IOWA INSTRUCTION 210-385 – LiDAR FOR ENGINEERING

1. PURPOSE:

   This information provides guidance to maximize the appropriate use of elevation data collected via LiDAR (Light Detection and Ranging) for the planning and design of engineering conservation practices in Iowa.

2. BACKGROUND:

   Statewide LiDAR data collection for Iowa occurred from 2007 to 2010.

   LiDAR provides an immense amount of elevation data and it is important to determine the appropriate use of that data for engineering projects.

   The data quality can be affected by canopy, ground cover, and collection method. The type of engineering project determines what quality of data is needed for planning purposes and for final design purposes.

3. EXPLANATION:

   Iowa LiDAR Acquisition (2007-2010): Specifications & Data Delivery

   Two categories were used for the LiDAR specifications in Iowa. LiDAR data for about 80% of the state will meet a "Standard LiDAR" specification while the remaining 20% will meet a "FEMA Compliant" specification.

   The horizontal and vertical accuracy for both Standard & FEMA specifications are the same, with the differences involving the verification process and the removal of bad points. The vertical accuracy in the specifications is listed as Root Mean Square Error (RMSEz). A comparison of Standard and FEMA specifications are shown in Table 1.

   NRCS and Iowa DOT provided GPS bare earth field survey across the state in order to allow additional quality assurance of the data delivered.

   Metadata about the LiDAR provides an indication of the how the data was collected. Example Metadata: Block- CSW 11

   Airborne LiDAR Flight Details
   Flight Altitude – 4600 feet
   Airspeed - 120 - 140 knots
   Field of View - 40 degrees
   Avg. Point Spacing - 12.9 square feet
   Pass Spacing – 2340 feet
   Survey Baseline Distance – 28 miles

   The LiDAR data provided by the vendor consists of LAS files and XYZI files. The LAS files include the bare earth along with vegetation, buildings, and other points. The XYZI files contain only points considered to be bare earth. No breakline information was produced.

Table 1. Iowa LiDAR Data Specifications

	Standard LiDAR	***FEMA Compliant LiDAR***
Average Point Spacing	4.6’	4.6’
Vertical Accuracy -Bare earth, $RMSE_z$ -Vegetation, $RMSE_z$	 0.6’ 1.2’	 0.6’ 1.2’
Horizontal Accuracy, $RMSE_r$	3.3’	3.3’
Breaklines	None	None
Filtering removal	Automatic Only	Automatic & Manual
Artifact removal	89%	90%
Outlier removal	90%	95%
Vegetation removal	90%	95%
Building removal	95%	98%
Other	---	Field Verification

4. LIMITATIONS OF LiDAR:

a. *Site changes* - LiDAR data is snapshot of the elevations on one day in time and does not reflect any changes to a site due to erosion or construction activities.

b. *Grade breaks* - LiDAR data is gathered using a random pattern of collection, not at changes in grade as a field survey would. This may cause a misrepresentation of ditch bottoms, banks, and other important grade breaks.

c. *Vegetation* – Ground cover at the time of data collection may cause the ground to appear higher than actual. Tillage may affect the surface smoothness. Canopy may provide a reduced density of ground points, in turn reducing the accuracy of a surface model developed.

d. *Site specific features* – Items that need labeling are not identified well by LiDAR. Examples:

- Exposed geological features
- Fences
- Wells
- Underground utility markers
- Property line boundaries & elevations
- Culvert inlets & outlets
- Tile intakes & outlets
- Road right-of-way
- Power poles
- Buildings

e. *Water* - Elevations below water level are not able to be determined with this type of LiDAR equipment. LiDAR elevation points collected within water features such as ponds, lakes, and rivers, have an unknown accuracy, and should not be considered valid.

5. LiDAR SURFACES AND ACCURACY:

Surfaces

TIN – Triangulated Irregular Networks are surface representations based on triangles built between points and their nearest neighbors. This surface representation of LiDAR is the closest to the true surface if all bare earth points are used and if breaklines are utilized.

DEM – A Digital Elevation Model is a surface representation using a uniform grid spacing. It is derived from a TIN as the source surface for the grid sampling.

Contours – Contours lines are a feature that can be developed from TIN or DEM surfaces. Using contour lines as a source to create a surface downgrades the accuracy.

