FGDC Document Number

National Spatial Data Infrastructure

Content Standards for Framework Land Elevation Data

Subcommittee on Base Cartographic Data
Federal Geographic Data Committee

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Federal Geographic Data Committee
Department of Agriculture • Department of Commerce • Department of Defense • Department of Energy
Department of Housing and Urban Development • Department of the Interior • Department of State
Department of Transportation • Environmental Protection Agency
Federal Emergency Management Agency • Library of Congress
National Aeronautics and Space Administration • National Archives and Records Administration
Tennessee Valley Authority

Federal Geographic Data Committee

Established by Office of Management and Budget Circular A-16, the Federal Geographic Data Committee (FGDC) promotes the coordinated development, use, sharing, and dissemination of geographic data.

The FGDC is composed of representatives from the Departments of Agriculture, Commerce, Defense, Energy, Housing and Urban Development, the Interior, State, and Transportation; the Environmental Protection Agency; the Federal Emergency Management Agency; the Library of Congress; the National Aeronautics and Space Administration; the National Archives and Records Administration; and the Tennessee Valley Authority. Additional Federal agencies participate on FGDC subcommittees and working groups. The Department of the Interior chairs the committee.

FGDC subcommittees work on issues related to data categories coordinated under the circular. Subcommittees establish and implement standards for data content, quality, and transfer; encourage the exchange of information and the transfer of data; and organize the collection of geographic data to reduce duplication of effort. Working groups are established for issues that transcend data categories.

For more information about the committee, or to be added to the committee's newsletter mailing list, please contact:

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1. INTRODUCTION

1.1 Objective

The objective of this standard is to define the elevation data theme of the digital geospatial data framework as envisioned by the FGDC. It is the intent of this standard to set a common baseline that will ensure the widest utility of elevation data for the user and producer communities through enhanced data sharing and the reduction of redundant data production. The Framework will provide a base on which to collect, register, and integrate digital geospatial information accurately. Digital elevation data is a part of this basic set of data described as framework data.

This standard is intended to facilitate the interchange and use of digital elevation data under the framework concept. Because of rapidly changing technologies in the geospatial sciences, this standard for digital elevation data covers a range of specification issues, many in general terms. This document also describes quality control and standards for testing digital elevation data.

1.2 Scope

This standard describes processing, accuracy, reporting, and applications considerations for NSDI Framework digital elevation data, and may be applicable to other data sets which employ the FGDC Framework concepts. This standard is classified as a **Data Content Standard** by the Federal Geographic Data Committee Standards Reference Model. Data content standards provide semantic definitions of a set of objects, such as those described above.

1.3 Applicability

This standard applies to NSDI Framework digital land elevation data produced, or disseminated by or for the Federal Government. According to Executive Order 12906, Coordinating Geographic Data Acquisition and Access: the National Spatial Data Infrastructure (Clinton, 1994, Sec. 4., Data Standards Activities), Federal agencies collecting or producing geospatial data, either directly or indirectly (e.g. through grants, partnerships, or contracts with other entities), shall ensure, prior to obligating funds for such activities, that data will be collected in a manner that meets all relevant standards adopted through the FGDC process.

1.4 Relationship to Existing Standards

Throughout this text there are numerous references to metadata and the FGDC's "Content Standard for Digital Geospatial Metadata" (6/94). Wherever a comment about metadata appears, the location of the data element description in that standard will be placed in parentheses ( ), or passages will be pointed to from the USGS digital elevation model metadata example in Appendix A. This document will also reference the Spatial Data Transfer Standards (FIPS173), the National Map Accuracy Standards (NMAS) and the draft FGDC National Standard for Spatial Data Accuracy (NSSDA).

1.5 Standards Development Procedures

The draft Standards for Digital Elevation Data have been developed by the Subcommittee on Base Cartographic Data of the FGDC. The development of this standard is guided by the FGDC Standards Reference Model. The Standards Reference Model, developed by the Standards Working Group of the FGDC, provides guidance to FGDC subcommittees for the standards development process. The model also defines the expectations of FGDC standards, describes different types of geospatial standards, and documents the FGDC standards process.

1.6 Maintenance

The U.S. Department of the Interior, United States Geological Survey (USGS), National Mapping Division, maintains the Standards for Digital Elevation Data for the Federal Geographic Data Committee. Address questions concerning this standard to: Chief, National Mapping Division, USGS, 516 National Center, Reston, VA 22092.

2. DATA DESCRIPTION

Elevation refers to a vertical position above or below a reference surface. This standard addresses land surface elevations. Framework elevation data is intended to model the land surface proper. However it may be useful to note that in some cases, such as in densely forested areas where the land surface is covered, it may be difficult to accurately model the land surface. For some applications, the user may wish to model the surface cover.

Elevation data can be produced in a variety of formats. The data format described by this standard is a matrix of elevation values at regularly spaced grid locations. Although no fixed spacing of grid posts is identified, elevation values will, ideally, be collected at post spacings of not greater than 2 arc-seconds. In areas of low relief, grid post spacings should be decreased.

3. SOURCES

Elevation data have traditionally come from a variety of sources, and several new technologies are emerging for acquiring elevation data. These sources include the following:

- Remotely sensed imagery- Aerial photographs and satellite data are used extensively for elevation data collection.

- Cartographic source - Topographic maps are valuable sources that include contours, spot elevations, and ridge and break lines. Hydrographic features, such as rivers and streams, and other water bodies may aid in resolving anomalies produced during the collection of digital elevation data. These feature types can be transformed from vector and point data into elevation grids, using suitable interpolation algorithms. When properly transformed, the elevation grid carries approximately the same accuracy as the source material. Note that cartographic sources may generalize terrain, and may not fully represent significant features. A substantial archive of these types of source maps exists within the public and private sector throughout the world.

- Non-Imaging remote sensing sources. - Radar Interferometry and laser systems are technologies that offer significant opportunities for elevation data collection.

- Mobile Survey Platforms - Mobile survey platforms mounted with mechanical or electronic positioning devices such as gyroscopic stabilized motion sensors, or geopositioning devices such as Global Positioning System (GPS) receivers. The platform mounted system is moved from location to location to collect horizontal or vertical positions.

- Ground Surveys - Terrestrial collection systems such as distance ranging, geodetic leveling, and angle measuring may be used to collect highly accurate spot elevations, or to build generalized planar surfaces which represent the general slope and trend of the surrounding terrain.

4. DIGITAL ELEVATION DATA STRUCTURE

Two types of coordinate systems, the geographic coordinate system and the Universal Transverse Mercator (UTM) coordinate system, are illustrated and described in this standard. Use of the geographic coordinate system is highly desirable for framework data. Elevation data may be portrayed utilizing other types of coordinate systems, such as State Plane Coordinate Systems. The UTM illustration is provided as an example of elevation data in a rectangular gridded coordinate system. The examples cited here are for four sided figures. Use of more than or less than four bounding coordinates leads to a more complicated description of the data ordering (row/column order, and grid spacing). The coordinate system, bounding coordinates and data ordering for the data shall be documented in the metadata field:
(Spatial_Reference_Information/Horizontal_Coordinate_System_Definition),
(Identification_Information/Spatial_Domain),
(Spatial_Reference_Information/Planar_Coordinate_Information).

