RECLAMATION

Managing Water in the West

Technical Guidance

Surveying, Mapping, and Aerial Photography

General Instructions

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

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Mission Statements

The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Acronyms

A-E	Architect-Engineering
APFO	Aerial Photography Field Office (USDA)
ASPRS	American Society for Photogrammetry and Remote Sensing
BIA	Bureau of Indian Affairs
BLM	Bureau of Land Management
CAD	computer aided design
DSLR	digital single-lens reflex
DEM	digital elevation model
DSM	digital surface model
DTM	digital terrain model
EM	Engineering Manual
EROS	Earth Resources Observation and Science Center (USGS)
FGDC	Federal Geographic Data Committee
FSA	Farm Service Agency
Forest Service	U.S. Forest Service (USDA)
GIS	geographic information system
GSD	ground sample distance
IDIQ	indefinite delivery/indefinite quantity
IFSAR	interferometric synthetic aperture radar
LiDAR	light detection and ranging
NAIP	National Agriculture Imagery Program (USDA)
NGA	National Geospatial-Intelligence Agency (U.S. Department of Defense)
NGS	National Geodetic Survey
NIR	near-infrared
NRCS	Natural Resources Conservation Service (USDA)
OMB	Office of Management and Budget
PLSS	Public Land Survey System
Reclamation	Bureau of Reclamation
RGB	red-green-blue

RI	Reclamation Instructions
TSC	Technical Service Center (Reclamation)
U.S.	United States
UAS	unmanned aerial systems
UC	Upper Colorado Region (Reclamation)
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey

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Appendices

I. Scope of Surveying and Mapping Activities

Definition. The term "surveying and mapping," used in these instructions, is restricted to measurement of the earth's surface; layout and measurement of project facilities; and the preparation of maps. This Part 368 presents the administrative instructions for the surveying and mapping activities of the Bureau of Reclamation (Reclamation).

Classification of Surveys. The surveying and mapping activities performed by or for Reclamation may be classed as control, topographic, planimetric, cadastral, route, structure, photogrammetric, hydrographic, and sedimentation surveys. These activities are common to the general field of surveying and mapping and are defined in standard surveying textbooks and manuals.

A. Intensity of Survey

Order of Survey. The intensity of survey is associated with the standards required for the level of work being performed. Standards guiding the performance of surveys have been established by the Federal Geodetic Control Committee by which surveys are classified as first-, second-, third-, and fourth-order surveys. This classification supersedes all recent editions of most standard textbooks.

Planning Surveys. Planning activities are divided into Project Investigation and Advance Planning grade investigations.

- Project investigations and reconnaissance surveys are rapid or critical inspections of the potential features of a project. Fourth order or even lower-grade surveys are usually performed for these investigations.

- Advance planning surveys are to obtain basic data for designs and estimates. Third- order surveys are usually performed for these investigations.

Preconstruction Surveys. These surveys are made preparatory to construction of the project. They are the basis for preparation of final designs and specifications. Second- and third-order surveys are the usual standards for this work, the higher standards being required for establishing primary project controls. There are exceptions for precise structural work such as bridges and tunnels for which surveys of first or second order may be required. The primary controls established during preconstruction surveys may be used during the construction period.

Construction Surveys. These surveys are performed in connection with any construction operations, including "as-built" surveys of structures. Second- and third-order surveys are the usual standards for this work with the exception of unusual features requiring higher standards.

Post-Construction Surveys. These surveys are made to record the behavior of structures following completion of construction. They are also made to record changes in stream channels and reservoirs caused by construction and operation of the project. These surveys establish a base for future sedimentation surveys and may also be used in legal actions. The performance grade of these surveys varies with the fineness of measurements to be recorded. Specific instructions for each type of survey may be found in Reclamation Instructions (RI) Series 550, Surveying and Mapping Techniques and Standards.

II. Responsibilities and Coordination

A. National Mapping Program

Introduction. Several agencies of the Federal Government are responsible for conducting standard surveys within the area of Reclamation activity. Other surveys have and are being performed for special purposes.

Cadastral Surveys. Cadastral surveys are for the purpose of making an official register of the quantity and ownership of real estate. The cadastral survey of public lands has been conducted by the Federal Government under the public land laws of the United States (U.S.). Public land surveys were made beginning with the territory northwest of the Ohio River. Texas is not subject to the Federal public land laws. The survey of lands is under the jurisdiction of the Bureau of Land Management (BLM). Detailed information on cadastral surveys may be obtained from the *Manual of Instructions for the Survey of Public Lands of the United States*, 2009 is the current version published by BLM.

Primary Horizontal and Vertical Control. A network of primary horizontal and vertical control has been established by the National Geodetic Survey (NGS), an agency of the Department of Commerce. Adjustment and extensions to the network are in continual progress. The NGS should be consulted for the latest information on adjustments and control available. The U.S. Geological Survey (USGS) establishes additional control as required in its topographic mapping program.

Topographic Mapping. A systematic program of topographic mapping is conducted by the Geological Survey. Maps of various types and scales are published by the Survey.

Aerial Photography. Extensive aerial photographic coverage has been acquired by the Department of Agriculture (USDA). The Farm Service Agency (FSA), Natural Resources Conservation Service (NRCS), and U.S. Forest Service (Forest Service) have covered most of the agricultural and forest areas of the Western States with vertical stereoscopic aerial photographs (beginning 1950s) and digital orthoimagery (beginning 2003). In addition, the National Agriculture Imagery Program (NAIP), administered by the FSA through the USDA Aerial Photography Field Office (APFO) in Salt Lake City, Utah, acquires aerial imagery during the agricultural growing seasons in the continental U.S.

The USGS has acquired considerable aerial photography and light detection and ranging (LiDAR) data in connection with its topographic mapping work. Other federal agencies that acquire aerial photography include the BLM, National Geospatial-Intelligence Agency (NGA), U.S. Army Corps of Engineers (USACE), NGS. Private aerial mapping and satellite imagery companies are also an excellent source of aerial photography and imagery. The EROS Data Center, USGS, 10th and Dakota Avenue, Sioux Falls South Dakota, 57198, maintains records of aerial photographic coverage, based upon reports received from Federal and State agencies and commercial concerns. Many of these entities offer on-line web based search engines that facilitate the locating and ordering of aerial photography and related imagery for any project area.

.**Navigation and Aeronautical Charts.** The National Oceanic and Atmospheric Administration compiles and publishes navigation charts of navigable streams, lakes, bays, and ocean waters in or appurtenant to the U.S. and its possessions. This agency also compiles and prints sectional aeronautical charts of the U.S. and its possessions.

B. Coordination with Other Agencies

Policy. The Office of Management and Budget (OMB, formerly Bureau of the Budget) has issued *Circular No. A-16* and exhibits describing the responsibilities of Federal agencies with respect to coordination of the Federal surveying and mapping activities financed in whole or in part by Federal funds. (See appendix B.) It is the policy of Reclamation to recognize the responsibilities of and to cooperate with Government mapping and surveying agencies in accordance with OMB *Circular No. A-16 Revised* (2002-2010). Where a specific responsibility of another agency is recognized, coordination is necessary. To accomplish this coordination, it is essential that all Reclamation offices present their program of mapping and survey needs as far in advance as possible. This will include needs for high order accuracy horizontal and vertical control, cadastral surveys, and large-scale area mapping. Reclamation's Technical Service Center (TSC) in Denver, Colorado, shall be the coordinating office for Reclamation.

National Geodetic Survey (NGS)**.** Reclamation Regional Directors should present any program for extensive control requirements of first or second order accuracy to TSC as early as possible. These requirements should be discussed with the NGS at the National level. If it fits into the National Control Program or if funds and personnel are or can be made available, the Survey may perform the work without cost to Reclamation. Otherwise it is possible arrangements can be made with the NGS to perform the work on a reimbursement basis.

Bureau of Land Management (BLM). Any survey or resurvey of public lands shall be approved or performed by BLM. Requests for such work shall be cleared through Reclamation's Regional Office. Informal contacts with regional or State offices of BLM may indicate the possibility of arranging for assistance before a formal request to Reclamation's Regional Office is made.

Entry for Surveys. Prior to entry on private lands to make surveys, the manager in charge shall secure permission of the owner. Where permission is refused because of impending damages, it may be possible to negotiate a contract for entry. When entry is refused and cannot be negotiated, bridging by aerotriangulation may be specified, or action may be taken through condemnation proceedings in a Federal Court to obtain entry. The Secretary of the Department of the Interior will initiate condemnation proceedings through the Department of Justice upon request of Reclamation's Commissioner (Commissioner). Reclamation's Regional Director is responsible for ensuring that the right of entry is adequately covered in all contract work. They may elect either to make the right of entry a responsibility of the contractor or include it as a provision in the contract, or to secure the right of entry for the contractor.

- **Indian Reservation Lands.** Reclamation's Regional Director shall request permission for entry on Indian Reservation lands from the Tribal Council through the Superintendent, Bureau of Indian Affairs (BIA). If permission is refused, the Commissioner may appeal the decision to the BIA.

- **Other Lands Controlled by the Department of the Interior.** The Commissioner will request permission from the Secretary of the Department of the Interior for entry to National Parks, National Monuments, Wildlife Refuges, Wilderness Areas, and National Recreational Areas.

- **Lands Controlled by Other Agencies.** Permission for entry to lands controlled by other Federal, State, or local agencies should be arranged by Reclamation's Regional Director or his representatives.

- **Military Areas.** There may be specific areas within or adjoining the general area to be covered by aerial photography that are restricted for military or other reasons. Reclamation's Regional Director is responsible for elimination of these areas from the survey or for enforcing limitations that may be imposed upon use of the data.

C. Initiation of Surveys

Existing Surveys and Maps. One of the first steps in a new investigation is an inventory and assembly of existing surveys, maps, and aerial photography. The USGS Earth Explorer and USDA Geospatial Data Gateway websites are a basic source for this information. Outlined below is a list of data that may be available and where it may be obtained.

Table 1.—General Base Maps (scale, 1:125,000 to 1:1,000,000)

State maps	USGS, BLM, State engineer, or other agency
County maps	County engineer or surveyor, private cartographic firms, State Highway Department
Aeronautical charts	Department of Commerce
Transportation map	Bureau of Public Roads, State or County Highway Departments
Indian Reservations	BIA Tribal Council
Forest maps	Forest Service
Sectional maps	National Parks Service, USGS
Soils maps	NGA
Land plats	NRCS, State Land Office, BBLM, County Recorder or Assessor, private engineering or cartographic firms, abstractors

Table 2.—General Topographic Maps (scale 1:24,000 to 1:250,000)

Quadrangle series	USGS (including National Geospatial-Intelligence Agency and Forest Service)
Special areas - scale 1:12,000 to 1:25,000	
Indian Reservation	BIA
National forests	Forest Service
Timber areas	Forestry or lumber firms

Table 3.— Special Topographic Maps (scale 1:1,200 to 1:48,000)

River plan-profiles	Geological Survey, USACE
NGS	NGS
Reservoir and dam sites and conduit lines (filing maps)	USACE, State engineers
Hydropower sites	Federal Power Commission, Forest Service, USGS

Table 4.— Detailed Planimetric Maps (scale 1:7,920 to 1:250,000)

Forest areas	Forest Service, State Forestry Service
Land plats	BLM, county records
Aerial photographs and mosaics	USGS, Forest Service, NRCS, Farm Service Agency, USACE, BLM NGA, State and local governments, lumber companies, photogrammetric firms
Vertical and horizontal control data	NGS, USGS, USACE, State Highway Departments, county engineer

Bureau of Reclamation Surveys. Initiation of surveys as planned and issuance of instructions for carrying out surveying and mapping operations is the responsibility of the office having direct supervision of the survey party, subject only to the limitations outlined herein and as additionally prescribed by Reclamation's Regional Director and Reclamation's Commissioner. Detailed instructions for submission of design data are contained in RI 133, and specific practices concerning accuracy and coverage for various stages and kinds of work are presented in RI 550. Specific, rather than general, surveying and mapping requirements for unusual project features may be requested by Reclamation's Denver Office, Denver, Colorado. Reclamation's Regional Director will be advised in these instances.

Record of Survey Monument. Each Reclamation's Regional and Area Office performing field surveys involving the establishment of permanently monumented horizontal control points or benchmarks shall prepare and maintain a file of individual sheet descriptions of each such monument. Such descriptions shall be on material suitable for reproduction with available equipment, by the Regional or Area Office maintaining the record of survey monuments.

General. Planning investigations are either project investigation or advance planning evaluations of a potential water resource development Project investigations are rapid and inexpensive, with considerable reliance on experience and judgment. Advance planning investigations are in sufficient detail to produce a reliable plan and estimate. Field surveys should be conducted commensurate with objectives and requirements of the planning investigations. The intensity and accuracy of surveys are associated with the specific requirements of the different features. General requirements for consideration in resource planning are given in RI 110; land classification requirements are given in RI 115 and RI 510; and design data requirements are listed in RI 133. Surveying and mapping techniques and standards are discussed in RI 550.

The first step in any planning investigation is to secure all the necessary existing available data. Field surveys are then programmed to augment existing survey data in meeting the investigation requirements.

Project Investigations and Reconnaissance Surveys. Project investigations are synonymous with and similar to reconnaissance surveys described in surveying text books, RI 368, RI 510, RI 550, and standards established by the USGS, NGS, other Federal agencies, State agencies, and professional societies. In the interest of national and international communication uniformity, reconnaissance will be retained in Reclamation terminology and RI from a surveying, mapping, and photogrammetry aspect. These surveys are rapid reconnaissance or even a critical inspection of an area. Every effort should be made to use existing survey data before conducting field surveys. When field surveys are necessary, fourth order or even lower grade accuracy is the usual performance standard. Toe technical adequacy of project investigation reports is the responsibility of the Reclamation Regional Director; hence, they and their staff will establish the performance standards.

- **Reservoirs.** Accurate determination of reconnaissance reservoir capacities is not required. Existing quadrangle maps with a contour interval not more than one-fourth to one-fifth of the reservoir depth is adequate. If surveys are required, photogrammetric plotting from existing photos and reconnaissance control should be considered for large or inaccessible areas.

- **Storage Dams.** Storage dams may be estimated from reservoir survey data or quadrangle maps for large structures. A check profile along the axis is desirable. Irregular spillway or foundation conditions and thin arch dams will usually require sketch topography with supplementary control.

- **Diversion Dams.** Diversion damsites may be adequately defined with a profile. When major flood channels or long earth embankments with off-channel spillways are anticipated, sketch topography should be taken. Data on maximum flood stage or downstream channel conditions may be required.

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- **Tunnels.** Information required for tunnel sites includes approximate portal positions, definition of thin cover areas, and general area topography. A flagged field location will be necessary to permit geologic inspection. Profile or sketch topography will be required for locating portals in areas with relatively flat slopes.

- **Main Supply Canals.** Reconnaissance canal design and estimates can usually be prepared from contour maps. Plan-in-hand field inspection may reveal undulating topographic areas where large error can be expected, and it may be advisable to supplement the topographic data with a profile. If contour maps are not available, a profile should be obtained. It is wise to have an experienced canal designer accompany the survey crew to direct the profile alignment to the proper hydraulic gradient and appropriate curvature, locate and define major structures, and define right-of-way problems. A limited number of cross sections should be taken to define severe cross-slope reaches. Aerial photographs can be used to good advantage with the profile survey.

- **Lateral Distribution Systems.** Lateral distribution system estimates can usually be made from layouts using contour maps. The layout should be appraised by a critical field inspection. If adequate topographic maps are not available, estimates developed for selected sample areas may be projected for a total cost. Sample area layouts should be based upon profile surveys.

- **Other Route Surveys.** Roads, railroads, and transmission lines are given only reconnaissance field inspections, with appropriate notes on items controlling cost and location. General maps or aerial photographs are usually used for the field inspection.

- **Service Areas.** Service areas may be delineated on existing maps or photographs. A limited amount of surveying may be required to establish control points or approximate photograph scales.

Advance Planning Surveys. Surveys performed for advance planning investigations are for land classification, location and design data, and right-of-way estimates. Land classification mapping requirements are outlined in RI 115 and RI 510. Route surveying and mapping requirements for obtaining design data are outlined in RI 133 and in RI 550. Design data for specialized or unusual cases should be discussed with representatives of the Denver Office. Special surveying and mapping requirements should be outlined in these discussions. Surveys required for computing tailwater curves, backwater conditions, and river profiles are outlined in the *Guide for Computing Water Surface Profiles*, a manual available from the Denver Office.

Reservoir topography required for design data is outlined in RI 133. The area-capacity data developed from the reservoir topography will be used in hydrologic studies and, in most cases, will be the data used for reservoir operation until the reservoir is resurveyed. Hydrologic and operation purposes require an area-capacity curve accurate to within 10 percent. In addition to these requirements, reservoir surveys should anticipate the data that may be needed for recreation and fish and wildlife development. See RI 211 for land acquisition policies.

IV. Preconstruction Surveys

General. Design data surveys as used herein refer to the surveys performed during the period of investigations immediately preceding construction and subsequent to appropriation of funds for construction. The major purpose of these surveys is to obtain data for preparation of specification designs. Surveys may also be required as a basis of securing right-of-way. Design data requirements are outlined in RI 133. It may be noted by comparing these requirements that project investigation survey data may be used for some features. Controls established in the performance of these surveys will be used during the construction period. Coordination with other agencies, as outlined in RI 368.2, is required in conducting these surveys.

Control Surveys. A primary project control network will be established at this time that will be used for all subsequent project needs. The primary control should be established to at least second order standards. Some projects may include special features such as tunnels and long, low-gradient canals that may require greater accuracy. Basic control extending from the primary network will be established to the standards required for the individual feature served. Control points established should be permanent, accessible, and well documented. The control will conform to the requirements of the OMB *Circular A-16*, tied to the National network, and comply with the latest standards as published by the Federal Geodetic Control Committee. The control should be established to provide a uniform reference to the overall project and envision potential project expansion. In almost any case, the control should be taken from that used for existing regional surveys. The NGS base with the latest adjustment will usually meet these requirements. In addition to making use of existing data, survey evidence presented in legal actions is more acceptable to the courts if it conforms to the accepted regional control.

V. Construction Surveys

General. The term “construction surveys” includes all types of surveying which are performed for construction activities. Construction surveys are intended to furnish guidance to the construction forces to assure that the work is in physical compliance with the designs. The standards and limiting accuracies will vary with the type of construction. Measurements to the nearest 30 millimeters may be sufficient for earth embankments, but the setting of major hydraulic or electrical machinery may require readings to within 25 micrometers. (See RI 555 and 556).

The following paragraphs discuss the responsibilities of Reclamation personnel in performing construction surveys and briefly mention some of the various types of construction surveys.

Responsibilities. Reclamation specifications generally provide that the Government will establish a primary control system, a stationed centerline, benchmarks, and/or principal control points for commencement of the work. It is usual procedure for the Government to make initial cross sections, profiles, and preconstruction surveys for contract record purposes of the structure site and borrow areas. It is also usual procedure for the Government to make final surveys of the completed work for payment and as-built records. If these surveys are provided by other than Government forces such as a professional service contract or contractor forces, a Government-qualified survey inspector will be assigned to provide quality assurance of the work.

All other surveys and layout will be performed by the contractor unless specified to be performed by the Government.

Surveys for installation of major mechanical, hydraulic, and electrical equipment will be performed by contractor's forces under the guidance, when necessary, of the manufacturer's representative. The contractor will make the necessary surveys for estimating monthly progress payments, if required by specifications.

The survey parties perform Reclamation construction surveys, work under the general direction of the construction engineer or a delegated responsible officer. The survey chiefs must be familiar with all details of the work for which the surveys are required. They must devise and carry out procedures necessary to accomplish the required surveys. They must diligently avoid errors which would result in redoing portions of the work and cause claims against the Government. The obligations of the survey chiefs include, so far as their jurisdiction applies, assuring that the surveys are accurate and sufficient to permit construction work of the quality required by Reclamation specifications.

Control Surveys. “Control surveys for construction” refers generally to an extension of the primary project control system so that references for both vertical and horizontal measurement will be available near the site of the work. The establishment of the primary and extended basic control is discussed in RI 368.4.2 and in RI 553. The basic control surveys for construction will vary with the type of structure and the local terrain. Extension of the primary control system to basic control near the construction site should be performed with at least third order accuracy. All primary control points established for construction purposes should be made a part of the national network, although conversion to local datum may be necessary for high elevation work. (See RI 553.)

Excavation Surveys. Excavation activities will vary from surface skimming to excavation of deep pits and open cuts. The Government may establish stationed centerline and control and may cross section the area for the basis of payment. (However, some roads are built on a per mile unit basis, and excavation is not measured.) Original ground cross sections or grids may be established either by ground surveys or by photogrammetric methods based upon third order basic control surveys or better and aerial photography of a scale and quality to provide comparable accuracy. These surveys should be made in advance of the start of the construction and must not hold up the contractor's operations. A requirement for notification by the contractor of the need for surveys and the responsibility of the Government in obtaining them are usually included in the specifications. If there are different types of excavation which vary in unit price, surveys should be made to provide a basis for payment. Intermediate stage surveys for progress payments shall be made by methods which may be agreed upon between contracting officer and contractor, but in case of dispute, shall be performed as for final payment purposes; photogrammetric methods are preferably used to provide an essentially instantaneous and permanent record of conditions existing at the time of dispute. Laser beam methods may be used for operational control during construction. Final cross sections may be taken by Government forces or by professional services photogrammetric contract as a basis for payment. Stationing and performance standards should be consistent with the original surveys for this purpose.

Embankment Surveys. Surveys for placing embankment are similar to those made in connection with open-cut excavation. There is little difference in the basic surveying operations.

Tunnel Surveys. Aside from certain specialized procedures and the accuracy required, there are no basic differences between surveys underground and those on the surface of the earth.

Special instruments have been developed to facilitate and speed the work. Also, some differences in procedure have been developed which are described in any recognized handbook or text on surveying.

Shaft Surveys. Excavation of shafts is basically the same operation as tunnel excavation.

Reclamation specifications normally include "Excavation in tunnels and shafts" as a pay item with one unit price. The basic difference between shaft surveys and tunnel surveys is due to the alignment being in a vertical rather than a horizontal plane. Differences in elevation are usually determined by vertical chaining rather than direct leveling. Projection of alignment must be accomplished by use of a mining transit, plumb-bob, or other means rather than by a regular transit. Aside from this difference, all instructions for tunnel work can be applied to construction control surveys in the excavation of shafts.

Structure Surveys. Structures built by Reclamation vary from simple lateral drops and turnouts to extremely complex concrete dams and powerhouses. The amount of surveying needed during the construction of any given structure will depend on its size and complexity. Basic surveys made during construction are primarily an extension of the primary control surveys, since in the final analysis, survey work is the furnishing of control so far as construction activities are concerned. In the case of a small lateral structure, an extension of the control grid to establish a reference point convenient to the structure site and an extension of the vertical control system to furnish elevation at the same point, will probably be all that is required in the way of construction surveys. Construction surveyors will transfer line and grade from the reference point to the structure with sufficient accuracy for all practical purposes. For more complex structures, considerably more surveying must be done and a higher degree of accuracy must be attained.

Other Surveys. Other construction survey work includes providing line, grade, and other required points for construction jobs such as railroads, highways, canal lines, distribution and drainage systems, power and telephone lines, and campsites. No unusual problems are normally encountered on these types of surveys, the procedures being similar to those which are followed in making preconstruction surveys for the same features.

Machinery Installation Surveys. Surveys for gate, valve, and machinery installations differ from other construction surveying operations only in the precision required. The setting of major hydraulic or electrical equipment will require measurements to the nearest 25 micrometers, and certain modifications of ordinary surveying techniques are necessary to accomplish this accuracy. During the construction of wheel-pits and generator foundations, design dimensions can be used in locating the embedded anchor bolts, etc. Where possible, design dimensions should be supplemented by shop dimensions furnished by the manufacturer. It may be necessary to use measurements from the equipment, since discrepancies have been found between shop drawings and the equipment delivered. The setting of gates and valves usually does not require the same degree of accuracy described for heavy machinery and can be done from local benchmarks by normal surveying methods provided sufficient care is taken.

Special Construction Surveys. In addition to the standardized types of surveys previously discussed, there are special surveys to fit conditions peculiar to a particular project. Because of this variety, it is impossible to predict what surveys will be needed and the performance to fulfill requirements. Such problems must be solved by ingeniously adopting standard procedures. A problem which may occur on a project is that of river sounding. River cross sections and plans may be required for channel alterations associated with dam, siphon, and river rectification construction. The complexity of this operation will depend on the size of the river and the swiftness of the current. These surveys may require special equipment and methods associated with hydrographic surveying.

Reservoir sedimentation ranges and river channel degradation and aggradation ranges are also established, when necessary, during the construction stage. Administrative procedures for these surveys are discussed in RI 368.7. Technical requirements and procedures are discussed in RI 550. The limiting accuracies for any special survey are dictated by the purpose of the survey. If these requirements are met, the particular procedures used to solve the problem are less important.

VI. Post-Construction Surveys

General. Post-construction surveys consist primarily of surveys to determine and record the behavior of a structure and the physical changes caused by resource development. These data are not only valuable design information, but may be basic evidence in legal actions. Reservoir sedimentation, reservoir delta, and channel surveys are discussed in RI 368.7. Survey instructions for establishing and maintaining a groundwater observation network are contained in RI 550, Surveying and Mapping Techniques and Standards. These surveys may be made periodically over a long period of time. It is important that all survey notes be well documented and stored in permanent and accessible archives.

Surveys for Structural Behavior. Surveys for structural behavior are performed to determine what distortion, deflection, or other movement takes place in the structure. Special instructions, outlining procedures and survey performance standards, will be issued by the Denver Office for each structure to be surveyed.

VII. Special Surveys

General. This chapter discusses the aspects of some special types of surveys which Reclamation personnel are often required to perform. The list of surveys herein discussed is not intended to be complete. Many other types of surveys will be needed from time to time under special circumstances. However, it is believed that no unusual administrative procedures will be required which are not discussed herein. If so, they can be determined by special correspondence. Contract surveys are discussed in RI 368.8.

A. Cadastral Surveys

Definition. Cadastral surveys are surveys relating to the establishment of land boundaries and subdivisions made to create or define limitations of titles.

Sources of Information. The Director of the BLM is the custodian of the records of the original land surveys. Copies of all plats, notes, and other data may be secured from this agency. State land offices, county clerks, recorders, surveyors, engineers, assessors, landowners, and court records may provide useful information. It has frequently been found necessary to search the court records to determine the actual ownership of a property. Errors by the clerk and recorder have made the regular transcribed records inaccurate. It is usually advisable to consult the actual filed deed rather than depend on the transcribed records.

Township and Section Surveys. Reclamation often has a requirement to retrace or reestablish township and section lines. Officially established and recognized township and section corners must be located on the ground before such lines can be retraced or reestablished.

- **Surveys by BLM.** When a general survey is required, BLM shall be requested to perform the survey. Requests for cadastral resurveys shall be made through the Reclamation Regional Director. These resurveys should be limited to reestablishment of the corners and the area necessary to meet requirements of the project development and settlement responsibilities under Reclamation Law and Departmental Orders. When such requests are made, arrangements shall also be made for appropriate reimbursement to BLM for the cost of the survey. Regional or project forces are permitted to restore township and section corners on scattered townships and section corners that need to be restored when BLM authorizes Reclamation to perform the actual survey work. BLM will provide the necessary instructions, guidance, and official approval of the records in these cases.

- **Land Surveys by Reclamation.** The authority of Reclamation to execute cadastral surveys is limited to such instances whereby BLM has authorized specific actual survey work and provided the necessary instructions, guidance, and official approval of the project. Some projects have had specific authority delegated by Congress in the enabling legislation to perform said resurveys. Resurveys authorized in the Columbia Basin Project Act of March 19, 1943, are an example.

  - **Withdrawn Lands.** Reclamation has been given specific authority to conduct cadastral surveys on certain public lands withdrawn for Reclamation purposes, but these surveys must still be conducted using BLM instructions and approval.

  - **Private Lands.** After title has passed from the U.S. to an individual (patented lands), and a boundary dispute arises, final determination in the matter of fixing the position of the disputed land boundary rests with the local courts of competent jurisdiction. (See *Manual of Surveying Instructions,* BLM, 2009 edition, paragraphs 6-7.)

    Reclamation's authority to survey private lands either by contract or by Government forces is the same as any private landholder. If property boundary surveys are required for right-of-way or land rights purposes, they may be performed by a licensed surveyor registered by the State. This would require the preparation of a plat of the survey to be sealed and signed by the surveyor and filed with the appropriate county official. These surveys, performed on lands between Reclamation and owners of private lands, are intended to be in harmony with the local court decisions in suits involving boundary disputes.

    - **Disputes.** Where court action of trespass on Federal lands is involved, BLM or a surveyor authorized by BLM must be engaged to perform any surveys on behalf of the U.S. and defend the U.S. interests in court.

    - **Public Land Survey System** (PLSS)**.** Record of the PLSS, approved by BLM, is the only record recognized by the Judicial System in disputes of Federal *vs.* private landowners. (See Pappas *vs.* U.S.)

- **Laws and Regulations.** These surveys, and maps showing the results, must conform to existing laws and regulations. The law requires that the original comers or markers not be disturbed. Even when discrepancies are found in the original surveys, the original corners or markers remain fixed as the legal boundaries. In some States, original land grants were made to individuals by former sovereignties other than the U.S. Surveys were seldom made originally, and the boundary descriptions are vague. Surveys to establish or reestablish these land boundaries are quire involved and may require a search of records and court decisions.

Maps. Accurate maps or plats are required for Reclamation work. Resurveys and further subdivision are often required for procurement of rights-of-way or purchase of property. The resulting maps must show land boundaries and ownership as required by BLM regulations and conform to all previously registered or recorded maps. Maps of townsites or camps should be made with the same accuracy, as they may later form the basis for subdivision and private ownership.

Relations with Landowners. Land surveyors, in order to get access to and information about property, must be extremely careful, diplomatic, and considerate in their relations with landowners. Boundary disputes and water rights are extremely important to most landowners, and landowners may not permit access to surveyors or allow survey of their land. Legal action may be required to gain access.

Subdivision of Sections. The rules for subdivision of sections are established by laws governing the surveys of public lands. When advice of BLM is needed, the letter of inquiry to Reclamation's Office of the Commissioner should, in every instance, contain a description of the particular tract or comer, with reference to township, range, and section. The inquiry should include a diagram showing the condition found, with distances shown.

Supplemental Survey Plats. Whenever supplemental surveys are needed to subdivide farm units or other land areas, BLM will perform or delegate the work, and proper instructions will be provided.

Townsite Survey. The term "townsite survey" in public land surveying practice is applied to the marking of lines and corners within one or more regular units of the township subdivision by which the land is divided into blocks, streets, and alleys as a basis for the disposal of title in parcels known as village or town lots.

For additional information, refer to Townsite Surveys, in the BLM *Manual of Surveying Instructions*, latest edition.

B. Farm-Unit Plats

General Requirements. Before lands on Reclamation projects can be opened for entry and settlement, it is necessary (under the laws governing the administration of such lands) that the plats which legally describe the farm units be prepared, approved, and filed by BLM. The plat should include one township and should show the lands open to irrigation, public and private. Section and subdivision lines should extend only as far as necessary. The portion of the township not embracing irrigable lands should be left blank. These plats are photolithographed and copies are filed in BLM, local land offices, and appropriate Reclamation office. They form the official record to which homestead-entry and water-right applications, if required, must be made to conform.

C. Sedimentation Surveys

Purpose. The purpose of a reservoir sedimentation survey is to obtain data on the changes in the stream channel caused by construction of a dam and to obtain information on current reservoir storage capacity and the quantity and distribution of the sediment accumulations in the reservoir. Owing to the accumulation of sediment above the dam and the release of relatively clear water below the dam, changes in the stream channel are likely to occur at considerable distances both upstream and downstream.

Types of Sedimentation Surveys. Sedimentation surveys may be divided into two types. The first type is a base sedimentation survey normally made prior to completion of a new dam and before storage of water has begun. The second type may be either the resurvey of a reservoir or the survey of an operating reservoir on which no base sedimentation survey was originally made.

Responsibility and Costs. The Reclamation Regional Director is responsible for adequate estimates, programs, and budget requests for funds required for sedimentation surveys. Permanent sedimentation ranges and markers should be established during the initial survey, the cost of which will normally be charged to project construction cost. The cost of the resurveys, as required at regular intervals, will normally be a part of the operation and maintenance costs of the project.

Records. The Reclamation Deputy Commissioner of Operations is responsible for technical review of sedimentation surveys proposed or made by the Reclamation Regional Directors and for making recommendations relative to those surveys. Copies of all data obtained from sedimentation surveys should be furnished to the Reclamation Deputy Commissioner of Operations (96-00000).

VIII. Contract Surveying and Mapping

General. Reclamation may contract for Surveying and Mapping Services under the existing laws and regulations pertaining to Reclamation authority. These services are to be acquired pursuant to Federal Acquisition Regulation Subpart 36.6 (48 CFR 36.6), Department of the Interior Acquisition Regulation Subpart 1436.3 (48 CFR 1436.6) and the Reclamation Acquisition Regulations.

IX. Aerial Photography and Photogrammetric Mapping

Introduction. Photogrammetric mapping is the process of preparing maps from photographs of the earth's surface. Detail shown on maps prepared either from aerial photography or ground methods may not satisfy all purposes. Photographs record surficial detail, and photo interpretation will depend upon the objective. Hence, photography may have value in addition to that for map preparation. A vertical aerial exposure is not a map but merely a perspective view from the exposure point. Special equipment and processes are needed to develop true maps from such exposures. This chapter sets forth guiding policies and procedures governing photogrammetric mapping and aerial photography for Reclamation requirements.

General Types of Aerial Photography. The uses, procedures, and equipment for aerial photography are in a rapidly developing stage. Performance specifications for different types of aerial photography are also changing with development of new equipment and procedures.

Programs for aerial photography should be prepared only after investigation of the latest techniques and costs. This information may be obtained through consultation with the USGS, practicing photogrammetrists, the American Society of Photogrammetry and Remote Sensing, and the Denver Office. Outlined below are the general types of aerial photographs and their uses which are discussed in more detail in RI 558.

- Aerial photographs for photogrammetric mapping taken at specified time and flying height with special metric cameras of precision or calibrated-type lens magazine combination, which are manufactured to certain standards for use with stereoscopic plotting instruments. These photographs combined with ground control are used in preparation of topographic maps. Traditional large-format (9”x9” exposure frame), film based, metric aerial cameras are quickly becoming a thing of the past. Although some entities maintain large-format metric aerial cameras that still deliver high-quality aerial photography, 9”x9” aerial film is no longer manufactured in the quantities it once was, and some film types are no longer available. A majority of commercial aerial survey-mapping companies have already made the transition to an entirely digital image capture, processing and production system for photogrammetric based topographic mapping projects. In fact, because of the decline in use of analog aerial mapping cameras and the transition to digital aerial cameras; the USGS will be closing its Optical Science Laboratory that does large-format analog aerial camera calibrations by March 31, 2017.

- Large-format digital aerial cameras designed for use in either a helicopter or a single/multi-engine fixed-wing aircraft are primarily used for topographic mapping projects today (2016). These digital imaging systems typically have integrated global positioning system and inertial measurement unit components and associated software capabilities that augment the photogrammetric workflow process. And, depending on the application and accuracy requirements, these digital camera systems can significantly reduce the amount of surveyed ground control targets/panels needed for a topographic mapping project, as compared to an analog-aerial film based project. Panchromatic, red-green-blue (RGB), and near-infrared wavelength bands are typically captured by these digital cameras/sensors. Digital camera specifications vary by manufacturer; depending on the application and associated accuracy requirements various lenses are available, flying heights during image capture are generally higher when compared to an analog camera, image swath widths vary between camera systems depending on project specifications, and bit depths of the imagery can range from 8 to 16-bit.

- Unmanned aerial systems (UAS) and associated photogrammetric software have shown promise in recent years to deliver high-resolution and high-accuracy geospatial data products, such as orthoimagery and digital surface models (DSM), especially for smaller project areas, in a timely and cost-effective manner. Keep in mind that if true bare-earth elevation data (digital elevation model (DEM) or digital terrain model (DTM)) is a desired product, additional photogrammetric processing and editing in a stereo-viewing environment will likely be required. Reclamation is in the early stages (2016) of investigating the utility of UAS platforms for our potential applications. Currently there are three basic types of small UAS (weighing under 55 pounds) commercially available; a fixed-wing version, a single-blade helicopter type, and a multi-rotor (typically 4 or more blades) type of UAS platform. Currently (2016) small UAS operations are restricted to a maximum altitude of 400-feet above ground level or remain within 400-feet of a structure, although an exemption may be requested. The number and type of sensors and digital cameras available for UAS platforms continue to expand. For small UAS; there are a variety of digital camera options, from smaller point-and-shoot types to heavier professional grade digital single-lens reflex (DSLR) or industrial-type digital cameras are available. Multi-spectral (multiple spectral bands), hyperspectral (hundreds of spectral bands), thermal-infrared, and LiDAR sensors are available for some small UAS platforms, depending on your project requirements. Sub-inch level or better pixel/GSD resolution imagery can be acquired using a UAS, depending on your project requirements. Current costs for a small UAS, range from under $1,000 to several hundred thousand dollars.

- Satellite imagery. For some applications and projects, such as those at the preliminary, appraisal, or feasibility levels, satellite imagery might fulfill some planimetric and topographic data needs if other suitable data sources do not currently exist. Some current (2016) commercial high-resolution satellites are capable of delivering at least panchromatic imagery (black & white) at up to a 0.31-meter (~12-inch) spatial resolution. There are commercial satellites with 20 or more sensor bands, at varying spatial resolutions for acquiring remote sensing data. Once again, although these satellite data products may not meet the needs for engineering design level projects, they may be sufficient for preliminary, appraisal, and feasibility level projects or other scientific applications for Reclamation.

- Other sources for imagery, topographic, elevation, and planimetric data. Radar, interferometric synthetic aperture radar (IFSAR), and LiDAR sensors; either terrestrial, mobile (motor vehicle, boat, underwater robotic or unmanned vehicle), UAS, helicopter, fixed-wing aircraft, or satellite based platforms can be used to acquire and produce elevation and imagery data products, and perhaps derive some planimetric data sets. Some of these sensors and platforms may not be able to deliver engineering design level data, but can perhaps meet the needs for preliminary, appraisal, feasibility level projects or scientific applications. Radar and LiDAR sensors can not only deliver elevation data, but can also derive imagery type data in the form of intensity images (black & white) that may be suitable for some applications. Through the processes of either Radargrammetry or LiDARgrammetry and related software, breakline data can be derived that would be useful in a DTM type of dataset.

Existing Aerial Photography. Almost the entire U.S., portions of Alaska being the main exception, has been covered by either aerial photography or satellite imagery, by commercial Geospatial related companies or government agencies. The EROS Data Center, USGS, 47914 252nd Street, Sioux Falls, South Dakota, 57198, maintains records of aerial photographic coverage (see RI 368.2.5), the USGS Earth Explorer website is a portal for searching and accessing their aerial photography and satellite imagery holdings. The USDA, FSA, APFO, 2222 West 2300 South, Salt Lake City, Utah 84119, manages both the NAIP and the USDA aerial photography archive that dates back to the 1950s. The NRCS Geospatial Data Gateway is a website that offers access-download to some of their imagery and geospatial data holdings. The USDA-APFO offers Imagery Catalogs through their website to search and order from their extensive aerial photography holdings. The BLM currently maintains an extensive aerial photography archive, primarily of the 17 Western States, at their National Operations Center in Building 50 on the Denver Federal Center (access via their GeoCommunicator website), Denver, Colorado. The U.S. National Archives and Records Administration, Aerial Photographs Team-Cartographic and Architectural Reference Section (NWCS-Cartographic), in the Washington, D.C. area, maintains an extensive collection of pre-World War II (pre-1945) aerial photography. Several universities; such as the University of New Mexico-Albuquerque, and the University of California-Santa Barbara have extensive historic aerial photography holdings, and also have an online-website access portal to these holdings. Commercial aerial survey-mapping companies can also have an extensive historic aerial photography archive, topographic and planimetric data, as can commercial satellite imagery companies. Many larger U.S. cities and counties, through their engineering-survey-mapping- geographic information system (GIS)-computer aided design (CAD) departments, can also be an excellent source of current or historic aerial photography, topographic, or planimetric data, and should be contacted if a Reclamation project includes their jurisdiction.

Contracts and Specifications. The following subparagraphs discuss the administrative aspects which must be considered for the acquisition and performance of aerial photography and mapping by private contractors.

- Procedure. The procedure to be followed in contracting for photogrammetric surveys is outlined in the Federal Acquisition Regulation Subpart 36.6 (48 CFR 36.6), Department of the Interior Acquisition Regulations Subpart 1436.3 (48 CFR 1436.6), and the Reclamation Acquisitions Regulations.

- Typically at least one Reclamation Region, currently (2016) the Upper Colorado (UC) Region, maintains an Architect-Engineering (A-E), indefinite delivery/indefinite quantity (IDIQ) type of contract for the acquisition of Aerial Photography, Surveying, Mapping and related Geospatial services. These A-E IDIQ contracts, when available, typically exist for up to 5-years. The current UC Region contract is available until September 15, 2021.

- Other Federal agencies, including Reclamation, can use the A-E IDIQ contracts set up by either the USGS-Geospatial Product and Service Contracts in Rolla, Missouri (MO), (currently 6 contract firms), or the USACE Center of Expertise for Photogrammetric Mapping in St. Louis, MO, (currently 10 contract firms) to acquire aerial photography and related geospatial services. Both of these agencies do a significantly higher volume of aerial photography-photogrammetry-geospatial contracting than Reclamation on an annual basis, and are well equipped to help meet other agencies aerial photography-geospatial acquisition needs for a minimal fee. In the past, frequently citing the Economy Act, Reclamation entities have successfully used these contracts to acquire geospatial related data. General Services Administration schedule contractors are also available to Reclamation offices for the acquisition of aerial photography and related geospatial services.

- The National Geospatial-Intelligence Agency (NGA) in the Washington, D.C. area, via the USGS or other mechanisms, can be a source of high-resolution commercial or other satellite imagery. Once again, this imagery may not meet engineering design level project needs, but it may be useful at the preliminary, appraisal, feasibility project levels, or for scientific applications.

- An excellent discussion on the evolution of map accuracy standards and specifications can be found in the current version of the USACE Engineering Manual, EM 1110-1-1000, Engineering Design, Photogrammetric and LiDAR Mapping (April 30,2015). The USACE has aligned their mapping accuracy standards with the American Society for Photogrammetry and Remote Sensing (ASPRS) Positional Accuracy Standards for Digital Geospatial Data (November 2014).

X. Map Compilation and Cartography

References. Adequate maps are necessary for a clear presentation of a plan. Requirements for maps for planning reports and hearings are given in Part 118. Requirements for maps as part of design data are presented in Part 133. Drafting instructions are given in Part 134 and its appendix A. Techniques and standards for map preparation in relation to surveying and aerial photography are discussed in Series 550.

If new aerial photography and digital elevation data are procured, in particular for an engineering design level pipeline, canal, or corridor type project; it is advisable to plan for the ground surveyed control (using aerial panels or targets) to cover the entire swath width of the acquired aerial photography, to the most practical level possible. Doing this may help ensure that enough aerial photography and ground control data are available to cover minor project alignment changes, without additional aerial photography or control data needing to be acquired. If bare-earth mass point and breakline data, used to produce DTM and orthoimagery are already a component of the project deliverables, it would also be advisable, if practical, to have the contractor produce those data to the extent of the aerial photography and ground control data.

APPENDIX A

REFERENCES

References

Public Law 92-582. Brooks Architect-Engineer Act; Public Law 92-582, as amended; 40 United States Code (U.S.C.) 1101-1104.

Executive Order 12906. Coordinating Geographic Data Acquisition and Access: The National Spatial Data Infrastructure

Bureau of Land Management Manual of Surveying Instructions–For the Survey of the Public Lands of the United States. 2009.

U.S. Army Corps of Engineers, Engineering and Design, Photogrammetric and LiDAR Mapping, Engineer Manual, EM 1110-1-1000. April 30, 2015.

U.S. Army Corps of Engineers, Engineering and Design, Control and Topographic Surveying, Engineer Manual, EM 1110-1-1005. January 1, 2007.

US Army Corps of Engineers, Engineering and Design, NAVSTAR Global Positioning System Surveying, Engineer Manual, EM 1110-1-1003. February 28, 2011.

U.S. Army Corps of Engineers, Engineering and Design, Hydrographic Surveying, Engineer Manual, EM 1110-2-1003. November 30, 2013.

U.S. Army Corps of Engineers, Engineering and Design, Survey Markers, and Documentation, Engineer Manual, EM 1110-1-1002. March 1, 2012

U.S. Army Corps of Engineers, Engineering and Design, Geospatial Data, and Systems, Engineer Manual, EM 1110-1-2909. September 1, 2012.

U.S. Army Corps of Engineers, Engineering and Design, Structural Deformation Surveying, Engineer Manual, EM 1110-2-1009. June 1, 2002.

U.S. Army Corps of Engineers, Engineering and Design, Geodetic and Control Surveying, Engineer Manual, EM 1110-1-1004. June 1, 2002.

APPENDIX B

OMB-CIRCULAR A16 – REVISED 2002-2010

Circular No. A-16 Revised

M-11-03, Issuance of OMB Circular A-16 Supplemental Guidance (November 10, 2010) (34 pages, 530 kb)

August 19, 2002

TO THE HEADS OF EXECUTIVE DEPARTMENTS AND ESTABLISHMENTS

SUBJECT: Coordination of Geographic Information and Related Spatial Data Activities

This Circular provides direction for federal agencies that produce, maintain or use spatial data either directly or indirectly in the fulfillment of their mission. This Circular establishes a coordinated approach to electronically develop the National Spatial Data Infrastructure and establishes the Federal Geographic Data Committee (FGDC).

The Circular has been revised from the 1990 version to reflect changes in technology, further describe the components of the National Spatial Data Infrastructure (NSDI), and assign agency roles and responsibilities for development of the NSDI. The revised Circular names the Deputy Director for Management of OMB as Vice-Chair of the Federal Geographic Data Committee.

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BACKGROUND

1. **What is the purpose of this Circular?**

This revised Circular provides for improvements in coordination and use of spatial data. Spatial data refers to information about places or geography, and has traditionally been shown on maps. This Circular describes the effective and economical use and management of spatial data assets in the digital environment for the benefit of the government and the nation. The Circular affirms and describes the National Spatial Data Infrastructure (NSDI) as the technology, policies, standards, human resources, and related activities necessary to acquire, process, distribute, use, maintain, and preserve spatial data. The Circular describes the management and reporting requirements of Federal agencies in the acquisition, maintenance, distribution, use, and preservation of spatial data by the Federal Government. The Circular establishes the FGDC as the interagency coordinating body for NSDI-related activities, chaired by the Secretary of the Interior with the Deputy Director for Management, Office of Management and Budget (OMB) as Vice-Chair.

This revised Circular supersedes Circular No. A-l6 dated October 19, 1990, and incorporates Executive Order 12906. It will remain in effect until replaced pursuant to section 8.e.(j) of this Circular. A basic list of authorities is included in Appendix A.

2. **What is the National Spatial Data Infrastructure (NSDI)?**

a. What is the vision for the NSDI?

The NSDI assures that spatial data from multiple sources (federal, state, local, and tribal governments, academia, and the private sector) are available and easily integrated to enhance the understanding of our physical and cultural world. The NSDI honors several key public values:

- Privacy and security of citizens' personal data and accuracy of statistical information on people, both in raw form and in derived information products.
- Access for all citizens to spatial data, information, and interpretive products, in accordance with OMB Circular A-130.
- Protection of proprietary interests related to licensed information and data.
- Interoperability of federal information systems to enable the drawing of resources from multiple federal agencies and their partners.

The NSDI supports and advances the building of a Global Spatial Data Infrastructure, consistent with national security, national defense, national intelligence, and international trade requirements. International compatibility is an important aspect of the NSDI. Federal agencies will develop their international spatial data in compliance with international voluntary consensus standards, as defined by Circular A-119.

b. What are the components of the NSDI?

The components of the NSDI are data themes, metadata, the National Spatial Data Clearinghouse, standards, and partnerships.

(1) What are data themes?

Data themes are electronic records and coordinates for a topic or subject, such as elevation or vegetation. This Circular requires the development, maintenance, and dissemination of a standard core set of digital spatial information for the Nation that will serve as a foundation for users of geographic information. This set of data consists of themes of national significance (see Appendix E). Themes providing the core, most commonly used set of base data are known as framework data, specifically geodetic control, orthoimagery, elevation and bathymetry, transportation, hydrography, cadastral, and governmental units. Other themes of national significance are also an important part of the NSDI, and must be available to share with others. Additional data themes may be added with the approval of the FGDC.

NSDI data themes developed with appropriate metadata, using FGDC standards and served through the Clearinghouse, facilitate interoperability and information exchange across administrative boundaries.

(2) What are metadata?

Metadata are information about data and/or geospatial services, such as content, source, vintage, spatial scale, accuracy, projection, responsible party, contact phone number, method of collection, and other descriptions. Metadata are critical to document, preserve and protect agencies' spatial data assets. Reliable metadata, structured in a standardized manner, are essential to ensuring that geospatial data are used appropriately, and that any resulting analysis is credible. Metadata also can be used to facilitate the search and access of data sets or geospatial services within a Clearinghouse or data library. All spatial data collected or derived directly or indirectly using federal funds will have FGDC metadata.

(3) What is the National Spatial Data Clearinghouse?

The National Spatial Data Clearinghouse is an electronic service providing access to documented spatial data and metadata from distributed data sources. These sources include a network of data producers, managers, and users, linked through the Internet and other communications means, and accessible through a common interface. All spatial data collected by federal agencies or their agents, as described in section 5, will be made available through the Clearinghouse. Spatial data users will have access to the NSDI through the National Spatial Data Clearinghouse.

(4) What are standards?

Standards are common and repeated rules, conditions, guidelines or characteristics for data, and related processes, technology and organization. To broaden the global use of federal data and services, international standards and protocols must be used. NSDI is made possible by the universal use of standards and protocols for data development, documentation, exchange, and geospatial services.

(5) How are NSDI standards developed?

NSDI standards are developed and promulgated by the FGDC in accordance with OMB Circular A-119 using an established process determined by the FGDC with input from a broad range of data users and providers. Specifically, the FGDC adopts national and international standards in lieu of federal standards whenever possible and will restrict its standards development activities to areas of spatial data standardization not covered by other voluntary standards consensus bodies, as defined by OMB Circular A-119. Through active participation in voluntary consensus standards bodies, the FGDC works to link its standardization activities to the work of those standards bodies and thereby create an integrated suite of standards for the NSDI. No federal funds will be used directly or indirectly for the development of spatial data not complying with NSDI standards, as specified by FGDC.

(6) What is the importance of collaborative partnerships?

Building an effective NSDI will require a well-coordinated effort among federal, tribal, state, local government, and academic institutions, as well as a broad array of private sector geographic, statistical, demographic, and other business information providers and users. Involving these stakeholders in the development of the NSDI will aid in meeting the needs of end-users.

Federal agencies will promote and fully utilize partnerships that promote cost-effective data collection, documentation, maintenance, distribution, and preservation strategies, and that leverage federal and other resources. New collaborative efforts and partnerships are encouraged.

(7) What are the federal activities and technology that support the NSDI?

Federal agencies and the FGDC carry out the activities required to implement their responsibilities as described in section 8 of this Circular. Agencies will provide or develop the required technology and services required to enable and provide access to NSDI data and information. The OMB will work with affected budget offices to provide appropriate resources in support of these activities.

3. **What are the benefits of the NSDI?**

   Spatial data is a national capital asset. The NSDI facilitates efficient collection, sharing, and dissemination of spatial data among all levels of government institutions, as well as the public and private sectors, to address issues affecting the Nation's physical, economic, and social well-being. A coordinated approach for developing spatial data standards that apply to collecting, maintaining, distributing, using, and preservation of data will improve the quality of federal spatial data and reduce the cost of derivative products created by federal and non-federal users. Applications using spatial data that adhere to FGDC standards enable cost effective public and private policy development, management, and operations.

   Implementation of this Circular is essential to help federal agencies eliminate duplication, avoid redundant expenditures, reduce resources spent on unfunded mandates, accelerate the development of electronic government to meet the needs and expectations of citizens and agency programmatic mandates, and improve the efficiency and effectiveness of public management.

   Many applications are dependent upon accurate spatial data. The benefits of the NSDI for these applications include creating a more secure Nation. Some examples include the analysis and management of utility infrastructures, transportation, energy, emergency management and response, natural resource management, weather and climate analysis, disaster recovery, homeland defense, law enforcement, protection planning, public health and other civilian or military strategic issues. The seamless spatial information needed for these applications can range from highly detailed local data, such as the nature of specific hazardous material stored in a particular room of a single building, to the various data needed for real-time projection of the probable effects of natural disasters.

4. **What is the Federal Geographic Data Committee (FGDC)?**

   The FGDC is an interagency committee responsible for facilitating Circular A-l6 related activities and implementation of the NSDI.

a. What is the FGDC structure and membership?

   The FGDC is chaired by the Secretary of the Department of the Interior, with the Deputy Director for Management, OMB, serving as Vice-Chair. Chair and Vice-Chair may designate an individual to act in their stead. All agencies responsible for spatial data themes are required to be members of the FGDC. Departments or agencies that are members of the FGDC as of the date of this revision will continue as members and are listed in Appendix B. Departments or agencies that are not members of the FGDC and that have activities in geographic information or spatial data collection or use will become members by requesting membership in writing to the Chair of the FGDC.

b. What are the FGDC procedures?

   The FGDC will establish procedures and committee structures as are necessary and sufficient to carry out interagency coordination and the implementation of the NSDI, in accordance with existing law, statute, and policy. Departments may elect or be assigned the lead responsibility for certain subcommittees, working groups or other committees, consistent with each Department's or agency's existing authority as described in its mission (e.g., statutory authority or Public Law), or implied as part of its program responsibilities. The current FGDC governing structure and bylaws are carried forward and remain in force under this Circular, and may be modified according to existing procedures. The Department of the Interior will provide administrative support to the FGDC.

POLICY

5. **Does this Circular apply to my agency?**

   This Circular applies to your agency if it collects, produces, acquires, maintains, distributes, uses, or preserves analog (e.g., paper maps) or digital spatial data to fulfill your mission, either directly or through a relationship with other organizations. Such organizations include, but are not limited to, State and local governments, tribes, academia, federal government business partners and contractors, and citizens.

6. **What types of data activities does the Circular apply to?**

a. All spatial data and geographic information systems activities - financed directly or indirectly, in whole or in part, by federal funds.

b. As examples, this Circular applies to, but is not limited to: The National Mapping Program, the National Spatial Reference System, the National Geologic Mapping Program, the National Wetlands Inventory, the National Cooperative Soil Survey Program, the National Public Land Survey System, Geographic Coordinate Database, the National Oceanic and Atmospheric Administration (NOAA) nautical charting and nautical data collection and information programs, the U.S. Army Corps of Engineers (USACE) inland waterway charting program, the Offshore Minerals Program, the NASA's Earth Science Enterprise, FEMA's Flood Plain Mapping program and other federal activities that involve national surveying, mapping, remote sensing, spatially referenced statistical data, and Global Positioning System (GPS). Additional spatial data programs may be added to this list at any time.

c. Any activities that result in the geospatial representation of international boundaries other than those of the United States with Canada or Mexico, which are governed by international boundary commissions.

d. Any future federal spatial data programs or activities that may be established, except as noted in section 7 below.

7. **What types of data activities are exempt from this Circular?**

The following spatial data activities may be exempt from provisions within this Circular, as determined by the appropriate official(s) noted below:

(1) Spatial data activities of tribal governments not paid for by federal funds, as specifically determined by the tribal governments.

(2) Classified national security-related spatial data activities of the Department of Defense, unless declassified by Executive Order 12951, as specifically determined by the Secretary of Defense; also those activities of the Department of Energy, as specifically determined by the Secretary of Energy.

(3) Intelligence spatial data activities, as specifically determined by the Director of the Central Intelligence Agency.

AGENCY RESPONSIBILITIES AND REPORTING REQUIREMENTS

8. **What are the federal responsibilities?**

a. What are the general federal agency responsibilities?

In order to use federal resources wisely, and to build the NSDI, all agencies that collect, use, or disseminate geographic information and/or carry out related spatial data activities will, both internally and through their activities involving partners, grants, and contracts:

(1) Prepare, maintain, publish, and implement a strategy for advancing geographic information and related spatial data activities appropriate to their mission, in support of the NSDI Strategy. Annually report to OMB on your achievements relative to you strategies, and include spatial data assets within Exhibit 300 submissions (see OMB Circular A-11, sec. 300).

(2) Collect, maintain, disseminate, and preserve spatial information such that the resulting data, information, or products can be readily shared with other federal agencies and non-federal users, and promote data integration between all sources. Ensure that data information products and other records created in spatial data activities are included on agency record schedules that have been approved by the National Archives and Records Administration. These activities will adhere to appropriate standards and be conducted in accordance with existing regulations.

(3) Allocate agency resources to fulfill the responsibilities of effective spatial data collection, production, and stewardship.

(4) Use FGDC data standards, FGDC Content Standards for Digital Geospatial Metadata, and other appropriate standards, documenting spatial data with the relevant metadata, and making metadata available online through a registered NSDI-compatible Clearinghouse node.

(5) Coordinate and work in partnership with federal, state, tribal and local government agencies, academia and the private sector to efficiently and cost-effectively collect, integrate, maintain, disseminate, and preserve spatial data, building upon local data wherever possible.

(6) Use spatial information to enhance electronic government initiatives, to make federal spatial information and services more useful to citizens, to enhance operations, to support decisionmaking, and to enhance reporting to the public and to the Congress.

(7) Protect personal privacy and maintain confidentiality fully consistent with federal policy and law.

(8) Support emergency response activities requiring spatial data in accordance with provisions of the Stafford Act and other governing legislation.

(9) Participate in determining, when applicable, whether data declassified pursuant to Executive Order 12951 can contribute to and become a part of the NSDI.

(10) Search all sources, including the National Spatial Data Clearinghouse, to determine if existing federal, state, local or private data meets agency needs before expending funds for data collection.

(11) Appoint a contact to coordinate with lead agencies for collection, acquisition, maintenance, or dissemination of the spatial data themes used by their organization.

b. How does my agency report spatial data assets within the budget and performance review process?

Before the obligation of funds, ensure that all expenditures for spatial data and related systems activities financed directly or indirectly, in whole or in part, by federal funds are compliant with the standards and provisions of the FGDC. All Information Technology systems which process spatial data should identify planned investments for spatial data and compliance with FGDC standards within the Exhibit 300 capital asset and business plan submission (see OMB Circular A-11, sec. 300).

c. What are the lead federal agencies for the NSDI data themes?

Certain federal agencies have lead responsibilities for coordinating the national coverage and stewardship of specific spatial data themes. The data themes in the NSDI, their description, and the responsible lead for each theme are listed in Appendix E. Lead agency responsibilities and new data themes may be added or altered by recommendation of the FGDC and concurrence by the OMB.

d. What are the responsibilities of lead federal agencies for the NSDI data themes?

(1) Provide leadership and facilitate the development and implementation of needed FGDC standards, especially a data content standard for each data theme. Agencies will assess existing standards, identify anticipated or needed data standards, and develop a plan to originate and implement needed standards with relevant community and international practices in accordance with OMB Circular A-119, consistent with or included in the plan described in section 8.d.(2) below.

(2) Provide leadership and facilitate the development and implementation of a plan for nationwide population of each data theme. Plans will include the development of partnership programs with States, Tribes, academia, the private sector, other federal agencies, and localities that meet the needs of users, address human and financial resource needs, identify needs for standards, metadata, and the Clearinghouse, and advance a timetable for the development of NSDI data themes.

(3) Under section 8.a of this Circular, will prepare goals that support the NSDI strategy and, as needed, collect and analyze information from users about their needs for spatial data, including these in strategies related to their theme responsibilities.

(4) Administratively:

(a) Designate a point of contact within the lead agency who will be responsible for development, maintenance, coordination, and dissemination of data using the National Spatial Data Clearinghouse;

(b) Provide a performance report, at least annually, that documents data theme activities and implementation status, including progress toward goals identified in 8.d.(1), 8.d.(2) and 8.d.(3) above.

(c) Publish maps or comparable graphics online showing the current extent and status of the spatial data themes for which they have the lead, and encourage all other sources of data for those same themes to provide access to their data through the Clearinghouse. Leads will coordinate with those in charge of the Clearinghouse and always use FGDC specified Web mapping conventions; and

(d) Identify and publish proven practices for the use and application of agency data sets.

e. What are the FGDC responsibilities and reporting requirements?

The FGDC leads and supports the NSDI strategy, spatial data policy development, management, and operational decision making. The FGDC also aids geographic information system use, directs and facilitates national implementation of the system of Framework Data and other themes in the NSDI, implements the NSDI Clearinghouse, and advises federal and other spatial data users on their NSDI implementation responsibilities.

The FGDC will:

(a) Prepare and maintain a strategic plan for the development and implementation of the NSDI.

(b) Serve as the lead federal executive body charged with the leadership, development, implementation, and review of spatial data standards, the NSDI Clearinghouse network, and a plan for federal agencies responsible for the NSDI Framework and other data themes to collect and provide broad access to spatial data assets.

(c) Communicate with and foster communication among federal agencies and others concerning spatial data technology development, transfer, and exchange.

(d) Promote and guide cooperation and coordination among federal, state, tribal and local government agencies, academia and the private sector in the collection, production, sharing and use of spatial information, the implementation of the NSDI, and the identification of proven practices.

(e) Coordinate with international organizations having an interest in the National or Global Spatial Data Infrastructures.

(f) Provide and update at least annually:

(i) An online status summary for each data theme authored by the lead agencies, the FGDC, or other subcommittees, working groups, and advisory committees.

(ii) An online collection of periodic technical publications, management articles and reports related to the NSDI.

(iii) An online FGDC membership directory, including current subcommittee and working group memberships.

(g) Ensure consistency of the NSDI with national security, national defense, and emergency preparedness program policies regarding data accessibility.

(h) Support the development of electronic government with spatial data.

(i) Support and promote the infrastructure of networks, systems, services, and standards that provide a digital representation of the Earth to users for many applications.

(j) Through the Chair and Vice Chair, take actions where required to recommend appropriate additions, revisions, or deletions to this Circular.

9. **How are differences settled among agencies?**

Any major differences among agencies with respect to coordination or conduct of activities covered by this Circular that cannot be resolved by the FGDC leadership will be referred in writing by the head of any agency concerned to the Director of the OMB. Copies of such referrals will be provided to the Chair and Vice Chair of the FGDC and to the heads of those agencies directly involved or affected by the outcome of the decision.

10. **How can I check that my agency is compliant with the latest NSDI requirements and standards?**

The FGDC website (www.fgdc.gov) will serve as an up to date resource for reviewing the latest data standards, the source for spatial data that is already collected, boilerplate procurement language, laws and regulations regarding spatial data and information on the latest geospatial technologies.

Mitchell E. Daniels, Jr.
Director

Appendix A: Authorities

This Circular provides requirements and guidance for the management of data and federal information assets that relate to geographic locations. The revised OMB Circular A-16 incorporates Executive Order 12906. A basic list of authorities is listed below:

- The Paperwork Reduction Act
- The Government Paperwork Elimination Act of 1999
- The Government Performance and Results Act of 1993
- The Federal Records Act

- OMB Circular A-130 (on Management of Federal Information Resources)
- OMB Circular A-119 (Federal Participation in the Development and Use of Voluntary Consensus Standards and In Conformity Assessment Activities)
- The Freedom of Information Act and the Electronic Freedom of Information Act Amendments of 1996
- The Privacy Act
- The Clinger-Cohen Act of 1996
- The Stafford Act
- Federal Acquisition Regulations
- The National Technology Transfer and Advancement Act of 1995
- Executive Order 12906 (Coordinating Geographic Data Acquisition and Access: The National Spatial Data Infrastructure)
- Executive Order 12951 (Release of Imagery Acquired by Space-Based National Intelligence Reconnaissance Systems)
- Rehabilitation Act, Sec. 508, Electronic and Information Technology, and
- Other relevant statutes

The OMB may amend this list as new authorities are approved.

Appendix B: FGDC Member Agencies

FGDC Members (August 2002)

Department of Agriculture
Department of Commerce
Department of Defense
Department of Energy
Department of Health and Human Services
Department of Housing and Urban Development
Department of the Interior
Department of Justice
Department of State
Department of Transportation
Environmental Protection Agency
Federal Emergency Management Agency
General Services Administration
Library of Congress
National Archives and Records Administration
National Aeronautics and Space Administration
National Science Foundation
Tennessee Valley Authority

Appendix C: History and Background of Circular A-16

This Circular was originally issued in 1953, revised in 1967, and revised again in 1990. The Bureau of the Budget (now the OMB) issued Circular No. A-16 on January 16, 1953. Appended to this Circular were Exhibits, occasionally revised, that dealt with procedures for programming and coordinating of federal Topographic Mapping Activities, National Atlas, Geodetic Control Surveys and International Boundaries.

The purpose of the 1953 Circular was "to insure (sic) that surveying and mapping activities may be directed toward meeting the needs of federal and state agencies and the general public, and will be performed expeditiously, without duplication of effort." The original Circular references Executive Order No. 9094, dated March 10, 1942. This Executive Order directs the Director of the Bureau of the Budget to coordinate and promote the improvement of surveying and mapping activities of the Government. Furthermore, it passes on functions carried out by the Federal Board of Surveys and Maps, established by Executive Order No. 3206, dated December 30, 1919. Thus, the OMB is directed to make recommendations to agencies and to the President regarding the coordination of all governmental map making and surveying. Executive Order No. 3206 superseded an Executive Order, dated August 10, 1906, that granted advisory power to the United States Geographic Board to review mapping projects to avoid duplication and to facilitate standardized mapping.

A revised Circular A-16 was issued on May 6, 1967. The most significant change in this revision is the addition of a new section on Responsibility for Coordination. This section outlines the responsibilities of three federal departments (Department of the Interior (DOI), Department of Commerce (DOC) and Department of State (DOS)). Both the original and the 1967 revision of the Circular focus on providing a guide for the development of annual programs of the individual agencies and, through the Exhibits, established extensive reporting requirements.

A second revised Circular A-16 was issued on October 19, 1990. This revision expanded the Circular to include not only surveying and mapping, but also the related spatial data activities. Specifically, it included geographically referenced computer-readable (digital) data. In addition, the Exhibits are no longer referenced and a short reporting requirements section is added.

The 2002 updated Circular calls for continued improvements in spatial data coordination and the use of geographical data. Objectives for this revision are to reflect the changes that have taken place in geographic information management and technology, and to clearly define agency and FGDC responsibilities. The proposed revision displays an integrated infrastructure system approach to support multiple government services and electronic government.

Appendix D: Informative Definitions

Analog: Of, relating to, or being a device in which data are represented by variable measurable physical quantities. In this Circular, refers to "paper" maps.

Preserve: The process of saving and storing data or records. May also refer to the place where data or information is kept.

Clearinghouse: A distributed network of data producers, managers, and users linked electronically, such as over the Internet. Through the Clearinghouse, users can use a single interface to search and access metadata and/or data for the themes they seek. The Clearinghouse includes the sites across the country where the metadata and data are stored, usually at the site of the producer or intermediary.

Data: Factual information, especially information organized for analysis or used to reason or make decisions. In Computer Science, numerical or other information represented in a form suitable for processing by computer.

Data Theme: Electronic records and coordinates for a topic or subject, such as elevation, vegetation, or hydrography. In this Circular, data theme refers to a Geographic Information System (GIS), or location-based data theme.

Framework Data: Seven themes of geospatial data that are used by most GIS applications (geodetic control, orthoimagery, elevation and bathymetry, transportation, hydrography, cadastral and governmental units). These data include an encoding of the geographic extent of the features and a minimal number of attributes needed to identify and describe the features.

Framework: The NSDI framework is an initiative to develop a readily available set of basic geographic data. It includes the information, operational environment, and technology to provide access to these data, and the institutional setting to sustain its development.

Geographic Information: Coordinate and attribute data for location-based features, usually in the categories of point (e.g., a well), line (e.g., a road), polygon (e.g., a forest), cell (e.g., a raster-based "rectangle"), or coordinates (e.g., the latitude-longitude of a point on the ground).

Geographic Information System: A computer system for the input, editing, storage, retrieval, analysis, synthesis, and output of location-based information. GIS may refer to hardware and software, or include data.

Georeference: A set of datums by which the location of each point can be uniquely identified.

Geospatial Data: Information that identifies the geographic location and characteristics of natural or constructed features and boundaries on the Earth. This information may be derived from, among other things, remote sensing, mapping, and surveying technologies. Statistical data may be included in this definition at the discretion of the collecting agency.

Geospatial Services: A collection of operations, accessible through an interface that allows a user to evoke a behavior of value to the user.

Global Positioning System: A satellite-based system deployed to determine locations on the Earth's surface. It is commonly used for surveying, mapping, and navigation on land and water.

Metadata: Information about data, such as content, source, vintage, accuracy, condition, projection, responsible party, contact phone number, method of collection, and other characteristics or descriptions.

National Spatial Data Infrastructure: The technology, policies, standards, human resources, and related activities necessary to acquire, process, distribute, use, maintain, and preserve spatial data (e.g., information and process discovery, publishing data, publishing symbol libraries, query filtering, data fusing, Earth imaging, photogrammetry, location processing, and spatial analysis).

Proven Practices: Methods and activities that are "tried and true" including, but not limited to "best practice."

Spatial Data: Information that identifies the geographic location and characteristics of natural or constructed features and boundaries on the Earth. This information may be derived from remote sensing, mapping, charting, surveying technologies, GPS, or statistical data, among other sources.

Spatial Data Standards: Descriptions of objects, features, or other geographically located items that are collected, automated, or affected by activities or functions of agencies, and may be structured in a model.

Standards: Documented agreements containing technical specifications or other precise criteria to be used consistently as rules, guidelines, or definitions of characteristics to ensure that materials, products, processes, or services are fit for their purposes.

Technology: The scientific method and material used to achieve a commercial or industrial objective. Jargon for "software," "hardware," "protocol," or something technical in nature.

Appendix E: NSDI Data Themes, Definitions, and Lead Agencies

The lead federal agencies with responsibilities for NSDI spatial data themes are as follows:

Baseline (Maritime): Co-leaders: DOC, NOAA and DOI, Minerals Management Service (MMS)

Baseline represents the line from which maritime zones and limits are measured. Examples of these limits include the territorial sea, contiguous zone, and exclusive economic zone. The spatial extent of the baseline is defined as "ordinary low water," interpreted as mean lower low water, as depicted on National Ocean Service nautical charts and/or appropriate supplemental information.

Biological Resources: DOI, U.S. Geological Survey (USGS)

This dataset includes data pertaining to or descriptive of (nonhuman) biological resources and their distributions and habitats, including data at the suborganismal (genetics, physiology, anatomy, etc.), organismal (subspecies, species, systematics), and ecological (populations, communities, ecosystems, biomes, etc.) levels.

***Cadastral:** DOI, Bureau of Land Management (BLM)

Cadastral data describe the geographic extent of past, current, and future right, title, and interest in real property, and the framework to support the description of that geographic extent. The geographic extent includes survey and description frameworks such as the Public Land Survey System, as well as parcel-by-parcel surveys and descriptions.

***Cadastral (Offshore):** DOI, MMS

Offshore Cadastre is the land management system used on the Outer Continental Shelf. It extends from the baseline to the extent of United States jurisdiction. Existing coverage is currently limited to the conterminous United States and portions of Alaska. Maximum extent of United States jurisdiction is not yet mathematically calculated.

Climate: Co-leaders, Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS) and DOC, NOAA

Climate data describe the spatial and temporal characteristics of the Earth's atmosphere/hydrosphere/land surface system. These data represent both model-generated and observed (either in situ or remotely sensed) environmental information, which can be summarized to describe surface, near surface and atmospheric conditions over a range of scales.

Cultural and Demographic Statistics: DOC, U.S. Census Bureau (USCB)

These geospatially referenced data describe the characteristics of people, the nature of the structures in which they live and work, the economic and other activities they pursue, the facilities they use to support their health, recreational and other needs, the environmental consequences of their presence, and the boundaries, names and numeric codes of geographic entities used to report the information collected.

Cultural Resources: DOI, National Park Service

The cultural resources theme includes historic places such as districts, sites, buildings, and structures of significance in history, architecture, engineering, or culture. Cultural resources also encompass prehistoric features as well as historic landscapes.

***Digital Ortho Imagery:** DOI, USGS

This dataset contains georeferenced images of the Earth's surface, collected by a sensor in which image object displacement has been removed for sensor distortions and orientation, and terrain relief. For very large surface areas, an Earth curvature correction may be applied. Digital orthoimages encode the optical electromagnetic spectrum as discrete values modeled in an array of georeferenced pixels. Digital orthoimages have the geometric characteristics of a map, and image qualities of a photograph.

Earth Cover: DOI, USGS

The Earth Cover theme uses a hierarchical classification system based on observable form and structure, as opposed to function or use. This system transitions from generalized to more specific and detailed class divisions, and provides a framework within which multiple land cover and land use classification systems can be cross-referenced. This system is applicable everywhere on the surface of the Earth. This theme differs from the Vegetation and Wetlands themes, which provide additional detail.

***Elevation Bathymetric:** Co-leaders: DOC, NOAA (U.S. waters outside channels) and US Army Corps of Engineers (USACE) (inland waterways)

The bathymetric data for Inland and Intercoastal waterways is highly accurate bathymetric sounding information collected to ensure that federal navigation channels are maintained to their authorized depths. Bathymetric survey activities support the Nation's critical nautical charting program. This data is also used to create Electronic Navigational Charts. The bathymetric sounding data supports the elevation layer of the geospatial data framework.

***Elevation Terrestrial:** DOI, USGS

This data contains georeferenced digital representations of terrestrial surfaces, natural or manmade, which describe vertical position above or below a datum surface. Data may be encapsulated in an evenly spaced grid (raster form) or randomly spaced (triangular irregular network, hypsography, single points). The elevation points can have varying horizontal and vertical resolution and accuracy.

Buildings and Facilities: General Services Administration

The facility theme includes federal sites or entities with a geospatial location deliberately established for designated activities; a facility database might describe a factory, military base, college, hospital, power plant, fishery, national park, office building, space command center, or prison. Facility data is submitted from several agencies, since there is no one party responsible for all the facilities in the Nation, and facilities encompass a broad spectrum of activities. The FGDC promotes standardizing on database structures and schemas to the extent practical.

Federal Land Ownership Status: DOI, BLM

Federal land ownership status includes the establishment and maintenance of a system for the storage and dissemination of information describing all title, estate or interest of the federal government in a parcel of real and mineral property. The ownership status system is the portrayal of title for all such federal estates or interests in land.

Flood Hazards: Federal Emergency Management Agency

National Flood Insurance Program has prepared flood hazard data for approximately 18,000 communities. The primary information prepared for these communities is for the 1 percent annual chance (100-year) flood, and includes documentation of the boundaries and elevations of that flood.

***Geodetic Control:** DOC, NOAA

Geodetic control provides a common reference system for establishing coordinates for all geographic data. All NSDI framework data and users' applications data require geodetic control to accurately register spatial data. The National Spatial Reference System is the fundamental geodetic control for the United States.

Geographic Names: DOI, USGS

This dataset contains data or information on geographic place names deemed official for federal use by the U.S. Board on Geographic Names as pursuant to Public Law 80-242. Geographic Names information includes both the official place name (current, historical, and aliases) and locative direct (i.e., geographic coordinates) and indirect (i.e., State and County where place is located) geospatial identifiers and categorized as populated places, schools, reservoirs, parks, streams, valleys, and ridges.

Geologic: DOI, USGS

The geologic spatial data theme includes all geologic mapping information and related geoscience spatial data (including associated geophysical, geochemical, geochronologic, and paleontologic data) that can contribute to the National Geologic Map Database as pursuant to Public Law 106-148.

***Governmental Units:** DOC, USCB

These data describe, by a consistent set of rules and semantic definitions, the official boundary of federal, state, local, and tribal governments as reported/certified to the U.S. Census Bureau by responsible officials of each government for purposes of reporting the Nation's official statistics.

Housing: Department of Housing and Urban Development (HUD)

HUD's database maintains geographic data on homeownership rates, including many attributes such as HUD revitalization zones, location of various forms of housing assistance, first-time homebuyers, underserved areas, and race. Data standards have not yet been formalized.

***Hydrography:** DOI, USGS

This data theme includes surface water features such as lakes, ponds, streams and rivers, canals, oceans, and coastlines. Each hydrography feature is assigned a permanent feature identification code (Environmental Protection Agency Reach Code) and may also be identified by a feature name. Spatial positions of features are encoded as centerlines and polygons. Also encoded is network connectivity and direction of flow.

International Boundaries: Department of State

International boundary data include both textual information to describe, and GIS digital cartographic data to depict, both land and maritime international boundaries, other lines of separation, limits, zones, enclaves/exclaves and special areas between States and dependencies.

Law Enforcement Statistics: Department of Justice

Law enforcement statistics describe the occurrence of events (including incidences, offenses and arrests) geospatially located, related to ordinance and statutory violations and the individuals involved in those occurrences. Also included are data related to deployment of law enforcement resources and performance measures.

Marine Boundaries: Co-leaders: DOC, NOAA and DOI, MMS

Marine boundaries depict offshore waters and seabeds over which the United States has sovereignty and jurisdiction.

Offshore Minerals: DOI, MMS

Offshore minerals include minerals occurring in submerged lands. Examples of marine minerals include oil, gas, sulfur, gold, sand and gravel, and manganese.

Outer Continental Shelf Submerged Lands: DOI, MMS

This data includes lands covered by water at any stage of the tide, as distinguished from tidelands, which are attached to the mainland or an island and cover and uncover with the tide. Tidelands presuppose a high-water line as the upper boundary; whereas submerged lands do not.

Public Health: Department of Health and Human Services

Public health themes relate to the protection, improvement and promotion of the health and safety of all people. For example, public health databases include spatial data on mortality and natality events, infectious and notifiable diseases, incident cancer cases, behavioral risk factor and tuberculosis surveillance, hazardous substance releases and health effects, hospital statistics and other similar data.

Public Land Conveyance (patent) Records: DOI, BLM

Public land conveyance data are the records that describe all past, current, and future, right, title, and interest in real property. This is a system of storage, retrieval and dissemination of documents describing the right, title, and interest of a parcel.

Shoreline: DOC, NOAA

Shorelines represent the intersection of the land with the water surface. The shoreline shown on NOAA Charts represents the line of contact between the land and a selected water elevation. In areas affected by tidal fluctuations, this line of contact is the mean high water line.

Soils: USDA, NRCS

Soil data consist of georeferenced digital map data and associated tabular attribute data. The map data describe the spatial distribution of the various soils that cover the Earth's surface. The attribute data describe the proportionate extent of the various soils as well as the physical and chemical characteristics of those soils. The physical and chemical properties are based on observed and measured values, as well as model-generated values. Also included are model-generated assessments of the suitability or limitations of the soils to various land uses.

***Transportation:** Department of Transportation, Bureau of Transportation Statistics

Transportation data are used to model the geographic locations, interconnectedness, and characteristics of the transportation system within the United States. The transportation system includes both physical and non-physical components representing all modes of travel that allow the movement of goods and people between locations.

Transportation (Marine): USACE

The Navigation Channel Framework consists of highly accurate dimensions (geographic coordinates for channel sides, centerlines, wideners, turning basins, and River Mile Markers) for every federal navigation channel maintained by USACE. The Navigation Framework will provide the basis for the marine transportation theme of the geospatial data framework.

Vegetation: USDA, U.S. Forest Service

Vegetation data describe a collection of plants or plant communities with distinguishable characteristics that occupy an area of interest. Existing vegetation covers or is visible at or above the land or water surface and does not include abiotic factors that tend to describe potential vegetation.

Watershed Boundaries: Co-leaders: DOI, USGS and USDA, NRCS

This data theme encodes hydrologic, watershed boundaries into topographically defined sets of drainage areas, organized in a nested hierarchy by size, and based on a standard hydrologic unit coding system.

Wetlands: DOI, Fish and Wildlife Service

The wetlands data layer provides the classification, location, and extent of wetlands and deepwater habitats. There is no attempt to define the proprietary limits or jurisdictional wetland boundaries of any federal, state, or local agencies.

Lead Agency responsibilities and new data themes may be added or altered by recommendation of the FGDC and concurrence by the OMB.

***** Indicates framework theme

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EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF MANAGEMENT AND BUDGET
WASHINGTON, D.C. 20503

November 10, 2010

M-11-03

MEMORANDUM TO HEADS OF EXECUTIVE DEPARTMENTS AND AGENCIES

FROM: Vivek Kundra
Federal Chief Information Officer

SUBJECT: Issuance of OMB Circular A-16 Supplemental Guidance

Data-management, and particularly geospatial data-management, is one of the essential components for addressing the management of the business of government and for supporting the effective and economical use of tax dollars. It is, however, susceptible to constant renewal, information quality, and information management challenges. A portfolio-centric model cures the single agency, stovepipe model by applying consistent policy, improved organization, better governance, and understanding of the public to deliver outstanding results.

The Office of Management and Budget (OMB) Circular A-16, "Coordination of Geographic Information and Related Spatial Data Activities," provides for improvements in the coordination and use of spatial data, and describes effective and economical use and management of spatial data assets in the digital environment for the benefit of the Federal Government and the Nation. This Supplemental Guidance document further defines and clarifies selected elements of OMB Circular A-16 to facilitate the adoption and implementation of a coordinated and effective Federal geospatial asset management capability that will improve support of mission-critical business requirements of the Federal Government and its stakeholders.

This updated guidance is effective for agencies to use immediately through coordination with the Federal Geographic Data Committee. Please contact egov@omb.eop.gov and have the term "A-16 Supplemental" in the subject line of the email if you have any questions regarding this guidance.

Attachment

GEOSPATIAL LINE OF BUSINESS

OMB CIRCULAR A–16 SUPPLEMENTAL GUIDANCE

NOVEMBER 10, 2010

Contents

1. Introduction

1.1. Background and Purpose

The Office of Management and Budget (OMB) Circular A-16, "Coordination of Geographic Information and Related Spatial Data Activities" (revised 2002)[1], provides for improvements in the coordination and use of spatial data, and describes effective and economical use and management of spatial data assets in the digital environment for the benefit of the government and the Nation. This Supplemental Guidance document further defines and clarifies selected elements of OMB Circular A-16 to facilitate the adoption and implementation of a coordinated and effective Federal geospatial asset management capability that will improve support of mission-critical business requirements of the Federal Government and its stakeholders. Its primary focus is on geospatial data as a capital asset. It provides the foundation for a portfolio management approach to a National Geospatial Data Asset (NGDA) Portfolio comprised of National Geospatial Data Asset Themes (NGDA Themes) and their associated National Geospatial Data Asset Datasets (NGDA Datasets)[2]. NGDA Themes are synonymous with OMB Circular A-16 Themes[3]. The balance of this Supplemental Guidance speaks to NGDA Portfolio management in the context of the NGDA Themes and their associated NGDA Datasets and sets forth a systematic process whereby both within-theme and crosscutting portfolio management enables direct performance toward a shared enterprise-wide "target state" that optimizes the value of the NGDA Portfolio.

Data management and particularly geospatial data management is one of the essential components for addressing the management of the business of government and for supporting the effective and economical use of tax dollars. It is, however, susceptible to constant renewal, information quality, and information management challenges. A portfolio-centric model cures the single agency stovepipe model

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[1] The complete text of OMB Circular A-16 (2002) can be found at *http://www.whitehouse.gov/omb/circulars/a016/a016_rev.html*

[2] A NGDA Dataset is defined as a geospatial dataset that has been designated as such by the FGDC Steering Committee and meets at least one of the following criteria: Supports mission goals of multiple federal agencies; statutorily mandated; Supports Presidential priorities as expressed by Executive Order or by OMB.

[3] An A-16 Theme is defined as representations of conceptual topics describing digital spatial information for the Nation. Themes contain associated datasets (with attribute records and coordinates) that are documented, verifiable, and officially designated to meet recognized standards. A theme contains one or more datasets of geographic information to be used in common and from which other datasets can be derived. Themes are listed in OMB Circular A–16.

by applying consistent policy, improved organization, better governance, and understanding of the electorate to deliver outstanding results.

Portfolio management is the process of tracking, maintaining, expanding, and aligning assets to address and solve the business needs of an enterprise. Portfolio management approaches include a number of components:

- Strategic portfolio planning;
- Coordinated development and resource pooling;
- Established goals and performance measures, indicating the benefits of each asset investment, and how it contributes to the overarching goals (particularly completion/renewal) of the portfolio;
- Investment selection criteria; and
- Processes for reviewing the health of, and return on, asset investments that inform investment decisions, redistribution of resources, management of issues and mitigation of risks to the portfolio.

Each NGDA Theme consists of a related group of NGDA Datasets selected from a larger, constantly changing universe of geospatial datasets because they meet the inclusion criteria for the NGDA Theme. The overall assets involved include geospatial data, funding, infrastructure, hardware, software, personnel, applications, services, and products[4]. Portfolio management provides a systematic way to manage overall assets. In this Supplemental Guidance, only data assets are specifically addressed. Hardware and software funding is tracked in parallel processes under the Capital Planning and Investment Control (CPIC) process developed in Clinger-Cohen. Awareness of this hardware and software funding is relevant to the data asset management process but is not directly involved in it.

As governance of Federal geospatial assets matures toward administration of Federal geospatial assets as a cross-cutting portfolio, the roles and responsibilities for managing assets beyond data will in many instances require closer ties between agency managers. These include geospatial program managers, agency Chief Information Officers (CIO) and Chief Financial Officers (CFO), and the managers of the Federal geospatial portfolio through the Federal Geographic Data Committee (FGDC). These relationships will particularly be needed to identify geospatial data, capabilities, services, and tools that should be elevated from a program level to a Federal level for resourcing and management because they can better serve as a valuable Federal-wide geospatial asset. The resourcing, management, and

[4] The geospatial portfolio includes establishing the resources for platform, geospatial data and applications management. The Supplemental Guidance links all portfolio elements to geospatial data assets.

maintenance of these assets at a Federal level, e.g. cross-agency funding for a shared service, or designation of a single program as the lead for a specific capability, will be a result of, and become a part of, the overall geospatial portfolio management process.

1.2. Guidance, Goals, and Authority

This guidance further defines the elements, roles, responsibilities, management processes and investment strategies needed for systematic and effective execution of the Federal agency responsibilities, referenced in OMB Circular A–16, via implementation of the NGDA Portfolio, the principal component of the full Federal geospatial portfolio. It establishes the framework for lifecycle-based NGDA Dataset management, interagency NGDA Theme management, and government-wide NGDA Portfolio management. It specifies and incorporates reporting processes intended to increase transparency of the development and maintenance of NGDA Datasets. It also establishes a "collaborative investment process" whereby peer review and consultation regarding the NDGA Themes and their associated NGDA Datasets are conducted annually and whereby recommended interagency priorities are provided to OMB to inform the budget process. This Supplemental Guidance was developed by the FGDC under authority granted to it by Executive Order 12906 and OMB Circular A-16. While this Supplemental Guidance expands upon and clarifies some of the language and responsibilities contained in OMB Circular A–16, it is a supportive document that does not alter the current language of OMB Circular A–16. Note that OMB Circular A–16 Appendix A includes a list of other authorities that "provide requirements or guidance pertaining to management of data and Federal information assets related to geographic locations…OMB may amend the list [of authorities] as new authorities are approved."[5]

1.3. Why the guidance is needed

Issues affecting both citizens and mission-critical government functions are often place-based or location-specific. The Supplemental Guidance is needed to link interagency portfolios, portfolio enhancement, reuse, and programmatic benefit to Department/Agency missions and the larger stakeholder community. To support mission-critical functions, the Federal Government makes large investments in acquiring and developing geospatial data. Historically these investments were largely uncoordinated and often lacked transparency, and sometimes resulted in data deficiencies, lack of standardization, inefficient use of resources, lack of interoperability, or inability to share data. The enterprise-wide adoption and execution of these practices not only foster improved operating efficiencies in Federal and partner programs but also include reporting that supports government transparency.

[5] Language taken directly from OMB Circular A–16 Appendix A (Revised 2002) available at http://www.whitehouse.gov/omb/rewrite/Circulars/a016/a016_rev.html

1.4. Who should use the guidance

This guidance is primarily directed to Federal agencies designated by OMB as Theme Lead Agencies[6] who work with their partners to develop, maintain, and manage NGDA Themes and their associated NGDA Datasets. It has received broad Federal, stakeholder, and OMB review.

Fully implementing this guidance across all agencies will take a number of years, as agencies shift resources to address a more robust management of NGDA Themes and NGDA Datasets. In the sense that at promulgation it represents a future scenario of operations, this guidance recommends that all involved entities take steps to develop and annually execute plans and report to the FGDC Steering Committee on their progress in implementing this guidance. The FGDC Steering Committee will annually recommend government-wide steps for achievement of the portfolio management approach, will annually report the NGDA Portfolio status to agency CFOs and CIOs and OMB, and will ensure that appropriate resources are identified in the agency budget requests to OMB. The FGDC Secretariat will consult with agencies to support definition and development of their agency-specific roles, responsibilities, and obligations through education and use of standards.

1.5. Non-Federal stakeholders

The development of NGDA Datasets often results from partnerships involving multiple levels of government. Therefore NGDA Theme Leads and NGDA Dataset Managers need to be informed of the requirements and activities of the State, Tribal, and local levels of government, especially since in aggregate these other levels of government annually acquire more geospatial data than does the Federal Government.

While coordination between government and non-government organizations is an ongoing aspect of geospatial data collection, management and sharing, the FGDC structure also includes an official body that represents non-Federal constituents. The National Geospatial Advisory Committee (NGAC) was established under the Federal Advisory Committee Act (FACA) and is sponsored by the U.S. Department of the Interior, the FGDC Chair. The NGAC is an advisory body that provides advice and recommendations on Federal geospatial policy and management issues and serves as a forum to convey views and priorities representative of the broad geospatial community. Consultation with such stakeholders allows the FGDC to consider the implications of its recommendations for the overall

[6] The definition for the term Theme Lead Agency can be found in the Lexicon of Geospatial Terminology found on the FGDC web site (www.fgdc.gov)

National Spatial Data Infrastructure (NSDI)[7], rather than just the Federal portion of the NSDI, and to consider intergovernmental priorities, views, and initiatives in its portfolio management process.

1.6. Organization of the guidance

Sections 2 through 5 of this Supplemental Guidance describe the framework for NGDA Portfolio management. The information covered in these sections includes:

- Section 2: Elements of the National Geospatial Data Asset Portfolio—what the NGDA Portfolio contains

  NGDA Datasets are organized into NGDA Themes that make up the NGDA Portfolio. NGDA Portfolio elements and relationships are defined and described in this section.
- Section 3: Portfolio Management of National Geospatial Data Assets—how the NGDA Portfolio is managed

  Portfolio management processes are described from both a long-term and an annual perspective, and a future portfolio management approach is articulated.
- Section 4: Roles and Responsibilities Pursuant to OMB Circular A-16 Section 8–who manages the NGDA Portfolio

  Roles and responsibilities related to OMB Circular A–16 are defined for Federal agencies involved in geospatial activities. This section clarifies leadership and stewardship roles to minimize or eliminate confusion, facilitate communication and partnering between Federal agencies and other stakeholders, and enhance NGDA Portfolio management accountability and transparency.
- Section 5: National Geospatial Data Asset Portfolio Investment Strategy—setting priorities for the NGDA Portfolio

  The section describes a recommended priority setting process for the NGDA Portfolio at many levels of government. The FGDC Steering Committee makes recommendations of high level NGDA Portfolio-wide priorities based on key Federal mission needs, Presidential priorities, Congressional mandates, and FGDC planning processes. All of these have implications for each NGDA Theme and its associated NGDA Datasets.
- Appendix A: Glossary of Acronyms

  This Appendix provides a list of acronyms used throughout this Supplemental Guidance.

[7] The definition for the term National Spatial Data Infrastructure can be found in the Lexicon of Geospatial Terminology found on the FGDC web site (www.fgdc.gov)

Additional Supplemental Guidance Reference Materials have been developed to further inform and assist with the implementation of this guidance. The materials listed here were developed in tandem with the Supplemental Guidance document. These materials, and any future reference materials, are available on the FGDC website: http://www.fgdc.gov/policyandplanning/a-16

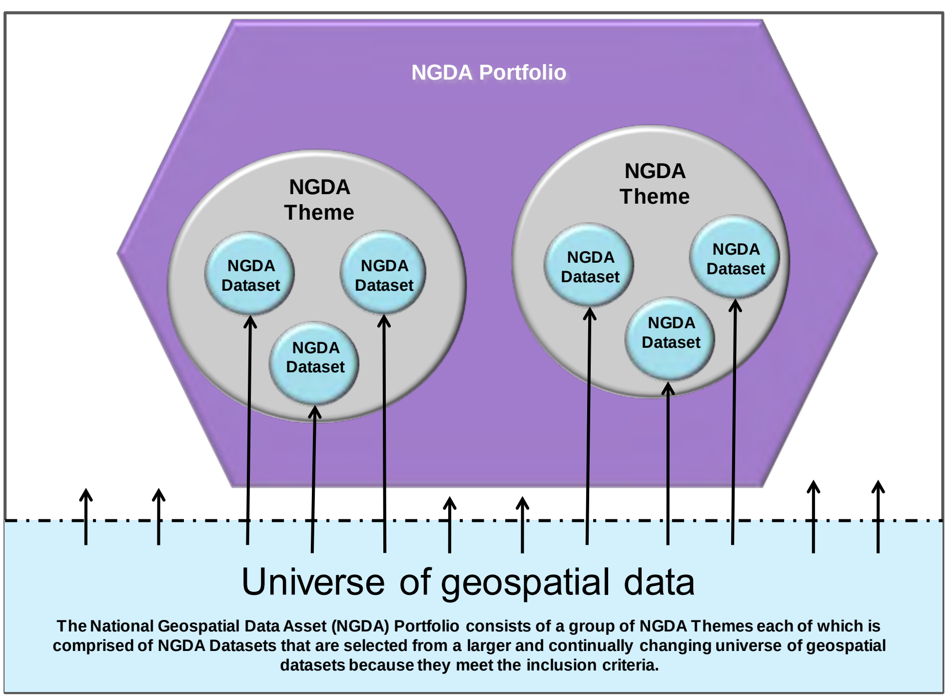
- Reference Material: FGDC Structure and Federal Agency and Bureau Representation, available at: http://www.fgdc.gov/policyandplanning/a-16
  The FGDC is an interagency committee responsible for facilitating OMB Circular A-16 related activities and implementation of the NSDI. The FGDC is chaired by the Secretary of the Interior, with the Deputy Director for Management, OMB serving as Vice-Chair. All agencies responsible for NGDA Themes (as designated in OMB Circular A-16 Appendix E) are required to be members of the FGDC.
- Reference Document: Process for adjusting OMB Circular A–16 Appendix E: NSDI Geospatial Data Theme Principles, available at: http://www.fgdc.gov/policyandplanning/a-16
  NSDI geospatial data theme principles define the characteristics of NGDA Themes and serve as guidelines for inclusion of a NGDA Theme in OMB Circular A–16 Appendix E. These principles are a precursor to establishing a predictable and repeatable process for designation and management of NGDA Themes under the authority of OMB Circular A–16 and listed in OMB Circular A–16.
- Reference Material: Lexicon of Geospatial Terminology, available at: http://www.fgdc.gov/policyandplanning/a-16
  The Lexicon of Geospatial Terminology provides a common set of geospatially-related terms and concepts to encourage consistent use of terminology and to promote a clearer understanding of the commonly used terms.
- Reference Document: Stages of the Geospatial Data Lifecycle pursuant to OMB Circular A-16 Sections 8(e)(d) , 8(e)(f), and 8(e)(g), available at: http://www.fgdc.gov/policyandplanning/a-16
  This document describes the Geospatial Data Lifecycle stages that NGDA Dataset Managers should employ when developing, managing, and reporting on NGDA Datasets under the auspices of OMB Circular A–16. The matrix establishes a framework of standard terminology and processes for seven Geospatial Data Lifecycle stages.
- Reference Document: Key Roles and Responsibilities, available at: http://www.fgdc.gov/policyandplanning/a-16
  This document describes the key roles and responsibilities of each party to NGDA Portfolio management in detail.

2. Elements of the National Geospatial Data Asset Portfolio

2.1. NGDA Portfolio

The NGDA Portfolio is envisioned as a group of NGDA Themes, each of which is comprised of related NGDA Datasets selected from a much larger and continually changing universe of geospatial datasets (Figure 1). There are a large number of Federal geospatial datasets that, to varying degrees, are useful to Federal agencies, their business partners, stakeholders, and the public. Only a select subset of these will rise to the significance required for NGDA Dataset designation as recommended by the relevant NGDA Theme Lead, concurred on by the FGDC Coordination Group, and designated by the FGDC Steering Committee. The number of NGDA Themes in the NGDA Portfolio should remain relatively stable once defined, but the number and character of the NGDA Datasets comprising each NGDA Theme may change over time in response to geospatial and other business drivers.

Figure 1. Structure of the NGDA Portfolio



2.2. NGDA Theme

A NGDA Theme (synonymous with "A-16 Theme") is an organizational construct under which multiple related NGDA Datasets are logically grouped and managed as a unit. The NSDI geospatial data theme principles summarized below and described in more detail in Reference Document: Process for adjusting OMB Circular A-16 Appendix E: NSDI Geospatial Data Theme Principles provide guidance on selecting the geospatial themes that fall under the purview of OMB Circular A–16.

- **Principle 1:** Themes are logical groupings of related national capital assets serving the needs of citizens, readily discoverable, and accessible to anyone.
- **Principle 2:** Themes are national in scope and are created and managed in response to well-defined spatial data requirements that are common across multiple Federal agencies and other organizations.
- **Principle 3:** Themes reflect legislated mandates, clearly defined directives, or core spatial reference datasets.
- **Principle 4:** Themes promote cohesive and collaborative development, maintenance, and evolution of multiple related datasets across Federal, State, Tribal, and local governments and the private or nonprofit sectors.
- **Principle 5:** Themes focus on the spatial representation of natural and manmade assets that are important to the Nation, including boundaries (jurisdictional, legal, and analytical).

The FGDC community will use these principles to establish, modify, and maintain the list of NGDA Themes that comprise the NGDA Portfolio.

2.3. NGDA Datasets

Geospatial datasets will be routinely inventoried and recommended for inclusion in the NGDA Portfolio when merited. The inventory process is considered a collaborative responsibility of NGDA Theme Leads and Thematic Committees. For approval by the FGDC Steering Committee as an NGDA Dataset, a geospatial dataset must meet at least one of the following criteria:

- Used by multiple agencies or with agency partners such as State, Tribal and local governments;
- Applied to achieve Presidential priorities as expressed by OMB;
- Required to meet shared mission goals of multiple Federal agencies; or
- Expressly required by statutory mandate.

To ensure quality and usability of NGDA Datasets by a broad range of agencies and programs, the data must be:

- Discoverable – published and available;

- Reliable – coordinated by a recognized national steward;
- Consistent – supported by defined schema, standards and understood content definitions to ensure their integrity (including conformance with FGDC Standards as applicable);
- Current and applicable – maintained regularly and adaptable to current needs; and
- Resourced – established and recognized as an enterprise investment.

