**SOUTHERN NEVADA WATER AUTHORITY**

**REQUEST FOR PROPOSAL**
**RFP NO. 652-15**
**DIGITAL AERIAL IMAGERY**

The Southern Nevada Water Authority (SNWA) is soliciting proposals from qualified and interested firms to enter into a professional services agreement to provide Digital Aerial Imagery requirements from date of award through December 31, 2016 with the option to renew for two additional imagery acquisition and rectification projects. For further information, please contact Thomas Borland, Senior Purchasing Analyst, at (702) 258-3200.

A Pre-Proposal Conference will be held at 1:00 p.m. on April 22, 2015 at:

Southern Nevada Water Authority
Molasky Corporate Center, 7th Floor
100 City Parkway
Las Vegas, Nevada 89106

The purpose of the Pre-Proposal Conference is to afford an opportunity to collectively review, critique, clarify the RFP documents, and answer any pertinent questions. Potential PROPONENT(s) and any other interested parties are encouraged and invited to attend the Pre-Proposal Conference. If travel to attend is not possible, PROPONENT(s) may request to participate via conference call by contacting the Purchasing Help Desk at: 702-258-3200 or purchasing_help_desk@lvvwd.com no later than COB May 14, 2015.

Requests for Proposal packages are available at the Las Vegas Valley Water District, 1001 South Valley View Boulevard, Las Vegas, NV. 89107, telephone (702) 258-3200. Hearing impaired customers may obtain information by calling TT/TDD: Relay Nevada toll-free (800) 326-6868.

Selected firms may be afforded an opportunity to participate in formal interviews in person or via teleconference to further demonstrate their firm's capabilities. The time and place for these interviews/presentations will be scheduled with each selected prospective firm. The firm's formal proposal documents will be the source used to select those firms.

Proposals will be received at the Las Vegas Valley Water District Purchasing Division, 1001 South Valley View Boulevard, Las Vegas, Nevada 89153 on, or before 4:00 p.m. on May 14, 2015. Proposals submitted must be received no later than 4:00 p.m. on the proposal due date.

**GENERAL CONDITIONS**
**RFP NO. 652-15**
**DIGITAL AERIAL IMAGERY**

1. PURPOSE

The purpose of this Request for Proposals is to solicit proposals from qualified firms to provide Digital Aerial Imagery services and associated products for the Southern Nevada Water Authority (SNWA) and the seven member agencies, through a cooperative agreement with the United States Geological Survey (USGS).

2. TERMS AND EXHIBITS

- The term "OWNER", as used throughout these documents will mean the Southern Nevada Water Authority General Manager, Director, or Staff Designated representative.
- The term "RFP" as used throughout these documents will mean Request for Proposal.
- The term "PROPONENT(s)" as used throughout these documents will mean the respondents to this Request for Proposal.
- The term "SNWA" as used throughout these documents, unless otherwise specifically stated individually, will mean the Southern Nevada Water Authority.
- The term "BOARD" as used throughout these documents will mean the Southern Nevada Water Authority Board of Directors.

3. BACKGROUND

The SNWA is a cooperative agency formed in 1991 to address Southern Nevada's unique water needs on a regional basis. The member agencies provide water and/or wastewater services to Southern Nevada. The SNWA's mission is to manage the region's water resources and develop solutions that will ensure adequate future water supplies for the Las Vegas Valley. SNWA is governed by a seven-member agency comprised of representatives from each of the following member organizations:

- Big Bend Water District
- Boulder City
- Clark County Reclamation District
- Henderson
- Las Vegas
- Las Vegas Valley Water District
- North Las Vegas

4. OVERVIEW OF PROJECT

In the late 1990's, the SNWA began a rebate incentive program for property owners in Southern Nevada to convert their turf landscaped areas into a more natural, desert-friendly landscape that promotes water conservation and efficiency. This program, which is now known as the Water Smart Landscape (WSL) Program, has received positive

response by customers since its inception. Over 150 million square feet of turf conversion has been completed, with an estimated water savings of over 7.4 billion gallons.

A significant aspect of this WSL Program is the use of aerial imagery to help the property owner and SNWA staff, identify what areas will be converted. The aerial imagery is very important with assisting the measuring and calculation of area square footage for conversion. The imagery and conversion areas are later printed to a hardcopy map for the customer and Authority, who files each final, signed-off map into the system.

Additionally, there is an opportunity to acquire high-resolution LiDAR digital elevation data through the USGS 3-Dimensionsal Elevation Program (3DEP) that can help identify different types of vegetation throughout the Las Vegas Valley and improve overall accuracy of ongoing vegetation analysis associated with the WSL Program.

The SNWA is seeking proposals from qualified firms to provide Digital Aerial Imagery services and associated products and is interested in continuing a program where new imagery is provided to the SNWA standards. The period of performance is from date of award through December 31, 2016 with the option to renew for two (2) additional one-year periods. The imagery will be utilized by the SNWA and its seven member agencies and it is anticipated that the resulting rectified imagery will be used as a backdrop in conjunction with other SNWA Geographical Information System (GIS) data. The project area for the digital aerial imagery is graphically summarized in Exhibit A.

