DTM/CONTOURS

Introduction

The intent of this topic is to describe how survey information was collected and processed into topographic maps in the past and to illustrate how data is currently processed into digital terrain models, with resultant products, such as contours.

Definitions

Planimetry – the location of the features.

Topography – the configuration of the ground.

Contour – an imaginary line of constant elevation on the ground surface.

Contour line – a line on the map representing a contour.

Contour interval – the constant vertical distance between two successive contour lines.

Index contour line – a contour usually represented by a heavier line drawn at every fifth contour to make the map easier to read. These contour lines are usually labeled.

MAPPING CONTOURS – THEN

Maps

Originally two separate maps were created:

- *Planimetric map* – a 2 dimensional graphical representation of the positions on the earth's surface of the natural and artificial features of a given locality.

- *Topographic map* – a map representing the configuration of the terrain or ground with contour lines constructed from plotted points of elevation.

Topographic maps

Contours for topographic maps were created from field data by several methods:

- Transit-tape
- Transit-stadia
    - Chasing contours
    - 'Controlling points' method
- Cross sections
- 'Dirty sheet'
- Grid or Coordinate squares
- Plane-table with alidade
- Photogrammetry

Note: All methods depended on the assumption that there was a uniform slope between any two ground points located in the field. Spot elevations were usually given for critical points such as peaks, sags, streams, and highway crossings.

Transit-tape method

This was the most accurate, but the slowest and most costly method. Consequently it usually wasn't used for topographic mapping.

Transit-stadia method

Contours were found by either the chasing (tracing) contours or by the 'controlling points' method.

- Chasing contours

  This method was used when the exact location of a particular contour line was needed. It was effectively performed by use of a plane table, but was also done by the transit-stadia survey method.

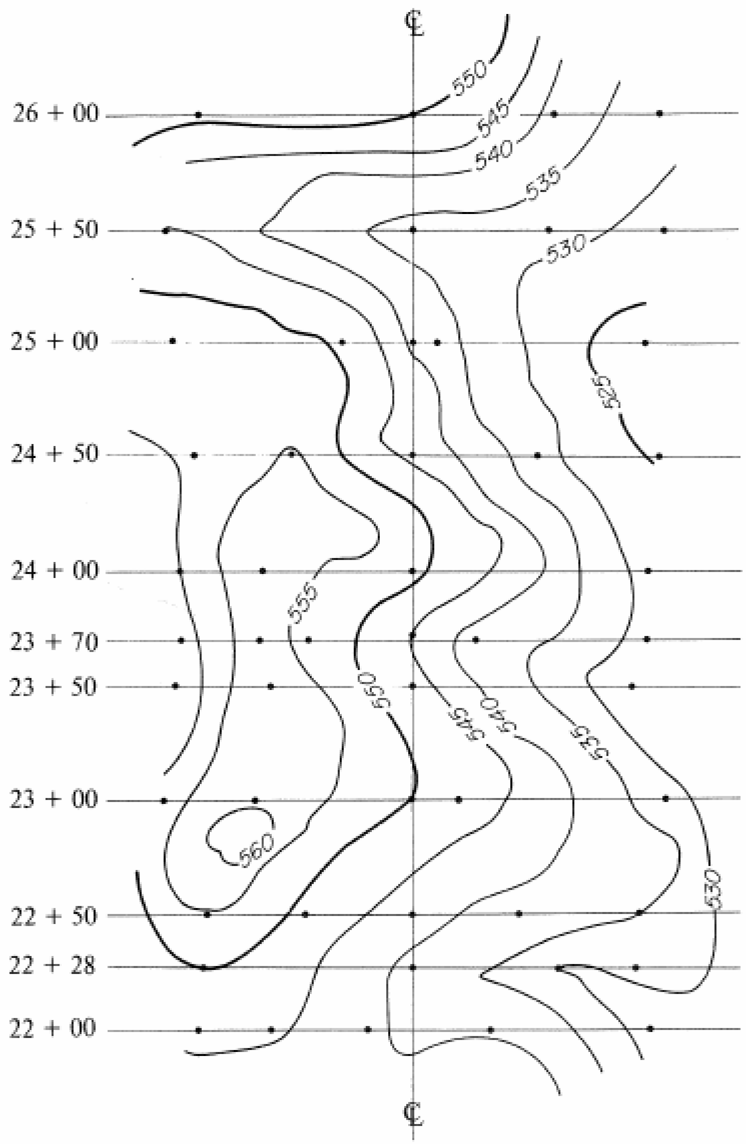
  The rod reading (foresight) which must be subtracted from the height of the instrument to give the contour elevation was determined (sometimes referred to as the 'grade rod'). The rod person then was directed uphill or downhill until the required rod reading was found. The distance and azimuth were then read with the transit. This work could all be done with the transit, but it was greatly enhanced when supplemented with a level used to direct the rod person uphill or downhill. The work was also sped up by using a piece of flagging or a device that could be adjusted on the stadia rod to the required 'grade rod' reading.

- 'Controlling points' method

  The 'controlling points' method was suitable for maps of large area and small scale. The selection of ground points was very important. The accuracy of the contours depended on the knowledge and experience of the survey party. The stadia rod shots were taken on critical points where there were changes in the ground slope (breaklines) and plotted before interpolations were made. The elevations were obtained with a level to save time in reducing data. Interpolations were made in much the same way as they were made using the grid method.

Cross section method

It was accomplished using level and tape or transit-stadia. In fairly uniform ground cross sections were taken from a control line, center line or base line. The sections were plotted with elevations of each cross section shot written on the map. Contour lines were interpolated from the sections and plotted on the map, as in the grid and 'controlling points' methods.



Contour lines interpolated from cross-section notes

Once the contour lines were smoothed, index contour lines were made heavier than the other lines, and the elevation of the index contour was written in a break in the line.

‘Dirty sheet’ method

This method was most useful when the terrain was fairly flat and accurate contour lines had to be located. It was also used in steep terrain, but other methods, such as transit-stadia served as well and were quicker.

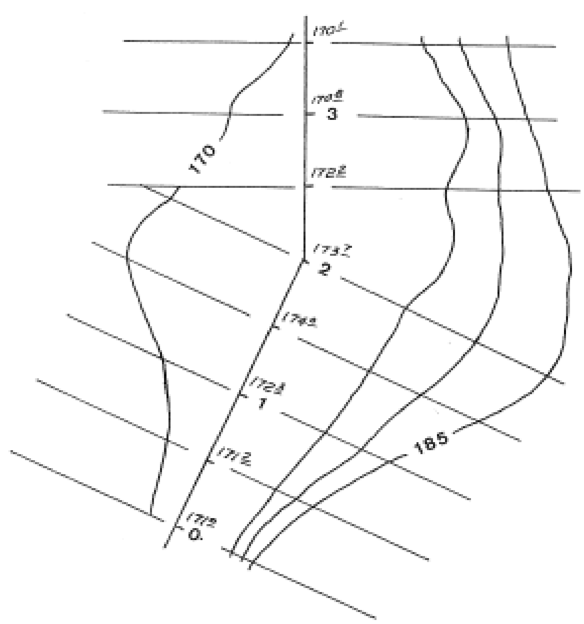
The procedure was as follows:

1. Run traverses through the area to be contoured and station the traverses.
2. Run levels over the traverses.
3. Plot the traverses on convenient size sheets to the desired scale. Mylar film was very good for this as it was not affected by moisture.
4. There were several ways of locating the contours.

    a. In steep terrain, the hand level and tape method was most often used. An H.I. was obtained and the rod reading for each contour elevation was computed. The rod person moved out at right angles to each station up or down slope until the desired elevation was located. The distance was taped and the point was located on the map.

    b. If the terrain was fairly level, a transit or level could be used instead of the hand level. Then you could work several stations from a single set up.

