4-100 GENERAL

Surveying is basic to all civil engineering projects. In transportation engineering, surveying provides the foundation and continuity for route location, design, land acquisition, and all other preliminary engineering. A survey sets up a basic "framework" of control, or positioning, that contractors and engineers use in constructing and inspecting transportation projects. Surveying is the single engineering function that links all the elements of a project, from conception; through design, land acquisition, and construction; to establishing final survey monuments.

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 projects.
- 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 project 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.

Within the Nevada Department of Transportation, both the Location Division and the Construction Division perform surveys.

- The Location Division establishes permanent survey monuments for construction projects and for property lines. To comply with state law (Nevada Revised Statutes, NRS), a Nevada State licensed land surveyor directs Location Division surveys. The Location Division manual, *Special Instructions for Survey, Mapping or GIS Consultants*, is available through NDOT's Web site at http://www.nevadadot.com/business/contractor/GIS_Manual.
- The Construction Division establishes and maintains horizontal and vertical survey controls needed to construct a transportation project. For information about construction surveying and staking, refer to the NDOT *Construction Stakeout Manual*, available from the Construction Division.

4-200 LOCATION SURVEY

The Location Division frequently performs location surveys several years before construction begins. To eliminate extensive surveys during construction, location surveys establish permanent horizontal and vertical construction control points in locations where they are least likely to be disturbed or destroyed. These construction control points, or reference points, are semi-permanent and are stamped with a unique name or number. Orange posts mark the location. These reference points provide the basis for all staking on the construction project.

The specific location of each control point is identified by coordinates. NDOT uses three types of coordinate systems, as follows:

- 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)
- 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)
- 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)

A project survey crew establishes the roadway centerline from control points established by the Location Division survey. Control points used in a construction survey commonly are located by reference to a specific point on the roadway centerline (station) and the distance between the centerline and the reference point (offset). The Location Control sheets list information for each control point established by the Location Division for a project. The Location Control sheets are contained in the project construction plans. If control points are found in the field, but not listed in the project control sheets, the control point should not be used, unless approved by the Location Division.

Typically, project location control sheets list coordinates using the Nevada State Plane Coordinate System, which means these coordinates are Northings (identifiers in the north-south direction) and Eastings (identifiers in the east-west direction). To reduce survey errors over large areas, Nevada is divided into three geographic zones: West, East, and Central. State law describes the zone in which each county is located as follows:

East Zone: Clark, Elko, Eureka, Lincoln, and White Pine counties

Central Zone: Lander and Nye counties

West Zone: Carson City and Churchill, Douglas, Esmeralda, Humboldt, Lyon, Mineral, Pershing, Storey, and Washoe counties

Following is an example of a control point listing in a project set of plans:

Control Point Information		Explanation
Name:	763013M	Assigned by Location Division
Northing:	14768375.36	North, or Y, coordinate
Easting:	2231499.45	East, or X, coordinate
Elevation:	6434.721	Elevation above sea level
New Station:	"L" 183+42.46 POC	Centerline station, Point On Curve
Distance:	66.179	Distance right of centerline
Note:	NDOT FENO MONUMENT	Description of monument type

Information relating to a specific control point is based on an important piece of information: the Location Project Number, or LPN. The example above is based on LPN 925. LPNs identify a specific geographical area that the Location Division has surveyed. An NDOT construction project may have control points that are in several LPNs. Exercise care to ensure that control point survey information is consistent with the specific LPN designation.

The location of a roadway and its design elements are influenced by topography, physical features, land use, and surrounding development. The location survey includes measurements that describe physical features such as drainage areas, waterways, buildings, fences, roads, telephone and power lines, and any other features that may influence the design.

Coordinating the horizontal alignment and vertical profile is one of the first important steps in designing a roadway. Proper design coordination increases the utility and safety, encourages uniform speed, and improves the appearance of the constructed roadway.

The Location Division develops the necessary engineering survey data to select and design the most economical and useful route locations. The construction survey crew is primarily concerned with the project area's control point information. The Location Division provides this information through Location Construction Control sheets. These control sheets are generally completed when the design is 30 percent complete. The control sheets 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.