5. DESIGNATED CONTACTS

The Owner's representative will be Thomas Borland, Senior Purchasing Analyst, (702) 258-3200. This representative will respond to all questions concerning the scope of work and selection process for this RFP Questions regarding the solicitation should be directed in writing via email to thomas.borland@lvvwd.com or fax at (702) 258-3900. Questions and answers will be compiled and published to all PROPOSER(s) via a written addendum.

6. CONTACT WITH OWNER DURING RFP PROCESS

Communication between a PROPONENT(s) and a non-designated Owner contact regarding the selection of a PROPONENT(s) or award of this contract is prohibited from the time the RFP is advertised until the item is posted on an agenda for the selection of a PROPONENT(s) or award of the contract. Questions pertaining to this RFP shall be addressed to the designated contact specified in the RFP document.

Failure of a PROPONENT(s) or any of its representatives, to comply with this paragraph may result in their proposal being rejected.

7. TENTATIVE DATES AND SCHEDULE

| | |
|---|---|
| Pre-Proposal Conference | April 22, 2015 |
| Cut-off Date for Questions | April 29, 2015 |
| Addendum with Answers to all questions published | May 5, 2015 |
| **Proposals DUE** | May 14, 2015 |
| Evaluation of Proposals Completed: | May 28, 2015 |

| | |
|---|---|
| Finalist Presentations | June 15-18, 2015 |
| Recommended PROPONENT Selection & Negotiations: | June 22-24, 2015 |
| Date of Award | September 17, 2015 |

8. METHODS OF EVALUATION AND AWARD

Since the services requested in this RFP are considered to be a professional services competitive bidding exception, award will be in accordance with the provisions of the Nevada Revised Statutes, Chapter 332, Purchasing: Local Governments, Section 332.115.1(b)

The proposals will reviewed by a cross-functional staff committee to select finalists. The finalists may be requested to provide a presentation. The committee may consider the responses, as well as any requested presentations and/or oral interviews to gather information that will assist in making the recommendation for award. Multiple awards may be made based on the entire project as outlined in Exhibit A. To be considered for award, PROPONENT(s) must submit pricing.

The OWNER reserves the right to award the contract based on objective and/or subjective evaluation criteria. The contract will be awarded on the basis of which proposal(s) the OWNER deems best suited to fulfill the requirements of the RFP. The OWNER also reserves the right not to make an award if it is deemed that no proposal fully meets the requirement of this RFP or for any other reason.

Proposed discount rates and any other proposed costs and fees may be subject to negotiation with the finalist(s) by an appointed District representative.

9. EVALUATION INFORMATION

Proposals submitted for this Request for Proposal should contain the following information, which will be evaluated by the OWNER on a competitive basis:

a. Executive Summary

Describe the general background and history of your firm including name, age of the company, location of all offices and addresses, duration of performing digital aerial imagery services and any projected changes in your organization in the foreseeable future. Discuss company overall philosophy and approach, various client base, and significant achievements or awards.

The executive summary should also include a list of any high-risk areas that are reasons for concern. PROPONENT will not be evaluated on this paragraph and cannot lose evaluation points for listing areas of concern. These concerns will be addressed with the successful PROPONENT during negotiation.

In this section, firms may also indicate if they are certified as a small, minority, women-owned or disadvantaged business enterprise using the form provided or furnishing a copy of a current certification. This is for information only and will not be used in determining selection for award.

b. Experience

In this section, provide a brief summary of all similar contracts your firm has performed for the past three (3) years. Desired experience should include similar work for public agencies and work performed in arid, desert riparian and urban environments. For each contract listed, provide the following information: a) agency name and type of business b) name and phone number of a contact person for reference purposes, c) dollar amount of the contract d) project size and location e) contract deliverables and, f) project timeline from notice to finish.

c. Staff Qualifications and Availability

Provide resume information concerning the educational background, relevant experience, and professional credentials of those persons who would most likely perform work on the contract. Describe staffing structure to ensure that the PROPONENT(s) can mobilize as requested per Special Conditions. For privacy, personnel names may be omitted from the resumes and provided to OWNER upon selection as a finalist or awardee. Resume experience can be limited to project work that is similar to that contained in this RFP to assist proponents in meeting the specified page count.

d. Conceptual Treatment of Contract and Mobilization Plan

Provide an Overall Response Scenario describing in detail the approach to the mobilization and delivery contract requirements for each line item. This plan shall include methodology of detailed ground control plans, acquiring imagery and/or LiDAR, processing imagery and/or LiDAR, accuracy level that can be obtained, and other details associated with the proposal. Submit plan based on previous projects worked on, in relation to the proposed areas of acquisition outlined with this proposal.

