FDM 9-45-1 General

November 15, 2024

The Surveying & Mapping Section coordinates all requests for products and services produced through photogrammetric methods (aerial imagery) and related sensor technologies (LiDAR scanning) as directed in the FDM 9-5-15 policy statement. Region staff should direct requests for aerial imagery and LiDAR products to the region survey coordinator. Other DOT staff may contact dotaerialmapping@dot.wi.gov. Consultants should request aerial imagery and LiDAR products through the DOT project manager (see FDM 9-5-15).

Aerial imagery is used to acquire data that is required for planning, designing, constructing, and maintaining transportation facilities. The most common data derived from aerial imagery is planimetric mapping (PMAP) and digital terrain model (DTM) data. Aerial imagery is also an excellent reference for historical, environmental and land use studies, public displays, and to support legal actions.

Unmanned Aircraft Systems (a.k.a. UAS, UA, UAV, drones) are an emerging technology. See FDM 9-45-30 for further information.

See Attachment 1.1 for a list and descriptions of available Geospatial Products.

Request Considerations

Before requesting products, the project manager, project designer, and survey coordinator should consider the following.

1. Type of Project - Different types of projects (see FDM 3-5-2) will require different types and amounts of data acquisition to support the design of the project (see FDM 9-43-1).
2. Terrain and Geographic Area - In heavily wooded areas, field survey methods may be more advantageous to produce necessary elevation information than aerial photogrammetry. Aerial mapping photogrammetry methods require a clear view of the ground surface and can be supplemented with field survey methods for obscure areas.

   In high traffic areas and in rolling, rugged, or hilly terrain, aerial photogrammetry methods may be more expedient and safer for field personnel. In an area with many owners/occupants and particularly with an uncooperative owner/occupant, aerial photogrammetry may save time by eliminating the need for field personnel to obtain the cooperation of each owner/occupant, so field survey methods can be used.
3. Size of Project and Region Workload - Projects requiring a large amount of data may be expedited by using aerial imagery or LiDAR. Small projects may be accomplished by LiDAR or field survey methods.
4. Time Frame - The time frame of requesting aerial imagery or LiDAR, the requested delivery date, and type of product needed may be significant in determining the method of data acquisition. Some types of data acquisition are dependent upon the season of the year (see FDM 9-43-5 and FDM 9-45-15).
5. Multiple Counties - When using the Wisconsin Coordinate Reference System (WISCRS), there are several options to consider at county boundaries. Depending upon how far the project extends into the adjacent county, the coordinates for the project may be in the same county zone for the entire project, may need to be shown in both county zones, or may be shown in one county zone for part of the project and in the other county zone for another part of the project (see FDM 9-20-27 and FDM 9-20-28). (removed outdated information)

LIST OF ATTACHMENTS

Attachment 1.1	Geospatial Products

FDM 9-45-5 Aerial Imagery Products April 16, 2015

Attachment 5.1 provides examples of aerial imagery products listed in Table 5.1. Region staff should request aerial imagery products through the region survey coordinator. Other DOT staff may contact dotaerialmapping@dot.wi.gov. Consultants should request aerial imagery products through the DOT project manager (see FDM 9-5-15).

Table 5.1 List of Aerial Imagery Products

Subsection	Product Name	Product Description
FDM 9-45-5.1	Vertical Aerial Imagery	Stand-alone product Required for all aerial photogrammetry products (FDM 9-45-10.1 to 10.5) Required for Products FDM 9-45-5.2 and 5.3
FDM 9-45-5.2	Digital Aerial Mosaic	Stand-alone product
FDM 9-45-5.3	Digital Geo-Referenced Imagery (GeoRef)	Stand-alone product
FDM 9-45-5.4	Oblique Aerial Imagery	Stand-alone product

5.1 Vertical Aerial Imagery

Vertical aerial imagery is captured using a calibrated photogrammetric camera located in the bottom of an aircraft. The camera axis is pointed vertically so that the film surface is approximately parallel to the earth's surface. Vertical aerial imagery is acquired using black and white aerial film or may be acquired using a digital photogrammetric camera. Aerial film is scanned into digital format for a variety of uses. Other types of film (color or infrared) may be used but are rarely needed for transportation projects and are more expensive and difficult to use than black and white film.

Vertical aerial imagery which has an analytical triangulation solution is called controlled imagery. Vertical aerial imagery which does not have surveyed ground control, nor an analytical triangulation solution is uncontrolled imagery.

Due to distortions caused by ground relief and radial position in the image, the resulting raw image is not as accurate as a map for quantitative measurements. The image may be used to create a digital imagery product with improved accuracy, such as a geo-referenced image (see FDM 9-45-5.3) or a digital ortho image (see FDM 9-45-10.5) can be produced.

New vertical aerial imagery has a typical scale of approximately 1 inch = 250 feet, resulting in a map with a scale of 1 inch = 50 feet, but the scale for each project will be determined based on the intended use and accuracy needed.

An index to vertical aerial imagery acquired after 1998 is available through DOTView. Older archived statewide imagery can be researched by aerial imaging staff when township, range, and section or address is provided. Reproductions are available as digital files or inkjet plots. Files are delivered via the LAN or externally via FTP. Imagery is typically scanned at 600 dpi but varies by needs. Requests should include the roll and exposure number of existing imagery (from DOTView, unless ordering new imagery) and a map indicating the area to be enlarged. Indicate the requested scale, size and resolution of the finished product; and whether a digital file or print is desired. Aerial imagery staff can offer advice regarding product scale, resolution and file format based on intended use.

Vertical aerial imagery may be used for:

- Plan sheets
- Engineering exhibits
- Land use drawings
- Resurfacing plans
- Qualitative information such as land use, soils, vegetation type, and geology
- Exhibits in reports and legal documents
- Exhibits at public meetings

- Monitoring land use and changing conditions
- Digital mosaics
- Geo-referenced imagery
- Ortho imagery

5.2 Digital Aerial Mosaic

A digital mosaic consists of two or more aerial images that have been scanned to produce raster files and are then overlapped to form a single continuous image. Digital mosaics can be produced from ortho imagery, geo-referenced imagery or uncontrolled scanned vertical aerial imagery.

Requests for digital mosaics from previously acquired imagery should include the roll and exposure number of existing imagery (from DOTView) and a map indicating the area. Also indicate the requested resolution of the finished product and the desired file format (unless a print is desired). Aerial imagery staff can offer advice regarding product scale, resolution, and file format based on intended use.

Digital aerial mosaics may be used for:

- Photo indexes
- Design investigations
- Report illustrations
- Resurface plan sheets

5.3 Digital Geo-Referenced Imagery

A geo-referenced image is a raster aerial image that has been warped to fit points from a vector file or visible points from a coordinate correct raster image (i.e. an existing ortho or georef). Georeferenced imagery is less accurate than ortho imagery and does not have a guaranteed accuracy.

