Hydrologic conditioning of a DEM

Hydrologic conditioning refers to the modification of topographic data in a raw or “bare earth” Digital Elevation Model (DEM) through a series of GIS processing steps to more accurately represent the movement of water across the landscape. The process includes filling spurious sinks or pits, breeching digital dams (roadbeds and bridges which block the modeled flow of water across the DEM), and enforcing drainage connections such as culverts, storm sewers, and known tile drainage.

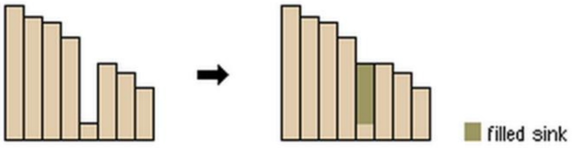
The hydrologic conditioning process is iterative, because altering the DEM in an upstream area modifies how water moves downstream. Several iterations are generally needed to achieve the final conditioned DEM. The hydrologic conditioning process can be accomplished to a high level at the computer desktop; however, the practitioner can ensure a higher quality product by incorporating local knowledge of drainage patterns as well as bridge and culvert locations.

Steps:

1. Create a “raw” DEM (3 meter or 5 meter resolution) for watershed area of interest.

2. If a culvert inventory is available, use it to modify the elevation of the DEM at known culvert locations (create a provisional DEM). The alignments of the subsurface drainage paths are referred to as “burn lines”. The process of “burning in” refers to artificially lowering the DEM along the subsurface drainage structure to allow flow accumulation through a digital dam. Conversely, “wall lines” are needed in some instances to raise the elevation values in order to create accurate flow paths and delineations.

3. Fill the DEM to remove spurious sinks that are often data errors or artifacts of the LiDAR data generation due to the tessellation of a continuous surface (create a sinkless provisional DEM).



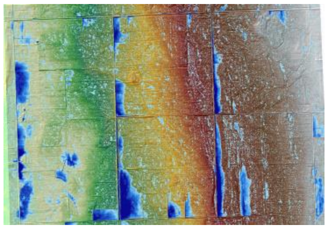
Profile view of a sink before and after running Fill

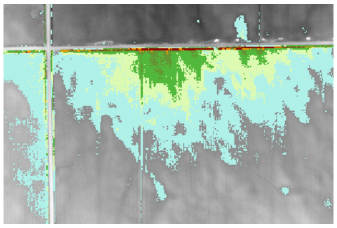
Image courtesy of ESRI Inc.

4. Compile and create a suite of data products to facilitate a systematic review of the sinkless provisional DEM from step 3 including:
    a. Raw DEM (1m)
    b. Air photo
    c. Hillshade DEM (1m)
    d. Depth grid (subtract an unfilled from a filled DEM)
    e. Catchments boundaries (40 acres for stream definition)
    f. Stream lines (40 acres for stream definition)
    g. Topographic Position Index (TPI) layer with “fire” symbology. For more information go to http://www.corridordesign.org/downloads

TPI display

5. Systematically **review the depth grid:**
    a. Display the depth grid with the symbology set to classified with several depth intervals and exclude values that correspond to the RMSE of the original Lidar data (e.g. 0 – 0.15 meter).





    b. Depressions in the depth grid that occur next to roads identify areas where water would pool indicating a culvert is likely present to prevent flooding of the roadway. Often the deepest cell of a depressions in a depth grid is the approximate location of a culvert.

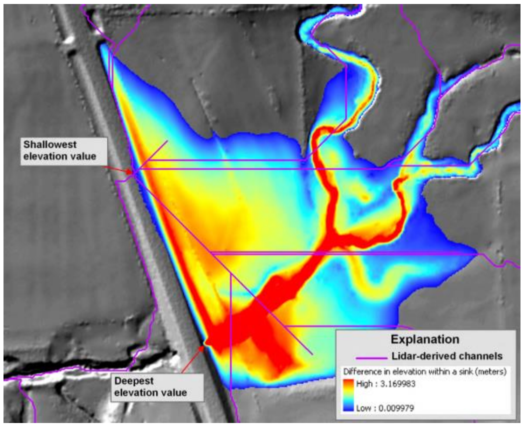
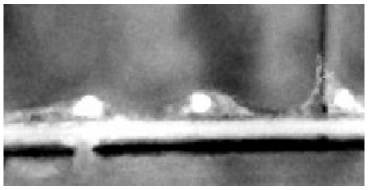
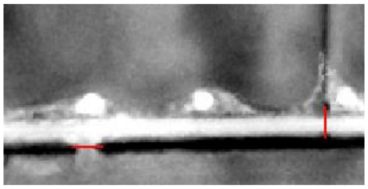


Image courtesy of USGS 2009

    c. Find culvert signatures in 1-meter DEM and in aerial imagery (Google Earth) near deepest point of depression and draw burn lines where needed.



