SURVEY TECHNICAL STANDARDS MANUAL

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NHDOT SURVEY TECHNICAL STANDARDS

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GENERAL INFORMATION

Public Relations and the Surveyor's Responsibilities

Surveyors working on New Hampshire Highway Department (NHDOT) projects are professionals representing a public service agency. Whether a surveyor is an NHDOT employee or a member of a crew under contract, it is important to the Department that these representatives maintain good public relations in their work. Surveyors are required to be courteous and tactful with citizens seeking information on a project. The surveyors may answer reasonable questions relating to the project, but should not speculate about possible alignment changes, easements or takings, or any aspect of a proposed design. Any requests for information or questions of more than a basic nature should be referred to the Project Manager. Conduct of survey crew members must be professional and proper at all times. Care should be used when marking survey points. Paint, flagging, and other marking techniques should be used sparingly. Crew chiefs should use good judgment in laying out surveys to minimize property damage and avoid creating hazardous conditions. When line cutting is required, the brush should be removed from the line and disposed of properly. Where pedestrian traffic is likely, stakes should be hubbed (set flush), or other surface marks should be used. On those occasions when the crew chief must perform calculations in the vehicle, he/she should find duties for the rest of the crew.

Right of Entry for Survey Purposes

Existing laws within this State authorize the Commissioner or representatives to make surveys on private properties for highway purposes. The specific law is hereby quoted:

RSA 498-A:10 Right to Enter Property Prior to Condemnation. Prior to the time of filing the declaration of taking, the condemnor or its employees or agents shall have the right to enter upon any land or improvement which it has the power to condemn, in order to make studies, surveys, tests, soundings, and appraisals; provided, however, that the condemnee has been notified 10 days prior to entry on the property. Such entry and related activities shall not constitute a trespass, but the condemnor shall be liable for any actual damages caused thereby. This liability may be enforced in a civil action against the condemnor brought in the superior court in the county in which the property is located, with damages to be assessed by the board in the manner provided in RSA 498-A:24."

RSA 228:33 Right to Enter. The commissioner and his agents may enter private lands to make surveys and establish boundaries of highways.

Private property ownership and rights shall be treated respectfully at all times and any property damage avoided. It is the policy of the Department that only brush will be cut in wooded areas. Ornamental shrubs and trees will not be damaged in any way. Trees larger than 3 inches (0.08 m) in diameter may be cut only after special permission from the landowner is received. Care must be exercised to maintain the appearance of areas through which a survey is being made. Cut brush and trees, survey stakes, risers, flagging, and debris of any kind, must be reduced to a minimum or made as inconspicuous as humanly possible in a manner that is consistent with an expedient operation. Special care must be utilized when work is being accomplished near lawns, gardens, ornamental trees, shrubs, waterways etc.

Safety

Survey personnel, whether NHDOT employees or employees of survey contractors or sub-consultants, are required to conform to NHDOT safety requirements, applicable safety laws and regulations, and the latest version of the following publications:

- Federal Highway Administration's Manual on Uniform Traffic Control Devices (MUTCD). http//mutcd.fhwa.dot.gov/

- NHDOT's Guidelines for Implementation of the Work Zone Safety and Mobility Policy.

- U.S. Occupational Safety and Health Administration's Safety and Health Regulations for Construction, Part 1926.

Personal Safety

Survey personnel must wear safety glasses while using any hand tools, including line cutting tools. One of the most frequent tasks crew members do is setting a mark to occupy or to use as a tie. A sledge hammer, the common means of driving stakes, rods or pipes, is also the major source of eye injury for surveyors. Use of safety glasses is extremely important when driving stakes, especially in cold weather when a frost pin is needed to set most marks. Hard hats are also a requirement at all construction sites. All employees must report for work suitably dressed for protection against environmental elements. If any employee is not suitably dressed for work, he/she will not be permitted to work until suitably attired.

Roadway Safety

Survey crews spend a good part of their time on roadways of many different types from country roads to city streets to high speed expressways, under a variety of climatic conditions. With the advancement of modern technology the need for survey crew members to be in the traveled way is minimized. However, the crew chief is expected to act responsibly by analyzing every situation and to take any action necessary to ensure the safety of the crew members as well as the motoring public. The roadway shall be properly signed and coned; all crew members shall wear proper safety gear and shall stay alert.

NHDOT Survey Technical Standards

Section I

Geodetic Control Surveys

I.1 Geodetic Control Surveys

Survey standards may be defined as the minimum accuracies deemed necessary to meet specific objectives. Specifications are the procedural requirements that will achieve the required accuracy, an indication of the survey's precision. This document provides a common methodology for reporting the accuracy of horizontal and vertical coordinate values for clearly defined features where the location is represented by a point. Examples are active survey monuments, such as Continuously Operating Reference Stations (CORS), passive survey monuments, such as brass disks and rod marks; and temporary points, such as photogrammetric control points or construction stakes. It provides equivalent methods to achieve project requirements, using either positional or proportional methods. Modern Geographic Information Systems (GIS) allow us to store more, possibly duplicate information. It is increasingly important for users to know the coordinate values and the accuracy of those values, so users can decide which coordinate values represent the best estimate of the true value for their application.

The NHDOT standards for survey accuracy are based on the standards set by the FGCS (NGS) Geospatial Positioning Accuracy Standards. The Standards for Geodetic Networks use metric units as the standards of accuracy, and GNSS surveys can be measured and adjusted in metric units before being converted to U.S. Survey feet.

Geodetic Control surveys establish a common, consistent network of physical monuments that are the basis for the horizontal and vertical location of transportation improvement projects and facilities. Project control monuments provide consistent and accurate horizontal and vertical control for NHDOT projects. Secondary control surveys provide a densification of the project control to facilitate photogrammetric, planning, engineering, construction, and right of way, post construction, and as-built surveys.

These policies, standards, and procedures apply to all geodetic control surveys for all NHDOT involved transportation improvement projects:

All horizontal data for NHDOT projects are required to be in the New Hampshire State Plane Coordinate System on the North American Datum of 1983 (NAD 83). All Vertical Data shall be on the North American Vertical Datum of 1988 (NAVD 88).

All NHDOT primary control surveys will be based on the National Spatial Reference System (NSRS). Global Navigation Satellite System (GNSS) surveys will be based on a minimum of three monuments.

Control surveys must be performed in compliance with appropriate standards.

The standard unit of length for NHDOT land surveying and mapping is the US Survey foot. Baselines shall use 100-foot survey stationing. The standard interval for marking baseline, taking detail and/or cross sectioning shall be 50 feet. NHDOT conforms to the National Geodetic Survey (NGS) policy and NH Statues Chapter 1-A, section 1-A:4 for providing state plane coordinates (SPCs) in meters and decimals of a meter and United States survey feet and decimals of a foot when dealing with the North American Datum of 1983 (NAD 83).

When the previous datum (NAD 27) became law, the "U.S. survey foot" was the standard unit of length. The distinction between the "U.S. Survey Foot" and the "international foot" is a subtle but important one. The "international foot" is defined as 0.3048 m exactly and the U. S. Survey Foot is defined as 1200/3937 m, or 0.30480061 m. The "international foot" is shorter than the "U.S. survey foot" by 2 parts per million. This difference may not be a factor in distance measuring, but can introduce major errors in coordinate conversions if not considered.

By statute and regulation, for conversion of meters to U.S. survey feet "...the meters shall be multiplied by 39.37 and divided by 12 which results in a constant multiplier having a value of 3.280833333333 to 12 significant figures."

The preferred primary geodetic control monuments are active stations such as CORS (Continually Operating Reference System) or CGPS (Continuous Global Positioning System) stations with a 95% network accuracy of 1 centimeter (0.03’) or less. Passive monuments that are a part of the NSRS observed by GNSS should still be viable primary control for projects, and when practical, should be included in the network as held control that may be weighted if proof of necessity exists.

When using active stations (CORS / CGPS) as primary control, horizontal project control monuments will meet the 2 cm (0.065’) network accuracy standards if possible.

When feasible, Primary Geodetic Control will be established using GNSS surveys complying with 1 cm accuracy standard. When GNSS survey methods cannot be used for all or part of a horizontal project control survey, a Total Station Survey traverse network meeting the accuracy standard is acceptable.

All project primary control must, at a minimum, meet the 2 cm (0.065’) network accuracy standards.

Primary control surveys provide the geodetic foundation for NHDOT project control surveys along transportation corridors. Project control surveys will be performed when NHDOT involved transportation improvement projects require land surveys. New Hampshire State Plane Coordinate System of 1983 (2011) coordinates or later readjustment or realizations will be used to define the spatial positions of project facilities.

I.2 Project Planning

A project surveyor will be assigned to a project requiring land surveys. For the purpose of this Chapter, the term “Project Surveyor” refers to that person in responsible charge of preparing, signing and sealing the control record of survey. The project surveyor, in consultation with the field supervisor and party chief, is responsible for designing and establishing the project control network.

Project control surveys should provide adequate and permanent horizontal and vertical survey control for engineering, construction, right of way, and final monumentation surveys for the duration of the project. A work plan for establishing the project control should be developed early in the planning phase after consulting the Project Manager.

Designing the project control network so it will allow surveys to meet the needs of all project team members through the life of the project is critical.

Key steps in the control planning process are:

- Research the existing horizontal and vertical control networks.
- Recover and evaluate existing control.
- Design the project control network and select methods to accomplish the required precision and accuracy.
- Develop a survey work schedule that meets the needs of the project schedule.
- Plan supplemental control.
- Safety and sustainability considerations.

If possible, project control should be designed so project control monuments serve as both horizontal and vertical control.

New coordinate values for existing control should be determined by network adjustment of field observations. All primary control monuments must have the same datum tag and epoch date. All primary control monuments must have network accuracy estimates better than or equal to the survey accuracy you are attempting to achieve.

Primary Geodetic Control surveys must be performed using GNSS survey methods. Surveys should be performed in compliance with 1 cm (0.03') horizontal survey standards referenced and adjusted to four NSRS Stations.

Survey procedures, equipment, results, and documentation must conform to NGS specifications if survey results will be submitted to NGS for inclusion in the National Spatial Reference System (NSRS).

I.3 Methodology for Horizontal Control Surveys

I.3.1 Reconnaissance Control

Reconnaissance Control information should be obtained from the NHDOT Survey Office. Recovered monuments should be inspected for damage or movement, and the physical condition, description, etc., checked.

Some requirements for laying out the traverse:

1. Position and azimuth should be connected to known control;
2. Courses should be long and balanced;
3. There should be few sharp angles in traverse alignment;
4. Sight clearance should be about 3 feet;

5. Traverse point locations should be sound and practical, with marks not likely to be disturbed or destroyed and well tied down. Ties are only to be used for locating the traverse points and not for replacing destroyed or disturbed points;
6. All main monuments should have azimuth marks. Azimuths may be turned to spires or other prominent features, or azimuths and distances taken to local bounds, etc. 200 feet or more from station.

I.3.2 Monumentation

Disks for permanent points should be set in 48" concrete or granite monuments, or in concrete structures, ledge, etc. For semi-permanent points, existing solid boundary and right-of-way monuments may be used or punch marks should be made in 3/8" spikes 10"-12" long or similar material driven flush with the ground or countersunk in areas subject to traffic. The primary control traverse shall be set beyond the beginning and end of the proposed construction limits. Intermediate points along the proposed route shall be set outside the limits of construction wherever practicable. Wood hubs and tacks are not suitable control points for the primary control traverse and their use should be restricted to secondary uses such as topographical detail.

I.3.3 Field Checks

Standard field procedure is to close an angle traverse by azimuths or bearings, and to check forward and back measurement runs, and all notes and figures. Fieldbooks books must be indexed and cross-indexed, and should always contain a plan or sketch of each project. Fieldbooks are to be scanned and filed daily in the survey job files.

The crew chief does not normally adjust the traverse or perform computations unnecessary for field work. However, if a data collector has closure capabilities, it is prudent to check the closure in the field to avoid a return trip. If recording is done manually, enough checking should be done to ensure that the traverse is complete and will close.

I.4 Vertical Control

NHDOT currently specifies NAVD 88 datum for all new project surveys. The NHDOT vertical accuracy is based on NOAA Manual NOS NGS 3 –Geodetic Leveling, Table 1.1, Page 1-5. The NHDOT Licensed Land Surveyor may allow use of NGVD 29, existing local benches, or even an "assumed" bench for small isolated projects. Written approval for deviation of NAVD 88 is required.

Vertical control for a project shall be connected and adjusted to published bench marks of an equal or higher order. At least two published benches shall be used and these should be checked for relative difference of elevation.

The NHDOT Land Surveyor will investigate the benefit cost analysis of the time/cost and accuracy to run in levels verses using GPS constrained to published control which may be adequate.

I.5 Methodology for Vertical Control

Although some general guidelines are detailed here, Appendix A-11 should be reviewed for FGCC standards for differing instrumentation and field procedures by order and class.

Level lines shall originate at and close upon First-Order bench marks when available or be run in closed circuits. At least two bench marks, shown by new leveling not to have changed their relative elevations, must be used as the starting point.

Third-Order levels should be run by three wire leveling and be run in sections between permanently marked bench marks not more than 2 km in length.

All lines are to be leveled independently in both the forward and backward directions, preferably under different atmospheric conditions (such as forward in the morning and back in the afternoon).

Portable turning points such as 0.3 - 0.5 m iron pins may be used. Turning plates should be used if pins are inappropriate.

Any permanent or temporary bench mark that is established on the forward run must be included on the back run. The thermometer should be read to the nearest degree at the beginning and end of each section.

A daily observation of the collimation error of the level should be made and recorded on a separate page of the level book, using the CFactor method. If "C" is greater than .05 mm/m, the level must be adjusted.

The difference between lengths of foresight and of backsight shall not exceed 10 m. The length of sight should be great enough so that 5% to 15% rerunning may be expected. Short sights and a small amount of rerunning may indicate lack of production and excessive caution.

Longer sights of not exceeding 60 m generally indicate satisfactory production. Experience will show ideal lengths of sight for a survey party.

A temporary bench mark should never be used to begin or end the day's work unless it is properly recorded in the notebook. It must be permanent in nature such as the top of a bolt or pin in a concrete base, a chiseled square on solid concrete, etc. Setups should be "broken", i.e., the instrument height (HI) at the end of the forward run should be changed before the back run is begun.

I.6 Monumentation

Passive monuments will be along transportation corridors in secure locations. The station site will be selected with safety considerations given highest priority for the land surveyor and the traveling public. Locate monuments to minimize disturbance by construction and to be clear of traffic and accessible, preferably within a public right of way or easement and accessible to the public.

Typical locations are:

- Along freeway ramps near the junction of the right of way for the ramp and the local street.
- Within county or city street right of way.
- Bridge abutments.
- On public property or at public facilities (canals, parks, etc.).

Select station locations that can be easily described. When several locations are equally satisfactory, choose the one near features that will aid in future monument recovery.

Project control monuments will be constructed to ensure permanency. Monument type will be chosen to suit the local conditions.

If the survey results will be included in the NSRS, use brass or aluminum disks specifically designed and manufactured for NGS survey station identification.

For projects that will require GNSS Real Time Kinematic (RTK) site calibration, a minimum of four passive monuments will be established. Each of these monuments must be within a different quadrant relative to the project, and the project must lie within the perimeter of the monuments. These monuments must have both horizontal and vertical coordinates, and will establish the site calibration for all subsequent GNSS RTK surveys performed on the project.

For projects that will use Total Station Survey techniques, two sets of “Azimuth Pairs” at the beginning and end of each project is typical. Small projects may have a minimum of three monuments. For larger projects, intermediate azimuth pairs should be spaced a maximum of three miles apart (where conditions allow) along the project main line, or at major “conform” locations, such as interchanges.

I.7 Secondary Control Surveys

Secondary control surveys are undertaken to densify project control surveys. Secondary control is used for establishing aerial mapping control, establishing setup points for engineering surveys, construction staking, locating land net monuments, and setting right of way monuments. Secondary control points may be used for both horizontal and vertical control.

Supplemental control becomes essential to projects when the contractor is implementing Automated Machine Guidance (AMG) to control line and grade.

I.8 Accuracy

Horizontal supplemental control surveys will meet 0.07 ft. local accuracy or *Third Order* survey standards. Vertical control must meet *Third Order* standards.

I.9 Secondary Monumentation

Monuments should be set where needed, preferably out of the way of construction and in stable ground. Supplemental monuments may not last the life of a project, and may be set using lesser quality materials. Typically they are spikes, P.K. nails in paving, chiseled crosses in concrete or similar materials. The party chief will determine the expected life of the supplemental control monument, and select the proper material accordingly. “Temporary” points may be wood hub and tack.

I.10 Post-Construction Control Surveys

With most construction projects, primary project and secondary control points are lost or obliterated due to the new construction. Once the construction has been completed the survey crew should re-establish project control within the project boundary. The re-established project control will be used to complete the final monumentation of the new right of way, or the perpetuation or replacement of lost or obliterated right of way or boundary monuments. The post construction project control will facilitate any surveys required by construction for the settlement of claims. Post construction control will be included in the Survey Report filed by the project surveyor.

I.10.1 Accuracy

Monuments must be tied to the primary project control network, and set to 0.07 ft. local accuracy. Vertical control must meet Secondary Project control standards.

I.10.2 Monumentation

All post-construction project control monuments must meet the monument standards. At a minimum, there must be two monuments set at the beginning and ending of the project. They need not be inter-visible, but they must be easily occupied with conventional survey equipment.

I.11 Evaluation and Adjustment

All control surveys will be evaluated, checked and adjusted by a combined least squares using observation equations before being used as a basis for any project survey.

The project surveyor assembles all research materials and completed field data into a project control survey file. The file is then evaluated by:

- Reviewing field notes for completeness and accuracy.
- Reviewing all closures (residuals), adjustments, and conformance to standards.
- Reviewing final adjusted horizontal and vertical coordinate values.

I.12 GPS, GNSS Horizontal Project Control Surveys

Primary project control surveys establish control for transportation improvement projects. All subsequent horizontal surveys for a project are based on the primary project control.

I.13 Methods

Most primary project control surveys are hybrid projects combining GNSS passive control monuments surrounding the project with total station traverse networks between GNSS azimuth pairs.

The specifications for Post Processed GPS Surveys described are based on FGCS (NGS) Geospatial Positioning Accuracy Standards. GPS, GNSS survey specifications are to be used for all NHDOT involved transportation improvement projects.

I.14 Post Processed GPS Specifications

I.14.1 Static GPS Surveys

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. A minimum of two observations per control point separated by a period of a minimum of four hours

I.14.2 Fast-static GPS Surveys

Fast-static GPS surveys are 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. Typically, the fast-static GPS method should not be used for corridor control or other surveys requiring horizontal accuracy greater than *first order*.

I.14.3 Kinematic GPS Surveys

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.

I.14.4 RTN

Realtime Network surveys make use of a group of base stations that collect GNSS observations and send them in real-time to a central processing system. The Central processor will then combine the observations from the base stations and compute a network solution. From this network solution the observation errors and their corrections are computed and broadcast to rovers working within the bounds of the RTN. There are different RTN approaches in use including the virtual reference station (VRS). Using proper procedures, RTK and RTN methods can provide relative 3D accuracies to within 0.03 feet horizontally or 0.05 – 0.10 feet vertically.

I.14.5 OPUS GPS Surveys

The NGS On-line Positioning User Service (OPUS) allows users to submit individual GPS unit data files directly to NGS for automatic processing. Each data file that is submitted is processed with respect to 3 CORS sites. OPUS solutions shall not be used for producing final coordinates or elevations on any NHDOT survey; however OPUS solutions may be used as a verification of other procedures.

I.15 GPS Equipment

Post processed GPS surveying equipment generally consists of two major components: the receiver and the antenna.

I.15.1 Receiver Requirements

When performing specific types of GPS surveys (i.e. static, fast-static, and kinematic), receivers and software shall be suitable for the specific survey as specified by the manufacturer. Dual frequency GNSS receivers shall be used

I.15.2 Antennas

All antennas used for a project should be identical. Antennas shall be mounted on a tripod or a stable supporting tower with optical plummets or collimators to ensure accurate centering over marks.

I.15.3 Miscellaneous Equipment Requirements

All equipment must be properly maintained and regularly checked for accuracy. Errors due to poorly maintained equipment must be eliminated to ensure valid survey results. Level vials, optical plummets, and collimators shall be calibrated at the beginning and end of each GPS survey. If the duration of the survey exceeds a week, these calibrations shall be repeated weekly for the duration of the survey. Fixed height tripods should be used whenever feasible.

I.16 Network Design

I.16.1 Baselines (Vectors)

Baselines are developed by processing data collected simultaneously by GPS units at each end of a line. For each observation session, there is one less independent (non-trivial) baseline than the number of receivers collecting data simultaneously during the session. Three receivers placed on stations 1, 2, and 3 for Session "A" yield two independent baselines and one dependent (trivial) baseline. Magnitude (distance) and direction for dependent baselines are obtained by separate processing, but use the same data used to compute the independent baselines. Therefore, the errors are correlated. Dependent baselines shall not be used to compute or adjust the position of stations.

I.16.2 Loops

A loop is defined as a series of at least three independent, connecting baselines, which start and end at the same station. Each loop shall have at least one baseline in common with another loop. Each loop shall contain baselines collected from a minimum of two sessions.

I.16.3 Networks

Networks shall only contain closed loops. Each station in a network shall be connected with at least two different independent baselines. Avoid connecting stations to a network by multiple baselines to only one other network station. Primary and secondary GPS control networks shall consist of a series of interconnecting closed-loop, geometric figures.