Point vs. Surface Accuracy

The Root Mean Square Error (RSMEz) value of the LiDAR data can be used to compute the maximum elevation error expected for the best 95% of the points (95% Confidence Level). Table 2 shows the 95% confidence levels of point errors and the supported contour intervals associated with the accuracies in the Iowa LiDAR project specification.

Table 2. Iowa LiDAR Vertical Accuracy Specifications

	Root Mean Square Error, RMSEz (ft)	***95% Confidence Level, Error (ft)***		***Contour Interval Supported (ft)***
Bare-earth	0 6’	1.2’		2’
Vegetation	1.2’	2.4’		4’

Increasing the grid spacing of a DEM to a value larger than the spacing of the original data can reduce the resulting accuracy. Creating a TIN using only a sampled percentage of the points can also reduce the resulting accuracy of the surface.

Applying a “smart thinning” process to a TIN can reduce the number of points used while maintaining accuracy by evaluating whether point deletion adversely affects the surface.

The TIN model may be preferable to a DEM when it is critical to preserve the precise location of narrow or small features in the data model, such as levees, or ditch or stream centerlines.

6. USE OF LiDAR FOR CONSERVATION ENGINEERING PRACTICES:

Planning

Using the Iowa LiDAR data in the form of TIN or DEM surfaces or Contour lines is very well suited for planning all engineering practices.

Final Design

The following examples show surface accuracies needed for final design of portions of engineering practices and how LiDAR might be able to be used.

a. Dams

	Accuracy Needed & *How Obtained*
Stage – Storage Computation	4' Contours *-LiDAR*
Earthwork	1' Contours -Field survey or -LiDAR w/ Survey verification*
Elevations & locations – Property line, downstream toe, CL embankment, ditch bottom elevations	*-Field Survey*
Benchmark & Control Points	-Survey Grade GPS Field survey

b. Grassed Waterways

	Accuracy Needed & *How Obtained*
Stable Outlet	-Field verification*
Grade (Waterways S > 2% & DA<30 acres)	4' Contours *-LiDAR*
Grade (Waterways S < 2% or DA>30 acres)	2' Contours *-Field survey* or *-LiDAR w/ Survey verification**
Elevations for Machine controlled construction	1' contours *-Field Survey* -LiDAR w/ Survey verification*
Benchmark & Control Points	-Survey Grade GPS Field survey

c. Terraces & Basins

	Accuracy Needed & *How Obtained*
Tile Outlet	-Field verification*
Storage	2' Contours if > 5' deep 1' Contours if <= 5' deep *-Field survey* or *-LiDAR w/ Survey verification**
Earthwork	1' Contours *-Field survey* or *-LiDAR w/ Survey verification**
Benchmark & Control Points	-Survey Grade GPS Field survey

d. Animal Waste Management

	Accuracy Needed & *How Obtained*
Stage – Storage Computation	1' Contours *-Field survey* or *-LiDAR w/ Survey verification**
Earthwork	1' Contours *-Field survey* or *-LiDAR w/ Survey verification**
Elevations & locations – Buildings, lots, fences, wells	-Field Survey
Benchmark & Control Points	-Survey Grade GPS Field survey

e. Wetland Topography Enhancement

	Accuracy Needed & *How Obtained*
Earthwork	1' Contours *-Field survey* or *-LiDAR w/ Survey verification**
Elevations & locations – Property lines	-Field Survey
Benchmark & Control Points	-Survey Grade GPS Field survey

f. Wetland Storage

	Accuracy Needed & *How Obtained*
Stage – Storage Computation	1' Contours *-Field survey* or *-LiDAR w/ Survey verification**
Earthwork	1' Contours *-Field survey* or *-LiDAR w/ Survey verification**
Elevations & locations – Property lines, downstream toe, CL embankment	*-Field Survey*
Benchmark & Control Points	-Survey Grade GPS Field survey

*Survey verification of LiDAR includes the following:

1. Establish on-site benchmark & control points (see GPS surveying instructions).
2. Gather site specific survey (see 4B, 4D, & 4E).
3. Determine if current site conditions are reflected correctly by LiDAR (see 4A).
4. Verify local elevation accuracy due to vegetation (see 4C) and relative to survey datum.

*Field verification consists of:

1. On-site visual inspection or
2. Field survey.

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