Requests for digital geo-referenced imagery from previously acquired imagery should include the roll and exposure number of existing imagery (from DOTView) and a map indicating the area. Also, indicate the requested resolution of the finished product and the desired file format (unless a print is desired). Aerial imagery staff can offer advice regarding product scale, resolution, and file format based on intended use.

Geo-referenced imagery may be used for:

- Plan sheets
- Engineering exhibits
- Land use drawings
- Mosaics
- Exhibits for public meetings

5.4 Oblique Aerial Imagery

Oblique aerial imagery is taken with the camera axis inclined at an angle to the surface of the earth. If the horizon shows in the image, it is a high oblique. If the horizon does not show, the image is a low oblique.

Color oblique aerial imagery is taken with a high resolution digital single-lens reflex camera, which is held out the window of the aircraft as the pilot circles the subject area. This product is useful when a broad area of coverage is needed for display purposes. The images can be delivered as digital files or digital inkjet plots.

Requests should include a county map which shows the location requested. Also include additional maps (e.g., quad map, city plat, or aerial mosaic) to highlight the specific area to be photographed. Indicate the type of oblique (i.e., high or low) and the desired file format or whether prints are desired. To request additional prints or enlargements from existing obliques, provide the oblique number(s) and the quantity and enlargement size desired. Aerial imagery staff can offer advice regarding resolution and file format based on intended use.

Oblique aerial imagery may be used for:

- Displays for public informational meetings
- Design reports
- Design awards
- Documentation of existing / changing conditions

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Attachment 5.1 Aerial Imagery Product Examples

FDM 9-45-10 Aerial Photogrammetry Products

April 16, 2015

Aerial Photogrammetry products require vertical stereo imagery, ground control and an analytical triangulation solution. A list of all aerial photogrammetry products is included in Table 10.1.

Table 10.1 List of Aerial Photogrammetry Products

Subsection	Product Name	Product Description
FDM 9-45-10.1	Digital Terrain Model (DTM)	Stand-alone or with PMAP, Required for ORTHO
FDM 9-45-10.1	High-Flight DTM (HFDTM)	Stand-alone or with PMAP, Required for ORTHO
FDM 9-45-10.1	Final DTM (FDTM)	Stand-alone product
FDM 9-45-10.2	Planimetric Map (PMAP)	Stand-alone or with DTM
FDM 9-45-10.3	Expedient Planimetric Map (EXP)	Stand-alone product
FDM 9-45-10.4	Extensions to DTM and Mapping Products	Request as needed
FDM 9-45-10.5	Digital Ortho Imagery (ORTHO)	Requires a DTM to be produced

A pair of vertical aerial images that overlap by 60% creates a stereo model. When viewed through a stereoscope, stereo plotting instrument, or digital softcopy station, the stereo model is viewed in three-dimensions. The stereo model is the basis for creating maps and collecting DTM data by the photogrammetry process.

Ground control consists of targets painted or placed on the ground or surveyed photo identifiable points (see FDM 9-45-35). The targets and photo identifiable points are surveyed as close to the time of flight as possible.

Analytical triangulation is a mathematical process of measuring the ground control and fourteen additional locations on each stereo model. An analytical triangulation solution is the result of a polynomial adjustment of all of the measurements and compensates for relief displacement and radial distortion at all locations in the stereo model. The analytical triangulation solution ties the imagery to the earth’s surface to allow accurate compilation of the earth’s features and accurate collection of horizontal and vertical data.

FDM 9-43-1 provides a list of suggested mapping products correlated to various improvement projects.

Attachment 1.1 summarizes accuracy and related information. Region staff should request DTM and mapping through the region survey coordinator. Other DOT staff may contact dotaerialmapping@dot.wi.gov. Consultants should request DTM and mapping through the DOT project manager (see FDM 9-5-15).

10.1 Digital Terrain Model (DTM)

Mapping and digital terrain model (DTM) data is critical to transportation improvement projects. A DTM is used to investigate alignment alternatives, to cut cross sections, to cut profiles, to generate contours, and to generate quantities between existing and final surfaces. Reference FDM 9-65 for more information on surface modeling.

A digital terrain model (DTM) is a mathematical model of the existing earth's surface.

Data collection is performed using 3D stereoscopic systems (stereoplotter or softcopy workstation) interfaced to MicroStation. The operator collects sufficient points to define the surface and adds break lines to define sharp changes in elevation (curbs, ditches, etc.). The points and break lines are used to create a triangulated irregular network (TIN) from which the DTM is generated.

A DTM can also be generated from LiDAR point cloud data (see FDM 9-45-20).

The data is collected in a 3D MicroStation format and the DTM data is delivered in an ASCII formatted SRV file along with a LOG file that lists the number and type of break lines and points that are in the dataset. A delivery email message is sent to the region survey coordinator and CADD coordinator. The region survey data coordinator will then determine if the obscured areas need supplemental survey data. The region survey data coordinator will then forward the data to designers. The MicroStation DGN files and DTM files are archived in the File Cabinet storage system.

These methods are used to offer various products:

- DTM (DTM) - final design grade accuracy used for design of improvement projects; typically delivered with the planimetric mapping.
- High-Flight DTM (HFDTM) - planning grade accuracy used for investigating corridors; typically delivered with the planimetric mapping.
- Final DTM (FDTM) - flown and compiled to final grade accuracy after the contractor has completed the earthwork such that the data can be used for construction final quantity measurements.

DTM data may be used for:

- Preliminary design
- Final design
- Drainage studies
- Structure survey report
- Plan sheets
- Right of way sheets
- Exhibits at public meetings
- Highway corridor studies
- Earthwork computations (finals)
- Creation of ortho imagery
- Areas of unique design
- Land use studies

10.2 Planimetric Map

A planimetric map depicts the horizontal position of natural and constructed features. A planimetric map (PMAP) may be a stand-alone product, but the imagery is tied to horizontal and vertical ground control so that a DTM may also be provided. Features are depicted by standardized lines and cells as specified in FDM 15-5. The features are collected in three-dimensions but are converted to a two-dimensional file for use in Civil 3D. The MicroStation 2d file is exported to a DWG, then imported and exploded in Civil 3D for highway design.

A planimetric map may be used for:

- Plan sheets
- Right of way sheets
- Preliminary design
- Final design
- Railroad abandonment project
- Structure survey reports

10.3 Expedient Planimetric Map

An expedient planimetric map depicts the horizontal position of natural and constructed features; vertical information is not included. Expedient planimetric maps are usually compiled from aerial imagery at a higher altitude and may be taken either in the spring or fall. This imagery cannot be used for DTMs because vertical information is not provided to control the imagery, however this imagery may be geo-referenced (see FDM 9-45-5.3).

