Introduction

Intended as the first in a series of workshops related to LiDAR and allied analyses, “Basics of LiDAR” will serve as both a prerequisite and jumping-off-point for following workshops:

- Terrain Analysis
- Hydrologic Applications
- Engineering
- Wetland Mapping
- Forest and Ecological Applications

Conservation Applications of LiDAR Data

Workshops funded by:
Minnesota Environment and Natural Resources Trust Fund

Presented by:
University of Minnesota
Co-sponsored by the Water Resources Conference

In collaboration with:
Minnesota Board of Water and Soil Resources
USDA Natural Resources Conservation Service
Minnesota Department of Natural Resources

Presented by:
University of Minnesota, Dept of Soil, Water, and Climate

Basics of Using LiDAR Data

Joel Nelson
Univ of Minnesota, Dept of Soil, Water, and Climate

Basics of Using LiDAR Data

tsp.umn.edu/lidar

Introductions - Logistics

Course Instructor – Joel Nelson
Workbooks
Breaks
Restrooms

Basics of Using LiDAR Data
Introductions – Student Intros

Students
- Who uses ArcGIS 10?
- Who uses LiDAR data currently?
- Who calculates products or does raster processing from LiDAR data?

Course Objectives

Lecture and Hands-on Format
- Raster Data
- What is LiDAR?
- LiDAR Products

Lecture 1 – Raster Data

About Raster Data

Raster Data
- Less used today than the vector data model
- Raster environment and principles not as well understood
- Most users familiar with aerial photos or satellite imagery

Raster Data

Structure/Model
- Regular set of cells in a grid pattern
- Typically square
- Attribute values associated with each location (cell)
- Models “continuous” data well

Key features
- Cell size
- Units

Basics of Using LiDAR Data
**Raster Data Analysis - Advantages**

- History
- Flexible
  - Data structure
  - Wide range of variables
  - Simple to complex – single cell, networks, groups of cells
  - Well-developed
  - Wide variety of applications
- Continuous Data – i.e. elevation

**Raster Data Analysis – Disadvantages**

- Precision limited to cell size
  - Tradeoff – higher resolution comes at greater storage cost and speed of processing
- “Stairstep” edges
- Often assigned a single “value” for a single attribute rather than a host of attributes per cell

**Raster Data Analysis**

- Basic to complex
- Mathematical (Map Algebra), neighborhood (moving window) distance, surface, statistical, etc.

**Map Algebra – Raster Calculator**

- Raster layers combined via mathematical combinations
- Cell-by-cell – added, subtracted, divided, or multiplied

**Variety of uses**

- Change detection – e.g. year 2000 data subtracted from year 2010 data
- Terrain attributes – e.g. SPI – multiply effect of one variable by another

**Working with Raster Data**

**Neighborhood Functions**

- Moving window of cells swept across all raster cells, typically multiplying values by data found around center cell
- Very common in raster analysis
- Slope, hillshade, filter, and kriging calculations for example, all employ a moving-window approach
Working in the Raster Environment

Raster = Grid
- File Structure
- Grid Alignment
- Resampling
- Aggregation

File Structure
Arc GRIDS are not single files
- Several folders with associated files
- Linked – cannot work independent of one another
- Use ArcCatalog to copy, move or rename
- Can export into variety of single file-types – .img, .e00, etc.

Grid Alignment
Proper Grid Alignment = Snap Raster Settings

Snap Raster Setting
- The cells in the output raster are aligned with the cells of the snap raster.
- The lower-left corner of the extent is snapped to a cell corner of the snap raster.
- The output cell size is same as the snap raster cell size.