5. As each contour was located and plotted on the sheet, they were connected to make up the topography map.

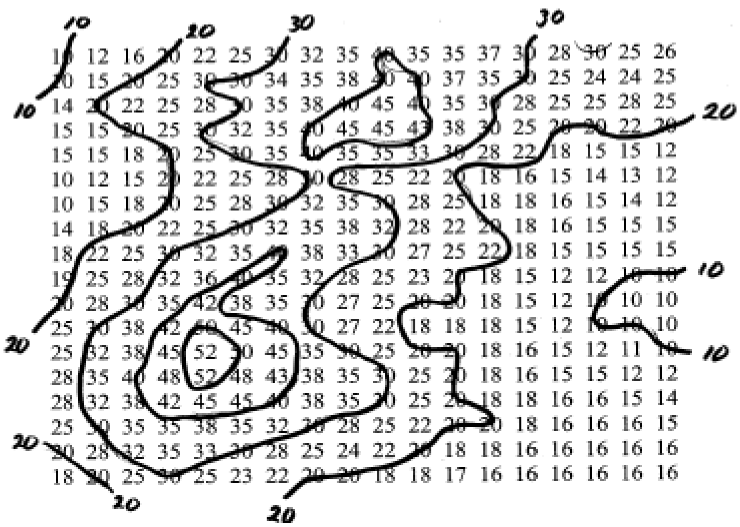


Other information was also plotted on the dirty sheet, such as buildings, trees, streams, roads, fences, etc. However, in some cases it was easier to tie these features by other means and plot them on the map from notes.

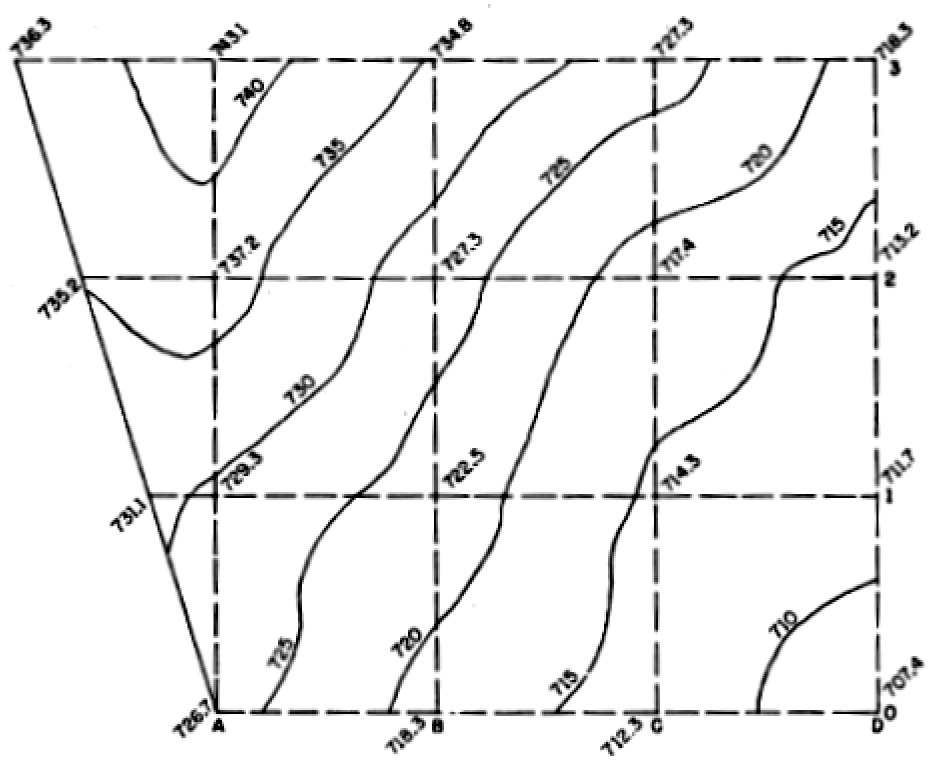
<u>Grid method</u>

The grid method was very effective in locating contours in a relatively small area of fairly uniform slope. The area was typically divided into squares of 10, 20, 50, or 100 feet on a side (depending on the scale of the map and the contour interval desired). Stakes were set at each intersection and at any other points of slope change, such as at breaklines.

Elevations were set on the corners with a level. Contours were interpolated (either by estimation or mathematical proportion) between the corner elevations (along the sides of the blocks but sometimes diagonally also) by estimation, or by calculated proportional distances.
After the crossing points were located by interpolation, the crossing points for each contour were connected. The contour lines were then smoothed. Small irregularities were taken out so that the contour lines were more like the contours on the ground.



Contour interval = 10 ft.



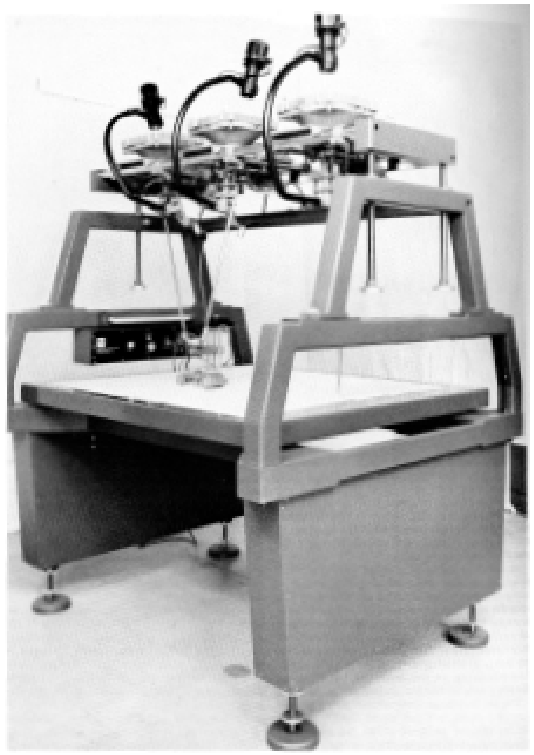
Contour interval = 5 ft.

<u>Plane-table method</u>

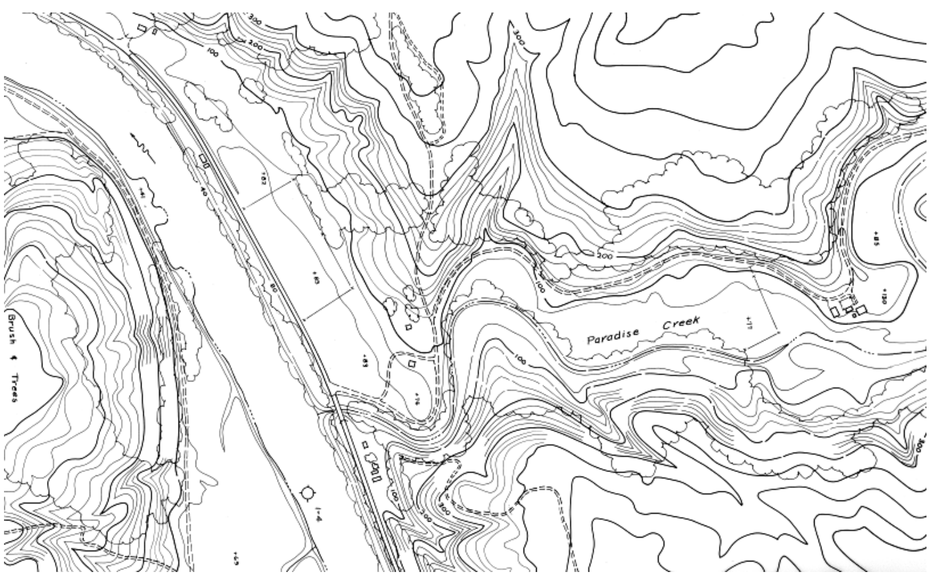
In the plane-table method the sheet may have been prepared beforehand by plotting the control or control line(s) to the desired map scale, marking the positions of the stations, and entering the elevations obtained from leveling directly on the plane-table sheet. In the field the board was leveled and then oriented by backsighting along the line on the ground with the blade of the alidade aligned along the position of the line. The alidade was foresighted on a level rod held at points to be located and the distances, typically obtained by stadia, and the vertical angles were read. The direction of the line was drawn along the alidade ruler, thus eliminating the need for measuring or recording any horizontal angles. Vertical angles could be avoided by using the alidade as a level. Differential leveling could even be done with the plane-table alidade. The instrument person sketched contours directly on the plane table sheet by either the ‘chase contour’ method or by the ‘controlling points’ method while looking at the area, and checking the coverage while in the field.