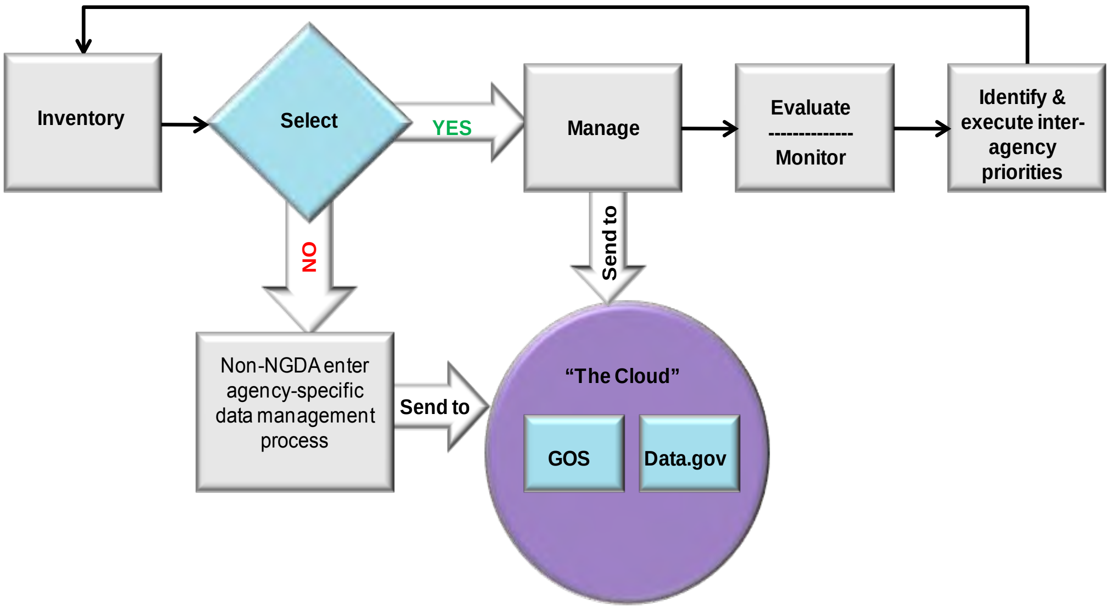
3. Portfolio Management of National Geospatial Data Assets

3.1. Portfolio Management

This section of the guidance describes a governance process for portfolio management of NGDA Themes and their associated NGDA Datasets. The portfolio management approach includes both a multi-year dimension premised on continual improvements and annual reporting on implementation progress. NGDA Datasets are essential to support agency mission and program needs, satisfy a multi-agency or stakeholder requirement and in simple words meet business-driven requirements.

NGDA Portfolio management consists of the inventory, selection, organization, management, evaluation, monitoring, and setting of Federal geospatial dataset priorities to ensure that NGDA Datasets are available to support the mission needs of the Federal Government and its partners, as determined by Federal agencies and their partners and as recommended to OMB. The activity flow within each stage of the NGDA Portfolio management process is shown in Figure 2.

Figure 2. NGDA Portfolio Management Process



1. **Inventory** – identify existing geospatial datasets that may be considered National Geospatial Data Assets (NGDAs)
2. **Select** - determine if the datasets are NGDA Datasets and if they should become part of the NGDA Portfolio
3. **Manage** – develop and manage NGDA Datasets per the OMB Circular A-16 Supplemental Guidance
4. **Evaluate/monitor** – manage NGDA Datasets according to NGDA Theme plan, milestones and performance measures
5. **Identify and execute** – develop NGDA Theme and NGDA Dataset development and funding and priorities

3.2. Inventory

To identify geospatial datasets that comprise the NGDA Portfolio universe, the FGDC Steering Committee must know what geospatial data exist and how they support the business requirements of the Federal Government and its partners. Datasets compare to each other in characteristics such as definition, content, quality, application, and validity. Obtaining this information requires a recurring inventory and selection process. This initial inventory activity will be conducted to create a baseline portfolio, which will be routinely maintained on at least an annual basis. NGDA Theme Leads will work with their respective Thematic Committees and other appropriate communities of interest to constantly identify and evaluate geospatial datasets that are candidates for consideration as NGDA Datasets within the NGDA Theme. NGDA Theme Leads, the FGDC Coordination Group, or the FGDC Steering Committee can annually create, update or replace (delete) themes and/or datasets through the collaborative review process – OMB must be informed upon the addition or deletion of NGDA Themes accepted by the FGDC Steering Committee.

3.3. Select

NGDA Theme Leads will recommend datasets for inclusion under their data themes to the FGDC Coordination Group. The FGDC Coordination Group will work with communities of interest to determine which geospatial datasets should be part of the NGDA Portfolio under each NGDA Theme. The Coordination Group will present recommendations based on their determinations on NGDA Dataset candidates to the FGDC Steering Committee annually. Determinations by the FGDC Coordination Group will be based on the following high-level criteria:

- Used by multiple agencies and partners;
- Applied to achieve Presidential priorities as expressed by OMB;
- Required to meet shared mission goals of multiple Federal agencies; or
- Expressly required by statutory mandates.

The FGDC Coordination Group will recommend to the FGDC Steering Committee candidate NGDA Themes and NGDA Datasets (with NGDA Theme assignments) for inclusion in the NGDA Portfolio. After the initial update of the NGDA Themes and their associated NGDA Datasets is complete, the selection process will primarily apply to addition, change, or deletion of datasets. NGDA Themes and their associated datasets have already changed on a limited basis within the span of OMB Circular A-16, and will surely continue to do so. Agencies are required to establish the proposal for a new NGDA Theme and/or a new NGDA Dataset therein. The FGDC Steering Committee reviews proposals for acceptance or rejection as part of the annual NGDA Portfolio management process.

3.4. Manage

The "manage" phase of portfolio management consists of activities at both the NGDA Theme and NGDA Dataset levels. Activities for this phase of portfolio management include:

- An initial baseline assessment of the state and maturity of each NGDA Dataset within the NGDA Portfolio.
- Annual development of an NGDA Theme Report that covers the status of each associated NGDA Dataset. The NGDA Theme Report will also address those areas where NGDA Datasets need to be developed and/or managed jointly to ensure that they can be used most effectively to support mission goals and objectives and that they are developed in a manner that is most cost effective by minimizing duplicate development and leveraging resources. An annual NGDA Portfolio Summary will roll up this information in support of continuously improving the quality and value of the NGDA Datasets.

- NGDA Theme Leads will periodically present NGDA Theme status based on NGDA Theme and NGDA Dataset Reports to the FGDC Coordination Group to address status, plans, and resources.

3.4.1. NGDA Dataset Management

NGDA Dataset Managers should use the Geospatial Data Lifecycle (Reference Document: Stages of the Geospatial Data Lifecycle pursuant to OMB Circular A-16 Sections 8(e)(d) , 8(e)(f), and 8(e)(g)) to plan, develop, maintain, evolve, and archive the NGDA Dataset(s) for which they are responsible. Figure 3 summarizes the Geospatial Data Lifecycle stages: Define Inventory/Evaluate, Obtain, Access, Maintain, Use/Evaluate, and Archive. Business requirements drive recommended management practices in each stage. The expected outcomes of adopting this lifecycle management framework include:

- Better understanding of the current maturity of NGDA Datasets;
- Identification of management practices that NGDA Dataset Managers use to develop NGDA Datasets;
- Provision of timely and high-quality geospatial data to support business processes and operations;
- Creation of stronger partnerships and coordination across all levels of government (and when appropriate, the private sector) to increase cost efficiency and return on investment;
- Improved strategies for completing and maintaining the NGDA Themes and their associated NGDA Datasets to enhance services to citizens; and
- Improved efficiencies in addressing Federal and national priorities.

NGDA Dataset Managers should evaluate their NGDA Dataset(s) against the Geospatial Data Lifecycle stages in order to report on their maturity and status. They should also report on how they are conforming to the NGDA Dataset Managers' responsibilities, expended resources (dollars and full time equivalent [FTE]) staff), and other performance measures concurred upon by the FGDC Steering Committee. If funding information is not currently available, NGDA Dataset Managers should work with their agency leadership to develop means of tracking this financial information. The NGDA Dataset Manager will annually submit an NGDA Dataset Report to the relevant NGDA Theme Lead and will assist with incorporation of that information into a comprehensive annual NGDA Theme Report. The NGDA Theme Report will be submitted to the FGDC Secretariat for analysis by the FGDC Coordination Group and development of a NGDA Portfolio Summary. Based on their analysis the FGDC Coordination Group will make annual recommendations to the FGDC Steering Committee on NGDA Portfolio actions.

Figure 3. The Geospatial Data Lifecycle

Stage 1. Define: Characterization of data requirements based upon business-driven user needs.

Stage 2. Inventory/Evaluate: The creation and publication of a detailed list of data assets and data gaps (both internal and external) as they relate to business-driven user needs.

Stage 3. Obtain: Identify the mechanism(s) for the collection, purchase, conversion, transformation, sharing, exchanging, or creation of geospatial data that were selected to meet the business needs

Stage 4. Access: Making data produced known and retrievable to the community through documentation and discovery mechanisms so the users can meet their business requirements.

Stage 5. Maintain: Ongoing processes and procedures for data operation and maintenance to ensure that the data continue to meet business requirements.

Stage 6. Use/Evaluate: The ongoing assessment, validation, and potential enhancement of data to meet user needs and business requirements.

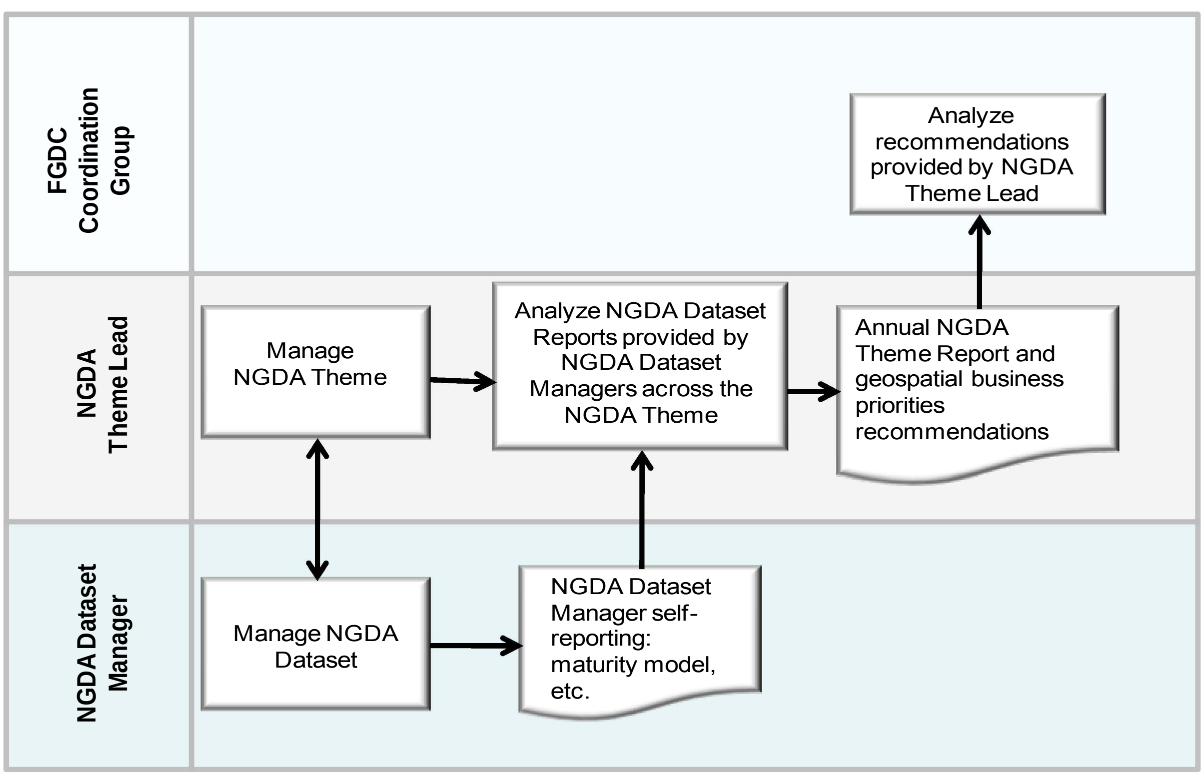
Stage 7. Archive: Required retention of data and the data's retirement into long-term storage.

3.4.2. NGDA Theme Management

Figure 4 depicts a standard process for NGDA Theme management and evaluation. NGDA Theme Leads should comprehensively coordinate with their NGDA Dataset Managers to provide overall management for the NGDA Datasets associated with the NGDA Theme. This will ensure that their NGDA Datasets effectively support the business processes reliant on them and that they are produced in the most cost effective manner. Coordination and integration of NGDA Dataset management will frequently occur across agencies, making interagency coordination a key responsibility of the NGDA Theme Lead. NGDA Theme Leads will also coordinate with other NGDA Theme Leads to ensure that NGDA Datasets applicable to more than one NGDA Theme are effectively co-developed. The FGDC Secretariat will facilitate these coordination activities.

The baseline and subsequent annual NGDA Dataset Reports comprise a key foundational element of the NGDA Theme Lead's ability to collaborate with the NGDA Dataset Managers associated with the NGDA Theme, and to identify and execute common practices and shared services across NGDA Datasets within the NGDA Theme.

Figure 4. Standard Process for NGDA Theme Management



3.5. Evaluate/Monitor

Completion, maintenance, and evolution of the NGDA Portfolio will require the governance and organizational structures described in this Supplemental Guidance to be in-place. As noted earlier, the NGDA Dataset Managers will annually submit NGDA Dataset Reports to their relevant NGDA Theme Leads and will assist with incorporation of that information into a comprehensive annual NGDA Theme Report. NGDA Theme Leads will develop NGDA Theme Reports that capture plans for, milestones for, and progress in establishing the necessary organizational structures and resources. Theme Lead Agencies will submit NGDA Theme Reports to the FGDC Secretariat for summarization, and to the FGDC Coordination Group for analysis and development of a NGDA Portfolio Summary. Based on this analysis the FGDC Coordination Group will make annual recommendations to the Steering Committee on NGDA Portfolio actions.

3.6. Identify and Execute Interagency Priorities

A key goal of NGDA Portfolio management is to enable the FGDC Steering Committee to make informed decisions on setting both short- and long-term priorities on NGDA Themes and NGDA Datasets as well as cross-agency collaboration targets for NGDA Dataset development and funding. Portfolio-wide metrics will provide a comprehensive picture of the NGDA Portfolio allowing better enterprise-level decision-making than is possible under the current decision process. Under the current process where decisions are made without the benefit of inter-agency discussions, decisions are often "stove-piped"[8] and made with insufficient information in terms of the benefits and risks associated with multiple investment paths. Under the new process, NGDA Theme Leads and the FGDC Coordination Group are responsible for identifying collaboration opportunities. This more inclusive process is one of the advantages of NGDA Portfolio management.

NGDA Theme Leads and members of the FGDC Coordination Group have roles in identifying and recommending NGDA Dataset development priorities to the FGDC Steering Committee; the FGDC Steering Committee, in turn, assesses them and makes/shares the recommendations with agency CFOs and CIOs and OMB. NGDA Theme Leads will periodically make presentations to both the FGDC Coordination Group and FGDC Steering Committee providing updates on NGDA Theme requirements as determined by their Thematic Committees and communities of interest, as incorporated in the annual NGDA Theme Report, or as requested by agency or FGDC leadership.

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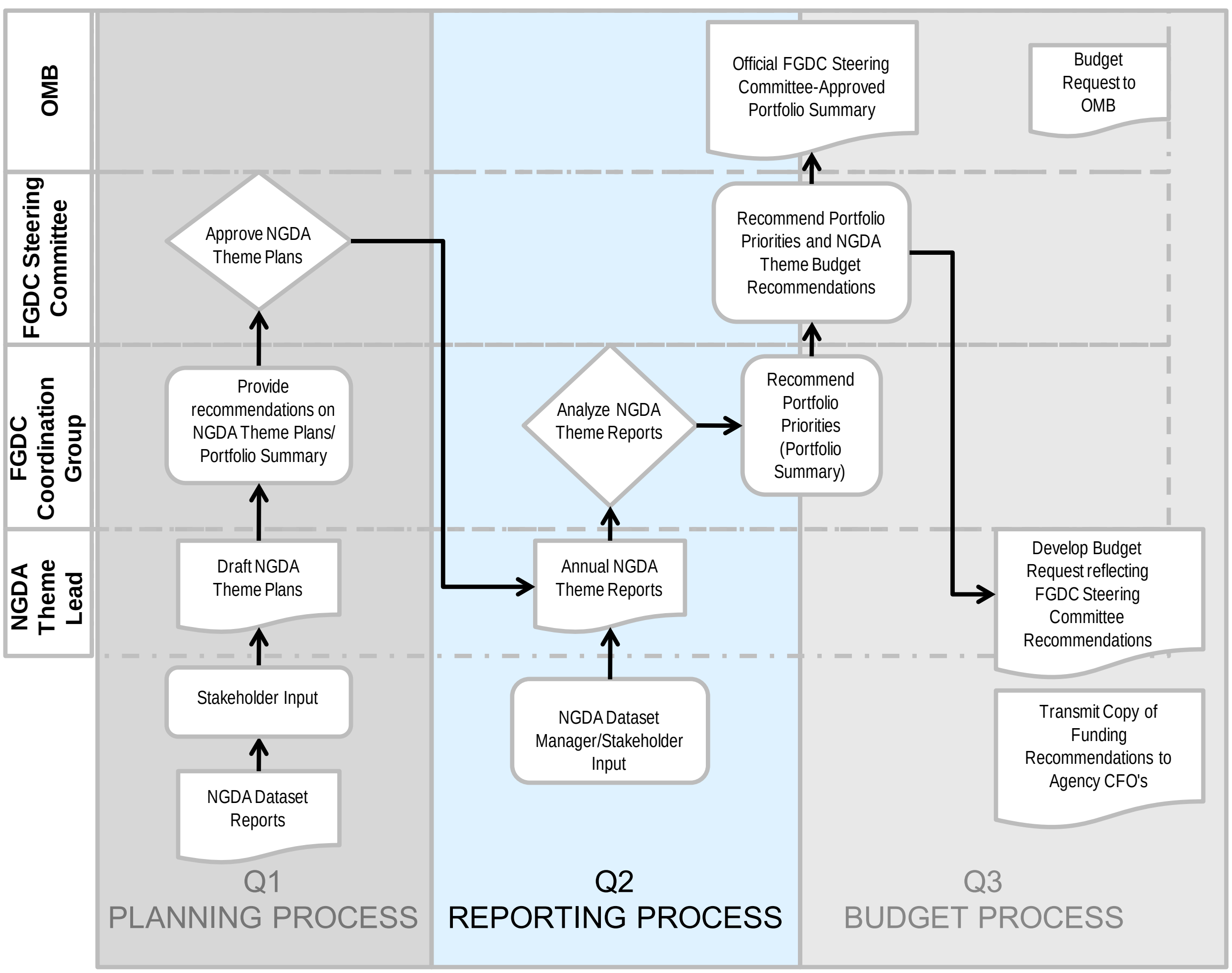
[8] "Stove-piped - to develop, or be developed, in an isolated environment; to solve narrow goals or meet specific needs in a way not readily compatible with other systems." (http://www.doubletongued.org/index.php/dictionary/stove_pipe/)

The FGDC Coordination Group will use NGDA Theme Lead presentations in conjunction with performance metrics contained in or derived from the annual NGDA Theme Reports to make annual recommendations on cross-agency NGDA Theme and NGDA Dataset development and investment to the FGDC Steering Committee. The FGDC Steering Committee will be responsible for 1) assessing the recommendations in the context of overall FGDC strategic goals and objectives; 2) coming to concurrence on cross-agency NGDA Dataset development and funding priorities; and 3) presenting these recommendations to agency CFOs and OMB. Linkages between NGDA Theme planning, annual NGDA Theme progress reporting, and setting cross-agency funding priorities are portrayed in Figure 5. Budget activities remain under the purview of the agencies and OMB.

Figure 5. Relationship of the NGDA Theme planning, reporting, and budget advisory processes



4. Roles and Responsibilities Pursuant to OMB Circular A–16 Section 8

4.1. Purpose of Roles and Responsibilities Framework

This section of the Supplemental Guidance defines the roles and responsibilities of Federal agencies as they implement OMB Circular A-16. Implementation of OMB Circular A-16 via these roles and responsibilities will help ensure that the Nation has a rich collection of NGDA Themes and NGDA Datasets that are accessible to Federal, State, Tribal, and local agencies and their clients to support their business needs, requirements, and priorities. Reference Document: Key Roles and Responsibilities defines in greater detail what is expected of participants in the NGDA Portfolio management process. As the NGDA Portfolio management process matures, Reference Document: Key Roles and Responsibilities will be updated as needed.

Successful management of the NGDA Portfolio requires coordination across a wide variety of organizations, each of which has specific roles to fulfill. Some of these roles and responsibilities involve management across NGDA Themes that helps maximize potential return on investment and identifies and reduces any overlap that currently exists. OMB Circular A–16 implementation promotes overall NGDA Portfolio management and leverages the Federal Enterprise Architecture.

Implementing the framework:

- Facilitates proactive execution of business and implementation strategies for each NGDA Theme and its associated NGDA Datasets;
- Helps NGDA Theme Leads and NGDA Dataset Managers identify, develop, quantify, allocate, and sustain the resources necessary to develop the NGDA Themes and NGDA Datasets for which they are responsible;
- Enables a range of people with business requirements for NGDA Datasets to be involved in every component of the NGDA Portfolio management process to ensure business requirements are satisfied;

- Ensures people involved in making management decisions about NGDA Themes and associated NGDA Datasets are fully apprised of implications for the NGDA Portfolio; and
- Helps ensure that NGDA Themes and NGDA Datasets meet OMB Circular A–16 and FGDC goals, objectives, and milestones.

4.2. Implementation of the Roles and Responsibilities Framework

The roles and responsibilities contained in this Supplemental Guidance describe activities needed for successful NGDA Portfolio management. All agencies are encouraged to make these roles and responsibilities operational, especially those agencies that have NGDA Theme Lead responsibilities. It is important to note that these roles are generic, particularly in the case of a Theme Lead Agency and its stakeholders. NGDA Theme Leads will work with their communities of interest and members of their Thematic Committees to customize the NGDA Portfolio management process in ways that meet the specific needs of their stakeholders. To accommodate the planning needs and timelines of agencies, NGDA Theme Leads and, by extension, the associated NGDA Dataset Managers should submit, through an initial NGDA Dataset and/or NGDA Theme to the FGDC Secretariat for development of a NGDA Portfolio Summary. The FGDC Steering Committee will annually submit to OMB the Portfolio Summary that includes the performance of each Theme Lead Agency in meeting its roles and responsibilities.

4.3. Roles and Responsibilities

A Federal agency may perform multiple functions and serve multiple roles related to NGDA Portfolio management. It may, for example, have leadership responsibility for one or more NGDA Theme, or be in a non-leadership role for a NGDA Theme but contribute NGDA Datasets to a NGDA Theme. Likewise it may not be leading or contributing to an NGDA Dataset, but may still have a programmatic interest associated with a NGDA Theme or NGDA Dataset. Whatever the case, any agency or individual with a role described in OMB Circular A-16 or this Supplemental Guidance is accountable to their SAOGI, the FGDC Steering Committee, and ultimately OMB for fulfilling their responsibilities.

Roles Specific to NGDA Theme Management

- **Executive NGDA Theme Champion** – A member of the Senior Executive Service or a senior level individual designated by a Theme Lead Agency's SAOGI, who advocates for, raises awareness of, and promotes the implementation of a NGDA Theme and its NGDA Datasets. An Executive NGDA Theme Champion provides recommendations to, and advises the SAOGI on, important matters relative to the NGDA Theme's role in the NGDA Portfolio.

- **NGDA Theme Lead** – Individuals who provide interdepartmental leadership and coordination at the NGDA Theme level. They work with component NGDA Dataset Managers to develop standards and provide guidance. The NGDA Theme Lead, or designee, chairs the NGDA Theme's Thematic Committee and manages the annual process of providing NGDA Dataset collaboration and funding recommendations to the FGDC Steering Committee for those NGDA Datasets within their NGDA Theme. Additionally, the NGDA Theme Lead reports to the Executive NGDA Theme Champion and the FGDC Coordination Group on the NGDA Theme's activities and investments (both current and planned).
- **NGDA Dataset Manager** – Individuals who provide coordination and standards for NGDA Datasets at a national level. NGDA Dataset Managers provide information to their NGDA Theme Lead for management and reporting.
- **Data Steward** – Data Stewards manage that part of a NGDA Dataset that their organization contributes to a seamless national dataset. They work with the NDGA Dataset Managers in providing coordination support, implementing needed changes to data, informing and cooperating with stakeholders, performing field work, ensuring data standards are followed, and performing data maintenance. Data Stewards are often not Federal employees, coming from other levels of government, academia, or the private sector.

The responsibility assignment matrix, or RACI matrix, (Table 1) describes the roles and responsibilities of the entities involved in NGDA Portfolio management. The matrix is simplest to follow by starting with the responsible party. For example, under Inventory – NGDA Dataset Managers, Data Stewards, and stakeholders are responsible for creation and update to NGDA Datasets whereas NGDA Theme Leads are accountable for coordination, review, and reporting on the inventory.

The RACI matrix is composed of the four key responsibility areas as follows:
Responsible (R) - the person or entity assigned to do the work including core work elements such as managing, executing, controlling, and implementing. Other work elements include prioritizing, evaluating, and directing.
Accountable (A) - the person or entity who makes decisions about and who has ultimate ownership of the work including core work elements such as deciding, approving, prioritizing, allocating, evaluating, or directing.
Consult (C) - the person or entity conferred with before a decision can be made or an action can be taken. This responsibility also includes facilitation and core work elements such as prioritizing. Other work elements will be done in consultation with persons or entities that are "accountable" and

"responsible", and may include functions such as approving, evaluating, or directing. This is usually a two-way communication.

Inform (I) - the person or entity that must be made aware that a decision or action is pending or has been taken. This is usually a one-way communication.

Facilitate (F) – the person who assists, coordinates, directs, or guides people or entities in various stages of the NGDA Portfolio management approach (added for the F this guidance).

Table 1. RACI Matrix

Entity	Inventory	Selection and Theme Placement	Manage (Portfolio, Theme and Dataset)	Evaluate/Monitor	Identify and Execute Interagency Priorities
OMB		Consult		Inform	Accountable
FGDC EC				Inform	Inform
FGDC SC		Accountable	Accountable (portfolio)	Accountable (portfolio)	Responsible
FGDC CG	Inform	Responsible	Inform	Inform, Consult	Responsible
FGDC Secretariat	Consult		Facilitate	Facilitate	Facilitate
Executive Champion		Inform, Consult	Inform, Consult (theme)	Accountable (theme)	Accountable
FGDC WG			Consult	Consult	Consult
FGDC Subcommittees	Consult		Responsible	Inform	Consult
Theme Lead	Accountable (theme)	Inform	Accountable (theme)	Responsible (theme)	Responsible
Dataset Manager	Accountable (dataset), Responsible		Accountable (dataset)	Responsible (dataset)	Facilitate
Data Steward	Responsible		Responsible	Responsible	
Stakeholders	Responsible		Responsible	Responsible	Consult
NGAC Advisory Committee			Consult	Consult	Consult
Theme Community of Interest		Consult		Inform	Consult
CIOC					Inform
CFOC					Inform

Key:
Responsible - an entity or person assigned to do the work
Accountable - an entity or person who makes the final decision and has ultimate ownership
Consult - an entity or person who must be conferred with before a decision or action can be taken
Inform - an entity or person who must be made aware that a decision or action is pending or has been taken
Facilitate - an entity or person who coordinates, directs, or guides activities or people

Due to the complexity of managing NDGA Datasets, multiple "accountable" designations may exist but will in each instance be specific to the NGDA Portfolio, NGDA Theme, or NGDA Dataset. In the RACI matrix, roles have been assigned to the lowest possible person or entity in the hierarchy. For each task, at least one person or entity must be "responsible", but again, due to the complexity of NGDA Portfolio management and the need for coordination among multiple people or entities, there may be more than one responsible party associated with each stage of the portfolio management process. For "consulted," only those persons or entities that must be always consulted are indicated. Consultations with persons or entities not included in this matrix may also occur, but are not always required. Detailed roles and responsibilities associated with each component of the NGDA Portfolio management process are contained in Reference Document: Roles and Responsibilities.

Descriptions and typical tasks for each person or entity involved in NGDA Portfolio management are listed in Table 2.

Table 2. Stakeholder Summary

Entity	Members	Role
1. OMB	OMB Deputy Director for Management, or his designee, is co-chair of the FGDC Steering Committee	a. Maintain OMB Circular A–16 and its appendices b. Consider NGDA Theme and NGDA Dataset funding recommendations of the FGDC Steering Committee *c. Budget Examiners participate at appropriate point with support from E-Gov Office*
2. FGDC Executive Committee	A subgroup of members of the FGDC Steering Committee appointed by the Chair, whose agencies produce or use geospatial data or technology. The FGDC Executive Committee is chaired by the FGDC Steering Committee Chair.	Advise the FGDC Steering Committee and establish agendas for FGDC Steering Committee meetings
3. FGDC Steering Committee	SAOGIs, designated by their agencies pursuant to OMB Memorandum 06-07[9] or agency officials as specified in the FGDC Steering Committee Charter[10]	a. Provide NGDA community leadership b. Represent Federal agencies on the FGDC Steering Committee c. Oversee agency NGDA Portfolio investments d. Provide funding recommendations by NGDA Theme and associated NGDA Datasets to OMB, the CIO Council, and the agency CFO community
4. FGDC Coordination Group	Representatives from Federal agencies as specified in the FGDC Coordination Group Charter[11]	a. Formulate recommendations by consensus on the NGDA Portfolio Summary for NGDA Portfolio management b. Advise the FGDC Steering Committee c. Increase awareness of efforts associated with OMB Circular A–16 implementation and portfolio management and foster partnerships at all levels of government to leverage efforts and reduce development and investment

[9] Memorandum available at http://www.whitehouse.gov/omb/memoranda/fy2006/m06-07.pdf
[10] Charter available at http://www.fgdc.gov/participation/steering-committee/steering-committee-charter.pdf
[11] Charter available at http://www.fgdc.gov/participation/coordination-group/coordination-group-charter

Entity	Members	Role
		redundancies
5. FGDC Thematic Committees	FGDC member agency representatives and FGDC-recognized stakeholder groups who have common interests that cross-cut or affect several NGDA Themes	a. Advise NGDA Theme Leads and associated NGDA Dataset Managers b. Respond to guidance from the FGDC Steering Committee by updating NGDA Theme -specific collaboration or funding recommendations for NGDA Datasets within each NGDA Theme, for consideration by the FGDC Steering Committee
6. FGDC working groups	Representatives from Federal agencies and FGDC-recognized stakeholder groups who have common interests that cross-cut or affect two or more NGDA Themes	Produce cross-NGDA Theme and cross-NGDA Dataset development and management guidance and procedures
7. FGDC Secretariat	Executive and support staff that support the FGDC and its interagency substructure and working groups	a. Assist agency NGDA Theme Leads and NGDA Dataset Managers b. Support the FGDC Steering Committee c. Support the FGDC Coordination Group d. Facilitate portfolio management activities with other FGDC activities and government initiatives
8. Theme Lead Agency	Federal agencies identified in OMB Circular A–16 Appendix E, to lead the coordination of a NGDA Theme	a. Oversee the development, implementation, and maintenance of NGDA Themes and associated NGDA Datasets, including chairing Thematic Committee meetings to develop funding recommendations for NGDA Datasets within the NGDA Theme and reflected in the annual NGDA Theme Report b. Provide Executive NGDA Theme Champion[12] c. Appoint NGDA Theme Lead[13] d. Designate and/or work with NGDA Dataset Manager[14] e. Designate and/or work with Data steward[15]
9. Stakeholder Community	a. Members can come from Federal, State, Tribal, or local governments as well as the private or nonprofit sectors or academia (may vary from theme to theme)	a. Serve as Data steward as designated b. Are data end users c. Are data producers
	d. NGAC composed of representatives from Federal, State, Tribal, and local governments and the private sector, the nonprofit sector, and academia	Provides advice and recommendations to FGDC Chair

[12] The definition of this term can be found in the Lexicon of Geospatial Terminology located on the FGDC web site (www.fgdc.gov)

[13] The definition of this term can be found in the Lexicon of Geospatial Terminology located on the FGDC web site (www.fgdc.gov)

[14] The definition for this term can be found in the Lexicon of Geospatial Terminology located on the FGDC web site (www.fgdc.gov)

[15] The definition for this term can be found in the Lexicon of Geospatial Terminology located on the FGDC web site (www.fgdc.gov)

Entity	Members	Role
	e. General users who may or may not have a relationship with a Federal agency	Data end users[16]

[16] The definition for this term can be found in the Lexicon of Geospatial Terminology located on the FGDC web site (www.fgdc.gov)

5. National Geospatial Data Asset Portfolio Investment Strategy

This guidance establishes an investment analysis and collaboration process integral to strategic management of the NGDA Portfolio. It provides a mechanism for annual peer review and consultation to inform both potential partner agencies and OMB as to the completeness, value of, and priorities for the NGDA Themes and their associated NGDA Datasets. By conducting such an annual investment review, the geospatial community will increase its effectiveness by better aligning its activities with other Federal investment processes and investments.

Two primary results arise from this approach: (1) partnering opportunities for investment collaboration are jointly identified and considered, providing the opportunity to align resources and improve mission delivery, and (2) on a timely basis during the annual budget process, OMB and the interagency CFO community are informed by government-wide geospatial experts about opportunities for improved geospatial resource alignment. This model is consistent with the CPIC process, which addresses other components of the geospatial portfolio (specifically hardware and software).

The planning, reporting, and budget processes form the basis for establishing interagency partnerships and provide linkages to the broader Federal agency budget process. This Supplemental Guidance establishes an 'investment collaboration process' whereby peer review and consultation for NDGA Themes and associated NGDA Datasets is conducted annually and whereby suggested interagency priorities are provided to Agency CFOs and OMB to inform the budget process. Budget activities remain under the purview of agencies and OMB. Budget information regarding NGDA Dataset investment informs the budget process and may inform prioritization--or funding adequacy-- where relevant. Agency SAOGIs and Executive NGDA Theme Champions update NGDA Theme Leads and NGDA Dataset Managers on final resource disposition to complete the process.

5.1 Benefits

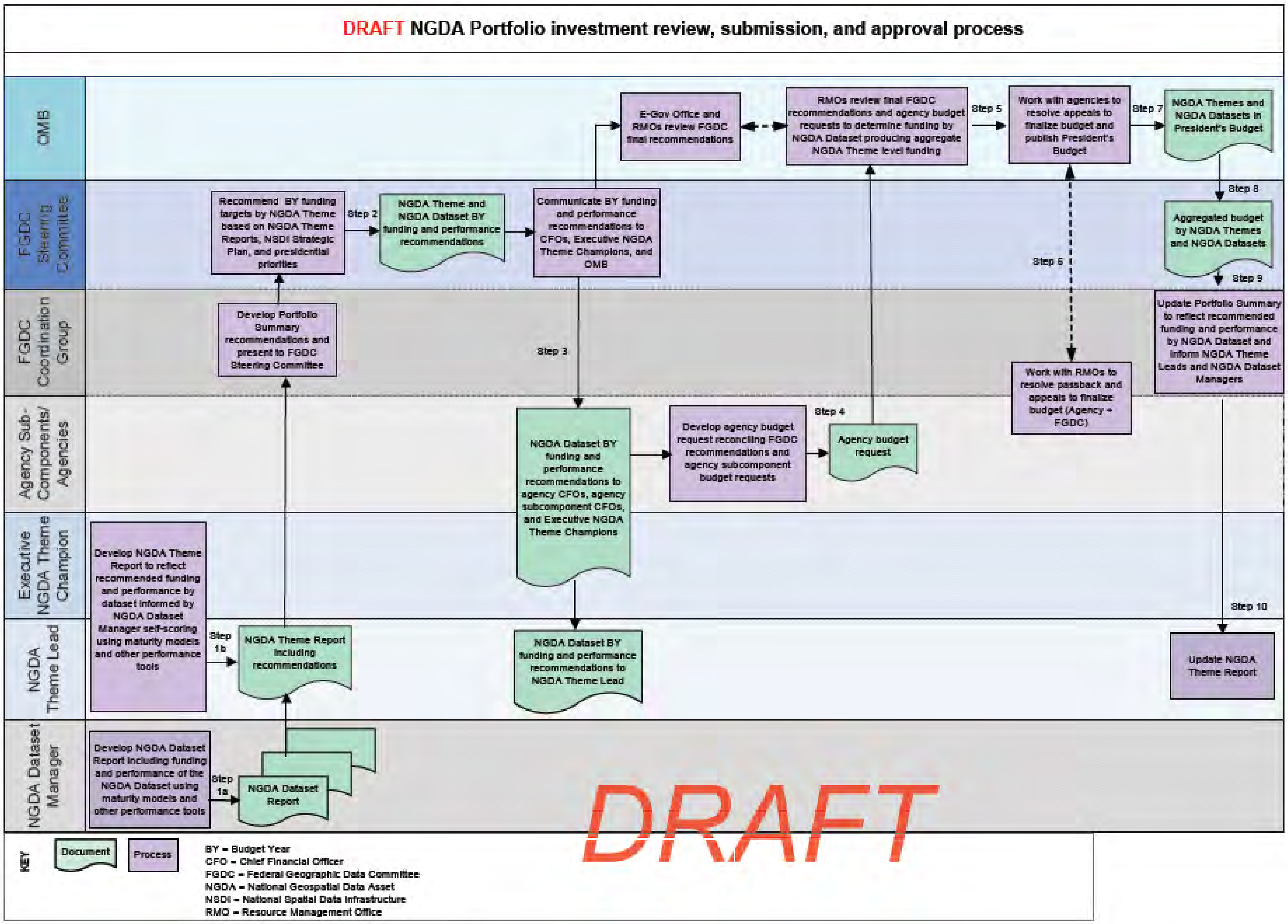
Conducting an annual investment review process increases the geospatial community's effectiveness by focusing investment and development efforts on those assets that are most critical for supporting missions and output goals and by integrating its activities into other Federal investment processes. The players traditionally active in the Federal agency budget formation process, most notably the agency CFO community, rarely have expertise in geospatial management or issues. At the same time, those with significant geospatial expertise rarely have a distinct role in the budget process. The fact that much Federal geospatial spending is subsumed unidentifiably within other program budgets, and therefore opaque to the CFO community, is one reason for this disconnect. The FGDC will work with OMB, NGDA Theme Leads, and NGDA Dataset Managers using the FGDC governance structure to lay out an aggressive but achievable process whereby funding levels for the NGDA Datasets become known over time. Achieving the transparency contemplated by this guidance will empower the FGDC to address broad long-term geospatial policy issues that are presently unresolved, facilitate annual initiatives, explore priorities across and within NGDA Themes, and enable all involved parties to assess the completeness and quality of management of individual NGDA Datasets. While the long-term NGDA Portfolio management activities described in Sections 3 and 4 of this Supplemental Guidance are evolving, the annual Federal budget process provides a shorter-term opportunity to begin improved management of, and priority setting for, the NGDA Portfolio.

5.2 The Process

The FGDC Steering Committee annually establishes a NGDA Portfolio Summary inclusive of funding recommendations and shares it with agency CFOs and OMB E-Gov and Resource Management Offices. This advice is timed so that it may be considered in routine agency budget formulation and operational plan development processes. Budget recommendations of the FGDC Steering Committee align with the budget formulation process of agency program managers and the CFO community to facilitate a government-wide perspective on NGDA Portfolio funding priorities (OMB Circular A-16, 2002; page 6).. Note: a publicly releasable geospatial Portfolio Summary will be included in the FGDC Annual Report.

The steps in the NGDA Portfolio investment review, submission, and approval process, as shown in Figure 6, are described below.

Figure 6: NGDA Portfolio investment review, submission, and approval process



- The process begins with NGDA Dataset Managers who develop annual NGDA Dataset Reports including current level of completion, prior year (PY) and current year (CY) spending amounts, NGDA Dataset Manager self-scoring and reporting using the Geospatial Data Lifecycle stages maturity model, and other information as required in FGDC reporting guidance. Upon approval by their agency SAOGI, the report is provided to the NGDA Theme Lead, who then collaborates with all NGDA Theme-related dataset managers (including those of possibly relevant non-NGDA Datasets) to identify opportunities for integration, collaboration, improved efficiency, or improvements such as greater completeness, accuracy, or precision across the NGDA Theme. (mid-February, after release of the President's Budget; Step 1A).
- NGDA Theme Leads develop NGDA Theme Reports, compiling their NGDA Dataset Reports and other information including potential opportunities for cross-agency collaboration, performance improvement, investment opportunities, and other information as required in FGDC reporting guidance. When developing NGDA Dataset BY funding recommendations, NGDA Theme Leads should take into account non-Federal sources of funding for the NGDA Datasets and the NGDA Dataset's significance in meeting the needs of both Federal and non-Federal levels of government.
- The FGDC Secretariat compiles NGDA Theme Reports into a NGDA Portfolio Summary for the FGDC Coordination Group. The FGDC Coordination Group develops recommendations aligned with the NSDI Strategic Plan and Presidential priorities, and informed by NGDA Theme Reports, NGDA Dataset Reports, and other relevant information. The FGDC Coordination Group presents the Portfolio Summary including their recommendations on BY spending amounts organized by NGDA Dataset (mid-February, at the same time as Step 1A and Step 1B).
- The FGDC Steering Committee concurs or recommends BY funding by NGDA Theme based on the Portfolio Summary, funding levels in the budget that were just released, NGDA Theme Lead recommendations, and any shifts in Presidential priorities not yet conveyed by the FGDC reporting guidance (mid-March; Step 2).
- The FGDC Steering Committee communicates its BY funding recommendations for NGDA Themes and their component NGDA Datasets, plus any corresponding performance recommendations, to OMB, the relevant members of the CFO community, Executive NGDA Theme Champions, and the NGDA Theme Leads via the Executive NGDA Theme Champions. Agency CIOs should also be informed to ensure alignment with the agency's CPIC process (late April; Step 3).
- Agency CFOs, in consultation with the SAOGIs and Executive NGDA Theme Champions within their agencies, develop and submit agency budget requests reconciling the FGDC recommendations and agency subcomponent budget requests. Agency budget requests should reflect suggested FGDC

investment collaboration status. Agency CIOs should be consulted to ensure alignment with respect to the agency's CPIC process (May-September; Step 4).

- OMB RMOs review FGDC Steering Committee recommendations and agency budget requests to determine consistency and funding by NGDA Dataset. In aggregate, OMB's individual NGDA Dataset funding decisions produce NGDA Theme level funding for the BY (October- November; Step 5).
- Agencies and OMB RMOs collaborate to resolve Passback and appeals to finalize the President's Budget (December; Step 6).
- OMB publishes the President's Budget (February; Step 7).
- The Steering Committee racks up the resolved agency appeals by collecting information from OMB RMOs by NGDA Dataset, and then organizes agency-specific information by NGDA Theme and communicates that information to the FGDC Coordination Group (mid-February; Step 8).
- The FGDC Coordination Group updates the Portfolio Summary to reflect recommended funding and performance by NGDA Dataset and informs NGDA Theme Leads and NGDA Dataset Managers of OMB decisions (mid-February; Step 9).
- NGDA Theme Leads update the NGDA Theme Reports to reflect the final budget decisions in the recently released President's Budget (late-February; Step 10).

5.3 Staged Process Implementation

All NGDA Datasets across all NGDA Themes will be involved in the NGDA Portfolio management process. In year one, the FGDC Steering Committee will indicate to OMB how and when the FGDC plans to progressively stage implementation of this portfolio budget recommendation process. In subsequent years, the FGDC Steering Committee will report to OMB on progress toward implementing the NGDA Portfolio management process and outcomes. Completion of two activities is critical before an enterprise NGDA Portfolio management process can be fully implemented. These are 1) the designation and active leadership of NGDA Theme Leads and associated NGDA Dataset Managers and 2) the documentation and availability of financial information for NGDA Datasets within a particular NGDA Theme.

Documenting and making financial information available presents a more complex challenge for some agencies than others. This is because the desired degree of transparency and accountability may depend on modest refinements to agency financial management and budget systems that would allow for NGDA Dataset spending to be identified within the larger budget structures. It may therefore be necessary to gradually increase over a period of years the number of NGDA Datasets within a particular NGDA

Theme that are capable of being fully included in this process. This is because achievement of the desired degree of transparency and accountability may depend on modest refinements to agency financial management and budget systems that would allow for NGDA Dataset spending to be individually identified within the larger budget structures. However, the FGDC need not wait until relevant financial information is available for all NGDA Datasets within a NGDA Theme before beginning to apply this process to that NGDA Theme. This process can begin when the FGDC determines it has the necessary financial information for a critical mass of NGDA Datasets associated with an NGDA Theme needed to derive value from the process.

The FGDC will coordinate with OMB and the agency CFO/CIO community to ensure a consistent approach to providing the required level of resolution of financial information for NGDA Datasets, recognizing that some agencies may require more time in order to satisfy the reporting requirements. This process will enable the FGDC Steering Committee to make informed decisions on setting both short- and long-term priorities on NGDA Themes and NGDA Datasets as well as cross-agency collaboration targets for NGDA Dataset development and funding. This collaborative process serves as an important component in the foundation of portfolio management in fulfillment of OMB Circular A-16.

Acronyms

Acronym	Definition
BY	Budget Year (in reference to the Federal Budget Process)
CFO	Chief Financial Officer
CIO	Chief Information Officer
CIO Council	Chief Information Officers Council
CPIC	Capital Planning and Investment Control
CY	Current Year (in reference to the Federal Budget process)
eGOV	E-Government Initiative
FACA	Federal Advisory Committee Act
FGDC	Federal Geographic Data Committee
FTE	Full-time equivalent
NGAC	National Geospatial Advisory Committee
NGDA	National Geospatial Data Asset
NSDI	National Spatial Data Infrastructure
OMB	Office of Management and Budget
PY	Prior Year (in reference to the Federal Budget)
RMO	Resource Management Office
SAOGI	Senior Agency Official for Geospatial Information

APPENDIX C

DOI DEPARTMENTAL MANUAL – SURVEYING AND MAPPING – GENERAL

Department of the Interior
Departmental Manual

Effective Date: 11/29/88
Series: Special Programs
Part 757: Surveying and Mapping
Chapter 1: General

Originating Office: U.S. Geological Survey

This chapter has been given a new release number.* No text changes were made.

757 DM 1

1.1 **Purpose**. This chapter provides background and scope for the succeeding chapters of this part that prescribe policy, responsibility, coordinating arrangements, and procedures for Departmental administration of its own surveying and mapping activities and its assigned responsibilities for coordinating Federal surveying and mapping activities.

1.2 **Background**.

A. Office of Management and Budget Circular A-16. In 1953 the Bureau of the Budget, now the Office of Management and Budget (OMB), issued Circular A-16 to improve programing and coordination of mapping and geodetic surveying activity in the Federal Government. This Circular established procedures and responsibilities for Federal surveying and mapping activities directed toward meeting the needs of Federal and State agencies and the public, and set forth OMB=s responsibility for programing and coordination of surveying and mapping.

Circular A-16 was revised in May 1967, assigning to the Departments of the Interior, Commerce, and State, certain responsibilities for the coordination of surveying and mapping activities (see Appendix 1). The Secretary delegated to the Geological Survey the responsibilities assigned to the Department of the Interior. Following the procedures set forth in the revised Circular, the Geological Survey established a system for coordinating the participation of Federal agencies in matters relating to the National Mapping Program. The National Oceanic and Atmospheric Administration (NOAA) established an interagency Federal Geodetic Control Committee (FGCC) to coordinate geodetic surveying activities.

B. Federal Interagency Coordinating Committee on Digital Cartography (FICCDC). Coordination of digital cartographic activities of Federal agencies was assigned to the Department of the Interior through the April 4, 1983, memorandum from the Director, Office of Management and Budget. The FICCDC was established to coordinate the collection and use of digital cartographic base data within the Federal Government. The Geological Survey has the responsibility for this coordination activity under its statutory authority to conduct the National Mapping Program.

C. Interagency Cadastral Coordination Council (ICCC). The Secretary of the Interior, by letter dated April 9, 1980, to the Honorable Sidney R. Yates, Chairman, Subcommittee on Interior and Related Agencies, Committee on Appropriations, 96th Congress, established the ICCC to coordinate Federal cadastral surveying activities. The Bureau of Land Management has the responsibility for this coordination as a part of its cadastral surveying activities and statutory authority.

D. Federal Mapping Task Force (FMTF) Report, July 1973). This OMB report documented the findings of a comprehensive study of the civil agency mapping and surveying programs, related activities, and supporting research and development activities. The report made significant recommendations for Federal mapping, charting, and geodesy program improvements and organizational changes. Subsequently, the Department has taken positive action toward increasing responsiveness to national mapping requirements and toward improving coordination in surveying and mapping activities.

1.3 **Scope.** In order to implement the Department=s position on Federal mapping and surveying policy and programs coordination, systems have been developed for coordination and program planning both within the Department of the Interior and with other agencies as described in paragraph 1.2. In addition, the Department coordinates its cadastral, engineering, geodetic, and cartographic surveying activities through lead agency assignments; has established the National Mapping Program (defined in 757 DM 3) to meet base mapping needs of the Department, other agencies and the general public; has developed the National Cartographic Information Center to provide a central information system for all users including the general public on aerial photography, surveying, mapping, and related data; and coordinates its mapping and surveying research and development. The Department=s policies and programs for implementing each of these areas are explained in 757 DM 2 (Surveying) and 757 DM 3 (Mapping).

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757 DM 1
Appendix 1

Executive Office of the President
Bureau of the Budget
Washington, DC 20503

May 6, 1967

CIRCULAR NO. A-16
Revised

TO THE HEADS OF EXECUTIVE DEPARTMENTS AND ESTABLISHMENTS

SUBJECT: Coordination of surveying and mapping activities

1. Purpose. This revised Circular describes the responsibilities of Federal Agencies with respect to coordination of the Federal surveying and mapping activities described in paragraph 2, below. It rescinds and replaces Circular No. A-16, dated January 16, 1953. Exhibits A, B, C, and D to that Circular will remain in effect until replaced pursuant to paragraph 4 of this Circular.

2. Coverage. The coordinating procedures established by this Circular extend to all surveying and mapping activities financed in whole or in part by Federal funds which:

a. Can contribute to the National Topographic Map Series of the United States and outlying areas of sovereignty and jurisdiction, the National Atlas of the United States of America, the National Networks of Geodetic Control, or such other national geodetic control and topographic mapping programs as may be established; or

b. Result in cartographic representation of international boundaries other than those of the United States with Canada and Mexico.

Surveying and mapping activities conducted or supported by a Federal agency to meet specific program needs of the agency which are not met by the national surveying and mapping programs specified in paragraph 2A above and which cannot practicably or economically contribute to the national programs are excluded from coverage. Determination of the surveying and mapping activities which are required to meet program needs is the responsibility of the program agency. However, evaluation of the potential contribution of those activities to a national surveying or mapping program should be made by such agency in consultation, or pursuant to a general agreement, with the responsible agency as described below.

3. Responsibility for coordination.

a. The Department of the Interior is responsible for the National Topographic Map Series of the United States and outlying areas of sovereignty and jurisdiction and for the National Atlas of the United States of America. It also operates the Map Information Office, which collects and furnishes to potential users information concerning aerial photography, topographic mapping, and survey data available from Federal agencies for general use, and the sources from which they may be obtained.

In carrying out these functions the Department exercises Government-wide leadership in assuring coordinated planning and execution of its national topographic mapping, National Atlas, and map information activities and the cartographic activities of other Federal agencies related thereto, including activities financed in whole or in part by such agencies to the end that:

(1) The topographic mapping, National Atlas, and map information needs of Government agencies and the public at large are met in the most expeditious and economical manner possible with available resources;

(2) All mapping activities financed in whole or in part by Federal funds contribute to the national topographic mapping program when it is practicable and economical to do so; and

(3) Aerial photography, topographic mapping, and survey data produced by Federal agencies are conveniently accessible for use in meeting the cartographic needs of other Federal agencies and federally assisted programs.

The Department will also arrange through periodic meetings or other appropriate means, for an exchange of information among Federal agencies concerning technological developments in civilian agencies with respect to cartographic activities.

b. The Department of Commerce is responsible for the National Networks of Geodetic Control and publishes status maps of geodetic control which meet the standards for inclusion in the national networks.

In carrying out this function the Department exercises Government-wide leadership in assuring coordinated planning and execution of its national geodetic control surveys and the related survey activities of Federal agencies, including activities financed in whole or in part by such agencies, to the end that:

(1) The geodetic control needs of Government agencies and the public at large are met in the most expeditious and economical manner possible with available resources; and

(2) All surveying activities financed in whole or in part by Federal funds contribute to the National Networks of Geodetic Control when it is practicable and economical to do so.

c. The Department of State exercises Government-wide leadership to assure that cartographic representatives of international boundaries, other than those of the United States with Canada or Mexico, by all Federal agencies are consistent and conform to United States foreign policy.

4. Establishment of coordinating mechanisms. Each agency named in paragraph 3 above will, in consultation with other Federal agencies concerned, establish such standards, procedures, interagency agreements, and other mechanisms as are necessary to carry out its Government-wide coordinating responsibilities and to replace, where required, Exhibit A, B, C, or D of this Circular.

5. Responsibilities of other Federal agencies. Each Federal agency is responsible for (a) cooperating as requested in the development

of appropriate coordinating mechanisms; (b) supplying necessary information to the coordinating agency concerning its cartographic requirements, programs, activities, and products; and (c) conducting its surveying, mapping, and product distribution activities in a manner which provides effective Government-wide coordination and efficient service to the general public.

6. Differences among agencies. Any major differences which cannot be resolved through consultation among agencies with respect to the coordination of cartographic activities covered by this Circular may be referred by the head of any agency concerned to the Director of the Bureau of the Budget.

PHILLIP S. HUGHES
Acting Director
*
11/29/88 #3552
Replaces 11/29/88 #2821

APPENDIX D

DOI DEPARTMENTAL MANUAL – SURVEYING AND MAPPING – SURVEYING

Department of the Interior

Departmental Manual

Effective Date: 11/29/88
Series: Special Programs
Part 757: Surveying and Mapping
Chapter 2: Surveying

Originating Office: U.S. Geological Survey

This chapter has been given a new release number.* No text changes were made.

757 DM 2

2.1 **Purpose**. This chapter prescribes policy, responsibility, coordination, and procedures for geodetic, cartographic, and cadastral surveys performed by the bureaus and offices of the Department.

2.2 **Definitions**. For the purpose of this chapter, the following definitions apply:

A. Geodetic Surveying. Includes first-, second-, and third-order horizontal and vertical control surveys by precise measurement of distances, angles, and elevation differences; satellite surveys to determine relative and absolute position including elevation difference derived through geoid studies; gravimetric surveys; astronomic observations for latitude, longitude, and azimuth; and computations for latitude, longitude, and azimuth; and computations and adjustments of the field observations.

B. Cartographic Surveying. Includes photoidentification and establishment of field control as needed for specific mapping projects, and the extension of control by photogrammetric aerotriangulation.

C. Cadastral Surveying (Public Lands). Consists of the creation and reestablishment of public land boundaries, the subdivision of these areas and the determination of the amount of area within such surveys; the preparation of the official plat and written record of these surveys to be used in describing lands for patents, leases, or retention for Federal management purposes. Includes the preparation of protracted Federal boundaries over unsurveyed lands and offshore areas on the Outer Continental Shelf. Refer also to 757 DM 2.3C, Public Land Survey System and 2.3D, the Offshore Protraction Survey Program.

2.3 **National Programs**.

A. The National Geodetic Control Networks (NGCN). The NGCN are the responsibility of the National Geodetic Survey Division, Charting and Geodetic Services, National

Ocean Service, NOAA, Department of Commerce, and consist of monumented and described first- and second-order vertical and horizontal geodetic network stations. The vertical network provides accurate elevations, and the horizontal network provides accurate geographic positions. Those networks consist of:

(1) Net Control. The basic frameworks of first-order lines and control.

(2) Area Control. Lines and stations, generally second-order, but also including third-order, that fill in where high density of control is needed.

Note: The networks are not complete, and monuments are subject to attrition. In an effort to support completion and maintenance of the NGCN, OMB directed, through Circular A-16, that Federal agencies should plan their surveys so as to assist in the establishment, densification, and maintenance of the NGCN whenever practical and economical. The Federal Mapping Task Force on Mapping, Charting, Geodesy and Surveying, in its report of July 1973, reaffirmed this charge, and the Department of the Interior has agreed.

B. National Mapping Program (NMP). The NMP is the responsibility of the Geological Survey, as defined in 757 DM 3. It includes those activities necessary to make available a family of maps and basic map data. Cartographic surveying, which is one of those activities, is required, along with geodetic surveying, to assure that the basic maps and map data meet horizontal and vertical accuracy standards as promulgated by the Bureau of the Budget in 1941, revised 1943 and 1947. These accuracy standards appear as Appendix 1 to this chapter. The monuments established under the Public Land Survey System and their data values are used to supplement the geodetic control required in the NMP.

C. Public Land Survey System (PLSS). The PLSS is the responsibility of the Bureau of Land Management (BLM) and is the official system for establishing, reestablishing, and describing the boundaries of the public lands of the United States. The system was authorized by the Land Ordinance of 1785 and includes the creation of land boundaries following a prescribed rectangular pattern, the establishment of monuments in/on the ground, and the preparation of a narrative and graphic record of the survey which, upon official acceptance and approval, becomes a quasi-legal document and enters the public domain. These records are then used in two general areas of local and national importance: they form the basis of and become a part of the patents issued when public lands pass out of Federal ownership; and they form the basis for the overall administration and management of the lands retained in Federal ownership. Modern needs create a demand for more explicit data in these survey records, and sophisticated instruments and methods are used in establishing the survey grid on the ground. The Bureau of Land Management has the authority to survey all Federal interest lands, trust territories, and Indian lands (see 1973 edition, AManual of Surveying Instructions....,@ published by BLM). The legal responsibility of the Department and Bureau of Land Management for physical corner positions ends when all land and mineral rights controlled by the corner positions pass from Federal ownership.

However, under certain conditions, specified in the United States Code, BLM can resurvey in private land areas. Geographic positions of certain land corners continue as a Federal concern insofar as they relate to the responsibilities of the National Mapping Program (see 757 DM 3) and to other public and Federal automated mapping needs. The BLM Public Land Survey System (PLSS) is the foundation for all legal land parcel descriptions in the public land States, whether Federal, State, local, or private. The BLM Geographic Coordinate Data Base (GCDB) is derived from the PLSS and provides the mechanism for graphic representation of legal parcels and the registration of land records and resources information to a common geographic coordinate reference.

D. The Offshore Protraction Survey Program. The grid protraction and determination of offshore boundaries on the Outer Continental Shelf are required for management of the Federal offshore mineral leasing program. The Minerals Management Service (MMS) is responsible for the preparation of the official graphic record of such protracted areas, Supplemental Official Block Diagrams, Outer Continental Shelf Official Protraction Diagrams and Leasing Maps.

2.4 **Policy Guidelines.**

A. The Department is committed to support the development and maintenance of the NGCN, the accomplishment of cartographic surveys in support of the NMP, and is bound by statute to carry out and maintain the PLSS.

B. Geodetic control surveys will be connected to NGCN and will be documented and monumented to Federal Geodetic Coordinating Committees (FGCC) standards wherever practical. These standards are titled, AStandards and Specifications for Geodetic Control Networks,@ Department of Commerce, 1984.

C. Geographic positions of PLSS corners will be established by direct ties or by calculation to aid in computer and graphic use of PLSS data.

D. The limits and delineation of the boundaries of the Outer Continental Shelf for natural resource administration, management, and development purposes will be determined by the MMS, following statutory and judicial guidelines.

2.5 **Geodetic Surveying.**

A. Policy. Departmental geodetic surveys will, where practical, contribute to the development and maintenance of the NGCN as well as the control needs of other Interior and national programs. Bureaus with significant survey programs will:

(1) Determine the status of the NGCN in projected areas. If NGCN control is deficient, Bureau plans will be augmented to improve NGCN status if practical.

(2) Connect all second- and third-order surveys to NGCN.

(3) Monument and describe according to Federal Geodetic Control Committee (FGCC) standards.

B. Responsibilities.

(1) Lead Bureau. The Geological Survey (GS) will provide the Department representative to the FGCC and will coordinate the Department=s geodetic survey requirements in cooperation with bureaus and offices and with FGCC. The BLM is, however, a member of the FGCC for cadastral survey matters. Geological Survey will also make Departmental geodetic data available through the National Cartographic Information Center (NCIC) until it is available from the National Geodetic Survey Division (NGSD), at which time the responsibility will be assumed by the National Geodetic Survey Information Center (NGSIC) of NGSD.

(2) Other Bureaus and Offices. Other Interior bureaus and offices will cooperate and coordinate with the Geological Survey in planning and establishing geodetic surveys, and will furnish all new geodetic data to GS for transmittal to NGSD.

(3) National Geodetic Survey Division (NGSD), Charting and Geodetic Services (C&GS), National Ocean Service, NOAA, Department of Commerce. NGSD has agreed to store, retrieve, and distribute geodetic data provided to them in accordance with FGCC standards.

C. Coordination. Bureaus and offices should use one or both of the following approaches:

(1) Long-range Planning. Bureaus and offices should determine the status of NGCN control for planning, with Geological Survey assistance if necessary. They should then review survey plans with GS to determine what modifications might be practical to contribute to NGCN or other control survey needs.

(2) Isolated Surveys. Bureaus and offices should evaluate surveys that do not fit 757 DM 2.5C(1), Long-range Planning, to determine whether they contribute to NGCN. Planning should include consultations with GS on the best procedures to follow.

D. Funding. Wherever feasible, bureaus and offices will absorb extra costs required to execute geodetic surveys to NGCN standards, including monumentation. If funding is not available, the bureau or office and GS will develop plans and means for appropriate action.

2.6 **Cartographic Surveying.**

A. Policy. Cartographic surveys will be conducted in such a way as to contribute to the overall control requirements of the Department as well as to the NGCN wherever practical. Surveys of third-order accuracy or better, performed as part of a cartographic project, are geodetic surveys and will be treated as stated in 757

DM 2.5, Geodetic Surveying.

B. Responsibilities.

(1) Lead Bureau. The Geological Survey is the lead bureau for coordination of the Department=s cartographic surveys.

(2) Other Bureaus and Offices. Other Interior bureaus and offices will cooperate and coordinate with GS in establishing cartographic surveys.

C. Coordination. Bureaus and offices should request the current status of control from the GS for planning, then review their plans with GS to determine what modifications, if any, are necessary to meet NGCN requirements, increase area control coverage, other otherwise meet Departmental survey needs.

2.7 **Cadastral Surveying.**

A. Policy. Departmental cadastral surveying will follow the Manual of Instructions for the Survey of the Public Lands of the United States (1973 edition), and its amendments and supplements published by BLM.

B. Responsibilities.

(1) Lead Bureau. The Bureau of Land Management is responsible for the administration, coordination, and execution of the PLSS. This includes the establishment and maintenance of a system for the storage and dissemination of survey data for use by local and national realty, land title, and mapping interests. BLM is developing an automated Geographic Coordinate Data Base (GCDB) of all corner positions established or reestablished under, or directly related to, the PLSS. BLM is the custodian of the official U.S. public land survey records and maintains public information centers in these states which still have active cadastral survey programs and in Washington, D.C. BLM is responsible for establishing a direct line of cadastral survey data communication to the Department=s National Mapping Program (GS) on a continuing basis (see 757 DM 2.3B, National Mapping Program).

(a) BLM responsibilities include the segregation by survey of valid private rights acquired from a variety of public land laws including the general mining laws.

(b) BLM is also authorized (43 USC 773) to perform PLSS surveys for other Federal departments and agencies, State and local Governments, and certain private interests.

(2) Minerals Management Service is responsible for determining the Federal offshore boundaries on the Outer Continental Shelf for minerals management purposes.

(3) All Interior bureaus and offices will coordinate their

cadastral surveying needs with BLM. They will report to BLM all actions taken which serve to change the official PLSS records. The Bureau of Reclamation has specific authority to conduct cadastral surveys on certain public lands withdrawn for reclamation purposes under BLM instructions and with BLM approval. BLM is specifically required to execute cadastral surveys for the Bureau of Indian Affairs on Indian reservations.

C. Coordination. All bureaus and offices shall submit their requirements for cadastral surveys to BLM with adequate lead time for program implementation. BLM working through the ICCC will determine the appropriate action necessary to satisfy the needs of each request. This may include the use of existing survey data or original surveys or resurveys by BLM. In those cases where BLM authorizes other agencies to perform the actual survey work, BLM will provide the necessary instructions, guidance, and official approval of the records. The records of such surveys will then also enter the public domain.

D. New (original) cadastral surveys requested by the Interior bureaus and other Federal agencies will normally be funded by BLM. Most resurveys required by non-BLM agencies will require reimbursement to BLM.

2.8 **General Coordination.** In accordance with responsibilities assigned in this Chapter, GS and BLM will:

A. Coordinate surveying needs of bureaus and offices for geodetic or cartographic and cadastral surveys, respectively.

B. Assist other bureaus and offices in long-range planning for surveys.

C. Provide technical guidance and assistance, as appropriate, where needed to attain Departmental objectives.

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757 DM 2
Appendix 1

UNITED STATES NATIONAL MAP ACCURACY STANDARDS

With a view to the utmost economy and expedition in producing maps which fulfill not only the broad needs for standard or principal maps, but also the reasonable particular needs of individual agencies, standards of accuracy for published maps are defined as follows:

1. Horizontal accuracy. For maps on publication scales larger than 1:20,000, not more than 10 percent of the points tested shall be in error by more than 1/30 inch, measured on the publication scale;

for maps on publication scales of 1:20,000 or smaller, 1/50 inch. These limits of accuracy shall apply in all cases to positions of well defined points only. AWell defined@ points are those that are easily visible or recoverable on the ground, such as the following: monuments or markers, such as bench marks, property boundary monuments; intersections of roads, railroads, etc.; corners of large buildings or structures (or center points of small buildings); etc. In general what is Awell defined@ will also be determined by what is plottable on the scale of the map within 1/100 inch. Thus while the intersection of two road or property lines meeting at right angles, would come within a sensible interpretation, identification of the intersection of such lines meeting at an acute angle would obviously not be practicable with 1/100 inch. Similarly, features not identifiable upon the ground within close limits are not to be considered as test points within the limits quoted, even though their positions may be scaled closely upon the map. In this class would come timber lines, soil boundaries, etc.

2. Vertical accuracy, as applied to contour maps on all publication scales, shall be such that not more than 10 percent of the elevations tested shall be in error more than one-half the contour interval. In checking elevations taken from the map, the apparent vertical error may be decreased by assuming a horizontal displacement within the permissible horizontal error for a map of that scale.

3. The accuracy of any map may be tested by comparing the positions of points whose locations or elevations are shown upon it with corresponding positions as determined by surveys of higher accuracy. Tests shall be made by the producing agency, which shall also determine which of its maps are to be tested, and the extent of such testing.

4. Published maps meeting these accuracy requirements shall note this fact in their legends, as follows: AThis map complies with national map accuracy standards.@

5. Published maps whose errors exceed those aforestated shall omit from their legends all mention of standard accuracy.

6. When a published map is a considerable enlargement of a map drawing (Amanuscript@) or of a published map, that fact shall be stated in the legend. For example, AThis map is an enlargement of a 1:20,000 scale map drawing,@ or AThis map is an enlargement of a 1:24,000 scale published map.@

7. To facilitate ready interchange and use of basic information for map construction among all Federal mapmaking agencies, manuscript maps and published maps, wherever economically feasible and consistent with the uses to which the map is to be put, shall conform to latitude and longitude boundaries, being 15 minutes of latitude and longitude, or 7 1/2 minutes, or 3 3/4 minutes in size.
*
11/29/88 #3553
Replaces 11/29/88 #2821

APPENDIX E

DOI DEPARTMENTAL MANUAL – SURVEYING AND MAPPING – MAPPING

Department of the Interior

Departmental Manual

Effective Date: 11/29/88
Series: Special Programs
Part 757: Surveying and Mapping
Chapter 3: Mapping

Originating Office: U.S. Geological Survey

This chapter has been given a new release number.* No text changes were made.

757 DM 3

3.1 **Purpose**. This chapter prescribes policy, responsibility, coordinating arrangements, and procedures for Departmental administration of mapping activities.

3.2 **The National Mapping Program**. In response to the findings and recommendations of the Federal Mapping Task Force cited in 757 DM 1, the Department has modified, extended, and renamed its National Topographic Program to serve better the basic cartographic data needs of the country. This new program, the National Mapping Program, includes those activities necessary to make available basic map data and a family of general-purpose maps. Certain of these map data categories (such as roads, structures, topography, streams, lakes, and shorelines) are identified as base map data categories. Other map data of public value may also be incorporated into the National Mapping Program and will be identified as non-base categories. The non-base categories will be developed and maintained by the responsible agencies and will be made available under cooperative agreement for the preparation of maps and other forms of cartographic display through the National Mapping Program=s coordination and dissemination arrangements.

3.3 **Definitions.**

A. Cartography. The art and science of expressing graphically or digitally by the use of maps, charts, or other displays, the known physical features of the Earth or extraterrestrial bodies, usually including the works of man and his varied activities.

B. Map. A spatial representation, usually on a plane surface, at scale, of a part or a whole of the Earth=s physical features (natural, artificial, or both), by the use of signs, symbols, or numeric representation. Also, a similar representation of an extraterrestrial body.

C. Mapping. The process of collecting and preparing data on spatially relatable features for presentation in graphical or digital form.

D. Base Map. A map showing selected fundamental information for multipurpose use; a general-purpose map.

E. Digital Map Data. Numerical data representing spatially-relatable physical features (natural, artificial, or both) that can be used in computations, statistical analysis, and graphical output.

F. Geographic Information System. A computer hardware and software system designed to collect, manage, analyze, and display spatially referenced data.

G. Base Map Data Category. A set of map data, at scale and of a prescribed level of content, that is normally produced in preparation of general-purpose maps. This set of basic map data can be available as individual features such as roads, streams, contours, etc., or in combinations. Base map data categories are:

(1) Reference systems B geographic and other coordinate systems except the public land survey network.

(2) Hypsography - contours, slopes, and elevations.

(3) Hydrography B streams and rivers, lakes and ponds, wetlands, reservoirs, and shorelines.

(4) Surface cover B woodland, orchards, vineyards, etc. (general categories only).

(5) Non-vegetative features B surface features normally designated by names or special symbols other than contour lines, such as playas, dunes, and barren waste areas.

(6) Boundaries B portrayal of political jurisdictions, national parks and forests, military reservations, etc. This category shows the boundaries as established by the various concerned agencies and jurisdictions and does not definitively set forth land ownership or land use.

(7) Transportation systems - roads, railroads, trails, canals, pipelines, transmission lines, bridges, tunnels, etc.

(8) Significant manmade structures such as buildings, airports, dams, and other landmark structures or objects.

(9) Identification and portrayal of geodetic control, survey monuments, and other survey markers.

(10) Geographic names.

(11) Orthophotographic imagery.

H. Non-base Map Data Category. A set of map data in graphical or digital form on specific themes or topics (such as land use or land ownership) that has general public value. These are generally combined with one or more of the base map data categories.

3.4 **Coverage.** The provisions of this chapter apply to all base maps and base map data categories and to those non-base map data categories that have general use and can be developed economically under cooperative agreement with the responsible agency. The provisions of this Chapter may not apply to those maps (such as recreational maps and statistical maps) that are essentially pictorial or schematic.

3.5 **Policy.** The base mapping activities of the bureaus will be part of the National Mapping Program through partnership arrangements with the Geological Survey. To avoid duplication of effort, and assure compatibility of data, mapping and map production processes will be adapted when practical to use the categories available under the National Mapping Programs. Bureaus will not independently develop such categories.

3.6 **Responsibilities.**

A. Lead Agency. The Geological Survey is the lead agency for the administration of the National Mapping Program. This includes coordinating, planning, managing, compiling, defining, and approving the National Mapping Program categories, and assuring the availability of the resulting map data and materials to users.

B. Base Map Data Categories. The Geological Survey is responsible for defining and maintaining the base map categories of the National Mapping Program and will make these data available in forms that contribute to their timely and effective use. In cases where the base map category data is not available, the Geological Survey and the requiring bureau or office shall determine the developmental actions to be taken so that data will be available and also incorporated into the basic files of the National Mapping Program.

C. Non-base Map Data Categories. The agency which is responsible for a data system that produces spatial data not included in the base categories will generally develop and maintain these non-base category data. Agencies will evaluate their data collection systems in cooperation with the Geological Survey to review the overall need for cartographic data that is or can be derived from the agency data systems. When sufficient general need is determined the category should be incorporated into the National Mapping Program. Should the non-base category become a requirement of the National Digital Cartographic Data Base, the agency maintaining the non-base cartographic data is responsible for modifying its processes for the data for compatibility with the National Mapping Program standards. The responsible agency will also establish, by agreement with the Geological Survey, the arrangements for making the non-base category information available through the National Mapping Program.

D. Map Printing. Each agency is responsible for the efficient and economical printing of the maps it produces. In exercising this responsibility the bureau or office will consider the map reproduction capabilities of the Geological Survey and use them where appropriate.

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11/29/88 #3554
Replaces 11/29/88 #2821

APPENDIX F

ASPRS POSITIONAL ACCURACY STANDARDS FOR GEOSPATIAL DATA – VERSION 1.0) – NOVEMBER 2014

ASPRS Positional Accuracy Standards for Digital Geospatial Data

(EDITION 1, VERSION 1.0. - NOVEMBER, 2014)

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FOREWORD

The goal of American Society for Photogrammetry and Remote Sensing (ASPRS) is to advance the science of photogrammetry and remote sensing; to educate individuals in the science of photogrammetry and remote sensing; to foster the exchange of information pertaining to the science of photogrammetry and remote sensing; to develop, place into practice, and maintain standards and ethics applicable to aspects of the science; to provide a means for the exchange of ideas among those interested in the sciences; and to encourage, publish and distribute books, periodicals, treatises, and other scholarly and practical works to further the science of photogrammetry and remote sensing.

This standard was developed by the ASPRS Map Accuracy Standards Working Group, a joint committee under the Photogrammetric Applications Division, Primary Data Acquisition Division, and Lidar Division, which was formed for the purpose of reviewing and updating ASPRS map accuracy standards to reflect current technologies. A subcommittee of this group, consisting of Dr. Qassim Abdullah of Woolpert, Inc., Dr. David Maune of Dewberry Consultants, Doug Smith of David C. Smith and Associates, Inc., and Hans Karl Heidemann of the U.S. Geological Survey, was responsible for drafting the document.

ASPRS POSITIONAL ACCURACY STANDARDS FOR DIGITAL GEOSPATIAL DATA

1. PURPOSE

The objective of the *ASPRS Positional Accuracy Standards for Digital Geospatial Data* is to replace the existing *ASPRS Accuracy Standards for Large-Scale Maps* (1990), and the *ASPRS Guidelines, Vertical Accuracy Reporting for Lidar Data* (2004) to better address current technologies.

This standard includes positional accuracy standards for digital orthoimagery, digital planimetric data and digital elevation data. Accuracy classes, based on RMSE values, have been revised and upgraded from the 1990 standard to address the higher accuracies achievable with newer technologies. The standard also includes additional accuracy measures, such as orthoimagery seam lines, aerial triangulation accuracy, lidar relative swath-to-swath accuracy, recommended minimum Nominal Pulse Density (NPD), horizontal accuracy of elevation data, delineation of low confidence areas for vertical data, and the required number and spatial distribution of checkpoints based on project area.

1.1 Scope and Applicability

This standard addresses geo-location accuracies of geospatial products and it is not intended to cover classification accuracy of thematic maps. Further, the standard does not specify the best practices or methodologies needed to meet the accuracy thresholds stated herein. Specific requirements for the testing methodologies are specified as are some of the key elemental steps that are critical to the development of data if they are to meet these standards. However, it is the responsibility of the data provider to establish all final project design parameters, implementation steps and quality control procedures necessary to ensure the data meets final accuracy requirements.

The standard is intended to be used by geospatial data providers and users to specify the positional accuracy requirements for final geospatial products.

1.2 Limitations

This standard is limited in scope to addressing accuracy thresholds and testing methodologies for the most common mapping applications and to meet immediate shortcomings in the outdated 1990 and 2004 standards referenced above. While the standard is intended to be technology independent and broad based, there are several specific accuracy assessment needs that were identified but are not addressed herein at this time, including:

1. Methodologies for accuracy assessment of linear features (as opposed to well defined points);
2. Rigorous total propagated uncertainty (TPU) modeling (as opposed to – or in addition to – ground truthing against independent data sources);
3. Robust statistics for data sets that do not meet the criteria for normally distributed data and therefore cannot be rigorously assessed using the statistical methods specified herein;
4. Image quality factors, such as edge definition and other characteristics;
5. Robust assessment of checkpoint distribution and density;
6. Alternate methodologies to TIN interpolation for vertical accuracy assessment.

This standard is intended to be the initial component upon which future work can build. Additional supplemental standards or modules should be pursued and added by subject matter experts in these fields as they are developed and approved by the ASPRS.

At this time this standard does not reference existing international standards. International standards could be addressed in future modules or versions of this standard if needed.

1.3 Structure and Format

The standard is structured as follows: The primary terms and definitions, references, and requirements are stated within the main body of the standard, according to the ASPRS standards template and without extensive explanation or justification. Detailed supporting guidelines and background information are attached as Annexes A through D. Annex A provides a background summary of other standards, specifications and/or guidelines relevant to ASPRS but which do not satisfy current requirements for digital geospatial data. Annex B provides accuracy/quality examples and overall guidelines for implementing the standard. Annex C provides guidelines for accuracy testing and reporting. Annex D provides guidelines for statistical assessment and examples for computing vertical accuracy in vegetated and non-vegetated terrain.

2. CONFORMANCE

No conformance requirements are established for this standard.

3. REFERENCES

American Society for Photogrammetry and Remote Sensing (ASPRS), 2013. *ASPRS Accuracy Standards for Digital Geospatial Data (DRAFT)*, *PE&RS*, December 2013, pp 1073-1085.

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National Geodetic Survey (NGS), 1997. NOAA Technical Memorandum NOS NGS-58, V. 4.3: Guidelines for Establishing GPS-Derived Ellipsoid Heights (Standards: 2 cm and 5 cm), URL: *https://www.ngs.noaa.gov/PUBS_LIB/NGS-58.html* (last date accessed: 22 January 2015)

National Geodetic Survey (NGS), 2008. NOAA Technical Memorandum NOS NGS-59, V1.5: Guidelines for Establishing GPS-Derived Orthometric Heights, URL: *http://www.ngs.noaa.gov/PUBS_LIB/NGS592008069FINAL2.pdf* (last date accessed: 22 January 2015).

Additional informative references for other relevant and related guidelines and specifications are included in Annex A.

4. AUTHORITY

The responsible organization for preparing, maintaining, and coordinating work on this guideline is the American Society for Photogrammetry and Remote Sensing (ASPRS), Map Accuracy Standards Working Group, a joint committee formed by the Photogrammetric Applications Division, Primary Data Acquisition Division, and the Lidar Division. For further information, contact the Division Directors using the contact information posted on the ASPRS website, www.asprs.org.

5. TERMS AND DEFINITIONS

absolute accuracy – A measure that accounts for all systematic and random errors in a data set.

accuracy – The closeness of an estimated value (for example, measured or computed) to a standard or accepted (true) value of a particular quantity. Not to be confused with *precision*.

bias – A systematic error inherent in measurements due to some deficiency in the measurement process or subsequent processing.

blunder – A mistake resulting from carelessness or negligence.

confidence level – The percentage of points within a data set that are estimated to meet the stated accuracy; e.g., 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 are equal to or smaller than the reported accuracy value.

consolidated vertical accuracy (CVA) – Replaced by the term Vegetated Vertical Accuracy (VVA) in this standard, CVA is the term used by the NDEP guidelines for vertical accuracy at the 95th percentile in all land cover categories combined.

fundamental vertical accuracy (FVA) – Replaced by the term Non-vegetated Vertical Accuracy (NVA), in this standard, FVA is the term used by the NDEP guidelines for vertical accuracy at the 95% confidence level in open terrain only where errors should approximate a normal error distribution.

ground sample distance (GSD) – The linear dimension of a sample pixel's footprint on the ground. Within this document GSD is used when referring to the collection GSD of the raw image, assuming near-vertical imagery. The actual GSD of each pixel is not uniform throughout the raw image and varies significantly with terrain height and other factors. Within this document, GSD is assumed to be the value computed using the calibrated camera focal length and camera height above average horizontal terrain.

horizontal accuracy − The horizontal (radial) component of the positional accuracy of a data set with respect to a horizontal datum, at a specified confidence level.

inertial measurement unit (IMU) – The primary component of an INS. Measures 3 components of acceleration and 3 components of rotation using orthogonal triads of accelerometers and gyros.

inertial navigation system (INS) – A self-contained navigation system, comprised of several subsystems: IMU, navigation computer, power supply, interface, etc. Uses measured accelerations and rotations to estimate velocity, position and orientation. An unaided INS loses accuracy over time, due to gyro drift.

kurtosis –The measure of relative "peakedness" or flatness of a distribution compared with a normally distributed data set. Positive kurtosis indicates a relatively peaked distribution near the mean while negative kurtosis indicates a flat distribution near the mean.

local accuracy – The uncertainty in the coordinates of points with respect to coordinates of other directly connected, adjacent points at the 95% confidence level.

mean error – The average positional error in a set of values for one dimension (x, y, or z); obtained by adding all errors in a single dimension together and then dividing by the total number of errors for that dimension.

network accuracy – The uncertainty in the coordinates of mapped points with respect to the geodetic datum at the 95% confidence level.

non-vegetated vertical accuracy (NVA) – The vertical accuracy at the 95% confidence level in non-vegetated open terrain, where errors should approximate a normal distribution.

percentile – A measure used in statistics indicating the value below which a given percentage of observations in a group of observations fall. For example, the 95th percentile is the value (or score) below which 95 percent of the observations may be found. For accuracy testing, percentile calculations are based on the absolute values of the errors, as it is the magnitude of the errors, not the sign that is of concern.

pixel resolution or pixel size – As used within this document, pixel size is the ground size of a pixel in a digital orthoimage, after all rectifications and resampling procedures.

positional error – The difference between data set coordinate values and coordinate values from an independent source of higher accuracy for identical points.

positional accuracy – The accuracy of the position of features, including horizontal and vertical positions, with respect to horizontal and vertical datums.

precision (repeatability) – The closeness with which measurements agree with each other, even though they may all contain a systematic bias.

relative accuracy – A measure of variation in point-to-point accuracy in a data set.

resolution – The smallest unit a sensor can detect or the smallest unit an orthoimage depicts. The degree of fineness to which a measurement can be made.

root-mean-square error (RMSE) – The square root of the average of the set of squared differences between data set coordinate values and coordinate values from an independent source of higher accuracy for identical points.

skew – A measure of symmetry or asymmetry within a data set. Symmetric data will have skewness towards zero.

standard deviation – A measure of spread or dispersion of a sample of errors around the sample mean error. It is a measure of precision, rather than accuracy; the standard deviation does not account for uncorrected systematic errors.

supplemental vertical accuracy (SVA) – Merged into the Vegetated Vertical Accuracy (VVA) in this standard, SVA is the NDEP guidelines term for reporting the vertical accuracy at the 95^{th} percentile in each separate land cover category where vertical errors may not follow a normal error distribution.

systematic error – An error whose algebraic sign and, to some extent, magnitude bears a fixed relation to some condition or set of conditions. Systematic errors follow some fixed pattern and are introduced by data collection procedures, processing or given datum.

uncertainty (of measurement) – a parameter that characterizes the dispersion of measured values, or the range in which the "true" value most likely lies. It can also be defined as an estimate of the limits of the error in a measurement (where "error" is defined as the difference between the theoretically-unknowable "true" value of a parameter and its measured value).Standard uncertainty refers to uncertainty expressed as a standard deviation.

vegetated vertical accuracy (VVA) – An estimate of the vertical accuracy, based on the 95^{th} percentile, in vegetated terrain where errors do not necessarily approximate a normal distribution.

vertical accuracy – The measure of the positional accuracy of a data set with respect to a specified vertical datum, at a specified confidence level or percentile.

For additional terms and more comprehensive definitions of the terms above, reference is made to the *Glossary of Mapping Sciences*; *Manual of Photogrammetry,* 6^{th} edition; *Digital Elevation Model Technologies and Applications: The DEM Users Manual,* 2^{nd} edition; and/or the *Manual of Airborne Topographic Lidar*, all published by ASPRS.

6. SYMBOLS, ABBREVIATED TERMS, AND NOTATIONS

ACC_r – the horizontal (radial) accuracy at the 95% confidence level
ACC_z – the vertical linear accuracy at the 95% confidence level
ASPRS – American Society for Photogrammetry and Remote Sensing
CVA – Consolidated Vertical Accuracy
DEM – Digital Elevation Model
DTM – Digital Terrain Model
FVA – Fundamental Vertical Accuracy
GSD – Ground Sample Distance
GNSS - Global Navigation Satellite System
GPS – Global Positioning System
IMU – Inertial Measurement Unit
INS – Inertial Navigation System
NGPS − Nominal Ground Point Spacing
NPD − Nominal Pulse Density
NMAS − National Map Accuracy Standard
NPS − Nominal Pulse Spacing
NSSDA − National Standard for Spatial Data Accuracy
NVA − Non-vegetated Vertical Accuracy
$RMSE_r$ − the horizontal linear RMSE in the radial direction that includes both x- and y-coordinate errors.
$RMSE_x$ − the horizontal linear RMSE in the X direction (Easting)
$RMSE_y$ − the horizontal linear RMSE in the Y direction (Northing)
$RMSE_z$ − the vertical linear RMSE in the Z direction (Elevation)
RMSE − root-mean-square-error
$RMSD_z$ − root-mean-square-difference in elevation (z)
SVA – Supplemental Vertical Accuracy
TIN – Triangulated Irregular Network
VVA − Vegetated Vertical Accuracy
$\bar{x}$ − sample mean error, for x
s − sample standard deviation
γ_1 − sample skewness
γ_2 − sample kurtosis

7. SPECIFIC REQUIREMENTS

This standard defines accuracy classes based on RMSE thresholds for digital orthoimagery, digital planimetric data, and digital elevation data.

Testing is always recommended but may not be required for all data sets; specific requirements must be addressed in the project specifications.

When testing is required, horizontal accuracy shall be tested by comparing the planimetric coordinates of well-defined points in the data set with coordinates determined from an independent source of higher accuracy. Vertical accuracy shall be tested by comparing the elevations of the surface represented by the data set with elevations determined from an independent source of higher accuracy. This is done by comparing the elevations of the checkpoints with elevations interpolated from the data set at the same x/y coordinates. See Annex C, Section C.11 for detailed guidance on interpolation methods.

All accuracies are assumed to be relative to the published datum and ground control network used for the data set and as specified in the metadata. Ground control and checkpoint accuracies and processes should be established based on project requirements. Unless specified to the contrary, it is expected that all ground control and checkpoints should normally follow the guidelines for network accuracy as detailed in the Geospatial Positioning Accuracy Standards, Part 2: Standards for Geodetic Networks, Federal Geodetic Control Subcommittee, Federal Geographic Data Committee (FGDC-STD-007.2-1998). When local control is needed to meet specific accuracies or project needs, it must be clearly identified both in the project specifications and the metadata.

7.1 Statistical Assessment of Horizontal and Vertical Accuracies

Horizontal accuracy is to be assessed using root-mean-square-error (RMSE) statistics in the horizontal plane, i.e., $RMSE_x$, $RMSE_y$ and $RMSE_r$. Vertical accuracy is to be assessed in the z dimension only. For vertical accuracy testing, different methods are used in non-vegetated terrain (where errors typically follow a normal distribution suitable for RMSE statistical analyses) and vegetated terrain (where errors do not necessarily follow a normal distribution). When errors cannot be represented by a normal distribution, the 95th percentile value more fairly estimates accuracy at a 95% confidence level. For these reasons vertical accuracy is to be assessed using $RMSE_z$ statistics in non-vegetated terrain and 95th percentile statistics in vegetated terrain. Elevation data sets shall also be assessed for horizontal accuracy where possible, as outlined in Section 7.5.

With the exception of vertical data in vegetated terrain, error thresholds stated in this standard are presented in terms of the acceptable RMSE value. Corresponding estimates of accuracy at the 95% confidence level values are computed using *National Standard for Spatial Data Accuracy* (NSSDA) methodologies according to the assumptions and methods outlined in Annex D, Accuracy Statistics and Examples.

7.2 Assumptions Regarding Systematic Errors and Acceptable Mean Error

With the exception of vertical data in vegetated terrain, the assessment methods outlined in this standard, and in particular those related to computing NSSDA 95% confidence level estimates, assume that the data set errors are normally distributed and that any significant systematic errors or biases have been removed. It is the responsibility of the data provider to test and verify that the data meet those requirements including an evaluation of statistical parameters such as the kurtosis, skew, and mean error, as well as removal of systematic errors or biases in order to achieve an acceptable mean error prior to delivery.

The exact specification of an acceptable value for mean error may vary by project and should be negotiated between the data provider and the client. As a general rule, these standards recommend that the mean error be less than 25% of the specified RMSE value for the project. If a larger mean error is negotiated as acceptable, this should be documented in the metadata. In any case, mean errors that are greater than 25% of the target RMSE, whether identified pre-delivery or post-delivery, should be investigated to determine the cause of the error and to determine what actions, if any, should be taken. These findings should be clearly documented in the metadata.

Where RMSE testing is performed, discrepancies between the x, y, or z coordinates of the ground point check survey and the data set that exceed three times the specified RMSE error threshold shall be interpreted as blunders and should be investigated and either corrected or explained before the data is considered to meet this standard. Blunders may not be discarded without proper investigation and explanation in the metadata.

7.3 Horizontal Accuracy Standards for Geospatial Data

Table 7.1 specifies the primary horizontal accuracy standard for digital data, including digital orthoimagery, digital planimetric data, and scaled planimetric maps. This standard defines horizontal accuracy classes in terms of their $RMSE_x$ and $RMSE_y$ values. While prior ASPRS standards used numerical ranks for discrete accuracy classes tied directly to map scale (i.e., Class 1, Class 2, etc.), many modern applications require more flexibility than these classes allowed. Furthermore, many applications of horizontal accuracy cannot be tied directly to compilation scale, resolution of the source imagery, or final pixel resolution.

A Scope of Work, for example, can specify that digital orthoimagery, digital planimetric data, or scaled maps must be produced to meet ASPRS Accuracy Standards for 7.5 cm $RMSE_x$ and $RMSE_y$ Horizontal Accuracy Class.

Annex B includes extensive examples that relate accuracy classes of this standard to their equivalent classes according to legacy standards. $RMSE_x$ and $RMSE_y$ recommendations for digital orthoimagery of various pixel sizes are presented in Table B.5. Relationships to prior map accuracy standards are presented in Table B.6. Table B.6 lists $RMSE_x$ and $RMSE_y$ recommendations for digital planimetric data produced from digital imagery at various GSDs and their equivalent map scales according to the legacy standards of ASPRS 1990 and NMAS of 1947. The recommended associations of $RMSE_x$ and $RMSE_y$, pixel size, and GSD that are presented in the above mentioned tables of Annex B are based on current status of mapping technologies and best practices. Such associations may change in the future as mapping technologies continue to advance and evolve.

7.4 Vertical Accuracy Standards for Elevation Data

Vertical accuracy is computed using RMSE statistics in non-vegetated terrain and 95th percentile statistics in vegetated terrain. The naming convention for each vertical accuracy class is directly associated with the RMSE expected from the product. Table 7.2 provides the vertical accuracy classes naming convention for any digital elevation data. Horizontal accuracy requirements for elevation data are specified and reported independent of the vertical accuracy requirements. Section 7.5 outlines the horizontal accuracy requirements for elevation data.

Annex B includes examples on typical vertical accuracy values for digital elevation data and examples on relating the vertical accuracy of this standard to the legacy map standards. Table B.7 of Annex B lists 10 common vertical accuracy classes and their corresponding accuracy

TABLE 7.1 HORIZONTAL ACCURACY STANDARDS FOR GEOSPATIAL DATA

Horizontal Accuracy Class	Absolute Accuracy			Orthoimagery Mosaic Seamline Mismatch (cm)
	$RMSE_x$ and $RMSE_y$ (cm)	$RMSE_r$ (cm)	Horizontal Accuracy at 95% Confidence Level (cm)	
X-cm	≤*X*	≤1.414**X*	≤2.448**X*	≤ 2**X*

TABLE 7.2 VERTICAL ACCURACY STANDARDS FOR DIGITAL ELEVATION DATA

Vertical Accuracy Class	Absolute Accuracy			Relative Accuracy (where applicable)		
	$RMSE_z$ Non-Vegetated (cm)	NVA[1] at 95% Confidence Level (cm)	VVA[2] at 95th Percentile (cm)	Within-Swath Hard Surface Repeatability (Max Diff) (cm)	Swath-to-Swath Non-Vegetated Terrain ($RMSD_z$) (cm)	Swath-to-Swath Non-Vegetated Terrain (Max Diff) (cm)
X-cm	≤*X*	≤1.96**X*	≤3.00**X*	≤0.60**X*	≤0.80**X*	≤1.60**X*

values and other quality measures according to this standard. Table B.8 of Annex B provides the equivalent vertical accuracy measures for the same ten classes according to the legacy standards of ASPRS 1990 and NMAS of 1947. Table B.9 provides examples on vertical accuracy and the recommended lidar points density for digital elevation data according to the new ASPRS 2014 standard.

The Non-vegetated Vertical Accuracy at the 95% confidence level in non-vegetated terrain (NVA) is approximated by multiplying the accuracy value of the Vertical Accuracy Class (or $RMSE_z$) by 1.9600. This calculation includes survey checkpoints located in traditional open terrain (bare soil, sand, rocks, and short grass) and urban terrain (asphalt and concrete surfaces). The NVA, based on an $RMSE_z$ multiplier, should be used only in non-vegetated terrain where elevation errors typically follow a normal error distribution. $RMSE_z$-based statistics should not be used to estimate vertical accuracy in vegetated terrain or where elevation errors often do not follow a normal distribution.

The Vegetated Vertical Accuracy at the 95% confidence level in vegetated terrain (VVA) is computed as the 95th percentile of the absolute value of vertical errors in all vegetated land cover categories combined, including tall weeds and crops, brush lands, and fully forested areas. For all vertical accuracy classes, the VVA standard is 3.0 times the accuracy value of the Vertical Accuracy Class.

Both the $RMSE_z$ and 95th percentile methodologies specified above are currently widely accepted in standard practice and have been proven to work well for typical elevation data sets derived from current technologies. However, both methodologies have limitations, particularly when the number of checkpoints is small. As more robust statistical methods are developed and accepted, they will be added as new Annexes to supplement and/or supersede these existing methodologies.

7.5 Horizontal Accuracy Requirements for Elevation Data

This standard specifies horizontal accuracy thresholds for two types of digital elevation data with different horizontal accuracy requirements:

- **Photogrammetric Elevation Data:** For elevation data derived using stereo photogrammetry, the horizontal accuracy equates to the horizontal accuracy class that would apply to planimetric data or digital orthoimagery produced from the same source imagery, using the same aerial triangulation/INS solution.
- **Lidar Elevation Data:** Horizontal error in lidar derived elevation data is largely a function of positional error as derived from the Global Navigation Satellite System (GNSS), attitude (angular orientation) error (as derived from the INS) and flying altitude; and can be estimated based on these parameters. The following equation[3] provides an estimate for the horizontal accuracy for the lidar-derived data set assuming that the positional accuracy of the GNSS, the attitude accuracy of the Inertial Measurement Unit (IMU) and the flying altitude are known:

$$Lidar\ Horizontal\ Error\left(RMSE_r\right) = \sqrt{\left(GNSS\ positional\ error\right)^2 + \left(\frac{\tan(IMU\ error)}{0.55894170}\ x\ flying\ altitude\right)^2}$$

The above equation considers flying altitude (in meters), GNSS errors (radial, in cm), IMU errors (in decimal degrees), and other factors such as ranging and timing errors (which is estimated to be equal to 25% of the orientation errors). In the above equation, the values for the "GNSS positional error" and the "IMU error" can be derived from published manufacturer specifications for both the GNSS receiver and the IMU.

If the desired horizontal accuracy figure for lidar data is agreed upon, then the following equation can be used to estimate the flying altitude:

$$Flying\ Altitude \approx \frac{0.55894170}{\tan(IMU\ error)}\sqrt{\left(Lidar\ Horizontal\ Error\left(RMSEr\right)\right)^2 - \left(GNSS\ positional\ error\right)^2}$$

Table B.10 can be used as a guide to estimate the horizontal errors to be expected from lidar data at various flying altitudes, based on estimated GNSS and IMU errors.

[1] Statistically, in non-vegetated terrain and elsewhere when elevation errors follow a normal distribution, 68.27% of errors are within one standard deviation (s) of the mean error, 95.45% of errors are within (2 * s) of the mean error, and 99.73% of errors are within (3 * s) of the mean error. The equation (1.9600 * s) is used to approximate the maximum error either side of the mean that applies to 95% of the values. Standard deviations do not account for systematic errors in the data set that remain in the mean error. Because the mean error rarely equals zero, this must be accounted for. Based on empirical results, if the mean error is small, the sample size sufficiently large and the data is normally distributed, 1.9600 * $RMSE_z$ is often used as a simplified approximation to compute the NVA at a 95% confidence level. This approximation tends to overestimate the error range as the mean error increases. A precise estimate requires a more robust statistical computation based on the standard deviation and mean error. ASPRS encourages standard deviation, mean error, skew, kurtosis and RMSE to all be computed in error analyses in order to more fully evaluate the magnitude and distribution of the estimated error.

[2] VVA standards do not apply to areas previously defined as low confidence areas and delineated with a low confidence polygon (see Appendix C). If VVA accuracy is required for the full data set, supplemental field survey data may be required within low confidence areas where VVA accuracies cannot be achieved by the remote sensing method being used for the primary data set.

[3] The method presented here is one approach; there are other methods for estimating the horizontal accuracy of lidar data sets, which are not presented herein (Abdullah, Q., 2014, unpublished data).

Guidelines for testing the horizontal accuracy of elevation data sets derived from lidar are outlined in Annex C.

Horizontal accuracies at the 95% confidence level, using NSSDA reporting methods for either "produced to meet" or "tested to meet" specifications should be reported for all elevation data sets.

For technologies or project requirements other than as specified above for photogrammetry and airborne lidar, appropriate horizontal accuracies should be negotiated between the data provider and the client. Specific error thresholds, accuracy thresholds or methods for testing will depend on the technology used and project design. The data provider has the responsibility to establish appropriate methodologies, applicable to the technologies used, to verify that horizontal accuracies meet the stated project requirements.

7.6 Low Confidence Areas for Elevation Data

If the VVA standard cannot be met, low confidence area polygons shall be developed and explained in the metadata. For elevation data derived from imagery, the low confidence areas would include vegetated areas where the ground is not visible in stereo. For elevation data derived from lidar, the low confidence areas would include dense cornfields, mangrove or similar impenetrable vegetation. The low confidence area polygons are the digital equivalent to using dashed contours in past standards and practice. Annex C, Accuracy Testing and Reporting Guidelines, outlines specific guidelines for implementing low confidence area polygons.

