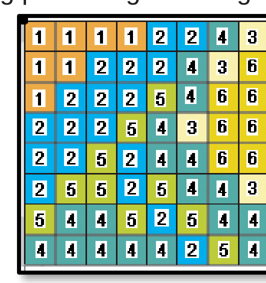
How well do you know your elevation model?

My father taught me how to read topo maps back in days of folded paper, declination angles, and determining direction of flow from contours. Having used airborne LIDAR data for over the past 15 years, I think I'm on safe ground saying:

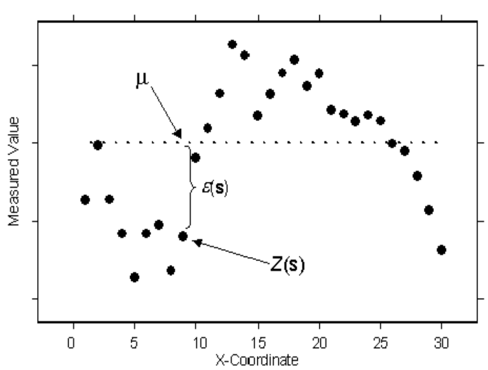
"This aint your fathers topo map".

At GroundPoint Engineering, one of our interests is in using high resolution digital terrain data to support hydrology and hydraulic modeling (H&H) on small to medium sized projects. Projects shouldn't have to be the scale of a full DFRIM Floodplain Mapping project to be able to take advantage of the latest in mapping technologies, but understanding some of the issues associated with digital terrain data can help save significant headaches later on.

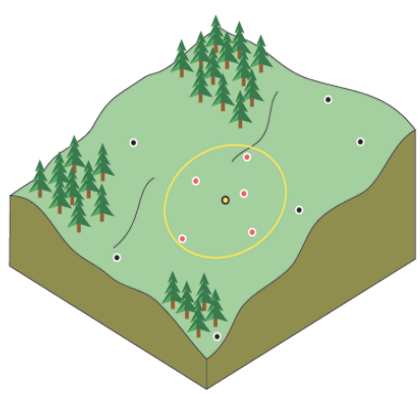
1- **The Standards.** The reference standard for LiDAR in the US is the USGS QL2 (Quality Level 2). The USGS LiDAR Base Specification defining these "quality levels" also requires all water features wider than 100ft or 2acres be mapped. More importantly, those features are used as breaklines when generating a digital elevation model (DEM). These water polygons provide three dimensional "edge of water" reference locations for all water features meeting those minimum size thresholds. The centerlines of these river polygons can be a good starting point for generating stream reach geometries for H&H models, and the polygons themselves can provide important land/water surface locations in cross section. But beware the size threshold. QL2 water doesn't mean ALL water.



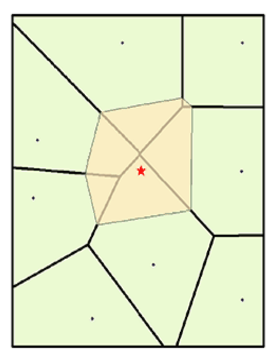
2- **The GRID**. The DEM generated from LIDAR is a regularly spaced grid of elevation values representing a continuous surface. Each cell value is typically based on the average of all intersecting "ground" points. Cells with no points (i.e., void areas) are interpolated from nearby surrounding cells. ***There are many, many methods for assigning values to cells*** such as "kriging", "inverse distance weighting" and "nearest neighbor", to name a few. And many of the methods include one or more variable parameters that can be adjusted as desired. Suffice it to say, ***"It aint automatic"***, and you should do some due diligence on your own DEM before going too far down the rabbit hole.



