TRANSPORTATION CABINET
Frankfort, Kentucky 40622
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DESIGN MEMORANDUM NO. 03-13

TO: **Chief District Engineers**
Design Engineers
Active Consultants

FROM: **Jeff Jasper, Director**
Division of Highway Design

DATE: **August 26, 2013**

SUBJECT: **Highway Design Manual Update**
HD-300, Surveying, and
Survey Adjustment Factor

HD-300, Surveying

The Division of Highway Design has developed new guidance for Surveying. Effective with this memorandum, the attached updated chapter HD-300 on Surveying should be utilized for all new projects or for existing projects that have not advanced beyond the Preliminary Line and Grade stage.

Projects that have advanced beyond Preliminary Line and Grade may use the criteria and features from the previous Highway Design Manual. However, it is allowable to use any of the guidance written in the updated chapter HD-300 on Surveying for these projects if necessary or desired by the Project Manager/Project Team.

Survey Adjustment Factor

Beginning January 1, 2014, the latest NAD83 adjustment, NAD83(2011) epoch 2010.00, released by the National Geodetic Survey in July 2012 shall be used as the national reference frame from which state plane coordinates (KYSZ) are derived during the development of projects. The realization of NAD83(2011) supersedes NAD83(NSRS2007) and NAD83(CORS96) providing a unified reference frame for both passive control (such as bench marks) and active control (CORS). The new NGS geoid model, GEOID12A, will be used with NAD83(2011) epoch 2010.00 to convert ellipsoid heights to orthometric heights in respect to the NAVD88 vertical datum.

Horizontal Positioning
Coordinate System – Kentucky Single Zone
Map Projection – Lambert Conformal Conic
Reference Frame – NAD83(2011) epoch 2010.00

Ellipsoid – GRS80

Vertical Positioning
Orthometric Height Datum – NAVD88
Geoid Model – GEOID12A

Any questions regarding this memorandum should be directed to this office.

JDJ:DF:ja

Attachment

EXPLANATION: Surveying is used throughout the design process from initial topographic data collection, which identifies features that need to be accommodated by the project design, to construction staking to assist in properly building the highway project. In addition, other survey activities may be used by the project team to provide additional data, including, but not limited to, boundary surveys, environmental surveys, cemetery relocations and hydrologic surveys.

Survey work shall generally follow the “Standards of Practice” as specified by the Commonwealth of Kentucky, State Board of Licensure for Professional Engineers and Land Surveyors (201 KAR 18:150). For additional references on survey-related items, see the Division of Highway Design Survey Coordination Web page.

Standards

- Deliverables from KYTC Consultants shall be MicroStation (DGN) files with all graphics being submitted to the current KYTC CADD standards and ASCII files.

- Survey data shall meet an accuracy of H<=0.10 ft and V<=0.10 ft unless specified in the project scope and approved by the Project Manager and State Survey Coordinator.

- The default KYTC standard for design mapping is a scale of 1 inch = 50 feet with 2-foot contours. Other scales and intervals may be acceptable based on the request of the project manager and the design team.

- Right of Way Monumentation shall be set with a horizontal closure of 1:15,000 relative to primary control. Right-of-Way Monumentation is further discussed in **HD-306**.

- Primary control shall be as prescribed by the HD-302. KYTC requires that all First- and Second-Order (see **Exhibit 300-02**) Class II horizontal and vertical control be monumented and described.

- All supplemental control (horizontal and vertical) shall be set using Second-Order, Class II or better, Specifications (see **Exhibit 300-02**).

- Allowable GPS methods include static, fast static, and RTK (Real Time Kinematic) for supplemental control. Virtual Reference Stations (VRS) specific equipment, if used, must be rated 2cm for horizontal and 4cm for vertical distance and relative position accuracy (smaller than the deliverable accuracy necessary) See Chapter **HD-302** for GPS survey control specifications.

- LiDAR will be tested to meet the 95th Confidence Interval RMSE; Accuracy H<=0.10 ft ; V<=0.10 ft

Kentucky Single Zone
The State Plane Coordinate system known as Kentucky Single Zone shall be used for the survey and development of all projects. The Kentucky Single Zone is defined as:

- Datum=NAD83/GRS80 Ellipsoid
- Central Meridian=85°45' West Longitude
- Parallel of Grid Origin (Base Parallel)=36°20' North Latitude
- Southern Standard Parallel=37°05' North Latitude
- Northern Standard Parallel=38°40' North Latitude
- False Northing=1,000,000 meters (3,280,833.333 feet*)
- False Easting=1,500,000 meters (4,921,250.000 feet*)

*The Kentucky Single Zone is to be used with the U.S. Survey linear foot of measure.

All design and construction mapping and surveying products will be delivered in Kentucky Single Zone State Plane coordinates (parameters defined in FIPS 1600, and units of U.S. Survey Feet), NAD83* geometric datum (most current adjustment), and NAVD88 vertical datum. The most current adjustment and geoid model available from the National Geodetic Survey shall be used.

KYCORS
The Kentucky Continually Operating Reference System (KYCORS) provides a three-dimensional geodetic network that combines horizontal and vertical monuments. This network allows horizontal and vertical coordinates within 2cm accuracy horizontally and 4cm accuracy vertically. KYCORS provides geodetic control by replacing benchmarks that have been destroyed or are otherwise unsuitable for use with GNSS.

A map of the current KYCORS stations and their status can be viewed at on the KYTC Survey Coordination website. These and surrounding state CORS/GNSS are available and should be used when referencing highway projects when possible. Conventional reference point and benchmarks may be used in lieu of CORS stations when beyond the RTK when coordinated with the Highway Design State Survey Coordinator.

PROCEDURES:

Safety
Surveyors work in hazardous environments such as rugged terrain and high-speed traffic using potentially hazardous surveying tools and construction equipment. Working in these conditions requires a constant awareness of the need for safety.

Survey crew signing must be in place before work on the survey begins and will be coordinated with the District. The crew should watch for special circumstances, which may require additional signing. If the traffic causes an extreme hazard for the survey crew, a flag person or cones should be used to block off the lane the instrument is set up in. Survey conditions should be suspended when uncontrollable hazards develop, and work resumed only when safe working conditions have been restored. Personnel must be particularly aware of the need to avoid creating hazards when working on private property.

Property Entry

As with all field activities, ground survey crews should respect the rights of individual property owners and ask for permission before entering their property. For more information, see **Chapter HD-305**, "Other Survey Activities."

The Cabinet's intent is that all property owners be contacted and informed about any need to access their property. During the survey function, it is the surveyors' responsibility to assure that property owners are advised of when, where, and why their property will be accessed. Property owners are more likely to grant permission for entry if they receive a complete explanation, a promise not to cause undue damage, and an assurance to repair damages caused by the activity.

Procedures: The individual property owners are to be contacted before entry upon their property. Contact should be made face-to-face, via phone, and/or by certified mail. The District Preconstruction Engineer is responsible for determining how and when this contact is made and who will make the contact for field surveys, sounding work, and other activities. The individual assigned this responsibility shall maintain a log of these contacts, which will be provided to the project manager. The log shall include dates and names of persons contacted and a synopsis of the discussion. The name, address, and telephone number should also be included. Consultants contracted by the department for engineering and related work must follow this same procedure.

If the property owner refuses permission for entry, the state has the right to enter upon private property for studies and related activities and may exercise its rights over refusal by the owner. The statute describing this right is KRS 416.560(4) and reads as follows:

> "(4) Prior to the filing of the petition to condemn, 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 that the owner of the land or the party in whose name the property is assessed has been notified ten (10) days prior to entry on the property. Any actual damages sustained by the owner of a property interest in the property entered upon by the condemnor shall be paid by the condemnor and shall be assessed by the court or the court may refer the matter to commissioners to ascertain and assess the damages sustained by the condemned, which award shall be subject to appeal."

When property owners refuse permission for entry upon their property, the District Preconstruction Engineer shall be responsible for initiating action.

This action may include personal contact, contact with local officials for assistance, alternative methods of obtaining data, or other efforts as appropriate. Ultimately the use of KRS 416.560(4) may be necessary to ensure timely completion of planned activities. A certified letter providing 10 days' notice shall be given before entry upon property to initiate this process. The Preconstruction Branch Manager will be responsible for action. The date of entry should be included in the letter along with a commitment to exercise care while obtaining the necessary data.

Damages: Compensation will be afforded for substantiated damages. Payment for these damages generally occurs after the actual damage and after a value has been assigned.

The Preconstruction Branch Manager shall initiate the process of compensation for damages. For amounts up to $1,000, the Preconstruction Branch Manager submits directly to the Division of Accounts appropriate documentation and a request for payment.

For amounts over $1,000, the Preconstruction Branch Manager requests a damage assessment from the District Right of Way Office. The District Right of Way Office shall determine the value of the damage. The damage value and supporting documentation shall be submitted to the director of the Division of Highway Design for approval and endorsement to the Division of Accounts for payment.