Photogrammetry

Topography was plotted from measurements on aerial photographs. This method was advantageous for large and rugged areas. The vast majority of topographic mapping was accomplished by photographic methods; however a certain amount of field completion and field editing had to be done by ground methods.



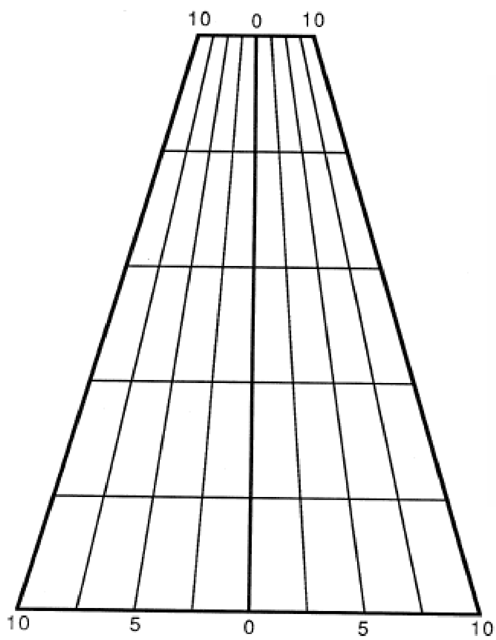
Kelsh Plotter – stereoscopic mapping instrument



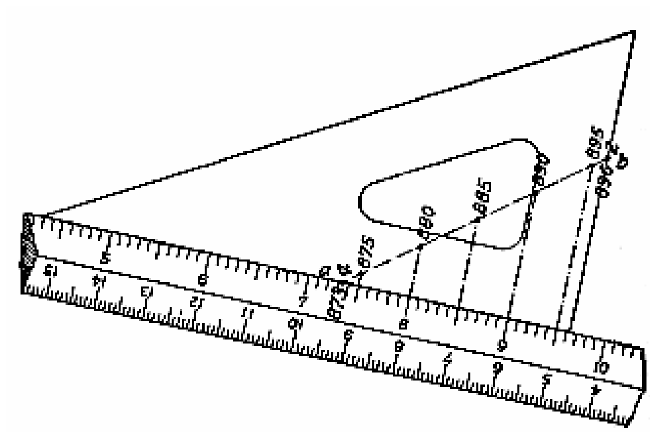
Topographic map created using a stereoscopic plotter

Interpolation methods

- Estimation
- Direct calculation
  - o Measure the intervening horizontal distance and proportion the correct position for each line.
- Mechanical interpolation
  - o A rubber band marked with a uniform series of marks can be stretched to find the correct interval for each line.
  - o Spacing dividers – a drafting instrument with 11 legs arranged to proportion a distance spanned into equal parts.
- Graphic



Clear plastic interpolator



MAPPING CONTOURS – NOW

Modern Topographic Maps

Most modern topographic maps are produced on a computer in 3 dimensions and can be viewed and plotted from any angle or position. The maps contain both planimetric and topographic features and show the horizontal distances between the features and their elevations above a given datum. Design systems can interact with these 3D maps to aid in the design of highways, etc. Topographic maps are not only essential to the planning, design and layout of projects, but are also essential to persons directing military operations. They are also of great benefit to some rescue operations and for recreational use.

A topographic map without contours is a basemap.

Digital Terrain Model

Electronic data from the field, field notes, and data from photogrammetric sources are input into software used to create a Digital Terrain Model (DTM). A Digital Terrain Model is a numerical representation of the configuration of the terrain consisting of a very dense network of points of known X,Y,Z coordinates. A computer processes the data into a form from which it can interpolate a three dimensional position anywhere within the model. A DTM forms the basis for modern highway location and design. A digital terrain model surface can generate triangles, contours, cross sections, profiles, analyze alternate design alignments, compute volumes, etc.

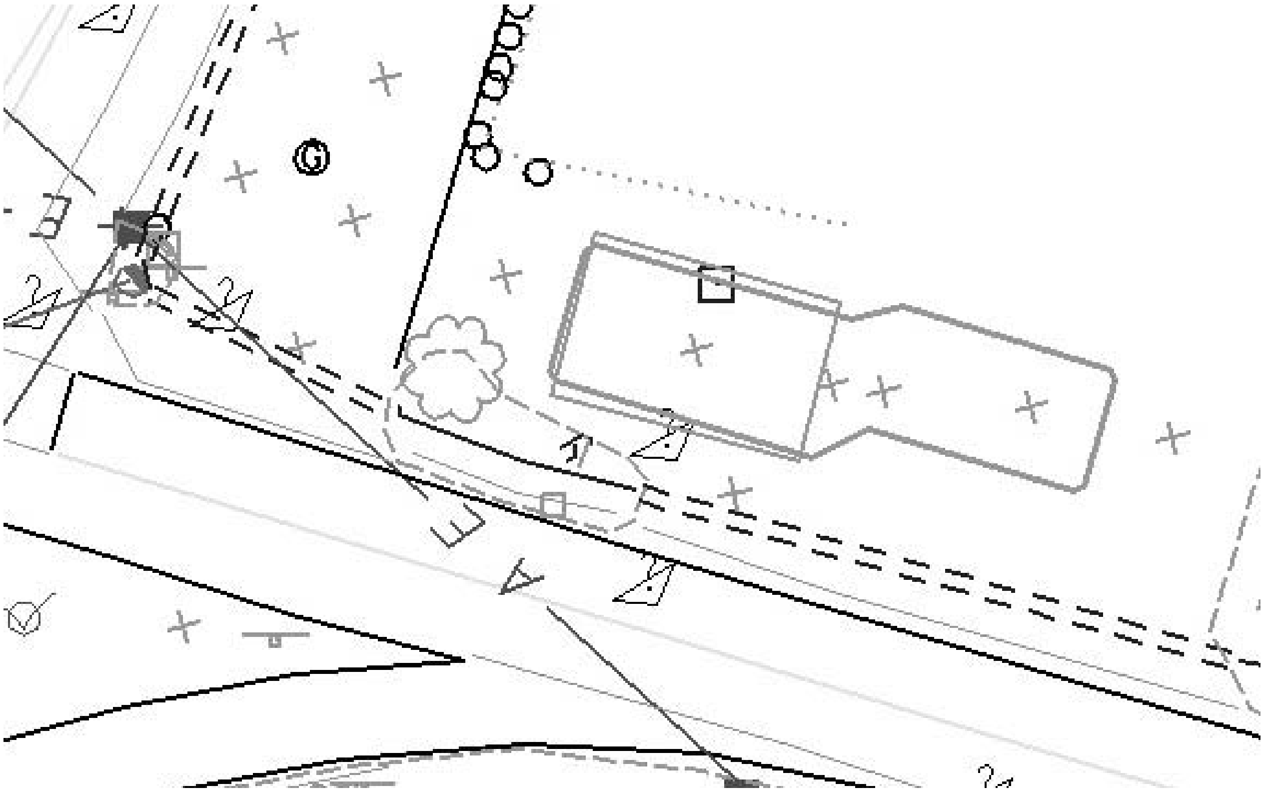
DTM Products

A digital terrain model can generate:

