DEM Practice

University of Oklahoma/HyDROS
Module 3.1
Outline – Day 3

DEM PRACTICE

• Review creation and processing workflow
• Pitfalls and potential problems
• Prepare topographical files for Example 3
• EF5 DEM options

CALIBRATION PRACTICE

DROUGHT

COBB CREEK EXAMPLE
It takes many different forms, but in EF5 we need three pieces of topographical data

**DEM** – Digital Elevation Model

**FDR** – Flow DiRection (also called DDM in EF5)

**FAC** – Flow ACcumulation

These follow a specific order

You always have to start with a DEM
An FDR is created from a DEM
And the FAC is created from the FDR
This DEM $\rightarrow$ FDR $\rightarrow$ FAC process only works in this direction
Remember that a DEM (Digital Elevation Model) is required to run any hydrological model.

Without the DEM, the hydrological model does not know how water will flow across the land surface of the modeled domain.

In the context of modeling, horizontal resolution and extent are the key properties of any DEM and its derivatives.
The greater the horizontal resolution, the larger the DEM file size and the longer the model takes to run.

Generally, increasing the resolution implies a more accurate DEM:
- BUT, if the DEM was produced with questionable methods, it may actually be better to use it at lower resolution to “smooth out” some of the problems
- Increasing the resolution can also make the model simulation more complex and harder to calibrate

Once you know what resolution you’ll use, pick basin edges several grid cells wider all around than the true basin edges.
The reason we add this large buffer (red) is because the algorithms that produce FDR and FAC grids are very susceptible to edge effects.
In other words, if I have a cell in my basin on the edge of my domain, that edge “flows downstream” into the rest of my basin, potentially corrupting it.

This is mostly noticeable in the FAC grid, which is why it’s important to *always check* that grid to make sure it looks “natural” and similar to how the river you’re modeling looks on a map.
Remember that the DEM is a grid of numbers, and the numbers are elevations.

The grid cells of the DEM must exactly match the grid cells of the FDR, the FAC, and the hydrological model in both extent and resolution.
Most simple modeling work starts with pre-conditioned DEMs

These will work at their original resolution with a hydrological model basically “out-of-the-box”

BUT, as soon as you change the resolution of the DEM (also known as resampling), errors will be introduced and those have to be fixed
The most common error is a “pit” or “sink”

A pit is a place where water flows in but not out.

Some pits are natural, like the Okavango Delta of Botswana.

Pits cause problems in hydrological models.

In the figure, the cell with an elevation of 130 is a pit, because water cannot flow out of it to the edge of the DEM.
Pits and sinks can be fixed

In TauDEM, the “Pit Remove” function we used in Module 1.4 is the easiest way to do this. It adds elevation to the cell or cells in a pit until the water can freely flow downstream again.

In the figure, the pit would be easily fixed by increasing the elevation of the pit from 130 to something between 180 and 200.
**DEM Review**

**Natural pits and sinks are treated differently**

We want to model natural pits and sinks, usually.

So, if the pit exists at the cell with an elevation of 130, we change our domain to remove the bottom two rows of cells, and now the cell with 200 is our outlet and the pit has been removed.

This gives the flow into the pit from the upper cells (Flow 1).

To get the flow into the pit from the opposite side (Flow 2), model the two bottommost rows of cells separately.

Then Flow 1 + Flow 2 is the total flow into the natural pit.

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<th>520</th>
<th>600</th>
<th>650</th>
<th>730</th>
<th>770</th>
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<td>500</td>
<td>550</td>
<td>610</td>
<td>700</td>
</tr>
<tr>
<td></td>
<td>530</td>
<td>410</td>
<td>330</td>
<td>400</td>
<td>450</td>
<td>540</td>
</tr>
<tr>
<td></td>
<td>460</td>
<td>360</td>
<td>260</td>
<td>200</td>
<td>380</td>
<td>450</td>
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</tbody>
</table>

Flow 1

<table>
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<tr>
<th></th>
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<th>370</th>
<th>270</th>
<th>130</th>
<th>270</th>
<th>340</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>490</td>
<td>380</td>
<td>280</td>
<td>180</td>
<td>220</td>
<td>250</td>
</tr>
</tbody>
</table>

Flow 2
A flow direction grid, or FDR, is a grid containing values that tell you where water is flowing.

Imagine flipping our DEM cartoon forward.
Let’s keep rotating it until we’re looking at it dead-on

Now I have a grid, with the same size, resolution, and extent as my DEM, and this grid exists only to tell me in what direction my water is flowing
Flow direction maps have a coding scheme

There are many possibilities, but the most common are the ArcMap and TauDEM schemes

You just have to tell EF5 which you’re using
In the “eight-direction flow model” or “D8”, the biggest elevation difference (or steepest flow) is used to determine which route the water will take.

FDR creation is one of the reasons we need DEMs larger than our river basins – the edge of the FDR often contains no information because the computer does not know where water flowed from to reach your DEM.
Flow Accumulation

The FAC is a grid of numbers corresponding to the number of cells flowing into \textit{that cell}.