In such instances, the Branch Manager for Preconstruction shall submit to the director of the Division of Highway Design:

- A memorandum explaining the necessity for entering the property and a description of damage
- Documentation describing the property and location of the damage (include parcel number when applicable)
- Property owner's name, address, and social security number
- A copy of the release agreement

The district's right-of-way personnel will compute an assessment of losses and obtain necessary agreements and releases. The Location Engineer will be responsible for taking this request and preparing a letter of transmittal from the Director, Division of Highway Design, to the Director, Division of Accounts, requesting payment from Design funds. The social security number is needed to determine a vendor number for the property owner. The check should be directed to the Preconstruction Branch Manager, who will present the check to the designated payee upon obtaining the property owner's signature on the release agreement. This agreement, along with a copy of the check, is to be placed in the project file.

Consultants performing work for the department are encouraged to schedule and conduct their work to avoid damages to private property. Unjustified damages caused by consultant personnel shall remain the responsibility of the consultant. In the event that time constraints given to the consultant will not allow for normal scheduling of work, unavoidable damages are compensated through the Preconstruction Branch Manager in the manner described in the preceding material. The Preconstruction Branch Manager is to be contacted and his or her concurrence obtained prior to initiating actions that will cause damage. Such damage must be minimized to the extent practicable and should generally be outlined in direct communication with the property owner before the damage.

GPS Methods

GPS Methods are acceptable, including Virtual Reference Stations (VRS) and Real-Time Kinematic (RTK). These and older GPS methods are acceptable for topographic and boundary surveys, provided the equipment and processing used meet the accuracy standards for KYTC. Boundary and topographic survey accuracy is located in this chapter. Questions regarding new and emerging technologies developed should be directed to the KYTC Survey Coordinator.

DELIVERABLES:

It is unacceptable to submit assumed (0,0) coordinate system files as deliverables to KYTC for design or construction purposes.

Project specific survey deliverables shall be listed in the project scope.

The final **Survey Report** shall contain:

- Project name & identification: County, Route, Postmile, E.A. or Project Identification, etc.
- Survey date, limits, and purpose
- Datum, epoch, and units
- Control found, held, and set for the survey
- Personnel, equipment, and surveying methods used
- Problems encountered
- Any other pertinent information such as GNSS observation logs
- Dated signature and seal of the Party Chief or other person in responsible charge
- Purpose of the survey
- Number of intervisible monuments set and any supplemental physical feature points
- A map to scale of the project area, showing all primary and supplemental (horizontal and vertical) control monumentation established with appropriate designation
- Type of equipment used in the survey
- Primary and project control held or established
- Validation points
- Description of all NGS control points used in the project
- Closures of all traverses

- Unadjusted and adjusted information of traverses
- Project datum factor that relates to the Kentucky State Plane Coordinates
- Type of receivers used
- Date of observations
- Time interval of each observation
- Number of times occupying each control point
- Adjustment report for control

Submit the report as a PDF document to the Project Manager.

Document all pertinent information of all control on a Department control monument information sheet (available from Department) and submit it with the final control survey report. The survey report will not be accepted unless signed, dated, and stamped by a registered land surveyor for the State of Kentucky, certifying the accuracy of the report submitted and the accuracy of all control monuments set for the Department, unless otherwise described in the project scope .

Contract Documents

Survey deliverables will be electronic (on a CD) including maps which are to be delivered as a PDF and include, at a minimum:

- Property Entry Forms
- Survey Report
- DTM Surfaces-Existing
- Boundary and Right of Way (See **HD-306)**
    - Deed Research Packet
    - Related Plats and Exhibits
    - ROW Field Monumentation
    - ROW Monument Control Plan
    - ROW Acquisition Plat

QA/QC:

Quality of the survey data is integral to the quality of the highway design and the roadway construction. Each section of the Survey chapters includes key items for quality review and checking. The survey party chief is responsible for daily quality assurance. The office technician who then downloads the data has “fresh eyes” to give quality checks.

One critical review item for all survey project types is accuracy. Accuracy is the degree of conformity with a standard or measure of closeness to a value. Accuracy relates to the quality of the result obtained when compared to the standard. KYTC surveys and deliverables shall follow the United States National Map Accuracy Standards as shown on **Exhibit 300-3.**

Another critical review item is completeness. By using the “map” feature on any electronic data collector, a crew can generally identify missed areas from a grid-based topographic survey or detailed outline, before they leave the project site. It is also recommended that crews download data into

InRoads daily, as a quick check. Checking your electronic data and field notes the day it was collected gives many benefits. Remember that field notes include “measure down” and pipe diameter information----essential information that the highway designer will need to know.

EXPLANATION: Horizontal and vertical control should be established for use in design, right-of-way, and construction phases of projects.

Control Types

Projects will have the following types of Control Survey applications, each of which have slightly different requirements, as described in the appropriate chapter:

- Primary
- Supplemental
- Aerial Mapping
- Mobile Mapping

PROCEDURES: **Field Control Reconnaissance**

The traditional geodetic reference system consists of benchmark monuments, typically metal disks set in concrete pillars or on rods driven in the ground. Many of these benchmarks have been destroyed and the National Geodetic Survey (NGS) is not replacing or further maintaining physical markers. Physical, passive markers may continue to be recoverable and useable but that is not guaranteed.

The surveyor should make every effort to obtain information for any existing control of the project area. If any primary control exists from National Geodetic Survey (NGS) or from others that may have set control for the Department of Highways, it is highly recommended that this control be used for further densification of the project. Recovered control monumentation must be evaluated before being used as a basis for new control surveys.

Ground Control Point preference should be given to points associated to permanent structures, recoverable so as to be used in future survey work. Examples are manholes, curbs, utilities structures, etc.

Primary Control

The Department requires that projects have pairs of permanent monumentation spaced along the project not more than 2,000 feet apart. If possible, the surveyor should locate the monuments to avoid destroying or disturbing them during construction. Primary Control monuments shall be installed in intervisible pairs consisting of a primary monument and an azimuth monument, each with an accurate coordinate position and elevation. See Chapter **HD-306** for Monumentation details.

GNSS shall be the standard method of developing control. Control extended from GNSS shall use differential positioning techniques, with a minimum of three receivers observing no fewer than four satellites for a minimum of 60 minutes in 15-second epochs or less. If control is not possible to be established by GNSS or is proposed to be established using conventional methods for unique circumstances, the Statewide Survey Coordinator should be contacted for requirements.

Horizontal Control

KYTC provides free Real Time Networking service for horizontal and vertical positioning through registered user IDs. Registration and access is available at http://kycors.ky.gov GPS receivers must be survey grade and must be able to connect to the Internet over a cell phone or modem card that has dial up networking (DUN) capability to utilize this service.

Vertical Control

Elevations obtained from GPS methods are to originate from the GNSS networks when possible (post processing is not the preferred method and must be documented). The surveyor should distribute the monuments equally, covering the entire project area.

Supplemental Control

Supplemental control can be defined as additional points set when further densification of primary control is needed. Supplemental vertical control should be conveniently located and accessible and of a stable, permanent nature. See Chapter **HD-306** for Monumentation details.

Aerial Mapping Control (Photogrammetric)

All control set for KYTC Aerial Mapping shall be classified as primary control.

Panel Points

Control points utilized in photogrammetry are commonly referred to as "panel points" and shown as an "x," "v," or "open center cross" with approximately 5ft legs. The legs of the cross are made of cloth, plastic or paint. The panels are usually white in order to contrast with the ground; however, on concrete pavements and extremely colored barren soils, it is best to use dark gray or black materials. Control points should be paneled in advance of flying to ensure visibility of the acquired photography.

Spacing

For Statewide projects, the density of ground control points (GCP) will be no less than twenty (20) GCP per type of NSSDA major land cover class. GCP preference should be given to panel points associated to permanent structures, recoverable so as to be used in future survey work. Examples are manholes, curbs, utilities structures, etc. The complete set of KGRN (formerly known as HARN) points in Kentucky will be used, as dictated by availability.

Local and Regional projects shall have control as set by the following **Figure 302-1** and **Table 302-2**. The distances are near maximum and can be shortened by 10 to 15 percent without significant effect on the triangulation accuracies. Wherever obstructions such as lakes, sloughs, etc, make it impossible to set the control points according to the diagrams, the points are to be moved back (nearer the last previous point) as far as necessary to avoid the obstruction.