I.16.4 Redundancy

GPS control networks shall be designed with sufficient redundancy to detect and isolate blunders and/or systematic errors. Redundancy of network design is achieved by:

- Connecting each network station with at least two independent baselines
- Series of interconnecting, closed loops
- Repeat baseline measurements

I.16.5 Reference Stations

The reference (controlling) stations for a GPS Survey shall meet the following requirements:

- Same or higher order of accuracy as that intended for the project

- All on the NAD83 datum.
- All of the same epoch, or adjusted to the same epoch using National Geodetic Survey (NGS) procedures
- Evenly spaced throughout the survey project and in a manner that no project station is outside the area encompassed by the exterior reference stations

I.17 Satellite Geometry

Satellite geometry factors to consider when planning a GPS survey are:

- Number of satellites available
- Minimum elevation angle for satellites (elevation mask)
- Obstructions limiting satellite visibility
- Positional Dilution of Precision (PDOP)
- Vertical Dilution of Precision (VDOP) when performing vertical GPS surveys

Type	Relative Accuracy (95%)	Maximum PDOP	Minimum # of Satellites	Site Calibration
Static GNSS	0.07’ + 1:20,000	5	4	No
RTK GNSS	0.07’+1PPM Distance from base	3	5	Yes
VRS GNSS	0.07’	3	5	No

I.18 Field Procedures

I.18.1 Reconnaissance

Proper field reconnaissance is essential to the execution of efficient, effective GPS surveys. Reconnaissance should include:

- Station setting or recovery
- Checks for obstructions and multipath potential
- Preparation of station descriptions (monument description, to-reach descriptions, etc.)
- Development of a realistic observation schedule

I.18.2 Station Site Selection

The most important factor for determining GPS station location is the project’s requirements (needs). After project requirements, consideration must be given to the following limitations of GPS:

- Stations should be situated in locations, which are relatively free from horizon obstructions. In general, a clear view of the sky 15 degrees above the horizon is required. Satellite signals do not penetrate metal, buildings, or trees and are susceptible to signal delay errors when passing through leaves, glass, plastic and other materials.

- Locations near strong radio transmissions should be avoided because radio frequency transmitters, including cellular phone equipment, may disturb satellite signal reception.

- Avoid locating stations near large flat surfaces such as buildings, large signs, fences, etc., as satellite signals may be reflected off these surfaces causing multipath errors.

With proper planning, some obstructions near a GPS station may be acceptable. For example, station occupation times may be extended to compensate for obstructions.

I.18.3 Weather Conditions

Generally, weather conditions do not affect GPS survey procedures. Wet or snow covered trees can increase the potential for multipath errors.

Significant changes in weather or unusual weather conditions should be noted in the observation log (field notes). Horizontal GPS surveys should generally be avoided during periods of significant weather changes. Vertical GPS surveys should not be attempted during these periods.

I.19 Accuracy

I.19.1 Horizontal Order of Accuracy

NHDOT follows the FGCS (NGS) Geospatial Positioning Accuracy Standards for survey work. If a surveyor deems it necessary to vary from these standards, prior approval should be obtained from the NHDOT Licensed Land Surveyor or NHDOT Geodesist in writing.

Error of closure is only one of the many factors, which determine the accuracy of a survey. Proper procedures and instrumentation as detailed in FGCS Geospatial Positioning Accuracy Standards should be used.

I.19.2 Vertical Control Order of Accuracy

- NHDOT follows NOAA Manual NOS NGS 3- Geodetic Leveling, Table 1.1 page 1-5.

- Control bench marks should meet First-Order, Class 2 standards.

- Second-Order, Class 1 is normally required for major bridges, tunnels and all structures of such size and importance as to justify geodetic precision.

- Second-Order, Class 2 applies to the majority of NHDOT projects, most highways and roads except minor ways.

Third-Order accuracy is a minimum requirement, to be used where higher accuracy is not needed.

I.19.3 Reduction of Repeated Raw Survey Measurements

Repeating survey measurements is standard practice for all traverse operations. It is possible to achieve suitable survey accuracies and closures without repeating traverse measurements. However, the advantages derived from repetition, the elimination of systematic errors through equal numbers of direct and reverse observations, and the possible increase in precision through averaging repeated measurements, far outweigh the short increase in observation time.

In addition to repetition, another recommended practice when using a total station or EDM is having a prism or reflector height measurement on all backsights. This enables checks on the horizontal distance and elevation change measured in opposite directions and on errors which repetition will not disclose such as in height of instrument (HI), height of target (HT) or reflector (HR), instrument setup over the point and reflector setup over the point.

If performing a series of sideshots from a control point backsighting another control point, a prism on the backsighted station can provide an excellent mathematical check by comparing the horizontal distance and elevation change to values derived from the control coordinates.

The reduction of repetitions is generally a simple averaging process. As a byproduct of that process, standard deviations, standard deviations in the mean and the maximum spread of any single measurement from the average can be computed. The maximum spread should be the major factor in assessing the quality of a series of repetitions. Horizontal distances should generally not have a deviation of more than 0.03' + 10 ppm; trigonometric elevation difference maximum spread should not exceed 0.07' + 50 ppm; differential rod readings which are repeated should not exceed twice the least count of the rod; in three-wire leveling the average of the upper and lower wires should not differ from the middle wire reading by more than two times the least count of the rod. The horizontal angle maximum spread should not be more than twice the Smallest Measuring Ability (SMA) on lines longer than 800'. On shorter lines, the sine of maximum spread times the length of the shortest line (backsight or foresight) should not exceed 0.03'.

A particular project may require specific standards for standard deviation in a single observation or standard error in the mean. The maximum spread from the mean remains the best indicator of the possibility of error in a repetition.

An obvious outlier should be discarded and not used in determining the mean. The most common standard for an acceptable angle is +/- 5" from the mean. When there is an unusually large spread between angles or if the angles appear to be creeping up or down in a consistent manner, the instrument and reflector setup data should be checked.

I.20 Reduction to a Datum

While some surveys may be based on assumed plane coordinates, most highway projects are of sufficient dimension that geodetic aspects must be considered. Computation of coordinates with respect to a datum may involve production of:

I.20.1 Geocentric Coordinates: an earth centered system within which GPS primarily works. If a combined GPS/traverse control network has been observed, this may be the most realistic system for coordinate production as the conventional measurements are also definable in this system. No application of scale or elevation factors to horizontal distances are required in such a system. Software can readily convert values to state plane coordinates.

I.20.2 Latitude, Longitude and Elevation: the conventional geodetic coordinate system is well documented and applicable to their computation based on survey measurements. Unfortunately, the equations are not simple and are unavailable in most commercial survey reduction software. Horizontal distances must be reduced to the datum surface (ellipsoid) before coordinates are computed.

I.20.3 State Plane (SPC) or Universal Transverse Mercator (UTM) Coordinates: These are probably the most widely used geodetic reference systems for reduction of conventional survey traverse data, with state plane predominating for survey applications. Plane survey equations can be used if scale and elevation factors are applied to horizontal distances and convergence angles and LaPlace correction factors are applied to any astronomic azimuth determinations.

It is critical to label distances as slope, horizontal, ellipsoidal/sea level, or grid. Likewise directions need to be defined as geodetic, astronomic, or grid when state plane or UTM coordinates and computations are being utilized.

I.21 Horizontal Control Coordinates and Horizontal Datums

In the 1980s the reprocessing of the data, which made up NAD 27, along with measurements made subsequent to that time, resulted in the North American Datum of 1983 (NAD 83). WGS 84 and GRS 80, two nearly identical ellipsoids that are associated with NAD 83, can be considered the same for all conventional survey applications. This reprocessing (a least-squares analysis of the measurement data) produced "readjusted" latitudes and longitudes for all control stations. The shifts in positional information can amount to more than 300’ but are very systematic in magnitude and direction in a localized area. The geodetic direction between two points in a local area stays consistent (the change is normally less than one second) between datums. Unfortunately, an unlabelled latitude and longitude makes it difficult to tell which datum it belongs to, as the change in values between datums is at the level of seconds of arc.

State plane coordinate zones were redefined with different false eastings to make it easier to identify whether the coordinates belonged to NAD 27 or NAD 83, and all coordinates were published in meters instead of feet. A link to existing English units was critical and the U.S. Survey Foot conversion (1 m = 3.2808333333333..... ft. or an exact conversion of 1 m = 39.37 in.) has been adopted by New Hampshire as the standard for conversion between units for all survey work. This conversion is required for all NAD 83 coordinates, which are in feet, bench mark elevations in feet, and any horizontal distances or elevation differences in feet. Since NAD 27 is an English-units based system, all work should be based on the NAD 83 datum.

If NAD 83 equivalents are not available for NAD 27 coordinates, an accepted transformation procedure is NADCON, an NGS program that reads a data base of gridded estimates of coordinate shifts between NAD 27 and NAD 83 and computes weighted shifts for the desired station based on its relative location. The grid was developed from all control stations which had both NAD 27 and NAD 83 coordinates.

Coordinates developed by NADCON should always be clearly identified as such. NADCON only performs the computation in latitude and longitude. If a direct transformation from NAD 27 to NAD 83 state plane coordinates is desired, CORPSCON, a U.S. Army Corps of Engineers program, uses NADCON algorithms in the transformation process and in addition does all the conversions between state plane and latitude/longitude. Both NADCON and CORPSCON are public domain programs because they were developed by government agencies.

NAD 27 coordinates are generally of lower quality than those of NAD 83 because for NAD 83 much more data was available and the computations were performed on computer. It is preferable, therefore, to use control created in NAD 83 rather than NAD 83 control which has been transformed from NAD 27 coordinates.

New Hampshire is part of a New England High Accuracy Regional Network (HARN) based on NAD 83-92. This system was established after publication of NAD 83, so one may find local distortion between existing NAD 83 control and HARN control. If use of HARN is desired, control derived from HARN can be used and all coordinate information generated only from HARN, but the produced coordinates may not "fit" NAD 83 control coordinates in that local area.

I.22 Reduction of Averaged Raw Survey Data

The first reduction of conventional slope distance/zenith angle/height of instrument/height of reflector values (averaged, if repetition is used) is to horizontal distance and elevation change.

Except in precise surveys where correction for earth curvature and atmospheric refraction must occur, the horizontal distance is derived from the slope distance multiplied by the sine of the zenith angle; the elevation change is derived from the height of instrument, plus the slope distance multiplied by the cosine of the zenith angle, minus the reflector height.

The same horizontal distance or elevation change measured on multiple instrument setups (in same direction or in opposite direction via a prism on a backsight) should be averaged.

Horizontal angles, which are repeated, should also be averaged based on the raw horizontal circle readings. If a series of traverse points are being observed, the backsight should generally be the longest line.

Any astronomic observations should be reduced by the standard hour/angle method. Repetitions are critical to assure the quality of this type of measurement. Care should be taken to avoid introducing a systematic error in the time or geodetic position used in the computations. The LaPlace Correction conversion of astronomic to geodetic direction should be applied if significant.

I.23 Production of Horizontal Coordinates - State Plane Reductions

If work is in an assumed coordinate system, no factors will be applied to the values derived in the reduction described above.

Since most transportation work is related to the state plane grid system, care must be taken to apply realistic scale and elevation factors to all horizontal distances, and convergence angles to any astronomic observations or geodetic azimuth mark values.

Elevation factors are computed by: $\mathbf{DS = DH \times [R / (R + h)]}$

where:

DS is the horizontal distance reduced to the ellipsoid (often called sea level in this reduction), in meters;
DH is the reduced "ground" horizontal distance in meters;
R is the approximate radius of the earth, 6,372,200 m; and
h is the ellipsoid height derived from the following: $\mathbf{h = H + N}$

where:

N is the Geoid Height in meters
H is the orthometric height (commonly called the elevation), in meters.

While the ellipsoid is the reference surface for horizontal computations, the height of a point above it was rarely known prior to the introduction of GPS. Since the difference between an ellipsoid height and an elevation rarely exceeds 30 m, using elevation in this reduction causes a systematic error of approximately 1/200,000, which is negligible for most survey applications. To avoid the difficulty in obtaining ellipsoid height, elevation can be used.

One elevation "factor" can generally be used for an entire project. The elevation factor for the lowest and highest elevations of the project should be computed and any error introduced in using one project elevation factor should be verified as not significant. If it is significant, multiple or individual elevation factors must be used.

Scale factor is a function of the location of one's position in the zone and changes slowly in an area. Scale factor does not change in a north-south direction in Transverse Mercator zones like those in New Hampshire.

Scale factors for the corners of a project should be computed and it should be verified whether use of one scale factor will not adversely affect the results. If the scale factor change is significant, multiple or individual scale factors should be used.

The use of software, which automatically calculates all scale factors, elevation factors and convergence angles, is highly recommended. Software, which requires user input of these values, creates the opportunity for transposition and misinterpretation errors.

Software is also available which computes all coordinates in a geodetic fashion although conversion of this to state plane coordinates will invariably be required. Sideshot distances must be reduced to grid prior to coordinate calculations. Grid distance (state plane distance) should not be used for physical distance, i.e. bridge spans, roadways. Final Right-of-Way plans will show Grid distances. The plan should also note the combined scale factor to apply for ground distances.

I.24 Coordinates, Closures, Adjustments, etc.

Any redundant survey measurements produce some type of lack of fit due to random error, usually called closure. In complicated surveys there are many closures which can be calculated as one builds checks by closing traverse routes to, or through, known control points and bench marks, and by creating loop traverses. The least-squares approach is generally recognized as the most suitable adjustment of the random errors in a survey and it has effective reproducibility of results.

Independent of the process used, the amount of adjustment placed on measured distances, angles, astronomic azimuths and elevation differences, generally termed a residual, should be looked at. If a measured horizontal distance reduced to grid is 1640.59’, and after adjustment is 1640.66, the residual is 0.07’.

Residuals should be within the random error measuring limits of your equipment and procedures. Generally, horizontal distance residuals should not exceed 0.05 + 10 ppm, horizontal angle residuals should not exceed 1.5 times the least count of the instrument, except on short lines where the distance multiplied by the sine of the residual should not exceed 0.05’ and trigonometry-derived elevation change residuals should not exceed 0.10’ + 20 ppm. Trigonometric leveling residual limits will be a function of the desired product, the equipment and procedures used, and the job requirements.

Care must be taken to ensure poor control does not systematically enlarge the magnitude of survey measurement residuals. Control values, which prevent job requirements from being met, must be identified and resolved.

I.25 Least-Squares Analysis and Error Estimation

The least squares adjustment shall be a combined adjustment of both the horizontal and vertical level data.

Least squares are the most accepted process for analyzing a GPS network. The limit of the loop closure is that it can only look at a portion of the data. Least squares uses the error estimates of the measurements in evaluating where misclosures on vectors, called residuals, should exist. For example, a vector with a DX error estimate of 0.30' will generally have a larger residual than a vector with a DX error estimate of 0.03'. It is possible that the first DX may have a smaller residual simply because it fits the rest of the data better. A residual can thus be considered the difference between the measured and the adjusted quantity based on the produced final coordinates.

Error estimates for vectors being subjected to the least squares are usually generated by one of the following methods:

a) Error estimate results from baseline processing are used, or

b) The error estimates are similar to electronic distance measurement errors, which are usually a constant plus a ppm. A line receives an error estimate no matter how short it is (constant error) and the error estimate grows for longer measured lines (ppm error).

Each method of error estimation is considered valid, each is suitable for least-squares analysis and each is used by commercially available software. NHDOT recommends method (a) above as those error estimates are related to the conditions that existed at the time of the data collection, e.g. noise, atmosphere, window blockage, cycle slips, etc.

I.26 Minimally Constrained Least-Squares Analysis

The first goal in network analysis (as opposed to individual loop analysis) is verification of the internal fit of the GPS vectors among themselves. In this analysis the final coordinates are not important and the standard procedure is to hold one of the stations fixed in 3-D position based on its approximate coordinate values from single point positioning data generated during vector processing. Holding only one point fixed (minimally constrained) ensures the residuals of the GPS vectors will not be influenced by control coordinates. Mathematically there is no check on control coordinates in a network with only one fixed station and likewise any error in control coordinates will not be propagated into the residuals in the GPS vectors.

The minimally constrained adjustment is an indicator of the quality of the GPS independent of the control which was occupied and is analogous to a conventional traverse with one known horizontal station, one bench mark and one fixed bearing. The value of residuals in DX, DY, DZ components should be close to their error estimates and if it is more than three times the error estimate the measurement is considered suspect. A ratio error of closure can be calculated for the vector by dividing the square root of the sum of the squares of the DX, DY, DZ residuals by the length of the line and that can be converted to a ppm equivalent. No 1/x or ppm derived from the residuals should exceed the tolerances for the job based on the survey accuracy required. The exclusion is short lines in which independent of 1/x, a linear residual of less than 0.03' is acceptable for most survey applications.

I.27 Constrained Least-Squares Analysis

When suitable results from the minimally constrained analysis are confirmed, the next step is to see how the GPS vectors fit the existing control stations, which are part of the network. One difficulty in GPS surveying is that the measurements can often be of better quality than the control coordinates. Holding less precise control coordinates fixed will result in GPS vectors with larger residuals than reflected by the minimally constrained analysis.

I.27.1 Control Issues

Control can be 3-D, 2-D or 1-D in nature. While in route projects the 3rd dimension is elevation relative to the Geoid, often approximated and referred to as mean sea level, GPS does not directly measure elevation differences. The third dimension in GPS is distance up or down from the ellipsoid (Clarke 1866 in NAD 27 and GRS 80 in NAD 83).

I.27.2 Relation of the Ellipsoid to the Geoid

In a local area (no larger than 6 miles in any direction) where no gravity anomalies are present, an ellipsoid height difference and an elevation difference between two stations will be within 0.30’. The direction of gravity and a perpendicular to the ellipsoid will also be near coincident and the ellipsoid height difference between two stations can be assumed to be very near the elevation difference in magnitude for GPS networks in a local area. This assumption is valid for surveys where precise elevations are not required and is within the accuracy limits of trigonometric leveling. The exact difference between ellipsoid and orthometric heights can be determined by comparing ellipsoid height difference obtained by GPS with orthometric height difference obtained by leveling.

In a local area, the elevations can be considered ellipsoid heights in what could be called a local ellipsoid solution. In a least-squares adjustment to determine 3-D position, the correct elevation should always be the ellipsoid height. To test the reliability of elevations being produced, withhold some of the bench mark elevations as control and see how close the least squares results are to their published values.

The solution to resolving the ellipsoid height to elevation issue is to occupy three or more bench marks in every GPS network. At least three horizontal control points should also be included in every GPS network, because if one of the GPS points is in error, having only two control points can identify the problem but not resolve it. While lack of window due to obstructions or time constraints may prevent some control points from being occupied, preference is that all control of suitable quality in an area should be part of a GPS survey to ensure its consistency.

It is highly recommended that all GPS surveys be tied into the HARN (High Accuracy Regional Network). An important reason for using HARN is that it provides an accurate ellipsoid height. To obtain good orthometric heights for a GPS network, several things are required:

- At least one, and preferably more, accurate ellipsoid heights;
- At least three accurate elevations of GPS points;
- A method of determining Geoidal separation at all points within the network.

I.27.3 Biased Constraints

The constrained least-squares analysis normally allows "biased constraints" to be defined, which allows rotation of the GPS vectors to better fix the control points in the area. This is especially useful when using elevations directly because the Geoid/ellipsoid separation changes slowly over an area, which amounts to a rotation. The biased constraints should be used with extreme caution as "rotating" the GPS survey to fit unreliable control coordinates is an incorrect process. The unreliable coordinates should be identified and not used.

I.27.4 Control Evaluation Process

The most logical way to start the constrained least-squares evaluation process is to add control in sequentially. Start with the best horizontal and vertical control station(s). One 2-D and one 1-D as control is the equivalent of a minimally constrained analysis. Run the least squares and examine the "closeness" of the produced coordinates of control, which was withheld to the published values. If the results appear in close agreement, those control coordinates can probably be added to the adjustment without adverse effect. Control coordinates that don't match well should be added last or not at all due to lack of fit with the other control coordinates in the network.

As you add more control the least-squares analysis, statistics may worsen, due to imperfections in control coordinates. If the data becomes dramatically worse, a suspect control coordinate has been entered and must be eliminated or otherwise resolved (e.g., the coordinate may have been entered in the computer incorrectly).

I.27.5 Identifying a Realistic Analysis Result

A realistic constrained analysis will produce vector residuals, which are no worse than the job accuracy requirement. If desired accuracy is 1/50,000 (20 ppm) no vector should have a residual greater than 20 ppm except for extremely short lines where the 0.03' residual can be used. If the minimally constrained analysis produces reliable results, and if with all control entered the constrained analysis shows results, which do not meet, desired accuracy, the surveyor must determine which control points are suspect and they should be removed from the constrained analysis.

All control coordinates must be in the same datum. HARN network coordinates may not match some local control performed by conventional traverse in even fairly recent years. Two vertical datums exist in North America and they cannot be mixed. Final results must produce coordinates, which are precise relative to one another and from which a route project can realistically be developed.

I.28 Documentation

The final GPS Survey project file should include the following information:

- Project report
- Project sketch or map showing independent baselines used to create the network
- Station descriptions
- Station obstruction diagrams
- Observation logs
- Raw GPS observation (tracking) data files
- Baseline processing results
- Loop closures
- Repeat baseline analysis
- Combined least squares unconstrained adjustment results
- Combined least squares constrained adjustment results
- Final coordinate list

I.29 General

For Post-Processed GPS surveys, raw GPS observation (tracking) data shall be collected and post processed for results and analysis. The primary post-processed results that are analyzed are:

- Baseline processing results
- Loop closures
- Repeat baseline differences
- Results from least-squares network adjustments

Post-processing software shall be capable of producing relative-position coordinates and corresponding statistics which can be used in a three-dimensional least squares network adjustment. This software shall also allow analysis of loop closures and repeat baseline observations.

