and code. Select the Here button down on the bottom. This will give you a general location of your base station and allow you to calibrate on the control points.

4. Disconnect data cable and key in Grid Coordinates and ortho elevations of the control points that were selected. Use the point names from the project control sheets.

5. Turn on the rover and wait for it to initialize before you leave the base.

**CALIBRATION**

To obtain a site calibration:

1. Attach the bipod legs to your rover rod (this is mandatory).

2. Face the antenna to the North for each measurement.

3. Go to control points that are outside the limits of your job usually before, after, in the middle and outside of the Right-of-Way if possible. You want to try and surround your jobsite if possible. Shoot at least six to eight control points for the calibration and remember that you should only shoot within 6 miles of your base. Always remember to name the shots you do in the calibration the number that is in the LPN sheet with a “G” placed in front of it to keep the points straight.

4. At the occupied point, face your predetermined direction and place the rod tip in the divet, firmly step on the bipod feet to sink them into the ground, level up, select Start Survey, then wait for the rover to initialize. Select Measure Points and select Observed Control Point for your choice of shot type.

5. After the 3-minute shot, collapse the legs and pick up and go to the other monuments for their shots.

6. Once you have completed all of the shots you want to do, you may start the field calibration in your data collector.

7. Select Key in / Points from the main menu. Set the type field to Coordinates. Check that the coordinate fields are North, East, and Elevation. Enter in any control points that have not been entered already.

8. Select the point pairs that you want to use for the calibration by selecting the LPN coordinates number and then your survey shots with the same name and the “G” prefix.

9. Once you select the point pairs, evaluate the vertical and horizontal residuals. You want to do the horizontal first. Try to hold the furthest points out from the job to get the widest calibration possible. Toggle on/off the horizontal portion of the selections on each of the pairs to determine if you get better residuals. Once you get the horizontal residual to be .03 or less, work on getting the vertical as low as possible. Once you get both as good as you can get them, fix the scale factor to 1 and then hit Apply.

10. Once the calibration is complete and you accept the results, never re-calibrate on this area as you do not want to change the relationship between all of the control points and the subsequent points you shoot. Multiple calibrations along a roadway should be connected at the ends by using one or two of the same control points in each of the associated calibrations. This enables the two calibrated surfaces to be held together at this point and removes the possibility of elevation breaks that can plague some contracts.

11. Once you have a calibrated site, you should be able to set up your base receiver on any of your control points you have in your data collector.

**FIELD OBSERVATION**

RTK GPS surveying is similar to a Total Station radial survey. The protocols used in point collection are the same in both methods of surveying.

Once the gear is set up and you have started the base receiver, you can initialize and start the survey. It is generally best to make sure you have a radio signal from the base, and the rover is initialized before leaving the area.
Measuring points can take a couple of different forms:

- **Topo Point method** is a shot that takes approximately three seconds to take once you hit measure. This is a very accurate shot and should be taken when shooting concrete and/or plantmix bituminous surfaces, flow lines of pipe or drop inlets, and basically any time that good elevation is required.

- **Continuous Topo** is another option where the vehicle or rod mounted rover can take a shot in a selected time or distance interval.

- **Rapid Point** has the least quality of the methods. It only takes about a second to take one of these shots, and this method should only be used on cross sections for borrow pits and original surfaces on dirt.

- **Stake out.** Once calibrated, the project's alignment can be entered into the data collector or downloaded from a personal computer in the office. Any point on the alignment can be staked out and offset as long as it is inside the calibrated area.

**FEATURE CODES**

Always remember to use the proper feature code on your points. (Refer to file:\dat srv1\1017Public\FeatureCodeLibraries\SUE for more information.) Improper coding is the number one problem when trying to create breaklines and surfaces and can lead to costly mistakes. Features should be shot sequentially whenever possible to reduce the amount of editing on breaklines in the office.

**TROUBLESHOOTING**

If you are having trouble getting your base and rover to communicate via radio link, consider the following:

- Are both the base and the rover set to CMR+ (in "Broadcast format" in the survey style on the controller)?

- Is the correct antenna type in the survey style for both the base and the rover?

- Is the correct radio type in the survey style for both the base and the rover?

- Is the power setting for the base radio appropriate for the distance between the base and rover?

- Does the base radio frequency and wireless mode settings match on the base and the rover?

- Is the coordinate system appropriate for the region?

- Is the base radio in the right broadcast mode?

- Check that all cables are correct.

- Check batteries.

- Power the receivers and Data Collector off and then back on and restart the base with the Data Collector. Sometimes a power cycle is all that is needed.

**NOTE:** Different manufacturers may refer to these methods by different names so read through the operator's manual for the correct procedures for your equipment. This guide was created with Trimble GPS equipment in mind.
CONSTRUCTION STAKEOUT
OVERVIEW

Survey classifications can describe the survey activity (such as construction surveys) or the survey methodology (such as geodetic surveys). Following are some of the types of surveying available:

- **Geodetic Surveys:** This type of survey has occurred in Nevada since 1965 and establishes control networks on a mathematical datum that closely approximates the shape of the earth. The introduction of the Global Positioning System (GPS) made this type of surveying easier and essential on most contracts.

- **Control Surveys:** This type of survey establishes the horizontal or vertical positions of arbitrary points to be used as a reference in past and future surveys.

- **Cadastral/Boundary Surveys:** This type of survey retraces and establishes property boundaries, including highway right-of-way. To conform to state law, a Professional Land Surveyor (PLS) must perform these surveys.

- **Topographic Surveys:** This type of survey determines the ground configuration (contour and relief) and location of physical or manmade objects.

- **Engineering Surveys:** This type of survey helps to estimate the design and cost of fixed works.

- **Route Surveys:** This type of survey helps to do the following:
  - Locate, design, and construct transportation facilities.
  - Establish construction control monuments.
  - Establish alignment for proposed roadways, structures, and other appurtenances.
  - Determine the terrain and the location of significant features, such as structures and utilities along the proposed route.
  - Establish the location of the route by survey lines.

- **Construction Surveys:** This type of survey establishes ground stakes and other reference points at known horizontal and vertical positions. These stakes define the construction location and size, which enables contract inspection and provides a basis for payment for work.

- **Aerial Survey or Photogrammetry:** This is a measurement method applicable to various surveying activities. Normally, it utilizes aerial photographs and specialized office equipment to perform control, engineering, topographic, and other surveys.

The construction surveys for a roadway consist essentially in (1) staking out earthwork and structures preparatory to, and during the process of, grading and construction, and (2) making the measurements necessary to determine the volume of work actually performed up to a given date, as a basis for payment to the Contractor.

Construction survey parties are under the direction of the Resident Engineer, and it is necessary that they be familiar with effective methods of staking. The Resident Engineer is directly responsible for survey marks and stakes set. Regardless of how the survey parties are organized, the Resident Engineer must have full knowledge of the methods used and results accomplished.