Example of ordinary kriging with one spatial dimension

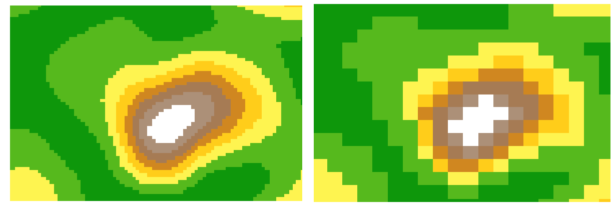


IDW neighborhood for selected point



Example of Voronoi polygon created around interpolation point

3- **Smoothing.** It is important to understand that the DEM is already a "smoothed" or resampled version of the original LiDAR data. The amount of smoothing depends on the cell size (or point spacing) in the grid. Larger cell sizes imply more averaging/smoothing simply because of their geometry. The most ridiculous example would be to represent your entire project area with just one cell. That being said, there is no practical reason to use cell sizes of 1inch or 1cm. The typical resolution of a DEM derived from airborne LiDAR is 1m. In theory, stream reach and basin geometries can be generated from a DEM using standard GIS hydrologic routing and basin delineation tools. In practice, however, the 1m gridded DEMs produced through the standard USGS delivery process (or the classified LiDAR point clouds) are NOT going to work right out of the box. There is just WAY TOO much detail in the data at that scale. So, one of three options arise depending on the size and characteristics of your watershed:



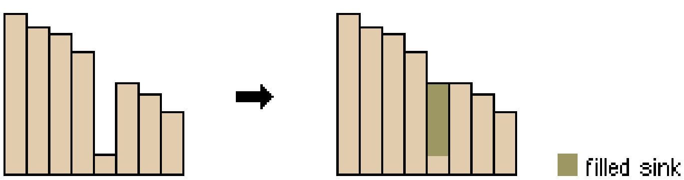
1) use the older/coarser resolution USGS DEMs (not LiDAR based) which are typically 10m resolution. These are from the 1:24K “traditional” topo maps and are freely downloadable from USGS,

2) thin/resample the 1m LIDAR DEM down to a coarser resolution, such as 10m.

3) Hydro-condition the 1m LiDAR DEM as a new “artificial” drainage surface

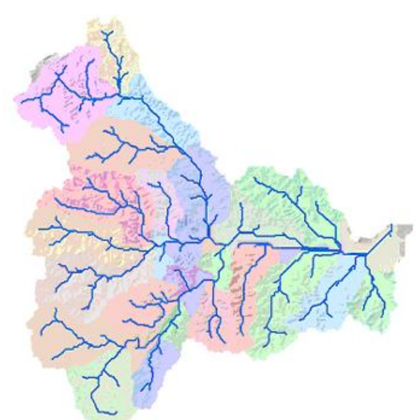
4- **Hydro-flattening.** Note that water points are NOT used in the generation of the DEM. The 3D water breaklines are used to “flatten” the elevation model wherever water occurs. Lake and pond surfaces are assumed to be completely flat, while river surfaces are assumed to be level from bank to bank with a continuous downhill slope. Most H&H projects, however, likely require definition of water edges at scales far larger than 100ft wide and 2 acres, so creation of additional water feature breaklines may be a necessity. Being able to manipulate the point cloud to conflate elevation values onto polyline and polygon vertices while enforce flattening and monotonicity rules becomes critical.

5- **Hydro-conditioning and Sinks.** Regardless of where you start, your DEM is going to contain lots of "sinks". Sinks occur where water can’t be routed downstream. Flow is forced to stop at a low point, causing routing and basin delineation tools to not work properly. A classic case is water being routed along a roadside ditch that arrives at the inlet of culvert. Culverts are not represented in a DEM, so they appear effectively like a dam, blocking flow. Stormwater drains also often as sinks. Keep in mind that each cell in a 10m resolution raster actually represents 100m^2 on the ground (or about 1100ft^2), so it is not uncommon for DEMs at that resolution to “smooth over” important drainage features. In such instances, water may be routed digitally in a different direction from where it actually flows on the ground.



Profile view of a sink before and after running Fill

Because the existence of “sinks” will impact the resulting drainage paths and drainage area calculations, the typical fix is to simply remove them (fill them in) using automated tools thereby creating a "depressionless DEM". Removing ALL the sinks is fine to resolve digital processing issues but is dangerous if your goal is to reflect reality. Sinks should be analyzed and accounted for in a purposeful way, or the calculated basin geometries and derived stream networks will be wrong. This is particularly evident in very flat areas or in already complex (aka urban) terrain. For very large projects with large drainage areas, this is less of an issue, and 10m DEMs may work just fine. But as project sizes and drainage areas of interest get smaller, the need for higher resolution detail, and potential for error to impact results goes up significantly.



The bottom line is that to support your H&H efforts, you need stream channels and drainage basins delineated, with area/length, elevation and slope attributes. Many tools have the ability to do this for you, but they all assume you are providing a “valid” elevation model (DEM). Which brings us full circle to the question posed at the beginning of this article:

How well do you know your elevation model?