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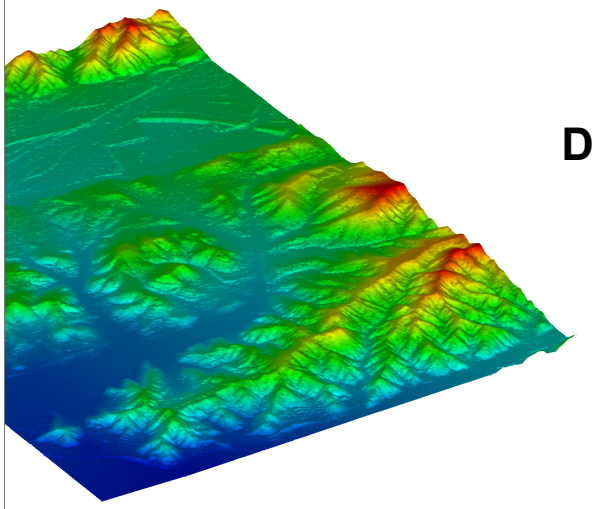
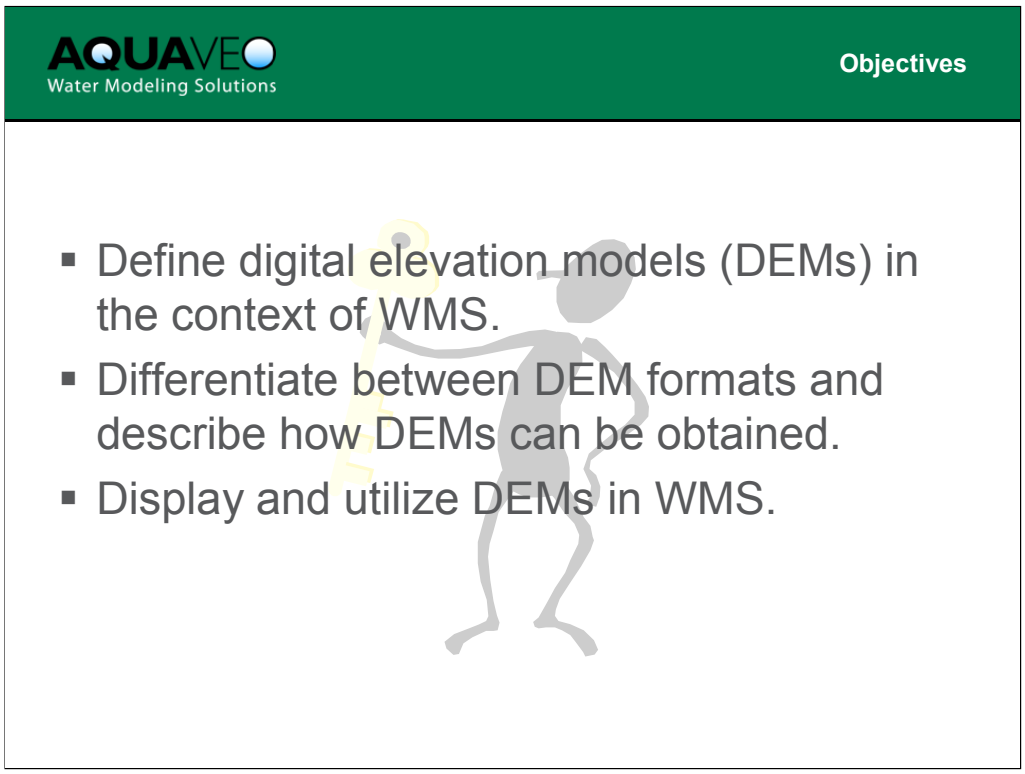