4.1 Arc-Second Structured Data

A typical four sided arc-second data set is shown in figure 1. The north and south rows are coincident with the north and south parallels, respectively. The grid spacing of elevation data along and between each profile is regular. The geographic (latitude, longitude) coordinate system has the characteristic of being seamless, omnidirectional, and scaleless. The main weakness of the geographic coordinate system is that two dimensional scale and distance measurements can only be produced after cross reference to an appropriate map projection.

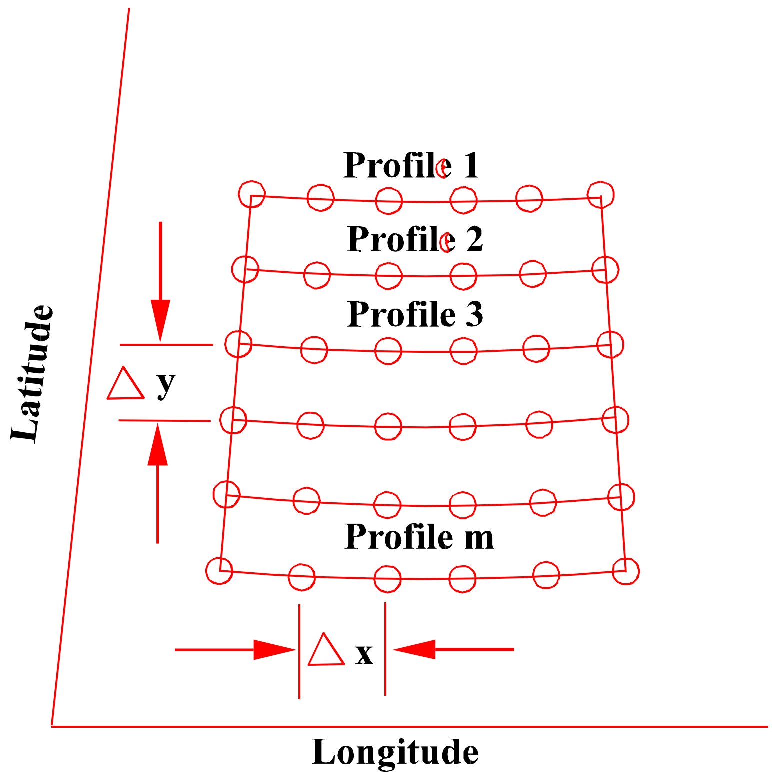

Figure 1
Structure of digital elevation
data, arc-second grid.

4.2 UTM Structured Data

The UTM grid coordinate system is one of several possible rectangular grid systems which are employed in lieu of the geographic coordinate system. Rectangular grid systems, such as UTM, are useful for displaying and manipulating raster data.

For any given UTM zone, the UTM grid is coincident with the geographic grid only along the central meridian. As illustrated in figure 2, the geographic grid diverges from the UTM to either side of the central meridian. North-south and east-west UTM grid tiles match perfectly within the traditional 6 degree wide UTM zones. However, the grid tiles do not join between adjacent UTM zones. For additional information about map projections see: Map Projections-A Working Manual: by John Snyder, 1987, USGS, pp. 1395.

The hypothetical UTM grid is shown as a rectangular gridded tile in figure 2. Within that rectangular tile a hypothetical geographic based quadrangle is shown. Note that the geographic quadrangle corner points and neat lines are contained wholly within the UTM defined rectangular tile. The regularly spaced rows of the UTM tile intersect the straight line intercepts between the four bounding geographic corners that are contained within the tile. The geographic quadrangle is not a rectangle; instead it is a quadrilateral, in which two sides are not parallel, while the UTM tile sides are parallel and perpendicular.

In order to accommodate the irregular shape of the geographic quadrilateral, provision should be made not only to describe the overall bounding coordinates, but also the starting and ending coordinates of each grid row. A simplified version of the geographic quadrilateral may be accomplished by padding the elevation rows into a rectangular UTM structure defined by the UTM bounding coordinates. The pad data may be either valid over-edge elevations or a flagged data value (example pad value = -32,767 the smallest possible negative 16 bit ASCII number).

Another, more complicated, method of describing the geographic quadrilateral is by listing the UTM coordinates of the four geographic corners (bounds) and the UTM coordinates of the starting points of each row to be fully contained within the geographic neat line bounds. These coordinates describe the complex shape resulting from the intersection of the UTM grid with the geographic based quadrilateral and the variable x, y starting position of each row. Because of the variable orientation of the geographic quadrilateral in relation to the UTM grid, rows intersect the north and south neat lines as well as the east and west neat lines, as shown in figure 2. In addition, row easting values are continuous from one data set to the adjoining data set only if the adjoining data set is contained within the same UTM zone. Rows that pass within the bounds of the geographic quadrilateral, but are void of elevation grid points, are not represented in the data. This condition occurs occasionally at the first or last row. Typically such a row intersects the quadrilateral corner, but there is no grid node within the tile bounds.