I.30 Total Station Surveys

Total Station Surveys include a total station survey instrument and an electronic data collecting system. The system also includes tripods, tribrachs, prisms, targets and prism poles.

Total Station Surveys are used to perform the conventional survey methods of traverse, network, resection, multiple ties, and trigonometric leveling.

I.31 General Total Station Survey Specifications

I.31.1 Redundancy

When proper procedures are followed, a total station survey generally can easily meet the necessary accuracy standards. These procedures include redundancy of observations, thereby reducing the possibility of blunders. Also, a complete set of angles is observed whenever establishing or tying existing critical points such as control points and boundary monuments. Redundant observations such as multiple ties should be observed to improve the information available for least squares adjustments and to strengthen survey control networks.

I.31.2 Equipment Checks

Systematic errors due to poorly maintained equipment must be eliminated to ensure the collection of valid survey data. Optical plummets, laser plummets, tribrachs, tripods, and leveling bubbles should be checked and adjusted regularly.

I.31.3 Height of instrument and target

Measure and enter the H.I. and H.T. into the data collector at the beginning of each set up. It is advisable to check target and instrument heights at the completion of each set up along with the plummet's position over the point.

I.31.4 Field Notes

Handwritten survey notes shall be used to supplement the data collector notes. These notes can include sketches, detailed descriptions as appropriate and other general comments about the survey.

Original survey notes for all total station survey observations are maintained by the data collector and the data collector program. Metadata shall be complete and comments about observations that could affect data reduction should be added to the data collector file. Data for all points that will be used as control and any property corner monuments shall be collected as foresight observations not radial observations in the data collector.

I.31.5 Survey Adjustments

All control points used for data gathering and stake out, including photo control, shall be analyzed by the method of least squares. Residuals should not exceed equipment specifications. Resected control points are adjusted for horizontal position by least squares before they are used in the field.

I.32 Applications

I.32.1 Primary Project Control Surveys

Total stations can be used for horizontal and vertical Project Control Surveys to densify project control established by GPS.

Methods of establishing Primary Project Control:

Traverse with cross ties

Trigonometric leveling

Operation/Specification	Traverse/Network
Check vertical index error	Daily
Check horizontal collimation	Daily
Measure instrument height and target heights	Begin and end of each setup
Use plummet to check position over point instrument and targets	Begin and end of each set up
Observe traverse multiple ties	As feasible
Close all traverses	Required
Horizontal, Vertical and Distance observations	3 Direct, 3 Reverse
Angular rejection limit, residual not to exceed	5”
Maximum value for the mean of the standard of error of horizontal and vertical angles	0.8”
Distance rejection limit: residual not to exceed	0.005 foot +/- 2ppm
Minimum distance measurement	300 feet

I.32.2 Secondary Control Surveys

Secondary control surveys include:

- Supplemental Control Surveys for Construction and Engineering Surveys
- Photogrammetric Control
- Boundary Location Control
- Monumentation Control
- Major Structure and Interchange Staking

Secondary control points are points that will be used as set-up points to gather topographic data, locate boundary monuments, perform Construction Staking and set-out other control and R/W monuments.

Method for establishing Secondary Control:

• Traverse

• Resection: This method locates the unknown position of a set-up point by observing known positions from the unknown set-up point. Data for resected points are collected as foresight observations. Generally, points should be resected by observing three known points of third order or greater accuracy. Two point resections may be acceptable if the angle between the observed points is less than 135 degrees or greater than 225 degrees. All specifications for must be met.

• Multiple Tie (Intersection): This method locates points of unknown position by observing the points from two or more control points. These observations must be collected as foresight observations not as radial observations.

Operation/Specification	Traverse/Network
Check vertical index error	Daily
Check horizontal collimation	Daily
Measure instrument height and target heights	Begin and end of each setup
Use plummet to check position over point instrument and targets	Begin and end of each set up
Observe traverse multiple ties	As feasible
Close all traverses	Required
Horizontal, Vertical and Distance observations	1 Direct, 1 Reverse
Angular rejection limit, residual not to exceed	5”
Maximum value for the mean of the standard of error of horizontal and vertical angles	1.2”
Distance rejection limit: residual not to exceed	0.01 foot +/- 2ppm
Minimum distance measurement to meet horizontal accuracy standard	160 feet

I.32.3 General-Order Surveys

General order surveys include:

- Engineering Survey collected topographical data
- Construction Survey, staked points
- GIS Surveys
- Environmental Surveys
- Right of Way Surveys, staked points

Method for establishing General Order Control

The radial survey method is used for all general-order surveys. Data for general-order points are gathered as radial observations in the data collector and are not available for least squares adjustment.

For construction staking, staked positions are rejected, when the difference between the “set” (observed) position and the theoretical design position exceeds the allowable tolerance.

Engineering survey data points are checked by various means including reviewing the digital terrain model, reviewing data terrain lines in profile, and redundant measurements to some points from more than one setup.

Operation/Specification	Traverse/Network
Check vertical index error	Daily
Check horizontal collimation	Daily
Measure instrument height and target heights	Begin and end of each setup
Use plummet to check position over point instrument and targets	Begin and end of each set up
Observe traverse multiple ties	As feasible
Close all traverses	Required
Horizontal, Vertical and Distance observations	1 Direct
Maximum measurement distance to meet vertical accuracy standard for hard surface measurements	500 feet

ORDER	STANDARDS		MONUMENT SPACING AND SURVEY METHODS			APPLICATION - TYPICAL SURVEYS		SPACING OF AZIMUTH PAIRS
	CLASSICAL		MONUMENT SPACING	TYPICAL SURVEY METHOD				
	HORIZONTAL	VERTICAL	(TYPICAL)	HORIZONTAL	VERTICAL	HORIZONTAL	VERTICAL	
PRIMARY GEODETIC CONTROL	1 : 50,000	$e = 0.025'\sqrt{M}$		TOTAL STATION TRIG	DIGITAL BAR CODE LEVEL WITH INVAR STAFF	PRECISE CONTROL FOR STRUCTURES AND TUNNELS (NOT REQUIRED FOR TYPICAL PROJECTS)		
PRIMARY PROJECT CONTROL	1 : 20,000	$e = 0.035'\sqrt{M}$	TSSS 930 Ft. Min	TOTAL STATION TRIG NETWORK TRAVERSE	3-WIRE OPTICAL LEVELING TRIG LEVELING	CORRIDOR AND PROJECT CONTROL - HORIZONTAL	PREFERRED PROJECT CONTROL	1860' ≈ 2cm 930' ≈ 1cm
SECONDARY CONTROL	1 : 15,000	$e = 0.05'\sqrt{M}$	≥ 160'	TOTAL STATION NETWORK TRAVERSE	TOTAL STATION - TRIG LEVELING	SUPPLEMENTAL CONTROL CONSTRUCTION CONTROL PHOTO. CONTROL - HORIZONTAL RIGHT OF WAY SURVEYS CONSTRUCTION SURVEYS ENGINEERING SURVEYS	PROJECT CONTROL - VERTICAL SUPPLEMENTAL CONTROL PHOTO. CONTROL - VERTICAL CONSTRUCTION SURVEYS ENGINEERING SURVEYS	928' ≈ 2cm 464' ≈ 1cm
SUPPLEMENTAL CONTROL	1;7500	$e = 0.05'\sqrt{M}$	≤ 500'	TOTAL STATION RADIAL SURVEY	TOTAL STATION: TRIG LEVELING, SINGLE WIRE, DIRECT ELEVATION ROD, HAND LEVEL	TOPOGRAPHIC SURVEYS (DATA POINTS), SUPPLEMENT DESIGN DATA SURVEYS, CONSTRUCTION SURVEYS (STAKED POINTS), RIGHT OF WAY FLAGGING, ASSET INVENTORY SURVEYS, ARCHEOLOGICAL SURVEYS, ENVIRONMENTAL SURVEYS, HISTORICAL PRESERVATION SURVEYS, MONITORING SURVEYS, EARTHWORK SURVEYS SUCH AS STOCKPILES, BORROW PITS		

ORDER	STANDARDS		PROCEDURES				TYPICAL APPLICATIONS	
	POSITIONAL ACCURACY		MONUMENT SPACING		SURVEY METHODS			
	HORIZONTAL	VERTICAL	HORIZONTAL	VERTICAL	HORIZONTAL	VERTICAL	HORIZONTAL	VERTICAL
1.0 cm (0.03 ft) Network Accuracy PRIMARY GEODETIC CONTROL	0.010 m (0.03 ft) or less 95% confidence circle Network Accuracy		2300 ft min. (700 m)	Average Spacing 1.0 mi (1.6km)	GNSS : Static / Fast Static	Differential : Digital Level / Invar bar code rod	Corridor or Project control: Azimuth Pairs-Basis of Coordinates / Bearings	Geodetic Control - Used in lieu of FGDC Second Order Class I porportional verical surveys
2.0 cm (0.07 ft) Network Accuracy PRIMARY Project CONTROL	0.020 m (0.07 ft) or less 95% confidence circle Network Accuracy		1860 ft min. (570 m)	Average Spacing 4.3 miles (7 km)	GNSS : Static / Fast Static Total Station Traverse	GNSS : Static/ Fast-Static Differential : Digital or Optical Level with standard rod	Primary Project Control, Base Stations and Azimuth Pairs to be saved for future projects.	Used in lieu of Third Order Proportional vertical surveys for GNSS network surveys
0.07 ft (2.0 cm) Local Accuracy Secondary Project CONTROL	0.07 ft (0.02 m) or less 95% confidence circle Local Accuracy		500 ft min. (140 m)	Maximum Spacing 10 turns (4400 ft)	GNSS : Static / Fast Static / Real Time Kenematic (RTK); Total Station Traverse	Differential : Digital or Optical Levels with Standard rod; Total Station - trigonometric leveling	Boundary Surveys and Supplemental Project Control - Traverse between Azimuth Pairs	Densification of vertical Project Control Network
0.2 ft (Five centimeter) Local Accuracy SUPPLEMENTAL CONTROL	0.2 ft (0.05 m) or less 95% confidence circle Local Accuracy		N/A	N/A	GNSS : RTK Total Station: Sideshot within 500 ft (Ground)	GNSS : RTK ; Total Station - Same as Horizontal ; Optical level or better	Topographical features (signs, water valves, etc.), High-Risk utilities, existing culverts	Original Ground Elevations, utility As-Builts

NHDOT Survey Technical Standards

Section II

Boundary and Right-of-Way Surveys

II.1 Right-of-Way Surveys

Right of Way surveys are performed to gather data on existing property lines, areas where unwritten rights may exist, and any other evidence for use in conjunction with existing land records and right of way requirements to determine, delineate, appraise, acquire, demarcate, monument, and map the Department's rights of way.

The right-of-way survey specifications in this chapter should be used for all Department-involved transportation improvement projects, including special-funded projects. All Department employees and consultants performing right-of-way surveying tasks should use them. It is the Department employees' and consultant's responsibility to adhere to all relevant processes, workflows, and specifications stated in this chapter. Questions about this chapter should be directed to the Departments Licensed Land Surveyor. Any deviation from these standards requires advance written approval from the Licensed Land Surveyor. This section provides policies, general information, and procedures regarding the right-of-way surveys process for the surveyors use as deemed appropriate.

II.2 General Policy

The Department's policy regarding right-of-way surveys, as defined by this section, is to provide, in a timely manner, complete and accurate survey information.
It is also the Department's policy that all right-of-way surveys shall be based upon other requirements in the rest of the Department's Survey Manual as necessary. Additionally, it is the Department's policy to adhere to all laws pertaining to land surveying.

II.3 General Information

Right-of-way surveys are used to help define and demarcate the boundaries of the Department's right-of-way in relation to existing property boundaries. Right-of-way surveys are not intended to monument boundaries of the adjoining property owners, other than the common boundary between the Department's right-of-way and the adjoining property. However, there may also be situations where it is necessary to define the adjoining owners' property line in areas where the right-of-way or other easements were acquired along a property line.

The primary purpose of a right-of-way survey is to provide sufficient survey data necessary for the proper retracement of the existing right-of-way and associated easements.

The retracement of the existing right-of-way and associated easements may be used for the following:

- Creation of project lay out plans for new acquisitions
- Legal descriptions and deed preparation
- Negotiation purposes

- Condemnation purposes
- Right-of-way flagging, staking and monumentation
- Encroachment and trespass resolution
- Tort cases

Right-of-way surveys are an integral element of the Department's acquisition and disposal of property rights.

These property rights may include:

- Parcels and/or interest in parcels acquired for the Department's transportation facilities
- Relocated right-of-way to be discontinued
- Lands that have been declared surplus (no longer needed by the Department)

II.4 Unit of Length

The standard unit of length for NHDOT land surveying and mapping is the US Survey foot. Baselines shall use 100-foot survey stationing. The standard interval for marking baseline, taking detail and/or cross sectioning shall be 50 feet. NHDOT conforms to the National Geodetic Survey (NGS) policy and NH Statues Chapter 1-A, section 1-A:4 for providing state plane coordinates (SPCs) in meters and decimals of a meter and United States survey feet and decimals of a foot when dealing with the North American Datum of 1983 (NAD 83).

When the previous datum (NAD 27) became law, the "U.S. survey foot" was the standard unit of length. The distinction between the "U.S. Survey Foot" and the "international foot" is a subtle but important one. The "international foot" is defined as 0.3048 m exactly and the U. S. Survey Foot is defined as 1200/3937 m, or 0.30480061 m. The "international foot" is shorter than the "U.S. survey foot" by 2 parts per million. This difference may not be a factor in distance measuring, but can introduce major errors in coordinate conversions if not considered.

By statute and regulation, for conversion of meters to U.S. survey feet "…the meters shall be multiplied by 39.37 and divided by 12 which results in a constant multiplier having a value of 3.280833333333 to 12 significant figures."

II.5 Horizontal And Vertical Datums

The horizontal datum in use by NHDOT is the North American Datum of 1983. The ellipsoid that forms the basis for NAD 83 is the Geodetic Reference System of 1980 (GRS 80) Ellipsoid. The previous system, the North American Datum of 1927 (NAD 27), used the Clarke Spheroid of 1866 and was the basis for the State' Transverse Mercator Projection. The difference between the two ellipsoids is the major reason for the coordinate shift from NAD 27 to NAD 83. The GRS 80 Ellipsoid provides improved values for the earth's size and shape and removed previous distortions. Surveys performed for NHDOT should be in NAD 83 state plane coordinate values.

The vertical datum in use by NHDOT for many years is the National Geodetic Vertical Datum of 1929 (NGVD 29), formerly known as Mean Sea Level datum. NGS has developed an improved vertical datum, the North American Vertical Datum of 1988 (NAVD 88). NHDOT is now using the NAVD 88 datum on all bench marks.

Any questions on local control or the proper datum to be used, or for conversion from one datum to another, should be referred to the NHDOT Licensed Land Surveyor.

II.6 Control Surveys

Control surveys establish a common, consistent network of physical points that are the basis for controlling the horizontal and vertical positions of transportation improvement projects. Corridor control surveys ensure that adjacent projects have compatible control.

Project control surveys provide consistent and accurate horizontal and vertical control for all subsequent project surveys-photogrammetric, mapping, planning, design, construction and right-of-way.

All horizontal data for NHDOT highway and bridge projects are required to be in the New Hampshire State Plane Coordinate System (SPCS) on the North American Datum of 1983 (NAD 83), except for those excluded by the Department. The SPCS in New Hampshire is a Transverse Mercator Projection.

All vertical data on NHDOT highway and bridge projects are required to be on the North American Vertical Datum of 1988 (NAVD 88).

Some projects, usually small isolated ones, may not be within reasonable distance of geodetic control. The NHDOT Licensed Land Surveyor reserves the right to exclude such projects from standard control requirements.

The latest available information on the location, suitability, and known condition of New Hampshire Geodetic Survey and National Geodetic Survey (NGS) control is available at the NHDOT Survey Office. That office should be consulted before survey work requiring geodetic control is undertaken.

II.7 Surveys by Consultants

All surveys performed for the Department by consultants (design engineers, survey contractors, survey sub-consultants, etc.) are subject to the Department's inspection at all stages of a project.

Such consultants are directed to seek advice and information from the NHDOT Survey Office for the best available control in the area of a project before they estimate survey costs or begin reconnaissance. Control anticipated to be good may be destroyed or inadequate and new control may have been added that will simplify the survey operation. Circumstances may warrant the Department to expand or readjust control. Survey consultants working on NHDOT projects will run control only with prior NHDOT approval and based on NGS control approved as sufficient.

II.8 Horizontal Control

NHDOT will use Global Positioning System (GPS) procedures to establish control at most NHDOT projects as a base for all survey work to be performed. See NHDOT Survey Technical Standards Section I.

Horizontal control surveys establish control for transportation improvement projects. All subsequent horizontal surveys for a project are based on the horizontal project control.

On most large projects, basic horizontal control consists of a random-type traverse connected and adjusted to NGS control. Such traverses are usually run out using electronic total stations or theodolites with electronic distance measuring devices (EDMs), of suitable quality to obtain the desired precision.

Any reproduced highway baseline included in the control must be measured and tied in to meet the required precision. Primary control should be tied in strongly to NGS control unless other control has been stipulated. Secondary control should be connected to control of equal or better precision.

Unless a closed survey is made, the use of control that is not part of the project's particular net is not recommended since other points may not be compatible.

Supplemental control surveys are undertaken to densify project control surveys. Supplemental control is used for establishing photogrammetric control, locating terrain data for engineering surveys, establishing setup points for construction staking, locating property monuments and setting right-of-way monuments.

Generally monumentation for supplemental control is temporary. Monuments should be set where needed, but out of the way of construction when possible and in stable ground.

Supplemental control surveys shall meet NHLSA Code of Ethics and Standards.

All control surveys will be evaluated, checked and adjusted by method of least squares before being used as a basis for any project survey.

The project surveyor is responsible for assembling all research materials along with the completed field data and field notes into a project control survey file. The file will then be evaluated by reviewing all closures (residuals), adjustments and conformance to standards and calculating final positional values.

II.9 Boundary Control and Geodetic Survey

The boundary control and geodetic survey establishes the geodetic positioning and primary control traverse for use in determining boundaries and establishing additional control points to be used in NHDOT projects.

Needed information includes baseline data, property lines, etc. The Department now does most preliminary survey electronically using a total station and electronic data collector, often called an electronic field book (EFB). Use of a traditional field book is still required for all NHDOT survey operations, so that supplemental information and sketches can be recorded. EFBs allow substantial time and labor savings in processing and plotting field data to create an "as-built" plan. Much design work is rehabilitation and reconstruction of existing structures so that the as-built information becomes the base plan.

The Survey Supervisor will furnish survey parties with instructions and data needed such as plans, survey books, administrative information, property plans, deeds, record layouts, utility information, monument search plans etc.

NHDOT survey notebooks are required to be used for all surveys performed for the Department whether or not data is gathered electronically.

The Land Surveyor will supervise and periodically check on the conduct of the work. The supervisor shall meet prior to, periodically during and after the survey is completed to ensure the standards are being met.

II.10 Baselines, Sidelines and Property Location

The term "baseline" has acquired a variety of meanings over the years. Its definition herein is: a reference line of known dimension and bearing, from which various data can be related through field measurements.

Some common baseline types are:

1. Survey Baseline – The survey baseline is any alignment that was originally used to layout or determine the right-of-way. Prior to electronic data collection, the Survey baseline has historically been the reference line laid out on the ground by the survey party so that detail and cross sections could be tied by station and offset and recorded in a survey notebook. For a new roadway in virgin terrain, the survey baseline would often be a random traverse line located in the field by the survey party. In some cases a preliminary alignment would be given to the survey party to layout.

2. Historical Layout Records – These baselines would include those laid out by the towns, counties and courts. The historical baseline is the original line laid out and on which the taking was defined and the road constructed. These layouts typically described the centerline direction by nearest quarter of a degree and length in rods and links. These descriptions were run from angle point to angle point and rarely included defined curves. It is rarely possible to exactly recreate the baseline of record because the original ties are usually destroyed.

3. State of NH Returns of Layout – These baselines are defined in the return with a geometric definition that included both tangent and curved section. These baselines included centerline stationing referenced to a plan. The takings were defined as left and right of the return baseline between stationing. When this line is required, it has become standard practice to recreate the line from the best witnesses available: the sideline monuments that were set from the record baseline during construction. On an existing roadway this line would be established from monumentation and appear similar to the baseline of record. It would be an approximation, however, because distances would be apportioned both longitudinally and transversely to conform to record stationing.

In the DOT layouts the right-of-way was acquired by takings from a determined alignment, either as strip takings parallel to the centerline or, more currently, by varying distances defined by station and offset to the alignment. By this method the original defined centerline alignment becomes the controlling element to determine the limits of the taking for current projects. Because of that it is paramount that the original or legacy alignment be reestablished for the current project. This means that the legacy alignment needs to be tied to the existing project through ground control survey on the State Plane Coordinate System.

4. Construction Baseline **-** The baseline is provided on the construction drawings, also called the design baseline. This line is most often, but not always, the centerline of construction. It is created by the designer for estimating, design and construction operations. Construction plans should include detailed sketches of ties relating the construction baseline to the survey baseline at several locations, by geometry and by coordinates. Ties between baselines should be shown on a geometric layout plan on complex right-of-way projects.

Reconstruction in areas of an existing layout baseline should utilize the original baseline of record whenever possible in order to maintain continuity and to maintain right-of-way lines that are parallel and concentric with the baseline.

Many older roads in New Hampshire have no known records defining their location and width and are prescriptive highways. Survey work along these sections will create a baseline based on the existing traveled way.

