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1. **ABBREVIATIONS AND DEFINITIONS**

- **ASPRS** – American Society for Photogrammetry & Remote Sensing
- **CADD** – Computer Aided Design & Drafting
- **CSDGM** – Content Standard for Digital Geospatial Metadata
- **DEM** – Digital Elevation Model
- **ESRI** – Environmental Systems Research Institute
- **F.A.C.** – Florida Administrative Code
- **FGDC** – Federal Geographic Data Committee
- **FIPS** – Federal Information Processing Standards
- **FCDOP** – Florida County Digital Orthoimagery Program
- **FPRN** – Florida Permanent Reference Network
- **F.S.** – Florida Statutes
- **GeoTIFF** – Raster image file. GeoTIFF fully complies with the TIFF 6.0 specifications, and its extensions do not in any way go against the TIFF recommendations, nor do they limit the scope of raster data supported by TIFF. GeoTIFF uses a small set of reserved TIFF tags to store a broad range of georeferencing information, catering to geographic as well as projected coordinate system needs.
- **GNSS** – Global Navigation Satellite System (includes GPS)
- **GSD** – Ground Sample Distance
- **IMU** – Inertial Measurement Unit
- **Lidar** – Light Detection and Ranging
- **LAS –** A binary file standard supported by ASPRS for storing point location and attribute information primarily used for Lidar data.
- **NAVD88 –** North American Vertical Datum of 1988
- **NSRS –** National Spatial Reference System
- **NSSDA –** National Standard for Spatial Data Accuracy
- **Orthoimagery (Digital)** – Digital orthoimages are georeferenced images of the earth's surface that have been collected by a sensor and then, by correcting for sensor distortions and orientation as well as terrain relief, have had image object displacement removed. They encode the optical intensity of sensed radiation in one or more bands of the electromagnetic spectrum as discrete values in an array of georeferenced pixels that model the scene observed. *Federal Geographic Data Committee FGDC-STD-014.2-2015 Geographic Information Framework Data Content* Standard Part 2: Digital Orthoimagery
- **Orthorectification –** A special case of image resampling whereby the effects of image perspective and relief displacement are removed so that the resulting orthoimage has uniformly scaled pixels, resembling a planimetric map. (Source: American Society for Photogrammetry and Remote Sensing *Manual of Photogrammetry Fifth Edition*, 2004, page 963)
- **Photogrammetry** – The art, science and technology of obtaining reliable information about physical objects and the environment through processes of recording measuring and interpreting photographic images and patterns of electromagnetic radiant energy

and other phenomena. (Source: American Society for Photogrammetry and Remote Sensing *Manual of Photogrammetry Fifth Edition*, 20, page 2)

- **PSM** – Professional Surveyor and Mapper
- **RMSE** – Root Mean Square Error
- **USft** – United States Survey Feet
- **USGS** – United States Geological Survey
- **XML** – Extensible Markup Language

2. INTRODUCTION

Since 1972, Florida Statutes have stipulated cooperation between USGS, FDOT, and the State Water Management Districts to facilitate statewide topographic mapping efforts. Currently, the horizontal component of the statewide topographic map is being accomplished through the FCDOP. The FCDOP is supported by partnerships and agreements between several state and county agencies. The current FCDOP mapping efforts consist of statewide orthoimagery coverage of Florida on a three-year cycle, with a maximum GSD resolution of 0.5 feet.

3. PURPOSE

This document defines the minimum standards for providing digital orthoimagery products for inclusion into the FCDOP. All final data will be considered public record as defined by applicable Florida Statutes.

Any products created from oblique aerial imagery acquired during the orthoimagery project orthoimagery collection are beyond the scope of this document.

All work performed must be in accordance with the *Standards of Practice* as set forth in *Rule Chapter 5J-17, F.A.C.*, pursuant to *Chapter 472, F.S.*

4. ORTHOIMAGE SPECIFICATIONS

4.1. Digital Camera

All imagery shall be collected using a digital aerial camera capable of collecting multispectral imagery in natural color (RGB) bands and near infrared band (N). The sensor must also have a documented bore-sight calibration performed within six months of image acquisition.