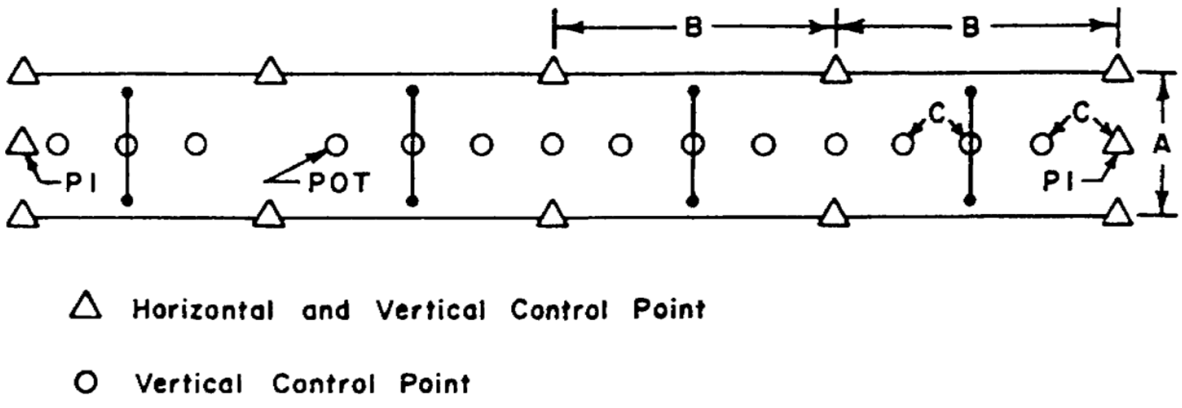

Figure 302-1

Photo Scale	Map Scale	Distance A	Distance B	Distance C	Centerline to A
1" = 1000'	1" = 200'	5600'	14000'	3600'	2800'
1" = 500'	1" = 100'	2800'	7200'	1800'	1400'
1" = 400'	1" = 80'	2400'	5700'	1440'	1200'
1" = 250'	1" = 50'	1400'	3600'	990'	700'

Table 302-2

<u>Aerial Mapping Control (LiDAR)</u>
All control set for KYTC Aerial Mapping shall be classified as primary control.

Aerial LiDAR differs from Photogrammetry in that features are not visible in LiDAR datasets as in Photography (for example, a manhole would not be a discernible feature in an aerial LiDAR dataset). For that reason, control placed for Aerial LiDAR projects do not need to be paneled, and can be placed after the LiDAR acquisition is complete, assuming ground conditions have not changed between LiDAR acquisition and control survey.

<u>Mobile Terrestrial Laser Scanning (MTLS) Control.</u>
MTLS or Mobile Mapping control stations that will be used to control the post-processed kinematic adjustment of the MTLS data shall be placed at a maximum of 10-mie intervals to ensure that under normal circumstances, no case should the processed baseline exceed five (5) miles in length. Short baselines contribute to the best possible positional accuracy outcome. Dual redundant GNSS base stations are highly recommended to guard against the possibility of wasted effort and useless data from base station failure due to equipment, accident or human error in station setup. Dual base stations also allow redundant post-processing and 10-mile baseline post-processing in case of a base station failure.

Locate one base station near the beginning of the project and another one near the end of the project. The horizontal accuracy standard of control stations shall be second order or better and the vertical accuracy standard shall be third order or better as defined in HD-301.

Mobile Mapping control falls under the categories of “Transformation” or “Validation” control points. Transformation points serve as control for processing of the point clouds. Validation points are used to check the geospatial data adjustment to the transportation points and allow for QA/QC checks of the adjusted scan data, Both types of points should be places throughout at even intervals. Transformation points should be placed before and after expected obstructions, such as bridges. See **Figure 302-3** for placement of control.

For MTLS surveys, the scanned area shall have control on both sides of the roadway with transformation points at a maximum of 1500-foot roadway centerline stationing intervals and validation points at a maximum of 500ft roadway center stationing intervals. MTLS surveys require local points to have surveyed local positional accuracies of Hz ≤ 0.10 foot & Vt ≤ 0.10 foot or better. The preferred method of establishing transformation and validation point elevations is differential digital leveling.

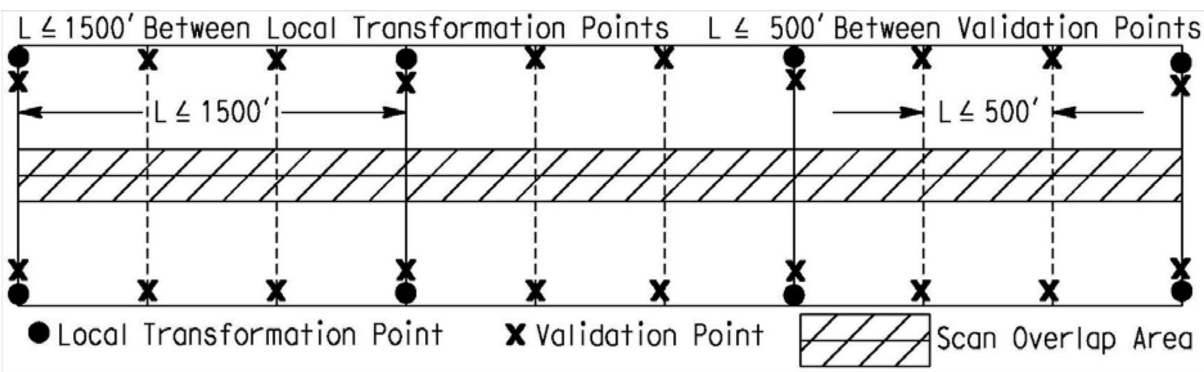

Figure 302-3 Typical MTLS Transformation and Validation Point Layout

<u>Stationary Terrestrial Laser Scan (STLS) Control</u>

Total station targets reduce pointing error when placed at long distances. Laser scanning targets, however, are designed for a specific distance. Most laser scanners do not have telescopes to orient the instrument to a backsight. Vendor-specific targets, which are tuned for the laser scanner frequency, are recommended.

A minimum of two targeted control points are required for each setup in a level orientation using a dual-axis compensator, occupying, backsighting, and foresighting control points with known X,Y, and Z coordinate values. When using a scanner that does not meet these criteria, or if the compensator is off, a minimum of three targeted control points are required for each set-up. When known control is not occupied, backsighted, and foresighted, a minimum of four (4) targeted control points are required for each set-up.

Independent control validation points (confidence measurements) to confirm registration are a minimum of three per scan.

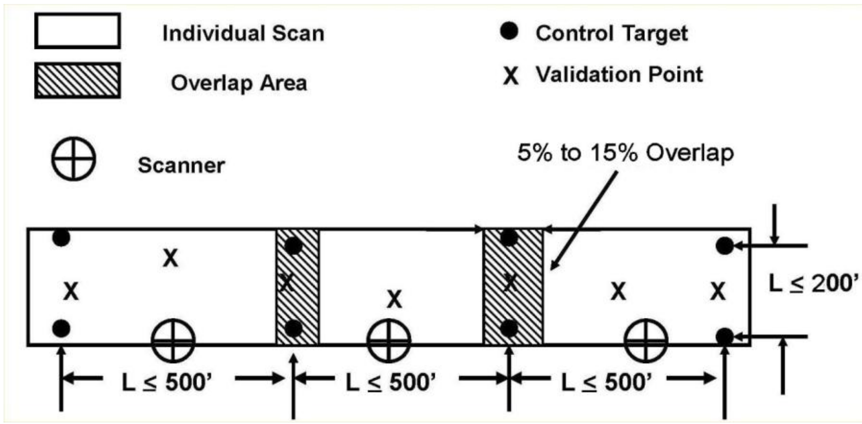

Figure 302-4 Target Placement and Scan Coverage for general applications

DELIVERABLES:

Files shall have non-proprietary format point data showing applied corrections. All point, elevation, and metadata data used to calibrate, process, and validate control points shall be submitted on portable media. A Surveyor's Report is required (see **HD-301**).

QA/QC:

Quality of the control data is essential to the quality of the entire survey and, by extension, the entire project. Have you checked:

- Correct coordinate system
- Correct elevation datum
- Project Datum Factor
- Unedited raw files included
- Rotation
- Translation
- Correction Factors
- Shown ties to existing Benchmarks
- Labeled types of monuments

OVERVIEW: Determine the degree of precision of all surveys by the final intended use of the data. Generally, a preliminary survey should be to the same order as that required for the final survey. In some situations, a preliminary survey for mapping or reconnaissance studies may be to a lesser order with approval of the director of the Division of Highway Design.

SURVEY FIELD CREW RESPONSIBILITIES:

For all KYTC projects, survey field crews are responsible for processing their data and delivering a design (.dgn) file, digital terrain model (.dtm) file, and geometry (.alg) file. Field crews are responsible for final checking and the assurance of the accuracy of all survey products delivered to the design office.

ELECTRONIC DATA COLLECTORS: The electronic data collectors (electronic field books) selected for use in the Cabinet shall not allow the data to be deleted until it has been sent to a printer or a computer. If an error is made in the field, the data collector retains both the error and the correction.

As standard procedure to ensure that a permanent record of the original fieldwork is available, any agent of the Cabinet using electronic data collectors should comply with the following practices:

1. Download the original data into a computer and copy (unedited) to a permanent medium.

2. Produce a hard-copy printout of the data before any editing takes place.

3. Do any editing or subsequent changes to the data on copies of the original data. Never alter the original data.

4. In any subsequent submittals of project information, treat the permanent medium and the hardcopy printout, cited before, as a traditional field book.

Electronic data files submitted should be in the approved KYTC format. If it is submitted in a text file, the following format shall be used: point number, Northing, Easting, elevation, feature code.

FEATURE CODING: All survey and DTM information for KYTC projects shall utilize the KYTC feature codes list. The current feature codes list can be found on the KYTC Highway Design Web site under “Survey Coordination.”