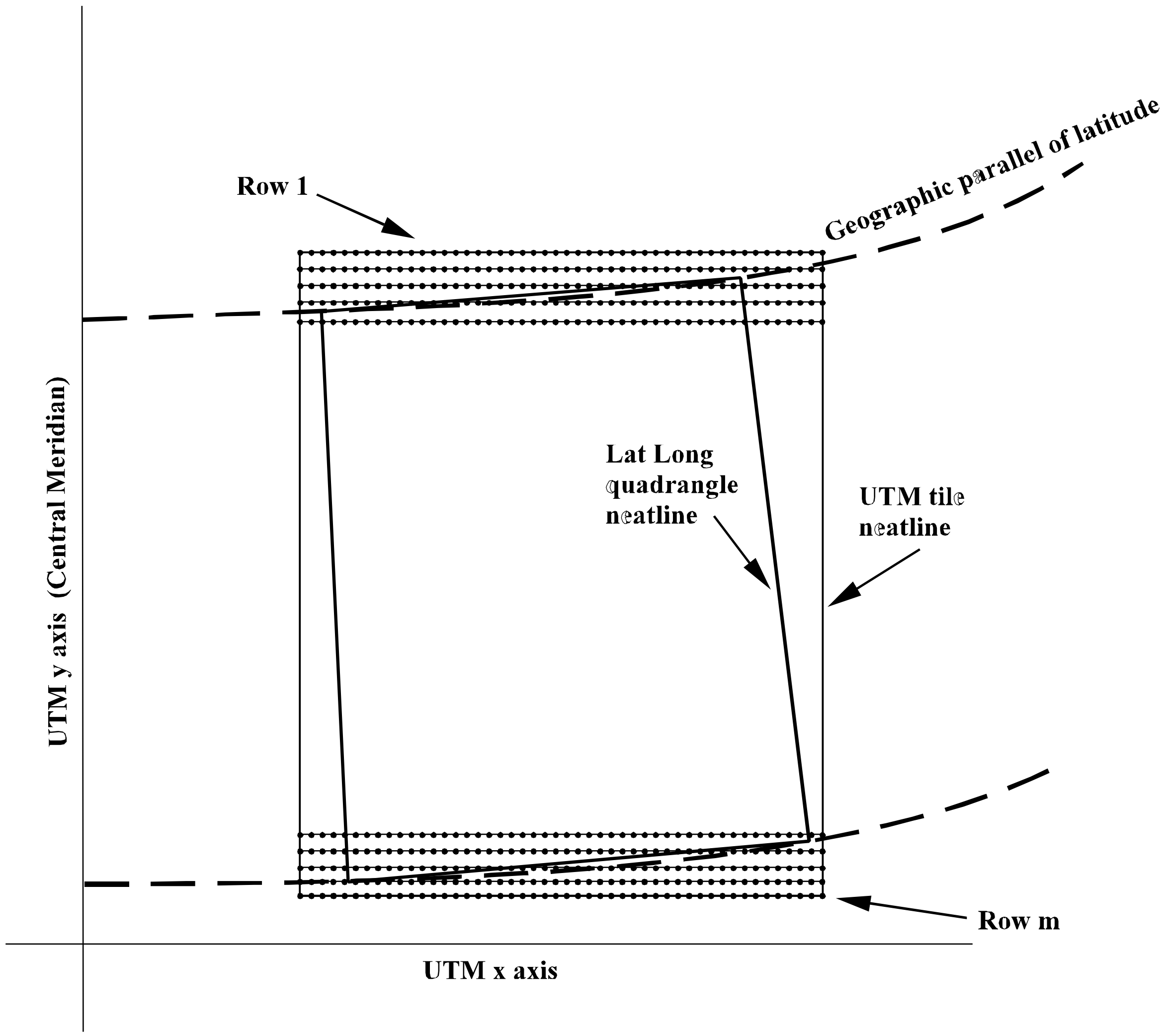

Figure 2
Structure of digital elevation
data, UTM meter grid

5. DATUM

The FGDC has defined default datums for framework elevation data. For framework elevation data, the default reference for horizontal datum is to the North American Datum of 1983 (NAD83) and the default vertical datum reference is the North American Vertical Datum of 1988 (NAVD88). Other datums may be referenced, in recognition of the significant application of other widely accepted datums throughout the digital geospatial community. In any case, it is important to document the reference datums in the metadata. The horizontal and vertical datum shall be documented in the metadata field:

(Spatial_Reference_Information/Horizontal_Coordinate_System_Definition/Geodetic_Model)

(Spatial_Reference_Information/Vertical_Coordinate_System_Definition/Altitude_System_Definition)

6. GEOMETRY

Profiles are the basic building blocks of an elevation grid and are defined as one-dimensional arrays, i.e., arrays of n columns by 1 row, where n is the length of the profile.

Figure 3 illustrates the internal horizontal relationship (x_p, y_p) of elevations ordered as profiles in which the spacing of the elevations along each profile is ? x and the spacing between profiles is ? y. The formulas in Figure 3 relate the internal array structure to ground coordinates (x_{gp}, y_{gp}) based on an origin of the digital elevation data file at the upper left corner (x_{go}, y_{go}) and a rotation angle measured counter clockwise from the ground (x_g), to the first axis (profile) of the coordinate projection system. The rotation angle of the digital elevation data file is normally considered as zero if data are ordered by rows (90^o to the reference or central meridian) or is set to 270^o, if data are ordered by columns. The rotation angle for all arc second digital elevation data is always set to zero.

Summary: The equations in figure 3 have their origins in standard text describing the mathematics of coordinate transformation with the following exceptions. There are three critical points that must be considered regarding the subtle changes required for manipulating raster formatted grids.

> Origin: The origin of raster formatted data is upper left, Xgo, Ygo (X grid origin, Y grid origin). This contrasts with the origin in the lower left corner for the simple case definition of coordinate systems using the right hand rule.

Handedness: Indexing of raster formatted grids is in the negative Y direction. The direction of Y axis is left handed. All equations of coordinate transformation remain in the right hand rule (rotation counter clockwise).

Y coefficient: The negative direction of indexing in the Y axis requires a reverse of the sign of the Y coefficient terms of equations for computing X and Y coordinate values in the coordinate transformation equations, as illustrated in figure 3.

$$x_p = (i-1)\Delta x$$
$$y_p = -(j-1)\Delta y$$

$$\begin{pmatrix} x_{ij} \\ y_{ij} \end{pmatrix} = \begin{pmatrix} \cos\phi & \sin\phi \\ \sin\phi & \cos\phi \end{pmatrix} \begin{pmatrix} (i-1)\Delta x \\ -(j-1)\Delta y \end{pmatrix} + \begin{pmatrix} x_{go} \\ y_{go} \end{pmatrix}$$

expanded to give x_{gp} , y_{gp} yields:

$$x_{gp} = x_{go} + x_p \cos\phi + y_p \sin\phi$$
$$y_{gp} = y_{go} + x_p \sin\phi - y_p \cos\phi$$

Terms:

p = grid point
go = grid origin
x_g , y_g = real world coordinate axis
Δx, Δy = grid spacing
ϕ = counter clockwise rotation from positive x_g axis (east) to the first grid profile
i, j = grid node indices
x_{gp} , y_{gp} = ground point coordinate

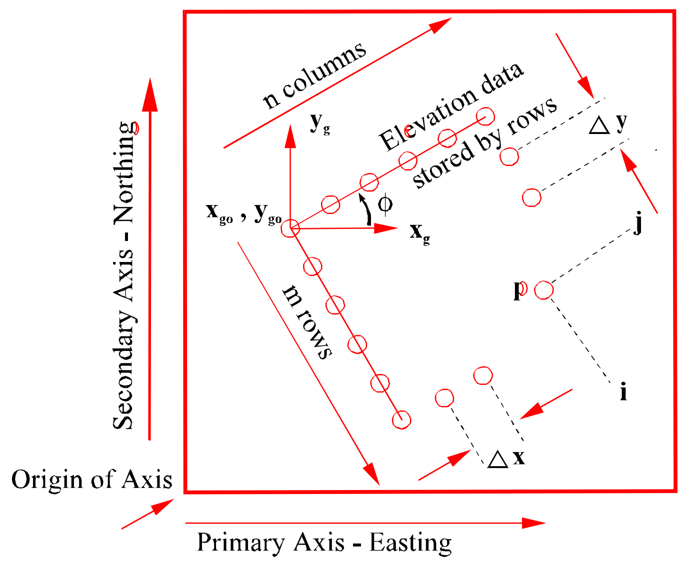

Figure 3
Geometry and nomenclature
of the digital elevation data file.

7. AREAS OF CONSTANT ELEVATION

When elevation data are generated, they may contain areas of constant elevation derived from areas within the graphic or digital source containing estimated or false elevations. These areas include void areas and water bodies.

7.1 Void Areas

Void areas can occur as a result of local interruptions of the source from which elevations are acquired. For example, contours represented on a source graphic may have been substituted by photo images. Each elevation post located within a void area is assigned a discrete false value representing the void. For example, elevation posts located within a void area may be assigned a false value of -32,767. Treatment of void areas shall be documented in the metadata field: (Data_Quality_Information/Completeness_Report).