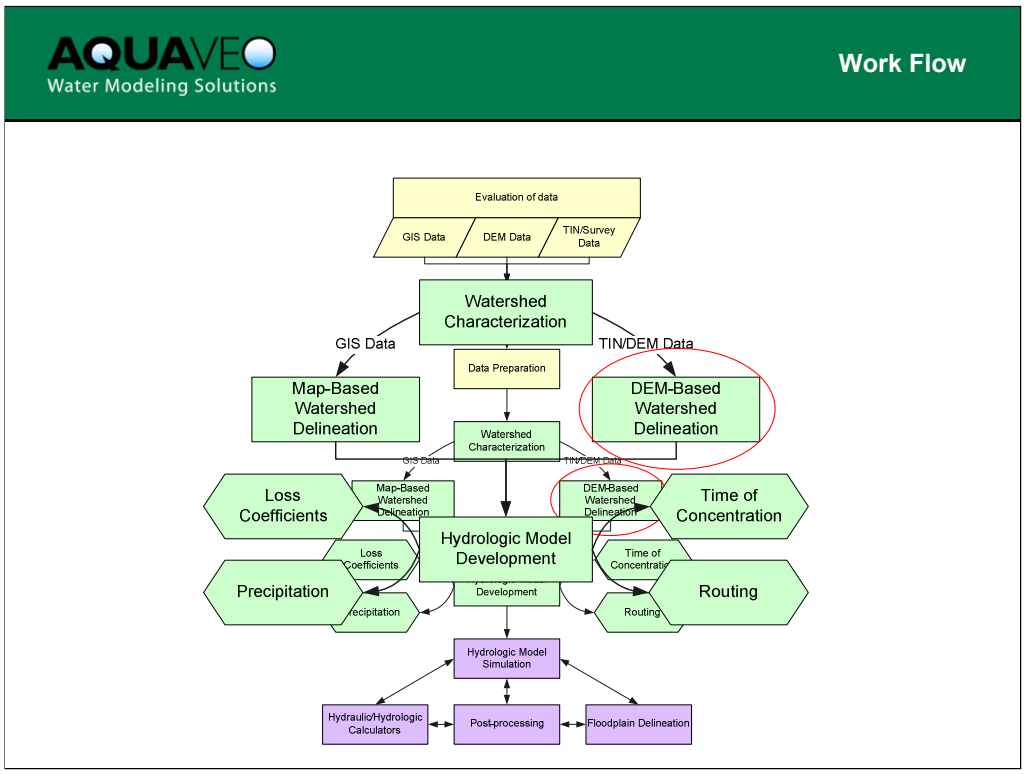
DEM Basics

Lesson 5

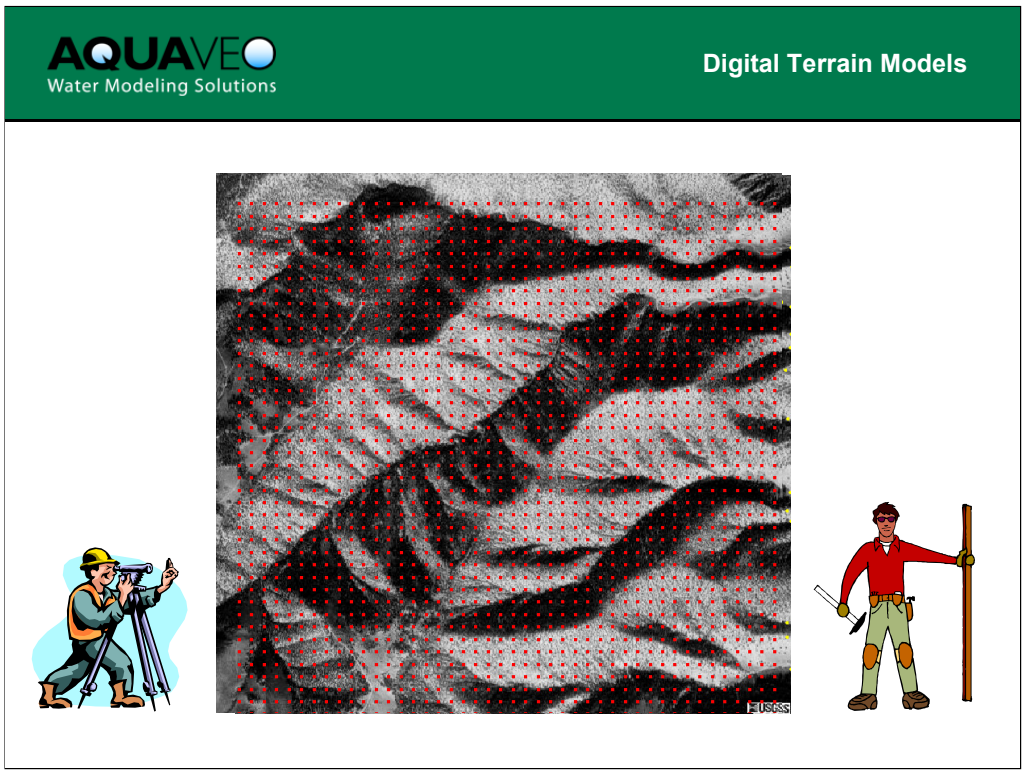


Basic topics to be covered in this presentation are:

1. What is a DEM?
2. DEM formats
3. Downloading DEMs
4. Trimming and Displaying DEM data



This lesson provides important background information for performing DEM based watershed delineation. You can see where it fits into the WMS work flow process from the chart above.



In WMS a digital terrain model (DTM) is used to classify both digital elevation models (DEMs) and triangulated irregular networks (TINs). Both, in fact, are digital representations of the terrain surface, with DEMs being developed on a structured grid (2-D array of elevation points) and TINs from scattered elevation points.

As a surveyor you want to try and measure the fewest possible number of points that will result in the best representation of the terrain. This is most easily done with a TIN, because you can place the points right where you want them (e.g. ridges and valleys), and take just enough to accurately represent the terrain. With a DEM, the resolution determines how often and where points get sampled.

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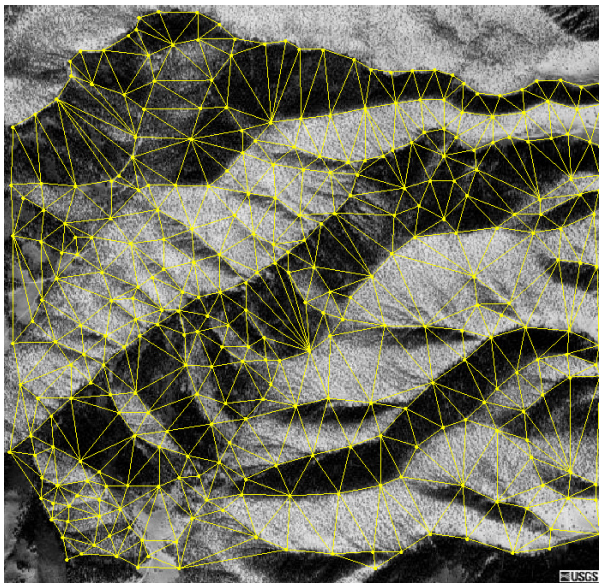
Triangulated Irregular Networks (TINs)



A TIN is very efficient because we only need points where we have changes in slope (curvature). Triangles are formed from the vertices in order to create a piece-wise linear surface of the terrain.