The contractor’s operations dictate surveying activities during construction. For example, if the contractor is planning to clear and grub, the survey crew completes surveying to support the clearing and grubbing operation. Detailed planning, with the coordination of the Contractor, and timely start of staking is required. The Resident Engineer should instruct his Surveyor to anticipate as near as possible the Contractor’s needs in regard to staking or taking measurements. Under no circumstances shall any delay in staking be permitted that will hinder the construction operation. The Contractor shall provide a written request for survey to the Resident Engineer/Crew Chief, who will track all requests.
Survey operations on a contract may consist of any or all of the following:

- Reproducing centerline
- Referencing control points
- Setting clearing and grubbing limits
- Setting slope stakes
- Staking culverts and structures
- Data collection (pre-and post-construction)
- Signs and electrical
- Staking permanent survey monuments
- Setting construction bench marks
- Staking Right of Way fences
- Cross sectioning and measuring borrow pits, etc.
- Preserving monuments and markers
- Staking curb/gutter, barrier rail, and guardrail

Survey field notes shall be recorded in a manner that allows for easy access and retrieval. Methods for recording data vary. TBC reports, IDR’s, or other electronic forms of reporting data collection are preferred. Notes shall be clear and in sufficient detail to be thoroughly understood by anyone not familiar with the contract. Too much detail is better than too little.

FIELD OFFICE PREPARATION

The Resident Engineer must rely to a large extent upon crew personnel to prepare the necessary stakeout data prior to the start of construction on a contract. For this reason, it is essential that the Resident Engineer select and train competent personnel for utilization in the field office.

Preliminary plans are generally submitted prior to award of the contract. Most stakeout calculations can be started and some may even progress to a completion stage before the final plans are received. If this occurs, all data should be checked for accuracy before any field stakeout begins.

As in all phases of construction engineering, a general order for stakeout computation completion can be created, but the sequence will not apply in all instances. The following list will provide a very brief overview of some of the initial computations which must be made prior to the start of construction:

- Alignment: Construction alignment books should be compiled as soon as possible. In most cases, the original alignment must be reproduced and any changes in length noted and necessary distance measurements adjusted. All curve deflections, tangent lengths, etc., should be calculated and checked prior to sending the book to the field.

- Slope stake: Slope stake data for the roadways must be prepared and checked. The slope stake books should include all of the information necessary for the construction crew to accurately set the slope stakes in the field. Stations, grade percent, vertical curve information, elevations, shoulder distance, ditch, and slope information must all be indicated in the slope stake book.

- Structures: Structure books must be completed for the culvert and bridge structures if required. Care should be exercised when calculating structures as they have a definite bearing on the durability of the finished roadway.

- Grade books: Grade books should be completed by the time subgrade is complete to aid the construction crew in setting “red heads” or grade stakes.
It should be stressed that the above stakeout computations should be accurate and complete. All computations and all other stakeout data must be checked and verified.

**NOTE:** If mistakes are made, line them out and write the correction above or below. Never erase or use correction fluid, ink, or tape.

**GRADE STAKES**

Use grade stakes, or “Red Heads,” to control the required grade for subgrade and gravel base courses. Follow these guidelines when setting grade stakes:

- Typically, set grade stakes on the shoulders, centerline, and intermediate points on the roadway. Must be close enough for moldboard to span grade stakes.
- Set grade stakes for subgrade at all stations and half stations.
- Set the grade stakes at closer intervals on sharp horizontal curves and vertical curves.
- Always set grade stakes at right angles to centerline.
- Set the top of the grade stakes within 0.03 foot of the desired grade.
- When the roadway grades are less than one percent, also set the grade stakes in the roadway ditch every 50 feet.

Grade stakes for the gravel base course are set on the same stations and half stations as for subgrade. Grade stakes should be long enough to ensure they will not be moved or pulled out while the contractor is grading. Use a steel pin to make a pilot hole to make driving the grade stake easier.

**GRADE FOR MACHINE LAY DOWN**

Specifications that require mixing and machine lay down of base and surface aggregates have created the need for more exacting methods of grade and slope control. The specific method used depends on the contractor’s preferences and the type of equipment used.

Shortly after construction begins, determine the type of placement equipment that will be used. This information is important for preparing grade books and placing grade controls in the field.

You can use several methods for grade control, depending on equipment or contractor preference. Coordinate between the survey crew chief and the contractor to determine the best grade control method.

For elevation control, drive a metal pin, long nail, or hub with nail in convenient locations near, but outside, the roadway section, at least every 50 feet. In curves, you may need control points at 25-foot intervals. You may need control points on only one side of the roadway. In this case, establish alternate check controls on the opposite side of the roadway at 100-200 foot intervals.

The Resident Engineer and the contractor should determine the transverse location of the control points. In most cases, locate control points in accessible and convenient positions. You can protect the control point by placing the top of the control point approximately 0.1 foot beneath the surface of the subgrade or select material base.

Following are the two methods to set elevation control points. Maintain uniformity with either method:

- Drive them to a specific elevation below finish grade, for example, 25 inches below finish grade (24 inches surfacing, 1 inch beneath subgrade).
- Drive them to a random elevation below finish grade, and compute the fill to the finish grade.

Provide a reference or guard stake for each elevation control point. The reference stake should show the amount of fill to finish grade as well as the cross slope or crown at the particular station. The contractor should be familiar with the information on the reference stake and should ensure that grade setters and equipment operators are also familiar with the information. The Resident Engineer should set elevation control points only once to avoid confusion.
COMMON STAKES AND MARKERS

HUB
Wood (1 1/2” x 1 1/2” x 12”) to be used (with a “hub tack”) for all control points.

Figure 7-1: Hub

GUINEA
Wood (3/4” x 3/4” x 6” or 8”) to be used for all non-control points (centerline, slope stakes, fence points, guide posts, etc.)

Figure 7-2: Guinea
**LONG STAKE**

Wood (1 1/2” x 3/4” x 16”) to be written on with “lumber crayon” or “paint pen” to provide information about the “Hub”, “Guinea”, or any other point which it is witness to. It should be driven near (6 to 12 inches) the point it describes (leaning slightly toward it) and far enough away as to not disturb the point.

**SHORT STAKE**

Wood (1 1/2” x 3/4” x 8”) to be used for grade stakes (redheads), level loops, etc.
CONCRETE NAIL AND SHINER

Metal (various sizes) to be used as a Guinea in surfaces such as asphalt or concrete.

LATH

Wood (3/8" x 1 1/2" x 36") to be used to mark all points of importance. Care should be taken as not to cover any information on the stake nor disturb the “Hub” or “Guinea” when setting the lath. When cut into thirds or quarters, they are used to guard “redheads”.

Figure 7-5: Railroad Spike

Figure 7-6: Concrete Nail and Shiner
Figure 7-7: Lath

FLAGGING
Plastic ribbon is tied onto lath in order to help identify just what the point is that the lath is set next to.

