National Mapping Program
Technical Instructions

Part 1
General

Standards for
Digital Orthophotos

U.S. Department of the Interior
U.S. Geological Survey
National Mapping Division

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Standards for Digital Orthophotos
Part 1: General

1.   GENERAL

1.1   DEFINITIONS
           The terms "digital orthophoto" and "DOQ" are used throughout this
           document to refer to both the 1-meter ground resolution
           quarter-quadrangle digital orthophoto (3.75- x 3.75-minutes in
           extent) and the one or two-meter ground resolution quadrangle
           digital orthophoto (7.5- x 7.5-minutes in extent). Although the
           primary digital orthophoto of concern is the 1-meter quarter-
           quadrangle, "DOQ" will refer to both the quarter-quadrangle and
           quadrangle digital orthophotos unless otherwise noted. Ground
           resolution, for DOQs, is synonymous with ground sample distance
           (GSD). The terms one and two-meter ground resolution refer to the
           distance on the ground represented by each pixel in the x and y
           components. They do not infer the minimum distance that can be
           detected between two adjacent features, or the minimum size of a
           feature expressed in size of objects or distances on the ground.
           The term gray-scale refers to an 8-bit image having up to 256 gray
           levels. Black and white refers to gray-scale images from
           panchromatic film while monochrome refers to a gray-scale image
           containing light from one wavelength band (red, green, blue, or
           infrared).

           Digital orthophoto - A digital image that has the properties of an
           orthographic projection. It is derived from a digitized perspective
           aerial photograph or other remotely sensed image data by
           differential rectification so that image displacements caused by
           camera tilt and terrain relief are removed.

           Orthophoto chips - A digital orthophoto may be made up of several
           images mosaicked together to form the final image. Each separate
           piece of the mosaic that contributes to the final image is called a
           "chip".

           National Aerial Photography Program (NAPP)- A multiple agency
           program coordinated by the USGS that provides panchromatic and color
           infrared coverage of the United States at 1:40,000 photo scale.

           National High Altitude Aerial Photography Program (NHAP) - A
           multiple agency program coordinated by the USGS that acquired
           1:80,000 photo-scale panchromatic and 1:58,000 photo-scale color
           infrared photography of the 48 conterminous United States from the
           years 1980-1987.

1.2   OBJECTIVES
           The U.S. Geological Survey (USGS) is designated as a lead Federal
           agency for the collection and distribution of digital cartographic
           data. The standards specified in this document pertain to the
           collection, processing, archive, and quality control of digital
           orthophoto data. Data produced to this standard will be archived in
           the National Digital Cartographic Data Base (NDCDB).

           The U.S. Department of Agriculture, Natural Resources Conservation
           Service (NRCS), the Farm Services Agency (FSA), the U.S. Forest
           Service (USFS), and the U.S. Geological Survey, National Mapping
           Division (NMD) are partners in the National Digital Orthophoto
           Program (NDOP). The program was created to ensure that each agency's
           digital orthophoto requirements are met, and to serve the needs of
           the broader user community for digital imagery data. The NRCS uses
           digital orthophotos as a common base map to facilitate the
           collecting, organizing and sharing of natural resource data at
           county field offices. The FSA uses digital orthophotos to assist in
           tracking producer records at county field offices. The Forest
           Service employs digital orthophotos as a means to more accurately
           inventory the national forests. NMD extracts digital base category
           data directly from digital orthophotos. The Standards for Digital
           Orthophotos supports these orthophoto requirements. Given that the
           requirements and technologies involved in producing digital
           orthophotos will remain dynamic for some time, the Standards for
           Digital Orthophotos outlines many key dependencies involved in
           producing digital orthophotos and, in some cases, alternative
           methods of production.

           This document also provides USGS components with guidelines for
           performing quality control and acceptance of digital orthophoto data
           into the NDCDB. Data generated by NRCS, FS, NMD and other Federal
           agencies, or procured from the private sector, must conform to this
           standard, to be accepted for entry in the NDCDB.

1.3   PRODUCT DESCRIPTION
           A digital orthophoto is a geo-referenced image prepared from a
           perspective photograph, or other remotely-sensed data in which the
           displacement within the image due to sensor orientation and terrain
           relief has been removed. Orthophotos combine the image
           characteristics of a photograph with the geometric qualities of a
           map. They serve a variety of purposes, from interim maps to field

references for earth science investigations and analysis. The digital orthophoto is useful as a layer of a geographic information system and as a tool for revising digital line graphs. Image processing algorithms can be applied to the image data to support planimetric image classification, three-dimensional modeling, and many other spatial applications. A digital orthophoto, as described in these standards, can be produced from any scale of photography. However, the program is oriented primarily toward the production of 1-meter gray-scale and color-infrared digital orthophoto quarter-quadrangles from 1:40,000-scale National Aerial Photography Program (NAPP) or NAPP-like photography. Production of one or two-meter digital orthophoto quadrangles will be primarily supported by mosaicking digital orthophoto quarter-quadrangles. Presently, hard-copy outputs from the digital orthophotos include 1:12,000-scale orthophoto quarter-quadrangles and 1:24,000-scale orthophoto quadrangles.