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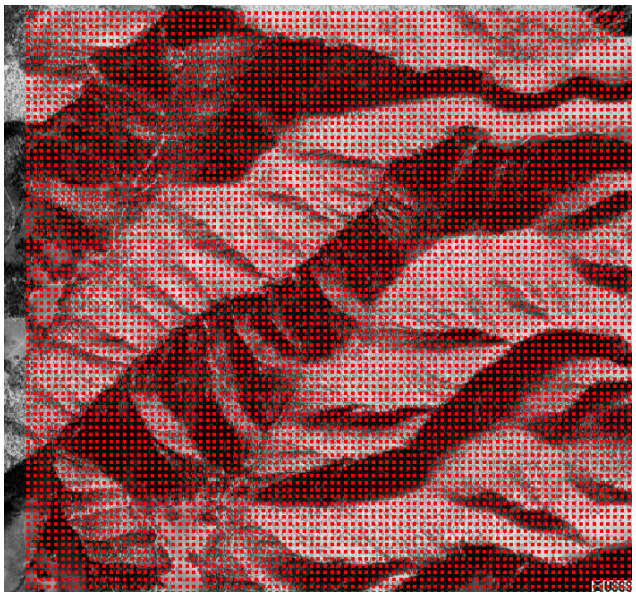
DEMs



In order to accurately capture important features with DEMs you must have a high resolution. Because you don't decide where the points are placed, you need a lot of them to ensure that important features (e.g. ridges and valleys) are accurately represented in the terrain model. Notice that there are no lines (triangle edges) connecting the points, however each point does have "neighbors" at regular intervals.

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Summary of Digital Terrain Models

- DEMs
  - Structured grids
  - "Dumb" or redundant
  - But… easy and available everywhere
  - Used in hydrologic modeling applications in WMS
- TINs
  - Unstructured, or scattered x, y, z values
  - "Intelligent"
  - Representation of linear features better
  - Not easy to find or expensive to generate
  - Used in hydraulic modeling applications in WMS
    - Can be used for hydrology, but not as common anymore

In summary DEMs are easy to work with but can be quite large compared to TINs when dealing with the same level of accuracy. TINs are a more intelligent data structure (because of the triangles connecting the points), however, because they are more complicated to work with, there is often less you can do with them. Further, there are no equivalent data download sites to those where DEMs are easily obtained.

In WMS we primarily use the DEMs for watershed delineation and hydrologic modeling, whereas the TINs are used in the hydraulic modeling and floodplain delineation.

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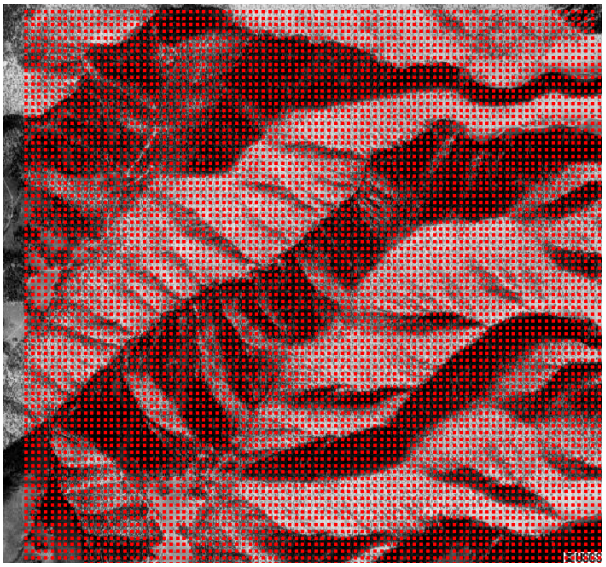
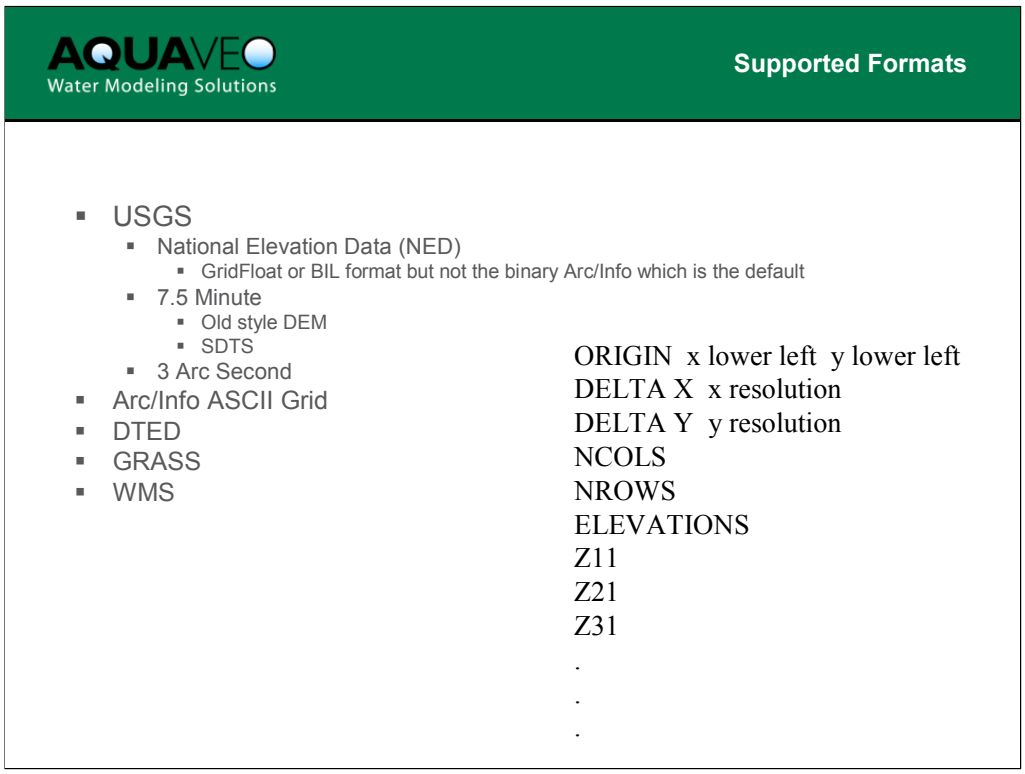
How are DEMs Created?