4.2. Image Spatial Resolution

The consultant shall deliver images that have been resampled to the desired resolution of 0.5 feet. The original imagery must have native sensor resolution less than or equal to the desired final resolution of the orthoimagery. Orthoimagery that has been resampled to a higher

resolution than the original raw imagery GSD will NOT be accepted. The allowable RMSEx and RMSEy shall be less than or equal to 1.0 feet (2 pixels) per *FDOT Surveying and Mapping Handbook (October 10, 2016)*.

4.3. Horizontal and Vertical Datum

Unless otherwise requested, the orthoimagery and other topographic products shall be referenced to NAD83(2011). The map projection referenced shall be the appropriate Florida State Plane Coordinate System in units of USft. Orthoimagery and other topographic products shall be referenced to the NAVD88 in units of USft.

4.4. Horizontal Orthoimage Accuracy

The final horizontal accuracy of orthoimagery products shall be determined using well defined photo identifiable check points. Computed local horizontal accuracy shall meet or exceed 2.5 feet at the 95% confidence interval as specified in the *FDOT Surveying and Mapping Handbook (October 2016)*. The minimum number and spacing of check points shall meet the requirements set forth in the *ASPRS "Positional Accuracy Standards for Digital Geospatial Data" (Edition 1, Version 1.0 – November 2014)*. See *Table C.1* of the aforementioned document.

4.5. Digital Elevation Model

A DEM adequate to support accuracy specifications identified for this project must be created to accurately orthorectify the imagery. The consultant is responsible for evaluating the accuracy of the DEMs used in the orthorectification process and, if necessary, collect supplemental data to further enhance the DEM.

The consultant will submit information in the final survey report and metadata which documents the source, enhancements made, and density of the DEMs utilized for the orthoimage mapping project.

In addition, if lidar data is acquired as part of the project, the classified scan data must be provided in LAS file format as per ASPRS LAS Specification 1.4 with associated metadata.

4.6. Ground Control

A sufficient number of ground control points shall be established to support orthoimage mapping. All control shall meet the requirements of the FCDOP, see *Attachment A.*

The consultant will coordinate with agency staff in planning ground control surveys and methodology used for all horizontal and vertical control surveys.

4.7.   Airborne GNSS/INS Corrections

Unless otherwise approved, all orthoimagery collection shall be directly referenced to the FPRN.

4.8.   Flight Season

The specified flight season will be from October 1st through March 15th. Every effort should be made to collect imagery prior to January 30th. Imagery collected outside of this flight season will require written approval from contracting agency.

4.9.   Image Quality

Imagery shall be acquired to minimize excessive tilt/lean in buildings, obstruction by shadows, image smear, environmental conditions (clouds, haze, smoke, glare, solar reflection over water bodies, etc.), vegetative conditions, etc. Every effort should also be made to acquire imagery under optimum tide conditions. Radiometric and color balancing of the imagery is described in Section *5: Orthoimage Deliverables*. All images must be collected with a sun angle no less than 30°. Imagery shall be acquired at sufficient overlap coverage in "high-rise" urban areas to ensure all transportation infrastructure is clearly visible.

4.10.   Historical Images

To maintain consistency between images collected during different years, historical examples of imagery shall be reviewed. If applicable color balancing should be performed that is consistent with previous FCDOP imagery.

5.   ORTHOIMAGERY DELIVERABLES

All deliverables will be the property of the contracting agency and are considered public record. The consultant will document all data deliveries with an itemized transmittal letter. Written permission from the agency must be obtained to release data to any party prior to final publication. Per *Rule Chapter 5J-17, F.A.C.*, the consultant shall keep a copy of the original data for a minimum of six (6) years. The consultant shall contact the agency before destroying the data.

5.1.   File Formats and Image Types

Consultants shall deliver imagery that complies with the requirements below.

5.1.1. Original Source Imagery

Original source imagery shall be delivered as uncompressed four-band TIFF images consisting of natural color (RGB) and near infrared (N) at the native bit-depth per band of the sensor.

5.1.2. Tiled Orthoimagery

The consultant shall deliver ortho-rectified, uncompressed four-band GeoTIFF image tiles. These image tiles shall consist of natural color (RGB) and near infrared (N) bands at a bit-depth of 8-bits per band, with valid projection header information. Orthoimagery tiles shall be produced using a four-band workflow meaning all processes affecting final orthoimagery tile shall be performed using the afore mentioned four-band imagery. Tiled orthoimagery shall meet the requirements set forth in the *Federal Geographic Data Committee FGDC-STD-014.2-2015 Geographic Information Framework Data Content Standard Part 2: Digital Orthoimagery*.