Resolution
Cell size should be same for all inputs
If not →
- Nearest neighbor resampling automatically occurs
- Resampled to coarsest resolution of all inputs
- Esp. not recommended for continuous data – i.e. Elevation

Aggregate/Resample
- Changing the resolution (Upscaling) – if cells evenly divisible, use AGGREGATE
- If not evenly divisible or changing the alignment, then use RESAMPLE
- You can downscale, but this does not create any new information

Elevation Data - DEMs
Raster Elevation Data Sources

- Stereo photography
- Topographic maps (elevation contours)
- Ground survey (GPS, other)
- LiDAR

Stereo Photography

- View shape of topographic surface
- Overlapping photographs
- View from two perspectives (parallax)
- Old technology – has been used extensively in Soil Survey and forestry

Topographic/Contour Data

- Also called contour maps
- Contour line joins points of equal elevation
- Can interpret slope, relief, shape/size of valleys and hills
- Paper and digital
  - Digital leaves visualization up to the user

Survey

- GPS survey or Total Station
- Small areas
- Labor intensive
- Very precise

Raster Elevation Data Formats

Models of Topography

- Multiple ways of representing elevation
  - Triangulated irregular network
  - Contours (Vector)
  - Digital elevation model (Raster)

Each has advantages and disadvantages

DEM is used most often for terrain analysis and watershed delineation

Digital Elevation Model (DEM)

What is a DEM?

- Digital file that:
  - Contains elevation of terrain over a specified area
  - Is arranged as a fixed-grid interval over the earth surface
  - Is geo-referenced
  - Can be manipulated to create other elevation-dependent data products
Digital Elevation Model (DEM)

- Consists of pixels or cells
- Value assigned represents average elevation of grid cell

DEM Characteristics

Resolution
- Density of elevation measurements
- Determines level of detail of surface representation
- 30m coarse – 1m fine

Interpolation
- Calculation used to find elevation of unspecified location
- Various techniques/algorithms: Kreiging, Theissen Polygons, Spline, IDW, Bilinear, Nearest Neighbor

DEM Comparison

Why so much interest in LiDAR?
- Higher resolution data than we ever thought possible
- Opens up opportunities to describe and characterize landscapes in ways previously not feasible

Comparison to existing national standard product

<table>
<thead>
<tr>
<th></th>
<th>USGS DEM</th>
<th>LiDAR DEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal Resolution</td>
<td>30 meters</td>
<td>~1 meter</td>
</tr>
<tr>
<td>Vertical Resolution</td>
<td>7-15 meters</td>
<td>~15 cm</td>
</tr>
<tr>
<td>Contour Interval</td>
<td>5-20 feet</td>
<td>1-3 feet</td>
</tr>
</tbody>
</table>

DEM Resolution Tradeoff

Lower resolution = faster processing
Higher resolution = more precision, maintains small features
**Basics of Using LiDAR Data**

**DEM Comparison**

USGS 30m DEM

LiDAR 3m DEM

**USGS Standard DEM**

Cell Size: 30 meter sq
Vertical Error: “Equal to or better than 15 m.”

1600 points / sq mile

**LiDAR Derived DEM**

Cell Size: 1 meter sq
Vertical Error: 15 cm

1.5 mil points / sq mile

1 Varies based on project specifications
2 http://edc.usgs.gov/guides/dem.html

Credit – Tim Loesch - MNDNR

**DEM Comparison**

10-meter DEM from contours

12:41 DEM from LiDAR

**USGS 30 meter Elevation Data**

**LiDAR 3 meter Elevation Data**

**Hillshade DEM 3m vs 30m**
Contour Comparison – Vector Product

2 ft contours created from LIDAR data
10 ft contours created from standard 30m DEM data

End of Lecture 1
Questions/Comments?

Lecture 2 – What is LiDAR?