7.7 Accuracy Requirements for Aerial Triangulation and INS-based Sensor Orientation of Digital Imagery

The quality and accuracy of the aerial triangulation (if performed) and/or the Inertial Navigation System-based (INS-based) sensor orientations (if used for direct orientation of the camera) play a key role in determining the final accuracy of imagery derived mapping products.

For photogrammetric data sets, the aerial triangulation and/or INS-based direct orientation accuracies must be of higher accuracy than is needed for the final, derived products.

For INS-based direct orientation, image orientation angles quality shall be evaluated by comparing checkpoint coordinates read from the imagery (using stereo photogrammetric measurements or other appropriate method) to the coordinates of the checkpoint as determined from higher accuracy source data .

Aerial triangulation accuracies shall be evaluated using one of the following methods:

1. By comparing the values of the coordinates of the checkpoints as computed in the aerial triangulation solution to the coordinates of the checkpoints as determined from higher accuracy source data;
2. By comparing the values of the coordinates read from the imagery (using stereo photogrammetric measurements or other appropriate method) to the coordinates of the checkpoint as determined from higher accuracy source data.

For projects providing deliverables that are only required to meet accuracies in x and y (orthoimagery or two-dimensional vector data), aerial triangulation errors in z have a smaller impact on the horizontal error budget than errors in x and y. In such cases, the aerial triangulation requirements for $RMSE_z$ can be relaxed. For this reason the standard recognizes two different criteria for aerial triangulation accuracy:

- Accuracy of aerial triangulation designed for digital planimetric data (orthoimagery and/or digital planimetric map) **only**:

  $RMSE_{x(AT)}$ or $RMSE_{y(AT)}$ = ½ * $RMSE_{x(Map)}$ or $RMSE_{y(Map)}$

  $RMSE_{z(AT)}$ = $RMSE_{x(Map)}$ or $RMSE_{y(Map)}$ of orthoimagery

  Note: The exact contribution of aerial triangulation errors in z to the overall horizontal error budget for the products depends on ground point location in the image and other factors. The relationship stated here for an $RMSE_z$ (AT) of twice the allowable RMSE in x or y is a conservative estimate that accommodates the typical range of common camera geometries and provides allowance for many other factors that impact the horizontal error budget.
- Accuracy of aerial triangulation designed for elevation data, or planimetric data (orthoimagery and/or digital planimetric map) and elevation data production:

  $RMSE_{x(AT)}$, $RMSE_{y(AT)}$ or $RMSE_{z(AT)}$ = ½ * $RMSE_{x(Map)}$, $RMSE_{y(Map)}$or $RMSE_{z(DEM)}$.

Annex B, Data Accuracy and Quality Examples, provides practical examples of these requirements.

7.8 Accuracy Requirements for Ground Control Used for Aerial Triangulation

Ground control points used for aerial triangulation should have higher accuracy than the expected accuracy of derived products according to the following two categories:

- Accuracy of ground control designed for planimetric data (orthoimagery and/or digital planimetric map)production **only**:

  $RMSE_x$ or $RMSE_y$ = 1/4 * $RMSE_{x(Map)}$ or $RMSE_{y(Map)}$,

  $RMSE_z$ = 1/2 * $RMSE_{x(Map)}$ or $RMSE_{y(Map)}$
- Accuracy of ground control designed for elevation data, or planimetric data **and** elevation data production:

  $RMSE_x$, $RMSE_y$ or $RMSE_z$= 1/4 * $RMSE_{x(Map)}$, $RMSE_{y(Map)}$ or $RMSE_{z(DEM)}$

Annex B, Data Accuracy and Quality Examples, provides practical examples of these requirements.

7.9 Checkpoint Accuracy and Placement Requirements

The independent source of higher accuracy for checkpoints shall be at least three times more accurate than the required accuracy of the geospatial data set being tested.

Horizontal checkpoints shall be established shall be established at well-defined points. A well-defined point represents a feature for which the horizontal position can be measured to a high degree of accuracy and position with respect to the geodetic datum. For the purpose of accuracy testing, well-defined points must be easily visible or identifiable on the ground, on the independent source of higher accuracy, and on the product itself. For testing orthoimagery, well-defined points shall not be selected on features elevated with respect to the elevation model used to rectify the imagery.

Unlike horizontal checkpoints, vertical checkpoints are not necessarily required to be clearly defined or readily identifiable point features.

Vertical checkpoints shall be established at locations that minimize interpolation errors when comparing elevations interpolated from the data set to the elevations of the checkpoints. Vertical checkpoints shall be surveyed on flat or uniformly-sloped open terrain and with slopes of 10% or less and should avoid vertical artifacts or abrupt changes in elevation.

7.10 Checkpoint Density and Distribution

When testing is to be performed, the distribution of the checkpoints will be project specific and must be determined by mutual agreement between the data provider and the end user. In no case shall an NVA, digital orthoimagery accuracy or planimetric data accuracy be based on less than 20 checkpoints.

A methodology to provide quantitative characterization and specification of the spatial distribution of checkpoints across the project extents, accounting for land cover type and project shape, is both realistic and necessary. But until such a methodology is developed and accepted, checkpoint density and distribution will be based primarily on empirical results and simplified area based methods.

Annex C, Accuracy Testing and Reporting Guidelines, provides details on the recommended checkpoint density and distribution. The requirements in Annex C may be superseded and updated as newer methods for determining the appropriate distribution of checkpoints are established and approved.

7.11 Relative Accuracy of Lidar and IFSAR Data

Relative accuracy assessment characterizes the internal geometric quality of an elevation data set without regard to surveyed ground control. The assessment includes two aspects of data quality: within-swath accuracy (smooth surface repeatability), and swath-to-swath accuracy. Within-swath accuracy is usually only associated with lidar collections. The requirements for relative accuracy are more stringent than those for absolute accuracy. Acceptable limits for relative accuracy are stated in Table 7.2.

For lidar collections, within-swath relative accuracy is a measure of the repeatability of the system when detecting flat, hard surfaces. Within-swath relative accuracy also indicates the internal stability of the instrument. Within-swath accuracy is evaluated against single swath data by differencing two raster elevation surfaces generated from the minimum and maximum point elevations in each cell (pixel), taken over small test areas of relatively flat, hard surfaces. The raster cell size should be twice the NPS of the lidar data. Suitable test areas will have produced only single return lidar points and will not include abrupt changes in reflectivity (e.g., large paint stripes, shifts between black asphalt and white concrete, etc.), as these may induce elevation shifts that could skew the assessment. The use of a difference test normalizes for the actual elevation changes in the surfaces. Acceptable thresholds for each accuracy class are based on the maximum difference between minimum and maximum values within each pixel.

For lidar and IFSAR collections, relative accuracy between swaths (swath-to-swath) in overlap areas is a measure of the quality of the system calibration/bore-sighting and airborne GNSS trajectories.

Swath-to-swath relative accuracy is assessed by comparing the elevations of overlapping swaths. As with within-swath accuracy assessment, the comparisons are performed in areas producing only single return lidar points. Elevations are extracted at checkpoint locations from each of the overlapping swaths and computing the root-mean-square-difference ($RMSD_z$) of the residuals. Because neither swath represents an independent source of higher accuracy, as used in $RMSE_z$ calculations, the comparison is made using the RMS differences rather than RMS errors. Alternatively, the so called "delta-z" raster file representing the differences in elevations can be generated from the subtraction of the two raster files created for each swath over the entire surface and it can be used to calculate the $RMSD_z$. This approach has the advantages of a more comprehensive assessment, and provides the user with a visual representation of the error distribution.

Annex C, Accuracy Testing and Reporting Guidelines, outlines specific criteria for selecting checkpoint locations for swath-to-swath accuracies. The requirements in the annex may be superseded and updated as newer methods for determining the swath-to-swath accuracies are established and approved.

7.12 Reporting

Horizontal and vertical accuracies shall be reported in terms of compliance with the RMSE thresholds and other quality and accuracy criteria outlined in this standard. In addition to the reporting stated below, ASPRS endorses and encourages additional reporting statements stating the estimated accuracy at a 95% confidence level in accordance with the FGDC NSSDA standard referenced in Section 3. Formulas for relating the RMSE thresholds in this standard to the NSSDA standard are provided in Annexes B and D.

If testing is performed, accuracy statements should specify that the data are "tested to meet" the stated accuracy.

If testing is not performed, accuracy statements should specify that the data are "produced to meet" the stated accuracy. This "produced to meet" statement is equivalent to the "compiled to meet" statement used by prior standards when referring to cartographic maps. The "produced to meet" method is appropriate for mature or established technologies where established procedures for project design, quality control and the evaluation of relative and absolute accuracies compared to ground control have been shown to produce repeatable and reliable results. Detailed specifications for testing and reporting to meet these requirements are outlined in Annex C.

The horizontal accuracy of digital orthoimagery, planimetric data, and elevation data sets shall be documented in the metadata in one of the following manners:

- "This data set was tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a ___ (cm) $RMSE_x$ / $RMSE_y$ Horizontal Accuracy Class. Actual positional accuracy was found to be $RMSE_x$ = ___ (cm) and $RMSE_y$ = ___ cm which equates to Positional Horizontal Accuracy = +/- ___ at 95% confidence level." [4]
- "This data set was produced to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a ___ (cm) $RMSE_x$ / $RMSE_y$ Horizontal Accuracy Class which equates to Positional Horizontal Accuracy = +/- ___ cm at a 95% confidence level." [5]

The vertical accuracy of elevation data sets shall be documented in the metadata in one of the following manners:

- "This data set was tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a___ (cm) $RMSE_z$ Vertical Accuracy Class. Actual NVA accuracy was found to be $RMSE_z$ = ___ cm, equating to +/- ___ cm at 95% confidence level. Actual VVA accuracy was found to be +/- ___ cm at the 95th percentile."[4]
- "This data set was produced to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a ___ cm $RMSE_z$ Vertical Accuracy Class equating to NVA =+/-___cm at 95% confidence level and VVA =+/-___cm at the 95th percentile[5]

[4] "Tested to meet" is to be used only if the data accuracies were verified by testing against independent check points of higher accuracy.

[5] "Produced to meet" should be used by the data provider to assert that the data meets the specified accuracies, based on established processes that produce known results, but that independent testing against check points of higher accuracy was not performed.

ANNEX A - BACKGROUND AND JUSTIFICATIONS (INFORMATIVE)

A.1 LEGACY STANDARDS AND GUIDELINES

Accuracy standards for geospatial data have broad applications nationally and/or internationally, whereas specifications provide technical requirements/acceptance criteria that a geospatial product must conform to in order to be considered acceptable for a specific intended use. Guidelines provide recommendations for acquiring, processing and/or analyzing geospatial data, normally intended to promote consistency and industry best practices.

The following is a summary of standards, specifications and guidelines relevant to ASPRS but which do not fully satisfy current requirements for accuracy standards for digital geospatial data:

- The *National Map Accuracy Standard* (NMAS) of 1947 established horizontal accuracy thresholds for the *Circular Map Accuracy Standard* (CMAS) as a function of map scale, and vertical accuracy thresholds for the *Vertical Map Accuracy Standard* (VMAS) as a function of contour interval - both reported at the 90% confidence level. Because NMAS accuracy thresholds are a function of the map scale and/or contour interval of a printed map, they are inappropriate for digital geospatial data where scale and contour interval are changed with a push of a button while not changing the underlying horizontal and/or vertical accuracy.
- The *ASPRS 1990 Accuracy Standards for Large-Scale Maps* established horizontal and vertical accuracy thresholds in terms of RMSE values in X, Y, and Z at ground scale. However, because the RMSE thresholds for Class 1, Class 2, and Class 3 products pertain to printed maps with published map scales and contour intervals, these ASPRS standards from 1990 are similarly inappropriate for digital geospatial data.
- The *National Standard for Spatial Data Accuracy* (NSSDA), published by the Federal Geographic Data Committee (FGDC) in 1998, was developed to report accuracy of digital geospatial data at the 95% confidence level as a function of RMSE values in X, Y, and Z at ground scale, unconstrained by map scale or contour interval. The NSSDA states, "The reporting standard in the horizontal component is the radius of a circle of uncertainty, such that the true or theoretical location of the point falls within that circle 95% of the time. The reporting standard in the vertical component is a linear uncertainty value, such that the true or theoretical location of the point falls within +/- of that linear uncertainty value 95% of the time. The reporting accuracy standard should be defined in metric (International System of Units, SI) units. However, accuracy will be reported in English units (inches and feet) where point coordinates or elevations are reported in English units. The NSSDA uses root-mean-square error (RMSE) to estimate positional accuracy. 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 NSSDA does not define threshold accuracy values, stating "Agencies are encouraged to establish thresholds for their product specifications and applications and for contracting purposes." In its Appendix 3-A, the NSSDA provides equations for converting RMSE values in X, Y, and Z into horizontal and vertical accuracies at the 95% confidence levels. The NSSDA assumes normal error distributions with systematic errors eliminated as best as possible.
- The National Digital Elevation Program (NDEP) published the *NDEP Guidelines for Digital Elevation Data* in 2004, recognizing that lidar errors of Digital Terrain Models (DTMs) do not necessarily follow a normal distribution in vegetated terrain. The NDEP developed Fundamental Vertical Accuracy (FVA), Supplemental Vertical Accuracy (SVA) and Consolidated Vertical Accuracy (CVA). The FVA is computed in non-vegetated, open terrain only, based on the NSSDA's $RMSE_z$ * 1.9600 because elevation errors in open terrain do tend to follow a normal distribution, especially with a large number of checkpoints. SVA is computed in individual land cover categories, and CVA is computed in all land cover categories combined - both based on 95th percentile errors (instead of RMSE multipliers) because errors in DTMs in other land cover categories, especially vegetated/forested areas, do not necessarily follow a normal distribution. The NDEP Guidelines, while establishing alternative procedures for testing and reporting the vertical accuracy of elevation data sets when errors are not normally distributed, also do not provide accuracy thresholds or quality levels.
- The *ASPRS Guidelines: Vertical Accuracy Reporting for Lidar Data*, published in 2004, essentially endorsed the NDEP Guidelines, to include FVA, SVA, and CVA reporting. Similarly, the ASPRS 2004 Guidelines, while endorsing the NDEP Guidelines when elevation errors are not normally distributed, also do not provide accuracy thresholds or quality levels.
- Between 1998 and 2010, the Federal Emergency Management Agency (FEMA) published *Guidelines and Specifications for Flood Hazard Mapping Partners* that included $RMSE_z$ thresholds and requirements for testing and reporting the vertical accuracy separately for all major land cover categories within floodplains being mapped for the National Flood Insurance Program (NFIP). With its *Procedure Memorandum No. 61 - Standards for Lidar and Other High Quality Digital Topography*, dated 27 September 2010, FEMA endorsed the *USGS Draft Lidar Base Specifications V13*, relevant to floodplain mapping in areas of highest flood risk only, with poorer accuracy and point density in areas of lesser flood risks. USGS' draft V13 specification subsequently became the *USGS Lidar Base Specification V1.0* specification summarized below. FEMA's Guidelines and Procedures only address requirements for flood risk mapping and do not represent accuracy standards that are universally applicable.
- In 2012, USGS published its Lidar Base Specification, Version 1.0, which is based on $RMSE_z$ of 12.5 cm in open terrain and elevation post spacing no greater than 1 to 2 meters. FVA, SVA, and CVA values are also specified. This document is not a standard but a specification for lidar data used to populate the National Elevation Dataset (NED) at 1/9th arc-second post spacing (~3 meters) for gridded Digital Elevation Models (DEMs).
- In 2012, USGS also published the final report of the *National Enhanced Elevation Assessment* (NEEA), which considered five Quality Levels of enhanced elevation data to satisfy nationwide requirements; each Quality Level having different $RMSE_z$ and point density thresholds. With support from the National Geospatial Advisory Committee (NGAC), USGS subsequently developed its new 3D Elevation Program (3DEP) based on lidar Quality Level 2 data with 1' equivalent contour accuracy ($RMSE_z$<10 cm) and point density of 2 points per square meter for all states except Alaska in which IFSAR Quality Level 5 data are specified with $RMSE_z$ between 1 and 2 meters and with 5 meter post spacing. The 3DEP lidar data are expected to be high resolution data capable of supporting DEMs at 1 meter resolution. The 3DEP Quality Level 2 and Quality Level 5 products are expected to become industry standards for digital elevation data, respectively replacing the older elevation data from the USGS' National Elevation Dataset.
- In 2014, the latest USGS Lidar Base Specification Version 1.2 was published to accommodate lidar Quality Levels 0, 1, 2 and 3.

A.2 NEW STANDARD FOR A NEW ERA

The current standard was developed in response to the pressing need of the GIS and mapping community for a new standard that embraces the digital nature of current geospatial technologies. The following are some of the justifications for the development of the new standard:

- Legacy map accuracy standards, such as the ASPRS 1990 standard and the NMAS of 1947, are outdated. Many of the data acquisition and mapping technologies that these standards were based on are no longer used. More recent advances in mapping technologies can now produce better quality and higher accuracy geospatial products and maps. New standards are needed to reflect these advances.
- Legacy map accuracy standards were designed to deal with plotted or drawn maps as the only medium to represent geospatial data. The concept of hardcopy map scale dominated the mapping industry for decades. Digital mapping products need different measures (besides scale) that are suitable for the digital medium that users now utilize.
- Within the past two decades (during the transition period between the hardcopy and softcopy mapping environments), most standard measures for relating GSD and map scale to the final mapping accuracy were inherited from photogrammetric practices using scanned film. New mapping processes and methodologies have become much more sophisticated with advances in technology and advances in our knowledge of mapping processes and mathematical modeling. Mapping accuracy can no longer be associated with the camera geometry and flying altitude alone. Many other factors now influence the accuracy of geospatial mapping products. Such factors include the quality of camera calibration parameters, quality and size of a Charged Coupled Device (CCD) used in the digital camera CCD array, amount of imagery overlap, quality of parallax determination or photo measurements, quality of the GPS signal, quality and density of ground control, quality of the aerial triangulation solution, capability of the processing software to handle GPS drift and shift and camera self-calibration, and the digital terrain model used for the production of orthoimagery. These factors can vary widely from project to project, depending on the sensor used and specific methodology. For these reasons, existing accuracy measures based on map scale, film scale, GSD, c-factor, and scanning resolution no longer apply to current geospatial mapping practices.
- Elevation products from the new technologies and active sensors such as lidar and IFSAR are not considered by the legacy mapping standards. New accuracy standards are needed to address elevation products derived from these technologies.

A.2.1 Mapping Practices During the Film-based Era

Since the early history of photogrammetric mapping, film was the only medium to record an aerial photographic session. During that period, film scale, film-to-map enlargement ratio, and c-factor were used to define final map scale and map accuracy. A film-to-map enlargement ratio value of 6 and a c-factor value of 1800 to 2000 were widely accepted and used during this early stage of photogrammetric mapping. C-factor is used to determine the flying height based on the desired contour interval from the following formula:

$$\text{c-factor} = \frac{\text{flying altitude}}{\text{contour interval}}$$

Values in Table A.1 were historically utilized by the mapping community for photogrammetric mapping from film.

Table A.1. Common Photography Scales Using Camera with 9″ Film Format and 6″ Lens

Film Scale	1″ = 300′	1″ = 600′	1″ = 1200′	1″ = 2400′	1″ = 3333′
	1:3,600	1:7,200	1:14,400	1:28,800	1:40,000
Flying Altitude	1,800′ / 550 m	3,600′ / 1,100 m	7,200′ / 2,200 m	14,400′ / 4,400 m	20,000′ / 6,100 m
Map Scale	1″ = 50′	1″ = 100′	1″ = 200′	1″ = 400′	1″ = 1000′
	1:600	1:1,200	1:2,400	1:4,800	1:12,000

A.2.2 Mapping Practices During the Softcopy Photogrammetry Era

When the softcopy photogrammetric mapping approach was first introduced to the mapping industry in the early 1990s, large format film scanners were used to convert the aerial film to digital imagery. The mapping community needed guidelines for relating the scanning resolution of the film to the supported map scale and contour interval used by legacy standards to specify map accuracies. Table A.2 relates the resulting GSD of the scanned film and the supported map scale and contour interval derived from film-based cameras at different flying altitudes. Table A.2 assumes a scan resolution of 21 microns as that was in common use for many years. The values in Table A.2 are derived based on the commonly used film-to-map enlargement ratio of 6 and a c-factor of 1800. Such values were endorsed and widely used by both map users and data providers during and after the transition period from film to the softcopy environment.

Table A.2 Relationship between Film Scale and Derived Map Scale

	Common Photography Scales (with 9” film format camera and 6” lens)				Scanning Resolution (um)
Photo Scale	1″ = 300′	1″ = 600′	1″ = 1200′	1″ = 2400′	
	1:3,600	1:7,200	1:14,400	1:28,800	
Flying Altitude	1,800′ / 550 m	3,600′ / 1,100 m	7,200′ / 2,200 m	14,400′ / 4,400 m	
Approximate Ground Sampling Distance (GSD) of Scan	0.25′ / 7.5 cm	0.50′ / 0.15 m	1.0′ / 0.3 m	2.0′ / 0.6 m	21
	Supported Map/Orthoimagery Scales and Contour Intervals				
GSD	3″ / 7.5 cm	6″ / 15 cm	1.0′ / 30 cm	2.0′ / 60 cm	
C.I.	1.0′ / 30 cm	2.0′ / 60 cm	4′ / 1.2 m	8′ / 2.4 m	
Map Scale	1″ = 50′	1″ = 100′	1″ = 200′	1″ = 400′	
	1:600	1:1,200	1:2,400	1:4,800	

A.2.3 Mapping Practices during the Digital Sensors Photogrammetry Era

Since first introduced to the mapping community in 2000, digital large format metric mapping cameras have become the main aerial imagery acquisition system utilized for geospatial mapping. The latest generation of digital metric mapping cameras have enhanced optics quality, extended radiometric resolution through a higher dynamic range, finer CCD resolution, rigid body construction, and precise electronics. These new camera technologies, coupled with advances in the airborne GPS and mathematical modeling performed by current photogrammetric processing software, make it possible to extend the limits on the flying altitude and still achieve higher quality mapping products, of equal or greater accuracy, than what could be achieved with older technologies.

Many of the rules that have influenced photogrammetric practices for the last six or seven decades (such as those outlined in Sections A.2.1 and A.2.2 above) are based on the capabilities of outdated technologies and techniques. For instance, standard guidelines like using a film-to-map enlargement ratio value of 6 and a c-factor between 1,800 to 2,000 are based on the limitations of optical-mechanical photogrammetric plotters and aerial film resolution. These legacy rules no longer apply to mapping processes utilizing digital mapping cameras and current technologies.

Unfortunately, due to a lack of clear guidelines, outdated practices and guidelines from previous eras are commonly misapplied to newer technologies. The majority of users and data providers still utilize the figures given in Table A.2 for associating the imagery GSD to a supported map scale and associated accuracy, even though these associations are based on scanned film and do not apply to current digital sensors. New relationships between imagery GSD and product accuracy are needed to account for the full range factors that influence the accuracy of mapping products derived from digital sensors.

ANNEX B — DATA ACCURACY AND QUALITY EXAMPLES (NORMATIVE)

B.1 AERIAL TRIANGULATION AND GROUND CONTROL ACCURACY EXAMPLES

Sections 7.7 and 7.8 describe the accuracy requirements for aerial triangulation, IMU, and ground control points relative to product accuracies. These requirements differ depending on whether the products include elevation data. Tables B.1 and B.2 provide an example of how these requirements are applied in practice for a typical product with $RMSE_x$ and $RMSE_y$ of 50 cm.

Table B.1 Aerial Triangulation and Ground Control Accuracy Requirements, Orthoimagery and/or Planimetric Data Only

Product Accuracy ($RMSE_x$, $RMSE_y$) (cm)	A/T Accuracy		Ground Control Accuracy	
	$RMSE_x$ and $RMSE_y$ (cm)	$RMSE_z$ (cm)	$RMSE_x$ and $RMSE_y$ (cm)	$RMSE_z$ (cm)
50	25	50	12.5	25

Table B.2 Aerial Triangulation and Ground Control Accuracy Requirements, Orthoimagery and/or Planimetric Data and Elevation Data

Product Accuracy ($RMSE_x$, $RMSE_y$) (cm)	A/T Accuracy		Ground Control Accuracy	
	$RMSE_x$ and $RMSE_y$ (cm)	$RMSE_z$ (cm)	$RMSE_x$ and $RMSE_y$ (cm)	$RMSE_z$ (cm)
50	25	25	12.5	12.5

B.2 DIGITAL ORTHOIMAGERY HORIZONTAL ACCURACY CLASSES

This standard does not associate product accuracy with the GSD of the source imagery, pixel size of the orthoimagery, or map scale for scaled maps.

The relationship between the recommended $RMSE_x$ and $RMSE_y$ accuracy class and the orthoimagery pixel size varies depending on the imaging sensor characteristics and the specific mapping processes used. The appropriate horizontal accuracy class must be negotiated and agreed upon between the end user and the data provider, based on specific project needs and design criteria. This section provides some general guidance to assist in making that decision.

Example tables are provided to show the following: The general application of the standard as outlined in Section 7.3 (Table B.3); a cross reference to typical past associations between pixel size, map scale and the 1990 ASPRS legacy standard (Table B.4); and, typical values associated with different levels of accuracy using current technologies (Table B.5).

Table B.3 presents examples of 24 horizontal accuracy classes and associated quality criteria as related to orthoimagery according to the formula and general requirements stated in Section 7.3.

As outlined in Annex A, in the transition between hardcopy and softcopy mapping environments, users and the mapping community established generally accepted associations between orthoimagery pixel size, final map scale and the ASPRS 1990 map accuracy classes. These associations are based primarily on relationships for scanned film, older technologies and legacy standards. While they may not directly apply to digital geospatial data produced with newer technologies, these practices have been in widespread use for many years and many existing data sets are based on these associations. As such, it is useful to have a cross reference relating these legacy specifications to their corresponding $RMSE_x$ and $RMSE_y$ accuracy classes in the new standard.

Table B.4 lists the most common associations that have been established (based on users interpretation and past technologies) to relate orthoimagery pixel size to map scale and the ASPRS 1990 legacy standard map accuracy classes.

Given current sensor and processing technologies for large and medium format metric cameras, an orthoimagery accuracy of 1-pixel $RMSE_x$ and $RMSE_y$ is considered achievable, assuming proper project design and best practices implementation. This level of accuracy is more stringent by a factor of two than orthoimagery accuracies typically associated with the ASPRS 1990 Class 1 accuracies presented in Table B.4.

Achieving the highest level of accuracy requires specialized consideration related to sensor type, ground control density, ground control accuracies, and overall project design. In many cases, this results in higher cost. As such, the highest achievable accuracies may not be appropriate for all projects. Many geospatial mapping projects require high resolution and high quality imagery, but do not require the highest level of positional accuracy. This fact is particularly true for update or similar projects where the intent is to upgrade the image resolution, but still leverage existing elevation model data and ground control data that may originally have been developed to a lower accuracy standard.

Table B.5 provides a general guideline to determine the appropriate orthoimagery accuracy class for three different levels of geospatial accuracy. Values listed as “Highest accuracy work” specify an $RMSE_x$ and $RMSE_y$ accuracy class of 1-pixel (or better) and are considered to

Table B.3 Common Horizontal Accuracy Classes According to the New Standard[6]

Horizontal Accuracy Class $RMSE_x$ and $RMSE_y$ (cm)	$RMSE_r$ (cm)	Orthoimage Mosaic Seamline Maximum Mismatch (cm)	Horizontal Accuracy at the 95% Confidence Level (cm)
0.63	0.9	1.3	1.5
1.25	1.8	2.5	3.1
2.50	3.5	5.0	6.1
5.00	7.1	10.0	12.2
7.50	10.6	15.0	18.4
10.00	14.1	20.0	24.5
12.50	17.7	25.0	30.6
15.00	21.2	30.0	36.7
17.50	24.7	35.0	42.8
20.00	28.3	40.0	49.0
22.50	31.8	45.0	55.1
25.00	35.4	50.0	61.2
27.50	38.9	55.0	67.3
30.00	42.4	60.0	73.4
45.00	63.6	90.0	110.1
60.00	84.9	120.0	146.9
75.00	106.1	150.0	183.6
100.00	141.4	200.0	244.8
150.00	212.1	300.0	367.2
200.00	282.8	400.0	489.5
250.00	353.6	500.0	611.9
300.00	424.3	600.0	734.3
500.00	707.1	1000.0	1223.9
1000.00	1414.2	2000.0	2447.7

reflect the highest tier accuracy for the specified resolution given current technologies. This accuracy class is appropriate when geospatial accuracies are of higher importance and when the higher accuracies are supported by sufficient sensor, ground control and digital terrain model accuracies. Values listed as "Standard Mapping and GIS work" specify a 2-pixel $RMSE_x$ and $RMSE_y$ accuracy class. This accuracy is appropriate for a standard level of high quality and high accuracy geospatial mapping applications. It is equivalent to ASPRS 1990 Class 1 accuracies, as interpreted by users as industry standard and presented in Table B.4. This level of accuracy is typical of a large majority of existing projects designed to legacy standards. $RMSE_x$ and $RMSE_y$ accuracies of 3 or more pixels would be considered appropriate for "visualization and less accurate work" when higher accuracies are not needed.

Users should be aware that the use of the symbol ≥ in Table B.5 is intended to infer that users can specify larger threshold values for $RMSE_x$ and $RMSE_y$. The symbol ≤ in Table B.5 indicates that users can specify lower thresholds at such time as they may be supported by current or future technologies.

The orthoimagery pixel sizes and associated $RMSE_x$ and $RMSE_y$ accuracy classes presented in Table B.5 are largely based on experience with current sensor technologies and primarily apply to large and medium format metric cameras. The table is only provided as a guideline for users during the transition period to the new standard. These associations may change in the future as mapping technologies continue to advance and evolve.

Table B.4 Examples on Horizontal Accuracy for Digital Orthoimagery Interpreted from ASPRS 1990 Legacy Standard

Common Orthoimagery Pixel Sizes	Associated Map Scale	ASPRS 1990 Accuracy Class	Associated Horizontal Accuracy According to Legacy ASPRS 1990 Standard	
			$RMSE_x$ and $RMSE_y$ (cm)	$RMSE_x$ and $RMSE_y$ in terms of pixels
0.625 cm	1:50	1	1.3	2-pixels
		2	2.5	4-pixels
		3	3.8	6-pixels
1.25 cm	1:100	1	2.5	2-pixels
		2	5.0	4-pixels
		3	7.5	6-pixels
2.5 cm	1:200	1	5.0	2-pixels
		2	10.0	4-pixels
		3	15.0	6-pixels
5 cm	1:400	1	10.0	2-pixels
		2	20.0	4-pixels
		3	30.0	6-pixels
7.5 cm	1:600	1	15.0	2-pixels
		2	30.0	4-pixels
		3	45.0	6-pixels
15 cm	1:1,200	1	30.0	2-pixels
		2	60.0	4-pixels
		3	90.0	6-pixels
30 cm	1:2,400	1	60.0	2-pixels
		2	120.0	4-pixels
		3	180.0	6-pixels
60 cm	1:4,800	1	120.0	2-pixels
		2	240.0	4-pixels
		3	360.0	6-pixels
1 meter	1:12,000	1	200.0	2-pixels
		2	400.0	4-pixels
		3	600.0	6-pixels
2 meter	1:24,000	1	400.0	2-pixels
		2	800.0	4-pixels
		3	1,200.0	6-pixels
5 meter	1:60,000	1	1,000.0	2-pixels
		2	2,000.0	4-pixels
		3	3,000.0	6-pixels

It should be noted that in Tables B.4 and B.5, it is the pixel size of the final digital orthoimagery that is used to associate the horizontal accuracy class, not the Ground Sample Distance (GSD) of the raw image. When producing digital orthoimagery, the GSD as acquired by the sensor (and as computed at mean average terrain) should not be more than 95% of the final orthoimage pixel size. In extremely steep terrain, additional consideration may need to be given to the variation of the GSD across low lying areas in order to ensure that the variation in GSD across the entire image does not significantly exceed the target pixel size.

[6] For tables B.3 through B.8, values were rounded to the nearest mm after full calculations were performed with all decimal places.

Table B.5 Digital Orthoimagery Accuracy Examples for Current Large and Medium Format Metric Cameras

Common Orthoimagery Pixel Sizes	Recommended Horizontal Accuracy Class $RMSE_x$ and $RMSE_y$ (cm)	Orthoimage $RMSE_x$ and $RMSE_y$ in terms of pixels	Recommended use[7]
1.25 cm	≤1.3	≤1-pixel	Highest accuracy work
	2.5	2-pixels	Standard Mapping and GIS work
	≥3.8	≥3-pixels	Visualization and less accurate work
2.5 cm	≤2.5	≤1-pixel	Highest accuracy work
	5.0	2-pixels	Standard Mapping and GIS work
	≥7.5	≥3-pixels	Visualization and less accurate work
5 cm	≤5.0	≤1-pixel	Highest accuracy work
	10.0	2-pixels	Standard Mapping and GIS work
	≥15.0	≥3-pixels	Visualization and less accurate work
7.5 cm	≤7.5	≤1-pixel	Highest accuracy work
	15.0	2-pixels	Standard Mapping and GIS work
	≥22.5	≥3-pixels	Visualization and less accurate work
15 cm	≤15.0	≤1-pixel	Highest accuracy work
	30.0	2-pixels	Standard Mapping and GIS work
	≥45.0	≥3-pixels	Visualization and less accurate work
30 cm	≤30.0	≤1-pixel	Highest accuracy work
	60.0	2-pixels	Standard Mapping and GIS work
	≥90.0	≥3-pixels	Visualization and less accurate work
60 cm	≤60.0	≤1-pixel	Highest accuracy work
	120.0	2-pixels	Standard Mapping and GIS work
	≥180.0	≥3-pixels	Visualization and less accurate work
1 meter	≤100.0	≤1-pixel	Highest accuracy work
	200.0	2-pixels	Standard Mapping and GIS work
	≥300.0	≥3-pixels	Visualization and less accurate work
2 meter	≤200.0	≤1-pixel	Highest accuracy work
	400.0	2-pixels	Standard Mapping and GIS work
	≥600.0	≥3-pixels	Visualization and less accurate work
5 meter	≤500.0	≤1-pixel	Highest accuracy work
	1,000.0	2-pixels	Standard Mapping and GIS work
	≥1,500.0	≥3-pixels	Visualization and less accurate work

B.3 DIGITAL PLANIMETRIC DATA HORIZONTAL ACCURACY CLASSES

Table B.6 presents 24 common horizontal accuracy classes for digital planimetric data, approximate GSD of source imagery for high accuracy planimetric data, and equivalent map scales per legacy NMAS and ASPRS 1990 accuracy standards. In Table B.6, the values for the approximate GSD of source imagery only apply to imagery derived from common large and medium format metric cameras. The range of the approximate GSD of source imagery is only provided as a general recommendation, based on the current state of sensor technologies and mapping practices. Different ranges may be considered in the future depending on future advances of such technologies and mapping practices.

B.4 DIGITAL ELEVATION DATA VERTICAL ACCURACY CLASSES

Table B.7 provides vertical accuracy examples and other quality criteria for ten common vertical accuracy classes. Table B.8 compares the ten vertical accuracy classes with contours intervals from legacy ASPRS 1990 and NMAS 1947 standards. Table B.9 provides ten vertical accuracy classes with the recommended lidar point density suitable for each of them.

[7] "Highest accuracy work" in Table B.5 refers only to the highest level of achievable accuracies relative to that specific resolution; it does not indicate "highest accuracy work" in any general sense. The final choice of both image resolution and final product accuracy class depends on specific project requirements and is the sole responsibility of the end user; this should be negotiated with the data provider and agreed upon in advance.

Table B.6 Horizontal Accuracy/Quality Examples for High Accuracy Digital Planimetric Data

ASPRS 2014				Equivalent to map scale in		
Horizontal Accuracy Class $RMSE_x$ and $RMSE_y$ (cm)	$RMSE_r$ (cm)	Horizontal Accuracy at the 95% Confidence Level (cm)	Approximate GSD of Source Imagery (cm)	ASPRS 1990 Class 1	ASPRS 1990 Class 2	Equivalent to map scale in NMAS
0.63	0.9	1.5	0.31 to 0.63	1:25	1:12.5	1:16
1.25	1.8	3.1	0.63 to 1.25	1:50	1:25	1:32
2.5	3.5	6.1	1.25 to 2.5	1:100	1:50	1:63
5.0	7.1	12.2	2.5 to 5.0	1:200	1:100	1:127
7.5	10.6	18.4	3.8 to 7.5	1:300	1:150	1:190
10.0	14.1	24.5	5.0 to 10.0	1:400	1:200	1:253
12.5	17.7	30.6	6.3 to12.5	1:500	1:250	1:317
15.0	21.2	36.7	7.5 to 15.0	1:600	1:300	1:380
17.5	24.7	42.8	8.8 to 17.5	1:700	1:350	1:444
20.0	28.3	49.0	10.0 to 20.0	1:800	1:400	1:507
22.5	31.8	55.1	11.3 to 22.5	1:900	1:450	1:570
25.0	35.4	61.2	12.5 to 25.0	1:1000	1:500	1:634
27.5	38.9	67.3	13.8 to 27.5	1:1100	1:550	1:697
30.0	42.4	73.4	15.0 to 30.0	1:1200	1:600	1:760
45.0	63.6	110.1	22.5 to 45.0	1:1800	1:900	1:1,141
60.0	84.9	146.9	30.0 to 60.0	1:2400	1:1200	1:1,521
75.0	106.1	183.6	37.5 to 75.0	1:3000	1:1500	1:1,901
100.0	141.4	244.8	50.0 to 100.0	1:4000	1:2000	1:2,535
150.0	212.1	367.2	75.0 to 150.0	1:6000	1:3000	1:3,802
200.0	282.8	489.5	100.0 to 200.0	1:8,000	1:4000	1:5,069
250.0	353.6	611.9	125.0 to 250.0	1:10,000	1:5000	1:6,337
300.0	424.3	734.3	150.0 to 300.0	1:12,000	1:6000	1:7,604
500.0	707.1	1223.9	250.0 to 500.0	1:20,000	1:10000	1:21,122
1000.0	1414.2	2447.7	500.0 to 1000.0	1:40000	1:20000	1:42,244

Table B.7 Vertical Accuracy/Quality Examples for Digital Elevation Data

Vertical Accuracy Class	Absolute Accuracy			Relative Accuracy (where applicable)		
	RMSEz Non-Vegetated (cm)	NVA at 95% Confidence Level (cm)	VVA at 95th Percentile (cm)	Within-Swath Hard Surface Repeatability (Max Diff) (cm)	Swath-to-Swath Non-Veg Terrain (RMSDz) (cm)	Swath-to-Swath Non-Veg Terrain (Max Diff) (cm)
1-cm	1.0	2.0	3	0.6	0.8	1.6
2.5-cm	2.5	4.9	7.5	1.5	2	4
5-cm	5.0	9.8	15	3	4	8
10-cm	10.0	19.6	30	6	8	16
15-cm	15.0	29.4	45	9	12	24
20-cm	20.0	39.2	60	12	16	32
33.3-cm	33.3	65.3	100	20	26.7	53.3
66.7-cm	66.7	130.7	200	40	53.3	106.7
100-cm	100.0	196.0	300	60	80	160
333.3-cm	333.3	653.3	1000	200	266.7	533.3

Table B.8 Vertical Accuracy of the New ASPRS 2014 Standard Compared with Legacy Standards

Vertical Accuracy Class	$RMSE_z$ Non-Vegetated (cm)	Equivalent Class 1 contour interval per ASPRS 1990 (cm)	Equivalent Class 2 contour interval per ASPRS 1990 (cm)	Equivalent contour interval per NMAS (cm)
1-cm	1.0	3.0	1.5	3.29
2.5-cm	2.5	7.5	3.8	8.22
5-cm	5.0	15.0	7.5	16.45
10-cm	10.0	30.0	15.0	32.90
15-cm	15.0	45.0	22.5	49.35
20-cm	20.0	60.0	30.0	65.80
33.3-cm	33.3	99.9	50.0	109.55
66.7-cm	66.7	200.1	100.1	219.43
100-cm	100.0	300.0	150.0	328.98
333.3-cm	333.3	999.9	500.0	1096.49

Table B.9 Examples on Vertical Accuracy and Recommended Lidar Point Density for Digital Elevation Data According to the New ASPRS 2014 Standard

Vertical Accuracy Class	Absolute Accuracy		Recommended Minimum NPD[8] (pls/m^2)	Recommended Maximum NPS[8] (m)
	$RMSE_z$ Non-Vegetated (cm)	NVA at 95% Confidence Level (cm)		
1-cm	1.0	2.0	≥20	≤0.22
2.5-cm	2.5	4.9	16	0.25
5-cm	5.0	9.8	8	0.35
10-cm	10.0	19.6	2	0.71
15-cm	15.0	29.4	1	1.0
20-cm	20.0	39.2	0.5	1.4
33.3-cm	33.3	65.3	0.25	2.0
66.7-cm	66.7	130.7	0.1	3.2
100-cm	100.0	196.0	0.05	4.5
333.3-cm	333.3	653.3	0.01	10.0

[8] Nominal Pulse Density (NPD) and Nominal Pulse Spacing (NPS) are geometrically inverse methods to measure the pulse density or spacing of a lidar collection. NPD is a ratio of the number of points to the area in which they are contained, and is typically expressed as pulses per square meter (ppsm or pls/m^2). NPS is a linear measure of the typical distance between points, and is most often expressed in meters. Although either expression can be used for any data set, NPD is usually used for lidar collections with NPS <1, and NPS is used for those with NPS ≥1. Both measures are based on all 1st (or last)-return lidar point data as these return types each reflect the number of pulses. Conversion between NPD and NPS is accomplished using the equation $NPS = 1/\sqrt{NPD}$ and $NPD = 1/NPS^2$. Although typical point densities are listed for specified vertical accuracies, users may select higher or lower point densities to best fit project requirements and complexity of surfaces to be modeled.

B.5 CONVERTING ASPRS 2014 ACCURACY VALUES TO LEGACY ASPRS 1990 ACCURACY VALUES

In this section easy methods and examples will be provided for users who are faced with the issue of relating the standard (ASPRS 2014) to the legacy ASPRS 1990 Accuracy Standards for Large-Scale Maps. A major advantage of the new standard is it indicates accuracy based on RMSE at the ground scale. Although both the new 2014 standard and the legacy ASPRS map standard of 1990 are using the same measure of RMSE, they are different on the concept of representing the accuracy classes. The legacy ASPRS map standard of 1990 uses Class 1 for higher accuracy and Classes 2 and 3 for data with lower accuracy while the new 2014 standard refers to the map accuracy by the value of RMSE without limiting it to any class. The following examples illustrate the procedures users can follow to relate horizontal and vertical accuracies values between the new ASPRS standard of 2014 and the legacy ASPRS 1990 Accuracy Standards for Large-Scale Maps.

Example 1: Converting the Horizontal Accuracy of a Map or Orthoimagery from the New 2014 Standard to the Legacy ASPRS Map Standard of 1990.

Given a map or orthoimagery with an accuracy of $RMSE_x = RMSE_y$ = 15 cm according to new 2014 standard, compute the equivalent accuracy and map scale according to the legacy ASPRS map standard of 1990, for the given map or orthoimagery.

Solution:

1. Because both standards utilize the same RMSE measure, then the accuracy of the map according to the legacy ASPRS map standard of 1990 is $RMSE_x = RMSE_y$ = 15 cm
2. To find the equivalent map scale according to the legacy ASPRS map standard of 1990, follow the following steps:
    a. Multiply the $RMSE_x$ and $RMSE_y$ value in centimeters by 40 to compute the map scale factor (MSF) for a Class 1 map, therefore:
    MSF = 15 (cm) × 40 = 600
    b. The map scale according to the legacy ASPRS map standard of 1990 is equal to:
        i. Scale = 1:MSF or 1:600 Class 1;
        ii. The accuracy value of $RMSE_x = RMSE_y$ = 15 cm is also equivalent to Class 2 accuracy for a map with a scale of 1:300.

Example 2: Converting the Vertical Accuracy of an Elevation Dataset from the New Standard to the Legacy ASPRS Map Standard of 1990.

Given an elevation data set with a vertical accuracy of $RMSE_z$ = 10 cm according to the new standard, compute the equivalent contour interval according to the legacy ASPRS map standard of 1990, for the given dataset.

Solution:
The legacy ASPRS map standard of 1990 states that:

"The limiting rms error in elevation is set by the standard at one-third the indicated contour interval for well-defined points only. Spot heights shall be shown on the map within a limiting rms error of one-sixth of the contour interval."

1. Because both standards utilize the same RMSE measure to

express the vertical accuracy, then the accuracy of the elevation dataset according to the legacy ASPRS map standard of 1990 is also equal to the given $RMSE_z$ = 10 cm

2. Using the legacy ASPRS map standard of 1990 accuracy measure of $RMSE_z$ = 1/3 x contour interval (CI), the equivalent contour interval is computed according to the legacy ASPRS map standard of 1990 using the following formula:

   CI = 3 × $RMSE_z$ = 3 x 10 cm = 30 cm with Class 1,

   or CI = 15 cm with Class 2 accuracy

   However, if the user is interested in evaluating the spot height requirement according to the ASPRS 1990 standard, then the results will differ from the one obtained above. The accuracy for spot heights is required to be twice the accuracy of the contours (one-sixth versus one-third for the contours) or:

   For a 30 cm CI, the required spot height accuracy, $RMSE_z$ = 1/6 × 30 cm = 5 cm

   Since our data is $RMSE_z$ = 10 cm, it would only support Class 2 accuracy spot elevations for this contour interval.

B.6 CONVERTING ASPRS 2014 ACCURACY VALUES TO LEGACY NMAS 1947 ACCURACY VALUES

In this section easy methods and examples will be provided for users who are faced with the issue of relating the new standard (ASPRS 2014) to the legacy National Map Accuracy Standard (NMAS) of 1947. In regard to the horizontal accuracy measure, the NMAS of 1947 states that:

"Horizontal Accuracy: For maps on publication scales larger than 1:20,000, not more than 10 percent of the points tested shall be in error by more than 1/30 inch, measured on the publication scale; for maps on publication scales of 1:20,000 or smaller, 1/50 inch." This is known as the Circular Map Accuracy Standard (CMAS) or Circular Error at the 90% confidence level (CE90).

Therefore, the standard uses two accuracy measures based on the map scale with the figure of "1/30 inch" for map scales larger than 1:20,000 and "1/50 inch" for maps with a scale of 1:20,000 or smaller. As for the vertical accuracy measure, the standard states:

"Vertical Accuracy, as applied to contour maps on all publication scales, shall be such that not more than 10 percent of the elevations tested shall be in error more than one-half the contour interval." This is known as the Vertical Map Accuracy Standard (VMAS) or Linear Error at the 90% confidence level (LE90).

The following examples illustrate the procedures users can follow to relate horizontal and vertical accuracy values between the new ASPRS standard of 2014 and the legacy National Map Accuracy Standard (NMAS) of 1947.

Example 3: Converting the horizontal accuracy of a map or orthoimagery from the new ASPRS 2014 standard to the legacy National Map Accuracy Standard (NMAS) of 1947.

Given a map or orthoimagery with an accuracy of $RMSE_x$ = $RMSE_y$ = 15 cm according to the new 2014 standard, compute the equivalent accuracy and map scale according to the legacy National Map Accuracy Standard (NMAS) of 1947, for the given map or orthoimagery.

Solution:

1. Because the accuracy figure of $RMSE_x$ = $RMSE_y$ = 15 cm is relatively small, it is safe to assume that such accuracy value is derived for a map with a scale larger than 1:20,000. Therefore, we can use the factor "1/30 inch."

   Use the formula CMAS (CE90) = 2.1460 × $RMSE_x$ = 2.1460 × $RMSE_y$

   CE90 = 2.1460 × 15 cm = 32.19 cm

2. Convert the CE90 to feet

   32.19 cm = 1.0561 foot

3. Use the NMAS accuracy relation of CE90 = 1/30 inch on the map, compute the map scale

   CE90 = 1/30 × (ground distance covered by an inch of the map), or ground distance covered by an inch of the map = CE90 × 30 = 1.0561 foot × 30 = 31.68 feet

4. The equivalent map scale according to NMAS is equal to 1″ = 31.68′ or 1:380

Example 4: Converting the vertical accuracy of an elevation dataset from the new ASPRS 2014 standard to the legacy National Map Accuracy Standard (NMAS) of 1947.

Given an elevation data set with a vertical accuracy of $RMSE_z$ = 10 cm according to the new ASPRS 2014 standard, compute the equivalent contour interval according to the legacy National Map Accuracy Standard (NMAS) of 1947, for the given dataset.

Solution:

As mentioned earlier, the legacy ASPRS map standard of 1990 states that:

"Vertical Accuracy, as applied to contour maps on all publication scales, shall be such that not more than 10 percent of the elevations tested shall be in error more than one-half the contour interval."

Use the following formula to compute the 90% vertical error:

1. VMAS (LE90) = 1.6449 × $RMSE_z$ = 1.6449 x 10 cm = 16.449 cm
2. Compute the contour interval (CI) using the following criteria set by the NMAS standard:

   VMAS (LE90) = 1/2 CI, or

   CI = 2 × LE90 = 2 × 16.449 cm = 32.9 cm

B.7 EXPRESSING THE ASPRS 2014 ACCURACY VALUES ACCORDING TO THE FGDC NATIONAL STANDARD FOR SPATIAL DATA ACCURACY (NSSDA)

In this section easy methods and examples will be provided for users who are faced with the issue of relating the new standard (ASPRS 2014) to the FGDC National Standard for Spatial Data Accuracy (NSSDA).

Example 5: Converting the horizontal accuracy of a map or orthoimagery from the new 2014 standard to the FGDC National Standard for Spatial Data Accuracy (NSSDA)

Given a map or orthoimagery with an accuracy of $RMSE_x$ = $RMSE_y$ = 15 cm according to new 2014 standard, express the equivalent accuracy according to the FGDC National Standard for Spatial Data Accuracy (NSSDA), for the given map or orthoimagery.

Solution:
According to NSSDA, the horizontal positional accuracy is estimated at 95% confidence level from the following formula:

$$\text{Accuracy at 95\% or Accuracy}_r = 2.4477 \times RMSE_x = 2.4477 \times RMSE_y$$

If we assume that:

$RMSE_x = RMSE_y$ and $RMSE_r = \sqrt{RMSE_x^2 + RMSE_y^2}$, then

$$RMSE_r = \sqrt{2RMSE_x^2} = \sqrt{2RMSE_y^2} = 1.4142 \times RMSE_x = 1.4142 \times RMSE_y = 1.4142 \times 15 = 21.21 \text{ cm}$$

also

$$RMSE_x \text{ or } RMSE_y = \frac{RMSE_r}{1.4142}.$$

Then,

$$\text{Accuracy}_r = 2.4477\left(\frac{RMSE_r}{1.4142}\right) = 1.7308(RMSE_r) = 1.7308(21.21 \text{ cm}) = 36.71 \text{ cm}$$

Example 6: Converting the vertical accuracy of an elevation dataset from the new ASPRS 2014 standard to the FGDC National Standard for Spatial Data Accuracy (NSSDA)

Given an elevation data set with a vertical accuracy of $RMSE_z = 10$ cm according to the new ASPRS 2014 standard, express the equivalent accuracy according to the FGDC National Standard for Spatial Data Accuracy (NSSDA), for the given dataset.

Solution:
According to NSSDA, the vertical accuracy of an elevation dataset is estimated at 95% confidence level according to the following formula:

$$\text{Vertical Accuracy at 95\% Confidence Level} = 1.9600(RMSE_r) = 1.9600(10) = 19.6 \text{ cm}$$

B.8 HORIZONTAL ACCURACY EXAMPLES FOR LIDAR DATA

As described in Section 7.5, the horizontal errors in lidar data are largely a function of GNSS positional error, INS angular error, and flying altitude. Therefore for a given project, if the radial horizontal positional error of the GNSS is assumed to be equal to 0.11314 m (based on 0.08 m in either X or Y), and the IMU error is 0.00427 degree in roll, pitch, and heading, the following table can be used to estimate the horizontal accuracy of lidar derived elevation data.

Table B.10 provides estimated horizontal errors, in terms of $RMSE_r$, in lidar elevation data as computed by the equation in section 7.5 for different flying altitudes above mean terrain.

Different lidar systems in the market have different specifications for the GNSS and IMU and therefore, the values in Table B.10 should be modified according to the equation in section 7.5.

Table B.10 Expected Horizontal Errors ($RMSE_R$) for Lidar Data in Terms of Flying Altitude

Altitude (m)	Positional $RMSE_r$ (cm)	Altitude (m)	Positional $RMSE_r$ (cm)
500	13.1	3,000	41.6
1,000	17.5	3,500	48.0
1,500	23.0	4,000	54.5
2,000	29.0	4,500	61.1
2,500	35.2	5,000	67.6

B.9 ELEVATION DATA ACCURACY VERSUS ELEVATION DATA QUALITY

In aerial photography and photogrammetry, the accuracy of the individual points in a data set is largely dependent on the scale and resolution of the source imagery. Larger scale imagery, flown at a lower altitude, produces smaller GSDs and higher measurement accuracies (both vertical and horizontal). Users have quite naturally come to equate higher density imagery (smaller GSD or smaller pixel sizes) with higher accuracies and higher quality.

In airborne topographic lidar, this is not entirely the case. For many typical lidar collections, the maximum accuracy attainable, theoretically, is now limited by physical error budgets of the different components of the lidar system such as laser ranging, the GNSS, the IMU, and the encoder systems. Increasing the density of points does not change those factors. Beyond the physical error budget limitations, all data must also be properly controlled, calibrated, boresighted, and processed. Errors introduced during any of these steps will affect the accuracy of the data, regardless of how dense the data are. That said, high density lidar data are usually of higher *quality* than low density data, and the increased quality can manifest as *apparently* higher accuracy.

In order to accurately represent a complex surface, denser data are necessary to capture the surface details for accurate mapping of small linear features such as curbs and micro drainage features, for example. The use of denser data for complex surface representation does not make the individual lidar measurements any more accurate, but does improve the accuracy of the derived surface at locations between the lidar measurements (as each reach between points is shorter).

In vegetated areas, where many lidar pulses are fully reflected before reaching the ground, a higher density data set tends to be more accurate because more points will penetrate through vegetation to the ground. More ground points will result in less interpolation between points and improved surface definition because more characteristics of the actual ground surface are being measured, not interpolated. The use of more ground points is more critical in variable or complex surfaces, such as mountainous terrain, where generalized interpolation between points would not accurately model all of the changes in the surface.

Increased density may not improve the accuracy in flat, open terrain where interpolation between points would still adequately represent the ground surface. However, in areas where denser data may not be necessary to improve the vertical accuracy of data, a higher density data set may still improve the *quality* of the data by adding additional detail to the final surface model, by better detection of edges for breaklines, and by increasing the confidence of the relative accuracy in swath overlap areas through the reduction of interpolation existing within the data set. When lidar intensity is to be used in product derivation or algorithms, high collection density is always useful.

ANNEX C - ACCURACY TESTING AND REPORTING GUIDELINES (NORMATIVE)

When errors are normally distributed, accuracy testing can be performed with RMSE values, standard deviations, mean errors, maximum and minimum errors, and unit-less skew and kurtosis values. When errors are not normally distributed, alternative methods must be used. If the number of test points (checkpoints) is sufficient, testing and reporting can be performed using 95th percentile errors. A percentile rank is the percentage of errors that fall at or below a given value. Errors are visualized with histograms that show the pattern of errors relative to a normal error distribution.

The ability of RMSE, 95th percentile, or any other statistic to estimate accuracy at the 95% confidence level is largely dependent on the number and accuracy of the checkpoints used to test the accuracy of a data set being evaluated. Whereas100 or more is a desirable number of checkpoints, that number of checkpoints may be impractical and unaffordable for many projects, especially small project areas.

C.1 CHECKPOINT REQUIREMENTS

Both the total number of points and spatial distribution of checkpoints play an important role in the accuracy evaluation of any geospatial data. Prior guidelines and accuracy standards typically specify the required number of checkpoints and, in some cases, the land-cover types, but defining and/or characterizing the spatial distribution of the points was not required. While characterizing the point distribution is not a simple process and no practical method is available at this time, characterizing the point distribution by some measure and, consequently, providing a quality number is undoubtedly both realistic and necessary. ASPRS encourages research into this topic, peer reviewed, and published in *Photogrammetric Engineering & Remote Sensing* for public testing and comment.

Until a quantitative characterization and specification of the spatial distribution of checkpoints across a project is developed, more general methods of determining an appropriate checkpoint distribution must be implemented. In the interim, this Annex provides general recommendations and guidelines related to the number of checkpoints, distribution across land cover types, and spatial distribution.

C.2 NUMBER OF CHECKPOINTS REQUIRED

Table C.1 lists ASPRS recommendations for the number of checkpoints to be used for vertical and horizontal accuracy testing of elevation data sets and for horizontal accuracy testing of digital orthoimagery and planimetric data sets.

Using metric units, ASPRS recommends 100 static vertical checkpoints for the first 2,500 square kilometer area within the project, which provides a statistically defensible number of samples on which to base a valid vertical accuracy assessment.

For horizontal testing of areas >2500 km^2, clients should determine the number of additional horizontal checkpoints, if any, based on criteria such as resolution of imagery and extent of urbanization.

For vertical testing of areas >2,500 km^2, add five additional vertical checkpoints for each additional 500 km^2 area. Each additional set of five vertical checkpoints for 500 km^2 would include three checkpoints for NVA and two for VVA. The recommended number and distribution of NVA and VVA checkpoints may vary depending on the importance of different land cover categories and client requirements.

C.3 DISTRIBUTION OF VERTICAL CHECKPOINTS ACROSS LAND COVER TYPES

In contrast to the recommendations in Table C.1, both the 2003 and the current FEMA guidelines reference the five general land cover types, and specify a minimum of 20 checkpoints in each of three to five land cover categories as they exist within the project area, for a total of 60 to 100 checkpoints. Under the current FEMA guidelines, this quantity applies to each 5,180 square kilometer (2000 square mile) area, or partial area, within the project.

ASPRS recognizes that some project areas are primarily non-vegetated, whereas other areas are primarily vegetated. For these reasons, the distribution of checkpoints can vary based on the general proportion of vegetated and non-vegetated area in the project. Checkpoints should be distributed generally proportionally among the various vegetated land cover types in the project.

Table C.1 Recommended Number of Checkpoints Based on Area

Project Area (Square Kilometers)	Horizontal Accuracy Testing of Orthoimagery and Planimetrics	Vertical and Horizontal Accuracy Testing of Elevation Data sets		
	Total Number of Static 2D/3D Checkpoints (clearly-defined points)	Number of Static 3D Checkpoints in NVA[9]	Number of Static 3D Checkpoints in VVA	Total Number of Static 3D Checkpoints
≤500	20	20	5	25
501-750	25	20	10	30
751-1000	30	25	15	40
1001-1250	35	30	20	50
1251-1500	40	35	25	60
1501-1750	45	40	30	70
1751-2000	50	45	35	80
2001-2250	55	50	40	90
2251-2500	60	55	45	100

[9]Although vertical check points are normally not well defined, where feasible, the horizontal accuracy of lidar data sets should be tested by surveying approximately half of all NVA check points at the ends of paint stripes or other point features that are visible and can be measured on lidar intensity returns.

C.4 NSSDA METHODOLOGY FOR CHECKPOINT DISTRIBUTION (HORIZONTAL AND VERTICAL TESTING)

The NSSDA offers a method that can be applied to projects that are generally rectangular in shape and are largely non-vegetated. These methods do not apply to the irregular shapes of many projects or to most vegetated land cover types. The NSSDA specifies the following:

> "Due to the diversity of user requirements for digital geospatial data and maps, it is not realistic to include statements in this standard that specify the spatial distribution of checkpoints. Data and/or map producers must determine checkpoint locations.
>
> Checkpoints may be distributed more densely in the vicinity of important features and more sparsely in areas that are of little or no interest. When data exist for only a portion of the data set, confine test points to that area. When the distribution of error is likely to be nonrandom, it may be desirable to locate checkpoints to correspond to the error distribution.
>
> For a data set covering a rectangular area that is believed to have uniform positional accuracy, checkpoints may be distributed so that points are spaced at intervals of at least 10% of the diagonal distance across the data set and at least 20% of the points are located in each quadrant of the data set. (FGDC, 1998)"[10]

ASPRS recommends that, where appropriate and to the highest degree possible, the NSSDA method be applied to the project and incorporated land cover type areas. In some areas, access restrictions may prevent the desired spatial distribution of checkpoints across land cover types; difficult terrain and transportation limitations may make some land cover type areas practically inaccessible. Where it is not geometrically or practically applicable to strictly apply the NSSDA method, data vendors should use their best professional judgment to apply the spirit of that method in selecting locations for checkpoints.

Clearly, the recommendations in Sections C.1 through C.3 offer a good deal of discretion in the location and distribution of checkpoints, and this is intentional. It would not be worthwhile to locate 50 vegetated checkpoints in a fully urbanized county such as Orange County, California; 80 non-vegetated checkpoints might be more appropriate. Likewise, projects in areas that are overwhelmingly forested with only a few small towns might support only 20 non-vegetated checkpoints. The general location and distribution of checkpoints should be discussed between and agreed upon by the vendor and customer as part of the project plan.

C.5 VERTICAL CHECKPOINT ACCURACY

Vertical checkpoints need not be clearly-defined point features. Kinematic checkpoints (surveyed from a moving platform), which are less accurate than static checkpoints, can be used in any quantity as supplemental data, but the core accuracy assessment must be based on static surveys, consistent with NOAA Technical Memorandum NOS NGS-58, *Guidelines for Establishing GPS-Derived Ellipsoid Heights (Standards: 2 cm and 5 cm)*, or equivalent. NGS-58 establishes ellipsoid height accuracies of 5 cm at the 95% confidence level for network accuracies relative to the geodetic network, as well as ellipsoid height accuracies of 2 cm and 5 cm at the 95% confidence level for accuracies relative to local control.

As with horizontal accuracy testing, vertical checkpoints should be three times more accurate than the required accuracy of the elevation data set being tested.

C.6 TESTING AND REPORTING OF HORIZONTAL ACCURACIES

When errors are normally distributed and the mean is small, ASPRS endorses the NSSDA procedures for testing and reporting the horizontal accuracy of digital geospatial data. The NSSDA methodology applies to most digital orthoimagery and planimetric data sets where systematic errors and bias have been appropriately removed. Accuracy statistics and examples are outlined in more detail in Annex D.

Elevation data sets do not always contain the type of well-defined points that are required for horizontal testing to NSSDA specifications. Specific methods for testing and verifying horizontal accuracies of elevation data sets depend on technology used and project design.

For horizontal accuracy testing of lidar data sets, at least half of the NVA vertical checkpoints should be located at the ends of paint stripes or other point features visible on the lidar intensity image, allowing them to double as horizontal checkpoints. The ends of paint stripes on concrete or asphalt surfaces are normally visible on lidar intensity images, as are 90-degree corners of different reflectivity, e.g., a sidewalk corner adjoining a grass surface. The data provider has the responsibility to establish appropriate methodologies, applicable to the technologies used, to verify that horizontal accuracies meet the stated requirements.

The specific testing methodology used should be identified in the metadata.

C.7 TESTING AND REPORTING OF VERTICAL ACCURACIES

For testing and reporting the vertical accuracy of digital elevation data, ASPRS endorses the *NDEP Guidelines for Digital Elevation Data*, with slight modifications from FVA, SVA, and CVA procedures. This ASPRS standard reports the Non-vegetated Vertical Accuracy (NVA) at the 95% confidence level in all non-vegetated land cover categories combined and reports the Vegetated Vertical Accuracy (VVA) at the 95th percentile in all vegetated land cover categories combined.

If the vertical errors are normally distributed, the sample size sufficiently large, and the mean error is sufficiently small, ASPRS endorses NSSDA and NDEP methodologies for approximating vertical accuracies at the 95% confidence level, which applies to NVA checkpoints in all open terrain (bare soil, sand, rocks, and short grass) as well as urban terrain (asphalt and concrete surfaces) land cover categories.

In contrast, VVA is computed by using the 95th percentile of the absolute value of all elevation errors in all vegetated land cover categories combined, to include tall weeds and crops, brush lands, and lightly-to fully-forested land cover categories. By testing and reporting the VVA separate from the NVA, ASPRS draws a clear distinction between non-vegetated terrain where errors typically follow a normal

[10] Federal Geographic Data Committee. (1998). FGDC-STD-007.3-1998, Geospatial Positioning Accuracy Standards, Part 3: National Standard for Spatial Data Accuracy, FGDC, c/o U.S. Geological Survey, www.fgdc.fgdc.gov/standards/documents/standards/accuracy/chapter3

distribution suitable for RMSE statistical analyses, and vegetated terrain where errors do not necessarily follow a normal distribution and where the 95th percentile value more fairly estimates vertical accuracy at a 95% confidence level.

C.8 LOW CONFIDENCE AREAS

For stereo-compiled elevation data sets, photogrammetrists should capture two-dimensional closed polygons for "low confidence areas" where the bare-earth DTM may not meet the overall data accuracy requirements. Because photogrammetrists cannot see the ground in stereo beneath dense vegetation, in deep shadows or where the imagery is otherwise obscured, reliable data cannot be collected in those areas. Traditionally, contours within these obscured areas would be published as dashed contour lines. A compiler should make the determination as to whether the data being digitized is within NVA and VVA accuracies or not; areas not delineated by an obscure area polygon are presumed to meet accuracy standards. The extent of photogrammetrically derived obscure area polygons and any assumptions regarding how NVA and VVA accuracies apply to the photogrammetric data set must be clearly documented in the metadata.

Low confidence areas also occur with lidar and IFSAR where heavy vegetation causes poor penetration of the lidar pulse or radar signal. Although costs will be slightly higher, ASPRS recommends that "low confidence areas" for lidar be required and delivered as two-dimensional (2D) polygons based on the following four criteria:

1. Nominal ground point density (NGPD);
2. Cell size for the raster analysis;
3. Search radius to determine average ground point densities; and
4. Minimum size area appropriate to aggregate ground point densities and show a generalized low confidence area (minimum mapping unit).

This approach describes a raster-based analysis where the raster cell size is equal to the Search Radius listed for each Vertical Data Accuracy Class. Raster results are to be converted into polygons for delivery.

This section describes possible methods for the collection or delineation of low confidence areas in elevation data sets being created using two common paradigms. Other methodologies currently exist, and additional techniques will certainly emerge in the future. The data producer may use any method they deem suitable provided the detailed technique is clearly documented in the metadata.

Table C.2 lists the values for the above low confidence area criteria that apply to each vertical accuracy class.

Low confidence criteria and the values in Table C.2 are based on the following assumptions:

- **Ground Point Density**: Areas with ground point densities less than or equal to ¼ of the recommended nominal pulse density (pulse per square meter) or twice the nominal pulse spacing are candidates for Low Confidence Areas. For example: a specification requires an NPS of 1 meter (or an NPD of 1 ppsm) but the elevation data in some areas resulted in a nominal ground point density of 0.25 point per square meter (nominal ground point spacing of 2 meters). Such areas are good candidate for "low confidence" areas.
- **Raster Analysis Cell Size**: Because the analysis of ground point density will most likely be raster based, the cell size at which the analysis will be performed needs to be specified. The recommendation is that the cell size equals the search radius.
- **Search Radius for Computing Point Densities**: Because point data are being assessed, an area must be specified in order to compute the average point density within this area. The standards recommend a search area with a radius equal to 3 * NPS (*not the Low Confidence NGPS*). This distance is small enough to allow good definition of low density areas while not being so small as to cause the project to look worse than it really is.
- **Minimum Size for Low Confidence Polygons**: The areas computed with low densities should be aggregated together. Unless specifically requested by clients, structures/buildings and water should be removed from the aggregated low density polygons as these features are not true Low Confidence.

Aggregated polygons greater than or equal to the stated minimum size as provided in Table C.2 should be kept and defined as Low Confidence Polygons. In certain cases, too small an area will "checker board" the Low Confidence Areas; in other cases too large an area will not adequately define Low Confidence Area polygons. These determinations should be a function of the topography, land cover, and final use of the maps.

Acres should be used as the unit of measurement for the Low Confidence Area polygons as many agencies (USGS, NOAA, USACE, etc.) use acres as the mapping unit for required polygon collection. Approximate square meter equivalents are provided for those whose work is exclusively in the metric system. Smoothing algorithms could be applied to the Low Confidence Polygons, if desired.

Table C.2 Low Confidence Areas

Vertical Accuracy Class	Recommended Project Min NPD (pls/m²) (Max NPS (m))	Recommended Low Confidence Min NGPD (pts/m²) (Max NGPS (m))	Search Radius and Cell Size for Computing NGPD (m)	Low Confidence Polygons Min Area (acres (m²))
1-cm	20 (0.22)	5 (0.45)	0.67	0.5 (2,000)
2.5-cm	16 (0.25)	4 (0.50)	0.75	1 (4,000)
5-cm	8 (0.35)	2 (0.71)	1.06	2 (8,000)
10-cm	2 (0.71)	0.5 (1.41)	2.12	5 (20,000)
15-cm	1 (1.0)	0.25 (2.0)	3.00	5 (20,000)
20-cm	0.5 (1.4)	0.125 (2.8)	4.24	5 (20,000)
33.3-cm	0.25 (2.0)	0.0625 (4.0)	6.0	10 (40,000)
66.7-cm	0.1 (3.2)	0.025 (6.3)	9.5	15 (60,000)
100-cm	0.05 (4.5)	0.0125 (8.9)	13.4	20 (80,000)
333.3-cm	0.01 (10.0)	0.0025 (20.0)	30.0	25 (100,000)

There are two distinctly different types of low confidence areas:

- The first types of low confidence areas are identified by the data producer - *in advance* - where passable identification of the bare earth is expected to be unlikely or impossible. These are areas where no control or checkpoints should be located and where contours, if produced, should be dashed. They are exempt from accuracy assessment. Mangroves, swamps, and inundated wetland marshes are prime candidates for such advance delineation.
- The second types of low confidence areas are valid VVA areas, normally forests that should also be depicted with dashed contours, but where checkpoints *should* be surveyed and accuracy assessment *should* be performed. Such low confidence areas are delineated subsequent to classification and would usually be identifiable by the notably reduced density of bare-earth points.

Providing Low Confidence Area polygons allows lidar data providers to protect themselves from unusable/unfair checkpoints in swamps and protects the customer from data providers who might try to alter their data.

If reliable elevation data in low confidence areas is critical to a project, it is common practice to supplement the remote sensing data with field surveys.

C.9 ERRONEOUS CHECKPOINTS

Occasionally, a checkpoint may be erroneous or inappropriate for use at no fault of the lidar survey. Such a point may be removed from the accuracy assessment calculation:

- if it is demonstrated, with pictures and descriptions, that the checkpoint was improperly located, such as when a vertical checkpoint is on steep terrain or within a few meters of a significant breakline that redefines the slope of the area being interpolated surrounding the checkpoint;
- if it is demonstrated and documented that the topography has changed significantly between the time the elevation data were acquired and the time the checkpoint was surveyed; or
- if (a) the point is included in the survey and accuracy reports, but not the assessment calculation, with pictures and descriptions; (b) reasonable efforts to correct the discrepancy are documented, e.g., rechecked airborne GNSS and IMU data, rechecked point classifications in the area, rechecked the ground checkpoints; and (c) a defensible explanation is provided in the accuracy report for discarding the point.
- An explanation that the error exceeds three times the standard deviation (>3 *s) is NOT a defensible explanation.

C.10 RELATIVE ACCURACY COMPARISON POINT LOCATION AND CRITERIA FOR LIDAR SWATH-TO-SWATH ACCURACY ASSESSMENT

To the greatest degree possible, relative accuracy testing locations should meet the following criteria:

1. include all overlap areas (sidelap, endlap, and crossflights);
2. be evenly distributed throughout the full width and length of each overlap area;
3. be located in non-vegetated areas (clear and open terrain and urban areas);
4. be at least 3 meters away from any vertical artifact or abrupt change in elevation;
5. be on uniform slopes; and,
6. be within the geometrically reliable portion of both swaths (excluding the extreme edge points of the swaths). For lidar sensors with zigzag scanning patterns from oscillating mirrors, the geometrically reliable portion excludes about 5% (2.5 % on either side); lidar sensors with circular or elliptical scanning patterns are generally reliable throughout.

While the $RMSD_z$ value may be calculated from a set of specific test location points, the Maximum Difference requirement is not limited to these locations; it applies to all locations within the entire data set that meet the above criteria.

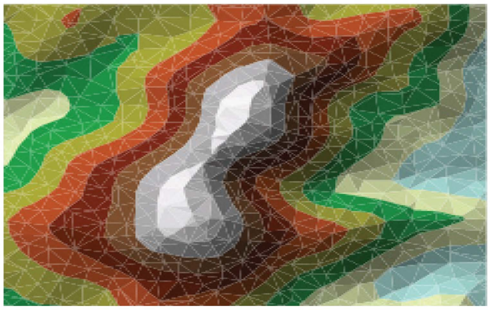
C.11 INTERPOLATION OF ELEVATION REPRESENTED SURFACE FOR CHECKPOINT COMPARISONS

The represented surface of an elevation data set is normally a TIN (Plate C.1) or a raster DEM (Plate C.1).

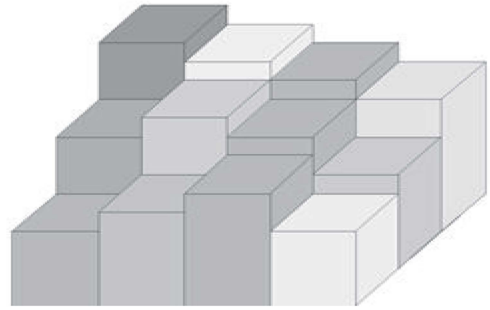
Vertical accuracy testing is accomplished by comparing the elevation of the represented surface of the elevation data set to elevations of checkpoints at the horizontal (x/y) coordinates of the checkpoints. The data set surface is most commonly represented by a TIN or raster DEM.

Vertical accuracy of point-based elevation datasets should be tested by creating a TIN from the point based elevation dataset and comparing the TIN elevations to the checkpoint elevations. TINs should be used to test the vertical accuracy of point based elevation datasets because it is unlikely a checkpoint will be located at the location of a discrete elevation point. The TIN methodology is the most commonly used method used for interpolating elevations from irregularly spaced point data. Other potentially more accurate methods of interpolation exist and could be addressed by future versions of this standard as they become more commonly used and accepted.

Vertical accuracy of raster DEMs should be tested by comparing the elevation of the DEM, which is already a continuous surface, to the checkpoint elevations. For most DEM datasets, it is recommended that the elevation of the DEM is determined by extracting the elevation of the pixel that contains the x/y coordinates of the checkpoint. However, in some instances, such as when the DEM being tested is at a lower resolution typical of global datasets or when the truth data has an area footprint associated with it rather than a single x/y coordinate, it may be better to use interpolation methods to determine the elevation of the DEM dataset. Vendors should seek approval from clients if methods other than extraction are to be used to determine elevation values of the DEM dataset. Vertical accuracy testing methods listed in metadata and reports should state if elevation values were extracted from the tested dataset at the x/y location of the checkpoints or if further interpolation was used after the creation of the tested surface (TIN or raster) to determine the elevation of the tested dataset. If further interpolation was used, the interpolation method and full process used should be detailed accordingly.



Represented as a TIN



Represented as a Raster DEM

Plate C.1. Topographic Surface

ANNEX D — ACCURACY STATISTICS AND EXAMPLE (NORMATIVE)

D.1 NSSDA REPORTING ACCURACY STATISTICS

The National Standard for Spatial Data Accuracy (NSSDA) documents the equations for computation of $RMSE_x$, $RMSE_y$, $RMSE_r$ and $RMSE_z$, as well as horizontal (radial) and vertical accuracies at the 95% confidence levels, $Accuracy_r$ and $Accuracy_z$, respectively. These statistics assume that errors approximate a normal error distribution and that the mean error is small relative to the target accuracy.

Example on the NSSDA Accuracy Computations:

For the purposes of demonstration, suppose you have five checkpoints to verify the final horizontal and vertical accuracy for a data set (normally a minimum of 20 points would be needed). Table D.1 provides the map-derived coordinates and the surveyed coordinated for the five points. The table also shows the computed accuracy and other necessary statistics. In this abbreviated example, the data are intended to meet a horizontal accuracy class with a maximum $RMSE_x$ and $RMSE_y$ of 15 cm and the 10 cm vertical accuracy class.

Computation of Mean Errors in x/y/z:

$$\bar{x} = \frac{1}{(n)} \sum_{i=1}^{n} x_i$$

where:

x_i is the i^{th} error in the specified direction

n is the number of checkpoints tested,

i is an integer ranging from 1 to n.

Mean error in Easting:

$$\bar{x} = \frac{-0.140 - 0.100 + 0.017 - 0.070 + 0.130}{5} = -0.033\,\text{m}$$

Mean error in Northing:

$$\bar{y} = \frac{-0.070 - 0.100 - 0.070 + 0.150 + 0.120}{5} = 0.006\,\text{m}$$

Mean error in Elevation:

$$\bar{z} = \frac{-0.070 + 0.010 + 0.102 - 0.100 + 0.087}{5} = 0.006\text{m}$$

Table D.1 NSSDA Accuracy Statistics for Example Data set with 3D Coordinates

Point ID	Map-derived values			Survey Check Point Values			Residuals (Errors)		
	Easting (E)	Northing (N)	Elevation (H)	Easting (E)	Northing (N)	Elevation (H)	Δx Easting (E)	Δy Northing (N)	Δz Elevation (H)
	meters	meters	meters	meters	meters	meters	meters	meters	meters
GCP1	359584.394	5142449.934	477.127	359584.534	5142450.004	477.198	–0.140	–0.070	–0.071
GCP2	359872.190	5147939.180	412.406	359872.290	5147939.280	412.396	–0.100	–0.100	0.010
GCP3	395893.089	5136979.824	487.292	359893.072	5136979.894	487.190	0.017	–0.070	0.102
GCP4	359927.194	5151084.129	393.591	359927.264	5151083.979	393.691	–0.070	0.150	–0.100
GCP5	372737.074	5151675.999	451.305	372736.944	5151675.879	451.218	0.130	0.120	0.087
Number of check points							**5**	**5**	**5**
Mean Error (m)							**–0.033**	**0.006**	**0.006**
Standard Deviation (m)							**0.108**	**0.119**	**0.006**
RMSE (m)							**0.102**	**0.106**	**0.081**
RMSEr (m)							**0.147**	**=SQRT($RMSE_x^2$ + $RMSE_y^2$)**	
NSSDA Horizontal $Accuracy_r$ (ACCr) at 95% Confidence Level							**0.255**	**=RMSEr × 1.7308**	
NSSDA Vertical $Accuracy_z$ (ACCz) at 95% Confidence Level							**0.160**	**=RMSEz × 1.9600**	

Computation of Sample Standard Deviation:

$$s_x = \sqrt{\frac{1}{(n-1)}\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2}$$

where:

x_i is the i^{th} error in the specified direction,

$\bar{x}$ is the mean error in the specified direction,

n is the number of checkpoints tested,

i is an integer ranging from 1 to n.

Sample Standard Deviation in Easting:

$$s_x = \sqrt{\frac{\left(-0.140-(-0.033)\right)^2 + \left(-0.100-(-0.033)\right)^2 + \left(0.017-(-0.033)\right)^2 + \left(-0.070-(-0.033)\right)^2 + \left(0.130-(-0.033)\right)^2}{(5-1)}}$$

$= 0.108\,\text{m}$

Sample Standard Deviation in Northing:

$$s_y = \sqrt{\frac{(-0.070-0.006)^2 + (-0.100-0.006)^2 + (-0.070-0.006)^2 + (0.150-0.006)^2 + (0.120-0.006)^2}{(5-1)}}$$

$= 0.119\,\text{m}$

Sample Standard Deviation in Elevation:

$$s_z = \sqrt{\frac{(-0.071-0.006)^2 + (0.010-0.006)^2 + (0.102-0.006)^2 + (-0.100-0.006)^2 + (0.087-0.006)^2}{(5-1)}}$$

$= 0.091\,\text{m}$

Computation of Root Mean Squares Error:

$$RMSE_x = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(x_{i(map)} - x_{i(surveyed)}\right)^2}$$

where:

$x_{i(map)}$ is the coordinate in the specified direction of the i^{th} checkpoint in the data set,

$x_{i(surveyed)}$ is the coordinate in the specified direction of the i^{th} checkpoint in the independent source of higher accuracy,

n is the number of checkpoints tested,

i is an integer ranging from 1 to n.

$$RMSE_x = \sqrt{\frac{(-0.140)^2 + (-0.100)^2 + (0.017)^2 + (-0.070)^2 + (0.130)^2}{5}} = 0.102\text{m}$$

$$RMSE_y = \sqrt{\frac{(-0.070)^2 + (-0.100)^2 + (-0.070)^2 + (0.150)^2 + (0.120)^2}{5}} = 0.107\text{m}$$

$$RMSE_z = \sqrt{\frac{(-0.071)^2 + (0.010)^2 + (0.102)^2 + (-0.100)^2 + (0.087)^2}{5}} = 0.081\text{m}$$

$$RMSE_r = \sqrt{RMSE_x^{\,2} + RMSE_y^{\,2}}$$

Computation of NSSDA Accuracy at 95% Confidence Level:

(Note: There are no significant systematic biases in the measurements. The mean errors are all smaller than 25% of the specified RMSE in Northing, Easting, and Elevation.)

Positional Horizontal Accuracy at 95% Confidence Level =

$$2.4477\left(\frac{\text{RMSE}_r}{1.4142}\right) = 1.7308\left(\text{RMSE}_r\right) = 1.7308\left(0.148\right) = \mathbf{0.255m}$$

Vertical Accuracy at 95% Confidence Level =

$1.9600(\text{RMSE}_z) = 1.9600(0.081) = \mathbf{0.160\ m} =$

$$\sqrt{\left(\left(0.102^2\right) + \left(0.107^2\right)\right)} = 0.148\text{m}$$

D.2 COMPARISON WITH NDEP VERTICAL ACCURACY STATISTICS

Whereas the NSSDA assumes that systematic errors have been eliminated as best as possible and that all remaining errors are random errors that follow a normal distribution, the ASPRS standard recognizes that elevation errors, especially in dense vegetation, do not necessarily follow a normal error distribution, as demonstrated by the error histogram of 100 checkpoints at Figure D.1 used as an example elevation data set for this Annex.

In vegetated land cover categories, the ASPRS standard (based on NDEP vertical accuracy statistics) uses the 95th percentile errors because a single outlier, when squared in the RMSE calculation, will unfairly distort the tested vertical accuracy statistic at the 95% confidence level. Unless errors can be found in the surveyed checkpoint, or the location of the checkpoint does not comply with ASPRS guidelines for location of vertical checkpoints, such outliers should not be discarded. Instead, such outliers should be included in the calculation of the 95th percentile because: (a) the outliers help identify legitimate issues in mapping the bare-earth terrain in dense vegetation, and (b) the 95th percentile, by definition, identifies that 95% of errors in the data set have errors with respect to true ground elevation that are equal to or smaller than the 95th percentile - the goal of the NSSDA.

Example Elevation Data set

Figure D.1, plus Tables D.2 and D.3, refer to an actual elevation data set tested by prior methods compared to the current ASPRS standard.

Plate D.1 shows an actual error histogram resulting from 100 checkpoints, 20 each in five land cover categories: (1) open terrain, (2) urban terrain, concrete and asphalt, (3) tall weeds and crops, (4) brush lands and trees, and (5) fully forested. In this lidar example, the smaller outlier of 49 cm is in tall weeds and crops, and the larger outlier of 70 cm is in the fully forested land cover category. The remaining 98 elevation error values appear to approximate a normal error distribution with a mean error close to zero; therefore, the sample standard deviation and RMSE values are nearly identical. When mean errors are not close to zero, the sample standard deviation values will normally be smaller than the RMSE values.

Without considering the 95th percentile errors, traditional accuracy statistics, which preceded these *ASPRS Positional Accuracy Standards for Digital Geospatial Data*, would be as shown in Table D.2. Note that the maximum error, skewness (γ_1), kurtosis (γ_2), standard deviation and RMSE$_z$ values are somewhat higher for weeds and crops because of the 49 cm outlier, and they are much higher for the fully forested land cover category because of the 70 cm outlier.

The ASPRS standards listed in Table 7.5 define two new terms: Non-vegetated Vertical Accuracy (NVA) based on $RMSE_z$ statistics and Vegetated Vertical Accuracy (VVA) based on 95th percentile statistics. The NVA consolidates the NDEP's non-vegetated land cover categories (open terrain and urban terrain, in this example), whereas the VVA consolidates the NDEP's vegetated land cover categories (weeds and crops, brush lands, and fully forested, in this example). Table D.3 shows ASPRS statistics and reporting methods compared to both NSSDA and NDEP.

D.3 COMPUTATION OF PERCENTILE

There are different approaches to determining percentile ranks and associated values. This standard recommends the use of the following equations for computing percentile rank and percentile as the most appropriate for estimating the Vegetated Vertical Accuracy.

Note that percentile calculations are based on the absolute values of the errors, as it is the magnitude of the errors, not the sign, that is of concern.

Table D.2 Traditional Error Statistics for Example Elevation Data set

Land Cover Category	# of Checkpoints	Min (m)	Max (m)	Mean (m)	Mean Absolute (m)	Median (m)	γ_1	γ_2	s (m)	$RMSE_z$ (m)
Open Terrain	20	–0.10	0.08	–0.02	0.04	0.00	–0.19	–0.64	0.05	0.05
Urban Terrain	20	–0.15	0.11	0.01	0.06	0.02	–0.84	0.22	0.07	0.07
Weeds & Crops	20	–0.13	0.49	0.02	0.08	–0.01	2.68	9.43	0.13	0.13
Brush Lands	20	–0.10	0.17	0.04	0.06	0.04	–0.18	–0.31	0.07	0.08
Fully Forested	20	–0.13	0.70	0.03	0.10	0.00	3.08	11.46	0.18	0.17
Consolidated	100	–0.15	0.70	0.02	0.07	0.01	3.18	17.12	0.11	0.11

Table D.3 Comparison of NSSDA, NDEP, and ASPRS Statistics for Example Elevation Data Set

Land Cover Category	NSSDA Accuracyz at 95% confidence level based on $RMSE_z$ * 1.9600 (m)	NDEP FVA, plus SVAs and CVA based on the 95th Percentile (m)	NDEP Accuracy Term	ASPRS Vertical Accuracy (m)	ASPRS Accuracy Term
Open Terrain	0.10	0.10	FVA	0.12	NVA
Urban Terrain	0.14	0.13	SVA		
Weeds & Crops	0.25	0.15	SVA	0.167	VVA
Brush Lands	0.16	0.14	SVA		
Fully Forested	0.33	0.21	SVA		
Consolidated	0.22	0.13	CVA	N/A	N/A

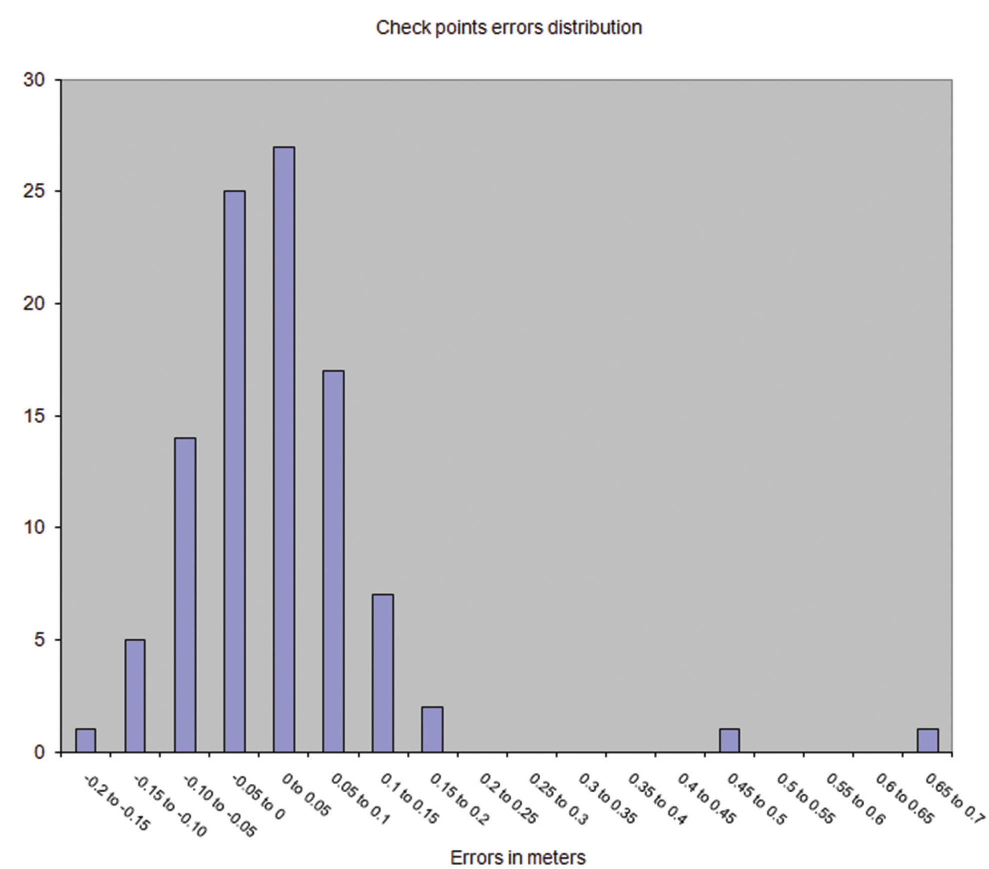


Plate D.1 Error Histogram of Typical Elevation Data Set, Showing Two Outliers in Vegetated Areas.

The percentile rank (n) is first calculated for the desired percentile using the following equation:

$$\boldsymbol{n}=\left(\left(\left(\frac{\boldsymbol{P}}{100}\right)*(\boldsymbol{N}-1)\right)+1\right)$$

where: n is the rank of the observation that contains the P^{th} percentile, P is the proportion (of 100) at which the percentile is desired (e.g., 95 for 95th percentile), and N is the number of observations in the sample data set.

Once the rank of the observation is determined, the percentile (Q_p) can then be interpolated from the upper and lower observations using the following equation:

$$\boldsymbol{Q_p}=\left(\boldsymbol{A}[\boldsymbol{n_w}]+\left(\boldsymbol{n_d}*\left(\boldsymbol{A}[\boldsymbol{n_w}+1]-\boldsymbol{A}[\boldsymbol{n_w}]\right)\right)\right)$$

where: Q_p is the P^{th} percentile; the value at rank n, A is an array of the absolute values of the samples, indexed in ascending order from 1 to N, $A[i]$ is the sample value of array A at index i (e.g., n_w or n_d) - i must be an integer between 1 and N - n is the rank of the observation that contains the P^{th} percentile, n_w is the whole number component of n (e.g., 3 of 3.14), and n_d is the decimal component of n (e.g., 0.14 of 3.14).

Example:

Given a sample data set $\{X_1, X_2 \ldots X_N\}$ =

{7, –33, –9, 5, –16, 22, 36, 37, 39, –11, 45, 28, 45, 19, -46, 10, 48, 44, 51, -27}

(N = 20),

calculate the 95th percentile *(P = 95)*:

Step 1: Take the absolute value of each observation:

{7, 33, 9, 5, 16, 22, 36, 37, 39, 11, 45, 28, 45, 19, 46, 10, 48, 44, 51, 27}

Step 2: Sort the absolute values in ascending order:

A = {5, 7, 9, 10, 11, 16, 19, 22, 27, 28, 33, 36, 37, 39, 44, 45, 45, 46, 48, 51}

Step 3: Compute the percentile rank n for P=95:

$$n=\left(\left(\left(\frac{P}{100}\right)*(N-1)\right)+1\right)=\left(\left(\left(\frac{95}{100}\right)*(20-1)\right)+1\right)=19.05$$

The 95th percentile rank (n) of the sample data set is 19.05

Step 4: Compute the percentile value Q_p by interpolating between observations 19 and 20:

$$Q_p=\left(A[n_w]+\left(n_d*\left(A[n_w+1]-A[n_w]\right)\right)\right)=\left(48+\left(0.05*(51-48)\right)\right)=48.15$$

The 95th percentile (Q_p) of the sample data set is 48.15.

APPENDIX G

USGS – THE NATIONAL MAP – STANDARDS AND SPECIFICATIONS

The National Map

The National Map Home

The National Map Viewer & Download Platform

3DEP: 3D Elevation Program

US Topo: Maps for America

Historical Topographic Map Collection

Products and Services

Fact Sheets, Videos, and Information Products

News & Events

The National Map Corps

The National Map Partner and User Engagement

About *The National Map*

Contact *The National Map*

The National Geospatial Program

National Geospatial Program Standards and Specifications

Standards and specifications are essential to facilitate the development and sharing of geospatial data and products. The USGS standards and specifications define the requirements to ensure that all products and data prepared by the USGS under the National Geospatial Program are consistent in accuracy, structure, format, style, and content. Geospatial data and products are available via the USGS Store, *The National Map*, The National Map Small-Scale Collection, and the Geo.Data.Gov websites.

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Overview of NGP Standards and Specifications

Digital Product Standards and Specifications | Digital Data Standards | Printed Map Standards | Additional Standards | Non-NGP Standards | Help

NGP standards documents and subsequent updates or changes dated prior to 2010 were approved and authorized by the National Mapping Division Standards Review Board. Beginning in 2010 standards and specifications are published according to the USGS Fundamental Science Practices (FSP) policies. Also offered are standards documents that are in the draft stages of the approval process. These documents will be labeled, "*DRAFT*," or if the document has approval for use by USGS contractors and for USGS internal production, it will be labeled, "*DRAFT FOR IMPLEMENTATION*." **All draft documents are subject to change without notice!** Standards documents may be periodically updated to reflect changes in policy or to define new or improved data and map specifications. The standards are current as of the version date indicated; please check this site often for the most current document.

Top

Digital Product Standards and Specifications

- **US Topo Product Standard** - Standard that defines a digital topographic map, based on the 1:24,000-scale quadrangle design and containing orthoimagery and data from the geographic themes of transportation, hydrography, elevation, boundaries, names, structures, and land cover.

- **Historical Topographic Map Collection Product Standard** - Standard that defines the digital map product of the U.S. Geological Survey (USGS) Historical Topographic Map Collection (HTMC). The HTMC is a digital archive of about 190,000 printed topographic quadrangle maps published by the USGS from the inception of the topographic mapping program in 1884 until the last paper topographic map using lithographic printing technology was published in 2006.
- **Historical Topographic Map Collection Specification** - Specification that defines the detailed requirements for producing, archiving and disseminating a comprehensive digital collection of printed topographic quadrangle maps published by the USGS from the inception of the topographic mapping program in 1884 until the last paper topographic map using lithographic printing technology was published in 2006.

Top

Digital Data Standards and Specifications

- **Digital Orthoimagery Base Specification V1.0** -- Specifications that define the minimum parameters for acquiring and procuring digital orthoimagery at one meter, one foot, six inch, and three inch resolutions. These specifications include sections on: Project and File Management, Acquisition and Processing, Metadata, Deliverables, and Quality Assessment and Testing by USGS. There are also appendices for Buy-Up Options and Film-Based Orthoimagery.
- **Digital Elevation Model Standards** -- Standards that define a digital file consisting of terrain elevations for ground positions at regularly spaced intervals. A digital elevation model is often referred to as a DEM.
- **Digital Line Graph Standards** -- Standards that define digital vector files containing line data, such as roads or streams, digitized from quadrangle maps. A digital line graph is often referred to as a DLG. The standards cover both DLG-3 and DLG-F series.
- **Digital Orthophoto Standards** -- Standards that define a digital image of an aerial photograph in which displacements caused by the camera and the terrain have been removed. A digital orthophoto quadrangle is often referred to as a DOQ. A DOQ combines the image characteristics of a photograph with the geometric qualities of a map.
- **Digital Raster Graphic Standards** -- Standards that define a digital image which is scanned from a USGS quadrangle map. A digital raster graphic is often referred to as a DRG. A DRG is georeferenced to the surface of the Earth, inside the map neatline.
- **Lidar Base Specification** -- Specifications that define the minimum parameters for acquiring and procuring light detection and ranging (lidar) data, including: specifications for raw point cloud (las format) data stored in swaths, classified point cloud

(las format) data stored in tiles, gridded DEM derivative products stored in tiles, and breakline information stored as PolyLines or PolyAreas. The NGP Lidar Base Specification Version 1.0 is the official publication of what is widely known as "the v13 Spec.".

- **National Hydrography Dataset Standards** -- The USGS and the Environmental Protection Agency (EPA) are jointly preparing standards for the National Hydrography Dataset (NHD) and the National Hydrography Dataset - High Resolution (NHD - HR). Both the NHD and NHD - HR are digital vector files of cataloging units that uniquely identify and interconnect the stream segments or "reaches" that comprise the country's surface water drainage system.
- **Raster Feature Separate Standards** -- Standards that define an archive format for a raster feature separate image file of a USGS topographic or planimetric map.

Top

Printed Map Standards

- **Primary Series Quadrangle Map Standards** -- Standards that define primary series topographic maps which include 1:24,000- or 1:25,000-scale quadrangles of the conterminous United States and Hawaii, 1:63,360-scale quadrangles of Alaska, and 1:20,000-scale quadrangles of Puerto Rico. These quadrangle maps show the positions of features and represent their vertical position in a measurable form.
- **100,000-Scale Quadrangle Map Standards** – Standards that define the USGS 1:100,000-scale quadrangles.

Top

Additional Standards and Instructions

- **Metadata Standards** -- Standards that define content for digital geospatial metadata for USGS NGP digital products.
- **Miscellaneous Instructions** -- These documents provide detailed instructions or guidelines to support products or processes not covered by other standards or documents.
- **National Map Accuracy Standards** -- Standards that define the accuracy for published maps.
- **Supplemental Technical Instructions** -- These technical instructions are supplements to the USGS NGP technical instructions. They provide clarifications for both graphic and digital mapping specifications on the basis of changing requirements and interpretations.

Top

Important Non-NGP Standards Information

- Federal Geographic Data Committee Standards (FGDC)
- Spatial Data Transfer Standard (SDTS)

- United States National Grid (FGDC)
- U.S. National Grid Conversion (NGS/NOAA)
- Links to Other Standards Sites

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Help -- Instructions

The Help page explains procedures for viewing and downloading the standards documents to your system. Documents on this site are available in Portable Document Format (PDF).

If you have comments and (or) questions about any **USGS NGP standards documents**, please e-mail nmpstds@usgs.gov.

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APPENDIX H

(FGDC(STANDARDS PUBLICATIONS

(/)

STANDARDS PUBLICATIONS

Home (https://www.fgdc.gov) / Standards (https://www.fgdc.gov/standards) / Publications

Standards developed internally by FGDC

External Standards Publications

Standards developed internally by FGDC

For FGDC-endorsed internally developed standards, select from the following list. The standards are not copyrighted and are free of charge.