Responses must include the following elements:

- PROPONENT(s) proposed account management plan and staffing contacts.
- Any assumptions.
- Any constraints.
- PROPONENT(s)’s proposed methodology of acquiring imagery, including flight diagram
- PROPONENT(s)’s proposed methodology of acquiring LiDAR, including flight diagram
- PROPONENT(s)’s detailed ground control plan (plan does not have to be designed by licensed surveyor, but field work would be performed by one)
- PROPONENT(s)’s accuracy level to be obtained for imagery and/or LiDAR
- PROPONENT(s)’s method of rectification and processing of imagery and/or LiDAR data
- Deliverable QA/QC Procedures in detail

- State why the PROPONENT(s) is best suited to perform the services for this contract.

e. Compliance with the OWNER's Standard Agreement

Indicate any exceptions that your firm would have to take in order to accept the attached Standard Agreement and Authority terms, conditions and insurance requirements. Be advised that any exception that is determined to be material may be grounds for elimination in the selection process. Alternate boilerplates terms and conditions from PROPONENT(s) should not be included with proposals and may be grounds for rejection.

f. Pricing Proposal Form

Complete and submit Exhibit B for all items.

PROPONENT will propose a per tile cost for the Digital Aerial Imagery. A tile size equates to a Public Land Survey System (PLSS) Section. Exact tile counts will not be determined prior to Contract Award. The size of the area of the overall area of interest is between 1,350 – 1,500 square miles. Exhibit A shows the acquisition area for 2015, which is representative of past and future flights.

PROPONENT will propose a per square mile cost for LiDAR digital elevation data. The total size of proposed acquisition area is 7,832 square miles (Exhibit D). Depending on amount of grant money received, project could extend into multiple years. In this case, exact tile counts for 2016 acquisition will not be determined prior to the RFP process but will be specified as part of the Contract Award process. See Pricing Sheets for options.

g. Camera Resolution

Provide your camera's Ground Sample Distance (GSD) technical specifications, as provided by the camera Manufacturer. Please list beginning at 4000' and continuing to 7500', in 250' increments.

h. Credentials/Licenses /Certifications

A current USGS digital aerial sensor type certification is required. The PROPONENT(s) and/or principal professionals involved in this project must possess appropriate Professional Licenses. Provide copies as appropriate. Also, provide a copy of PROPONENT'(s) required business license.

i. Affiliations

If any of the project were to be accomplished through an affiliation or joint venture of several firms, furnish the names and addresses of those firms and indicate which tasks they would be performing. Provide staffing information for all sub-contractor or affiliate staff members who would work on the contract. To ensure consistency and quality of deliverables, joint ventures or affiliations should remain constant throughout the contract. No substitutions or deviations to firms will be allowed without prior OWNER approval with substantial justification.

j. Insurance

Provide evidence of the PROPONENT'(s) ability to provide the required certificates of insurance as indicated in the attached Standard Agreement.

k. Financial Responsibility

Provide a financial statement (balance sheet, income statement, and cash flow statement) that will support the PROPONENT's financial ability to adequately support the PROPONENT's financial responsibilities and obligations for this agreement (i.e., employee payroll, payroll taxes, payment of fringe benefits, etc.). If a joint venture is part of the PROPONENT's submittal, the statements must be provided for all parties. Financial statements will be submitted to Owner's Finance Division for review and approval only if chosen as a Finalist.

l. Other

PROPONENT(s) may include in this section other pertinent information regarding capability, competence, and performance record for Authority's consideration.

10. FEDERAL FUNDING

This Contract may be funded in whole or in part by a grant from the Federal government and, if so, a bidder may be consider ineligible for award if the bidder or an affiliate has been debarred or suspended.

11. SUBMITTAL REQUIREMENTS

**NOTE** - Failure to follow submittal requirements can delay the review and award process and may also affect PROPONENT'(s) selection as a finalist.

Proposals should not exceed 30 printed pages covering the digital aerial imagery portion and no more than 30 printed pages for the LiDAR portion of the proposal, e.g. if the proposal covers both digital imagery and LiDAR the total page count is not to exceed 30 pages printed on both sides. The lowest acceptable font size is 11. Insurance, financial documents and certificates or licenses are not counted in the proposal page count. Resumes are included in page count. Other attachments may be included with no guarantee of review.

All proposals shall be on 8-1/2" x 11" paper bound with **tabbed dividers labeled by section** to correspond with the evaluation information requested, i.e. experience; compliance; etc.

The PROPONENT(s) shall submit 1 clearly labeled original and 5 copies of their proposal. The name of the PROPONENT'(s) firm shall be indicated on the spine and/or cover of each binder.

All proposals must be submitted in a sealed envelope, box or appropriate package clearly marked with the name and address of the PROPONENT(s) and the **RFP number and title**. No responsibility will attach

to the OWNER or any official or employee thereof, for the pre-opening of, post-opening of, or the failure to open a proposal not properly addressed and identified.