DIGITAL TERRAIN MODELING: A Digital Terrain Model (DTM) is a three-dimensional representation of the surface of the earth. The accuracy of the DTM should reflect its intended use.

Cross-sections and profiles needed for plan development and documentation shall be derived from the DTMs.

DTMs are created from breaklines and random points. Breaklines are linear features that locate "breaks" (changes) in the earth's surface such as changes in slope. Examples of breaklines are the crown of pavement, edge of pavement, edge of shoulder, flow line, top of curb, bottom of slope, top of slope, bottom of ditch, and top of ridge.

Random points are used to define the surface between breaklines. These points are spot elevations at various or key locations. Random points are generally collected in a gridded manner with a nominal spacing of 25 to 50 feet. This spacing can vary widely depending on the regularity of the surface being surveyed.

The surveyor shall be responsible for adequate breaklines and random points to ensure that the DTM accurately reflects the surface. Additional care shall be taken in the collection of breaklines in areas around bridges, other structures, streams, and other sensitive locations. At bridge abutments, wing walls, ends of pipes and culverts, curbs, retaining walls, and any other vertical-type situation, breaklines at both the top and bottom of the feature are necessary for the definition of the surface.

Take breakline data in a directional sequence and do not jump back and forth on the same breakline.

The rodman should be knowledgeable of the data collection process and how the collected data influences the quality of the DTM. Thus the rodman is key to the collection process.

The surveyor is responsible for the processing, final checking, and validating of the DTM.

TOPOGRAPHIC FEATURES:

Topography is defined as the graphic delineation of all natural and manmade features of an area. Collect all topographic feature data within the project area. Where appropriate, elevations should be collected. For overhead utilities, identify the ownership, pole number(s), and low wire elevation(s). Collect the major topographic features of the area such as buildings, septic systems, existing roads, drainage structures, and utilities. The types of construction and descriptions for all buildings and existing roadway surfaces shall be noted. In addition, collect any item that may influence project decisions.

EXISTING STRUCTURES:

Accurate depiction of existing structures is particularly important to the design process. Field information should completely define the structure and surrounding terrain. Additional information should be collected to describe the components of the structure (beam depths, pier heights, bridge seats, headwalls, abutments, wingwalls, etc.). A written description of the structure should also be documented.

PROPERTY LINE FEATURES:

All property lines, easement lines, lease lines, and special agreement lines, etc., within the limits of the project and in some instances in the general proximity must be identified (including KYTC's permits and agreements). All monuments and features that can aid in the description of property lines should be located.

Other information to be collected to help establish property lines may include deed descriptions, PVA maps, plats, and subdivision plans.

The names of all property owners are to be collected as recorded in the deed book, along with the deed book and page numbers and acreage or square footage.

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EXPLANATION OF TYPES:

The relocation of underground utilities is a primary concern during project development. Complete and concise locations of existing utilities shall be obtained early in the design process. Utility company archives may not be sufficient to identify all utilities within the project corridor.

The quality level that is utilized in the location of existing utilities should be based on the stage of development for a roadway project. During the corridor study to determine potential alternatives, the use of existing records or verbal information from utility companies typically will suffice. The quality level utilized in locating existing utilities should improve as alternatives are developed and their subsequent location refined. Location of utilities should include the horizontal position (and vertical position when appropriate) of the utility, the material of which it is composed, the size, and any other pertinent data concerning the facility. The following is a description of the differing quality levels of utility location:

- **Quality Level D (QL D)**: Information derived solely from existing records or verbal recollections

- **Quality Level C (QL C)**: Information obtained by surveying and plotting visible aboveground utility features and by using professional judgment in correlating this information to Quality Level D information

- **Quality Level B (QL B)**: Information obtained through the application of appropriate surface geophysical methods to identify the existence and approximate horizontal position of subsurface utilities

  Quality Level B data should be reproducible by surface geophysics at any point of the utility's depiction. This information is surveyed to applicable tolerances and reduced onto plan documents.

- **Quality Level A (QL A)**: Information obtained by the actual exposure (or verification of previously exposed and surveyed utilities) of subsurface utilities, using (typically) minimally intrusive excavation equipment to determine their precise horizontal and vertical positions, as well as their other utility attributes

  This information is surveyed and reduced onto plan documents. Accuracy should be to applicable horizontal survey and mapping accuracy and should be within $\pm$ 0.05 foot vertical.

PROCEDURES:

Locating existing utilities to a certain level should occur even during the Pre-Design and/or Conceptual Design phase of a project, whenever there are either large concentrations of utilities or the existence of a major utility facility. At any stage of design, the utility companies should be an integral part of the design process and should be invited to key meetings to be advised of and consulted about impacts of the roadway to their facilities. Invitations to utility companies should be extended for public involvement meetings as well, to afford the companies the opportunity to give input. The choice of alternatives for the proposed roadway should reflect this information in an effort to first avoid the utility conflict, secondarily minimize the effect, and thirdly mitigate the conflict.

The project team shall determine the quality level (QL) of utility locations for the various stages of project development conceptual design. QL A will be done as needed, based on potential conflicts.

To more adequately and expeditiously effect the location of utilities, the project team should specify in the advertisement for consultant services that the consultant will be required to locate utilities to the differing levels dictated by the project development stages. It may appear to be fiscally advantageous to place the brunt of relocation costs on private companies, while avoiding publicly owned utilities simply to avoid the direct cost of utility relocation by the Cabinet. The ultimate cost in time and money to the public should compel the designer to consider all the impacts of utility relocation whenever decisions are made as to the location of a roadway.

All of the above quality level work shall be completed in accordance with Section 5: Utility Quality Level Attributes as documented in CI/ASCE 38-02, the *Standard Guideline for the Collection and Depiction of Existing Subsurface Utility Data* by the American Society of Civil Engineers.

DELIVERABLES:

The utilities must be identified and located on plan documents. All underground utilities depicted shall be QL B unless the particular utility is labeled “QL C” or “QL D” (See **Exhibit 303-01** and **Features Checklist Form TC61-1** in the online e-Forms Libary**.**) QL A is applicable only where direct observations of the exposed utility are made.

A summary sheet will be included to document in the plans the QL A horizontal and vertical locations noted. The QL A data shall be documented by station, offset, northing, easting, and elevation. (See sample in **Exhibit 303-02,** form **TC61-3.**) The Quality level (and specific locations for QL A) should be chosen for each project and listed during scoping on the Features Checklist.

QAQC:

The following are areas where emphasis and care should be given to establish complete and accurate location of underground utilities:

- The urban highway construction project with high potential for anticipated utility conflicts
- Projects with complex utility networks, either aged or of significantly high potential for expensive utility relocations
- Limited, narrow, and congested existing rights of way
- High-profile highway projects that have critical schedule

PROPERTY BOUNDARY SURVEYS: Occasionally, it becomes necessary to perform a property boundary survey. Boundary surveys are to be conducted in accordance with requirements defined by the Commonwealth of Kentucky, State Board of Licensure for Professional Engineers and Land Surveyors—normally, the closed traverse method with an error of closure within the limits for the particular type of survey. When practical, the boundary survey is to be tied to the roadway centerline on active design projects and to either the centerline or right-of-way line on existing highway.

All boundary surveys and gravesite location work are to be performed under the supervision of a registered land surveyor. Consultant contracts are available to accomplish this work, if needed.

All survey work for these types of surveys shall meet or exceed the "minimum standards of practice" as specified by the Commonwealth of Kentucky, State Board of Licensure for Professional Engineers and Land Surveyors (201 KAR 18:150).

GENERAL ORDER SURVEYS: Once the Primary and Supplemental Control has been established, a General Order Survey can be done. These types of surveys can be done to Third-Order Specifications (see **Exhibit 300-02**). The types of applications for these types of surveys may be additional topographic points, staking points from a radial method, GIS surveys, and environmental surveys.

CEMETERY: Cemetery relocation requires a boundary survey, and any gravesites within the right of way must be located in relation to the roadway centerline or boundary-survey base line.

All gravesite locations and boundary surveys of cemeteries are to be performed under the supervision of a registered land surveyor. All survey work for these types of surveys shall meet or exceed the "minimum standards of practice" as specified by the Kentucky Board of Engineers and Surveyors (201 KAR 18:150).

DRAINAGE: Major drainage situations that will have an impact on roadway location require sufficient fieldwork for a hydraulic analysis. Methods and procedures to follow for different types of situations can be found in the *Drainage Design Guidance Manual*.

Situation surveys are required for all bridges, box culverts, and structures 54 inches or greater in diameter (or equivalent). Additional fieldwork may be necessary for other drainage features. Complete details for the requirements for situation surveys are contained in the *Drainage Design Guidance Manual.*

The necessary drainage sections and profiles (and flood plain cross sections when practical) should be extracted from the DTM. Densification and/or additional data will most likely be needed.

In order for hydraulic analysis to be completed, key information is to be obtained. This information shall include all pertinent information on existing stream, i.e., top of bank, bottom of bank, flow line, edge of water. This includes sufficient terrain data to accurately describe bridge and culvert ends. DTM data shall be taken at regular intervals (depending on the size and the uniformity of the stream) and at any point the water velocity changes. The type of material in the streambed shall be described, and it shall be noted if banks are subject to scour.