Content Standard for Digital Geospatial Metadata

- *Base* Content Standard for Digital Geospatial Metadata (version 2.0) (https://www.fgdc.gov/standards/projects/FGDC-standards-projects/metadata/base-metadata/v2_0698.pdf), FGDC-STD-001-1998
- Part 1, Biological Data Profile (https://www.fgdc.gov/standards/projects/FGDC-standards-projects/metadata/biometadata/biodatap.pdf), FGDC-STD-001.1-1999

- Part 2, Metadata Profile for Shoreline Data (http://www.csc.noaa.gov/metadata/sprofile.pdf), FGDC-STD-001.2-2001

Spatial Data Transfer Standard (SDTS)

- Parts 1-4 (http://mcmcweb.er.usgs.gov/sdts/standard.html), FGDC-STD-002.1
- Part 5 (https://www.fgdc.gov/standards/projects/FGDC-standards-projects/SDTS/sdts_pt5/srpe0299.pdf): Raster Profile with Basic Image Interchange Format (BIIF) Extension, FGDC-STD-002.5
- Part 6 (https://www.fgdc.gov/standards/projects/FGDC-standards-projects/SDTS/sdts_point/sdts_pt6.pdf): Point Profile, FGDC-STD-002.6
- Part 7 (https://www.fgdc.gov/standards/projects/FGDC-standards-projects/SDTS/sdts_cadd/caddprof.pdf): Computer-Aided Design and Drafting (CADD) Profile, FGDC-STD-002.7-2000

Cadastral Data Content Standard (http://nationalcad.org/download/cadastral-data-content-standard-ver-1-4/), FGDC-STD-003

Classification of Wetlands and Deepwater Habitats in the United States (http://www.fws.gov/wetlands/Documents/FGDC-Wetlands-Mapping-Standard.pdf), FGDC-STD-004

National Vegetation Classification Standard (Version 2.0) (https://www.fgdc.gov/standards/projects/FGDC-standards-projects/vegetation/NVCS_V2_FINAL_2008-02.pdf/download), FGDC-STD-005-2008

Soil Geographic Data Standard (https://www.fgdc.gov/standards/projects/FGDC-standards-projects/soils/soil997.PDF), FGDC-STD-006

Geospatial Positioning Accuracy Standards

- Part 1: Reporting Methodology, (https://www.fgdc.gov/standards/projects/FGDC-standards-projects/accuracy/part1/chapter1) FGDC-STD-007.1-1998

- Part 2: Standards for Geodetic Networks (https://www.fgdc.gov/standards/projects/FGDC-standards-projects/accuracy/part2/chapter2), FGDC-STD-007.2-1998
- Part 3: National Standard for Spatial Data Accuracy (https://www.fgdc.gov/standards/projects/FGDC-standards-projects/accuracy/part3/chapter3), FGDC-STD-007.3-1998
- Part 4: Architecture, Engineering, Construction, and Facilities Management (https://www.fgdc.gov/standards/projects/FGDC-standards-projects/accuracy/part4/FGDC-endorsed-standard), FGDC-STD-007.4-2002

- Part 5: Standards for Nautical Charting Hydrographic Surveys (https://www.fgdc.gov/standards/projects/FGDC-standards-projects/accuracy/part5/FGDC-STD-007.5-2005.pdf), FGDC-STD-007.5-2005

Content Standard for Digital Orthoimagery (https://www.fgdc.gov/standards/projects/FGDC-standards-projects/orthoimagery/orth_299.pdf), FGDC-STD-008-1999

Content Standard for Remote Sensing Swath Data (https://www.fgdc.gov/standards/projects/FGDC-standards-projects/swath_data/FGDC-STD-009-1999.doc), FGDC-STD-009-1999

Utilities Data Content Standard (https://www.fgdc.gov/standards/projects/FGDC-standards-projects/utilities/utilities.pdf), FGDC-STD-010-2000

Standard for a U.S. National Grid (https://www.fgdc.gov/standards/projects/FGDC-standards-projects/usng/fgdc_std_011_2001_usng.pdf), FGDC-STD-011-2001

Content Standard for Digital Geospatial Metadata: Extensions for Remote Sensing Metadata (https://www.fgdc.gov/standards/projects/FGDC-standards-projects/csdgm_rs_ex/MetadataRemoteSensingExtens.pdf), FGDC-STD-012-2002

Digital Cartographic Standard for Geologic Map Symbolization (http://ngmdb.usgs.gov/fgdc_gds/geolsymstd/fgdc-geolsym-all.pdf), FGDC-STD-013-2006

Geographic Information Framework Data Standard

- Part 0, Base document, FGDC-STD-014.0-2008 (https://www.fgdc.gov/standards/projects/FGDC-standards-projects/framework-data-standard/GI_FrameworkDataStandard_Part0_Base.pdf)

- Part 1, Cadastral, FGDC-STD-014.1-2008 (https://www.fgdc.gov/standards/projects/FGDC-standards-projects/framework-data-standard/GI_FrameworkDataStandard_Part1_Cadastral.pdf)
- Part 2, Digital Orthoimagery, FGDC-STD-014.2-2008 (https://www.fgdc.gov/standards/projects/FGDC-standards-projects/framework-data-standard/GI_FrameworkDataStandard_Part2_DigitalOrthoimagery.pdf)
- Part 3, Elevation, FGDC-STD-014.3-2008 (https://www.fgdc.gov/standards/projects/FGDC-standards-projects/framework-data-standard/GI_FrameworkDataStandard_Part3_Elevation.pdf)
- Part 4, Geodetic Control, FGDC-STD-014.4-2008 (https://www.fgdc.gov/standards/projects/FGDC-standards-projects/framework-data-standard/GI_FrameworkDataStandard_Part4_GeodeticControl.pdf)
- Part 5, Governmental Unit and Other Geographic Area boundaries, FGDC-STD-014.5-2008 (https://www.fgdc.gov/standards/projects/FGDC-standards-projects/framework-data-standard/GI_FrameworkDataStandard_Part5_GovernmentalUnitBoundarie
- Part 6, Hydrography, FGDC-STD-014.6-2008 (https://www.fgdc.gov/standards/projects/FGDC-standards-projects/framework-data-standard/GI_FrameworkDataStandard_Part6_Hydrography.pdf)
- Part 7, Transportation Base, FGDC-STD-014.7-2008 (https://www.fgdc.gov/standards/projects/FGDC-standards-projects/framework-data-standard/GI_FrameworkDataStandard_Part7_Transportation_Base.pdf)
- Part 7a, Transportation - Air NOT endorsed
- Part 7b, Transportation - Rail, FGDC-STD-014.7b-2008 (https://www.fgdc.gov/standards/projects/FGDC-standards-projects/framework-data-standard/GI_FrameworkDataStandard_Part7b_Transportation_Rail.pdf)
- Part 7c, Transportation - Road, FGDC-STD-014.7c-2008 (https://www.fgdc.gov/standards/projects/FGDC-standards-projects/framework-data-standard/GI_FrameworkDataStandard_Part7c_Transportation_Road.pdf)

- Part 7d, Transportation - Transit, FGDC-STD-014.7d-2008 (https://www.fgdc.gov/standards/projects/FGDC-standards-projects/framework-data-standard/GI_FrameworkDataStandard_Part7d_Transportation_Transit.pdf
- Part 7e, Transportation - Inland Waterways, FGDC-STD-014.7e-2008 (https://www.fgdc.gov/standards/projects/FGDC-standards-projects/framework-data-standard/GI_FrameworkDataStandard_Part7e_Transportation_Waterways

Wetlands Mapping Standard, FGDC-STD-015-2009 (https://www.fgdc.gov/standards/projects/FGDC-standards-projects/wetlands-mapping/2009-08%20FGDC%20Wetlands%20Mapping%20Standard_final.pdf)

United States Thoroughfare, Landmark, and Postal Address Data Standard, FGDC-STD-016-2011 (https://www.fgdc.gov/standards/projects/FGDC-standards-projects/street-address/FGDC_endorsedAddressStandard.zip)

Federal Trails Data Standard, FGDC-STD-017-2011 (https://www.fgdc.gov/standards/projects/FGDC-standards-projects/trail-data-standard/Federal_Trail_Data_Standards_FGDC-STD-017-2011.pdf)

Coastal and Marine Ecological Classification Standard, FGDC-STD-018-2012 (https://www.fgdc.gov/standards/projects/FGDC-standards-projects/cmecs-folder/CMECS_Version_06-2012_FINAL.pdf)

External Standards Publications

For FGDC-endorsed standards, visit www.fgdc.gov/standards/fgdc-endorsed-external-standards/index_html (http://www.fgdc.gov/standards/fgdc-endorsed-external-standards/index_html)

ISO and ANSI standards

ISO and ANSI standards may be purchased through the ANSI eStandards Store (http://webstore.ansi.org/). These standards are copyrighted.

OGC standards

Standards developed by the Open Geospatial Consortium may be downloaded via OpenGIS® Specifications (Standards) | OGC® (http://www.opengeospatial.org/standards) at no cost. OGC standards are copyrighted.

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APPENDIX I

FGDC GEOSPATIAL POSITIONING ACCURACY STANDARDS – PART 1: REPORTING METHODOLOGY

FGDC-STD-007.1-1998

NSDI

ational Spatial Data Infrastructure

Geospatial Positioning Accuracy Standards
Part 1: Reporting Methodology

Federal Geodetic Control Subcommittee
Federal Geographic Data Committee

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

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

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CONTENTS

1.1 Introduction

1.1.1 Objective

This document provides a common methodology for reporting the accuracy of horizontal coordinate values and vertical coordinate values for clearly defined features where the location is represented by a single point coordinate: examples are survey monuments, such as brass disks and rod marks; prominent landmarks, such as church spires, standpipes, radio towers, tall chimneys, and mountain peaks; and targeted photogrammetric control points. It provides a means to directly compare the accuracy of coordinate values obtained by one method (e.g., a cartographically-derived value) with that obtained by another method (e.g., a Global Positioning System (GPS) geodetic network survey) for the same point. It is increasingly important for users to not only know the coordinate values, but also the accuracy of those coordinate values, so users can decide which coordinate values represent the best estimate of the true value for their applications.

1.1.2 Scope

Activities which collect or produce data coordinates include geodetic network and crustal motion surveys; national, regional, state, and county topographic mapping; bathymetric mapping and nautical charting; engineering, construction, and facilities management mapping and drawing; cadastral and boundary surveying; etc. These activities support geospatial data applications in areas such as transportation, community development, agriculture, emergency response, environmental management, and information technology.

This document is being developed in parts to address various activities. Each data activity will apply the same general accuracy standard to develop a reporting classification scheme for its particular data. The following parts have been submitted to date:

Part 2, STANDARDS FOR GEODETIC NETWORKS. Geodetic control surveys are usually performed to establish a basic control network (framework) from which supplemental surveying and mapping work, covered in other parts of this document, are performed. Geodetic network surveys are distinguished by use of redundant, interconnected, permanently monumented control points that comprise the framework for the National Spatial Reference System (NSRS) or are often incorporated into the NSRS. These surveys must be performed to far more rigorous accuracy and quality assurance standards than control surveys for general engineering, construction, or topographic mapping. Geodetic network surveys included in the NSRS must be performed to meet automated data recording, submission, project review, and least squares adjustment requirements established by the National Geodetic Survey (NGS). The lead agency is the Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, NGS; the responsible FGDC unit is the Federal Geodetic Control Subcommittee (FGCS).

Part 3, NATIONAL STANDARD FOR SPATIAL DATA ACCURACY. The National Standard for Spatial Data Accuracy (NSSDA) implements a testing and statistical methodology for positional accuracy of fully georeferenced maps and digital geospatial data, in either raster, point, or vector format, derived from sources such as aerial photographs, satellite imagery, and ground surveys. The NSRS is the framework that references positions to the national datums. Positional accuracy of geodetically surveyed points in the National Spatial Reference System is reported according to Part 2, Standards for Geodetic Control Networks, Geospatial Positioning Accuracy Standards. NSRS points may also be selected as an independent source of higher accuracy to test positional accuracy of maps and geospatial data according to the NSSDA. The lead agency is the Department of the Interior, U.S. Geological Survey, National Mapping Division. The responsible FGDC unit is the Subcommittee on Base Cartographic Data.

In addition, two other parts have been identified for inclusion in this document and are under development:

Part 4, ENGINEERING, CONSTRUCTION, AND FACILITIES MANAGEMENT. This part will provide accuracy standards for engineering surveys and maps used to support planning, design, construction, operation, maintenance, and management of facilities, installations, structures, transportation systems, and related projects. It uses the NSSDA for accuracy testing and verification of fully georeferenced maps for A/E/C and Facility Management applications such as preliminary site planning and reconnaissance mapping. It will also provide guidance in developing positional accuracy specifications for geospatial data products, such as architectural and engineering drawings, construction site plans, regional master planning maps, and related Geographical Information Systems (GIS), Computer-Aided Drafting and Design (CADD), and Automated Mapping/Facility Management (AM/FM) products, that may not be referenced to a national datum and where accuracy is based on survey closure ratios or elevation differences. The lead agency is the Department of Defense, U.S. Army Corps of Engineers. The responsible FGDC unit is the Facilities Working Group.

Part 5, NAVIGATION CHARTS AND HYDROGRAPHIC SURVEYS. This part will specify minimum standards for hydrographic surveys so that hydrographic (sounding) data are sufficiently accurate and spatial uncertainty is adequately quantified for safe use by mariners. The accuracy of hydrographic surveying is highly dependent upon knowledge of tidal datum planes and the special accuracy requirements to support safe navigation. This part will provide a standardized methodology for evaluating survey data and reporting resultant data quality through a standard statistical approach. It will be based on the recently revised International Hydrographic Organization (IHO) Standard for Hydrographic Surveys, which is in the final stages of review by the international community. The lead agency is Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office of the Coast Survey. The responsible FGDC subcommittee is the Bathymetric and Nautical Chart Subcommittee.

1.1.3 Applicability

Use Geospatial Positioning Accuracy Standards to evaluate and report the positional accuracy of spatial data produced, revised, 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, item d), “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."

1.1.4 Related Standards

1.1.4.1 FGDC Standards

The Spatial Data Transfer Standard (SDTS) (ANSI-NCITS, 1998) specifies that a data quality report accompany the data in a standard transfer. Because the quality report will function in the assessment for fitness of use, it must also be obtainable in its entirety and separately from the actual data. The quality report consists of five portions: lineage, **positional accuracy**, attribute accuracy, logical consistency, and completeness. Positional accuracy reported according to Geospatial Positioning Accuracy Standards will be included in the data quality report.

Part 2, Data Quality Information, of Content Standards for Digital Geospatial Metadata (Federal Geographic Data Committee, 1998) adopts the five elements of data quality specified by SDTS. Consequently, positional accuracy reported according to Geospatial Positioning Accuracy Standards will be encoded in Metadata.

1.1.4.2 ISO Technical Committee (TC) 211 Geographic Information/Geomatics Standards

ISO Standard 15046-13, Geographic Information - Quality Principles defines a data quality model and identifies **positional accuracy** as a data quality element and various subelements of positional accuracy. It provides a means of measuring how well the data set maps geospatial phenomena according to its product specification.

ISO Standard 15046-14, Geographic Information - Quality - Evaluation Procedures provides data quality evaluation models for both data producers and data users. The procedures are used to determine data quality results consistent with the data quality model defined by ISO Standard 15046-13. They establish a framework to report data quality results in metadata and when necessary, in a separate data quality report.

1.1.5 Standards Development Procedures

Part 2, Standards for Geodetic Networks and Part 3, National Standard for Spatial Data Accuracy (NSSDA) were originally developed independently. Following the first public review of the NSSDA, in its previous version as National Cartographic Standards for Spatial Accuracy, the NSSDA was aligned with emerging standards from the Federal Geodetic Control Subcommittee (FGCS). The FGCS has broad participation from various Federal agencies. Noting how individual FGDC subcommittees and working groups were developing accuracy standards, the FGCS membership agreed to sponsor an FGDC standards project to compile the various accuracy standards into one document and minimize redundancies. The FGDC Standards Working Group has endorsed this approach. This is the first FGDC standards project to integrate standards for various data themes and applications.

1.1.6 Maintenance Authority

The U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, National Geodetic Survey, maintains Part 1, Reporting Methodology, Geospatial Positioning Accuracy Standards for the Federal Geographic Data Committee. Address questions concerning Part 1, Reporting Methodology, Geospatial Positioning Accuracy Standards to: Director, National Geodetic Survey, NOAA, N/NGS, 1315 East-West Highway, Silver Spring, Maryland 20910.

1.2 Accuracy Standard

All spatial data activities should develop a classification scheme following the standard given below. The standard for reporting positional accuracy is defined for horizontal and/or vertical coordinates, depending on the characteristics of the data sets.

Horizontal: The reporting standard in the horizontal component is the radius of a circle of uncertainty, such that the true or theoretical location of the point falls within that circle 95-percent of the time.

Vertical: The reporting standard in the vertical component is a linear uncertainty value, such that the true or theoretical location of the point falls within +/- of that linear uncertainty value 95-percent of the time. The reporting accuracy standard should be defined in metric (International System of Units, SI) units. However, accuracy will be reported in English (inch-pound) units where the point coordinates or elevations are reported in English units.

The method used to evaluate accuracy should be described. Examples include: statistical testing, least squares adjustment results, comparison with values of higher accuracy, repeat measurements, estimation, etc. The accuracy standard for point data in each part of the document will identify the type of application and if applicable, the accuracy level recommended for that application.

Coordinate values should be based on National datums. Horizontal coordinate values should preferably be referenced to the North American Datum of 1983 (NAD 83). Vertical coordinate values should preferably be referenced to North American Vertical Datum of 1988 (NAVD 88). However, it is recognized that many legacy maps and geospatial data are referenced to older national datums, such as the North American Datum of 1927 (NAD 27) and the National Geodetic Vertical Datum of 1929 (NGVD 29).

If coordinate values are not referenced to the National datum but their relationship to the national datum is known, identify the datum and its relationship to a National datum. If the relationship between the local datum and the National datum is not specified, identify the datum, but state that its relationship to a National datum is unspecified.

1.3 References

American National Standards Institute, Information Technology - Spatial Data Transfer Standard (SDTS) (ANSI-NCITS 320:1998): New York, New York.

Clinton, William J., 1994, Coordinating Geographic Data Acquisition and Access: The National Spatial Data Infrastructure. Washington, D.C., Federal Register, Volume 59, Number 71, pp. 17671-17674.

Federal Geographic Data Committee, 1998, Content Standards for Digital Geospatial Metadata (version 2.0), FGDC-STD-001-1998: Washington, D.C., Federal Geographic Data Committee, 66 p.

Geodetic Survey Division, 1996, Accuracy Standards for Positioning, Version 1.0: Ottawa, Canada, Natural Resources Canada, 28 p.

National Geodetic Survey, 1986, Geodetic Glossary: Rockville, Maryland, National Geodetic Survey, 274 p.

Subcommittee for Base Cartographic Data, 1998, Final Draft Content Standards for Digital Gridded Land Elevation Data: Reston, Virginia, U.S. Geological Survey, 37 p.

Draft standards not released to the public:

ISO/Technical Committee 211 Geographic information/Geomatics, Working Group 3 - Geospatial Data Administration, ISO Standard 15046-13 Geographic Information - Quality - Principles

ISO/Technical Committee 211 Geographic information/Geomatics, Working Group 3 - Geospatial Data Administration, ISO Standard 15046-14 Geographic Information - Quality - Evaluation Procedures

Appendix 1-A
Glossary of Terms
(informative)

The following are definitions of various terms used throughout the Geospatial Positioning Accuracy Standards.

accuracy - closeness of an estimated (e.g., measured or computed) value to a standard or accepted [true] value of a particular quantity. (National Geodetic Survey, 1986).

> NOTE Because the true value is not known, but only estimated, the accuracy of the measured quantity is also unknown. Therefore, accuracy of coordinate information can only be estimated (Geodetic Survey Division, 1996).

accuracy testing - process by which the accuracy of a data set may be checked.

check point - one of the points in the sample used to estimate the positional accuracy of the data set against an independent source of higher accuracy.

component accuracy - positional accuracy in each x, y, and z component.

confidence level - the probability that the true (population) value is within a range of given values.

> NOTE in the sense of this standard, the probability that errors are within a range of given values.

dataset - identifiable collection of related data.

datum - any quantity or set of such quantities that may serve as a basis for calculation of other quantities. (National Geodetic Survey, 1986)

elevation - height of a point with respect to a defined vertical datum.

ellipsoidal height - distance between a point on the Earth's surface and the ellipsoidal surface, as measured along the perpendicular to the ellipsoid at the point and taken positive upward from the ellipsoid.

> NOTE also called geodetic height (National Geodetic Survey, 1986)

horizontal accuracy - positional accuracy of a dataset with respect to a horizontal datum. (Adapted from Subcommittee for Base Cartographic Data, 1998)

horizontal error - magnitude of the displacement of a feature's recorded horizontal position in a dataset from its true or more accurate position, as measured radially and not resolved into x, y.

independent source of higher accuracy - data acquired independently of procedures to generate the dataset that is used to test the positional accuracy of a dataset.

> NOTE the independent source of higher accuracy shall be of the highest accuracy feasible and practicable to evaluate the accuracy of the data set.

local accuracy - The *local accuracy* of a control point is a value that represents the uncertainty in the coordinates of the control point relative to the coordinates of other directly connected, adjacent control points at the 95-percent confidence level. The reported local accuracy is an approximate average of the individual local accuracy values between this control point and other observed control points used to establish the coordinates of the control point.

network accuracy - The *network accuracy* of a control point is a value that represents the uncertainty in the coordinates of the control point with respect to the geodetic datum at the 95-percent confidence level. For NSRS network accuracy classification, the datum is considered to be best expressed by the geodetic values at the Continuously Operating Reference Stations (CORS) supported by NGS. By this definition, the local and network accuracy values at CORS sites are considered to be infinitesimal, i.e., to approach zero.

orthometric height - distance measured along the plumb line between the geoid and a point on the Earth's surface, taken positive upward from the geoid. (adapted from National Geodetic Survey, 1986).

positional accuracy - describes the accuracy of the position of features (adapted from ISO Standard 15046-13)

precision - in statistics, a measure of the tendency of a set of random numbers to cluster about a number determined by the set. (National Geodetic Survey, 1986).

> NOTE If appropriate steps are taken to eliminate or correct for biases in positional data, precision measures may also be a useful means of representing accuracy. (Geodetic Survey Division, 1996).

root mean square error (RMSE) - square root of the mean of squared errors for a sample.

spatial data - information that identifies the geographic location and characteristics of natural or constructed features and boundaries of earth. This information may be derived from, among other things, remote sensing, mapping, and surveying technologies (Federal Geographic Data Committee, 1998).

> NOTE also known as geospatial data.

vertical accuracy - measure of the positional accuracy of a data set with respect to a specified vertical datum. (adapted from Subcommittee for Base Cartographic Data, 1998).

vertical error - displacement of a feature's recorded elevation in a dataset from its true or more accurate elevation.

well-defined point - point that represents a feature for which the horizontal position is known to a high degree of accuracy and position with respect to the geodetic datum.

APPENDIX J

FGDC GEOSPATIAL POSITIONING ACCURACY STANDARDS – PART 2: STANDARDS FOR GEODETIC NETWORKS

FGDC-STD-007.2-1998

NSDI

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Geospatial Positioning Accuracy Standards
Part 2: Standards for Geodetic Networks

Federal Geodetic Control Subcommittee
Federal Geographic Data Committee

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
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World Wide Web: http://fgdc.er.usgs.gov/fgdc.html

CONTENTS

2.1 Introduction

2.1.1 Objective

This document provides a common methodology for determining and reporting the accuracy of horizontal coordinate values and vertical coordinate values for geodetic control points represented by survey monuments, such as brass disks and rod marks. It provides a means to directly compare the accuracy of coordinate values obtained by one method (e.g., a classical line-of-sight traverse) with the accuracy of coordinate values obtained by another method (e.g., a Global Positioning System (GPS) geodetic network survey) for the same point.

2.1.2 Scope

Geodetic control surveys are usually performed to establish a basic control network (framework) from which supplemental surveying and mapping work, covered in other parts of this document, is performed. Geodetic network surveys are distinguished by use of redundant, interconnected, permanently monumented control points that comprise the framework for the National Spatial Reference System (NSRS) or are often incorporated into the NSRS.

These surveys must be performed to far more rigorous accuracy and quality assurance standards than those for control surveys for general engineering, construction, or topographic mapping purposes. Geodetic network surveys included in NSRS must be performed to meet automated data recording, submittal, project review, and least squares adjustment requirements established by the Federal Geodetic Control Subcommittee (FGCS).

2.1.3 Applicability

Geodetic network surveys are often employed when large geopolitical area (e.g., county-level or larger) mapping control is required, and where seamless connection with adjacent political areas is critical. Accurate network control may also be required for controlling interstate transportation corridors (highways, pipelines, railroads, etc.); long-span bridge construction alignment; geophysical studies; structural deformation monitoring of dams, buildings, and similar facilities.

2.1.4 Related Standards

Part 6: Point Profile, The Spatial Data Transfer Standard (FGDC, 1998) defines the format to be used to transfer geodetic coordinate data, including the accuracy of the coordinate values, between geographic information systems.

Part 3, National Standard for Spatial Data Accuracy (NSSDA), Geospatial Positioning Accuracy Standards (FGDC, 1998)provides the statistical and testing methodology for estimating the accuracy of point coordinate values produced from maps and other digital geospatial data with respect to geo-referenced ground positions of higher accuracy.

The public review draft of Part 4, Standards for A/E/C and Facility Management, Geospatial Positioning Accuracy standards, uses the NSSDA for accuracy testing and verification. The NSSDA may be used for fully geo-referenced maps for A/E/C and Facility Management applicaitons such as preliminary site planning and reconnaissance mapping.

2.1.5 Standards Development Procedures

Draft accuracy standards for geodetic networks were developed by the FGCS Methodology Work Group, Federal Geographic Data Committee. The draft accuracy standards were released for public review through the FGCS and evolved into the final form presented in Table 2.1 of this publication.

2.1.6 Maintenance

The U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, National Geodetic Survey, maintains accuracy standards for geodetic networks for the Federal Geodetic Control Subcommittee, Federal Geographic Data Committee. Address questions concerning accuracy standards for geodetic networks to: Director, National Geodetic Survey, NOAA, N/NGS, 1315 East-West Highway, Silver Spring, Maryland 20910.

2.2 Testing Methodology And Reporting Requirements

2.2.1 Accuracy Standards

Note that the following accuracy standards supersede and replace the accuracy standards found in FGCC 1984 and FGCC 1988 (see Section 2.3). The classification standard for geodetic networks is based on accuracy. Accuracies are categorized separately according to Table 2.1 for horizontal, ellipsoid height, and orthometric height. Note: although the largest entry in Table 2.1 is 10 meters, the accuracy standards can be expanded to larger numbers if needed.

Table 2.1 -- Accuracy Standards
Horizontal, Ellipsoid Height, and Orthometric Height

Accuracy Classification	95-Percent Confidence Less Than or Equal to:
1-Millimeter	0.001 meters
2-Millimeter	0.002 "
5-Millimeter	0.005 "
1-Centimeter	0.010 "
2-Centimeter	0.020 "
5-Centimeter	0.050 "
1-Decimeter	0.100 "
2-Decimeter	0.200 "
5-Decimeter	0.500 "
1-Meter	1.000 "
2-Meter	2.000 "
5-Meter	5.000 "
10-Meter	10.000 "

When control points in a survey are classified, they have been verified as being consistent with all other points in the network, not merely those within that particular survey. It is not observation closures within a survey which are used to classify control points, but the ability of that survey to duplicate already established control values. This comparison takes into account models of crustal motion, refraction, and any other systematic effects known to influence survey measurements.

2.2.2 Accuracy Determination

The classification standard for NSRS is based on Table 2.1.

The procedure leading to classification involves four steps:

l. The survey measurements, field records, sketches, and other documentation are examined to verify compliance with the specifications for the intended accuracy of the survey. This examination may lead to a modification of the intended accuracy.

2. Results of a minimally constrained, least squares adjustment of the survey measurements are examined to ensure correct weighting of the observations and freedom from blunders.

3. Local and network accuracy measures computed by random error propagation determine the provisional accuracy. In contrast to a constrained adjustment where coordinates are obtained by holding fixed the datum values of the existing network control, accuracy measures are computed by weighting datum values in accordance with the network accuracies of the existing network control.

4. The survey accuracy is checked by comparing minimally constrained adjustment results against established control. The result must meet a 95 percent confidence level. This comparison takes into account the network accuracy of the existing control, as well as systematic effects such as crustal motion or datum distortion. If the comparison fails, then both the survey and network measurements must be scrutinized to determine the source of the problem.

Users with specialized applications that require more exacting accuracy estimates at the CORS sites should contact NGS. It is not necessary to directly connect to a CORS to compute the network accuracy of a control point. However, it is necessary that the survey be properly connected to existing NSRS control points with established network accuracy values.

By supporting both local accuracy and network accuracy, the diverse requirements of NSRS users can be met. Local accuracy is best adapted to check relations between nearby control points. For example, a surveyor checking closure between two NSRS points is mostly interested in a local accuracy measure. On the other hand, someone constructing a Geographic or Land Information System (GIS/LIS) will often need some type of positional tolerance associated with a set of coordinates. Network accuracy measures how well coordinates approach an ideal, error-free datum.

Thus, for control points in the NSRS, both local accuracy and network accuracy will be reported for each geodetic component (horizontal control, ellipsoidal height, and orthometric height).

2.2.3 Accuracy Reporting

When providing geodetic point coordinate data, a statement should be provided that the data meets a particular accuracy standard for both the *local accuracy* and the *network accuracy*. For example, these geodetic control data meet the 2-centimeter local accuracy standard for the horizontal coordinate values and the 5-centimeter local accuracy standard for the vertical coordinate values (heights) at the 95-percent confidence level. A similar statement should be provided for these same data reporting the network accuracy.

Note: In the above statement the data may comply with one accuracy value for the horizontal component and a different accuracy value for the vertical component. If a dataset does not contain elevation data, label it for horizontal accuracy only; conversely, when a dataset does not contain horizontal data, label it for vertical accuracy only.

It is preferred that accuracy value(s) be reported in metric units; however, feet shall be used when the dataset coordinates are in feet (i.e., State Plane Coordinates in feet). The number of significant digits for the accuracy value(s) shall be consistent with the number of significant digits for the dataset point coordinates. For most geodetic control network applications, centimeters should be used for reporting local accuracy and network accuracy values.

2.3 References

Federal Geodetic Control Committee, 1984, Standards and Specifications for Geodetic Control Networks: Silver Spring, Maryland, National Geodetic Survey, National Oceanic and Atmospheric Administration, 29 p.

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APPENDIX K

FGDC GEOSPATIAL POSITIONING ACCURACY STANDARDS – PART 3: NATIONAL STANDARD FOR SPATIAL DATA ACCURACY

FGDC-STD-007.3-1998

ational Spatial Data Infrastructure

Geospatial Positioning Accuracy Standards
Part 3: National Standard for Spatial Data Accuracy

Subcommittee for Base Cartographic Data
Federal Geographic Data Committee

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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CONTENTS

3.1 Introduction

3.1.1 Objective

The National Standard for Spatial Data Accuracy (NSSDA) implements a statistical and testing methodology for estimating the positional accuracy of points on maps and in digital geospatial data, with respect to georeferenced ground positions of higher accuracy.

3.1.2 Scope

The NSSDA applies to fully georeferenced maps and digital geospatial data, in either raster, point, or vector format, derived from sources such as aerial photographs, satellite imagery, and ground surveys. It provides a common language for reporting accuracy to facilitate the identification of spatial data for geographic applications.

This standard is classified as a **Data Usability Standard** by the Federal Geographic Data Committee Standards Reference Model . A Data Usability Standard describes how to express "the applicability or essence of a dataset or data element" and includes "data quality, assessment, accuracy, and reporting or documentation standards" (FGDC, 1996, p. 8)

This standard does not define threshold accuracy values. Agencies are encouraged to establish thresholds for their product specifications and applications and for contracting purposes. Ultimately, users identify acceptable accuracies for their applications. Data and map producers must determine what accuracy exists or is achievable for their data and report it according to NSSDA.

3.1.3 Applicability

Use the NSSDA to evaluate and report the positional accuracy of maps and geospatial data produced, revised, 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, item d), "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."

Accuracy of new or revised spatial data will be reported according to the NSSDA. Accuracy of existing or legacy spatial data and maps may be reported, as specified, according to the NSSDA or the accuracy standard by which they were evaluated.

3.1.4 Related Standards

Data producers may elect to use conformance levels or 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 truly applicable for digital geospatial data.

Positional accuracy of geodetically surveyed points is reported according to Part 2, Standards for Geodetic Control Networks (Federal Geographic Data Committee, 1998), Geospatial Positioning Accuracy Standards. Ground coordinates of points collected according to Standards and Specifications for Geodetic Control Networks (Federal Geodetic Control Committee, 1984) are used in the National Spatial Reference System (NSRS). NSRS is a consistent national coordinate system that defines latitude, longitude, height, scale, gravity, and orientation throughout the Nation, and how these values change with time. Consequently, it ties spatial data to georeferenced positions. NSRS points may be selected as an independent source of higher accuracy to test positional accuracy of maps and geospatial data according to the NSSDA.

Part 4, Standards for A/E/C and Facility Management (Facilities Working Group, 1997), uses the NSSDA for accuracy testing and verification. The NSSDA may be used for fully georeferenced maps for A/E/C and Facility Management applications such as preliminary site planning and reconnaissance mapping.

3.1.5 Standards Development Procedures

The National Standard for Spatial Data Accuracy was developed by the FGDC *ad hoc* working group on spatial data accuracy, with the intent to update the United States National Map Accuracy Standards (NMAS) (U.S. Bureau of the Budget, 1947). The ASPRS Accuracy Standards for Large-Scale Maps (ASPRS Specifications and Standards Committee, 1990) formed the basis for update of the NMAS. The NSSDA, in its former version as the draft National Cartographic Standards for Spatial Accuracy (NCSSA), extended the ASPRS Accuracy Standards to map scales smaller than 1:20,000. The NCSSA were released for public review through the Federal Geographic Data Committee and were substantially rewritten as a result.

The geospatial data community has diversified to include many data producers with different product specifications and many data users with different application requirements. The NSSDA was developed to provide a common reporting mechanism so that users can directly compare datasets for their applications. It was realized that map-dependent measures of accuracy, such as publication scale and contour interval, were not fully applicable when digital geospatial data can be readily manipulated and output to any scale or data format. Principal changes included requirements to report numeric accuracy values; a composite statistic for horizontal accuracy, instead of component (x,y) accuracy, and alignment with emerging Federal Geographic Control Subcommittee (FGCS) accuracy standards (FGDC, 1998). The NCSSA was renamed the National Standard for Spatial Data Accuracy to emphasize its applicability to digital geospatial data as well as graphic maps.

3.1.6 Maintenance

The U.S. Department of the Interior, U.S. Geological Survey (USGS), National Mapping Division, maintains the National Standard for Spatial Data Accuracy (NSSDA) for the Federal Geographic Data Committee. Address questions concerning the NSSDA to: Chief, National Mapping Division, USGS, 516 National Center, Reston, VA 20192.

3.2 Testing Methodology And Reporting Requirements

3.2.1 Spatial Accuracy

The NSSDA uses root-mean-square error (RMSE) to estimate positional accuracy. RMSE is the square root of the average of the set of squared differences between dataset coordinate values and coordinate values from an independent source of higher accuracy for identical points[1].

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 dataset 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.

3.2.2 Accuracy Test Guidelines

According to the Spatial Data Transfer Standard (SDTS) (ANSI-NCITS, 1998), accuracy testing by an independent source of higher accuracy is the preferred test for positional accuracy. Consequently, the NSSDA presents guidelines for accuracy testing by an independent source of higher accuracy. The independent source of higher accuracy shall the highest accuracy feasible and practicable to evaluate the accuracy of the dataset.[2]

The data producer shall determine the geographic extent of testing. Horizontal accuracy shall be tested by comparing the planimetric coordinates of well-defined points[3] in the dataset with coordinates of the same points from an independent source of higher accuracy. Vertical accuracy shall be tested by comparing the elevations in the dataset with elevations of the same points as determined from an independent source of higher accuracy.

Errors in recording or processing data, such as reversing signs or inconsistencies between the dataset and independent source of higher accuracy in coordinate reference system definition, must be corrected before computing the accuracy value.

A minimum of 20 check points shall be tested, distributed to reflect the geographic area of interest and the distribution of error in the dataset.[4] When 20 points are tested, the 95% confidence level allows one point to fail the threshold given in product specifications.

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[1] see Appendix 3-A

[2] see Appendix 3-C, section 2

[3] see Appendix 3-C, section 1

[4] see Appendix 3-C, section 3

If fewer than twenty points can be identified for testing, use an alternative means to evaluate the accuracy of the dataset. SDTS (ANSI-NCITS, 1998) identifies these alternative methods for determining positional accuracy:

- Deductive Estimate
- Internal Evidence
- Comparison to Source

3.2.3 Accuracy Reporting

Spatial data may be compiled to comply with one accuracy value for the vertical component and another for the horizontal component. If a dataset does not contain elevation data, label for horizontal accuracy only. Conversely, when a dataset, e.g. a gridded digital elevation dataset or elevation contour dataset, does not contain well-defined points, label for vertical accuracy only.

A dataset may contain themes or geographic areas that have different accuracies. Below are guidelines for reporting accuracy of a composite dataset:

- If data of varying accuracies can be identified separately in a dataset, compute and report separate accuracy values.
- If data of varying accuracies are composited and cannot be separately identified AND the dataset is tested, report the accuracy value for the composited data.
- If a composited dataset is not tested, report the accuracy value for the least accurate dataset component.

Positional accuracy values shall be reported in ground distances. Metric units shall be used when the dataset coordinates are in meters. Feet shall be used when the dataset coordinates are in feet. The number of significant places for the accuracy value shall be equal to the number of significant places for the dataset point coordinates.

Accuracy reporting in ground distances allows users to directly compare datasets of differing scales or resolutions. A simple statement of conformance (or omission, when a map or dataset is non-conforming) is not adequate in itself. Measures based on map characteristics, such as publication scale or contour interval, are not longer adequate when data can be readily manipulated and output to any scale or to different data formats.

Report accuracy at the 95% confidence level for data *tested* for both horizontal and vertical accuracy as:

Tested ____ (meters, feet) horizontal accuracy at 95% confidence level
____ (meters, feet) vertical accuracy at 95% confidence level

Use the "compiled to meet" statement below when the above guidelines for testing by an independent source of higher accuracy cannot be followed and an alternative means is used to evaluate accuracy. Report accuracy at the 95% confidence level for data *produced according to procedures that have been demonstrated to produce data with particular horizontal and vertical accuracy values* as:

Compiled to meet ____ (meters, feet) horizontal accuracy at 95% confidence level
____ (meters, feet) vertical accuracy at 95% confidence level

Report accuracy for data *tested* for horizontal accuracy and *produced according to procedures that have been demonstrated to comply with a particular vertical accuracy value* as:

Tested ____ (meters, feet) horizontal accuracy at 95% confidence level
Compiled to meet ____ (meters, feet) vertical accuracy at 95% confidence level

Show similar labels when data are *tested* for vertical accuracy and *produced according to procedures that have been demonstrated to produce data with a particular horizontal accuracy value*.

For digital geospatial data, report the accuracy value in digital geospatial metadata (Federal Geographic Data Committee, 1998, Section 2), as appropriate to dataset spatial characteristics:

(Data_Quality_Information/Positional_Accuracy/Horizontal_Positional_Accuracy/Horizontal_Positional_Accuracy_Assessment/Horizontal_Positional_Accuracy_Value)
and/or
(Data_Quality_Information/Positional_Accuracy/Vertical_Positional_Accuracy/Vertical_Positional_Accuracy_Assessment/Vertical_Positional_Accuracy_Value)

Enter the text "National Standard for Spatial Data Accuracy" for these metadata elements (Federal Geographic Data Committee, 1998, Section 2), as appropriate to dataset spatial characteristics:

(Data_Quality_Information/Positional_Accuracy/Horizontal_Positional_Accuracy/Horizontal_Positional_Accuracy_Assessment/Horizontal_Positional_Accuracy_Explanation)
and/or
(Data_Quality_Information/Positional_Accuracy/Vertical_Positional_Accuracy/Vertical_Positional_Accuracy_Assessment/Vertical_Positional_Accuracy_Explanation)

Regardless of whether the data was tested by a independent source of higher accuracy or evaluated for accuracy by alternative means, provide a complete description on how the values were determined in metadata, as appropriate to dataset spatial characteristics (Federal Geographic Data Committee, 1998, Section 2):

(Data_Quality_Information/Positional_Accuracy/Horizontal_Positional_Accuracy/Horizontal_Positional_Accuracy_Report)
and/or
(Data_Quality_Information/Positional_Accuracy/Vertical_Positional_Accuracy/Vertical_Positional_Accuracy_Report)

3.3 NSSDA and Other Map Accuracy Standards

Accuracy of new or revised spatial data will be reported according to the NSSDA. Accuracy of existing or legacy spatial data and maps may be reported, as specified, according to the NSSDA or the accuracy standard by which they were evaluated. Appendix 3-D describes root mean square error (RMSE) as applied to individual x-, y- components, former NMAS, and ASPRS Accuracy Standards for Large-Scale Maps. These standards, their relationships to NSSDA, and accuracy labeling are described to ensure that users have some means to assess positional accuracy of spatial data or maps for their applications.

If accuracy reporting cannot be provided using NSSDA or other recognized standards, provide information to enable users to evaluate how the data fit their applications requirements. This information may include descriptions of the source material from which the data were compiled, accuracy of ground surveys associated with compilation, digitizing procedures, equipment, and quality control procedures used in production.

No matter what method is used to evaluate positional accuracy, explain the accuracy of coordinate measurements and describe the tests in digital geospatial metadata (Federal Geographic Data Committee, 1998, Section 2) , as appropriate to dataset spatial characteristics:

(Data_Quality_Information/Positional_Accuracy/Horizontal_Positional_Accuracy/Horizontal_Positional_Accuracy_Report)
and/or

(Data_Quality_Information/Positional_Accuracy/Vertical_Positional_Accuracy/Vertical_Positional_Accuracy_Report)

Provide information about the source data and processes used to produce the dataset in data elements of digital geospatial metadata (Federal Geographic Data Committee, 1998, Section 2) under (Data_Quality_Information/Lineage).

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Appendix 3-A.
Accuracy Statistics
(normative)

EXPLANATORY COMMENTS

1. Horizontal Accuracy

Let:

$RMSE_x = sqrt[\sum(x_{data, i} - x_{check, i})^2/n]$
$RMSE_y = sqrt[\sum(y_{data, i} - y_{check, i})^2/n]$

where:
$x_{data, i}$, $y_{data, i}$ are the coordinates of the i th check point in the dataset
$x_{check, i}$, $y_{check, i}$ are the coordinates of the i th check point in the independent source of higher accuracy
n is the number of check points tested
i is an integer ranging from 1 to n

Horizontal error at point i is defined as $sqrt[(x_{data, i} - x_{check, i})^2 + (y_{data, i} - y_{check, i})^2]$. Horizontal RMSE is:

$$RMSE_r = sqrt[\sum((x_{data, i} - x_{check, i})^2 + (y_{data, i} - y_{check, i})^2)/n]$$
$$= sqrt[RMSE_x^2 + RMSE_y^2]$$

Case 1: Computing Accuracy According to the NSSDA when $RMSE_x = RMSE_y$

If $RMSE_x = RMSE_y$,
$$RMSE_r = sqrt(2*RMSE_x^2) = sqrt(2*RMSE_y^2)$$
$$= 1.4142*RMSE_x = 1.4142*RMSE_y$$

It is assumed that systematic errors have been eliminated as best as possible. If error is normally distributed and independent in each the x- and y-component and error, the factor 2.4477 is used to compute horizontal accuracy at the 95% confidence level (Greenwalt and Schultz, 1968). When the preceding conditions apply, $Accuracy_r$, the accuracy value according to NSSDA, shall be computed by the formula:

$$Accuracy_r = 2.4477 * RMSE_x = 2.4477 * RMSE_y$$
$$= 2.4477 * RMSE_r /1.4142$$
$$Accuracy_r = 1.7308 * RMSE_r$$

Case 2: Approximating circular standard error when $RMSE_x \neq RMSE_y$

If $RMSE_{min}/RMSE_{max}$ is between 0.6 and 1.0 (where $RMSE_{min}$ is the smaller value between $RMSE_x$ and $RMSE_y$ and $RMSE_{max}$ is the larger value), circular standard error (at 39.35% confidence) may be approximated as $0.5*(RMSE_x + RMSE_y)$ (Greenwalt and Schultz, 1968). If error is normally distributed and independent in each the x- and y-component and error, the accuracy value according to NSSDA may be approximated according to the following formula:

$$Accuracy_r \sim 2.4477 * 0.5 * (RMSE_x + RMSE_y)$$

2. Vertical Accuracy

Let:

$RMSE_z = sqrt[\sum(z_{data\ i} - z_{check\ i})^2/n]$

where

$z_{data\ i}$ is the vertical coordinate of the i th check point in the dataset.
$z_{check\ i}$ is the vertical coordinate of the i th check point in the independent source of higher accuracy
n = the number of points being checked
i is an integer from 1 to n

It is assumed that systematic errors have been eliminated as best as possible. If vertical error is normally distributed, the factor 1.9600 is applied to compute linear error at the 95% confidence level (Greenwalt and Schultz, 1968). Therefore, vertical accuracy, $Accuracy_z$, reported according to the NSSDA shall be computed by the following formula:

$$Accuracy_z = 1.9600 * RMSE_z.$$

Appendix 3-B
Horizontal Accuracy Computations
(informative)

Horizontal Accuracy Computations

The data for horizontal accuracy computations come from the draft National Mapping Program (NMP) Technical Instructions, Procedure Manual for Map Accuracy Testing (National Mapping Division, 1987). Positions on the Crider, Kentucky 1:24,000-scale USGS topographic quadrangle were tested against a triangulated solution of positions independent of the control solution used to produce the map. The photography used to collect the independent source was different from that used for the map compilation, and a different control configuration was utilized.

- Coordinates are on the State Plane Coordinate System (south zone), based on NAD 27. Units are in feet.
- x (computed) and y (computed) are coordinate values from the triangulated solution.
- x (map) and y (map) are coordinate values for map positions.

Table 1 assumes that $RMSE_x = RMSE_y$. Therefore, the accuracy value according to the NSSDA, at 95% confidence, is computed by the formula given in Case 1 in Appendix 3-A (normative). The accuracy value according to the NSSDA is 35 feet. Of twenty-five points tested, only point # 10360 has a positional error that exceeds 35 feet.

Table 2 uses the formula given in Case 2 in Appendix 3-A (normative) to estimate accuracy when $RMSE_x \neq RMSE_y$. The accuracy value according to the NSSDA, at 95% confidence, is 35 feet.

Table 1.
Accuracy Calculations for Crider, Kentucky USGS 1:24,000-scale Topographic Quadrangle
$RMSE_x = RMSE_y$ assumed

Number	Description	x (computed)	x (map)	diff in x	squared diff in x (1)	y (computed)	y (map)	diff in y	squared diff in y (2)	(1) +(2)	square root of [(1) +(2)]
10351	T-RD-W	1373883	1373894	11	121	298298	298297	-1	1	122	11.05
10352	T-RD-E	1370503	1370486	-17	289	303727	303747	20	400	689	26.25
10353	RD AT RR	1361523	1361537	14	196	302705	302705	0	0	196	14.00
10354	T-RD-SW	1357653	1357667	14	196	298726	298746	20	400	596	24.41
10355	T-RD-SE	1348121	1348128	7	49	299725	299755	30	900	949	30.81
10356	RD AT RR	1345601	1345625	24	576	309911	309910	-1	1	577	24.02
10357	T-RD-E	1350505	1350507	2	4	318478	318477	-1	1	5	2.24
10358	X-RD	1351781	1351792	11	121	307697	307698	1	1	122	11.05
10359	T-RD-E	1352361	1352379	18	324	311109	311099	-10	100	424	20.59
10360	X-RD	1360657	1360645	-12	144	316720	316761	41	1681	1825	42.72
10361	Y-RD-SW	1368215	1368202	-13	169	309842	309869	27	729	898	29.97
10362	T-RD-W	1370299	1370282	-17	289	316832	316849	17	289	578	24.04
10363	T-RD-S	1373855	1373839	-16	256	319893	319886	-7	49	305	17.46
10364	Y-RD-W	1379981	1379962	-19	361	311641	311633	-8	64	425	20.62
10365	T-RD-E	1378625	1378628	3	9	334995	335010	15	225	234	15.30
10366	T-RD-SE	1374735	1374742	7	49	333909	333922	13	169	218	14.76
10367	T-RD-NW	1370581	1370576	-5	25	324098	324095	-3	9	34	5.83
10368	Y-RD-SE	1359379	1359387	8	64	328690	328691	1	1	65	8.06
10369	T-RD-S	1346459	1346479	20	400	330816	330812	-4	16	416	20.40
10370	T-RD-E	1347101	1347109	8	64	335869	335850	-19	361	425	20.62
10371	T-RD-SE	1350733	1350748	15	225	332715	332725	10	100	325	18.03
10372	T-RD-N	1354395	1354411	16	256	335337	335345	8	64	320	17.89
10373	T-RD-S	1358563	1358570	7	49	335398	335406	8	64	113	10.63
10374	X-RD	1365561	1365574	13	169	333873	333877	4	16	185	13.60
10375	X-RD	1373645	1373643	-2	4	339613	339609	-4	16	20	4.47
									sum	10066	
									average	402.64	
									RMSEr	20.07	
									Accuracy per NSSDA (2.4477 * RMSEr)	35	

Table 2.
Accuracy Computations for Crider, Kentucky USGS 1:24,000-scale Topographic Quadrangle
$RMSE_x \neq RMSE_y$

Number	Description	x (computed)	x (map)	diff in x	squared diff in x	y (computed)	y (map)	diff in y	squared diff in y
10351	T-RD-W	1373883	1373894	11	121	298298	298297	-1	1
10352	T-RD-E	1370503	1370486	-17	289	303727	303747	20	400
10353	RD AT RR	1361523	1361537	14	196	302705	302705	0	0
10354	T-RD-SW	1357653	1357667	14	196	298726	298746	20	400
10355	T-RD-SE	1348121	1348128	7	49	299725	299755	30	900
10356	RD AT RR	1345601	1345625	24	576	309911	309910	-1	1
10357	T-RD-E	1350505	1350507	2	4	318478	318477	-1	1
10358	X-RD	1351781	1351792	11	121	307697	307698	1	1
10359	T-RD-E	1352361	1352379	18	324	311109	311099	-10	100
10360	X-RD	1360657	1360645	-12	144	316720	316761	41	1681
10361	Y-RD-SW	1368215	1368202	-13	169	309842	309869	27	729
10362	T-RD-W	1370299	1370282	-17	289	316832	316849	17	289
10363	T-RD-S	1373855	1373839	-16	256	319893	319886	-7	49
10364	Y-RD-W	1379981	1379962	-19	361	311641	311633	-8	64
10365	T-RD-E	1378625	1378628	3	9	334995	335010	15	225
10366	T-RD-SE	1374735	1374742	7	49	333909	333922	13	169
10367	T-RD-NW	1370581	1370576	-5	25	324098	324095	-3	9
10368	Y-RD-SE	1359379	1359387	8	64	328690	328691	1	1
10369	T-RD-S	1346459	1346479	20	400	330816	330812	-4	16
10370	T-RD-E	1347101	1347109	8	64	335869	335850	-19	361
10371	T-RD-SE	1350733	1350748	15	225	332715	332725	10	100
10372	T-RD-N	1354395	1354411	16	256	335337	335345	8	64
10373	T-RD-S	1358563	1358570	7	49	335398	335406	8	64
10374	X-RD	1365561	1365574	13	169	333873	333877	4	16
10375	X-RD	1373645	1373643	-2	4	339613	339609	-4	16
				sum	4409				5657
				average	176.36				226.28
				RMSE	13.28				15.04
				$RMSE_{min}/RMSE_{max}$					0.88

Since $RMSE_{min}/RMSE_{max}$ is between 0.6 and 1.0, the formula $Accuracy_r \sim 2.4477 * 0.5 * (RMSE_x + RMSE_y)$ may be used to estimate accuracy according to the NSSDA.
$Accuracy_r$ ~35 feet.

Appendix 3-C.
Testing guidelines
(informative)

1. Well-Defined Points

A well-defined point represents a feature for which the horizontal position is known to a high degree of accuracy and position with respect to the geodetic datum. For the purpose of accuracy testing, well-defined points must be easily visible or recoverable on the ground, on the independent source of higher accuracy, and on the product itself. Graphic contour data and digital hypsographic data may not contain well-defined points.

The selected points will differ depending on the type of dataset and output scale of the dataset. For graphic maps and vector data, suitable well-defined points represent right-angle intersections of roads, railroads, or other linear mapped features, such as canals, ditches, trails, fence lines, and pipelines. For orthoimagery, suitable well-defined points may represent features such as small isolated shrubs or bushes, in addition to right-angle intersections of linear features. For map products at scales of 1:5,000 or larger, such as engineering plats or property maps, suitable well-defined points may represent additional features such as utility access covers and intersections of sidewalks, curbs, or gutters.

2. Data acquisition for the independent source of higher accuracy

The independent source of higher accuracy shall be acquired separately from data used in the aerotriangulation solution or other production procedures. The independent source of higher accuracy shall be of the highest accuracy feasible and practicable to evaluate the accuracy of the dataset.

Although guidelines given here are for geodetic ground surveys, the geodetic survey is only one of many possible ways to acquire data for the independent source of higher accuracy. Geodetic control surveys are designed and executed using field specifications for geodetic control surveys (Federal Geodetic Control Committee, 1984). Accuracy of geodetic control surveys is evaluated using Part 2, Standards for Geodetic Networks (Federal Geographic Data Committee, 1998). To evaluate if the accuracy of geodetic survey is sufficiently greater than the positional accuracy value given in the product specification, compare the FGCS **network accuracy** reported for the geodetic survey with the accuracy value given by the product specification for the dataset.

Other possible sources for higher accuracy information are Global Positioning System (GPS) ground surveys, photogrammetric methods, and data bases of high accuracy point coordinates.

3. Check Point Location

Due to the diversity of user requirements for digital geospatial data and maps, it is not realistic to include statements in this standard that specify the spatial distribution of check points. Data and/or map producers must determine check point locations. This section provides guidelines for distributing the check point locations.

Check points may be distributed more densely in the vicinity of important features and more sparsely in areas that are of little or no interest. When data exist for only a portion of the dataset, confine test points to that area. When the distribution of error is likely to be nonrandom, it may be desirable to locate check points to correspond to the error distribution.

For a dataset covering a rectangular area that is believed to have uniform positional accuracy, check points may be distributed so that points are spaced at intervals of at least 10 percent of the diagonal distance across the dataset *and* at least 20 percent of the points are located in each quadrant of the dataset.

Appendix 3-D.
Other Accuracy Standards
(informative)

1. Root-Mean-Square Error (RMSE) Component Accuracy

1.1 Relationship between NSSDA (horizontal) and RMSE (x or y)

From Appendix 3-A, Section 1, assuming $RMSE_x = RMSE_y$ and error is normally distributed and independent in each the x- and y-component, $RMSE_x$ and $RMSE_y$ can be estimated from $RMSE_r$ using:

$$RMSE_x = RMSE_y = RMSE_r /1.4142$$

Using the same assumptions, $RMSE_x$ and $RMSE_y$ can also be computed from $Accuracy_r$, the accuracy value according to NSSDA:

$$RMSE_x = RMSE_y = Accuracy_r/2.4477$$

1.2 Relationship between NSSDA (vertical) and RMSE (vertical)

From Appendix 3-A, Section 2, if vertical error is normally distributed, $RMSE_z$ can be determined from $Accuracy_z$, vertical accuracy reported according to the NSSDA:

$$RMSE_z = Accuracy_z/1.9600$$

1.3 RMSE Accuracy Reporting

Label data or maps as described in Section 3.2.3, "Accuracy Reporting," but substitute "RMSE" for "accuracy at 95% confidence level." For horizontal accuracy, provide separate statements for each RMSE component.

For digital geospatial metadata, follow the guidelines for preparing metadata in Section 3.2.3, "Accuracy Reporting," but substitute “Root-Mean-Square Error” for “National Standard for Spatial Data Accuracy” for these metadata elements (Federal Geographic Data Committee, 1998, Section 2), as appropriate to dataset spatial characteristics:

(Data_Quality_Information/Positional_Accuracy/Horizontal_Positional_Accuracy/Horizontal_Positional_Accuracy_Assessment/Horizontal_Positional_Accuracy_Explanation)
and/or
(Data_Quality_Information/Positional_Accuracy/Vertical_Positional_Accuracy/Vertical_Positional_Accuracy_Assessment/Vertical_Positional_Accuracy_Explanation)

2. Former National Map Accuracy Standards (NMAS)

2.1 Relationship between NSSDA and NMAS (horizontal)

NMAS (U.S. Bureau of the Budget, 1947) specifies that 90% of the well-defined points that are tested must fall within a specified tolerance:

- For map scales larger than 1:20,000, the NMAS horizontal tolerance is 1/30 inch, measured at publication scale.
- For map scales of 1:20,000 or smaller, the NMAS horizontal tolerance is 1/50 inch, measured at publication scale.

If error is normally distributed in each the x- and y-component and error for the x-component is equal to and independent of error for the y-component, the factor 2.146 is applied to compute circular error at the 90% confidence level (Greenwalt and Schultz, 1968). The circular map accuracy standard (CMAS) based on NMAS is:

$$\begin{aligned} CMAS &= 2.1460 * RMSE_x = 2.1460 * RMSE_y \\ &= 2.1460 * RMSE_r / 1.4142 \\ &= 1.5175 * RMSE_r \end{aligned}$$

The CMAS can be converted to accuracy reported according to NSSDA, $Accuracy_r$, using equations from Appendix 3-A, Section 1:

$$Accuracy_r = 2.4477/2.1460 * CMAS = 1.1406 * CMAS.$$

Therefore, NMAS horizontal accuracy reported according to the NSSDA is:

1.1406* [S * (1/30")/12"] feet, or 0.0032 * S, for map scales larger than 1:20,000
1.1406* [S * (1/50")/12"] feet, or 0.0019 * S, for map scales of 1:20,000 or smaller

where S is the map scale denominator.

2.2 Relationship between NSSDA and NMAS (vertical)

NMAS (U.S. Bureau of the Budget, 1947) specifies the maximum allowable *vertical* tolerance to be one half the contour interval, at all contour intervals. If vertical error is normally distributed, the factor 1.6449 is applied to compute vertical accuracy at the 90% confidence level (Greenwalt and Schultz, 1968). Therefore, the Vertical Map Accuracy Standard (VMAS) based on NMAS is estimated by the following formula:

$$VMAS = 1.6449 * RMSEz$$

The VMAS can be converted to $Accuracy_z$, accuracy reported according to the NSSDA using equations from Appendix 3-A, Section 2:

$$Accuracy_z = 1.9600/1.6449 * VMAS = 1.1916 * VMAS.$$

Therefore, vertical accuracy reported according to the NSSDA is (1.1916)/2 * CI = 0.5958 * CI, where CI is the contour interval.

2.3 NMAS Reporting

Map labels provide a statement of conformance with NMAS, rather than reporting the accuracy value. Label maps, as appropriate to dataset spatial characteristics:

> This map complies with National Map Accuracy Standards of 1947 for horizontal accuracy
> OR
> This map complies with National Map Accuracy Standards of 1947 for vertical accuracy
> OR
> This map complies with National Map Accuracy Standards of 1947 for horizontal and vertical accuracy

For digital geospatial data evaluated by the NMAS, follow the guidelines for preparing metadata in Section 3.2.3, "Accuracy Reporting," but substitute “U.S. National Map Accuracy Standards of 1947" for “National Standard for Spatial Data Accuracy” for these metadata elements (Federal Geographic Data Committee, 1998, Section 2), as appropriate to dataset spatial characteristics:

(Data_Quality_Information/Positional_Accuracy/Horizontal_Positional_Accuracy/Horizontal_Positional_Accuracy_Assessment/Horizontal_Positional_Accuracy_Explanation)
and/or
(Data_Quality_Information/Positional_Accuracy/Vertical_Positional_Accuracy/Vertical_Positional_Accuracy_Assessment/Vertical_Positional_Accuracy_Explanation)

3. American Society for Photogrammetry and Remote Sensing (ASPRS) Accuracy Standards for Large-Scale Maps

3.1 Explanation of ASPRS Accuracy Standards for Large-Scale Maps

ASPRS Accuracy Standards for Large-Scale Maps (ASPRS Specifications and Standards Committee, 1990) provide accuracy tolerances for maps at 1:20,000-scale or larger “prepared for special purposes or engineering applications.” RMSE is the statistic used by the ASPRS standards. Accuracy is reported as Class 1, Class 2, or Class 3. Class 1 accuracy for horizontal and vertical components is discussed below. Class 2 accuracy applies to maps compiled within limiting RMSE’s twice those allowed for Class 1 maps. Similarly, Class 3 accuracy applies to maps compiled within limiting RMSE's three times those allowed for Class 1 maps.

3.2 Relationship between NSSDA and ASPRS Accuracy Standards for Large-Scale Maps (horizontal)

ASPRS Accuracy Standards for Large-Scale Maps (ASPRS Specifications and Standards Committee, 1990) evaluates positional accuracy for the x-component and the y-component individually. Positional accuracy is reported at ground scale. Table 3 shows Class 1 planimetric limiting RMSE *in feet* associated with typical map scales, while Table 4 shows Class 1 planimetric limiting RMSE *in meters* associated with typical map scales.

Table 3
ASPRS Accuracy Standards for Large-Scale Maps
Class 1 horizontal (x or y) limiting RMSE for various map scales
at ground scale for *feet* units

Class 1 Planimetric Accuracy, limiting RMSE (feet)	Map Scale
0.05	1:60
0.1	1:120
0.2	1:240
0.3	1:360
0.4	1:480
0.5	1:600
1.0	1:1,200
2.0	1:2,400
4.0	1:4,800
5.0	1:6,000
8.0	1:9,600
10.0	1:12,000
16.7	1:20,000

Table 4
ASPRS Accuracy Standards for Large-Scale Maps
Class 1 horizontal (x or y) limiting RMSE for various map scales
at ground scale for *metric* units

Class 1 Planimetric Accuracy Limiting RMSE (meters)	Map Scale
0.0125	1:50
0.025	1:100
0.050	1:200
0.125	1:500
0.25	1:1,000
0.50	1:2,000
1.00	1:4,000
1.25	1:5,000
2.50	1:10,000
5.00	1:20,000

See Section 1.1 of this appendix on the relationship between horizontal accuracy reported according to the NSSDA and RMSE.

3.3 Relationship between NSSDA and ASPRS Accuracy Standards for Large-Scale Maps (vertical)

Vertical map accuracy is defined by the ASPRS Accuracy Standards (ASPRS Specifications and Standards Committee, 1990) as the RMSE in terms of the project's elevation datum for well-defined points only. See Section 1.3 of this appendix on the relationship between vertical accuracy reported according to the NSSDA and RMSE.

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For Class 1 maps according to the ASPRS Accuracy Standards, the limiting RMSE is set at one-third the contour interval. Spot elevations shall be shown on the map with a limiting RMSE of one-sixth the contour interval or less.

3.4 ASPRS Accuracy Standards for Large-Scale Maps Reporting

Maps evaluated according to ASPRS Accuracy Standards for Large-Scale Maps are labeled by a conformance statement, rather than a numeric accuracy value.

Label maps produced according to this standard:

THIS MAP WAS COMPILED TO MEET THE ASPRS
STANDARD FOR CLASS (1., 2., 3.) MAP ACCURACY

Label maps checked and found to confirm to this standard:

THIS MAP WAS CHECKED AND FOUND TO CONFORM
TO THE ASPRS
STANDARD FOR CLASS (1., 2., 3.) MAP ACCURACY

APPENDIX L

FGDC GEOSPATIAL POSITIONING ACCURACY STANDARDS – PART 4: STANDARDS FOR ARCHITECTURE, ENGINEERING, CONSTRUCTION (A/E/C), AND FACILITY MANAGEMENT

FGDC-STD-007.4-2002

National Spatial Data Infrastructure

Geospatial Positioning Accuracy Standards PART 4: Standards for Architecture, Engineering, Construction (A/E/C) and Facility Management

Facilities Working Group
Federal Geographic Data Committee

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:

Federal Geographic Data Committee Secretariat
c/o U.S. Geological Survey
590 National Center
Reston, Virginia 22092

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World Wide Web: http://fgdc.er.usgs.gov/fgdc.html

CONTENTS

TABLES

4.1 INTRODUCTION

4.1.1 Objective

PART 4 provides accuracy standards for engineering drawings, maps, and surveys used to support planning, design, construction, operation, maintenance, and management of facilities, installations, structures, transportation systems, and related projects. It is intended to support geospatial mapping data used in various engineering documents, such as architectural, engineering, and construction (A/E/C) drawings, site plans, regional master planning maps, and related Geographical Information System (GIS), Computer-Aided Drafting and Design (CADD), and Automated Mapping/Facility Management (AM/FM) products. These products are typically created from terrestrial, satellite, acoustic, or aerial mapping techniques that output planimetric, topographic, hydrographic, or feature attribute data.

4.1.2 Scope

This standard defines accuracy criteria, accuracy testing methodology, and accuracy reporting criteria for object features depicted on A/E/C spatial data products and related control surveys. It references established voluntary standards that may be used for some smaller-scale A/E/C mapping applications. In addition, Appendix A contains general guidance for specifying accuracy criteria for selected types of A/E/C features or control surveys. Using the standards and guidance contained in this section, end users of A/E/C products (e.g., planners, designers, constructors) can specify surveying and mapping accuracy requirements needed for their projects or specific CADD/GIS layers, levels, or entities. From these specifications, data producers (e.g., surveyors, mappers, photogrammetrists) can determine the instrumentation, procedures, and quality control processes required to obtain and verify the defined accuracies.

4.1.3 Applicability

These standards are applicable to geospatial data products used on various A/E/C or facilities management projects. A/E/C projects are normally confined to small geographical areas typically less than 4,000 ha (10,000 acres) where simple survey techniques are employed to establish project control points, perform topographic or photogrammetric mapping, or provide construction layout and alignment control. Unlike geospatial map products covered under PART 3, A/E/C data products are often only locally referenced within a project site, may not contain absolute georeferenced coordinates, and are typically compiled at scales larger than 1:20,000 (1 in = 1,667 ft). These standards may apply to the following types of engineering applications: transportation systems (roads, railroads, airfields, canals); utility systems (water supply, sanitary sewer, fuel, communication, electrical, mechanical); residential, commercial, recreational, and industrial structures and facilities; flood control and navigation systems (dams, levees, locks); architectural site or landscape plans; engineering master planning studies; environmental mapping, modeling, and assessment studies; hydraulic and hydrological studies; geophysical exploration surveys; and construction measurement and payment surveys. These standards do not generally apply to - architectural, mechanical, or electrical detail data inside of a building or structure that are typically used with a CADD system for engineering and design.

4.1.4 Related Standards

This standard was largely taken from existing U.S. Army Corps of Engineers engineering, surveying, and mapping standards, and from Department of Defense Tri-Service Facility Engineering CADD/GIS standards--see References. The American Society for Photogrammetry and Remote Sensing (ASPRS) "Accuracy Standards for Large-Scale Maps" outlined in PART 3, Appendix B, also is directly applicable to PART 4--see paragraph 4.4.1 for specific relationships between ASPRS and Part 4.

This PART 4 may be used in conjunction with, or independent of, other Parts of the overall Geospatial Positioning Accuracy Standard.

PART 1 Reporting Methodology applies directly to this Part, in particular, accuracy standard reporting. Certain portions of Part 2, Standards for Geodetic Networks, apply to A/E/C projects or features within an A/E/C project that are connected by control surveys to an established regional geodetic control network (i.e., geo-referenced).

PART 2 does not apply to engineering, construction, topographic, or photogrammetric mapping surveys that are referenced to boundary control or physical features (streets, structures, etc.) within, or adjacent, to the project site. If A/E/C projects, or sub features within a project, are connected by control surveys to an established regional geodetic control network (i.e., geo-referenced), then certain portions of PART 2 may be applicable.

PART 3, National Standard for Spatial Data Accuracy, applies to those A/E/C map products that are fully geo-referenced. The spatial accuracy definitions, accuracy testing, and accuracy reporting criteria in PART 3 may be used for georeferenced A/E/C map products.

PART 4 applies to engineering drawings, maps, and surveys used to support planning, design, construction, operation, maintenance, and management of facilities, installations, structures, transportation systems, and related projects. Part 4 also applies to marine construction and dredging of navigation channels, including related hydrographic surveying support.

PART 5 should be consulted for hydrographic surveying standards applicable to preparation of nautical charts.

4.1.5 Standards Development Procedures

This standard was developed and periodically reviewed by the FGDC Facilities Working Group during the period 1996-1998. The initial draft of the standard was taken from U.S. Army Corps of Engineers Engineer Circular 1110-1-87, Standards for Maps, Drawings, Engineering Surveys, Construction Site Plans, and Related Geospatial Data Products.

4.1.6 Maintenance Authority

The U.S. Army Corps of Engineers is responsible for developing and maintaining the A/E/C geospatial positional accuracy data standards for the Facilities Working Group of the Federal Geographic Data Committee. Address questions concerning the standards to: Headquarters, U.S. Army Corps of Engineers, ATTN: CECW-EP, 20 Massachusetts Avenue NW, Washington, D.C. 20314-1000.

4.2 SPATIAL ACCURACY

As defined in PART 1, horizontal spatial accuracy is the circular error of a data set's horizontal coordinates at the 95% confidence level. Vertical spatial accuracy is defined by the linear error of a data set's vertical coordinates at the 95% confidence level. A spatial data set may include CADD/GIS object features, such as points, lines, areas, volumes. Accuracy reported at the 95% confidence level means that 95% of positional accuracies will be equal to or smaller than the reported accuracy value. The reported accuracy value is the cumulative result of all uncertainties, including those introduced by local project control coordinates, field topographic surveys, photogrammetric compilation, or final extraction of ground coordinate values in the spatial data. The reference scheme for radial or linear errors must be defined as relative to absolute geospatial reference networks or local (internal construction) schemes. Spatial data may be compiled to comply with one level of accuracy in the vertical component and another in the horizontal component.

4.3 REFERENCE DATUMS AND COORDINATE SYSTEMS

A/E/C projects should be referenced to local boundary control, spatial datums, plane coordinate grids, or vertical reference planes commonly used in the project area. Where practical and feasible, A/E/C projects should be referenced to national coordinate systems: horizontal coordinates should be in a system (e.g., State Plane Coordinate System, Universal Transverse Mercator Grid) based upon the North American Datum of 1927 (NAD 27) or North American Datum of 1983 (NAD 83), and vertical coordinates should be based on the National Geodetic Vertical Datum of 1929 (NGVD 29) or the North American Vertical Datum of 1988 (NAVD 88)--see PART 2. In most instances, however, A/E/C projects are not referenced to geodetic datums but are accurately tied into existing project or boundary control schemes relevant to the work. Reference datums and coordinate systems used shall be clearly identified in reporting A/E/C project data sets--see PART 1.

4.3.1 Local Construction Control

Projects that are not referenced to national coordinate systems based on geodetic datums shall be classified and reported as having a local reference or construction control system--local X-Y grid, chainage-offset, local reference benchmark elevation, etc. Accuracies of spatial data points are determined, reported, and certified relative to this local construction control scheme. If the relationship between the local coordinate system and a National coordinate system is known, describe the relationship between the two systems. If the relationship between the local coordinate system and a National coordinate system is unknown, identify the local coordinate system but state that the relationship in "UNKNOWN"--see PART 1.

4.3.2 NSRS Referenced Control

Accuracies of A/E/C data set coordinates that are referenced to a National coordinate system are determined and reported relative to NSRS accuracies.

4.4 ACCURACY STANDARDS FOR A/E/C MAPS AND DRAWINGS

A/E/C drawings and related spatial data sets may have accuracy standards specified relative to (1) a required performance standard based on detailed project requirements, or (2) an established standard such as National Map Accuracy Standard (NMAS) or ASPRS. Typically, detailed site plan drawings at scales as large as 1:360 (1 in = 30 ft) have acceptable quality levels relative to critical construction specifications (e.g., required accuracy of invert elevations, road/curb grades, building locations, etc.). Preliminary planning or reconnaissance maps at smaller scales typically use general industry standards, such as ASPRS, NMAS, etc. Both types of standards may be specified for portions of CADD levels on the same project. Accuracy is evaluated and reported based on intended field data acquisition methodology or independent tests. For most A/E/C mapping, performance-based (outcome-based) specifications detail the end results to be achieved (i.e., map feature accuracy or accuracy standard) and not the means, or technical procedures, used to achieve those results. Performance specifications define the required accuracy criteria standards for each feature, object, class, layer, level, etc. of topographic and planimetric features depicted, along with related mapping limits, feature location and attribute requirements, scale, contour interval, map format, sheet layout, final data transmittal, archiving or storage requirements, and quality assurance procedures that will be used to verify conformance with the specified accuracy. Table A-3 in Appendix A provides examples of accuracy specifications commonly used for various types of A/E/C projects.

4.4.1 ASPRS Large-Scale Accuracy Standards

For generalized A/E/C site mapping work at scales from 1:2,400 (1 in = 200 ft) to 1:20,000 (1 in = 1,667 ft), the ASPRS "Accuracy Standards for Large-Scale Maps" may be used as a reference accuracy standard. The ASPRS accuracy standard is linearly dependent on the target horizontal scale or target contour interval; thus it is only applicable to mapped features that are compiled using a consistent type of data acquisition process (e.g., photogrammetry) where all spatial objects receive approximately the same accuracy. The ASPRS standard may not be especially applicable to detailed CADD/GIS features at larger scales down to 1:240 (1 in. = 20 ft) where CADD/GIS accuracies are usually project dependent, not scale dependent, and where accuracy standards are best defined based on project needs. As described in PART 3, the ASPRS standard defines map accuracy by comparing the mapped location of selected well-defined points to their "true" location, as determined by a more accurate, independent field survey. Alternately, when no independent check is feasible or practicable, a map's accuracy may be estimated based on the accuracy of the technique used to locate mapped features--e.g., photogrammetry, GPS, total station, planetable. The ASPRS standard may be specified for site plans that are developed using conventional ground topographic surveying techniques (i.e., electronic total stations, planetables, kinematic DGPS).

4.4.2 Multiple Accuracies in A/E/C Drawings or CADD Levels

4.4.2.1 Horizontal and Vertical Accuracies

Spatial data may have different accuracies in the horizontal and vertical components.

4.4.2.2 A/E/C CADD/GIS Feature Layer/Level Accuracies

A/E/C data is often separated into various layers or levels in CADD/GIS systems. For example, planimetric features, utility invert elevations, and topographic elevations are often separated into three different levels or layers. These layers often contain objects or geographic areas that were surveyed/compiled to widely differing accuracies--e.g., utility invert elevations accurate to 0.05 ft versus topographic contours accurate to only 5 ft . If readily available, useful, and practical, these variable accuracies may be retained as an attribute to the layer or feature. In addition, accuracy information about these layers or features should be recorded in the accuracy section of the metadata for this database.

4.5 ACCURACY STANDARDS FOR A/E/C CONTROL SURVEYS

Control surveys are performed to locate, align, and stake out construction for civil and military projects, e.g., buildings, utilities, roadways, runways, flood control and navigation projects, training ranges, etc. They provide the base horizontal and vertical control used for preliminary studies, photogrammetric and topographic mapping, detailed site plan drawings for construction plans, construction stake out, construction measurement and payment, preparing as-built drawings, installation master planning mapping, and future maintenance and repair activities. Two types of survey accuracies may be specified: (1) Positional accuracy or (2) Relative closure ratio accuracy. PART 2 geodetic survey accuracy standards are not applicable to locally referenced A/E/C projects covered under this PART 4 standard.

4.5.1 Positional Accuracy

Base control surveys should be performed to a 95% positional confidence level consistent with the engineering or construction application or specifications. In general, horizontal and vertical control point accuracies should be twice as accurate as positional or elevation tolerances required for features or objects on the site plans or maps. Determination and verification of 95% radial positional accuracies will require use of rigorous least-squares adjustment techniques similar to that required under PART 2.

4.5.2 Relative Closure Ratio Accuracy

The accuracy of A/E/C control surveys may be evaluated, classified, and reported based on closure ratios for the horizontal point or the vertical elevation difference, as obtained in the field when points or benchmarks are redundantly occupied. This relative accuracy standard is applicable to most types of survey equipment and practices (e.g., total station traverses, differential GPS, differential spirit leveling). Many state codes and/or state minimum technical standards require that accuracies of A/E/C surveys be evaluated and reported using survey closure ratios. Tables A-1 and A-2 in Appendix A contain orders of closure commonly specified in A/E/C work. There is no simple correlation between relative closure accuracies and 95% radial positional accuracies; thus, determining a closure order based on a specified feature accuracy requirement is, at best, only an approximate process (see guidance in Appendix A). Where practical and allowable, positional accuracy standards should be used instead of closure accuracy standards.

4.6 ACCURACY TESTING AND VERIFICATION

Project specifications will specify the geographic extent of data to be tested and the amount of testing (if any). Map testing should be performed within a fixed time period after delivery. Normally, a mapping organization will perform quality control tests under quality assurance oversight by the requesting agency. Accuracies of A/E/C features are reported at the 95% confidence level. Field observed X, Y or Z coordinate differences are converted to 95% confidence errors following the procedures outlined in PART 3. Horizontal accuracy is tested by comparing the planimetric coordinates of well-defined ground points with coordinates of the same points from an independent source of higher accuracy, following the methodology outlined under PART 3. Vertical accuracy is tested by comparing the elevations of well-defined points with elevations of the same points as determined from a source of higher accuracy, also following the methodology outlined in PART 3. Both ground surface topography and object elevations may be tested.

4.7 ACCURACY REPORTING AND CERTIFICATION

4.7.1 Tested Products

Maps, surveys, and related geospatial data that are tested and found to comply with a specified standard shall have a certification statement. If applicable, the statement shall clearly indicate the target map scale at which the map or feature layer was developed.

4.7.2 Untested Products

Due to the high cost of field testing, not all deliverable map products will be tested. In such cases, the statement shall clearly indicate that the procedural ground surveying or aerial mapping specifications were designed and performed to meet a certain accuracy standard (project dependent, ASPRS, NMAS, etc.), but that the accuracy is estimated. An estimated accuracy statement is especially applicable to CADD, GIS, or FM databases that may be compiled from a variety of sources containing known or unknown accuracy reliability.

4.7.3 Reporting Units

Report accuracy of A/E/C spatial data in ground units using either metric (SI) units or English (IP) units, consistent with the project units.

4.7.4 Variable Accuracies

Report varying accuracies in the same spatial data set if information exists that relates accuracy to individual portions/objects of the data set, and only if such detailed sub-feature data set reporting is practical and warranted. If data of varying accuracies are composited and cannot be separately identified AND the data set is tested, report the accuracy value for the composited data. If a composited data set is not tested, report the accuracy value for the least accurate data set component.

4.7.5 Reporting Statements

Report tested and non-tested accuracies following general guidance provided in PART 3 (Accuracy Reporting).

4.8 REFERENCES

American Society for Photogrammetry and Remote Sensing (ASPRS) Specifications and Standards Committee, 1990, ASPRS Accuracy Standards for Large-Scale Maps: Photogrammetric Engineering and Remote Sensing, v. 56, no. 7, p. 1,068-1,070.

Federal Geographic Data Committee, Part 1, Reporting Methodology, Geospatial Positioning Accuracy Standards, FGDC-STD-0007.1-1998, Washington, D.C., 1998.

Federal Geographic Data Committee, Part 2., Standards for Geodetic Networks, Geospatial Positioning Accuracy Standards, FGDC-STD-007.2-1998: Washington, D.C., 1998.

Federal Geographic Data Committee, Part 3., National Standard for Spatial Data Accuracy, Geospatial Positioning Accuracy Standards, FGDC-STD-007.3-1998: Washington, D.C., 1998.

U.S. Army Corps of Engineers, Engineer Circular 1110-1-87, Standards for Maps, Drawings, Engineering Surveys, Construction Site Plans, and Related Geospatial Data Products, 1 July 1996.

U.S. Department of Defense, Tri-Service CADD/GIS Technology Center, Tri-Service A/E/C CADD Standards and Spatial Data Standards, (latest version at <http://tsc.wes.army.mil>)

APPENDIX A

RECOMMENDED A/E/C SURVEYING AND MAPPING STANDARDS

(Informative)

A.1 A/E/C CONTROL SURVEY STANDARDS

Engineering and construction surveys are normally specified, classified, and reported based on the horizontal (linear) point closure ratios or the vertical elevation difference closures. This performance criterion is most commonly specified in Federal agency, State, and local surveying standards. These control surveys are performed to establish control, location, alignment, and grade of various types of construction.

Local accuracy standards for survey control will vary with the type of construction. Commonly specified and reported Orders of horizontal closure accuracy standards are shown in Table A-1. Relative accuracy closure ratios for horizontal A/E/C surveys typically range from a minimum of 1:2,500 up to 1:20,000. Lower accuracies (1:2,500-1:5,000) are acceptable for earthwork, dredging, embankment, beach fill, and levee alignment stakeout and grading, and some site plan, curb and gutter, utility building foundation, sidewalk, and small roadway stakeout. Moderate accuracies (1:5,000) are used in most pipeline, sewer, culvert, catch basin, and manhole stakeouts, and for general residential building foundation and footing construction, major highway pavement, bridges, and concrete runway stakeout work. Somewhat higher accuracies (1:10,000-1:20,000) are used for aligning longer bridge spans, tunnels, and large commercial structures. For extensive bridge or tunnel projects, 1:50,000 or even 1:100,000 relative accuracy alignment work may be specified.

Orders of elevation closure ratio standards are shown in Table A-2. Most construction work is performed to Third-Order standards. These standards are applicable to most types of engineering and construction survey equipment and practices (e.g., total station traverses, differential GPS, differential spirit leveling).

Table A-1
Minimum Closure Standards for Engineering and Construction Control Surveys

Classification Order	Closure Standard	
Engr & Const Control	Distance (Ratio)	Angle (Secs)
Second-Order, Class I	1:50,000	3oN [1]
Second-Order, Class II	1:20,000	5oN
Third-Order, Class I	1:10,000	10oN
Third-Order, Class II	1: 5,000	20oN
Construction (Fourth-Order)	1: 2,500	60oN

[1] N = Number of angle stations

Table A-2
Minimum Elevation Closure Standards for Vertical Control Surveys

Classification Order	Elevation Closure Standard (ft)[1]	(mm)
First-Order, Class I	0.013oM	3oK
First-Order, Class II	0.017oM	4oK
Second-Order, Class I	0.025oM	6oK
Second-Order, Class II	0.035oM	8oK
Third-Order	0.050oM	12oK
Construction Layout	0.100oM	24oK

[1] oM or oK = square root of distance in Miles or Kilometers

A.2 TYPICAL ACCURACY STANDARDS FOR SELECTED A/E/C PROJECTS

General guidance for determining project-specific mapping accuracy standards is contained in Table A-3 at the end of this Appendix. This table may be used in developing specifications for map scales, feature location and elevation tolerances, and contour intervals for typical A/E/C projects. Since Table A-3 is based on current industry practices (and primarily those used by the Corps of Engineers), the scales and corresponding 95% positional tolerances shown in this table will differ from the ASPRS positional or elevation accuracy standards. Where available, project-specific accuracy standards should be used rather than generic standards such as ASPRS. Metric (SI) conversions from IP units are only approximate since standardized use of SI units is still under development.

A.2.1 Target Scale and Contour Interval Specifications

Table A-3 provides commonly used map scales and contour intervals for a variety of A/E/C applications. The selected target scale for a map or construction plan should be based on the detail necessary to portray the project site. Topographic elevation density or related contour intervals are specified consistent with existing site gradients and the accuracy needed to define site layout, drainage, grading, etc., or perform quantity take offs. Photogrammetric mapping flight altitudes or ground topographic survey accuracy and density requirements are determined from the design map target scale and contour interval. In practice, design or real property features are located or layed out during construction to a far greater relative accuracy than that which can be scaled at the target (plot) scale, such as property corners, utility alignments, first-floor or invert elevations, etc. Coordinates/elevations for such items are usually directly input as feature attributes in a CADD or AM/FM database.

A.2.2 Feature Location Tolerances

Table A-3 indicates recommended positional and elevation tolerances of planimetric features at the 95% confidence level. These tolerances define the primary topographic mapping effort necessary to delineate physical features on the ground. A/E/C feature tolerances are defined relative to adjacent points within the confines of a specific area, map sheet, or structure--not to the overall project, installation boundaries, or an external geodetic control network. These relative accuracy tolerances are determined between two points that must functionally maintain a given accuracy tolerance between themselves, such as adjacent property corners; adjacent utility lines; adjoining buildings, bridge piers, approaches, or abutments; overall building or structure site construction limits; runway ends; catch basins; levee baseline sections; etc. Feature tolerances indicated are determined from the functional requirements of a typical project/structure (e.g., field construction/fabrication, field stakeout or layout, alignment, etc.). Few A/E/C projects require that relative accuracies be rigidly maintained beyond the range of the detailed design drawing for a project/structure (or its equivalent CADD design file limit). In many instances, a construction feature may need to be located to an accuracy well in excess of its plotted/scaled accuracy on a construction site plan; therefore, feature location tolerances should not be used to determine the required scale of a drawing. In these instances, surveyed coordinates, internal CADD grid coordinates, or rigid relative dimensions are used.

A.3 A/E/C TOPOGRAPHIC SURVEYS AND CONSTRUCTION SITE PLANS

Topographic surveys and construction site plan surveys are performed for the master planning, design, and construction of installations, buildings, housing complexes, roadways, airport facilities, flood control structures, navigation locks, etc. Construction plans are developed using electronic/DGPS total stations, plane tables, or low-altitude photogrammetric mapping methods. Some of the more common surveys are described below:

A.3.1 Reconnaissance Topographic Surveys

Reconnaissance surveys are typically performed at scales from 1:4,800 (1 in = 400 ft) to 1:12,000 (1 in = 1,000 ft). They provide a basis for general studies, site suitability decisions, or preliminary site layouts. General location of existing roads and facilities are depicted, and only limited feature and rough elevation detail is shown – 5- to 10-foot contour intervals usually being adequate. Enlarged USGS 1:24,000 maps may be substituted in many cases.

A.3.2 General/Preliminary Site Plans.

General or Preliminary site plans are performed at scales from 1:2,400 (1 in = 200 ft) to 1:4,800 (1 in = 400 ft). They depict general layout for potential construction, proposed transportation systems, training areas, and existing facilities.

A.3.3 Detailed Topographic Surveys for Construction Plans

These surveys are performed at scales from 1:240 (1 in = 20 ft) to 1:2,400 (1 in = 200 ft) and at contour intervals of 0.2 m or 0.5 m (1 or 2 ft). They are performed to prepare a base map for detailed site plans (general site layout plan, utility plan, grading plan, paving plan, airfield plan, demolition plan, etc.). The scope of mapping is confined to an existing/proposed building area. These drawings are used as a base for subsequent as-built drawings of facilities and utility layout maps (i.e., AM/FM databases).

A.3.4 As-Built Surveys and AM/FM Mapping

As-built drawings may require topographic surveys of constructed features, especially when field modifications are made to original designs. These surveys, along with original construction site plans, should be used as a base framework for a facility's AM/FM database. Periodic topographic surveys also may be required during maintenance and repair projects in order to update the AM/FM database.

**Table A-3. RECOMMENDED ACCURACIES AND TOLERANCES:
ENGINEERING, CONSTRUCTION, AND FACILITY MANAGEMENT PROJECTS**

Project or Activity	Target Map Scale SI/IP	Feature Position Tolerance Horizontal SI/IP	Feature Position Tolerance Vertical SI/IP	Contour Interval SI/IP
DESIGN, CONSTRUCTION, OPERATION & MAINTENANCE OF MILITARY FACILITIES				
Maintenance and Repair (M&R)/Renovation of Existing Installation Structures, Roadways, Utilities, Etc				
General Construction Site Plans & Specs:	1:500	100 mm	50 mm	250 mm
Feature & Topographic Detail Plans	40 ft/in	0.1-0.5 ft	0.1-0.3 ft	1 ft
Surface/subsurface Utility Detail Design Plans	1:500	100 mm	50 mm	N/A
Elec, Mech, Sewer, Storm, etc	40 ft/in	0.2-0.5 ft	0.1-0.2 ft	
Field construction layout		0.1 ft	0.01-0.1 ft	
Building or Structure Design Drawings	1:500	25 mm	50 mm	250 mm
	40 ft/in	0.05-0.2 ft	0.1-0.3 ft	1 ft
Field construction layout		0.01 ft	0.01 ft	
Airfield Pavement Design Detail Drawings	1:500	25 mm	25 mm	250 mm
	40 ft/in	0.05-0.1 ft	0.05-0.1 ft	0.5-1 ft
Field construction layout		0.01 ft	0.01 ft	
Grading and Excavation Plans	1:500	250 mm	100 mm	500 mm
Roads, Drainage, Curb, Gutter etc.	30-100 ft/in	0.5-2 ft	0.2-1 ft	1-2 ft
Field construction layout		1 ft	0.1 ft	
Recreational Site Plans	1:1,000	500 mm	100 mm	500 mm
Golf courses, athletic fields, etc.	100 ft/in	1-2 ft	0.2-2 ft	2-5 ft
Training Sites, Ranges, and Cantonment Area Plans	1:2,500	500 mm	1,000 mm	500 mm
	100-200 ft/in	1-5 ft	1-5 ft	2 ft
General Location Maps for Master Planning	1:5,000	1,000 mm	1,000 mm	1,000 mm
AM/FM and GIS Features	100-400 ft/in	2-10 ft	1-10 ft	2-10 ft
Space Management Plans	1:250	50 mm	N/A	N/A
Interior Design/Layout	10-50 ft/in	0.05-1 ft		
As-Built Maps: Military Installation Surface/Subsurface Utilities (Fuel, Gas, Electricity, Communications, Cable,		100 mm	100 mm	250 mm
		0.2-1 ft	0.2 ft	1 ft

Table A-3 (Contd). RECOMMENDED ACCURACIES AND TOLERANCES: ENGINEERING, CONSTRUCTION, AND FACILITY MANAGEMENT PROJECTS

Project or Activity	Target Map Scale SI/IP	Feature Position Tolerance Horizontal SI/IP	Feature Position Tolerance Vertical SI/IP	Contour Interval SI/IP
Storm Water, Sanitary, Water Supply, Treatment Facilities, Meters, etc.)	1:1000 or 50-100 ft/in (Army) 1:500 or 50 ft/in (USAF)			
Housing Management GIS (Family Housing, Schools, Boundaries, and Other Installation Community Services)	1:5,000 100-400 ft/in	10,000 mm 10-15 ft	N/A	N/A
Environmental Mapping and Assessment Drawings/Plans/GIS	1:5,000 200-400 ft/in	10,000 mm 10-50 ft	N/A	N/A
Emergency Services Maps/GIS Military Police, Crime/Accident Locations, Post Security Zoning, etc.	1:10,000 400-2000 ft/in	25,000 mm 50-100 ft	N/A	N/A
Cultural, Social, Historical Plans/GIS	1:5000 400 ft/in	10,000 mm 20-100 ft	N/A	N/A
Runway Approach and Transition Zones: General Plans/Section	1:2,500 100-200 ft/in	2,500 mm 5-10 ft	2,500 mm 2-5 ft	1,000 mm 5 ft
Approach maps	1:5,000 (H) 1:1,000 (V)			
Approach detail	1:5,000 (H) 1:250 (V)			
DESIGN, CONSTRUCTION, OPERATIONS AND MAINTENANCE OF CIVIL TRANSPORTATION & WATER RESOURCE PROJECTS Site Plans, Maps & Drawings for Design Studies, Reports, Memoranda, and Contract Plans and Specifications, Construction plans & payment				
General Planning and Feasibility Studies, Reconnaissance Reports	1:2,500 100-400 ft/in	1,000 mm 2-10 ft	500 mm 0.5-2 ft	1,000 mm 2-10 ft
Flood Control and Multipurpose Project Planning, Floodplain Mapping, Water Quality Analysis, and Flood Control Studies	1:5,000 400-1000 ft/in	10,000 mm 20-100 ft	100 mm 0.2-2 ft	1,000 mm 2-5 ft

Table A-3 (Contd). RECOMMENDED ACCURACIES AND TOLERANCES: ENGINEERING, CONSTRUCTION, AND FACILITY MANAGEMENT PROJECTS

Project or Activity	Target Map Scale SI/IP	Feature Position Tolerance Horizontal SI/IP	Vertical SI/IP	Contour Interval SI/IP
Soil and Geological Classification Maps	1:5,000 400 ft/in	10,000 mm 20-100 ft	N/A	N/A
Land Cover Classification Maps	1:5,000 400-1,000 ft/in	10,000 mm 50-200 ft	N/A	N/A
Archeological or Structure Site Plans & Details (Including Non-topographic, Close Range, Photogrammetric Mapping)	1:10 0.5-10 ft/in	5 mm 0.01-0.5 ft	5 mm 0.01-0.5 ft	100 mm 0.1-1 ft
Cultural and Economic Resource Mapping Historic Preservation Projects	1:10,000 1000 ft/in	10,000 50-100 ft	N/A	N/A
Land Utilization GIS Classifications Regulatory Permit Locations	1:5,000 400-1000 ft/in	10,000 mm 50-100 ft	N/A	N/A
Socio-Economic GIS Classifications	1:10,000 1000 ft/in	20,000 mm 100 ft	N/A	N/A
Grading & Excavation Plans	1:1,000 100 ft/in	1,000 mm 0.5-2 ft	100 mm 0.2-1 ft	1,000 mm 1-5 ft
Flood Control Structure Clearing & Grading Plans (e.g., revetments)	1:5,000 100-400 ft/in	2,500 mm 2-10 ft	250 mm 0.5 ft	500 mm 1-2 ft
Federal Emergency Management Agency Flood Insurance Studies	1:5,000 400 ft/in	1,000 mm 20 ft	250 mm 0.5 ft	1,000 mm 4 ft
Locks, Dams, & Control Structures Detail Design Drawings	1:500 20-50 ft/in	25 mm 0.05-1 ft	10 mm 0.01-0.5 ft	250 mm 0.5-1 ft
Spillways & Concrete Channels Design Plans	1:1,000 50-100 ft/in	100 mm 0.1-2 ft	100 mm 0.2-2 ft	1,000 mm 1-5 ft
Levees and Groins: New Construction or Maintenance Design Drawings	1:1,000 100 ft/in	500 mm 1-2 ft	250 mm 0.5-1 ft	500 mm 1-2 ft

Table A-3 (Contd). RECOMMENDED ACCURACIES AND TOLERANCES: ENGINEERING, CONSTRUCTION, AND FACILITY MANAGEMENT PROJECTS

Project or Activity	Target Map Scale SI/IP	Feature Position Tolerance Horizontal SI/IP	Vertical SI/IP	Contour Interval SI/IP
Construction In-Place Volume Measurement Granular cut/fill, dredging, etc.	1:1,000 40-100 ft/in	500 mm 0.5-2 ft	250 mm 0.5-1 ft	N/A
Beach Renourishment/Hurricane Protection Project Plans	1:1,000 100-200 ft/in	1,000 mm 2 ft	250 mm 0.5 ft	250 mm 1 ft
Project Condition Survey Reports				
Base Mapping for Plotting Hydrographic Surveys: line maps or aerial plans	1:2,500 200-1,000 ft/in	10,000 mm 5-50 ft	250 mm 0.5-1 ft	500 mm 1-2 ft
Dredging & Marine Construction Surveys				
New Construction Plans	1:1,000 100 ft/in	2,000 mm 6 ft	250 mm 1 ft	250 mm 1 ft
Maintenance Dredging Drawings	1:2500 200 ft/in	5,000 mm 15 ft	500 mm 2 ft	500 mm 2 ft
Hydrographic Project Condition Surveys	1:2500 200 ft/in	5,000 mm 16 ft	500 mm 2 ft	500 mm 2 ft
Hydrographic Reconnaissce Surveys	-	5,000 m 15 ft	500 mm 2 ft	250 mm 2 ft
Offshore Geotechnical Investigations Core Borings /Probings/etc.	-	5,000 mm 5-15 ft	50 mm 0.1-0.5 ft	N/A
Structural Deformation Monitoring Studies/Surveys				
Reinforced Concrete Structures: Locks, Dams, Gates, Intake Structures, Tunnels, Penstocks, Spillways, Bridges	Large-scale vector movement diagrams or tabulations	10 mm 0.03 ft (long term)	2 mm 0.01 ft	N/A
Earth/Rock Fill Structures: Dams, Floodwalls	N/A	(same as above)	30 mm	15 mm

Table A-3 (Contd). RECOMMENDED ACCURACIES AND TOLERANCES: ENGINEERING, CONSTRUCTION, AND FACILITY MANAGEMENT PROJECTS

Project or Activity	Target Map Scale SI/IP	Feature Position Tolerance Horizontal SI/IP	Vertical SI/IP	Contour Interval SI/IP
Levees, etc. -- slope/crest stability & alignment		0.1 ft (long term)	0.05 ft	
Crack/Joint & Deflection Measurements: piers/monoliths--precision micrometer	tabulations	0.2 mm 0.01 inch	N/A	N/A
<u>REAL ESTATE ACTIVITIES: ACQUISITION, DISPOSAL, MANAGEMENT, AUDIT</u> Maps, Plans, & Drawings Associated with Military and Civil Projects				
Tract Maps, Individual, Detailing Installation or Reservation Boundaries, Lots, Parcels, Adjoining Parcels, and Record Plats, Utilities, etc.	1:1,000 1:1,200 (Army) 50-400 ft/in	10 mm 0.05-2 ft	100 mm 0.1-2 ft	1,000 mm 1-5 ft
Condemnation Exhibit Maps	1:1,000 50-400 ft/in	10 mm 0.05-2 ft	100 mm 0.1-2 ft	1,000 mm 1-5 ft
Guide Taking Lines/Boundary Encroachment Maps: Fee and Easement Acquisition	1:500 20-100 ft/in	50 mm 0.1-1 ft	50 mm 0.1-1 ft	250 mm 1 ft
General Location or Planning Maps	1:24,000 2,000 ft/in	10,000 mm 50-100 ft	5,000 mm 5-10 ft	2,000 mm 5-10 ft
GIS or LIS Mapping, General Land Utilization and Management, Forestry Management, Mineral Acquisition	1:5,000 200-1,000 ft/in	10,000 mm 50-100 ft	N/A	N/A
Easement Areas and Easement Delineation Lines	1:1,000 100 ft/in	50 mm 0.1-0.5 ft	50 mm 0.1-0.5 ft	-
<u>HAZARDOUS, TOXIC, RADIOACTIVE WASTE (HTRW) SITE INVESTIGATION, MODELING, AND CLEANUP</u>				
General Detailed Site Plans HTRW Sites, Asbestos, etc.	1:500 5-50 ft/in	100 mm 0.2-1 ft	50 mm 0.1-0.5 ft	100 mm 0.5-1 ft

Table A-3 (Contd). RECOMMENDED ACCURACIES AND TOLERANCES: ENGINEERING, CONSTRUCTION, AND FACILITY MANAGEMENT PROJECTS

	Target	Feature Position Tolerance		Contour
	Map Scale	Horizontal	Vertical	Interval
Project or Activity	**SI/IP**	**SI/IP**	**SI/IP**	**SI/IP**
Surface Geotoxic Data Mapping and Modeling	1:500 20-100 ft/in	100 mm 1-5 ft	500 mm 1-2 ft	500 mm 1-2 ft
Contaminated Ground Water Plume Mapping/Modeling	1:500 20-100 ft/in	1,000 mm 2-10 ft	500 mm 1-5 ft	500 mm 1-2 ft
General HTRW Site Plans & Reconnaissance Mapping	1:2,500 50-400 ft/in	5,000 mm 2-20 ft	1,000 mm 2-20 ft	1,000 mm 2-5 ft

APPENDIX M

FGDC GEOSPATIAL POSITIONING ACCURACY STANDARDS – PART 5: STANDARDS FOR NAUTICAL CHARTING HYDROGRAPHIC SURVEYS

FGDC Document Number FGDC-STD-007.5-2005

National Spatial Data Infrastructure

Geospatial Positioning Accuracy Standards
Part 5: Standards for Nautical Charting Hydrographic Surveys

Subcommittee on Marine and Coastal Spatial Data
Federal Geographic Data Committee

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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5.1 Introduction

5.1.1 Objective

This document provides minimum standards for the horizontal and vertical accuracy of features associated with hydrographic surveys that support nautical charting. Such features include, but are not limited to, water depths, objects on the seafloor, navigational aids, and shoreline.