DEMs are created, as mentioned before, by sampling (interpolating) data on a regular, specified resolution. There is no way to ask the sampling to follow ridges or valleys. In order to capture important detail you must have a high resolution DEM. The high resolution DEMs can be very large and difficult to work with.



A DEM in any of these formats can be read directly into WMS. Other formats of DEMs exist, but they can be converted to one of these formats fairly easily.

A DEM file will typically contain the elements listed above in the example, though they may be in a different order.

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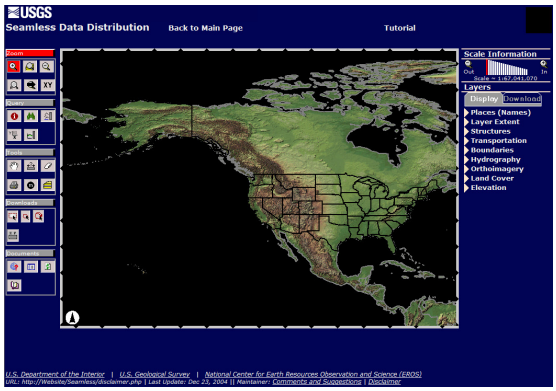
National Elevation Dataset

- Seamless coverage
  - Various products at different resolutions
  - **Must Convert from Arc Grid to GridFloat for WMS**



By far the simplest way to get DEM data into WMS is using the USGS's newest site for delivering DEM data: The National Elevation Data Set or NED. The NED is seamless for the US and was derived from earlier USGS products. The resolution of the data includes 1 and 1/3 of a second geographic coordinates (latitude and longitude), which translates to approximately 30 and 10 meters respectively.

Data are also coming online for other continents at approximately 90 meters resolution.

By default these data are delivered in the native Arc/Info Grid format which is not supported by WMS (unless you can enable the ArcObjects in the GIS module). However, before downloading you can "Modify" your request and change to the GridFloat command which is supported by WMS.

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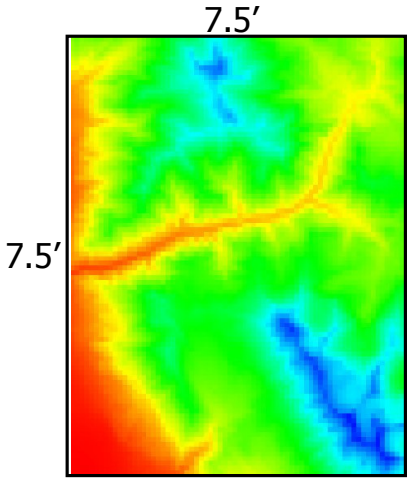
USGS - 7.5' DEMs

- Covers US at 30 Meter Resolution
  - Old Single File
  - SDTS



Traditionally DEMs were distributed by quadrangle maps according to the 7.5 series of USGS maps. Because of this there are still many agencies that archive and make available DEMs in this format. The standard DEMs are at a resolution of 30 meters, but 10 meter resolution DEMs are also available.

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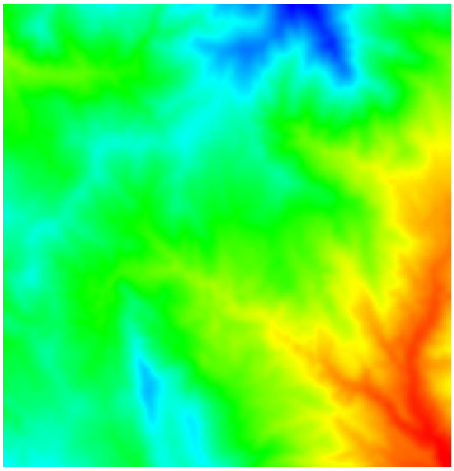
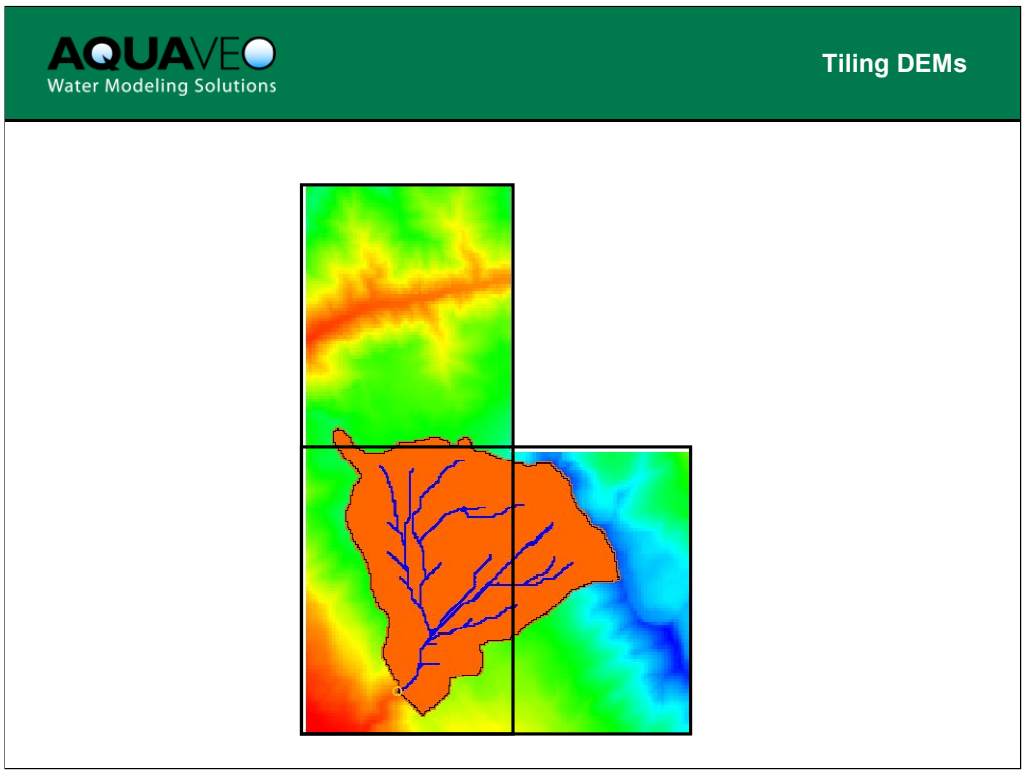
ARC/INFO DEM Format

