Options for Acquiring Elevation Data

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As applications for GRASS (the Geographic Resources Analysis Support System) have increased, the ability to develop useful, accurate, and up to date digital map layers has become very important. There are many geographical themes that can be developed into digital map layers. Legal boundaries, roads, hydrography, soils, watersheds, and elevation are a few of the layers commonly developed for GRASS databases. This document explores the options for production and acquisition of digital elevation data.

A digital elevation data file consists of a sampled array of elevations for ground positions that are generally at regularly-spaced intervals. Some of the applications of elevation data include the generation of slope data, direction of slope data (aspect), and 3-D graphics. Elevation can also be used in combination with other data types as, for example, with vegetation or soils to depict changes in vegetation or soil types with height. Other applications include hydrologic modeling, soil erosion evaluation/prediction, and line of sight analysis.

Currently, the Land Analysis Group is aware of three sources that produce digital elevation data. They are:

1) The Defense Mapping Agency
2) The United States Geological Survey
3) Private Companies

The remainder of this document discusses the digital elevation products available from the above sources.

Defense Mapping Agency

The Defense Mapping Agency (DMA) produces an elevation product called Digital Terrain Elevation Data (DTED). DTED is available in two levels, DTED-1 and DTED-2. The level refers to the resolution of the elevation data. The resolution is the amount of space between each sample elevation point in the data file. DTED-1 has a resolution of roughly 100 meters, while DTED-2 has a resolution of roughly 30 meters.

Characteristics of the DTED-1:

* The unit of coverage is a 1-degree x 1-degree block. This corresponds to the east or west half of a 1:250,000 USGS map sheet. However, these blocks are referenced by their

southwest corner coordinates (Lat., Long.) rather than by the names of the corresponding USGS map sheets.

* Coverage is available for many regions worldwide, although predominantly for those within the Northern Hemisphere.

* The data are ordered from south to north in profiles that are ordered from west to east.

* Elevation points along each profile are spaced at intervals of 3 arc-seconds (roughly 100 meters). This provides for a 100 meter resolution data file. The information content is approximately equivalent to the contour information on a 1:250,000 scale map.

* Spacing of the elevation points between each profile varies by latitude. From 0 degrees N to 50 degrees N, the spacing is 3 arc-seconds. From 50 degrees N to 70 degrees N, the spacing is 6 arc-seconds. North of 70 degrees N, the spacing is 9 arc-seconds.

* Elevations are in meters relative to mean sea level.

Characteristics of the DTED-2:

* Coverage is limited. Production has only been done for special projects. Inquire at the DMA about coverage for your area of interest.

* The data are ordered from south to north in profiles that are ordered from west to east.

* Elevation points along each profile are spaced at intervals of 1 arc-second (roughly 30 meters). This provides for a 30 meter resolution data file. The information content is approximately equivalent to the contour information on a 1:50,000 scale map.

* Elevations are in meters relative to mean sea level.

The DTED is produced using cartographic and photographic sources.[1] Cartographic sources include any map series from 1:24,000 scale to 1:250,000 scale. The hypsographic features (contours, ridge lines, spot elevations) and prominent hydrographic features (drainage lines, lakes) are digitized or scanned and then processed into the required matrix format (profiles) of elevation points.

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[1] "National Mapping Program, Technical Instructions: Data Users Guide 5," United States Geological Survey, Reston, VA., 1987. p. 5.

Elevation data is derived from photographic sources using manual and automated stereo-photogrammetric equipment. The elevations are weighted with additional information such as drainage lines, ridge lines, water and spot elevations and processed into the required matrix format (profiles) of elevation points.

The DMA has a comprehensive distribution program for DTED (available free of charge to organizations within the Department of Defense). All non-Department of Defense agencies and private companies can obtain the DTED-1 data, but must purchase it from the U.S. Geological Survey (see USGS 1-Degree DEM below). The Army has recently established a single point-of-contact at the U.S. Army Engineer Topographic Laboratories (USAETL) for all matters related to the acquisition and use of digital terrain data. Orders for DMA data must be submitted by letter request through the Concepts and Analysis Division (CAD) at ETL. For more information on the availability and ordering of DMA elevation products contact:

Jeff Messmore (202) 355-2759
Rob Lambert (202) 355-2764
U.S. Army Engineer Topographic Laboratories
CEETL-TL-CR
Fort Belvoir, Virginia 22060-5546

United States Geological Survey

The U.S. Geological Survey (USGS) produces and distributes elevation products called Digital Elevation Models (DEM). Two types of DEM products, called 1-Degree DEM and 7.5 minute DEM, are available from USGS. The 1-Degree DEM has a resolution of 100 meters, while 7.5 minute DEM has a resolution of 30 meters. The characteristics of these two DEM types are provided below.

Characteristics of 1-Degree DEM:

* The actual elevation data for this product is produced by the Defense Mapping Agency, but is distributed by the USGS in a different tape format. See description of DTED-1 above for specific information on this product.

* Product is distributed in 1-degree x 1-degree blocks. Each block corresponds to the east or west half of a standard USGS 1:250,000 scale map series quadrangle.

* Only the contiguous United States, Hawaii, and limited portions of Alaska are distributed.

* Price is $75.00 for each 1-degree x 1-degree block.

Characteristics of 7.5 Minute DEM:[2]

* The unit of coverage is a 7.5 minute x 7.5 minute block. Each block provides the same coverage as a standard USGS 1:24,000 scale map series quadrangle.