LiDAR

What is LiDAR?
- Light Detection And Ranging – a remote sensing system used to collect topographic data
- Produces high-resolution, accurate, land-elevation information

LiDAR Survey Equipment

Light Detection and Ranging
- Laser Rangefinder
- IMU (INS)
- GPS
- On board computer
Produces accurate land elevation data

LiDAR

How is LiDAR data collected?
Airborne survey:
- Covers the surface with multiple discrete laser pulses
  - Up to 150,000 per second
- Collects the returns
  - Time = distance + GPS = Location

Basics of Using LiDAR Data
LiDAR Survey Equipment

Laser Rangefinder
- Records distance to target
  - Time * c / 2
- Wavelengths differ
  - 1064 nm
- Various scan rates

LiDAR Survey Equipment

Inertial Measurement Unit (IMU)
- Gyroscopes and accelerometer
- Records roll, pitch, yaw of aircraft
  - .005 degree pitch & roll
  - .008 degree heading

LiDAR Survey Equipment

Global Positioning System (GPS)
- Differentially corrected
- Provides cm accuracy of aircraft
- Allows cm accuracy of laser pulse

LiDAR Survey Equipment

On board computer
- Records data
  - Laser distance and intensity
  - IMU info
  - GPS info
- Converts into
  - X, Y, Z
  - Millions of points
- On-board display

LiDAR Data Resolution

Based on collection density
- 1 point/meter to 8 points/meter with ground control point validation
- Supports 2 foot contours to sub 1-foot contours depending on collect

LiDAR Products

- End-product is accurate, with geographically registered longitude, latitude, and elevation (x,y,z) for every data point
- Several file types and derivative products available to end-users
- LAS point cloud, DEM, contours, hydrologic breaklines
**LiDAR Data Collection**

LiDAR Returns: Multiple discrete return pulses

LiDAR Intensity: Magnitude or strength-of-return pulse

Metadata: Information about how data was collected—READ IT!

All returns can be used
- Forest canopy
- Intensity image
- Vegetation mapping

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**Intensity**

- Intensity = amount of energy reflected for each return
- Different surfaces reflect differently based on wavelength of laser
- Example at 1064nm (NIR), water absorbs, vegetation highly reflective
- Can be used to build black and white near-IR images
Minnesota Mapping Initiative

In the beginning ...

- Red River Collect – 2006
- Obi Sium – DNR Waters/FEMA
- Technical Group to develop standards
  - Governor’s Council on Geographic Information
    - Digital Elevation Committee
      - Working to achieve publicly available, high accuracy elevation data statewide
      - Federal, State and County representatives

High Resolution Elevation Data?

Credit – Tim Loesch - MNDNR

Minnesota Mapping Initiative

Several unsuccessful attempts to secure funding at the state level

Worked with counties to ensure consistent data
- Technical advice and assistance
- Standards and accuracy

Minnesota Mapping Initiative

Clean Water Fund of the Legacy Amendment
- Citizens of the state have invested in Water Quality
- High Resolution Elevation data can be used for all future water quality projects

Secured $5.6 million in funding
- Funds in Division of Ecological Resources/Waters
- Project led by Management Resources/MIB

Credit – Tim Loesch - MNDNR

Minnesota Mapping Initiative

Multi-Government Partnership
- USGS, EPS
  - Technical Advice
  - Potential funding opportunities
- MnDOT, MnDNR, MnGEO
  - GIS technical expertise
  - Project management
  - Survey and Validation Coordination
  - Data Coordination
- County and Local Governments
  - Survey Points and Data validation

Statewide LiDAR Coordination and Collaboration

Two committees are tasked with LiDAR data development, management, and deployment

1. MN Digital Elevation Committee
   - http://www.mngeo.state.mn.us/committee/elevation

2. MN Digital Elevation Committee - Research and Education Subcommittee
   - http://www.mngeo.state.mn.us/committee/elevation/research_education
   - Mission Statement:
     - Design and promote best practices with LiDAR data for Minnesota Ensure there is consistency in data development, application, and training.
   - Training:
     - Course Planning and Design
     - Survey
LiDAR Acquisition

Standards
- Defined by the MN Digital Elevation Committee
- Based on the recent USGS Base LiDAR Specification.
  - <= 15 centimeter RMSEz.
  - 2-foot vertical accuracy (95% confidence).
  - 1-meter horizontal accuracy.