7.2 Water Body Areas

Water body areas are naturally occurring areas of constant elevation. For consistent treatment, oceans or estuaries may be assigned an elevation value of zero. All other water bodies are assigned their known or an estimated elevation. Refer to section 12.1 for additional criteria regarding water body areas, including the assignment of estimated elevations.

7.3 Population of Full Digital Elevation Data Grid Array

In all cases where void areas or water body areas occur in the data, the full data array should be populated regardless of areal extent. This requirement includes data sets containing large expanses of oceans or lakes.

8. METADATA

The FGDC emphasizes the importance of good metadata, to provide quality information about data which will allow users to match data to their needs. This standard describes a general set of specifications, and as such, places most of the burden on the user to assess quality and applicability of data. Appropriate metadata facilitates this process. Certainly, for the user, data with documentation is more useful than data that has none. The more high quality metadata there is for a product, the more it can support the user’s determination of its reliability, quality, and accuracy. Metadata is intended to be of value to the producer as well as to the user.

The FGDC’s "Content Standards for Digital Geospatial Metadata" will be the source for all issues relating to terminology and definitions relating to metadata. Executive Order 12906 "Coordinating Geographic Data

Acquisition and Access: The National Spatial Data Infrastructure," requires all Federal agencies to use the standard to document data that they produce beginning in 1995. For more information about the FGDC and the Content Standard for Digital Geospatial Metadata, contact:

Federal Geographic Data Committee Secretariat
c/o U.S. Geological Survey
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Anonymous FTP: ftp://www.fgdc.gov
World Wide Web (WWW): http://www.fgdc.gov

Appendix A contains an example of a metadata file for a specific elevation model. The example cited is for a 7.5-minute USGS digital elevation model.

9. DATA TRANSFER FORMATS

Data transfer formats for digital elevation data will not be specified in this standard. However, data producers are encouraged to use the Raster Profile of the Spatial Data Transfer Standard (SDTS) as the model for formatting their digital elevation data files. As Federal Information Processing Standard 173, SDTS is a requested minimum for Federal data producers. The SDTS was developed in order to help reduce technical barriers to data sharing. While other data transfer formats are permitted, data producers are encouraged to employ the more widely used and accepted raster formats. The "Content Standards for Digital Spatial Metadata" contains a list of many of the recognized formats. In all cases, it will be necessary for producers to provide detailed descriptions of the format. Copies of the "Spatial Data Transfer Standard" (Federal Information Processing Standard 173) are available from the :

National Technical Information Service
U.S. Department of Commerce
Springfield, VA 22161

or are available on the World Wide Web at:

ftp://sdts.er.usgs.gov/pub/sdts/standard/

10. RESOLUTION

In the context of gridded elevation data, resolution is related to the horizontal post spacing and vertical precision.

10.1 Horizontal Post Spacing

The horizontal post spacing is the smallest distance between two discrete points that can be explicitly represented in the data. It is important to note that features of a size equal to, or even greater than the post spacing, may not be detected or explicitly represented, in a gridded model. For gridded elevation data the horizontal post spacing may be referenced as the cell size, the grid spacing, the posting interval, or the ground sample distance. Horizontal post spacing shall be documented in the metadata field: (Spatial_Reference_Information:Horizontal_Coordinate_System_Definition/Planar_Coordinate_Information/Coordinate_Representation)

10.2 Vertical Precision

The vertical precision determines the smallest vertical increment that can be represented in the data. Vertical precision should not be confused with vertical accuracy. Adjacent grid cell values may differ by as little as one unit of measure (the vertical precision), but this does not imply that the individual grid cells are accurate to that one unit of measure. Vertical precision shall be documented in the metadata field:

(Spatial_Reference_Information:Vertical_Coordinate_System_Definition/Altitude_System_Definition/Altitude_Resolution)

11. ACCURACY

Framework digital elevation data accuracy shall employ the National Standard for Spatial Data Accuracy (NSSDA), which implements a statistical and testing methodology for estimating the positional accuracy of points in digital geospatial data, with respect to georeferenced ground positions of higher accuracy. This reporting methodology provides a common language for reporting positional accuracy so that users can evaluate data sets for fitness of use for their applications. The NSSDA uses root-mean-square error (RMSE) to estimate positional accuracy. Accuracy is reported in ground distances at the 95% confidence level. Accuracy reported at the 95% confidence level means that 95% of the positions in the data set will have an error with respect to true ground position that is equal to or smaller than the reported accuracy value. The reported accuracy value reflects all uncertainties, including those introduced by geodetic control coordinates, compilation, and final computation of ground coordinate values in the product.

The NSSDA does not define threshold accuracy values. Users are encouraged to establish thresholds for their product specifications and applications and for contracting purposes. Data producers may elect to use accuracy thresholds in standards such as the National Map Accuracy Standards of 1947 (U.S. Bureau of the Budget, 1947) or Accuracy Standards for Large-Scale Maps [American Society for Photogrammetry and Remote Sensing (ASPRS) Specifications and Standards Committee, 1990] if they decide that these values are applicable to their digital geospatial data accuracy requirements. However, accuracy of new or revised data products will be reported according to the NSSDA. Data producers shall ensure that all critical components have known accuracies suitable for the construction of elevation data, and that those accuracies are reported in the metadata.

Methods for determining both horizontal and vertical accuracy shall be documented in the metadata fields:
(Data_Quality_Information/Positional_Accuracy/Horizontal_Positional_Accuracy/Horizontal_Positional_Accuracy_Report)
(Data_Quality_Information/Positional_Accuracy/Vertical_Positional_Accuracy/Vertical_Positional_Accuracy_Report)

11.1 Accuracy

Accuracy describes how close a data value is to truth. It relates the value to an established standard reference.

11.2 Absolute Accuracy

Absolute accuracy is a measure that accounts for all systematic and random errors in a data set. Absolute accuracy is stated with respect to a defined datum or reference system.

11.3 Relative Accuracy

Relative accuracy is a measure that accounts for random errors in a data set. Relative accuracy may also be referred to as point-to-point accuracy. The general measure of relative accuracy is an evaluation of the random errors (systematic errors and blunders removed) in determining the positional orientation (e.g. distance, azimuth) of one point or feature with respect to another.

11.4 Absolute Horizontal Accuracy

Absolute horizontal accuracy is a measure of the positional (planimetric) quality of data with respect to a reference datum. Absolute horizontal accuracy is related to the grid spacing. It is difficult to measure the horizontal accuracy directly from a matrix, because terrain features are generalized in the surface represented by a gridded elevation model, and the terrain which falls between posts is not represented,. For this reason, it is useful to report the positional accuracy of the source material (imagery or map) from which the data was produced. If available, the computed value for the absolute horizontal accuracy shall be documented in the metadata field:
(Data_Quality_Information/Positional_Accuracy/Horizontal_Positional_Accuracy/Horizontal_Positional_Accuracy_Assessment/Horizontal_Positional_Accuracy_Value).