When there is an option, stationing for baselines should run south to north, and west to east.

II.11 Reestablishing Baselines and Sidelines

Replacing baselines and sidelines is a common survey function and may range in difficulty from recovering a section of sideline to rerunning the baseline and recovering the sidelines of a major highway for alteration or reconstruction purposes.

Historical layouts typically contain a description of an alignment along with a defined width. While most of these layouts only define the tangent sections some include curves. Though not always impossible it is usually quite difficult to recreate the alignment and tie it back to the existing roadway and when done the alignment will usually deviate from the current road location. For this reason the limits of right-of-way will normally rely on the element of prescriptive rights and what is known as practical location. Practical location would take into account the known width and set off that width based upon a controlling element, in the case of a highway the controlling element would be the center of the traveled way. Deviations in the original defined width will occur in areas where there are old stone walls and fences as these should be considered as monuments of the original layout and recognition of the public right.

Prescriptive highways are those that have not been defined either by plan or by written description can usually be located by physical evidence, the most common being the location of stone walls which parallel the traveled way. Distances between the walls and fences can vary considerably. It should be noted that the records of many legally defined roadways have been lost. It is important that the surveyor locate all physical data such as fences, property corners, buildings, ditch lines and other evidence of viatic use. All of this data should be shown as detail.

Historical and Prescriptive highways require more detail to be considered than newer highway layouts. In both instances the existing centerline of the traveled way will be used to create an alignment. Detail of existing highway structures, drainage and supporting slopes need to located. All stone walls, fences, monumentation and elements of possession also need to be located. The limits of the right-of-way may vary considerably dependent on the locations of detail surveyed. The right –of-way is established by practical location, acquiescence and recognition. NHDOT policy for areas lacking any controlling physical location or evidence of the right-of-way is to hold a minimum of 25 feet from the center of the travelled way or 10 feet beyond the limit of the shoulder, whichever is greater.

For recent roadway layouts, record data such as layout plans and notebooks are usually readily available, making the survey a relatively routine process. However, the work is of some technical difficulty, especially on limited access highways, requiring survey personnel with skill in baseline work. The party must check all work possible, add ties where needed, and note any discrepancies.

In working on older Return of Layout baselines, surveyors will generally run into problems. Bounds may be missing, damaged or out of position. The surveyor is responsible for accurately locating the original sidelines even if incorrectly set originally. The surveyor must also recover all physical evidence, including New Hampshire Highway Bounds and any other indications of ownership, such as property corners, fences, walls, etc. This information is a necessary part of both detail and baseline notes.

The surveyor should also recreate the baseline geometry and determine the best fit adjustment to the existing bounds and travelled way. In these instances the original alignment may contain errors due to the original survey limitations. The original survey alignment may be from a transit and tape traverse and require station equations to adjust for linear error. A best fit solution will usually require holding the tangents and correcting in the curve with the station equation on the PT to bring the stationing back to match the original PT station.

II.12 Property Location

Property surveys performed for the Department vary in scope from the taking of routine detail to a determination of complete property boundaries. Property boundary surveys shall conform to the current regulations by NH law, Board of Licensure for Land Surveyors Chapter 500 Rules and the NHLSA Code of Ethics and Standards. Although thoroughness of property work should be limited to only what is needed, the surveyor may also be required to obtain additional data and establish new property lines, etc. Accurate boundary locations are required for takings and easements. Properly indexed record evidence should be researched and weighed according to land surveying principles, reference is made to NH Rules 500 Appendix B; the locus should be determined from the best evidence, and the property tied in accurately to the baseline or traverse line. All research data should be turned in with the survey. Surveyors are expected to understand and apply principles of property survey so that they provide reliable data.

II.13 Specific Instructions

The Surveyor shall specify in detail to the Crew Chief any property work needed for NHDOT survey purposes. When a land taking is involved, a plan of the property may be required. Although it may not be necessary to run an entire field survey, the proposed taking and connections to the remainder must be measured. Plans of proposed private projects that abut a roadway like subdivisions, individual property surveys, site plans etc. should be obtained and tied into the baseline control.

All monuments found shall be located to aid in locating the parcel in relation to the highway layout. Monumentation that is recovered should be noted as "fnd," with physical condition noted.

Conflicting evidence and descriptions are commonly encountered in this type of work. The surveyor should locate the property from the evidence, not relocate it.

Layout evidence such as property corners and courses should be shown in the detail for every project whether or not it appears significant. Fences, walls, etc., along the layout should be located to 0.10’.

Every tree line, stonewall or iron pin found adjacent to the highway should be treated as though it is or might be a property line. Stonewalls, iron pins, stone monuments, fences or a row of bushes could be evidence of a property line. When locating these features all evidence of lines of occupation and possession need to be delineated. Provide full detailed descriptions of all elements located, IE: 1” iron pipe 12” tall leaning, located at base, centerline 2’high stone wall 3’ wide, finished face of 4’ high stockade fence, etc.

II.14 FIELD OPERATIONS WITH CONVENTIONAL SURVEY EQUIPMENT

NHDOT control surveys follow FGCS Geospatial Positioning Accuracy Standards for procedures, instrumentation and monumentation.

Different job requirements dictate different field equipment and survey procedures. The description of a point and its 3-D coordinates are the desired data for some types of survey. In route surveying, it is necessary to relate a point to a defined centerline and to have much of the collected data linked to a defined project centerline by station and offset.

Most NHDOT traverses start and end on pairs of geodetic control points of known state plane coordinate values. The initial and terminal bearing or azimuths are computed from a grid inverse on the control points. Some traverses may start or end on a single point which has a known grid azimuth to a reference object (spire, water tank, tower, etc.). Any other control points, which lay in or near the path of the traverse, should be incorporated into it.

The two primary forms of traverse are the loop (closed) and the link (open ended). The loop begins and ends at the same point of known coordinates. The initial bearing for the traverse can be derived from coordinate inverse of the GPS control points. The link traverse starts and ends at two different points of known coordinates. Determination of the starting bearing can be similar to that of the loop, or it can be derived from the bearing between the known coordinates of the endpoints. Computationally, this last procedure requires starting on an assumed bearing. When the end station is reached, the traverse can be rotated to the bearing defined by the link traverse endpoints although NHDOT does not recommend this practice. Since simple link and loop traverses can close well despite systematic errors, they should be checked carefully.

In route surveys, the control traverse often becomes a series of interconnected link and loop traverses. The surveyor should make additional angle and distance measurements between intervisible stations whenever possible to increase the number of checks on the accuracy of the survey and add more geometry to the survey "network." The traverse should tie into all control points in the area so that the integrity of the existing coordinates is verified.

When traversing, prisms shall always be mounted on tribrachs rather than prism poles to ensure quality measurements. This provides a check on the change in distance and elevation shot when the backsight station was occupied and also when the presently occupied station was foresighted. It also eliminates some environmental systematic errors when the elevation difference measured in opposite directions is averaged.

If elevation is a desired product of the traverse, it is critical to measure precise heights of instruments and heights of targets at all setups and sighted stations. It is also important to sight prisms precisely, both vertically and horizontally, and to ensure that the instrument's vertical collimation is correct and level at 90°00'00" and 270°00'00".

Theoretically sound practice is to measure both angles and distances an equal number of times in the direct and reverse (D&R) positions and then to average. This eliminates the instrument's horizontal collimation errors. The average of a D&R reading is considered one repetition or set.

Requirements for a particular job will dictate needed accuracies for the angles and distances, an acceptable least count for an instrument, the number of repetitions required, closure limits/precisions, monumentation, etc. A common angular accuracy requirement is a standard deviation (SD) of 3" for one repetition; a common distance accuracy requirement is 5 mm +/-5 ppm for one measurement.

The final survey report shall include copies of all control used with published values, description and sketches of all points established, copies of traverse and level adjustments and a listing of state plane coordinates on NAD 83 and elevations based on NAVD 88 for all traverse points and bench marks established.

II.15 FIELDBOOKS AND DIGITAL DATA COLLECTION

Historically, the surveyor's field book has stored all of the numerical, graphical and descriptive data required to produce the desired final product. The surveyor's notebook also usually contains considerable information about the job, which may not affect the final product but is invaluable for survey indexing and validation purposes if questions arise regarding the survey.

The ability to collect survey data in digital form using a total station and data collector (electronic field book, or EFB) has the potential for replacing much of the measurement information entered by hand in a conventional field book. An EFB also usually has the capability of storing keyboard-entered attribute and other descriptive information, as well as non-total station survey measurement data such as taping, leveling (rod readings), station/offset, and eccentric distances.

If an EFB is being used but does not allow collection of desired attribute or descriptive information, this information must be recorded in a conventional field book along with the EFB data and all field sketches. Use of a NHDOT Survey Notebook is required for all surveys conducted by or for the Department.

II.16 Electronic Field book (EFB) Data

The use of an EFB to collect and store raw data should follow the procedures previously described in this Section. Original raw data should always be preserved and any changes or corrections made to field data, such as station name, height of instrument or target, should be documented. Raw field data should also be preserved in hard copy output form similar to how a conventional field book is preserved. Copies of the field book notes and EFB files will be included in the survey job files.

II.17 Right-of-Way Survey Field Notes

The Party Chief shall produce field notes that are a combination of electronically recorded measurement data and hand-written or computer generated notes that together represent an accurate, clear, complete, and concise record of everything that occurred during the course of the right-of-way survey. The final quality of all record maps and documents depends on the quality of the information and data contained in these notes. (The Party Chief should keep in mind that survey field notes are of such vital importance that they are at times called into review by courts.) Field notes should include all evidence even if it may disagree with record data, a recovered monument, or with an analysis of its location.

The field notes shall contain information related to describing the found and searched for but not found monuments. If a found monument appears damaged or disturbed, or its condition or orientation do not agree with record data, the Party Chief shall describe the condition and provide monumentation location sketch drawing in the field book.

The description of the found monument shall include but is not limited to the following:

- Monument type and size.
- Monument markings on survey caps or disks.
- Monument condition: New, old, bent, damaged, remains, etc.
- Reference points to the monument.
- All collateral evidence related to the monument.
- Description of any surrounding physical features that may be related to the corner and/or corner location (e.g. fence lines, fence corners, etc.).

Field survey data and sketches which cannot be efficiently recorded in the EFB should be recorded in a conventional field book and stored with copies of the electronic data.

II.18 Right-of-Way Survey Job Files

The right-of-way survey job file will be evaluated for following criteria:

- Recovery of sufficient monumentation to retrace the right-of-way and associated easements.
- Neat, complete, legible, accurate and uncluttered field notes.

- The original search maps marked with clear and legible notations.
- Clear, complete, and accurate found monument descriptions. • Field observation adjustment documentation.
- All documents produced during the adjustment of the survey observations will be included in the right-of-way survey job file.

After the right-of-way survey job file is completed, the job file will be delivered to the Project Surveyor.

II.19 Boundary Analysis and Retracement

The Land Surveyor shall review the completed right-of-way survey job file for completeness. The boundary analysis and retracement will then be performed in accordance with accepted professional land surveying practices, NHLSA Ethics and Standards and NH laws.

II.20 Right of Way Flagging and Staking

Right-of-way flagging is a temporary, limited, and usually less accurate substitute for right-of-way staking. One of its uses is to demarcate, approximate landlines and right-of-way lines that will be viewed during appraisal, acquisition, disposal of land, or utility relocation planning and estimating. Other uses may be for legal purposes or anytime the Department's right-of-way needs to be generally viewed for any purpose.

The right-of-way lines that may be requested to be flagged include but are not limited to:

- Appraisal, to aid appraisers in determining severance damages.
- Acquisition, for use by right-of-way agents in reviewing and discussing right-of-way requirements with the landowner.
- Utilities, for utility relocation planning and estimating activities.
- Legal, flagged for legal purposes such as condemnation hearings or encroachments.
- Surplus property, flagged for the benefit of both the Department and prospective buyers.

II.21 Final Monumentation of Right of Way

The final stage of a transportation improvement project for Land Surveys is the monumenting of the Department's new right-of-way and filing of the layout plan with the County Registry of Deeds. The Project Surveyor will provide the final coordinates of all angle points, beginning and ending of curve points and radii in the Department's right-of-way for the right-of-way survey project.

The Surveyor will set right-of-way monuments at the following locations:

- Primary points: right-of-way monuments set at all angle points, and beginning and end of curves. Note: Monument the State's final boundary along facilities to be relinquished.
- Supplemental points: Additional right-of-way monuments set along tangents and along curves at a maximum of 1000 feet.
- Intersection points: right-of-way monuments set at the intersections of the Department's right-of-way with municipal right–of-way or other lines of basic importance.

The Surveyor shall establish durable, permanent monuments that contain markings indicating the Department at the requested locations. However, the Party Chief may set the monuments at a different location if the requested location is not practical, it is impossible to set a monument, or the location has safety considerations. These revised reference locations must be noted on the final bound location plans.

The Surveyor should set bound points as time and construction conditions allow. A complete record of the bound work including the location of all bounds, dates set and by whom, angles and distances used to set them, all ties, etc., should be entered in the field book.

As bounds are permanent witnesses to the legal layout as well as an aid in reproducing the baseline in the future, they should be accurately and carefully located on the ground. Bounds are defined in position on the layout plan by station, bearing and distance. Bound points should be checked independently of the method used to set them. Checks can be made to other points, to the baseline, or to another bound.

A bound point set by Survey is usually a hub with a small nail, with the hub set solidly into the ground. Close ties 6' or less from the point may consist of straddle stakes, from which string lines may be run to cross over the point, are usually preferred by the worker actually setting the bound. Strong, long ties should also be utilized to enable crew members to check or relocate the point.

Tie distances should be written on stakes and other ties. A witness stake, with bound identification written on it, should also be set.

Marking a bound usually is done when the project is nearly completed and after the bound has had a chance to settle. A NHDOT Survey disc is set in the drilled hole on the bound. The survey disc will then be punch marked and is an indication that the surveyors have made a final check on the point and that the location is accurate.

The bound should never be marked from short ties. The surveyors should run the bound point in again from the baseline or from good control and check the work against the long ties.

Final right-of-way layout plans are prepared to legally document the Department's right-of-way, associated easements and related final monument locations. The plans are filed with the County Registry of Deeds and become part of the public record as required under RSA 230:32. A project is not considered complete until perpetuation of monuments is accomplished and a layout plan is filed. Right-of-way layout plans will be prepared and filed in accordance with New Hampshire Laws and the New Hampshire Land Surveyors Association Code of Ethics and Standards. The final plans are required to be approved, stamped and signed only by the Licensed Land Surveyor in direct charge of all work involved.

NHDOT Survey Technical Standards

Section III

Engineering Surveys

III.1 Engineering Surveys

Engineering surveys gather data for use in the planning and design of projects. Engineering surveys generally produce topographic maps and/or a digital terrain model (DTM). Conventional (on the ground) and photogrammetric methods can both be used to gather data for engineering surveys. This section provides procedures and general information for performing conventional engineering surveys.

III.2 Right of Entry for Survey Purposes

Existing laws within this State authorize the Commissioner or representatives to make surveys on private properties for highway purposes. The specific law is hereby quoted:

RSA 498-A:10 Right to Enter Property Prior to Condemnation. Prior to the time of filing the declaration of taking, the condemnor or its employees or agents shall have the right to enter upon any land or improvement which it has the power to condemn, in order to make studies, surveys, tests, soundings, and appraisals; provided, however, that the condemnee has been notified 10 days prior to entry on the property. Such entry and related activities shall not constitute a trespass, but the condemnor shall be liable for any actual damages caused thereby. This liability may be enforced in a civil action against the condemnor brought in the superior court in the county in which the property is located, with damages to be assessed by the board in the manner provided in RSA 498-A:24."

RSA 228:33 Right to Enter. The commissioner and his agents may enter private lands to make surveys and establish boundaries of highways.

Private property ownership and rights shall be treated respectfully at all times and any property damage avoided. It is the policy of the Department that only brush will be cut in wooded areas. Ornamental shrubs and trees will not be damaged in any way. Trees larger than 3 inches (0.08 m) in diameter may be cut only after special permission from the landowner is received. Care must be exercised to maintain the appearance of areas through which a survey is being made. Cut brush and trees, survey stakes, risers, flagging, and debris of any kind, must be reduced to a minimum or made as inconspicuous as humanly possible in a manner that is consistent with an expedient operation. Special care must be utilized when work is being accomplished near lawns, gardens, ornamental trees, shrubs, waterways etc.

III.3 Prejob Meeting

As soon as a project is known, e.g., appears on the Project Review Report, the Project Surveyor should schedule a meeting with the Project Manager to discuss anticipated survey requests.

The meeting with the Project Manager should cover:

- Project Schedule
- Acquisition of any critical information not included in the initial survey request such as as-builts, alignments, etc.
- Overall project survey needs
- Alternative survey methods
- Safety considerations
- Recommendations for survey methods
- Appointment of Project Surveyor to the Project Development Team
- Surveys that might be eliminated because of existing data
- Accuracy requirements for the survey
- Additional surveys needed (right of way, construction, etc.)
- Underground Utility

III.4 Engineering Survey Request

All engineering surveys are initiated by a written request from the Project Manager or designee. Requests shall be directed to the Chief Surveyor.

Survey requests should contain the following information:

- Requestor's name, phone number, and functional area
- Date of request
- County, Route, and post mile of beginning and end of project
- Authorized project number
- Applicable work codes
- Specific date needed (ASAP is not acceptable)
- Description of work requested
- Expected work product
- Sketch of the area to be surveyed showing lateral limits (for clarity as a solid line, not dashed or cloud shaped line) for the survey and beginning and end of work area
- Signature of the Project Engineer or Project Manager (senior level or above)

III.5 Planning

Planning begins with the meeting between the Survey Supervisor and the Project Manager/Engineer to discuss the proposed survey request. From a planning perspective, an important part of this meeting is obtaining information about anticipated future related survey requests for the project or adjacent future projects. Consideration of future right of way surveys and construction surveys should be part of the planning process so that the most efficient survey work plan for the overall project can be formulated.

III.6 Safety Planning

Safety should be a prime consideration in all survey planning and especially with engineering surveys, which often require work in and around traffic. A key planning consideration is to reduce (minimize) the overall exposure of surveyors to traffic. This can be accomplished in part, by carefully selecting the survey method, choosing the time to perform the survey, and employing special survey techniques.

III.7 Safety Procedures

The NHDOT Safety Manual and amendments will govern safety procedures and NHDOT Policies & Procedures will be followed as a minimum, additional safety precautions noted in this Manual and in the Job Hazard Analysis' may have to be utilized in other situations.

III.8 Research

Research for the engineering surveys should be part of the research for the overall project. Research for engineering surveys and control surveys should be undertaken at the same time.

Identify existing survey control in the area. When necessary, plan a Primary Geodetic control survey that will meet the requirements of the initial survey request as well as anticipated future project surveying needs.

III.9 Office Preparation

The Chief Surveyor, in consultation with the field supervisor and party chief, is responsible for the development of the necessary instructions and information (field package) for performing the requested engineering surveys. Survey and Land Titles office staff, under the direction of the Chief Surveyor, generally prepare the field package using information obtained from the research, together with other compiled and computed data. The field package should contain all the necessary information and data to efficiently complete the field work required by the survey request.

Typical information/data that may be included are:

- Copy of survey request (always included)
- Special instructions including safety and hazardous waste considerations (always included)
- Control diagram and station listing
- As-built plans
- Monumentation and right of way maps and monument listing
- Maps of record
- Utility maps
- Utility easement descriptions

- Data in digital format
- Control data: descriptions, coordinates, elevations
- Monumentation data: descriptions, coordinates
- Topo data: descriptions, coordinates, elevations
- Alignment data

III.10 General

Data collectors should be downloaded daily. Files should be transferred to a computer hard drive and then backed up to other media. File naming conventions (dictate file name convention, for example ProjectNo-dd-mm-yy-crew chief initials) can be used to keep track of raw data files for each day of work for large survey requests. Data files for each job should be located in a job directory. Any comments, descriptions of special circumstances, and narratives of the work should be stored in a subdirectory of the job directory.

Field crews should check their own work before sending it to the office section. Field crews located in remote areas must check their work before returning to their headquarters office. All work by field crews must be independently checked. Field crews should be provided with a cad drawing for review before finalizing.

III.11 General Procedure

The notes of the preliminary survey must show the actual physical conditions as they are at the time the survey is made. Particular attention must be given to all details underground, on the surface, or overhead, which may in anyway affect the location of the proposed highway. The notes must be complete and neatly entered in the notebooks.

Before starting the survey, the Survey Supervisor shall obtain the Primary Vertical and Horizontal Geodetic Control for the area to be surveyed. The Supervisor shall also compile any old plans that exist, any secondary control traverse information, all NHDOT field books that would be pertinent to the project, project number and any other necessary data. If the project is large and more than one crew will be assigned to the project, the Area Supervisor may want to assign blocks of numbers for control points and also assign file naming conventions so as to minimize duplicate point numbers and duplicate file names.

Prior to entry onto any private property, Right-to-Enter letters will be sent to all property owners that are in the project area. These property owners will be given ten working days to respond to said letters in accordance with RSA 498-A:10

Once the ten-day waiting period has elapsed, the preliminary survey generally proceeds in the following manner:

1. On projects with temporary points set by Geodetics, a benchmark will be set.
2. A traverse is performed to establish secondary control in the project area. The secondary control traverse shall begin and end on the primary geodetic control points. This secondary control traverse will be three-dimensional and the traverse points will be placed advantageously so as to adequately cover the area to be surveyed accurately and maximize the

crew's safety. The minimum standards for accuracy will be 1:15,000 Horizontal and 0.05 ft. times the sq. root of the distance in miles vertically.