FAC grids should be checked by comparing the value of the FAC at the basin outlet to the known or estimated drainage area of the basin.

<table>
<thead>
<tr>
<th>FAC Grid</th>
<th>FAC Grid with Values</th>
</tr>
</thead>
</table>

![Diagram of FAC grid]
Flow Accumulation

Overland vs. channel cells

Like we mentioned when we first started discussing DEMs, think of these as cells in the river channel.

You may recall we briefly mentioned the TH parameter in EF5 back in Modules 1.3 and 1.4.

That parameter is the threshold for a river channel cell, so here TH would be 5.
Let’s process our own DEM files and create a DDM/FDR and an FAC

Example 3 will be the Nzoia River Basin in Kenya upstream of Lake Victoria
Create a new folder on your Desktop and name it **nzoia**

You’ve already extracted Africa DEM data from HydroSHEDS to your **okavango** folder so you can just point QGIS to that location for this project

Open QGIS and add the Africa DEM data (remember, it’s a raster and it’s called **w001001.adf**) and the Africa river shapefile (remember, it’s a vector called **af_riv_30s.shp**) to QGIS
Clipping a DEM

You should see something like this…
Create a new shapefile layer so we can add the Nzoia outlet to our map

Call it nzoia_outlet.shp and save to your nzoia folder

In the “Layers” box at the left of the QGIS window, drag “af_riv_30s” up so it’s plotted over “w001001”

And we want to “Select features using an expression”

Type UP CELLS > 800, then “Select”, and then “Close”
You should see large rivers highlighted in a different color.

Turn on “Toggle Editing”

And zoom in near the area of 34.087, 0.120 in the “Coordinate:” box at the bottom of the QGIS window.

Now select “Add Feature” (note the pencil icon next to “nzoia_outlet”)
And then click exactly at 34.087, 0.120 (it should be along one of the highlighted rivers)

Type 1 in the “id” box

Hopefully you see something like this →
Now turn off “Toggle Editing”, save changes to layer “nzoia_outlet”, and zoom out.

Using your mouse and the “Coordinate:” box, try to guess what the edges of a box covering the entire upstream area of our point would be.

Remember: you must catch all the area of the basin, plus some extra just to be safe.
Clipping a DEM

Here’s what can go wrong...

This is a bad Nzoia FAC, where red pixels have low values (they’re overland cells) and green pixels have high values (they’re in the river channel).

White cells have no data.
Clipping a DEM

I clipped the DEM too close to the edge of the true river basin near the top of the image (circled)

The “no data” values along that edge got carried into the main river channel and “flowed” down through the whole thing, ruining the FAC
Clipping a DEM

My edges were:
- Top: 1.5 deg N
- Bottom: 0.5 deg S
- Left: 33.5 deg E
- Right: 36 deg E

So, the top edge is a definite problem and the bottom looks a little too close for comfort.

Try it out with a top edge of 2 degrees north and the bottom as 1 degree south.
Clipping a DEM

Now go to the “Raster” menu, “Projections” and click “Warp (Reproject)” …

On this screen, click “Select…” by “Output file” and then save to your nzoia directory – I use the name clipped_raster.tif

Then check “Resampling method” and pick “Near”

Check “No data values” and type -32768

Then click the pencil icon below “Load into canvas when finished”
Clipping a DEM

Now you should be able to type in the text box at the bottom.

After `-r near`, type `-te 33.5 -1 362 -tr 0.0625 0.0625`

Remember, that’s “–te” (extent) and then the left, bottom, right, and top edges in degrees latitude and longitude.

And “-tr” tells QGIS the resolution of the grid in degrees – we are going to use a sixteenth of a degree.
Clipping a DEM

Click “OK”, “OK”, “OK”, and then “Close”

I’ve outlined the basin in orange and you can see we are clearly safe with this size DEM!
Now right-click af_riv_30s and select “Save As…”

Click “Browse” and then save in your nzoia directory as large_rivers.shp

Check “Save only selected features”

And check “Extent (current: user defined)”

Then type in the appropriate values for north, south, east, and west, and click “OK”
Now we need to fix any sinks or pits we’ve introduced

In “Processing Toolbox”, select “Pit Remove” from “Recently used algorithms”

Pick “clipped_raster” in the “Elevation Grid” drop down box and for “Pit Removed Elevation Grid” click the “….” and “Save to file…”

Then pick an appropriate location and name (I used corrected_dem.tif)
Now we want to “burn” our rivers into the corrected DEM to make sure the model knows where the streams are.

Go to the “Raster” menu, “Conversion” and “Rasterize (Vector to Raster)…”

Select “large_rivers” for the input file.

And for the output file, I chose rasterized_rivers.tif.