culvert signatures visible in 1m DEM



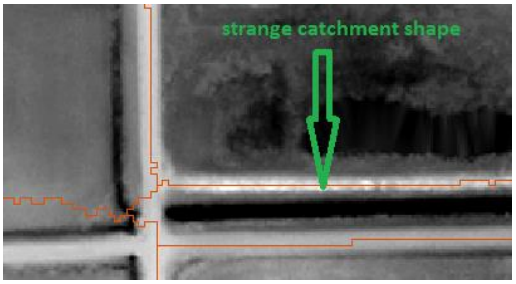
edited burn lines in red

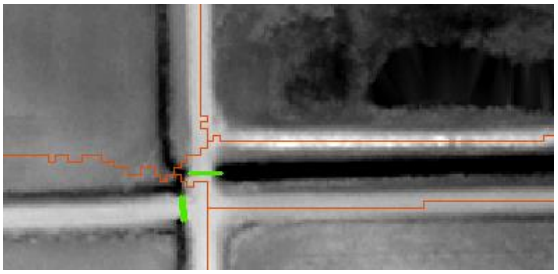
culvert pipes visible in Google Earth

6. **Delineate 40-acre catchment boundaries and stream networks** (lines) starting from a sinkless DEM to ensure continuous surface water flow. Systematically review catchment boundaries and stream lines and add burn lines and wall lines. Review procedures along each catchment boundary at a scale of 1:3,000 to 1:5,000 using the help data listed under step 4. Look for features that seem suspicious including:
    a. Catchments with unnatural shapes such as long straight lines (often along roads).
    b. Small and extremely small catchment areas (e.g. some catchments may only be a few cells large).

c. Catchments with high perimeter to area ratios. These occur most often are long narrow catchments that run along channelized streams.

d. Catchments with “panhandles”.





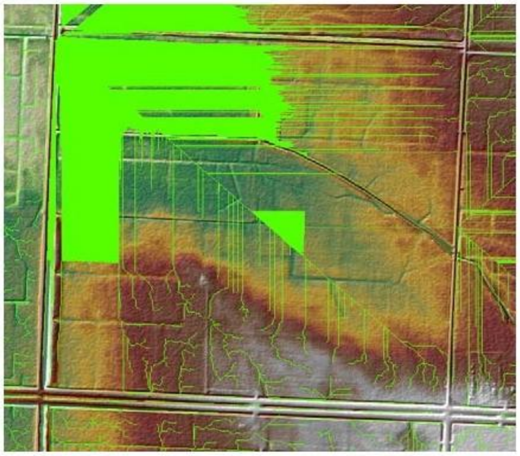
e. Catchments located within large expanses of wetlands particularly those dominated by cattails.

f. Catchments located in lakes and open water areas particularly those with a cattail fringe.

g. Catchment boundaries crossing ditches.

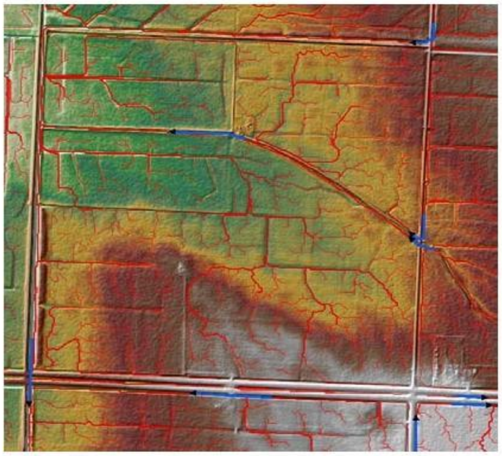
h. Drainage divides going through wetlands, lakes etc.

i. Parallel flow lines.



Flow network from filled DEM derived from raw 3-meter DEM

Parallel flow lines in green are incorrect



Resulting flow network with hydrologic conditioning (6-meter DEM)

Dendritic flow lines in red seem more natural

j. Check if stream lines follow streams and ditches, use ‘arrow at end’ symbology to display direction of stream lines.

7. Create another provisional DEM which incorporates new burn lines and wall lines.

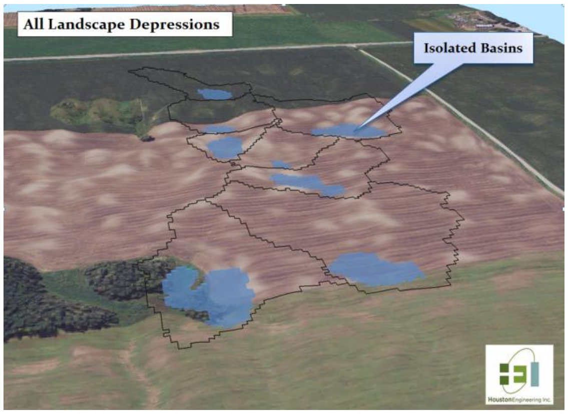
8. Fill spurious sinks in the new DEM.