When collecting field data for the situation survey, a reach of two flood plain widths up and down stream is to be included. Surveyors should obtain information about the flood plain from available mapping, such as FEMA.

High and normal water information shall be collected and recorded with a description of how these levels were determined (include event date, if possible). If the high-water level is a result of backwater, then the source should be identified.

RAILROADS:

Typically the location and topography of a railroad can be obtained from project mapping. When the location of the rail is critical, densification and/or additional survey data may be needed. In order to index the railroad mapping to the project mapping, the distance to the nearest railroad milepost on each side of the highway centerline will be measured and the information on the mileposts recorded.

When the location of the rail is critical, the surveyor shall be responsible for adequate breaklines and random points to ensure that the DTM accurately reflects the railroad in the project area. When collecting the additional data, all topography for 500 feet on each side of the highway centerline is to be located.

If a highway underpass is considered, topography is typically needed a minimum of 1,500 feet on each side of the centerline for use in railroad detour plans. The topographic features include:

- Railroad switches
- Signal equipment
- Flashers
- Gates
- Pole lines (with number of wires)
- Switch-points
- Right-of-way limits
- Drainage features
- Size and type of all structures

Additionally, each rail of the tracks shall be located with the elevations taken at 50-foot intervals. In the event that drainage is to be diverted toward railroad right of way, additional data may be needed through the affected area.

All survey stakes within 15 feet of the centerline of the tracks shall be driven flush to the existing grade to avoid interference with railroad train traffic; guard stakes are not to be used within this area.

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EXPLAINATION OF TYPES:

The right-of-way boundaries for newly acquired right of way shall be established and monumented for all projects. The existing right of way boundaries will not be permanently monumented. The intent is to define new right-of-way boundaries on our plans and in the field.

Standard Monumentation Types

Monumentation shall be placed in accordance with the Standard Drawings RGX-005-05) and the Special Note for Right-of-Way Monuments.

Monumentation includes:

- Type 1&1A – concrete post with KYTC R/W disk
- Type 2 – (witness)-concrete post with KYTC W-R/W disk
- Witness posts - 48inch carsonite post or six foot high orange fiberglass post with KYTC decal
- Temporary-36 inch wood stakes
- Supplemental-24inch rebar with plastic or aluminum KYTC cap

Temporary KYTC Routes

- Type 3&3A – concrete post, **no** KYTC label, R/W disk
- Type 4 – (witness)-concrete post, **no** KYTC label W-R/W disk

In instances where KYTC will be purchasing right of way for an LPA, the Project Development Team/Project Manager may decide that monumenting right of way is not necessary. In these situations, and/or where the Project Development Team has identified extenuating circumstances, the Project Manager can request an exception from the Cabinet's Right of Way Monumentation policy. Such requests must be submitted to the Statewide Survey Coordinator.

PROCEDURES:

Right-of-way monuments and witness monuments shall be flagged on the plans sheets with station and offset, and they will be documented on the coordinate control sheets with northing, easting, station, and offset. Coordinate control sheets shall be included in the right-of-way and construction plans.

All right-of-way monumentation shall be defined by the survey standards set in HD-301 and the project datum factor. A project datum factor that relates the State Plane Coordinates and project datum coordinates for the right of way shall be published on the coordinate control sheets in the design plans. All right-of-way monumentation (including witness monuments) shall be established from the monumented survey control with an accuracy shown in HD-301.

All right-of-way monumentation shall be set under the direct supervision of a Kentucky Licensed Professional Land Surveyor.

To aid others in the field location of the right-of-way or witness monuments, a six-foot orange witness post may be used. The land surveyor in charge of monumentation is encouraged to place a witness post for the right-of-way monuments where practical and feasible. If possible, a minimum of three witness posts per project should be placed. A witness post is to be set within one foot of the monument location and shall be set on the property of the Transportation Cabinet. A witness post shall have a label recognizing that the point is Kentucky Right of Way.

There are times when there may be several monuments in close proximity (e.g., when the right-of-way lines are making several short 90-degree turns) to one another, possibly in someone's "front yard" that becomes unsightly to property owners. In this situation, it is recommended setting only 36-inch wooden stakes within one foot of the monument. This gives the property owner notice of where the property line is.

The project development team is still encouraged to stake the right-of-way during the right-of-way process if deemed necessary to communicate with property owners. It may also be necessary to stake the right of way for construction.

DELIVERABLES:

<u>Coordinate Control Sheets</u>

The coordinate control sheet(s) document the control information that facilitates the field survey process. Right-of-way monuments and witness monuments are documented on the coordinate control sheets with northing, easting, station, and offset. Coordinate control sheets shall be included in the right-of-way plans so that monumentation can be established during the project's right-of-way phase.

EXPLANATION: Aerial mapping methods are used most commonly for statewide data collection as a result of statewide interagency coordinated efforts. Base Resolution Aerial LIDAR, Orthophotography, and Photogrammetry data is widely available for planning level accuracy. Project Managers should check for available data before requesting new data. Higher Resolution Orthophotos, Aerial LiDAR, and Photogrammetry for design grade data may be available from KYTC or other state agencies or may obtained through the inter-agency statewide aerial photography and LiDAR contract.

Typically, aerial surveys are most cost effective for design project over 2 miles in length. For shorter projects ground surveys (conventional or GNSS) are generally more cost effective and suggested. Ground surveys are generally necessary to supplement aerial surveys for underground or obscured items such as sizes of pipes and inverts for inlets. See Chapter HD-302 for methods on establishing ground control for aerial surveys.

When requesting aerial mapping, the limits of work should be clearly specified for each project, including a buffer on all sides (typically 1000 foot). It best to request project limits with wide buffers to allow for unforeseen design decisions nearby. The need to send out survey crews to pick up items later is expensive and can generally be avoided with a reasonable buffer for data collection with the beginning and end limits and corridor width.

Definitions of Terms:

- Aerial Photography-does not have a uniform scale. It is not possible to measure distances. It is not a map because it contains image displacements caused by the tilting of the camera and terrain relief (topography).
- Aerial LiDAR is an optical remote sensing technology that measures properties of scattered light to find range and/or other information of a distant target.
- Digital Elevation Model (DEM) is a digital model or 3-D representation of the bare earth surface created from terrain elevation data. KYTC uses DEM’s for planning purposes only.
- Digital Terrain Model (DTM) is a three-dimensional representation of the surface of the earth, with survey grade accuracy.
- Orthophoto-is a uniform-scale photograph. It is a photographic map from which measurements are possible. It can serve as a base map.
- Orthorectified imagery is created using National Grid control points and a DTM. This means that the distortions inherent in a flat photograph of a three-dimensional object (the earth's surface) are more completely and accurately corrected. An orthorectified image is positionally more accurate, and geometric fidelity (shape) is retained in all terrain, including hilly areas.
- Photogrammetry has been defined by the American Society for Photogrammetry and Remote Sensing (ASPRS) as the art, science, and technology of obtaining reliable information about physical objects

and the environment through processes of recording, measuring and interpreting photographic images

PROCEDURES: Requests for aerial surveys are submitted to the KYTC Survey Coordinator but supplemental photography, mapping, etc. can be downloaded from statewide/regional files at http://kygeonet.ky.gov or designers can download project level photos, surveys, etc. from ProjectWise.

Photogrammetry. Photogrammetry is a time and cost effective way to gather survey data on large projects. Photogrammetry begins with aerial photography that is either captured on film or captured by high resolution digital cameras. The film is then scanned on a special high resolution photogrammetric scanner into a digital file. Certified Photogrammetrists (PG) then identify the ground control targets in the files and use a special aerotriangulation (AT) package, which uses a least squares adjustment. The software and experienced operator then fix problems and complete the AT process.

For images captured with digital cameras, use Exterior Orientations (EOs) for each mission from the GPS data collected from: CORS stations, GPS unit in the plane, and POS data from the IMU in place of AT. AT may still be used to fix problems or for high accuracy projects. The post-processed digital file is then used to create a base map in as much detail as the scope of work requests. AT is also tool to resolve problems with digital photography; however, it is not a required step/process with good digital data.

All aerial photography and photogrammetry services are to comply with the conditions and specifications described in the *Reference Guide Outline, Specifications for Aerial Surveys and Mapping by Photogrammetric Methods for Highways.* They are also to comply with the U.S. Department of Transportation, Federal Highway Administration, and the terms and conditions of the contract agreement between the Department of Highways and the company furnishing the aerial and photogrammetric services.

Digital Orthophotos. The intended use of Orthophotography includes design level mapping, especially when using combined with (GIS) Geographic Information System data. Orthophotos begin with the DTMs and other planimetric files created by photogrammetry and then are tied together geographically with the aerial photograph to make photomosaics. The geographically rectified mosaics are then color balanced. Seams and artifacts are removed.

Some special considerations in collecting digital orthophotos are listed below.