Coordinate system
- UTM Zone 15, NAD83 horizontal datum.
- NAVD88 vertical datum Vertical units in meters.

LiDAR Status

LiDAR Data in Minnesota and Surrounding Area
Status and Availability 2/2012

MN LiDAR Data – What’s Available – What’s Not

Available for Download
- Elevation Data
  - Bare Earth points
  - DEM – 1m and 3m
  - Hillshade
  - Contours
  - Terrain/TIN
- Associated Data
  - Hydro Breaklines
  - Buildings

Calculate on your own
- Elevation Data
  - Hydrologically conditioned DEM
  - Custom resolution DEM or contours – e.g. 5m
- Derived Products
  - Slope
  - Flow Accumulation
  - Stream Power Index (SPI)
  - Compound Topographic Index (CTI)

MN LiDAR Project Activities

Point Classification
- Points are processed to determine what they bounced off of
  - Bare Earth
  - Buildings
  - Cars and other anthropomorphic things
  - Bridge decks
  - Vegetation (High, Medium, and Low)
  - Water
- ASPRS has developed a set of standard classifications for LiDAR derived data

Credit – Tim Loesch - MNDNR

National Digital Elevation Program (NDEP)
Status of Elevation Data

1996 - 2011
- 28% coverage - 49 states
- 15% coverage – Alaska
- 10-year replacement cycle
- Program is efficient – less than 10% overlap of coverage
- Cooperative data projects work
- Data quality variable

Why is this a problem?
- Remaining 72% coverage is old or more years old.
- Alaska – very poor quality
- More 15% of need. Current approach is merging needs requires more higher quality data.
MN LiDAR Project Activities

Point Classification
- Automated Classification
  - Can identify features with 70-74% accuracy
- Manual Classification
  - Needed to get higher accuracies
  - Typically done with Air Photos and other sources of data
  - Typically the most time consuming portion of any project and the most likely to be farmed overseas

MN LiDAR Data Validation

Vertical Accuracy QA/QC
- Purpose:
  - Data Validation – we got what we bought
  - Data Integrity – we want people to trust the data
- Compare LiDAR elevations with Surveyed Points
  - 100 surveyed validation points per county
  - 20 points in each of 5 cover categories
  - Help from county surveyors

LiDAR Error and Accuracy

What’s the value of your data?
How is accuracy measured?
- National Standard for Spatial Data Accuracy (NSSDA)
  - Addresses accuracy of the product at ground scale
  - Squared Root Mean Square Error (RMSE^2)
- National Map Accuracy Standard (NMAS)
  - Accuracy based on Contour Interval at published map scale

<table>
<thead>
<tr>
<th>NMAS Contour Interval Equivalent</th>
<th>NSSDA RMSE (z)</th>
<th>NSSDA Accuracy (z^2)</th>
<th>Required Accuracy for Tested Data for “Tested to Meet”</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>0.15 ft or 4.60 cm</td>
<td>0.30 ft or 9.10 cm</td>
<td>0.10 ft</td>
</tr>
<tr>
<td>1</td>
<td>0.30 ft or 9.25 cm</td>
<td>0.60 ft or 18.2 cm</td>
<td>0.20 ft</td>
</tr>
<tr>
<td>2</td>
<td>0.61 ft or 18.5 cm</td>
<td>1.19 ft or 36.3 cm</td>
<td>0.40 ft</td>
</tr>
<tr>
<td>4</td>
<td>1.22 ft or 37.0 cm</td>
<td>2.38 ft or 72.8 cm</td>
<td>0.79 ft</td>
</tr>
<tr>
<td>5</td>
<td>1.52 ft or 46.3 cm</td>
<td>2.98 ft or 80.8 cm</td>
<td>0.99 ft</td>
</tr>
<tr>
<td>10</td>
<td>3.04 ft or 92.7 cm</td>
<td>5.98 ft or 181.6 cm</td>
<td>1.98 ft</td>
</tr>
</tbody>
</table>