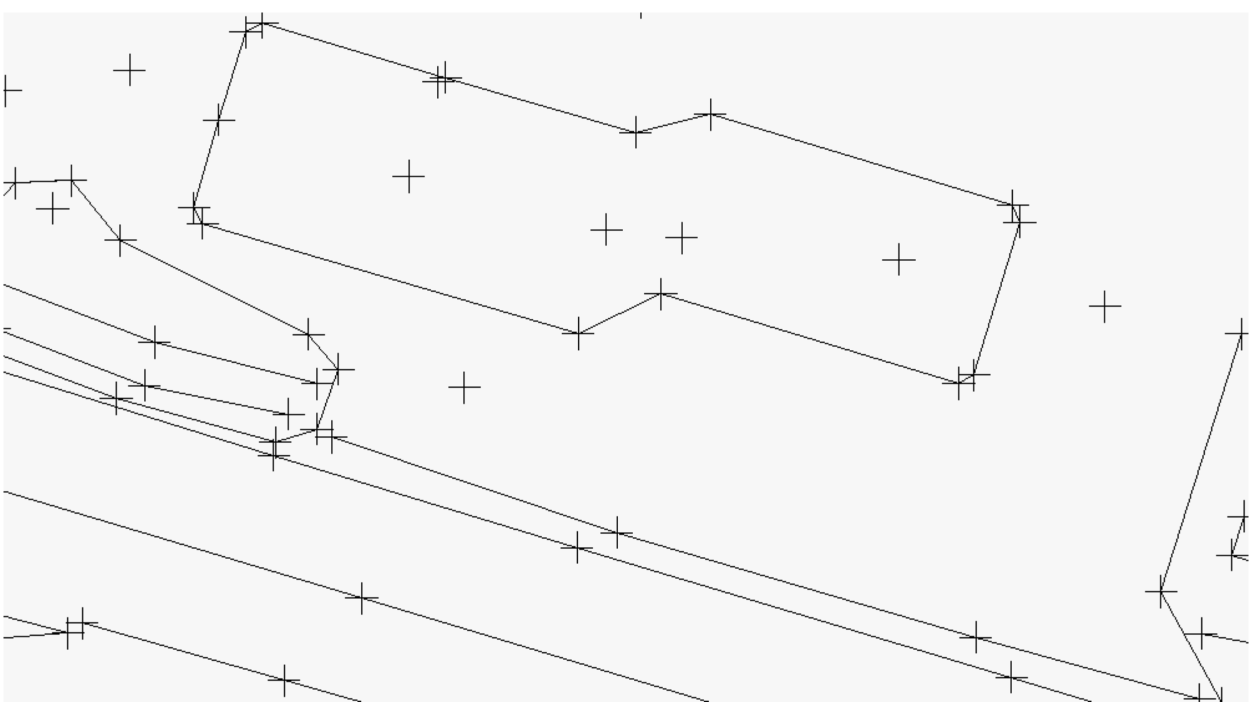
- Surface Triangles
- Contours
- 3D Grid
- Cross Sections
- Profiles
- Flood Plains
- Water Catchment Areas
- Water Flow Models
- Pond Volumes

Triangles

'Controlling points' method – Selected data (contourable survey points and breaklines) is loaded into the active DTM surface database as DTM points and DTM breaklines. This data will control the creation of the triangles in a model. The points will form triangle vertices. No triangle will be allowed to cross a breakline. Any data loaded into a DTM surface database must have elevations.