- Leaf Off Data Collection
- Minimal shadow and cloud conditions

- Interfering weather should be considered

Aerial Light Detection and Ranging (LIDAR). Aerial Light Detection and Ranging (LIDAR) data may be used for KYTC projects and is best used for fast and detailed collection of 3-D point clouds of the earth for the production of true orthophotos and DTMs. Because LiDAR can be flown at the same time as other methods, Higher Resolution LiDAR may be available by data-mining the statewide LiDAR consultant contract. Base Resolution LiDAR is helpful in Planning level documents.

Traditional orthophoto generation does not use a digital surface model (DSM), and often suffers from obscured areas and unsharp edges. By improving the surface modeling more accurate true orthophotos can be produced. LiDAR is best used for increased accuracy on a project, such as near a flood wall or railroad, or a very complex interstate interchange.

The use of Aerial LIDAR and or Photogrammetry will still require limited field survey methods, especially for items not visible from the sky (i.e. manhole depth, underside of bridge, headwall pipe diameter, etc.) The project manager may consider the use of Subsurface Utility Engineering SUE, (See Chapter 304), for many of the features not visible from the air.

LIDAR data collection, processing and delivery shall be consistent with the most recent version of the LAS file specification as defined by the American Society for Photogrammetry & Remote Sensing (ASPRS) and be in agreement with the specifications set forth by the Kentucky Division of Geographic Information (DGI). For a full list of applicable specifications refer to the KYTC State Survey Coordinator website.

DELIVERABLES: Aerial mapping deliverables shall be produced in MicroStation and delivered as DGN files with all graphics being submitted to the current KYTC graphic standards. All mapping products will be delivered in Kentucky Single Zone State Plane coordinates. For the current listing of required geometric and vertical datums, adjustments, and geoids, refer to the KYTC State Survey Coordinator's website.

The horizontal accuracy of the orthorectified imagery shall be higher than 2-foot RMSEXY (1.41 foot RMSE - X or Y) in the case of 12-inch spatial resolution, and 1-foot RMSE (0.7 foot RMSE - X or Y) in the case of 6-inch spatial resolution.

Control Points. The plotted position of each control point shall lie to an accuracy of one-hundredth (1/100) of an inch of its true position, as expressed by the State Plane coordinate for that point. Control point coordinates will be submitted as a dataset. See Chapter 302.

The default KYTC standard for design mapping is a scale of 1 inch = 50 feet with 2-foot contours. Other scales and intervals may be acceptable based on the request of the project manager and the design team.

A survey report, as described in the "Survey Report" **Section HD-301,** shall be prepared by the responsible party and submitted to the project manager. The project manager shall submit the survey report to the KYTC Survey Coordinator for Review.

Specific deliverables shall be specified by the project team, as necessary for to meet the individual scope of the project. General requirements for each deliverable are presented below.

Digital Orthophotos. In addition to the processed image, deliverables for orthophotos should include the following, which may be included in the survey report. :

1. Source Imagery:
   a. Calibration Reports
   b. Camera Station Control:
      i. Airborne GPS:
      ii. IMU Data:
   c. Supplemental Ground Control: (See Chapter 302)
   d. Flight Diagram:
   e. Photography and Supplemental Report(s)
   f. Digital Frames

Aerial LIDAR. LIDAR Survey reports shall contain the following information.

- Survey Report detailing the collection of control and reference points used for calibration and QA/QC.

- Processing Report detailing calibration, classification, and product generation procedures including methodology used for breakline collection and hydro-flattening *(see Section V or more information on hydro-f lattening)*.

- QA/QC Reports (detailing the analysis, accuracy assessment and validation of:

   - The point data (absolute, within swath, and between swath)
   - The bare-earth surface (absolute)
   - Other optional deliverables as appropriate

- Control and Calibration points: All control and reference points used to calibrate, control, process, and validate the LiDAR point data or any derivative products are to be delivered.

LIDAR data may be requested with various levels of post processing, depending upon the specific project needs, and computing and processings capabilities of the project. Each of these deliverables are presented briefly below.

Raw Point Cloud data are mass irregularly-spaced points with each containing 3D coordinates (x, y and z). Raw point clouds can be used to determine surface elevations within a project.

Classified point clouds are processed based on the intensity return of the laser pulse to classify the point as bare earth, vegetation, hard surface etc. Classified point clouds are necessary to determine elevations in developing a digital elevation or digital terrain model as it allows the differentiation of earth from vegetative readings. A full listing of point cloud classifications is provided in the table below.

Table 1: Point Cloud Code Description

Code	Description
0	Never classified
1	Unassigned
2	Ground
3	Low vegetation
4	Medium vegetation
5	High vegetation
6	Building
7	Noise
8	Model key
9	Water

All point cloud data shall be submitted in compliance with LAS file format requirements as defined by ASPRS. Refer to the KYTC State Survey Coordinator for identification of the current LAS file version in use.

A Bare Earth Surface Raster (DEM) is a grid of bare-earth z-values at regularly spaced intervals in x and y directions. DEMs may be used for a large variety of automated analyses, mathematical models, and 3D simulations and visualization.

Breaklines are linear features that describe a change in the smoothness or continuity of a surface. Breaklines are typically used to define edges of hard surface, such as roadways and may be placed from either orthophoto processing or field survey measurements.

The project team may also request hydroflattening of LIDAR data to define the surface of lakes, streams and rivers which may be undefined in DEMs and DTMs due to triangulation patterns when hydroflattening is not used. In the absence of hydroflattening, field survey data collection may be required to better define contours near water features.

EXPLANATION OF USES:

Terrestrial Mapping includes the use of Mobile and Stationary Light Detection and Ranging (LiDAR) systems. LiDAR uses lasers to make measurements from a tripod or other stationary mount, a mobile surface vehicle, or an aircraft. The term LiDAR is sometimes used interchangeably with laser scanning, but is more often associated with the airborne method, performed from an airplane, helicopter, or other aircraft. This terrestrial laser scanning (TLS) as discussed in this chapter does not pertain to airborne LiDAR or Airborne Laser Scanning (ALS). A glossary of scanning terms is included in this Chapter.

Terrestrial LiDAR (a specialty survey) has the potential to acquire millions of survey points in a short time, especially in dangerous areas that are not conducive to traditional methods of data collection. Every detail of an overpass that is visible can be picked up from one short field trip with Tripod Scanning or Mobile Mapping, without inverted survey rods (and the negative sign errors), requisite field sketches, or climbing on and around pilings or bents. While the scanning collects the data very quickly, the post-processing can be very difficult and time consuming. ***Safety, higher levels of accuracy, and efficiency of data collection are compelling reasons to use terrestrial laser scanning for some projects***.

Mobile Mapping is also known as Mobile Terrestrial Laser Scanning (MTLS). Mobile Mapping is an emerging technology that uses laser scanner technology in combination with Global Navigation Satellite Systems (GNSS) and other sensors to produce accurate and precise geospatial data from a moving vehicle. MTLS platforms may include Sport Utility Vehicles, Pick-up Trucks, Hi-Rail vehicles, boats, and other types of vehicles (See **Figure 307-1**). Data collection on 20 miles of highway per day is achievable.

Stationary Terrestrial Laser Scanning (STLS) is commonly referred to as Tripod Scanning (See **Figure 307-2**). Tripod Scanning has many of the same advantages of Mobile Mapping, but is generally applied to smaller projects or spot improvements. Currently, there are many more providers of Tripod Scanning than Mobile Mapping. This is because Tripod Scanning has a more broad range of applications outside of KYTC work than corridor Mobile Mapping.

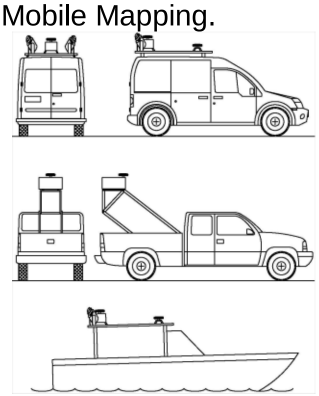

Figure 307-1 Typical Mobile Scanning Platforms

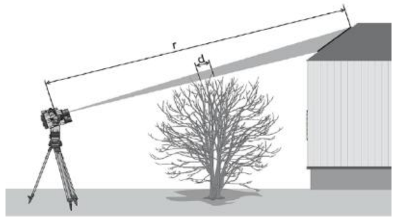

Figure 307-2 Typical Tripod Scanning

Uses of Mobile Mapping

The following are a few factors to consider when determining if MTLS is appropriate for a particular project:

- Safety of in-lane survey crews for project area. Mobile Mapping reduces the exposure of surveyors to traffic. (Traditional Survey methods are still required for the placement of transformation and validation points)
- Project time constraints. Mobile Mapping may be faster than traditional crews, if equipment is available.
- Length/size of project. Less than 2 miles without an overpass may not be as cost effective for Mobile Mapping. Long corridors, repairs of overpasses or critical cross slope areas are excellent candidates for MTLS. Shorter corridors with a high level of complexity are also excellent candidates for MTLS.
- High Traffic volumes in project area. Crew has availability to survey during congestion or at night with Mobile Mapping. (Photos are not included in nighttime data collection so some value is lost in this scenario), but the point cloud accuracy is unaltered in night time conditions.
- Projects requiring a high prevision are excellent candidates for MTLS surveys; however, traditional survey crews may be adequate.
- Complexity of project. Corridors or nearly any length with a high level of complexity i.e. full ROW survey) are excellent candidates for MTLS, due in part to the ability to ‘mine’ additional data from an MTLS point cloud, reducing the need for return trips for additional data gathering. This is highly beneficial in more remote project sites.