11.5 Relative Horizontal Accuracy

Relative horizontal accuracy is a measure of the point-to-point horizontal accuracy within a specific data set. To determine relative horizontal accuracy, the horizontal distance between two points is measured and then compared to the corresponding measure on the reference. The difference between the two distances represents the relative accuracy. As with absolute accuracy, it may be more meaningful to report the relative horizontal accuracy of the source material. Relative horizontal accuracy shall be documented in the metadata field:
(Data_Quality_Information/Positional_Accuracy/Horizontal_Positional_Accuracy/Horizontal_Positional_Accuracy_Report)

11.6 Absolute Vertical Accuracy

Absolute vertical accuracy is a measure that relates the stated elevation to the true elevation with respect to an established vertical datum. The computed value for the absolute vertical accuracy, if available, shall be documented in the metadata field:
(Data_Quality_Information/Positional_Accuracy/Vertical_Positional_Accuracy/Vertical_Positional_Accuracy_Assessment/Vertical_Positional_Accuracy_Value).

11.7 Relative Vertical Accuracy

Relative vertical accuracy is a measure of the point-to-point vertical accuracy within a specific data set. To determine relative vertical accuracy, the vertical difference between two points is measured. That difference is then compared to the difference in elevation for the same two points on the reference. The difference between the two measures represents the relative accuracy. The reference must have at least three times the accuracy of the intended product accuracy, insuring that all systematic errors and blunders have been removed. Relative vertical accuracy is an important characteristic of elevation data used for calculating slope. Slope is usually calculated from raster elevation models by analyzing the local differences among adjacent grid cells. Random error contained in neighboring elevation cells decreases the relative (point-to-point) accuracy of the elevation model and the accuracy of the calculated slope. Relative vertical accuracy shall be documented in the metadata field:
(Data_Quality_Information/Positional_Accuracy/Vertical_Positional_Accuracy/Vertical_Positional_Accuracy_Report)

12. RELATIVE ACCURACY VERIFICATION

12.1 Water Bodies

The elevation of a water body surface is represented in both land elevation data. The water level datum is the common surface of reference from which depths are measured and from which the elevation of the surface is reported. This datum shall be documented in the metadata field: (Data_Quality_Information/Lineage/Process_Step/Process_Description)

Water body editing serves to improve the data quality and should be employed wherever practical. Edit criteria are dependant upon the intended use of the product.

Ideally, the slope along drainage channels should be continuous and not constricted by artifacts such as benching across the drainage channel.

Shoreline and coastline elevation values should be higher than the adjacent water elevations. Extremely shallow land just interior to coastlines but not classified as swamp or otherwise inundated should have a higher elevation value than the sea by at least one unit of resolution to force land/ water boundary portrayal. Shoreline elevation information can be obtained from NOAA hydrographic surveys and is depicted on NOAA coastal zone maps. For reservoirs, lakes, or other standing water bodies, give the frame of reference used to indicate the pool elevation. Treatment of water bodies shall be documented in the metadata field: (Data_Quality_Information/Lineage/Process_Step/Process_Description)

12.2 Slope

Elevation data are frequently used to develop representations of slope. To support the derivation of accurate slope and aspect, elevation data should be smooth within the grid and continuous from node to node, except at natural break points such as streams, cliffs, and craters.

13. VISUAL VERIFICATION

Visual verification, as a means of quality control, should be performed as a normal extension of the digital elevation data production process. Testing should be performed using a digital elevation data editing system to aid in the identification of blunders, such as irregularly gridded data, mis-tagged tops, mis-tagged depressions, and spikes. These blunders are generally identified by displaying the data with the aid of an edit system, that employs color banding of elevation gradients, stereoscopic viewing using anaglyphic filters, and shaded-relief enhancement. The elevation matrix should be analyzed for suspect areas and corrections made as required. Verification methodology shall be documented in the metadata field: (Data_Quality_Information/Lineage/Process_Step/Process_Description)

Verification includes:

1. Identification of the maximum and minimum elevations contained in the digital elevation data file and comparison with a reference, such as the maximum and minimum values represented by contours or spot elevations on the best available map product of the area. The maximum and minimum grid points should be verified against a reliable reference. The data and reference should be examined to determine the reason for any discrepancy and the data edited.

2. Verification of all elevations below sea level according to the best available reference product of the area and, if unsupported, adjustment to the surrounding terrain.

Appendix A

(informative)

Example of a FGDC Metadata File for a

USGS Digital Elevation Model

These metadata describe a specific Digital Elevation Model quadrangle (Mannboro, Virginia) produced by the USGS, and demonstrates a file specific implementation of the Content Standards for Digital Geospatial Metadata (6/8/94). The elevation data described in this example is merely one interpretation of the standard and does not imply that the characteristics of the data described are necessarily required by, or compatible with the FGDC Standards for Digital Elevation Data. Numbers preceding element names indicate the location of the element definition in the metadata standard. Element names are in bold type.

1. **Identification_Information:**

1.1 **Citation:**

8.1 **Originator**: U.S. Geological Survey

8.2 **Publication_Date:** 19940111

8.4 **Title:** Mannboro, VA

8.8 **Publication_Information:**

8.8.1 **Publication_Place**: Reston, VA

8.8.2 **Publisher**: U.S. Geological Survey

1.2 Description:

1.2.1 **Abstract:**

A Digital Elevation Model (DEM) contains a series of elevations ordered from south to north with the order of the columns from west to east. The DEM is formatted as one ASCII header record (A-record), followed by a series of profile records (B- records) each of which include a short B-record header followed by a series of ASCII integer elevations per each profile. The last physical record of the DEM is an accuracy record (C-record).

The 7.5-minute DEM (30- by 30-m data spacing) is cast on the Universal Transverse Mercator (UTM) projection. It provides coverage in 7.5- by 7.5-minute blocks. Each product provides the same coverage as a standard USGS 7.5-minute quadrangle but the DEM contains over edge data. Coverage is available for the contiguous United States, Hawaii, and Puerto Rico, but is not complete.

1.2.2 **Purpose:**

DEM's can be used as source data for digital orthophotos and as layers in geographic information systems for earth science analysis. DEM's can also serve as tools for volumetric analysis, for site location of towers, or for drainage basin delineation. These data are collected as part of the National Mapping Program.

1.2.3 **Supplemental_Information:**

7.5-minute DEMs have rows and columns which vary in length and are staggered. The UTM bounding coordinates form a quadrilateral (no two sides are parallel to each other), rather than a rectangle. The user will need to pad out the uneven rows and columns with blanks or flagged data values, if a rectangle is required for the user's application. Some software vendors have incorporated this function into their software for input of standard formatted USGS DEMs.