Click okay on the pop-up warning.
Converting Rivers

Click the pencil icon down near the bottom

In the text box, delete `-a ARCID -ts 3000 3000` and replace it with `-burn -10 -te 33.5 -1 36 2 -tr 0.0625 0.0625`

We are telling QGIS to write the number `-10` every pixel in which a river occurs, using the same extent and resolution as the DEM we already created.
Click “OK”, “OK”, and then “Close”

You should see something like this →

Now remember the dark cells have values of -10

Let’s add the rivers to the DEM…
In the “Raster” menu, select “Raster Calculator”

In the “Output Layer” box, save the file as burned_dem.tif

In “Raster bands”, double-click the “Pit Removed Elevation Grid”

In the box at the bottom, after Pit Removed Elevation Grid@1, type +()*3 then move your mouse between the parentheses and double-click “rasterized_rivers@1”
Click “OK” and you should see this →

We basically lowered the elevation of each pixel in the river channel by 30 meters

This is called “burning the rivers into the DEM”

Run “Pit Remove” on this burned DEM one more time
Creating an FDR

Save the new Pit Removed Elevation Grid as `dem.tif`

This is the final DEM

( Remove the old “Pit Removed Elevation Grid” from the Layers panel to avoid confusion)

Now in “Processing Toolbox”, open the “TauDEM (hydrologic analysis)” section, then “D8 Flow Directions”
Creating an FDR

Save the new FDR as `flow_dir.tif`

You should see what’s on the lower left…
Creating an FDR

We need to convert this to a format EF5 can read

In the “Raster” menu, select “Conversion” and then “Translate (Convert Format)…”

In “Output file”, save this file as `fdr.tif`

Then click the pencil at the bottom and type `-ot Float32` in place of `-of GeoTIFF` after `gdal_translate`

Click “OK”, “OK”, and “Close”
Finally, it’s time to create the FAC

In the “Processing Toolbox”, go to “TauDEM (hydrologic analysis)” and then “Basic Grid Analysis tools” and then “D8 Contributing Area”

Select “fdr” for the “D8 Flow Direction Grid” and then save the “D8 Contributing Area Grid” as fac.tif
Creating an FAC

Click “Run”

You should get something like this →

The lighter the color, the more cells are contributing to the flow at that point

What’s really important is that the gauge point, in the red box, looks like the river flowing into it properly follows the path of the original rivers shapefile
Check the FAC

The drainage area of the Nzoia at our outlet is 12,696 km²

In QGIS I can use the “Identify Features” tool to find the value of the FAC at the outlet point

- I get 298 grid cells
- Each grid cell is 1/16th deg by 1/16th deg
- And 1/16th deg is about 6 km
- So multiply 298 by 6 km and by 6 km again, and you get 10,728 km², which is about the same as 12,696 km²
- This means our DEM, FAC, and FDR are ready to go!
Compare FACs

Compare the new FAC (left) to the old one I had created (right)
Prepare Files for EF5

Save your QGIS project in your nzoia folder and exit QGIS

Out of all the files now in your nzoia folder, we care about dem.tif, fac.tif, and fdr.tif

Copy these three files to EF5_training\examples\nzoia\basic

Now copy your control.txt file from the Okavango example to EF5_training\examples\nzoia
Open `control.txt`

The “DEM”, “DDM”, and “FAM” lines should already point to your new files, as shown:

```
[Basic]
DEM=basic\dem.tif
DDM=basic\fdr.tif
FAM=basic\fac.tif
PROJ=geographic
ESRIDDMM=false
SelfFAM=true
```
In the [Basic] block there are a few other options to know about

**PROJ**
- This tells EF5 how the topographical data is projected
- There are currently two options, geographic and laea
  - geographic is for files using latitude and longitude, like ours
  - laea is for files using the Lambert Azimuthal Equal-Area Projection with a standard parallel of 45N and the central meridian at 100W

**ESRIDDM**
- This tells EF5 how the FDR is coded
- If false, then the TauDEM coding structure of 1-8 is used
- If true, then the ArcMap coding structure of 1, 2, 4, 8, 16, 32, 64, and 128 is used

**SELFFAM**
- This tells EF5 how pixels in the FAC are counted
- If true, then all FAC includes the current grid cell in the flow count, like TauDEM does (all cells have values > zero)
- If false, then the FAC does not include the current grid cell in the count (cells could equal zero)
Two file formats are supported for the DEM, DDM, and FAM .ASC

- ESRI ASCII format
- Text file with space-delimited row order, with each row separated by the ENTER key
- Header information consists of the number of cell columns and rows, the cell size, the NoData value, and the coordinates of the grid origin, which is the lower left cell
Two file formats are supported for the DEM, DDM, and FAM .TIF

- Float32 GeoTiff format
- EF5 will tell you if your DDM/FDR file is an unsupported format
- The easiest fix is to open it in QGIS and use Raster → Conversion → Translate (Convert Format)…
- Pick a location for the input and output files and then use the command `gdal_translate -ot Float32` to complete the translation
Coming Up….

The next module is

Calibration Practice

You can find it in your \EF5_training\presentations directory

Module 3.2 References

EF5 v0.2 Readme, (March 2015).
EF5 Training Doc 4 – EF5 Control File, (March 2015).

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