* The data are ordered from south to north in profiles that are ordered from west to east.

* Elevation points are spaced at intervals of 30 meters along and between each profile. This provides for a 30 meter resolution for the data file.

* Elevations are in either meters or feet relative to mean sea. level. DEM's that are generated of low-relief terrain, or from contour maps with intervals of 5 feet or less, are generally recorded in feet. DEM's generated of moderate-to-high-relief terrain, or from contour maps with intervals in excess of 5 feet, are generally recorded in meters.

* Price is $100.00 for each 7.5 minute x 7.5 minute block.

The 7.5 minute DEM data are produced either from contour overlays that have been digitized, or from automated or manual scanning of National High-Altitude Photography program (NHAP) quad-centered photographs.[3]

The USGS has used four processes to collect the digital elevation data from the above sources for production of the 7.5 minute DEM's: (1) the Gestalt Photo Mapper II (GPM2), (2) manual profiling from photogrammetric stereomodels, (3) stereomodel digitizing of contours, and (4) derivation from DLG hypsography and hydrography categories.[4] For more information on these methods obtain the following guide from the USGS: "National Mapping Program Technical Instructions," Data Users Guide 5 -- Digital Elevation Models.

Currently, the 7.5 minute DEM's are only available for selected quadrangles. Although the USGS will eventually have full 7.5 minute DEM coverage for the United States, only about 30% coverage exists now. An index showing available 7.5 minute DEM's is published semi-annually and can be requested from the USGS (see reference below).

When DEM data is not available for an area, there are two methods by which the project can be expedited. The first is by prepayment of the standard purchase price ($100.00). Prepaid projects are worked ahead of most other projects. Although there is no guaranteed completion date, the data will be available sooner than it would otherwise be.

The second method involves sharing production costs. Under this type of arrangement two parties split the estimated production costs. Cost sharing projects cost $500.00 per quad and are worked on before prepaid projects. They have an average production time of about 14 months. Though the production time is very long, the price is very reasonable. Without use

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[2] Ibid., p. 2-3.

[3] Ibid., p. 3.

[4] Ibid., p. 3.

of cost sharing needed quads might not be completed for years.

The USGS has a comprehensive distribution program for the 7.5 minute and 1-Degree DEM's, along with other digital data and map products. For more information about USGS products use the following reference.

Questions regarding availability and ordering of any USGS digital cartographic and geographic data should be addressed to :

National Cartographic Information Center
U.S. Geological Survey
507 National Center
Reston, Virginia 22092
(703) 860-6045

Private Companies

Most of the information for this section has been provided to us by the Markhurd Corporation of Minnesota.

Due to the limitations of elevation products available from the DMA and USGS (i.e., only 100 meter or 30 meter data, and limited availability), the Land Analysis Group of USACERL's Environmental Division has been investigating the private sector as a source of elevation data. Private companies are a viable source because of their ability to produce high resolution data for any geographic area, in a short time period. For example, if one needed to acquire elevation data for one 1:24,000 quad that was unavailable from the USGS, a private company could produce the elevation data in roughly three to four months at a resolution of 15 meters. The cost charged by a private company, which averages $2000.00-$5000.00 per USGS quad, is significantly higher, however.

Private companies have the flexibility of producing elevation data for specific geographical areas (e.g., only areas within installation boundaries, half of a USGS quad, etc.), and can use two different data sources to produce the Digital Terrain Models (DTM). NOTE: While the DMA dubs its elevation product DTED, and the USGS calls its product DEM, private companies will generally refer to elevation data as Digital Terrain Models (DTM).

The two data sources from which DTM's can be produced are contour plates and stereoscopic air photos. A contour plate is a clear base positive of only the contours. Contour plates can be obtained from the USGS or DMA for any existing topographic map. Contour plates are used in conjunction with drainage and ridge lines to produce a DTM, with the resolution and accuracy of the DTM dependent upon the contour interval and accuracy of the contour plate. The Markhurd Corporation can produce DTM's with 15 meter resolution and an accuracy of half the contour interval from a USGS 1:24,000 contour plate.

The use of stereoscopic photos is more expensive, but can result in a DTM with very high resolution and accuracy. Generally, this method will result in a more accurate DTM than would be generated using the contour plate as a source. However, this will depend on the scale and ground control of the air photos. Two steps occur in the production of a DTM from stereoscopic air photos.

The first step is to perform an Areal Triangular Solution. An Areal Triangular Solution is performed using ground control points provided to the company along with the aerial photos. This will provide geographic control and removal of distortion from the photographs. The more accurate the control points provided are, the more accurate the resultant DTM.

The second step is the actual production of the DTM from the air photos using the Aerial Triangular Solution. This is accomplished using stereophotogrammetric equipment. The highest possible resolution of the DTM is a function of the scale of the air photos. Larger scale air photos will allow higher resolution DTM's. However, the actual resolution of the DTM product is a parameter to be defined by the customer.

Private companies generally do not have comprehensive production and distribution programs like those of the DMA and USGS. However, the private sector is a viable source for obtaining elevation data for many geographical areas, at higher resolutions (if desirable) than are available from the DMA and USGS, in a brief time period. Although many companies undoubtedly can provide elevation data, we have thus far primarily been in contact with the following company:

Markhurd Corporation
345 Pennsylvania Ave. S.
Minneapolis, Minnesota 55426
(612) 545-2583
POC: Joe Kiesow