

# NENA GIS Data Collection and Maintenance Standards



NENA GIS Data Collection and Maintenance Standards  
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National Emergency Number Association (NENA) Data Technical Committee, Data Management  
Subcommittee, GIS Mapping Working Group

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## **1 Executive Overview**

### **1.1 Purpose and Scope of Document**

This document is the NENA recommended standard for GIS data collection and GIS data maintenance. This document is meant to provide PSAP management, vendors, and other interested parties necessary guidelines for collecting and maintaining GIS data. Collection and maintenance of GIS data is most reliably accomplished by qualified, trained individuals or vendors that have received formal GIS training and instruction.

This standard also provides information on data collection to meet accuracy requirements for wireless and Voice over Internet Protocol (VoIP) 9-1-1 technologies that use x, y, z coordinates to provide location of the 9-1-1 caller.

### **1.2 Reason to Implement**

Mapping information at a Public Safety Answering Point (PSAP) is critical to provide emergency service providers location information. Inaccurate Geographical Information System (GIS) data could mean the difference between several feet or several hundred feet, impeding effective delivery of emergency response, thus impacting lives and property.

### **1.3 Benefits**

Use of this document will:

- Ensure that GIS data collected for 9-1-1 purposes meet an accuracy standard
- Provide specific 9-1-1 GIS data maintenance guidelines

### **1.4 Operational Impacts Summary**

This document is written for 9-1-1 Authorities and GIS vendors involved in the development and maintenance of GIS data for inclusion in an Enhanced 9-1-1 system. A review of existing practices for collecting and maintaining GIS data, for use with the 9-1-1 system, may need to be performed to ensure that the data will meet these guidelines. Adherence to these guidelines will improve the credibility of GIS data used by telecommunicators in PSAPs.

### **1.5 Document Terminology**

The terms "shall ", "must " and "required" are used throughout this document to indicate required parameters and to differentiate from those parameters that are recommendations. Recommendations are identified by the words "desirable" or "preferably".

### **1.6 Reason for Issue**

This standards document is meant to specify 9-1-1 GIS data standards so that 9-1-1 Authorities and/or GIS vendors can ensure the accuracy and integrity of the GIS data collected and maintained for use in PSAPs and 9-1-1 data bases.

### 1.7 Reason for Reissue

NENA reserves the right to modify this document. Upon revision, the reason(s) will be provided in this paragraph.

### 1.8 Date Compliance

All systems that are associated with the 9-1-1 process shall be designed and engineered to ensure that no detrimental, or other noticeable impact of any kind, will occur as a result of a date/time change up to 30 years subsequent to the manufacture of the system. This shall include embedded application, computer based or any other type application.

To ensure true compliance, the manufacturer shall upon request, provide verifiable test results to an industry acceptable test plan such as Telcordia GR-2945 or equivalent.

### 1.9 Anticipated Timeline

Deployment or implementation will take place as required.

### 1.10 Costs Factors

Some existing processes for collecting and maintaining GIS data for 9-1-1 may need to be modified.

### 1.11 Cost Recovery Considerations

Normal business practices shall be assumed to be the cost recovery mechanism.

### 1.12 Acronyms/Abbreviations

This is not a glossary! See NENA 00-001 - NENA Master Glossary of 9-1-1 Terminology located on the NENA web site for a complete listing of terms used in NENA documents.

<b>The following Acronyms are used in this document:</b>	
ALI	Automatic Location Identification
ANI	Automatic Number Identification
GIS	Geographic Information System
PDOP	Position Dilution of Precision
SNR	Signal to Noise Ratio
GPS	Global Positioning System
GCP	Ground Control Points
DEM	Digital Elevation Model
SA	Selective Availability
CE	Circular Error
RMSE	Root mean square error

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**The following Acronyms are used in this document:**

RF	Radio Frequency
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## **2 GIS Database Development**

### **2.1 Overview**

A GIS database for Enhanced 9-1-1 purposes shall be constructed using the most spatially accurate data available. The overall accuracy of GIS vector data shall meet National Map Accuracy Standards at 1:5000.

Data collection procedures will vary depending on budget constraints and the availability of existing source materials. Some typical procedures are:

- Digital vector source materials enhanced with in vehicle data capture (e.g., state DOT digital maps supplemented with vehicular GPS data collection)
- Digital vector source updated with aerial photography or satellite imagery (e.g., local tax assessment digital maps updated with current photography/imagery if needed)
- Analog source materials converted to digital vector (e.g., the digitizing of orthoimagery film)

### **2.2 Source Map Compilation**

The ultimate quality of the GIS data is dependent on the source data and the methods used to incorporate the data into the GIS. Whether new GIS data are being compiled onto a basemap or old maps are being recompiled onto a new base data, certain procedures need to be addressed. Precise procedures, although very important, will not improve an inferior source of map data. Geo-referenced, rectified photographs and images, as well as vector basemaps may serve as source GIS data. Source map data standards are:

- 1:24,000 or better shall be the standard for GIS vector data.
- Digital Orthoimagery data or raster data standard shall be 1:2400 or better.

### 3 GPS Data Collection

#### 3.1 GPS Data Collection Standard

GPS data shall be collected with accuracy of 10 feet (3.048 meters) or less 95% of the time with a PDOP of 6.0 or less.<sup>1</sup>

Various methods are used to collect high precision GPS data. The particular method used depends on several factors, including objectives, desired precision, available equipment, sample rate, and field logistics. Higher precision typically requires a more rigorous field methodology and longer occupation times.

To obtain sub-meter accuracy it is necessary to stay in one location for a period of time so the location reading can be collected and averaged by the GPS equipment. A rule of thumb is to collect data for a minimum of 10 minutes per point for this level of precision. The longer occupation times significantly increase the accuracy.

For point features it is recommended that a minimum of 30 positions be collected at 1 second intervals and then averaged together for the location.

For line and or polygon features a good rule of thumb is to use a 2-5 second interval for walking and for road driving, depending on the road type and speed of the vehicle. At each corner and / or road intersection it is desirable to force (i.e. manually collect or wait for an update) a position. For curves in the road and / or any change in direction of the roadway, a minimum of 3 positions should be taken to define the change and / or curve.

Line and or polygon features, e.g. street centerlines, can be improved dramatically through the adoption of integrated GPS and inertial systems which use vehicle dynamics to provide coordinate fill-in during periods of GPS outage. Without the use of inertial technology, it is not uncommon to experience periods where it is not possible to obtain a GPS position for the receiver. Integrated GPS and inertial systems can be costly and result in higher data collection costs. In areas where GPS signals do not meet the recommended standard of a maximum PDOP of 6, 95% of the time, the cost and data quality of these types of systems may be justified.