5.1.2 Scope

For the purposes of this Standard, hydrographic surveys are defined as those surveys conducted to determine the configuration of the bottom of water bodies and to identify and locate all features, natural and man-made, that may affect navigation. Nautical charts are compilations of data from numerous sources, principally hydrographic surveys, designed specifically to meet the requirements of marine navigation. The scope of these standards includes the coastal waters of the U.S. and its territories.

5.1.3 Applicability

These standards are intended to be used by federal agencies and their contractors for conducting hydrographic surveys that will be used for updating nautical charts. They do not apply to hydrographic surveys for river and harbor navigation projects or surveys for project construction which are covered by Part 4 of the FGDC Geospatial Positioning Accuracy Standards. Local authorities may also prescribe these standards for high quality surveys for other purposes.

5.1.4 Related Standards

These standards may be used in conjunction with, or independent of, other Parts of the overall Geospatial Positioning Accuracy Standard. Part 1 (Reporting Methodology) applies directly to this part with the exception that vertical coordinate values should be referenced to the applicable chart datum and not one of the geodetic vertical datums (NAVD 88 or NGVD 29). See section 5.3.

There may be occasions where geodetic control points need to be established to support hydrographic surveys. In such instances, the specifications in Part 2 (Standards for Geodetic Networks) should be referenced. The accuracy testing described in Part 3 (National Standard for Spatial Data Accuracy) is generally inapplicable to this Part 5 since the referenced features are not repeatedly measured. Part 4 (Standards for Architecture, Engineering, Construction (A/E/C) and Facility Management) provide accuracy standards for other categories of hydrographic surveys (Contract Payment, Project Condition and Reconnaissance) that are not explicitly conducted to support nautical charts.

5.1.5 Standards Development Procedures

This standard was developed by the FGDC Bathymetric Subcommittee during 1998 and generally follows the Standards for Hydrographic Surveys adopted by the International Hydrographic Organization in April 1998.

5.1.6 Maintenance

The U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office of Coast Survey, is responsible for developing and maintaining Standards for Nautical Charting Hydrographic Surveys for the FGDC Subcommittee on Marine and Coastal Spatial Data. Address questions concerning the standards to: Director, Office of Coast Survey, NOAA, N/CS, 1315 East-West Highway, Silver Spring, Maryland 20910.

5.2 Spatial Accuracy

As defined in Part 1, horizontal spatial accuracy is the two-dimensional circular error of a data set?s horizontal coordinates at the 95% confidence level. Vertical spatial accuracy is defined by the one-dimensional linear error of depths at the 95% confidence level.

5.3 Reference Datums

The horizontal reference datum should be the North American Datum of 1983 (NAD 83). If other datums or coordinate systems are used, their relationship to NAD 83 should be documented. Vertical coordinate values should be referenced to the applicable chart datum and not one of the geodetic vertical datums (NAVD 88 or NGVD 29). The Mean Lower Low Water (MLLW) datum is used for Atlantic, Pacific and Gulf coast charts. The nautical chart vertical datum for each of the Great Lakes is referenced to the International Great Lakes Datum (1985). Other water level-based datums are used on lakes and rivers.

5.4 Classification of Surveys

To accommodate in a systematic manner different accuracy requirements for areas to be surveyed, four orders of survey are defined. These are described below, with specific details provided in Table 1.

5.4.1 Special Order

Special Order hydrographic surveys approach engineering standards and their use is intended to be restricted to specific critical areas with minimum underkeel clearance and where bottom characteristics are potentially hazardous to vessels. These areas must be explicitly designated by the agency responsible for survey quality. Examples are harbors, berthing areas, and associated critical channels. All error sources must be minimized. Special Order requires the use of closely spaced lines in conjunction with side scan sonar, multi-transducer arrays or high resolution multibeam echosounders to obtain 100% bottom search. It must be ensured that cubic features greater than 1 meter can be discerned by the sounding equipment. The use of side scan sonar in conjunction with a multibeam echosounder may be necessary in areas where thin and dangerous obstacles may be encountered. Side scan sonar should not be used for depth determination but to define areas requiring more detailed and accurate investigation.

5.4.2 Order 1

Order 1 hydrographic surveys are intended for harbors, harbor approach channels, recommended tracks, inland navigation channels, and coastal areas of high commercial traffic density where underkeel clearance is less critical and the geophysical properties of the seafloor are less hazardous to vessels (e.g. soft silt or sand bottom). Order 1 surveys should be limited to areas with less than 100 m water depth. Although the requirement for seafloor search is less stringent than for Special Order, full bottom search is required in selected areas where the bottom characteristics and the risk of obstructions are potentially hazardous to vessels. For these areas searched, it must be ensured that cubic features greater than 2 m up to 40 m water depth or greater than 10% of the depth in areas deeper than 40 m can be discerned by the sounding equipment. In some areas the detection of 1-meter cubic features may be specified.

5.4.3 Order 2

Order 2 hydrographic surveys are intended for areas with depths less than 200 m not covered by Special Order and Order 1 and where a general description of the bathymetry is sufficient to ensure there are no obstructions on the seafloor that will endanger the type of vessel expected to transit or work the area. It is the criteria for a variety of maritime uses for which higher order hydrographic surveys cannot be justified. Full bottom search may be required in selected areas where the bottom characteristics and the risk of obstructions may be potentially hazardous to vessels.

5.4.4 Order 3

Order 3 hydrographic surveys are intended for all areas not covered by Special Order, and Orders 1 and 2 in water depths in excess of 200 m.

TABLE 1
Summary of Minimum Standards for Hydrographic Surveys

ORDER	**Special**	**1**	**2**	**3**
Examples of Typical Areas	Harbors, berthing areas, and associated critical channels with minimum underkeel clearances	Harbors, harbor approach channels, recommended tracks and some coastal areas with depths up to 100 m	Areas not described in Special Order and Order 1, or areas up to 200 m water depth	Offshore areas not described in Special Order, and Orders 1 and 2
Horizontal Accuracy (95% Confidence Level)	2 m	5 m + 5% of depth	20 m + 5% of depth	150 m + 5% of depth
Depth Accuracy for (1) **Reduced Depths (95% Confidence Level)** (2)	a = 0.25 m b = 0.0075	a = 0.5 m b = 0.013	a = 1.0 m b = 0.023	Same as Order 2
100% Bottom Search (3)	Compulsory	Required in selected areas	May be required in selected areas	Not applicable
System Detection Capability	Cubic features > 1 m	Cubic features > 2 m in depths up to 40 m; 10% of depth beyond 40 m	Same as Order 1	Not applicable
Maximum Line Spacing (4)	Not applicable, as 100% search compulsory	3 x average depth or 25 m, whichever is greater	3-4 x average depth or 200 m, whichever is greater	4 x average depth

(1) To calculate the error limits for depth accuracy the corresponding values of a and b listed in Table 1 should be introduced into:

$$? \sqrt{[a^2 + (b * d)^2]}$$

where:

a is a constant depth error, i.e. the sum of all constant errors, b*d is the depth dependent error, i.e. the sum of all depth dependent errors where b is a factor of depth dependent error, and d is depth.

(2) The confidence level percentage is the probability that an error will not exceed the specified maximum value.
(3) A method of exploring the seabed which attempts to provide complete coverage of an area for the purpose of detecting all features addressed in this publication.
(4) The line spacing can be expanded if procedures for ensuring an adequate sounding density are used

The rows of Table 1 are explained as follows:
Row 1 "Examples of Typical Areas" gives examples of areas to which an order of survey might typically be applied.
Row 2 "Horizontal Accuracy" lists positioning accuracies to be achieved to meet each order of survey.
Row 3 "Depth Accuracy" specifies parameters to be used to calculate accuracies of reduced depths to be achieved to meet each order of survey.
Row 4 "100% Bottom Search" specifies occasions when full bottom search should be conducted.
Row 5 "System Detection Capability" specifies the detection capabilities of systems used for bottom search.
Row 6 "Maximum Line Spacing" is to be interpreted as either (1) spacing of sounding lines for single beam sounders or (2) distance between the outer limits of swaths for swath sounding systems

5.5 Positioning

The horizontal accuracy, as specified in Table 1, is the accuracy of the position of soundings, dangers, and all other significant submerged features with respect to a geodetic reference frame, specifically NAD 83. The exception to this are Order 2 and Order 3 surveys using single-beam echo sounders where it is the positional accuracy of the sounding system sensor. In such cases, the agency responsible for the survey quality should determine the accuracy of the positions of soundings on the seafloor.

If the accuracy of a position is affected by different parameters, the contributions of all parameters to the total position error should be accounted for. A statistical method, combining different error sources, for determining positioning accuracy should be adopted. The position error, at 95% confidence level, should be recorded together with the survey data. Although this should preferably be done for each individual sounding, the error estimate may also be derived for a number of soundings or even for an area, provided differences between error estimates can be safely expected to be negligible.

It is strongly recommended that whenever positions are determined by terrestrial systems, redundant lines of position should be observed. Standard calibration techniques should be completed prior to and after the acquisition of data. Satellite systems should be capable of tracking at least five satellites simultaneously; integrity monitoring for Special Order and Order 1 surveys is recommended.

Primary shore control points should be located by ground survey methods to a relative accuracy of 1 part in 100,000. When geodetic satellite positioning methods are used to establish such points, the error should not exceed 10 cm at 95% confidence level. Secondary stations for local positioning, which will not be used for extending the control, should be located such that the error does not exceed 1 part in 10,000 for ground survey techniques or 50 cm using geodetic satellite positioning.

The horizontal positions of navigation aids and other important features should be determined to the accuracy stated in Table 2, at 95% confidence level.

Table 2

Summary of Minimum Standards for Positioning of Navigation Aids and Important Features

	Special Order surveys	Order 1 surveys	Order 2 and 3 surveys
Fixed aids to navigation and features significant to navigation	2 m	2 m	5 m
Natural Coastline	10 m	20 m	20 m
Mean position of floating aids to navigation	10 m	10 m	20 m
Topographical features	10 m	20 m	20 m

5.6 Depths

The navigation of commercial vessels requires increasingly accurate and reliable knowledge of the water depth in order to exploit safely the maximum cargo capabilities. It is imperative that depth accuracy standards in critical areas, particularly in areas of marginal underkeel clearance and where the possibility of obstructions exists, be more stringent than those established in the past and that the issue of adequate bottom coverage be addressed.

In determining the depth accuracy of the reduced depths, the sources of individual errors should be quantified and combined to obtain a Total Propagated Error (TPE) at the 95% confidence level. Among others these errors include:

a) measurement system and sound velocity errors
b) tidal measurement and modeling errors, and
c) data processing errors.

A statistical method for determining depth accuracy by combining all known errors should be adopted and checked. Recognizing that both constant and depth dependent errors affect the accuracy of depths, the formula under Table 1 is to be used to compute the allowable depth errors at 95% confidence level by using the values from row 3 for a and b. As an additional check on data quality, an analysis of redundant depths observed at crossline intersections should be made.

For wrecks and obstructions which may have less than 40 m clearance above them and may be dangerous to normal surface navigation, the least depth over them should be determined either by high definition sonar examination or physical examination (diving). Mechanical sweeping may be used when guaranteeing a minimum safe clearance depth.

All anomalous features previously reported in the survey area and those detected during the survey should be examined in greater detail and, if confirmed, their least depth should be determined. The agency responsible for survey quality may define a depth limit beyond which a detailed seafloor investigation, and thus an examination of anomalous features, is not required.

Measured depths should be reduced to chart or survey datum, by the application of tidal or water level height. Tidal reductions should not be applied to depths greater than 200 m, except when tides contribute significantly to the TPE.

5.7 Sounding Density

In planning the density of soundings, both the nature of the seabed in the area and the requirements of the users have to be taken into account to ensure adequate bottom coverage. It should be noted that no method, not even 100% search, guarantees by itself the reliability of a survey nor can it disprove with certainty the existence of hazards to navigation, such as isolated natural hazards or man made objects such as wrecks, between survey lines.

Line spacing for the various orders of hydrographic surveys is proposed in Table 1. The results of a survey should be assessed using procedures developed by the agency responsible for the survey quality. Based on these procedures the adequacy of the sounding density should be determined and the line spacing reduced if warranted.

5.8 Bottom Sampling

The nature of the seabed should be determined by sampling or may be inferred from other sensors (e.g. single beam echo sounders, side scan sonar, sub-bottom profiler, video, etc.) up to the depth required by local anchoring or trawling conditions. Under normal circumstances sampling is not required in depths greater than 200 meters. Samples should be spaced according to the seabed geology, but should normally be 10 times that of the main scheme line spacing. In areas intended for anchorages, density of sampling should be increased. Any inference technique should be substantiated by physical sampling.

5.9 Tidal Observations

Tidal height observations should be made throughout the course of a survey for the purpose of providing tidal reductions for soundings, and providing data for tidal analysis and subsequent prediction. Observations should extend over the longest possible period, and if possible, for not less than 29 days. Tidal heights should be observed so that the total measurement error at the tide gauge, including timing error, does not exceed +/- 5 cm at 95% for Special Order surveys. For other surveys +/- 10 cm should not be exceeded.

5.10 Metadata

To allow a comprehensive assessment of the quality of survey data it is necessary to record or document certain information together with the survey data. Such information is important to allow exploitation of survey data by a variety of users with different requirements, especially as requirements may not be known when survey data is collected. The information describing the data is called metadata. Examples of metadata include overall quality, data set title, source, positional accuracy and copyright. Metadata is data implicitly attached to a collection of data.

Metadata should comprise at least the following information:

- the survey in general (e.g. date, area, equipment used, name of survey platform)
- the horizontal and vertical datum
- calibration procedures and results
- sound velocity for corrections to echo soundings
- tidal datum and reduction procedures
- accuracies achieved and the respective confidence levels.

Metadata should preferably be in digital form in compliance with the FGDC-endorsed Content Standard for Digital Geospatial Metadata (version 2.0), FGDC-STD-001-1998, and an integral part of the survey record. Shoreline metadata should comply with the Metadata Profile for Shoreline Data. If this is not feasible, similar information should be included in the documentation of a survey. It is recommended that agencies responsible for the survey quality systematically develop and document a list of metadata used for their survey data.

It is understood that each sensor (i.e. positioning, depth, heave, pitch, roll, heading, seabed characteristic sensors, water column parameter sensors, tidal reduction sensor, data reduction models etc.) possesses unique error characteristics. Each survey system should be uniquely analyzed to determine appropriate procedure(s) to obtain the required spatial statistics. These analysis procedure(s) should be documented or referenced in the survey record.

5.11 Elimination of Doubtful Data

To improve the safety of navigation it is desirable to eliminate doubtful data, i.e. data which are usually denoted on charts by PA (Position Approximate), PD (Position Doubtful), ED (Existence Doubtful), SD (Sounding Doubtful) or as "reported danger". To confirm or disprove the existence of such data it is necessary to carefully define the area to be searched and subsequently survey that area according to the standards outlined in this publication.

No empirical formula for defining the search area can suit all situations. For this reason, it is recommended that the search radius should be 3 times the estimated position error of the reported hazard at the 95% confidence level as determined by a thorough investigation of the report on the doubtful data by a qualified hydrographic surveyor. If such report is incomplete or does not exist at all, the position error must be estimated by other means as, for example, a more general assessment of positioning and depth measurement errors during the era when the data in question was collected.

The methodology for conducting the search should be based on the area in which the doubtful data is reported and the estimated danger of the hazard to navigation. Once this has been established, the search procedure should be that of conducting a hydrographic survey of the extent defined in the preceding paragraph, to the standards established in this publication. If not detected, the agency responsible for the survey quality shall decide whether to retain the hazard as charted or to expunge it.

5.12 Quality Control

To ensure that the required accuracies are achieved it is necessary to check and monitor performance. Establishing quality control procedures which ensure that data or products meet certain standards and specifications should be a high priority for hydrographic authorities. This section provides guidelines for the implementation of such procedures.

Quality control for positioning ideally involves observing redundant lines of position and/or monitor stations which are then analyzed to obtain a position error estimate. If the positioning system offers no redundancy or other means of monitoring system performance, rigorous and frequent calibration is the only means of ensuring quality.

A standard quality control procedure should be to check the validity of soundings by conducting additional depth measurements. Differences should be statistically tested to ensure compliance of the survey with the standards given in Table 1. Anomalous differences should be further examined with a systematic analysis of contributing error sources. All discrepancies should be resolved, either by analysis or re-survey during progression of the survey task.

Crosslines intersecting the principal sounding lines should always be run to confirm the accuracy of positioning, sounding, and tidal reductions. Crosslines should be spaced so that an efficient and comprehensive control of the principal sounding lines can be effected. As a guide it may be assumed that the interval between crosslines should normally be no more than 15 times that of the selected sounding lines.

The proposed line spacing from Table 1 may be altered depending on the configuration of the seafloor and the likelihood of dangers to navigation. In addition, if side scan sonar is used in conjunction with single beam or multibeam sonar systems, the specified line spacing may be increased.

Multibeam sonar systems have great potential for accurate seafloor coverage if used with proper survey and calibration procedures. An appropriate assessment of the accuracy of measurements with each beam is necessary for use in areas surveyed to Special Order and Order 1 standards. If any of the outer beams have unacceptable errors, the related data may be used for reconnaissance but the depths should be otherwise excluded from the final data set. All swaths should be intersected, at least once, by a crossline to confirm the accuracy of positioning, depth measurements and depth reductions.

References

International Hydrographic Organization, April 1998, IHO Standards for Hydrographic Surveys, Special Publication No. 44, 4th Edition, 23p.

APPENDIX N

U. S. NATIONAL MAP ACCURACY STANDARDS – 1947
(PUBLISHED MAPS)

United States National Map Accuracy Standards

With a view to the utmost economy and expedition in producing maps which fulfill not only the broad needs for standard or principal maps, but also the reasonable particular needs of individual agencies, standards of accuracy for published maps are defined as follows:

1. **Horizontal accuracy.** For maps on publication scales larger than 1:20,000, not more than 10 percent of the points tested shall be in error by more than 1/30 inch, measured on the publication scale; for maps on publication scales of 1:20,000 or smaller, 1/50 inch. These limits of accuracy shall apply in all cases to positions of well-defined points only. Well-defined points are those that are easily visible or recoverable on the ground, such as the following: monuments or markers, such as bench marks, property boundary monuments; intersections of roads, railroads, etc.; corners of large buildings or structures (or center points of small buildings); etc. In general what is well defined will be determined by what is plottable on the scale of the map within 1/100 inch. Thus while the intersection of two road or property lines meeting at right angles would come within a sensible interpretation, identification of the intersection of such lines meeting at an acute angle would obviously not be practicable within 1/100 inch. Similarly, features not identifiable upon the ground within close limits are not to be considered as test points within the limits quoted, even though their positions may be scaled closely upon the map. In this class would come timber lines, soil boundaries, etc.
2. **Vertical accuracy,** as applied to contour maps on all publication scales, shall be such that not more than 10 percent of the elevations tested shall be in error more than one-half the contour interval. In checking elevations taken from the map, the apparent vertical error may be decreased by assuming a horizontal displacement within the permissible horizontal error for a map of that scale.
3. **The accuracy of any map may be tested** by comparing the positions of points whose locations or elevations are shown upon it with corresponding positions as determined by surveys of a higher accuracy. Tests shall be made by the producing agency, which shall also determine which of its maps are to be tested, and the extent of the testing.
4. **Published maps meeting these accuracy requirements** shall note this fact on their legends, as follows: “This map complies with National Map accuracy Standards.”
5. **Published maps whose errors exceed those aforestated** shall omit from their legends all mention of standard accuracy.
6. **When a published map is a considerable enlargement** of a map drawing (manuscript) or of a published map, that fact shall be stated in the legend. For example, “This map is an enlargement of a 1:20,000-scale map drawing,” or “This map is an enlargement of a 1:24,000-scale published map.”
7. **To facilitate ready interchange and use of basic information for map construction** among all Federal mapmaking agencies, manuscript maps and published maps, wherever economically feasible and consistent with the uses to which the map is to be put, shall conform to latitude and longitude boundaries, being 15 minutes of latitude and longitude, or 7.5 minutes, or 3-3/4 minutes in size.

Issued June 10, 194l
Revised April 26, 1943
Revised June 17, 1947

U.S. BUREAU OF THE BUDGET

APPENDIX O

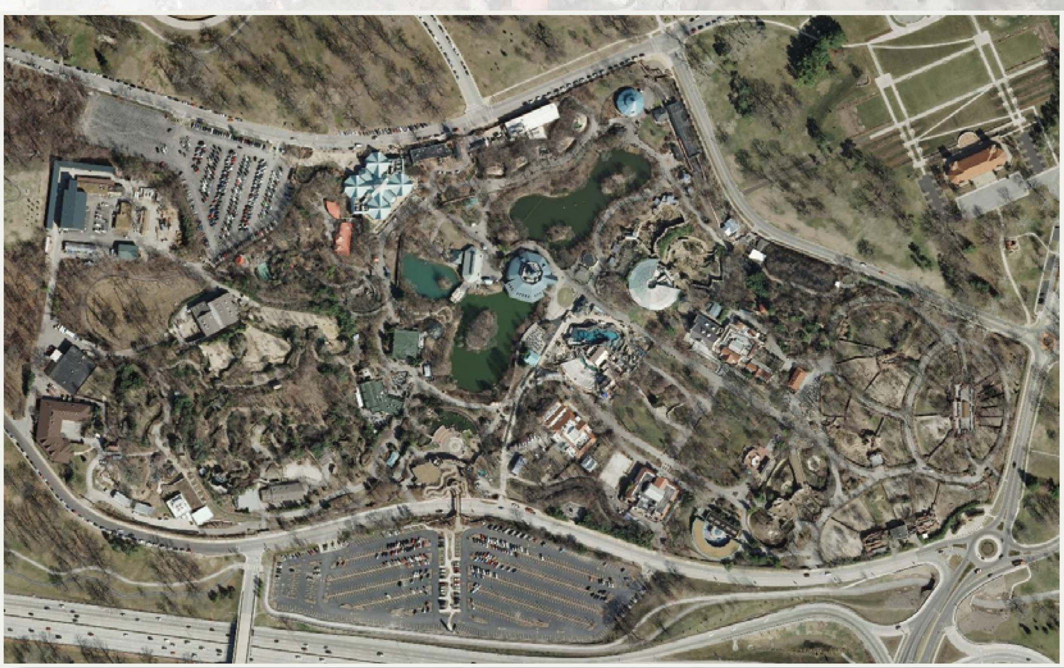
USGS DIGITAL ORTHOIMAGERY BASE SPECIFICATION – V 1.0

USGS
science for a changing world

National Geospatial Program

Digital Orthoimagery Base Specification V1.0

Chapter 5 of
Section B, U.S. Geological Survey Standards
Book 11, Collection and Delineation of Spatial Data



Techniques and Methods 11–B5

U.S. Department of the Interior
U.S. Geological Survey

Cover. St. Louis Zoo, St. Louis, Missouri, East-West Gateway Council of Governments, 2012.

Digital Orthoimagery Base Specification V1.0

By Philip P. Rufe

Chapter 5 of
Section B, U.S. Geological Survey Standards
Book 11, Collection and Delineation of Spatial Data

National Geospatial Program

Techniques and Methods 11–B5

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
SALLY JEWELL, Secretary

U.S. Geological Survey
Suzette M. Kimball, Acting Director

U.S. Geological Survey, Reston, Virginia: 2014

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
International foot (ft)	0.3048	meter (m)
U.S. Survey Foot	0.3048006[a]	meter (m)
mile (mi)	1.609	kilometer (km)
mile, nautical (nmi)	1.852	kilometer (km)
yard (yd)	0.9144	meter (m)

SI to Inch/Pound

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	International foot (ft)
meter (m)	3.28083[b]	U.S. Survey Foot
kilometer (km)	0.6214	mile (mi)
kilometer (km)	0.5400	mile, nautical (nmi)
meter (m)	1.094	yard (yd)

[a]0.30488006 is an approximate conversion factor. Conversions from U.S. Survey Foot should use the exact value of 1200/3937.

[b]3.28083 is an approximate conversion factor. Conversions to U.S. Survey Foot should use the exact value of 39.39/12.

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Elevation, as used in this report, refers to distance above the vertical datum.

Digital Orthoimagery Base Specification V1.0

By Philip P. Rufe

Introduction

The resolution requirement for orthoimagery in support of the *The National Map* of the U.S. Geological Survey (USGS) is 1 meter. However, as the Office of Management and Budget A-16 designated Federal agency responsible for base orthoimagery, the USGS National Geospatial Program (NGP) has developed this base specification to include higher resolution orthoimagery. Many Federal, State, and local programs use high-resolution orthoimagery for various purposes including critical infrastructure management, vector data updates, land-use analysis, natural resource inventory, and extraction of data. The complex nature of large-area orthoimagery datasets, combined with the broad interest in orthoimagery, which is of consistent quality and spatial accuracy, requires high-resolution orthoimagery to meet or exceed the format and content outlined in this specification.

The USGS intends to use this specification primarily to create consistency across all NGP funded and managed orthoimagery collections, in particular, collections in support of the National Digital Orthoimagery Program (NDOP). In the absence of other comprehensive specifications or standards, the USGS intends that this specification will, to the highest degree practical, be adopted by other USGS programs and mission areas, and by other Federal agencies.

This base specification, defining minimum parameters for orthoimagery data collection. Local conditions in any given project area, specialized applications for the data, or the preferences of cooperators, may mandate more stringent requirements. The USGS fully supports the acquisition of more detailed, accurate, or value-added data that exceed the base specification outlined herein. A partial list of common "buy-up" options is provided in appendix 1 for those areas and projects that require more stringent or expanded specifications.

Applicability

This document is applicable to orthoimagery data and deliverables funded in whole or in part by the USGS.

Maintenance Authority

The USGS NGP is the maintenance authority for this document.

Background

The USGS has cooperated in the collection of numerous orthoimagery datasets across the Nation for a wide array of applications. A single base set of specifications is used that defines minimum collection parameters and a consistent set of deliverables to facilitate these collections.

This set of specifications for 1-meter or better, high-resolution orthoimagery is based, in part, on a draft high-resolution imagery specification supplied by the Commercial Partnerships Team, National Geospatial Technical Operations Center, NGP, USGS.

It is recognized that the USGS NGP also uses orthoimagery for specialized scientific research and other projects whose requirements are incompatible with the provisions of this set of specifications. In such cases, and with properly documented justification supporting the need for the variance, exceptions to any part or all of this set of specifications may be granted by the USGS or one of its partners.

It is conceivable that in some cases, based on specific topography, land cover, intended application, or other factors, the USGS NGP may require specifications more rigorous than those defined in this document.

It is not the intention of the USGS to stifle the development of the orthoimagery industry, nor to discourage innovation within the technology. Technical alternatives to any part of this document may be submitted with any proposal and will be given due professional consideration.

Project and File Management

This section provides requirements for project and file management. It includes specific requirements for documenting the geographic extent of the project, how to handle non-image data, and use and distribution rights.

Geographic Extent

Each orthoimagery project shall cover the assigned area with a minimum 300 meter (m) or 1,000 foot (ft) buffer on all exterior project edges. Extents shall be computed by projecting the geographic corners and side midpoints to the appropriate projection, then adding the buffer on each side of the resulting minimum bounding rectangle (or polygon, if the project has an irregular shape). If a project contains multiple, noncontiguous polygons, the 300 m or 1,000 ft buffer will apply to each polygon in the project.

It is the preference of the USGS for orthoimagery to be divided into 1,500 m by 1,500 m or 5,000 ft by 5,000 ft tiles. Other tile sizes may be acceptable if approved in advance by the USGS. Each image tile will be stored in its own image file. The extent and grid of the image files shall be approved per project area. For the purpose of this and supporting documents, the term dataset will represent the gridded extent of the project area. The term "tile" will be synonymous with "file" and will represent an individual tile used to cover an equal subdivisional portion of the overall extent of the dataset. The relation between dataset and tile/file is one-to-many. The relation between tile and file is one-to-one. An individual tile is composed of one or more image chips. Chips are pieces or snippets of imagery that are used to cover the extent of an image tile. The relation between tile/file and chip is one-to-many.

Non-Image Data

Orthoimagery chips shall not contain any non-image data. Non-image data include items such as photographic frame borders, fiducial marks, artifacts, and titling.

Use and Distribution Rights

All imagery and data delivered under these specifications shall become the property of the U.S. Government. All deliverable data and documentation shall be free from restrictions regarding use and distribution. Data and documentation delivered under these specifications shall be freely distributable by USGS or other government agencies.

Acquisition and Processing

The following specifications pertain to the acquisition and delivery of the required high-resolution natural-color aerial imagery [color-infrared (IR) and 4-band are optional, and may have different specifications]. All USGS acquisitions shall be digital images. Other customers using this set of specifications may, at their discretion, request either film-based photographs or digital images. If film is selected, requirements in appendix 2 should be observed.

Acquisition Conditions

1. Acceptable window—The acceptable window (that is, range of dates) for the acquisition part of this task shall be specific to the project area and as approved by the customer.
2. Time of day and year—Image acquisition shall occur when the sun angle is greater than 30 degrees above the horizon. In urban areas containing many high-rise structures, a higher sun angle may be specified to minimize shadows. Depending on project area and project specifics, the 30-degree sun angle may be relaxed to 28 degrees with prior approval.
3. Topographic conditions—Imagery shall be acquired to minimize:
    a. The amount of tilt in buildings and other raised features that obscure ground detail.
    b. The obstruction of transportation features by buildings or shadows.
    c. The obstruction of features in the interior of a city block by tall buildings.
    d. The clipping of features (for example, radio towers, water tanks, buildings) at image file boundaries.
4. Image smear—Imagery shall be acquired with outsmearing.
5. Environmental conditions—Imagery shall be acquired under conditions free from clouds and cloud shadows, smoke, haze, light streaks, nonpermanent snowpack, flooding, and excessive soil moisture.
6. Vegetation conditions—Leaf-off imagery is encouraged but leaf-on projects may be considered on a project-by-project basis.
7. Tide coordination—Tide-coordinated imagery can be considered on a project-by-project basis.
8. Image coverage—The extent of image coverage over the project area shall be sufficient to ensure void areas do not exist in resulting delivered orthoimage tiles. Full image tiles that meet or exceed the 300 m or 1,000 ft buffer specified in the section titled "Geographic Extent", above, are required. Partial tiles are considered unacceptable.

Sensor Station Control

Airborne Global Positioning System (AGPS)—Sensor position (latitude, longitude, and ellipsoid height) shall be recorded during image capture with AGPS. AGPS data shall be differentially corrected and organized as individual datasets grouped by corresponding flight line or film roll. Differentially corrected AGPS positional data shall be stored on portable media, in a nonproprietary format mutually agreeable to the customer and their contractor. Preference is for shapefile format. Inertial Measurement Unit (IMU) Exterior Orientation Data (Optional)—If IMU data are included as a component of the sensor station control, the contractor shall record the sensor attitude during image capture. The IMU data shall be adjusted and organized as individual datasets grouped by corresponding film roll or flight line (digital imagery).

Supplemental Ground Control

Ground control used to supplement the AGPS positional adjustment, whether conventionally surveyed or surveyed by differential global positioning system (GPS), will conform to conventions and processes to produce orthoimagery that meet required accuracies. Ground control data shall be stored on portable media, in a nonproprietary format mutually agreeable to the customer and their contractor. Preference is for shapefile format. The contractor shall prepare and submit a Supplemental Ground Control report that contains narrative, computations, field notes/photos, and coordinates/elevations for all points surveyed as supplemental ground control.

Resolution and Accuracy

The source imagery shall be of sufficient resolution without downward resampling to support production of digital orthorectified images to the specified ground pixel resolution and to the specifications contained in the next section titled “Product Generation.”

Product Generation

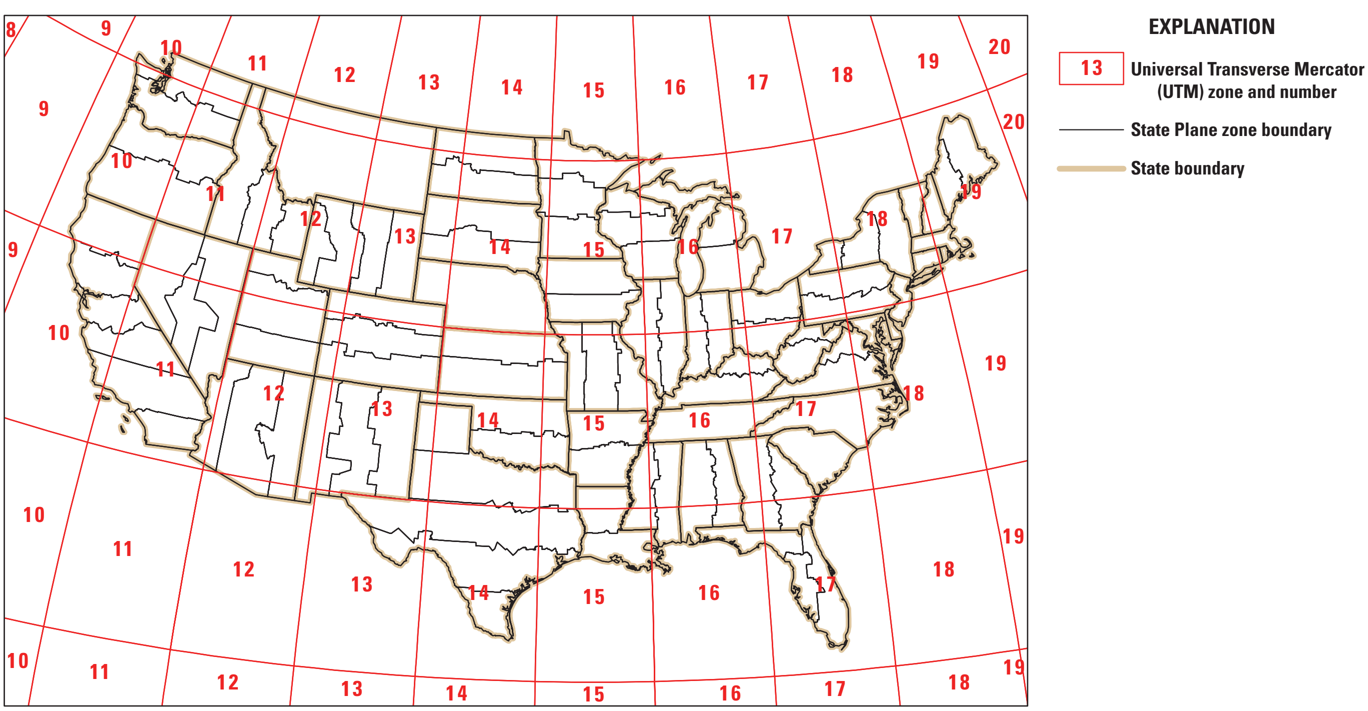
Product generation includes specifications and parameters for generating orthoimagery from aerial imagery.

Aerotriangulation Data

Aerotriangulation (AT) data, if used in the orthorectification process, shall consist of a minimum of exterior orientation parameters, refined image coordinates and adjusted ground coordinates. If AT is performed, the contractor shall provide an AT report including initial approximations and adjusted values for absolute orientation parameters and their residuals. If surveyed ground control coordinates are used in the adjustment, then surveyed and adjusted ground control values and their residuals shall also be included.

Datums and Coordinates

All high-resolution orthoimagery shall be projected in the North American Datum of 1983 (NAD 83), using the corresponding native Universal Transverse Mercator (UTM) zone or State Plane zone representing the predominance of the project area (see fig. 1, UTM zones). Coordinates shall be in meters or feet, any adjustments to the datum are to be specified



Base modified from Esri, 2013

Figure 1. Universal Transverse Mercator (UTM) and State Plane Zones.

on a project by project basis. Data projected in UTM with units of meters are desirable. If feet are used, all references to the linear unit of measure “Feet” or “Foot” must specify either “International” or “U.S. Survey.” If a subsequent adjustment of NAD 83 is used [for example, NAD 83(HARN), NAD 83(NSRS2007), NAD 83(NSRS2011), NAD 83(CORS)], the exact adjustment must be specified. The vertical datum for the supporting elevation data used to create high-resolution digital orthoimagery shall be the North American Vertical Datum of 1988 (NAVD 88). The project will be controlled using the latest available National Geodetic Survey (NGS) control adjustment of the project area, unless an alternative adjustment is specifically requested and described by the customer. The data provider will verify the latest available NGS control adjustment(s) pertinent to the geographic extent of the project area.

Digital Orthorectified Image Color

The default type for images is natural color. Color-IR and 4-band may be substituted for natural color as “buy-up” options.

Spatial Resolution

The natural color or four band source imagery shall be of sufficient resolution to support production of digital orthorectified images to the specified ground pixel resolution. Data units of meters are desirable. Orthoimagery produced under this specification shall not be resampled from the original image, original scan or original capture, with resolution greater or less than the numbers shown in table 1.

Table 1. Product ground pixel resolution and image resolution.

[m, meter; ft, foot]

Ground pixel resolution (GPR)	Original image resolution (maximum)	Original image resolution (minimum)
1.0 m	0.5 m	1.1 m
3.28 ft	1.64 ft	3.6 ft
0.3 m	0.15 m	0.35 m
1 ft	0.5 ft	1.1 ft
0.15 m	0.08 m	0.17 m
0.5 ft	0.25 ft	0.55 ft
0.08 m	0.04 m	0.1 m
0.25 ft	0.125 ft	0.275 ft

Horizontal Accuracy

Orthoimagery accuracy shall be determined using independent ground check points of higher accuracy not used in aerotriangulation or initial georeferencing of the imagery. Computed accuracy must meet or exceed the 95 percent National Standard for Spatial Data Accuracy (NSSDA) Confidence Interval as shown in table 2 (Federal Geographic Data Committee,1998b).

Table 2. Product ground pixel resolution and horizontal accuracy.

[m, meter; ft, foot; *r*, radial]

Ground pixel resolution (GPR)	Horizontal accuracy$_r$
1.0 m	10.30 m
3.28 ft	33.79 ft
0.3 m	1.52 m
1.0 ft	5.06 ft
0.15 m	0.76 m
0.5 ft	2.5 ft
0.08 m	0.38 m
0.25 ft	1.25 ft

Product Accuracy Information Reporting

Product accuracy information shall be reported according to NSSDA guidelines for tested accuracy, which are available at *http://www.fgdc.gov/standards/projects/FGDC-standards-projects/accuracy/part3/chapter3* (Federal Geographic Data Committee,1998b). At a minimum, statements concerning source materials and production processes used must be provided at the project level sufficient to meet the requirements for horizontal accuracy as listed in table 2.

Digital Orthorectified Image Format

The USGS prefers uncompressed data. USGS will accept data in a loss-less compression but reserves the right to obtain and review any compression technique in order to better understand the methodology before making a decision agreeing to its use. Images shall be submitted in ArcGIS readable, GeoTIFF file format, Version 1.8.2, (*http://www.remotesensing.org/geotiff/spec/geotiffhome.html*) (Ritter and Ruth, 1995) with no internal overviews (pyramid layers). Presence of compression artifacts will be cause for rejection.

GeoTIFF files shall include (as a minimum) the following GeoTIFF tags and keys:

- ModelTiepointTag
- ModelPixelScaleTag

or

- ModelTransformation Tag

and

- GTModelTypeGeoKey
- GTRasterTypeGeoKey
- ProjectedCSTypeGeoKey
- PCSCitationGeoKey (or GTCitationGeoKey)
- ProjLinearUnitsGeoKey

Digital Orthorectified Image Tiles

Orthorectified GeoTIFF files shall represent tiles as defined in the project tiling scheme with no chip-overedge. Corner coordinates will be based on the UTM grid or State Plane grid. Image files shall be accompanied by a project index in shapefile format suitable for loading into ArcGIS. The project index shall include image tile boundaries and filenames, and shall be georeferenced in latitude/longitude coordinates.

Image Mosaicking

Orthoimagery may be created using multiple digital images (that is, chips) to produce the final product. Specular reflections and other artifacts should be minimized, especially in developed areas, by patching the area using chips from adjacent overlapping imagery. Above ground features appearing in the orthoimage imagery, such as building roof tops, water towers, and radio towers, shall not be clipped at seamlines or between individual image files.

Radiometry Balance

When a mosaic of two or more images is made, the brightness and color values of the other images will be adjusted to match that of the principal image. The seamlines between the overlapping images will be chosen to minimize tonal variations. Localized adjustment of the brightness and color values will be done to reduce radiometric differences between join areas. Changes in color balance across the project, if they exist, shall be gradual. Abrupt tonal variations between image files are not acceptable.

Edge Matching

Excessive horizontal displacement along seamlines or at image file boundaries is not allowed. The maximum allowable mis-join between transportation features or other well-defined linear features is 3 product Ground Sample Distance (GSD) pixels.

Radiometric Resolution

1. Color imagery—All color imagery shall be no less than 8-bit per band Red, Green, Blue (RGB) image in accordance with section 6, RGB Full Color Images, of the Tagged Image File Format TIFF™ Specification, Revision 6 (Adobe Developers Association, 1992) Color-IR and 4-band are optional, and may have different specifications
2. Color Infrared Imagery (CIR)—All color infrared imagery shall be no less than 8-bit per band Near-IR, RG image in accordance with section 6 of TIFF™ Specification, Revision 6 (Adobe Developers Association, 1992).
3. 4-Band Imagery—All imagery that contains both natural color and near-IR shall meet the same requirements as color imagery specified in the Color Infrared Imagery bullet above and shall have the bands saved in the following order: Red, Green, Blue, and Near-Infrared.
4. Imagery with greater than 8 bits per pixel is allowed providing that the following TIFF tags are included in the image header:
    a. SampleFormat,
    b. MinSampleValue,
    c. MaxSampleValue.

File Naming Convention

For projects in UTM/meters, file names for the orthoimage files shall be derived from the southwest corner of each image chip and shall be based on the U.S. National Grid, [Federal Geographic Data Committee (FGDC), 2001]. File names will include Grid Zone Designation (GZD), 100,000 meter block designator and X and Y grid coordinates truncated to 100 meters. Supplemental information on the National Grid can be accessed at the FGDC U.S. National Grid website *http://www.fgdc.gov/usng*.

For projects in State Plane/feet, file names for the orthoimage files shall be derived from the southwest corner of each image chip. The file name will consist of the X and Y State Plane coordinate of the southwest corner, truncated to 1,000 feet.

Alternative naming conventions may be approved to meet customer requirements.

Elevation Data

Elevation data used during the orthorectification process shall have sufficient resolution and density to produce orthoimagery that meets the horizontal accuracy requirements outlined in the sections titled "Spatial Resolution" and "Horizontal Accuracy."

Metadata

Project metadata describing the orthoimage production process and tile level metadata for each image file shall be submitted as a deliverable. Federal Geographic Data Committee (FGDC) compliant metadata shall be provided in extensible markup language (.xml) format for each orthorectified image file. FGDC compliant metadata for each orthoimage file shall be delivered on portable media. The Web site below contains the files designed to define and support production of FGDC compliant metadata. Download the following files from *ftp://ftpext.usgs.gov/pub/cr/mo/rolla/release/xmlinput/*.

- XMLInput1_64.zip—Contains an application (XMLInput) for creating and editing .xml metadata files. It is not mandatory that this software is used; it is merely available for use. When the zip file is unzipped, it also contains a template (133UAtemplate.xml) and a dtd (csdgm2.dtd) to help with FGDC compliance. The XMLInput.jar is the executable file.
- Help.pdf and XMLInput123.doc—User's guide for XML Input. Use this guide to install and use XMLInput.
- metadata_overview.doc—Additional information about metadata.

Deliverables

This section describes requirements for orthoimagery deliverables. These deliverables include the source imagery, digital orthoimagery, and supporting data.

Source Imagery

Sensor Station Control

a. AGPS—Positional data and statistical summary report shall be submitted on portable media, in a nonproprietary format mutually agreeable to the customer and the contractor. In addition, the contractor shall produce a statistical report summarizing the results of the AGPS adjustment.

b. IMU Data—If IMU exterior orientation data are part of the contractor's technical proposal, the contractor shall submit this sensor orientation data and a statistical summary report on portable media, in a nonproprietary format mutually agreeable to the customer and the contractor. The contractor also shall produce a statistical report summarizing the overall accuracy of the adjusted IMU data.

Supplemental Ground Control

If used, conventional survey or differentially corrected GPS Ground Control points used to supplement the AGPS positional data shall be delivered on portable media, in a nonproprietary format mutually agreeable to the USGS and the contractor. Preference is for shapefile format.

Flight Diagram

A flight diagram or flight index that illustrates the project area outline, the location of the flight lines and the approximate location of image centers, if relevant, shall be included as a deliverable. This diagram shall be provided in digital shapefile format suitable for loading into ArcGIS.

Independent Check Points

If required or available, independent check points used for accuracy assessment shall be included as a deliverable. These check points shall be delivered on portable media, in a nonproprietary format mutually agreeable to the USGS and the contractor. Preference is for shapefile.

Digital Orthoimagery and Supporting Data

Aerotriangulation Data

Aerotriangulation data, if used in the orthorectification process, shall be submitted to the USGS in digital format. Aerotriangulation data shall consist of a minimum of exterior orientation parameters, refined image coordinates, adjusted ground coordinates, and a statistical summary report.

Elevation Data

Elevation data created or modified for use in the orthorectification process shall be submitted as a deliverable in a nonproprietary format on portable media. Format shall be mutually agreeable between the USGS and contractor. Elevation data provided by the USGS as Government Furnished Material (GFM) does not require submittal, unless said data are modified by the contractor.

Delivery Medium and Format

Digital orthorectified images, in GeoTIFF format, shall be submitted on portable media. Image files shall be accompanied by a project index in shapefile format suitable for loading into ArcGIS.

Metadata

Metadata shall be delivered as described in the section titled "Metadata."

Quality Assessment and Testing by USGS

Quality control will be performed by the USGS to ensure that all processes and procedures used, and metadata produced by the contractor, are adequate to meet all specifications cited as deliverables.

Visual inspection of the data will be performed for the following items:

1. Completeness of data to cover the specified geographic extent, with no omissions or corrupt data.
2. Tonal balancing problems across the project.
3. Extreme tonal or color variation across seamlines.
4. Ground pixel resolution to ensure that orthoimagery meets the specified resolution.
5. Cloud cover, smoke/haze, corrupt data, and void areas.
6. Excessive horizontal displacement along seamlines in images (more than 3 pixels along transportation features, unless project specifications state otherwise).
7. Amount of tilt in buildings and other raised features that obscures ground detail.
8. Transportation features obstructed by buildings or shadows.
9. Tall buildings in urban areas that obscure features in the interior of a city block.
10. Clipping of features (for example, radio towers, water tanks, buildings) at image file boundaries.
11. Building/structure, bridge, or road warp that may indicate bad elevation data.
12. Smearing.
13. Evidence of oversaturation or undersaturation as a result of image processing or histogram manipulation.
14. Artifacts caused by image compression.

Horizontal Accuracy Test

Testing is performed on submitted check points. If other suitable control is available, it may also be included in the accuracy test. Check points must be completely independent of control used during aerotriangulation and data production.

Metadata Adequacy

The USGS will verify that accompanying metadata is complete and compliant with FGDC Content Standards for Digital Geospatial Metadata (Federal Geographic Data Committee,1998a).

Acknowledgments

The following U.S. Geological Survey personnel were consulted in the compilation of this document: Dale Benson (retired), Doug Binnie, Russ Caton, Dan Daniels, Bryon Ellingson (retired), Buel (Rusty) Grout, C. Robert Kelly, George Lee, Lori Phillips, Tim Saultz, and Joseph W. Scott (retired).

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Federal Geographic Data Committee, 1998a, Content Standard for Digital Geospatial Metadata (revised June 1998): Washington, D.C., Federal Geographic Data Committee, 59 p. plus appendixes, accessed April 25, 2013, at *http://www.fgdc.gov/metadata/csdgm/*.

Federal Geographic Data Committee, 1998b, Geospatial Positioning Accuracy Standards, Part 3—National Standard for Spatial Data Accuracy (FGDC-STD-007.3-1998): Accessed April 25, 2013, at *http://www.fgdc.gov/standards/projects/FGDC-standards-projects/accuracy/part3/index_html/?searchterm=FGDC-STD-007.3-1998*.

Federal Geographic Data Committee, 2001, U.S. National Grid Standard (FGDC-STD-011-2001): Reston, Virginia, Federal Geographic Data Committee, 13 p. plus appendixes, accessed April 25, 2013, at *http://www.fgdc.gov/standards/projects/FGDC-standards-projects/usng/fgdc_std_011_2001_usng.pdf/view?searchterm=FGDC-STD-011-2001*).

Ritter, Niles, Ruth, Mike, 1995, GeoTIFF Format Specification (ver. 1.8.2), accessed April 25, 2013, at *http://www.remotesensing.org/geotiff/spec/geotiffhome.html*.

Appendixes

Appendix 1

Buy-Up Options

Buy-up options are those specifications beyond the minimum requirements for orthoimagery outlined in this specification. The cost of a buy-up option is based on the increased level of effort in addition to the cost for baseline imagery. The following are considered buy-up options:

- Color-infrared—An option where a false color composite image is generated by collecting imagery in the green, red, and near-infrared wavelengths and assigning blue, green, and red display colors to those relative wavelengths. This may be a no cost option.
- Panchromatic—An option for panchromatic (grayscale) imagery. This may be a no cost option.
- Four-band—An option where imagery is collected in four bands: blue, green, red, and near-infrared. This may be a no cost option.
- Multi-spectral (five or more bands)—An option where imagery is collected in five or more bands.
- Hyperspectral—An option where imagery is collected in a multitude of narrow spectral ranges.
- Increased horizontal accuracy—Improved accuracy for x and y values.
- Reduced resolution (requires resampling)—Resampling collected imagery from 1 foot to 1 meter, and so on.
- Oblique—In nonproprietary format.

Appendix 2

Film-Based Orthoimagery

Acquisition and Processing

Film

Contractors may choose a film that processes to either a negative or positive image. If imagery is captured on aerial film for any reason, the following emulsions are preferred.

- Color Positive Film—Kodak Aerochrome III MS Film 2427™, AGFA Aviphot Chrome 200 PE1™ (or equivalent)
- Color Negative Film—AGFA X100 PE1™ film (or equivalent)
- Color Infrared Positive Film—Kodak SO-734 Aerochrome III Infrared NP™ (or equivalent).

Special Acquisition Conditions

- Calibration: Aerial Film Camera(s) used to acquire project imagery shall have a U.S. Geological Survey (USGS) Camera Calibration Report(s) dated less than 3 years before image acquisition.

Imagery Supplemental Report

The imagery supplemental report shall show the flight line numbers and exposure station or strip numbers. The contractor shall use the USGS Aerial Photography Supplemental Report form. An example of this form is included at the end of appendix 2.

Titling

Each exposure shall be clearly titled along the north edge (if flown north-south) or west edge (if flown east-west) of the photograph. Each exposure shall be marked clearly with a numerical abbreviation of the month, day and year of exposure, the number of the roll, the number of the exposure on the roll, the photo scale expressed as a ratio, and the three letter designator (for example, BOS for rolls of film used on a Boston, Massachusetts project) shall be numbered consecutively, beginning with number 1; and the exposures on each roll shall be numbered consecutively, beginning with the number 1. Coarse airborne global positioning system (AGPS) position shall be included in the title as encoded in the camera data chamber. For cameras that do not have camera station positional encoders, the contractor shall manually add the coarse camera position on the opposite edge of the film from the roll exposure designator. An example of titling is included as figure 2 at the end of appendix 2.

Product Generation

Digital Orthorectified Image Characteristics

Image artifacts introduced during the scanning process and appearing in the final orthoimages are unacceptable, except for minimal artifacts falling in noncritical coverage areas. A minimal artifact, for example, would be a small piece of lint appearing in a timbered area.

Deliverables

Project Diagram

The contractor shall provide a project diagram delineating the project area. An example of a project diagram is included as figure 3 at the end of appendix 2.

Film

The contractor shall provide the original film acquired for the task order. The contractor shall use the standard USGS film can label form included at the end of in appendix 2.

Calibration Reports

If film cameras are used, camera calibration report(s) for aerial camera(s) used shall be included as a deliverable.

Photography and Supplemental Report(s)

A photography supplemental report of all the imagery flown shall be produced for the project. The report shall show the flight line numbers and exposure station or strip numbers, and should agree with the values shown in the flight diagram. The contractor shall use the USGS aerial photography supplemental report form. An example of this form is included at the end of appendix 2.

Example of Supplemental Forms List

Attached Supplementary Forms

USGS Film Can Label

2012FilmCanLabelEnabled.pdf

USGS Aerial Photography Supplemental Report

2012AerialPhotographySupplRepEnabled.pdf

USGS Aerial Camera Specifications

2012AerialMappingCameraSpecifications.pdf

Boston MA, 133UA Ortho

Sample Film Titling

(north or west edge)

MO/DY/YR 1:SCALE ROLL-PHOTO# CITY ABR.

COARSE AGPS POSITION*

(9X9 FILM)

*For cameras that have camera station position encoders the coarse airborne global positioning system (AGPS) position can be placed along the edge as placed by the camera.

Figure 2–1. Example of film titling.

ATTACHMENT 'A'
Boston, MA 133 UA
PROJECT DIAGRAM

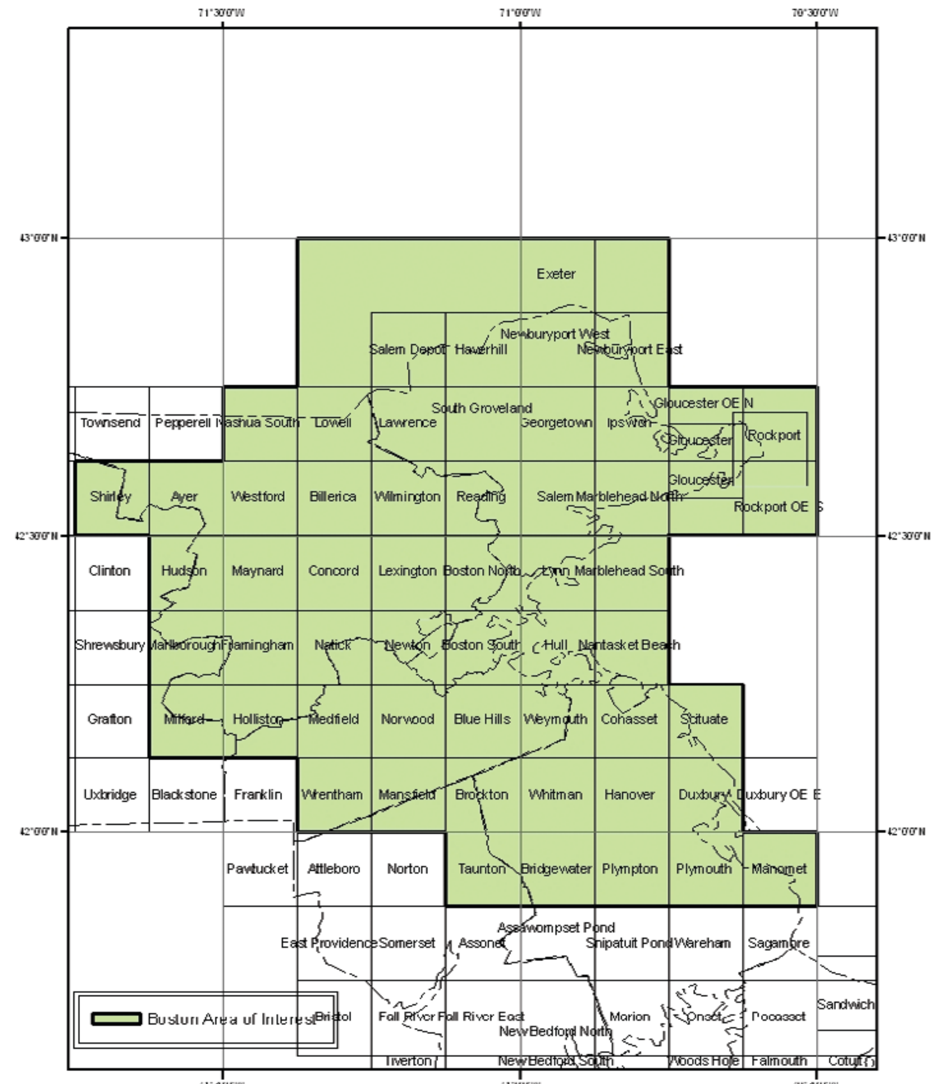

Figure 2–2. Example of project diagram.

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APPENDIX P

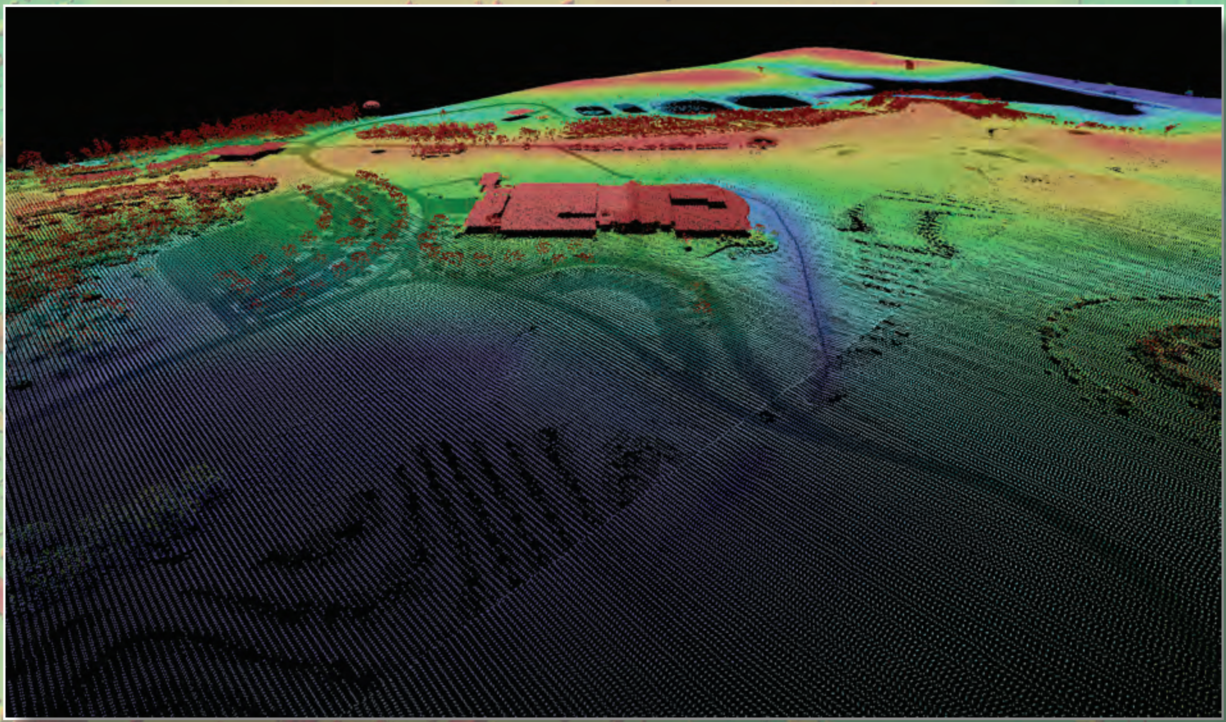
USGS LIDAR
BASE SPECIFICATION – V 1.2

USGS
science for a changing world

National Geospatial Program

Lidar Base Specification

Chapter 4 of
Section B, U.S. Geological Survey Standards
Book 11, Collection and Delineation of Spatial Data



Techniques and Methods 11–B4
Version 1.0, August 2012
Version 1.1, October 2014
Version 1.2, November 2014

U.S. Department of the Interior
U.S. Geological Survey

Cover. Background: Image depicts a hillshade first-return lidar surface of a suburban area of Sioux Falls, South Dakota.
Front cover inset: Image depicts a perspective view of an all-return lidar point cloud.
Back cover inset: Image depicts a hillshade perspective view of a hydro-flattened bare-earth lidar surface of Palisades State Park in Garretson, South Dakota.

Lidar Base Specification

By Hans Karl Heidemann

Chapter 4 of
Section B, U.S. Geological Survey Standards
Book 11, Collection and Delineation of Spatial Data

National Geospatial Program

Techniques and Methods 11–B4
Version 1.0, August 2012
Version 1.1, October 2014
Version 1.2, November 2014

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
SALLY JEWELL, Secretary

U.S. Geological Survey
Suzette M. Kimball, Acting Director

U.S. Geological Survey, Reston, Virginia:
First release: 2012
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Revised: November 2014 (ver. 1.2)

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To order this and other USGS information products, visit http://store.usgs.gov.

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Contents

Tables

Conversion Factors and Datum

SI to Inch/Pound

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
meter (m)	39.37/12	U.S. Survey foot (ft)
meter (m)	1/0.3048	International foot (ft)
meter (m)	1.094	yard (yd)
	Area	
square meter (m^2)	0.0002471	acre
square kilometer (km^2)	247.1	acre
square meter (m^2)	10.76	square foot (ft^2)
square kilometer (km^2)	0.3861	square mile (mi^2)

Elevation, as used in this specification, refers to the distance above the geoid, unless specifically referenced to the ellipsoid.

Abbreviations

2D	two-dimensional
3D	three-dimensional
3DEP	3D Elevation Program
ACC_r	$accuracy_r$
ACC_z	$accuracy_z$
ANPD	aggregate nominal pulse density
ANPS	aggregate nominal pulse spacing
ARRA	American Reinvestment and Recovery Act
ASPRS	American Society for Photogrammetry and Remote Sensing
BPA	buffered project area
cm	centimeter
CRS	Coordinate Reference System
CONUS	Conterminous United States
CVA	consolidated vertical accuracy
DEM	digital elevation model
DPA	defined project area
DSM	digital surface model
DTM	digital terrain model
EDNA	Elevation Derivatives for National Applications
EPSG	European Petroleum Survey Group
Esri	Environmental Systems Research Institute
FGDC	Federal Geographic Data Committee
FVA	fundamental vertical accuracy
GB	gigabyte
GIS	geographic information system
GPS	global positioning system

ID	identification
IMU	inertial measurement unit
km	kilometer
km^2	square kilometer
LAS	LAS file format (.las)
lidar	light detection and ranging
m	meters
mp	Metadata Parser
m^2	square meters
n/a	not available
NAD 83	North American Datum of 1983
NAVD 88	North American Vertical Datum of 1988
NDEP	National Digital Elevation Program
NED	National Elevation Dataset
NEEA	National Enhanced Elevation Assessment
NGP	National Geospatial Program
NGS	National Geodetic Survey
NIR	near infra red
NPD	nominal pulse density
NPS	nominal pulse spacing
NSSDA	National Standards for Spatial Data Accuracy
NVA	nonvegetated vertical accuracy
OGC	Open Geospatial Consortium
pls/m^2	pulses per square meter
QA/QC	quality assurance/quality control
QL	quality level
RMSD	root mean square difference
$RMSD_z$	root mean square difference in the *z* direction (elevation)
RMSE	root mean square error
$RMSE_r$	horizontal linear RMSE in the radial direction that includes both *x* and *y* errors
$RMSE_x$	horizontal linear RMSE in the *x* direction (Easting)
$RMSE_y$	horizontal linear RMSE in the *y* direction (Northing)
$RMSE_z$	vertical linear RMSE in the *z* direction (Elevation)
SPCS	State Plane Coordinate System
SVA	supplemental vertical accuracy
TIN	triangulated irregular network
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator
VVA	Vegetated Vertical Accuracy
WKT	Well Known Text
XML	eXtensible Markup Language

Lidar Base Specification

By Hans Karl Heidemann

Abstract

In late 2009, a $14.3 million allocation from the "American Recovery and Reinvestment Act" for new light detection and ranging (lidar) elevation data prompted the U.S. Geological Survey (USGS) National Geospatial Program (NGP) to develop a common base specification for all lidar data acquired for *The National Map*. Released as a draft in 2010 and formally published in 2012, the USGS–NGP "Lidar Base Specification Version 1.0" (now Lidar Base Specification) was quickly embraced as the foundation for numerous state, county, and foreign country lidar specifications.

Prompted by a growing appreciation for the wide applicability and inherent value of lidar, a USGS-led consortium of Federal agencies commissioned a National Enhanced Elevation Assessment (NEEA) study in 2010 to quantify the costs and benefits of a national lidar program. A 2012 NEEA report documented a substantial return on such an investment, defined five Quality Levels (QL) for elevation data, and recommended an 8-year collection cycle of Quality Level 2 (QL2) lidar data as the optimum balance of benefit and affordability. In response to the study, the USGS–NGP established the 3D Elevation Program (3DEP) in 2013 as the interagency vehicle through which the NEEA recommendations could be realized.

Lidar is a fast evolving technology, and much has changed in the industry since the final draft of the "Lidar Base Specification Version 1.0" was written. Lidar data have improved in accuracy and spatial resolution, geospatial accuracy standards have been revised by the American Society for Photogrammetry and Remote Sensing (ASPRS), industry standard file formats have been expanded, additional applications for lidar have become accepted, and the need for interoperable data across collections has been realized. This revision to the "Lidar Base Specification Version 1.0" publication addresses those changes and provides continued guidance towards a nationally consistent lidar dataset.

Introduction

As the designated Office of Management and Budget Circular A–16 lead agency for topographic elevation data, the U.S. Geological Survey (USGS), through the National Geospatial Program (NGP, hereafter, USGS–NGP), has developed and adopted this specification as the base specification for the National interagency 3D Elevation Program (3DEP). This specification, developed with input from a broad coalition of Federal, state, and industry light detection and ranging (lidar) interests, also may serve, in whole or in part, as the foundation for many other lidar specifications. Overall movement throughout the industry toward more consistent practices in the collection, handling, processing, documentation, and delivery of lidar point cloud data will allow the technology and data to become more useful to a broader user base, and thereby benefit the Nation as a whole.

Although lidar data have been used in research and commercial mapping applications for more than a decade, lidar is still a relatively new technology (Stoker, 2013). Advancements and improvements in instrumentation, software, processes, applications, and understanding are constantly refined or developed. It would not be possible to develop a set of guidelines and specifications that addresses and keeps pace with all of these advances. This specification is based on the experience and research of the USGS–NGP pertaining to the lidar technology being used in the industry. Furthermore, the USGS–NGP acknowledges that a common set of best practices has not been developed or adopted by the industry for numerous processes and technical assessments (for example, measurement of density and distribution, classification accuracy, and calibration quality). The USGS encourages the development of such best practices with industry partners, other government agencies, and the appropriate professional organizations.

Unlike most other lidar data procurement specifications, which largely focus on the products derived from lidar point cloud data such as the bare-earth digital elevation model (DEM), this specification places particular emphasis on the handling of the source lidar point cloud data. These specifications are intended to ensure that the complete source dataset remains intact and viable to support the wide variety of DEM and non-DEM science and mapping applications that can benefit from lidar technology. The source dataset includes the data, metadata, descriptive documentation, quality information, and ancillary data—collected in accordance with the minimum parameters described within this specification.

Adherence to the specifications of the National Enhanced Elevation Assessment (NEEA) Quality Level 2 (QL2) and Quality Level 1 (QL1) lidar data ensures that point cloud and derivative products are suitable for the 3DEP and the National Elevation Dataset (NED) (Gesch, 2007). Data meeting Quality Level 3 (QL3) requirements will be suitable for incorporation into the NED. The 3DEP's goal to fully realize the benefits documented in the NEEA report depends on the ability to manage, analyze, and exploit a lidar dataset spanning the Nation; the vast quantity of lidar data requires these functions be handled through computerized, machine-driven processes that will require uniformly formatted and organized data. Presidential Executive Order 13642, "Making Open and Machine Readable the New Default for Government Information," requires agencies to implement an Open Data Policy, which makes government data easily accessible and usable (Obama, 2013). Adherence to these specifications ensures that the point cloud source data are handled in a uniform manner by all data providers and are consistently delivered to the USGS in clearly defined formats.

Purpose and Scope

The USGS intends to use this specification to acquire and procure lidar data and to create consistency across all USGS–NGP and partner-funded lidar collections, in particular those that support the NED and the 3DEP.

This base specification covers three different data QLs, defining minimum parameters for acceptance of the acquired lidar data for each QL. Local conditions in any given project, specialized applications for the data, or the preferences of cooperators, may mandate more stringent requirements. In these circumstances, the USGS may support or require the collection of more detailed, accurate, or value-added data. A list of common upgrades to the minimum requirements defined in this specification is provided in appendix 1, "Common Data Upgrades."

A summary of the changes between the previous version of this specification (Version 1.0) and this revision (Version 1.1) is provided in the section "Changes in Version 1.1."

Applicability

These specifications and guidelines are applicable to lidar data and deliverables supported in whole or in part with financial or in-kind contributions by or for the USGS–NGP or the 3DEP.

Maintenance Authority

The USGS–NGP is the maintenance authority for this specification.

Requirement Terminology

Individual requirements are captured throughout this specification as "shall" or "will" statements.

- A "shall" statement means that the requirement must be met in all cases.
- A "will" statement indicates that the requirement is expected to be met wherever possible, but exceptions to implementation may exist.

Background

The USGS–NGP has cooperated in the collection of many lidar datasets across the Nation for a wide array of applications. These collections have used a variety of specifications and have had a diverse set of product deliverables; however, the end result was incompatible datasets making cross-project analysis extremely difficult. The need for a single base specification was apparent, one that defined minimum collection parameters and a consistent set of deliverables

Because of the "American Reinvestment and Recovery Act" (ARRA) funding for *The National Map* (that began in late 2009), the rate of lidar data collection increased. This increase made it imperative that a single data specification be implemented to ensure consistency and improve data utility. Although the development of this specification was prompted by funding through the ARRA, the specification is intended to remain durable beyond ARRA-funded USGS–NGP projects.

The need for a single data specification has been reinforced by the inception of the 3DEP after the completion of the NEEA. The 3DEP is a cooperatively funded national elevation program led by the USGS. This program has been designed to meet the mission-critical data needs of the 3DEP partners and other users. A target state would produce full national QL2 (at least at this level) coverage in 8 years with lidar data in 49 States and Alaska being mapped at QL5 using other technologies. Products derived from 3DEP data would be available for the high-priority needs of partners and other users, who also would be able to use the original data to create their own products and services.

In addition, the USGS–NGP also uses lidar technology for specialized scientific research and other projects whose requirements are incompatible with the provisions of this specification. In such cases, and with properly documented justification supporting the need for the variance, waivers of any part or all of this specification may be granted by the USGS–NGP. In some cases, based on specific topography, land cover, intended application, or other factors, the USGS–NGP may require standards more rigorous than those defined in this specification. For any given collection, technical alternatives that enhance the data or associated products are encouraged and may be submitted with any proposal and will be given due professional consideration by the USGS–NGP.

Changes in Version 1.1

1. For clarification, numerous sections of the specification have been editorially revised, and there has been minor reorganization of the document.

2. Glossary definitions have been updated to align with those in the new American Society for Photogrammetry and Remote Sensing (ASPRS) Positional Accuracy Standards for Digital Geospatial Data (American Society for Photogrammetry and Remote Sensing, 2014) and other industry publications, and several new definitions have been added. Notable among these are:
    - Aggregate nominal pulse density (and spacing),
    - Bridge and culvert,
    - Vegetated (and nonvegetated) vertical accuracy, and
    - Percentile.

3. Coincident with this revision of the specification, ASPRS also developed its own Positional Accuracy Standards for Digital Geospatial Data (American Society for Photogrammetry and Remote Sensing, 2014). With regard to elevation data, the new standards redefine how elevation accuracy is described and reported, and although any accuracy could be its own accuracy "class," a number of common classes are explicitly defined. The previous ASPRS vertical accuracy standard (American Society for Photogrammetry and Remote Sensing, 1990) was based on contour interval (usually expressed in feet [ft]), resulting in non-integer accuracy thresholds when converted to the metric units typically used with lidar (for example, 9.25 centimeters [cm]). The new ASPRS standard abandons the dependency on contour interval and is based entirely in metric units; its common classes are integer (for example, 10.0 cm). The NEEA QL definitions used common accuracy classes based on the earlier accuracy definitions and, to eliminate confusion about accuracy requirements as 3DEP moves forward, the QL accuracy definitions were adjusted to match the new ASPRS classes. Another quality level, QL0, was added as a placeholder for the higher quality data anticipated with future advances in lidar technology. The requirements stated for QL0 are somewhat arbitrary and are subject to change in future revisions of this specification. The changes relevant to lidar data QLs in this revision of the specification are as follows:
    - QL0 was added with accuracy of 5.0 cm root mean square error in *z* ($RMSE_z$) and density of 8 pulses per square meter (pls/m^2). This accuracy aligns with the ASPRS 5-cm vertical accuracy class.
    - QL1 accuracy was changed from 9.25 cm $RMSE_z$ to 10.0 cm $RMSE_z$. This accuracy does not correspond directly to any ASPRS accuracy class; it is a hybrid of QL2 accuracy and QL0 pulse density.
    - QL2 accuracy was changed from 9.25 cm $RMSE_z$ to 10.0 cm $RMSE_z$. This accuracy aligns with the ASPRS 10-cm vertical accuracy class.
    - QL3 accuracy was changed from 18.5 cm $RMSE_z$ to 20.0 cm $RMSE_z$ and density was changed from 0.7 pls/m^2 to 0.5 pls/m^2. This accuracy aligns with the ASPRS 20-cm vertical accuracy class.

4. Also to align with the new ASPRS accuracy standards, accuracy is reported based on nonvegetated vertical accuracy (NVA) and vegetated vertical accuracy (VVA). These two classes replace the previously used fundamental, supplemental, and consolidated vertical accuracy (FVA, SVA, and CVA) classes.

5. The new ASPRS standards include recommendations tying the quantity of vertical accuracy check points required for a project to the areal extent of the project. Adherence to these recommendations is required by this specification.

6. QL2 has been established as the minimum required QL for new USGS–NGP lidar data collections.

7. Relative accuracy requirements for lidar data, within swath (intraswath) and between overlapping swaths (interswath) have been refined and established for each QL. A more detailed methodology for assessing and reporting these metrics is provided.

8. Lidar point data delivery is required in LAS v1.4 (American Society for Photogrammetry and Remote Sensing, 2011), Point Data Record Format 6, 7, 8, 9, or 10. Proper use of the Overlap and Withheld bit flags is required.

9. The block of lidar-specific metadata tags recommended in the previous version of this specification has been modified to reflect the other updates to the specification. The inclusion of this block is required in all lidar point data eXtensible Markup Language (XML) metadata files.

10. The 2 gigabyte (GB) limit on swath file size has been removed, although the method for splitting large swath files remains in the specification for use in situations where a data producer needs to produce smaller files.

11. The test area for assessing classification accuracy was changed from 1 kilometer square to 1 square kilometer.

12. Two additional point classification types are required:
    - Class 17, Bridges, and
    - Class 18, High Noise.

13. Anticipating that projects will more frequently use multiple coverage collection (for example, overlap greater than 50 percent) to achieve the higher required pulse density, terminology and requirements for this data organization have been added.

14. Requirements for datum and coordinate reference systems have been refined and clarified.
15. Development and delivery of breaklines is required for all hydro-flattened water bodies, regardless of the methodology used by the data producer for hydro-flattening.
16. Requirements and guidelines for flightline overlap and scan angle limits have been removed. Data producers are cautioned to be more rigorous about gaps in and the relative accuracy of the point cloud data.

Changes in Version 1.2

1. For clarification, the publication was modified to omit versioning from the main title. No changes were made to the content of the specification.

Collection

Collection Area

The defined project area (DPA) shall be buffered by a minimum of 100 meters (m) to create a buffered project area (BPA). Data collection is required for the full extent of the BPA.

In order for all products to be consistent to the edge of the DPA, all products shall be generated to the full extent of the BPA. Because data and products are generated for the complete BPA, they shall also be delivered to the customer. Data and products in the buffer (the area between the DPA and the BPA) will not be tested for any quality requirement. Control points may be located in the buffer; check points shall not be located in the buffered area.

Quality Level

The minimum acceptable QL for USGS–NGP and 3DEP collections is QL2, as defined in this specification.

Multiple Discrete Returns

Deriving and delivering multiple discrete returns is required in all data collection efforts. Data collection shall be capable of at least three returns per pulse. Full waveform collection is acceptable and will be promoted; however, full waveform data are regarded as supplemental information.

Intensity Values

Intensity values are required for each multiple discrete return. The values recorded in the LAS files shall be normalized to 16 bit, as described in the LAS Specification version 1.4 (American Society for Photogrammetry and Remote Sensing, 2011).

Nominal Pulse Spacing

The term nominal pulse spacing (NPS) has been in use across the industry since its beginnings; the counterpart term, nominal pulse density (NPD), came into use when collection densities began to fall below 1 pls/m^2. These terms were used by instrument manufacturers and data producers to describe instrument performance and collection targets and, in these contexts, the terms almost always refer to single swath, first return only collection. For much of the history of lidar use, most collections were planned and executed as single-coverage flight missions: thus, these terms also were used by data consumers, whose interests are naturally focused on the net result of a collection. Thus, the terms NPS and NPD could be used by the entire community without misunderstanding.

The trend towards achieving the specified “NPS” for a project through multiple passes, overlap greater than 50 percent, multi-channel instruments, and multiple instruments on a single collection platform has expanded the industry’s options and flexibility in designing lidar collection missions. Complexity and confusion have also been added to assessment and reporting standards. The net pulse density of a collection may be several times greater than the planned density of a single swath. The terms “NPS” and “NPD” can have quite different meanings to different members of the lidar community.

In this specification, the terms NPS and NPD will continue to reference single instrument, single swath, first return only lidar point data. Maintaining this terminology provides a consistent and understandable metric for communication regarding data collection.

Multiple channels of data from a single instrument are regarded as a single swath. In this sense, a single instrument is regarded as one in which both channels meet the following criteria:

- They share fundamental hardware components of the system, such as global positioning system (GPS), Inertial Measurement Unit (IMU), laser, mirror or prism, and detector assembly,
- They share a common calibration or boresighting procedure and solution, and
- They are designed and intended to operate as a single-sensor unit.

Assessment and reporting of the NPS is made against single swath, single instrument, first return only data, including only the geometrically usable part of the swath (typically the center 95 percent) and excluding acceptable data voids. The NPS can be predicted using flight planning software, or empirically calculated by delineating a 1 square kilometer (km^2) (or greater) polygon that is representative of the overall pulse density of the swath. The NPS is the square root of the average area per point (the area of the polygon divided by the number of points it contains). These two techniques will produce slightly different values. The NPS is largely regarded as a mission design and planning metric.

Higher net densities of lidar point measurements are being achieved more often by using multiple coverages, creating a need for a separate new term to prevent confusion with NPS and NPD. This specification will use the terms aggregate nominal pulse spacing (ANPS) and aggregate nominal pulse density (ANPD) to describe the net overall pulse spacing and density, respectively. On projects designed to achieve the ANPS through a single coverage, ANPS and NPS are equal.

Like NPS, ANPS includes only the geometrically usable part of the swaths (typically the center 95 percent), excludes acceptable data voids, and can be empirically calculated using the method described above for NPS. Conversion between ANPS and ANPD is the same as for NPS and NPD. ANPS is the metric of a lidar dataset for users.

The table “Aggregate nominal pulse spacing and density, Quality Level 0–Quality Level 3” (table 1) lists the required ANPS and ANPD by QL. Dependent on the local terrain and land cover conditions in a project, a greater pulse density may be required on specific projects.

Table 1. Aggregate nominal pulse spacing and density, Quality Level 0–Quality Level 3.

[m, meters; pls/m^2, pulses per square meter; ≤, less than or equal to; ≥, greater than or equal to]

Quality Level (QL)	Aggregate nominal pulse spacing (ANPS) (m)	Aggregate nominal pulse density (ANPD) (pls/m^2)
QL0	≤0.35	≥8.0
QL1	≤0.35	≥8.0
QL2	≤0.71	≥2.0
QL3	≤1.41	≥0.5

Data Voids

Data voids, in lidar, are gaps in the point cloud coverage, caused by surface absorbance or refraction of the lidar pulse (or both absorbance and refraction simultaneously), instrument or processing anomalies or failure, obstruction of the lidar pulse, or improper collection because of flight plans. A data void is considered to be any area greater than or equal to $4\left(ANPS^2\right)$, which is measured using first returns only. Data voids within a single swath are not acceptable, except in the following circumstances:

- Where caused by water bodies,
- Where caused by areas of low near infrared (NIR) reflectivity, such as asphalt or composition roofing, or
- Where appropriately filled in by another swath.

For projects designed to achieve the required ANPS through multiple coverage, the entire BPA shall be covered with the designed number of swaths. Areas meeting the size threshold defined above for single coverage that are not covered by the designed number of swaths are data voids. For example, consider a project designed to achieve a minimum required ANPD of 2 pls/m^2, using an NPD of 1.2 pls/m^2 and 55 percent overlap. During preprocessing, the outer edges of the swaths are determined to be geometrically unreliable, those points are tagged as Withheld, and the usable width of the swath is narrowed. In addition, normal variations in flight stability and the resulting undulations in the linearity of the swath edges then leave areas between the overlaps where the surface is covered by only one swath. Because the design of the project is for double coverage, the areas covered by only one swath and exceeding the size limit defined above are regarded as data voids. The project will be rejected unless these areas are later augmented with fill-in swaths.

Spatial Distribution and Regularity

The spatial distribution of geometrically usable points will be uniform and regular. Although lidar instruments do not produce regularly gridded points, collections shall be planned and executed to produce an aggregate first return point cloud that approaches a regular lattice of points, rather than a collection of widely spaced, high-density profiles of the terrain. The regularity of the point pattern and density throughout the dataset is important and will be assessed by using the following steps:

- Generating a density grid from the data with cell sizes equal to twice the design ANPS and a radius equal to the design ANPS.
- Ensuring at least 90 percent of the cells in the grid contain at least one lidar point.
- Using individual (single) swaths, with only the first return points located within the geometrically usable center part (typically 95 percent) of each swath.
- Excluding acceptable data voids previously identified in this specification.

The process described in this section relates only to regular and uniform point distribution. The process does not relate to, nor can it be used for, the assessment of NPS or ANPS. The USGS–NGP may allow lower passing thresholds for this requirement in areas of substantial relief where maintaining a regular and uniform point distribution is impractical.

Collection Conditions

Conditions for collection of lidar data will follow these guidelines:

- Atmospheric conditions shall be cloud and fog free between the aircraft and ground during all collection operations.
- Ground conditions shall be snow free. Very light, undrifted snow may be acceptable in special cases, with prior approval.
- Ground conditions shall be free of extensive flooding or any other type of inundation.

Although leaf-off vegetation conditions are preferred, many factors beyond human control may affect dormant conditions at the time of any collection, therefore, the USGS–NGP only requires that penetration to the ground be adequate to produce an accurate and reliable bare-earth surface for the prescribed QL. With prior approval from the USGS–NGP, collections for specific research projects may be exempt from this requirement.

Data Processing and Handling

The ASPRS LAS File Format

All processing will be carried out with the understanding that all point deliverables are required to be fully compliant with ASPRS LAS Specification, version 1.4, using Point Data Record Format 6, 7, 8, 9 or 10. Data producers are encouraged to review the LAS Specification version 1.4 in detail (American Society for Photogrammetry and Remote Sensing, 2011).

Full Waveform

If full waveform data are recorded during collection, the waveform packets shall be delivered. LAS Specification version 1.4 deliverables including waveform data shall use external auxiliary files with the extension .wdp to store waveform packet data. *See* the LAS Specification version 1.4 for additional information (American Society for Photogrammetry and Remote Sensing, 2011).

Time of Global Positioning System Data

The time of global positioning system (GPS) data shall be recorded as Adjusted GPS Time, at a precision sufficient to allow unique timestamps for each pulse. Adjusted GPS Time is defined to be Standard (or satellite) GPS time minus 10^9. The encoding tag in the LAS header shall be properly set. *See* the LAS Specification version 1.4 for additional information (American Society for Photogrammetry and Remote Sensing, 2011).

Datums

All data collected shall be tied to the datums listed below:

1. For the Conterminous United States (CONUS), unless otherwise specified by the user and agreed to in advance by the USGS–NGP:
   - The horizontal datum for latitude and longitude and ellipsoid heights will be the North American Datum of 1983 (NAD 83) using the most recently published adjustment of the National Geodetic Survey (NGS) (currently NAD 83, epoch 2010.00).
   - The vertical datum for orthometric heights will be the North American Vertical Datum of 1988 (NAVD 88).
   - The geoid model used to convert between ellipsoid heights and orthometric heights will be the latest hybrid geoid model of NGS, supporting the latest realization of NAD 83 (currently GEOD12A model).
2. For Alaska, American Samoa, Commonwealth of the Northern Mariana Islands, Guam, Hawaii, Puerto Rico, U.S. Virgin Islands, and other areas:
   - Horizontal and vertical datums, ellipsoids, and geoids shall be specified and agreed to by the USGS–NGP and all collection partners in advance of collection.

Coordinate Reference System

Lidar data for CONUS will be processed and delivered in the most accurate Coordinate Reference System (CRS) available for a project location, usually State Plane Coordinate System (SPCS) or a state system. Universal Transverse Mercator (UTM) also may be used, particularly when a single suitable local SPCS is not available, UTM is needed for compatibility with existing data for the area, or is needed for other reasons. Other CRSs may be used with prior approval from the USGS–NGP.

For Alaska, American Samoa, Commonwealth of the Northern Mariana Islands, Guam, Hawaii, Puerto Rico, U.S. Virgin Islands, and other areas, the horizontal and vertical CRS (specifically including the units) shall be specified and agreed to in advance of collection by the USGS–NGP and all collection partners.

Each project shall be processed and delivered in a single CRS, except in cases where a project area covers multiple CRSs such that processing in a single CRS would introduce unacceptable distortions in part of the project area. In such cases, the project area is to be split into subareas appropriate for each CRS. Each subarea shall be processed and delivered as a separate subproject with its own CRS. All requirements for a single project will apply to each subproject, notably the inclusion of the required buffer area and delivery of DPA and BPA boundaries. These boundaries are required to ensure that the datasets can subsequently be merged without introducing duplicate points. The DPA boundaries of adjacent subareas shall have topologically coincident boundaries along their common borders.

In all cases, the CRS that is used shall be recognized and published by the European Petroleum Survey Group (EPSG) and correctly recognized by industry standard geographic information system (GIS) software applications.

Units of Reference

All references to the unit of measure “Feet” and “Foot” shall specify “International,” “Intl,” “U.S. Survey,” or “US.”

Swath Identification

At the time of its creation and prior to any further processing, each swath shall be assigned a unique File Source Identification (ID), and each point within the swath shall be assigned a Point Source ID equal to the File Source ID. The Point Source ID on each point will be persisted unchanged throughout all processing and delivery. *See* the LAS Specification version 1.4 (American Society for Photogrammetry and Remote Sensing, 2011).

Point Families

Point families (multiple return “children” of a single “parent” pulse) will be maintained throughout all processing before tiling. Multiple returns from a given pulse will be stored in sequential (collected) order.

Swath Size and Segmentation

The widespread adoption of 64-bit operating systems in mainstream computing (most notably Windows-7, 64-bit or newer operating systems) has obviated the earlier need for 2 GB limits on swath file sizes. Unless otherwise required by the data producer, lidar swaths may be of any file size supported within a 64-bit computing system. In cases where segmentation of the swaths is required by the data producer, the following requirements apply:

- Subswath segments of a given original swath will be of comparable size.
- Each subswath shall retain the File Source ID of the original complete swath.
- Points within each subswath shall retain the Point Source ID of the original complete swath.
- Each subswath file shall be named identically to the original complete swath, with the addition of an ordered alphabetic suffix to the name (“-a,” “-b,” …, “-n”). The order of the named subswaths shall be consistent with the collection order of the points (“-a” will be the first subswath; “-n” will be the last subswath).
- Point families will be maintained intact within each subswath.
- Subswaths will be broken at the edge of the scan line.

Scope of Collection

All collected swaths shall be delivered as part of the Raw Data Deliverable, including, calibration swaths and cross-ties. All collected returns within each swath shall also be delivered. No points are to be deleted from the swath LAS files. Exceptions to this rule are the extraneous data outside of the BPA (such as aircraft turns, transit between the collection area and airport, and transit between fill-in areas). These points may be permanently removed from swaths. Swaths that are being completely discarded by the vendor and reflown do not need to be delivered.

Positional Accuracy Validation

Before classification of and development of derivative products from the point cloud, the absolute and relative vertical accuracy of the point cloud shall be verified. A detailed report of the validation processes used shall be delivered.

Relative Vertical Accuracy

Relative vertical accuracy refers to the internal geometric quality of a lidar dataset, without regard to surveyed ground control. Two primary factors need to be considered in lidar data vertical accuracy:

- Smooth surface repeatability (intraswath), and
- Overlap consistency (interswath).

In ideal theoretical conditions, smooth surface repeatability is a measure of variations documented on a surface that would be expected to be flat and without variation. Users of lidar technology commonly refer to these variations as “noise.” Single-swath data will be assessed using only single returns in nonvegetated areas. Repeatability will be evaluated by measuring departures from planarity of single returns from hard planar surfaces, normalizing for actual variation in the surface elevation. Repeatability of only single returns will then be assessed at multiple locations within hard surfaced areas (for example, parking lots or large rooftops).

Each sample area will be evaluated using a signed difference raster (maximum elevation − minimum elevation) at a cell size equal to twice the ANPS, rounded up to the next integer. Sample areas will be approximately 50 square meters (m^2). The maximum acceptable variations within sample areas at each QL are listed in the table "Relative vertical accuracy for lidar-swath data, Quality Level 0–Quality Level 3" (table 2). Isolated noise is expected within the sample areas and will be disregarded.

Overlap consistency is a measure of geometric alignment of two overlapping swaths; the principles used with swaths can be applied to overlapping lifts and projects as well. Overlap consistency is the fundamental measure of the quality of the calibration or boresight adjustment of the data from each lift, and is of particular importance as the match between the swaths of a single lift is a strong indicator of the overall geometric quality of the data, establishing the quality and accuracy limits of all downstream data and products.

Overlap consistency will be assessed at multiple locations within overlap in nonvegetated areas of only single returns. The overlap areas that will be tested are those between the following:

- Aadjacent, overlapping parallel swaths within a project,
- Cross-tie swaths and the intersecting project swaths, and
- Adjacent, overlapping lifts.

Each overlap area will be evaluated using a signed difference raster with a cell size equal to twice the ANPS, rounded up to the next integer. The difference rasters will be visually examined using a bicolor ramp from the negative acceptable limit to the positive acceptable limit. Although isolated excursions beyond the limits are expected and accepted, differences in the overlaps shall not exceed the limits listed in table 2 for the QL of information that is being collected.

The difference rasters will be statistically summarized to verify that root mean square difference in *z* ($RMSD_z$) values do not exceed the limits set forth in the table "Relative vertical accuracy for lidar-swath data, Quality Level 0–Quality Level 3" (table 2) for the QL of information that is being collected. Consideration will be given for the effect of the expected isolated excursions over limits.

Check Points

The Positional Accuracy Standards for Digital Geospatial Data (American Society for Photogrammetry and Remote Sensing, 2014) ties the required number of check points for vertical accuracy assessment to the areal extent of the project. Data producers are encouraged to carefully review the new and revised requirements in that document.

Check points for NVA assessments shall be surveyed in clear, open areas (which typically produce only single lidar returns), devoid of vegetation and other vertical artifacts (such as boulders, large riser pipes, and vehicles). Ground that has been plowed or otherwise disturbed is not acceptable. The same check points may be used for NVA assessment of the point cloud and DEM.

Check points for VVA assessments shall be surveyed in vegetated areas (typically characterized by multiple return lidar). Although the nature of vegetated areas makes absolute definition of a suitable test area difficult, these areas will meet the requirements below.

Suitable areas for check point survey are defined as having a minimum homogeneous area of $(ANPS \times 5)^2$, with less than one-third of the required $RMSE_z$ deviation from a low-slope (less than 10 degrees) plane. In land covers other than forested and dense urban, the tested point will have no obstructions above 45 degrees over the horizon (to improve GPS reception and maximize lidar point collection). Check points will not be surveyed in areas of extremely high NIR absorption (fresh asphalt, wet soil, or tar), or in areas that are near abrupt changes in NIR reflectivity (asphalt pavement with runway stripes or white beach sand adjacent to water) because these abrupt changes usually cause unnatural vertical shifts in lidar elevation measurements. All tested locations will be photographed showing the position of the survey tripod and the ground condition of the surrounding area. Additionally, control points used in the calibration process for data acquisition shall not be used as check points. Check points shall be an independent set of points used for the sole purpose of assessing the vertical accuracy of the project.

As stated in the National Standards for Spatial Data Accuracy (NSSDA) (Federal Geographic Data Committee, 1998) and reiterated in the ASPRS Positional Accuracy Standards for Digital Geospatial Data (American Society for

Table 2. Relative vertical accuracy for lidar-swath data, Quality Level 0–Quality Level 3.

[cm, centimeter; $RMSD_Z$, root mean square difference in z; ≤, less than or equal to; ±, plus or minus]

Quality Level (QL)	Smooth surface repeatability (cm)	Swath overlap difference, $RMSD_Z$ (cm)	Swath overlap difference, maximum (cm)
QL0	≤3	≤4	±8
QL1	≤6	≤8	±16
QL2	≤6	≤8	±16
QL3	≤12	≤16	±32

Photogrammetry and Remote Sensing, 2014), it is unrealistic to prescribe detailed requirements for check point locations, as many unpredictable factors will affect field operations and decisions, and the data producer must often have the freedom to use their best professional judgment. The quantity and location of check points shall meet the following requirements, unless alternative criteria are approved by the USGS–NGP in advance:

1. The ASPRS-recommended total number of check points for a given project size shall be met.
2. The ASPRS-recommended distribution of the total number of check points between NVA and VVA assessments shall be met.
3. Check points within each assessment type (NVA and VVA) will be well-distributed across the entire project area. *See* the glossary at the end of this specification for a definition of "well-distributed."
4. Within each assessment type, check points will be distributed among all constituent land cover types in approximate proportion to the areas of those land cover types (American Society for Photogrammetry and Remote Sensing, 2014).

Absolute Vertical Accuracy

Absolute vertical accuracy of the lidar data and the derived DEM will be assessed and reported in accordance with the ASPRS Positional Accuracy Standards for Digital Geospatial Data (American Society for Photogrammetry and Remote Sensing, 2014). Two broad land cover types shall be assessed: vegetated and nonvegetated. The Guidelines And Specifications For Flood Hazard Mapping Partners (Federal Emergency Management Agency, 2003) identifies seven land cover types; the "Guidelines For Digital Elevation Data" (National Digital Elevation Program, 2004) and the "Vertical Accuracy Reporting For Lidar" (American Society for Photogrammetry and Remote Sensing, 2004) reiterate the first five of those types. The table "Land cover classes" (table 3) presents how each of the seven classes was reported under the previous standards and how they are reported under the new ASPRS standards and by this specification.

Three absolute accuracy values shall be assessed and reported: NVA for the point cloud, NVA for the DEM, and VVA for the DEM. The minimum NVA and VVA requirements for all data, using the ASPRS methodology, are listed in the tables "Absolute vertical accuracy for lidar-swath data, Quality Level 0–Quality Level 3" (table 4) and "Absolute vertical accuracy for digital elevation models, Quality Level 0–Quality Level 3" (table 5). Both the NVA and VVA required values shall be met. For projects dominated by dense forests, the USGS–NGP may accept higher VVA values.

The unclassified point cloud shall meet the required NVA before further classification and processing. The NVA for the point cloud is assessed by comparing check points surveyed in clear, open, nonvegetated areas (which typically produce only single lidar returns) to a triangulated irregular network (TIN) constructed from the single return lidar points in those areas. The NVA and VVA for the DEM are assessed by comparing check points to the final bare-earth surface.

The minimum required thresholds for absolute and relative accuracy may be increased when any of the following items are met:

- A demonstrable and substantial increase in cost is needed to obtain this accuracy.
- An alternate specification is needed to conform to previously contracted phases of a single larger overall collection effort such as for multiyear statewide collections.

Table 3. Land cover classes.

[FVA, fundamental vertical accuracy; NVA, nonvegetated vertical accuracy; SVA, supplemental vertical accuracy; VVA, vegetated vertical accuracy; n/a, not applicable]

<table>
<tr><th>Class number</th><th>Land cover class or description</th><th>Previous reporting group</th><th>Current reporting group</th></tr>
<tr><td>1</td><td>Clear or open, bare earth, low grass;
for example, sand, rock, dirt, plowed fields, lawns, golf courses</td><td>FVA</td><td rowspan="2">NVA</td></tr>
<tr><td>2</td><td>Urban areas; for example, tall, dense man-made structures</td><td>SVA</td></tr>
<tr><td>3</td><td>Tall grass, tall weeds, and crops; for example, hay, corn, and wheat fields</td><td>SVA</td><td rowspan="3">VVA</td></tr>
<tr><td>4</td><td>Brush lands and short trees; for example, chaparrals, mesquite</td><td>SVA</td></tr>
<tr><td>5</td><td>Forested areas, fully covered by trees; for example, hardwoods, conifers, mixed forests</td><td>SVA</td></tr>
<tr><td>6</td><td>Sawgrass</td><td>n/a</td><td rowspan="2">n/a</td></tr>
<tr><td>7</td><td>Mangrove and swamps</td><td>n/a</td></tr>
</table>

Table 4. Absolute vertical accuracy for lidar-swath data, Quality Level 0–Quality Level 3.

[$RMSE_Z$, root mean square error in z; cm, centimeter; NVA, nonvegetated vertical accuracy; ≤, less than or equal to]

Quality Level (QL)	$RMSE_z$ (nonvegetated) (cm)	NVA at 95-percent confidence level (cm)
QL0	≤5.0	≤9.8
QL1	≤10.0	≤19.6
QL2	≤10.0	≤19.6
QL3	≤20.0	≤39.2

Table 5. Absolute vertical accuracy for digital elevation models, Quality Level 0–Quality Level 3.

[$RMSE_Z$, root mean square error in z; cm, centimeter; NVA, nonvegetated vertical accuracy; VVA, vegetated vertical accuracy; ≤, less than or equal to]

Quality Level (QL)	$RMSE_z$ (nonvegetated) (cm)	NVA at 95-percent confidence level (cm)	VVA at 95th percentile (cm)
QL0	≤5.0	≤9.8	≤14.7
QL1	≤10.0	≤19.6	≤29.4
QL2	≤10.0	≤19.6	≤29.4
QL3	≤20.0	≤39.2	≤58.8

- The USGS–NGP agrees that the use of an alternate specification is reasonable and in the best interest of all stakeholders.

Use of the LAS Withheld Flag

Outliers, blunders, noise points, geometrically unreliable points near the extreme edge of the swath, and other points the data producer deems unusable are to be identified using the Withheld Flag, as defined in the LAS Specification version 1.4 (American Society for Photogrammetry and Remote Sensing, 2011).

The Withheld Flag is primarily used to denote points identified during preprocessing or through automated post-processing routines as geometrically unusable.

Noise points subsequently identified during manual classification and quality assurance/quality control (QA/QC) are typically assigned the appropriate standard LAS classification values for noise–Class 7 is used for Low Noise and Class 18 is used for High Noise.