- Common interchange format
  - Different sizes
  - Different resolutions



The Arc/Info ASCII grid format is a common format used by data developers (aerial photography) and publishers. Resolutions and coverage will vary. WMS supports the ASCII grid format.



Any number of DEMs may be tiled in WMS; however, practical limits such as computer hardware limitations exist.

Occasionally, when you tile multiple DEMs together, there are small slivers of NODATA cells left along the seam of the DEMs due to round-off errors. It may not be noticeable until you actually try performing hydrologic calculations (flow paths will not trace through the boundary because there is a series of NODATA cells). If this occurs, you can use the Fill command to have WMS interpolate new elevation values for the missing gap based on the elevations defined for the surrounding DEM.

Some limitations exist in tiling DEMs in WMS due to coordinate system conventions. For example, the UTM coordinate system is divided (starts over at 0.0) along six degree boundaries.

Tiling of blocks downloaded from the NED site is not allowed. However, this site is one large seamless DEM so if your first attempt did not capture the entire study area, you can go back and grab a larger area for download.

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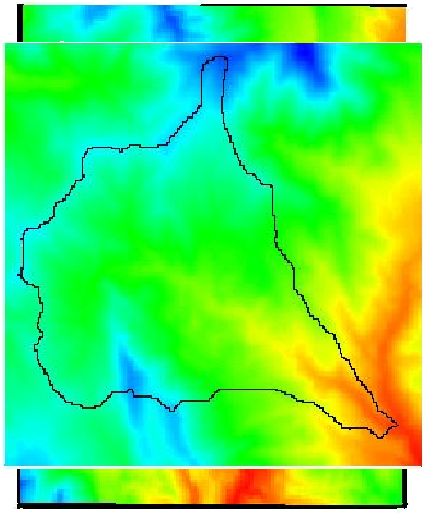
Trimming a DEM

- Define the area
  - Existing polygon
  - Enter interactively



A DEM can be trimmed using the DEM | Trim command. An existing feature polygon can be used, or you may enter a bounding box interactively after issuing this command. The DEM or bounding box of the polygon remains, while everything on the exterior is deleted.

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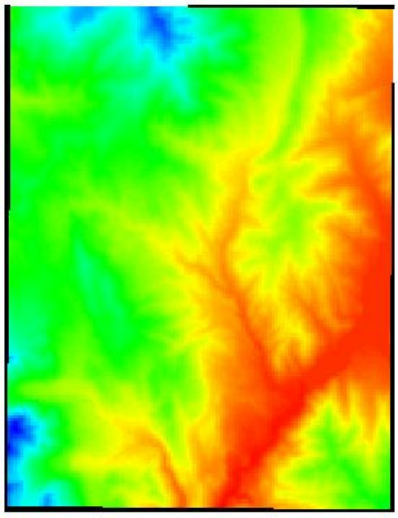
Active, Inactive, and NODATA DEM Points

- Typical 7.5' Quad
- NODATA



DEMs must always be stored as a rectangular array of elevations. However, sometimes you will not have a complete rectangle of elevation points. In these cases the DEM points are assigned a value of NODATA. You may also want to reduce the size of the elevation array you are currently working with. WMS allows you to select blocks of DEM points and inactivate (or activate) them. An inactive DEM point is different than a NODATA point because there is an elevation defined, thus it is just disabled. You may delete inactive DEM points at any time to reduce the overall number of DEM points that are being stored/manipulated by WMS.