For many years, the Construction Division established reference monuments at the completion of a construction project. In 1999, the Director established policy that directed the Location Division to set construction control before the project design. Location Division personnel are available as needed during construction to assist with survey needs.

4-300 CONSTRUCTION SURVEY

4-301 GENERAL

The following general surveying concepts provide information for those who are new to NDOT roadway construction. You can find a more detailed discussion of construction surveying and staking in the NDOT *Construction Stakeout Manual* available from the Construction Division.

Construction surveys for roadway projects generally consist of the following operations:

- Staking in preparation of earthwork and structure construction
- Establishing construction limits and construction easements
- Establishing centerline
- Establishing control points
- Setting slope stakes
- Setting clearing stakes
- Staking fence line
- Making initial measurements to provide the basis of payment for items of work
- Pilot lining (or "Marking for pavement striping")
- Staking drainage structures
- Obtaining cross sections
- Setting grade stakes
- Preserving monuments and markers

The Resident Engineer is responsible for surveys performed on a construction project. The Resident Engineer's crew plans and coordinates all surveying efforts with the contractor. To complete the various surveys without delaying construction, the survey crew chief must anticipate the contractor's survey needs. If NDOT does not complete surveys on time, it may be liable for delays.

Construction surveys utilize a variety of specialized instruments. Following are the two most common technologies used for construction surveys:

- Total Station – The Total Station is an instrument that replaces the outdated Transit/Theodolite. It measures angles, electronically measures distances, and provides the ability of robotic survey, in which the user remotely operates the instrument from the area to be staked. It allows the user to include accurate elevation information for every staked point. The Total Station is limited by sight distance and radio strength, but is more accurate than GPS.

- Global Positioning System (GPS) – GPS is preferred because of its mobility and efficiency—only one or two people are required to perform the survey. Because the technology uses satellites, the survey coverage area is extensive.

NDOT has established survey standards for various construction survey activities. Refer to the "Special Instructions for Survey, Mapping or GIS Consultants," prepared by the Location Division. Survey standards identify the accuracy required for various types of surveys.

Construction survey crews and Location Division survey crews have different areas of responsibility. Construction survey crews conduct survey activities within the limits of the construction project. In contrast, Location Division crews survey outside the project limits. For example, Location Division crews survey right-of-way and install property controlling monuments. Construction crews survey right-of-way fences, which may or may not be on the right-of-way, which is a property line.

4-302 CONTRACTOR SURVEYING

Occasionally, NDOT staffing limitations require that outside personnel perform the construction surveying. In these cases, NDOT may hire contract surveyors or allow the contractor's surveyors to conduct the construction surveying. The Resident Engineer assigns NDOT personnel to oversee and crosscheck the work of the contract surveyors.

When performing NDOT surveys, contract survey crews must conform to the guidelines in the *Construction Stakeout Manual* and the *Special Instructions for Survey, Mapping or GIS Consultants*. Contract survey crews may also find beneficial information in this *Construction Manual*. Additionally, when surveying is an item of work under the construction project, Section 200 of the specifications addresses the contractor's surveying activities.

4-303 BEFORE CONSTRUCTION

Several survey activities can be started and even completed before the contractor arrives at the jobsite. The common sequence of survey activities on a construction project is as follows:

1. Establish horizontal and vertical control points
2. Survey the roadway centerline
3. Take cross sections for quantity verification
4. Establish slope stakes

4-303.1 OFFICE ACTIVITIES

For each of these activities, the Resident Engineer relies on the survey crew chief to calculate stakeout data before construction begins. Preliminary plans are commonly submitted to the field crew before the award of the project. The survey crew chief can start and sometimes finish most stakeout calculations before receiving the final plans. The survey crew chief receives the final plans and checks the preliminary stakeout calculations against the final plans for accuracy.

As in all phases of construction engineering, you can create a general order for stakeout computation completion, but the sequence may not apply in all instances. The following list provides a brief overview of some of the initial computations performed by the field office staff and survey crew chief.