Accuracy is dependent on a number of factors. Several factors that can significantly impact data accuracy can be monitored in the field: the number of satellite vehicles, Positional Dilution of Precision (PDOP), signal-to-noise (SNR) and Estimated Horizontal Error (EHE). One should always acquire at least 4 satellites. More satellites are better than fewer. PDOP relates to satellite geometry at a given time and location. Keep the PDOP as low as possible when collecting mapping data. Some

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<sup>1</sup> Position Dilution of Precision (PDOP) can be monitored by setting the receiver to collect data with a PDOP of 6.0 or less. This will insure that the satellite vehicles are adequately distributed. Collecting fixed positions during periods when the PDOP is higher than 6.0 could result in less accurate data.

receiver's have the ability to limit collection of GPS data if certain GPS quality measures are out of range. These are referred to as masking.

Differential corrections should be used whenever possible. This removes the greatest source of errors remaining in the GPS error budget. Real-time differential corrections are available through the NDGPS/Coast Guard Beacon System, the WAAS (FAA) satellite based differential system, OmniStar, or a variety of paid private differential services. Post-process differential GPS can be obtained from the NGS base stations available from the web or local community base stations.

Real-time differential corrections should be used whenever possible. This saves both time and money in the long run. ALWAYS do differential corrections, either real-time or post processed.

**Additional reference - <http://www.gps.gov/>**

See Appendix A for Mapping Grade GPS Receiver Specifications

## **4 Quality Assurance/Quality Control**

The attribute and spatial information of 9-1-1 GIS data must be accurate in order for 9-1-1 calls to locate properly. Taking into account the nature of static resources, attributes and spatial features of the GIS data shall be validated at a minimum of once a year against one or more of the following data resources:

### **4.1 Attribute Validation**

The following data resources are recommended for validation of street names, address ranges, community names and Emergency Service Number (ESN) assignment:

#### **4.1.1 Automatic Location Information (ALI) Data Base and Master Street Address Guide (MSAG)**

Conflicting information between the ALI Data Base and the GIS data layers become more likely without a constant effort to keep the two systems synchronized.

By comparing the GIS data and either the entire ALI Data Base or a data base of daily service order changes that have “passed edit entry,” will ensure that the GIS and ALI are synchronized. Using a data base of daily service order changes will also require checking these data against the entire ALI dataset and correcting the GIS and/or ALI Data Base in order to be synchronized. This ensures that each ALI address is represented in the GIS data layer.

If a 9-1-1 Authority cannot obtain a copy or access the ALI Data Base due to economic or confidentiality issues then an alternative would be to use the Data Base Management System Provider (DBMSP's) MSAG to compare GIS data with MSAG road ranges, road names and (ESN's).

#### **4.1.2 Tax Assessment Information**

For municipalities that work with 9-1-1 Authorities on addresses and new road centerlines, tax assessment information provided by the municipality can be used as another means to obtain site and road information not captured on the orthoimagery. However, there needs to be constant coordination between municipalities and 9-1-1 Authorities in order for tax assessment information to be effective.

#### **4.1.3 Utility Meters**

Information obtained from local utility companies is another means to ensure that the GIS data for Enhanced 9-1-1 includes site and street address information that corresponds to the street address of where an electric or water utility meter is located. Obtaining meter data from a utility company may require the 9-1-1 Authority to enter into a confidentiality agreement with one or more utility companies. Utility companies may even facilitate addressing due to the need to locate infrastructure. Facilities such as guard stations, barns, private subdivision entries, and cable TV pedestals may have utility services as well as telecommunications services and meet the need for a site and street address information. The utility data may not “match” the MSAG names, so procedures need to be in place to correct the data, which may impact, the MSAG, the utility data, or both.

#### **4.1.4 Building Point Files**

A point located on a building with related address tables attached is another dataset that can be used to verify address ranges on a GIS centerline dataset. These points are often maintained by a planning authority at a municipality and are updated when new building permits are granted.

### **4.2 Spatial Validation**

The following data resources are recommended for positional accuracy validation:

#### **4.2.1 Orthoimagery**

This document refers to standards related to orthoimagery using film. As digital technology becomes more prevalent, this document will be revised to reflect the use of such technologies.

See Appendix B for Orthoimagery Specifications.

#### **4.2.2 Satellite Imagery**

There are three basic types of satellite imagery:

- i) Black and White  
Panchromatic imagery delivered as a single band.
- ii) Multispectral

Imagery delivered as one file with three separate bands in true color (red, green, blue) or false color (near infrared, red, green); or imagery delivered as four files with one band each.

iii) Color

Imagery delivered as one file with a composite of the three bands in true color (red, green, blue) or falsecolor (near infrared, red, green); or imagery delivered as four files with one band each.

#### **4.2.2.1 Advantages of Satellite Imagery**

- i) Relatively inexpensive when compared to acquiring orthoimages from traditional aerial photography.
- ii) Using satellite imagery makes it easy and affordable to acquire images over the same area at different time periods. This provides a tool for monitoring change over time. Remote Sensing & GIS applications often have an ability to perform change detection analysis on images to determine areas to be updated.
- iii) Relatively easy to acquire very accurate ground control data used for orthorectifying data. This is best done with a differential GPS to collect highly accurate ground control points.
- iv) Relatively flat regions can be orthorectified to spatial accuracies to near 1 meter, with good ground control points (GCP).

#### **4.2.2.2 Disadvantages of Satellite Imagery**

- i) An orthorectified satellite image that has spatial accuracies equal to traditional orthophotography is very difficult to obtain.
- ii) Cloud cover is the eternal problem when trying to acquire a satellite image. The less cloud cover, the better, but it may come at a higher cost.
- iii) The laws of atmospheric optics make it impossible to obtain satellite imagery with a resolution of 6 inches or better.
- iv) Satellite Imagery should be accomplished if feasible during a period when deciduous trees have lost their foliage for the season.

#### **4.2.2.3 Important Considerations Regarding Satellite Imagery**

Accurate orthorectification of imagery in remote areas will be very difficult, if not impossible. This is because of difficulty in obtaining highly accurate ground control positions and the lack of high resolution Digital Elevation Models (DEMs). DEMs are used to rectify aerial imagery.

The collection of a highly accurate ground control is very important in the orthorectification process. To obtain the best accuracy for orthorectification, it is best to collect ground control points (GCPs) at accuracies better than the pixel resolution of the imagery. For example, if you need 1 meter resolution, you need sub-meter GCPs. If you need 1 foot resolution, you need GCPs accurate to a few inches.

It is important to realize that collecting accurate GPS location points is time intensive and may be a considerable portion of the overall cost in producing an orthorectified image.