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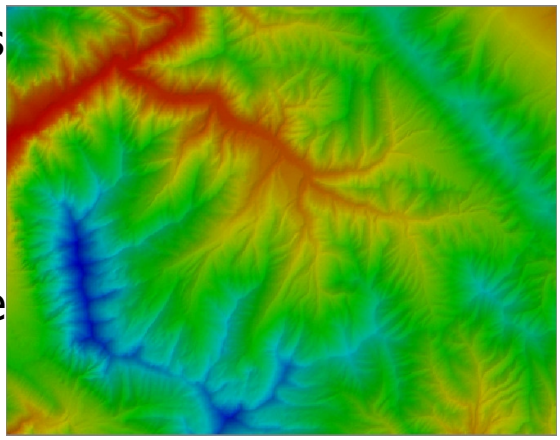
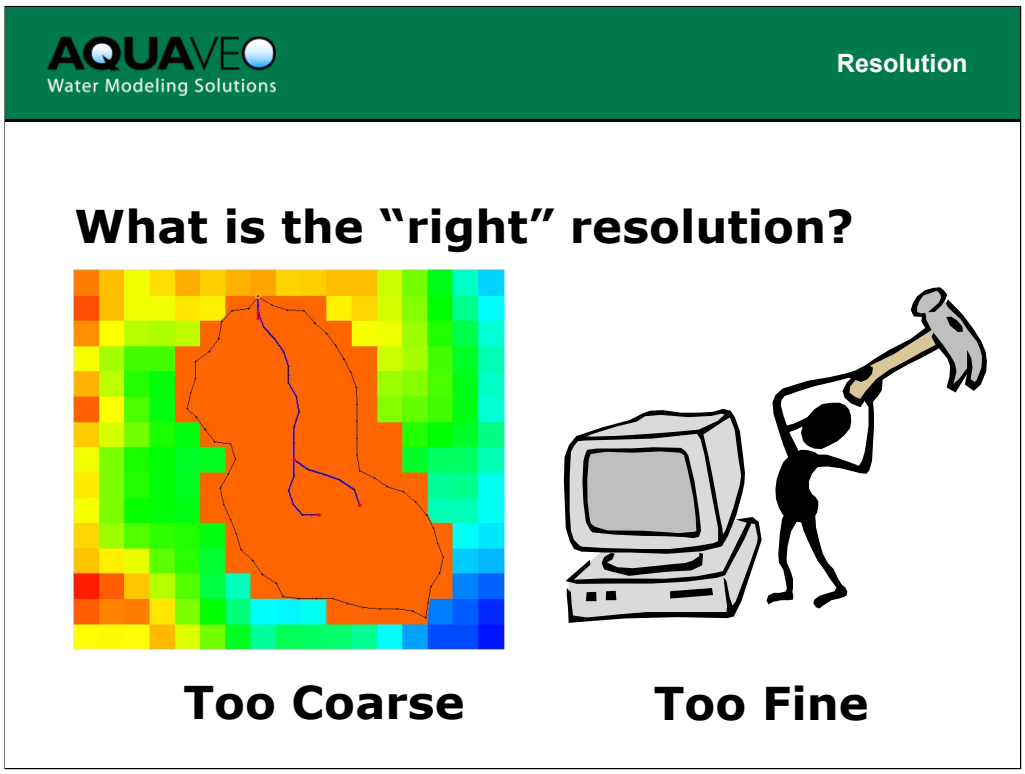
Display Options

- Linear Contours
- Color Contours
  - Display Step
- B&W Hill Shade
- Color Hill Shade



There are several contour display options that can be used to present your DEM data including linear contours, color filled contours and shaded images. Because of the volume of DEM data, contouring can often be slow and time consuming. A display step can be set so that only every nth DEM point is used to draw contours. This will make the display somewhat more coarse (although most of the time it is adequate) but much faster.



What is the appropriate resolution?

This question has no definite answer. However, you will know if the resolution is too coarse if the area of one DEM cell is significant relative to the area of the watershed. Too fine is the opposite: however it is difficult to decide when it is too fine except that you will feel like destroying your computer because computations are so slow. If your data is too fine, you can choose to read in every other or every nth DEM cell to reduce the overall resolution.

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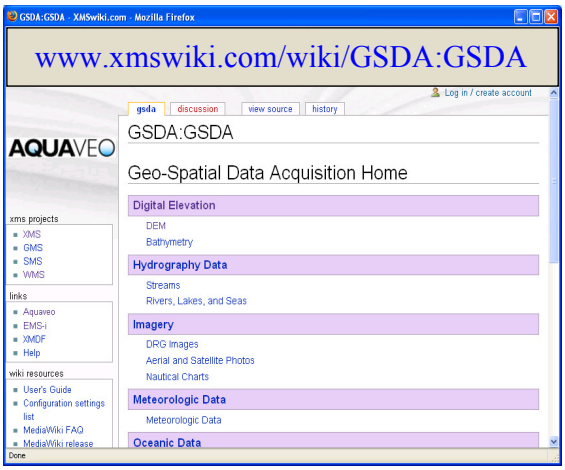
Downloading DEMs

- GeoSpatial Data Acquistion (GSDA)



The GSDA website (http://xmswiki.com/wiki/GSDA:GSDA) maintained by Aquaveo is your gateway to useful digital data that can be used by WMS. The DEM link identifies some of the most useful websites for DEM data download. You should become very familiar with the downloading of DEMs from the seamless site housed by the USGS (first link in download data option for DEMs).

The GSDA website contains many useful tips and instructions for downloading and properly preparing (getting it in the right format) your DEM information.

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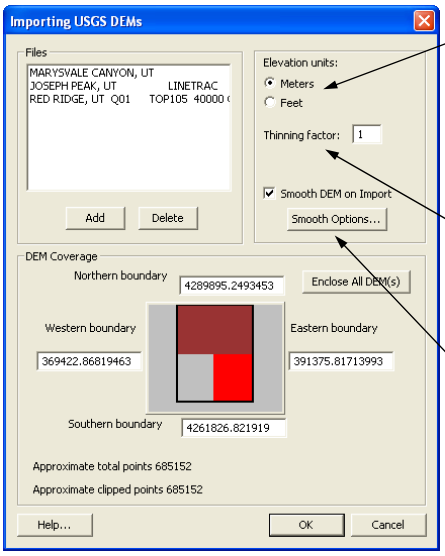
Loading DEMs Into WMS



Elevation Units -
Occasionally DEMs have different elevation units and this will help you make them consistent.