**FAXED PROPOSALS ARE NOT ALLOWED AND WILL NOT BE CONSIDERED.**

The following are detailed delivery/mailing instructions for proposals:

| **Hand Delivery** | **U.S. Mail Delivery** | **Express Delivery** |
|---|---|---|
| Las Vegas Valley Water District<br>1001 South Valley View Blvd<br>Main Lobby<br>Las Vegas, Nevada 89107 | Las Vegas Valley Water District<br>1001 South Valley View Blvd<br>Purchasing Division-Mail Stop 740<br>Las Vegas, Nevada 89153 | Las Vegas Valley Water District<br>1001 South Valley View Blvd<br>Purchasing Division-Mail Stop 740<br>Las Vegas, Nevada 89107 |

**Regardless of the method used for delivery, PROPONENT(s) shall be wholly responsible for the timely delivery of submitted proposals.**

12. REJECTION OF PROPOSAL

OWNER reserves the right to reject any and all proposals received by reason of this request.

13. PROPOSAL COSTS

There shall be no obligation for the OWNER to compensate PROPONENT(s) for any costs associated with responding to this RFP.

14. ADDENDA AND INTERPRETATIONS

If it becomes necessary to revise any part of the RFP, a written addendum will be provided to all PROPONENT(s) by the OWNER'S designated contact. OWNER is not bound by any specifications by OWNER's employees, agents, or contractors, unless such clarification or change is provided to PROPONENT(s) in written addendum form from the Purchasing Division.

15. PUBLIC RECORDS

The OWNER is a public agency as defined by state law, and as such, it is subject to the Nevada Public Records Law (Chapter 239 of the Nevada Revised Statutes). Under that law, all of the OWNER's records are public records (unless otherwise declared by law to be confidential) and are subject to inspection and copying by any person. PROPONENT(s) are advised that once a proposal is received by the OWNER, its contents will become a public record and nothing contained in the proposal will be deemed to be confidential except proprietary information. PROPONENT(s) shall not include any information in their proposal that is proprietary in nature or that they would not want to be released to the public. Proposals must contain sufficient information to be evaluated and a contract written without reference to any proprietary information.

If a PROPONENT(s) feels that they cannot submit their proposal without including proprietary information, they must adhere to the following procedure or their proposal may be deemed unresponsive and will not be recommended to the OWNER for selection.

16. COLLUSION

Any evidence of agreement or collusion among PROPONENT(s) and prospective PROPONENT(s) acting to illegally restrain freedom of competition by agreement to offer a fixed price, or otherwise, will render the offers of such PROPONENT(s) void.

Advance disclosures of any information to any particular PROPONENT(s) which gives that particular PROPONENT(s) any advantage over any other interested PROPONENT(s), in advance of the opening of proposals, whether in response to advertising or an employee or representative thereof, will operate to void all proposals of that particular proposal solicitation or request.

17. AGREEMENT

A sample of OWNER's Standard Agreement is attached. Any proposed modifications to the terms and conditions of the Standard Agreement are subject to review and approval by the Las Vegas Valley Water Authority's General Counsel.

18. NOTICE OF AWARD

Upon OWNER's final approval and insurance compliance, award of this proposal will be by Purchase Order issued by the Purchasing Division. The contract document shall include this RFP document, an agreement, any associated Addenda, and the successful PROPONENT'(s) response, including the RFP Proposal Form as signed by the successful PROPONENT(s).

19. FEDERAL, STATE, LOCAL LAWS

All PROPONENT(s) will comply with all Federal, including those required by the ARRA, State, and local laws relative to conducting business in Clark County. The laws of the State of Nevada will govern as to the interpretation, validity, and effect of this RFP, its award, and any contract entered into.

20. TAXES

OWNER is exempt from State Retail Tax and Federal Excise Tax. The prices proposed must be net, exclusive of taxes.

21. EMPLOYMENT OF UNAUTHORIZED ALIENS

In accordance with the Immigration Reform and Control Act of 1986, the Successful PROPONENT(s) agrees that they will not employ unauthorized aliens in the performance of this contract.

22. DURATION OF OFFER

All proposals submitted in association with this RFP shall be considered valid offers for a minimum of 90 calendar days after the date of proposal opening in order to allow the OWNER to evaluate and consider award.

23. FISCAL FUNDING OUT

Owner reasonably believes that funds can be obtained sufficiently to make all payments during the term of this contract. If Owner does not have or fails to allocate funds to continue the purchase of the product and/or service, this contract shall be terminated when appropriated funds expire. Owner also reserves the right to purchase any number or none of the products for each Block during any contract year if not funded similarly.

24. USE BY OTHER GOVERNMENTAL ENTITIES

Nevada Revised Statutes 332.195 states that local governments and the State of Nevada may use the contracts of other local governments within Nevada, if approved by the

Successful Bidder. The local government that originally awarded the contract is not liable for the obligations of the local government, which uses the contract.

25. DISCLOSURE OF OWNERSHIP/PRINCIPALS FORM

PROPONENTS shall complete the Disclosure of Ownership/Principals Form and include with their submittal.