Error and Accuracy Comparison of NSSDA and NMAS

Error and Accuracy

- Validation Points
  - Level ground away from breaks in topography
  - Open, visible sky
- Five cover classes – 20 points per class (30 preferred)
  - L1O – Open terrain
  - L2T – Tall Grass
  - L3B – Brush
  - L4F – Forested
  - L5U - Urban
Error and Accuracy

Types of Accuracy
• Fundamental Accuracy = Best Case Scenario
  ○ Open terrain tested to 95% accuracy
• Supplemental Accuracy
  ○ Accuracy for Cover Classes other than Open terrain
• Consolidated Accuracy
  ○ All Cover Class Accuracies Combined

Error and Accuracy

RMSE Calculations
• \( \text{RMSE}_{(z)} = \sqrt{\text{sum}(Z_{\text{data}}(i) - Z_{\text{Check}}(i))^2 / n} \)
• Vertical Accuracy 95% Rate = \( 1.96 \times \text{RMSE}^2 \)

Error and Accuracy...

Report Summary

Error Mean:              -0.116
Error Range:             [-0.435,0.143]
Skew:                    -0.305
RMSE(z):                 0.161

Accuracy(z) (95% CI):   ±0.315

176 control points included in summary out of 176
- 8 control points returned no-data

Control Points

Error and Accuracy

Winona County Validation Points

LiDAR Project Activities

Open  Tall grass  Brush  Forested  Urban  Overall
LiDAR Project Activities
Winona County Validation Report

Accuracy Comparisons

<table>
<thead>
<tr>
<th>Contour Interval</th>
<th>NMAS 90% Conf</th>
<th>NSSDA 95% Conf</th>
<th>NSSDA RMSEz</th>
</tr>
</thead>
<tbody>
<tr>
<td>2'</td>
<td>1'</td>
<td>1.2'</td>
<td>0.6' 18.5 cm</td>
</tr>
<tr>
<td>4'</td>
<td>2'</td>
<td>2.4'</td>
<td>1.2' 37.0 cm</td>
</tr>
</tbody>
</table>

Accuracy and What it Means...
National Accuracy Standards Specifications
- USGS Base LiDAR Specifications V13
- NDEP Guidelines For Digital Elevation Data

LiDAR System
Limitations
- Cannot penetrate:
  - Water (near-infrared Lasers)
  - Heavy canopy cover
  - Rain, snow, clouds
- Limited window of opportunity to collect
  - Vegetation and snow free periods in the spring and fall
  - Flooding is bad too!
  - High winds hinder collection

End of Lecture 2
Questions/Comments?

Lecture 3 – LiDAR Applications and Products
**Basics of Using LiDAR Data**

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### Potential LiDAR Applications

#### Water Resources
- Floodplain mapping
- Storm water management
- Drainage basin delineation
- Shoreline erosion

#### Geology
- Sinkhole identification
- Geologic/geomorphic mapping

#### Transportation
- Road and culvert design
- Cut and fill estimation
- Archaeological site identification

#### Agriculture
- Erosion control structure design
- Soils mapping
- Precision farming

#### Water Quality
- Watershed modeling
- Wetland reconstruction
- Land cover/land use mapping

#### Forestry
- Forest characterization
- Fire fuel mapping

#### Fish and Wildlife Management
- Drainage and water control
- Walk-in Accessibility
- Habitat Management

#### Emergency Management
- Debris removal
- Hazard Mitigation

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**Credit – Tim Loesch – MN DNR**

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**LIDAR – Emergency Management**

- How much debris and where?
- Volume cut/fill statistics
- Aid Debris Removal

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**LIDAR**

- May 2004 – Pre-Ivan

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**LIDAR**

- September 2004 – Post-Ivan

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**Basics of Using LiDAR Data**