Control points shall be color-coded as follows:

- Orange with White: Centerline control and reference points (alignment)
- Red with White: Reserved for Bench Marks (usually “barber-poled” around lath)
- Blue with White: Drainage, Pipe, Drop Inlets, RCB Stakeout
- Yellow with White: Electrical stakeout
- Green with Orange: Slope stakes
- Red with Blue: Right-of-Way Fence stakeout, temporary easements
Figure 7-8: Flagging Ribbon

Combinations of flagging are used in order for our points not to be confused with the Standard Flagging being used by utility companies.

**NOTE:** Other combinations should be used to mark points which are not covered previously.

**ALIGNMENT AND HORIZONTAL CONTROL**

Establishing alignment and horizontal control is one of the initial field activities undertaken by the survey crew. The horizontal control is typically established with Total Station or GPS instruments.

The centerline of construction shall be reproduced from the plans and shall be marked by witness stakes driven on centerline facing the initial station of the survey.

In case the line to be constructed differs from the line originally staked, the line to be constructed shall be established to connect with adjacent portions of the centerline. In staking these revisions, care should be exercised to ensure that the relationship is maintained between the original and revised line. An accurate tie shall be made to the original line at the end of the revision.

When reproducing centerline and a discrepancy is found with that shown on the plans, the work shall be checked until the Resident Engineer is satisfied that a discrepancy exists and the location and amount of discrepancy is known. At the point where the discrepancy is found, an equation shall be made and the plan station shall then be carried forward from that point. This must be done so that construction records will agree closely as possible to the plans and estimates designed for the contract.
Reference points may be set at the same time that the centerline is being reproduced, or immediately thereafter. A sufficient number of control points shall be referenced so that the centerline can be reproduced at any time without retracing any great length when only a short section is required.

Reference points should be placed in such places so that they are protected from any construction operation. They should be set so that the point referenced can be reestablished in the same manner as the original. The angle of intersection between the reference line and the centerline shall be measured and noted in the transit book along with the horizontal measurements to the reference hubs. As far as possible, the measurements should be made without the benefit of slope chaining or breaking chain. For horizontal control, the survey accuracy is 0.02 foot.

The planned location of Right-of-Way monuments should be reviewed prior to referencing, as it is entirely possible that staking of the Right-of-Way monuments and the referencing of centerline points may be accomplished at the same time.

 NOTE: Methods for recording data vary. TBC reports, IDR’s, or other electronic forms of reporting data collection are preferred.
Figure 7-9: Sample Alignment Stakes
Figure 7-10: Centerline Stake

Figure 7-11: Reference Point
VERTICAL CONTROL

Establish construction benchmarks no more than 500 feet apart. In case a benchmark is disturbed, this spacing provides a nearby benchmark. To preserve benchmarks and reduce the possibility of disturbance, establish benchmarks away from construction activities, such as near the right-of-way line.

A benchmark establishes vertical control and is a stable, physical point, such as a length of reinforcing steel driven into the ground or a railroad spike driven into a utility pole, with the elevation of the point written on a witness stake.

Construction bench marks should be set to avoid running level circuits a considerable distance to establish an elevation. Construction bench marks are usually required near major structures, special construction areas, or where the terrain is rugged and preliminary bench marks are difficult to reach. Construction bench marks shall be established by the same procedure and to the degree of accuracy as required for preliminary bench marks set by the Location Division. All bench marks, whether they are Line Designated (“X” BM) or Construction Designated (Con. BM), should be numbered to coincide with the stationing. (i.e. Con. BM #13 would be located either left or right of station 13+00.)

DEGREE OF ACCURACY

Closed Circuit Accuracy – 0.02 ft between established bench marks

Structures, Culverts, Bridges, etc. – 0.02 ft between bench marks

BENCH MARK STAKES

To be used as a witness stake to a steel pin or any other object designated to be the bench mark. The stake should be driven far enough away from the bench (front facing centerline) so as not to disturb it.

Figure 7-12: Sample Bench Mark Stake

CROSS SECTIONS

Cross sections may be required in some cases due to alignment change, insufficient cross sections taken during original survey, or for various other reasons. When this is required, the same minimum requirement as set out for location surveys will be followed.
Cross sections shall normally be taken on stations, plus 50’s and equations. Additional plus stations shall be added as necessary to show such things as drainage, slip outs, drop-offs, etc. Cross sections shall be taken at right angles to the centerline on tangents and on radial lines on curves. If this is not possible due to physical limitations or obstacles, enter the reason for deviating and the angle that it was taken on.

**NOTE:** Methods for recording data vary. TBC reports, IDR’s, or other electronic forms of reporting data collection are preferred.

**SLOPE STAKES**

Slope stakes are set at locations where the top of cut slopes and the toes of fill slopes meet the original ground and shall be known as the “catch point”. The markings on slope stakes pertaining to the cut or fill and the distance shall be large enough to be easily read, and the back of the slope stake shall have the station of the section staked. The sides of the slope stake should contain all pertinent information necessary, such as subgrade shoulder distance, slopes, depth of roadway ditches, etc.

A guinea shall be set at the catch point and at the same elevation as the catch point was computed. The cut or fill information shall be written on the slope stake, and it shall be driven far enough beyond the guinea so as not to disturb it. The cut or fill information shall face centerline of the roadway. A guard lath shall be placed 6 to 8 inches back on-line from the guinea to protect it.

The use of a guinea has a two-fold purpose. The guinea shows the contractor where the rod reading (shot) was taken, and that he has a definite take-off point to begin construction. Also, if the slope stake is accidentally knocked out or moved during construction, the catch point can be recovered. If a slope stake has been stuck in the ground and no guinea is present, the contractor and the engineering personnel will know immediately that it is not a catch point.

Slope stakes shall be set at right angles to the centerline on tangents and on the radial lines of curves. Use an instrument for this if necessary. Stations, plus 50’s and equations shall be slope staked and any other pluses that will be helpful to the contractor to produce a well contoured roadway.

Elevations and distances are measured and recorded to the nearest tenth of a foot. Only cloth tapes that are in good shape shall be used.
Slope stakes may be set by several different methods, depending upon the terrain of the area. The most efficient method shall be used. The selection shall be based on the judgment of the Resident Engineer.

The following methods apply:

- The use of level, tripod, level rod, and cloth tape. This method is generally best suited to relatively flat terrain where it is possible to run the profile of centerline and set the slope stakes while at the same instrument set up. It is often supplemented by use of the hand level to establish slope stakes when it is not possible to set the stakes from the instrument set up.

- Use of a hand level, level rod, and cloth tape. Prior to use of this method of slope staking, it is necessary to run a centerline elevation and determine the cut or fill. From the centerline data, it is then possible to set the slope stakes by use of the hand level. This method is suited to locations where visibility with an instrument is restricted, or where the terrain is moderately rough.

- Use of instrument, level rod, and tape or electronic measurement. This method is employed in any terrain but especially mountainous country where it is more expedient to transfer elevations and distances by means of slope measuring than by hand leveling.

- Due to advancements made in technology, especially with the advent of the Total Station and GPS, there is now the "radial method" of slope staking. This is one of the most expedient methods in use today. However, as with any method used, care must be exercised in establishing all points being occupied.