# EXHIBIT A

## SCOPE OF WORK

PART I – LiDAR DIGITAL ELEVATION DATA

1. GENERAL REQUIREMENTS

a. Ground Control

The CONSULTANT shall provide the OWNER with a Microsoft Excel spreadsheet of coordinates of proposed control points, in U.S. Stateplane Feet, and a related map depicting the project control plan within a minimum of 90 days prior to the intended first date of LiDAR data acquisition. The OWNER will perform necessary work in acquiring Ground Control based on CONSULTANT's plan.

b. Acquisition and Delivery Requirements

The LiDAR digital elevation data will be no earlier than April 15 and no later than July 1, with initial delivery of rectified LiDAR samples no later than August 1. Review and approval/disapproval of the sample data will be accomplished by the OWNER within four (4) working days. OWNER will work with PROPONENT to divide up overall project area into working areas that will be processed and delivered following schedule below.

The delivery schedule for LiDAR data will be as follows:

- September 1 - Raw Point Cloud at fully compliant LAS Specification version 1.4, Point Data Record Format 8
- October 1 - Classified Point Cloud fully compliant LAS Specification version 1.4 Point Data Record Format 8
- November 1 - Bare Earth Surface Digital Elevation Model and Breaklines

c. Sensor Type

All LiDAR data must be collected using a sensor that is capable of collecting data to meet a minimum of Quality Level 2 (QL2) standards, following the USGS' National Geospatial Program LiDAR Base Specification, the relevant excerpt is included as Attachment G, with the possible flight height restrictions listed below.

d. Conditions During LiDAR Data Acquisition

LiDAR digital elevation data acquisition will be performed when atmospheric conditions are cloud free, and shall not be acquired during obstruction conditions (e.g. fog, snow, smog, smoke, haze, or dust). Ground conditions shall be snow free, except for very small ground accumulations that might be present in mountain terrain, and only with prior approval from OWNER. Ground conditions shall also be free from extensive flooding and any other type of inundation.

e. Flight Height Permissions & Restrictions

The Federal Aviation Administration (FAA) has set a minimum flight height of 7500' above Mean Sea Level (MSL) for any imagery or LiDAR data acquisition in the Las Vegas Valley over the past several years. Note that the surface elevation for the Las Vegas

Valley region varies from 1200' above MSL in the eastern part of the Valley to over 3200' above MSL in the Western side. Elevation changes are more dramatic throughout the whole of Clark County, ranging from 550' above MSL in southeastern Clark County to nearly 12,000' above MSL in west central Clark County. Additionally, the U.S. Air Force utilizes large tracts of air space in Clark County, and CONSULTANT will need to contact them to arrange access to those areas.

2. PRODUCT TECHNICAL AND DELIVERY SPECIFICATIONS

The LiDAR acquisition, processing, and subsequent deliverables will follow the USGS' National Geospatial Program LiDAR Base Specification, the relevant excerpt is included as Attachment G, or also found at the following website: http://pubs.usgs.gov/tm/11b4/pdf/tm11-B4.pdf . Please follow the guidelines and specifications of this document, unless otherwise stated by OWNER.

a. LiDAR Quality Level: Quality Level 2 (QL2)

b. Tiling, Overlap, and Naming Conventions: Per the USGS' Specification document (Appendix A), the Raw Point Cloud data will be delivered in its original swaths. Classified Point Cloud LiDAR digital elevation data will be tiled by the CONSULTANT based on specifications provided by OWNER, which mimic the Public Land Survey System (PLSS) Township/Range/Section model. There will be no overlap for each of the tiles. Naming convention for each tile will be based on the Clark County imagery naming convention, which will be given to CONSULTANT upon award. The Bare-Earth Surface (Raster Digital Elevation Model) will be tiled similarly to the Classified Point Cloud, and will also have no overlap. Breaklines will not be tiled.

c. Supplemental Ground Control: The ground control plan needed for the project will be provided by the CONSULTANT to the OWNER. Both OWNER and CONSULTANT will sign off on final ground control plan, and OWNER will implement the final plan prior to LiDAR data acquisition.

d. Projection – Datum & Coordinates: Per the guidelines on pages 6-7 on the LiDAR Base Specification under sections titled "Datums" and "Coordinate Reference System", digital LiDAR data files will be projected and delivered in State Plane NAD83 Nevada East FIPS 2701 in US Survey feet. The vertical datum for the elevation data shall be North American Vertical Datum of 1988 (NAVD88 Geoid 2012A).

e. Vertical and Horizontal Accuracy: Absolute vertical accuracy and horizontal accuracy of the LiDAR data and the derived DEM will be assessed and reported in accordance with the American Society for Photogrammetry and Remote Sensing (ASPRS) Positional Accuracy Standards for Digital Geospatial Data (American Society for Photogrammetry and Remote Sensing, 2014). (http://www.asprs.org/a/society/committees/standards/ASPRS_Positional_Accuracy_Standards_Edition1_Version100_November2014.pdf) The required number of check points for vertical accuracy assessment will be tied to the areal extent of the project per the ASPRS Positional Accuracy Standards for Digital Geospatial Data (American Society for Photogrammetry and Remote Sensing, 2014.

f. Delivery Media: All files shall be delivered on portable hard drives.