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LiDAR Applications

Bare Earth, Vegetative, and Structural Applications

Bare Earth Analysis

- Buildings and trees removed
- Automatic and manual filtering
- Shows bare earth surface DEM
- Provides elevation “base layer” for further calculations

Basics of Using LiDAR Data
Basics of Using LiDAR Data

**Bare Earth** – Example of Removing Artifacts
Initial Bare Earth Surface from LiDAR

**Bare Earth** –
Filtered Bare Earth Surface

**Bare Earth** –
Contours – Initial Bare Earth Surface

**Bare Earth** –
Contours - Filtered Bare Earth Surface

**Terrain Analysis**
Model real landscape processes
Utilize base layer DEM

**Hydrologic Modeling**
- Identify appropriate water conveyance
- Watersheds
Basics of Using LiDAR Data
Bare Earth DEM
(no vegetation or buildings)

Difference Image
– height of buildings and trees

Software
ArcGIS, IDRISI, Open Source GIS viewers
ArcHydro
TauDEM
LAS Reader
ArcMAP Extensions
LiDAR Analyst, LP360, etc
Stand-Alone Programs
MARS
AutoCAD
Civil 3D
Stand-Alone Viewers (free)
Qcoherent (www.qcoherent.com)
Fugro EarthData (www.fugroviewer.com)
Sanborn (http://www.sanborn.com/technologies/lidar.asp)

Software – Training Purposes
ESRI – ArcGIS
• Spatial Analyst
  o Hydrologic modeling
  o Raster analysis
• 3D Analyst (ArcScene, ArcGlobe)
  o Cut/Fill
  o Line of Sight
  o 3D Perspective

Spatial Analyst
ESRI Extension – Additional cost
Fairly robust set of general raster processing tools
• Surface (Slope, Curvature)
• Reclassify
• Zonal Statistics
• Conditional
• Neighborhood
• Raster Calculator
Some specialized tools
• Hydrology
• Groundwater

Basics of Using LiDAR Data
Basics of Using LiDAR Data

3D Analyst
- ESRI Extension – Additional cost
- Specifically designed for elevation data
- 3D visualization
- Creating & working with TINs
- Cross-section tool

ArcHydro
- Free Extension for ArcGIS (Maidment)
- Suite of tools for geospatial hydrology
- Semi-complicated install
- Terrain analysis focused on stream and watershed delineation
- Tools for analyzing sinks and reconditioning DEM
- AGREE

Tau DEM
- Free toolbox for ArcGIS 9.3 (Tarboton)
- Easy install
- Specialized terrain analysis tools focused on stream and watershed delineation
- Tools not found in the standard ArcGIS extensions or ArcHydro
- D-infinity flow direction

Whitebox GAT
- Free stand alone program (Lindsay)
- Open source
- Fairly robust suite of terrain analysis tools
- Handles LAS data (LiDAR)
- Many hydrologic analyses
- Uses Python as native language

Getting Ready for LiDAR – Hardware
- Bigger is better
- Workstations
  - Duo or Quad Core
  - > 3.0ghz
  - > 4Gb RAM
  - 256 RAM Display OPEN GL
- High Speed disks – storage is cheap
- External hard drive for backup

LiDAR Representations
Credit – Tim Loesch - MNDNR
LiDAR Representations

Point Cloud
Triangulated Irregular Network (TIN)
Raster – DEM
Vector – Contours
Terrain

Interpolating to Raster

LiDAR Representations

Point Cloud
Triangulated Irregular Network (TIN)
Raster – DEM
Vector – Contours
Terrain

Vector Contours

Contours
• Interpolation process

Terrain Data Structure

• Data structure specific to elevation data
• TIN model represents surfaces
• Terrains use pyramids to represent multiple levels of resolution
• Data Inputs
  • Mass Points – TIN
  • Breaklines
• Data Outputs
  • TINS
  • Rasters

Basics of Using LiDAR Data
**LiDAR Products**

- Several file types and derivative products available to end-users
- LAS point cloud, DEM, contours, hydrologic breaklines, etc.