Uses of Tripod Scanning

STLS is utilized under the same situations as MTLS, but normally is most efficient for smaller projects. The following are a few examples where STLS may be preferred over MTLS for a particular project:

- Safety of in-lane or railroad right-of-way survey crews for critical spot improvement
-
- Bridge Re-hab projects

- Project time constraints. STLS is faster than traditional crews, if equipment is available (It is more readily available than MTLS).
- Pavement Analysis Scans
- Structures and Bridge Clearance Surveys
- Architectural and Historic Preservation Surveys
- Intersections or other small-site surveys

Technology

Mobile Mapping data collection takes place from a vehicle with multiple LiDAR sensors, cameras, GPS beacons, and other measuring devices (such as Inertial Measuring Units, IMU) all mounted in an elevated position on the vehicle. Data collection is monitored in real time to ensure that satellite connections are not broken and to provide other high level quality review. Tripod Scanning is a non-moving, simplified version of Mobile Mapping where the scanner rotates 360 degrees on a tripod with either technology.

Survey field crews are necessary to set survey control points to adequately tie down both the vertical and horizontal values to state plane coordinates (see **Chapter HD-302**).

Post-processing of LiDAR involves transformation of scan data using control points. Multiple checks for accuracy and precision should be performed. Post-processed LiDAR is utilized to generate the deliverables requested, such as 3d CADD files.

Best Uses

Terrestrial Scanning accuracy for KYTC is the same as other survey methods. For unique projects where higher accuracy is considered, contact the Highway Design State Survey Coordinator for requirements.

Standard Applications

- GIS maps
- Engineering topographic surveys
- As-built surveys
- Structures and bridge clearance surveys
- Corridor study and planning surveys
- Asset inventory and management surveys
- Environmental Surveys
- Sight distance analysis surveys
- Earthwork Surveys such as stockpiles, borrow pits, and landslides
- Erosion analysis

Equipment

All of the equipment used to collect scanning data shall meet ASPRS and NSSDA standards.

PROCEDURES: Scanning GNSS equipment must correspond with the requirements stated in Chapter 301 of the HDGM. TLS kinematic post-processing must comply with ASPRS and NSSDA standards. MTLS kinematic GNSS/IMU data must be post-processed in forward and reverse directions (from beginning-to-end and end-to-beginning).

Calibration

Sensor alignment (bore sighting) procedures shall be performed prior to scanning if the system has been disassembled for transport. Following scanning, collected data shall be adjusted to transportation points collected for the project.

Data Collection

Monitoring various component operations during the scan session is an important step in the QA/QC process. The system operator should be aware and note when the system encountered the most difficulty and be prepared to take appropriate action in adverse circumstances.

The scanning equipment shall be monitored throughout the data collection. If a fault is detected, additional scanning may be necessary to provide the accuracy of the project scope.

Policies

Lane Closure and Time of Day requirements shall be made at the District Level and might change during the project. It is important to specify these details in the scope of services and contracts. MUTCD standards for Rolling or Fixed Lane Closures will be followed when lane closures are deemed necessary due to expected high volumes of traffic; vehicles operating continuously or in close proximity to the collection vehicle, which results in breaks in scan coverage, or high volumes of tractor trailers on route causing satellite breaks. Traffic control for vehicular data collection should be consistent with MUTCD requirements.

Planning a Mobile Mapping Project

Before the scanning project commences a mission planning session should be conducted to assure that there are enough satellites available during the data collection and that the Positional Dilution of Precision (PDOP) meets the requirements. During the data collection there shall be a minimum of five (5) satellites in view for the GNSS Control Stations and the GNSS unit in the MTLS system. Additionally, the maximum PDOP value during acquisition shall be five (5). The project area shall be reconnoitered to determine the best time to collect the data to minimize excessive artifacts in the data collection from surrounding traffic or other factors, and to identify obstructions that may cause GNSS signal loss. Identify areas in the project that have poor satellite visibility and develop a plan to minimize the effect on the data, such as a network of transformation points and validation points. Planning for data collection shall also include the use of classification schema in **Table 307-4**. A checklist for MTLS projects is included as **TC61-1**.

1. MTLS data collection shall be collected so that there is an overlap, which means that either more than one pass in the same direction on the project, overlapping passes in opposite directions, or both shall be collected. Overlap dimensions: minimum of 20% sidelap.
2. Data points collected using scanning are checked by various means including comparing scan points to validation points, reviewing the digital terrain model, reviewing data terrain lines in profile, and comparing redundant measurements. Redundant measurements with MTLS or STLScan only be accomplished by multiple scans that offer overlapping coverage.

Planning a Tripod Scanning Project

Before the STLS project commences, the project area shall be reconnoitered to determine the best time to collect data to minimize excessive “artifacts” from traffic or other factors, ad to identify obstructions that may cause data voids or shadows. Check weather forecast to fog, rain, snow, smoke, or blowing dust. All tripod setups may be used to help reduce artifacts and obstructions from traffic and pedestrians. Area I the project that will be difficult to scan should be identified and a plan developed to minimize the effect on the final data through additional set-ups or alternate methods of data collection. Safety should always be taken into consideration when selecting setup locations.

STLS data collection shall have minimum overlap of 5-15%. Maximum measurement distance to meet vertical accuracy for horizontal (pavement) surface measurements for Type A: 260 feet. Maximum pavement measurement distance for pavement Analysis Scans is 150 feet.

Operation/Specification	MTLS Scan Application
Transformation and Validation Point positional accuracy	<=0.10 ft (hor. and vert.)
Control Placement	Ends of project and spacing below, both sides of roadway
Stationing spacing on each side of roadway	1500 ft (mobile) 500 ft (stationary)
Maximum PDOP	5
Minimum Number of Satellites	5
Maximum post-processed baseline length	5 miles
Sidelap	5-15% (STLS); 20% (MTLS)

Table 307-3 Scanning Specifications

DELIVERABLES:

Items in Addition to Standard Survey Report

- Those indicated on the form **TC61-1 Survey Features Checklist – Table 1** and **Table 307-4** Classification Schema. This may include a point cloud, classified point cloud, metadata, imagery/video, or other items in the scope. The more data requested, the higher the cost for that task. ***Because of the unmanageable size of TLS datasets, the maximum file size per swath shall be 2GB.***
- Additional Scanning Narrative in Survey Report
- Quality Management Plan (QMP) and related QA\QC report

Point Cloud

The simplest form of the processed TLS data is a "point cloud", which can be saved in a LAS format (v1.2 or later). If image overlay data is available, the post-processed point cloud may be delivered with an RGB value for each collected point.

While a point cloud is the simplest deliverable form, it is also the largest and most difficult to manipulate. A typical TLS point cloud can include billions on individual XYZ positions, which most software cannot work with. All points collected shall be included in the final report, even though some points will not be used in the production of deliverables for various reasons.

Point cloud data can be imported into various software packages. Further data manipulation, infusing other types of data and the use of analytical tools with the imported point cloud create a variety of value-added products. It is anticipated that raw point clouds will rarely be requested by KYTC; rather, classified point clouds will be the more common deliverable.

Classified Point Cloud

A 'classified point cloud' contains all TLS point data collect, but differs from a 'point cloud' in that each point is assigned to a classification indicative of the type of feature reflecting the laser beam. If a classified point cloud is required, classification specifications should be noted with reference to Table 307-4. Note that not all classifications are required for all projects, and only classifications usable on a specific project should be requested.

Metadata

A geospatial metadata file specifying the units and datum of the point cloud should be provided with all scopes for this type of work.

Imagery/Video

Videoor image files should also be delivered if they are available. If delivered, file must be in common (non-proprietary) format. Note that imagery collected with a TLS sensor is from the perspective of the scanning equipment and does not include aerial photography.

Survey Report- Additional Narrative

The documentation of TLS projects must show clear data lineage from the published primary control to the final deliverables. The data path of the entire process must be defined, documented, assessable, and allow for identifying adjustment or modification. 3D data without a documented lineage is susceptible to imbedded mistakes, and difficult to adjust or modify to reflect changes in control. An additional concern is that a poorly documented data lineage would not be legally supportable.

The Terrestrial LiDAR survey narrative report, completed by the person in responsible charge of the survey (typically the Party Chief), shall contain the following general information, the specific information required by each survey method, and any appropriate supplemental information, including geospatial metadata files conforming to the current KYTC standard.