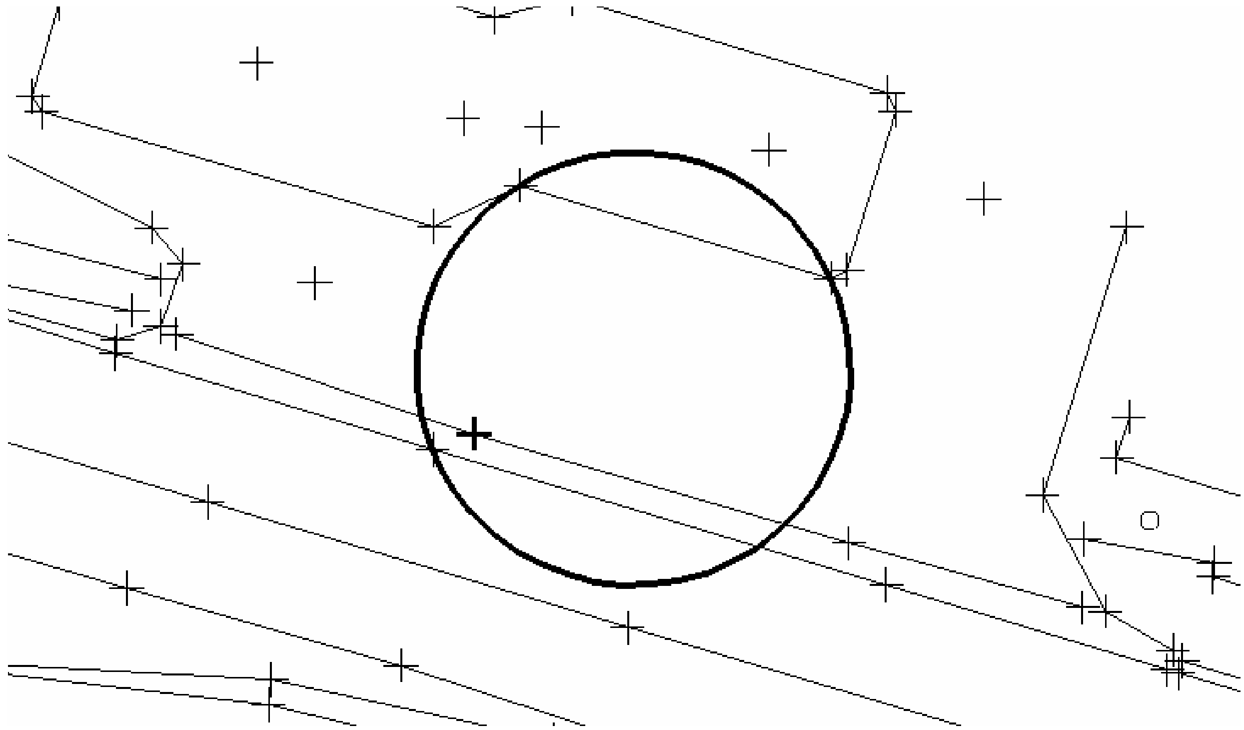


Contourable and non-contourable survey points and lines

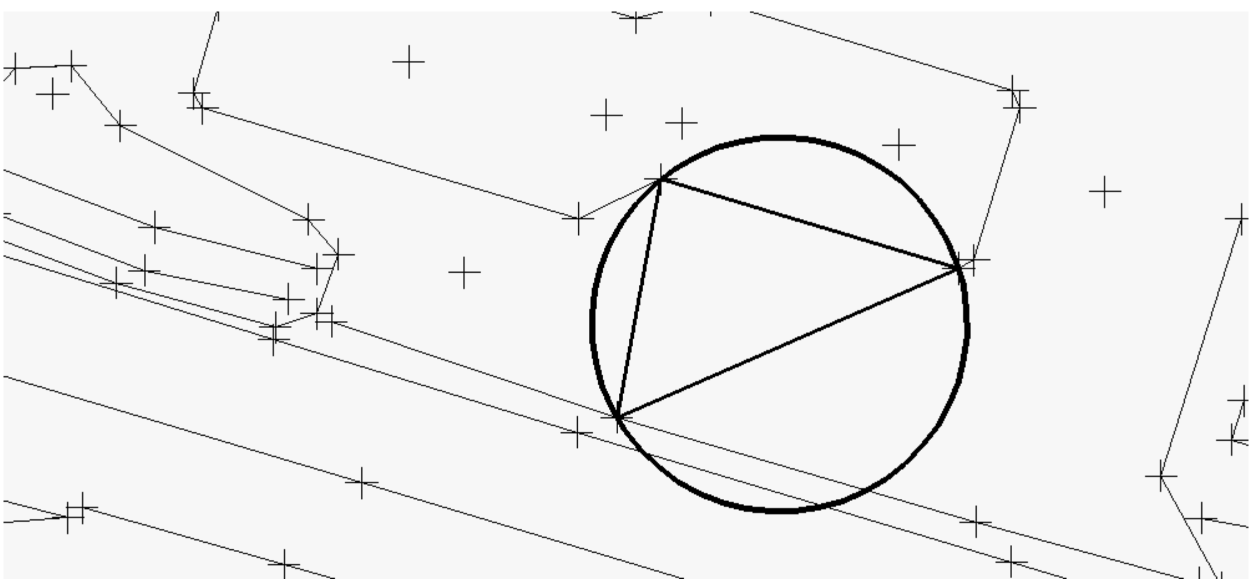


Contourable points and breaklines loaded into the DTM surface

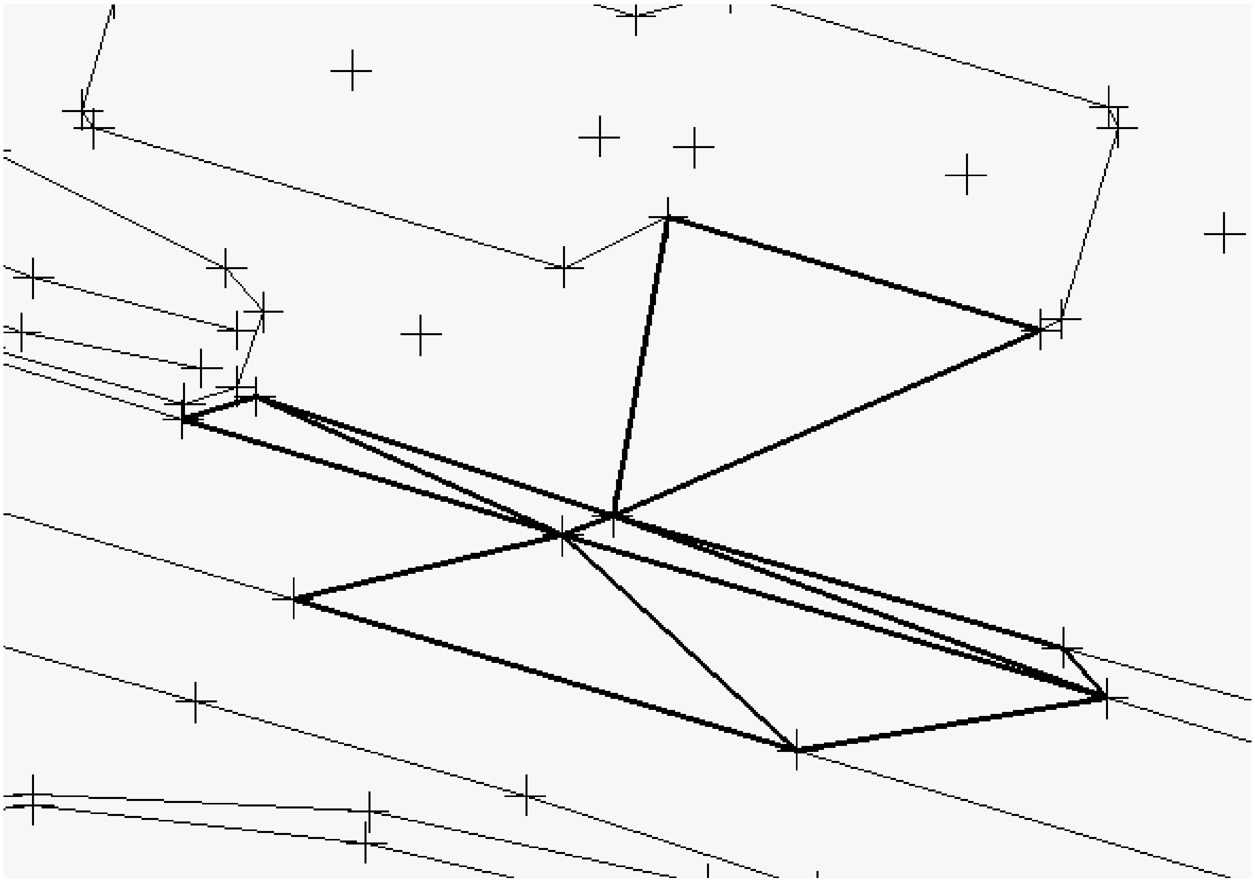
Triangles are created and displayed according to the surface parameters, properties and viewing settings. One algorithm for creating triangles consists of selecting three points and drawing a circle that passes through them. No circle can contain any other points. If it does the algorithm selects a new combination of three points at least one, or more, of which was contained inside the previous circle. The circle is recreated until no points fall within the circle.



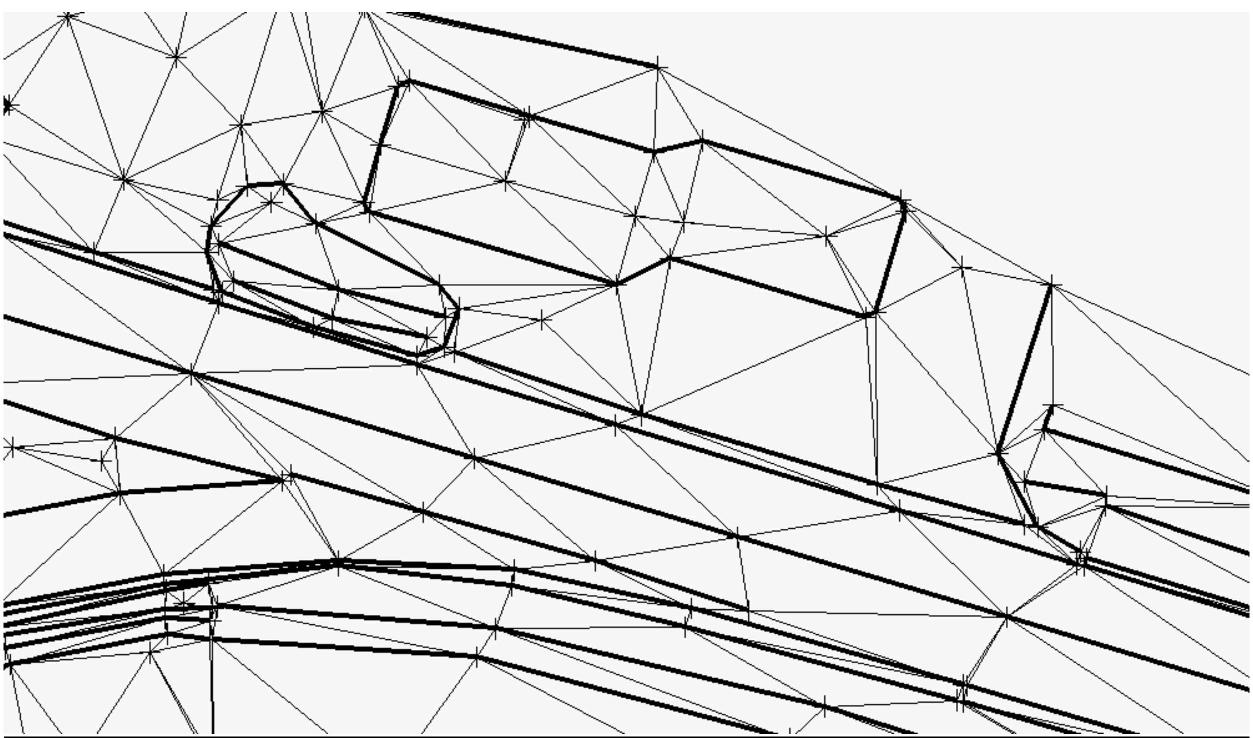
A triangle will <u>not</u> be created in the above picture, from the three DTM points with the circle drawn through them, because another DTM point falls within the circle.