**NOTE:** No matter which method is employed to slope stake, all work (calculations, angles, distances, etc.) must be recorded in an appropriate manner so that it may be checked in the field office. Methods for recording data vary. TBC reports, IDR’s, or other electronic forms of reporting data collection are preferred.
Figure 7-14: Typical Roadway Section

Figure 7-15: Sample Slope Stake Book
**WRITING SLOPESTAKES**

*Note: the front on the stake is to face centerline*

<table>
<thead>
<tr>
<th>LEFT SLOPESTAKES</th>
<th>RIGHT SLOPESTAKES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>&quot;Fr&quot; 11+50</strong></td>
<td></td>
</tr>
<tr>
<td><img src="image1" alt="Stake Diagram" /></td>
<td><img src="image2" alt="Stake Diagram" /></td>
</tr>
<tr>
<td><strong>&quot;Fr&quot; 11+00</strong></td>
<td></td>
</tr>
<tr>
<td><img src="image3" alt="Stake Diagram" /></td>
<td><img src="image4" alt="Stake Diagram" /></td>
</tr>
<tr>
<td><strong>&quot;Fr&quot; 10+50</strong></td>
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</tr>
<tr>
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<td><img src="image6" alt="Stake Diagram" /></td>
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<tr>
<td><img src="image7" alt="Stake Diagram" /></td>
<td><img src="image8" alt="Stake Diagram" /></td>
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</table>

Figure 7-16: Sample Slope Stakes
Figure 7-17: Catch Points of Various Typical Sections
Figure 7-18: Various Methods to Establish Catch Points
Figure 7-19: Field Report of Slope Stakes
Figure 7-20: Slope Stake Showing Cut/fill Information; Backslope, Ditch and Foreslope

Figure 7-21: Slope Stake Showing Station, Superelevation, and Shoulder
Figure 7-22: Slope Stake on I-580 (Contract 3292)

Figure 7-23: Slope Stake on I-580 (Contract 3292)
Figure 7-24: I-580 Freeway Prior to Construction

Figure 7-25: I-580 Freeway Under Construction
DRAINAGE

Pipe and storm drain should be staked as soon as possible and the “pipe list” prepared. Delay in staking of pipe can cause delay in the contractor’s operation, which may lead to delay of the contract and/or a claim against the Department. Construction bench marks (Con. BM’s) set near the pipe, as well as preparing a pipe book with all pertinent information, will expedite the staking and also give better control for installing the same. Further aid in the staking of pipe can be accomplished by having the pipe stations located at the same time the centerline is being reproduced.

The centerline of pipe shall be indicated by hubs driven on the centerline produced at such a distance from the end of pipes (or headwall) to protect them from disturbance. Elevations should be taken on the hubs and the cut or fill to flow-line of the pipe determined, and the necessary information plainly marked on the stakes. Designers typically add additional length to culverts depending on fill slope. Be sure to reference the minimum culvert installation detail in the Standard Plans if additional length of culvert is necessary.

Figure 7-26: RCP Stakeout (1 of 3)
Reinforced Concrete Boxes should be staked as soon as possible also. This information is very important to you as well as the contractor. If there are any changes, such as length or skew, all concrete and reinforcing steel will require recalculation.

Figure 7-29: Reinforced Concrete Box Stakeout

NOTE: The following samples include various stakeout data for drainage features recorded in “traditional” field books. Methods for recording data vary. TBC reports, IDR’s, or other electronic forms of reporting data collection are preferred.
Figure 7-30: Manhole Layout
**Figure 7-31: Pipe Run Sample (1 of 15)**

<table>
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**Figure 7-32: Pipe Run Sample (2 of 15)**

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<td>Stakeout Data</td>
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<td>...</td>
<td>...</td>
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</table>

State of Nevada Department of Transportation Construction Division
Construction Survey Manual
November 2017
Figure 7-33: Pipe Run Sample (3 of 15)

Figure 7-34: RCB Layout Sample (4 of 15)
Figure 7-35: Pipe Run Sample (5 of 15)

Figure 7-36: Drop Inlet Sample (6 of 15)
Figure 7-37: Drop Inlet, Pipe Run, and Manhole Sample (7 of 15)

Figure 7-38: Drop Inlet, Pipe Run, and Manhole Sample (8 of 15)
Figure 7-39: Manhole Sample (9 of 15)

Figure 7-40: Manhole with Pipe Run Sample (10 of 15)
Figure 7-41: RCB with Headwalls Sample (11 of 15)

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</tr>
<tr>
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</tr>
<tr>
<td>D.T.</td>
<td>10.69</td>
</tr>
<tr>
<td>L.I.E.</td>
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<tr>
<td>H.T.</td>
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<tr>
<td>Tow of Draw Str.</td>
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</tr>
<tr>
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<td>6.78</td>
</tr>
<tr>
<td>P.S. Stiffn.</td>
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</tr>
<tr>
<td>Fl. Angle</td>
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<tr>
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</tr>
<tr>
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</tr>
<tr>
<td>25 Feet</td>
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</tr>
<tr>
<td>30 Feet</td>
<td>75.79</td>
</tr>
<tr>
<td>40 Feet</td>
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<td>Total Length</td>
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Figure 7-42: RCB with Headwalls Sample (12 of 15)

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<tr>
<td>30 Feet</td>
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<tr>
<td>Total Length</td>
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</tr>
</tbody>
</table>
Figure 7-43: RCB with Headwalls Sample (13 of 15)

Figure 7-44: RCB with Headwalls Sample (14 of 15)
BORROW PITS

The reason for layout and cross sectioning a borrow pit is usually to enable us to determine the cubic yards of Borrow Excavation used on a particular contract.
The actual cross sectioning is very similar to that shown in “Cross Sections”, in this chapter; the layout, however, is somewhat more involved. As you are taking the “original” cross sections, you should keep in mind the fact that you really do not know exactly how the contractor is going to mine the withdrawal area. Consequently, you must be sure to catch all “breaks” which lie within the withdrawal limits.

By using a Total Station or GPS, it is possible to data collect the borrow pit before and after to get a total withdrawal for the area by comparing the two surfaces. Methods for recording data vary. TBC reports, IDR’s, or other electronic forms of reporting data collection are preferred.
CURB/GUTTER AND SIDEWALK

As when staking anything, extreme care must be taken when staking curb or curb and gutter. Not only is it highly visible, but it is almost always designed to carry drainage away from roadways. Additionally, many times it is placed prior to paving.

Figure 7-47: Curb and Gutter Stakeout

Consequently, it becomes the control for placement of the plantmix bituminous surface. Good communication with the contractor is essential so that distances along lay out line and lay out line offsets are most effective, yet will not be disturbed.