- Control Lineage or Pedigree
- Primary & project control held or established
- Local transformation points
- Validation points
- Adjustment report for control and validation points
- Base station observation logs (occupation data, obstruction diagram, atmospheric conditions, etc.)
- Control for Scanner Registration and QC
- Local transformation points
- Validation points
- GNSS Accuracy Report-GNSS satellite visibility and PDOP IMU Accuracy Report
- Trajectory reports
- Registration Reports
- Results of target and cloud to cloud registration
- Results of finished products to validation points
- Geospatial metadata files conforming to current KYTC standard
- QA/QC reports

QA/QC:

The TLS data provider shall provide a Quality Management Plan (QMP) that includes descriptions of the proposed quality control and quality assurance plan. The QMP shall address the requirements set forth in HD-307 as well as other project specific QA/QC measures (See the MTLS checklist, TC-61X).

For an STLS survey, the QA/QC report shall list (at a minimum)::

- Control survey reports
- STLS system reports
- Statistical comparison of point cloud data and transformation points
- Statistical comparison of adjusted point cloud data and validation points

For an MTLS survey, the QA/QC report shall list (at a minimum):

- Control survey reports
- MTLS system reports
- PDOP values during the survey
- Separation of forward and reverse solutions (difference between forward and reverse post-processed roll, pitch, yaw and XYZ positions solution). Forward and reverse refers to time: processing from beginning-to-end and end-to-beginning.
- Areas of the project that the data collected exceeded the maximum elapsed time or distance traveled of uncorrected IMU drift due to degraded, lost, or obstructed GNSS signal reception.
- Comparison of elevation data from overlapping (sidelap) runs
- Comparison of points at the area of overlap (endlap) if more than one GNSS base is used.
- Statistical comparison of point cloud data and finished products to validation points
- Statistical comparison of adjusted point cloud data and redundant validation points

Accuracy

The term “accuracy” has commonly been used in the industry to refer to the tested $RMSE_Z$ of the LiDAR data. Technically, this is improper usage: NSSDA accuracy is defined as: the 95% confidence level, equal to ($RMSE_Z$*1.96) in a set of errors to be normally distributed. In keeping with common usage to reduce confusion, this Specification’s use of the term “accuracy” is indicative of the RMSE value and will be annotated as such.

KYTC requires the surveyor to specify: “Tested to Meet 0.10ft horizontal and vertical RMSE accuracy.”

KYTC will not accept deliverables that do not meet the defined project scope. If errors exist, it is incumbent on the consultant to re-collect or re-process the data without additional fee.

Common Problems

- Smoothed Contours—too much editing that detail is lost or not enough smoothing to "look right." It is suggested that this issue be discussed during scoping.
- Point Cloud misunderstandings—discuss expectations in scoping.
- Asking a consultant for an unclassified point cloud (as a cost savings) and not knowing what to do with it or who in the Cabinet can process it.

Table 307-4 Classification Schema

Classification	
TERRESTRIAL SCHEMA	
processed not otherwise classified	101
bare-earth ground	102
low vegetation	103
medium vegetation	104
high vegetation	105
Reserved	106
noise (low or high, manually identified if needed)	107
Reserved	108
Water	109
ignored ground (proximity to breakline)	110
Centerline	111
Lane Line	112
Edge of Pavement	113
Long Line Striping	114
Other Pavement Marking	115
Railroad Tracks	116
Signage (incl. Structural Members)	117
Visible Utility Items	118
Drainage Visible (incl. Centerlines)	119
Limit of Trees/Maintenance	120
Guardrail/Barriers	121
Fences (ID types)	122
Retaining Walls	123
Bridge Members	124
Building Faces	125
Curb Top of Face, ID Type in Codes	126
Curb, Bottom of Face	127
Curb, Top of Back	128
Front of Sidewalk	129
Back of Sidewalk	130
HC Ramps	131
Signal/Strain Poles/Mast Arms	132
Traffic Signal Equipment/Controller	133
Traffic Signal Loops/Pullboxes	134
Point Cloud, Classified	135
DTM, ___m grid	136

DEM	137
TIN	138
Contours, Major Interval _____	139
Contours, Minor Interval _____	140
Cross Slope	141
Existing Best Fit Vertical Alignment	142
Pavement Type: Concrete/Asphalt	143
Earthwork Volume	144
Rock Volume	145
Edge of Water	146
Driveways, ID Type in Codes	147
Mailboxes	148
Trees in ROW, ID Diameter	149
PVA lines, owners	150
Storm Drain Invert Elev.	151
Storm Drain Size	152
Bridge Deck	153
Above Ground Tanks or Pumps, ID Type	154
Cemeteries	155
Video	156
Photo Mosaic Files	157
Intensity images (8-bit gray scale, tiled)	158
Billboards	159
Edge of Graded Shoulder	160

REFERENCES:

1. USGS NGP Guidelines and Base Specification Version 13 – ILMF 2010
2. FEMA "Guidelines an Specifications for Flood Hazard Mapping Partners" http://www.fema.gov/libary/viewRecord.do?id=2206
3. FEMA Procedure Memorandum No. 61 – Standards for LiDAR and Other High Qualiy Digital Topography. http://www.fema.gov/library/viewRecord=?id=4345
4. http://www.fgdc.gov/standards/projects/FGDC-standards-projects/accuracy/part3/chapter3 .
5. USGS NED www.ned.usga.gov, USGS CLICK www.LiDAR.cr.usgs.gov
6. CALTRANS Survey Manual, 2006 by California Department of Transportation

Table 307-5 Glossary

SEE ALSO: ASTM E57 DEFINITIONS ASTM E2544 (3D Imaging Standards): http://www.astm.org/Standards/E2544.htm

ACSM-American Congress on Surveying and Mapping

Artifacts – Erroneous data points that do not correctly depict the scanned area. Objects moving through the scanner's field of view, temporary obstructions, highly reflective surfaces, and erroneous measurements at edges of objects (also known as "Edge Effects") can cause artifacts. Erroneous depiction of features can be due to inadequate or uneven scan point density.

ASPRS – American Society of Photogrammetry and Remote Sensing

Data Voids – Gaps in scan data caused by temporary obstructions or inadequate scanner occupation positions. Overlapping scans and awareness of factors causing data shadows can help mitigate data voids. Some data voids are caused by temporary obstructions such as pedestrians and vehicles.

Decimation – Reduction of the density of the point cloud.

DEM-Digital Elevation Mode

DMI-Distance Measuring Instrument

DTM-Digital Terrain Model

HDGM-Highway Design Guidance Manual

Inertial Measurement Unit (IMU) – A device that senses and quantifies motion by measuring the forces of acceleration and changes in attitude in the pitch, roll, and yaw axes using accelerometers and gyroscopes.

Intensity – A value indicating the amount of laser light energy reflected back to the scanner.

LiDAR – Light Detection and Ranging

Noise – Erroneous measurement data resulting from random errors.

NSSDA –National Standard for Spatial Accuracy

MTLS-Mobile Terrestrial Laser Scanning, also known as Mobile Mapping

PDOP-Position Dilution of Precision

Phantom Points – See "Artifacts" above.

Point Cloud – The 3D point data collected by a laser scanner from a single observation session. A point cloud may be merged other point clouds to form a larger composite point cloud. Data from within a point cloud may be used to produce traditional survey products, and point clouds may be specified as a deliverable.

Point Density – The average distance between XYZ coordinates in a point cloud, typically at a specified distance from the scanner. The point density specified by the client or selected by the contractor should be understood as the maximum value for the subject in question and should be dense enough to achieve extraction of detail at the scales specified for the project.

Registration – The process of joining point clouds together or transforming them onto a common coordinate system. Registration can be by use of a) known coordinates and orientations b) target transformation or c) surface matching algorithms.

Resolution – The ability to detect HDGMall objects or object features in the point cloud. See: Investigating Laser Scanner Accuracy, W. Boehler, M. Bordas Vicent, A. Marbs, i3mainz, Institute for Spatial Information and Surveying Technology, April 2004. http://scanning.fh-mainz.de/scannertest/results200404.pdf

ROW-Right of Way

RTK –Real Time Kinematic (GPS Survey)

Scan – The acquiring of point cloud data by a Lidar system.

STLS-Stationary Terrestrial Laser Scan, also known as Tripod Scanning

Detail Scan – A higher point density scan.

Overview Scan – A scan to gather general details of an area.

Scan Density – See “Point Density” above.

Scan Speed – The rate at which individual points are measured and recorded.

Time-of-flight measurement – Distance measurements based on the time between emitting a pulse of light and the detecting the reflection of the pulse.

TIN-Triangulated Irregular Network

TLS-Terrestrial Laser Scan, including MTLS and STLS

Trajectory report – MTLS system and positional performance data from each scanning pass produced by post-processing software. Reported parameters may include satellites in view, PDOP, GDOP, uncorrected IMU distance, uncorrected IMU duration, difference in positional solutions between forward and backward processing, and estimated positional accuracy.

Wave-form processing – Also called “echo digitization.” Scanner system that uses the pulsed time-of-flight technology and internal real-time processing capabilities of multiple returns to identify multiple targets.

XYZI – ASCII format showing X & Y coordinate, Z elevation and reflection Intensity values from NSSDA.

XYZIRGB– ASCII format showing X & Y coordinate, Z elevation, reflection Intensity, and Red, Green, Blue color values from NSSDA.