Many satellite vendors may consider imagery acceptable if it contains 20% or less cloud cover. Customers may specify imagery collection with less than 20% cloud cover. It is possible that a cloud might cover a critical area for which the image is being acquired.

Circular error (CE) and root mean square error (RMSE) are commonly used to characterize the accuracy for satellite image features. CE is the distance between the apparent position of a distinct feature in a map or orthophoto and its true position. Map accuracy is commonly specified by CE at 90% probability, written as CE90. This means that locations of objects are represented on the image within the stated accuracy 90% of the time. This CE90 accuracy level can be related to Root Mean Square Error (RMSE) as well as the U.S. National Map Accuracy Standards (NMAS).

See Appendix C for Satellite Imagery Specifications.

### **4.3 GIS Data and Spatial Audits**

At a minimum, the digital mapping system shall include the following GIS data and spatial audits with accompanying metadata:

#### **4.3.1 Sites**

- i) Valid attribute values
- ii) Duplicate sites identification – sites with the same address
- iii) Parity address check
- iv) Site address matches to ALI Data Base

#### **4.3.2 Roads**

- i) Valid attribute values
- ii) Duplicate line segment identification
- iii) Route connectivity errors (Vital for network and routing analysis)
- iv) Overlapping address ranges within the same ESN

#### **4.3.3 Road Names**

- i) Valid attribute values
- ii) Duplicate road names in same town (MSAG Community)
- iii) Road names in the MSAG/ALI should agree with the road names in GIS

- iv) Address ranges shall include ranges in MSAG

#### **4.3.4 Emergency Service Zone (ESZ)**

- i) Relation check of ESZ, ESN, Emergency Service Agency (ESA)
- ii) Remove empty (null/sliver) polygons
- iii) ESZ, ESN info matches to MSAG/ALI
- iv) Eliminate gap and overlapping polygons
- v) ESZ Boundaries should be joined to jurisdictional boundaries where appropriate (e.g. roads, rivers, municipality). All coincident boundaries should be exact (joined vertices to vertices)

#### **4.3.5 Topology cleanup**

- i) Line (road) segments shall be split on intersections, ESZ boundaries, and jurisdictional boundaries.
- ii) The flow of the line direction shall reflect the increasing address range. The flow may have to accommodate an address that is out of sequence.
- iii) Invalid dangle nodes should be removed.

### **4.4 Map Discrepancy Reporting**

The map data that reside in mapping software require updates on a regular basis. The call taker interacts with the map data on a daily basis and therefore is a good reference when determining the accuracy of the map data. If a street is missing or an address range is incorrect, the call taker can be the first line of defense. Therefore, there must be a means for the call taker to communicate mapping issues as they arise. Generally the call taker is not a trained GIS technician so the communication method shall be at a non-technical level. It is preferable that the method for reporting be imbedded directly into the mapping software. This streamlines the reporting process and allows the call taker to graphically display the mapping area in question. It is not the call taker's responsibility to determine what the problem is but to be able to communicate the concerns to supervisory staff. The method should also include a mechanism by which call takers are notified of the discrepancy resolution.

The reporting form, at a minimum, must include the following:

- i) A snapshot of the map data in question so that the area is visible on the report. The bounding coordinates of the area. This is helpful to determine the exact location of the mapping question.
- ii) The error type. This can also be in the form of a drop down menu with selection of common mapping errors. Mapping errors including, but not limited to: incorrect address range, incorrect location, street direction change, missing site, missing street, and missing landmark.
- iii) Date/Time of report as well as user name. This will allow other personnel to determine who filled out the form if additional questions are required.

- iv) ANI/ALI information
- v) A transfer process for communicating the report to supervisors; such as printing, emailing, faxing, etc. This process can be unique to the configuration of the individual systems, or, an automatic log report into a work order queue stored within a database so discrepancies can be worked as they are identified

## 5 Data Maintenance

### 5.1 Purpose

There are several purposes for maintaining GIS data for Enhanced 9-1-1.

The key element is to provide accurate spatial data for a PSAP to properly locate 9-1-1 calls. Spatial information can be used for a map display which includes, among other functions, display of the location of each emergency call, alternative means of determining emergency location, and spatial query tools. Computer Aided Dispatch Systems (CAD) may require spatial data in order to build the information needed for CAD emergency response and operations.

Pinpointing emergency locations with a high degree of accuracy is one reason for properly maintaining GIS data. To properly represent the ever-changing real world, the GIS requires constant maintenance and updating of the underlying data layers.

GIS data of any worthwhile size contain errors. Eliminating all errors is an unrealistic expectation. The goal is to quickly correct any discrepancies found. What is expected is a consistently applied program to identify and correct errors. The longer GIS data goes without an update, the less accurate the information will become and the integrity of the data diminishes. There are several options for the entity responsible for performing GIS data maintenance:

- i) PSAP staff
- ii) Local GIS department(s) (i.e. government, police, utilities, etc)
- iii) GIS Mapping vendor

Maintaining data integrity within the GIS and keeping the data synchronized with existing tabular files, MSAG, and ALI files requires high levels of coordination. The MSAG coordinator, PSAP personnel and GIS personnel must work closely together to resolve MSAG and GIS discrepancies.

Timeliness of the update of the GIS data is key to maintaining an accurate map data layer within a PSAP. It is important that the users of the map data retain confidence in the data accuracy. GIS data applications in other departments within a jurisdiction may not require up-to-date data. When discussing map updates a jurisdiction needs to remember, not only is it important for the data to be updated with the newest information, this updated information must be made available to the telecommunicator. The installation of a GIS mapping system must include a long term solution for the maintenance and updating of the map data within the system. The approved personnel, i.e.

personnel qualified and trained to maintain GIS data, must understand the needs and requirements of the GIS mapping system such as attribute requirements, column headings and map projections.

It is recommended GIS updates be processed as part of the Enhanced 9-1-1 GIS data within five business days of receipt and verification of an address. The updated GIS data layer shall be provided to the PSAPs in a timely manner. The GIS updates must be submitted in an electronic format according to the GIS Data Model in NENA 02-010.

9-1-1 Authorities shall be aware that the higher the GPS accuracy level chosen, above the 10 feet (3.048 meter) standard, the higher the costs to collect and maintain their GIS data. Refer to section 3.1 GPS Data Collection Standard

## 5.2 Roads Data Layer

Roads are renamed, added, relocated, and occasionally removed in the real world. These changes must be accommodated in the map data. As structures are constructed or demolished, geo-coding shall be updated on the road centerline layer to accommodate these changes. As structures are constructed or demolished, the road centerline layer must be updated to accommodate these changes and thus preserve the ability to geocode accurately. Maintenance of the one-way and closed roads within the map's road centerline layer requires updating and possibly, seasonal adjustment. Changes may be received from the 9-1-1 addressing coordinators, transportation departments or from the DBMS service providers, or jurisdictional entities.