Thinning Factor -
Make your imported DEM have a coarser resolution

Smoothing -
Is done automatically to Remove integer roundoff errors

WMS treats the DEM as a single rectangular area. If you download DEM data from the USGS seamless site, this will not be a problem since it too treats the entire block of data as a single continuous DEM. However, if you are loading multiple DEM quadrangles, you need to remember that WMS must combine the multiple tiles in order to be able to process the elevations for other operations like watershed delineation. Because of this limitation each time you load a set of DEMs into WMS, any existing DEM may be deleted (a warning dialog will appear asking if you want to keep the existing DEM(s)). Therefore, if you need to open multiple tiles as illustrated in this dialog, load and open all of them at the same time.

Some available options that can facilitate loading include:

• When reading the initial DEM it will appear in the dialog, but if you want to load multiple tiles, choose the "Add" button to open additional tiles before selecting "OK." You can also multi-select DEM files to add them all at once.

• If you "Add" a tile that is incorrect you can highlight it in the "Files" window and choose the Delete button.

• Most DEM files have units in meters including elevations. However, for some reason, some of the older DEM files used elevations of Feet. Use the Elevation Units option to make them consistent if you find this to be the case. We recommend that you choose units of meters since the XY units will be meters.

• Sometimes you will have a high resolution DEM (like 10 meters) covering a large area. This can result in too much data and lengthy processing times that are not justified for the detail of the answer (like significant figures). You can use the Thinning factor option to reduce the resolution. Specifying a thinning factor of 2 causes WMS to only read every other DEM point from every other row of data (a reduction of 75% of the data).

• Smoothing removes any integer roundoff error that may have been introduced as a means of more efficient data storage. If DEMs are already floating point, then this option could be turned off.

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Cataloging DEMs and other Data

All_Utahala_sample.txt - Notepad

File Edit Format View Help

```
DEM-30Meter      XMIN     XMAX     YMIN     YMAX
C:\DEMCatalog\36109h1.dem       666807.1241     678177.1241     4082661.413     4096731.413
C:\DEMCatalog\36109h2.dem       655677.1481     667047.1481     4082451.559     4096491.559
C:\DEMCatalog\36109h3.dem       644547.2541     655887.2541     4082251.706     4096291.706
.
.
.

IMAGE-Topo       XMIN     XMAX     YMIN     YMAX
C:\ImageCatalog\pq4342.tif      666807.1241     678177.1241     4082661.413     4096731.413
C:\ImageCatalog\pq4341.tif      655677.1481     667047.1481     4082451.559     4096491.559
C:\ImageCatalog\pq4340.tif      644547.2541     655887.2541     4082251.706     4096291.706
.
.
.

SHAPEFILE-Landuse       XMIN     XMAX     YMIN     YMAX
C:\LandUseCatalog\brigham_city.shp      247581  417145  4543056 4650342
C:\LandUseCatalog\caliente.shp          588871  763368  4095334 4210132
C:\LandUseCatalog\cedar_city.shp        232895  412204  4099021 4206280
.
.
.

SHAPEFILE-Soiltype      XMIN     XMAX     YMIN     YMAX
C:\Soils\Catalog\soils_Project.shp      226700  674700  4099900 4654900
```

Ln 1, Col 1

You can organize DEMs, images, and Land use or soils shapefiles into a common directory and then develop a text file database with bounding box coordinates for each file so that data pertinent to hydrologic analysis with WMS can be loaded automatically. This is similar to the concept of the web services for the Terra Server for loading DRG and satellite imagery (and can be used in conjunction with), except that the files are compiled and managed on a local or network drive.

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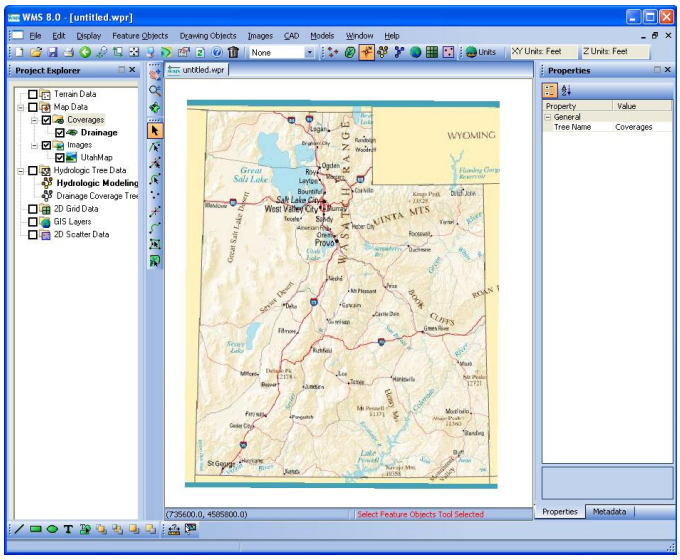
Reference Map



An image or other data files can serve as a reference map for identifying the location of DEMs and other data to be loaded from a catalog. The important thing to remember is that the reference map must be registered, or defined in the same coordinate system as the bounding box coordinates of the catalog.