A triangle is created in the above picture, using the algorithm, because no other DTM points fell within the circle.

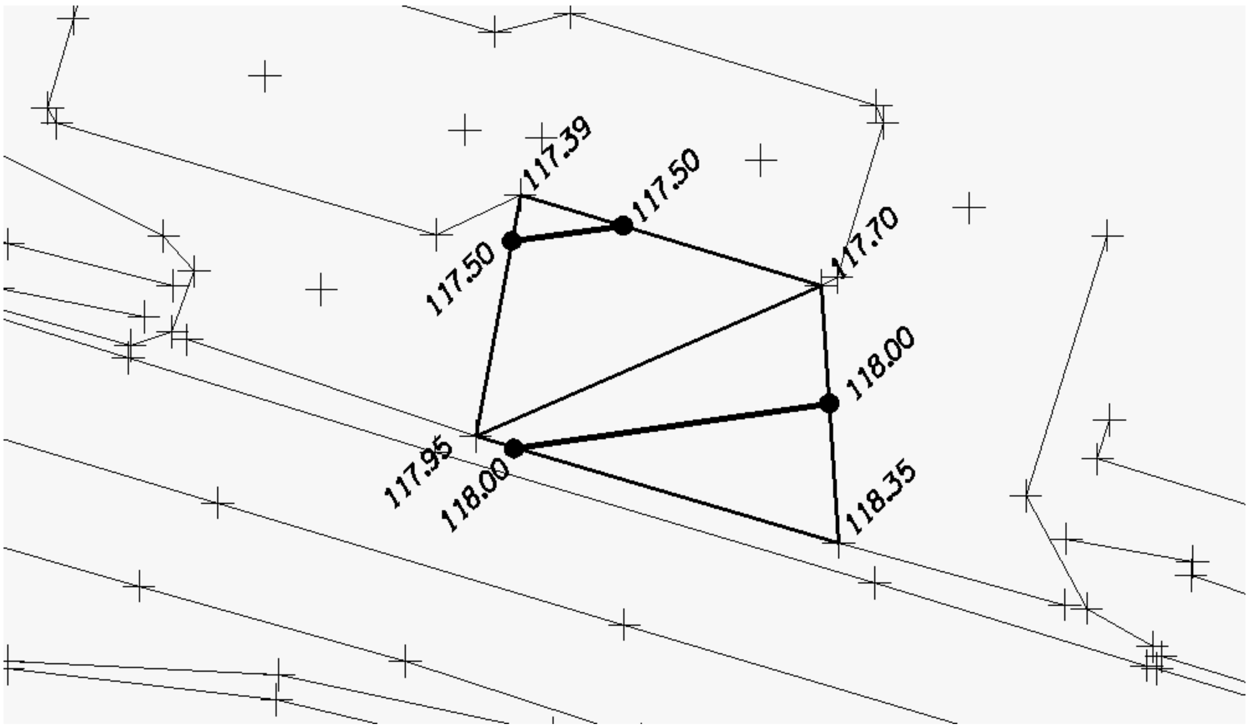


DTM points form triangle vertices. Triangles do not cross breaklines.



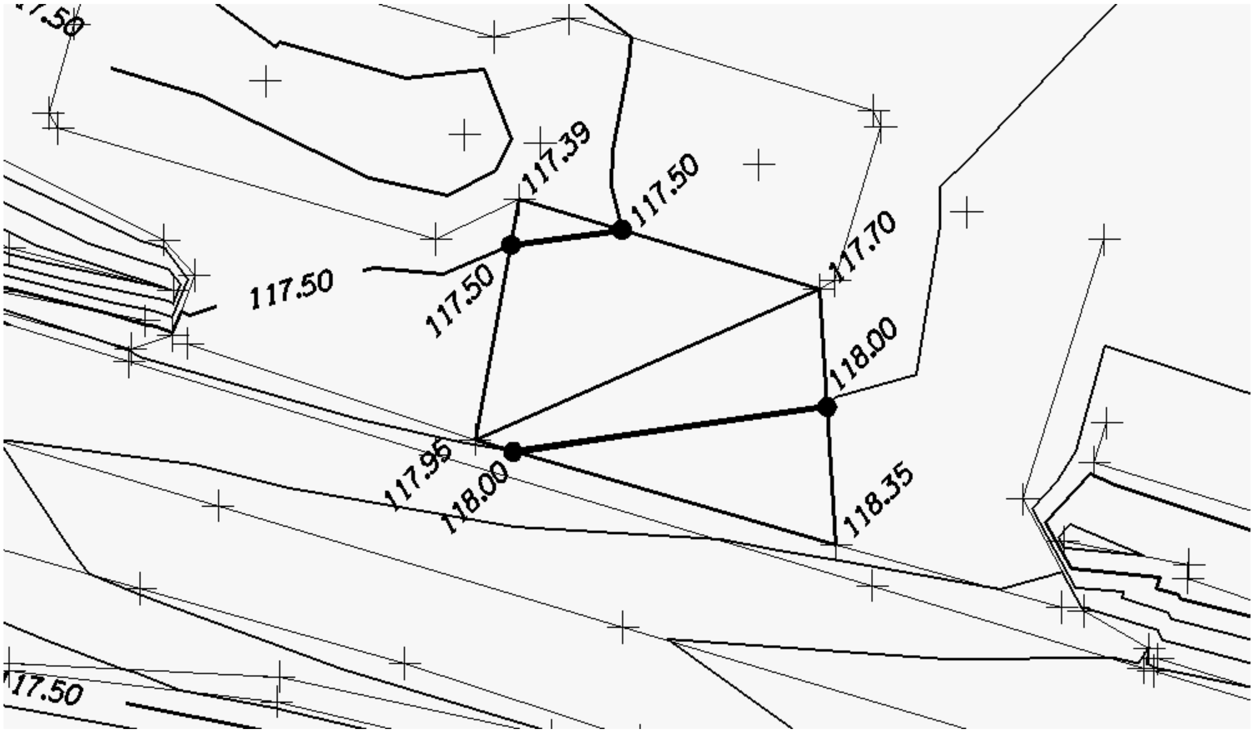
Contours

The triangulated surface is the basis for computing contours, as well as all other DTM products. DTM points, which form the vertices for the surface triangles, have known horizontal and vertical positions. Hence the length and the slope of each triangle side can be computed. Contours can then be accurately interpolated along the sides between the triangle vertices.