3. Take full topographic coverage of the area outlined in the Survey Request including river topography if required. This coverage will include enough points to provide accurate contours to 1 ft.

4. All survey procedures will include adequate checks to a degree commensurate with the character of the work to insure the required accuracy and precision.

5. Review entire project with Survey Supervisor as a check on the completeness of the survey.

6. Complete check on books for indexing, cross-referencing, proper page headings, dates, lined-out superseded information.

III.12 Topographic Survey

Topography, commonly referred to as detail, is generally taken after the completion of the secondary control traverse. Detail includes all physical features that will influence the proper design of the project. Current NHDOT string label and naming conventions will be utilized for all projects.

Topographic surveys are undertaken to determine the configuration of the earth's surface and the locations of natural and manmade objects and features. The products of topographic surveys, DTMs and topographic maps are the basis for planning studies and engineering designs.

A DTM is a representation of the surface of the earth using a triangulated irregular network (TIN). The TIN models the surface with a series of triangular planes. Each of the vertices of an individual triangle is a coordinated (x,y,z) topographic data point. The triangles are formed from the data points by a computer program, which creates a seamless, triangulated surface without gaps or overlaps between triangles. Triangles are created so that their sides do not cross breaklines. Triangles on either side of breaklines have common sides along the breakline.

Breaklines define the points where slopes change in grade (the intersection of two planes). Examples of breaklines are the crown of pavement, edge of pavement, edge of shoulder, flow line, top of curb, back of sidewalk, toe of slope, top of cut, and top of bank. Breaklines within existing highway rights of way are clearly defined, while breaklines on natural ground are more difficult to determine.

DTMs are created by locating topographic data points that define breaklines and random spot elevation points. The data points are collected at random intervals along longitudinal break lines with observations spaced sufficiently close together to accurately define the profile of the breakline. Like contours, breaklines do not cross themselves or other breaklines.

Cross-sections can be generated from the finished DTM for any given alignments.

III.13 DTM survey guidelines:

• Visualize the TIN that will be created to model the ground surface and how breaklines control placement of triangles.

• Use proper topo codes, point numbering, and line numbers.

• Use appropriate terrain coding for critical points between breaklines, around drop inlets and culverts, and on natural ground in relatively level areas.

• Do not change breakline codes without creating a new line.

• Take shots on breaklines at approximately 50 foot intervals and at changes in grade.

• Locate data points at high points and low points and on a grid of approximately 50 foot centers when the terrain cannot be defined by breaklines.

• If ground around trees is uniform, tree locations may be used as DTM data points by using appropriate terrain coding.

• Keep site distances to a length that will ensure that data point elevations meet desired accuracies.

• Gather an extra terrain line 15 to 30 feet outside the work limits.

Accuracy Standard: Data points located on paved surfaces or any engineering works should be located within ±0.03 foot horizontally and ±0.02 foot vertically. Data points on original ground should be located within ±0.1 foot horizontally and vertically.

Checking: Check data points by various means including reviewing the resultant DTM, reviewing breaklines in profile, and locating some data points from more than one setup if needed.

Dimensions must be shown in their entirety. Descriptive notes should be applied to all buildings, such as 1 1/2-story house, wooden; commercial, garage, brick, include steps in foundations etc.

Wells and springs will show diameter.

Isolate trees, list type of tree and circumference of trunk at 4 ft. above ground level. Stumps will show circumference. Ornamental trees, regardless of size, will show circumference and type.

Locate private septic systems within normal survey area to include approximate size of fields.

All historical markers will be located and recorded along with an exact wording of any inscription(s).

Whenever a proposed location is adjacent to an airport the following data must be secured in order to determine the glide angle:

1. The distance from the end of the runway to the proposed center line.
2. The elevation of the end of the runway.
3. Width of the landing area and runway.
4. The airport boundary adjacent to the project.

The Area Supervisor or the Crew Chief must coordinate with the airport authorities prior to entering any flight areas. When surveys are made under winter conditions, notations should be appropriately entered in the book indicating what survey detail and topography, should be retaken or checked under bare ground conditions.

III.14 Property Lines, Tree Lines, etc.

Every tree line, stonewall or iron pin found adjacent to the highway should be treated as though it is or might be a property line. Stonewalls, iron pins, stone monuments, fences or a row of bushes could be evidence of a property line. When locating these features all evidence of lines of occupation and possession need to be delineated. Provide full detailed descriptions of all elements located, i.e. 1" iron pipe 12" tall leaning, located at base, surveyors cap LLS #, centerline 2'high stone wall 3' wide, finished face of 4' high stockade fence, etc.

III.15 Utilities

Utilities located above ground - power, telephone and telegraph poles, hydrants, etc., should be located. Always record the utility company identification and numbers (if any) that are on the pole. When poles are in joint usage, the owning utility is listed first, for example - a pole used by New England Telephone, but owned by Public Service Company:

PSCO 27

NET 34

Utility lines crossing the proposed location should be located for at least 200 ft. from center line in each direction, to include at least two poles each side that will not normally be affected by construction. Running a spur traverse along the pole line is a convenient method. Poles with guys should be noted "guy". Heavy guying, such as on transmission poles, should be located at the point of entry into the ground.

Any overhead major utility line - other than service lines to individual buildings - which crosses the proposed location shall be located and the elevation of the wire where it crosses the center line shall be determined using remote elevation procedures.

III.16 Underground Utilities

Surveys requiring the location of underground utilities should follow CI/ASCE 38-02 "Standard Guideline for the Collection and Depiction of Existing Subsurface Utility Data"

III.17 Bridge Surveys

Where stream, road, railroad, etc., crossings necessitate a structure, information must be accurately obtained to enable designers to adequately design a structure to fit the conditions.

Survey detail should include:

1. Complete Topography of the river to include at least 200 ft. upstream & 100 ft. downstream
2. Locate all ledge outcrops, abandoned piers and abutments, and large boulders.
3. Record approximate location, type and size of nearest structure upstream and downstream.

Note any other information, which may be beneficial to the designers.

Special in-depth surveys may be requested to determine any lateral or vertical movement of an existing structure. This survey will usually involve complete detail of the structure, horizontally and vertically. Detailed instructions will be furnished to the Crew Chief on each project.

III.18 Railroad Crossings

Active lines require a railroad flagger prior to entry unto the rail line.

The following information will be collected for railroad crossing surveys:

1. Alignment and detail along both roadway and track for three hundred feet on ninety-degree crossings, more if the crossing is on a skew. Alignment shall be in the centerline of the existing roadway at the crossing if possible.

2. Profiles of the road and both rails.

3. Existing drainage and conditions of it.

4. Check AAR-DOT number of crossing (Should be on signal post, crossbuck or nearest pole.)

5. General comments on crossing and protection, if any, description and condition of crossing.

6. General detail wanted: width of road, shoulders, paved or gravel, switches, frogs, telephone poles, tree lines, building, utilities (sewer, water, drainage, power, fiber optics, etc.).

7. Establish a bench mark on the project. Do not use railroad equipment for a bench mark as it will probably be removed during construction.

III.19 Channel Changes

Extensive channel change surveys are sometimes required to conform to highway relocation proposals. Information regarding high and low water conditions, existing retaining walls, area drainage patterns, adjacent facilities using water from a stream and its purpose, and any other existing conditions or items that in some way have a direct bearing on the proposal, ecologically or otherwise, must be obtained. Generally a full topographic survey will be taken with an accuracy of 1 ft.

III.20 Hydrographic Surveys

1. In waters not affected by tides, the usual objective of the survey is to ascertain water volume or the underwater contour features.

2. In tidal streams, adjacent to existing structures where erosion exists, periodic evaluations are made to determine any subsequent changes caused by erosion.

III.21 Hydraulic Surveys

This section provides procedures for the most direct means of acquiring survey measurements for the hydraulic analysis of culverts and stream crossings. Many times the survey information is needed as part of an emergency response, therefore, the request for survey should have the required cross section measurements without a complete topographic survey of the area, which is not required nor is it cost effective. The extra details involve additional survey time, as well as plan preparation and consequently delay the hydraulic analysis.

Planning and orientation of traverse points:

- GPS control is needed for hydraulic surveys because most of the watersheds are delineated using USGS Quads and other information on State plane coordinates.

Vertical control:

- At least two TBMs will be set.

Spacing and naming of cross sections:

- At least four cross sections will be measured upstream of the crossing and three sections will be measured downstream of the crossing.

- Two of the cross sections will be within two (2) ft of the inlet and the outlet of the culvert or bridge. This is to determine convergence and divergence of flow entering and leaving the culvert.

- There will be a cross section taken approximately 20 ft upstream of the inlet in order to further detail the convergence at the headwater pool.

- There will be two additional cross sections required on each side of the road. These sections will be selected based on the best representation of the natural stream channel known as a "reach". Generally, it is useful to space the additional cross sections to provide a representation of the change in the gradually varied flow. The exact location of these cross sections will be determined and flagged by the engineer.

- Occasionally it may be required to monument a cross section with iron rods in order to monitor long-term sediment transport and migration of the stream channel.

Points acquired at the cross section:

- Measurements should be taken with a total station unless the conditions are favorable for reliable survey grade GPS.

- Points acquired within a cross section must start from left to right, looking downstream. This is how the data is entered into the hydraulic engineering software.

- Cross sections must be numbered starting from the downstream end. The labeling scheme is 10, 20,30,40,50,60, 70 with 30 & 40 typically being immediately upstream and downstream of the culvert or bridge. This labeling scheme allows room for additional cross sections that can be interpolated or measured.

- There are 4 locations required to accurately determine capacity of a given reach. Survey points are needed at the thalweg, bottom of bank, top of bankfull, and twice bankfull depth for each cross section. The hydraulics section will flag the cross section locations and individual shots.

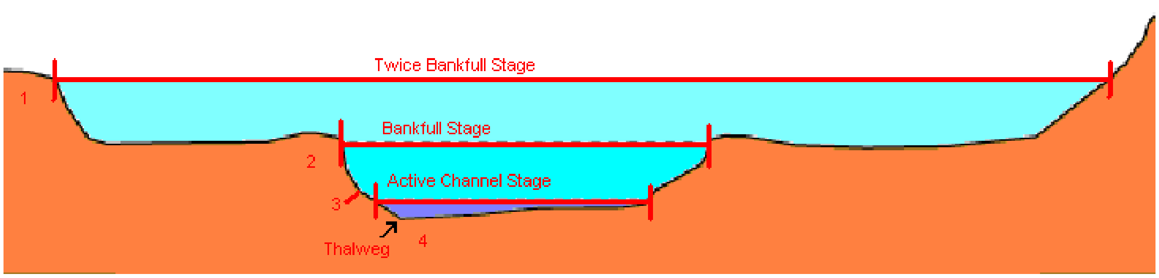
- Thalweg- The deepest part of the channel at the given cross section (not the center of the reach).
- Bottom of Bank- this point is delineated by a transverse break in stream channel slope
- Top of Bank (bankfull elevation)- This stage is delineated by the elevation point of incipient flooding, marked by deposits of sand or silt at the active scour mark, break in stream bank slope, perennial vegetation limit, rock discoloration, and root hair exposure
- Twice Bankfull- this is the flood prone area of a given reach. These survey points should delineate the width of the stream provided it were running at 2 times the depth at bankfull.

Sketch:

- The survey sketch should show the road and the stream as well as all cross sections and control points and any other relevant features.
- Inverts, several centerline stream elevations, and the elevation of the road at the culvert should be shown on the sketch.
- The culvert material and the length must be shown on the sketch.
- The sketch should include a description of the channel bed material (boulders, gravel, pebbles, sand, silt, clay)
- Any known buildings that have flooded need to be shown on the field sketch and the address must be recorded. The building and sill should be located.

Field Notes:

- Shots on a sections will be coded PELV, with a note for the description. Shots not located on a section will be coded with the appropriate code. Figure names of X10, X20, X30, etc… need to be used for the cross section strings when collected from left to right as seen looking downstream.
- Changes in rod height should be kept to a minimum.



Looking downstream the sequence of these shots is left to right. These shots are mirrored on the opposite bank.

1. Twice Bankfull
2. Bankfull
3. Bottom of Bank
4. Thalweg

III.22 Boring Layouts

The location of these points must be accurately laid out as described on bridge boring plans, which accompany each request. Ground elevations should be noted at each point. In some cases, it may be impractical to place stakes at the exact location of the boring, therefore it may be necessary to place other stakes that give direction and offset information to these points. The points should be flagged with pink flagging.

The loose-leaf field notes or the excel spreadsheet, is to be returned with boring layout plans after completion of layout, will be complete as to descriptions, computations, project number, date, weather, names of crew members, etc.

III.23

MOSS STRING LABEL CONVENTION

GENERAL USE:	String Label:
Bench mark, Survey disk	PBMK
Boring, Test Pit	PBOR
Level string	L
Elevation Point Survey	PELV
Elevation Point Survey - Not at Ground	PEVV

BOUNDARIES:	String Label:
Bound	PBND
Drill hole	PDHL
Iron pin or pipe	PIPN
Project marker	PRJM
State line marker	PSLM
Town line marker	PTLM

ROADWAY FEATURES:	String Label:
Center of road	CO
Edge of Gravel Road	EG
Edge of traveled way	TW
Edge of pavement	EP
Lane markings	LM
Driveway	DR
Trail	TL
Curb - Left	CL
Curb - Right	CR
Curb - Top	TC
Beam guard rail - Left	BL
Beam guard rail - Right	BR
Cable guard rail - Left	GL
Cable guard rail - Right	GR
Double face beam guard rail	DF
Jersey barrier	JB
Ditch line	DL
Bottom of slope	BS
Top of slope	TS

<u>BRIDGE FEATURES</u>:	<u>String Label:</u>
Arch - Bottom	**BK**
Bridge deck	**BG**
Bridge abutment - Top	**TB**
Bridge abutment - Bottom	**BB**
Expansion joint	**EJ**
Exposed bridge footing - Top	**TF**
Exposed bridge footing - Bottom	**BF**
Pier - Top	**TP**
Pier - Bottom	**BJ**
Scupper	**PSBD**
Wing wall - Top	**WT**
Wing wall - Bottom	**WB**
Rip-rap	**RP**
Bridge spot elevations	**PEBV**
Bridge miscellaneous detail features - point string	**PMBF**

<u>RAILROAD FEATURES</u>:	<u>String Label:</u>
Railroad	**RR**
Railroad sign	**PRSN**
Railroad signal	**PRSL**
Railroad switchstand	**PRSW**

<u>STRUCTURES:</u>	<u>String Label:</u>
Building at ground	**BE**
Sill Point	**PSIL**
Catch basin top	**PCBD**
Catch basin/Drop inlet sump	**PSUM**
Concrete Pad (gas station island; etc.)	**CP**
Dam - top	**DM**
Dam - bottom	**DB**
Drainage pipe (Survey: use IGL for dir. shots)	**DP**
Drop inlet top	**PDID**
Fence - Barbed wire	**FB**
Fence Other	**FO**
Flushing Basin	**PFLS**
Foundation/Ruin	**FD**
Retaining wall - Left ---^---^---	**RL**
Retaining wall - Right ---v---v---	**RW**

Retaining wall - Top	**TR**
Sidewalk / Patio	**SK**
Sound Wall	**SA**
Steps	**SP**

UTILITIES:	**String Label:**
Camera Pole	**PCPC**
Fiber Optic Delineator	**PFDD**
Fiber Optic Splice Vault	**PSVF**
Fire hydrant	**PHYD**
Fuel Tank	**PFTK**
Gas Pump	**PGAS**
Gas pumps	**GP**
Gas shutoff	**PGSO**
Guy pole or stub	**PGUY**
Guy wire anchors	**PANC**
Headwall, culvert end - Bottom	**BH**
Headwall - Top	**TH**
Intelligent Transportation Systems	**IT**
ITS Equipment Cabinet	**PITS**
Joint power and telephone pole	**PJNT**
Junction box	**PJCT**
Light on joint pole	**PLTJ**
Light on power pole	**PLTP**
Light pole	**PLIT**
Manhole - Drainage	**PMHD**
Manhole - Electric	**PMHE**
Manhole - Gas	**PMHG**
Manhole - Sewer	**PMHS**
Manhole - Telephone	**PMHT**
Manhole - Unknown	**PMHU**
Manhole - Water	**PMHW**
Overhead Wire	**AE**
Pole	**PPOL**
Power pole	**PPWR**
Sluiceway	**SU**
Storage tanks	**SG**
Storage tank fill cap	**PSTT**
Public telephone	**PBTH**

Telephone/telegraph pole	**PTEL**
Tower - all types	**PPTR**
Underground Cable TV	**UC**
Underground Electric	**UE**
Underground Fiber Optics	**UP**
Underground Fire Alarm	**UF**
Underground Gas	**UG**
Underground Sewer	**US**
Underground Telephone	**UT**
Underground Water	**UW**
Variable Speed Limit Sign	**PVSL**
Water gate	**PWGT**
Water shutoff	**PWSO**

SIGNING/SIGNALS:	**String Label:**
Controller cabinet	**PCCT**
Loop detector	**SD**
Magnetic detector sleeve	**DS**
Mast arm pole	**PMAP**
Meter Pedestal	**PMTR**
Pedestrian Signal Pole	**PWLK**
Pullbox	**PPBX**
Sign - Single post	**PSGN**
Sign - Double post	**PSND**
Sign - Billboard or other large sign (string feature)	**SN**
Signal conduit	**SC**
Street light conduit	**LC**
Traffic signal without mast arm	**PSGL**

OTHER GROUND FEATURES:	**String Label:**
Athletic Field	**AF**
Berm	**BM**
Boulder	**PBDR**
Bush	**PBUS**
Cemetery	**CM**
Gate	**GA**
Ground light/yard light	**PGLT**
Flag pole	**PFPL**
Gravestone	**PGRV**

Hedge	**HE**
High water mark	**HW**
Intermittent or small stream	**ST**
Lamp post	**PLPT**
Leachfield	**LF**
Mail box	**PMBX**
Miscellaneous detail features - Point string	**PMDF**
Miscellaneous detail features - Not at Ground	**PMVF**
Miscellaneous detail features - Feature string	**FM**
Monuments/statues or other related items	**PMON**
Ornamental features (flower beds; etc.)	**OR**
Parking Meter	**PARK**
Pool	**QP**
Post - all types	**PPST**
Ramp - Boat; etc.	**RM**
Ridge line	**RD**
Rock outcrop Left	**RO**
Rock outcrop Right	**RK**
Satellite dish	**PDAT**
Septic Tank	**PSTK**
Shore line - Left	**SL**
Shore line - Right	**SR**
Stockpile	**SO**
Stone wall	**SW**
Stump	**PSTP**
Swamp/marsh or wet area	**WA**
Tree - Coniferous	**PTCS**
Tree - Deciduous	**PTDS**
Vent pipe - Outlet	**PVNT**
Waterfall	**WF**
Well	**PWEL**
Woods line or brush line - Left	**WL**
Woods line or brush line - Right	**WR**

ENVIRONMENT:	**String Label:**
Invasive Species	**VA**
Monitoring Well	**PMWL**
HOTL	**VT**
MHT	**VM**

OHT	**VK**
OHW	**VH**
Prime Wetland	**VR**
Special Aquatic Site	**VS**
TBZ	**VZ**
TOB	**VB**
TOBOHW	**VO**
Vernal Pool	**VP**
Wetland Delineated	**WD**

PIT SURVEYS:	**String Label:**
Limit of pit	**LP**
Limit of work	**LW**
Old ground	**OG**

III.24

SURVEY CODE DESCRIPTIONS

GENERAL USE:

Bench mark: PBMK

Locate with a single shot. This code is for both Benchmarks and Survey Disks. Please note in book.

Boring: PBOR

Locate with a single shot. This code is also used for Test Pits and Vacuum Extraction Pits. Please note in book.

Level string: L

A string line used to show elevations. Follow your major changes in contours, do not zig zag across ridges, swales, ditches, etc. If located behind a curved feature, (curb, ep, etc.) locate with a 202 code.

Spot elevations: PELV

Single shot to show high or low spot when string line is not needed when taking general topo. May also be used to show high points of stockpiles, ledge outcrops, etc.

Spot elevations - Not at Ground: PEVV

Same as a PELV but will not be used for contouring.

BOUNDARIES:

NOTE: All property boundary points will have the angle and distances doubled.

Bound: PBND

Locate center. Note the height, size and type (concrete, granite, etc.) in book.

Drill hole: PDHL

Locate center. Note the size of the drill hole and size of rock in book.

Iron pin or pipe: PIPN

Locate center. (If leaning, locate at base and note in book.) Note the height, size and type in book.

Project marker: PRJM

Locate center. Note the height, size and type (concrete, granite, etc.) in book.

State line marker: PSLM

Locate center. Note the height, size and type with description of marker (Bronze, Aluminum tablet, Drill hole, etc.) in book.

Town line marker: PTLM

Locate center. Note the height, size and type with description of marker (Bronze, Aluminum tablet, Drill hole, etc.) in book.

ROADWAY FEATURES:

Center of road: CO

Locate with a string line.

Edge of Gravel Road: EG

Locate with a string line.

Edge of traveled way: TW

Locate with a string line.

Edge of pavement: EP

Locate with a string line.

Lane markings: LM

Locate with a string line.

Driveway: DR

Locate with a string line. Note material in book.

Trail: TL

Locate the center with a string line. Note average width and type in book.

Curb - Left: CL

Locate with a string line. Note type and sloped or straight in book.

Curb - Right: CR

Locate with a string line. Note type and sloped or straight in book.

Curb - Top: TC

Locate with a string line.

Beam guard rail - Left: BL

Locate with a string line.

Beam guardrail - Right: BR

Locate with a string line.