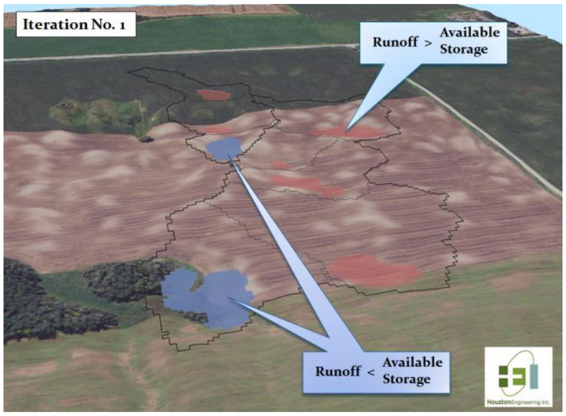
9. Create new depth grid, catchment boundaries and stream lines.

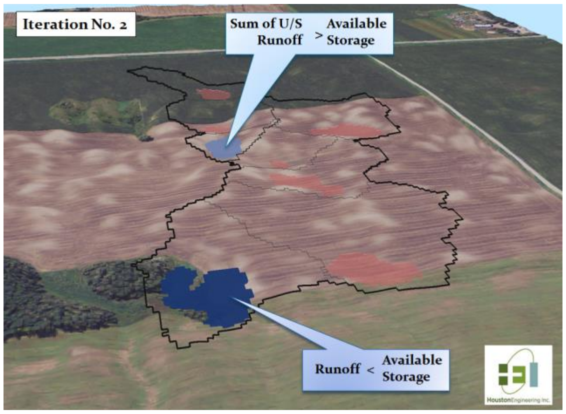
10. Review areas where catchment boundaries and stream lines have changed between interim versions of the DEM. Add more lines as needed.

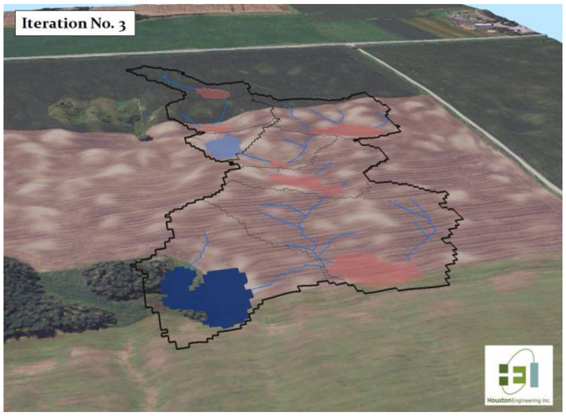
11. Repeat steps 5 to 8 until satisfied and comfortable with conditioned DEM.

12. Perform a **non-contributing area analysis** for a 10-year, 24-hour precipitation event (or 100-year, 10-day).
    a. Not all areas contribute equally during a rain event. Surficial depressed areas (e.g. sinks, wetlands, potholes) are naturally-occurring features in many landscapes that provide runoff storage. Non-contributing areas are defined as closed basins with sufficient storage to contain runoff from a certain rain event depending on the magnitude of the runoff event. They are delineated using an iterative process that compares the available surficial storage of a depressional area to the runoff volume generated from the contributing watershed of the depressional area. This iterative "fill and spill" process routes the excess runoff of contributing areas through subsequent downstream depressional areas until no excess runoff is produced. Flow paths terminate at the minimum elevation cell within each non-contributing depressional area. This process results in a hydrologically conditioned DEM that accounts for non-contributing areas.









    b. Review non-contributing areas with aerial imagery and check if they align with potholes, wetlands, and lakes.

    c. If shapes of non-contributing areas look unnatural or if they have linear borders following roads which points to digital dams obstructing the surface flow of water, add burn lines to allow drainage accordingly.

13. Create a new hydrologic conditioned DEM and repeat step 12 until satisfied with hydrologic conditioned DEM.

14. Final QC check by independent reviewer.

General Remarks

Keep in mind that the scale and landscape differ from one project to another. In addition, demands for accuracy and precision might vary depending on the successive usage of the conditioned data. Iterations most appropriate for hydrologic conditioning on one project may be too little or overkill for another project.

- Hydrologic conditioning a flat landscape will require more attention to subsurface drainage structures than conditioning an area with greater topographic relief.
- Modeling water flow in areas of high imperviousness (urban areas) will vary substantially from modeling agricultural areas.
- Areas of recent disturbance or change may not be reflected in datasets used in hydrologic modeling.

August 2015

For more information contact:

Grit May
GIS Specialist, International Water Institute
grit@iwinst.org
701.261.0330

Or

Henry VanOffelen
Red River Basin Coordinator, MN DNR Ecological and Water Resources
Henry.Van.Offelen@state.mn.us
218.846.8406