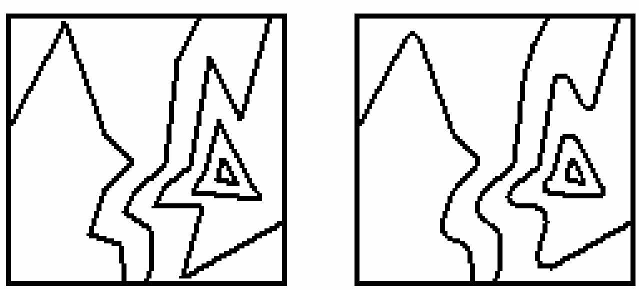


Contours interpolated along sides of triangles

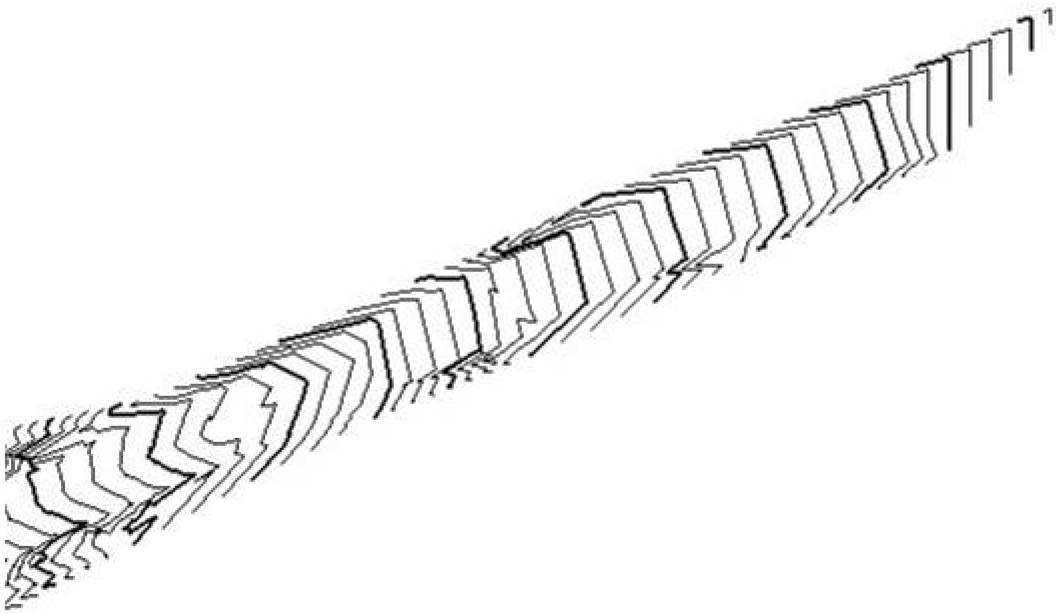
Once the triangles have been computed, contours can be automatically generated and displayed according to the surface parameters, properties and viewing settings.



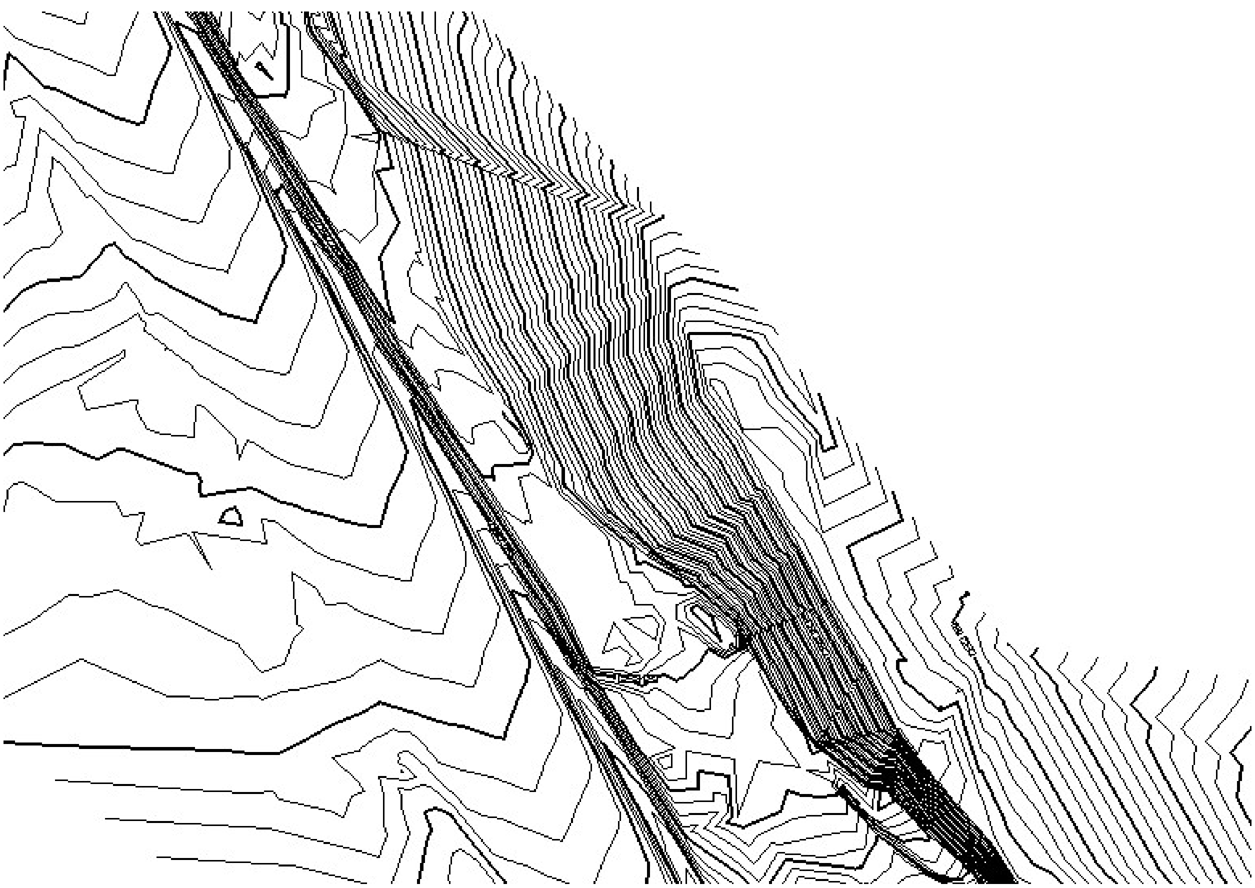
Smoothing – When contours are computed they first take on the appearance of a series of straight lines. If smoothing is enabled the contouring routine will then attempt to smooth the contours. Although smoothing helps make the contour lines look more realistic, they do not improve the accuracy of the model. Also, smoothed contours may sometimes ‘appear’ to cross when smoothing is applied. Unsmoothed contours are superior for visually analyzing possible problems.