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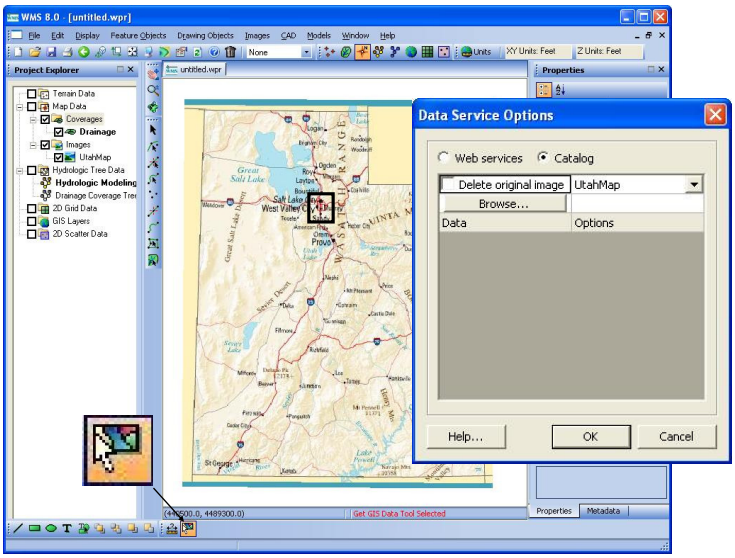
Using a Catalog



With the reference map loaded, the Get Data tool can be used to identify a bounding box for the area you wish to read in data (e.g. DEMs, images) from the catalog. The referenced map provides the appropriate coordinate system and the tool lets you specify the bounding box. After dragging a box with the Get Data tool, you will be asked to identify the catalog text file that contains the archived file names and bounding coordinates. After specifying the catalog file the options for available data will appear in the spreadsheet allowing you to select the options you wish to load. When you select OK in the Data Service Options dialog, WMS will load the specified data from the catalog whose bounding coordinates fall within the box identified with the Get Data tool. You can optionally delete the reference map, but only if it is a geo-referenced image.

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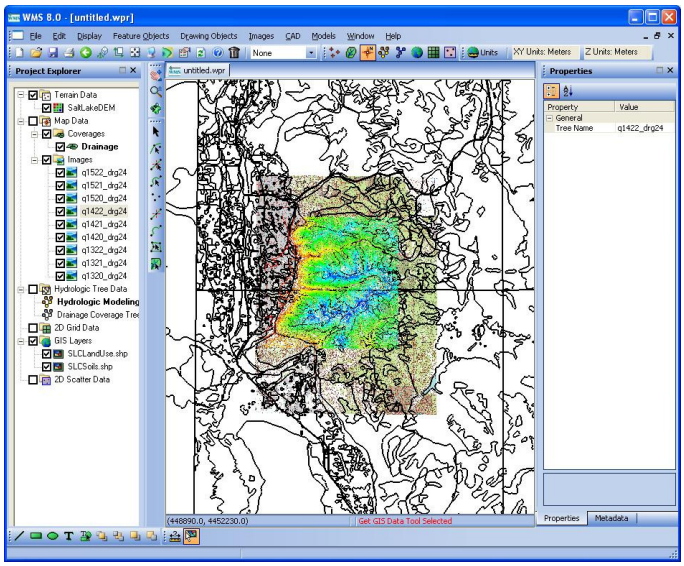
Using a Catalog



DEMs, USGS topographic maps (DRG images), and land use polygons that fall within the bounding box are referenced through the catalog and automatically opened into WMS.

The demonstrated catalog covers Utah and was developed for the Utah Department of Transportation. To develop a localized catalog, you need to identify the data sources, their bounding coordinates, and set up the text file catalog. The procedure may take several hours to several days to complete but the effort may save every engineer within an organization from learning how to download DEM, image, and other data in a consistent file format and coordinate system.

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Summary

- DEMs (gridded data) may be obtained from several sources.
  - The USGS Seamless site is most useful
- DEMs are opened into WMS using the File | Open command.
  - Multiple DEMs can be tiled together
- There are many options for contouring and displaying DEMs.

DEMs are the most widely available data source. Understanding their structure and how they are defined will help make the most of them in developing watershed models.

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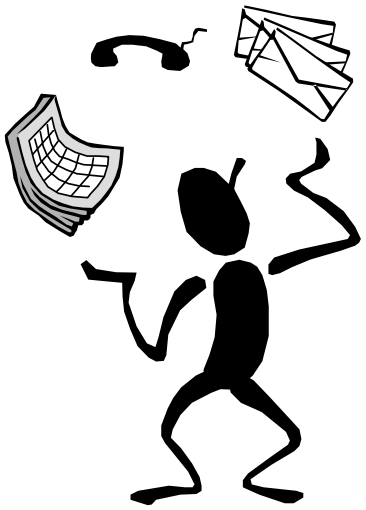
Demonstration



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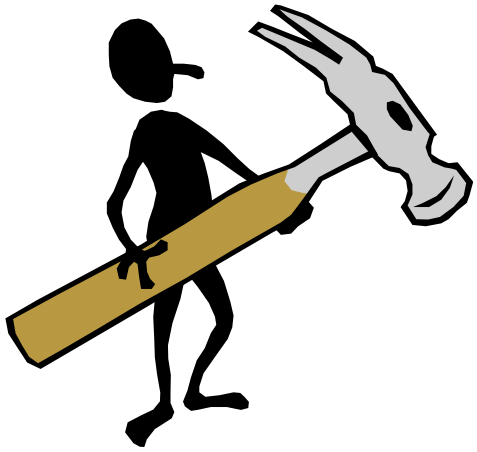
Workshop



The files that will be used for this workshop can be found in the tutorials directory in the folder named **dembasics**.

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Review & Discuss

- Objectives
  - Define digital elevation models (DEMs) in the context of WMS.
  - Differentiate between DEM formats and describe how DEMs can be obtained.
  - Display and utilize DEMs in WMS.
- Applications