1.3 Time_Period_of_Content:

9.1 Single_Date/Time:

9.1.1 **Calendar_Date:** 19870000

1.3.1 **Currentness_reference:** ground condition

1.4 **Status:**

1.4.1 **Progress:** complete

1.4.2 **Maintenance and update frequency:** irregular

1.5 **Spatial_Domain:**

1.5.1 **Bounding _Coordinates:**

1.5.1.1 **West_Bounding_Coordinate: -**77.875

1.5.1.2 **East_Bounding_Coordinate: -**77.75

1.5.1.3 **North_Bounding_Coordinate:** 37.375

1.5.1.4 **South_Bounding_Coordinate:** 37.25

1.6 **Keywords:**

1.6.1 **Theme:**

1.6.1.1 **Theme_Keyword_Thesaurus:** none

1.6.1.2 **Theme_Keyword:** DEM

1.6.1.2 **Theme_Keyword:** digital elevation model

1.6.1.2 **Theme_Keyword:** digital terrain model

1.6.1.2 **Theme_Keyword:** hypsography

1.6.1.2 **Theme_Keyword:** altitude

1.6.1.2 **Theme_Keyword:** height

1.6.1.2 **Theme_Keyword:** contour line

1.6.1.2 **Theme_Keyword:** digital contours

1.6.2 **Place:**

1.6.2.1 **Place_Keyword_Thesaurus:**

Department of Commerce, 1987, Codes for the Identification of the States, The District of Columbia and the Outlying Areas Of The United States, and Associated Areas (Federal Information Processing Standard 5-2): Washington, Department of Commerce, National Institute of Standards and Technology

1.6.2.2 **Place_Keyword:** US

1.6.2.2 **Place_Keyword:** DC

1.6.2.2 **Place_Keyword:** VA

1.7 **Access_Constraints:** none

1.8 **Use_Constraints:** None. Acknowledgment of the U.S. Geological Survey would be appreciated in products derived from these data.

1.13 **Native_Data_Set_Environment:** LT4X 3.1 11/11/93, Infotec Development, Inc.

2. **Data_Quality_Information:**

2.1 **Attribute_Accuracy:**

2.1.1 **Attribute_Accuracy_Report:**

The accuracy of a DEM is dependent upon the level of detail of the source and the grid spacing used to sample that source. The primary limiting factor for the level of detail of the source is the scale of the source materials. The proper selection of grid spacing determines the level of content that may be extracted from a given source during digitization.

2.2 **Logical_Consistency_Report:**

The fidelity of the relationships encoded in the data structure of the DEM are automatically verified using a USGS software program upon completion of the data production cycle. The test verifies full compliance to the DEM specification.

2.3 **Completeness_Report:**

The DEM is visually inspected for completeness on a DEM view and edit system for the purpose of performing a final quality control and if necessary, edit of the DEM. The physical format of each digital elevation model is validated for content completeness and logical consistency during production quality control and prior to archiving in the National Digital Cartographic Data Base.

Due to the variable orientation of the quadrilateral in relation to the Universal Transverse Mercator (UTM) projection grid, profiles that pass within the bounds of the DEM quadrilateral may be void of elevation grid points and are not represented in the DEM. This condition occurs infrequently and is always the first or last profile of the data set.

Level 2 DEM's may contain void areas due to breaks in contours in the source graphic or DLG. Void area elevation grid posts are assigned the value of -32,767. In addition, suspect elevation areas may exist in the DEM but are not specifically identified. Suspect areas can be located on the source graphic as a "disturbed surface", symbolized by contours overprinted with photo revised or other surface patterns.

2.4 **Positional_Accuracy:**

2.4.1 **Horizontal_Positional_Accuracy:**

2.4.1.1 **Horizontal_Positional_Accuracy_Report:**

The horizontal accuracy of the DEM is expressed as an estimated root mean square error (RMSE). The estimate of the RMSE is based upon horizontal accuracy tests of the DEM source materials with equal to or less than intended horizontal RMSE error of the DEM. The testing of horizontal accuracy of the source materials is accomplished by comparing the planimetric (X and Y) coordinates of well-defined ground points with the coordinates of the same points as determined from a source of higher accuracy.

2.4.1.2 **Quantitative_Horizontal_Positional_Accuracy_Assessment:**

2.4.1.2.1 **Horizontal_Positional_Accuracy_Value:** 3 meters [estimated]

2.4.1.2.2 **Horizontal_Positional_Accuracy_Explanation:** Digital elevation models meet horizontal National Map Accuracy Standards (NMAS) accuracy requirements.

2.4.2 **Vertical_Positional_Accuracy:**

2.4.2.1 **Vertical_Positional_Accuracy_Report:**

The vertical RMSE statistic is used to describe the vertical accuracy of a DEM. It encompasses both random and systematic errors introduced during production of the data. The RMSE is encoded in element number 5 of record C of the DEM. Accuracy is computed by a comparison of linearly interpolated elevations in the DEM with corresponding known elevations. Test points are well distributed, representative of the terrain, and have true elevations with accuracies well within the DEM accuracy criteria. Acceptable test points include, in order of preference: field control, aerotriangulated test points, spot elevations, or points on contours from existing source maps with appropriate contour interval. A minimum of 28 test points per DEM is required to compute the RMSE, which is composed of a single test using 20 interior points and 8 edge points. Edge points are those which are located along, at, or near the quadrangle neat lines and are deemed by the editor to be useful to evaluating the accuracy of the edge of the DEM. Collection of test point data and comparison of the DEM with the quadrangle hypsography are conducted by the quality control units within the USGS.

There are three types of DEM vertical errors: blunder, systematic, and random. These errors are reduced in magnitude by editing but cannot be completely eliminated. Blunders are errors of major proportions and are easily identified and removed during interactive editing. Systematic errors follow some fixed pattern and are introduced by data collection procedures and systems. Systematic error artifacts include vertical elevation shifts, misinterpretation of terrain surface due to trees, buildings, and shadows, fictitious ridges, tops, benches, and striations. Random errors result from unknown or accidental causes.

DEM's are edited to correctly depict elevation surfaces that correspond to water bodies of specified size.

Level 1 DEM: A RMSE of 7-meters or less is the desired accuracy standard. A RMSE of 15-meters is the maximum permitted. A 7.5-minute DEM at this level has an absolute elevation error tolerance of 50 meters (approximately three times the 15-meter RMSE) for blunders for any grid cell when compared to the true elevation. Any group of points in the DEM can not contain more than 49 contiguous elevations in error by more than 21 meters (three times the 7-meter RMSE). Systematic errors within stated accuracy standards are tolerated.

Level 2 DEM: A vertical RMSE of one-half of the contour interval of the source map is the maximum permitted. Systematic errors may not exceed the contour interval of the source graphic. Level 2 DEMs have been processed or smoothed for consistency and edited to remove identifiable systematic errors.

2.4.2.2 **Quantitative_Vertical_Positional_Accuracy_Assessment:**

2.4.2.2.1 **Vertical_Positional_Accuracy_Value:** 7 meters

2.4.2.2.2 **Vertical_Positional_Accuracy_Explanation:** DEMs meet vertical National Map Accuracy Standards (NMAS) accuracy requirements.