NOTE: The following samples include various stakeout data for Type 5 Curb recorded in “traditional” field books. Methods for recording data vary. TBC reports, IDR’s, or other electronic forms of reporting data collection are preferred.
### Figure 7-48: Stakeout Data Curb Sample (1 of 2)

<table>
<thead>
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<th>Measurement 2</th>
<th>Result</th>
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<td>+6.25</td>
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### Figure 7-49: Stakeout Data Curb Sample (2 of 2)

<table>
<thead>
<tr>
<th>Description</th>
<th>Measurement 1</th>
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<tr>
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</tr>
<tr>
<td>+6.25</td>
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</tr>
</tbody>
</table>
Barrier rail and guardrail are typically staked to the front face of rail. The beginning, end, terminals, transitions or angle points are some examples of items which need stakes. As noted before, good communication with the contractor is essential so that distances along lay out line and lay out line offsets are most effective, yet will not be disturbed.

Figure 7-50: Barrier Rail Stakeout
SIGNS AND ELECTRICAL

Signs, pull boxes, transformers, cabinets, lights, etc. are typically staked out to the center of the installation. In some cases, offset stakes will be necessary to assist with proper alignment of the installation. Refer to the Standard Plans to ensure proper stakeout and placement.
Figure 7-52: Electrical Stakeout

**UTILITIES REFERENCING**

In urban areas, utility access points, such as manholes and valve box covers, are commonly located in the roadway. If planned construction will disturb or alter the utility access point, the utility access point must be preserved. To do this, the cover is first lowered and the roadway is constructed. Each access point is then relocated and adjusted to match the final roadway elevation. At times, contractors have not found all of the lowered access points. To help relocate access points, identify and reference the location of existing utility access points before construction begins.
OVERVIEW

The following chapter is an outline for requesting and purchasing equipment, inventory responsibilities and repair request procedures.

PURCHASING AUTHORITY

Purchasing of budget items for construction survey will need to be directed through the Construction Division. In the spring of each year, the Chief Construction Engineer will send out the budgetary requests for equipment over $5,000 for the fiscal year. This will be the Resident Engineer’s opportunity to request new equipment for the next fiscal year. Your request must be returned to the chief for review and approval.

Purchasing of non-budget items for construction also need to be requested through the Construction Division by phone or e-mail, or with a completed “Combination Request for Supplies, Equipment and Shipping Record” form (aka “Form 51”). This will ensure timely delivery of parts and services and less confusion for vendors.

The Construction Division requests that all repairs be coordinated through the Construction Division, and suggests that all Trimble equipment be sent to Carson City for distribution. (If you are close to Reno, deliver directly to Monsen Engineering and notify the Construction Division). All Leica equipment is serviced by Kuker Ranken, Inc. This will better facilitate repair of survey equipment and provide a single point of contact, so the Department can improve the tracking and documentation of repair for future equipment replacement and repairs. Please consider the use of the construction sample runner for shipping. This approach will save the state money and ensure safe arrival of equipment.

For further information, contact the following:

- **NDOT Division, Quality Assurance Section:** Equipment purchasing, repairs, parts and shipping
  775-888-7460

- **Monsen Engineering:** Trimble repair and software
  775-359-6671
  [http://www.monsenengineering.com/reno-location.htm](http://www.monsenengineering.com/reno-location.htm)

- **Kuker Ranken, Inc.:** Leica sales and service
  702-604-1872
  [http://www.krinc.net/contact-us.html](http://www.krinc.net/contact-us.html)

INVENTORY RESPONSIBILITIES

All survey inventory items over $5,000 will receive a blue asset tag attached to that piece of equipment; this tag is issued by state purchasing and is recorded in the state inventory records. Please make sure the tag is installed on your equipment in a permanent place on a non-removable part.

Each construction crew has the responsibility of keeping their inventory intact. If a piece of equipment is to be traded, moved or decommissioned, proper paper work must be completed to remove that equipment from crew inventory before the beginning of a state inventory inspection. Once a calendar year, the Construction Division will perform a state-wide survey equipment inventory inspection with construction crews. The inventory review will ideally be scheduled during the slower part of the construction season and will be announced. Survey equipment will be inspected for asset tags, condition and age; this would be an ideal time to obtain the necessary service, parts or small equipment.
Contract XXXX

Survey

- Backup Files
- Control
- Cross Section
- Data Collection
- Drainage
- Electrical
- Forms
- InRoads
- Miscellaneous
- Redheads
- Requested Survey
- Right of Way
- Rail
- Structures
- Signs
- Slopes Stakes
- Walls
**TOTAL STATION**

**CONFIGURATION**

1. Set-up and level your backsight and the Total Station on their appropriate tripods.

2. Connect the power carriage to the Total Station and the Data Collector (recommend both on the same side).

   **NOTE:** There are several ways to provide power, refer to your user's manual.

3. Turn on the Total Station by powering up the Data Collector.

   **WARNING:** Wait for the fisheye level screen to appear on the Data Collector prior to pressing any keys or selecting screen functions. A failure to do so could result in a system lockup, which requires a hard reset of the Data Collector.

4. Fine tune the leveling of the Total Station and accept the conditions.

5. Parameter settings appear on the next screen, where you can enter the temperature, barometric pressure, and prism constant. These settings need a onetime entry from the Data Collector.

6. The basic screen then displays. At this point, you can zero the Total Station on your backsight, measure a quick distance, and turn an angle from this screen, without entering a contract/job file. Otherwise, you may escape from this screen.

7. The Main Screen appears for Survey Controller.

8. Create a new job by selecting: Files > New Job > [enter job name]. Select Coordinate System > Scale Factor=1.00 (always), then select Units (meters or US feet) > Accept to return to the main screen for the job you just created.

9. Open an existing job by selecting: Files > Open Job, then tap on desired job.

   **NOTE:** Refer to your equipment manufacturer's owner's manual for actual input methods. Software compatibility issues may require additional research and updates for accurate data management.

**STATION SETUP**

1. Follow steps 1 - 5 in “Configuration”.

2. From the Survey Controller main screen, select: Survey > [MODEL] >Station Setup > Enter;
   - Occupied point (from either the point list or shoot the point)
   - Backsight point (from either the point list or shoot the point)
   - Total Station height
   - Backsight height

3. Measure [ ] the point/Accept/Store (only if residuals are accurate)

4. Go to “Robotic Surveys” to perform topography-shots, stakeouts, 2-person mode surveys and robotic surveys. Otherwise, go to step 5.

5. After station setup, select Survey > End Survey to prompt Shutdown.
6. Enter No > Survey > Start Robotic. When Auto Centered is fine? is displayed, select Ok > Yes. The Total Station will shutdown.

7. Disconnect the Data Collector cable from the Total Station battery pack and connect the cable to the bottom port on the side of the pole-mounted radio. It takes approximately 30 seconds for the radio to power on and render a beep, which indicates a remote connection is established. During the wait time, you can turn on your prism on top of the pole (green LED’s will flash) and set your prism height on the telescoping pole.

**ROBOTIC SURVEYS**

1. At this point, the Data Collector screen will display the same leveling screen, and you can adjust the bubble accordingly. However, remember heavy level adjustments will force a new station setup. Proceed to the station setup screen and use your last setup if no large leveling adjustments were performed, which will save you redundant entries.