An expedient planimetric map may be used for:

- Geo-referenced imagery
- Corridor location study
- Preliminary design
- Final design

10.4 Extensions to DTM and Mapping Products

One of the advantages of Photogrammetry is the ability to gather more data from the aerial imagery after analytical triangulation has been performed. For example, a designer may determine they need more data along a side road. The designer then asks the region survey coordinator to request an extension. The region survey coordinator works with the Photogrammetry Unit to determine if the existing imagery and ground control placement on the imagery will allow the collection of additional data.

Extensions may be requested on aerial imagery that is up to ten years old.

10.5 Digital Ortho Imagery

An ortho image is a raster aerial image with distortions removed. It looks like an aerial photograph but has the geometric characteristics of a stereo-compiled map drawn to scale. The ortho image can provide a designer with more information than traditional vector mapping, and it can provide the public with a better concept of a highway project.

Ortho imagery is produced by draping a scanned vertical aerial image over a Triangulated Irregular Network (TIN) file produced from a Digital Terrain Model (DTM) and a camera orientation parameter file generated from analytical triangulation. Ortho imagery can be produced from existing or newly requested imagery and the corresponding DTM.

Requests for digital ortho imagery from previously acquired imagery should include the roll and exposure number of existing imagery (from DOTView) and a map indicating the area. Also, indicate the requested resolution of the finished product and the desired file format (unless a print is desired). Aerial imagery staff can offer advice regarding product scale, resolution and file format based on intended use.

Digital ortho imagery may be used for:

- Plan sheets
- Engineering exhibits
- Land use maps
- Exhibits for public meetings

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Attachment 10.1 Geospatial Product Examples

FDM 9-45-15 Aerial Photogrammetry Work Flow *April 16, 2015*

Acquisition of quality imagery requires optimal conditions to produce a quality product. Attachment 15.1 shows the work flow required for Aerial Photogrammetry products (see FDM 9-45-10) and is detailed below. If the request is for uncontrolled products from vertical aerial imagery (see FDM 9-45-5.1) follow step 1 below.

1. Region staff should request projects through the region survey coordinator. Other DOT staff may contact dotaerialmapping@dot.wi.gov. Consultants should request photogrammetric services through the DOT project manager (see FDM 9-5-15).

   Fall and spring aerial photogrammetry flights should be requested as early as possible. As a guideline, fall requests should be received by August 15 and spring requests should be received by September 15. Requests received past these guidelines can be accommodated but will receive lower priority in the mapping schedule.

   Requests for mapping and DTM products should include the following:

   - valid project ID
   - project mileage
   - project limits, highway, county
   - coordinate system, horizontal datum, and vertical datum (in accordance with FDM 9-5-10)
   - type of mapping and other imagery product(s) needed
   - mapping due date (ortho due date, if needed)
   - A scan of county map(s) showing the general project area with the project extents highlighted.
   - A large-scale map showing the specific project area with details for the begin and end limits and the width of data needed left and right of the mainline and side roads.

2. The region or consultant surveyor researches appropriate horizontal and vertical ground control.
   - Wisconsin Continuously Operating Reference Stations (WISCORS) network
   - Wisconsin Height Modernization Project (WHMP) network
   - National Geodetic Survey (NGS) geodetic control
   - County networks
   - United States Geological Survey (USGS) control
   - Control from past DOT projects

   Suggested resources include:

- the Wisconsin State Cartographer's Office (SCO) Control Finder (https://maps.sco.wisc.edu/surveycontrolfinder/)
- NGS DSWorld (plots NGS network points by state, county and type (vertical or horizontal) in Google Earth (which must be installed first) (http://www.ngs.noaa.gov/PC_PROD/PARTNERS/index.shtml)

Ground control established by the Department is available from the region survey office. The surveyor may need to extend ground control to the project area if adequate nearby control is not available (refer to FDM 9-45-35.1 and FDM 9-45-35.2).

3. Photogrammetry staff prepares a digital target document. The target document is typically a PDF with Google Earth imagery as a backdrop to the display of flight lines and the stereo models created by the overlapping pairs of images. The target document also identifies the locations of all needed targeted ground control points. Photogrammetry staff sends the document to the region survey coordinator along with an ASCII GCP (ground control point) file of target names and coordinates. The region survey coordinator reviews the target document to ensure the proposed flight lines and stereo models cover the requested area and to determine if additional coverage or revisions are needed. The region survey coordinator provides confirmation to the Photogrammetry Unit that each target document is acceptable.
4. Photogrammetry staff and the surveyor work together to revise the target document to accommodate field conditions and to consider using existing horizontal and vertical control within project limits.
5. Photogrammetry staff prepares the mapping schedule to identify interim due dates (e.g., ground control) to meet delivery due dates. Dates will be discussed with the region before being entered into the Photogrammetry Unit Milestone database. Deadlines can be renegotiated between the regions and the Photogrammetry Unit throughout the year.
6. The surveyor places targets at the designated locations. The surveyor should contact Photogrammetry staff for advice when the target cannot be placed as planned. The surveyor notifies Photogrammetry when all targets have been placed and field conditions are suitable for the flight to proceed.
7. Photogrammetry staff acquires aerial imagery at the optimum time (refer to Table 15.1).

***Table 15.1* List of Aerial Photogrammetry Products**

Spring (March - May)	Fall (October - November)	Anytime
Spring imagery is suitable for any mapping project including those that require DTM because vegetation is matted down from the snow.	Fall imagery may be used for final DTM due to the lack of vegetation in the recently constructed roadway.	Vertical and oblique imagery for special projects such as wetlands, special events, airports, construction exhibits.
Before trees and bushes leaf out.	After most trees and bushes have lost leaves and ground cover plants (including weeds) do not have leaves.	For obliques, consider fall color to enhance exhibits.
The ground, including ditches, is snow free.		Snow drift studies
Water is not standing in fields or ditches, except perhaps in an occasional ditch.		Flood studies
The area is cloud free.		
The winds aloft are acceptable.		

8. Photogrammetry processes film as soon as possible after acquisition to determine if quality of imagery is acceptable or if the area needs to be reflown (e.g., due to shadows from clouds, missing coverage, etc.).
9. Photogrammetry evaluates the imagery for quality and finds all visible targets. When imagery is approved, Photogrammetry notifies the surveyor to remove plastic targets. If some targets are not visible on the imagery, Photogrammetry may select image points and ask the surveyor to provide coordinates. Photogrammetry scans aerial film negatives into digital raster files.

10. Region surveyor coordinator submits ground control data (see FDM 9-45-40) to Photogrammetry according to the schedule, including coordinates and metadata of targeted ground control and any image points.
11. Region survey coordinator submits detailed mapping limits (e.g., to specify width of coverage along mainline and side roads).
12. Photogrammetry performs analytical triangulation (AT), a mathematical densification of ground control, by measuring targets, image points, and pass/terrain points.
13. Photogrammetry compiles mapping and DTM data. High priority projects will be reflected in the schedule, but compilation is scheduled year-around. The requestor should notify Photogrammetry immediately of any changes to the requested due date or if the project is canceled. Photogrammetry may ask the region survey coordinator if due dates can be flexible to meet highest priorities. The scheduled delivery date will be evaluated with respect to production capability and the delivery dates for other projects. Ortho imagery is created.
14. Photogrammetry emails region survey coordinator with notification of completed project. Files are stored in the File Cabinet archival system for retrieval by region staff.