Use of the LAS Overlap Flag

The LAS Specification version 1.4 (American Society for Photogrammetry and Remote Sensing, 2011) includes a new overlap flag. Although strictly speaking, the term "overlap" means all lidar points lying within any overlapping areas of two or more swaths, the flag is intended to identify overage points, which are only a subset of overlap points. *See* the glossary for more information on the difference between overlap and overage. Having overage points identified allows for their easy exclusion from subsequent processes where the increased density and elevation variability they introduce is unwanted (for example, DEM generation).

Overage points have commonly been identified using Class 12, precluding other valuable classification (for example, bare earth, water). The overlap flag provides a discrete method to identify overage points while preserving the ability to classify the points in the normal way.

Overage points shall be identified using the LAS overlap flag in all point cloud deliverables.

Point Classification

The minimum scheme required for lidar point clouds is listed in the table “Minimum classified point cloudclassification scheme” (table 6). Additional classes may be required on specific projects. The following requirements apply to point classification:

- In the raw LAS deliverable, no classifications are required; however, Overage (overlap) and Withheld Flags will be properly set.
- In the Classified LAS deliverable,
  - All points not identified as Withheld shall be classified.
  - No points in the Classified LAS deliverable shall remain assigned to Class 0.
  - Overage points shall only be identified using the Overlap Flag, as defined in the LAS Specification version 1.4 (American Society for Photogrammetry and Remote Sensing, 2011). Use of the point classification field in any way for overage/overlap identification is prohibited.

Table 6. Minimum classified point cloud classification scheme.

Code	Description
1	Processed, but unclassified.
2	Bare earth.
7	Low noise.
9	Water.
10	Ignored ground (near a breakline).
17	Bridge decks.
18	High noise.

Classification Accuracy

- Following classification processing, no nonwithheld points will remain in Class 0.
- For QL3 data, within any 1 km^2, no more than 2 percent of nonwithheld points will have demonstrable errors in the classification value.
- For QL2 data, within any 1 km^2, no more than 1 percent of nonwithheld points will have demonstrable errors in the classification value.
- For QL1 and QL0 data, within any 1 km^2, no more than 0.5 percent of nonwithheld points will have demonstrable errors in the classification value.
- Points remaining in Class 1 that should be classified in any other required class are subject to these accuracy requirements and will be counted towards the percentage thresholds.

The USGS–NGP may relax these requirements to accommodate collections in areas where classification is particularly difficult.

Classification Consistency

Point classification is to be consistent across the entire project. Noticeable variations in the character, texture, or quality of the classification between tiles, swaths, lifts, or other nonnatural divisions will be cause for rejection of the entire deliverable.

Tiles

A single non-overlapping project tiling scheme will be established and agreed upon by the data producer and the USGS–NGP before collection. This scheme will be used for all tiled deliverables:

- The tiling scheme shall use the same coordinate reference system and units as the data.
- The tile size shall be an integer multiple of the cell size for raster deliverables.
- The tiles shall be indexed in *x* and *y* to an integer multiple of the *x* and *y* dimensions of the tile.
- The tiled deliverables shall edge-match seamlessly and without gaps.
- The tiled deliverables shall conform to the project tiling scheme without added overlap.

Digital Elevation Model Hydro-Flattening

Hydro-flattening pertains only to the creation of derived DEMs (refer to appendix 2, “Hydro-Flattening Reference” for more information on hydro-flattening). No geometric changes are to be made to the originally computed lidar points. Breaklines developed for use in hydro-flattening may be used to support classification of the point data.

Bare-earth lidar points that are near the breaklines shall be classified as Ignored Ground (class value equal to 10) and excluded from the DEM generation process. This process prevents unnatural surface artifacts from being created between mass points and breakline vertices. The proximity threshold for reclassification as Ignored Ground is at the discretion of the data producer, but in general will not exceed the ANPS.

The goal of the USGS–NGP is not to provide accurately mapped, geographically corrected water-surface elevations within the NED—it is to produce topographic DEMs that, with respect to water surfaces, resemble DEMs derived from traditional photogrammetric methods and to the degree practical are free of unnatural triangulation effects. Best professional judgment should be used to achieve this traditional smooth water-surface effect.

The requirements for hydro-flattening are listed below. These requirements also define the minimum features for which breaklines shall be collected and delivered.

1. Inland ponds and lakes:
   - Water bodies of 8,000 m^2 (2 acres) or greater surface area at the time of collection shall be flattened.
   - Flattened water bodies shall present a flat and level water surface (a single elevation for every bank vertex defining the water body's perimeter).
   - The entire water-surface edge shall be at or below the immediately surrounding terrain (the presence of floating water bodies will be cause for rejection of the deliverable).
   - Long impoundments—such as reservoirs, inlets, and fjords, whose water-surface elevations decrease with downstream travel—shall be treated as streams or rivers.

2. Inland streams and rivers:
   - Streams and rivers of a 30-m (100-ft) nominal width shall be flattened.
   - Streams or rivers whose width varies above and below 30 meters will not be broken into multiple segments; data producers will use their best professional cartographic judgment in determining when a stream or river has attained a nominal 30-m width.
   - Flattened streams and rivers shall present a flat and level water surface bank-to-bank (perpendicular to the apparent flow centerline).
   - Flattened streams and rivers shall present a gradient downhill water surface, following the immediately surrounding terrain.
   - In cases of sharp turns of rapidly moving water, where the natural water surface is notably not level bank-to-bank, the water surface will be represented as it exists while maintaining an aesthetic cartographic appearance.
   - The entire water-surface edge shall be at or below the immediately surrounding terrain.
   - Stream channels shall break at culvert locations leaving the roadway over the culvert intact.
   - Bridges in all their forms shall be removed from the DEM.
   - Streams shall be continuous at bridge locations.
   - When the identification of a structure as a bridge or culvert cannot be made definitively, the feature shall be regarded as a culvert.

3. Non-tidal boundary waters:
   - Boundary waters, regardless of size, shall be represented only as an edge or edges within the project; collection does not include the opposite shore.
   - The entire water-surface edge shall be at or below the immediately surrounding terrain.
   - The water-surface elevation will be consistent throughout the project.
   - The water surface shall be flat and level, as appropriate for the type of water body (level for lakes, a gradient for streams and rivers).
   - Any unusual changes in the water-surface elevation during the course of the collection (such as increased upstream dam discharge) shall be documented in the project metadata.
   - In the event of an unusual change in water-surface elevation, the water body shall be handled as described in "4. Tidal Waters" (below).

4. Tidal waters:

   Tidal water bodies are defined as any water body that is affected by tidal variations, including oceans, seas, gulfs, bays, inlets, salt marshes, and large lakes. Tidal variations during data collection or between different data collections will result in lateral and vertical discontinuities along shorelines. As it is the USGS–NGP's intent for the DEM to represent as much ground as the collected data permits, lidar ground points shall not be removed for the sake of adjusting a shoreline inland to match another shoreline. Likewise, adjusting a shoreline outland will create an equally unacceptable area of unmeasured land in the DEM. It is recommended that, to the highest degree practical, collections be planned to minimize tidal differences at the land-water interface. In addition to meeting the requirements for inland water bodies listed in "1. Inland ponds and lakes" and "2. Inland streams and rivers," above, as appropriate, the treatment of tidal water bodies shall also meet the following requirements:

   - Within each water body, the water surface shall be flat and level for each different water-surface elevation.
   - Vertical discontinuities within a water body resulting from tidal variations during the collection are considered normal and shall be retained in the final DEM.
   - Horizontal discontinuities along the shoreline of a water body resulting from tidal variations during the collection are considered normal and shall be retained in the final DEM.

Long tidal water bodies that also exhibit downhill flow (such as a fjord) can present unusual challenges; data producers are to exercise their best professional judgment in determining the appropriate approach solution to meet the overall goal of hydro-flattening as described in this section. For projects located in coastal areas, cooperating partners may impose additional requirements for tidal coordination.

5. Islands:
   - Permanent islands 4,000 m^2 (1 acre) or larger shall be delineated within all water bodies.

Single-Line Streams or Additional Breaklines

Cooperating partners may require collection and integration of breaklines representing single-line streams, rivers, culverts, and other features within their lidar projects. Although the USGS does not require these breaklines to be collected or integrated into the DEMs, the USGS does require that if collected and incorporated into the DEMs, the following requirements are met:

- All vertices along single-line stream breaklines shall be at or below the immediately surrounding terrain.
- Breaklines representing single-line streams, culverts, or other hydrographic features shall not be used to introduce hydrologic flow paths through road crossings (culverts), dams, or other similar topographic features.
- All additional breaklines developed for the project shall be delivered to the USGS.
- The final DEM shall be a hydro-flattened (not hydro-enforced) topographic DEM suitable for integration into the NED (refer to appendix 2, “Hydro-Flattening Reference” for more information on hydro-enforcement).

Deliverables

The USGS requires unrestricted rights to all delivered data and reports, which will then be placed in the public domain. This specification places no restrictions on the rights of the data provider to resell data or derivative products.

Metadata

The term “metadata” refers to all descriptive information about the project, and metadata includes text reports, graphics, and supporting shapefiles. Product metadata files shall comply with the Federal Geographic Data Committee (FGDC) standards, which facilitate the development, sharing, and use of geospatial data. Metadata deliverables shall include the following:

- A collection report detailing mission planning and flight logs.
- A survey report detailing the collection of all ground control, including the following:
  - Control points used to calibrate and process the lidar and derivative data.
  - Check points used to validate the lidar point data or any derivative product.
- A processing report detailing calibration, classification, and product generation procedures including methodology used for breakline collection and hydro-flattening. *See* the section “Digital Elevation Model Hydro-Flattening” and appendix 2, “Hydro-Flattening Reference” for more information on hydro-flattening.
- A QA/QC report, detailing procedures for analysis, accuracy assessment and validation of the following:
  - Point data (absolute vertical accuracy [NVA], relative vertical accuracy).
  - Bare-earth surface (absolute vertical accuracy [NVA and VVA]).
  - Other optional deliverables as appropriate.
- A georeferenced, digital spatial representation of the detailed extents of each delivered dataset.
  - The extents shall be those of the actual lidar source or derived product data, exclusive of TIN artifacts or raster void areas.
  - A union of tile boundaries or minimum bounding rectangles is not acceptable.
  - For the point clouds, no line segment in the boundary will be further than the four times the ANPS from the nearest lidar point.
  - Esri polygon shapefile or geodatabase is required.
- Product metadata (FGDC-compliant, XML format metadata).
  - Metadata files for individual data files are acceptable but not required.
  - FGDC-compliant metadata shall pass the USGS Metadata Parser (MP) without errors.
  - One XML file is required for each of the following datasets:
    - The Overall Project—Describing the project boundary, the intent of the project, the types of data collected as part of the project, the various deliverables for the project, and other project-wide information.

- Each Lift—Describing the extents of the lift, the swaths included in the lift, locations of GPS base stations and control for the lift, preprocessing and calibration details for the lift, adjustment and fitting processes applied to the lift in relation to other lifts, and other lift-specific information.
- Each deliverable product group—
  - Classified point data.
  - Bare-earth DEMs.
  - Breaklines.
  - Any other datasets delivered (digital surface models [DSM], intensity images, height above ground surfaces, and others).

A block of lidar-related metadata tags specified by the USGS shall be included in FGDC metadata files for all lidar point data deliverables. All tags are required. This block was developed so information often provided in reports or in free-text metadata fields can be made machine-discoverable in a predictable location in a single file. The descriptive template of this lidar metadata block and a completed example are provided in appendix 3, "Lidar Metadata Example" and appendix 4, "Lidar Metadata Template."

Raw Point Cloud

Delivery of the raw point cloud is a requirement for USGS–NGP lidar projects. Raw point cloud deliverables shall include or conform to the following procedures and specifications:

- All collected points, fully calibrated, georeferenced, and adjusted to ground, organized and delivered in their original swaths, one file per swath, one swath per file.
- If production processing required segmentation of the swath files, the requirements listed in the section "Swath Size and Segmentation," shall be met.
- Fully compliant LAS Specification version 1.4, Point Data Record Format 6, 7, 8, 9, or 10.
- If collected, waveform data in external auxiliary files with the extension .wdp. *See* the LAS Specification version 1.4 (American Society for Photogrammetry and Remote Sensing, 2011) for additional information.
- Correct and properly formatted georeference information as Open Geospatial Consortium (OGC) well known text (WKT) in all LAS file headers.
- GPS times recorded as Adjusted GPS Time at a precision sufficient to allow unique timestamps for each pulse.
- Intensity values, normalized to 16-bit. *See* the LAS Specification version 1.4 (American Society for Photogrammetry and Remote Sensing, 2011) for additional information.
- A report of the assessed relative vertical accuracy of the point cloud (smooth surface repeatability and overlap consistency). Relative vertical accuracy requirements are listed in table 2. Raw swath point cloud data shall meet the required accuracy levels before point cloud classification and derivative product generation.
- A report of the assessed absolute vertical accuracy (NVA only) of the unclassified lidar point data in accordance with the guidelines set forth in the Positional Accuracy Standards for Digital Geospatial Data (American Society for Photogrammetry and Remote Sensing, 2014). Absolute vertical accuracy requirements using the ASPRS methodology for the raw point cloud are listed in table 4. Raw swath point cloud data shall meet the required accuracy levels before point cloud classification and derivative product generation.

Classified Point Cloud

Delivery of a classified point cloud is a requirement for USGS–NGP lidar projects. Specific research projects may be exempt from this requirement. Classified point cloud deliverables shall include or conform to the following procedures and specifications:

- All project swaths, returns, and collected points, fully calibrated, adjusted to ground, and classified, by tiles. Project swaths exclude calibration swaths, cross-ties, and other swaths not used and not intended to be used, in product generation.
- Fully compliant LAS Specification version 1.4 Point Data Record Format 6, 7, 8, 9 or 10.
- If collected, waveform data in external auxiliary files with the extension .wdp. *See* the LAS Specification version 1.4 (American Society for Photogrammetry and Remote Sensing, 2011) for additional information.
- Correct and properly formatted georeferenced information as OGC WKT included in all LAS file headers.
- GPS times recorded as Adjusted GPS Time at a precision sufficient to allow unique timestamps for each pulse.
- Intensity values, normalized to 16-bit. *See* the LAS Specification version 1.4 (American Society for Photogrammetry and Remote Sensing, 2011) for additional information.
- Tiled delivery, without overlap, using the project tiling scheme.
- Classification, as defined in table 6, at a minimum.

Bare-Earth Surface (Raster Digital Elevation Model)

Delivery of a hydro-flattened bare-earth DEM is a requirement for USGS–NGP lidar projects. Specific research projects may be exempt from some or all these requirements. Bare-earth surface deliverables shall include or conform to the following procedures and specifications:

- Bare-earth DEM, generated to the limits of the BPA.
- DEM resolution as shown in the table “Digital elevation model cell size, Quality Level 0–Quality Level 3” (table 7).
- An industry-standard, GIS-compatible, 32-bit floating point raster format (ERDAS .IMG preferred).
- Georeference information in or accompanying each raster file.
- Tiled delivery without overlap.
- DEM tiles with no edge artifacts or mismatch. A quilted appearance in the overall DEM surface will be cause for rejection of the entire DEM deliverable, whether the rejection is caused by differences in processing quality or character among tiles, swaths, lifts, or other nonnatural divisions.
- Void areas (for example, areas outside the BPA but within the project tiling scheme) coded using a unique “NODATA” value. This value will be identified in the appropriate location within the raster file header or external support files (for example, .aux).
- Hydro-flattening as outlined in the section “Digital Elevation Model Hydro-Flattening.” Depressions (sinks), whether natural or man-made, are not to be filled (as in hydro-conditioning and hydro-enforcement). The methodology used for hydro-flattening is at the discretion of the data producer (refer to appendix 2, “Hydro-Flattening Reference” for more information on hydro-flattening).
- Bridges removed from the surface (refer to the glossary for the definition of a bridge).
- Road or other travel ways over culverts intact in the surface (refer to the glossary for the definition of a bridge).
- QA/QC analysis materials for the absolute vertical accuracy assessment.
- A report on the assessed absolute vertical accuracy (NVA and VVA) of the bare-earth surface in accordance with the guidelines set forth in the “Positional Accuracy Standards for Digital Geospatial Data” (American Society for Photogrammetry and Remote Sensing, 2014). Absolute vertical accuracy requirements using the ASPRS methodology for the bare-earth DEM are listed in “Absolute vertical accuracy for digital elevation models, Quality Level 0–Quality Level 3” (table 5).

Table 7. Digital elevation model cell size, Quality Level 0–Quality Level 3.

[m, meter; ft, feet]

Quality Level (QL)	Minimum cell size (m)	Minimum cell size (ft)
QL0	0.5	1
QL1	0.5	1
QL2	1	2
QL3	2	5

Breaklines

Delivery of the breaklines representing all hydro-flattened features in a project, regardless of the method used for hydro-flattening, is a requirement for USGS–NGP lidar projects. Specific research projects may be exempt from these requirements. Breakline deliverables shall include or conform to the following procedures and specifications:

- Breaklines developed to the limit of the BPA.
- Breaklines delivered in shapefile or file geodatabase formats, as PolylineZ and PolygonZ feature classes, as appropriate to the type of feature represented and the methodology used by the data producer.
- Breaklines in the same coordinate reference system and units (horizontal and vertical) as the lidar point delivery.
- Properly formatted and accurate georeferenced information for each feature class, stored in that format’s standard file system location. Each shapefile shall include a correct and properly formatted .prj file.

Breakline delivery may be in a single layer or in tiles, at the discretion of the data producer. In the case of tiled deliveries, all features shall edge-match exactly across tile boundaries in both the horizontal (x, y) and vertical (z) spatial dimensions. Delivered data shall be sufficient for the USGS to effectively re-create the delivered DEMs using the lidar points and breaklines without substantial editing.

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Glossary

Note: Many of the following definitions are from Maune (2007) and American Society for Photogrammetry and Remote Sensing (2014) and are used with permission.

A

accuracy The closeness of an estimated value (for example, measured or computed) to a standard or accepted (true) value of a particular quantity. *See* precision.

- **absolute accuracy** A measure that accounts for all systematic and random errors in a dataset. Absolute accuracy is stated with respect to a defined datum or reference system.
- **accuracy$_r$ (ACC$_r$)** The National Standards for Spatial Data Accuracy (NSSDA) (Federal Geographic Data Committee, 1998) reporting standard in the horizontal component that equals the radius of a circle of uncertainty, such that the true or theoretical horizontal location of the point falls within that circle 95 percent of the time. $ACC_r = 1.7308 \times RMSE_r$.
- **accuracy$_z$ (ACC$_z$)** The NSSDA reporting standard in the vertical component that equals the linear uncertainty value, such that the true or theoretical vertical location of the point falls within that linear uncertainty value 95 percent of the time. $ACC_z = 1.9600 \times RMSE_z$.
- **horizontal accuracy** The horizontal (radial) component of the positional accuracy of a dataset with respect to a horizontal datum, at a specified confidence level. *See* accuracy$_r$.
- **local accuracy** The uncertainty in the coordinates of points with respect to coordinates of other directly connected, adjacent points at the 95-percent confidence level.
- **network accuracy** The uncertainty in the coordinates of mapped points with respect to the geodetic datum at the 95-percent confidence level.
- **positional accuracy** The accuracy at the 95-percent confidence level of the position of features, including horizontal and vertical positions, with respect to horizontal and vertical datums.
- **relative accuracy** A measure of variation in point-to-point accuracy in a data set. In lidar, this term may also specifically mean the positional agreement between points within a swath, adjacent swaths within a lift, adjacent lifts within a project, or between adjacent projects.
- **vertical accuracy** The measure of the positional accuracy of a data set with respect to a specified vertical datum, at a specified confidence level or percentile. *See* accuracy$_z$.

aggregate nominal pulse density (ANPD) A variant of nominal pulse density that expresses the total expected or actual density of pulses occurring in a specified unit area resulting from multiple passes of the light detection and ranging (lidar) instrument, or a single pass of a platform with multiple lidar instruments, over the same target area. In all other respects, ANPD is identical to nominal pulse density (NPD). In single coverage collection, ANPD and NPD will be equal. *See* aggregate nominal pulse spacing, nominal pulse density, nominal pulse spacing.

aggregate nominal pulse spacing (ANPS) A variant of nominal pulse spacing that expresses the typical or average lateral distance between pulses in a lidar dataset resulting from multiple passes of the lidar instrument, or a single pass of a platform with multiple lidar instruments, over the same target area. In all other respects, ANPS is identical to nominal pulse spacing

(NPS). In single coverage collections, ANPS and NPS will be equal. *See* aggregate nominal pulse density, nominal pulse density, nominal pulse spacing.

artifacts An inaccurate observation, effect, or result, especially one resulting from the technology used in scientific investigation or from experimental error. In bare-earth elevation models, artifacts are detectable surface remnants of buildings, trees, towers, telephone poles or other elevated features; also, detectable artificial anomalies that are introduced to a surface model by way of system specific collection or processing techniques. For example, corn-row effects of profile collection, star and ramp effects from multidirectional contour interpolation, or detectable triangular facets caused when vegetation canopies are removed from lidar data.

attitude The position of a body defined by the angles between the axes of the coordinate system of the body and the axes of an external coordinate system. In photogrammetry, the attitude is the angular orientation of a camera (roll, pitch, yaw), or of the photograph taken with that camera, with respect to some external reference system. With lidar, the attitude is normally defined as the roll, pitch and heading of the instrument at the instant an active pulse is emitted from the sensor.

B

bald earth Nonpreferred term. *See* bare earth.

bare earth (bare-earth) Digital elevation data of the terrain, free from vegetation, buildings and other man-made structures. Elevations of the ground.

blunder A mistake resulting from carelessness or negligence.

boresight Calibration of a lidar sensor system equipped with an Inertial Measurement Unit (IMU) and global positioning system (GPS) to determine or establish the accurate:

- Position of the instrument (x, y, z) with respect to the GPS antenna, and
- Orientation (roll, pitch, heading) of the lidar instrument with respect to straight and level flight.

breakline A linear feature that describes a change in the smoothness or continuity of a surface. The two most common forms of breaklines are as follows:

- A ***soft breakline*** ensures that known z values along a linear feature are maintained (for example, elevations along a pipeline, road centerline or drainage ditch), and ensures that linear features and polygon edges are maintained in a triangulated irregular network (TIN) surface model, by enforcing the breaklines as TIN edges. They are generally synonymous with three-dimensional (3D) breaklines because they are depicted with series of x, y, z coordinates. Somewhat rounded ridges or the trough of a drain may be collected using soft breaklines.
- A ***hard breakline*** defines interruptions in surface smoothness (for example, to define streams, rivers, shorelines, dams, ridges, building footprints, and other locations) with abrupt surface changes. Although some hard breaklines are 3D breaklines, they are typically depicted as two-dimensional (2D) breaklines because features such as shorelines and building footprints are normally depicted with series of x, y coordinates only, often digitized from digital orthophotos that include no elevation data.

bridge A structure carrying a road, path, railroad, canal, aircraft taxiway, or any other transit between two locations of higher elevation over an area of lower elevation. A bridge may traverse a river, ravine, road, railroad, or other obstacle. “Bridge” also includes but is not limited to aqueduct, drawbridge, flyover, footbridge, overpass, span, trestle, and viaduct. In mapping, the term “bridge” is distinguished from a roadway over a culvert in that a bridge is a man-made, elevated deck which is not underlain with earth or soil. *See* culvert.

C

calibration (lidar systems) The process of identifying and correcting for systematic errors in hardware, software, or data. Determining the systematic errors in a measuring device by comparing its measurements with the markings or measurements of a device that is considered correct. Lidar system calibration falls into two main categories:

- **instrument calibration** Factory calibration includes radiometric and geometric calibration unique to each manufacturer's hardware, and tuned to meet the performance specifications for the model being calibrated. Instrument calibration can only be assessed and corrected by the instrument manufacturer.

- **data calibration** The lever arm calibration determines the sensor-to-GPS-antenna offset vector (the lever arm) components relative to the antenna phase center. The offset vector components are redeterminded each time the sensor or aircraft GPS antenna is moved or repositioned. Because normal aircraft operations can induce slight variations in component mounting, the components are normally field calibrated for each project, or even daily, to determine corrections to the roll, pitch, yaw, and scale calibration parameters.

calibration point Nonpreferred term. *See* control point.

cell (pixel) A single element of a raster dataset. Each cell contains a single numeric value of information representative of the area covered by the cell. Although the terms "cell" and "pixel" are synonymous, in this specification "cell" is used in reference to non-image rasters such as digital elevation models (DEMs), whereas "pixel" is used in reference to image rasters such as lidar intensity images.

check point (checkpoint) A surveyed point used to estimate the positional accuracy of a geospatial dataset against an independent source of greater accuracy. Check points are independent from, and may never be used as, control points on the same project.

classification (of lidar) The classification of lidar point cloud returns in accordance with a classification scheme to identify the type of target from which each lidar return is reflected. The process allows future differentiation between bare-earth terrain points, water, noise, vegetation, buildings, other man-made features and objects of interest.

confidence level The percentage of points within a dataset that are estimated to meet the stated accuracy; for example, accuracy reported at the 95-percent confidence level means that 95 percent of the positions in the data set will have an error with respect to true ground position that are equal to or smaller than the reported accuracy value.

consolidated vertical accuracy (CVA) Replaced by the term vegetated vertical accuracy (VVA) in this specification, CVA is the term used by the National Digital Elevation Program (NDEP) guidelines for vertical accuracy at the 95th percentile in all land cover categories combined (National Digital Elevation Program, 2004). *See* percentile, vegetated vertical accuracy.

control point (calibration point) A surveyed point used to geometrically adjust a lidar dataset to establish its positional accuracy relative to the real world. Control points are independent from, and may never be used as, check points on the same project.

CONUS Conterminous United States, the 48 states.

culvert A tunnel carrying a stream or open drainage under a road or railroad, or through another type of obstruction to natural drainage. Typically, constructed of formed concrete or corrugated metal and surrounded on all sides, top, and bottom by earth or soil.

D

data void In lidar, a gap in the point cloud coverage, caused by surface nonreflectance of the lidar pulse, instrument or processing anomalies or failure, obstruction of the lidar pulse, or improper collection flight planning. Any area greater than or equal to (four times the aggregate nominal pulse spacing [ANPS]) squared, measured using first returns only, is considered to be a data void.

datum A set of reference points on the Earth's surface against in which position measurements are made, and (usually) an associated model of the shape of the Earth (reference ellipsoid) to define a geographic coordinate system. Horizontal datums (for example, the North American Datum of 1983 [NAD 83]) are used for describing a point on the Earth's surface, in latitude and longitude or another coordinate system. Vertical datums (for example, the North American Vertical Datum of 1988 [NAVD 88]) are used to measure elevations or depths. In engineering and drafting, a datum is a reference point, surface, or axis on an object against which measurements are made.

digital elevation model (DEM) *See* four different definitions below:

- A popular acronym used as a generic term for digital topographic and bathymetric data in all its various forms. Unless specifically referenced as a digital surface model (DSM), the generic DEM normally implies *x*, *y* coordinates and *z* values of the bare-earth terrain, void of vegetation and manmade features.
- As used by the U.S. Geological Survey (USGS), a DEM is the digital cartographic representation of the elevation of the land at regularly spaced intervals in *x* and *y* directions, using *z* values referenced to a common vertical datum.
- As typically used in the United States and elsewhere, a DEM has bare-earth *z* values at regularly spaced intervals in *x* and *y* directions; however, grid spacing, datum, coordinate systems, data formats, and other characteristics may vary widely.
- A "D-E-M" is a specific raster data format once widely used by the USGS. These DEMs are a sampled array of elevations for a number of ground positions at regularly spaced intervals.

digital elevation model (DEM) resolution The linear size of each cell of a raster DEM. Features smaller than the cell size cannot be explicitly represented in a raster model. DEM resolution may also be referred to as cell size, grid spacing, or ground sample distance.

digital surface model (DSM) Similar to digital elevation models (DEMs) except that they may depict the elevations of the top surfaces of buildings, trees, towers, and other features elevated above the bare earth. Lidar DSMs are especially relevant for telecommunications management, air safety, forest management, and 3D modeling and simulation.

digital terrain model (DTM) *See* two different definitions below:

- In some countries, DTMs are synonymous with DEMs, representing the bare-earth terrain with uniformly-spaced z values, as in a raster.
- As used in the United States, a "DTM" is a vector dataset composed of 3D breaklines and regularly spaced 3D mass points, typically created through stereo photogrammetry, that characterize the shape of the bare-earth terrain. Breaklines more precisely delineate linear features whose shape and location would otherwise be lost. A DTM is not a surface model; its component elements are discrete and not continuous; a TIN or DEM surface must be derived from the DTM. Surfaces derived from DTMs can represent distinctive terrain features much better than those generated solely from gridded elevation measurements. A lidar point dataset combined with ancillary breaklines is also considered a DTM.

discrete return lidar Lidar system or data in which important peaks in the waveform are captured and stored. Each peak represents a return from a different target, discernible in vertical or horizontal domains. Most modern lidar systems are capable of capturing multiple discrete returns from each emitted laser pulse. *See* waveform lidar.

E

elevation The distance measured upward along a plumb line between a point and the geoid. The elevation of a point is normally the same as its orthometric height, defined as *H* in the equation: $H = h - N$, where *h* is equal to the ellipsoid height and *N* is equal to the geoid height.

F

first return (first-return) The first important measurable part of a return lidar pulse.

flightline A single pass of the collection aircraft over the target area. Commonly misused to refer to the data resulting from a flightline of collection. *See* swath.

fundamental vertical accuracy (FVA) Replaced by the term nonvegetated vertical accuracy (NVA), in this specification, FVA is the term used by the NDEP guidelines for vertical accuracy at the 95-percent confidence level in open terrain only where errors should approximate a normal error distribution. *See* nonvegetated vertical accuracy, accuracy, confidence level.

G

geographic information system (GIS) A system of spatially referenced information, including computer programs that acquire, store, manipulate, analyze, and display spatial data.

geospatial data Information that identifies the geographic location and characteristics of natural or constructed features and boundaries of earth. This information may be derived from—among other things— remote-sensing, mapping, and surveying technologies. Geospatial data generally are considered to be synonymous with spatial data. However, the former always is associated with geographic or Cartesian coordinates linked to a horizontal or vertical datum, whereas the latter (for example, generic architectural house plans) may include dimensions and other spatial data not linked to any physical location.

ground truth Verification of a situation, without errors introduced by sensors or human perception and judgment.

H

hillshade A function used to create an illuminated representation of the surface, using a hypothetical light source, to enhance terrain visualization effects.

horizontal accuracy Positional accuracy of a dataset with respect to a horizontal datum. According to the NSSDA, horizontal (radial) accuracy at the 95-percent confidence level is defined as ACC_r.

hydraulic modeling The use of digital elevation data, rainfall-runoff data from hydrologic models, surface roughness data, and information on hydraulic structures (for example, bridges, culverts, dams, weirs, and sewers) to predict flood levels and manage water resources. Hydraulic models are based on computations involving liquids under pressure and many other definitions of hydraulic modeling exist that are not associated with terrain elevations, for example, modeling of hydraulic lines in aircraft and automobiles.

hydrologic modeling The computer modeling of rainfall and the effects of land cover, soil conditions, and terrain slope to estimate rainfall runoff into streams, rivers, and lakes. Digital elevation data are used as part of hydrologic modeling.

hydrologically conditioned (hydro-conditioned) Processing of a DEM or TIN so that the flow of water is continuous across the entire terrain surface, including the removal of all isolated sinks or pits. The only sinks that are retained are the real ones on the landscape. Whereas hydrologically enforced is relevant to drainage features that generally are mapped, hydrologically conditioned is relevant to the entire land surface and is done so that water flow is continuous across the surface, whether that flow is in a stream channel or not. The purpose for continuous flow is so that relations and (or) links among basins and (or) catchments can be known for large areas.

hydrologically flattened (hydro-flattened) Processing of a lidar-derived surface (DEM or TIN) so that mapped water bodies, streams, rivers, reservoirs, and other cartographically polygonal water surfaces are flat and, where appropriate, level from bank-to-bank. Additionally, surfaces of streams, rivers, and long reservoirs demonstrate a gradient change in elevation along their length, consistent with their natural behavior and the surrounding topography. In traditional maps that are compiled photogrammetrically, this process is accomplished automatically through the inclusion of measured breaklines in the DTM. However, because lidar does not inherently include breaklines, a DEM or TIN derived solely from lidar points will depict water surfaces with unsightly and unnatural artifacts of triangulation. The process of hydro-flattening typically involves the addition of breaklines along the banks of specified water bodies, streams, rivers, and ponds. These breaklines establish elevations for the water surfaces that are consistent with the surrounding topography, and produce aesthetically acceptable water surfaces in the final DEM or TIN. Unlike hydro-conditioning and hydro-enforcement, hydro-flattening is not driven by any hydrologic or hydraulic modeling requirements, but solely by cartographic mapping needs.

hydrologically enforced (hydro-enforced) Processing of mapped water bodies so that lakes and reservoirs are level and so that streams and rivers flow downhill. For example, a DEM, TIN or topographic contour dataset with elevations removed from the tops of selected drainage structures (bridges and culverts) so as to depict the terrain under those structures. Hydro-enforcement enables hydrologic and hydraulic models to depict water flowing under these structures, rather than appearing in the computer model to be dammed by them because of road deck elevations higher than the water levels. Hydro-enforced TINs also use breaklines along shorelines and stream centerlines, for example, where these breaklines form the edges of TIN triangles along the alignment of drainage features. Shore breaklines for streams and rivers would be 3D breaklines with elevations that decrease as the stream flows downstream; however, shore breaklines for lakes or reservoirs would have the same elevation for the entire shoreline if the water surface is known or assumed to be level throughout.

I

intensity (lidar) For discrete-return lidar instruments, intensity is the recorded amplitude of the reflected lidar pulse at the moment the reflection is captured as a return by the lidar instrument. Lidar intensity values can be affected by many factors, such as the instantaneous setting of the instrument's automatic gain control and angle of incidence and cannot be equated to a true measure of energy. In full-waveform systems, the entire reflection is sampled and recorded, and true energy measurements can be made for each return or overall reflection. Intensity values for discrete returns derived from a full-waveform system may or may not be calibrated to represent true energy.

Lidar intensity data make it possible to map variable textures in the form of a gray-scale image. Intensity return data enable automatic identification and extraction of objects such as buildings and impervious surfaces, and can aid in lidar point classification. In spite of their similar appearance, lidar intensity images differ from traditional panchromatic images in several important ways:

- Lidar intensity is a measure of the reflection of an active laser energy source, not natural solar energy.
- Lidar intensity images are aggregations of values at point samples. The value of a pixel does not represent the composite value for the area of that pixel.
- Lidar intensity images depict the surface reflectivity within an extremely narrow band of the infra-red spectrum, not the entire visible spectrum as in panchromatic images.
- Lidar intensity images are strongly affected by the angle of incidence of the laser to the target, and are subject to unnatural shadowing artifacts.
- The values on which lidar intensity images are based may or may not be calibrated to any standard reference. Intensity images usually contain wide variation of values within swaths, between swaths, and between lifts.

For these reasons, lidar intensity images must be interpreted and analyzed with unusually high care and skill.

L

LAS A public file format for the interchange of 3D point cloud data between data users. The file extension is .las.

last return The last important measurable part of a return lidar pulse.

lattice A 3D vector representation method created by a rectangular array of points spaced at a constant sampling interval in *x* and *y* directions relative to a common origin. A lattice differs from a grid in that it represents the value of the surface only at the lattice mesh points rather than the elevation of the cell area surrounding the centroid of a grid cell.

lever arm A relative position vector of one sensor with respect to another in a direct georeferencing system. For example, with aerial mapping cameras, lever arms are positioned between the inertial center of the IMU and the phase center of the GPS antenna, each with respect to the camera perspective center within the lens of the camera.

lidar An instrument that measures distance to a reflecting object by emitting timed pulses of light and measuring the time difference between the emission of a laser pulse and the reception of the pulse's reflection(s). The measured time interval for each reflection is converted to distance, which when combined with position and attitude information from GPS, IMU, and the instrument itself, allows the derivation of the 3D-point location of the reflecting target's location.

lift A lift is a single takeoff and landing cycle for a collection platform (fixed or rotary wing) within an aerial data collection project, often lidar.

local accuracy *See* accuracy.

M

metadata Any information that is descriptive or supportive of a geospatial dataset, including formally structured and formatted metadata files (for example, eXtensible Markup Language [XML]-formatted Federal Geographic Data Committee [FGDC] metadata), reports (collection, processing, quality assurance/quality control [QA/QC]), and other supporting data (for example, survey points, shapefiles).

N

nominal pulse density (NPD) A common measure of the density of a lidar dataset; NPD is the typical or average number of pulses occurring in a specified areal unit. The NPD is typically expressed as pulses per square meter (pls/m^2). This value is predicted in mission planning and empirically calculated from the collected data, using only the first (or last) return points as surrogates for pulses. As used in this specification, NPD refers to single swath, single instrument data, whereas aggregate nominal pulse density describes the overall pulse density resulting from multiple passes of the lidar instrument, or a single pass of a platform with multiple lidar instruments, over the same target area. The term NPD is more commonly used in high-density collections (greater than 1 pls/m^2), with its inverse, nominal pulse spacing (NPS), being used in low-density collections (less than or equal to 1 pls/m^2). Assuming meters are being used in both expressions, NPD can be calculated from NPS using the formula $NPD = 1 / NPS^2$. *See* aggregate nominal pulse density, aggregate nominal pulse spacing, nominal pulse spacing.

nominal pulse spacing (NPS) A common measure of the density of a lidar dataset, NPS the typical or average lateral distance between pulses in a lidar dataset, typically expressed in meters and most simply calculated as the square root of the average area per first return point. This value is predicted in mission planning and empirically calculated from the collected data, using only the first (or last) return points as surrogates for pulses. As used in this specification, NPS refers to single swath, single instrument data, whereas aggregate nominal pulse spacing describes the overall pulse spacing resulting from multiple passes of the lidar instrument, or a single pass of a platform with multiple lidar instruments, over the same target area. The term NPS is more commonly used in low-density collections (greater than or equal to 1 meter NPS) with its inverse, nominal pulse density (NPD), being used in high-density collections (less than 1 meter NPS). Assuming meters are being used in both expressions, NPS can be calculated from NPD using the formula $NPS = 1 / \sqrt{NPD}$. *See* aggregate nominal pulse density, aggregate nominal pulse spacing, nominal pulse density.

nonvegetated vertical accuracy (NVA) Replaces fundamental vertical accuracy (FVA). The vertical accuracy at the 95-percent confidence level in nonvegetated open terrain, where errors should approximate a normal distribution. *See* fundamental vertical accuracy.

O

overage Those parts of a swath that are not necessary to form a complete single, non-overlapped, gap-free coverage with respect to the adjacent swaths. The non-tenderloin parts of a swath. In collections designed using multiple coverage, overage are the parts of the swath that are not necessary to form a complete non-overlapped coverage at the planned depth of coverage. In the LAS Specification version 1.4 (American Society for Photogrammetry and Remote Sensing, 2011), these points are identified by using the incorrectly named "overlap" bit flag. *See* overlap, tenderloin.

overlap Any part of a swath that also is covered by any part of any other swath. The term overlap is incorrectly used in the LAS Specification version 1.4 (American Society for Photogrammetry and Remote Sensing, 2011) to describe the flag intended to identify overage points. *See* overage, tenderloin.

P

percentile A measure used in statistics indicating the value below which a given percentage of observations (absolute values of errors) in a group of observations fall. For example, the 95th percentile is the value (or score) below which 95 percent of the observations may be found.

- There are different approaches to determining percentile ranks and associated values. This specification recommends the use of the following equations for computing percentile rank and percentile as the most appropriate for estimating the VVA. Note that percentile calculations are based on the absolute values of the errors, as it is the magnitude of the errors, not the sign that is of concern.
- The percentile rank (n) is first calculated for the desired percentile using the following equation:

$$n = \left(\left(\left(\frac{P}{100} \right) \times (N-1) \right) + 1 \right) \quad (1)$$

where

n is the rank of the observation that contains the P^{th} percentile,
P is the proportion (of 100) at which the percentile is desired (for example, 95 for 95^{th} percentile),
N is the number of observations in the sample data set.

- Once the rank of the observation is determined, the percentile (Q_p) can then be interpolated from the upper and lower observations using the following equation:

$$Q_p = \left(A[n_w] + \left(n_d \times \left(A[n_w + 1] - A[n_w] \right) \right) \right) \quad (2)$$

where

Q_p is the P^{th} percentile; the value at rank n,
A is an array of the absolute values of the samples, indexed in ascending order from *1* to N,
$A[i]$ is the sample value of array A at index i (for example, n_w or n_d). i must be an integer between *1* and N,
n is the rank of the observation that contains the P^{th} percentile,
n_w is the whole number component of n (for example, 3 of 3.14),
n_d is the decimal component of n (for example, 0.14 of 3.14).

pixel *See* cell.

point classification The assignment of a target identity classification to a particular lidar point or group of points.

point cloud One of the fundamental types of geospatial data (others being vector and raster), a point cloud is a large set of three dimensional points, typically from a lidar collection. As a basic GIS data type, a point cloud is differentiated from a typical point dataset in several key ways:

- Point clouds are almost always 3D,
- Pint clouds have an order of magnitude more features than point datasets, and
- Individual point features in point clouds do not typically possess individually meaningful attributes; the informational value in a point cloud is derived from the relations among large numbers of features.

See raster, vector.

precision (repeatability) The closeness with which measurements agree with each other, even though they may all contain a systematic bias. *See* accuracy.

point family The complete set of multiple returns reflected from a single lidar pulse.

preprocessing In lidar, the preprocessing of data most commonly refers to those steps used in converting the collected GPS, IMU, instrument, and ranging information into an interpretable *x, y, z* point cloud, including generation of trajectory information, calibration of the dataset, and controlling the dataset to known ground references.

post processing In lidar, post processing refers to the processing steps applied to lidar data point clouds, including point classification, feature extraction (for example, building footprints, hydrographic features, and others), tiling, and generation of derivative products (DEMs, DSMs, intensity images, and others).

R

raster One of the fundamental types of geospatial data (others being vector and point cloud), a raster is an array of cells (or pixels) that each contain a single piece of numeric information representative of the area covered by the cell. Raster datasets are spatially continuous; with respect to DEMs this quality creates a surface from which information can be extracted from any location. As spatial arrays, rasters are always rectangular; cells are most often square. Co-located rasters can be stored in a single file as layers, as with color digital images. *See* raster, vector.

resolution The smallest unit a sensor can detect or the smallest unit a raster DEM depicts. The degree of fineness to which a measurement can be made. Resolution is also used to describe the linear size of an image pixel or raster cell.

root mean square difference (RMSD) The square root of the average of the set of squared differences between two dataset coordinate values taken at identical locations. The term RMSD differentiates from root mean square error (RMSE) because neither dataset is known to be more or less accurate and the differences cannot be regarded as errors. An RMSD value is used in lidar when assessing the differences between two overlapping swaths of data. *See* RMSE.

root mean square error (RMSE) The square root of the average of the set of squared differences between dataset coordinate values and coordinate values from an independent source of higher accuracy for identical points. The RMSE is used to estimate the absolute accuracy of both horizontal and vertical coordinates when standard or accepted values are known, as with GPS-surveyed check points of higher accuracy than the data being tested. In the United States, the independent source of higher accuracy is expected to be at least three times more accurate than the dataset being tested. The standard equations for calculating horizontal and vertical RMSE are provided below:

- **RMSE$_x$** The horizontal root mean square error in the *x* direction (easting):

$$\sqrt{\sum \frac{(x_n - x'_n)^2}{N}} \tag{3}$$

where

x_n is the set of N x coordinates being evaluated,
x'_n is the corresponding set of check point x coordinates for the points being evaluated,
N is the number of x coordinate check points, and
n is the identification number of each check point from 1 through N.

- **RMSE$_y$** The horizontal root mean square error in the *y* direction (northing):

$$\sqrt{\sum \frac{(y_n - y'_n)^2}{N}} \tag{4}$$

where

y_n is the set of N y coordinates being evaluated,
y'_n is the corresponding set of check point y coordinates for the points being evaluated,
N is the number of y coordinate check points, and
n is the identification number of each check point from 1 through N.

- **RMSE$_r$** The horizontal root mean square error in the radial direction that includes both *x* and *y* coordinate errors:

$$\sqrt{\left(RMSE_x^{\,2} + RMSE_y^{\,2}\right)} \tag{5}$$

where

$RMSE_x$ is the RMSE in the x direction, and
$RMSE_y$ is the RMSE in the y direction.

- **RMSE$_z$** The vertical root mean square error in the *z* direction (elevation):

$$\sqrt{\sum \frac{(z_n - z'_n)^2}{N}} \tag{6}$$

where

z_n is the set of N z values (elevations) being evaluated,
z'_n is the corresponding set of check point elevations for the points being evaluated,
N is the number of z check points, and
n is the identification number of each check point from 1 through N.

S

spatial distribution In lidar, the regularity or consistency of the point density within the collection. The theoretical ideal spatial distribution for a lidar collection is a perfect regular lattice of points with equal spacing on *x* and *y* axes. Various factors prevent this ideal from being achieved, including the following factors:

- Instrument design (oscillating mirrors),
- Mission planning (difference between along-track and cross-track pulse spacing), and
- In-flight attitude variations (roll, pitch, and yaw).

standard deviation A measure of spread or dispersion of a sample of errors around the sample mean error. It is a measure of precision, rather than accuracy; the standard deviation does not account for uncorrected systematic errors.

supplemental vertical accuracy (SVA) Merged into the vegetated vertical accuracy (VVA) in this specification, SVA is the NDEP guidelines term for reporting the vertical accuracy at the 95th percentile in each separate land cover category where vertical errors may not follow a normal error distribution. *See* percentile, vegetated vertical accuracy.

swath The data resulting from a single flightline of collection. *See* flightline.

systematic error An error whose algebraic sign and, to some extent, magnitude bears a fixed relation to some condition or set of conditions. Systematic errors follow some fixed pattern and are introduced by data collection procedures, processing or given datum.

T

tenderloin The central part of the swath that, when combined with adjacent swath tenderloins, forms a complete, single, non-overlapped, gap-free coverage. In collections designed using multiple coverage, tenderloins are the parts of the swath necessary to form a complete non-overlapped, gap-free coverage at the planned depth of coverage. *See* overage, overlap.

triangulated irregular network (TIN) A vector data structure that partitions geographic space into contiguous, non-overlapping triangles. In lidar, the vertices of each triangle are lidar points with *x, y,* and *z* values. In most geographic applications, TINs are based on Delaunay triangulation algorithms in which no point in any given triangle lies within the circumcircle of any other triangle.

U

uncertainty (of measurement) a parameter that characterizes the dispersion of measured values, or the range in which the "true" value most likely lies. It can also be defined as an estimate of the limits of the error in a measurement (where "error" is defined as the difference between the theoretically-unknowable "true" value of a parameter and its measured value). Standard uncertainty refers to uncertainty expressed as a standard deviation.

V

vector One of the fundamental types of geospatial data (others being raster and point cloud), vectors include a variety of data structures that are geometrically described by *x* and *y coordinates,* and potentially *z* values. Vector data subtypes include points, lines, and polygons. A DTM composed of mass points and breaklines is an example of a vector dataset; a TIN is a vector surface. *See* point cloud, raster.

vegetated vertical accuracy (VVA) Replaces supplemental vertical accuracy (SVA) and consolidated vertical accuracy (CVA). An estimate of the vertical accuracy, based on the 95th percentile, in vegetated terrain where errors do not necessarily approximate a normal distribution. *See* percentile, nonvegetated vertical accuracy.

W

waveform lidar Lidar system or data in which the entire reflection of the laser pulse is fully digitized, captured, and stored. Discrete return point clouds can be extracted from the waveform data during post processing. *See* discrete return lidar.

well-distributed For a dataset covering a rectangular area that has uniform positional accuracy, check points should be distributed so that points are spaced at intervals of at least 10 percent of the diagonal distance across the dataset and at least 20 percent of the points are located in each quadrant of the dataset (adapted from the NSSDA of the Federal Geographic Data Committee, 1998). As related to this specification, these guidelines are applicable to each land cover class for which check points are being collected.

withheld Within the LAS file specification, a single bit flag indicating that the associated lidar point is geometrically anomalous or unreliable and should be ignored for all normal processes. These points are retained because of their value in specialized analysis. Withheld points typically are identified and tagged during preprocessing or through the use of automatic classification routines. Examples of points typically tagged as withheld are listed below:

- Spatial outliers in either the horizontal or vertical domains, and
- Geometrically unreliable points near the edge of a swath.

Supplemental Information

USGS National Elevation Dataset (NED) Web site:
http://ned.usgs.gov

MP-Metadata Parser:
http://geology.usgs.gov/tools/metadata

FGDC Content Standard for Geospatial Metadata:
http://www.fgdc.gov/metadata/csdgm/

National Geodetic Survey, National Adjustment of 2011 Project:
http://www.ngs.noaa.gov/web/surveys/NA2011/

National Geodetic Survey, Geoid and Deflection Models:
http://www.ngs.noaa.gov/GEOID/models.shtml

Appendix 1. Common Data Upgrades

Appendix 1 contains a partial list of common upgrades, which is neither comprehensive nor exclusive.

- Independent third-party quality assurance/quality control (QA/QC) by another contractor.
- Full waveform collection and delivery.
- Additional environmental constraints:
  - Tidal coordination, flood stages, crop or plant growth cycles.
  - Shorelines corrected for tidal variations within a collection.
- Top-of-Canopy (first return) Raster Surface (tiled):
  - Raster representing the highest return within each cell is preferred.
- Intensity images (8-bit gray scale, tiled):
  - Interpolation based on first returns.
  - Interpolation based on all-returns, summed.
- Detailed classification (additional classes):
  - Class 3: Low vegetation.
  - Class 4: Medium vegetation (use for single vegetation class).
  - Class 5: High vegetation.
  - Class 6: Buildings, other man-made structures.
  - Class *n*: Additional classes or features as agreed upon in advance.
- Hydrologically enforced (Hydro-Enforced) digital elevation models (DEM) as an additional deliverable.
- Hydrologically conditioned (Hydro-Conditioned) DEMs as an additional deliverable.
- Breaklines (PolylineZ and PolygonZ) for additional hydrographic and topographic features:
  - Narrower double-line streams and rivers.
  - Single-line streams and rivers.
  - Smaller ponds.
  - Culverts and other drainage structures.
  - Retaining walls.
  - Hydrologic areas, for example swamp or marsh.
  - Appropriate integration of additional features into delivered DEMs.
- Extracted buildings (PolygonZ):
  - Footprints with maximum elevation or height above ground as an attribute.
- Other products as defined by requirements and agreed upon before a funding commitment.

Appendix 2. Hydro-Flattening Reference

The subject of variations of lidar-based digital elevation models (DEM) is somewhat new and substantial diversity exists in the understanding of the topic across the industry. The material in this appendix was developed to provide a definitive reference on the subject only as it relates to the creation of DEMs intended to be integrated into the U.S. Geological Survey (USGS) National Elevation Dataset (NED). The information presented in this appendix is not meant to supplant other reference materials and should not be considered authoritative beyond its intended scope.

As used in this specification, “hydro-flattened” describes the specific type of DEM required by the USGS National Geospatial Program (NGP) for integration into the NED. Hydro-flattening is the process of creating a lidar-derived DEM in which water surfaces appear and behave as they would in traditional topographic DEMs created from photogrammetric digital terrain models (DTMs). A hydro-flattened DEM is a topographic DEM and should not be confused with hydro-enforced or hydro-conditioned DEMs, which are hydrologic surfaces.

Traditionally, topography was depicted using contours on printed maps and, although modern computer technology provides superior alternatives, the contour map remains a popular and widely used product. The NED was initially developed as a topographic DEM from USGS contour maps and it remains the underlying source data for newly generated contours. To ensure that USGS contours continue to present the same type of information as they are updated, DEMs used to update the NED must also possess the same basic character as the existing NED.

A traditional topographic DEM such as the NED represents the actual ground surface, and hydrologic features are handled in established ways. Roadways crossing drainages passing through culverts remain in the surface model because they are part of the landscape (the culvert beneath the road is the manmade feature). Bridges, manmade structures above the landscape, are removed.

For many years, the source data for topographic raster DEMs were mass points and breaklines (collectively referred to as a DTM) compiled through photogrammetric compilation from stereographic aerial imagery. The DTM is converted into a triangulated irregular network (TIN) surface from which a raster DEM could be generated. Photogrammetric DTMs inherently contain breaklines that clearly define the edges of water bodies, coastlines, and single- and double-line stream and rivers. These breaklines force the derived DEM to appear, and contours to behave, in specific ways: water surfaces appear flat, roadways are continuous when on the ground, and rivers are continuous under bridge locations; contours follow water body banks and cross streams are perpendicular to the centerline.

[Note: DEMs developed solely for orthophoto production may include bridges, because their presence prevents distortion in the image and reduces the amount of post processing for corrections of the final orthophotos. These are special use DEMs and are not relevant to this specification.]

Computer technology allows hydraulic and hydrologic modeling to be performed using digital DEM surfaces directly. For these applications, traditional topographic DEMs present a variety of problems that are solved through modification of the DEM surface. The DEM Users’ Manual (Maune, 2007) provides the following definitions related to the adjustment of DEM surfaces for hydrologic analyses:

Hydrologically Conditioned (Hydro-Conditioned) Processing of a DEM or TIN so that the flow of water is continuous across the entire terrain surface, including the removal of all spurious sinks or pits. Whereas “hydrologically-enforced” is relevant to drainage features that are generally mapped, “hydrologically-conditioned” is relevant to the entire land surface and is done so that water flow is continuous across the surface, whether that flow is in a stream channel or not. The purpose for continuous flow is so that relations/links among basins/catchments can be known for large areas. This term is specifically used when describing Elevation Derivatives for National Applications (EDNA), the dataset of NED derivatives made specifically for hydrologic modeling purposes.

Hydrologically Enforced (Hydro-Enforced) Processing of mapped water bodies so that lakes and reservoirs are level and so that streams flow downhill. For example, a DEM, TIN or topographic contour dataset with elevations removed from the tops of selected drainage structures (bridges and culverts) so as to depict the terrain under those structures. Hydro-enforcement enables hydrologic and hydraulic (H&H) models to depict water flowing under these structures, rather than appearing in the computer model to be dammed by them because of road deck elevations higher than the water levels. Hydro-enforced TINs also use breaklines along shorelines and stream centerlines, for example, where these breaklines form the edges of TIN triangles along the alignment of drainage features. Shore breaklines for streams would be 3-D breaklines with elevations that decrease as the stream flows downstream; however, shore breaklines for lakes or reservoirs would have the same elevation for the entire shoreline if the water surface is known or assumed to be level throughout. See also the definition for "hydrologically-conditioned" that has a slightly different meaning.

Hydro-enforcement and hydro-conditioning are important and useful modifications of the traditional topographic DEM, but they produce hydrologic surfaces that are fundamentally different at a functional level. Hydrologic surfaces are identical to topographic surfaces in many respects but they differ significantly in specific ways. In a topographic DEM, roadways over culverts are included in the surface as part of the landscape. From a hydrologic perspective however, these roadways create artificial impediments (digital dams) to the drainages and introduce sinks (undrained areas) into the landscape. Similarly, topographic DEMs obviously cannot reflect the drainage routes provided by underground storm water systems; hence, topographic DEM surfaces will invariably include other sinks. For topographic mapping, sinks are of no consequence—it is actually desirable to know their locations—but they can introduce errors into hydrologic modeling results.

Unlike the DTM, lidar data consists solely of mass points; breaklines are not automatically created during lidar data collection. Although as mass points, lidar is substantially denser than a photogrammetric DTM, it by itself remains limited in its ability to precisely define the boundaries or locations of distinct linear features such as water bodies, streams, and rivers. The lack of breaklines in the intermediate TIN data structure causes triangulation to occur across water bodies, producing a water surface filled with irregular, unnatural, and visually unappealing triangulation artifacts. These artifacts are then carried into the derived DEM, and ultimately into contours developed from the NED. The representation of random irregular water surfaces in the NED is wholly unacceptable to the USGS–NGP and to users of the NED and its derivatives.

To achieve the same character and appearance of a traditional topographic DEM (or to develop a hydrologically enforced DEM) from lidar source data, breaklines must be developed separately using other techniques. These breaklines are then integrated with lidar points as a complete DTM, or used to modify a DEM previously generated without breaklines.

Hydrologic DEMs usually require flattened water surfaces as well, hence the breaklines required for hydro-flattening the topographic DEM can be equally useful for all DEM types well. *See* the note, below. Additional breaklines (and lidar point classifications) are needed to efficiently generate hydro-enforced DEMs. If properly attributed, breaklines for all DEM treatments can be stored in a single set of feature classes.

The use of breaklines is the predominant method used for hydro-flattening, though other techniques may exist. The USGS–NGP does not require that breaklines be used for flattening, but does require the delivery of breaklines for all flattened water bodies, and any other breaklines developed for each project. *See* the section "Digital Elevation Model Hydro-Flattening" for additional information.

[Note: Civil engineers and hydrologists may have requirements for the accuracy of water-surface elevations. With respect to elevation data, the USGS–NGP's interest is in accurate and complete representation of land topography, not water-surface elevations. Topographic lidar can be inconsistent and unreliable in water-surface measurements, and water-surface elevations fluctuate with tides, rainfall, and changes to manmade controls. It is therefore impractical to assert any accuracy for the water-surface elevations in the NED, and the USGS–NGP imposes no requirement for absolute accuracy of water-surface elevations in lidar and DEM deliveries.]

Appendix 3. Lidar Metadata Example


```xml
<?xml version="1.0" encoding="UTF-8"?>
<!--DOCTYPE metadata SYSTEM "fgdc-std-001-1998.dtd"-->
<metadata>
  <idinfo>
    <citation>
      <citeinfo>
        <origin>We Map 4U, Inc.</origin>
          <pubdate>20101208</pubdate>
          <title>Lidar data for Phelps and Dent Counties, MO
            MO_Phelps-Dent-CO_2010
          </title>
        <geoform>Lidar point cloud</geoform>
      </citeinfo>
    </citation>
    <descript>
      <abstract>Geographic Extent: This dataset is lidar point cloud
        data, which encompasses a 1,000 meter buffer around Phelps and Dent
        Counties in Missouri, approximately 829 square miles.
        Dataset Description: This dataset consists of 457 lidar point cloud LAS
        swath files. Each LAS file contains lidar point information, which has
        been calibrated, controlled, and classified. Each file represents a
        separate swath of lidar. Collected swath files that were larger than 2GB
        were initially written in multiple subswath files, each less than 2GB.
        Ground Conditions: water at normal levels; no unusual inundation;
        no snow; leaf off
      </abstract>
      <lidar>
        <ldrinfo>
          <ldrspec>USGS-NGP Base Specification v1.1</ldrspec>
          <ldrsens>Optech Gemini Airborne Laser Terrain Mappers (ALTM)</ldrsens>
          <ldrmaxnr>4</ldrmaxnr>
          <ldrnps>0.7071</ldrnps>
          <ldrdens>2</ldrdens>
          <ldranps>0.7071</ldranps>
          <ldradens>2</ldradens>
          <ldrfltht>3000</ldrfltht>
          <ldrfltsp>115</ldrfltsp>
          <ldrscana>26</ldrscana>
          <ldrscanr>40</ldrscanr>
          <ldrpulsr>120</ldrpulsr>
          <ldrpulsd>10</ldrpulsd>
          <ldrpulsw>3</ldrpulsw>
          <ldrwavel>1064</ldrwavel>
          <ldrmpia>0</ldrmpia>
          <ldrbmdiv>4.5</ldrbmdiv>
          <ldrswatw>1200</ldrswatw>
          <ldrswato>15</ldrswato>
          <ldrgeoid>National Geodetic Survey (NGS) Geoid09</ldrgeoid>
        </ldrinfo>
        <ldraccur>
          <ldrchacc>0.5</ldrchacc>
          <rawnva>0.11</rawnva>
          <rawnvan>27</rawnvan>
          <clsnva>0.09</clsnva>
          <clsnvan>27</clsnvan>
          <clsvva>0.188</clsvva>
          <clsvvan>123</clsvvan>
        </ldraccur>
```

```
    <lasinfo>
      <lasver>1.4</lasver>
      <lasprf>6</lasprf>
      <laswheld>Withheld (ignore) points were identified in these files
        using the standard LAS Withheld bit
      </laswheld>
      <lasolap>Swath "overage" points were identified in these files using
        the standard LAS overlap bit
      </lasolap>
      <lasintrz>11-bit</lasintrz>
      <lasclass>
        <clascode>1</clascode>
        <clasitem>Undetermined/Unclassified</clasitem>
      </lasclass>
      <lasclass>
        <clascode>2</clascode>
        <clasitem>Bare earth</clasitem>
      </lasclass>
      <lasclass>
        <clascode>4</clascode>
        <clasitem>All vegetation</clasitem>
      </lasclass>
      <lasclass>
        <clascode>6</clascode>
        <clasitem>All structures except bridges</clasitem>
      </lasclass>
      <lasclass>
        <clascode>7</clascode>
        <clasitem>Low noise</clasitem>
      </lasclass>
      <lasclass>
        <clascode>8</clascode>
        <clasitem>Model Key Points</clasitem>
      </lasclass>
      <lasclass>
        <clascode>9</clascode>
        <clasitem>Water</clasitem>
      </lasclass>
      <lasclass>
        <clascode>10</clascode>
        <clasitem>Ignored Ground</clasitem>
      </lasclass>
      <lasclass>
        <clascode>17</clascode>
        <clasitem>Bridges</clasitem>
      </lasclass>
      <lasclass>
        <clascode>18</clascode>
        <clasitem>High noise</clasitem>
      </lasclass>
    </lasinfo>
  </lidar>
  <purpose>The purpose of these lidar data was to produce a high accuracy 3D
    hydro-flattened Digital Elevation Model (DEM) with a 1.0 foot cell size.
    The data will be used by Federal Emergency Management Agency (FEMA) for
    floodplain mapping.
    These raw lidar point cloud data were used to create classified lidar
    LAS files, intensity images, 3D breaklines, hydro-flattened DEMs as
    necessary.
  </purpose>
 <supplinf>
    USGS Contract No. G10PC01234
    CONTRACTOR: We Map4U, Inc.
```

```
      SUBCONTRACTOR: Aerial Scanning Services, LLC
      Lidar data were acquired and calibrated by Aerial Scanning Services.
      All follow-on processing was completed by the prime contractor.
   </supplinf>
  </descript>
  <timeperd>
    <timeinfo>
      <rngdates>
        <begdate>20100216</begdate>
        <enddate>20100218</enddate>
      </rngdates>
    </timeinfo>
    <current>ground condition</current>
  </timeperd>
  <status>
    <progress>Partial: Lot 2 of 5</progress>
    <update>None planned</update>
  </status>
  <spdom>
    <bounding>
      <westbc>-91.750000</westbc>
      <eastbc>-91.250000</eastbc>
      <northbc>38.000000</northbc>
      <southbc>37.250000</southbc>
    </bounding>
    <lboundng>
      <leftbc>584800.00</leftbc>
      <rightbc>664800.00</rightbc>
      <topbc>4225400.00</topbc>
      <bottombc>4141400.00</bottombc>
    </lboundng>
  </spdom>
  <keywords>
    <theme>
      <themekt>None</themekt>
      <themekey>Elevation data</themekey>
      <themekey>Lidar</themekey>
      <themekey>Hydrology</themekey>
    </theme>
    <place>
      <placekt>None</placekt>
      <placekey>Missouri</placekey>
      <placekey>Phelps County</placekey>
      <placekey>Dent County</placekey>
      <placekey>Mark Twain National Forest</placekey>
    </place>
  </keywords>
  <accconst>No restrictions apply to this data.</accconst>
  <useconst>None. However, users should be aware that temporal changes may
    have occurred since this dataset was collected and that some parts of
    these data may no longer represent actual surface conditions. Users
    should not use these data for critical applications without a full
    awareness of its limitations. Acknowledgement of the U.S. Geological
    Survey would be appreciated for products derived from these data.
  </useconst>
  <ptcontac>
    <cntinfo>
      <cntorgp>
        <cntorg>We Map 4U, Data Acquisition Department</cntorg>
        <cntper>Jane Smith</cntper>
      </cntorgp>
      <cntaddr>
        <addrtype>mailing and physical</addrtype>
```

```
        <address>123 Main St.</address>
        <city>Anytown</city>
        <state>MO</state>
        <postal>61234</postal>
        <country>USA</country>
      </cntaddr>
      <cntvoice>555-555-1234</cntvoice>
      <cnttdd>555-555-1122</cnttdd>
      <cntfax>555-5550-1235</cntfax>
      <cntemail>jsmith@wemap4u.com</cntemail>
      <hours>Monday through Friday 8:00 AM to 4:00 PM (Central Time)</hours>
      <cntinst>If unable to reach the contact by telephone, please send an
        email. You should get a response within 24 hours.
      </cntinst>
    </cntinfo>
  </ptcontac>
  <native>Optech DASHMap 4.2200; ALS Post Processor 2.70 Build 15;
    GeoCue Version 6.1.21.4; Windows XP Operating System
    \\server\directory path\*.las
    17 GB
  </native>
</idinfo>
<dataqual>
  <logic>Data cover the entire area specified for this project.</logic>
  <complete>These raw LAS data files include all data points collected.
    No points have been removed or excluded.
    A visual qualitative assessment was performed to ensure data completeness.
    No void areas or missing data exist. The raw point cloud is of good
    quality and data passes Fundamental Vertical Accuracy specifications.
  </complete>
  <posacc>
    <vertacc>
      <vertaccr>The specifications require that only Nonvegetated Vertical
        Accuracy (NVA) be computed for raw lidar point cloud swath files.
        The vertical accuracy was tested with 25 independent survey located
        in open terrain. These check points (check points) were not used in
        the calibration or post processing of the lidar point cloud data.
        The survey check points were distributed throughout the project.
        Specifications for this project require that the NVA be 25 cm or
        better AccuracyZ at 95 percent confidence level.
      </vertaccr>
      <qvertpa>
        <vertaccv>0.19 meters AccuracyZ at 95 percent Confidence Interval
        </vertaccv>
        <vertacce>The NVA was tested using 25 independent surveys located in
          open terrain. The survey check points were distributed
          throughout the project area. The 25 independent check points were
          surveyed using the closed level loop technique. Elevations from
          the unclassified lidar surface were measured for the x,y location
          of each check point. Elevations interpolated from the lidar surface
          were then compared to the elevation values of the surveyed control.
          The RMSE was computed to be 0.097 meters. AccuracyZ has been tested
          to meet 19.0 cm Fundamental Vertical Accuracy at 95 percent
          confidence level using (RMSEz * 1.9600) as defined by the National
          Standards for Spatial Data Accuracy (NSSDA); assessed and reported
          using National Digital Elevation Program (NDEP)/ASPRS Guidelines.
        </vertacce>
      </qvertpa>
    </vertacc>
  </posacc>
  <lineage>
    <srcinfo>
      <srccite>
```

```
      <citeinfo>
        <origin>Jiffy Survey, Inc</origin>
        <pubdate>20100115</pubdate>
        <title>Ground Control for Phelps and Dent County, MO lidar project
        </title>
        <geoform>vector digital data and tabular data</geoform>
        <pubinfo>
          <pubplace>Jiffy Survey, Inc.</pubplace>
          <publish>Jiffy Survey, Inc., GPS department</publish>
        </pubinfo>
        <othercit>None</othercit>
        <onlink>ftp://JiffySurveyftp.com/data/outgoing/Task1/</onlink>
      </citeinfo>
    </srccite>
    <srcscale>50</srcscale>
    <typesrc>CD-ROM</typesrc>
    <srctime>
      <timeinfo>
        <sngdate>
          <caldate>201001003</caldate>
        </sngdate>
      </timeinfo>
      <srccurr>ground condition</srccurr>
    </srctime>
    <srccitea>Phelps_Co_lidar_gnd_ctrl</srccitea>
    <srccontr>This data source was used (along with the airborne GPS/IMU
      data) to georeference the lidar point cloud data.
    </srccontr>
  </srcinfo>
  <srcinfo>
    <srccite>
      <citeinfo>
        <origin>USDA</origin>
        <pubdate>20090606</pubdate>
        <title>NAIP Imagery for Phelps and Dent County, MO lidar project
        </title>
        <geoform>raster orthoimagery</geoform>
        <pubinfo>
          <pubplace>USGS-EROS</pubplace>
          <publish>USGS-EROS</publish>
        </pubinfo>
        <othercit>None</othercit>
        <onlink></onlink>
      </citeinfo>
    </srccite>
    <srcscale>50</srcscale>
    <typesrc>online</typesrc>
    <srctime>
      <timeinfo>
        <sngdate>
          <caldate>20090101</caldate>
        </sngdate>
      </timeinfo>
      <srccurr>ground condition</srccurr>
    </srctime>
    <srccitea>Phelps-Dent_Co_NAIP_Imagery</srccitea>
    <srccontr>This data source was used (along with the lidar intensity
      imagery) to classify the lidar point cloud data.
    </srccontr>
  </srcinfo>
  <srcinfo>
    <srccite>
      <citeinfo>
```

```
      <origin>We Map 4U, Inc.</origin>
      <pubdate>20101208</pubdate>
      <title>Lidar Intensity Imagery for Phelps and Dent County, MO
      </title>
      <geoform>raster orthoimagery</geoform>
      <pubinfo>
        <pubplace>USGS-EROS</pubplace>
        <publish>USGS-EROS</publish>
      </pubinfo>
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      <onlink></onlink>
    </citeinfo>
  </srccite>
  <srcscale>50</srcscale>
  <typesrc>online</typesrc>
  <srctime>
    <timeinfo>
      <rngdates>
        <begdate>20100216</begdate>
        <enddate>20100218</enddate>
      </rngdates>
    </timeinfo>
    <srccurr>ground condition</srccurr>
  </srctime>
  <srccitea>Phelps-Dent_Co_Lidar_Intensity_Imagery</srccitea>
  <srccontr>This data source was used (along with NAIP imagery)
    to classify the lidar point cloud data.
  </srccontr>
</srcinfo>
<procstep>
  <procdesc>Lidar Preprocessing: Airborne GPS and IMU data were merged
    to develop a Single Best Estimate (SBET) of the lidar system
    trajectory for each lift. Lidar ranging data were initially calibrated
    using previous best parameters for this instrument and aircraft.
    Relative calibration was evaluated using advanced plane-matching
    analysis and parameter corrections were derived. This relative
    calibration was repeated iteratively until residual errors between
    overlapping swaths, across all project lifts, was reduced to 2 cm or
    less. Data were then block adjusted to match surveyed calibration
    control. Raw data NVA were checked using independently surveyed check
    points. Swath overage points were identified and tagged within each
    swath file.
  </procdesc>
  <srcused>Phelps_Co_lidar_gnd_ctrl</srcused>
  <procdate>20100131</procdate>
  <proccont>
    <cntinfo>
      <cntorgp>
        <cntorg>We Map 4U, Data Acquisition Department</cntorg>
        <cntper>Manny Puntas</cntper>
      </cntorgp>
      <cntaddr>
        <addrtype>mailing and physical</addrtype>
          <address>123 Main St.</address>
          <city>Anytown</city>
          <state>MO</state>
          <postal>61234</postal>
          <country>USA</country>
        </cntaddr>
        <cntvoice>555-555-556</cntvoice>
        <cntfax>555-5550-1236</cntfax>
        <cntemail>mpuntas@wemap4u.com</cntemail>
        <hours>Monday through Friday 8:00 AM to 4:00 PM (Central Time)
```

```
          </hours>
          <cntinst>If unable to reach the contact by telephone, please send
            an email. You should get a response within 24 hours.
          </cntinst>
        </cntinfo>
      </proccont>
    </procstep>
    <procstep>
      <procdesc>Lidar Post-Processing: The calibrated and controlled lidar
        swaths were processed using automatic point classification routines
        in proprietary software. These routines operate against the entire
        collection (all swaths, all lifts), eliminating character
        differences between files. Data were then distributed as virtual
        tiles to experienced lidar analysts for localized automatic
        classification, manual editing, and peer-based QC checks.
        Supervisory QC monitoring of work in progress and completed editing
        ensured consistency of classification character and adherence to
        project requirements across the entire project. All classification
        tags are stored in the original swath files. After completion of
        classification and final QC approval, the NVA and VVA for the
        project are calculated. Sample areas for each land cover type
        present in the project was extracted and forwarded to the client,
        along with the results of the accuracy tests. Upon acceptance, the
        complete classified lidar swath files were delivered to the client.
      </procdesc>
      <srcused>Phelps-Dent_Co_NAIP_Imagery</srcused>
      <srcused>Phelps-Dent_Co_Lidar_Intensity_Imagery</srcused>
      <procdate>20100530</procdate>
      <proccont>
        <cntinfo>
        <cntorgp>
          <cntorg>We Map 4U, Data Acquisition Department</cntorg>
          <cntper>Manny Puntas</cntper>
        </cntorgp>
        <cntaddr>
          <addrtype>mailing and physical</addrtype>
          <address>123 Main St.</address>
          <city>Anytown</city>
          <state>MO</state>
          <postal>61234</postal>
          <country>USA</country>
        </cntaddr>
        <cntvoice>555-555-556</cntvoice>
        <cntfax>555-5550-1236</cntfax>
        <cntemail>mpuntas@wemap4u.com</cntemail>
        <hours>Monday through Friday 8:00 AM to 4:00 PM (Central Time)
        </hours>
        <cntinst>If unable to reach the contact by telephone, please send
          an email. You should get a response within 24 hours.
        </cntinst>
      </cntinfo>
    </proccont>
  </procstep>
</lineage>
</dataqual>
<spdoinfo>
  <direct>Vector</direct>
  <ptvctinf>
    <sdtsterm>
      <sdtstype>Point</sdtstype>
      <ptvctcnt>764,567,423</ptvctcnt>
    </sdtsterm>
  </ptvctinf>
```

```
</spdoinfo>
<spref>
  <horizsys>
    <planar>
      <gridsys>
        <gridsysn>Universal Transverse Mercator</gridsysn>
          <utm>
            <utmzone>15</utmzone>
            <transmer>
              <sfctrmer>0.9996</sfctrmer>
              <longcm>-117.000000</longcm>
              <latprjo>0.0</latprjo>
              <feast>500000</feast>
              <fnorth>0.0</fnorth>
            </transmer>
          </utm>
        </gridsys>
      <planci>
        <plance>coordinate pair</plance>
        <coordrep>
          <absres>0.01</absres>
          <ordres>0.01</ordres>
        </coordrep>
        <plandu>meters</plandu>
      </planci>
    </planar>
    <geodetic>
      <horizdn>North American Datum of 1983</horizdn>
      <ellips>Geodetic Reference System 80</ellips>
      <semiaxis>6378137</semiaxis>
      <denflat>298.257222101</denflat>
    </geodetic>
  </horizsys>
  <vertdef>
    <altsys>
      <altdatum>North American Vertical Datum of 1988</altdatum>
      <altres>0.01</altres>
      <altunits>meters</altunits>
      <altenc>Explicit elevation coordinate included with horizontal
        coordinates
      </altenc>
    </altsys>
  </vertdef>
</spref>
<distinfo>
  <distrib>
    <cntinfo>
      <cntperp>
        <cntper>Jim Brooks, GISP</cntper>
        <cntorg>Phelps-Dent Council of Government (PDCOG), GIS and Data
          Division
        </cntorg>
      </cntperp>
      <cntpos>Director</cntpos>
      <cntaddr>
        <addrtype>mailing and physical address</addrtype>
        <address>PDCOG, GIS Division</address>
        <address>123 ABD Street</address>
        <address>Suite 456</address>
        <city>Sometown</city>
        <state>MO</state>
        <postal>99999</postal>
        <country>USA</country>
```

```
        </cntaddr>
        <cntvoice>555-555-9999</cntvoice>
        <cntemail>jim.brooks@PDCOG.org</cntemail>
      </cntinfo>
    </distrib>
    <resdesc>The Phelps-Dent Council of Government (PDCOG)distributes data
      directly to program partners. Public access to the data is available
      from the USGS as listed below.
    </resdesc>
    <distliab>In no event shall the creators, custodians, or distributors of
      these data be liable for any damages arising out of its use, or from
      the inability of the customer to use these data for their intended
      application.
    </distliab>
  </distinfo>
  <metainfo>
    <metd>20101206</metd>
    <metrd>20101207</metrd>
    <metc>
      <cntinfo>
        <cntorgp>
          <cntorg>We Map 4U, Data Acquisition Department</cntorg>
          <cntper>John Smith</cntper>
        </cntorgp>
        <cntaddr>
          <addrtype>mailing and physical</addrtype>
          <address>123 Main St.</address>
          <city>Anytown</city>
          <state>MO</state>
          <postal>61234</postal>
          <country>USA</country>
        </cntaddr>
        <cntvoice>555-555-1234</cntvoice>
        <cnttdd>555-555-1122</cnttdd>
        <cntfax>555-5550-1235</cntfax>
        <cntemail>jsmith@wemap4u.com</cntemail>
        <hours>Monday through Friday 8:00 AM to 4:00 PM (Central Time)</hours>
        <cntinst>If unable to reach the contact by telephone, please send an
          email. You should get a response within 24 hours.
        </cntinst>
      </cntinfo>
    </metc>
    <metstdn>FGDC Content Standard for Digital Geospatial Metadata</metstdn>
    <metstdv>FGDC-STD-001-1998</metstdv>
    <metac>None</metac>
    <metuc>None</metuc>
    <metsi>
      <metscs>None</metscs>
      <metsc>Unclassified</metsc>
      <metshd>None</metshd>
    </metsi>
    <metextns>
      <onlink>None</onlink>
      <metprof>None</metprof>
    </metextns>
  </metainfo>
</metadata>
```