2. You are now ready to perform Topographic Surveys, Measure Points, Measure Rounds, or Stakeouts.

3. The next step is to lock the Total Station on to your remote pole prism. Walk away in-line from the telescope approximately 15 feet while holding the pole and towards the Total Station. If your prism is on the Total Station, it should “Autolock”. If the Autolock fails, select the instrument icon [ ] on the right side of the screen and select Autolock, where the [ ] icon appears while the Total Station searches for the prism. Once locked on, the lights should be solid [ ].

4. Once locked, you can commence performing the previously mentioned surveys.

All of these procedures and/or further information can be found in the device’s help menu or technical documentation.

**SURFACE SCAN**

Surface scanning is an automated direct reflex (DR) measuring process where measurements are automatically stored along a remote surface that you have defined.

To perform a surface scan:

1. Start a conventional survey.
2. From the Survey menu, select Surface Scan.
3. Enter the Start point name and code (if necessary).
4. In the Method field, select a measurement method.
5. Define the area for the scan and grid interval.
6. Tap the function button and set the EDM method (TRK is fastest). The total number of points to scan, scan grid dimensions, and estimated scan time are displayed.
7. Change the scan size, step sizes or EDM method to increase or decrease the number of points and scan time.
8. Tap Start.
DEFINE SCAN AREA

To define the scan area:

1. Do one of the following:
   - If the point already exists, enter the point name, or use menu arrow to select it from the list.
   - From the pop-up menu in the Top left and Bottom right fields, select Fast fix or Measure to measure and store points that define the limits of the search.

2. Follow the steps of the section corresponding to the desired setup method: “HA VA Interval”, “Rectangular Plane” or “Line and Offset”.

**NOTE:** With any selected method, the defined scan area may not exactly fit the grid interval. There may be an area left over along the scan extents that is smaller than the grid interval. If the width of this area is less than one-fifth of the grid interval, the points along this scan area will not be measured. If the width is more than one-fifth of the grid interval, then an extra point is scanned.

HA VA INTERVAL

Use this method on complex surfaces, when you cannot use a rectangular plane to approximate the surface you are scanning (see Figure D-1):

1. Aim to the top left corner of the scan area (1) and measure a point.
2. Aim to the bottom right corner of the scan area (2) and measure another point.
3. Define the angular grid interval, where:
   - 3 is the Horizontal angle.
   - 4 is the Vertical angle.

![Figure D-1: HV VA Method Setup](image)

**TIP:** To define a Horizontal only scan of a 360-degree scan area, set the Top left and Bottom right points to the same name and set the VA interval to null.

RECTANGULAR PLANE

Use this method on a plane surface where you need a regular grid interval.
DATA COLLECTOR SOFTWARE

Determines the angle of the plane and uses this and the grid interval to approximate how far to turn the instrument for each subsequent point.

1. Aim to the first corner of the scan area (1) and measure a point.
2. Aim to the second corner of the scan area (2) and measure another point.
3. Aim to the third point on the opposite side of the plane (3) and measure a point.
4. Define the distance and grid interval, where:
   - 4 is the Horizontal distance.
   - 5 is the Vertical distance.

![Figure D-2: Rectangular Plane Method Setup](image)

LINE AND OFFSET

Use this method to define the area to scan from a center line that has equal offsets to the left and right. Data Collector software defines the surface using horizontal offsets perpendicular to the center line. The software then uses this definition and the station interval to determine approximately how far to turn the instrument for each subsequent point (see Figure D-3):

1. Perform one of the following:
   - Two-point method:
     - Aim to the start point of the center line (1) and measure a point.
     - Aim to the end point of the center line (2) and measure another point. These two points (1 and 2) define the center line.
   - Access the pop-up menu in the Start point field. Change the method and then define the line by a start point with azimuth and length.
2. Define the station interval (3).
3. Define the maximum offset distance (4).
4. Define the offset interval (5).
Figure D-3: Line and Offset Method Setup

