Watershed Sciences 4930 & 6920
GEOGRAPHIC INFORMATION SYSTEMS

WEEK SIX – Lecture
DIGITAL ELEVATION MODELS
Joe Wheaton

HOUSEKEEPING - AFTER

• Something important on Feb 17th?
• Hang in there... it is going to step up. More important to keep pace and learn. Turn in something!

• Guys, Valentines Day is simple...
READING FOR TODAY

• I forgot, please read Chapter 11

WHERE IS THIS?

http://www.me-dem.org/index.php?option=com_rsgallery2&page=inline&id=1&Itemid=45
TODAY’S PLAN

I. Topographic Data

II. Ways of modeling Topographic Data
   I. Contours
   II. TINs
   III. Terrains
   IV. DEMs

III. Importance of Resolution

ALL TOPOGRAPHIC DATA IS VECTORIZED DATA

- A collection of points with attributes:
  Point Number, Easting (x), Northing (y), Elevation (z), Description, etc.
- Variety of acceptable formats:
  Ascii text (*.txt or *.asc or *.dat), tab or comma delimited (*.csv),
  excell (*.xls), or shape files (*.shp and *.shx).

Important to have a header & know units

Irregularly distributed point data
SECTION LEVELING

What do you know?

What do you want to know?

What can you measure?

VERTICAL LEVELING

What do you know?  What do you want to know?  What can you measure?

Calculation of Dip Between Contours

\[ H = \text{Horizontal Distance} \]
\[ V = \text{Contour Interval} \]
\[ \text{Dip} = \text{NAT. TAN} \alpha \]

NAT. TAN = \[ \frac{V}{H} \]

\[ \alpha = 18' \]

\[ \text{Height of Tree of Cliff} \]
\[ V = H \times \tan \alpha \]

\[ = 30.909 \times \tan 18' \]
\[ = 10.043 \text{ m} \]

\[ V = SD \times \sin \alpha \]
\[ = 32.5 \times \sin 18' \]
\[ = 10.043 \text{ m} \]

\[ H = SD \times \cos \alpha \]
\[ = 32.5 \times \cos 18' \]
\[ = 30.909 \text{ m} \]
2D or 2.5D TOPOGRAPHIC SURVEYING

What do you know? What do you want to know? What can you measure?

- Point Based Sampling
- Sampling Patterns?
  - Uniform grid?
  - Sections?
  - Irregular
  - Random
  - Feature-based

TOPOGRAPHIC SURVEY TECHNOLOGIES

Remotely Sensed or Aerial Surveys
- LiDaR (NIR)
- Bathymetric LiDaR (Green)
- Aerial Photogrammetry

Ground-Based Surveys
- Total Station Surveys
- rtkGPS
- Terrestrial Laser Scanning

Boat-Based Bathymetry Surveys
- Multibeam and Singlebeam Sonar
- Acoustic Doppler
## Typical Extent & Resolution

<table>
<thead>
<tr>
<th>Technology</th>
<th>Extent (Reach Lengths)</th>
<th>Resolution (pt./m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airborne LiDAR</td>
<td>10's - 100's km</td>
<td>1-8</td>
</tr>
<tr>
<td>Bathymetric LiDAR</td>
<td>10's - 100's km</td>
<td>0.5 - 4</td>
</tr>
<tr>
<td>Aerial Photogrammetry</td>
<td>10's - 100's km</td>
<td>0.1 - 1</td>
</tr>
<tr>
<td>Total Station Surveying</td>
<td>100 - 5,000 m</td>
<td>0.1 - 4</td>
</tr>
<tr>
<td>rtkGPS Surveying</td>
<td>100 - 5,000 m</td>
<td>0.1 - 4</td>
</tr>
<tr>
<td>Terrestrial Laser Scanning (aka ground-based LiDAR)</td>
<td>100 - 5,000 m</td>
<td>10 - 10,000</td>
</tr>
<tr>
<td>Multi-beam Sonar</td>
<td>1 - 25 km?</td>
<td>10 - 100 (per m linear)</td>
</tr>
<tr>
<td>Single-beam Sonar</td>
<td>5 - 100 km?</td>
<td>0.05 - 5</td>
</tr>
</tbody>
</table>

## Cost: Capital, Rental, Deployment

<table>
<thead>
<tr>
<th>Technology</th>
<th>Capital</th>
<th>Rental</th>
<th>Deployment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airborne LiDAR</td>
<td>Hire</td>
<td>NA</td>
<td>Flight (min. $10K)</td>
</tr>
<tr>
<td>Bathymetric LiDAR</td>
<td>Research Only</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Aerial Photogrammetry</td>
<td>Hire</td>
<td>NA</td>
<td>Flight (min. $5K)</td>
</tr>
<tr>
<td>Total Station</td>
<td>$5K - $15K</td>
<td></td>
<td>2 Man Crew</td>
</tr>
<tr>
<td>Total Station (auto-tracking)</td>
<td>$25K - $30K</td>
<td></td>
<td>2 Man Crew</td>
</tr>
<tr>
<td>Total Station (robotic)</td>
<td>$30K - $40K</td>
<td>$750 - $1000/wk</td>
<td>1 person</td>
</tr>
<tr>
<td>rtkGPS Surveying</td>
<td>$45K - $55K</td>
<td>$1000 - $1500/wk</td>
<td>1 person</td>
</tr>
<tr>
<td>Terrestrial Laser Scanning</td>
<td>$100K - $200K</td>
<td>$</td>
<td>1.5 persons</td>
</tr>
<tr>
<td>Multi-beam Sonar</td>
<td>$40K - $60K</td>
<td>?</td>
<td>2 people</td>
</tr>
<tr>
<td>Single-beam Sonar</td>
<td>$5K - $15K</td>
<td>?</td>
<td>2 people</td>
</tr>
</tbody>
</table>
WHAT ARE TYPICAL DEM ERRORS?