Cable guardrail - Left: GL

Locate with a string line.

Cable guardrail - Right: GR

Locate with a string line.

Double face beam guardrail: DF

Locate with a string line.

Jersey barrier: JB

Locate on top of barrier and measure height to use as prism height. Take an "L" string around base if needed.

Ditch line: DL

Locate center of ditch with a string line. Note average width in collector. If you want Plan Prep to offset the Ditch Line then put a note in the file.

Bottom of slope: BS

Locate with a string line. If located behind a curved feature, (curb, ep, etc.) locate with a 202 code.

Top of slope: TS

Locate with a string line. If located behind a curved feature, (curb, ep, etc.) locate with a 202 code.

BRIDGE FEATURES:

NOTE: Bridge features include the deck along with anything on or above it. The abutments, wings and piers should be taken when regular topo is taken. All bridge features should be taken as a unit so they can be removed as a unit with no regular topo features between start and finish. All features on the deck should have a "B" as the third character.

Arch – Bottom: BK

Locate with a string line on bottom edge of an arch.

Bridge deck: BG

Locate with a string line top outer edge.

Bridge abutment - Top: TB

Locate with a string line at top outer edge of abutment, see top of header example.

Bridge abutment - Bottom: BB

Locate with a string line at ground level of abutment, see bottom of header example.

Expansion joint: EJ

Locate with a string line.

Exposed bridge footing - Top: TF

Locate as a string line top of every corner that is exposed.

Exposed bridge footing - Bottom: BF

Locate as a string line bottom of every corner that is exposed.

Pier - Top: TP
  Locate with a string line top outer edge.
Pier - Bottom: BJ
  Locate at ground level with a string line, describe in book.
Scupper: PSBD
  Locate center. Describe in book.
Wing wall - Top: WT
  Locate as a string line top outer edge. Use close feature on side where it connects with header abutment.
Wing wall - Bottom: WB
  Locate as a string line ground level of wall.
Rip-rap: RP
  Use a string line following the outline of the rip rap.
Bridge spot elevations: PEBV

Bridge miscellaneous detail features - point string: PMBF

RAILROAD FEATURES:
Railroad: RR
  Locate top of east/north rail first with string line (locate in a west to east/south to north direction). Locate top of second rail with a string line, taking shots on second rail opposite shots taken of first rail in the same direction. Also locate the edge of the ballast with a FM code and note in book. Locate the top of slope on the ballast with a TS code.
Railroad sign: PRSN
  Locate with single shot. Note size and type in book.
Railroad signal: PRSL
  Locate with single shot. Note base size and type in book
Railroad switchstand: PRSW
  Locate with single shot. Describe in book.

STRUCTURES:
Building at Ground: BE
  Locate corners with a string line.
Sill Point: PSIL
  Locate the lowest sill elevation along the roadside face with a single shot.
Catch basin top: PCBD
  Locate with a point in center of grate.
Catch basin/Drop inlet sump: PSUM
  Locate at the bottom of basin with a point.
Concrete Pad (gas station island; etc.): CP
  Locate corners with a string line.
Dam: DM
  Locate top corners or angle points with a string line. Note material in book.
Dam - bottom: DB
  Locate corners and angle points with a string line.
Drainage pipe (Survey: use IGL for dir. shots): DP
  Locate invert of pipe. Note material and size in book. This is to be used for any drainage structure under 10 feet. Structures over 10 feet will be located in the same manners as a bridge.
Drop inlet top: PDID
  Locate with a point in center of grate.
Fence – Barbed Wire: FB
  Locate with a string line. Note type, condition, and how many strands in book.

Fence: FO
Locate with a string line. Note type, condition, and how many strands in book.
Flushing Basin: PFLS
Locate center. Describe in book.
Foundation/Ruin: FD
Locate corners with a string line. Describe in book.
Retaining wall - Left: RL
Locate with a string line. Note material in book.
Retaining wall - Right: RW
Locate with a string line. Note material in book.
Retaining wall - Top: TR
Locate with a string line.
Sidewalk: SK
Locate with a string line. Note material in book.
Sound Wall: SA
Locate the centerline of each support column at the roadside face. Note size and material of column and foundation in book.
Steps: SP
Locate corners with a string line. Note type and number of stairs in book.

UTILITIES:
Camera Pole: PCPC
Locate with a single point on roadside face
Fiber Optic Delineator: PFDD
Locate with a single shot
Fiber Optic Splice Vault: PSVF
Locate with a single shot in center. Note size and material in book.
Fire hydrant: PHYD
Locate with a point on top. This code also applies to Dry Hydrant. Note in book.
Fuel Tank: PFTK
Locate with a single shot at center of tank. Note size and type in book.
Gas Pump: PGAS
Locate with a single shot at center of pump. Note size and type in book.
Gas pumps: GP
Locate perimeter of pumps. Note size, type and number of pumps in book.
Gas shutoff: PGSO
Locate with single shot in center.
Guy pole or stub: PGUY
Locate with single shot at ground at the roadside face.
Guy wire anchors: PANC
Locate with single shot at ground.
Headwall: culvert end - Bottom: BH
Locate at ground level with a string line.
Headwall - Top: TH
Locate corner and angle points with a string line. Note type in book.
Intelligent Transportation Systems: IT
Locate as a string.
ITS Equipment Cabinet: PITS
Locate with single shot in center. Note size in book
Joint power and telephone pole: PJNT
Locate with single shot at the roadside face. Note in book any pole numbers and if it has a transformer.

Junction box: PJCT

Locate with single shot in center. Note size and material in book.

Light on joint pole: PLTJ

Locate with single shot at the roadside face. Note in book any pole numbers and if it has a transformer.

Light on power pole: PLTP

Locate with single shot at the roadside face. Note in book any pole numbers and if it has a transformer.

Light pole: PLIT

Locate with single shot at the roadside face. Note in book any pole numbers, type of pole, and if it has a transformer.

Manhole - Drainage: PMHD

Locate with single shot in center of cover.

Manhole - Electric: PMHE

Locate with single shot in center of cover.

Manhole - Gas: PMHG

Locate with single shot in center of cover.

Manhole - Sewer: PMHS

Locate with single shot in center of cover.

Manhole - Telephone: PMHT

Locate with single shot in center of cover.

Manhole – Unknown: PMHU

Locate with single shot in center of cover.

Manhole - Water: PMHW

Locate with single shot in center of cover.

Overhead Wire (Transmission line/Aerial electric lines): AE

Locate with a string line following the lines.

Pole: PPOL

Locate with single shot at the roadside face. Note in book any pole numbers and if it has a transformer.

Power pole: PPWR

Locate with single shot at the roadside face. Note in book any pole numbers and if it has a transformer.

Sluiceway: SU

Locate corners and angle points with a string line. Note material in book.

Storage tanks: SG

Locate footprint of tank with string line. Note size, type, and use in book if known.

Storage tank fill cap: PSTT

Locate with a single shot. Note type in book.

Public telephone: PBTH

Locate with single shot in center, if more than one locate separately. If it has a concrete pad, locate pad using concrete pad code.

Telephone/telegraph pole: PTEL

Locate with single shot at the roadside face. Note in book any pole numbers and if it has a transformer.

Tower: PPTR

Locate with a single shot. This is for Fire Towers, Cell Towers, Transmission Towers, and Radio Towers. Note size and type in book.

Underground Cable TV: UC

Locate with string line as marked on ground or pavement. Note in file any numbering.

Underground Electric: UE

Locate with string line as marked on ground or pavement. Note in file any numbering.

Underground Fiber Optic: UP

Locate with string line as marked on ground or pavement. Note in file any numbering.

Underground Fire Alarm: UF

Locate with string line as marked on ground or pavement. Note in file any numbering.

Underground Gas: UG

Locate with string line as marked on ground or pavement. Note in file any numbering.

Underground Sewer: US

Locate with string line as marked on ground or pavement. Note in file any numbering.

Underground Telephone: UT

Locate with string line as marked on ground or pavement. Note in file any numbering.

Underground Water: UW

Locate with string line as marked on ground or pavement. Note in file any numbering.

Variable Speed Limit Sign: PVSL

Locate with a single shot.

Water gate: PWGT

Locate with single shot on water main valve usually in pavement.

Water shutoff: PWSO

Locate with single shot on residents service valve usually in lawn or sidewalk.

SIGNING/SIGNALS:

Controller cabinet: PCCT

Locate with a single shot on top and note dimensions in book.

Loop detector: SD

Locate with a string line.

Magnetic Detector Sleeve: DS

Locate with a string line.

Mast arm pole: PMAP

Locate with a single shot, and then locate a “PMDF” below the end of mast arm.

Meter Pedestal: PMTR

Locate with a single shot.

Pedestrian Signal Pole: PWLK

Locate with a single shot.

Pullbox: PPBX

Locate with a single shot and note dimensions and material in book.

Sign - Single post: PSGN

Locate with a single shot. Note size, type, and message in book.

Sign - Double post: PSND

Locate with a single shot in the middle of posts. Note size, type, and message in book.

Sign - Billboard or other large sign (string feature): SN

Locate with a string line. Note size, type, and message in book.

Signal conduit: SC

Locate with a string line as marked on pavement or ground.

Street light conduit: LC

Locate with a string line as marked on pavement or ground.

Traffic signal without mast arm: PSGL

Locate with a single shot.

OTHER GROUND FEATURES:

Athletic Field: AF

Locate perimeter with a string line. Locate other features inside of area with a “FM” string and note in book.

Berm: BM

Locate perimeter with a string line. Fill in with level strings and spot elevations as needed.

Boulder: PBDR

Locate with a single shot on top. Note size in book.

Bush: PBUS

Locate with a single shot in center. Note type and size in book.

Cemetery: CM

Locate perimeter with a string line. Locate individual markers with “PGRV” code.

Gate: GA

Locate both end with a string line. Note type and height in book.

Ground light/yard light: PGLT

Locate with a single shot. Describe in book.

Flagpole: PFPL

Locate with a single shot at the roadside face. Note material and diameter of pole in book.

Gravestone: PGRV

Locate with a single shot. Note size in book.

Hedge: HE

Locate perimeter with a string line. Note height and type in book.

High water mark: HW

Locate with a string line. Only use when specifically asked for by requester.

Intermittent or small stream: ST

Locate the center with a string line. Note average width in book.

Lamp post/private light pole: PLPT

Locate with a single shot at the roadside face. Describe in book.

Leach field: LF

Locate with a string line.

Mailbox: PMBX

Locate post with single shot. If a line of mailboxes (as trailer parks, etc.) use FM string and note in book. Note how many mailboxes.

Miscellaneous detail features - Point string: PMDF

Use to locate an object with a single point that does not have a code. Describe in book.

Miscellaneous detail features - Not at Ground: PMVF

Locate a single shot. This will have an elevation but will not be used for contours. (i.e., ..elevation on a raised deck.)

Miscellaneous detail features - Feature string: FM

Use to locate an object with a string line that does not have a code. Describe in book.

Monuments/statues or other related items: PMON

Locate center with a single shot. Note size and type in book.

Ornamental features (flower beds; etc.): OR

Locate with a string line. Describe in book.

Parking Meter: PARK

Locate with a single shot. Describe in book.

Pool: QP

Locate with a string line. Note type, size, and height in book.

Post - all types: PPST

Locate center with a single shot. Note type, size, and height in book.

Ramp - Boat; etc.: RM

Locate with a string line. Note type in book.

Ridge line: RD

Locate with a string line.

Rock outcrop (***Left***): RO

Locate with a string line. Fill in with level strings and spot elevations as needed.

Rock outcrop (***Right***): RK

Locate with a string line. Fill in with level strings and spot elevations as needed.

Satellite dish: PDAT

Locate center with a single shot. Describe in book.

Septic Tank: PSTK

Locate center with a single shot. Describe in book.

Shore line - Left: SL

Locate with a string line.

Shore line - Right: SR

Locate with a string line.

Stockpile: SO

Locate footprint of pile with string line. Show top with level strings or spot elevations as needed. Describe type in book.

Stonewall: SW

Locate center with a string line. Note average width in collector. Use “L” string around wall.

Stump: PSTP

Locate center with a single shot. Note size in book.

Swamp/marsh or wet area: WA

Locate edge with a string line. This code is for non-delineated wetlands.

Tree - Coniferous: PTCS

Locate roadside face of tree. Note size and type in book.

Tree - Deciduous: PTDS

Locate roadside face of tree. Note size and type in book.

Vent pipe - Outlet: PVNT

Locate with a single shot. Note size and type in book.

Waterfall: WF

Locate perimeter of falls. Match to river or stream upstream and downstream.

Well: PWEL

Locate center with a single shot. Note size and type in book.

Woods line or brush line - Left: WL

Locate with a string line at the tree line. Locate a brush line with a separate string and note in book. *(Brush is defined as: Area of growth including grass, weeds, crops and trees measuring in circumference 12 in or less at a point 4 ft above the average ground.)*

Woods line or brush line - Right: WR

Locate with a string line at the tree line. Locate a brush line with a separate string and note in book *(Brush is defined as: Area of growth including grass, weeds, crops and trees measuring in circumference 12 in or less at a point 4 ft above the average ground.)*

ENVIRONMENT:

Invasive Species: VA

Locate flagged or marked points as a string line. Note in book. This code also applies to Shoreland Protection Permit Delineations.

Monitoring Well: PMWL

Locate the center with a point or as instructed in survey request.

HOTL: VT

Locate flagged or marked points as a string line. Note in book.

MHT: VM

Locate flagged or marked points as a string line. Note in book.

OHT: VK

Locate flagged or marked points as a string line. Note in book.

OHW: VH

Locate flagged or marked points as a string line. Note in book.

Prime Wetland: VR

Locate flagged or marked points as a string line. Note in book.

Special Aquatic Site: VS

Locate flagged or marked points as a string line. Note in book.

TBZ: VZ

Locate flagged or marked points as a string line. Note in book.

TOB: VB

Locate flagged or marked points as a string line. Note in book.

TOBOHW: VO

Locate flagged or marked points as a string line. Note in book.

Vernal Pool: VP

Locate flagged or marked points as a string line. Note in book.

Wetland: WD

Use this code only if wetland has been flagged. Locate each flag and note number in book.

PIT SURVEYS: (Survey use only):

Limit of pit: LP

Locate perimeter with a string line.

Limit of work: LW

Locate with a string line

Old ground: OG

Locate with a string line.

NHDOT Survey Technical Standards

Section IV

Construction Layout Surveys

IV.1 Construction Plans for Layout Work

The Survey Crew should thoroughly study the construction plans that are delivered. There will be a set of working plans which have been reduced photographically to approximately half scale, a set of right-of-way prints (where right-of-way is to be purchased) and a set of bridge plans, where needed will be furnished. Alignment stakeout report sheets, with coordinates, will also be provided.

IV.2 Construction Survey Request Procedures

All construction requests for services of a survey crew will be made by the Contract Administrator directly to the Land Title and Survey Section. All construction survey layout work will be coordinated by the Surveyor in charge. The Surveyor will verify that adequate survey control has been set prior to proceeding with any layout work.

IV.3 Care and use of Field Notebooks

The Survey Supervisor will issue the pertinent field books for Construction purposes. As soon as the State field office is set up, the Crew Chief will store these books each night in the office safe, in a drawer assigned by the Contract Administrator. It is important to leave the books at the field office, readily available to the Contract Administrator or to other survey crews that may be assigned to the project. Any transfer of books to the Concord Office during the construction phase must be made through the Survey Supervisor. The storage of the field books shall be coordinated with the Survey Area Supervisor at the termination of a project.

All rules pertaining to indexing, referencing and legibility found under ENGINEERING SURVEY will apply to the construction phase. Other special rules pertaining to the use of notebooks will be given under the various items of CONSTRUCTION SURVEY.

IV.4 Initial Alignment and Layout

The Primary Project Control Network shall be the basic control for all phases of the survey and construction layout. Traverse points set from these Geodetic Control Monuments are considered as a Secondary Control Network placed at intervals of approximately 750 ft. along the existing roadway. These points will be utilized for “setting out” the alignment and other control layout points required for construction. The Secondary Control Network traverse will be reviewed at NHDOT Land Titles and Survey Office in Concord to ensure that it meets the Horizontal and Vertical accuracy standards.

All primary and secondary control points referenced to the NHSPC system must be set under the responsible charge of a person authorized to practice land surveying in the State of NH.

The procedures mentioned hereafter should be followed in all alignment work.

To layout a given alignment and other control points, the Area Survey Supervisor will obtain the final adjusted traverse information, the coordinates of all control points and 50 ft. stationing, COGO reports supporting the alignment, and any plans showing the alignment with respect to the physical features on the ground. This information will be provided by the Land Surveyor in charge.

The Crew Chief will either keyboard enter the alignment information or have the Survey Office personnel upload the information into the Data Recorder. Electronic project files should always be available on projects developed with computer software programs and as such shall be downloaded directly. Keyboard entry shall be avoided whenever possible. The Instrument Operator will verify the information keyboard entered or uploaded is correct. When any information is received by the Survey Crew, the first task is to verify that the information received is correct.

IV.5 Construction Stakes, Lines, and Grades.

The Survey crew will set stakes and furnish data necessary to establish the line and grade of the finished surface, the lines and grades of all waterways and structures, and such other points and bench marks as are necessary to lay out the Work correctly. This “initial” layout will include control points, bench marks, line ties, and may also include leveled side stakes as required for grade control and reproduction of construction center line. It may also include bridge targets, line ties and reference stakes for bridges, retaining walls, and full span overhead sign structures. This work includes reference points, base lines, stakes and bench marks where applicable.

The Survey crew will stake and reference all required Rights-of-Way, easement limits and bounds in accordance with NHDOT Survey Technical Standards Section II, Boundary and Right-of-Way Surveys.

The Contractor shall cooperate in the setting and shall be responsible for the preservation of all “initial” layout stakes and marks, and if any of the construction stakes or marks have been carelessly or willfully destroyed or disturbed by the Contractor, the cost of replacing them will be charged against the Contractor and will be deducted from the payment for the work. Damaged or destroyed points, bench marks or stakes or any reference points damaged or made inaccessible by the progress of the construction shall be replaced or transferred by the Contractor, subject to verification by the Surveyor.

Replacement of all “initial” layouts (with the exception of side stakes or drainage reference stakes) shall be performed by or under the direction of a NH Licensed Land Surveyor.

The Contractor shall perform all necessary layout work not specified above in order to construct all elements of the Project as shown on the Plans and specified in the Contract. This work shall include, but shall not be limited to stakeout necessary for reestablishment of line and grade as earthwork operations progress; stakeout, layout, and elevations as required for structures, forms, pile layouts, and paving. Prior to paving, the Contractor shall perform all work necessary to set the control for fine grading.

The Contractor shall perform all required layout work with competent, qualified personnel to meet minimum survey accuracy and procedures (Horizontal: 1 in 10,000, Vertical: 0.05 ft. x √distance in miles).

Any error, apparent discrepancy, or absence of data in the Department's "initial" layout shall be referred to the Surveyor and Contract Administrator in writing for correction or interpretation. The Contractor is solely responsible for the accuracy of the Work. All computations necessary to establish the exact position of the Work from control points, shall be made and preserved by the Contractor. All computations, notes and other records necessary to accomplish the Work shall be neatly made. Such computations, notes and other records shall be made available to the Surveyor and/or Contract Administrator upon request.

The Engineer may check all or any portion of the layout, stake-out or notes made by the Contractor. Any necessary correction to the Work shall be made immediately by the Contractor. Such checking by the Engineer will not relieve the Contractor of any responsibilities for the accuracy or completeness of the work. Rechecking, by the Engineer, of any portion of the Contractor's layout, stakeout or notes will be charged against the Contractor and will be deducted from the payment for the work.

No claim will be considered because of alleged inaccuracies unless the Contractor notifies the Engineer thereof in writing immediately upon discovery of the alleged inaccuracies and affords the Engineer opportunity to check or verify the stakes or marks in question.

IV.6 Construction Line Offsets

Where access to Construction Centerlines is not possible, safe or reasonable, offset lines will be utilized. Offset lines shall be setoff as parallel and concentric to the alignment at an even foot increments.

IV.7 Alignment and Layout Checks

All alignment and layout work shall be checked for accuracy by closing the layout into additional control points outside of the ones used for the current layout. The tie in closure shall be noted in the field books and data recorder. Layout data and closure checks shall be added to the project survey report files.

IV.8 Line Ties

Most projects no longer require line ties, on those projects that do the following procedures shall be used.

Tie points should be established a maximum distance of 500 ft. apart along the centerline; sharp curves may require additional ties. The plan profile of finished grade should be studied for the location of vertical curves in order to insure sight distance between ties and control. Be sure that the nearest tie to the centerline is located a minimum of 20 ft. outside the clearing edge. Hub ties are preferable, using standard survey stakes or oak hubs driven flush with the ground, with nails driven through appropriate flagging. Three hub ties should be used on one side of the centerline. Where practical, there should be a minimum of 30 ft. and preferably not more than 50 ft. between each hub. It will also be helpful to place one of the hubs on the right-of-way line. A reference stake, slanted toward the hub, will be driven about 6 inches into the ground beside each tie point. The reference stake will be marked showing the station and offset distance from centerline. A tall riser flagged with appropriate flagging color will be driven on the opposite side of each tie point.

Hub ties will be set at 90 degrees to the centerline, and so shown in the alignment book on the sketch pages with the alignment. Occasionally it may be necessary to tie out a point on a skew angle, to avoid some object such as a large tree. Be sure to show the skew angle on your alignment sketch.

In urban areas it is a must that the Crew Chief asks for permission from the property owners before putting stakes of any kind outside of the State right-of-way. Any stakes placed on lawns must be driven flush. It is suggested that the top of the flushed stake be dabbed with a spot of yellow or white paint for easy identification. Existing line ties should be checked, and replaced or added to as needed.