Total Station scans the center line first, then the points on the right-hand side and the left-hand side.
<table>
<thead>
<tr>
<th>Glossary Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerial Mapping or Aerial Surveying</td>
<td>A geomatics method of collecting information by using aerial photography, LiDAR or from remote sensing imagery using other bands of the electromagnetic spectrum, such as infrared, gamma, or ultraviolet. It can also refer to the chart or map made by analyzing a region from the air. This is typically done using aeroplanes, helicopters, UAVs such as the InView Unmanned Aircraft System and in history with balloons. Aerial survey should be distinguished by satellite imagery technologies because of its better resolution, quality and atmospheric conditions.</td>
</tr>
<tr>
<td>Aerial Photography</td>
<td>The taking of photographs of the ground from an elevated position. The term usually refers to images in which the camera is not supported by a ground-based structure. Cameras may be hand held or mounted, and photographs may be taken by a photographer, triggered remotely or triggered automatically. Platforms for aerial photography include fixed-wing aircraft, helicopters, balloons, blimps and dirigibles, rockets, kites, poles, parachutes, and vehicle mounted poles.</td>
</tr>
<tr>
<td>Angle of Intersection</td>
<td>The angle between two lines.</td>
</tr>
<tr>
<td>Atmospheric Pressure</td>
<td>The force per unit area exerted into a surface by the weight of air above that surface in the atmosphere of Earth (or that of another planet).</td>
</tr>
<tr>
<td>Azimuth</td>
<td>The angle of horizontal deviation, measured clockwise, of a bearing from a standard direction, as from north or south.</td>
</tr>
<tr>
<td>Barometric Pressure</td>
<td>The value of standard or normal atmospheric pressure, equivalent to the pressure exerted by a column of mercury 29.92 in. (760 mm) high, or 1013 millibars (101.3 kilopascals).</td>
</tr>
<tr>
<td>Backsight</td>
<td>Point with known coordinates or known azimuth from the instrument point that is used to orientate the instrument during a station setup.</td>
</tr>
<tr>
<td>Back Slope</td>
<td>The slope from the back of the ditch to existing ground beyond the ditch.</td>
</tr>
<tr>
<td>Base Grade</td>
<td>The layer of material immediately beneath the pavement. It may be composed of crushed stone, crushed or uncrushed sand and gravel, or combinations of those materials known as aggregate base.</td>
</tr>
<tr>
<td>Bench Mark</td>
<td>A surveyor’s mark on a permanent object of predetermined position and elevation used as a reference point.</td>
</tr>
<tr>
<td>Bluetooth</td>
<td>A proprietary open wireless technology standard for exchanging data over short distances (using short-wavelength radio transmissions in the ISM band from 2400–2480 MHz) from fixed and mobile devices, creating personal area networks (PANs) with high levels of security.</td>
</tr>
<tr>
<td>Borrow Pit (Quarry)</td>
<td>A quarry is a type of open-pit mine from which rock or minerals are extracted. Quarries are generally used for extracting building materials, such as dimension stone, construction aggregate, riprap, sand, and gravel. They are often co-located with concrete and asphalt plants due to the requirement for large amounts of aggregate in those materials.</td>
</tr>
<tr>
<td>Breaklines</td>
<td>A surface feature consisting of a collection of spatial coordinates that have an implied linear relationship.</td>
</tr>
<tr>
<td>Calibration</td>
<td>The act of checking or adjusting (by comparison with a standard) the accuracy of a measuring instrument.</td>
</tr>
<tr>
<td>Catch Point</td>
<td>The point at which a fill slope intercepts the original surface.</td>
</tr>
<tr>
<td>Centerline</td>
<td>A line that bisects something into equal parts. Typically a painted line running along the center of a road or highway.</td>
</tr>
<tr>
<td>Glossary Term</td>
<td>Definition</td>
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<tr>
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</tr>
<tr>
<td>Clearing and Grubbing</td>
<td>The stage of construction in which vegetation is cleared from land (clearing) and a root rake or similar device employed to remove roots remaining in the soil (grubbing). The next stage is cutting and filling.</td>
</tr>
<tr>
<td>Constellation</td>
<td>An assemblage, collection, or group of usually related persons, qualities, or things.</td>
</tr>
<tr>
<td>Contour</td>
<td>Defined line of equal elevation on a map or plat.</td>
</tr>
<tr>
<td>Control</td>
<td>A system of points whose relative positions have been determined from survey data.</td>
</tr>
<tr>
<td>Control Point</td>
<td>A point whose position (horizontal or vertical) has been determined from survey data, and is used as a base for a dependent survey.</td>
</tr>
<tr>
<td>Coordinates</td>
<td>Linear or angular quantities, or both, which designate the position of a point in relation to a given reference frame.</td>
</tr>
<tr>
<td>Cross Section</td>
<td>The creation of a DTM from collecting grid elevations in a predetermined area or roadway section.</td>
</tr>
<tr>
<td>Cross Slope</td>
<td>A geometric feature of pavement surfaces; the transversal slope [%] with respect to the horizon.</td>
</tr>
<tr>
<td>Culvert Pipe</td>
<td>A conduit to convey a stream or runoff through an embankment.</td>
</tr>
<tr>
<td>Cut Slope</td>
<td>The cut which is created when a roadway is lower than the surrounding terrain.</td>
</tr>
<tr>
<td>Data Collector</td>
<td>Electronic Field Notebook.</td>
</tr>
<tr>
<td>Datum</td>
<td>A reference element such as a line or plane, in reference to which the positions of other elements are determined. See: Horizontal Datum and Vertical Datum.</td>
</tr>
<tr>
<td>Digital Terrain Model (DTM)</td>
<td>The DTM is considered as a continuous, usually smooth surface which, in addition to height values, also contains other elements that describe a topographic surface: slope, aspect, curvature, gradient, skeleton (pits, thalwegs, saddles, ridges, peaks), and others.</td>
</tr>
<tr>
<td>Dilution of Precision (DOP)</td>
<td>An indicator of the quality of a GPS position. DOP takes into account the location of each satellite relative to other satellites in the constellation, as well as their geometry relative to the GPS receiver. A low DOP value indicates a higher probability of accuracy. Standard DOPs for GPS applications are PDOP - Position (three coordinates), RDOP - Relative (Position, averaged over time), HDOP - Horizontal (two horizontal coordinates), VDOP - Vertical (height only), and TDOP-Time (Clock offset only).</td>
</tr>
<tr>
<td>Direct Reflex</td>
<td>Enables surveyors to accurately measure remote points without first locating a physical target at each point.</td>
</tr>
<tr>
<td>Easement</td>
<td>The right to use the real property of another for a specific purpose. The easement is itself a real property interest, but legal title to the underlying land is retained by the original owner for all other purposes.</td>
</tr>
<tr>
<td>Easting</td>
<td>One of the two values indicating the position of a point on a grid system. The easting coordinate is abbreviated: E. A term used in plane surveying that corresponds to the x-position on a Cartesian plane. See: Grid Coordinates.</td>
</tr>
<tr>
<td>Electromagnetic Radiation</td>
<td>Energy in the form of electromagnetic waves.</td>
</tr>
<tr>
<td>Electromagnetic Spectrum</td>
<td>The range of all possible frequencies of electromagnetic radiation.</td>
</tr>
<tr>
<td>Electronic Distance Measurement (EDM)</td>
<td>A surveying instrument that utilizes an infrared or laser beam to measure the distance from the source point.</td>
</tr>
<tr>
<td>Glossary Term</td>
<td>Definition</td>
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</tr>
<tr>
<td><strong>Elevation</strong></td>
<td>The distance of any point above or below a reference level (datum).</td>
</tr>
<tr>
<td><strong>Elevation Mask</strong></td>
<td>Filters out signals from satellites below a certain angle of elevation above the horizon.</td>
</tr>
<tr>
<td><strong>Fast-Static GPS Survey</strong></td>
<td>Similar to static GPS surveys, but with shorter observation periods (approximately 5 to 10 minutes). Fast-static GPS survey procedures require more advanced equipment and data reduction techniques than static GPS methods.</td>
</tr>
<tr>
<td><strong>Feature Codes</strong></td>
<td>The abbreviation used to define an object collected during a radial survey.</td>
</tr>
<tr>
<td><strong>Fill Slope</strong></td>
<td>The fill which is created when a roadway is higher than the surrounding terrain.</td>
</tr>
<tr>
<td><strong>Foreslope</strong></td>
<td>The segment of the ditch between the hinge and the ditch bottom.</td>
</tr>
<tr>
<td><strong>Geodetic Coordinates</strong></td>
<td>Refers to a location on earth defined by its latitude, longitude and elevation.</td>
</tr>
<tr>
<td><strong>Geoid</strong></td>
<td>The gravity model set up for the earth that closely approximates mean sea level.</td>
</tr>
<tr>
<td><strong>Geoid Model</strong></td>
<td>Separation between the Geoid and the WGS-84 datum.</td>
</tr>
<tr>
<td><strong>Geomatic</strong></td>
<td>The discipline of gathering, storing, processing, and delivering geographic information, or spatially referenced information.</td>
</tr>
<tr>
<td><strong>Global Positioning Satellite (GPS)</strong></td>
<td>A system of satellites, computers, and receivers that is able to determine the latitude and longitude of a receiver on Earth by calculating the time difference for signals from different satellites to reach the receiver.</td>
</tr>
<tr>
<td><strong>Grade</strong></td>
<td>Surface level of ground or rate/degree of slope.</td>
</tr>
<tr>
<td><strong>Grid</strong></td>
<td>A network composed of two sets of equidistant parallel lines intersecting at right angles.</td>
</tr>
<tr>
<td><strong>Grid Coordinates</strong></td>
<td>The numbers of a coordinate system that designate a point on a grid.</td>
</tr>
<tr>
<td><strong>Heat Shimmer</strong></td>
<td>Caused by temperature differences at varying heights in air. The different air layers have a different index of refraction causing light to bend as it passes from one layer to another, causing a shimmer.</td>
</tr>
<tr>
<td><strong>Horizontal Alignment</strong></td>
<td>Consists of straight sections of roadway, known as tangents, connected by horizontal curves.</td>
</tr>
<tr>
<td><strong>Horizontal Control</strong></td>
<td>Control stations whose grid coordinates are known.</td>
</tr>
<tr>
<td><strong>Horizontal Datum</strong></td>
<td>In plane surveying, the grid system of reference used for the horizontal control of an area; defined by the easting and northing of one station in the area, and the azimuth from this selected station to an adjacent station.</td>
</tr>
<tr>
<td><strong>Hub</strong></td>
<td>A wooden stake set in the ground, with a tack or other marker to indicate the exact position. A guard stake protects and identifies the hub.</td>
</tr>
<tr>
<td><strong>InRoads</strong></td>
<td>Enables you to transfer data from electronic fieldbooks (EFBs) to the MicroStation or AutoCAD environment, reducing time from field to finished drawings with interactive data editing capabilities. It produces plot-ready graphics immediately upon reading the data. Contours can be displayed, surveys adjusted and results visually verified before you leave the site. InRoads Survey's Fieldbook Data Editor helps you interactively edit your raw survey data.</td>
</tr>
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</table>
## Glossary