3. PRODUCTS AVAILABLE FOR SUCCESSFUL PROPONENT:

SNWA will provide the CONSULTANT access to available datasets to assist in rectification of the LiDAR digital elevation data, including the following:

a. Ability to tie into SNWA CORS sites in the Las Vegas Valley and surrounding region to assist in aero-triangulation (consistent communication is a must between OWNER's Survey Team & Successful Proponent for this to happen)

b. Any digital imagery previously collected by OWNER

c. Professional-surveyed control data in the area of interest (implementing CONSULTANT's ground control plan)

d. Any other geospatial data that is available that may assist in the acquisition and/or rectification of digital LiDAR data

4. DELIVERABLES

Deliverables for the LiDAR Digital Elevation project are described on pages 13-15 of the USGS' *National Geospatial Program LiDAR Base Specification*, which include:

a. Metadata

b. Raw Point Cloud at fully compliant LAS Specification version 1.4, Point Data Record Format 8

c. Classified Point Cloud at fully compliant LAS Specification version 1.4, Point Data Record Format 8

d. Bare-Earth Surface (Raster Digital Elevation Model)

e. Breaklines

5. PRODUCT ACCEPTANCE:

Product acceptance will be obtained once all the products pass the Quality Assurance guidelines outlined in Appendix A. The project will considered complete only after the OWNER and the USGS accept the data products.

6. REFLIGHTS:

Unacceptable coverage resulting in deviating from the LiDAR digital elevation data acquisition requirements shall be corrected at the CONSULTANT's expense. The same LiDAR sensor used on the original flights shall be used on any reflights, and should be done at the earliest opportunity, as directed by the OWNER. If the sensor is experiencing technical problems, the CONSULTANT will be responsible for obtaining a similar sensor to complete reacquisition.

7. OPTIONAL SERVICES AND PRODUCTS:

The OWNER may, in addition to the delivery of the products required through the USGS 3DEP, require additional products. The additional products listed below are contingent upon expanded participation of other agencies and new grant funding that is not currently available. Inclusion of these products at this time is for the purpose of identifying current and projected availabilities the CONSULTANT possesses and expected costs.

a. Quality Level (QL) 1 LiDAR digital elevation data for the metropolitan Las Vegas region (see Attachment C).

b. Elevation contour deliverables of either 1-foot or 2-foot interval for metropolitan Las Vegas region (Attachment C), in an ESRI compatible format (tiling schema will be the same as section 2, Product Technical and Delivery Specifications above.

(END OF PART I)

# LIST OF ATTACHMENTS

A Clark County Digital Aerial Imagery, Proposed 2016 Project Acquisition

B Digital Aerial Imagery, Las Vegas Strip & Downtown Corridors

C Las Vegas Metropolitan Digital Aerial Imagery, Proposed 3- or 4-Inch Resolution Acquisition

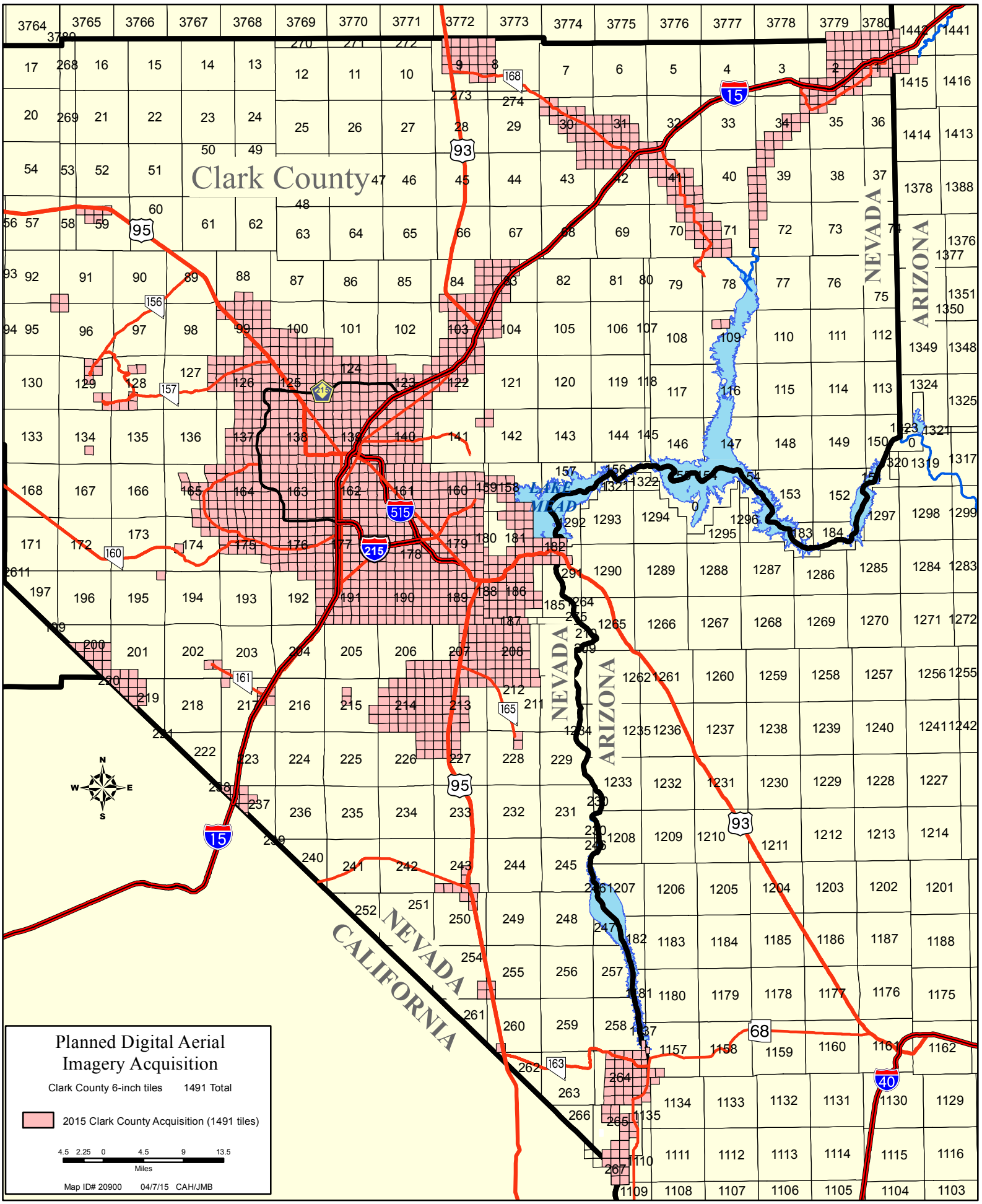
D Proposed LiDAR Acquisition, Clark County, NV