- *Natural Color Imagery* – The natural color, RGB, bands will be color balanced across the entire area of interest to allow viewing of the image tiles as a seamless mosaic. During radiometric processing care shall be taken to avoid loss of detail in shadows and overexposure on bright surfaces such as bare ground and light-colored building roofs.

- *Color Infrared Imagery* – The near infrared band will be radiometrically processed in a manner that preserves original image characteristics. Corrections for seasonal variations in ground cover are not to be performed. However, care should be taken to ensure appropriate coloration of different vegetation types (e.g. deciduous, evergreen, etc.) is evident.

One GeoTIFF file per tile matching approved index tile scheme is required. All orthoimages will be delivered according to the tile index provided.

Tiles will be contiguous and non-overlapping and will be suitable for creating a seamless image mosaic that includes no data void cells or gaps. Tile naming convention is as follows:

YYYY_NNNNNN.TIF

Where:

YYYY =   Ending year of the flying season that typically ends in March.

NNNNNN =   *A*ppropriate tile (cell) index number values from project tiling index provided.

Example: Orthoimage tile that was acquired during the 2016-2017 flying season.

2017_200001.tif

5.2.   Geospatial Metadata

A metadata file in XML format must be delivered for each GeoTIFF image file, the DEM used for orthoimage production, and any other relevant mapping files.

Metadata must be compliant with the *FGDC CSDGM*. CSDM validation can be performed with the *USGS Metadata Parser*.

5.3.   Image Seamline Feature Class

The consultant will include a file "*ProjectName_Seamlines*" in shapefile format, containing a feature class of non-overlapping polygons with no data voids for the area of interest. Each polygon will delineate images by capture date and time used in the mosaicking of images to produce orthoimagery. See *Figure 1*.

The feature class should conform to the area of interest, and have the following attributes:

FID	Shape	NAME	DOF	EXPOSURE	TIMESTAMP	HEIGHT
0	Polygon	035_0067	12-Feb-2016	6409_035_0067	19:14:59	4525
1	Polygon	033_0067	12-Feb-2016	6409_033_0067	19:40:01	4516
2	Polygon	016_0041	17-Feb-2016	6409_016_0041	16:09:09	4562
3	Polygon	017_0067	17-Feb-2016	6409_017_0067	15:53:49	4576
4	Polygon	019_0067	17-Feb-2016	6409_019_0067	15:27:24	4566
5	Polygon	023_0067	13-Feb-2016	6409_023_0067	17:14:11	4567
6	Polygon	018_0042	17-Feb-2016	6409_018_0042	15:42:43	4590
7	Polygon	015_0067	17-Feb-2016	6409_015_0067	16:20:22	4578
8	Polygon	032_0041	12-Feb-2016	6409_032_0041	19:55:05	4505
9	Polygon	029_0067	13-Feb-2016	6409_029_0067	15:53:47	4537
10	Polygon	022_0041	13-Feb-2016	6409_022_0041	17:29:45	4506
11	Polygon	021_0067	13-Feb-2016	6409_021_0067	17:40:42	4507

DOF = Date of Flight
EXPOSURE = Exposure filename
TIMESTAMP = GNSS time in HH:MM:SS
HEIGHT = Approximate height of aircraft at time of exposure

Figure 1 – Image Seamline Feature Class

5.4.   Survey Report

The consultant PSM will prepare a digital survey report that documents all processes and is compliant with relevant *Standards of Practice* as set forth in *Rule Chapter 5J-17, F.A.C.*, pursuant to *Chapter 472, F.S.* and shall, at a minimum, include the following items:

- Project title and reference number
- Name and address of corporation
- Certificate of authorization number
- Surveyor in responsible charge, including contact information
- Abbreviations and definitions
- Data sources