- Alignment – Compile construction alignment documents, or field books, as soon as possible. In most cases, you must reproduce the original alignment, note any changes in length, and adjust necessary distance measurements. Calculate and check all curve deflections, tangent lengths, and similar calculations before sending the documents to the field.
- Slope Stake – Prepare and check slope stake data for the roadways. Include all information necessary for the construction crew to set the slope stakes in the field, including engineering stationing, grade percent, vertical curve information, elevations, shoulder distance, ditch, and slope information. Figure 4-303.1 illustrates a typical roadway cross section that provides the data needed for preparing slope stakes. Refer to the *Construction Stakeout Manual* for more details on this subject.
- Structures – Complete structure documents for culverts, guardrails, curbs and gutters, and other roadway appurtenances. Survey data for these types of improvements are significantly important because these improvements are permanent.
- Grade Books – To help the construction crew set "red heads" or grade stakes, complete grade computations by the time subgrade is completed.

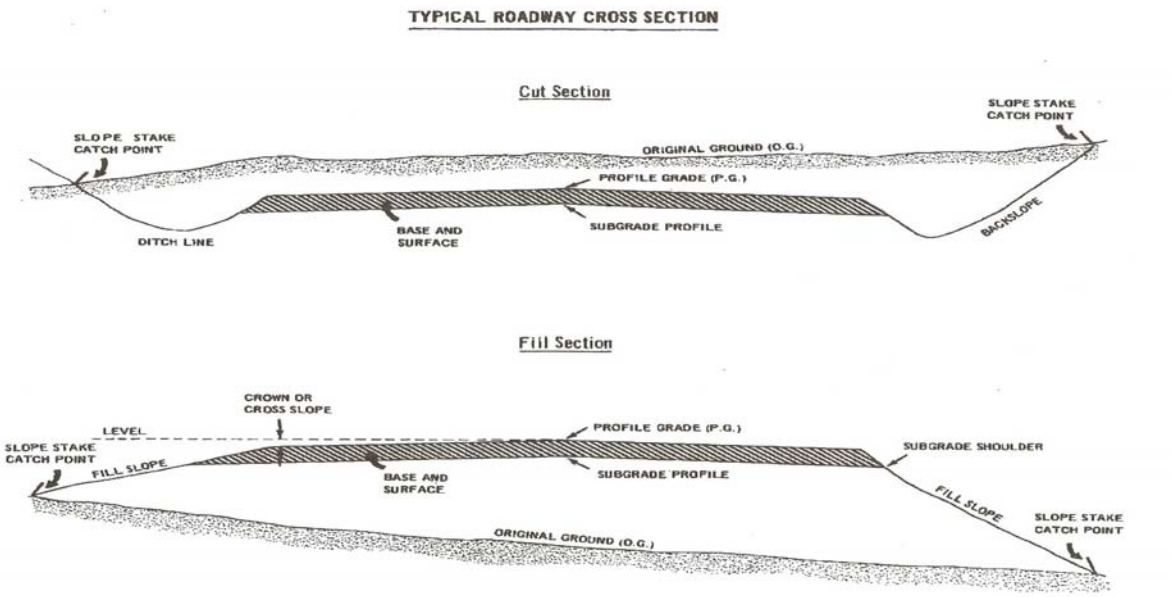

Figure 4-303.1. Typical Roadway Cross Section.

The Resident Engineer should allocate sufficient time to prepare books before stakeout. These books are also available to contractors who must do their own surveying on a project. Either the survey crew chief or contractor then completes the following tasks:

- Compute and print alignment and slope stake data based on the original design information included in the plans
- Prepare grade books (reports) for the roadway section depths (lifts) and distances that the Resident Engineer requests
- Print the computed information on field book-sized sheets

The Resident Engineer or survey crew chief examines the data and spot checks it for accuracy. If the calculated data is incorrect or otherwise unusable, resolve the discrepancies with the Design Division.