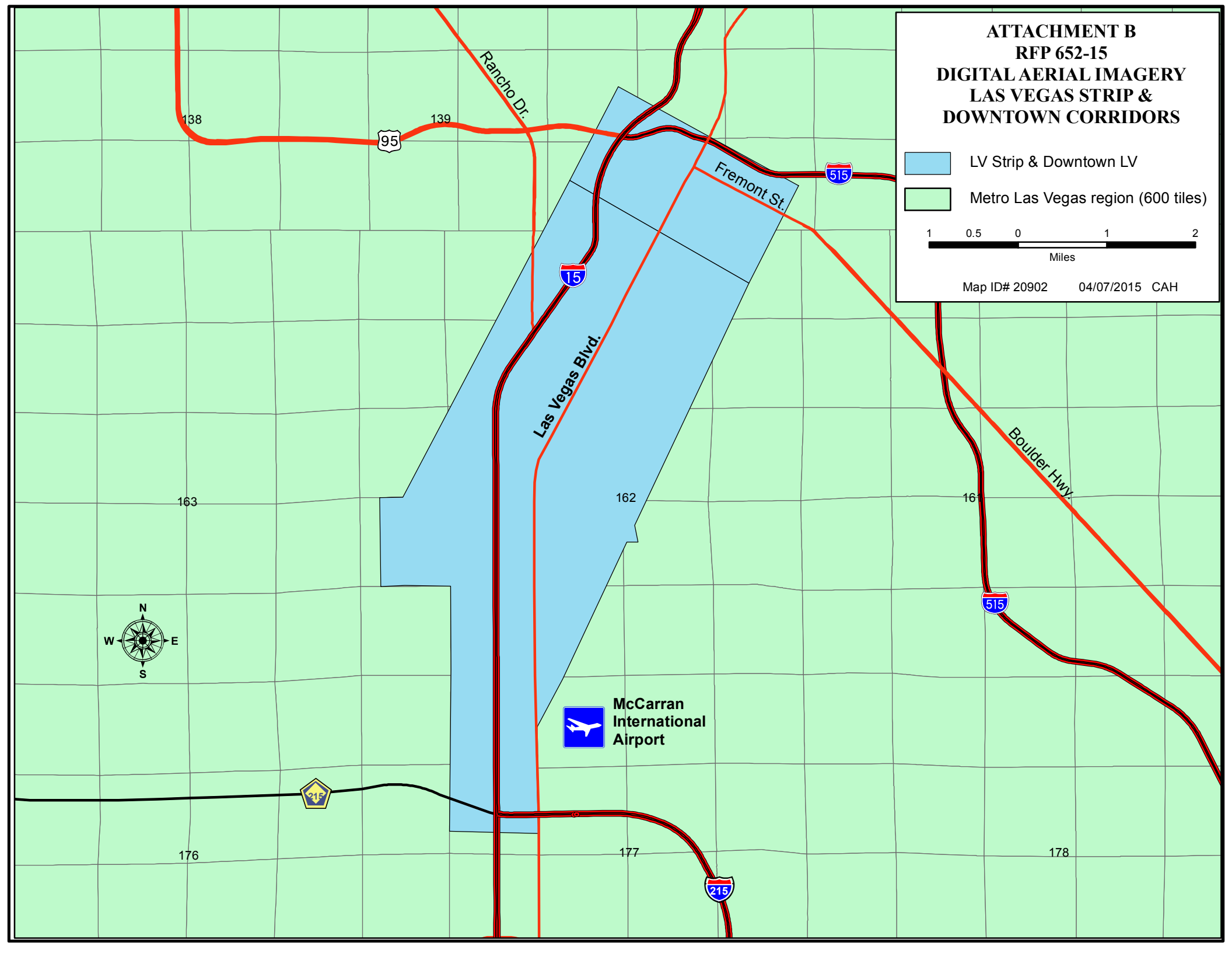
E Las Vegas Metropolitan Oblique Imagery Area of Interest