In order to geocode accurately, the road centerline layer requires maintenance of: 1) coordinate locations; 2) name changes; 3) new roads; 4) changed addressing start/end points; 5) the turn-table (one-way status); and 7) road classifications for symbology and routing (including overpass/underpass/no-turn attributes of intersections); 8) address range changes ; 9) municipality annexations; 10) speed limit or impedance field; 11) municipal route number field; and 12) source data field.

Changes in the road centerline layer may affect the ESZ topology. Adjustments to the ESZ information shall reflect those changes. It is recommended that the ESZ boundary be joined to the road centerline where the road forms the boundary between two different ESZs. Even though the road centerline forms the boundary, it may not always be the demarcation between two different ESZ's. (*See Figure 1*)

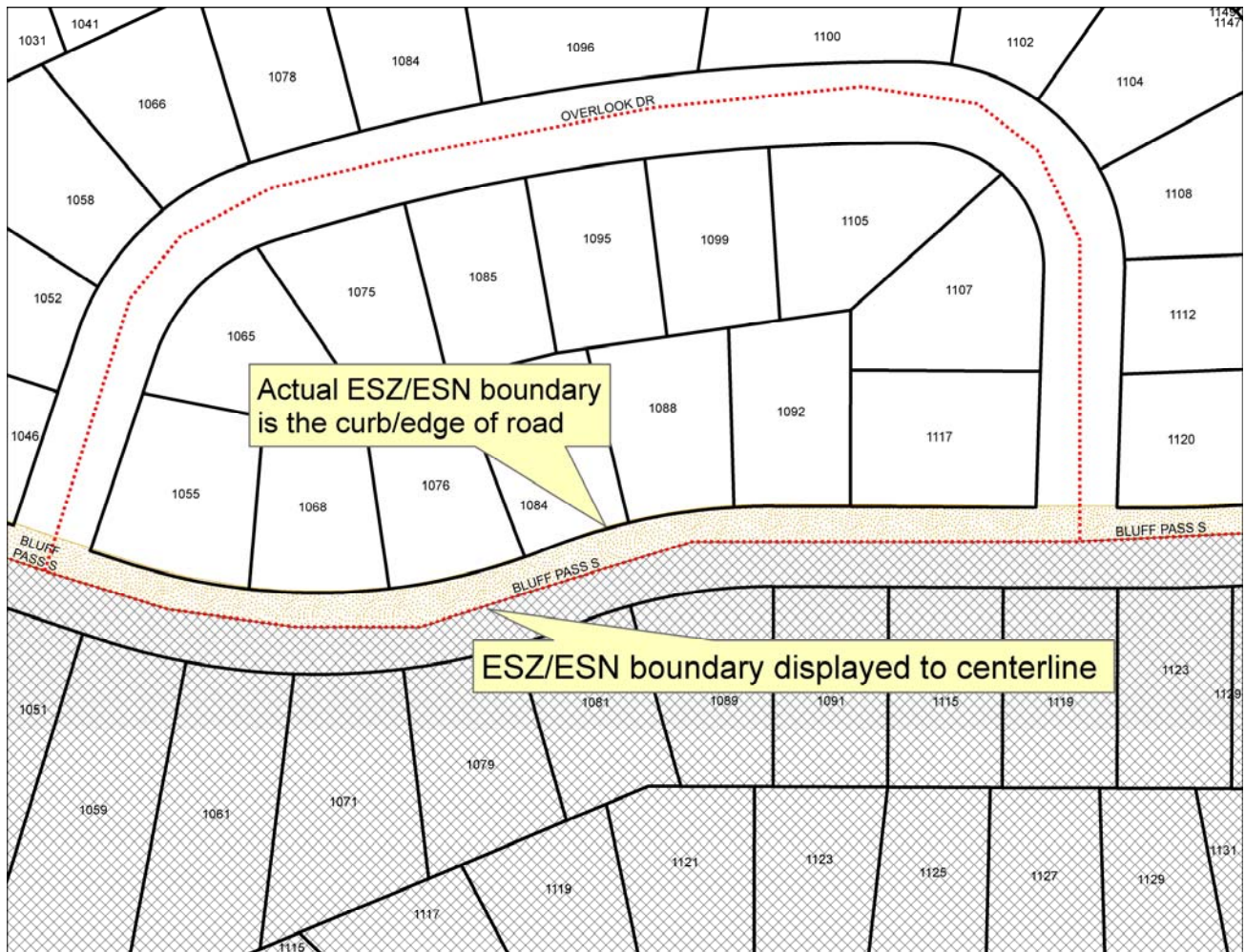


Figure 1

### 5.3 Site/Structure/Building Point File Location Layer

If a site/structure/building point file layer is utilized as a data layer for a PSAP, every effort shall be made to ensure that every address in the ALI Data Base matches to an address in the GIS data layer.

As buildings are constructed or demolished, SITE points need to be added or deleted. Existing sites may require a change of address. Information may be received from 1) the addressing authority, 2) as a discrepancy between the GIS data and a service order change, 3) as an ALI discrepancy, or (4) as determined as part of the spatial audit process.

In addition to adding or moving a site point, the ESZ polygon layer needs to be updated to ensure that the new or moved site point has an appropriate road name and that the address falls within the address range of the road centerline to which it was added. Sites may be added from atlas sketch maps, lat/long coordinate inputs or direct import from a digital map file.

#### **5.4 Emergency Service Data Layers**

Emergency Service Data layers are a combination of the point layer, Emergency Service Agency Location Layer and the ESZ polygon layer.

Emergency Service Agency Location layer includes the location of each responding emergency service provider. The location information is used to route emergency service calls from the correct emergency service provider to the emergency location.

The location of emergency service providers needs to be monitored. As providers are added, changed or removed, there needs to be a systematic approach of reviewing the changes and coordinating the data.

Emergency Service Agency Location updates are performed in a manner similar to Site updates.

Note: This assumes that the emergency service provider is a static point location. With the advent of mobile data terminals and the ability to track emergency service providers, a static location for an emergency service provider may not be applicable.

#### **5.5 Wireless Carrier Data Layers**

Cell Site Location Layer is a point data layer of the location of each wireless cell site that can receive calls for a 9-1-1 Authority. This layer may be linked to the Cell Site Coverage Layer through the Cell Site ID. Refer to the GIS Data Model in NENA 02-010. Attributes for the cell site include data regarding the cell site owner and characteristics. All new wireless cell sites shall have an MSAG valid address.