Unsmoothed Smoothed

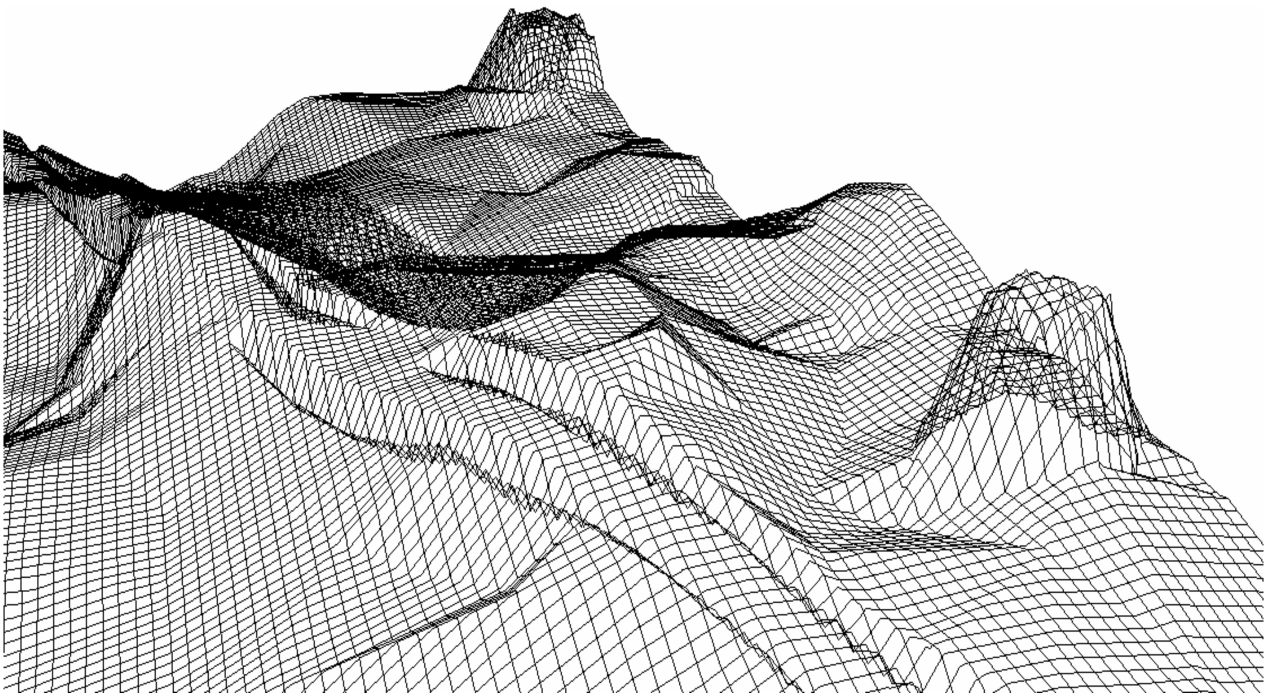


Straight line contours examples



3D Grid

A 3-D surface grid is computed over a user-defined area on a DTM surface. The 3-D grid is primarily used for perspective viewing of the DTM as a mesh surface.



Cross Sections and Profiles

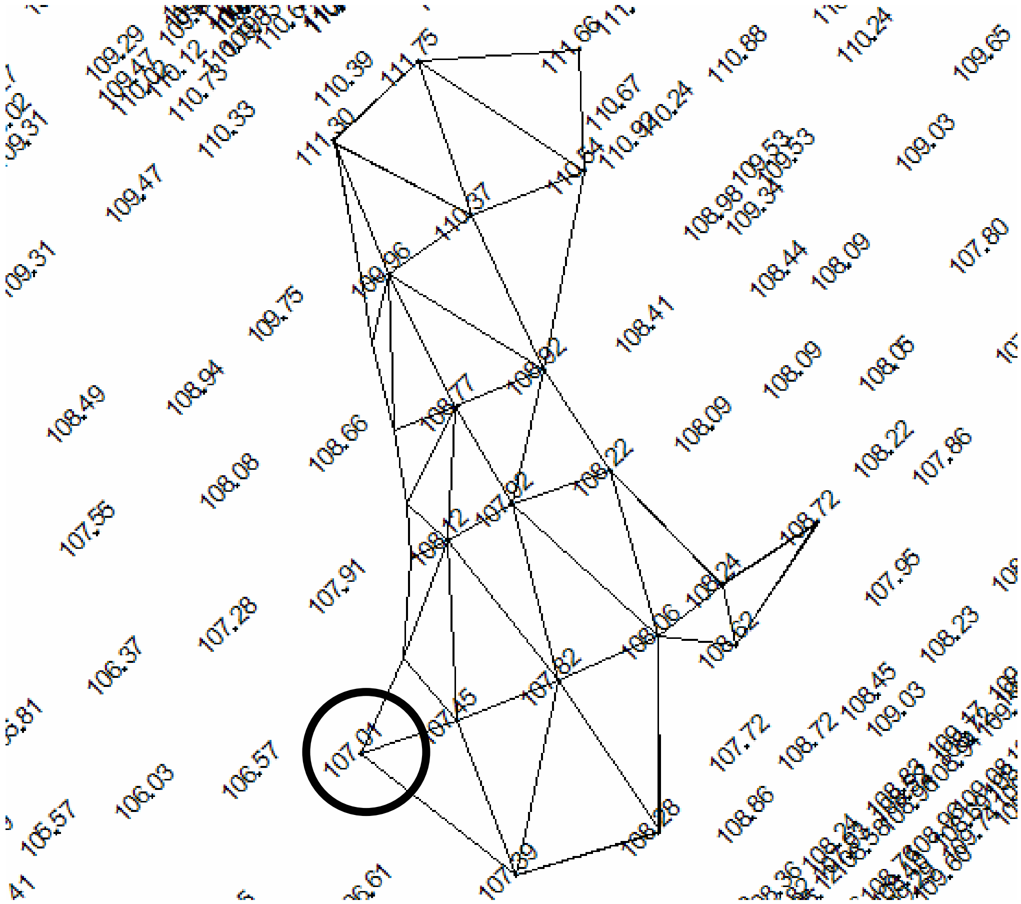
Using Cross Sections to represent the ground for earthwork computations is no longer necessary. Terrain Models provide the basis for all earthwork needs. Cross Sections, Profiles, Contours, etc. can be extracted from a terrain model without requiring additional field work.

Flood Plains

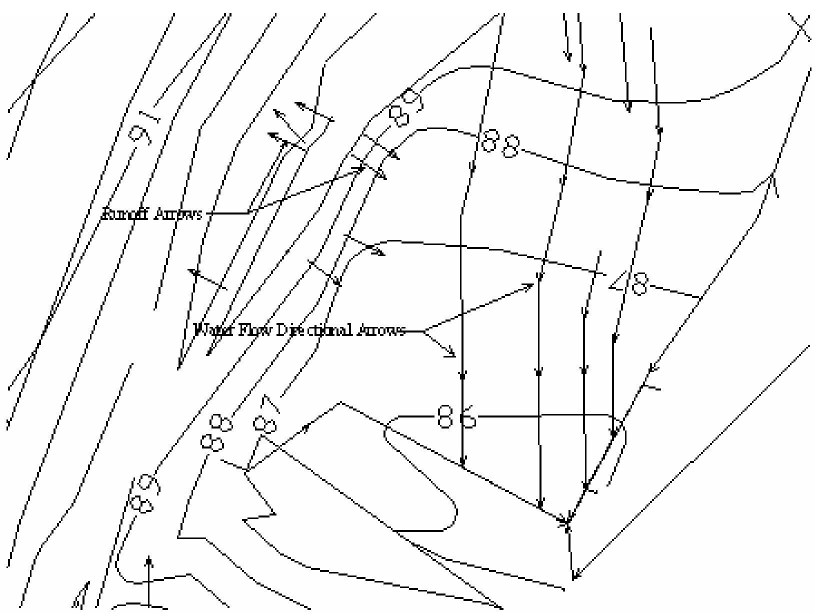
Information is provided on the area/volume that would be flooded if given an elevation. Values may be entered, data selected from a surface and Volume, Sloped Area and Planar Area can be calculated depending on the values used and the data selected from the surface. The flood plain may be stored and displayed.

Water Catchment Area

The Water Catchment Area is the contributing watershed area to an inlet. This area may be manipulated, controlled, calculated (plane area, sloped area, average slope, and maximum flow distance), stored and graphically displayed.



Water Flow Model



Calculated water flow directions across an active surface model.