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Attachment 15.1 Aerial Photogrammetry Work Flow Diagram

FDM 9-45-20 LiDAR Products *November 15, 2024*

LiDAR, which stands for *Light Detection and Ranging*, is a remote sensing method that uses light in the form of a pulsed laser to measure ranges to the Earth. The data, when combined with other data (GPS, ground control, IMU data), generates precise, three-dimensional information of a given area. LiDAR scanners provide an additional tool to accurately measure objects and areas quickly and efficiently, with fewer impacts to traffic and less exposure to traffic for surveyors. LiDAR collection can save time in the field; including time spent going back to sites to collect additional data, although the processing of the data in the office takes more time than processing traditional aerial imagery by means of photogrammetry.

LiDAR data creates a “point cloud” from which many different types of information can be extracted. The absolute accuracy of the LiDAR data depends on the amount of control that is held for the project (more control equals better accuracy levels of the point cloud), as well as how accurate the control is. Absolute accuracy is determined by comparing the measured LiDAR location of points with the actual known ground location. Relative accuracy is determined by comparing the measured LiDAR distance between two points with the actual distance between two points. Relative accuracy does not depend on the amount or quality of ground control. Both absolute and relative accuracy of LiDAR data depend on the particular LiDAR scanner used.

Accuracy of the information in the following sections is to the best of our knowledge at this time. LiDAR technology is rapidly evolving. We expect that accuracy of LiDAR data will continue to improve.

20.1 Scanner Types

There are three ways to collect LiDAR data. These are:

- aerial LiDAR (fixed-wing and helicopter),
- mobile LiDAR, and
- terrestrial (static) LiDAR.

20.1.1 Aerial LiDAR

Aerial LiDAR is collected from helicopters and fixed wing aircraft. When an airborne laser is pointed at a targeted area on the ground, the beam of light is reflected from the surface it encounters. The laser range data is combined with position and orientation data generated from GPS and Inertial Measurement Units (IMU), scan angles, and calibration data. The LiDAR data collected from the aircraft generates a point cloud that can then be used to extract the necessary information.

Fixed wing LiDAR is generally used for large areas. The wide swaths of collected data can be used in planning and final design of projects. Helicopter LiDAR is primarily used for corridor work due to the narrower swaths of collected data. This data can also be used for planning and final design.

The achievable accuracy of fixed wing LiDAR (with the necessary ground control in place) is up to 0.3’ from 1800’ flying height. The approximate width of coverage is 1,340 feet, but this value will vary with flying height. Due to the lower flying height, the achievable accuracy of helicopter LiDAR collection is 0.08’ - 0.1’. The width of coverage is much lower due to the lower altitude of flight and is approximately 690 feet. This value will vary with flying height as well.

20.1.2 Mobile LiDAR

Mobile LiDAR is primarily collected with a van or other vehicle at or near posted highway speeds. The accuracy of the data varies and is largely based on how much ground control has been set, in addition to what type of LiDAR scanner is used (engineering grade or mapping grade). Not all projects will need the same level of accuracy.

There are 6 main components of all mobile LiDAR platforms: laser scanners, GNSS receivers, Inertial Measuring Units, Distance Measuring Units, digital cameras, and a rigid platform which will provide a stable surface, so the devices will not move. These components influence what accuracy can be achieved and assist with data processing.

Mobile LiDAR is generally used for narrow swath, corridor projects. It is also used for hard surface projects, structure (bridge) clearances, overhead utilities, and projects where safety is of greatest concern (such as congested roadways).

Accuracy levels for mobile LiDAR collection will vary a great deal based on how much ground control is set, as well as what the data will be used for. Overall, the achievable accuracy of mobile LiDAR is from 0.04’ to 1.0’. The width of coverage is approximately 60 feet from the vehicle.

20.1.3 Static LiDAR

Static scanning is performed from a fixed point on the surface of the earth. The instrument will be set up on a survey tripod. Static LiDAR scanners (also known as terrestrial scanners or high-density scanners) typically use “time of flight”, “phase based”, or “waveform” technology to measure distances. Time of flight scanners send out a laser pulse and observe the time taken for the pulse to reflect off an object and return to the instrument. In phase-based scanners the phase difference is measured between the reflected beam and the transmitted amplitude modulated continuous wave laser beam. Phase based scanners typically are able to collect a greater number of points per second than time of flight; however, they have a shorter useful range. Phase based scanners are used generally for indoor applications, while time of flight are typically used outdoors. Waveform or echo digitization scanners are able to send out a single laser pulse and get back multiple returns back to the scanner. This allows for the collection of many more points per second than time of flight and phase-based scanners. This technology also allows the laser pulses to penetrate objects such as leaves on trees to reach the bare earth. This will make the end data more accurate and result in a better bare earth DTM. The bare earth DTM is generated from the filtering of the LiDAR point cloud to remove all data which is not the last return (the ground). Typically, a scanner generates multiple returns until it gets to the earth’s surface. An example of this is when the laser passes through leaves on a tree until it hits the ground. The bare earth DTM will remove these first returns until only the final, bare earth point remains.

Measurements from a static scanner are collected similar to a total station in that the scanner uses the speed of light to determine distances. However, static scanners use different laser light wavelengths, the amount and speed of point cloud data is much greater, field procedures and data post processing are different, and the error sources of the instrument itself are different.

WISDOT has a Riegl VZ-400 terrestrial scanner that uses echo digitization and online waveform processing which allows for accurate measuring in adverse atmospheric conditions and for the evaluation of multiple target echoes (returns). The scanner is placed on a tripod and moved to multiple scanner locations. The unit also comes equipped with a digital camera so that pictures of the area scanned can also be tied to the collected LiDAR data.

Static LiDAR is generally used for small projects, such as structures, bridge clearances, overhead utilities, roundabouts, intersections, short corridor work, and borrow pits. The achievable accuracy of the static LiDAR data is largely dependent on the ground control set but is generally between 0.04’ and 1.0’. The width of coverage is typically within a 150’ - 250’ radius of where the scanner is located. This radius is dependent on how high the tripod is set up for the scanner. A higher tripod setup will result in a larger radius.

20.2 Ground Control and Targeting

The amount of horizontal and vertical ground control should be enough to achieve the accuracy goals of the project. Control shall be surveyed to third order or better, both horizontally and vertically. More accurate data requires a higher order of survey and additional ground control. For more information regarding ground control see FDM 9-1-5.3 and FDM 9-1-5.4.