Remotely Sensed or Aerial Surveys
• LiDaR: +/- 12 to 25 cm
• Aerial Photogrammetry: +/- 10 to 15 cm

Ground-Based Surveys
• Total Station Surveys: +/- 2 to 10 cm
• GPS: +/- 3 to 12 cm
• Terrestrial Laser Scanning: +/- 0.5 to 4 cm

THREE KEY SAMPLING QUESTIONS

1. Is the sampling **smart** (i.e. requires judgment) or **systematic**?
2. Is higher density result of **judgement** or **brute force**?
3. Do I have to **see the point** to record it?
SOME TERMINOLOGY

- Section or Slope Profile – 1D Elevation Model (EM)
- Digital Elevation Model (DEM) 2D or 2.5D EM
- Digital Terrain Model (DTM) 3D EM
- Contour Map 2D
- Physical Terrain Model
- Resolution
- Spatial Resolution
- Triangular Irregular Network (TIN)
- Raster Data (Continuous)
- Vector Data (Discrete)

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DEM OF EARTH

- Raster Resolution: 1 km
- Source: Satellite

IS THIS A DEM?

- Why can I see the mountains?
  - Land Cover
  - Shadows (hillshade)
IMAGES DRAPED OVER DEMs
WHAT DO YOU THINK A MODEL IS?

• Conceptual
• Black Box (empirical / statistical)
• Physical
• Numerical
• Reduced-Complexity
PHYSICAL MODELS

- Scaled-down physical models
- Controlled setting (e.g. slope, sediment supply, water supply)
- Can be static, fixed-bed, dynamic

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CONTOURS

- Areas of equal elevation... helps when draped over a 3D hillshade...

YOU’RE FAMILIAR WITH CONTOURS...

E: 432,600  N: 4,621,300

Lat: 41° 44’ 40” W  Long: 111° 48’ 20” N
CONTOURS

• What points can I see in the photo?
• What does it mean if a contour disappears?

HOW TO DERIVE CONTOURS?

• Need a surface (e.g. TIN, Terrain or DEM)
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BUILDING A TIN FROM VECTOR DATA

A Triangular Irregular Network (TIN) is the simplest and most common interpolation technique for building surfaces with irregularly spaced elevation data (McCullagh, 1981)

Points → TIN

3D Surface Visualization of TIN

DETAILS OF TINs...

- Vertices connected with a series of edges to form network of triangles (continuous)
- ArcGIS uses Delaunay triangulation, which maximizes interior angles
- Resolution can vary
- Interpolation is linear
- Order matters!

CREATE TIN....
**INTERACTIVE TIN EDITING TOOLBAR**

- Remove busts
- Add points
- Add breaklines
- Change order

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WHAT A TERRAIN....

• Like a TIN... but with Pyramids generated on fly

• Can handle way more data! Billions of points...

TWO WAYS TO CREATE TERRAINS

• With a toolbox tool
• In geodatabase
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WHAT IS A RASTER DEM?

- A digital elevation model
- Raster representation of elevation
- Only one elevation value for every x-y
- DTM?
HOW DO I GET ONE FROM A TIN?

- Simple conversion...
- Three Key questions:
  - Float vs. Int
  - Method?
  - Resolution

TIN TO DEM.... THE KEY CHOICE
IS THIS A DEM?

• National Elevation Dataset (USGS)
  - 10 m, 30m and 90 m
• Location specific photogrammetric DEMs (1m to 10 m resolution)
• Location specific LiDaR DEMs (e.g. Open Topography; Utah GIS Portal)
  - 0.5 to 2 m resolution (typically 1 m)

MOST COMMON DEM PRODUCTS (IN US)
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A 100 m DEM...

100m DEM?
10 m vs. 100 m DEM

10m DEM WITH & WITHOUT CONTOURS

20 m contours
CONTOURS WITH & WITHOUT DEM

10 m DEM vs. 1 m DEM (LiDAR)
DEM & ITS HILLSHADE...

LiDAR (1m) vs. TOTAL STATION (.25 m)
A 3D VIEW OF THAT CATCHMENT...

A PHOTO DRAPEOvER THAT VIEW
**VOLCANIC ACTIVITY?**

- Mt. Saint Helens still going...
- Lidar from September 2003 and October 2004

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**BARE-EARTH OR ACTUAL..**
YOU CAN DO THIS....

- Using ArcScene:

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A DIFFERENT ONE

- A little easier than last one...
  - Rounded up elevations
- This one’s real
  - Derived from 10 m DEM
- Here’s a few hints:
  - It’s in the mountains
  - You can see the AP

YOUR TURN...

- Derive 10 meter Contours
- Make a TIN first
- Divide up the tin lines into your contour interval
- Connect the dots
- Label your Contours
YOUR TIN

• Once you’ve connected the dots
• Figure out how many contours would intersect each line (if any)
• Locate where they would intersect (label them lightly)

NEXT TWO LABS!

By the end of lab you should be able to:
• Know where to acquire DEMs
• Know how to manipulate and display DEMs
• Build high resolution DEM from ground-based topographic data
• Build high resolution DEM from airborne LiDaR data
READING FOR THURSDAY

• Read Chapter 11
• If you haven’t read Chapter 10: Topics in Raster Analyses
  – Read pp. 379-408