4-303.2 FIELD ACTIVITIES

4-303.2.1 ALIGNMENT, HORIZONTAL AND VERTICAL CONTROL

Use the plans to reproduce the roadway centerline and mark them with witness stakes. Drive the stakes on the centerline facing the initial survey station. Witness stakes provide information about adjacent surveyed points. Engineer stationing on projects typically increases numerically from south to north and from west to east.

If the line to be constructed differs from the originally staked line, the line to be constructed should connect with adjacent portions of the original centerline. In staking these revisions, be careful to maintain the relationship between the original and the revised line.

If you find a discrepancy with the plans when you reproduce the centerline, ensure that the Resident Engineer and the Design Division are aware of the discrepancy. Make an equation at the discrepancy point, and carry the plan station forward from that point. This ensures that construction records agree as closely as possible to the project plans and estimates.

You can set reference points when you reproduce the centerline, or immediately thereafter. Establish a sufficient number of control points so you can reproduce the centerline at any time without retracing a long section when you need only a short section.

Place reference points so they are protected from construction operations. Measure and note the following in the appropriate field book:

- Angle-of-intersection between the line to the reference point and centerline
- Horizontal measurements to the reference point

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. Benchmarks are usually required near major structures, special construction areas, or where the terrain is rugged and preliminary benchmarks are difficult to reach.

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. Vertical control is established by setting benchmarks using a manual or electronic level. For horizontal and vertical control, the survey accuracy tolerance is 0.02 foot.

Figure 4-303.2. Slope Stake and Guinea.

4-303.2.2 SLOPE STAKES

Set slope stakes at the "catch point"—the original ground locations where the toe of a fill slope and the top of a cut slope begin. Mark the front of the stakes (facing centerline) with the cut or fill and the ratio distance for the planned roadway's typical section. Mark the back of the stakes with the engineer's station of the section staked. Mark the side of the stakes with pertinent information such as subgrade shoulder distance, slopes, or roadway ditch depth. Make sure all markings are large and easy to read. Figure 4-303.2 shows an example of a slope stake and guinea.

Set a guinea at the originally computed catch point elevation. Then, drive the slope stake six inches behind the guinea. Place the slope stake so that cut or fill information faces the centerline of the road.

Guineas do the following:

- Show the contractor where the survey information was taken and identify where construction begins.
- Reestablish the catch point if the slope stake is accidentally destroyed or moved during construction. If a guinea is missing and the slope stake remains, the contractor and the engineering personnel will know it is not a catch point.

The survey crew, under the direction of the Resident Engineer, ensures that slope stakes are set at right angles to the centerline on tangents, and on the radial lines of curves. Place slope stakes at even stations, half stations, and other unique stations that will help the contractor produce a well-contoured roadway.

Measure and record slope stake elevations and distances to the nearest tenth of a foot. Use cloth tapes that are not frayed or well worn.

Following are three common methods of slope staking. The method used depends on variables such as terrain and available survey equipment, as well as the judgment of the survey crew chief and the Resident Engineer.

- Digital Level – This method uses an extremely accurate bar-coded elevation rod. You can read the information quickly and record it on a data collector.
- Total Station – As with digital leveling, you can store information from the Total Station instrument on a data collector. You can maneuver the Total Station from a remote control (Robotics) system, which gives you the freedom to leave the instrument and go to the intended stakeout point. Productivity limitations for this method depend on the terrain and location of control points.
- GPS (Global Positioning System) – GPS allows you to efficiently calculate, place, and document slope stakes. Productivity is limited only by battery endurance.

Another method of slope staking that supports the methods described above uses a level, tripod, level rod, and cloth tape. Use this method to reestablish a slope stake or to slope stake a small area. Sometimes, using a hand level supplements the level-and-cloth-tape method when you cannot set the stakes from the instrument setup.

On projects with substantial excavation or embankment quantities, it is advisable to cross section the area to develop original ground topography. This information provides a basis for checking actual quantities against planned quantities.

4-303.2.3 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.