For mobile and aerial LiDAR projects, targets must be set up before collection.

20.2.1 Ground Control for Static LiDAR

When ground control is needed for an in-house static scanning project, the BTS Surveying and Mapping Section LiDAR Specialist will prepare a control document (in TXT format), which will have the XY coordinates for all ground control that will need to be set. This document will be sent to the Region Survey Coordinator. The document will display the name and location of all needed ground control. The naming convention of the ground control will be 001, 002…999, unless a previously placed ground control location is in the project area. This location will keep the previously named ground control location name. A Google Earth KML file will also be provided to the Region Survey Coordinator by the LiDAR Specialist. This file will display the approximate location of the ground control to be placed.

If the ground control cannot be placed at the exact coordinates stated in the TXT file, it may be moved up to 10 feet of what is stated. Since the ground control locations will be occupied by either the static scanner, tripods, reflector targets, or operator, avoid placing the control within traffic lanes and narrow shoulders. Do not place control on any areas which may be obstructed in any way by tree branches, signs, or other objects. If there are any questions regarding the layout of the control, or if any control locations need to be changed more than 10 feet due to existing conditions, contact the LiDAR Specialist at (608)246-7937 for guidance.

The location of the ground control must be relatively flat, free of obstructions, and whenever possible on a hard surface. For hard surfaces, ground control should be placed with a PK nail or a chiseled cross inside a painted triangle so it can be found easily. For soft surfaces, use rebar and a plastic cap. Control on soft surfaces should be placed as close to ground elevation as possible. A lath should be placed next to control on soft surfaces for ease of locating.

Once all ground control locations have been placed and surveyed, a final Ground Control CSV file with point number and XYZ position shall be sent to the Region Survey Coordinator, who will then forward it to the LiDAR Specialist for importing into the static scanning software. For a sample Ground Control CSV files, see Attachment 40.3. A document which briefly describes the location of each ground control point, as well as how it was placed (PK nail, chiseled cross, etc.) shall also be provided for ease in locating. After importing the ground control into the software, data can be collected, and the scan positions can be referenced to the ground control.

20.2.2 Ground Control for Mobile and Aerial LiDAR

For information on placement of ground control for mobile and aerial LiDAR, see (FDM 9-45-35).

20.3 Accuracy Requirements

The accuracy of a LiDAR point cloud is only as good as the ground control set for a project. More control targets and GPS satellites for a given project will result in higher accuracy. The type of surface will also play a big part in LiDAR accuracy. Accuracy on data collected from hard surfaces, such as roads, will be higher than for grass or heavily vegetated areas. Accuracy levels will also diminish with distance from the scanner. Scanner angle also plays a big part in accuracy. The best accuracy is obtained from scanning perpendicular to the surface to be collected, rather than at an oblique angle.

20.4 How to Request a LiDAR Project

The request for a LiDAR project is similar to that for an aerial imagery or Photogrammetry project (see FDM 9-45-25). Region staff and consultants should request projects through the region survey coordinator. Other staff may contact dotaerialmapping@dot.wi.gov. Consultants should request LiDAR services through the DOT project manager (see FDM 9-5-15).

20.5 Deliverables

Deliverables will be based on specific project needs, but below are some of the deliverables that can be provided through LiDAR data:

1. DTM Data - will include manually entered breaklines, as well as key points from the LiDAR point cloud (see FDM 9-45-10.1)
2. Planimetric Data (see FDM 9-45-10.2)
3. LiDAR Intensity Images
4. Bare Earth Surface Models - all obstructions such as buildings, vehicles, etc. will be removed so that only the Earth’s surface is shown
5. Classified Point Clouds
6. LAS files (retained by Surveying and Mapping Section)
7. Google Earth KML file of scan position locations, as well as images for each position (7 per position).

20.6 Limitations

There are limitations to what the scanners can collect, depending on the method of collection. For example, when collecting mobile LiDAR, the resulting point cloud may show data voids where the ditches should be. This is due to the angle of the scan being taken. In addition, mobile scanners will only be able to collect the front side of buildings along roadways.

LiDAR cannot see through dense objects such as cars or other obstructions. Taking multiple scans or passes of an area will help to fill in many of these data gaps. The individual(s) collecting the data must be aware of when these are occurring.

The weather may also affect LiDAR collection. LiDAR data cannot be collected during rain, fog, or snow.

20.7 Factors to Consider when Selecting LiDAR for a Project

1. How much ground control will be needed to achieve the desired accuracy level for the project?
2. The cost of LiDAR collection and processing can be higher than traditional mapping methods, including Photogrammetry.
3. Which type of LiDAR collection will be able to achieve the necessary accuracy for the project?
4. Is the project a good fit for LiDAR, or would Photogrammetry or field surveys serve the purpose at lower cost?
5. What is the project schedule, and will the use of LiDAR accommodate that schedule?
6. Safety considerations. Will collecting the project with LiDAR be safer than traditional survey methods?
7. Is the amount of detail the project requires and the complexity of the area to be collected appropriate for a LiDAR project?
8. Size and type of project.

20.8 Conclusion

In conclusion, LiDAR is an additional mapping tool now available for use. LiDAR may be the only mapping tool used on a project, or it may be used along with other tools such as field survey and aerial imagery. LiDAR may not be appropriate for some projects.

Because LiDAR is a relatively new technology, it is evolving rapidly. Newer models of equipment and versions of software are constantly improving scanner range and accuracy.

LiDAR data is only as good as the ground control set for a project. Without good ground control, the desired level of accuracy for a project may not be met. The amount of ground control needed to achieve high accuracy for LiDAR projects may result in higher cost than for traditional mapping methods.

FDM 9-45-25 LiDAR Work Flow — April 16, 2015

A typical workflow for a LiDAR project follows. (Please Note: The time frame for delivery depends on the project size and departmental work load):

1. Region staff should request LiDAR projects through the region survey coordinator. Other DOT staff may contact dotaerialmapping@dot.wi.gov. Consultants should request LiDAR services through the DOT project manager (see FDM 9-5-15).

   Requests for mapping and DTM products should include the following:
   - valid project ID
   - project mileage
   - project limits, highway, county
   - coordinate system, horizontal datum, and vertical datum (in accordance with FDM 9-5-10)
   - type of mapping and other product(s) needed
   - mapping due date
   - A scan of county map(s) or Google Earth KML files showing the general project area with the project extents highlighted
   - A large-scale map showing the specific project area with details for the begin and end limits and the width of data needed left and right of the mainline and side roads
2. The region or consultant surveyor researches appropriate horizontal and vertical ground control.