### Kinematic GPS Surveys

Make use of two or more GPS units. At least one GPS unit is set up over a known (reference) station and remains stationary, while other (rover) GPS units are moved from station to station. All baselines are produced from the GPS unit occupying a reference station to the rover units. Kinematic GPS surveys can be either continuous or “stop and go”. Stop and go station observation periods are of short duration, typically under two minutes. Kinematic GPS surveys are employed where third-order or lower accuracy standards are applicable.

### Laser

A device that produces an intense, coherent, directional beam of light by stimulating electronic or molecular transitions to lower energy levels.

### Latitude

In plane surveying, the amount that one end of a line is north or south of the other end. As the plane coordinates of a point are known as the easting and northing of the point, the latitude is the difference between the northings of the two ends of the line, which may be either plus or minus.

### Level Circuit

Using a level and rod to transfer an elevation from one point to another and back to the original.

### LoS

Source for Survey Monument Control Points (LPN Sheets).

### Longitude

A measure of relative position east or west on the earth’s surface, given in degrees from a certain meridian, usually the prime meridian at Greenwich, England, which has a longitude of 0 degrees.

### Magnetic Storm

A disturbance or fluctuation in the earth’s magnetic field, associated with solar flares.

### MicroStation

A CAD software product for two- and three-dimensional design and drafting, developed and sold by Bentley Systems.

### Monument

A permanently placed survey marker such as a stone shaft sunk into the ground.

### NGS

National Geodetic Survey

### Northing

One of the two values indicating the position of a point on a grid system. The northing coordinate is abbreviated: N. A term used in plane surveying that corresponds to the y-position on a Cartesian plane. See: Grid Coordinates.

### Offset

Perpendicular interval; to parallel and continue a preceding course, line or boundary.

### PCCP

Portland Cement Concrete Pavement

### Perpendicular

A straight line at an angle of 90 degrees to a given line, plane, or surface.

### Plantmix Bituminous Surface

Consists of a surface course composed of mineral aggregate and bituminous material mixed in a central mixing plant and placed on a prepared course.

### Positional Tolerance

The allowable tolerance of how much something may deviate from its true location.

### Prism

A transparent polygonal solid, often having triangular bases, used for dispersing light into a spectrum or for reflecting rays of light.

### Prism Constant

A dimension on a prism which is an offset from the back of the glass to the center of the point.

### Project Control

A set of known survey monuments for use on a particular contract.

### Propagate

To travel through space or a material, using wave energy (as light, sound, or radio waves).
Radial Line
A line passing through the center of a circle or sphere.

Real Time GPS Survey (RTK)
A position location process whereby signals received from a reference device (such as a GPS receiver) can be compared using carrier phase corrections transmitted from a reference or base station to the user’s roving receiver.

Reinforced Concrete Box (RCB)
A structure used to convey a stream or runoff through an embankment.

Remote Sensing
The acquisition of information about an object or phenomenon, without making physical contact with the object. In modern usage, the term generally refers to the use of aerial sensor technologies to detect and classify objects on Earth (both on the surface, and in the atmosphere and oceans) by means of propagated signals.

Residuals
The difference between the mean of a set of observations and one particular observation.

Right of Way
A parcel of land, granted by deed or easement, for construction and maintenance according to a designated use. This may include highways, streets, canals, ditches or other uses.

Riprap
Embankment protection adjacent to a stream or lake, the bank is lined with broken concrete or rock to prevent erosion.

Roadway
The portion of a highway, including shoulders, for vehicular use.

Robotic Total Station
A multi-purpose electronic surveying instrument with a built in EDM capable of measuring horizontal distances, slope distances, angles, vertical height differences, and three-dimensional coordinates.

Satellite
A manufactured object or vehicle intended to orbit the earth, the moon, or another celestial body.

Slope Staking
A special form of leveling to determine the point at which the proposed slope intersects the existing ground.

Static GPS Survey
Static GPS survey procedures allow various systematic errors to be resolved when high-accuracy positioning is required. Static procedures are used to produce baselines between stationary GPS units by recording data over an extended period of time during which the satellite geometry changes.

Station
A numerical designation for points on a contract centerline which denote the distance of that point from another point on the same alignment.

Subgrade
A surface of native material upon which a road is laid.

Survey Monuments
A reference point marked by a permanently fixed marker.

Tangent
A straight line or plane that touches a curve or curved surface at a point, but if extended does not cross it at that point.

Terrestrial
The comparison of field survey between two known points to true values.

Theodolite
An optical surveying instrument with a rotating telescope for measuring horizontal and vertical angles.

Tie
A survey connection from a point of known position to a point whose position is desired.

Total Station
A Total Station is an electronic/optical instrument used in modern surveying. The Total Station is an electronic theodolite (transit) integrated with an electronic distance meter (EDM) to read distances from the instrument to a particular point.
### Glossary

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Traverse</td>
<td>To travel or pass through, over, or across a point.</td>
</tr>
<tr>
<td>Tri-Bracket</td>
<td>An instrument attachment plate with three leveling screws used to attach a theodolite or surveyor’s level to its tripod, level the instrument, and center it precisely over a point.</td>
</tr>
<tr>
<td>Trimble Survey Controller and Trimble Access</td>
<td>Are field software used in Trimble TSC2 and TSC3 data collectors. The older TSC2 uses Trimble Survey Controller and the newer TSC3 uses Trimble Access. Trimble has included on board help documentation in both versions that can be used by crews in the field.</td>
</tr>
<tr>
<td>Tripod</td>
<td>An adjustable three-legged stand which is the support for theodolite or level.</td>
</tr>
<tr>
<td>Vertical Alignment</td>
<td>A change in elevation along a roadway.</td>
</tr>
<tr>
<td>Vertical Curve</td>
<td>A curve on the longitudinal profile of a road to provide for change of gradient.</td>
</tr>
</tbody>
</table>