Cell Site Coverage Layer is a polygon data layer representing the maximum Radio Frequency (RF) area of each wireless cell sector as provided by the wireless carrier. A cell site may have one or more cell sectors. The information used to create the cell site polygon layer is provided by the wireless service provider on the initial wireless cell tower routing sheet. As wireless companies add new cell sites, not only are new sectors required, but update of existing sector coverage boundaries may be required as a result of configuration changes in these cell sites. It is important to note that actual cell coverage boundaries are fluid (i.e. they are constantly changing due to atmospheric conditions and a number of other factors). Refer to the GIS Data Model in NENA 02-010 for all the layers related to wireless carrier data.

To ensure 9-1-1 Authorities receive cell site and sector information consistently and accurately, PSAPs may need to enter into a Memorandum of Agreement (MOA) that requires wireless carriers to provide cell site and sector data according to the GIS Data Model in NENA 02-010. That includes providing information to 9-1-1 Authorities according to the Cell Site Location and Coverage Layers. The MOA shall also include requirements to provide new installation or changes in cell sites configuration before the cell site goes live. 9-1-1 Authorities may need to enter into

confidentiality agreements with wireless providers in order to obtain information as to cell site and sector information.

Once data are received from the wireless carriers, they shall be compared to the Enhanced 9-1-1 GIS data layer. 9-1-1 Authorities shall work with the carriers to resolve discrepancies.

## 5.6 Background Data Layers

Background Data Layers are optional layers used to help PSAP call handling capabilities. The background data layers need to be maintained as individual PSAP jurisdiction layers. As new information becomes available from the agency responsible for its creation, it shall be integrated into the appropriate PSAP jurisdictional layers using the same attribute coding.

- i) Hydrology Layer: Hydrology line coverage: stores the linear hydrology features such as streams or the arc delineating the edges of lakes or rivers. URL: [http://cfpub.epa.gov/surf/county\\_list.cfm](http://cfpub.epa.gov/surf/county_list.cfm) insert FIPS code here for your county
- ii) Hydrology polygon coverage: stores the coordinate information and label hydrology features that cover visible area at the display scale. Both the Hydrology line coverage and polygon coverage must contain the water body names (if known)
- iii) Railroad Layer: Review local and national data resources. URL: <http://www.fra.dot.gov/>
- iv) Mile Marker Location Layer: Local department of transportation. URL: <http://www.fhwa.dot.gov/webstate.htm>
- v) Highway Exit/Entrance Point Layer: Local department of transportation.
- vi) Electric Line Layer: High voltage transmission lines. URL: [http://www.electricity.doe.gov/program/electric\\_rd\\_distribution.cfm?section=divisions&level2=distribution](http://www.electricity.doe.gov/program/electric_rd_distribution.cfm?section=divisions&level2=distribution)
- vii) Petroleum/Natural gas lines and shut off valves.
- viii) Water Main Layer: Municipal water & sewer authorities
- ix) County Polygon Layer
- x) Zip Code Boundary Layer

- x) **Municipal Boundary Layer:** This polygon layer maintains only the jurisdictional boundaries for use in the map display. Attribute information for this polygon layer must include municipality, county and state. If it is not part of the ESZ coverage, it must align with this coverage where necessary.
  
- xii) **Landmarks/Significant Structure Layers:** The names of place points within a 9-1-1 Authority for navigational aids. One resource for this type of data is the USGS Geonames data. It must be used for automated placement of city and town names without using a symbol. If symbols are used, the points need to be adjusted to the road data. One resource for this type of data is the USGS GEONAMES data. URL: <http://geonames.usgs.gov/>

The above data layers are not necessarily maintained by the 9-1-1 Authority. Data for these layers can be obtained from alternate resources, like state, municipal, national or private agencies that originally created these layers. Updates shall be obtained for use at the PSAP in accordance with Section 4. Quality Assurance/Quality Control. URLs shown are just one example of possible resources for data layers listed above. Any GIS data received from a third party source shall be validated for accuracy.

## 5.7 Definitions

Dangle Node(s) an endpoint that is not connected to another line. This rule is used when line features must form closed loops, such as when they are defining the boundaries of polygon features. It may also be used in cases where lines typically connect to other lines, as with streets. In this case, exceptions can be used where the rule is occasionally violated, as with cul-de-sac or dead end street segments.

Digital Elevation Model (DEM) is a digital file consisting of points of elevations, sampled systematically at equally spaced intervals.

Digital orthoimage: a geo-referenced image prepared from a perspective photograph or other remotely-sensed data in which displacement of objects due to sensor orientation and terrain relief have been removed. It has the geometric characteristics of a map and the image qualities of a photograph. Digital orthoimages are composed of an array of geo-referenced pixels that encode ground reflectance as a discrete value. Digital orthoimagery comes from various sources and in a number of formats, spatial resolutions, and areas of coverage. Many geographic features, including some in other framework data themes, can be interpreted and compiled from an orthoimage. Accurately positioned, high resolution data are considered the most useful to support the compilation of framework features. (Ref. Federal Geographic Data Committee)

Ground Sample Distance (GSD) is the area on the ground represented by each pixel in a digital orthoimage.

Position dilution of precision (PDOP): is a value that indicates the quality of the geometric orientation of satellites being used to compute a position. The closer the PDOP value is to one, the better the geometry of the satellites and the likely position accuracy. If the satellites are close together, the geometry is not the best and the PDOP value may be greater than 6. The PDOP shall be less than six.

PDOP is a unit less figure of merit expressing the relationship between the error in user position and the error in satellite position, which is a function of the configuration of satellites from which signals are derived in positioning. Geometrically, PDOP is proportional to 1 divided by the volume of the pyramid formed by lines running from the receiver to four observed satellites. Small values, such as "3", are good for positioning while higher values produce less accurate position solutions. Small PDOP is associated with separated satellites. The spacing of satellites in orbit is arranged so that a minimum of five satellites will be in view to users worldwide, with a position dilution of precision (PDOP) of six or less.

### Spatial Data

Information about the locations and shapes of geographic features and the relationships between them, usually stored as coordinates and topology. Or, any data that can be mapped.