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**LiDAR Additional Products**

**Breaklines**
- Breaklines identify changes in landscape elevation
  - Too small or continuous to be reliably recorded with LiDAR
  - Stream banks, curbs, centerlines, water/land interface
- Used to influence interpolation for contours
- Can help enforce stream and lake elevations

Generated from
- Air Photos
- LiDARGrammetry

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**LiDARGrammetry**

- Classify points by intensity
- Trace around water intensity values to create a contour

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**MN LiDAR Data Delivery**

Credit – Tim Loesch - MNDNR
MN LiDAR Data Delivery

What Data Do People Use?
- Primary use products
  - Raster Digital Elevation Model
  - Contours
- Most consumers don’t bother with the raw LiDAR data
  - Not a lot of tools available but this list is growing
  - ArcGIS extensions are now available to read LAS format LiDAR data
- Derived products from LiDAR is a growing research field

MN LiDAR Data Delivery Four Ways

Data Currently Divided between Red River Valley and rest of the State
- Red River Valley - Complete
- Rest of State – In Progress
  - ftp.lidar.dnr.state.mn.us
  - ftp.lmic.state.mn.us/pub/data/elevation/lidar/data
  - Interactive Beta Viewer to come April 1st – Data Services May 11th

MN LiDAR Data Delivery – Red River

Interactive Viewer
- Graphically browse datasets – download customized extents

MN LiDAR Data Delivery Format

MN DNR FTP Site
- ftp.lidar.dnr.state.mn.us

MN GEO (formerly LMIC) FTP Site
- ftp.lmic.state.mn.us/pub/data/elevation/lidar/data

File Geodatabases
Data Organization
- Tiling Scheme
  - County
  - Project
  - Quarter quarter quarter quad (1/16th of a quad) (Raw)
Not all data types tiled the same
- Size limitations

Basics of Using LiDAR Data
Basics of Using LiDAR Data

MN LiDAR Data Delivery Format

- Beta Viewer Available April 1st
- Data Services Available May 11th
- Mobile App Available June 1st

Things to know…

- Use third party FTP Software - Filezilla
- Know what you want before you download
- Interactive web download page coming in near future
- RTM – Read the Manual!
  - Several helpful Readme’s

MN LiDAR Data Delivery Format - LAS Files

LAS – Common LiDAR Data Exchange Format

- Industry Standard
  - Easily transferred from system to system
  - Less volume and more easily transferred than ASCII
- Retains flight information and instrument parameters
  - GPS, IMU, Laser Pulse Range
- Current version is LAS 1.1 (5/05)
  - 1.2 has been proposed and in final review
  - 2.0 has been proposed


LAZ files = Compressed LAS files

Visualization

Lidar data can be visualized a number of ways

- Shaded Relief images can reveal very subtle relief
  - Especially with high detail data
  - Helpful for data validation and looking for anomalies and errors in the data
- 3-Dimensional viewing
- Cross-sections
- Contour generation
- Triangulated Irregular Networks (TIN)

Credit – Tim Loesch - MNDNR
Basics of Using LiDAR Data

Sinkhole

2006 color NAIP airphoto

Sinkhole

Sinkhole – Cross-section
Basics of Using LiDAR Data
Credits/Acknowledgements

- Tim Loesch – MN Dept. of Natural Resources
- Sean Vaughn – MN Dept. of Natural Resources
- Steve Kloiber – MN Dept. of Natural Resources
- Dr. Adam Birr – MN Dept. of Agriculture
- Jake Galzki – University of Minnesota
- Dr. Jay Bell – University of Minnesota
- Ann Lewandowski – University of Minnesota
- Les Everett – University of Minnesota

Basics of Using LiDAR Data