2.5 **Lineage:**

2.5.1 **Source_Information:**

2.5.1.1 **Source_Citation:**

8.1 **Originator:** U.S. Geological Survey

8.2 **Publication_Date:** 19920503

8.4 **Title:** Mannboro

8.8.1 **Publication_Place:** Reston VA

8.8.2 **Publisher:** U.S. Geological survey

2.5.1.3 **Type_of_Source_Media:** magnetic tape

2.5.1.4 **Source_Time_Period_of_Content:**

9.1 **Single_Date/Time:**

9.1.1 **Calendar_Date:** "Unknown"

2.5.1.4.1 **Source_Currentness_Reference:** ground condition

2.5.1.5 **Source_Citation_Abbreviation:** CONTOUR1

2.5.1.6 **Source_Contribution:** elevation values

2.5.1 **Source_Information:**

2.5.1.1 **Source_Citation:**

8.1 **Originator:** U.S. Geological Survey

8.2 **Publication_Date:** 19920503

8.4 **Title:** photo ID number

8.6 **Geospatial_Data_Presentation_Form:** remote-sensing image

8.8 **Publication_Information:**

8.8.1 **Publication_Place:** Reston, VA

8.8.2 **Publisher:** U.S. Geological Survey

2.5.1.3 **Type_of_Source_Media:** transparency

2.5.1.4 **Source_Time_Period_of_Content:**

9. **Time_Period_Information:**

9.1 **Single_Date/Time:** the date of the aerial photograph

2.5.1.4.1 **Source_Currentness_Reference:** ground condition

2.5.1.5 **Source_Citation_Abbreviation:** PHOTO1

2.5.1.6 **Source_Contribution:** elevation values

2.5.1 **Source_Information:**

2.5.1.1 **Source_Citation:**

8.1 **Originator:** U.S. Geological Survey or National Geodetic Survey (NGS)

8.2 **Publication_Date:** 19920503

8.4 **Title:** project control

8.8 **Publication_Information:**

8.8.1 **Publication_Place:** Reston, VA

8.8.2 **Publisher:** U.S. Geological Survey

2.5.1.3 **Type_of_Source_Media:** magnetic tape

2.5.1.4 **Source_Time_Period_of_Content:**

9.1 **Single_Date/Time:** Unknown

2.5.1.4.1 **Source_Currentness_Reference:** ground condition

2.5.1.5 **Source_Citation_Abbreviation:** CONTROL1

2.5.1.6 **Source_Contribution:** ground control points

2.5.2 **Process_Step:**

2.5.2.1 **Process_Description:**

The production procedures, instrumentation, hardware, and software used in the collection of standard U. S. Geological Survey (USGS) Digital Elevation Models (DEM's) vary depending on systems used at the contractor, cooperator, or National Mapping Division (NMD) production sites. This process step describes, in general, the process used in the production of standard USGS DEM data sets.

Level 1 DEM: Level 1 DEM's are acquired photogrammetrically by manual profiling or image correlation techniques from National Aerial Photography Program (NAPP) or equivalent source photographs. Level 1 30-minute DEM's may be derived or resampled from level 1 7.5-minute DEM's.

Level 2 DEM: Level 2 DEM's are produced by converting 1:24,000-scale and 1:100,000-scale hypsography digital line graph (DLG) data to DEM format or the DEM's are generated from vector data derived from scanned raster files of USGS 1:24.000-scale or 1:100,000-scale map series contour separates.

Level 3 DEM: Level 3 DEM's are created from DLG data that has been vertically integrated with all categories of hypsography, hydrography, ridge line, break line, drain files and all vertical and horizontal control networks. The production of level 3 DEMs requires a system of logic incorporated into the software interpolation algorithms that clearly differentiates and correctly interpolates between the various types of terrain, data densities and data distribution.

Water body editing: DEM surface areas corresponding to water bodies are flattened and assigned map specified or estimated surface elevations. Water body areas are defined as ponds, lakes, and reservoirs that exceed 0.5 inches at map scale and double line drainage that exceeds 0.25 inches at map scale. Water body shorelines are derived either from a hypsographic DLG or by interactive delineation from 1:24,000-scale or 1:100,000-scale USGS map series.

Edge matching and edge joining: DEM data sets within a project area (consisting of a number of adjacent files) are edge matched and edge joined to assure terrain surface continuity between files. Edge matching is the process of averaging adjacent elevation values along common edges within a zone of approximately 5 row or column grid posts on both edges. When edge values exceed 3 elevation units difference, edge joining is performed. Edge joining is an extensive level of editing and requires editing elevation values internal to the DEM in order to create more accurate terrain representations by correcting the alignment of ridges and drains, and overall topographic shaping within an approximately 25-30 row or column grid post zone on both edges.

Quality control: DEM's are viewed on interactive editing systems to identify and correct blunder and systematic errors. DEM's are verified for physical format and logical consistency at the production centers and before archiving in the National Digital Cartographic Data Base (NDCDB) utilizing the Digital Elevation Model Verification System (DVS) software.

2.5.2.3 **Process_Date:** Unknown

3. **Spatial_Data_Organization_Information:**

3.2 **Direct_Spatial_Reference_Method:** raster

3.4 **Raster_Object_Information:**

3.4.1 **Raster_Object_Type:** grid cell

3.4.2 **Row_Count:** 463

3.4.3 **Column_Count:** 383

4. **Spatial_Reference_Information:**

4.1 **Horizontal_Coordinate_System_Definition:**

4.1.2 **Planar:**

4.1.2.2 **Grid_Coordinate_System:**

4.1.2.2.1 **Grid_Coordinate_System_Name:** Universal Transverse Mercator

4.1.2.2.2 **Universal_Transverse_Mercator:**

4.1.2.2.2.1 **UTM_Zone_Number:** 18

4.1.2.1.2 **Transverse_Mercator:**

4.1.2.1.2.17 **Scale_Factor_at_Central_Meridian:** 0.9996

4.1.2.1.2.2 **Longitude_of_Central_Meridian: -**75.0

4.1.2.1.2.3 **Latitude_of_Projection_Origin:** 0.0

4.1.2.1.2.4 **False_Easting:** 500000

4.1.2.1.2.5 **False_Northing:** 0.0

4.1.2.4 **Planar_Coordinate_Information:**

4.1.2.4.1 **Planar_Coordinate_Encoding_Method:** row and column

4.1.2.4.2 **Coordinate_Representation:**

4.1.2.4.2.1 **Abscissa_Resolution:** 30

4.1.2.4.2.2 **Ordinate_Resolution:** 30

4.1.2.4.4 **Planar_Distance_Units:** meters

4.1.4 **Geodetic_Model:**

4.1.4.1 **Horizontal_Datum_Name:** North American Datum 1927

4.1.4.2 **Ellipsoid_Name:** Clark 1866

4.1.4.3 **Semi-major_Axis:** 6378206.4

4.1.4.4 **Denominator_of_Flattening_Ratio:** 294.9787

4.2 **Vertical_Coordinate_System_Definition:**

4.2.1 **Altitude_System_Definition:**

4.2.1.1 **Altitude_Datum_Name:** National Geodetic Vertical Datum of 1929

4.2.1.2 **Altitude_Resolution:** 1

4.2.1.3 **Altitude_Distance_Units:** meters

4.2.1.4 **Altitude_Encoding_Method:** explicit elevation coordinate included with horizontal coordinates

5. **Entity_and_Attribute_Information:**

5.1 **Overview_Description:**

5.2.1 **Entity_and_Attribute_Overview:**

The digital elevation model is composed of a elevation value linked to a grid cell location representing a gridded form of a topographic map hypsography overlay. Each grid cell entity contains a 6-character integer value between -32,767 and 32,768.