Appendix 4. Lidar Metadata Template

```
<?xml version="1.0" encoding="UTF-8"?>
<!--DOCTYPE metadata SYSTEM "fgdc-std-001-1998.dtd"-->
<metadata>
  <idinfo>
    <citation>
      <citeinfo>
        <origin>EXAMPLE: We Map 4U, Inc.
        <!--REQUIRED Element: Originator
          Name of the contractor that developed the dataset.
          Domain: "Unknown" free text
        -->
        </origin>
        <pubdate>20101208
        <!--REQUIRED Element: Publication Date
          Date that the dataset was RELEASED. The field MUST be formatted
          YYYYMMDD
          Domain: "Unknown" "Unpublished Material" YYYYMMDD free text
        -->
        </pubdate>
        <title>EXAMPLE: Lidar data for Phelps and Dent Counties, MO
          MO_Phelps-Dent-CO_2010
          <!--REQUIRED Element: Title
            The name by which the dataset is known.
            If a Project ID in the following format has been issued for this
            project, include it in the title element
            [State_description_aquisition-date].
            Domain: free text
          -->
        </title>
        <geoform>EXAMPLE: Lidar point cloud
          <!--REQUIRED Element: Geospatial Data Presentation Form
            The mode in which the geospatial data are represented.
            Domain: free text
          -->
        </geoform>
      </citeinfo>
    </citation>
    <descript>
      <abstract>EXAMPLE: Geographic Extent: This dataset is lidar point cloud
        data, which encompasses a 1,000 meter buffer around Phelps and Dent
        Counties in Missouri, approximately 829 square miles.
        Dataset Description: This dataset consists of 457 lidar point cloud LAS
        swath files. Each LAS file contains lidar point information, which has
        been calibrated, controlled, and classified. Each file represents a
        separate swath of lidar. Collected swath files that were larger than
        2GB were initially written in multiple subswath files, each less than
        2GB.
        Ground Conditions: water at normal levels; no unusual inundation; no
        snow; leaf off
        <!--REQUIRED Element: Abstract
          A brief narrative summary of the dataset.
          The Abstract should include a consolidated summary of other
          elements that are included elsewhere in this metadata file, for ease
          of use.
          Domain: free text
        -->
      </abstract>
      <lidar>
        <!--REQUIRED Section: for Project, Lift, and classified LAS metadata
          files
        -->
```

```
<ldrinfo>
  <!--REQUIRED Group: This group of tags contains metadata about the
    sensor and collection conditions.
  -->
  <ldrspec>EXAMPLE: USGS-NGP Base Lidar Specification v1.1
    <!--REQUIRED Element: the lidar specification applicable to the
      point cloud
    -->
  </ldrspec>
  <ldrsens>EXAMPLE: Optech Gemini Airborne Laser Terrain Mappers (ALTM)
    <!--REQUIRED Element: the lidar sensor make and model -->
  </ldrsens>
  <ldrmaxnr>EXAMPLE: 4
    <!--REQUIRED Element: the maximum number of returns per pulse -->
  </ldrmaxnr>
  <ldrnps>EXAMPLE: 1.2
    <!--REQUIRED Element: the Nominal Pulse Spacing, in Meters -->
  </ldrnps>
  <ldrdens>EXAMPLE: 2
    <!--REQUIRED Element: the Nominal Pulse Density, in Points Per
      Square Meter
    -->
  </ldrdens>
  <ldranps>EXAMPLE: 0.7071
    <!--REQUIRED Element: the Nominal Pulse Spacing, in Meters -->
   </ldranps>
  <ldradens>EXAMPLE: 2
    <!--REQUIRED Element: the Nominal Pulse Density, in Points Per
      Square Meter
    -->
  </ldradens>
  <ldrfltht>EXAMPLE: 3000
    <!--REQUIRED Element: the nominal flight height Above Mean Terrain
      for the collection, in Meters
    -->
  </ldrfltht>
  <ldrfltsp>EXAMPLE: 115
    <!--REQUIRED Element: the nominal flight speed for the collection,
      in Knots
    -->
  </ldrfltsp>
  <ldrscana>EXAMPLE: 26
    <!--REQUIRED Element: the sensor scan angle, total, in Degrees -->
  </ldrscana>
  <ldrscanr>EXAMPLE: 40
    <!--REQUIRED Element: the scan frequency of the scanner, in Hertz
    -->
  </ldrscanr>
  <ldrpulsr>EXAMPLE: 120
    <!--REQUIRED Element: the pulse rate of the scanner, in Kilohertz
    -->
  </ldrpulsr>
  <ldrpulsd>EXAMPLE: 10
    <!--REQUIRED Element: the pulse duration of the scanner, in
      Nanoseconds
    -->
  </ldrpulsd>
  <ldrpulsw>EXAMPLE: 3
    <!--REQUIRED Element: the pulse width of the scanner, in Meters -->
  </ldrpulsw>
  <ldrwavel>EXAMPLE: 1064
    <!--REQUIRED Element: the central wavelength of the sensor laser, in
      Nanometers
    -->
```

```
    </ldrwavel>
    <ldrmpia>EXAMPLE: 0
      <!--REQUIRED Element: Whether the sensor was operated with Multiple
        Pulses In The Air, 0=No; 1=Y
      -->
    </ldrmpia>
    <ldrbmdiv>EXAMPLE: 0.3
      <!--REQUIRED Element: the beam divergence, in Milliradians -->
    </ldrbmdiv>
    <ldrswatw>EXAMPLE: 1200
      <!--REQUIRED Element: the nominal swath width on the ground, in
        Meters
      -->
    </ldrswatw>
    <ldrswato>EXAMPLE: 15
        <!--REQUIRED Element: the nominal swath overlap, as a Percentage
        -->
    </ldrswato>
    <ldrgeoid>EXAMPLE: National Geodetic Survey (NGS) Geoid09
      <!--REQUIRED Element: Geoid used for vertical reference. -->
    </ldrgeoid>
  </ldrinfo>
  <ldraccur>
    <!--REQUIRED Group: This group of tags contains information on point
      cloud accuracy. Not all tags within this group are mandatory. The
      NVA of the raw point cloud is required. A VVA value for the
      classified point cloud is optional, but is required to be reported
      if it is available.
      ALL Values are reported in Meters.
    -->
    <ldrchacc>EXAMPLE: 0.5
      <!--REQUIRED Element: the required nonvegetated vertical accuracy
        (NVA) for the point cloud data.
        If none specified, enter 0.
      -->
    </ldrchacc>
    <rawnva>EXAMPLE: 0.11
      <!--REQUIRED Element: the calculated nonvegetated vertical accuracy
        of the raw point cloud data
      -->
    </rawnva>
    <rawnvan>EXAMPLE: 27
      <!--REQUIRED Element: the number of check points used to calculate
        the reported nonvegetated vertical accuracy of the raw point cloud
        data
      -->
    </rawnvan>
    <clsnva>EXAMPLE: 0.09
      <!--OPTIONAL Element: the calculated nonvegetated vertical accuracy
        of the classified point cloud data (required if available)
      -->
    </clsnva>
    <clsnvan>EXAMPLE: 27
      <!--REQUIRED Element: the number of check points used to calculate
        the reported nonvegetated vertical accuracy of the classified
        point cloud data (required if available)
      -->
    </clsnvan>
    <clsvva>EXAMPLE: 0.188
      <!--OPTIONAL Element: the calculated vegetated vertical accuracy of
        the classified point cloud data (required if available)
      -->
    </clsvva>
```

```
<clsvvan>EXAMPLE: 86
  <!--OPTIONAL Element: the number of check points used to calculate
    the vegetated vertical accuracy of the classified point cloud data
    (required if available)
  -->
</clsvvan>
</ldraccur>
<lasinfo>
  <!--REQUIRED Group: This group of tags contains information on the
    LAS version and classification values for the point cloud.
  -->
  <lasver>EXAMPLE: 1.4
    <!--REQUIRED Element: The version of the LAS Standard applicable to
      this dataset.
    -->
  </lasver>
  <lasprf>EXAMPLE: 6
    <!--REQUIRED Element: The Point Data Record Format used for the
      point cloud.
    -->
  </lasprf>
  <laswheld>EXAMPLE: Withheld (ignore) points were identified in these
    files using the standard LAS Withheld bit.
    <!--REQUIRED Element: Describe how withheld points are identified.
    -->
  </laswheld>
  <lasolap>EXAMPLE: Swath "overage" points were identified in these
    files using the standard LAS overlap bit.
    <!--REQUIRED Element: This element describes how overage points are
      identified.
    -->
  </lasolap>
  <lasintr>EXAMPLE: 11
    <!--REQUIRED Element: This element specifies the native radiometric
      resolution of intensity values, in Bits.
    -->
  </lasintr>
  <lasclass>
    <!--REQUIRED Section if LAS data are classified: Each lasclass
      section provides a code value and a description for that code.
    -->
    <clascode>EXAMPLE: 1</clascode>
      <!--REQUIRED Element: This element specifies classification code.
        Domain: positive integer between 0 and 255
      -->
    <clasitem>EXAMPLE: Undetermined/Unclassified</clasitem>
      <!--REQUIRED Element: This element describes the object
        identified by the classification code; the type of object from
        which the lidar point was reflected, or the status of the
        classification of point.
        Domain: free text
      -->
  </lasclass>
  <lasclass>
    <clascode>EXAMPLE: 2</clascode>
    <clasitem>EXAMPLE: Bare earth</clasitem>
  </lasclass>
  <lasclass>
    <clascode>EXAMPLE: 4</clascode>
    <clasitem>EXAMPLE: All vegetation</clasitem>
  </lasclass>
  <lasclass>
    <clascode>EXAMPLE: 6</clascode>
    <clasitem>EXAMPLE: All structures except bridges</clasitem>
```

```
      </lasclass>
      <lasclass>
        <clascode>EXAMPLE: 7</clascode>
        <clasitem>EXAMPLE: Low noise</clasitem>
      </lasclass>
      <lasclass>
        <clascode>EXAMPLE: 8</clascode>
        <clasitem>EXAMPLE: Model Key Points</clasitem>
      </lasclass>
      <lasclass>
        <clascode>EXAMPLE: 9</clascode>
        <clasitem>EXAMPLE: Water</clasitem>
      </lasclass>
      <lasclass>
        <clascode>EXAMPLE: 10</clascode>
        <clasitem>EXAMPLE: Ignored ground</clasitem>
      </lasclass>
      <lasclass>
        <clascode>EXAMPLE: 17</clascode>
        <clasitem>EXAMPLE: Bridges</clasitem>
      </lasclass>
      <lasclass>
        <clascode>EXAMPLE: 18</clascode>
        <clasitem>EXAMPLE: High Noise</clasitem>
      </lasclass>
    </lasinfo>
  </lidar>
  <purpose>The purpose of these lidar data was to produce high accuracy 3D
    hydro-flattened Digital Elevation Model (DEM) with a 1.0 foot cell size.
    The data will be used by FEMA for flood-plain mapping.
    These raw lidar point cloud data were used to create classified lidar
    LAS files, intensity images, 3D breaklines, hydro-flattened DEMs as
    necessary.
    <!--REQUIRED Element: Purpose
      Why was the dataset was created? For what applications?
      What other products this dataset will be used to create: tiled
      classified LAS, DEM, and others, required deliverables, or interim
      products necessary to complete the project. What scales are
      appropriate or inappropriate for use?
      Domain: free text
    -->
  </purpose>
  <supplinf>
    USGS Contract No. G10PC01234
    CONTRACTOR: We Map4U, Inc.
    SUBCONTRACTOR: Aerial Scanning Services, LLC
    Lidar data were acquired and calibrated by Aerial Scanning Services.
    All follow-on processing was completed by the prime contractor.
    <!--OPTIONAL Element: Supplemental Information
      Enter other descriptive information about the dataset.
      Desirable information includes any deviations from project
      specifications and reasons. It also may include any other information
      that the contractor finds necessary or useful, such as contract number
      or summary of lidar technology. Remove this tag or clear the contents
      of this tag if none.
      Domain: free text
    -->
  </supplinf>
</descript>
<timeperd>
```

```
<timeinfo>
  <!--REQUIRED Group: Time info: will be either:
    single date,
    OR multiple dates,
    OR a range of dates.
    Examples are provided for all three formats.
    Delete the ones that do not apply.
  -->
  <sngdate>
    <!--Begin the example of Single Date-->
    <caldate>20100216
      <!--REQUIRED Element: Calendar Date
        This date is the date of the lidar collection, if the collection
        was completed in one day.
        The field MUST be formatted YYYYMMDD
      -->
    </caldate>
  </sngdate>
  <mdattim>
    <!-- Begin example of a multiple dates -->
    <sngdate>
      <caldate>20100216
        <!--REQUIRED Element: Calendar Date
          This date is the first date of the lidar collection, when
          multiple collection dates are specified.
          The field MUST be formatted YYYYMMDD
        -->
      </caldate>
    </sngdate>
    <sngdate>
      <caldate>20100218
        <!--REQUIRED Element: Calendar Date
          This date is the second date of the lidar collection, when
          multiple collection dates are specified.
          The field MUST be formatted YYYYMMDD
          REPEAT the sngdate and caldate tags for each collection date
        -->
      </caldate>
    </sngdate>
  </mdattim>
  <rngdates>
    <!-- Begin example of a date range -->
    <begdate>20100216
      <!--REQUIRED Element: Beginning Date
        This date is the beginning date of lidar collection.
        The field MUST be formatted YYYYMMDD
      -->
    </begdate>
    <enddate>20100218
      <!--REQUIRED Element: Ending Date
        This date is the ending date of lidar collection.
        The field MUST be formatted YYYYMMDD
      -->
    </enddate>
  </rngdates>
</timeinfo>
<current>EXAMPLE: ground condition
  <!--REQUIRED Element: Currentness Reference
    Enter the basis on which the time period of content information is
    determined.
    Domain: "ground condition" "publication date" free text
  -->
```

```
    </current>
  </timeperd>
  <status>
    <progress>EXAMPLE: Partial: Lot 2 of 5
      <!--REQUIRED ELEMENT: Progress
        Enter the state of the dataset.
        Domain: "Complete" "Partial: Lot x of n"
      -->
    </progress>
    <update>EXAMPLE: None planned
      <!--REUIRED ELEMENT: Maintenance and Update Frequency
        Enter the repeat cycle for the project.
        Domain: "Annually" "Unknown" "None planned" free text
      -->
    </update>
  </status>
  <spdom>
    <bounding>
      <westbc>-91.750000
        <!--REQUIRED Element: West Bounding Coordinate
          This value is the coordinate of the western-most limit of coverage
          of the dataset expressed as longitude. This value will be negative
          in the United States, except for the extreme western Aleutian
          Islands.
          This value MUST be expressed in Decimal Degrees.
          Domain: -180.0<= West Bounding Coordinate< 180.0
        -->
      </westbc>
      <eastbc>-91.25000
        <!--REQUIRED Element: East Bounding Coordinate
          This value is the coordinate of the eastern-most limit of coverage
          of the dataset expressed as longitude. This value will be negative
          in the United States.
          This value MUST be expressed in Decimal Degrees.
          Domain: -180.0<= East Bounding Coordinate<= 180.0
        -->
      </eastbc>
      <northbc>38.00000
        <!--REQUIRED Element: North Bounding Coordinate
          This value is the coordinate of the northern-most limit of coverage
          of the dataset expressed as latitude. This value will be positive
          in the United States.
          This value MUST be expressed in Decimal Degrees.
          Domain: -90.0<= North Bounding Coordinate<= 90.0
        -->
      </northbc>
      <southbc>37.250000
        <!--REQUIRED Element: South Bounding Coordinate
          This value is the coordinate of the southern-most limit of coverage
          of the dataset expressed as latitude. This value will be positive
          in the United States.
          This value MUST be expressed in Decimal Degrees.
          Domain: -90.0<= South Bounding Coordinate<= 90.0
        -->
      </southbc>
    </bounding>
    <lboundng>
      <leftbc>584800
        <!--REQUIRED Element: The coordinate of the western-most limit of
          coverage of the dataset expressed in the Coordinate Reference
          System in which the data are delivered.
        -->
      </leftbc>
```

```
        <rightbc>664800
          <!--REQUIRED Element: The coordinate of the eastern-most limit of
            coverage of the dataset expressed in the Coordinate Reference
            System in which the data are delivered.
          -->
        </rightbc>
        <topbc>4225400
          <!--REQUIRED Element: The coordinate of the northern-most limit of
            coverage of the dataset expressed in the Coordinate Reference
            System in which the data are delivered.
          -->
        </topbc>
        <bottombc>4141400
          <!--REQUIRED Element: The coordinate of the southern-most limit of
            coverage of the dataset expressed in the Coordinate Reference
            System in which the data are delivered.
          -->
        </bottombc>
      </lboundng>
    </spdom>
    <keywords>
      <theme>
        <themekt>EXAMPLE: None
          <!--REQUIRED Element: Theme Keyword Thesaurus
            A formally registered thesaurus or a similar authoritative source of
            theme keywords.
            Domain: "None" free text
          -->
        </themekt>
        <themekey>EXAMPLE: Elevation data
          <!--REQUIRED Element: Theme Keyword: Elevation data (required)-->
        </themekey>
        <themekey>EXAMPLE: Lidar
          <!--REQUIRED Element: Theme Keyword: Lidar (required)-->
        </themekey>
        <themekey>EXAMPLE: Hydrology
          <!--Enter any additional applicable theme keywords.
            Use only ONE keyword for each themekey tag. Repeat the themekey tag
            as many times as necessary.
            Domain: free text
          -->
        </themekey>
      </theme>
      <place>
        <placekt>EXAMPLE: None
          <!--REQUIRED Element: Place Keyword Thesaurus
            Reference to a formally registered thesaurus or a similar
            authoritative source of place keywords.
            Domain: "None" "Geographic Names Information System" free text
          -->
        </placekt>
        <placekey>EXAMPLE: Missouri
          <!--REQUIRED Element: Place Keyword
            For multi-state projects, make a separate entry for each state.
            List only one state for each placekey tag.
          -->
        </placekey>
        <placekey>EXAMPLE: Phelps County
          <!--REQUIRED Element: Place Keyword
            For multi-county projects, make a separate entry for each county.
            List only one county for each placekey tag.
          -->
        </placekey>
```

```
    <placekey>EXAMPLE: Dent County
    </placekey>
    <placekey>EXAMPLE: Mark Twain National Forest
      <!--Enter any additional applicable place keywords, for example cities
        or landmarks.
        Use only one keyword for each placekey tag.
        Repeat the placekey tag as many times as necessary.
        Domain: free text
      -->
    </placekey>
  </place>
</keywords>
<accconst>EXAMPLE: No restrictions apply to these data.
  <!--REQUIRED Element: Access Constraints.
    Enter restrictions and legal prerequisites for
    accessing the dataset. These include any access constraints applied
    to assure the protection of privacy or intellectual property, and
    any special restrictions or limitations on obtaining the dataset.
    Domain: "None" free text
  -->
</accconst>
<useconst>EXAMPLE: None. However, users should be aware that temporal
  changes may have occurred since this dataset was collected and that some
  parts of these data may no longer represent actual surface conditions.
  Users should not use these data for critical applications without a full
  awareness of the limitations of the data. Acknowledgement of the U.S.
  Geological Survey would be appreciated for products derived from these
  data.
  <!--REQUIRED Element: Enter restrictions and legal prerequisites for
    using the dataset after access is granted. These include any use
    constraints applied to assure the protection of privacy or intellectual
    property, and any special restrictions or limitations on using the
    dataset.
    Domain: "None" free text
  -->
</useconst>
<ptcontac>
  <cntinfo>
    <cntorgp>
      <cntorg>EXAMPLE: We Map 4U, Data Acquisition Department
        <!--REQUIRED Element: Contact Organization:
          The name of the organization that created the data and is
          knowledgeable about the data.
          Domain: free text
        -->
      </cntorg>
      <cntper>EXAMPLE: Jane Smith
        <!--REQUIRED Element: Contact Person
          The name of the individual who is knowledgeable about the data.
          Domain: free text
        -->
      </cntper>
    </cntorgp>
    <cntaddr>
      <addrtype>EXAMPLE: mailing and physical
        <!--REQUIRED Element: Address Type
          The type of address that follows.
          Only required for "mailing" or "mailing and physical". If the
          contractor has a different mailing and physical address, the
          physical address does not need to be included. This section may be
          repeated if you would like to provide a separate physical address.
          Domain: "mailing" "physical" "mailing and physical", free text
        -->
```

```
    </addrtype>
    <address>EXAMPLE: 123 Main St.
      <!--REQUIRED Element: Address
        The address of the contractor.
        For multiple line addresses the address tag may be repeated as
        many times as needed.
        Domain: free text
      -->
    </address>
    <city>EXAMPLE: Anytown
      <!--REQUIRED Element: City
        The city of the address.
        Domain: free text
      -->
    </city>
    <state>EXAMPLE: MO
      <!--REQUIRED Element: State
        The state or province of the address.
        Domain: free text
      -->
    </state>
    <postal>EXAMPLE: 61234
      <!--REQUIRED Element: Postal Code
        Enter the ZIP or other postal code of the address.
        Domain: free text
      -->
    </postal>
    <country>EXAMPLE: USA
      <!--OPTIONAL Element: Country
        The country of the address.
        Domain: free text
      -->
    </country>
  </cntaddr>
  <cntvoice>EXAMPLE: 555-555-1234
    <!--REQUIRED Element: Contact Voice Telephone
      The telephone number by which individuals can speak to the
      organization or individual responsible for the data.
      Domain: free text
    -->
  </cntvoice>
  <cnttdd>EXAMPLE: 555-555-1122
    <!--OPTIONAL Element: Contact TDD/TTY Telephone
      The telephone number by which hearing-impaired individuals
      can contact the organization or individual.
      Domain: free text
    -->
  </cnttdd>
  <cntfax>EXAMPLE: 555-5550-1235
    <!--OPTIONAL Element: Contact Fax
      The telephone number of a facsimile machine of the organization
      or individual.
      Domain: free text
    -->
  </cntfax>
  <cntemail>EXAMPLE: jsmith@wemap4u.com
    <!--OPTIONAL Element: Contact E-mail Address
      The email address of the organization or individual.
      Domain: free text
    -->
  </cntemail>
  <hours>EXAMPLE: Monday through Friday 8:00 AM to 4:00 PM (Central Time)
    <!--OPTIONAL Element: Hours of Service
```

```
          The time period when individuals can speak to the organization or
          individual.
          Domain: free text
        -->
      </hours>
      <cntinst>EXAMPLE: If unable to reach the contact by telephone,
          please send an email. You should get a response within 24 hours.
        <!--OPTIONAL Element: Contact Instructions
          Supplemental instructions on how or when to contact the individual
          or organization.
          Domain: free text
        -->
      </cntinst>
    </cntinfo>
  </ptcontac>
  <native>EXAMPLE: Optech DASHMap 4.2200; ALS Post Processor 2.70 Build 15;
    GeoCue Version 6.1.21.4; Windows XP Operating System
    \\server\directory path\*.las
    17 GB
    <!--REQUIRED: Native dataset environment
      Description of the dataset in the producer's processing
      environment, including items such as the name of the software (including
      version), the computer operating system, file name (including host-,
      path-, and filenames), and the dataset size.
      Domain: free text
    -->
  </native>
</idinfo>
<dataqual>
  <logic>EXAMPLE: Data cover the entire area specified for this project.
    <!--REQUIRED Element: Logical Consistency Report
      Describe the fidelity of relations in the data
      structure of the lidar data: tests of valid values
      or topological tests. Identify software used and
      the date of the tests.
      Domain: free text
    -->
  </logic>
  <complete>EXAMPLE: These raw LAS data files include all data points
    collected. No points have been removed or excluded. A visual qualitative
    assessment was performed to ensure data completeness. No void areas or
    missing data exist. The raw point cloud is of good quality and data
    passes Fundamental Vertical Accuracy specifications.
    <!--REQUIRED Element: Completeness Report
      Document the inclusion or omissions of features for the dataset.
      Minimum width or area thresholds. Selection criteria or other rules
      used to derive the dataset.
      Domain: free text
    -->
  </complete>
  <posacc>
    <vertacc>
      <vertaccr>EXAMPLE: The specifications require that only Nonvegetated
        Vertical Accuracy (NVA) can be computed for raw lidar point cloud
        swath files. The vertical accuracy was tested with 25 independent
        surveys located in open terrain. These check points were not used
        in the calibration or post processing of the lidar point cloud data.
        The survey check points were distributed throughout the project.
        Specifications for this project require that the NVA be 25 cm or
        better AccuracyZ at 95 percent confidence level.
        <!--REQUIRED Element: Vertical Positional Accuracy Report
          An explanation of the accuracy of the vertical coordinate
          measurements and a description of the tests used.
```

```
          Domain: free text
        -->
      </vertaccr>
      <qvertpa>
        <vertaccv>EXAMPLE: 0.19 meters AccuracyZ at 95 percent Confidence
          Interval
          <!--REQUIRED Element: Vertical Positional Accuracy Value
            Vertical accuracy expressed in (ground) meters.
            Clearly state whether this value is RMSEz or AccuracyZ
            Domain: free text
          -->
        </vertaccv>
        <vertacce>The NVA was tested using 25 independent surveys located in
          open terrain. The survey check points were distributed throughout
          the project. The 25 independent check points were surveyed using the
          closed level loop technique. Elevations from the unclassified lidar
          surface were measured for the x,y location of each check point.
          Elevations interpolated from the lidar surface were then compared
          to the elevation values of the surveyed control. The RMSE was
          computed to be 0.097 meters. AccuracyZ has been tested to meet
          19.0 cm Fundamental Vertical Accuracy at 95 Percent confidence level
          using RMSE(z) x 1.9600 as defined by the National Standards for
          Spatial Data Accuracy (NSSDA); assessed and reported using National
          Digital Elevation Program (NDEP)/ASRPS Guidelines.
          <!--REQUIRED Element: Vertical Positional Accuracy Explanation
            Identification of the test that yielded the Vertical Positional
            Accuracy Value.
            Domain: free text
          -->
        </vertacce>
      </qvertpa>
    </vertacc>
  </posacc>
  <lineage>
    <srcinfo>
      <!--The srcinfo section of the metadata MUST be repeated for each data
        source that contributed to making this unclassified LAS swath dataset,
        including, but not limited to, 1) ground control used for calibrating
        the lidar data, 2) the actual lidar acquisition data, and 3)
        independent ground control used to assess the accuracy of the lidar
        point cloud.
      -->
      <srccite>
        <citeinfo>
          <origin>EXAMPLE: Jiffy Survey, Inc
            <!--REQUIRED Element: Originator
              This element is the name of an organization or individual that
              developed the dataset. If the creation of this data source was
              created by a subcontractor, the subcontractors name and contact
              information should be entered as the source for that
              contributing dataset.
              Domain: "Unknown" free text
            -->
          </origin>
          <pubdate>20100115
            <!--REQUIRED element: Date of Publication
              Enter the date when the dataset is published or otherwise made
              available for release.
              The format of this date must be YYYMMDD.
              Domain: "Unknown" "Unpublished material" free date
            -->
          </pubdate>
```

```
    <title>EXAMPLE: Ground Control for Phelps and Dent County, MO
      lidar project
      <!--REQUIRED Element: Title
        The name by which the first contributing dataset is known.
        Domain: free text
      -->
    </title>
    <geoform>EXAMPLE: vector digital data and tabular data
      <!--OPTIONAL Element: Enter the mode in which the geospatial data
        are represented.
        Domain: (the listed domain is partially from pp. 88-91 in
        Anglo-American Committee on Cataloguing of Cartographic
        Materials, 1982, Cartographic materials: A manual of
        interpretation for AACR2: Chicago, American Library
        Association):
        "atlas" "audio" "diagram" "document" "globe" "map" "model"
        "multimedia presentation" "profile" "raster digital data"
        "remote-sensing image" "section" "spreadsheet" "tabular
        digital data" "vector digital data" "video" "view"
        free text
      -->
    </geoform>
    <pubinfo>
      <pubplace>EXAMPLE: Jiffy Survey, Inc.
        <!--REQUIRED Element: Publication Place
          The name of the city (and state or province, and country, if
          needed to identify the city) the originator of the dataset.
          Domain: free text
        -->
      </pubplace>
      <publish>EXAMPLE: Jiffy Survey, Inc., GPS department
        <!--Enter the name of the individual or organization that
          published the dataset.
          Domain: free text
        -->
      </publish>
    </pubinfo>
    <othercit>EXAMPLE: None.
      <!--OPTIONAL Element: Other Citation Details
        Other information required to complete the citation.
        Domain: free text
      -->
    </othercit>
    <onlink>EXAMPLE: ftp://JiffySurveyftp.com/data/outgoing/Task1/
      <!--OPTIONAL Element: Online Linkage
        IF APPLICABLE: The URL of an online computer resource that
        contains the dataset.
        Domain: free text
      -->
    </onlink>
  </citeinfo>
</srccite>
<srcscale>Example: 50
  <!--OPTIONAL Element: Source Scale Denominator
    IF APPLICABLE: The denominator of the representative fraction on a
    map (for example, on a 1:24,000-scale map, the Source Scale
    Denominator is 24000).
    Domain: Source Scale Denominator > 1
  -->
</srcscale>
<typesrc>EXAMPLE: CD-ROM
  <!--REQUIRED Element: Type of Source Media
    The medium of the first source dataset.
```

```
      Domain: "paper" "stable-base material" "microfiche" "microfilm"
      "audiocassette" "chart" "filmstrip" "transparency" "videocassette"
      "videodisc" "videotape" "physical model" "computer program" "disc"
      "cartridge tape" "magnetic tape" "online" "CD-ROM"
      "electronic bulletin board" "electronic mail system" free text
    -->
  </typesrc>
  <srctime>
    <timeinfo>
      <sngdate>
        <caldate>201001003
          <!--REQUIRED Element: Calendar Date
            This date is the date of the first source dataset was created.
            The field MUST be formatted YYYYMMDD
          -->
        </caldate>
      </sngdate>
    </timeinfo>
    <srccurr>EXAMPLE: ground condition
      <!--REQUIRED Element: Source Currentness Reference
        The basis on which the source time period of content information
        of the source dataset is determined.
        Domain: "ground condition" "publication date" free text
      -->
    </srccurr>
  </srctime>
  <srccitea>EXAMPLE: Phelps_Co_lidar_gnd_ctrl
    <!--REQUIRED Element: Source Citation Abbreviation
      Enter short-form alias for the source citation.
      Each source MUST HAVE A UNIQUE ID.
      This ID will be used to reference these source data in the Process
      Step sections below.
      Domain: free text
    -->
  </srccitea>
  <srccontr>EXAMPLE: This data source was used (along with the airborne
    GPS/IMU Data) to georeferencing of the lidar point cloud data.
    <!--REQUIRED Element: Source Contribution
      Brief statement identifying the information contributed.
      Domain: free text
    -->
  </srccontr>
</srcinfo>
<srcinfo>
  <srccite>
    <citeinfo>
      <origin>USDA</origin>
      <pubdate>20090606</pubdate>
      <title>NAIP Imagery for Phelps and Dent County, MO lidar project
      </title>
      <geoform>raster orthoimagery</geoform>
      <pubinfo>
        <pubplace>USGS-EROS</pubplace>
        <publish>USGS-EROS</publish>
      </pubinfo>
      <othercit>None</othercit>
      <onlink></onlink>
    </citeinfo>
  </srccite>
  <srcscale>50</srcscale>
  <typesrc>online</typesrc>
  <srctime>
    <timeinfo>
      <sngdate>
```

```
        <caldate>20090101</caldate>
      </sngdate>
    </timeinfo>
    <srccurr>ground condition</srccurr>
  </srctime>
  <srccitea>Phelps-Dent_Co_NAIP_Imagery</srccitea>
  <srccontr>This data source was used (along with the lidar intensity
    imagery) to classify the lidar point cloud data.
  </srccontr>
</srcinfo>
<srcinfo>
  <srccite>
    <citeinfo>
      <origin>We Map 4U, Inc.</origin>
      <pubdate>20101208</pubdate>
      <title>Lidar Intensity Imagery for Phelps and Dent County, MO
      </title>
      <geoform>raster orthoimagery</geoform>
      <pubinfo>
        <pubplace>USGS-EROS</pubplace>
        <publish>USGS-EROS</publish>
      </pubinfo>
      <othercit>None</othercit>
      <onlink></onlink>
    </citeinfo>
  </srccite>
  <srcscale>50</srcscale>
  <typesrc>online</typesrc>
  <srctime>
    <timeinfo>
  <rngdates>
    <begdate>20100216</begdate>
    <enddate>20100218</enddate>
  </rngdates>
    </timeinfo>
    <srccurr>ground condition</srccurr>
  </srctime>
  <srccitea>Phelps-Dent_Co_Lidar_Intensity_Imagery</srccitea>
  <srccontr>This data source was used (along with NAIP imagery)
    to classify the lidar point cloud data.
  </srccontr>
</srcinfo>
<procstep>
  <procdesc>EXAMPLE: Lidar Preprocessing: Airborne GPS and IMU data were
    merged to develop a Single Best Estimate (SBET) of the lidar system
    trajectory for each lift. Lidar ranging data were initially calibrated
    using previous best parameters for this instrument and aircraft.
    Relative calibration was evaluated using advanced plane-matching
    analysis and parameter corrections derived. This process was repeated
    iteratively until residual errors between overlapping swaths, across
    all project lifts, was reduced to 2 cm or less. Data were then block
    adjusted to match surveyed calibration control. Raw data NVA were
    checked using independently surveyed check points. Swath overage
    points were identified and tagged within each swath file.
    <!--Enter an explanation of the event and related parameters or
      tolerances.
      Domain: free text
    -->
  </procdesc>
  <srcused>EXAMPLE: Phelps_Co_lidar_gnd_ctrl
    <!--Enter the Source Citation Abbreviation of a dataset used in the
      processing step.
      Domain: Source Citation Abbreviations from the Source Information
      entries for the dataset.
```

```
      -->
    </srcused>
    <procdate>20100131
      <!--Enter the date when the event was completed.
        Domain: "Unknown" "Not complete" free date
      -->
    </procdate>
    <srcprod>EXAMPLE: Lidar datasets with USGS classifications
      <!--Enter the Source Citation Abbreviation of an intermediate dataset
        that (1) is significant in the opinion of the data producer,
        (2) is generated in the processing step, and
        (3) is used in later processing steps.
        Domain: Source Citation Abbreviations from the Source Information
        entries for the dataset.
      -->
    </srcprod>
    <proccont>
      <cntinfo>
        <cntorgp>
          <cntorg>EXAMPLE: We Map 4U, Data Acquisition Department
            <!--Enter the name of the organization to which the contact type
              applies.
              Domain: free text
            -->
          </cntorg>
          <cntper>EXAMPLE: Manny Puntas
            <!--Enter the name of the individual to which the contact type
              applies.
              Domain: free text
            -->
          </cntper>
        </cntorgp>
        <cntaddr>
          <addrtype>mailing and physical</addrtype>
          <address>123 Main St.</address>
          <city>Anytown</city>
          <state>MO</state>
          <postal>61234</postal>
          <country>USA</country>
        </cntaddr>
        <cntvoice>555-555-556</cntvoice>
        <cntfax>555-5550-1236</cntfax>
        <cntemail>mpuntas@wemap4u.com</cntemail>
        <hours>Monday through Friday 8:00 AM to 4:00 PM (Central Time)
        </hours>
        <cntinst>If unable to reach the contact by telephone, please
          send an email. You should get a response within 24 hours.
        </cntinst>
      </cntinfo>
    </proccont>
  </procstep>
  <procstep>
    <procdesc>Lidar Post-Processing: The calibrated and controlled lidar
      swaths were processed using automatic point classification routines
      in proprietary software. These routines operate against the entire
      collection (all swaths, all lifts), eliminating character differences
      between files. Data were then distributed as virtual tiles to
      experienced lidar analysts for localized automatic classification,
      manual editing, and peer-based QC checks. Supervisory QC monitoring
      of work in progress and completed editing ensured consistency of
      classification character and adherence to project requirements across
      the entire project. All classification tags are stored in the original
      swath files. After completion of classification and final QC approval,
```

```
        the NVA and VVA for the project are calculated. Sample areas for each
        land cover type present in the project were extracted and forwarded
        to the client, along with the results of the accuracy tests. Upon
        acceptance, the complete classified lidar swath files were delivered
        to the client.
      </procdesc>
      <srcused>Phelps-Dent_Co_NAIP_Imagery</srcused>
      <srcused>Phelps-Dent_Co_Lidar_Intensity_Imagery</srcused>
      <procdate>20100530</procdate>
      <proccont>
        <cntinfo>
          <cntorgp>
            <cntorg>We Map 4U, Data Acquisition Department</cntorg>
            <cntper>Manny Puntas</cntper>
          </cntorgp>
          <cntaddr>
            <addrtype>mailing and physical</addrtype>
            <address>123 Main St.</address>
            <city>Anytown</city>
            <state>MO</state>
            <postal>61234</postal>
            <country>USA</country>
          </cntaddr>
          <cntvoice>555-555-556</cntvoice>
          <cntfax>555-5550-1236</cntfax>
          <cntemail>mpuntas@wemap4u.com</cntemail>
          <hours>Monday through Friday 8:00 AM to 4:00 PM (Central Time)
          </hours>
          <cntinst>If unable to reach the contact by telephone, please
            send an email. You should get a response within 24 hours.
          </cntinst>
        </cntinfo>
      </proccont>
    </procstep>
  </lineage>
</dataqual>
<spdoinfo>
  <direct>EXAMPLE: Vector
    <!--REQUIRED Element: Enter the system of objects used to represent
      space in the dataset.
      Domain: "Point" "Vector" "Raster"
    -->
  </direct>
  <ptvctinf>
    <sdtsterm>
      <sdtstype>EXAMPLE: Point
        <!--REQUIRED Element: SDTS Point and Vector Object Type
          Enter name of point and vector spatial objects used to locate
          zero-, one-, and two-dimensional spatial locations in the dataset.
          Domain: (The domain is from "Spatial Data Concepts," which is
          Chapter 2 of Part 1 in Department of Commerce, 1992, Spatial Data
          Transfer Standard (SDTS) (Federal Information Processing Standard
          173): Washington, Department of Commerce, National Institute of
          Standards and Technology):
          "Point"
        -->
      </sdtstype>
      <ptvctcnt>EXAMPLE: 764,567,423
        <!--OPTIONAL Element: Point and Vector Count
          Enter the total number of the point or vector object type occurring
          in the dataset.
          Domain: Point and Vector Object Count > 0
        -->
```

```
      </ptvctcnt>
    </sdtsterm>
  </ptvctinf>
</spdoinfo>
<spref>
  <horizsys>
    <planar>
      <gridsys>
        <!--REQUIRED Section: The section should be filled out with the
          relevant parameters for the coordinate reference system for the
          data. Usually it will be UTM or a State Plane Zone. Delete the
          irrelevant section below.
        -->
        <gridsysn>EXAMPLE: Universal Transverse Mercator
          <!--Enter name of the grid coordinate system.
            Domain: "Universal Transverse Mercator"
            "Universal Polar Stereographic"
            "State Plane Coordinate System 1927"
            "State Plane Coordinate System 1983"
            "ARC Coordinate System"
            "other grid system"
          -->
        </gridsysn>
        <utm>
          <utmzone>EXAMPLE: 15
            <!--Enter the  identifier for the UTM zone.
              Type: integer
              Domain:
              1 <= UTM Zone Number <= 60 for the northern hemisphere;
              -60 <= UTM Zone Number <= -1 for the southern hemisphere
            -->
          </utmzone>
          <transmer>
            <sfctrmer>0.9996
              <!--Enter a multiplier for reducing a distance obtained from a
                map by computation or scaling to the actual distance along the
                Central Meridian.
                Domain: Scale Factor at Central Meridian > 0.0
              -->
            </sfctrmer>
            <longcm>-117.000000
              <!--Enter the line of longitude at the center of a map
                projection generally used as the basis for constructing the
                projection.
                Type: real
                Domain: -180.0 <= Longitude of Central Meridian < 180.0
              -->
            </longcm>
            <latprjo>0.0
              <!--Enter latitude chosen as the origin of rectangular
                coordinates for a map projection.
                Domain: -90.0 <= Latitude of Projection Origin <= 90.0
              -->
            </latprjo>
            <feast>500000
              <!--Enter the value added to all "x" values in the rectangular
                coordinates for a map projection. This value is frequently
                assigned to eliminate negative numbers. Expressed in the unit
                of measure identified in Planar Coordinate Units.
                Domain: free real
              -->
            </feast>
```

```
    <fnorth>0.0
      <!--Enter the value added to all "y" values in the rectangular
        coordinates for a map projection. This value is frequently
        assigned to eliminate negative numbers. Expressed in the unit
        of measure identified in Planar Coordinate Units.
        Domain: free real
      -->
    </fnorth>
  </transmer>
</utm>
<spcs>
  <spcszone>
    <!--Enter identifier for the SPCS zone.
      Domain: Four-digit numeric codes for the State Plane Coordinate
      Systems based on the North American Datum of 1927 are documented
      in Department of Commerce, 1986, Representation of geographic
      information interchange (Federal Information Processing Standard
      70-1): Washington: Department of Commerce, National Institute of
      Standards and Technology.
      Codes for the State Plane Coordinate Systems based on the North
      American Datum of 1983 are documented in Department of Commerce,
      1989 (January), State Plane Coordinate System of 1983 (National
      Oceanic and Atmospheric Administration Manual NOS NGS 5): Silver
      Spring MD, National Oceanic and Atmospheric Administration,
      National Ocean Service, Coast and Geodetic Survey.
    -->
  </spcszone>
  <lambertc>
    <stdparll>
      <!--Enter line of constant latitude at which the surface of the
        Earth and the plane of projection intersect.
        Domain: -90.0 <= Standard Parallel <= 90.0
      -->
    </stdparll>
    <longcm>
      <!--Enter the line of longitude at the center of a map
        projection generally used as the basis for constructing the
        projection.
        Domain: -180.0 <= Longitude of Central Meridian < 180.0
      -->
    </longcm>
    <latprjo>
      <!--Enter latitude chosen as the origin of rectangular
        coordinates for a map projection.
        Domain: -90.0 <= Latitude of Projection Origin <= 90.0
      -->
    </latprjo>
    <feast>
      <!--Enter the value added to all "x" values in the rectangular
        coordinates for a map projection. This value is frequently
        assigned to eliminate negative numbers. Expressed in the unit
        of measure identified in Planar Coordinate Units.
        Domain: free real
      -->
    </feast>
    <fnorth>
      <!--Enter the value added to all "y" values in the rectangular
        coordinates for a map projection. This value frequently is
        assigned to eliminate negative numbers. Expressed in the unit
        of measure identified in Planar Coordinate Units.
        Domain: free real
      -->
    </fnorth>
```

```
</lambertc>
<transmer>
  <sfctrmer>
    <!--Enter a multiplier for reducing a distance obtained from a
      map by computation or scaling to the actual distance along the
      central meridian.
      Domain: Scale Factor at Central Meridian > 0.0
    -->
  </sfctrmer>
  <longcm>
    <!--Enter the line of longitude at the center of a map
      projection generally used as the basis for constructing the
      projection.
      Type: real
      Domain: -180.0 <= Longitude of Central Meridian < 180.0
    -->
  </longcm>
  <latprjo>
    <!--Enter latitude chosen as the origin of rectangular
      coordinates for a map projection.
      Domain: -90.0 <= Latitude of Projection Origin <= 90.0
    -->
  </latprjo>
  <feast>
    <!--Enter the value added to all "x" values in the rectangular
      coordinates for a map projection. This value is frequently
      assigned to eliminate negative numbers. Expressed in the unit
      of measure identified in Planar Coordinate Units.
      Domain: free real
    -->
  </feast>
  <fnorth>
    <!--Enter the value added to all "y" values in the rectangular
      coordinates for a map projection. This value is frequently
      assigned to eliminate negative numbers. Expressed in the unit
      of measure identified in Planar Coordinate Units.
      Domain: free real
    -->
  </fnorth>
</transmer>
<obqmerc>
  <sfctrlin>
    <!--Enter a multiplier for reducing a distance obtained from a
      map by computation or scaling to the actual distance along the
      center line.
      Domain: Scale Factor at Center Line > 0.0
    -->
  </sfctrlin>
  <obqlazim>
    <azimangl>
      <!--Enter angle measured clockwise from north, and expressed
        in degrees.
        Domain: 0.0 <= Azimuthal Angle < 360.0
      -->
    </azimangl>
    <azimptl>
      <!--Enter longitude of the map projection origin.
        Domain: -180.0 <= Azimuth Measure Point Longitude < 180.0
      -->
    </azimptl>
  </obqlazim>
  <obqlpt>
    <obqllat>
```

```
      <!--Enter latitude of a point defining the oblique line.
        Domain: -90.0 <= Oblique Line Latitude <= 90.0
      -->
    </obqllat>
    <obqllong>
      <!--Enter longitude of a point defining the oblique line.
        Domain: -180.0 <= Oblique Line Longitude < 180.0
      -->
    </obqllong>
  </obqlpt>
  <latprjo>
    <!--Enter latitude chosen as the origin of rectangular
      coordinates for a map projection.
      Domain: -90.0 <= Latitude of Projection Origin <= 90.0
    -->
  </latprjo>
  <feast>
    <!--Enter the value added to all "x" values in the rectangular
      coordinates for a map projection. This value is frequently
      assigned to eliminate negative numbers. Expressed in the unit
      of measure identified in Planar Coordinate Units.
      Domain: free real
    -->
  </feast>
  <fnorth>
    <!--Enter the value added to all "y" values in the rectangular
      coordinates for a map projection. This value is frequently
      assigned to eliminate negative numbers. Expressed in the unit
      of measure identified in Planar Coordinate Units.
      Domain: free real
    -->
  </fnorth>
</obqmerc>
<polycon>
  <longcm>
    <!--Enter the line of longitude at the center of a map
      projection generally used as the basis for constructing the
      projection.
      Domain: -180.0 <= Longitude of Central Meridian < 180.0
    -->
  </longcm>
  <latprjo>
    <!--Enter latitude chosen as the origin of rectangular
      coordinates for a map projection.
      Domain: -90.0 <= Latitude of Projection Origin <= 90.0
    -->
  </latprjo>
  <feast>
    <!--Enter the value added to all "x" values in the rectangular
      coordinates for a map projection. This value is frequently
      assigned to eliminate negative numbers. Expressed in the unit
      of measure identified in Planar Coordinate Units.
      Domain: free real
    -->
  </feast>
  <fnorth>
    <!--Enter the value added to all "y" values in the rectangular
      coordinates for a map projection. This value is frequently
      assigned to eliminate negative numbers. Expressed in the unit
      of measure identified in Planar Coordinate Units.
      Domain: free real
    -->
  </fnorth>
```

```
        </polycon>
      </spcs>
    </gridsys>
    <planci>
      <plance>EXAMPLE: coordinate pair</plance>
      <!--REQUIRED Element: Planar Coordinate Encoding Method - the means
        used to represent horizontal positions.
        Domain: : "coordinate pair" "distance and bearing" "row and column"
        free text
      -->
      <coordrep>
        <absres>0.01
          <!--REQUIRED Element: Horizontal Resolution in X: The minimum
            distance possible between two adjacent horizontal values in the
            X direction in the horizontal Distance Units of measure.
            Domain: Abscissa Resolution > 0.0
          -->
        </absres>
        <ordres>EXAMPLE: 0.01
          <!--REQUIRED Element: Horizontal Resolution in Y: The minimum
            distance possible between two adjacent horizontal values in the
            Y direction in the horizontal Distance Units of measure.
            Domain: Ordinate Resolution > 0.0
          -->
        </ordres>
      </coordrep>
      <plandu>EXAMPLE: meters
        <!--REQUIRED Element: Units in which elevations are recorded.
          Domain: "meters" "U.S. feet" "Intl. feet" free text
        -->
     </plandu>
    </planci>
  </planar>
  <geodetic>
    <horizdn>EXAMPLE: North American Datum of 1983
      <!--REQUIRED Element: Enter the identification given to the reference
        system used for defining the coordinates of points.
        Domain: "North American Datum of 1927"
        "North American Datum of 1983"
        free text
      -->
    </horizdn>
    <ellips>EXAMPLE: Geodetic Reference System 80
      <!--REQUIRED Element: Enter identification given to established
        representations of the Earth's shape.
        Domain: "Clarke 1866" "Geodetic Reference System 80" free text
      -->
    </ellips>
    <semiaxis>6378137
      <!--REQUIRED Element: Enter radius of the equatorial axis of the
        ellipsoid.
        Domain: Semi-major Axis > 0.0
      -->
    </semiaxis>
    <denflat>298.257222101
      <!--REQUIRED Element: Enter the denominator of the ratio of the
        difference between the equatorial and polar radii of the ellipsoid
        when the numerator is set to 1.
        Domain: Denominator of Flattening > 0.0
      -->
    </denflat>
  </geodetic>
</horizsys>
```

```
  <vertdef>
    <altsys>
      <altdatum>EXAMPLE: North American Vertical Datum of 1988
        <!--REQUIRED Element: Vertical Datum: The surface of reference from
          which vertical distances are measured.
          Domain: "National Geodetic Vertical Datum of 1929"
          "North American Vertical Datum of 1988"
          free text
        -->
      </altdatum>
      <altres>EXAMPLE: 0.01
        <!--REQUIRED Element: Vertical Resolution: The minimum distance
          possible between two adjacent elevation values, expressed in
          Distance Units of measure.
          Domain: Elevation Resolution > 0.0
        -->
      </altres>
      <altunits>EXAMPLE: meters
        <!--REQUIRED Element: Units in which elevations are recorded.
          Domain: "meters" "feet" free text
        -->
      </altunits>
      <altenc>EXAMPLE: Explicit elevation coordinate included with horizontal
        coordinates
        <!--REQUIRED Element: Encoding Method: The means used to encode the
          elevations.
          Domain: "Explicit elevation coordinate included with horizontal
          coordinates" "Implicit coordinate" "Attribute values"
        -->
      </altenc>
    </altsys>
  </vertdef>
</spref>
<eainfo>
  <!--OPTIONAL Section: Entity and Attribute Information
    THIS SECTION IS NOT REQUIRED FOR LIDAR LAS DELIVERABLES.
    This section is only required for deliverable data classified as a
    Feature Class.
  -->
</eainfo>
<distinfo>
  <!--OPTIONAL Section: Distribution Information: Information about the distributor
    of and options for obtaining the dataset.
    THIS SECTION SHOULD ONLY BE POPULATED IF SOME ORGANIZATION OTHER THAN
    USGS HAS DISTRIBUTION RIGHTS TO THE DATA.
  -->
  <distrib>
    <cntinfo>
      <cntorgp>
        <cntorg>Leave blank unless an organization outside of USGS has
          distribution rights to the data.
        </cntorg>
        <cntper>Leave blank unless an organization outside of USGS has
          distribution rights to the data.
        </cntper>
      </cntorgp>
      <cntaddr>
        <addrtype>Leave blank unless an organization outside of USGS has
          distribution rights to the data.
        </addrtype>
        <address>Leave blank unless an organization outside of USGS has
          distribution rights to the data.
        </address>
```

```
        <city>Leave blank unless an organization outside of USGS has
          distribution rights to the data.
        </city>
        <state>Leave blank unless an organization outside of USGS has
          distribution rights to the data.
        </state>
        <postal>Leave blank unless an organization outside of USGS has
          distribution rights to the data.
        </postal>
        <country>Leave blank unless an organization outside of USGS has
          distribution rights to the data.
        </country>
      </cntaddr>
      <cntvoice>Leave blank unless an organization outside of USGS has
        distribution rights to the data.
      </cntvoice>
      <cntemail>Leave blank unless an organization outside of USGS has
        distribution rights to the data.
      </cntemail>
    </cntinfo>
  </distrib>
  <resdesc>Leave blank unless an organization outside of USGS has
    distribution rights to the data.
  </resdesc>
  <distliab>Leave blank unless an organization outside of USGS has
    distribution rights to the data.
  </distliab>
</distinfo>
<metainfo>
  <!--REQUIRED Section: Metadata Reference Information: Information on the
    currentness of the metadata information, and the party responsible for
    the metadata.
  -->
  <metd>20101206
    <!--REQUIRED Element: Metadata Date: The date that the metadata were
      created or last updated.
      Must be in the format YYYYMMDD.
    -->
  </metd>
  <metrd>20101207
    <!--OPTIONAL Element: Metadata Review Date: The date of the latest
      review of the metadata entry.
      Must be in the format YYYYMMDD.
      Domain: Metadata Review Date later than Metadata Date
    -->
  </metrd>
  <metc>
    <cntinfo>
      <cntorgp>
        <cntorg>EXAMPLE: We Map 4U, Data Acquisition Department
          <!--REQUIRED Element: Contact Organization: The name of the
            organization that is responsible for creating the metadata.
            Domain: free text
          -->
        </cntorg>
        <cntper>EXAMPLE: John Smith
          <!--REQUIRED Element: Contact Person: The name of the individual
            who is the contact person concerning the metadata.
            Domain: free text
          -->
        </cntper>
      </cntorgp>
      <cntaddr>
```

```
  <addrtype>EXAMPLE: mailing and physical
    <!--REQUIRED Element: Address Type: The type of address that
      follows. Only required for "mailing" or "mailing and physical".
      If the contractor has a different mailing and physical address,
      the physical address does not need to be included.
      Domain: "mailing" "physical" "mailing and physical", free text
    -->
  </addrtype>
  <address>EXAMPLE: 123 Main St.
    <!--REQUIRED Element: Address: The address of the contractor
      responsible for the metadata. For multiple line addresses the
      address tag may be repeated as many times as needed.
      Domain: free text
    -->
  </address>
  <city>EXAMPLE: Anytown
    <!--REQUIRED Element: City: The city of the address.
      Domain: free text
    -->
  </city>
  <state>EXAMPLE: MO
    <!--REQUIRED Element: State: The state or province of the address.
      Domain: free text
    -->
  </state>
  <postal>EXAMPLE: 61234
    <!--REQUIRED Element: Postal Code: Enter the ZIP or other postal
      code of the address.
      Domain: free text
    -->
  </postal>
  <country>EXAMPLE: USA
    <!--OPTIONAL Element: Country: The country of the address.
      Domain: free text
    -->
  </country>
</cntaddr>
<cntvoice>EXAMPLE: 555-555-1234
  <!--REQUIRED Element: Contact Voice Telephone: The telephone number
    by which individuals can speak to the organization or individual
    responsible for the metadata.
    Domain: free text
  -->
</cntvoice>
<cnttdd>EXAMPLE: 555-555-1122
  <!--OPTIONAL Element: Contact TDD/TTY Telephone: The telephone number
    by which hearing-impaired individuals can contact the organization
    or individual.
    Domain: free text
  -->
</cnttdd>
<cntfax>EXAMPLE: 555-5550-1235
  <!--OPTIONAL Element: Contact Fax: The telephone number of a
    facsimile machine of the organization or individual.
    Domain: free text
  -->
</cntfax>
<cntemail>EXAMPLE: jsmith@wemap4u.com
  <!--OPTIONAL Element: Contact E-mail Address: The email address
    of the organization or individual.
    Domain: free text
  -->
</cntemail>
```

```
    <hours>EXAMPLE: Monday through Friday 8:00 AM to 4:00 PM (Central Time)
      <!--OPTIONAL Element: Hours of Service: The time period when
        individuals can speak to the organization or individual.
        Domain: free text
      -->
    </hours>
    <cntinst>EXAMPLE: If unable to reach the contact by telephone, please
      send an email. You should get a response within 24 hours.
      <!--OPTIONAL Element: Contact Instructions: Supplemental instructions
        on how or when to contact the individual or organization.
        Domain: free text
      -->
    </cntinst>
  </cntinfo>
</metc>
<metstdn>EXAMPLE: FGDC Content Standard for Digital Geospatial Metadata
  <!--REQUIRED Element: Metadata Standard: Enter the name of the metadata
    standard used to document the dataset.
    Domain: "FGDC Content Standard for Digital Geospatial Metadata"
    free text
  -->
</metstdn>
<metstdv>EXAMPLE: FGDC-STD-001-1998
  <!--REQUIRED Element: Metadata Standard Version. Enter identification of
    the version of the metadata standard used to document the dataset.
    Domain: free text
  -->
</metstdv>
<metac>EXAMPLE: None.
  <!--OPTIONAL Element: Metadata Access Constraints: Restrictions and legal
    prerequisites for accessing the metadata. These include any access
    constraints applied to assure the protection of privacy or intellectual
    property, and any special restrictions or limitations on obtaining the
    metadata.
    Domain: free text
  -->
</metac>
<metuc>EXAMPLE: None.
  <!--OPTIONAL Element: Metadata Use Constraints: Restrictions and legal
    prerequisites for using the metadata after access is granted. These
    include any metadata use constraints applied to assure the protection
    of privacy or intellectual property, and any special restrictions or
    limitations on using the metadata.
    Domain: free text
  -->
</metuc>
<metsi>
  <metscs>EXAMPLE: None.
    <!--REQUIRED IF APPLICABLE: Metadata Security Classification System:
      Name of the classification system for the metadata.
      Domain: free text
    -->
  </metscs>
  <metsc>EXAMPLE: Unclassified
    <!--REQUIRED IF APPLICABLE: Metadata Security Classification: Name of
      the handling restrictions on the metadata.
      Domain: "Top secret" "Secret" "Confidential" "Restricted"
      "Unclassified" "Sensitive" free text
    -->
  </metsc>
  <metshd>EXAMPLE: NONE
    <!--REQUIRED IF APPLICABLE: Metadata Security Handling Description:
      Additional information about the restrictions on handling the
      metadata.
```

```
        Domain: free text
      -->
    </metshd>
  </metsi>
  <metextns>
    <!--Metadata Extensions Group: REQUIRED IF APPLICABLE. A reference to
      extended elements to the standard that may be defined by a metadata
      producer or a user community. Extended elements are elements outside
      the Standard, but needed by the metadata producer. If extended elements
      are created, they must follow the guidelines in Appendix D, Guidelines
      for Creating Extended Elements to the Content Standard for Digital
      Geospatial Metadata.
    -->
    <!--This section may be repeated as necessary-->
    <onlink>EXAMPLE: None
      <!--REQUIRED IF APPLICABLE: Online Linkage: URL for the resource that
        contains the metadata extension information for the dataset.
      -->
    </onlink>
    <metprof>EXAMPLE: None
      <!--REQUIRED IF APPLICABLE: Profile Name: Name of a document that
        describes the application of the Standard to a specific user
        community.
      -->
    </metprof>
  </metextns>
 </metainfo>
</metadata>
```

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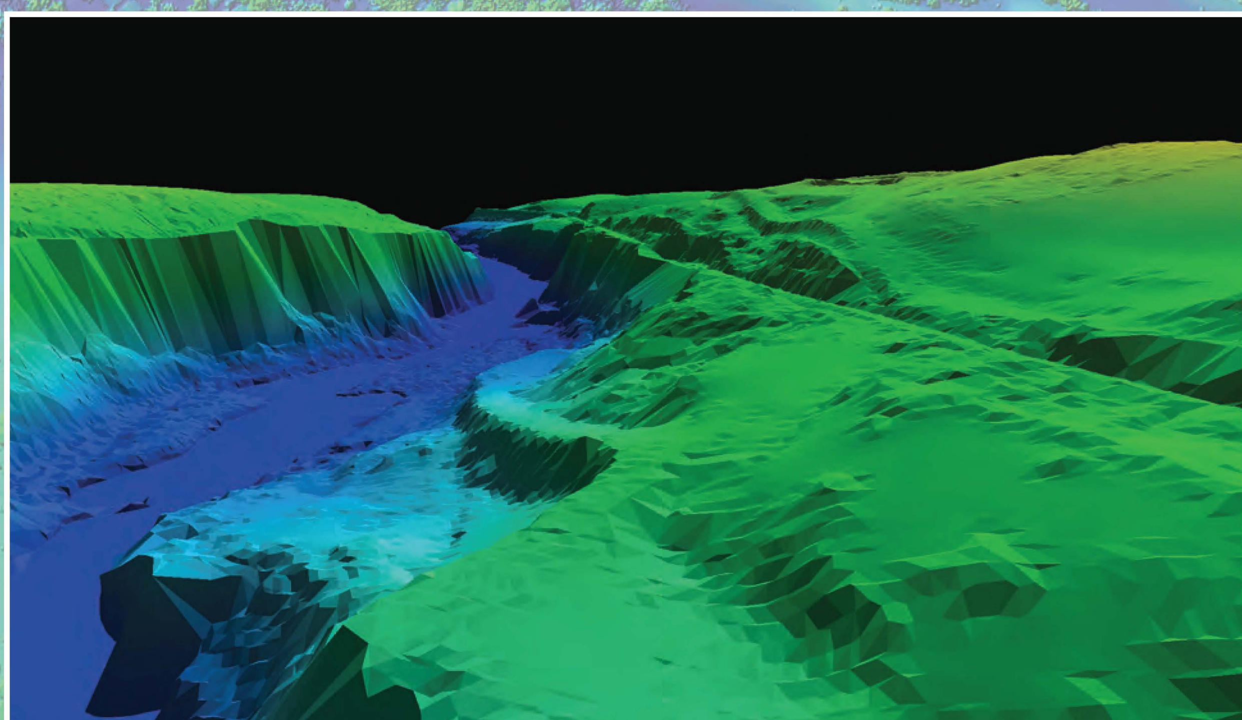
Heidemann—Lidar Base Specification—Techniques and Methods 11–B4, ver 1.2



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APPENDIX Q

USGS AERIAL CAMERA SPECIFICATIONS – ANALOG METRIC FILM CAMERA

USGS AERIAL CAMERA SPECIFICATIONS

PRECISION AERIAL MAPPING CAMERA

Tested and calibrated aerial cameras for taking aerial photographs are required. Camera systems must be compatible with precision stereoscopic mapping instruments and with analytical mensuration procedures used in photogrammetric surveys and in preparing accurate topographic maps.

1. Camera System "Report of Calibration"

One copy of the "Report of Calibration" from the U.S. Geological Survey, for any camera system to be used, is required to be either on file at the USGS, or submitted with contractor's solicitation bid. A camera system "Report of Calibration" will not be acceptable if more than three (3) years old at the scheduled opening date of the solicitation.

2. Calibration Tests

Tests to determine compliance with these specifications will be performed by the Optical Science Laboratory of the U.S. Geological Survey. The fee for the tests and the arrangements to have the tests performed are the responsibility of the contractor. Delays encountered in having camera systems tested by the USGS Optical Science Laboratory will not be considered reason for the USGS to accept bids lacking such reports. Each camera system submitted for calibration shall be accompanied by all magazines and filters that might be used with the camera. Controls and camera mounts should not be submitted unless requested by the calibrating laboratory.

2.1. Interval Between Tests

The interval between tests for camera system calibrations shall not exceed three (3) years, unless otherwise approved by the Contracting Officer. However, when there is any reason to believe that the dimensional relationship of the lens, fiducial marks, and film plane have been disturbed by partial disassembly or unusual mechanical shock, the camera must be submitted for recalibration at contractor expense.

2.2. Contact for Calibration Tests

U.S. Geological Survey
Optical Science Laboratory
518 National Center
Reston, Virginia 20192
Attention: Chief, Optical Science Laboratory
Phone: (703) 648-4793

2.3. Shipping Address for Calibration Tests

U.S. Geological Survey
Optical Science Laboratory
12201 Sunrise Valley Drive
Reston, Virginia 20192
Attention: Scott Stephens (703) 648-4793

3. Constructional Design Necessary to Permit Testing

To permit testing for determination of calibrated focal length, distortion, resolving power, fiducial mark locations, and stereomodel flatness, the constructional design of the camera shall be as follows:

3.1. Focal Plane

The focal plane shall be accessible from the rear so that a telescope placed behind the camera may view objects in front of the lens, limited only by the size of the focal plane opening. It shall be possible to place the surface of an optical flat having a thickness of 31 mm (1 1/4 in.) on the focal plane of the camera.

3.2. Focal Plane Frame

The focal plane frame shall be so constructed as to permit placement of a glass photographic plate on its surface so that the emulsion surface of the glass photographic plate lies in the true focal plane of the camera. The size of the frame image shall be 23 x 23 cm (9 x 9 inches).

4. Camera Components Required for Testing

4.1. Lens Cone Assembly

The lens cone assembly must be so constructed that the lens and fiducial marks comprise an integral unit. The design of the lens cone shall be such that it maintains the required precise relationship between the lens, fiducial marks, and focal plane on which the film platen shall be positioned. Construction shall be such as to maintain the dimensional relationship of these components under normal conditions of transportation, handling, and use, which can include considerable mechanical and thermal shock. The structure holding these components shall be supported in use in such a manner that stresses likely to change the required dimensional relationships cannot be transmitted to it from the supporting body or mount. The lens cone assembly shall be so designed and manufactured that all parts will return precisely to their original positions, should it be necessary for any reason to disassemble it. However, any disassembly of the lens cone assembly shall require recalibration at contractor's expense before further use.

4.2. Film Platen

Cameras shall be equipped with an approved means of flattening the film at the instant of exposure. The platen against which the film is held shall not depart by more than " 0.013 mm from a true plane, when the camera/magazine vacuum is applied.

4.3. Shutter

The camera shall be equipped with a between-the-lens shutter of the variable-speed type. The range of speed settings shall be such that, for all anticipated combinations of flight heights, aircraft speeds, film speeds, and light conditions, the camera will produce high-resolution photographs. The effective exposure time and efficiency of the shutter as mounted in the camera will be measured at a maximum aperture and shall have a minimum efficiency of 70 percent at a speed of 1/200 second. This test shall be made in accordance with International Standard ISO 516:1999(E). The shutter shall have a speed of 1/400 second and slower for exposing film negatives during calibration.

4.4. Fiducial Marks

Eight fiducial marks are required. The corner fiducial marks shall form a quadrilateral whose sides are equal within "0.50 mm. The midside fiducial marks shall be equidistant within "0.50 mm from the adjacent corner fiducial marks. All fiducial marks and other marks intended for precise measuring shall be clear and well-defined on the aerial film and shall be of such a form and contrast that the standard deviation of repeated reading of the coordinates of each made on a precision comparator shall not exceed 0.002 mm. For cameras with projection type fiducial marks the projected images of all marks must be in sharp focus on the emulsion surface. Drawings in figure 1 show acceptable fiducial marks and their arrangements. Fiducials without a center point mark or intersecting lines will not be acceptable. Glass or plastic mounts for fiducial marks will not be acceptable.

4.4.1. Fiducial Pairs

The lines joining opposite pairs of fiducial markers shall intersect at an angle within one minute of 90 degrees. (See figure 2.)

4.4.2. Fiducial Intersections

The intersection of lines between fiducials --the indicated principal point--shall not be further than 0.030 mm from the point of autocollimation. (See figure 2.)

4.5. Filter

Only glass filters with metallic antivignetting coating shall be used to reduce the illumination for uniform distribution of light over the focal plane format. A microdensitometer trace will be made from the antivignetting coating side of the filter to determine if any deterioration is present that would affect the uniformity of illumination in the focal plane. Deteriorations in excess of 50% of the height of the nominal curve for a lens type will be reason for rejection of a filter. The surface with the antivignetting coating shall be toward the camera lens. The filter shall have surfaces parallel within 10 seconds of arc, and its optical quality shall be such that its addition to the camera shall enhance the uniformity of focal plane illumination and not cause a reduction in image resolution.

5. Lens and Platen/Magazine Identification

The camera or lens number, and the most recent calibrated focal length shall be recorded clearly on the film for each frame either on the inside of the focal plane frame or on a data strip between frames. An alpha numeric mark (or symbol) contained in the platen/magazine which identifies the platen/magazine shall also be recorded on each frame of film. Data markers located on the inside of the focal plane frame shall not exceed 6.35 mm (0.25 inch) in height and 25.4 mm (1.0 inch) in length and shall not obscure any part of the fiducial marks.

6. Optical Requirements

Cameras will be given both a static and an operational type test made after final assembly of all parts of the camera system with the light filter in place on the lens. All tests of the lens cone assembly for determination of the calibration constants, calibrated focal length, distortion and resolution will be made using high contrast targets and AGFA APX Calibration Plates. Cameras will be operationally tested for stereomodel flatness and resolution by exposing Eastman Kodak Double -X Aerographic film 2405 in the camera while mounted on a multicollimator camera calibrator. (The optical requirements for distortion, model flatness, and resolution for various focal length cameras are defined and tabulated in table 1.)

6.1. Distortion

6.1.1. Radial

The distortion in image position as measured along radial lines from the principal point of symmetry. The value of the average radial distortion referred to the calibrated focal length shall not exceed the amount shown in table 1.

6.1.2. Decentering

Decentering distortion is the distortion in image position as measured perpendicular to radial lines from the principal point of symmetry. The value of the decentering distortion shall not exceed the amount shown in table 1.

6.2. Point of Symmetry

The calibrated principal point C the point of symmetry C shall not be further than 0.015 mm from the point of autocollimation for 153 mm focal length lenses and no further than 0.030 mm for all other focal length lenses. (See figure 2 and table 1.)

6.3. Resolution

Radial and tangential resolving power, in line pairs per millimeter, shall be no less than the value listed in table 1 for each focal length lens.

6.4. Test Aperture

All camera-lens calibration tests shall be made at the maximum aperture specified by the manufacturer for that lens.

6.5. Model Flatness

The model flatness test will be performed only for 153 mm and 88 mm cameras. Diapositives will be printed from two film exposures of the collimator targets on micro flat glass plates. Two stereomodels will be analytically formed from these using different halves of the exposures for each model. Each model thus formed will consist of a small fixed number of symmetrically arranged points. The allowable deviation from flatness, taken as the range between the maximum negative and the maximum positive value shall be no greater than " 1/8000 of the focal length of a nominal 6-inch (153-mm) camera, or " 1/5000 of the focal length of a nominal 3 1/2- inch (85-88 mm) camera. If elevation discrepancies exceed this value, the camera will not be acceptable. (See table 1.)

Figure 1
EXAMPLES OF ACCEPTABLE FORMS OF FIDUCIAL MARKS

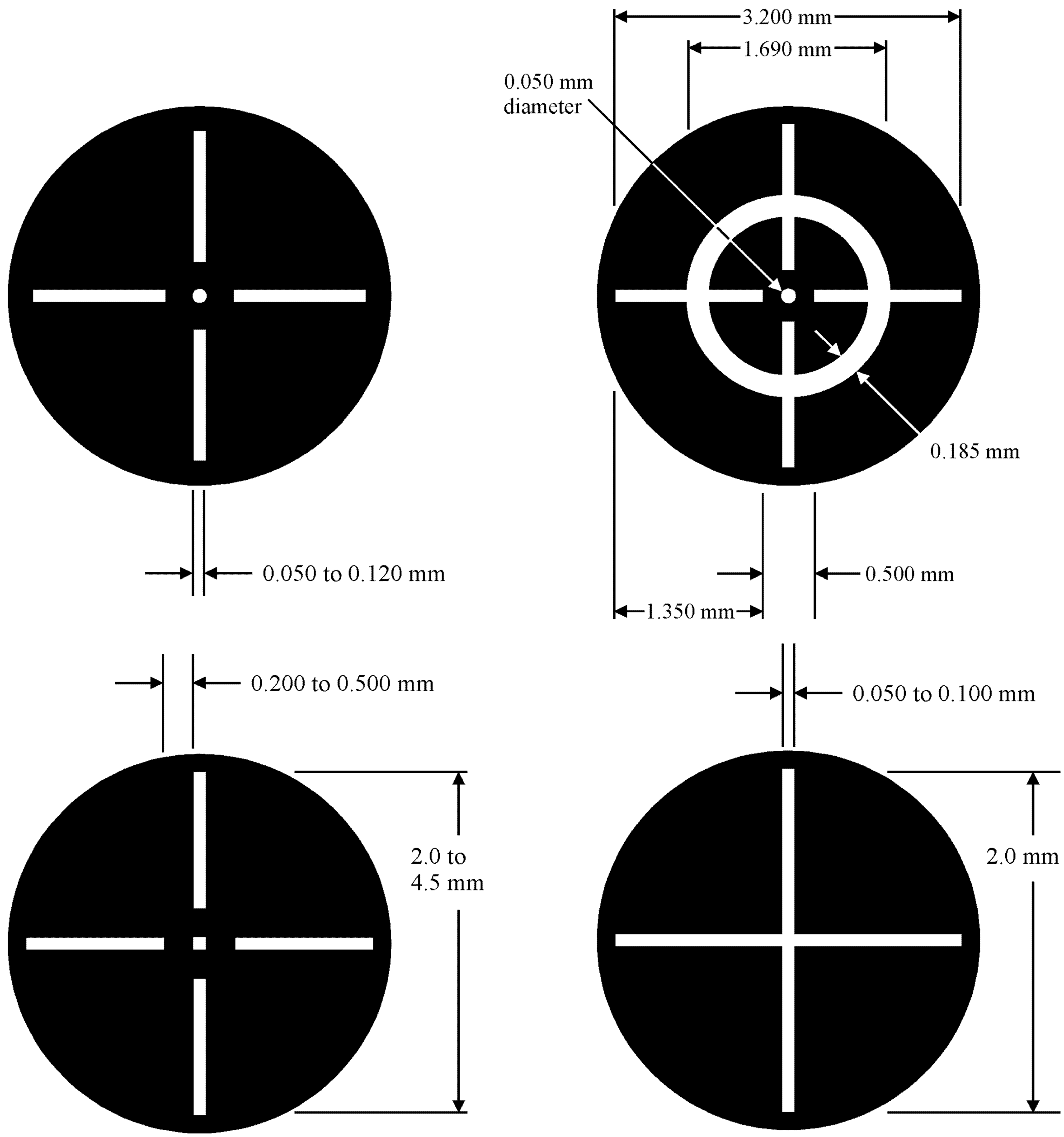
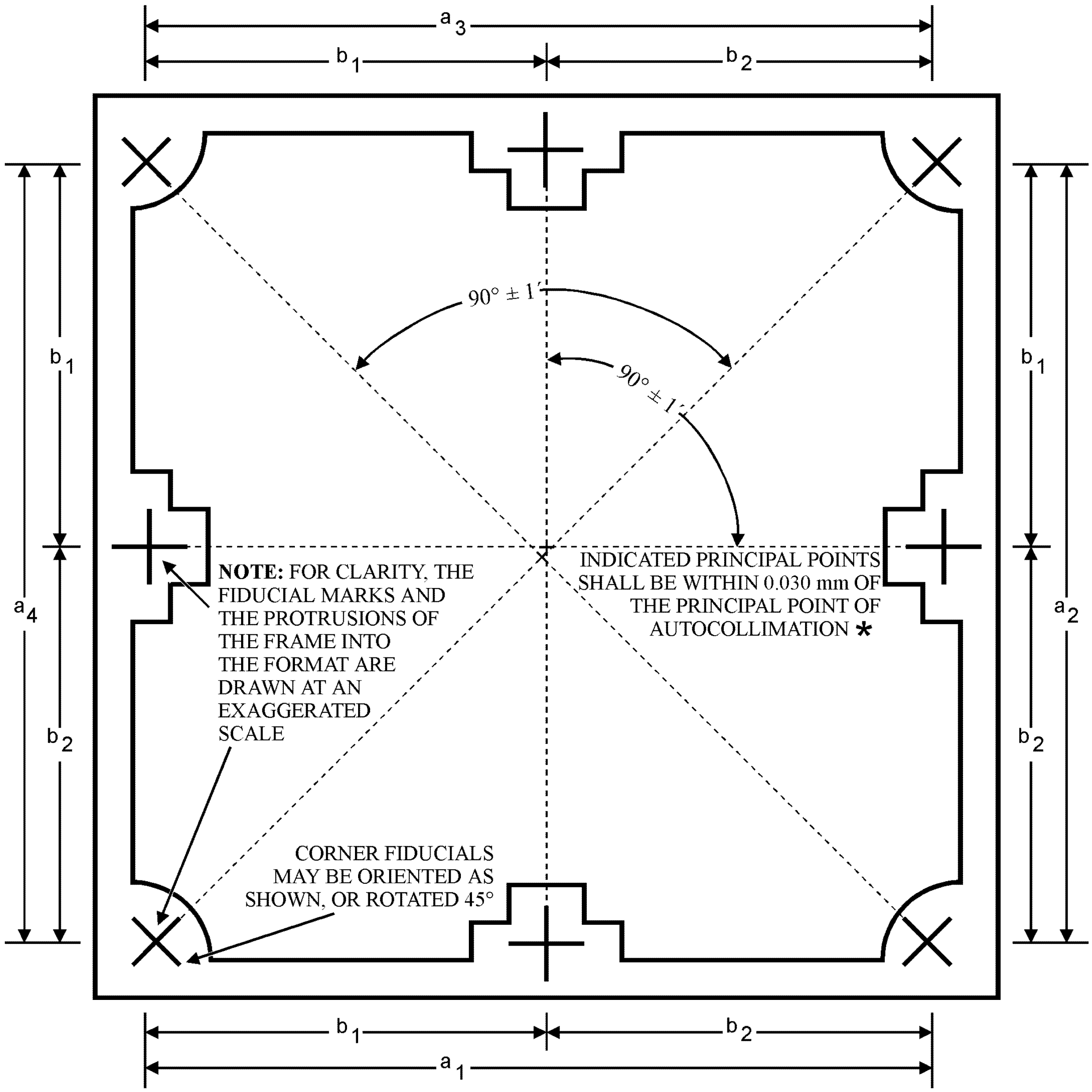


Figure 2
ARRANGEMENT OF FIDUCIAL MARKS



$a_1 = a_2 = a_3 = a_4$ (within 0.500 mm)

$b_1 = b_2$ (±0.500 mm)

* THE CALIBRATED PRINCIPAL POINT - THE POINT OF SYMMETRY - SHALL BE WITHIN 0.015 mm OF THE PRINCIPAL POINT OF AUTOCOLLIMATION FOR 153 mm LENSES AND 0.030 mm FOR ALL OTHER FOCAL LENGTH LENSES.

USGS OPTICAL REQUIREMENTS

Table 1

TABULATION OF OPTICAL REQUIREMENTS

Focal Length	88mm	153mm	210mm	305mm
Focal Length Within	" 4mm	" 3mm	" 4mm	" 5mm
Usuable Angular Field	120E	90E	70E	50E
Field Angle-From Axis out to:	54.5E	40E	30E	22.7E
DISTORTION - At Maximum Aperture				
Radial Distortion - Tolerance (Fm)	" 15	" 10	" 20	" 20
Decentering Distortion - Tolerance (Fm)	-	# 8	-	-
MODEL FLATNESS - (Fm) Total Difference	" 17	" 19	-	-

INDICATED PRINCIPAL POINTS (Fiducial Centers)
The indicated principal points - fiducial centers - shall fall within a 0.030mm radius circle around the principal point of autocollimation.

CALIBRATED PRINCIPAL POINT (Point of Symmetry)
The calibrated principal point - point of symmetry - shall fall within a 0.015mm radius circle around the principal point of autocollimation for 153mm focal length lenses and 0.030mm for all others.

RESOLUTION
Measured on Spectroscopic Plate at Maximum Aperture

Minimum Radial & Tangential Resolution in Line Pairs per mm
LENS HALF ANGLE

Lens		0E	7.5E	15E	22.7E	30E	35E	40E	45E	50E	54.5E
86mm	Wild Super Aviogon II Zeiss S-Pleogon A or equivalent	59	59	49	42	35	30	17	14	12	12
153mm	Wild U. Aviogon Zeiss Pleogon A Jena Lamegon Pl or equivalent	80	80	67	57	57	48	40			
	Wild N-Aviogon II										

210mm	Zeiss Topargon or equivalent	49	49	42	35	29					
305mm	Wild N. Aviotar Zeiss Topar or equivalent	48	48	28	24						

3/16/98

APPENDIX R

USGS AERIAL PHOTOGRAPHY SUPPLEMENT REPORT

United States Department of the Interior
U. S. Geological Survey

AERIAL PHOTOGRAPHY SUPPLEMENT REPORT

PROJECT: ______________

ROLL: ________________

Processing Laboratory (Name) ________________________________

Processing date:_________________

Processing Control No.___________

FILM NUMBER

Film Type______________
Batch No.______________
Mgf. Roll No.___________
Section No._____________
Slit No.________________
Spool No.______________

CAMERA DATA

Camera No._____________
Lens No.________________
Platen No._______________

CONTRACTOR (Name and Address)

____
____
____
____
____

Flight Line Number	Starting Exposure Station	Starting Frame Number	Ending Exposure Station	Ending Frame Number	Photography Date	Remarks

Exhibit 3

APPENDIX S

USGS AERIAL FILM CAN LABEL

AERIAL PHOTOGRAPHY SUPPLEMENT REPORT (Continuation Sheet)

PROJECT: _______________

ROLL: __________________

Flight line Number	Starting Exposure Station	Starting Frame Number	Ending Exposure Station	Ending Frame Number	Photography Date	Remarks

Exhibit 3

APPENDIX T

FAA SUMMARY OF SMALL UNMANNED AIRCRAFT RULE (PART 107) – JUNE 21, 2016

FAA News

Federal Aviation Administration, Washington, DC 20591

June 21, 2016

SUMMARY OF SMALL UNMANNED AIRCRAFT RULE (PART 107)

Operational Limitations	• Unmanned aircraft must weigh less than 55 lbs. (25 kg). • Visual line-of-sight (VLOS) only; the unmanned aircraft must remain within VLOS of the remote pilot in command and the person manipulating the flight controls of the small UAS. Alternatively, the unmanned aircraft must remain within VLOS of the visual observer. • At all times the small unmanned aircraft must remain close enough to the remote pilot in command and the person manipulating the flight controls of the small UAS for those people to be capable of seeing the aircraft with vision unaided by any device other than corrective lenses. • Small unmanned aircraft may not operate over any persons not directly participating in the operation, not under a covered structure, and not inside a covered stationary vehicle. • Daylight-only operations, or civil twilight (30 minutes before official sunrise to 30 minutes after official sunset, local time) with appropriate anti-collision lighting. • Must yield right of way to other aircraft. • May use visual observer (VO) but not required. • First-person view camera cannot satisfy “see-and-avoid” requirement but can be used as long as requirement is satisfied in other ways. • Maximum groundspeed of 100 mph (87 knots). • Maximum altitude of 400 feet above ground level (AGL) or, if higher than 400 feet AGL, remain within 400 feet of a structure. • Minimum weather visibility of 3 miles from control station. • Operations in Class B, C, D and E airspace are allowed with the required ATC permission. • Operations in Class G airspace are allowed without ATC permission. • No person may act as a remote pilot in command or VO for more than one unmanned aircraft operation at one time. • No operations from a moving aircraft. • No operations from a moving vehicle unless the operation is over a sparsely populated area. • No careless or reckless operations. • No carriage of hazardous materials.

	• Requires preflight inspection by the remote pilot in command.
	• A person may not operate a small unmanned aircraft if he or she knows or has reason to know of any physical or mental condition that would interfere with the safe operation of a small UAS.
	• Foreign-registered small unmanned aircraft are allowed to operate under part 107 if they satisfy the requirements of part 375.
	• External load operations are allowed if the object being carried by the unmanned aircraft is securely attached and does not adversely affect the flight characteristics or controllability of the aircraft.
	• Transportation of property for compensation or hire allowed provided that-
	  o The aircraft, including its attached systems, payload and cargo weigh less than 55 pounds total;
	  o The flight is conducted within visual line of sight and not from a moving vehicle or aircraft; and
	  o The flight occurs wholly within the bounds of a State and does not involve transport between (1) Hawaii and another place in Hawaii through airspace outside Hawaii; (2) the District of Columbia and another place in the District of Columbia; or (3) a territory or possession of the United States and another place in the same territory or possession.
	• Most of the restrictions discussed above are waivable if the applicant demonstrates that his or her operation can safely be conducted under the terms of a certificate of waiver.

Remote Pilot in Command Certification and Responsibilities	• Establishes a remote pilot in command position.
	• A person operating a small UAS must either hold a remote pilot airman certificate with a small UAS rating or be under the direct supervision of a person who does hold a remote pilot certificate (remote pilot in command).
	• To qualify for a remote pilot certificate, a person must:
	  o Demonstrate aeronautical knowledge by either:
	    ▪ Passing an initial aeronautical knowledge test at an FAA-approved knowledge testing center; or
	    ▪ Hold a part 61 pilot certificate other than student pilot, complete a flight review within the previous 24 months, and complete a small UAS online training course provided by the FAA.
	  o Be vetted by the Transportation Security Administration.
	  o Be at least 16 years old.
	• Part 61 pilot certificate holders may obtain a temporary remote pilot certificate immediately upon submission of their application for a permanent certificate. Other applicants will obtain a temporary remote pilot certificate upon successful completion of TSA security vetting. The FAA anticipates that it will be able to issue a temporary remote pilot certificate within 10 business days after receiving a completed remote pilot certificate application.
	• Until international standards are developed, foreign-

	certificated UAS pilots will be required to obtain an FAA-issued remote pilot certificate with a small UAS rating. A remote pilot in command must: • Make available to the FAA, upon request, the small UAS for inspection or testing, and any associated documents/records required to be kept under the rule. • Report to the FAA within 10 days of any operation that results in at least serious injury, loss of consciousness, or property damage of at least $500. • Conduct a preflight inspection, to include specific aircraft and control station systems checks, to ensure the small UAS is in a condition for safe operation. • Ensure that the small unmanned aircraft complies with the existing registration requirements specified in § 91.203(a)(2). A remote pilot in command may deviate from the requirements of this rule in response to an in-flight emergency.
Aircraft Requirements	• FAA airworthiness certification is not required. However, the remote pilot in command must conduct a preflight check of the small UAS to ensure that it is in a condition for safe operation.
Model Aircraft	• Part 107 does not apply to model aircraft that satisfy all of the criteria specified in section 336 of Public Law 112-95. • The rule codifies the FAA's enforcement authority in part 101 by prohibiting model aircraft operators from endangering the safety of the NAS.

APPENDIX U

WHITE HOUSE FACT SHEET:
ENABLING A NEW GENERATION OF AVIATION TECHNOLOGY – JUNE 21, 2016

the WHITE HOUSE

Briefing Room

Your Weekly Address

Speeches & Remarks

Press Briefings

Statements & Releases

White House Schedule

Presidential Actions

- Executive Orders
- Presidential Memoranda
- Proclamations

Legislation

- Pending Legislation
- Signed Legislation
- Vetoed Legislation

Nominations & Appointments

Disclosures

The White House

Office of the Press Secretary

For Immediate Release June 21, 2016

FACT SHEET: Enabling a New Generation of Aviation Technology

This week, the Obama Administration will be highlighting America's capacity for creativity and invention and how our innovative progress over the last seven and a half years has helped continue to make our economy the strongest and most durable in the world. To further grow our economy and encourage innovation, today, the Obama Administration is announcing **ground rules** to govern commercial, scientific, public safety and other non-recreational uses of unmanned aircraft systems (UAS) —commonly known as "drones—in the National Airspace System. These ground rules will enable the safe expansion of a new generation of aviation technologies that will create jobs, enhance public safety, and advance scientific inquiry.

Since President Obama took office in 2009, aviation technologies have emerged that are powering a revolution in unmanned flight. The development of these technologies has made drones commercially available at scale for the first time. Commercial operators are using unmanned aircraft for a wide variety of applications, and consumers can choose from scores of vehicles of different sizes and capacities, many of which can be taken out of a box, launched directly into flight, and operated from a smart phone or a tablet.

Today, the Department of Transportation is publishing the final "Small UAS" rule. This rule provides the first national, uniform guidelines for non-recreational operation of unmanned aircraft systems under 55 pounds. Under the new rule, drone flight will be permitted for commercial, scientific, public, and educational purposes, pursuant to a set of operational and safety requirements.

We are in the early days of an aviation revolution that will transform how we gather information about our world, enable more accurate science, move products around the country, and protect public health and the environment. In the short term, unmanned aircraft will provide significant benefits in areas like:

- =**Agriculture:** Unmanned aircraft can monitor crop health in real-time for farmers who are trying to manage farms that are hundreds or even thousands of acres. By reducing the need for manned aircraft in agricultural operations, drones can help reduce fatal agricultural aviation accidents and can increase crop yields by providing higher-quality data about the ground below.
- =**Safer infrastructure inspection:** Unmanned aircraft systems can also save lives by helping workers inspect cell phone towers, bridges, pipelines, electric lines, and oil rigs. For example, all 300,000 communications towers in the United States must be routinely inspected, and workers can be injured and even killed during these inspections. Using unmanned aircraft systems, workers can inspect towers—and other kinds of infrastructure, like utility

lines, bridges, or railways—more safely.

- 8**Scientific research**: Scientists and engineers can use unmanned aircraft for more effective environmental monitoring of our Nation's natural resources, wildlands, and waterways.

Industry estimates suggest that, over the next 10 years, commercial unmanned aircraft systems could generate more than $82 billion for the U.S. economy and by 2025, the industry could be supporting as many as 100,000 new jobs.

The Administration believes that expanded use of drones must be done responsibly, with clear rules of the road that ensure strong safety and privacy protections. Our aviation system has historically been designed around manned aircraft, and unmanned aircraft systems will need to be carefully integrated into the National Airspace System to protect airplanes, helicopters, and the people and property over which they will fly. The Federal Aviation Administration (FAA) will work closely with local and state governments, airports, pilots, and companies around the country in the months ahead to make sure the rule is safely implemented.

To advance strong privacy protections, last year the President issued a Presidential Memorandum, **Promoting Economic Competitiveness While Safeguarding Privacy, Civil Rights, and Civil Liberties in Domestic Use of Unmanned Aircraft Systems**. In line with the Presidential Memorandum, Federal agencies, including the Department of Defense, Department of Justice and Department of Transportation, have instituted strong unmanned aircraft systems privacy policies to protect the public. The National Telecommunications and Information Administration has also worked with industry and advocacy groups to develop national best practices, to which major companies like Amazon and Google have committed. Building on these efforts, the Administration is launching a new privacy campaign to educate pilots and companies. Among other steps, the FAA will direct potential commercial drone pilots—also called "remote pilots"—to review information on privacy protections as part of their certification process, and will promote strong privacy standards during the unmanned aircraft systems registration process.

To demonstrate the potential benefits of unmanned aircraft for the public, the Obama Administration is also announcing new Federal initiatives, including a partnership between the National Aeronautics and Space Administration (NASA) and the FAA related to unmanned aircraft systems traffic management, and other Federal programs to deploy unmanned aircraft to respond to disasters and manage and monitor the environment.

Further details on the rule, privacy actions and new initiatives are outlined below.

Safely Integrating Unmanned Aircraft

As a new technology, unmanned aircraft operations have to date been limited to hobbyists or have required a special exemption from the FAA. The new rule requires that unmanned aircraft to be flown according to a simple set of rules that will protect people on the ground and manned aircraft. Rules include:

- BA requirement to avoid operating unmanned aircraft over people;
- BA requirement for non-recreational remote pilots to pass a written knowledge test and to go through the same security vetting process as traditional manned-aircraft pilots;
- BA requirement for unmanned aircraft to stay at least 5 miles from airports and, among other reasonable restrictions, generally fly at an altitude below 400 feet, creating a safe buffer between unmanned and manned aircraft, which can generally fly no lower than 500 feet; and
- BA requirement for remote pilots to keep unmanned aircraft within visual sight.

More details will be available from the **FAA**.

Looking forward, in consultation with industry and research partners, the FAA is considering additional rules that will further enable safe unmanned aircraft operations—including, for example, to govern the flight of unmanned aircraft over people. This rule is the first step towards a long-term vision of the airspace of the future that will be fully integrated, allowing for the routine safe operation of unmanned aircraft alongside manned aircraft.

Protecting Privacy

While this rule prohibits unmanned aircraft flight over people for safety reasons, as commercial unmanned aircraft use expands, companies will be able to gather new kinds of data. While this possibility creates significant economic opportunities, it also raises important privacy considerations. Entities that plan to use unmanned aircraft systems to gather personal information should have plans in place for how they collect, use and protect personal information. Like basic safety precautions, privacy should be a building block of every flight plan and every unmanned aircraft system operation.

To advance these goals, and pursuant to the Presidential Memorandum, **Promoting Economic Competitiveness While Safeguarding Privacy, Civil Rights, and Civil Liberties in Domestic Use of Unmanned Aircraft Systems**, the Administration has taken important steps forward:

- 7**Instituted strong Federal standards:** The Departments of Defense, the Interior, Justice, and Transportation, and the National Aeronautics and Space Administration (NASA) have instituted unmanned aircraft systems privacy policies. These policies help guide Federal agencies in their use of unmanned aircraft to carry out agency missions while respecting the privacy of the American people. These policies also generally require Federal contractors to adhere to the same privacy standards as the agencies themselves, helping promote strong standards in the marketplace.
- 7**Developed industry-consensus best practices for protecting privacy:** To promote similarly strong standards in the private sector, the National Telecommunications and Information Administration (NTIA) has worked with privacy advocates and industry to develop recommended best practices for unmanned aircraft privacy, transparency, and accountability, **which NTIA published last month**. These best practices are supported by some of the largest companies in the unmanned aircraft industry, including Amazon and Google X, industry associations including Association for Unmanned Vehicle Systems International and the Commercial Drone Alliance, and civil advocates like the Center for Democracy and Technology and the Future of Privacy Forum. The Obama Administration encourages all drone operators and companies to review the best practices and to determine whether and how to apply the practices to their own unmanned aircraft operations.

Today, in connection with the release of the new rule, the Administration is taking additional steps to enhance privacy protections:

- 7**Launching a public education campaign on privacy**: The Federal Aviation Administration is launching a campaign to educate pilots and citizens on drone privacy, including providing all unmanned aircraft users with recommended privacy guidelines as part of the unmanned aircraft systems registration process and through the FAA's B4UFly mobile app; educating all commercial drone pilots on privacy during their pilot certification process; and issuing new guidance to local and state governments on drone privacy issues.

- **Issuing a call for commitments to protect privacy**: New technologies and business practices can also help protect privacy. Today, the Administration is **putting out a call** for private sector and nonprofit organizations to share commitments for new technologies or business practices that will protect privacy during drone operations. This call builds on actions already taken by industry. For example, one drone manufacturer is releasing a new tool that allows remote operators to create a map of where they want to fly and only captures images in that area, allowing operators to prevent the accidental collection of sensitive data. To take a second example, an unmanned aircraft software provider is integrating privacy considerations into software design by creating a pre-flight privacy checklist.

Deploying Unmanned Aircraft for Public Safety, Research, and the Environment

Unmanned aircraft systems are transforming the ability of local, state, and Federal agencies to carry out their missions, including in emergency assistance and disaster response, where they have been deployed by international emergency response teams in mudslides, wildfires, hurricanes, structural collapses, nuclear accidents, tsunamis, and more. They also improve our capability to conduct research, monitor wildlife, protect sensitive ecosystems, and manage and monitor the environment.

These tools are already being put to work by the Federal Government across a broad spectrum of application areas. Today, Federal agencies are announcing new steps to integrate unmanned aircraft systems into the National Airspace System, and to deploy these systems to protect public safety and advance scientific research:

- **Fighting wildfires and protecting the environment through the Department of the Interior (DOI):** DOI, which manages one-fifth of all land in the United States, has used unmanned aircraft systems since 2009, employing unmanned aircraft systems to conduct wildlife and vegetation surveys to protect endangered populations, archeological studies, emergency response, and wildfire management, where drones have expanded DOI's capability to suppress fires to 24 hours a day. DOI is committing to:
- **Make high-definition remote sensing capability via unmanned aircraft systems available to all nine of its bureaus by 2018 to support**

department missions: This technology, which can provide a 500-fold increase in resolution over traditional aerial imagery, will provide affordable high resolution data and assist with many critical missions, including invasive plant and animal detection, search and rescue, wildland firefighting, flood management, earthquake forecasting, volcano research, and oil spill response.

- 1**Finalize protocols to deploy drones to detect, assess, and attack wildfires; position crews; and enhance firefighter safety by Spring 2018.** No later than 2020, the Department also will equip all DOI firefighting teams with unmanned aircraft systems necessary to successfully perform these missions as part of their toolkit for fighting fires.
- 1**Have in place procedures for the rapid deployment of unmanned aircraft for emergency response anywhere in the country by 2020.**
- 1**Understanding and predicting changes in climate, weather, oceans, and coastal areas through the National Oceanic and Atmospheric Administration (NOAA):** NOAA has made significant strides since 2008 in deploying unmanned aircraft systems to improve or enhance weather, climate, and coastal and oceanic observations. Today, NOAA is announcing that it:
- 1**Commits to finalize operations, training, safety, and data management plans by 2019 for small unmanned aircraft systems to be used in the agency's routine operations,** increasing NOAA's capacity to work with other government agencies and stakeholders to develop rapid response imagery of storm damage, river flood conditions, marine wildlife and ecosystem environments, and sudden changes to polar sea ice fields, as well as oil and chemical spills impacting coasts, marshlands, and marine sanctuaries.
- 1**Is partnering with NASA, the U.S. Navy, the National Science Foundation, and other entities conducting a comprehensive assessment of unmanned aircraft observations for the improvement of weather forecasts of high-impact storms, such as hurricanes.** This work could improve our ability to forecast weather, and predict and minimize the damage done by hurricanes, tornadoes, and other extreme weather events, saving lives, property, and taxpayer dollars.
- 1**Developing air traffic management for low-altitude unmanned aircraft:** NASA and FAA are announcing the formation of a new research collaboration, called a Research Transition Team, to identify requirements to implement large-scale unmanned aircraft system operations in low-altitude airspace. This work will focus on research to support the development of Unmanned Aircraft System Traffic Management by providing remote pilots

with information needed to maintain separation from other aircraft and to make unmanned aircraft traffic safe and efficient through proper integration with the FAA's Air Traffic Management system. In 2016, NASA will conduct tests involving multiple unmanned aircraft systems operations beyond visual line of sight to define and refine these requirements, which will help inform future regulatory actions and, eventually, help achieve full airspace integration of unmanned aircraft systems.

- 3 **Engaging the government and the public on the future of unmanned aircraft:** The White House Office of Science and Technology Policy today announces that it will host an event with government, academic, and industry stakeholders at the White House later this year, focused on the potential of drones to enable high-impact research, create new jobs and industries, save lives, and improve the way government agencies and companies do business; and on potential actions to further address safety, security, and privacy in this emerging field. Tell the Administration more about what your organization is doing to support positive applications of unmanned aircraft systems technology and best practices around privacy protections **here**.

APPENDIX V

DOI OPERATIONAL PROCEDURES MEMORANDUM (OPM)-11: DOI USE OF UNMANNED AIRCRAFT SYSTEMS (UAS) – JANUARY 1, 2016

United States Department of the Interior
Office of Aviation Services
300 E. Mallard Dr., Ste 200
Boise, Idaho 83706-3991

DOI OPERATIONAL PROCEDURES MEMORANDUM (OPM) - 11

Subject: DOI Use of Unmanned Aircraft Systems (UAS)

Effective Date: January 1, 2016

Supersedes: OPM 13-11 dated October 20, 2014

Expiration: December 31, 2016

1. **PURPOSE.** The purpose of this OPM is to provide guidance on the operations and management of Unmanned Aircraft Systems (UAS).

2. **AUTHORITY.** This policy is established by the Director, Department of the Interior (DOI or Department), Office of Aviation Services (OAS) in accordance with the provisions of Departmental Manual 112 DM 12, 350 DM 1; Secretarial Order 3322 dated August 23, 2012, and the Presidential Memorandum on Promoting Economic Competitiveness While Safeguarding Privacy, Civil Rights, and Civil Liberties in Domestic Use of Unmanned Aircraft Systems, dated February 15, 2015.

3. **BACKGROUND.** Current Federal Aviation Administration (FAA) policy is provided in FAA Order 8900.1, Volume 16, Unmanned Aircraft Systems (UAS), dated June 23, 2014and subsequent. This national policy document contains the following fundamental provisions.

   A. Unmanned Aircraft are defined as "aircraft" flown by a "pilot" regardless of where the pilot is located. 14 CFR 1.1 defines "*aircraft"* as a device that is used or intended to be used for flight in the air.

   B. Aircraft and pilots must demonstrate compliance with applicable sections of Title 14 CFR to operate in the National Airspace System (NAS). The FAA retains the authority to approve UAS operations within the NAS in Class A, B, C, D, E and G airspace.

   C. When operating in Class A, B, C, D, E and G airspace, DOI UAS's must be operated with a FAA Certificate of Waiver or Authorization (COA).

   D. COAs are not required in Restricted, Prohibited, or Warning airspace. However, UAS operations in these specific airspaces will be regulated and approved by the Controlling Authority (a.k.a. "Range Control").

4. **POLICY.** UAS by definition are considered aircraft regardless of size or weight. While their methods of control and airspace utilization procedures are different than manned aircraft, the overall

responsibility for management within the DOI rests with the Office of Aviation Services (OAS). DOI bureaus and offices shall comply with the following protections and procedures when using any UAS operated by DOI or on behalf of DOI, whether DOI-owned or vendor-owned.

5. ROLES AND RESPONSIBILITIES.

A. The Office of Aviation Services (OAS) has overall responsibility for management, ownership, acquisition, assignment, and disposal of DOI-owned aircraft, including UAS. OAS oversees the UAS program and issues Department-wide policy, procedures, training, and a comprehensive actionable strategy for the use of UAS. In collaboration with Bureau and Office Aviation Programs, OAS establishes UAS requirements and standards to ensure aviation safety and individual privacy, civil rights, and civil liberties protections in compliance with applicable laws, regulations, and policies. Additionally, OAS coordinates with internal and external agencies, partners, and organizations on UAS policy, inspections, audits, compliance reviews, and proposed rulemaking.

B. The Office of the Chief Information Officer (OCIO) has overall responsibility for promulgation and oversight of Department-wide information management policies, guidelines and procedures to bureaus and offices for their implementation to ensure compliance with relevant Federal laws, regulations and policies. Such policies, guidelines and procedures include, but are not limited to, addressing requirements associated with privacy, IT security, and records management. The Departmental Privacy Officer within the OCIO formulates privacy policy, provides guidance, and collaborates with bureaus, offices, and program officials to evaluate program activities to ensure privacy considerations are addressed for the collection, use, retention, and dissemination of personally identifiable information and appropriate safeguards are implemented to protect individual privacy, civil rights, and civil liberties.

C. The Office of Civil Rights (OCR) is responsible for developing policy and guidelines to assure proper implementation of laws, Executive Orders, regulations, and Departmental initiatives relating to affirmative employment, equal opportunity, civil rights and educational partnerships. OCR oversees the management and evaluation of programs, activities, and services receiving Federal financial assistance, and ensures expedient processing and resolution of complaints of discrimination, prevention of discriminatory practices, and equal access to Federal financial assistance and federally conducted programs for all persons regardless of race, color, age, religion, sex, national origin, disability, and sexual orientation.

D. Bureaus and offices are responsible for implementing and executing Departmental and organization-specific policies, procedures, and protections consistent with applicable Federal laws, Executive Orders, regulations, policies, and standards.

6. PRIVACY, CIVIL RIGHTS, AND CIVIL LIBERTIES PROTECTIONS. The use of UAS significantly expands DOI's ability to obtain remote data critical to fulfilling diverse mission objectives. However, this use raises distinct privacy, civil rights, and civil liberties concerns that must be addressed in order to promote the responsible use of UAS and protections for individual privacy, civil rights, and civil liberties in accordance with the Constitution, Federal law, and applicable regulations and policies.

A. Privacy Protections. In light of the advancements in UAS technologies and diverse potential uses of UAS across Department and Bureau missions, it is imperative that DOI take appropriate steps to implement UAS policies that address privacy protections, procedures, and standards to ensure compliance with the Privacy Act of 1974, DOI Privacy Act regulations, Departmental privacy policies, and other applicable laws, regulations and policies. Accordingly, DOI Bureaus and Offices utilizing UAS or UAS-collected information shall meet the following privacy requirements:

1. DOI bureaus and offices shall only collect information using UAS, or use UAS-collected information, to the extent that such collection or use is consistent with and relevant to an authorized purpose and DOI privacy policy.

2. Information collected by or on behalf of DOI bureaus and offices using UAS that may contain personally identifiable information (PII) shall not be retained for more than 180 days unless retention of the information is determined to be necessary to an authorized mission, is maintained in a system of records covered by the Privacy Act, or is required to be retained for a longer period by any other applicable law or regulation.

3. DOI bureaus and offices shall take appropriate steps to ensure that UAS-collected information that is not maintained in a system of records covered by the Privacy Act is not disseminated outside of the agency unless dissemination is required by law, or fulfills an authorized purpose and complies with agency requirements established by appropriate authority.

B. Civil Rights and Civil Liberties Protections. To protect civil rights and civil liberties, DOI bureaus and offices shall:

1. Ensure that policies are in place to prohibit the collection, use, retention, or dissemination of data in any manner that would violate the First Amendment or in any manner that would discriminate against persons based upon their ethnicity, race, gender, national origin, religion, sexual orientation, or gender identity, in violation of law.

2. Ensure that UAS activities are performed in a manner consistent with the Constitution and applicable laws, Executive Orders, and other Presidential directives.

3. Ensure that adequate procedures are in place to receive, investigate, and address, as appropriate, privacy, civil rights, and civil liberties complaints.

C. Accountability. To provide for effective accountability, the Office of Aviation Services, in conjunction with the Office of the Chief Information Officer and the Office of Civil Rights, will provide collaborative oversight of the DOI UAS program within their respective areas of expertise and responsibility. DOI bureaus and offices employing UAS or UAS-collected information shall comply with Departmental oversight activities, and take additional appropriate steps to ensure effective oversight and accountability for their respective UAS programs. Accordingly, bureaus and offices shall ensure:

1. Oversight procedures are implemented for UAS use, including audits or assessments, in compliance with Departmental policies and regulations.

2. Bureau and office personnel and contractors comply with UAS program training requirements, Rules of Behavior, and procedures for reporting suspected cases of misuse or abuse of UAS technologies.

3. Policies and procedures are implemented that provide meaningful oversight of individuals who have access to sensitive information (including any PII) collected using UAS consistent with applicable Federal laws, regulations, and policies, as well as Departmental policy guidance.

4. Any data-sharing agreements or policies, data use policies, and records management policies applicable to UAS conform to applicable laws, regulations, and policies.

5. Policies and procedures are implemented to authorize the use of UAS in response to a request for UAS assistance in support of Federal, State, local, tribal, or territorial government operations. Any authorized use, letter of authorization, or memorandum of understanding must include the requirements of this policy and appropriate safeguards to protect privacy, civil rights, and civil liberties.

6. State, local, tribal, and territorial government recipients of Federal grant funding for the purchase or use of UAS for their own operations have in place policies and procedures to safeguard individuals' privacy, civil rights, and civil liberties prior to expending such funds.

D. Transparency. OAS will complete the following activities, in collaboration with bureau and office UAS programs, to promote transparency about DOI UAS activities within the NAS, while not revealing information that could reasonably be expected to compromise law enforcement or national security:

1. Provide notice to the public regarding where DOI's UAS are authorized to operate in the NAS.

2. Keep the public informed about the DOI UAS program as well as changes that would significantly affect privacy, civil rights, or civil liberties.

3. Make available to the public, on an annual basis, a general summary of DOI UAS operations during the previous fiscal year, to include a brief description of types or categories of missions flown, and the number of times the agency provided assistance to other agencies, or to State, local, tribal, or territorial governments.

7. PROCEDURES AND GUIDELINES.

A. Acquisition of UAS: There are three primary methods for bureaus and offices to acquire UAS assets and capabilities. Each requires a different acquisition process:

1. Assignment of UAS previously declared excess by federal agencies. OAS is responsible for acquisition and management of DoD bailed or transferred UAS acquired to satisfy bureau and office requirements. Since these UAS are typically acquired at virtually no cost to the Department, bureaus and office desiring to operate these systems are not required to submit an aviation business case analysis for approval by Department aviation governance. However, to ensure the appropriate level of oversight and support from bureau and office leadership, requestors must prepare a UAS operational test and evaluation (OTE) proposal, coordinated through the bureau or office National Aviation Manager (NAM) and vetted by the first senior executive in the requestor’s chain of command. Ultimately, the decision on whether to issue UAS will be made by the OAS Director based on the availability of assets, the requesting agency’s experience operating

UAS, and the concurrences of the requesting Bureau's Executive Aviation Committee (EAC) member on the distribution of these assets. The proposal shall contain the following elements.

a. Bureau or office designation.
b. Requestor name and contact information.
c. State whether this is a new requirement or program renewal.
d. Number and type of assets requested. Note: UAS typically are deployed in "kits" which may consist of multiple aircraft.
e. Proposed Start and End Dates. Indicate the date assets must be in place to support tests or schedule training.
f. Proposed/Planned/Anticipated Activities to Be Conducted. Briefly summarize the activities, with approximate dates, location, agency to be supported, objectives and number of hours to be flown.

   The OAS UAS program manager can provide a template for the proposal. The aircraft is assigned to the requesting bureau or office through a Memorandum of Agreement outlining expectations and responsibilities of both parties.

2. As with manned aircraft, Department operations of commercially available UAS is most efficient when acquisition is limited to a few proven systems that allow standardized training and procedures as well as simplified logistics. Further, until the FAA publishes airworthiness standards for the various classes of UAS, the Department will seek to limit its operational risk by purchasing commercial UAS that are direct derivatives of DOD procured systems OR have undergone extensive testing by an independent agency or group recognized by OAS for their expertise and objectiveness.

3. For commercial contracts, under which a contractor owned and operated UAS are utilized under the operational control of the bureau or office, the Department assumes responsibility for the airworthiness of the UAS and could be held liable for any injury or damages incurred during the operation. Procurement of contract UAS shall follow the existing DOI processes for aviation contract services. If a bureau or office determines that a commercial contract is the best way to satisfy their requirements, a primary point-of-contact must be appointed for the duration of the contract.

B. Cooperator UAS Operations: Cooperator UAS missions fall into two categories.

1. Operations in which DOI has operational control of the mission. For these types of missions the Cooperator aircraft and crew shall be approved by OAS. Requests for approval of cooperator UAS should follow the process outlined in 351DM4.

2. Operations in which DOI does not exercise operational control. In this example the Bureau is allowing a cooperator to utilize DOI lands for the purpose of takeoff and landing, and may or may not be utilizing the data captured by the cooperator UAS. Universities, other governmental agencies (CBP, NOAA) would be examples of this type of mission. This type of mission does not include commercial filming or other types of "commercial" operations. Approvals for takeoff and landings from DOI lands shall follow bureau land use permitting procedures (i.e. special use permit). Prior to bureaus approving/issuing a special use permit for this type of mission the following must occur: The cooperator must secure their FAA approved COA; The approving unit shall obtain a copy of the COA, and forward to the bureau NAM and OAS UAS specialist for review.

Once this is completed, then the permit may be issued. DOI will not sponsor COA's for these types of cooperator missions. These types of missions will not fall under DOI operational control.

Note: Operational control with respect to a flight means the exercise of authority over initiating, conducting, or terminating a flight. In order to reduce ambiguity, it is recommended that all DOI bureaus and offices operating in a multi-bureau/office/agency environment document the entity designated to exercise operational control over an activity prior to the commencement of flight operations. The minimum components and signature requirements are referenced in DM352 Chapter 1, the specifics can be found in OPM–06 Aviation Management Plans (7/21/2014).
http://oas.doi.gov/library/opm/CY2014/OPM-06.pdf

Examples of this authority include:

The following table provides some guidance to identify end product/service or flight service procurement. If the answer is YES in any block under a project, you have a flight service that must be procured through DOI OAS.

PROJECT

	Aerial photo remote sensing	Aerial application (spray/seed)	Animal inventory	Your project
Set pilot standards				
Direct aircraft maintenance				
Dispatch aircraft				
Other aircraft and pilot requirements				

a. Approving crewmembers and determining their qualifications to operate the aircraft;

b. Determining the aircraft configuration and specifying standards under which the aircraft shall be maintained.

c. Determining required dates and times of departure, departure and recovery bases. It does not include the specification of windows of time during which flights need to be flown to achieve mission objectives.

d. Determining the nature and quantities of cargo to be flown.
The NTSB maintains the ultimate authority for assigning operational control for all accidents and incidents investigated by that agency. For DOI investigations that do not involve the NTSB, OAS will assign operational control based on any pre-operation designation (if completed) and the preponderance of evidence relating to the actions of the involved individuals and entities.

C. Certificates of Authorization (COA)

1. FAA-issued Certificates of Authorization are required for all UAS operations within the National Airspace System, (NAS), excluding active Restricted or Warning Areas designated for aviation use. OAS has been designated as DOI's proponent for the purpose of applying for COA's. Until such time as the FAA begins to issue UAS type certificates or other means of certifying airworthiness, civil and commercial operators are not authorized to submit COA requests, except in very limited cases. The Department will not "sponsor" COA requests for UAS operations in which a DOI bureau does not exercise operational control.

2. A complete COA package includes, but is not limited to, the operational plan, PASP, risk assessment, airworthiness, airspace, pilot qualifications, frequencies and communication plan. All COAs will be developed and submitted using the COA online system (https://ioeaaa.faa.gov). Units with approved UAS projects will establish on-line COA accounts with the UAS Specialist at OAS who administers access to this account on behalf of the Department.

3. Units that do not have established UAS programs, but desire to employ UAS for short-term operations or feasibility testing, are encouraged to request support from a bureau with an ongoing program. By using experienced operators, offices new to UAS operations can benefit from shorter spin-up times and reduced vehicle "mortality." For offices with established program, this shared approach will help them maintain currency/proficiency with the systems.

4. Initial feasibility discussions for a proposed UAS operation (new location, mission area, sensors) should normally be conducted between the unit proposing the operation, the bureau regional aviation manager (RAM), and the respective NAM. The OAS UAS Specialist is also available to provide advice and clarification as necessary. The bureau NAM and OAS will coordinate in the designation of a bureau (or office) proponent for each bureau-approved UAS program.

5. COA's require issuance of a Notice to Airmen (NOTAM) to alert non-participating aircraft of the operation and advise them of the VHF/AM frequency which will be monitored while operations are being conducted (if required). Each COA contains the instructions for requesting the NOTAM. For operations under the DOI/FAA MOA, NOTAMS must be issues no later than 24 hours in advance of the operation.

6. The bureau proponent is responsible for obtaining spectrum authorization in the form of Special Temporary Authority (STA) issued by the National Telecommunications and Information Administration (NTIA) if using DOD frequencies.

7. Bureaus are responsible for coordinating with each other for sUAS operations over lands owned or managed by DOI.

8. For operations over other U.S. government, state or privately-owned or managed lands, excluding DOD restricted areas/airspace, Bureaus will coordinate with the appropriate authority and ensure the property owners have advance notice prior to the proposed sUAS operation. This coordination shall include anticipated periods of operation, purpose of the flights, and contact information for the responsible unit should questions or issues arise.

9. The bureau will complete the detailed COA application on-line. When the proponent feels the application is ready for review and submittal, it shall be forwarded through bureau channels to the bureau NAM for review and then to the OAS UAS Specialist. The UAS specialist will exercise the committal authority in the on-line COA system to transmit the approved COA request to the FAA.

10. The status of the COA can be followed on the COA on-line site. The COA, once issued, shall serve as the UAS Operations Plan in addition to the PASP, IAP, etc…

D. Operations Under the DOI/FAA MOA: Under the DOI/FAA Memorandum of Agreement for Operation of UAS in the NAS, dated Jan 23, 2014, bureaus operating OAS-approved UAS may conduct flights using COA via notification procedures subject to conditions of the DOI FAA MOA

1. Operations may only be conducted in Class G airspace, with UAS weighing 55 pounds or less, and are limited to scientific applications, wildlife surveys, and search and rescue (SAR) efforts. COA via notification procedures are not authorized for fire suppression operations or law enforcement missions.

2. Operations will be conducted within visual line of sight of the pilot/operator or trained observer utilizing Class G VFR weather requirements. UAS operations will follow the same right-of-way rules as any manned aircraft and shall give way to manned aircraft at all times. For operations below 1200 feet above ground level (AGL), the day minimums are one mile visibility and clear of clouds. At night, the requirements are 3 statute miles visibility and at least 500' below and 2000 feet horizontally from clouds.

3. Requests for COAs for operations meeting the above requirements will be made using the following COA via notification procedures. See the attached Class G notification procedures for details.

    a. Bureau proponents will enter mission data in the UAS COA Online System. This will include uploading the project aviation safety plan (PASP). The requirement to complete a PASP, minimum components and signature requirements are referenced in DM352 Chapter 1, the specifics can be found in OPM–06 Aviation Management Plans (7/21/2014). http://oas.doi.gov/library/opm/CY2014/OPM-06.pdf

    b. The bureau will request a NOTAM to alert non-participating aircraft of the operation and advise them of the VHF-AM frequency which will be monitored while operations are being conducted (if required).The NOTAM shall be requested 24 hours in advance of the operation.

4. COAs for UAS operations in support of active fire suppression or other emergency

operations will be requested as Emergency COAs using the UAS COA Online System, unless otherwise authorized by FAA. Any requests for an emergency COA will be routed through OAS UAS Specialist to the FAA.

5. Operations conducted entirely within Restricted/Prohibited and Warning areas do not require a COA; however, an MOU for UAS use will be established between the using bureau/OAS and the controlling agency ("range control").

E. Requirements for UAS Flights in the NAS:

1. General Limitations:

   a. Operations will not be conducted over populated areas, defined as those areas indicated in yellow on VFR sectional charts, unless authorized in the COA.

   b. Flights will be planned to avoid sustained/repeated overflight of heavily trafficked roads or highways but may briefly cross over active roads as necessary. Surveillance of roads or outside gatherings of people shall be accomplished with offset surveillance techniques to minimize risk to persons or property on the ground.

   c. If the COA dictates that telephone contact must be made with ATC for normal or emergency communication, the PIC shall have ready access to a telephone from the mission location (cellular, satellite, landline, etc…)

   d. Flights will be conducted in accordance with any applicable Part 93 Special Air Traffic Rules, a.k.a. Special Flight Rules Area (SFRA) considerations: Examples, Grand Canyon Special Federal Aviation Regulation, (SFAR 50-2), Washington DC, Anchorage, AK.

   e. Operations within Class G airspace underlying Class B or C airspace (Mode C veil) generally require either an independent UAS flight termination system or a transponder, or both.

   f. UAS will remain outside of five (5) NM (nautical miles) from any civil airport or heliport at or below 400 feet AGL except as authorized by the COA.

2. Night operations are permitted provided:

   a. The UAS meets the night lighting requirements as defined in 14 CFR 91.209.

   b. Flight Crews have been trained on the lighting configuration of the UAS and are in place 30 minutes prior to night operations to ensure night vision adaptation has occurred.

F. Overflight Responsibilities:

1. The bureau with operational control is responsible for obtaining authorization for flights operations to and from lands managed by States, other federal agencies such as USDA or NOAA, or other DOI bureaus. These areas include National Parks, National Wildlife Refuges, NOAA Olympic Marine Sanctuary, etc… These items must be addressed in the

PASP prior to operations.

2. For flights over other U.S. government or state managed lands, excluding DoD restricted areas/airspace; the bureau proponent will coordinate with the appropriate authority and notify them, in writing, prior to commencing the operation.

G. UAS Pilot/Mission Operator and Observer Responsibilities, Qualifications and Certification.

1. General UAS Pilot Responsibilities: The PIC of a UAS is directly responsible for and is the final authority as to the operation of that aircraft.

2. One PIC must be designated for each flight and recorded on the form OAS-2U.

3. Pilots are responsible to perform a thorough preflight inspection of the UAS in accordance with the operator's handbook. The PIC is responsible for determining that the aircraft is in a condition for safe flight, the PIC must discontinue a flight when the aircraft encounters un-airworthy mechanical, electrical, or structural conditions.

4. Pilots and observers will not have concurrent responsibilities during the mission. They may not perform more than one crew duty at a time (i.e. pilot/UAS Crewmember/observer).

5. Per 350 DM 1.8, Reporting Requirements, all UAS flight time must be recorded on an OAS 2U (fleet UAS) or OAS 23 (commercial UAS) for each flight.

6. UAS Pilot Certification Factors: Rating requirements for the UAS PIC depend on the conditions, airspace and UAS the flights are conducted with and fall into two categories.

H. DOI Specific Training and Certification for all UAS Pilots and Mission Operators:

1. Current Class II FAA medical certificate.

2. All DOI UAS pilots must complete a manufacturer's UAS-specific training course (approved by OAS), or OAS-developed UAS qualification course (or other Federal agency equivalent) for each make and model of UAS to be flown.

3. All DOI UAS pilots and operators must pass an initial qualification evaluation administered by a DOI UAS pilot inspector. The evaluation will include an oral evaluation of subjects covered in the OAS UAS ground school and a minimum of one evaluation flight. OAS will publish a practical test standard (PTS) for UAS. For systems requiring additions crewmember in addition to the PIC the crewmembers will be carded for specific duties (i.e., ground crew, backup pilot).