- Wisconsin Continuously Operating Reference Stations (WISCORS) network
- Wisconsin Height Modernization Project (WHMP) network
- National Geodetic Survey (NGS) geodetic control
- County networks
- United States Geological Survey (USGS) control
- Control from past DOT projects

Suggested resources include:

- Wisconsin State Cartographer's Office (SCO) ControlFinder (http://www.sco.wisc.edu/controlfinder/controlfinder.html)
- NGS DSWorld (plots NGS network points by state, county and type (vertical or horizontal) in Google Earth, which must be installed first) (http://www.ngs.noaa.gov/PC_PROD/PARTNERS/index.shtml)

Ground control established by the Department is available from the region survey office. The surveyor may need to extend ground control to the project area if adequate nearby control is not available (see FDM 9-45-35.1 and FDM 9-45-35.2).

3. Planning of proposed scan positions (for a static scanning project) is done by Photogrammetry staff.
4. Photogrammetry staff prepares a digital target document identifying the locations of all needed targeted ground control points and sends the document to the region survey coordinator along with a CSV or text file of target names and coordinates. The region survey coordinator reviews the target document to ensure the proposed scan area covers the requested area and to determine if additional coverage or revisions are needed. The region survey coordinator provides confirmation to the Photogrammetry Unit that each target document is acceptable.
5. Photogrammetry staff and the surveyor work together to revise the target document to accommodate field conditions and to consider using existing horizontal and vertical control within project limits.
6. The surveyor places targets at the designated locations. The surveyor should contact Photogrammetry staff for advice when the target cannot be placed as planned. The surveyor notifies Photogrammetry when all targets have been placed and field conditions are suitable for the scanning to proceed.
7. The region survey coordinator submits ground control data (see FDM 9-45-40) to Photogrammetry according to the schedule, including coordinates and metadata of targeted ground control and any image points.
8. The Statewide LiDAR Specialist or consultant collects the scan positions and registers the scanned data to the ground control.
9. The bare earth model is created and the planimetric features are extracted from the point cloud.
10. The data is output into LAS and MicroStation DGN/DWG files.
11. Photogrammetry staff emails the region survey coordinator with notification of completed project. Files are stored in the File Cabinet archival system for retrieval by region staff. Scans and files are also stored on the LiDAR drive for retrieval of data as needed.

FDM 9-45-30 Unmanned Aircraft Systems (a.k.a. UAS, UA, UAV, Drones) *April 16, 2015*

Unmanned Aircraft Systems (UAS) are an emerging technology which can be used to collect surveying and mapping information. Small UAS can employ light-weight digital cameras or LiDAR sensors for this purpose. These systems have advantages over traditional surveying and mapping methods in some situations, such as collecting data in areas that are difficult to access or dangerous. Small UAS can also be purchased and operated at relatively low cost.

At this time, the FAA requires a permit for operation of UAS and severely restricts use for safety reasons. A licensed pilot and special procedures are required for operation of UAS. A permit contains restrictions on operating a specific UAS for a limited period of time in a particular location or area. Generally, operations are not allowed above 400 feet, at night, near heavily populated areas, or near airports or manned aircraft.

For governmental operations, a Certificate of Authorization or Waiver (COA) may be issued by the FAA. COAs have been issued for law enforcement, firefighting, border patrol, disaster relief, search and rescue, military training, and other governmental missions.

For non-governmental (civil) operations, a Special Airworthiness Certificate, Experimental Category may be issued. Very few permits for commercial operations have been issued to date. Research and development, flight and sales demonstrations, and crew training are common operations allowed under Special Airworthiness Certificates.

The FAA is working to develop regulations which would safely integrate the operation of UAS into the national airspace. At the same time, privacy concerns have prompted the introduction and passage of legislation intended to restrict UAS operations in some states.

The Surveying & Mapping Section is leading an effort to learn more about UAS and to research and document areas of potential use. For more information, contact the Photogrammetry Unit Supervisor or visit the FAA website: http://www.faa.gov/uas/.

FDM 9-45-35 Ground Control *November 15, 2024*

Ground control is necessary to orient and position the imagery and/or LiDAR data relative to the ground. Almost every phase of photogrammetry requires targeted ground control or image points that are visible on the imagery. Field surveying is necessary to set monuments, lay targets, and establish ground coordinates.

Ground control surveys may be done in conjunction with performing primary (FDM 9-1-5.3) and secondary (FDM 9-1-5.4) control surveys for the project.

For information on ground control for static LiDAR, see (FDM 9-45-20.2.1).

35.1 Target Document

The target document, usually a raster image provided as a PDF for aerial LiDAR or imagery or a Google Earth KML for mobile LiDAR displays the name and location of all needed ground control. The name of each control point will be preceded with a letter; the following naming convention is used:

- H for horizontal control
- V for vertical control
- T for horizontal and vertical (total) control
- W for water elevation

A ground control point file is an ASCII file with an extension of GCP or TXT. This file lists the desired locations of the targets (point name, latitude, and longitude) used to guide the surveyor in selecting the target locations. The exact position is not as critical as the location attributes: relatively flat (avoid ditches or slopes), free of overhead obstructions, and preferably on hard surface (pavement). Ideally, the actual location should be within +/- 50 feet of the desired location for aerial acquisition or +/- 10 feet for mobile LiDAR acquisition.

The region survey coordinator and the survey crew chief should review the target document. If any target positions must be changed to fit existing field conditions, the surveyor should ask Photogrammetry staff for guidance since certain basic criteria for the layout of ground control must be met.

Attachment 35.1 provides guidance regarding: the location of the targets; the design and placement of the targets and monuments; and the appropriate target materials.

35.2 Surveying Photogrammetry and LiDAR Targets

All ground measurements should be made to the horizontal center of the monument or image point.

When an image point is used for ground control, the description must be recorded in the survey report as a part of the field observations.

Note that the region survey unit in consultation with the Central Office Surveying & Mapping Section may require additional or revised procedures for specific situations/projects.

35.2.1 Horizontal Targets

The same procedures should be followed for photogrammetry and LiDAR targets.

35.2.1.1 Using Conventional (Non-GPS) Survey Techniques

All measurements shall meet third order, Class I horizontal accuracy specifications, see FDM 9-35-5 (minimum closure of 1:10,000).

35.2.1.2 Using RTK GPS Survey Techniques

All horizontal coordinates shall meet the requirements of PROJECT CONTROL SPECIFICATIONS described in FDM 9-30 Real Time Kinematic (RTK) Surveys.

35.2.2 Vertical Targets

All LiDAR projects shall have conventionally leveled elevations. Specifications for surveying elevations are noted in FDM 9-45-35.2.2.1. GPS derived orthometric elevations are not acceptable.

All ground measurements should be made as follows:

- For all elevations obtained on soft-surfaces without a monument, caution shall be used when placing the prism/rover pole point so that it remains at ground level. The use of a ‘‘flat foot” at the end of the pole may also be considered. This is not an issue if a level rod is used.
- To the center of the monument or image point. If the monument for the target is not flush with the ground (±0.04 foot), then note the difference in the Ground Control CSV file and/or take the measurement at ground level. When there is a difference between the monument and ground elevation, it is good practice to note next to the elevation on what surface the elevation was obtained (ground or monument).