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An Introduction to Satellite Imagery and GIS, (January 2006), [http://www.npagroup.co.uk/imagery/rs\\_intro/index.htm](http://www.npagroup.co.uk/imagery/rs_intro/index.htm)

## Appendix A – Mapping Grade GPS Receiver Specifications:

1. GPS receivers must be:
  - Capable of producing and storing data in a format compatible with standard basestation data used to perform differential corrections (rinex, ssf, etc.)
  - Capable of storing attribute data about features collected
  - Capable of storing time and coordinates of features collected
  - Capable of exporting features collected to a format that can be used by a GIS
  
2. GPS Receiver Settings:

<u>Name</u>	<u>Standard</u>
Almanac <sup>2</sup>	acquired within 10 days
Altitude reference	Height above Ellipsoid (HAE) or Mean Sea Level (MSL); if MSL is used, indicate Geoid Model
Antenna heights <sup>3</sup>	1.0 – 2 meters
Datum	WGS-84
Elevation mask <sup>4</sup>	15 degrees
Feature types	point, line, area (polygon)
Logging intervals	Point 1 second Line / Area Walking 5 seconds Driving 1 second
<i>Note: To achieve the highest degree of accuracy the GPS receiver -logging rate must be synchronized with the base station supplying differential information logging rate. Otherwise, interpolation of points will occur, reducing the accuracy of the GPS receiver.</i>	
Minimum number of positions for a point feature	4
Mode	2D / 3D
PDOP Mask	6.0 or less
Position mode <sup>5</sup>	manual 3D
Satellite vehicles	3 (for 2D collection) / 4 (for 3D collection)
SNR Mask <sup>6</sup>	6.0 or greater

<sup>2</sup> An almanac provides information for satellite acquisition in the field and for mission planning in the office. Typically, almanacs are considered current for up to thirty days. In the field almanacs are acquired every 12 minutes when using a GPS receiver. For mission planning you shall acquire a fresh almanac. Almanacs can be acquired from a GPS receiver, GPS software, base station file, or the Internet.

<sup>3</sup> Antenna heights will vary depending on the specific application. Typically, the antenna height shall be set at 1.0 - 2 meters. The antenna height is directly related to vertical and horizontal accuracies. It is imperative to properly set the antenna height when collecting vertical GPS data.

<sup>4</sup> The elevation mask shall be set to 15 degrees. There are GPS projects that may require a higher or lower degree of mask, but these instances shall be reviewed and documented in the GPS metadata.

<sup>5</sup> The position mode setting on the GPS receiver shall be set to manual 2D or 3D. This will provide positions collected with a minimum of three or four satellites. The 3D mode will allow for horizontal and vertical data collection.

Unit of Measure	meters or feet
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An almanac provides information for satellite acquisition in the field and for mission planning in the office. Typically, almanacs are considered current for up to thirty days. In the field, almanacs are acquired every 12 minutes when using a GPS receiver. For mission planning you shall acquire a fresh almanac. Almanacs can be acquired from a GPS receiver, GPS software, base station file, or the Internet.

Antenna heights will vary depending on the specific application. Typically, the antenna height shall be set at 1.0 - 2 meters. The antenna height is directly related to vertical and horizontal accuracies. It is imperative to properly set the antenna height when collecting vertical GPS data.

Position Dilution of Precision (PDOP) can be monitored by setting the receiver to collect data with a PDOP of 6.0 or less. This will insure that the satellite vehicles are adequately distributed. Collecting fixed positions during periods when the PDOP is higher than 6.0 could result in less accurate data.

The elevation mask shall be set to 15 degrees. There are GPS projects that may require a higher or lower degree of mask, but these instances shall be reviewed and documented in the GPS metadata.

The position mode setting on the GPS receiver shall be set to manual 2D or 3D. This will provide positions collected with a minimum of three or four satellites. The 3D mode will allow for horizontal and vertical data collection.

Signal to noise ratio (SNR) refers to the strength of the code given off by the satellite vehicle. If the SNR falls below 6.0, the code is considered weak. The SNR shall be set to accept positions when the SNR is 6.0 or higher.

### 3. GPS Metadata Standards: (for GPS collected Data)

<i>Requirements</i>	<i>Example</i>
Type of receiver	Manufacturer / Type Racall- Mark IV Landstar Trimble- GeoExplorer III
Number of receiver channels	12
Number of available satellites	Minimum of 4 satellites
Horizontal accuracy of receiver (manufacturer's specifications for predicted error, including reporting statistic)	1-5 meters+ 2ppm (root mean square)
Vertical accuracy as stated by manufacturer	3-5 meters+ 2ppm (root mean square)

<sup>6</sup> Signal to noise ratio (SNR) refers to the strength of the code given off by the satellite vehicle. If the SNR falls below 6.0 the code is considered weak. The SNR shall be set to accept positions when the SNR is 6.0 or higher.

Approximate distance from the base station used for differential correction	20-30 miles
Base station used for differential correction	<a href="http://www.fs.fed.us/data_base/gps/clickmap/cbsmap.htm">http://www.fs.fed.us/data base/gps/clickmap/cbsmap.htm</a>
Coordinate system	Geographic (lat/long)
Datum	WGS 84
Date of collection	01/01/01
Time of Collection	Hours:minutes;seconds
GPS methodology utilized	autonomous, differential, or phase-differential
Altitude reference	Height above Ellipsoid (HAE) or Mean Sea Level (MSL); if MSL is used, indicate Geoid Model
Minimum number of positions for a point feature	4
PDOP Mask	Maximum of 6
SNR Mask	Minimum of 6
Units of Measure	Meters or feet

Metadata shall be prepared for all GPS features. GPS features require two forms of metadata. This document only addresses the documentation of metadata specific to the GPS receiver (GPS metadata). Refer to the GIS Data Model in NENA 02-010 for metadata standards for spatial data (features). GPS metadata shall include: accuracy of receiver, base station used for differential correction, coordinate system, dates of collection, datum, differential correction applied, elevation setting, horizontal and vertical accuracy, minimum number of positions collected, PDOP, SNR, type of receiver, and units of measure. The metadata shall be supplied with the feature data layer. (Refer to GPS Metadata Standards)

Supplying metadata will assist end-users of the spatial data with the information needed to employ its appropriate use. A number of projects or unavoidable circumstances may warrant receiver settings or collection methods outside of the standard presented above. When this occurs it shall be precisely documented in the metadata.

#### 4. Systematic Errors

Positions acquired using GPS receivers are determined based on a measurement of time and distance. Receivers calculate the time and distance from a minimum of three satellite vehicles to acquire a horizontal position and four satellite vehicles to acquire a 3D (horizontal and vertical) position. There are several known sources of error that shall be taken into consideration when collecting GPS positions.

Atmospheric delay occurs when GPS signals are interrupted by the earth's ionosphere and troposphere. As the signal is disrupted, the time it takes to reach the earth is altered, and can contribute approximately 1 meter of error. Since GPS positions are determined by time and distance, this alteration in time has an adverse effect on the accuracy of GPS fixed positions collected. The heat of the day is when atmospheric delay is greatest. Satellite vehicle signals low on the horizon also experience higher delays because the signal travels through more atmosphere.