4. DOI UAS pilots/crewmembers are required to maintain currency as Aircrew Members per. OPM-04. (A-116 one time, A-100, A-200 and A-110 (if using hazmat) every 3 years)

5. Supervisors of UAS personnel shall be current in the Supervisor training requirements outlined in OPM-04. Details can be found in the Interagency Aviation Training Guide (https://www.iat.gov/docs/IAT_Guide_2014_0331.pdf)

I. Operations requiring only a OAS UAS Pilot Qualification Card: The PIC will not be required to hold an FAA pilot certificate if all the following conditions are met:

1. UA operated solely within visual line of sight of pilot/operator. At an altitude of no more than 400 feet above ground level (AGL) at all times except as authorized in Restricted/Warning/Prohibited areas or by COA or MOA with FAA

2. In Class G or Restricted/Prohibited or Warning airspace.

3. Conducted in a sparsely populated location.

4. Conducted no closer than 5 NM from any airport or heliport.

5. In lieu of a FAA pilot certificate, DOI PIC operating UAS under the provisions of this paragraph must have:

   a. Successfully completed an FAA private pilot ground instruction, and have passed the written examination, or

   b. Completed the DOI/OAS A-450 Basic Small UAS Basic Operator's course, or OAS approved equivalent, which is a tailored aviation course approved by FAA and which covers applicable sections of the FAR/AIM or other aviation publications that will enable the pilot to safely operate a specific UAS in the class of airspace desired. This training also includes instruction and practical exercises in weather (as applicable to a UAS pilot), emergency procedures, aircraft mishap reporting, SAFECOM Program, lost link, Air Traffic Control (ATC communications) and NOTAM procedures, classes of airspace, system operating limitation all other applicable DMs and OPMs pertaining to aviation.

J. Operations that may require a FAA pilot certificate (plus OAS qualification card):

1. All operations approved for use in Class A, B, C, D, and E airspace.

2. All operations conducted under IFR (FAA instrument rating required).

3. Night time operations except in Restricted/Warning/Prohibited areas if authorized by the Controlling Authority, if specifically allowed in the Special Provisions Section of the COA, or as authorized in the DOI/FAA MOA.

4. All operations conducted at joint use or public airfields.

5. All operations conducted beyond line of sight, unless the flight is within restricted or prohibited airspace with the permission of the controlling agency.

6. Operations above 400 feet AGL or with visual line of sight conducted greater than one NM from the UAS observer. A FAA pilot certificate may not be required for altitudes to 1000 feet in Restricted/Warning/Prohibited areas if so authorized by the Controlling Authority. Also, the higher altitude is authorized without a FAA pilot certificate if specifically allowed in the Special Provisions Section of the COA.

7. At any time the FAA (as specified in the COA) has determined the need based on the UAS characteristics, mission profile, or other operational parameters.

8. For those operations that require a certificated pilot, the PIC, in order to exercise the privileges of his certificate, shall have flight reviews and maintain currency in manned aircraft per 14 CFR 61.56, *Flight Review* and 61.57, *Recent Flight Experience: Pilot in Command.*

9. For operations approved for night or IFR, the PIC shall maintain currency per 14 CFR 61.57, *Recent Flight Experience: Pilot in Command*, as applicable.

K. Flight Currency:

1. DOI UAS pilot or to act as PIC a DOI UAS pilot must demonstrate three takeoffs (launch) and landings (recovery) in the specific UAS in the previous 90 days. If currency is lost prior to a mission, operator must regain currency by flying three missions in the UAS simulator, performing 3 takeoffs and landings with the UAS or fly under the observation of a current UAS pilot.

2. DOI UAS pilots are required to fly each of the aircraft they are carded for at least once every six months. Operators failing to meet this requirement shall fly under the supervision of a carded and current DOI UAS pilot. Operational flights are acceptable to maintain currency.

    a. Medical Qualification: The PIC shall maintain, and have in their possession, at a minimum, a valid FAA Class 2 medical certificate issued under 14 CFR Part 67

L. General UAS Observer Responsibilities:

1. Observer duties include but are not limited to the following:

    a. Have a clear view of the area of operation.

    b. Be in communications with the PIC either within speaking distance or with a portable radio/cell phone equipped for immediate communication.

    c. Keep the pilot advised of any possible hazards such as power lines, birds, other aircraft, terrain, and hazardous weather conditions.

    d. The observer can also act as the launch person for a hand launched aircraft.

    e. Qualified UAS Pilots may act as observers, however observers may not act as a pilot or UAS crewmember unless they possess a valid OAS-30U qualification card.

2. Observer Training: Observers must have completed sufficient training to communicate to the pilot any instructions required to remain clear of conflicting traffic. This training, at a minimum, shall include knowledge of the rules and responsibilities described in 14 CFR 91.111, *Operating Near Other Aircraft;* 14 CFR 91.113, *Right-of-Way Rules: Except Water Operations;* and 14 CFR 91.155, *Basic VFR Weather Minimums;* knowledge of air traffic and radio communications, including the use of approved ATC/pilot phraseology, if applicable; and knowledge of appropriate sections of the *Aeronautical Information Manual*.

3. Observer Medical Qualification: All observers are required to have a current Class 2 FAA medical certificate, or FAA approved equivalent.

4. Supervisory Training: Supervisors of UAS crewmembers (Pilots, Mission Operators and/or Observers) shall maintain currency for “Supervisor” as outlined in OPM-04. (https://www.iat.gov/docs/IAT_Guide_2014_0331.pdf)

M. UAS Inspections and Maintenance:

1. PICs will:

   a. Conduct a conditional inspection of each UAS before every flight, and document any discrepancies on the OAS-2U.

   b. Record UAS flight time in the aircraft logbook (using the OAS-2U) and submit one copy of each form to OAS Technical Services at least monthly or at the conclusion of the project, whichever occurs first.

   c. Report monthly flight statistics to the FAA via the COA online site (https://ioeaaa.faa.gov/oeaaa/Welcome.jsp)

   d. Record malfunctions (loss of link), damage (parts that require repair to be airworthy again). Repairs to UAS beyond component replacement shall be coordinated with the OAS UAS specialist.

   e. Submit SAFECOM reports for any conditions, acts, observations, circumstances or maintenance problems that led to, or could have led to, an aircraft mishap. (www.safecom.gov)

   f. Immediately report any missing aircraft or a mishap involving injury to personnel or property on the ground or total loss of the air vehicle by calling the Aircraft Accident Reporting Hotline at 1-888-4MISHAP prior to continuing operations.

2. OAS UAS inspectors will be qualified in accordance with DOI OAS Instruction 5400-202. As a minimum, OAS UAS inspectors will receive formal training on preflight inspection, ground engine runs and systems/diagnostic checks for each make and model of UAS to be inspected and demonstrate proficiency in those tasks annually.

3. UAS will be inspected annually by an OAS approved inspector. Such inspections will be documented on OAS-36U. The inspector will utilize available military technical orders, FAA airworthiness guidance and manufacturer’s developed checklists, as available, to accomplish the following tasks.

   a. Confirm aircraft configuration conforms to original manufacturer’s design. All modifications, including sensor changes and/or upgrades must be approved by OAS UAS specialist.

   b. Inspect the airframe of general condition and serviceability.

   c. Note serial numbers of airframe and GCS.

d. Perform preflight checklist.

e. Run systems diagnostics to confirm all tests are nominal.

f. Conduct ground engine run to confirm proper operation.

g. Check battery charger and other peripherals for proper operation.

h. Document any missing kit items.

4. OAS UAS office in conjunction with Technical services will:

a. Receive and archive OAS-2U forms for a minimum of 5 years.

b. Track accumulated flight time per fuselage/airframe, and be able to generate and deliver overall usage reports when needed by the bureaus.

c. As able, develop use histories on major UAS components (e.g. batteries, GCUs, etc.).

d. Report UAS usage via FAIRS.

e. Review OAS-36U forms to confirm status of inventory.

f. Arrange for in-house or contract repair of damaged, inoperable UAS to the extent practical.

N. Oceanic and UAS Flights: DOI UAS operations over international waters typically do not lend themselves to compliance with International Civil Aviation Organization (ICAO) procedures due the low altitudes flown and lack of required avionics. For UAS flights in Oceanic Flight Information Regions (FIR) where the FAA is the air traffic provider, DOI owned and operated UAS shall be considered as “State Aircraft”. The following conditions are designed to provide a level of safety equivalent to that normally given by ICAO Air Traffic Control agencies and fulfill United States Government obligations under Article 3 of the Chicago Convention of 1944 which stipulates there must be “due regard for the safety of navigation of civil aircraft” when flight is not being conducted under ICAO flight procedures.

1. These conditions apply only to small UAS weighing 55 pounds or less.

2. The Ground Control Station (GCS) and UAS shall remain within uncontrolled airspace at all times.

3. The GCS shall remain greater than 12 NM (i.e. international waters) from the U.S. coastline during all phases of flight.

4. Operations will be limited to below 1200 feet AGL provided the UAS remains with ICAO Class G airspace at all times.

5. Operations will be conducted within visual line of sight of the pilot/observer. (The UAS shall remain within 5NM of the GCS at all times.)

6. All UAS flights will be flown in Visual Meteorological Conditions (VMC) only. If Instrument Meteorological Conditions (IMC) conditions are unintentionally encountered, the pilot will return the UAS to VMC conditions by the safest and most expeditious means possible.

7. Day or night operations are permitted, but associated risks and mitigations shall be addressed in each project-specific PASP.

8. UAS operating areas shall be selected so as not to interfere with established air routes and ocean shipping lanes

9. UAS operations shall not be conducted beneath ("under the veil") of Class B or C airspace.

10. The operating agency will request the FAA to publish a NOTAM for the affected airspace to alert non-participating aircraft of the operation and advise them of the VHF-AM frequency which will be monitored while operations are being conducted. The UAS operator and team must be equipped with an operable VHF-AM radio capable of transmitting and receiving on the monitored frequency and VHF guard frequency (121.5).

11. For launches conducted from ships equipped with search radar, the launch vessel shall conduct a surface search using its radar within (no later than) 10 minutes of the launch in order to identify other vessels within the operational area. A qualified radar operator should monitor the ship's radar display at all times the UAS is airborne. If another vessel is identified within a 5 NM operational radius of the GCS, the pilot shall take action to keep the UAS at least 2 NM from that vessel at all times unless identification of vessels is a requirement of the mission flight.

12. For UAS flights in Oceanic FIRs, where the air traffic service provider is a foreign government, coordination and approval with that government is required prior to commencing flight operations. Additional diplomatic clearances may also be required.

O. International UAS Flights: Any proposed international flights of DOI owned or operated UAS will be approved on a case-by-case basis by the Bureau or Office NAM and OAS. Proposals for international UAS activities should be forwarded in writing to the Bureau or Office NAM and OAS UAS specialist.

8. <u>EXCEPTIONS and LIMITATIONS</u>. Per 350 DM 1.9., Deviations from this OPM must be approved by the Director, Office of Aviation Services.

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Director, Office of Aviation Services

APPENDIX W

RECLAMATION:
NATIONAL AVIATION MANAGEMENT PLAN (NAMP) – FEBRUARY 2016

RECLAMATION

Managing Water in the West

National Aviation Management Plan (NAMP)

U.S. Department of the Interior
Bureau of Reclamation

February 2016

National Aviation Management Plan (NAMP)

Reviewed by:	
Jack Brynda National Aviation Manager	2/12/16 Date
Approved by:	
Bruce Muller Director, Security, Safety and Law Enforcement	2/12/16 Date

U.S. Department of the Interior
Bureau of Reclamation

February 2016

Mission Statements

The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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Acronyms

ABOD	Aviation Board of Directors
ALSE	Aviation Life Support Equipment
AMC	Aviation Management Council
AMD	Aviation Management Directorate
AMRB	Aircraft Mishap Review Board
AMIS	Aviation Mishap Information System
AMS	Aviation Management System
ARA	Aircraft Rental Agreement
CFR	Code of Federal Regulations
COA	Certificate of Authorization
DM	Departmental Manual
DOI	U.S. Department of the Interior
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulations
HAZMAT	Hazardous Materials
IAT	Interagency Aviation Training
IBC	Interior Business Center
IHOG	Interagency Helicopter Operations Guide
MSO	Management Services Office
NAM	National Aviation Manager
NAMP	National Aviation Management Plan
NASM	National Aviation Safety Manager
NTSB	National Transportation Safety Board
OAS	Office of Aviation Services
OMB	Office of Management and Budget
OPM	Operational Procedures Memoranda
PFD	Personal Flotation Device
PASP	Project Aviation Safety Plan
PIC	Pilot-in-Command
PPE	Personal Protective Equipment
RAM	Regional Aviation Manager
RAMP	Regional Aviation Management Plan
Reclamation	Bureau of Reclamation
RD	Regional Director
SAFECOM	Safety Communiqué
SME	Subject Matter Expert
STEP	Single Skid, Toe-In, Hover Exit/Entry Procedure
SOL	Solicitor of the U.S. Department of the Interior
RAM	Regional Aviation Manager
UAS	Unmanned Aerial Systems
USDA	U.S. Department of Agriculture
USFS	United States Forest Service

Definitions

Best Practices: Practices designed and implemented to ensure operational and organizational success. These practices typically include additional safety and service margins, and are often adopted as industry or Federal agency standards. They tend to be cost beneficial. These practices are dynamic because they are perpetually evolving with changes in customer expectations, as well as advances in the general knowledge base.

Complex Aviation Program: A program with three or more of the following components: Exclusive Use Aircraft Contracts, assigned fleet aircraft, high risk missions (helicopter external loads, helicopter Single Skid, Toe-In, Hover Exit/Entry Procedures [STEP], etc.), and Cooperator Aircraft.

Operational Control: With respect to a flight, operational control means the exercise of authority over initiating, conducting, or terminating a flight.

Additional aviation management definitions can be found in the Departmental Manual, 350 DM 1, Appendix 2, p. 8, which can be found at:
http://elips.doi.gov/ELIPS/DocView.aspx?id=1083

Chapter 1
Aviation Management Overview

1.1 Background and Purpose

The Bureau of Reclamation (Reclamation) National Aviation Management Plan incorporates instructions, requirements, and operational policies contained in Federal Property Management Regulations, Part 37; Government Aviation Administration and Coordination; the Federal Aviation Administration (FAA); and the U.S. Department of the Interior (DOI) Manual on Aviation Policy; Departmental Manual (DM) 350-354, Operational Procedures Memoranda (OPM), as well as using aviation best practices from other bureaus/agencies. FAA regulations can be found at: http://www.faa.gov/, and DOI policies can be found at https://www.doi.gov/aviation/library/.

With minor exceptions, this aviation plan applies to flight services other than those acquired on a seat-fare basis operating under Federal Aviation Regulations (FAR) Part 135 or from commercial air carriers (e.g., Delta, United) in the United States, Trust Territories, and Possessions operating under FAR Part 121.

1.2 Reclamation Management Policies

1.2.1 Administrative Use

Aviation is a necessary and acceptable management tool when used in a manner consistent with the Reclamation mission. Aviation activities will comply with all applicable policies and regulations issued by the DOI, the FAA, and Reclamation.

1.3 Organizational Responsibilities

Major responsibilities for each of the following organizations include, but are not limited to, those described below.

1.3.1 Department of the Interior

- Effective October 1, 2012, the Aviation Management Directorate (AMD), under the Interior Business Center (IBC), was moved to the Office of the Secretary and renamed the **Office of Aviation Services (OAS)**. OAS will maintain the same responsibilities as did the AMD. This plan will be updated as needed when Web sites and form numbers change. OAS is responsible for DOI-wide functions related to aircraft services and facilities in accordance with 350 DM 1.

- **The DOI Executive Aviation Board (EAB)** is responsible for the DOI aviation program. The EAB provides executive oversight and performance accountability and assures that Department-wide strategies and initiatives are developed and implemented consistently throughout the Department. The Deputy Commissioner for Policy, Administration and Budget serves on the EAB for the Bureau of Reclamation. In order to improve aviation governance within the DOI, the EAB has established the **Executive Aviation Committee (EAC)**. The EAC is comprised of Senior Executive Service level representatives from each DOI bureau and the OAS. The EAC functions as the primary executive committee responsible for developing strategic aviation objectives and initiatives as well as implementing EAB initiatives and strategies. Under the EAC, is the **Executive Aviation Subcommittee (EAS).** The EAS is comprised of the bureau **National Aviation Managers (NAM)** and **National Aviation Safety Managers (NASM)** who, as **Aviation Subject Matter Experts (SME)**, recommend changes in aviation policy through the EAC to the EAB; see 350 DM 1.

1.3.2 Bureau of Reclamation

- The **Director, Security, Safety and Law Enforcement (SSLE),** is responsible for the implementation, execution, and enforcement of DOI aviation policy and the development and execution of Reclamation aviation policy and program development and oversight. Those responsibilities are exercised through the NAM. Specific responsibilities are outlined in 350 DM 1. The Director is also a member of the DOI EAC.

- The **National Aviation Manager** serves as the principal aviation advisor for Reclamation.

    1. The NAM function and responsibility resides within Reclamation's SSLE Office in Denver and is specifically performed by the SSLE Risk Management Program Manager.

    2. The NAM serves as Reclamation representative to the EAS which reports to the EAC.

    3. Provides national direction to the aviation safety program.

    4. Disseminates aviation related policy and technical information.

    5. Coordinates with OAS for aviation support, when needed, and Reclamation aviation program evaluations.

6. Assigns representatives to accident review boards and actively works with other program managers to ensure operational aviation issues are addressed in program and policy decisions.

7. Coordinates fleet aircraft acquisition, replacement, and disposal to support agency programs.

8. Assigns a liaison to accident investigation teams.

9. The NAM is responsible for assisting OAS with the coordination of DOI Aviation Program Evaluations.

- **National Aviation Safety Manager (NASM)** serves as the principal aviation safety advisor for Reclamation.

    1. Primary responsibility is to implement the Reclamation aviation safety program.

    2. Coordinates with OAS for Reclamation aviation program evaluations and safety.

    3. Performs as the principal Reclamation representative for accident investigations and review boards.

    4. Manages the overall aviation safety effort of Reclamation and serves as principal advisor on all technical and administrative aviation safety matters.

    5. Analyzes accident and incident trends and monitors Aviation Mishap Information System (AMIS) Safety Communiqué (SAFECOM) reports and incidental serious safety concerns.

- **Regional Directors (RD)** are responsible for ensuring that a safe and efficient aviation program exists in their region.

    1. Ensures all aviation activities are assessed for risk.

    2. Supports and disseminate aviation policies and information.

    3. Ensures that aviation training is in compliance with requirements and that proper equipment is utilized.

    4. Ensures availability of aviation expertise to field managers who are responsible for aircraft operations.

    5. Assigns a liaison to aviation accident investigation teams.

6. Promote and support AMIS. Refer to appendix 4B.

7. Participates in or assigns a senior line officer from the region to participate in an Aircraft Mishap Review Board (AMRB) for incidents occurring within their region.

8. Identifies and submits program requirements.

9. Expands DOI pilot standards and crew requirements as needed.

- **Regional Aviation Manager (RAM)** provides technical expertise and aviation safety oversight in their geographic area. Observes regional aviation activities and provides liaison with the RD, NAM, NASM, Unit Aviation Manager, and other agencies as appropriate.

1. Reviews proposed changes in policy and procedure.

2. Coordinates flight services for personnel within their region

3. Coordinates or may instruct aviation training courses as requested.

4. Reviews, as requested, district/unit aviation management plans.

5. Reviews Project Aviation Safety Plans (PASP) (see appendix 3 for an example of topics that may be included in the plan); coordinates the planning and completion project plans and risk assessments.

6. May be delegated to perform as Reclamation representative for accident investigations and review boards.

- **Unit Aviation Manager** is responsible for providing operational oversight to all flight operations conducted at a field unit.

1. Responsible for writing and implementing the Unit Aviation Management Plan (see appendix 2 for an example of topics that may be included in the plan).

2. Reviews Project Aviation Safety Plans (PASP) (see appendix 3 for an example of topics that may be included in the plan) and coordinates the planning and completion of project plans and risk assessments.

3. Ensures that aircraft and pilots are appropriately approved for the mission.

4. Requests technical assistance for aviation problems.

5. Validates that all aviation users meet the training requirements of the *Interagency Aviation Training (IAT) Guide* and OPM-04, *Aviation User Training Program*, can be found at: https://www.doi.gov/sites/doi.gov/files/uploads/OPM-04.pdf.

6. Requests waivers, exemptions, or exceptions to policies, standards, procedures, or other instructions. Requests must be submitted to the appropriate authority through the RAM.

7. Ensures that Project Aviation Managers (individuals who plan, organize, and manage the aviation operations of a project using aircraft) are qualified per OPM-04.
8. Appraises the Field Unit and RAM of aviation concerns and problems.

- **Project Manager** plans and manages aircraft use according to applicable directives and policies, develops and submits project plans and risk assessments, and assigns fixed wing or helicopter managers to projects.

- **Pilot-in-Command (PIC)** is responsible for conducting aviation operations in accordance with applicable policy and directives; responsible for maintaining proficiency and qualification standards appropriate to the missions performed; responsible for the safety of the aircraft and personnel on board, and has the sole authority for operations of the aircraft; ensures airworthiness and operates aircraft for maximum safety and efficiency; provides aircraft briefings; reports unsafe operations, conditions, and situations using the AMIS system; complies with Aviation Life Support Equipment (ALSE) requirements; and completes payment documents.

- **Aircrew Member** working in and around aircraft is essential to ensure the safety and successful outcome of the mission. Aircrew members are required to either be on board or attend to the loading and unloading of passengers and cargo at all landings and takeoffs, attend to external loads, and ensure that passengers have received a safety briefing prior to all special use missions.

- **Dispatch Personnel** are responsible for dispatching and flight following aircraft in accordance with DOI and Reclamation policies. Some of their duties include procuring, scheduling, initiating flights, flight following, and processing payments.

- **Flight Followers** are responsible for monitoring aircraft flight activities in accordance with DOI and Reclamation policies. Flight followers must meet the requirements of the training listed in chapter 14.4 of the NAMP. They may work in a dispatch center or at a remote location where they have the ability to monitor a flight by radio or a satellite tracking system and the means to initiate an aircraft mishap emergency response should the need arise.

- **Employees** are responsible for knowing and following applicable policy and directives, maintaining training by attending required aviation training in accordance with DOI and Reclamation policies, using appropriate personal protective and life support equipment, reporting potential and actual problems, and ensuring the safety of themselves and others.

1.4 Evaluation and Monitoring

Periodic internal reviews of Reclamation aviation operating procedures are necessary to enhance safety, identify program strengths and weaknesses, help identify fiscal and personnel needs, and ensure the efficient use of aircraft under Reclamation control. These reviews may be supplemental to those conducted by DOI.

1.4.1 Regional Aviation Program Review

Each region's overall aviation program will be reviewed at least once every 5 years by OAS, in coordination with the NAM. The DOI program reviews conducted by the OAS will be in accordance with DOI policy, 352 DM 2, Aviation Program Evaluations.

- Any finding identified as a serious safety concern will be responded to in writing. The response will include corrective actions, effective date, and individual responsible for the correction.

Chapter 2
Aviation Directives

2.1 General

The following documents must be made available to all unit aviation managers using aviation resources.

2.2 Federal Aviation Regulations

These regulations are the basic guide for piloting and aircraft operations within DOI. Federal Aviation Regulations (Title 14, Chapter 1, of the Code of Federal Regulations [CFR]) may be obtained from the Government Printing Office, commercial book stores selling pilot and aviation materials, or may be viewed on the Internet at: http://www.faa.gov.

2.3 Departmental Manual

Departmental Manual (DM) Parts 350-354 are the aviation policies for all DOI agencies. The DM is available at "Document Library" located at: https://www.doi.gov/aviation/library/. OAS publications and forms, and Office of Management and Budget (OMB) circulars, may be obtained from OAS or viewed at the same Web site.

2.4 DOI Operational Procedures Memoranda

Operational Procedures Memoranda (OPM) are interim directives and may become final policies. They may also be viewed on the Internet at: https://www.doi.gov/aviation/library/.

2.5 DOI Handbooks/Interagency Guides/Standards

The current version of the following handbooks, plans, and guides (as annotated) constitute Reclamation aviation policy, except where noted. They may also be viewed on the Internet at: https://www.doi.gov/aviation/library/.

2.5.1 Handbooks

- Aviation Life Support Equipment Handbook
- Aviation Fuel Handlers Handbook
- Interagency Aviation Transport of Hazardous Materials Handbook

2.5.2 Guides

- *Interagency Helicopter Operations Guide* (IHOG). This guide provides best practice for helicopter operations and is found at: http://www.fs.fed.us/fire/aviation/av_library/index.html. **IHOG compliance is required for the Reclamation helicopter pilot and support personnel when participating in interagency wildland fire operations.**

2.5.3 Plans

- Reclamation NAMP
- Reclamation Regional Aviation Management Plans (RAMP)
- Reclamation Unit Aviation Plan
- Reclamation PASPs

2.6 DOI and Interagency Information Bulletins

Information bulletins, which contain material of a general nature and do not have a defined expiration date, can be found at: https://www.doi.gov/aviation/library/.

2.7 DOI and Interagency Safety Alerts

Safety alerts, which are time-sensitive documents that are published, as needed, can be found at: https://www.doi.gov/aviation/safety/safety_alerts..

2.8 DOI and Interagency Aviation Accident Prevention Bulletins

These bulletins, which contain material with wide application and are issued as needed, can be found at:
https://www.doi.gov/aviation/safety/accident_prevention_bulletins..

2.9 DOI and Interagency Technical Bulletins

Technical data and recommendations regarding aircraft are published in technical bulletins, when warranted, and can be found at:
http://amd.nbc.gov/dts/index.htm#Tech%20Bulletins.

2.10 Office of Management and Budget Circulars

OMB Circular No. A-11, Part 7, Exhibit 300 Process; A-123 (http://www.whitehouse.gov/omb/circulars_a123); and A-126 (http://www.whitehouse.gov/omb/circulars_a126) prescribe procedures for acquisition of fleet aircraft, internal program controls, and the management and use of Federal Government aircraft.

2.11 Waivers and Exceptions to Policy

Waivers are requests for departure from personnel protective equipment requirements of the *ALSE Handbook*. These waivers must follow the procedure outlined in the *ALSE Handbook*, which can be found at: https://www.doi.gov/aviation/library/..

Chapter 3

Records and Reports

3.1 DOI Aircraft Flight/Use and Aircraft Use Reports

For each flight on fleet aircraft, Form AMD-2, Aircraft Flight/Use Report, must be completed for billing and record purposes. For contract, rental, or charter aircraft, Form AMD-23E, Aircraft Use Report, must be used for the same purposes.

3.1.1 Aircraft Use Payment Systems

3.1.1.2 Aviation Management System

The Aviation Management System (AMS) is a Web-based flight use reporting and invoicing system, which replaces the paper versions of the AMD-2, Fleet Aircraft Flight Use Report, and AMD-23E, Flight Use Report. AMS may become the tracking system for maintenance of our fleet aircraft within the DOI.
AMS training can be found at: https://www.doi.gov/aviation/safety.

Additional information on AMS can be found at:
https://www.doi.gov/aviation/aqd.

3.2 Nonrevenue Flights

Each nonrevenue flight on approved cooperator aircraft (military or other public agencies) or approved privately owned aircraft used for personal transportation on Government travel must be documented on Form AMD-2 or AMD-23E; refer to 350 DM 1.9, which can be found at:
https://www.doi.gov/aviation/library/dm.
http://elips.doi.gov/ELIPS/DocView.aspx?id=1083

The comment "Not for payment purposes" must be included.

3. 3 Use of Non-Federal Public Aircraft

Reclamation reimbursement for the use of a State/local government owned and operated public aircraft as a first responder resource must be documented to show that consideration was given to commercial operators and that no commercial operator was available to respond to the incident in the same manner and timeframe as the non-Federal public aircraft. Documentation must be maintained with the incident records. (See Section 12.5.) Note: This section refers to the operation of an aircraft by a government agency that does not meet civil standards or that does not have a commercial operating certificate (if one is required).

Operations that are conducted by a government agency using civil certificated aircraft that do not require an operating certificate, may be utilized when approved as an affiliate aircraft by OAS.

3.4 Aviation Safety Training Records

Aviation training records for Reclamation employees must be maintained by the respective units in accordance with OPM-04, *Aviation User Training Program*, which can be found at: https://www.doi.gov/sites/doi.gov/files/uploads/OPM-04.pdf..

Field units may use the IAT records database to meet this requirement.
IAT modules received in NWCG/other training will be entered in the IAT records database, which can be found at: https://www.iat.gov/.

Pilot training records must be maintained in accordance with 351 DM 3.6; OPM 11-22, *Pilot Training Program*, which can be found at: https://www.doi.gov/sites/doi.gov/files/uploads/OPM-22.pdf..

Chapter 4

Fleet Aircraft Acquisition and Disposition

4.1 Acquisition

Aircraft bailed by DOI (on loan from another agency), owned by DOI, or leased by DOI with the intent to purchase are fleet aircraft as defined in 350 DM 1, appendix 2. DOI (OAS) fleet aircraft may be assigned to Reclamation by OAS. Fleet aircraft may be acquired by OAS from a variety of sources such as purchase, donation, excess, bailed, or seizure.

The addition of an aircraft to a local unit program, to include Unmanned Aerial Systems (UAS) must be requested through the NAM. The relative merits of purchase versus contracting must be evaluated in accordance with OMB Circular A-11, Part 7, and Exhibit 300 process. The justification shall include mission purpose, the amount and kind of usage, pilot arrangements, acquisition and operating costs, equipment enhancements, and financial reserves for aircraft replacement purposes. Proposals must also include information on opportunities for sharing use with other Reclamation offices or agencies.

Unmanned Aerial Systems are considered fleet aircraft and subject to all policy and procedures governing the acquisition, funding, and use. No field unit may acquire or use UAS for any purpose without advanced approval by the NAM and in compliance with OPM -11, DOI Use of Unmanned Aircraft Systems.

Additional congressional allocations for DOI aircraft must be requested by OAS on behalf of Reclamation well in advance of need and must be supported with detailed information.

Reclamation's Director may request the Associate Director, OAS, to reassign excess fleet aircraft to Reclamation units.

4.2 Disposition

The OAS is responsible for disposing of aircraft in accordance with Federal Property Management Regulations. Disposal of aircraft, to include UASs, must be coordinated with the NAM for possible reassignment or transfer of the aircraft reserve funds.

Chapter 5

Fleet Aircraft Equipment

5.1 General

Aircraft used in support of aviation activities within DOI must be equipped in accordance with 351 DM 2, found at: http://elips.doi.gov/ELIPS/DocView.aspx?id=1090.

5.2 Special

No equipment or device may be permanently added to any aircraft without the concurrence of the RAM. Final approval requires completion of AMD-74 and authorization from Chief, OAS, Technical Services Division.

All aircraft with external devices, such as tracking antennas, must be operated in accordance with the limitations of FAA approval (Supplemental Type Certificate, Form FAA-8110-2, for the aircraft make and model, or Form FAA-337, Major Repair and Alteration). Additional requirements for tracking antennas are found in 351 DM 2.2 H.

Chapter 6

Personal Protective Equipment/ Aviation Life Support Equipment

6.1 Personal Protective Equipment

Flight crew members, air crew members, and passengers are required to wear Personal Protective Equipment (PPE) on all special use flights (defined in OPM-29, *Special Use Activities and Revised Standards for Technical Oversight*). For most special use flights, PPE minimally consists of fire-resistant clothing (Nomex), aviator's protective helmet (except in multiengine fixed wing aircraft), leather boots extending above the ankles, and flight gloves made completely of Nomex or leather, or a combination of Nomex and leather. The *ALSE Handbook* contains additional information and can be found at: https://www.doi.gov/aviation/library/.

Wearing of materials with low temperature melting characteristics, such as synthetics (e.g., nylon, Dacron, polyester) and synthetic blends, are not permitted without a waiver or exception in accordance with the *ALSE Handbook*.

Procedures for requesting a waiver may be found in the *ALSE Handbook*.

6.2 Personal Protective Equipment Waiver Authority

This authority may be exercised by the Director, MSO, or by written delegation at a lower authority. Exercising this authority requires that the OAS Aviation Safety and Evaluations Division and appropriate OAS Regional Director be provided a copy of the waiver and any written delegation. A waiver must have an expiration date and cannot exceed 3 years.

Copies of waivers must be provided to the NAM, the Reclamation Regional Director, and the RAM.

6.3 First Aid and Survival Kits

6.3.1 First Aid Kits

First aid kits containing specific minimum items listed in the *ALSE Handbook* must be on board aircraft under operational control of Reclamation, except for those procured through the DOI rental system for nonspecial use flights. A survival kit containing the minimum items listed in the *ALSE Handbook* must be onboard all special use flights.

6.3.2 Personal Survival Kits

Survival following an aircraft mishap requires: (1) the desire to survive, (2) training, (3) survival items carried with you or available from the aircraft, and (4) use of environmental resources. When constructing a personal "survival kit," consider what would be practical, comfortable, and of the highest priority (fire and signal) during an unexpected survival situation.

Note: Aircraft accident experience has shown that survival equipment carried on your person is often the only equipment available to the survivors.

6.4 Personal Flotation Device

6.4.1 Single Engine Aircraft

For operations beyond power-off gliding distance to shore, Personal Flotation Devices (PFDs) will be worn for all flights.

6.4.2 Multiengine Aircraft

Portable flotation devices must be immediately available to each seated occupant.

Note: When water takeoffs or landings are performed, occupants of all aircraft must wear PFDs. **This policy includes Seat Fare operations, except as noted below.**

6.4.3 Exception

PFDs need not be worn, but must be immediately available to each seated occupant in multiengine-land aircraft. These PFDs must meet the over water performance capability required for FAA, Part 121, Air Carrier, and Part 135, Air Taxi and Commercial Operators.

6.5 Emergency Locator Transmitter

An emergency locator transmitter meeting *ALSE Handbook* requirements must be installed in all aircraft owned or operated by Reclamation. The emergency locator transmitter must be installed in the cabin or a conspicuous sign must indicate its location(s).

6.6 Flight Helmets

Instructions for fitting and maintenance/inspection of flight helmets may be found in the *ALSE Handbook* and the *Flight Helmet User's Guide*, which can be found at: https://www.doi.gov/aviation/library/..

Chapter 7

Aircraft Maintenance and Inspection

7.1 Maintenance

DOI-owned or operated aircraft must be maintained in accordance with the maintenance programs outlined in 351 DM 2, which can be found at: http://elips.doi.gov/ELIPS/DocView.aspx?id=1090.

7.2 Inspection Programs

DOI-owned or operated aircraft must be inspected in accordance with the inspection programs outlined in 351 DM 2.

7.3 Returning an Aircraft to Service

Fleet aircraft shall not be operated until it has been approved for return to service in accordance with 14 CFR 43. A functional flight test must be performed by a pilot certificated in accordance with 14 CFR 61 following: aircraft overhauls, major repairs, or replacement of engine, power train, rotor system, retractable landing gear system, flight controls, or adjustment of the flight control system. Flight test results shall be recorded in the aircraft maintenance record. No passenger shall be carried during a flight test. Questions regarding rental and/or contract aircraft should be directed to the Contracting Officer's Technical Representative.

Chapter 8

Aircraft Security

8.1 General

The PIC is responsible for the security and tie down of the aircraft. It is recommended that DOI aircraft be hangered whenever practical.

8.2 Fuel

The pilot must verify security, type, and quantity of fuel.

8.3 Facility Security

Each Reclamation location improved for aircraft takeoff and landing shall have a current written security evaluation in accordance with 352 DM 5, which can be found at: http://elips.doi.gov/ELIPS/DocView.aspx?id=1107 and the *Field Reference Guide for Aviation Security for Airports or other Aviation Facilities,* which can be found at: https://www.doi.gov/sites/doi.opengov.ibmcloud.com/files/uploads/Field_Reference_Guide_Aviation_Security_2006.pdf..

The NAM, with the RAM, will ensure that a facility reexamination will be conducted every 3 years.

8.4 Aircraft Security (See 352 DM 5 for Military/Cooperator Aircraft Exemption)

Aircraft must be dual locked whenever it is not under the direct control of a Reclamation employee. At any time DOI-owned or controlled aircraft is not directly attended by DOI-authorized flight or ground personnel, the aircraft will be physically secured and disabled via the dual-lock method. Examples of acceptable dual-lock devices and their conditions of use are listed in 352 DM 5, appendix 2, which can be found at: http://elips.doi.gov/ELIPS/DocView.aspx?id=1107.

Note: Locking aircraft doors and fenced or gated tie down areas are NOT acceptable methods of dual locking.

Chapter 9

Pilot Flight Authority

9.1 General

Due to the major safety, qualifications, operations, and fiscal issues associated with Reclamation employee pilots, managers must carefully consider the position alternatives when creating and recruiting employees who will have pilot responsibilities.

In maintaining flight proficiency, Reclamation employee pilots must fly a minimum of 100 hours in the PIC category in the preceding 12-month period. Reclamation employee pilots not meeting this requirement must complete a proficiency check ride with a Certified Flight Instructor (CFI) within 30 days of their scheduled OAS recurrent flight check per 351 DM 3. Pilots also must meet all other proficiency flight experience for special-use missions and attend flight crew workshops as required by the DOI Flight Crewmember policy found in the DMs, OPM 22.

Failure to meet flight experience and training requirements will result in withdrawal of Reclamation pilot authorization.

9.2 Reclamation GS-2181 Pilots

Pilots must meet all DOI criteria for flight authorization, qualification standards, and flight check requirements listed in the 351 DM 3 that apply to the operations they will perform.

- Piloting aircraft is the primary duty and comprises more than 50 percent of the employee’s duties.
- Position descriptions are classified in the 2181 (Pilot) series.
- Minimum pilot time requirements are higher than in other categories.

9.3 Charter/Contract Pilots

Charter/contract pilots must meet the flight experience, rating requirements, check ride, and carding requirements contained in 351 DM 3 or the procurement document.

9.4 Medical Certificates

Pilots will maintain a minimum Class II FAA Medical Certificate. UAS pilots and Observers will maintain medical certificates per OPM-11, DOI Use of Unmanned Aircraft Systems.

9.5 Pilot Qualifications for Special Use Activities

Pilots who perform special-use flight activities such as low level flight (within 500 feet of the surface), and helicopter external loads must meet additional PIC training and experience per 351 DM 3.

9.6 Pilot Suspension/Revocation

DOI Pilot Qualification Cards will be suspended temporarily or revoked by OAS after an aircraft accident or Incident With Potential. Failure of the pilot to conform to prescribed DOI standards may result in revocation of the DOI Pilot Qualification Card. Revocation, suspension, and reissuing process for DOI pilot authorization is outlined in the DOI Flight Crewmember policy, 351 DM 3. Under some circumstances, such as a recommendation from an AMRB, OAS may be requested to convene a Pilot Review Board or opt to do so on their own as outlined in OPM- 24, Pilot Review Board.

9.7 Request for Reclamation Pilot Carding and Checkrides

Request for pilot carding and checkrides must be routed through the RAM to OAS to maximize the Aviation Safety Compliance Specialist’s time and availability.

Chapter 10

Flight Operations

10.1 General

All aircraft, including UASs, under operational control of Reclamation will comply with applicable FARs, DOI aviation policy, DOI handbooks, and interagency guides as listed in chapter 2.5.

Anyone can refuse or curtail a flight when an unsafe condition may exist or if conditions change (e.g., weather, communication, priorities, personnel). However, stopping or suspending flight operations for any reason does not result in a suspension/revocation of a pilot's DOI Pilot Qualification Card.

10.2 DOI-Approved Aircraft and Pilots

Reclamation employees must use only aircraft and pilots approved or otherwise authorized by OAS or the United States Forest Service (USFS) for all flight services. OAS must approve the use of USFS carded aircraft in advance.

10.3 Aviation Management Plan

Each field unit that uses aviation resources will have a current Aviation Management Plan. The plan must be reviewed on an annual basis and updated every 3 years at a minimum. Appendix 2, Unit Aviation Management Plan, provides an outline of minimum topics.

10.4 Aviation Operation Planning

Mission planning will be completed for all flights as identified in each unit's aviation management plan. The Project Manager or Fleet Pilot is responsible for completing the information listed. (See Appendix 3, Sample Project Aviation Safety Plan, for an example.)

Aviation mission planning for special use flights will require a risk assessment to asses and verify the following:

1. Methods other than aviation have been considered to accomplish the mission more effectively and efficiently.

2. Reclamation employees meet all qualification and experience requirements to participate in the aviation operation.

3. Aircraft and pilot are approved or authorized by DOI for the mission.

4. The pilot is proficient and experienced for the mission and has qualification standards and familiarity with the aircraft and its operation.

5 Configuration of the aircraft is appropriate to the need.

6. Weather and other environmental conditions have been considered.

7. Any hazards in the flight path are known and plans are in place avoid them and/or ensure safety.

8. PPE and ALSE are present and in operable condition.

9. First aid/survival equipment is onboard.

10. Human factors and intangible pressures have been considered, such as urgency and time to accomplish the mission.

10.5 Flight Plan and Flight Following

Flight plans must be prepared and flight following must be conducted for all Reclamation aviation activities as outlined in the 351 DM 1.4, which can be found at: http://elips.doi.gov/ELIPS/DocView.aspx?id=1088.

Reclamation has established a required 30-minute minimum for flight following. To fulfill this requirement, regions are encouraged to establish agreements for flight following with other agency coordination and dispatch centers (i.e., the Bureau of Land Management, USFS).

All Reclamation Exclusive Use and Fleet aircraft using a satellite-based tracking system must be monitored by dispatch or flight following qualified personnel during all flight operations.

10.6 Passenger Manifest

The PIC must ensure that a manifest of all crew members and passengers has been completed. A copy of this manifest must remain at the point of initial departure. Manifest changes will be left at subsequent points of departure when practical. When multiple short flights will be made in a specific geographic area which involves frequent changes of passengers, a single manifest of all passengers involved may be left with an appropriate person to preclude unreasonable administrative burden.

10.7 Aircraft Preflight/Postflight

Pilots must conduct a visual inspection of the aircraft before and after each flight.

10.8 Checklists

Pilots must use written checklists for all phases of flight, per 351 DM 1.

10.9 Interagency Aircraft Data Card

An Interagency (DOI/USFS) Aircraft Data Card must be maintained in the aircraft and be physically inspected prior to each mission. (Approval of cooperator aircraft may be by letter or agreement process. See Section 13.3, Carding, Letters of Approval, or Memorandum of Understanding.

10.10 USDA-Interagency-DOI Airplane Pilot Qualification Card

The DOI Pilot Qualification Card must be carried by pilots and physically inspected by flight managers prior to each mission. If the card is unavailable, the pilot's authorization to fly the mission must be verified prior to the flight. (Approval of cooperator flight crew members may be by letter or agreement process. See Section 13.3, Carding, Letters of Approval, or Memorandum of Understanding.

10.11 Passenger Briefing

The PIC must ensure that each passenger receives a briefing prior to each mission per FAR 135.117 and 351 DM 1.5 B. It is also the responsibility of the Reclamation employee to ensure that they receive a passenger briefing.

10.12 Crew Duty Time Limitation

All activities must be conducted in accordance with 351 DM 3.6A and/or the procurement document that authorizes their work.

All flight crew members must have a minimum of 10 consecutive hours of rest (off duty), not including any preflight or postflight activity before any assigned duty period.

Time spent traveling to or from a nonlocal duty assignment must not be considered part of a crew rest period.

For a single pilot crew, the following limitations apply:

- A maximum of 8 hours of flight time during any assigned duty period.
- A maximum of 14 consecutive duty hours during any duty period.
- A maximum of 42 hours of flight time during any consecutive 6-day period. When a pilot acquires 36 or more flight hours in a consecutive 6-day period, the pilot must be granted a 24-hour period of rest (off duty), and then a new 6-day cycle can begin. In the conterminous United States, this 24-hour rest period shall be 1 calendar day off duty.

10.13 Instrument Flight Rules

Flights are permitted in accordance with FAR 61.57, 91.167 through 91.193, applicable areas of the FAR *Aeronautical Information Manual*, and 351 DM 1.

10.14 Transport of Hazardous Materials (HazMat) by Aircraft

Transport is allowed in accordance with the special permit granted to DOI by the Department of Transportation, provided that activities are conducted as stipulated in the *Interagency Aviation Transport of Hazardous Materials Handbook/Guide*. A current copy of that special permit, and other documents as stated in the special permit, must be in the aircraft and at the place of loading when utilizing the special permit, which can be found at: https://www.doi.gov/sites/doi.opengov.ibmcloud.com/files/uploads/HAZMAT_Handbook_2005.pdf..

The following regulations apply to the transport of hazardous materials by aircraft:

(1) Every 3 years, all involved employees, the pilot, and the ground crew must complete mandatory HazMat training, A-110, Aviation Transport of Hazardous Material

(2) The pilot must be notified in writing that HazMat is being transported

(3) Except for law enforcement officers with a duty belt holster specific to the chemical agent, pepper spray, mace, etc., may not be carried internally in an aircraft unless it is secured in a sealed, nonporous container (e.g., ammunition can).

10.15 Fuel Reserves

Aircraft must maintain fuel reserves (30-minute reserve) as stipulated in FAR 91.151 and FAR 91.167.

10.16 Transport of Cargo/Equipment

Only cargo and/or equipment necessary for mission accomplishment are permitted on board aircraft under operational control of Reclamation and must be transported in accordance with FARs and DOI policies. For helicopter best practices, refer to IHOG Chapter 11, Cargo Transport, which can be found at: https://www.doi.gov/aviation/library/guides..

External load flights for helicopters are permitted if they are conducted with suitably equipped helicopters that are flown by pilots approved by DOI/USFS for external load operations. The aircraft must also be operated in accordance with FAR 133 and 351 DM 1.5. Fixed wing external load operations will not be permitted, except when authorized by OAS.

10.17 Load Calculations/Weight and Balance

Load calculations/weight and balance will be accomplished by the PIC prior to each Reclamation flight they undertake. These calculations will consider weight of cargo and passengers, center of gravity, etc., relative to environmental conditions and performance capabilities of the aircraft. For helicopters, refer to IHOG Chapter 7, Helicopter Load Calculations and Manifests.

10.18 Environmental Considerations

Flight operations may be restricted because of environment factors such as darkness, temperature, wind, snow, rain, fog, and cloud cover. All flights shall be flowing in accordance with 351 DM 1 (http://elips.doi.gov/ELIPS/DocView.aspx?id=1088). Employees are required to terminate flight operations if the weather is below the applicable minimum by returning to the starting point or landing at the nearest safe spot. Flight operations are prohibited until the weather improves above the minimums. The pilot may set a more restrictive weather minimum if necessary for a safe flight. Additional helicopter guidance can be found in the IHOG.

10.19 Aviation Mishap Response Plan and Hazard Map

Each field unit or other Reclamation office using flight services must maintain a current and complete Aviation Mishap Response Plan in a readily accessible location. This plan must be reviewed and updated annually. Appendix 1 provides an Interagency Aviation Mishap Response Guide and Checklist.

Available hazard maps of the planned flight area and altitude must be reviewed prior to the mission. A hazard is any obstacle protruding into the planned flight altitude or path. Known and potential wire strike locations in the flight area must be reviewed, and the pilot must be informed about them during flight planning activities. Any new hazards found in the flight area must be added to the hazard map. Flight managers and pilots are responsible for reviewing hazard maps before each low-altitude flight.

10.20 Lap Belt/Shoulder Harness

Lap belts, shoulder, or approved restraining harness must be worn during all flights. Configuration of lap belt/shoulder harness must meet 351 DM 2, *ALSE Handbook.*

10.21 Special Use Flight Operations

"Special use" is defined in 350 DM 1 and OPM 29 as operations for which special pilot qualifications and techniques, special aircraft equipment, and PPE are required to ensure safe transportation of personnel and property. OAS authorization for both pilot and aircraft is required for special use operations.

Special use flight operations require, at a minimum, a Project Aviation Safety Plan, appendix 3, including a risk assessment, and the elements listed in 352 DM 1.9 C through I, which can be found at: http://elips.doi.gov/ELIPS/DocView.aspx?id=1099. For cooperators, full-service call-when-needed contracts, and end-service operations, refer to chapters 12 and 13 in this aviation plan.

10.21.1 Single Skid, Toe-In, and Hover Exit/Entry Procedures

These landings require special training and approval from the NAM and OAS. Approvals may be requested for each project or for a field unit program. The establishment of new STEP programs requires approval by the Director, MSO.

10.21.2 Unprepared Landing Areas

Fixed wing aircraft operations using unprepared landing areas are considered a special use operation by the Departmental Manual and require special pilot and/or equipment qualifications.

10.21.3 Aircraft Operations Below 500 Feet Above Ground Level

These operations (also known as "low level flight)," when authorized, may be conducted in accordance with FAR 91.119, subpart D of part 135; part 137; or FAA Exemption 3017B or further grant of exemption if applicable.

10.21.4 All Hazard Incidents

Reclamation aviation resources and personnel may be asked to respond to all hazard incidents. Response to all hazard incident flight operations may fall under special use flight activities for Reclamation response (i.e., search and rescue, law enforcement, earthquakes, hurricanes, tornadoes, floods, or declared national or State disasters).

10.22 In-Flight Emergency Situations

Pilots will take actions necessary to ensure the safety of personnel and aircraft. Any resulting deviation from applicable FARs, DOI aviation policy, and this NAMP must be reported in writing to the NAM.

10.23 Employee Prerogative

While performing their duties, Reclamation personnel may elect, without fear of reprisal, not to fly under any condition they consider to be unsafe. It is the employee's responsibility to immediately report any aviation hazard that compromises the safety of personnel or equipment via a Safety Communiqué (SAFECOM), which can be found at: https://www.safecom.gov/.

10.24 Unmanned Aerial Systems (UAS)

The FAA establishes rules regarding UAS operations. UAS operations under FAA Advisory Circular AC 91-57, Radio Controlled Aircraft, are intended for hobbyists, not Government or commercial operators. Certificate of Authorization (COA) is required for all UAS operations. Refer to OPM-11 https://www.doi.gov/sites/doi.gov/files/uploads/OPM-11.pdf. for DOI policy guidance. All requests to use UAS must be routed through the respective RAM to the NAM.

10.24.1 UAS Request/Approval Process

Reclamation shall not conduct UAS operations until requests are approved by the RAM, NAM, and OAS, and all minimum requirements have been met. Requests must be initiated at least 6 months (estimated) before the anticipated UAS mission start date.

1. **Request and Proposal by Reclamation Unit**. The local unit will prepare and submit to the RAM a formal request to initiate a UAS project. This proposal shall include the general purpose, objectives, and justification for using UAS.

2. **NAM Review.** The request shall be routed through the RAM office to the bureau NAM manager for review and approval/disapproval. If approved,

the proposal will be forwarded to OAS, and a request will be made for an online COA account for the project.

3. **OAS Review and Approval.** The OAS UAS Coordinator will review the proposal, communicate directly with the bureau requestor and NAM to gather information, and either approve or disapprove the request.

4. **Request for Certificate of Authorization.** If the bureau proposal is approved, the OAS UAS coordinator will work directly with bureau requestor and NAM to develop the FAA application for a COA. Collaboration and agreement will occur prior to official submission of the application. The OAS UAS coordinator will keep the bureau informed on the status and issuance of the COA. The COA, once issued, shall serve as the UAS operations plan.

10.24.2 Minimum Operational Requirements

The following requirements must be met prior to any operational use of UAS:

1. **PASP.** A PASP will be completed by the Unit Aviation Manager and project manager prior to submitting the COA.

2. **COA.** A valid and current COA issued by the FAA.

3. **DOI UAS Operator Training Requirements.** DOI operators of UAS vehicles must receive training for the specific vehicle they will operate. OAS will identify appropriate training in conjunction with FAA regulations. Operators must possess training certificates from OAS or OAS -approved sources before receiving OAS certification as a DOI UAS operator.

4. **Other DOI UAS Operator Requirements.** Other requirements (to be determined by OAS) may include FAA pilot certificate and FAA medical exams.

5. **DOI UAS Operator Letter of Authorization.** When a DOI employee has satisfied all requirements listed above, the OAS UAS coordinator will issue a DOI UAS Operator/ Pilot Letter of Authorization (LOA). The LOA must specify which UAS vehicle(s) the operator is approved to operate.

10.24.3 PRIVACY, CIVIL RIGHTS, AND CIVIL LIBERTIES PROTECTIONS WITH THE USE OF UAS.

On February 15, 2015, the White House issued a Presidential Memorandum (PM) regarding “Promoting Economic Competitiveness While Safeguarding Privacy, Civil Rights, and Civil Liberties in Domestic Use of Unmanned Aircraft

Systems." The guidance and direction from this PM were incorporated in the Department's Operational Procedures Memorandum (OPM) -11.

1. **Roles and Responsibilities.** Following are the roles and responsibilities within DOI (from Section 5 of OPM-11) as it pertains to privacy, civil rights and civil liberties protections with the use of UAS:

A. The Office of Aviation Services (OAS) has overall responsibility for management, ownership, acquisition, assignment, and disposal of DOI-owned aircraft, including UAS. OAS oversees the UAS program and issues Department-wide policy, procedures, training, and a comprehensive actionable strategy for the use of UAS. In collaboration with Bureau and Office Aviation Programs, OAS establishes UAS requirements and standards to ensure aviation safety and individual privacy, civil rights, and civil liberties protections in compliance with applicable laws, regulations, and policies. Additionally, OAS coordinates with internal and external agencies, partners, and organizations on UAS policy, inspections, audits, compliance reviews, and proposed rulemaking.

B. The Office of the Chief Information Officer (OCIO) has overall responsibility for promulgation and oversight of Department-wide information management policies, guidelines and procedures to bureaus and offices for their implementation to ensure compliance with relevant Federal laws, regulations and policies. Such policies, guidelines and procedures include, but are not limited to, addressing requirements associated with privacy, IT security, and records management. The Departmental Privacy Officer within the OCIO formulates privacy policy, provides guidance, and collaborates with bureaus, offices, and program officials to evaluate program activities to ensure privacy considerations are addressed for the collection, use, retention, and dissemination of personally identifiable information and appropriate safeguards are implemented to protect individual privacy, civil rights, and civil liberties.

C. The Office of Civil Rights (OCR) is responsible for developing policy and guidelines to assure proper implementation of laws, Executive Orders, regulations, and Departmental initiatives relating to affirmative employment, equal opportunity, civil rights and educational partnerships. OCR oversees the management and evaluation of programs, activities, and services receiving Federal financial assistance, and ensures expedient processing and resolution of complaints of discrimination, prevention of discriminatory practices, and equal access to Federal financial assistance and federally conducted programs for all persons regardless of race, color, age, religion, sex, national origin, and disability.

D. Bureaus and offices are responsible for implementing and executing Departmental and organization-specific policies, procedures, and protections consistent with applicable Federal laws, Executive Orders, regulations, policies, and standards.

The use of UAS significantly expands Reclamation's ability to obtain remote data critical to fulfilling diverse mission objectives. However, this use raises distinct privacy, civil rights, and civil liberties concerns that must be addressed in order to promote the responsible use of UAS and protections for individual privacy, civil rights, and civil liberties in accordance with the Constitution, Federal law, and applicable regulations and policies. Below is a summary of the principles in the PM and OPM-11 as it relates to Reclamation's use of UAS:

2. **Privacy Protections.** In light of the advancements in UAS technologies and diverse potential uses of UAS across Reclamation missions, it is imperative that Reclamation take appropriate steps to implement UAS policies that address privacy protections, procedures, and standards to ensure compliance with the Privacy Act of 1974, DOI Privacy Act regulations, Departmental privacy policies, and other applicable laws, regulations and policies. Accordingly, Reclamation Offices utilizing UAS or UAS-collected information shall meet the following privacy requirements:

A. Reclamation Offices shall only collect information using UAS, or use UAS-collected information, to the extent that such collection or use is consistent with and relevant to an authorized purpose and DOI privacy policy.

B. Information collected by or on behalf of Reclamation offices using UAS that may contain personally identifiable information (PII) shall not be retained for more than 180 days unless retention of the information is determined to be necessary to an authorized mission, is maintained in a system of records covered by the Privacy Act, or is required to be retained for a longer period by any other applicable law or regulation.

C. Reclamation offices shall take appropriate steps to ensure that UAS-collected information that is not maintained in a system of records covered by the Privacy Act is not disseminated outside of the agency unless dissemination is required by law, or fulfills an authorized purpose and complies with agency requirements established by appropriate authority.

3. **Civil Rights and Civil Liberties Protections.** To protect civil rights and civil liberties, Reclamation offices shall:

A. Ensure that policies are in place to prohibit the collection, use, retention, or dissemination of data in any manner that would violate the

First Amendment or in any manner that would discriminate against persons based upon their ethnicity, race, gender, national origin, or religion, in violation of law.

B. Ensure that UAS activities are performed in a manner consistent with the Constitution and all applicable laws, Executive Orders, and other Presidential directives.

C. Ensure that adequate procedures are in place to receive, investigate, and address, as appropriate, privacy, civil rights, and civil liberties complaints.

4. **Accountability.** To provide for effective accountability, the Office of Aviation Services, in conjunction with the Office of the Chief Information Officer and the Office of Civil Rights, will provide collaborative oversight of the DOI UAS program within their respective areas of expertise and responsibility. Reclamation offices employing UAS or UAS-collected information shall comply with Departmental oversight activities, and take additional appropriate steps to ensure effective oversight and accountability for their respective UAS programs. Accordingly, Reclamation offices shall ensure:

A. Oversight procedures are implemented for UAS use, including audits or assessments, in compliance with all Departmental policies and regulations.

B. Reclamation office personnel and contractors comply with UAS program training requirements, Rules of Behavior, and procedures for reporting suspected cases of misuse or abuse of UAS technologies.

C. Policies and procedures are implemented that provide meaningful oversight of individuals who have access to sensitive information (including any PII) collected using UAS consistent with all applicable Federal laws, regulations, and policies, as well as Departmental policy guidance.

D. Any data-sharing agreements or policies, data use policies, and records management policies applicable to UAS conform to applicable laws, regulations, and policies.

E. Policies and procedures are implemented to authorize the use of UAS in response to a request for UAS assistance in support of Federal, State, local, tribal, or territorial government operations. Any authorized use, letter of authorization, or memorandum of understanding must include the requirements of this policy and appropriate safeguards to protect privacy, civil rights, and civil liberties.

F. State, local, tribal, and territorial government recipients of Federal grant funding for the purchase or use of UAS for their own operations have in place policies and procedures to safeguard individuals' privacy, civil rights, and civil liberties prior to expending such funds.

5. **Transparency.** OAS will complete the following activities, in collaboration with bureau and office UAS programs, to promote transparency about DOI UAS activities within the NAS, while not revealing information that could reasonably be expected to compromise law enforcement or national security:

A. Provide notice to the public regarding where DOI's UAS are authorized to operate in the NAS.

B. Keep the public informed about the DOI UAS program as well as changes that would significantly affect privacy, civil rights, or civil liberties.

C. Make available to the public, on an annual basis, a general summary of DOI UAS operations during the previous fiscal year, to include a brief description of types or categories of missions flown, and the number of times the agency provided assistance to other agencies, or to State, local, tribal, or territorial governments.

The following page shows a flow chart which graphically shows how UAS data should be treated if it contains PII.

Retention of UAS data and information collected using UAS that may contain PII shall not be retained for **more than 180 days** unless retention of the information is **determined to be necessary to an authorized mission of the retaining agency, is maintained in a system of records covered by the Privacy Act, or** is **required to be retained for a longer period by any other applicable law or regulation**.

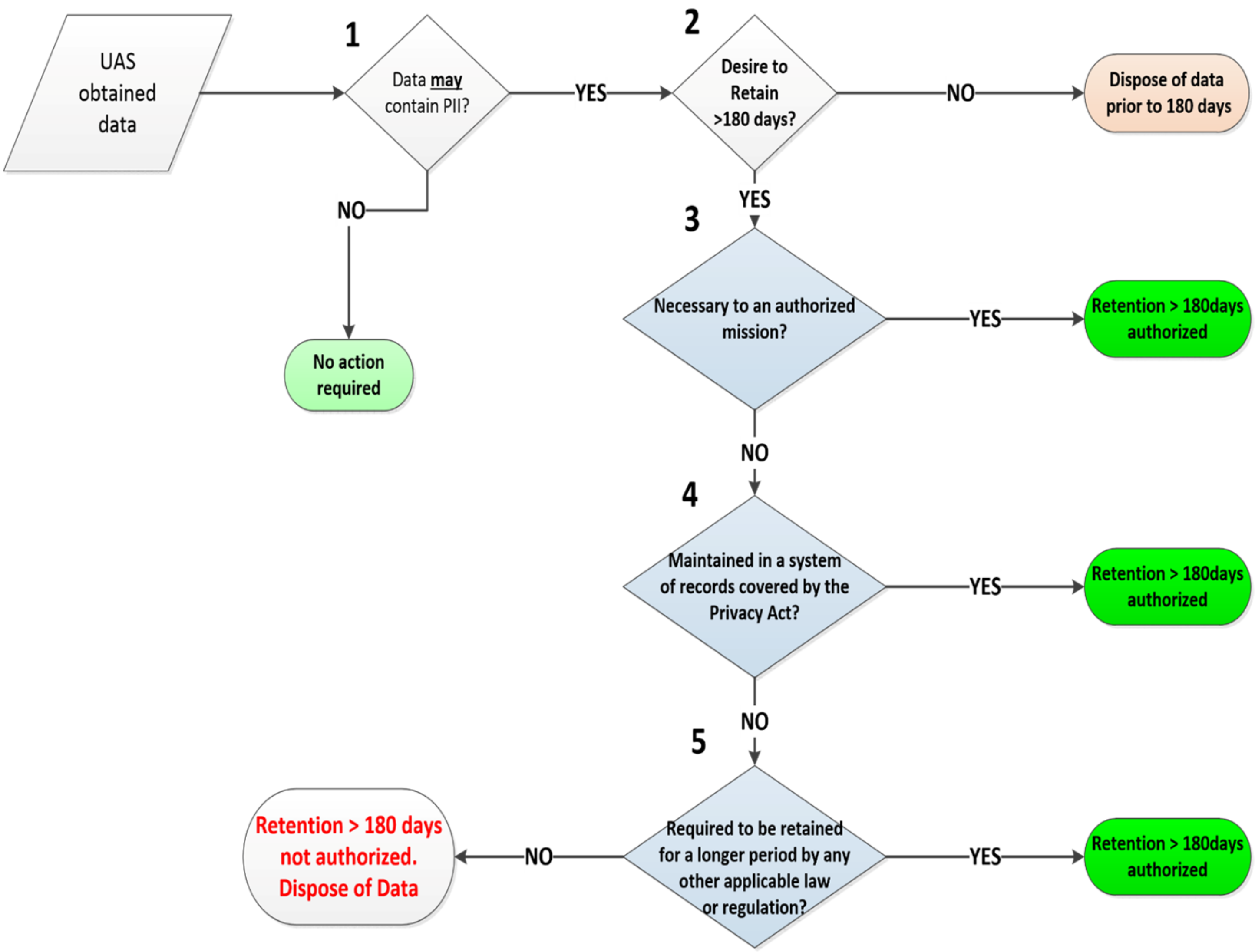


Figure 1

Chapter 11

Use of Government Aircraft and Solicitor Approvals

11.1 Administrative Travel Justification and Documentation

The primary intent of this process is that taxpayers should pay no more than necessary to transport Government officials. This chapter discusses official travel on Government aircraft and when the DOI Solicitor's (SOL) approval is required for Senior Executive Service (SES), Senior Federal officials, or non-Federal travelers.

- **Senior Executive** officials include all civilian officials appointed by the President or civilian employees of the Executive Office.

- **Senior Federal** officials include all SES employees.

- **Non-Federal** officials include congressional, legislative, State, cooperating agency, and partner officials.

11.2 OMB Circular A-126

The Office of Management and Budget's Circular A-126, Improving the Management and Use of Government Aircraft, breaks "official travel" into three categories, which are discussed below.

11.2.1 Mission Travel

Mission travel is transporting people whose presence aboard an aircraft is required to perform, or is associated with the performance of, a governmental function such as, but not limited to, aeronautical research or biological or geological resource management, firefighting, search and rescue, law enforcement, and other such activities. This OMB definition differs from what Reclamation considers a "mission."

11.2.2 Required Use Travel

Required use travel is rare. An employee is a "required use" traveler if the President or the head of the agency has determined that the person's travel qualifies as such.

11.2.3 Other Travel for Conducting Agency Business

The SOL considers almost all DOI travel at the SES level and above as nonmission official travel. Even when air travel is the only practical means of transportation to remote or roadless areas, Solicitor approval is required unless the flight is mission travel.

Note: If a SES or Senior Federal official boards an aircraft at Point A and returns to Point A without any stops, with the exception of fuel or bathroom stops, SOL approval is not required. See Information Bulletin 09-01, Revision 1, Guidelines for Requesting Approval from the Office of the Solicitor for SES Travel on Government Aircraft, which can be found at: https://www.doi.gov/aviation/library/ses_travel..

11.3 Requests for SOL Approval

OPM-7, Improving the Management and Use of Government Aircraft, will be used for documenting cost comparisons for administrative travel on Government aircraft. OPM-7 can be found at: https://www.doi.gov/sites/doi.gov/files/uploads/OPM-07.pdf.

- All travel on Government aircraft must have advanced authorization.

- There are two documents that may be required:
    - Travel Authorization (Form DI 1020)
    - Appendix 6: AMD-110, Travel Cost Analysis (https://www.doi.gov/aviation/aqd/ams)

Table 1 shows the documents and signatures required to approve various individuals to fly on Reclamation owned or operated aircraft.

Table 1. Requirements for Flying on Reclamation Owned or Operated Aircraft

Who Signs	Travel Authorization	AMD-110	
	Next Level Supervisor	File[1]	Office of the Solicitor
Reclamation and other Federal:	√		
Senior Executive	-	√	√
Senior Federal	-	√	√
GS-level employees	√	-	-
Non-Federal individuals	-	√	√

[1] Copy to be provided to the RAM. Maintain a copy on file for at least 3 years.

11.4 Space-Available Travel

Space-available travel is using aircraft capacity that would otherwise be unused on an already-scheduled flight. It is generally limited to Federal personnel and their families in remote locations that are not reasonably accessible to regularly scheduled commercial airline service. Space-available travel using Reclamation operated aircraft is not allowed on special-use flights. The use of space-available travel, for other than the transportation of Federal personnel and their families in remote locations, requires trip-by-trip approval by the Secretary of the Interior and requires reimbursement at the full coach rate fare (OMB A-126). Such requests must be processed through the RAM to the SOL at least 10 days prior to the planned travel, with a copy to the NAM.

11.5 Emergency Use

Reclamation supervisors may authorize the use of Federal Government aircraft to assist in life-threatening circumstances, disaster relief efforts, etc. The nature of the circumstances must be noted on Form AMD-2 or Form AMD-23E, with an informational copy to the RAM. Any deviation from policy requires submission of a SAFECOM.

Chapter 12

Contract, Rental, and Charter Aircraft

12.1 General

Aircraft operators who provide contract, individual charter, or hourly rental service to Reclamation must be approved by OAS. Pilots must meet DOI experience requirements and adhere to flight time and duty limitations.

12.2 Procurement

All aircraft services required by any Reclamation unit must be acquired through the OAS procurement process as outlined below, with the following exceptions:

- Seat fare on flights with scheduled air carrier.

- End Product/Service contracts can be used to obtain services and products such as aerial photographs, per head animal capture, or seeding/fertilization. Aircraft may be used to obtain the product or services; however, there are limits on specifying controls or specific types of aircraft in the solicitation. These types of contracts are not flight service contracts and do not need to be obtained through OAS. There are very strict guidelines that include "operational control" for the use of these types of contracts. Refer to OPM-35, Identification of End Product/ Service and Flight Service Procurement for further guidance, which can be found at: https://www.doi.gov/sites/doi.gov/files/uploads/OPM-35.pdf.

12.2.1 Procurement/Documentation of Competition

Any single procurement of flight services that exceeds $3,000 can be obtained through the Aircraft Rental Agreement (ARA) but must use a best value determination of at least three vendors. Cost comparisons must include all anticipated cost factors including ferry time. Pricing information contained in the OAS source list may be used for this comparison. Projects exceeding $25,000 require assistance through OAS contracting services.

12.2.2 Billee Code

Each unit or office using flight services, other than commercially scheduled carriers, must have an individual OAS billee code. This identifier is used for billing flight services and is required to complete Aircraft Flight/Use and Aircraft Use Reports (AMD-23E). Each office is responsible for reconciling billing discrepancies.

12.2.3 Other Services

Other aviation-related services, such as the purchase of aircraft components, parts and accessories, maintenance services, etc., must be procured through the OAS procurement system.

12.3 Billing/Payments

The aviation services provided to the Reclamation unit must be documented on an Aircraft Use Report (Form AMD-23E).

12.3.1 Approved Sources

Approved sources for flight services include: (1) DOI fleet aircraft, (2) USFS fleet aircraft, (3) OAS procured/contracted aircraft, and (4) Affiliate/Cooperator aircraft approved under an OAS agreement. (See chapter 13.)

12.3.2 Unauthorized Procurement

Unauthorized acquisition of aviation services may go through a ratification process and will include a penalty payment imposed by OAS. Specific details can be found in OPM-6, Services Provided and Use Rates.

12.4 Procurement of Flight Services from Other DOI Bureaus

Before using fleet aircraft assigned to other DOI bureaus, field units are responsible for contacting the provider of the service to determine the payment rates for the use of the aircraft, pilot services, and per diem.

12.5 Procurement of Flight Services from Non-Federal Public Agencies

It is Federal policy not to compete with private industry. Reclamation procurement of and reimbursement for flight services from non-Federal public agencies are generally not authorized unless:

1. That agency is providing the service as a commercial operator.

2. The operation is conducted with civil aircraft when no operating certificate is required.

3. The services are necessary to respond to an imminent threat to life or property, and no service by a commercial operator is reasonably available to meet the threat.

The decision not to use a commercial operator must be documented in writing and made part of the permanent incident record (14 CFR 1.1). Field units that anticipate using resources belonging to other Government agencies must establish the appropriate approval and agreement documents or cooperator aircraft approval with that unit through their RAM and OAS.

Services are acquired on an hourly rate basis and can be used when the cost of services is $25,000 per transaction or less. OAS provides an approved list of rental sources based on a standard ARA (OAS source list) from which all vendors must be selected.

12.6 Contract Services

If the cost for using non-Reclamation-owned aircraft will exceed $25,000, the aircraft service must be obtained by contract, rather than ARA, and be submitted on Form AMD-13, Request for Contract Services, approved by NAM, as well as an official who has authority to certify that funds are available and submitted to OAS.

12.6.1 Requesting Procedures

Requests for services to be performed in the contiguous 48 States must be submitted to the respective OAS regional office. The requesting office must submit the following:

1. Proposed contract requirements/specifications.
2. List of Government-furnished equipment.
3. Justification for other than full or open competition.
4. Justification for specific make and model.

Requests for contract services should be submitted at least 120 calendar days in advance of the anticipated date of contract award for competitive acquisitions and 160 calendar days for noncompetitive acquisitions.

12.6.2 Exclusive Use Contracts

Exclusive use contracts are awarded for a specific time period (30-day, 90-day, etc.). During this time period, the Government has exclusive use of the aircraft. The Government may, at its option, release the aircraft for other work for a specified period of time.

12.6.3 Aircraft Rental Agreements

The OAS has established ARAs with air taxi commercial operators throughout the contiguous United States, Alaska, and Hawaii, based on user needs. An ARA is not a contract; it is a written instrument of understanding that is negotiated between OAS and a vendor. Current Federal acquisition limitations restrict use of the ARA to procurements less than $25,000.

12.7 Emergency Aircraft Procurement

12.7.1 Definition of Emergency

The justification for the procurement of emergency aircraft services must meet the following criteria:

1. **Life Threatening.** A situation or occurrence of a serious nature, developing suddenly and unexpectedly, and demanding immediate action to prevent loss of life.

2. **Operational.** An unforeseen combination of circumstances that calls for immediate action but is not life threatening.

12.7.2 Ordering Emergency Aircraft Services

Authorized personnel from the requesting Reclamation unit can contact the appropriate OAS Flight Coordination Center or use the ARA for requests for charter aircraft services to meet emergency needs. Pilot and aircraft will be approved (carded) for the intended mission. If, due to the nature of the emergency, the pilot and/or aircraft are not approved for the intended mission, a SAFECOM will be submitted immediately after the mission.

Note: All such procurements will have a documented risk assessment completed.

Chapter 13

Cooperator Aircraft

13.1 General

A cooperator or affiliated aircraft can be from: (1) any branch of the military, (2) another public agency, or (3) a private entity. Aircraft and pilots must meet DOI standards for general or special-use flights, and Reclamation employees may not use such aircraft and pilots without prior OAS approval. Any costs incurred by OAS in approving cooperator aircraft, including an onsite inspection and pilot checkride for special-use flights, may be charged to the requesting unit.

Proper planning is critical for the proper development and execution of a cooperator or affiliate agreement. All Reclamation requests must be approved by the NAM prior to submission to OAS.

Additional information may be found in 351 DM 4, which can be found at: http://elips.doi.gov/ELIPS/DocView.aspx?id=1094.

13.2 Research Work Orders/Cooperative Agreements/Support Services Contracts

Cooperative Agreements or Support Services Contracts that contain provisions for aviation services must follow the policies of this NAMP and all other applicable DOI policies if Reclamation maintains mission operational control.

13.3 Carding, Letters of Approval, or Memoranda of Understanding

Interagency Aircraft Data Cards and DOI Pilot Qualification Cards, or Letters of Approval for aircraft and pilots, will be issued to cooperator aircraft and pilots. In situations involving numerous aircraft and pilots (military facilities, State Fish and Game agencies, etc.), a formal agreement by OAS may negate the need for individual aircraft and pilot cards.

Chapter 14

Aviation Safety Training

14.1 Aviation Training Equivalencies

The NAM, working with the OAS Training Division, is authorized to determine IAT equivalencies for training that has been acquired from sources other than IAT. This authorization may be delegated. See OPM-04, which can be found at: https://www.doi.gov/sites/doi.gov/files/uploads/OPM-04.pdf..

14.2 Required Aviation Safety Training

Regional and unit aviation managers are responsible for ensuring that all employees involved in the use or control of aviation resources receive the required level of aviation safety training. Qualification standards and requirements can be found in OPM-4.

14.3 Aviation User Training

OPM -04 and its appendix, IAT Requirements Matrix, list the recommended and required aviation user training:

Line Manager: Regional Directors and their deputies, and those acting in these positions, shall take M3: Aviation Management Training for Supervisors online or complete M2: Line Managers Briefing, every 3 years.

Supervisors: First and second level supervisors of employees who use aircraft to accomplish agency programs or mission shall, at a minimum, take M3: Aviation Management Training for Supervisors and A-200: Aviation Mishap Review online every 3 years.

Unit Aviation Managers: Unit aviation managers shall complete the aviation manager training as outlined in OPM-04.

Aircrew Members: B3 is the Combination Helicopter/Airplane Safety (also known as Basic Aviation Safety) training. Aircrew member training requirements may be found in OPM-04. These courses may be taken online. Training for these classes is required every 3 years. The following are the mandatory B3 training courses:

- A101: Aviation Safety
- A105: Aviation Life Support equipment

- A106: Aviation Mishap Reporting
- A108: Preflight Checklist Briefing/Debriefing (online only)
- A113: Crash Survival
- A-116: General Awareness Security Training
- A-200: Mishap Review (previous year's module acceptable)
- A-110: Transportation of hazardous materials (HAZMAT) (if involved in transport of HAZMAT)

14.4 Specialty Training

Helicopter Crewmember: Personnel involved in external load work must be qualified Aircrew Members and complete A-219 Units 1-4 and Unit 6. In addition, personnel desiring to become qualified as Helicopter Long Line Remote Hook Specialists are required to complete A-219 Units 1-4 and Unit 6.

It is recommended that Reclamation employees acting as crewmembers in float equipped aircraft or on over-water flights beyond gliding distance to shore complete Water Ditching and Survival training, IAT course A-312. This requirement can also be satisfied by having attended a DOI AM equivalent course (e.g., airline, military, Bureau Interagency or Part 141/142 course).

Flight Followers: Flight followers must have, as a minimum, the following training: B3, A104, A107, A109, A111, A112, A115, and A207 (all available online). Units or offices will identify in the Unit Aviation Plan the difference between a flight follower and a dispatcher (DOI has mandatory training requirements for aircraft dispatchers). Training for these classes is required every 3 years. The following are the required training courses:

- A-104: Overview of aircraft Capabilities and Limitations
- A-107: Aviation Policy and Regulations-1
- A-109: Aviation Radio Use
- A-11: Flight Payment Documents
- A-112: Mission Planning and Flight Request Process
- A-115: Automated Flight Following
- A-207: Aircraft Flight Scheduling

14.5 Reclamation Pilot Training

Pilot training will be conducted in accordance with the DMs and OPM 22 or AR-10 where applicable. A Reclamation pilot not in compliance with these documents is not authorized to pilot DOI aircraft.

14.6 Unmanned Aerial System Training

Unmanned Aerial Systems training and use must be requested through the NAM. Requirements can be found at OPM -11, DOI Use of Unmanned Aircraft Systems, which can be found at: https://www.doi.gov/sites/doi.gov/files/uploads/OPM-11.pdf..

Chapter 15

Aviation Safety Awards Program

15.1 DOI Aviation Awards Program

The NAM is responsible for the overall administration of the program.

Reclamation will use the DOI safety award qualification standards and procedures to recognize aviation safety practices per 352 DM 4 and OPM 06-42, Airwards, for the following categories:

15.1.1 Award for In-Flight Action

This award recognizes crew members and passengers who materially contribute to the successful recovery from an emergency or who minimize or prevent aircraft damage or injury to personnel during an emergency.

15.1.2 Award for Safe Flying

This award recognizes pilots who have distinguished themselves by flying accident free for specific periods of time.

15.1.3 Award for Significant Contribution to Aviation Safety

This award recognizes an individual, group, or organization for significant contribution to aviation safety or aircraft accident prevention within DOI. This award is restricted to DOI employees.

15.1.4 Secretary's Award for Outstanding Contributions to Aviation Safety

This award recognizes any individual or group, including other agencies and non-Government individuals, for outstanding contribution in aviation safety or aircraft accident prevention.

15.1.5 Airwards

This award is established to provide timely recognition to any individual who has demonstrated positive behavior or actions that promote DOI aviation safety, such as correcting a hazardous situation, submitting a good idea, or just making a difference.

Chapter 16

Aircraft Mishap Procedures

16.1 Aircraft Mishaps

All Aircraft Incidents and accidents will be reported, via SAFECOM, to the OAS Aviation Safety Manager and the NAM. Aircraft mishaps are broadly defined below.

16.1.1 Accidents

Accidents involve death, serious injury, or substantial damage to the aircraft. The National Transportation Safety Board (NTSB) is responsible for investigating aircraft accidents. All aviation accidents will be reported immediately to the NAM, RD, and OAS in accordance with 352 DM 3, Aircraft Mishap Notification, Investigation and Reporting and Reclamation policy, which can be found at: http://elips.doi.gov/ELIPS/DocView.aspx?id=1103

16.1.2 Incidents with Potential

Incidents with Potential are occurrences where a significant potential exists for substantial damage or serious injury. **Final classification will be determined by the OAS Aviation Safety Manager.**

16.1.3 Aircraft Incidents

Aircraft Incidents are occurrences that affect, or could affect, the safety of operations.

16.1.4 Mishap – Aviation Mishap

Mishaps include aircraft accidents, Incidents with Potential, Aircraft Incidents, aviation hazards, and aircraft maintenance deficiencies.

16.1.5 Accident/Incident Reclamation Review Process

The RD, in coordination with the Director, MSO, and NAM will determine within 14 days, whether an internal Reclamation review of the mishap is necessary.

16.2 Mishap Notification Procedures

In the event of an aircraft accident, Incident with Potential, or when any of the mishaps listed below occur, the aircraft operator, flight manager, pilot, or person with flight following responsibilities must immediately, and by the most expeditious method, notify the NAM, RD, and the OAS Safety Office, (24/7) at 1-888-4MISHAP (1-888-464-7427).

16.2.1 Reclamation Internal Aviation Notification and Routing Procedures

1. The NAM or designee is the primary focal point of contact within Reclamation, with the OAS Safety Office, and with other bureaus for notification of significant aviation related events and policy related matters. **Note:** Nothing in this plan should be interpreted to delay the notification of immediately needed and locally available resources in the event of a life threatening emergency or when notification could delay resolution of an ongoing problem.

2. For accidents, Incidents with Potential, serious safety concerns, aviation events of significant policy impact, or aviation events or actions with the potential to cause widespread interest both inside and outside Reclamation, the NAM will, upon receiving notification by any source, notify the Director, MSO, and the OAS Safety Office. If the RAM where the event occurred was not involved in the initial notification to the NAM, the NAM will contact the RAM who serves as the primary focal point of contact for aviation matters within the regions. The RAM will determine and ensure that the appropriate regional management has been notified.

3. Concurrently, the NAM will contact the appropriate person in DOI/OAS.

16.3 Aviation Mishap Response Plan

Each unit will develop an Aviation Mishap Response Plan that will specify national/regional/local points of contact and the necessary actions to be accomplished in the event of an aviation accident. A brief outline of the required actions is listed below (additional information can be found in Appendix 1, Interagency Aviation Mishap Response Guide and Checklist):

1. Take necessary action to rescue survivors.

2. Secure the site and surrounding area to protect the wreckage from further damage and to avoid injury to persons nearby.

3. Designate an Incident Commander to be in charge of the mishap site; get names, addresses, etc., of witnesses; and relay all media inquiries to the investigating team or Reclamation/NTSB public information official.

4. Secure all Reclamation records pertaining to the operation, flight, maintenance, crewmembers, etc.

5. Document the available information on the Aircraft Accident Checklist in Appendix 1, Interagency Aviation Mishap Response Guide and Checklist.

Provide the information to the OAS Safety Manager and RAM. Do not delay initial reporting to try to fill in all the blanks.

16.4 Aircraft Mishap Investigations

All DOI accidents are the domain of the NTSB and the OAS Safety Office. NTSB may authorize the OAS to investigate accidents for the NTSB. If this occurs, the OAS is working with the NTSB and is bound by 49 CFR 830-831. Reclamation will offer a qualified individual to assist with the investigating agency and may also independently review the mishap internally. The Reclamation RD, in conjunction with the NAM, will offer the appropriate individuals to the OAS Safety Manager. When NTSB investigates DOI accidents, OAS will be included and is the DOI's representative. NTSB and/or OAS may also choose to investigate other DOI Aircraft Incidents. Employee cooperation in mishap investigations involving the NTSB or OAS Safety Division (e.g., interviews, witness statements) is required.

16.5 Aircraft Mishap Review Board

An AMRB is responsible for developing mishap prevention recommendation for all DOI accidents and selected Incidents with Potential. Specific responsibilities, functions, and procedures to be followed are in accordance with 352 DM 3.

16.5.1 DOI Aircraft Mishap Review Board, Reclamation Attendance, Report Routing, and Follow-up Actions

Per 350 DM 1, appendix 4A.11, the NAM is responsible for assigning a bureau representative to the AMRB, who will usually be an aviation SME from an area outside the region where the event occurred. Reclamation policy requires that whenever an AMRB is convened by the Associate Director, OAS, in response to an aircraft mishap that a Senior Line Officer from the region involved in the event will participate in the AMRB as a nonvoting member. The NAM will coordinate with OAS for inclusion of this additional Reclamation participant on the AMRB.

Upon receipt of the AMRB report and final recommendations from the Associate Director, OAS, the NAM will route the report to senior Reclamation management. The NAM will concurrently route copies to the RAM in the affected region for distribution to RD.

Within 30 days of issuing an AMRB report, the RD of the region involved will convene a Board of Review. The Board of Review will include the regional Senior Line Officer who was present at the AMRB, the RAM, and Reclamation flight, air, or ground crew involved in the mishap. The Board of Review will task the responsible parties with responding to and/or implementing the AMRB recommendations in addition to any the Board of Review may develop.

16.6 Aircraft Mishap Documentation

16.6.1 Pilot/Operator Aircraft Accident Report

The aircraft operator must complete NTSB Form-6120.1/2, Pilot/Operator Aircraft Accident Report, and submit it to the nearest office of NTSB. In the case of DOI-owned/Reclamation-operated aircraft, a copy of the report must also be sent to the RD, NAM, and OAS Aviation Safety Manager within 10 days following an aircraft accident, or when requested by NTSB following any of the occurrences listed in section .2 above.

16.6.2 Aircraft Accident/Incident with Potential

The aircraft operator, passenger, or other person with knowledge of the accident/Incident with Potential must comply with the *Aviation Mishap Notification Investigation and Reporting Handbook*, per 352 DM 4.

16.6.3 Aviation Mishap Information System

The aircraft operator, flight manager, or any other person noting an aviation hazard, maintenance deficiency, airspace conflict, or incident should complete a SAFECOM report within 5 days and submit it to the OAS Aviation Safety Manager and the NASM.

16.6.3.1 Aviation Mishap Information System Definition

The AMIS is an electronic database that encompasses all aspects of aviation mishap reporting within DOI. Categories of reports include aircraft accidents, Incidents with Potential, incidents, aviation hazards, aircraft maintenance deficiencies, and airspace intrusions.

16.6.4 Aviation Safety Communique'

The AMIS system uses the SAFECOM, Form AMD-34/FS1500-14, to report any condition, observance, act, maintenance problem, or circumstance that has the potential to cause an aviation-related mishap. A SAFECOM's sole purpose is to prevent mishaps. Use of a SAFECOM for any other purpose is prohibited. A SAFECOM is not intended to fix blame and should not be utilized to bring disciplinary action against any employee.

16.6.5 SAFECOM Submissions

Any person directly associated with aviation activities within DOI may submit a SAFECOM. This includes contractors and other Government personnel who support DOI aviation activities. SAFECOMs may be submitted via the Internet or as a hard copy via the mail. The preferred method is through the Internet at http://www.safecom.gov . Hard copy SAFECOMS may be submitted through Reclamation channels or direct to the OAS Aviation Safety Office. Regardless of the method used, the submitter should always retain a copy for their records.

16.6.6 Use of SAFECOMs

Submitting a SAFECOM is not a substitute for “on-the-spot” corrections(s) to a safety concern. Rather, the SAFECOM is a tool used to document and track safety concerns and follow-up corrective action(s) related to those safety concerns. However, it is important to remember that utilization of the SAFECOM does not replace the requirement to initiate a DI-134, Report of Accident/Incident, as required in DM 485 DM 5.

16.6.7 Management Support of the SAFECOM System

All levels of management shall promote the AMIS program. SAFECOMs should be placed in areas where they are available to all individuals involved in aviation activities. Prompt replies to the originator and timely corrective actions will encourage continued program participation.

16.6.8 SAFECOM Access and Follow-up

The OAS Aviation Safety Manager shall ensure that SAFECOMs are stored in an electronic database and that access to the system is provided to bureau aviation program management personnel for corrective action follow-up as necessary. The responsibility for regularly reviewing the data base and taking appropriate corrective action rests initially with the bureaus. Bureau Aviation Safety Managers are encouraged to provide feedback to SAFECOM submitters and to resolve aviation safety-related issues identified within SAFECOMs at the lowest possible level. Appropriate action shall be taken on identified DOI aviation safety concerns by the OAS, following coordination with appropriate bureau aviation program management personnel.

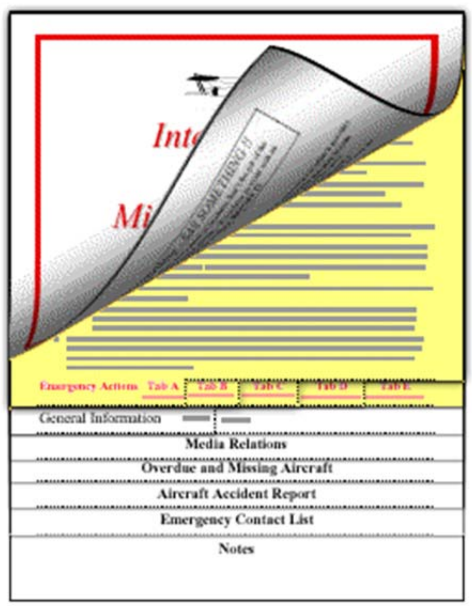
Appendix 1

Interagency Aviation Mishap Response Guide and Checklist

1.1 Approval

This Interagency Aviation Mishap Response Guide and Checklist has been approved for use by both the U.S. Department of the Interior - Office of Aviation Services Aviation Safety Manager and the U.S. Department of Agriculture - Forest Service National Aviation Safety and Training Manager. You can order this document through the cache system (NFES 2659). You may also download and print this document, which can be found at: https://www.doi.gov/aviation/safety/iamrgc.

1.2 What You Need to Do



After you download the document, you can tailor the plan to fit your organizational and local area needs by adding names and phone numbers. After printing, you will be able to literally "cut along the dotted lines" and assemble the plan into the familiar layered Interagency Aviation Mishap Response Guide and Checklist format.

We recommend that you print tabs A, B, C, D, and E (pages 3-7) on yellow or another bright colored paper to make those "immediate actions" stand out boldly.

1.3 What the Checklist Does for You

The checklist provides both immediate actions and general instructions to follow in the event of an aviation accident. It has intentionally been developed to be simple and generic. The "Aircraft Accident Report" consolidates the information required for missing aircraft, overdue missing aircraft, and accidents into a single form. We have made it generic to allow the widest possible use with a minimum of additional work.

Each region must customize according to the region and/or geographical area. This may require multiple response plans.

Appendix 2

Sample Unit Aviation Management Plan

The complexity of the Unit Aviation Management Plan should match the complexity of the aviation activities. Programs with limited aviation activities may only need a single page, which must include an aviation point of contact. The Unit Aviation Management Plan must contain the following topics:

I. Introduction/Purpose
   A. Bureau of Reclamation Policy
   B. Unit Aviation Policy

II. Program Management
   A. Organization and Responsibility (i.e., Unit Manager - Passengers)
   B. Qualifications/Training Needed to Manage Program
      1. Project Leader
      2. Flight Manager, if required
      3. Helicopter Manager, if required
   C. Dispatching and Controlling Flights
      1. Routine Flights
         a. Routine Flight Request/Flight Plan
         b. Process for Requesting Aircraft
      2. Nonroutine (Emergency) Flights
         a. Search and Rescue Operations
         b. Medical Evacuations
         c. Emergency Fire Operations
         d. Law Enforcement Emergencies
         e. Administrative Emergencies
            - Risk Analysis
            - Process For Requesting Aircraft
   D. Records and Reports

III. Aviation Operations
   A. Aircraft Safety
      1. Aircraft Data Cards
      2. Personal Protective Equipment
      3. Flight Manifest
      4. Load Calculations
      5. Flight Plans/Flight Following
      6. Communications
      7. Pilot Authority
      8. Pilot Duty Limitations
      9. Low Level Flights
      10. Transporting Hazardous Material
      11. Smoking

12. Fuel Reserves
13. Pilot Briefings
14. Flight Hazard Maps
15. Authorized Passengers, Cargo, and Flights
16. Air Space Restrictions

B. Aviation Security

1. Facilities
2. Aircraft

IV. Specific Missions

V. Emergency Procedures

VI. Program Coordination and Evaluation

Project Aviation Safety Plan Template

Title Project Aviation Safety Plan

Your Region/District Local Unit

Mission:	Project Name:	Unit:
Anticipated Project Date:	Start Time:	Ending Time:
Project Plan Prepared by:	Title:	Date:

Note: Signature by the preparer verifies that all personnel have the required training for the mission.

Attach map, clearly showing areas to be flown; aerial hazards must be indicated.

Project Plan Reviewed by:	Title:	Date:
Project Plan Reviewed by:	Title:	Date:
Project Plan Approved by:	Title:	Date:

Project Description:

Attachments: ☐ Map ☐ Other:

Project Supervisor:	Phone:	Cell:
Helicopter Manager:	Phone:	Cell:

Participants:

Type of Flight:	Desired Aircraft Type:	Charge Code:
Type Procurement:	Method of Payment:	Projected Cost:

Vendor:		Phone:	Cell:
Aircraft N#:	Make & Model:	Aircraft Color:	
Pilot Name:		Pilot Carded: ☐Yes ☐No	A/C Carded: ☐Yes ☐No
Flight Follow:		Request or Flight #:	
Method of Resource Tracking: ☐ Phone ☐ Radio		☐ Prior to Takeoff ☐ Each Stop Enroute ☐ Arrival at Dest.	
Scheduling Dispatch Phone:		Destination Dispatch Phone:	
FM Receive:	FM Transmit:	Tones:	
FM Receive:	FM Transmit:	Tones:	
FM Receive:	FM Transmit:	Tones:	
AM Air to Air:	AM Unicom:	Other:	

Search and Rescue Procedures: Contact Dispatch, Follow the Aviation Mishap Response Guide

Start Location	Latitude	Longitude	Elevation	Runway Length & Surface or Helispot Size
Destination Location	Latitude	Longitude	Elevation	Runway Length & Surface or Helispot Size

Passenger Name	Weight	Departure Point	Destination Point
Cargo Weight	Cubic Feet	Hazardous Material	Destination
		☐Yes ☐No	
		☐Yes ☐No	
		☐Yes ☐No	

Type of Flight	Personnel Protective Equipment Requirements
☐ Air Ops general/ground personnel	Nomex clothing, hardhat w/chin strap, gloves, leather boots, eye protection, hearing protection, fire extinguisher
☐ Fixed Wing point to point flights	Hearing protection
☐ Fixed Wing mission flights	Nomex clothing, gloves, leather boots, hearing protection
☐ Rotor Wing flights	Flight helmet, Nomex clothing, gloves, leather boots, eye protection, hearing protection, approved secondary restraint harness for doors off flights, PFD for all PAX as required

Justification statement for low-level flights:

Special Instructions:

Job Risk Analysis: Aircraft manager/pilot review with all participants as part of preflight briefing

Is everything approved with clear instructions, and is the aviation plan signed and reviewed?	☐ Yes	☐ No	☐ NA
Are communications and flight following established, including repeater tones?	☐ Yes	☐ No	☐ NA
Can terrain, altitude, temperature, or weather that could have an adverse effect be mitigated?	☐ Yes	☐ No	☐ NA
Are all aerial hazards identified and known to all participants?	☐ Yes	☐ No	☐ NA
Have mitigating measures been taken to avoid conflicts with military or civilian aircraft?	☐ Yes	☐ No	☐ NA
Have adequate landing areas been identified and or improved to minimum standards?	☐ Yes	☐ No	☐ NA
Are all agency personnel qualified for the mission?	☐ Yes	☐ No	☐ NA
Is the pilot carded and experienced for the mission to be conducted?	☐ Yes	☐ No	☐ NA
Are there enough agency personnel to accomplish the mission safely?	☐ Yes	☐ No	☐ NA
Will adequate briefings be conducted prior to flight to include pilot, passengers and dispatch?	☐ Yes	☐ No	☐ NA
Are all persons involved aware that the pilot has the final authority?	☐ Yes	☐ No	☐ NA
Is the aircraft capable of performing the mission with a margin of safety?	☐ Yes	☐ No	☐ NA
Are manifests of cargo and passengers, load calculations, and/or weight & balance completed?	☐ Yes	☐ No	☐ NA
Is the aircraft properly carded?	☐ Yes	☐ No	☐ NA
Do all personnel have the required personal protective equipment?	☐ Yes	☐ No	☐ NA
Fuel planning, adequate fuel on board, fuel truck location, availability of commercial fuel?	☐ Yes	☐ No	☐ NA
Remember; maps of areas/sites, handheld radios, cell phones, day/survival packs, motion sickness bags	☐ Yes	☐ No	☐ NA
Will the mission be conducted at low levels? (Below 500 feet above ground level?	☐ Yes	☐ No	☐ NA
Can the same objective be achieved by flying above 500 feet above ground level?	☐ Yes	☐ No	☐ NA
Are pilot flight and duty times compromised?	☐ Yes	☐ No	☐ NA
Is there an alternative method that would accomplish the mission more safely?	☐ Yes	☐ No	☐ NA

Job Hazard Analysis: Aircraft manager/pilot review with all participants as part of preflight briefing

Hazard	**Mitigation**
Military training routes	Practice risk management. Check routes in advance. Confirm that dispatch has made calls.
Private aircraft	See and avoid. Transmit in the blind on 122.925 near backcountry airstrips.
Airport traffic	Stay in radio contact. Announce intentions. Use established patterns.
Weather	Use weather advisory. Maintain visual flight rule minimums. Cancel mission if conditions deteriorate.
Terrain	Avoid performance related situations. Cross terrain at its lowest point. Consider downdrafts.
Low level obstacles	Complete a high level reconnaissance. No unnecessary low-level flight.
Unimproved landings	Reconnaissance landing zone. Download on first load. Stay in radio contact.
Doors off helicopter operations	Use approved secondary restraint harness. Remove loose items from cabin.
Pilot not familiar with area	Supply hazard maps. Complete high level recon prior to low level work.
Noise, rotor wash	Wear ear and eye protection. Use dust abatement.
Internal and external loads	Have trained personnel assigned to the mission. Plan around fuel. Hook and equipment checks.
Unplanned aircraft events	Equip all personnel with required PPE and train them in crash procedures. Maintain flight follow.
Hazardous materials	Trained personnel will handle. Inform pilot. Use Hazmat guide w/current exemption.
Nonaviation personnel	Maintain control. Provide thorough briefings.
Communications	Maintain communications at all times. Establish backup options and know alternate frequencies. Take handheld radio along. Call in prior to landing. If radio contact is lost, climb and check tones. If unable to reestablish radio contact, return to best suitable landing area and check in.
Overload conditions/center of gravity issues	Complete accurate load calculations and/or weight and balance.
Wintertime operations	Use appropriate clothing for varying altitudes/climatic conditions. Use winter survival kit.
Prop/rotor hazards	Pilot will perform aircraft safety brief, approach/depart sensibly after shutdown & prop/rotor stop
Multiple project aircraft	Adequate aerial supervision. Establish and maintain separation. Use common frequencies. Communications.
Aircraft fueling	Vendor responsibility. No agency personnel on board.

Aircraft Manager signature:	Date:	Pilot signature:	Date:

Chart 3-2: Risk Assessment Matrix			HAZARD PROBABILITY				
			Frequent	Likely	Occasional	Seldom	Unlikely
			A	B	C	D	E
EFFECT	Catastrophic	I	Extremely High	Extremely High	High	High	Medium
	Critical	II	Extremely High	High	High	Medium	Low
	Moderate	III	High	Medium	Medium	Low	Low
	Negligible	IV	Medium	Low	Low	Low	Low

RISK ASSESSMENT WORKSHEET

Assess the risks involved with the proposed operation. Use additional sheets if necessary.

Assignment: Date: **Describe Hazard:**	Probability (A-E)	Effect (I-IV)	Risk Level
1.			
2.			
3.			
4.			
5.			
6.			
Mitigation Controls:	Probability (A-E)	Effect (I-IV)	Risk Level
1.			
2.			
3.			
4.			
5.			
6.			

FINAL RISK EFFECT: **LOW MEDIUM HIGH** **(CIRCLE ONE)**

Project Risk Assessment Approved by:

Title: Date:

PROJECT AVIATION SAFETY PLAN BRIEFING

A copy of this briefing page will be submitted to the Unit Aviation Manager within 5 days of the completion of this project.

Briefing Leader: _________________

Briefing Date: __________ Time: _________ Location: __________

Discussion Items:

__ a. Hazard Analysis (as outlined in plan)
__ b. Safety Air Ops (ground)
__ c. Safety Air Ops (flight)
__ d. Military Training Routes
__ e. Flight Following
__ f. Frequencies
__ g. Fueling
__ h. Emergency Evacuation Plan
__ i. Authorities
__ j. Weather Considerations
__ k. Other
__ L. Other

Attendees Signature and Concurrence:

Technical Guidance

Surveying, Mapping, and Aerial Photography

General Instructions

Prepared by:

Alan Bell — 9/27/16

Alan Bell — Date

Peer Review Certification

This section has been reviewed and is believed to be in accordance with the service agreement and standards of the profession.

Peer reviewed by:

Patrick Wright — 9/27/16

Patrick Wright — Date