  Examples:

ID	Elevation
T101	965.21 (Monument)
T101	965.05 (Ground)

ID	Elevation
T101	965.21 (Monument)

  CM: NOTE THAT THE MONUMENT PROJECTS +0.16’ ABOVE THE GROUND

ID	Elevation
T102	981.50 (Monument)

  CM: NOTE THAT THE MONUMENT IS RECESSED -0.17’ BELOW THE GROUND

35.2.2.1 Using Conventional (Non-GPS) Survey Techniques

All vertical measurements should be made to Project-Order vertical accuracy specifications as detailed in FDM 9-40-5. Section or loop misclosure shall be better than 0.06 ft x $\sqrt{M}$ where M is defined as the distance in miles of the shorter one-way length of section, or loop. For any loop length M shall not be less than 1.0.

35.2.2.2 Using RTK GPS Survey Techniques

All vertical coordinates shall meet the requirements of PROJECT CONTROL SPECIFICATIONS detailed in FDM 9-30 Real Time Kinematic (RTK) Surveys.

35.2.3 Total (Horizontal and Vertical) Targets

All measurements should meet criteria in FDM 9-45-35.2.1 and FDM 9-45-35.2.2.

35.2.4 Digital Images and Sketches of Targets

All targets and image points should be supplemented with digital images and/or sketches.

Folder and File naming:

- Images shall be jpg format.
- It is preferable that the JPG filenames be in an Arial, ALL CAPS font.
- All target images will be placed in an electronic folder entitled with the project sy_archival name (i.e. SY_3DUCKCRK) as it appears on the target document.
- At a minimum, the following types of images should be taken:
  - Eye Level- An image of the target from eye height. It is recommended that the image be offset (non-vertical) to better show any height or depth variations near the target.
  - Horizontal- Image(s) taken horizontally to show target and its relation to any reference objects. The direction of the horizontal image should be noted in the image name (below). For targets in a road right-of-way, an image from the road is advised. More than one horizontal image should be taken. Use a bipod/range pole or other object to indicate location of the target if difficult to see.
  - Take as many images as necessary of the same type (i.e. eye level or horizontal in the northwest direction) to capture necessary information. Number the images ...-3N.JPG, -4N.JGP, etc.

    - Other images may be required by the WisDOT region.

JPG files of target locations shall be named in the following format:

- Format shall be: POINT NAME-DATE-IMAGE#&DIRECTION.JPG
- Point name is indicated on the target document and in the GCP file
- Date with year in 4-digit format and 2-digit month and day (YYYYMMDD, no spaces)
- Image Number- a sequential number for each image taken of a target.
    - For eye level images, a direction is not necessary. It is preferred that the eye level image have lower sequential number(s).
    - For horizontal images, an image number and camera direction (N, S, E, W, NE, NW, etc.)
- The point name, date and sequence/direction items should be separated by a hyphen.

Examples

- For eye level images-T101-20110215-1.JPG, T201-20150217-1.JPG, T201-20150217-2.JPG.
- For horizontal images-T101-20110215-2N.JPG, T101-20110215-3NW.JPG, T101-20110215-4NW.JPG.

Sketches of ground control locations relative to nearby features may be made in lieu of images. Please use WisDOT form DT2262 - Control Survey Station Record for sketches.

35.2.5 Survey Data File Formats

Any Survey Data File Format that is acceptable to the Department should be specified in the Work Order contract. All formats shall be electronic and be compatible with Civil3D. The WisDOT region survey data coordinator in consultation with the region survey coordinator and Central Office Surveying & Mapping Section will determine if a format is acceptable to the Department.

LIST OF ATTACHMENTS

Attachment 35.1 Geospatial Targeting Guidelines

FDM 9-45-40 Computation, Documentation and Distribution — November 15, 2024

40.1 Computation

40.1.1 Choice of Horizontal and Vertical Control Datum

The WisDOT region survey coordinator shall determine the appropriate horizontal and vertical control datum for geospatial projects. The survey coordinator is charged with overseeing the region’s survey projects, and generally knows best what other geodetic survey control exists in the area of a new project. The survey coordinator is best suited to decide which datum should be used for a new project. Unless there is strong evidence to the contrary, any new project should be on the most current geodetic survey datum and adjustment (see FDM 9-20-15, FDM 9-20-20 and DT1773).

40.1.2 Horizontal and Vertical Ground Control

All new photogrammetry projects shall be tied to the Wisconsin Height Modernization (HMP) passive geodetic survey control stations in the project vicinity unless the region survey coordinator has granted specific permission for the project to tie to other geodetic survey control monuments.

For projects not using the most current geodetic survey datum and adjustment, the region will provide a list of geodetic survey control stations to be used for a project. The list will include:

- Metadata associated with the station control listing within the Ground Control CSV file (see FDM 9-45-40.3.1.2)
- Station name
- Monument type of every station
- Grid horizontal control values to be used for each station (if applicable)
- Elevation of each station (if applicable)
- General location of station and station ties
- Any other pertinent details regarding the station(s)

In all cases, the region survey coordinator, if necessary, in consultation with the Central Office Geodetic Surveys Unit may designate other horizontal and vertical geodetic survey control stations and control station elevation/coordinate values that may be used for a photogrammetry project. Instructions on how to proceed with any other special circumstances will come from the Region Survey Coordinator.

40.2 Naming Standards

File name and folder structure standards exist for Ground Control CSV, LiDAR, mapping, and DTM data files.

The Region Survey Data Coordinator will provide ground control, map check data and project control data to the Surveying and Mapping Section using the Ground Control CSV format.

The Photogrammetry Unit delivers mapping and DTM data extracted from LiDAR and aerial imagery to the Regions by archiving the WSI, mapping, and DTM data files in File Cabinet and sending an email listing the project archival name, the file names and associated metadata.

The archival name for each geospatial project consists of: SY_, a number representing the original District number for the regions, and an abbreviation of the requested limits of the project. A number at the end generally indicates a portion or all of a project area was flown again and the number indicates the year of the flight. An “f” at the end usually indicates the project was flown as a “finals” after construction. The archival name is created by the Photogrammetry Unit.

Examples of archival names:

- SY_2BURL (Burlington – STH 100)
- SY_2BURL98 (partial flights around Burlington in 1998)
- SY_2BURLF (finals flown in 2008)

A copy of the files and data for each LiDAR project shall be stored on the central LiDAR server maintained by the Photogrammetry Unit. The region may also have a copy on their local server to improve performance. The Region Survey Data Coordinator or Photogrammetry staff will copy the data to the server using the conventions outlined in Attachment 40.1.