Dilution of Precision (DOP) is the combination of error factors caused by poor satellite vehicle geometry that can alter position and time solutions. The receiver is using trilateration to determine its fixed position. If the satellite vehicles are not properly spaced, the DOP values are higher and the horizontal position is degraded. Setting the receiver to accept positions when the PDOP is 6.0 or less (lower is better) will control this source of error by not allowing data with high DOPs to be saved by the receiver. Errors incurred by PDOP's higher than 6.0 can cause approximately 1 meter of inaccuracy.

Multipath error occurs when a satellite vehicle's signal is reflected off an object prior to reaching the receiver, thus causing a time delay. This can cause several meters of error. Buildings, trees, mountains, signs, etc, may cause multipath errors. Generally multipath errors are easily recognized when the GPS data collected is viewed in a geographic information system (GIS).

Obstruction errors occur when the GPS receiver loses a lock from a satellite vehicle from which it is receiving code. Receivers and base stations both require a clear view of the sky. Weather generally does not affect the functionality of a receiver. Extreme conditions could impede a receiver's performance. A clear view of the sky is one that is not blocked by solid objects.

Satellite vehicle clock error and receiver rounding error also contribute to GPS data inaccuracies. Operator error caused by using the wrong datum or coordinate system is the biggest source of error and may result in 100+ km of error.

Selective availability (SA) is an intentional degradation of the code sent from satellite vehicles. The Department of Defense degrades the code. On May 1, 2000 the Department of Defense turned off selective availability. Selective availability may be activated anytime and without notice. Errors caused by selective availability can be difficult to observe. Post-processing aids in removing time and location errors collected by the receiver. Most receivers come with post-processing software. Arkansas has a number of base stations that are available for public use. All fixed positions collected shall be post-processed. This will increase and standardize horizontal and vertical accuracies. Raw data from the receiver and base station shall be archived. Future software may allow for finer post-processing accuracies.

## 5. Systematic Error Reduction

Training: Individuals who are involved in collecting spatial data utilizing GPS technologies shall have adequate training. Prior knowledge of sources of error, the proper uses of GPS, and limitations will help ensure that quality spatial data is obtained with GPS receivers. Training classes are offered by a number of vendors, state agencies and universities.

Testing GPS receivers: GPS receivers shall be tested on a regular basis to ensure receivers are in proper working order. A zero baseline test will provide a degree of equipment reliability. Acquiring a fixed position on a known point on the earth's surface (such as a horizontal control station), post-

processing the data and comparing it to the known point is one way to determine a receiver's working condition.

Project planning considerations: Mission planning shall be conducted to determine which type of capture and processing best suits the project. There are a number of methods for capturing and processing GPS data including: autonomous, real-time correction, and post-processing. Each of these methods will produce different accuracies. It is important for GPS users to be aware of what method they are utilizing and make sure it is properly documented in the GPS metadata.

GPS data collection: GPS data shall be collected in one of three geometries (point, line or area). Each geometric shape requires a specific collection method. A point feature shall be collected at one-second intervals with a minimum of 4 measurements per point.

Line and area features shall be collected at five-second intervals if walking and one-second intervals if driving. An area shall be collected by closing the feature prior to returning to the first point acquired. This will reduce "bow ties" commonly found in area data.

Post-processing: The closest available base station shall be used for post-processing when possible. Post-processing shall always be done with data from a base station within a maximum of 300 miles of all positions collected. It is strongly recommended that positions be post-processed utilizing base station data within fifty to one hundred miles of the working area.

## Appendix B – Orthoimagery Specifications

### 1. Aerial Photography

#### a. Project Area

Aerial photography shall be obtained at a maximum scale of 1:2400, 1 foot pixel resolution which produces a **NSSDA Horizontal RMSE (Root Mean Squared Error) Accuracy level of 5 feet or better** and produces digital orthoimagery for the entire boundary.

#### b. Conditions during photography

Aerial photography shall be accomplished during a period when deciduous trees are barren (as local climactic conditions permit), and generally within two hours before and two hours after maximum sun angle, when the sun angle is not less than 30 degrees above the horizon. Photography will not be undertaken when the ground is obscured by cloud cover, haze, fog, or dust and when streams are not within their normal banks. The photographs will not contain objectionable shadows caused by relief or low solar altitude.

#### c. Flight Plan

The principal points for the first and last exposures of each flight strip will fall outside the boundaries of the project area.

#### d. Forward Overlap

Consecutive photos in each flight line shall have an average forward overlap of 60 percent and an average side overlap of 30 percent to ensure full stereoscopic coverage. In large metropolitan areas, due to building height the average forward overlap of 80 percent and an average side overlap of 60 percent shall be used.

#### e. Crab

Crab is the angle loss caused by the winds of loft. In other words, the plane might be flying straight but if the wings are not horizontal, it introduces problems between the exposures.

Crab in excess of (3) degrees with respect to both lines of flight may be cause for rejection of a flight strip or any portion thereof in which the excessive crab occurs. This includes relative crab between any two successive exposures.

#### f. Tilt

Tilt of the camera from vertical at the instant of exposure will not exceed (3) degrees, nor shall exceed (5) degrees between successive exposure stations.

#### g. Aircraft

The aircraft shall be adequately equipped with all essential, geodetic, and photographic instruments to meet the aerial photographic and airborne specifications of the project. A well-trained and experienced crew will operate the aircraft and all equipment and instruments. The design of the aircraft is such that, when the camera is mounted with all of its parts above the outer structure, an unobstructed view will be obtained, it will be shielded from exhaust gases, oil, effluence, and air turbulence. No window of glass or other material will be interposed between the camera and the ground to be photographed.

h. Aerial Camera

The aerial camera shall have a USGS Calibration Certificate no older than three years. Additionally, the camera will be equipped with a low distortion, high-resolution lens.

USGS does not currently issue calibration certificates for digital cameras. Current digital technology is becoming more cost effective in capturing aerial imagery and information needed for a digital elevation model. As digital technology becomes more prevalent this document will be revised to reflect such.

i. Aerial Film

Kodak 2405 aerial film or industry equivalent will be used for the project. The film will be fine grain, high-speed photographic emulsion on a dimensionally stable polyester base and will serve as the source for the creation of the digital orthoimagery. Outdated film will not be used. The film will be stored and handled in accordance with the manufacturer's instructions.

j. Film Processing and Image Quality

The development, fixing, washing, and drying of all exposed photographic film shall result in a quality image, with optimal contrast, tone, balance, resolution, uniformity in range of density, and fine grain exposures.

k. Aerial Film Edit

Once the aerial photography is taken and developed, it will be carefully examined with respect to scale, overlap/sidelap, crab, tip/tilt and image quality. Exposures that do not meet normal photogrammetric standards, or are in some other way deemed unacceptable, shall be re-flown as soon as conditions permit. All acceptable photography will be labeled with date, scale, project name, flight line number and exposure.

l. Film labeling

Each exposure will be clearly labeled by an automatic film titler at the edge of the negative, just inside the image area, on the north edge. No thermal processes shall be used. The labeling area will include the date of photography, scale of photography, roll number, strip number and exposure number.

