Digital Elevation Models

Using elevation data in raster format in a GIS
What is a Digital Elevation Model (DEM)?

- Digital representation of topography
  - Model based on scale of original data
- Commonly a raster dataset
Why use elevation data in a GIS?

- Easy to use
- Importance of terrain in hydrology and environmental modeling
- Visualization of landscapes
Creation of DEMs

- Conversion of paper maps
  - Scanned, vectorised contour lines
- From original photogrammetry
- From Space Shuttle topography mission (not available until 10/02)
Basic storage of data

<table>
<thead>
<tr>
<th>340</th>
<th>335</th>
<th>330</th>
<th>340</th>
<th>345</th>
</tr>
</thead>
<tbody>
<tr>
<td>337</td>
<td>332</td>
<td>330</td>
<td>335</td>
<td>340</td>
</tr>
<tr>
<td>330</td>
<td>328</td>
<td>320</td>
<td>330</td>
<td>335</td>
</tr>
<tr>
<td>328</td>
<td>326</td>
<td>310</td>
<td>320</td>
<td>328</td>
</tr>
<tr>
<td>320</td>
<td>318</td>
<td>305</td>
<td>312</td>
<td>315</td>
</tr>
</tbody>
</table>

DEM as matrix of elevations with a uniform cell size
# Adding geography to data

Cell index number x cell size defines position relative to Xmin, Ymin and Xmax, Ymax and infers an exact location.

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>340</td>
<td>335</td>
<td>330</td>
<td>340</td>
<td>345</td>
</tr>
<tr>
<td>337</td>
<td>332</td>
<td>330</td>
<td>335</td>
<td>340</td>
</tr>
<tr>
<td>330</td>
<td>328</td>
<td>320</td>
<td>330</td>
<td>335</td>
</tr>
<tr>
<td>328</td>
<td>326</td>
<td>310</td>
<td>320</td>
<td>328</td>
</tr>
<tr>
<td>320</td>
<td>318</td>
<td>305</td>
<td>312</td>
<td>315</td>
</tr>
</tbody>
</table>

Xmin, Ymin - XY are in projected units.
Uses of DEMs

- Determine aspects of terrain
  - Slope, aspect, spot elevations
  - Source for contour lines
- Finding terrain features
  - Watersheds, drainage networks, stream channels
- Modeling of hydrologic functions
Scale in DEMs

- Scale determines resolution (cell size)
- Depends on source data
- Resolution determines use of DEM and what features are visible
Scale ...
Errors in DEMs

- Typos occur frequently in DEMs
- Most common variety are “sinks” and “spires”.
  - Sinks occur when a very low elevation, relative to surrounding cells, is entered.
  - Spires occur when a very high elevation, relative to surrounding cells, is entered.
- Appear as tightly packed contours
Correcting sinks and spires

- Most GIS have a “Fill” function which looks for sinks and fills them or looks for spires and removes them.
- Sinks wreck havoc with hydrologic modeling functions in GIS software.
A natural sink?

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>340</td>
<td>335</td>
<td>330</td>
<td>340</td>
<td>345</td>
</tr>
<tr>
<td>337</td>
<td>332</td>
<td>330</td>
<td>335</td>
<td>340</td>
</tr>
<tr>
<td>330</td>
<td>228</td>
<td>320</td>
<td>330</td>
<td>335</td>
</tr>
<tr>
<td>328</td>
<td>326</td>
<td>310</td>
<td>320</td>
<td>328</td>
</tr>
<tr>
<td>320</td>
<td>318</td>
<td>305</td>
<td>312</td>
<td>315</td>
</tr>
</tbody>
</table>

By default, this “sink” is removed, whether or not it is real.
An example – finding slope using a DEM
Estimating slopes in a DEM

- Slopes are calculated locally using a neighborhood function, based on a moving 3*3 window.
- Distances are different in horizontal and vertical directions vs diagonal.
- Only steepest slopes are used.