- Final deliverable listing of files stating filename with extension and delivery date in the appendix of the survey report.
- Survey date(s) are the first and last date of field measurements.
- Introduction, purpose, objectives
- Scope of work
- Reference to ground control survey by title, survey date, corporation, and certifying PSM.
- Describe all equipment, software, etc.
- Image sensor description
- Digital orthoimage image acquisition dates and flight logs
- DEM acquisition (identify source and accuracy)
- If lidar data is collected, then the following items shall be included:
  - Data acquisition dates and logs
  - Sensor description and calibration report
- Digital orthoimagery image accuracy NSSDA analysis according to the *FGDC National Standard for Spatial Data Accuracy (FGDC-STD-007.3-1998)*.
- List of field and office personnel
- Digital survey reports will include map overlays which will display the following items:
  - All horizontal and vertical ground control identifying which points were constrained during aerial triangulation and which points were used for check during NSSDA analysis
  - Aerial triangulation blocks
  - Digital orthoimagery tile limits and layout
  - Lidar quality control locations and accuracy (if applicable)
  - Base map features (county boundaries, cities, major roads, major hydrography/water bodies, basin boundaries)

5.5. Digital Submittals

Digital files shall be submitted on an external hard drive (USB version 3.0 or later) and be accompanied by an itemized transmittal letter. All deliverables will become the property of the agency.

5.6. Contents

The hard drive shall contain:

- Digital copy of the orthoimagery survey report
- Digital copy of the control survey report (if separate from orthoimagery report)
- Four-band (RGBN) original source imagery
- Four-band (RGBN) orthoimagery image tiles
- Metadata XML file for each image tile
- Final elevation data used to rectify imagery

- Classified lidar data files (*.LAS) if collected
- Airborne sensor trajectory/exterior orientation report
- Image sensor calibration documentation
- Aerial triangulation control coordinates and aerial triangulation blocks along with statistical summaries
- Digital files (shapefile format) used for survey report map overlays:
  - All horizontal and vertical ground control identifying of which points were constrained during aerial triangulation and which points were used for check during NSSDA analysis
  - Outline polygon of each aero-triangulation block
  - Digital orthoimagery seamlines and dates associated with the photographs (see *Section 5.3*)
  - Digital orthoimagery tile limits and layout

5.7. Label

The drive shall be labeled on the outside with the following information:

- Project title
- Consultant name and contact information
- Contracting agency contract number
- Date of survey
- Mobile Survey Tracking System (MSTS) number (FDOT)

ATTACHMENT A – GROUND CONTROL SURVEY REQUIREMENTS

1.   **PURPOSE**

The purpose of this document is to specify the requirements for a geodetic control survey to support 0.5-foot ground sample distance resolution county aerial orthoimagery mapping. The positional accuracy required for this imagery resolution is 2.5 feet at the 95% confidence level.

All surveying and mapping work performed shall meet the *Standards of Practice* set forth in *Chapter 5J-17, F.A.C.,* pursuant to *Chapter 472, F.S.*

2.   **SURVEY CONTROL**

- GNSS techniques shall be used to establish horizontal and vertical positions on targeted and/or well-defined photo identifiable points that will be used as control for aerial photogrammetric mapping. New photo control point positions shall be identified in the field by a survey mark.
- When aerial panels are used, the vertical offset from top of mark to the panel surface shall be measured and recorded.
- Ground control shall be referenced to NAD83(2011) based on redundant ties to the FPRN.
- The photogrammetric ground control network shall meet the horizontal and vertical accuracies necessary to support the required map accuracy of the orthoimagery per the *FDOT Surveying and Mapping Handbook (October 2016).*
- A sufficient number (minimum four) of published NAVD88 benchmarks shall be included in the control network to ensure accurate elevations can be computed from GNSS measurements through local network adjustment using the latest *FPRN Geoid Model*.
- Where conditions dictate differential leveling may be used to establish elevations on photo control points from the nearest ground control network station or published NSRS vertical station within a 5-mile radius from the photo control point. Leveling procedures adequate to support vertical accuracy specifications of orthoimagery shall be observed and documented.
- In rare circumstances where the photo identifiable control point cannot be occupied directly, either horizontally and/or vertically, offset distances of less than 0.5 feet from the occupied survey mark may be used. Field survey measurements of sufficient precision must be collected and recorded to allow accurate coordinate computation of the photo identifiable point from the offset mark.
- With prior approval of the orthoimage project surveyor, ground control points may be moved from their original proposed locations to ensure safety, or if the proposed point is ambiguous or no longer exists. Such control points shall be documented as moved.
- A field sketch with survey date, GNSS satellite visibility and weather conditions at the time of GNSS data collection shall be prepared for each control point site.

- Digital photo(s) shall be taken showing the exact location of the control point, preferably while the point is occupied by the GNSS unit setup. Digital photo filenames shall include the control point name.