## 2. Geodetic Control

Airborne GPS with supplemental ground control points to support airborne GPS shall be utilized. Each of the supplemental ground control points will have GPS derived horizontal and vertical coordinates meeting the accuracy requirements set forth above. Each location shall be marked with a survey nail. Sufficient control shall be established to insure that the specified accuracies are met for all of the requested phases of work. Ground control surveys will be performed under the supervision of a Registered Professional Surveyor and Certified Photogrammetrist.

The aerial photography mission shall be flown with Airborne GPS for precise positioning of each photo center in order to minimize ground control, thus decreasing cost. For quality control of the aerial mission and adherence to Airborne GPS procedures, some ground control points shall be targeted and read during the aerotriangulation to verify the final Airborne GPS solution. The aerotriangulation process precisely orients aerial imagery to the mapping control. It is a mathematical process that allows for fewer control points.

To perform accurate photogrammetric measurement, horizontal and vertical control will be required at strategic locations throughout the project area. This control will be attained by performing a combination of Airborne GPS and ground GPS accurate enough to support compilation of all scales of digital orthophotography according to United States National Map Accuracy Standards.

## 3. Fully Analytical Aero triangulation

Fully analytical aerial triangulation will be used. This will provide supplemental control for setting individual stereo models in softcopy photogrammetric compilation instruments.

### a. Aerial Film Scanning

Scanning will be achieved directly from the aerial negative film. Electronic dodging eliminates the need for excessive handling and unnecessary reproduction. The fewer times aerial negative film is handled, the less opportunity for scratches, stains, dust, etc. No diapositives will be required for this process.

Prior to scanning, all film sources will be inspected for markings, dust, dirt, or any other foreign objects or markings that would degrade image quality. All such markings shall be removed without damaging the source. All fiducial marks shall be clearly visible in each scanned image.

A photogrammetric scanner specifically designed and manufactured for use on aerial film will be utilized. The scanner shall have geometric accuracy of

+/- 5 microns RMSE and is capable of a minimum scanning resolution of 7.5 microns. The aerial film shall be scanned at 15 microns or 1693 dpi.

b. Point Marking, Mensuration and Processing

A minimum of nine pass-points per stereo-image with tie points to adjacent flight line shall be digitally marked.

4. Digital Elevation Model (DEM)

All DEM data will be collected on a softcopy photogrammetric workstation in an interactive manner by experienced Stereo Plotter Operators.

Mass elevation points, 3D breaklines and 2D breaklines will be captured to support the DEM suitable for the development of the digital orthophotography. The density of the mass points will vary according to the terrain during collection. 3D visualization will assist in determining the density of mass points at the time of collection.

The resulting DEM data will be processed to produce a triangulated irregular network (TIN). The TIN surface will be used to remove relief displacement during the rectification process.

5. Rectification

The digital ortho algorithm shall trace a ray from the ground pixel position through the lens perspective center. The algorithm shall use the known bundle parameters to transfer the rays from image space to ground space one pixel at a time for the entire image.

6. Digital Image Mosaics

Perform a radiometric adjustment and tone balance as needed of individual digital orthoimages so that adjacent digital orthoimages can be displayed simultaneously without an obvious visual edge scan between them. Localized adjustment of the brightness, contrast and gamma values shall be performed to minimize tonal differences between the join areas. The radiometric adjustment shall not compromise the accuracy, clarity or resolution of the digital orthoimages.

7. Image Distortions

Orthoimagery shall not contain defects such as out-of-focus imagery, dust marks, scratches, or inconsistencies in tone and density between individual orthoimages and/or adjacent images. Enhancing the image quality of areas of this distortion is required. Careful photo selection and advanced image processing tools shall be used to correct or remove excessive distortions resulting from elevated surfaces in particular. This includes all bridges and overpasses. Mosaic lines will not pass through buildings or bridges.

8. Visual Verification  
Perform a visual verification of the images before all deliveries to insure image completeness and that no gaps occur in the image area or over edge coverage.
9. File Formats  
Digital orthoimages shall be delivered in agreed upon industry standard digital formats separated into map sheet tiles or image catalogs.
10. Quality Control  
Photogrammetric production quality control is necessary, and plays a role in every task to achieve the final deliverable product.

The following is a list of some of the QC steps:

- Inspection of the flight plan
- Inspection of the aerial film and aerial film edit
- Inspection and cleaning of each frame of the aerial film prior to scanning
- Scanner self calibration
- Review histogram and each image after scanning.
- Inspection of ground control data for proper photo ID, datum and project.
- Aerotriangulation, model measurement interior orientation, tie point analysis, strip adjustment and block adjustment.
- Model set-up interior and exterior orientation at the time of DEM collection.
- Three dimensional photo edit of the DEM data.
- Visual inspection of the digital orthoimagery
- Project specification assurance such as project boundary coverage, proper sheet outline and file formats for delivery.
- Mapping shall meet or exceed National Mapping Accuracy Standards.

## Appendix C – Satellite Imagery Specifications

### 1. Resolution

Resolution is the minimum distance between two adjacent features or the minimum size of a feature that can be detected by a remote sensing system. It needs to meet the National Map Accuracy Standards.

### 2. Scale

Scale is the ratio of distances on a map to those same distances on the earth's surface.

All satellite imagery must meet the National Mapping Standards. The National Map Accuracy Standard (NMAS) defines the requirements for meeting horizontal accuracy as 90% of all measurable points must be within 1/30th of an inch for maps at a scale of 1:20,000 or larger, and 1/50th of an inch for maps at scales smaller than 1:20,000.

Eight (8) bits per pixel imagery is sufficient for Enhanced 9-1-1 purposes as they are easy to use images for visual interpretation. 9-1-1 Authorities interested in full dynamic range shall select 11-bit images. Users of 11-bit imagery will require a viewer capable of reading 16-bit file.

### 3. Projection

Projection is to be WGS84. Refer to the GIS Data Model in NENA 02-010.

### 4. Digital Elevation Models (DEMs)

To orthorectify an image, an accurate DEM is necessary. The DEM has to be detailed enough to roughly show the topography in the satellite image. The DEM is used to correct the distortions in the raw imagery caused by the shape of the topography and the viewing angle of the satellite. Without a good DEM it is impossible to achieve high accuracy (less than 1-2 meters), no matter how good the ground control is.

Using an accurate imaging model and an accurate digital elevation model (DEM), a satellite image can be processed to create an orthorectified image. An orthorectified image has each pixel registered to the correct geographic position.