IV.9 Coordinate Ties

Coordinate tie points can be used instead of line ties for the project when arrangements with the Contract Administrator have been made. Coordinate tie points are based on the Primary and Secondary Control Network and will be used when robotic/rover instrumentation will be used by the Contract Administrator and the Contractor. The points should be set outside of all working areas for the project to avoid being destroyed.

IV.10 Construction Bench Line

Bench marks provide a series of semi-permanent marks of reference of known accurate elevation at frequent points along the construction line.

Bench marks shall be established at:

[a] Approximately 500 ft. intervals in flat terrain.

[b] At 50 ft. difference in elevation in hilly terrain.

[c] One per city block on urban surveys.

[d] Any others that may be considered useful during construction, such as structure locations, grade crossings, etc. On structures, two bench marks must be established, one high and one low.

All work involved in setting bench marks shall be done with the properly adjusted and calibrated auto level. Bench marks shall be established on some permanent object outside of construction limits and should be accessible for construction purposes. Bench marks should be set on permanent, solid objects. Trees in inhabited areas must not be scarred in any way. Bench marks shall be numbered to agree with the number of the full station preceding it. The description of the bench mark, stating actual station and offset distance, should be complete and accurate and recorded into the notebook.

A descriptive stake may be nailed to bench mark trees in wooded areas. Turning points (T.P.'s) should be established on a firm and distinct point for accurate work. T.P.'s must be numbered consecutively from the point of beginning starting with Number 1. A brief description of the T.P.'s shall be noted.

A bench line is run throughout the project with accuracy consistent with third order leveling, which is 0.05 ft. times the square root of the length of the level run in miles. Starting and ending where possible with a permanent bench mark of known elevation.

IV.11 Relocation of Bench Marks

All bench marks that fall within the clearing limits must be transferred prior to construction. The transfer should be made before the bench mark tree is cut; even though the root with the spike and washers may still be in the ground. The tree roots will occasionally shift position when relieved of the weight of the tree. All bench mark transfers should have the letter "A" suffixed to the number [e.g., B.M. 102-A]. Use the bench mark book to record all B.M. transfers, and void all those bench marks that have been destroyed.

If any Geodetic Control disk is found to be in the construction work area, notify the Survey Office. The Geodetic Survey Section will determine if replacement is warranted.

IV.12 Side-Staking Centerline

Most projects no longer require side staking; on those projects that do the following procedures shall be used.

As soon as construction alignments are set and final accuracy checks have been made, reference stakes (called side stakes) should be set at right angles to each 50 ft. construction centerline station. These stakes should be placed 20 ft. beyond the clearing edge.

Normally, side stakes should be set left and right of centerline. In certain situations it may be necessary to double-stake on one side only, but stake on both sides if possible. Double staking should be used on the right-of-way side of double barrel highways when the median strip is going to be worked during construction. There should be a minimum of 20 ft. between double stakes.

A side stake should be driven into the ground two-thirds of its length, leaving a wide face parallel to the centerline. The face seen from the centerline shall be marked with the station and offset distance, e.g., 192' over 72+50. A tall riser flagged with red plastic flagging [blue or white on ramp side stakes] shall be set within 1 ft. and directly behind each side stake.

Occasionally it is necessary to drive the side stakes flush with the ground, where they fall on a lawn or where there is extensive vandalism. When this is the case the top of the stake should be painted to aid in finding the stake. In urban areas, side stakes should not be set outside of the right-of-way, unless the Crew Chief has obtained permission from the property owner.

All side stake distances must be measured with a steel tape or Total Station EDM. It is customary to set all side stakes to an even distance. Be certain, after the stake is in the ground that the offset distance and station are still showing, and the distance on the stake agrees with the actual distance measured.

IV.13 Structure Layouts

On a construction project where one or more structures are to be built, the survey crew will be furnished with a full size set of bridge plans. Generally, a survey layout sketch is incorporated on one of the plan sheets for each bridge. If not, a suitable layout must be developed from the plans. The Survey Crew Chief will obtain the Survey Supervisors approval for the proposed layout. Occasionally, field conditions may warrant a change in the normal layout procedure. However, every layout, even if only a partial layout, must have a triangulation check as well as be tied into The Primary Control Network.

The Crew Chief will make a layout sketch in the field notebook. Use as many pages as needed to show all of the required information. It is important to show the bridge number and description and the stations and angles of crossing to the centerline or centerlines of construction.

Use the following steps for bridge layout procedures:

- It is acceptable for all working points on the original bridge layout to be set from two proven traverse points in the immediate vicinity of the work area.

- The purpose of the checks is to avoid costly mistakes. The accuracy needed in all field measurements cannot be over emphasized. This is especially true where multiple span structures are involved. The precision tolerance in checking diagonal check measurement should not be less than 1:20,000.

- The diagonal distance checks are very important, but angle checks are also helpful in determining errors in layout. As many working points as possible should be checked by span and diagonal inverse field measurements. Once the bridge layout has been completed and checked on one side of the centerline of bridge, intermediate tie points should be set on the same line of sight. After the tie points are all set on one side of the bridge, new line of sight should be taken on the furthest sight point and each point carefully checked. Any slight variation must be corrected. It is customary to use cup tacks to mark the line on the stakes.

- To establish the sight points on the same centerline of bearing on the opposite side of the centerline of bridge, the preferred method is to set the instrument on one of the outermost ties just established, then take line on the point just occupied on the centerline of bearing at the centerline of bridge and to project thru this point to set a tie point a maximum distance on the opposite side of the centerline of bridge. Intermediate tie points can now be set. Where possible, all of the points now established along the centerline of bearing should be checked from one set-up, by taking line from one outside point to the opposite outside point and making sure that each intermediate point is on a perfectly straight line.

- Where wing lines are laid out on skew angles, the accuracy of the layouts should be checked with additional diagonal measurements to the ends of the wings from the nearest centerline of bearing at the centerline of bridge.

- When bridge targets are used, it is important to have a hub tie directly under the target or within a few feet of the target. This will allow the Contract Administrator to accurately check the target to see if it has been disturbed.

- All bridge tie hubs shall be driven flush with the ground, with reference stakes clearly marked for each hub. "Bull pens" made with risers and spaced far enough apart to allow the setting up of an instrument between them, shall be set around each hub. The "bull pens" shall be well outlined with yellow plastic flagging. Bridge targets shall be nailed onto rugged frames, well braced and firmly attached to permanent objects or driven firmly into the ground. With the small bridge targets, it may not be necessary to make an elaborate frame.

- The preliminary bridge layout will include ties and targets as requested by the Contract Administrator along the centerline of bridge, the centerline of bearings for the abutments and piers and along the working lines for the wings. The centerline of bearings and the centerline of bridge should have a minimum of three ties each side of the location of the structure. There should be three hub ties for each skewed wing.

Following the complete bridge layout, a survey crew may be called back to check spans after the concrete has been poured. The Contract Administrator will set his own grades on abutments, piers and footers.

IV.14 Layout for Fencing along Right-of-Way

When right-of-way fencing alignment is required, it shall be done in accordance with NHDOT Survey Technical Standards Section II, Boundary and Right-of-Way Surveys.

Survey stakes, marked R.O.W. will be set along the line at approximately 100 ft. intervals. A riser, flagged in green plastic flagging, will be set beside each survey stake.

IV.15 Automated Machine Guidance (AMG)

Automated Machine Guidance (AMG) technology uses positioning devices, alone or in combination, such as the Global Navigation Satellite System (GNSS), Total Stations, and/or rotating laser levels to determine the real time X, Y, and Z position of construction equipment and compare that position against a 3D Digital Design Model (DDM) stored in an onboard computer. A computer display shows the operator or grade checker several perspectives and delta values of their position compared to the design surface. This technology has the potential to increase the Contractor's efficiency, increase the Contractor's productivity, reduce the number of survey stakes required, and reduce construction working days. <u>All AMG work shall be localized to NHDOT project control</u>. Real time satellite positioning is not to be used.

IV.16 AMG Project Control

AMG may require a higher density of control monuments than needed for conventional methods. Setting additional monuments for machine guidance is part of the secondary control network. The Contractor must utilize and constrain to the provided project survey control points for the Digital Terrain Model (DTM), DDM, and construction equipment locations to match.

GNSS satellite signals can be subject to interference from canyons, buildings, trees or even fencing. Additional monuments will be set when needed for adequate site coverage. Not all locations are suitable for AMG techniques, and it is the Contractor's responsibility to determine if the site conditions are practical for AMG.

Robotic total station guided equipment, such as paving machines, require a more dense survey control network of a higher order of vertical accuracy than GNSS controlled systems. Control should be staggered on either side of the highway to provide a good strength of figure. While the distance between control points should be no farther than 650 ft., the actual distance varies by the type of equipment used by the Contractor. The vertical accuracy of the control must be such that the total station elevation can be established with an accuracy of +/- 0.01 ft. Vertical control shall be established with a differential level loop with e=0.035'√Miles.

Surveys involvement in projects using AMG technology can vary from project to project, but in general may include the following:

a) Recover, verify, and evaluate project survey control used to develop the existing ground surface for consistency and create a site calibration prior to construction.

b) Perform terrain checks to identify any changes from earlier mapping.

c) Establish supplemental project control as needed for AMG operations.

d) Meet with the Contract Administrator and the Contractor to discuss control, calibration, and staking.

e) Provide the Contractor with the latest control points. Provide the Contract Administrator and Contractor with coordinates and elevation for the local survey control calibration points to ensure project consistency.

f) Review the Contractor's calibration report and compare with the Department's calibration.

g) Assist the Contract Administrator with inspection of line and grade in areas without conventional staking. Surveys may assist the Contract Administrator with project inspection using survey equipment, the project model, and survey control if so resourced and requested.

h) Surveys will set additional control to assist the Contract Administrator staff in checking and inspection of project.

i) Deliver the files necessary to the Contract Administrator in order for the Contract Administrator to evaluate work completed by AMG methods.

j) Act as an advisor to the Contract Administrator as requested on GNSS and AMG issues.

k) Set conventional slope stakes at all "conform" stations, beginning and end of curves, and begin and end of transitions to aid with inspections. Set stakes as requested by the Contract Administrator for inspection purposes.

l) Set other construction stakes as necessary. The use of AMG will not eliminate the need for the staking of structures, drainage, utilities, etc.

Additional reference is made to Special Provisions Specifications, Section 670- Miscellaneous Incidentals, Item 670.822 – GNSS Construction Inspection Equipment.

IV.17 Deviations from Established Procedures or Policies

Whenever there is any request for deviation in layout work covered by specific instructions previously issued by this office that is requested by the Contract Administrator or his representative, the Crew Chief shall contact the Land Surveyor in charge before proceeding. The Contract Administrator will provide all proposed deviations and instructions for such deviations to the Crew Chief and Land Surveyor for review and approval. All work pertaining to the layout, location or control of boundary, easements, property rights or survey methodology shall be the responsibility of the Land Surveyor. All work pertaining to the final structure location layout and construction shall be the responsibility of the Contract Administrator.

NHDOT Survey Technical Standards

GLOSSARY OF TERMS

Accuracy – Accuracy is how close measurements are to the accepted value of truth.

Adjustment – Adjustment is the process of determining and applying corrections to observations for the purpose of reducing errors in a network adjustment.

Angular closure – Angular closure for each condition is expressed as the number of seconds allowable for any angle multiplied by the square root of the number of angles in the traverse. This value should not be exceeded in any loop closure.

Antenna height – Antenna height is the height of a GPS antenna phase center above the point being observed. The uncorrected antenna height is measured from the observed point to a designated point on the antenna, and then corrected to the true vertical manually or automatically in the software.

Antenna phase center – Antenna phase center is the electronic center of the antenna. It often does not correspond to the physical center of the antenna. The radio signal is measured at the Antenna Phase Center.

Antenna phase correction – Antenna phase correction is the antenna phase correction is the phase center for a GPS antenna is neither a physical nor a stable point. The phase center for a GPS antenna changes with respect to the changing direction of the signal from a satellite. Most of the phase center variation depends on satellite elevation. Modeling this variation in antenna phase center location allows a variety of antenna types to be used in a single survey. Antenna phase, center corrections are not as critical when two of the same antennas are used since common errors cancel out.

Autonomous positioning – Autonomous positioning is a mode of operation in which a GPS receiver computes position fixes in real time from satellite data alone, without reference to data supplied by a base station. Autonomous positioning is the least precise positioning procedure a GPS receiver can perform, yielding position fixes that are precise to ±100 meters horizontal RMS when selective availability is in effect, and to ±10-20 meters when it is not. This is also known as absolute positioning and point positioning.

Azimuth – The azimuth is a surveying observation used to measure the angle formed by a horizontal baseline and geodetic north. When applied to GPS observations, it refers to a normal section azimuth.

Azimuth mark- A project control monument set at the end points of the project for use as a backsight.

Base station – A base station is an antenna and receiver set up on a known location. It is used for real-time kinematic (RTK) or differential surveys. Data can be recorded at the base station for later Postprocessing. In GPS surveying practice, the user may observe and compute baselines (that is, the position of one receiver relative to another). The base station acts as the position from which all other unknown positions are derived.

Baseline – A baseline is the position of a point relative to another point. In GPS surveying, this is the position of one receiver relative to another. When the data from these two receivers is combined, the result is a baseline comprising a three-dimensional vector between the two stations.

Bearing source – The source of the bearing (or course) must be stated in the report, on the Plat or in any description as one of the following:

- geodetic bearing
- grid bearing of the NH Coordinate System of 1983
- record bearing or the relation thereto, along a line monumented on the ground as called for in said record.

Bench marks – A bench mark is a relatively permanent object, natural or man-made, bearing a marked point, whose elevation above or below an adopted datum is known. Usually designated as "BM," such a mark is sometimes further qualified as a PBM (permanent bench mark) or as a TBM (temporary bench mark).

CAF – Combined Adjustment Factor. CAF is the product of the scale factor and the elevation factor. The CAF times the surface distance yields the corresponding distance on the state plane grid.

Chi-square test – Chi-square is an overall statistical test of the network adjustment. It is a test of the sum of the weight squares of the residuals, the number of degrees of freedom and a critical probability of 95 percent or greater. The purpose of this test is to reject or to accept the hypothesis that the predicted errors have been accurately estimated.

Collection rate – The rate at which a receiver collects SV data.

Combined scale factor - A conversion factor that uses the combination of the grid scale factor and the elevation scale factor of a point to reduce horizontal ground distances to grid distances.

Constellation – A constellation is a specific set of satellites used in calculating positions: three satellites for 2-D fixes, four satellites for 3D fixes. It is all of the satellites visible to a GPS receiver at one time. The optimum constellation is the constellation with the lowest PDOP.

Constrained – Constrained is a way to hold (fix) a quantity (observation and coordinate) as true in a network adjustment.

Constraint – Constraint is external limitations imposed upon the adjustable quantities (observations and coordinates) in a network adjustment.

Control – A control is a system of points whose relative positions have been determined from survey data.

Control point – A point that has a very accurate coordinate. This may be a published NGS point or one that was surveyed by other means. This is the type of point that a reference receiver should be placed on.

Control stations – Control stations are stations whose position (horizontal or vertical) has been determined from survey data and is used as a base for a dependent survey.

Control survey – A control survey is a survey that provides positions (horizontal or vertical) of points to which supplementary surveys are adjusted.

CORS - Continuously Operating Reference System – CORS is a network of the highest quality horizontal stations, forming the National Spatial Reference System and providing the public with 24-hour raw GPS data.

Cycle slips – A discontinuity in the measured carrier beat phase resulting from a temporary loss of lock in the carrier loop of a GPS receiver.

Data collector – A data collector is a handheld electronic field notebook. It connects to a total station, level, or GPS receiver to receive and temporarily store raw data.

Datum – Datum is a mathematical model of the earth designed to fit part or all of the geoid. It is defined by the relationship between an ellipsoid and a point on the topographic surface established as the origin of the datum. It is usually referred to as a geodetic datum. The size and shape of an ellipsoid, and the location of the center of the ellipsoid with respect to the center of the earth, usually define world geodetic datums.

Datum grid/multiple regression – Datum grid/multiple regression are datum transformations, usually convert data collected, in the WGS-84 datum (by GPS methods) onto datums used for surveying and mapping purposes in individual regions and countries.

Datum transformation – Datum transformation defines the transformation that is used to transform the coordinates of a point defined in one datum to coordinates in a different datum. There are a number of different datum transformation methods including seven-parameter and three-parameter (or Molodensky).

Deflection of the vertical – A deflection of the vertical is the angular difference between the upward direction of the plumb vertical line (vertical) and the perpendicular (normal) to the ellipsoid.

Degrees of freedom – Degrees of freedom is a measure of the redundancy in a network.

Differential positioning – Precise measurement of the relative positions of two receivers tracking the same GPS signals.

DOP – Dilution of Precision is a measure of the accuracy of a GPS position based on the relative positions of the satellites. DOP is an indicator of the quality of a GPS position. It takes account of each satellite's location relative to the other satellites in the constellation, and their geometry in relation to the GPS receiver. A low DOP value indicates a higher probability of accuracy.

Standard DOPs for GPS applications are:

- PDOP Position (three coordinates)
- HDOP Horizontal (two horizontal coordinates)
- VDOP Vertical (height only)
- TDOP Time (clock offset only).

Doppler shift – A doppler shift is the apparent change in frequency of a signal caused by the relative motion of satellites and the receiver.

Double differencing – Double differencing is an arithmetic method of differencing carrier phases simultaneously measured by two receivers tracking the same satellites. This method removes the satellite and receiver clock errors.

DTM – Digital Terrain Model. DTM is a representation in graphic form, on the computer, of the terrain through the area being surveyed.

Dual-frequency – A dual frequency is a type of receiver that uses both L1 and L2 signals from GPS satellites. A dual-frequency receiver can compute more precise position fixes over longer distances and under more adverse conditions because it compensates for ionospheric delays.

Elevation – is the vertical distance of a point above or below a datum plane.

Elevation scale factor- A multiplier used to change horizontal ground distances to geodetic (ellipsoid) distances.

Elevation mask – This is the angle above the horizon, below which satellite signals are not used.

Ellipsoid – The Earth is neither perfectly smooth nor round. Earth scientists (geodesists) have mathematically smoothed the surface of the Earth by averaging the highs and lows. This new calculation is called an ellipsoid. GPS uses WGS 84 as its ellipsoid base. The ellipsoid is a mathematical model of the earth formed by rotating an ellipse around its minor axis. For ellipsoids that model the earth, the minor axis is the polar axis, and the major axis is the equatorial axis.

- An ellipsoid is defined by specifying the lengths of both axes, or by specifying the length of the major axis and the flattening.
- Two quantities define an ellipsoid; these are usually given as the length of the semi-major axis, a, and the flattening, where b is the length of the semi-minor axis.

Ellipsoid distance – An ellipsoid distance is the length of the normal section between two points. Ellipsoid distance is not the same as the geodesic distance.

Ellipsoid height – An ellipsoid height is the distance, measured along the normal, from the surface of the ellipsoid to a point.

Epoch – An epoch is the time interval when the receiver logs data to its memory. An epoch is the measurement interval of a GPS receiver. The epoch varies according to the survey type.

Epoch date – The epoch date is the date, usually expressed in decimal years for which published coordinates and data are valid.

Epoch interval – Epoch interval is the measurement interval used by a GPS receiver; also called a cycle.

Fast ambiguity resolution – Fast ambiguity resolution is rapid static or fast static GPS surveying techniques, utilizing multiple observables (dual-frequency carrier phase, C/A and P codes) to resolve integer ambiguities, with shortened observation periods. The method may also be used for observations with the receiver in motion known as on-the-fly ambiguity resolution.

FastStatic – FastStatic is a method of GPS surveying using occupations of up to 20 minutes to collect GPS raw data, then postprocessing to achieve sub-centimeter precisions. Typically the occupation times vary based on the number of satellites (SVs) in view. FastStatic is also referred to as RapidStatic.

FGCS - Federal Geodetic Control Subcommittee

FGDC – Federal Geodetic Data Committee.

Fixed solution – A fixed solution is a solution obtained when the baseline processor is able to resolve the integer ambiguity search with enough confidence to select one set of integers over another. It is called a fixed solution because the ambiguities are all fixed from their estimated float values to their proper integer values.

Flattening – A flattening is a mathematical expression of the relative lengths of the major and minor axes of an ellipsoid.

Flattening inverse – A flattening inverse is an expression of the flattening that is easier to read and edit.

Float solution – A float solution is a solution obtained when the baseline processor is unable to resolve the integer ambiguity search with enough confidence to select one set of integers over another. It is called a float solution because the ambiguity includes a fractional part and is noninteger.

Free adjustment – Performs a network adjustment in which no point (coordinate) is constrained. The network adjustment uses inner constraints.

Frequency – Frequency is the size and spread of residuals in a data set; graphically shown in distribution histograms.

Fully constrained – Fully constrained is a network adjustment in which all points in the network that are part of a larger control network are held fixed to their published coordinate values. Fully constrained is used to merge smaller with larger control networks and old to newer networks.

GDOP - Geometric Dilution of Precision – GDOP is the relationship between errors in user position and time and errors in satellite range. See also DOP.

Geodetic azimuth – A geodetic azimuth is the angle between the geodetic meridian and the tangent to the geodesic line of the observer, measured in the plane perpendicular to the ellipsoid normal of the observer; clockwise from north.

Geodetic datum – A geodetic datum is a mathematical model designed to fit part or all of the geoid. It is defined by the relationship between an ellipsoid and a point on the topographic surface established as the origin of a datum.