4-304 DURING CONSTRUCTION

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. When the contractor begins operations, coordination between the survey crew and the contractor allows work to progress uninterrupted.

This section describes several common construction survey activities. Survey activities in each of the following sections must be documented in field books or other documents. Survey documentation provides information for others to reproduce the initial survey. The *Documentation Manual* and *Construction Stakeout Manual* describe documentation requirements.

4-304.1 CULVERTS AND STRUCTURES

Prepare a structure book with all pertinent data before staking the structure. Set construction benchmarks near culverts. You can expedite the stakeout of culverts and other drainage structures if you establish the location of structure stations when you establish the centerline.

Mark the centerline of culverts with hubs driven on the centerline. Locate them away from the end of the culvert or headwall to protect them from disturbance. After you take elevations on the hubs, determine the cut or fill to the flow line of the pipe or headwall. Clearly mark the relevant information on the stakes. Establish the headwall alignment so the headwalls are parallel to the shoulder of the road.

Establishing sufficient reference points near culverts and large structures allows you to reproduce all stakeout points. Throughout construction, you may frequently call upon the construction survey crew to set grade, establish line, and provide engineering dimensions. By setting sufficient reference points before construction begins, the construction survey crew can readily respond to the contractor's request for survey points.

The contractor, in accordance with the specifications, surveys bridge structures. The Resident Engineer checks and verifies the contractor's survey.

4-304.2 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.
- 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 0.02 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.

4-304.3 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.

4-304.4 PRESERVING MONUMENTS AND MARKERS

Before or during construction activities, the possible loss or destruction of control points or other survey monuments may be unavoidable. In most cases, the survey control sheets of the plans provide direction on the proper treatment of the monuments. When control points or survey monuments need to be perpetuated, the Location Division or a professional land surveyor (PLS) will perform the perpetuation after construction activities have ended. State law prohibits the willful damage or destruction of survey monuments set by a PLS.

Figure 4-304.1. Section Corner Monument.

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 4-304.2. USGS Benchmark.

During construction, if control points or survey monuments are found that are not listed on the control sheets, construction personnel must make every effort to preserve them. Refer to Transportation Policy 1-9-3 (TP 1-9-3, formerly TP 3-1-3) for information on perpetuating survey monuments. The following provides general guidance on preserving survey monuments:

- NDOT Control Points – NDOT control points are set by the Location Division or by construction survey crews. They are addressed in the control sheets contained in the construction plans. Contact the Location Division to determine the appropriate action to take for a specific point not listed on the control sheets.
- Section Corners and other property-controlling monuments – The corners established by the U.S. General Land Office are either iron pipes with brass caps, or stones. Iron pipes have section numbers and dates stamped on them. Stones have notches on the south and east sides, except quarter corners, which are marked with “1/4” on the south or west side. Figure 4-304.1 shows a typical section corner. If a section corner, property corner, or other property-controlling monument is found within the limits of construction, it must be perpetuated, and required documentation must be filed with the County Recorder. The perpetuation must be done by a PLS and in accordance with state law. The Location Division must be contacted for direction.
- Federal Monuments – Federal agency monuments have unique identifying markings. Monuments placed or established by federal agencies require preservation. Figure 4-304.2 shows a USGS benchmark. If a federal agency monument is destroyed, recover the monument cap and send it to the Location Division.

4-304.5 STRIPING EDGE LINES

Properly placing centerlines and edge lines on the completed roadway adds significant safety to the roadway. The American Association of State Highway Officials has established striping and edge line standards, which are documented in the *Manual on Uniform Traffic Control Devices* (MUTCD). Before striping a roadway project, the Resident Engineer should refer to the plans and MUTCD for the proper placement of striping and edge lines.

4-305 AFTER CONSTRUCTION

After construction is complete, the survey crew chief reviews all survey reports and documents for accuracy and completeness. Sometimes, the Resident Engineer may request that material quantities be checked to resolve questions or issues.

When the project is complete, transfer the final survey documents and reports to the Construction Division. Include notations or corrections made during field stakeout. The survey documentation becomes part of the project permanent records.