The digital orthophoto is created by scanning an aerial photograph transparency (diapositive) with a precision image scanner. The scanned data file is then digitally rectified to an orthographic projection by processing each image pixel through photogrammetric space resection equations. This process requires, as input, ground control points acquired from ground surveys or developed in aerotriangulation, conjugate photo-coordinates of ground control, camera orientation parameters, and a digital elevation model (DEM). The rectified digital image is then archived on suitable digital storage media with a keyword-based informational (metadata) header affixed to the beginning of the digital image.

1.4   SOURCES
The procedures and instrumentation used for production of digital orthophotos vary, depending on the systems available. Currently, NAPP or NAPP-like photography is the primary source used for the production of digital orthophotos by the USGS. NAPP photographs are quarter-quadrangle centered (3.75 minutes of longitude and latitude in geographic extent) and are exposed at a nominal flying height of 20,000 feet above mean terrain with a 6-inch (152.4 mm) focal-length camera (photo scale = 1:40,000). A quadrangle (7.5-minute) digital orthophoto is produced either by mosaicking 3.75-minute digital orthophotos or digital orthophoto chips or by generating the digital orthophoto from 1:80,000 photo-scale black and white photography from the National High Altitude Aerial Photography Program (NHAP). Color-infrared and natural color photographs may be used as a source

for digital orthophotos. Black and white DOQs may be generated from CIR and natural color source. Other aerial photographic or digital sources may be used in the future.

The photography is scanned with an aperture that can be adjusted between 7.5 and 30 micrometers (μm), depending upon the image scanner and desired output ground/pixel resolution. For example, an aperture between 25 and 30 μm yields a reasonable compromise between file size and adequate image resolution to support the present digital orthophoto program requirements. A 9 by 9 inch (240 mm square) black and white aerial photograph scanned with an aperture of 25 μm yields approximately 88 megabytes (MB) of raw data. Using 1:40,000-scale photographs, a 25 μm scan equates to a ground sample distance of 1 meter. A black and white quarter-quadrangle digital orthophoto generated and cropped from a 240- by 240-millimeter photograph, scanned at 25 μm, with the requisite overedge and header produces a rectified file between 45-50 megabytes.

1.5   DIGITAL ORTHOPHOTO STRUCTURE AND FORMAT

The line length of DOQs varies from file to file. The standard, uncompressed grayscale DOQ format contains an ASCII header (metadata) followed by a series of 8-bit image data lines. The keyword-based, ASCII header may vary in the number of data entries. The header is affixed to the beginning of the image and is composed of strings of 79 characters each ended with a newline character. Each keyword string contains information for either identification, display, or registration of the image. Additional strings of blanks are added to the header so that the length of a header line equals the number of bytes in a line of image data. See Part 2: Specifications, 2.10 Archive and Distribution Format.

The orientation of image data is by lines (rows) and samples (columns). Each line contains a series of pixels ordered from west to east. The order of the lines is from north to south. Digital orthophotos are archived and distributed so that when displayed on a computer graphics terminal, the projection grid north is at the top of the screen.

The standard DOQ format is either a 3.75-minute quarter-quadrangle or 7.5-minute quadrangle and is black and white, color-infrared (CIR), or natural color image. Both quarter-quadrangle and quadrangle DOQs contain overedge imagery. The 3.75-minute quarter-quadrangle DOQ has a ground pixel distance of 1 meter while the

7.5-minute quadrangle has a one or two-meter ground pixel distance. The digital orthophoto is in the Universal Transverse Mercator (UTM) coordinate system on the North American Datum of 1983 (NAD 83) for 1-meter, 3.75-minute quarter-quadrangles. Either North American Datum of 1927 (NAD 27) or NAD 83 for one or two-meter, 7.5-minute quadrangles (See Section 2.5, Datums and Coordinates) can be used.

The standard, archived, quarter-quadrangle DOQ is uncompressed and is approximately 45-50 megabytes (MB) in size. DOQs are distributed in both compressed and uncompressed format. The compressed DOQ is approximately 4-6 MB in size and is accompanied by a separate header file.

References

U.S. Geological Survey, 1986, Standards for Digital Elevation Models: National Mapping Program Technical Instruction.

U.S. Geological Survey, 1991, Standards for 1:12,000-scale Orthophoto Quarter-Quadrangles: National Mapping Program Technical Instructions, 18 p.

U.S. Geological Survey, 1992, Standards for 1:24,000-scale Orthophoto Quadrangles: National Mapping Program Technical Instructions, 20 p.