5.1.2 **Entity_and_Attribute_Detail_Citation:**

U.S. Department of the Interior, U.S. Geological Survey, 1992, Standards for digital elevation models: Reston, VA,

A hypertext version is available at:

http://www-nmd.usgs.gov/www/ti/DEM/standards_dem.html

Softcopy in ASCII format is available at:

ftp://www-nmd.usgs.gov/www/ti/DEM/stdempt1.txt

ftp://www-nmd.usgs.gov/www/ti/DEM/stdempt2.txt

ftp://www-nmd.usgs.gov/www/ti/DEM/stdempt3.txt

Softcopy in WordPerfect format is available at:

ftp://www-nmd.usgs.gov/www/ti/DEM/stdempt1.wp5

ftp://www-nmd.usgs.gov/www/ti/DEM/stdempt2.wp5

ftp://www-nmd.usgs.gov/www/ti/DEM/stdempt3.wp5

Softcopy in PostScript format is available at:

ftp://www-nmd.usgs.gov/www/ti/DEM/stdempt1.ps

ftp://www-nmd.usgs.gov/www/ti/DEM/stdempt2.ps

ftp://www-nmd.usgs.gov/www/ti/DEM/stdempt3.ps

6. **Distribution_Information:**

6.1 **Distributor:**

10. **Contact_Information:**

10.2 **Contact_Organization_Primary:**

10.1.2 **Contact_Orgainization:** Earth Science Information Center, U.S. Geological Survey

10.4 **Contact_Address:**

10.4.1 **Address_Type:** mailing address

10.4.2 **Address:** 507 National Center

10.4.3 **City:** Reston

10.4.4 **State_or_Province:** Virginia

10.4.5 **Postal_Code:** 20192

10.5 **Contact_Voice_Telephone:** 1 800 USA MAPS

10.5 **Contact_Voice_Telephone:** 1 800 872 6277

10.9 **Hours_of_Service:** 0800-1600 Monday -Friday

10.10 **Contact_Instructions:**

In addition to the address above there are other ESIC offices throughout the country. A full list of these offices is at:

http://www-nmd.er.usgs.gov/esic/esic_index.html

6.2 **Resource_Description:** 7.5-minute digital elevation models

6.2 **Resource_Description:** 7.5-minute DEM

6.3 **Distribution_Liability**

Although these data have been processed successfully on a computer system at the U.S. Geological Survey, no warranty expressed or implied is made by the USGS regarding the utility of the data on any other system, nor shall the act of distribution constitute any such warranty. The Geological Survey will warrant the delivery of this product in computer-readable format and will offer appropriate adjustment of credit when the product is determined unreadable by correctly adjusted computer input peripherals, or when the physical medium is delivered in damaged condition. Requests for adjustment of credit must be made within 90 days from the date of this shipment from the ordering site.

6.4 **Standard_Order_Process:**

6.4.2 **Digital_Form:**

6.4.2.1 **Digital_Transfer_Information:**

6.4.2.1.1 **Format_Name:** DEM

6.4.2.1.5 **Format_Information_Content:**

USGS standard DEM: The standard USGS DEM can be described as an ASCII formatted elevation file preceded by a metadata header file of one 1024 byte ASCII record.

6.4.2.1.7 **Transfer_Size:** 1

6.4.2.2 **Digital_Transfer_Option:**

6.4.2.2.2 **Offline_Option:**

6.4.2.2.2.1 **Offline_Media:** 9-track tape

6.4.2.2.2.2 **Recording_Capacity:** 180mb

6.4.2.2.2.2.1 **Recording_Density:** 6250

6.4.2.2.2.2.2 **Recording_Density_Units:** characters per inch

6.4.2.2.2.2.3 **Recording_Format:** ASCII; available unlabeled or with ANSI-standard labels; available block sizes are multiples of 1024 ranging from 1024 to 31,744 bytes. For efficiency, blocking factors less than 16,000 are discouraged.

6.4.2.2.2 **Offline_Option:**

6.4.2.2.2.1 **Offline_Media:** 3480 cartridge

6.4.2.2.2.2 **Recording_Capacity:** 250mb

6.4.2.2.2.2.1 **Recording_Density:** N/A

6.4.2.2.2.2.2 **Recording_Density_Units:** N/A

6.4.2.2.2.3 **Recording_Format:** ASCII; available unlabeled or with ANSI-standard labels; available block sizes are multiples of 1024 ranging from 1024 to 31,744 bytes. For efficiency, blocking factors less than 16,000 are discouraged.

6.4.2.2.1 **Offline_Option:**

6.4.2.2.2.1 **Offline_Media:** 8mm cassette

6.4.2.2.2.2 **Recording_Capacity:**

6.4.2.2.2.2.1 **Recording_Density:** High (4.5Gb)

6.4.2.2.2.2.1 **Recording_Density:** Low (2.3Gb)

6.4.2.2.2.2.2 **Recording_Density_Units:** N/A

6.4.2.2.2.3 **Recording_Format:** ASCII; available unlabeled or with ANSI-standard labels; available block sizes are multiples of 1024 ranging from 1024 to 31,744 bytes.

6.4.2.2.1 **Offline_Option:**

6.4.2.2.2.1 **Offline_Media:** CD-Recordable

6.4.2.2.2.2 **Recording_Capacity:** 650mb

6.4.2.2.2.2.1 **Recording_Density:** N/A

6.4.2.2.2.2.2 **Recording_Density_Units:** N/A

6.4.2.2.2.3 **Recording_Format:** ISO 9660; the files are placed in a flat directory on the CD with naming conventions that are ISO 9660 Level 1 compliant (DOS 8.3).

6.4.3 **Fees:**

The online copy of the data set (when available electronically) may be accessed after paying a fee for the data set(s). For 8-mm cartridge and 9-track tapes the costs are:

1 digital product = $40

2 digital products = $60

3 digital products = $80

4 digital products = $100

5 digital products = $120

6 or more = $90 plus $7 per each product over six

The cost of data sets on CD-ROM is $32 per CD-ROM.

7. **Metadata_Reference_Information:**

7.1 **Metadata_Date:** 19940608

7.4 **Metadata_Contact:**

10. **Contact_Information:**

10.2 **Contact_Organization_Primary:**

10.1.2 **Contact_Organization:** U.S. Geological Survey

10.4 **Contact_Address:**

10.4.1 **Address_Type:** mailing address

10.4.2 **Address:** 508 National Center

10.4.3 **City:** Reston

10.4.4 **State_or_Province:** Virginia

10.4.5 **Postal_Code:** 20192

10.5 **Contact_Voice_Telephone:** 1 703 648 4543

7.5 **Metadata_Standard_Name:** Content Standards for Digital Geospatial Metadata

7.6 **Metadata_Standard_Version:** 19940608