<table>
<thead>
<tr>
<th></th>
<th>1.41…</th>
<th>1</th>
<th>1.41…</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>1.41…</td>
<td>1</td>
<td>1.41…</td>
<td></td>
</tr>
</tbody>
</table>

* cell size
Slopes ...

\[
\begin{array}{ccc}
1.41... & 1 & 1.41... \\
0 & 1 & \\
1.41... & 1 & 1.41... \\
\end{array}
\]

\[
\begin{array}{ccc}
42.47... & 30 & 42.47... \\
30 & 0 & 30 \\
42.47... & 30 & 42.47... \\
\end{array}
\]

* 30

(distances)
## Slopes

<table>
<thead>
<tr>
<th></th>
<th>Elevations</th>
<th>Difference/Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>340</td>
<td>335</td>
<td>330</td>
</tr>
<tr>
<td>337</td>
<td>332</td>
<td>330</td>
</tr>
<tr>
<td>330</td>
<td>328</td>
<td>320</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Elevations</th>
<th>Difference/Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>8/42.47</td>
<td>3/30</td>
<td>2/42.47</td>
</tr>
<tr>
<td>5/30</td>
<td>0</td>
<td>-2/30</td>
</tr>
<tr>
<td>-2/42.47</td>
<td>-2/30</td>
<td>-12/42.47</td>
</tr>
</tbody>
</table>
Slopes

<table>
<thead>
<tr>
<th>Slope</th>
<th>Value 1</th>
<th>Value 2</th>
<th>Value 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1667</td>
<td>0</td>
<td>-0.0667</td>
<td>-0.286</td>
</tr>
<tr>
<td>-0.047</td>
<td>-0.0667</td>
<td>-0.286</td>
<td></td>
</tr>
</tbody>
</table>

-0.286 is the largest local slope
Hydrologic functions on DEMs

- Modeling the topographic form of a drainage basin
- Determining the drainage network and associated drainage divides
- Estimating slopes for understanding drainage patterns and processes
Flow Direction

- Useful for finding drainage networks and drainage divides
- Direction is determined by the elevation of surrounding cells
  - Water can flow only into one cell
- Water is assumed to flow into one other cell, unless there is a sink
  - GIS model assumes no sinks
Flow direction in a DEM

<table>
<thead>
<tr>
<th>340</th>
<th>335</th>
<th>330</th>
<th>340</th>
<th>345</th>
</tr>
</thead>
<tbody>
<tr>
<td>337</td>
<td>332</td>
<td>325</td>
<td>335</td>
<td>340</td>
</tr>
<tr>
<td>330</td>
<td>328</td>
<td>320</td>
<td>330</td>
<td>335</td>
</tr>
<tr>
<td>328</td>
<td>326</td>
<td>310</td>
<td>320</td>
<td>328</td>
</tr>
<tr>
<td>320</td>
<td>318</td>
<td>305</td>
<td>312</td>
<td>315</td>
</tr>
</tbody>
</table>

Flow directions for individual cells
Finding watersheds …

- Begin at a source cell of a flow direction database, derived from a DEM (not from the DEM itself)
- Find all cells that flow into the source cell
- Find all cells that flow into those cells
- All of the cells comprises the watershed
- The resulting watershed is generalized, based on the cell size of the DEM
Watersheds ...

Once done manually ...

Contour lines (brown)
Drainage (blue)
Watershed boundary (red)
Flow accumulation

- The number of cells, or area, which contribute to runoff of a given cell
- Accumulation, once it reaches a threshold appropriate to an region, forms a drainage channel
- Accumulation is the area of a watershed that contributes runoff to a given cell
Flow accumulation in a DEM

Flow accumulation for individual cells
Errors may occur at the edges of DEMs.
Flow accumulation as drainage network

Drainage network as defined by cells above threshold value for region.
Visibility

What land is visible from the selected location?