The mapping file naming standards have changed over time; this section describes the old and new versions since the region staff continue to access the older files. Prior to 2013, the mapping was delivered as a separate file for each stereo model that was used to compile the mapping. A one-mile project may have had six mapping files.

Mapping files with all numbers in the name are in Wisconsin State Plane Coordinate System. If there are nine numbers, then it is the roll number of the film for the project and the numbers for the left and right exposures used to create the stereo pair; e.g. 938100101.dgn is roll number 938 and exposures 100 and 101. If there are eight or fewer numbers then it is the strip number and the numbers for the left and right exposures used to create the stereo pair; e.g., 8201202.dgn is strip 8 and exposures 201 and 202.

Mapping files with four or more numbers followed by three letters are in WISCRS. See Attachment 40.2 for a listing of the county abbreviations. For example, 1255stc.dgn is strip 1, exposure 255 and it is in St. Croix County.

Since 2013, all of the mapping files for a project have been combined into one merged file called m(archival_name).dgn and .dwg. For example, m1orev16.dgn and m1orev16.dwg, contain the mapping data for the 2016 project that was south of Oregon. The .dgn file is a 2D MicroStation V8i file. The .dwg may be a 2010 or 2013 2D AutoCAD file. A project may contain more than one .dgn and .dwg file if the project extends into more than one county. The mapping will be delivered according to the county. For example, m6eauclrchp.dgn, m6eauclrchp.dwg, m6eauclreau.dgn, and m6eauclreau.dwg are in Eau Claire and Chippewa counties.

The DTM data is collected in a separate 3D MicroStation file for each stereo model that was used for the compilation. The naming format is the same as the compiled mapping files. Usually, the DTM data is compiled into the same files as the mapping data. These 3D files are in File Cabinet with an extension of DEM and are not used by region staff. The individual 3D MicroStation DTM files are merged by the Photogrammetry Unit to create one or more 3D MicroStation files. The DTM data is then extracted from the 3D files to create an ASCII .SRV file that is a proprietary format for CAiCE and Civil3D. The SRV file names have changed as the WisDOT has changed operating systems. All SRV files created on the Windows OS NT, XP or 7 are prefaced with the letters NT, XP, or D, respectively. If the SRV is not prefaced with NT, XP or D then the SRV was extracted using the UNIX OS.

A project may have one or more SRV files if the project is very large or crosses into multiple counties. D1orev16.SRV is the DTM data set for the 2016 project east of Oregon. D6eauclrchp.SRV and D6eauclreau.SRV contain the DTM data for a project that extends into Chippewa and Eau Claire counties.

A listing of the contents of the SRV files is provided in a companion file with an extension of LIS, LOG or XLSX. The UNIX SRV files have a LIS file. The NT and XP files have a LOG file and the Windows 7 SRV files have an

.XLSX file.

Each archival project for aerial imagery has at least one Adobe Acrobat file associated with it referred to as a model diagram. This file has rectangles to show the coverage of each stereo model from the imagery. The model diagram is named m, district number, archival name.PDF, for example, m1orev16.pdf. There is only one model diagram even if a project is in multiple counties. The metadata on the PDF indicates each county name.

40.3 Documentation and Distribution of Ground Control

A ground control book or electronic folder will be created and maintained for every geospatial project. For consultant survey projects, the consultant will create a ground control book under the direction of the Region Survey Coordinator. This ground control book will then subsequently be maintained by the region's survey unit. For in-house survey projects, the region survey unit will create and maintain the project book.

Any relevant information regarding the survey of a project should be contained in the ground control book. This information will be retained by the region survey unit and should be used as a resource for information regarding the survey of and the products created for a project.

40.3.1 Ground Control Book/Folder

The ground control book should contain the following items.

40.3.1.1 Model Diagram

Prepared and provided by the Central Office Surveying & Mapping Unit. The model diagram is typically on a County map base for standardization.

40.3.1.2 Aerial Index/Ground Control CSV File

The aerial index/ Ground Control CSV file contains control, target, and other survey related coordinates. See Attachment 40.3 for a sample Ground Control CSV files.

Suggested metadata header Information:

Project ID: 1067-02-07	<8-digit WisDOT Project ID>
Highway: I-94	<Project Roadway use I-XXX, USH XX, STH XXX, CTH XX>
Project: Lake Mills – Oconomowoc	<Project Limits>
County: Jefferson County	<County Project is in>
Coordinate System: WISCRS	<Horizontal coordinate system>
Zone: 9628	<Zone number (See Attachment 40.2)>
Horizontal Datum: NAD 83 (2011)	<Horizontal datum and adjustment year of project>
Vertical Datum: NAVD 88 (2012)	<Vertical Datum and adjustment year>
Geoid: GEOID18	<Name of Geoid used for survey>
Units: US Survey Feet	<Units of Length>
Summary By: Shawn Meyer - WisDOT	<Creator of CSV including firm name>
Date: 9/05/2024	<Date Created>
Revised by: Shawn Meyer – WisDOT – Added Validation Points	
<Name of people and firm for subsequent revisions>	
Date: 9/18/2024	<Date of subsequent revision>
Horizontal Data Collection Method: T101-T120 RTK, Except T109 Total Station	
<Vertical Data Collection>	
Vertical Data Collection Method: T101-T112 Level, T113-T114 Total Station, T115-T120 RTK	
<Horizontal Data Collection>	
Comments:	<Use as many lines as necessary>
Horizontal and Vertical Calibration completed on 6/14/2024	
Level Loop completed on 6/15/2024	

Ground Control CSV naming examples:

1. Cntrl-Targ-Aerial_I94_1067-02-07.csv.
2. Rev4sclmont_STH22_6054-06-02_GC.csv

40.3.1.3 Project Correspondence

- Desired mapping limits
- Special mapping requests
- Image point correspondence
- Horizontal and vertical adjustment problems/concerns
- Miscellaneous notes, memos, field crew comments etc...
- Correspondence between the Region and Central Office.

40.3.1.4 All Relevant Coordinate Determination Reports

- Point Derivation Reports
- Horizontal and Vertical Calibration Reports
- Level loop closures
- Any other reports relevant to the project
- Least squares adjustment reports

40.3.1.5 Geodetic Control Station Files

- Copies of control used for project. Typically, will be NGS Control Sheets, but may include USGS data, County HARN control, etc.)

40.3.1.6 Reference Ties/Photos

- Any target images taken mentioned in FDM 9-45-35.2.4.
- May include reference ties for all horizontal control points and picture image points (written description, location sketch, and visibility diagram).

40.3.1.7 Target Document

- Include the original target document
- Show any changes in target location, annotation, or additional targeted points.

LIST OF ATTACHMENTS

Attachment 40.1	Naming Standards for Folders and Files on the LiDAR Server
Attachment 40.2	Wisconsin County Coordinate System Numbers and Abbreviations
Attachment 40.3	Sample Ground Control CSV Files