- The size and shape of an ellipsoid and the location of the center of the ellipsoid with respect to the center of the earth define world geodetic datums. Various datums have been established to suit particular regions.
- For example, European maps are often based on the European datum of 1950 (ED-50). Maps of the United States are often based on the North American Datum of 1927 or 1983 (NAD-27, NAD-83). All GPS coordinates are based on the WGS-84 datum surface.

Geographic (geodetic) coordinates – Latitude, longitude, and ellipsoid height.

Geoid – A geoid is an Earth model that takes into account the Earth's gravity field. Geodesists have recalculated the Earth's surface so that an object does weigh the same no matter where it is placed. A geoid is the surface of gravitational equipotential that closely approximates mean sea level. It is not a uniform mathematical shape, but is an irregular figure.

- Generally, the elevations of points are measured with reference to the geoid. However, points fixed by GPS methods have heights established in the WGS84 datum (a mathematical figure).
- The relationship between the WGS-84 datum and the geoid must be determined by observation, as there is no single mathematical definition that can describe the relationship. The user must utilize conventional survey methods to observe the elevation above the geoid, and then compare the results with the height above the WGS84 ellipsoid at the same point.
- By gathering a large number of observations of the separation between the geoid and the WGS84 datum (geoidal separation), grid files of the separation values can be established.
- This allows the interpolation of the geoidal separation at intermediate positions. Files containing these grids of geoidal separations are referred to as geoid models. Given a WGS84 position that falls within the extents of a geoid model, the model can return the interpolated geoidal separation at this position.

Geoid model – A geoid model is a mathematical representation of the geoid for a specific area, or for the whole earth. The software uses the geoid model to generate geoid separations for the user's points in the network.

Geoid separation – Geoid separation is the distance between the ellipsoid and geoid at a given point.

Geomatics – Geomatics is the design, collection, storage, analysis, display, and retrieval of spatial information. The collection of spatial information can be from a variety of sources, including GPS and terrestrial methods. Geomatics integrates traditional surveying with new technology-driven approaches, making geomatics useful for a vast number of applications.

GPS - Global Positioning System – A GPS is based on a constellation of twenty-four (24) satellites orbiting the earth at a very high altitude.

GPS baseline – A GPS baseline is a three-dimensional measurement between a pair of stations for which simultaneous GPS data has been collected and processed with differencing techniques. This baseline is represented as delta X, delta Y, and delta Z; or azimuth, distance, and delta height.

GPS observation – A GPS observation is an uninterrupted collection of GPS data at a particular point in the field. A number of observations are done simultaneously in a session to create baselines by processing the data.

Grid – A grid is a two-dimensional horizontal rectangular coordinate system, such as a map projection.

Grid azimuth – A grid azimuth is measured from grid north.

Grid conversion – A grid conversion is the conversion between geographic and map projection coordinates.

Grid coordinates – Grid coordinates are the numbers of a coordinate system that designates a pointon a grid.

Grid declination - The angular difference in direction between grid north and true north at any given place.

Grid position – Grid position are the grid coordinates of a point.

Grid scale factor- A multiplier used to change geodetic distances based on the ellipsoid to the grid plane.

Ground control – Ground control, in photomapping, is the control obtained from surveys as distinguished from control obtained by photogrammetric methods.

Grid distance – The grid distance is the distance between two points that is expressed in mapping projection coordinates.

Ground distance – Ground distance is the distance (horizontal distance with curvature applied) between two ground points.

HDOP – Horizontal Dilution of Precision.

Height measurement – A height measurement is a measuring tool supplied with an external GPS antenna and used rod for measuring the height of the antenna above a point.

H. I. – Measurement from point on the ground to the antenna of either the base or rover receiver.

Horizontal control survey – is performed for the purpose of placing geographic coordinates of latitude and longitude on permanent monuments for referencing lower levels of surveys. A projection is used to place the coordinates on a plane of northing and easting values for simplified measurements. Scale and elevation factors are applied to make the distance measurements applicable to the exact project location on the working surface and the type of projection chosen is an "equal angle" type.

HTDP – Horizontal Time Dependent Positioning model. HTDP is a computer database and interpolation program developed by NGS to predict horizontal displacements between coordinate points over time. The program can work backwards in time where it includes earthquake parameter or forward in time where only the secular motion is analyzed.

Integer ambiguity – Inner ambiguity is the whole number of cycles in a carrier phase pseudorange between the GPS satellite and the GPS receiver.

Integer search – Integer search is the GPS baseline processing, whether real-time or postprocessed, requires fixed integer solutions for the best possible results. The software which processes the GPS measurements used to derive a baseline does an integer search to obtain a fixed integer solution. The search involves trying various combinations of integer values and selecting the best results.

Iono free – Ionospheric free solution (IonoFree). IonoFree is a solution that uses a combination of GPS measurements to model and remove the effects of the ionosphere on the GPS signals. This solution is often used for high-order control surveying, particularly when observing long baselines.

Ionosphere – The band of charged particles 80 to 120 miles above the Earth's surface.

Ionosperic delay – An ionospheric delay is a signal delay or acceleration as a wave propagates through the ionosphere. Phase delay depends upon the electron content and affects the carrier signal. Group delay depends upon the dispersion in the ionosphere as well, and affects the code signal.

ionospheric modeling – Ionospheric modeling is the time delay caused by the ionosphere varies with respect to the frequency of the GPS signals and affects both the L1 and L2 signals differently. When dual frequency receivers are used the carrier phase observations for both frequencies can be used to model and eliminate most of the ionospheric effects. When dual frequency measurements are not available an ionospheric model broadcast by the GPS satellites can be used to reduce ionospheric affects. The use of the broadcast model, however, is not as effective as the use of dual frequency measurements.

Iteration – An iteration is a complete set of adjustment computations that includes the formation of the observation equations, normal equations, coordinate adjustments, and computation of residuals.

Kinematic surveying – Kinematic surveying is a method of GPS surveying using short Stop and Go occupations, while maintaining lock on at least 4 satellites. It can be done in real-time or postprocessed to centimeter precisions.

Known point initialization – A known point initialization is used in conjunction with kinematic initialization. If two known points are available, the baseline processor can calculate an inverse between the two points and derive an initialization vector. This initialization vector, with known baseline components, is used to help solve for the integer ambiguity. If the processor is able to successfully resolve this ambiguity a fixed integer solution is possible, yielding the best solutions for kinematic surveys.

Least squares – A mathematical method for the adjustment of observations, based on the theory of probability. In this adjustment method, the sum of the squares of all the weighted residuals is minimized.

Level datum – A level datum is a level surface to which elevations are referred. The generally adopted level datum for leveling in the United States is mean sea level. For local surveys, an arbitrary level datum is often adopted and defined in terms of an assumed elevation for some physical mark (bench mark).

Leveling – is the operation of measuring vertical distances, directly or indirectly, to determine elevations.

Loop closure – Loop closures provide an indication as to the amount of error in a set of observations within a network.

- A loop closure is calculated by selecting a point from which one or more observations were taken, adding one of those observations to the point's coordinates, and calculating coordinates of the second point based on that observation.
- This process is repeated one or more times around a loop, finally ending at the original starting point. If there were no errors in the observations, the final calculated coordinate would be exactly the same as the original starting coordinate.
- By subtracting the calculated coordinate from the original coordinate a misclosure is determined. Dividing this error by the length of the line allows the error to be expressed in parts per million.
- This technique can also be used between two different points when both points are known with a high degree of accuracy. This is also known as a traverse closure.

Mapping angle – Mapping angle is the angle between grid north on a mapping projection and the meridian of longitude at a given point. Also know as convergence.

Map projections – These are representations of the Earth's features that are transferred to a flat two-dimensional plane, such as, paper maps and computer generated maps. Mapping projection is a rigorous mathematical expression of the curved surface of the ellipsoid on a rectangular coordinate grid.

Mask angle – Cut-off angle. A mask angle/cut-off angle is the point above the observer's horizon below which satellite signals are no longer tracked and/or processed. Ten to twenty degrees is typical.

Mean sea level – A mean sea level is the mean height of the surface of the ocean for all stages of the tide. Used as a reference for elevations.

Meridian – A meridian is a north-south line from which longitudes (or departures) and azimuths are reckoned.

Minimally constrained – A minimally constrained network is a network adjustment in which only enough constraints to define the coordinate system are employed. It is used to measure internal consistency in observations.

Multipath – A multipath is an interference (similar to ghosts on a television screen) that occurs when GPS signals arrive at an antenna after traveling different paths. The signal traveling the longer path yields a larger pseudorange estimate and increases the error. Multiple paths may arise from reflections from structures near the antenna.

Multipath errors – Errors caused by the interference of a signal that has reached the receiver antenna by two or more different paths. This occurs when the antenna is placed too close to a large object, such as water towers, overhead storage tanks, etc.

NAVDATA – NAVDATA is the 1500-bit navigation message broadcast by each satellite. This message contains system time, clock correction parameters, ionospheric delay model parameters, and details of the satellite's ephemeris and health. The information is used to process GPS signals to obtain user position and velocity.

Network adjustment – A network adjustment is a solution of simultaneous equations designed to achieve closure in a survey network by minimizing the sum of the weighted squares of the residuals of the observations.

Occupation time – An occupation time is the amount of time required on a station, or point, to achieve successful processing of a GPS baseline. The amount of time will vary depending on the surveying technique, the type of GPS receiver used, and the precision required for the final results. Occupation times can vary from a couple of seconds (kinematic surveys) to several hours (control or deformation surveys that require the highest levels of precision and repeatability).

OPUS – On-line Positioning User Service (OPUS) provides GPS users easier access to the National Spatial Reference System (NSRS) and is operated by the National Geodetic Survey (NGS). OPUS allow users to submit their GPS data files to NGS, where the data will be processed to determine a position using NGS computers and software. Each data file that is submitted will be process with respect to 3 CORS sites and the results are e-mailed to the user.

OPUS-RS – OPUS-RS is a version of OPUS designed to obtain geodetic quality positioning results from user data sets as short as 15 minutes. The reference station selection algorithm for OPUS-RS differs from that for regular OPUS. OPUS-RS searches the reference stations in order of increasing distance from the user's station (the rover), selecting reference stations that have suitable data.

Order of accuracy – An order of accuracy is a mathematical ratio defining the general accuracy of the measurements made in a survey.

Orthometric height – An orthometric height is the distance between a point and the surface of the geoid. It is usually called the elevation.

OTF search method – On-the-fly (OTF) search method is a GPS baseline processing, whether realtime or postprocessed, requires fixed integer solutions for the best possible results.

- Historically, this search was done using measurements collected while two or more receivers were stationary on their respective points. Modern receivers and software can use the measurements collected while the roving receiver is moving. Because the receiver is moving, the data is described as collected On-the-fly (OTF) and the integer search using this data is an OTF search.

PDOP – Position Dilution of Precision is an indication of the current satellite geometry. A PDOP is a unitless figure of merit expressing the relationship between the error in user position, and the error in satellite position. It is the result of a calculation, which takes into account each satellite's location relative to the other satellites in the constellation. A low PDOP indicates a higher probability of accuracy. Usually a PDOP of 6 or below gives excellent positions. Geometrically, PDOP is proportional to 1 divided by the volume of the pyramid formed by lines running from the receiver to four satellites that are observed. Values considered "good" for positioning are small, for example 3. Values greater than 7 are considered poor. Thus, small PDOP is associated with widely separated satellites.

PDOP is related to horizontal and vertical DOP by: PDOP2 = HDOP2 + VDOP2

PDOP cutoff – A receiver parameter specifying a maximum PDOP value for positioning. When the geometric orientation of the satellites yields a PDOP greater than the mask value, the receiver stops computing position fixes.

PDOP mask – A PDOP mask is the highest PDOP value at which a receiver will compute positions.

Phase center models – Phase center models are models used to apply a correction to a GPS signal based on a specific antenna type. The correction is based on the elevation of the satellite above the horizon and models electrical variations in the antenna phase center location. These models are useful for eliminating errors introduced when identical antennas are not used at both the base and rover points.

Phase difference processing – Relative positioning. Phase difference processing is a computation of the relative difference in position between two points by the process of differencing simultaneous reconstructed carrier phase measurements at both sites. The technique allows cancellation of all errors which are common to both observers, such as clock errors, orbit errors, and propagation delays. This cancellation effect provides for determination of the relative position with much greater precision than that to which a single position (pseudorange solution) can be determined.

Positional tolerance of any monument – The distance that any monument may be mislocated due to normal imperfect measurements opposed to its actual location by nearly perfect measurement.

- This value can be determined by dividing the length of any course of a closed traverse by the denominator of the required error of closure. The results of this calculation will establish the tolerance or radius around a point.
- No traverse adjustment shall be made to any distance larger than this positional error. If the measurements are checked with a one-second theodolite and a recently calibrated Distance measuring device of known high accuracy, the values must fall within the tolerance or radius calculated.

Post-processing – A procedure used to obtain accurate coordinates by correcting errors in the rover receiver data. This is accomplished by processing the rover receiver data with the base receiver data. The rover receiver and the base receiver must run concurrently and include the same satellites.

PPM - Parts per million – PPM is a standardized representation of a scale error in distance measurements. A 1 PPM error would result in 1 millimeter of measurement error for every 1000 meters of distance traveled.

Precision – How close multiple measurements of a single point are to each other.

Professional surveying –Means the practice of land, boundary, or property surveying or other similar professional practices.

- The term includes any service or work the adequate performance of which involves the application of special knowledge of the principles of mathematics, related applied and physical sciences, and relevant laws to the measurement and location of lines, angles, elevations, natural features, and existing man-made works, and, on the beds of bodies of water, the determination of areas and volumes, for:

- the location of real property boundaries
- the platting and layout of lands and subdivisions of land
- the preparation and perpetuation of maps, record plats, field note records, and real property descriptions that represent those surveys.

Pseudorange – A pseudorange is a measure of the apparent propagation time from the satellite to the receiver antenna, expressed as a distance. The apparent propagation time is determined from the time shift required to align a replica of the GPS code generated in the receiver with the received PGS code.

- The time shift is the difference between the time of signal reception (measured in the receiver time frame) and the time of emission (measured in the satellite time frame). Pseudorange is obtained by multiplying the apparent signal-propagation time by the speed of light.
- Pseudorange differs from the actual range by the amount that the satellite and receiver clocks are offset, by propagation delays, and other errors including those introduced by selective availability.

Pseudostatic GPS – Pseudostatic GPS, also known a pseudo-kinematic and repeat occupation, is a relative positioning technique which relies upon two or more simultaneous observations at a point pair, separated by some time interval (typically 60 minutes or more), in order to solve the integer bias terms from the change in satellite geometry occurring between the repeat observations.

Quality acceptance test – A quality acceptance test is one or more software evaluation tests, performed on raw GPS measurement data, to determine if the data passes or fails a set of tolerance values that the user defines. These tests either remove data from further processing or mark data requiring quality improvements.

QC records – Quality Control records. QC records are used with precise positioning applications. This receiver option allows a user to process RTCM-104 corrections and satellite data in real time to provide position precision statistics.

Ratio – A ratio is used during initialization. The receiver determines the integer number of wavelengths for each satellite. For a particular set of integers, it works out the probability that it is the correct set.

- Ratio is the ratio of the probability of correctness of the currently best set of integers to the probability of correctness of the next-best set.
- Thus, a high ratio indicates that the best set of integers is much better than any other set. This gives us confidence that it is correct. The ratio must be above 5 for new point and OTF initializations.

RDOP – Relative Dilution of Precision.

Real-time corrections – Real-time DGPS uses a data link (beacon or commercial) to transmit correctional data from the reference to the rover receiver. These corrections are used by the rover receiver to correct its errors as the satellite signal is received. No post-processing is required to obtain positions corrected to meter level accuracy.

Real-time kinematic – Real-time kinematic is a method of GPS surveying in real-time using short (stop and go) occupation, while maintaining lock on at least 4 satellites. The real-time kinematic method requires a wireless data link between the base and rover receivers.

Reference frame – A reference frame is the coordinate system of a datum.

Reference station – A reference station is a base station.

Relative errors – A relative errors are errors and precisions expressed for and between pairs of network-adjusted control points.

Relative precision – A relative precision is defined as a measure of the tendency of a set of numbers to cluster about a number determined by the set (e.g. the mean). The usual measure is the standard deviation with respect to the mean.

- Relative precision denotes the tendency for the various components (X, Y, Z) between one station and other stations in the network to be clustered about the adjusted values.
- Current custom is to express relative precision at the two-standard deviation (95% confidence) level. This may be stated in terms of a relative error ellipse or as a proportion of the separation distance (e.g. 10 ppm or 1:100,000).

Residual – A residual is the correction or adjustment of an observation to achieve overall closure in a control network. It is also, any difference between an observed quantity and a computed value for that quantity.

RINEX – Receiver INdependent EXchange format – A RINEX is a standard GPS raw data file format used to exchange files from multiple receiver manufacturers. An interchange format that permits data collected by one specific receiver to be read by another vendor's receiver.

RMS – Root Mean Square – A RMS expresses the accuracy of point measurement. It is the radius of the error circle within which approximately 68% of position fixes are found. It can be expressed in distance units or in wavelength cycles.

RMSE – Root Mean Square Error.

Rover – A mobile GPS receiver that when used in conjunction with a stationery receiver can obtain differentially corrected ground coordinates. Any receiver used in a dynamic mode is called a rover.

RTK – A real-time kinematic is a type of GPS survey.

Satellite constellation – The arrangement in space of a set of satellites.

Satellite geometry – A satellite geometry is a position and movement of GPS satellites during a GPS survey.

Secular motion – A secular motion is that portion of crustal motion which is continuous and at a constant velocity. Secular motion is uniformly predictable over time and is independent of any seismic events.

Signal to noise ratio (SNR) – An indicator of the strength of a satellite signal.

Site calibration – Site calibration is a process of computing parameters which establishing the relationship between WGS-84 positions (latitude, longitude and ellipsoid height) determined by GPS observations and local known coordinates defined by a map projection and elevations above mean sea level. The parameters are used to generate local grid coordinates from WGS-84 (and viceversa) real-time in the field when using RTK surveying methods.

Solution types – Solution types refer to a description of both the data and techniques used to obtain baseline solutions from GPS measurements.

- Typical solution types include descriptions such as code, float, and fixed. These describe techniques used by the baseline processor to obtain a baseline solution.
- Solution types also may include descriptions such as L1, L2, wide-lane, narrow-lane, or ionospheric free. These describe the way the GPS measurements are combined to achieve particular results.

Standard deviation – A standard deviation is a standard error. Surveying applications use the conventional formula for sample standard deviation. Standard deviation is a measure of the strength of a satellite signal. SNR ranges from 0 (no signal) to around 35.

Standard error – A standard error is a statistical estimate of error, according to which 68 percent of an infinite number of observations will theoretically have absolute errors less than or equal to this value.

Standard error of unit weight – A standard error of unit weight is a measure of the magnitude of observational residuals in an unit weight adjusted network as compared to estimated pre-adjustment observational errors.

Static (surveying) – Static is a method of GPS surveying using long occupations (hours in some cases) to collect GPS raw data, then postprocessing to achieve sub-centimeter precisions.

Static network – A static network is a network that describes the geometry and order in which GPS baselines collected using static and fast static techniques are organized and processed.

- The baseline processor first examines the project for points with the highest quality coordinates, and then builds the processing network from those points. The result is a set of static baselines that are derived using accurate initial coordinates.

Tropo correction – tropospheric correction. Tropo correction/tropospheric correction is the correction applied to a satellite measurement to correct for tropospheric delay.

Tropo model – tropospheric model – A tropo model occurs when GPS signals are delayed by the troposphere.

- The amount of the delay will vary with the temperature, humidity, pressure, height of the station above sea level, and the elevation of the GPS satellites above the horizon.
- Corrections to the code and phase measurements can be made using a tropo model to account for these delays.

Universal Transverse Mercador (UTM) – A projection created by the U.S. Army to obtain a series of maps that would encircle the Earth.

U.S. Survey Foot – 1200/3937 meter.

VDOP – Vertical dilution of precision.

Vector – A vector is a three-dimensional line between two points.

Vertical – A vertical is similar to the normal, except that it is computed from the tangent plane to the geoid instead of the ellipsoid.

Vertical adjustment – A vertical adjustment is a network adjustment of vertical observations and coordinates only.

Vertical control – A Vertical control is an established benchmarks.

Vertical control point – A vertical control point is a point with vertical coordinate accuracy only. The horizontal position is of a lower order of accuracy or is unknown.

Vertical control survey – is performed in order to accurately determine the orthometric height (elevation) of permanent monuments to be used as bench marks for lower quality leveling.

- spirit leveling is the usual method of carrying elevations across the country from “sea level” tidal gauges. However, GPS can be used indirectly but with less accuracy
- eight measurements from the ellipsoid (as opposed to the “sea level” geoid) can be determined very accurately with GPS and only with GPS
- trigonometric leveling with a total station is not acceptable for vertical control work

Vertical datum – A vertical datum is a set of precise levels that have been referenced to a geoid to establish mean sea level.

Vertical datum plane – is the level surface to which elevations are referred. In the past, mean (average) sea level was the most common datum used for the United States. Today, the more common reference datum is NAVD 88. This datum is required for all NHDOT surveys unless specifically directed otherwise by NHDOT.

WAAS – Wide Area Augmentation System. WASS is a satellite-based system that broadcasts GPS correction information. WAAS capable GPS receivers can track WAAS satellites. WAAS is synonymous with the European Geostationary Navigation Overlay (EGNOS) and Japan’s Multifunctional Transport Satellite Space-based Augmentation System (MSAS).

WGS84 – World Geodetic System. Datum referenced to the WGS 1984 ellipsoid. WGS is the mathematical ellipsoid used by GHPS since January 1987.

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