3. **SUBMITTAL ITEMS**

3.1. Survey Report

The PSM will prepare a certified digital control survey report that shall at a minimum include the following items:

- Project title and reference number
- Name and address of corporation
- Certificate of authorization number
- Surveyor in responsible charge, including contact information
- Abbreviations and definitions
- Data sources
- Final deliverable listing of files stating filename with extension and delivery date in the appendix of the survey report.
- Introduction, purpose and objective
- Description and scope of work
- Describe equipment, software, etc.
- Describe the accuracy standards and specifications, procedures and methodology for establishing ground control
- Describe and list the geodetic control (existing and newly-established), displaying the horizontal and vertical coordinates, datum used, geoid model and error estimates (95% confidence level)
- List the field and office personnel
- Survey dates (first and last date of field measurements)
- Describe monumentation recovered and set
- Map overlay which will display the following items:
    - GNSS baseline network, indicate repeated measurements
    - Existing horizontal and vertical geodetic control
    - Newly-established photogrammetric control
    - Base map features (county boundaries, cities, major roads, major hydrography/water bodies, basin boundaries)

3.2. Digital Submittals

Digital files shall be packaged and delivered with the final orthoimagery submittal as described in *Section 1.15* of this document and shall include:

- Digital copy of the control survey report

- Existing geodetic control recovery/to-reach descriptions, sketches, field notes, photographs, etc.
- Newly-established photogrammetric control location descriptions, sketches, field notes, photographs, etc.
- Copies of GNSS data logs and a listing of GNSS occupations
- All GNSS data observed and produced during the survey (digital format), including the raw observation data, processed baselines, loop closures and least squares adjustments (free and fixed)
- A Microsoft EXCEL spreadsheet file list of final control with datum header information along with point name, geographic (Latitude, Longitude), grid (State Plane Zone Northing and Easting), and elevation values for control points. Grid coordinates and elevations shall be in units of USft. Any horizontal and vertical mark offsets measured shall be identified and applied to the aerial panel or photo identifiable feature position and/or surface. Offset measurements shall be included to verify computations. See example in *CONTROL TABLE EXAMPLE*.
- Sketches and digital pictures of photo control point sites identifying measured point location and type of mark including target size and material if applicable.

GROUND CONTROL TABLE EXAMPLE

FINAL ADJUSTED HORIZONTAL AND ORTHOMETRIC HEIGHT VALUES FOR MARION COUNTY (PD6027) POST FLIGHT PHOTO POINT

UNITS ARE US Survey Feet (USft)

HORIZONTAL DATUM IS NAD 83 (2011)

STATE PLANE ZONE IS FLORIDA WEST ZONE 0902

ORTHOMETRIC HEIGHT DATUM IS NAVD 88

ALL CONTROL STATION VALUES ARE DERIVED BY STATIC GNSS OBSERVATIONS FROM PUBLISHED NGS CONTROL

	GNSS Control Station - Geographic			GNSS Control Station - USft			Offset from GNSS Station to Photo ID Point - USft			FINAL Photo ID Control - USft		
PHOTO_ID	LATITUDE	LONGITUDE	ELLIP_HGT (meters)	NORTHING	EASTING	ORTHO_HGT	Offset North	Offset East	Offset Vertical	**NORTHING**	**EASTING**	**ORTHO_HGT**
D510S010	29 29 44.73172	-82 24 24.26473	1.757	1876786.20	526773.97	97.18	0	0.5	0	1876786.20	526774.47	97.18
D510S011	29 28 42.07552	-82 03 20.32535	-4.497	1870232.35	638460.51	77.18	-0.5	-0.5	0	1870231.85	638460.01	77.18
D510S012	29 30 29.98811	-81 51 49.10517	10.530	1881156.88	699540.72	127.11	0	0	0	1881156.88	699540.72	127.11
D510S013	29 19 32.46883	-81 58 11.18511	-5.832	1814716.87	665798.44	72.96	0	0	0.5	1814716.87	665798.44	73.46
D510S014	29 21 52.50874	-81 44 25.40237	-16.367	1828952.74	738861.52	39.27	0	0	0	1828952.74	738861.52	39.27
D510S015	29 17 40.65095	-81 39 09.97229	-27.655	1803585.22	766847.02	2.34	0.5	0.3	0.5	1803585.72	766847.32	2.84