F Clark County LiDAR Project, Proposed Small Area Acquisition

G USGS National Geospatial Program LiDAR Base Specification Excerpt

**ATTACHMENT A**
**RFP 652-15**
**CLARK COUNTY DIGITAL AERIAL IMAGERY**
**PROPOSED 2016 PROJECT ACQUISITION**




ATTACHMENT B
RFP 652-15
DIGITAL AERIAL IMAGERY
LAS VEGAS STRIP &
DOWNTOWN CORRIDORS
LV Strip & Downtown LV
Metro Las Vegas region (600 tiles)
1 0.5 0 1 2
Miles
Map ID# 20902 04/07/2015 CAH
Rancho Dr.
Fremont St.
Las Vegas Blvd.
Boulder Hwy.
138
139
95
15
515
163
162
161
N
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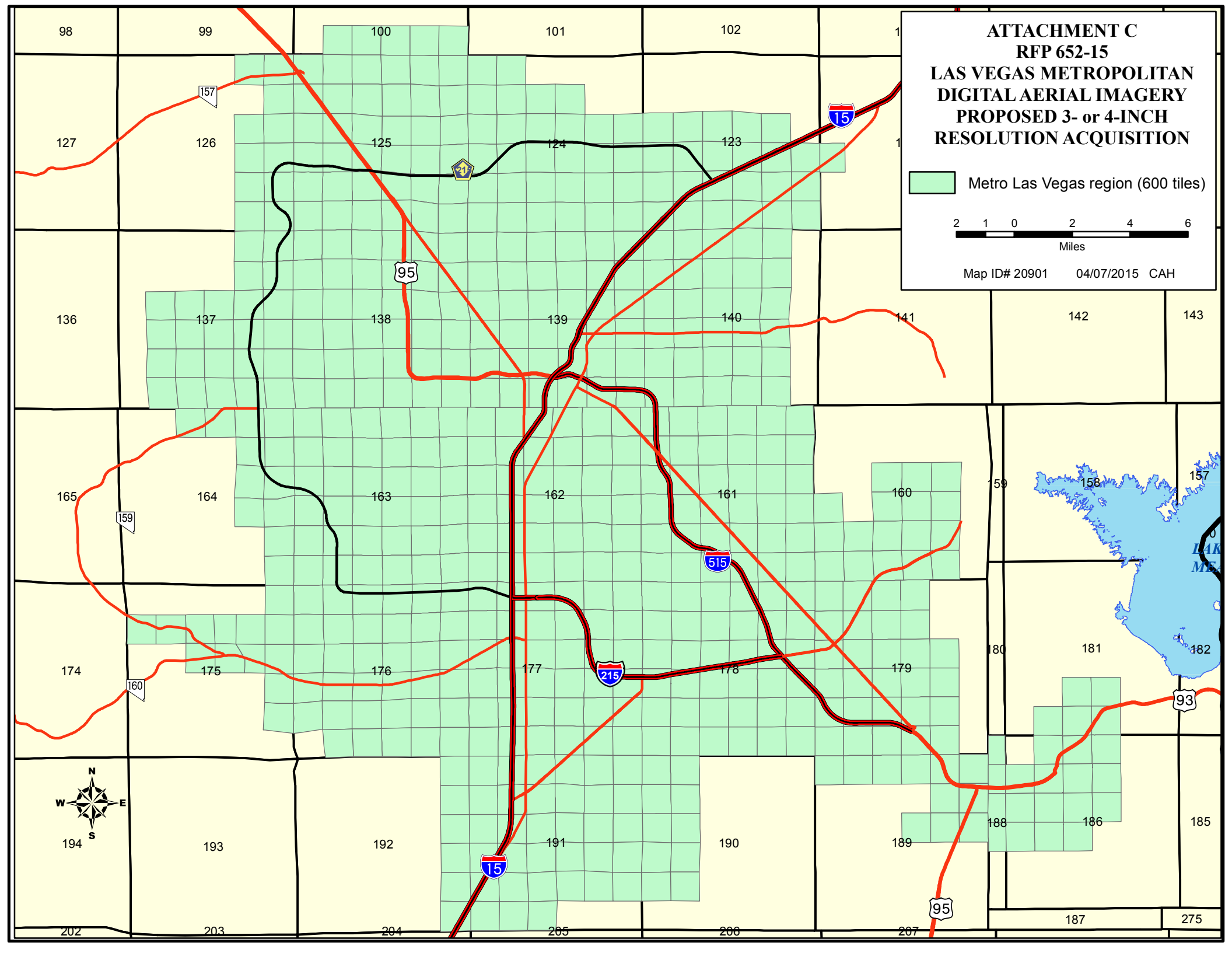
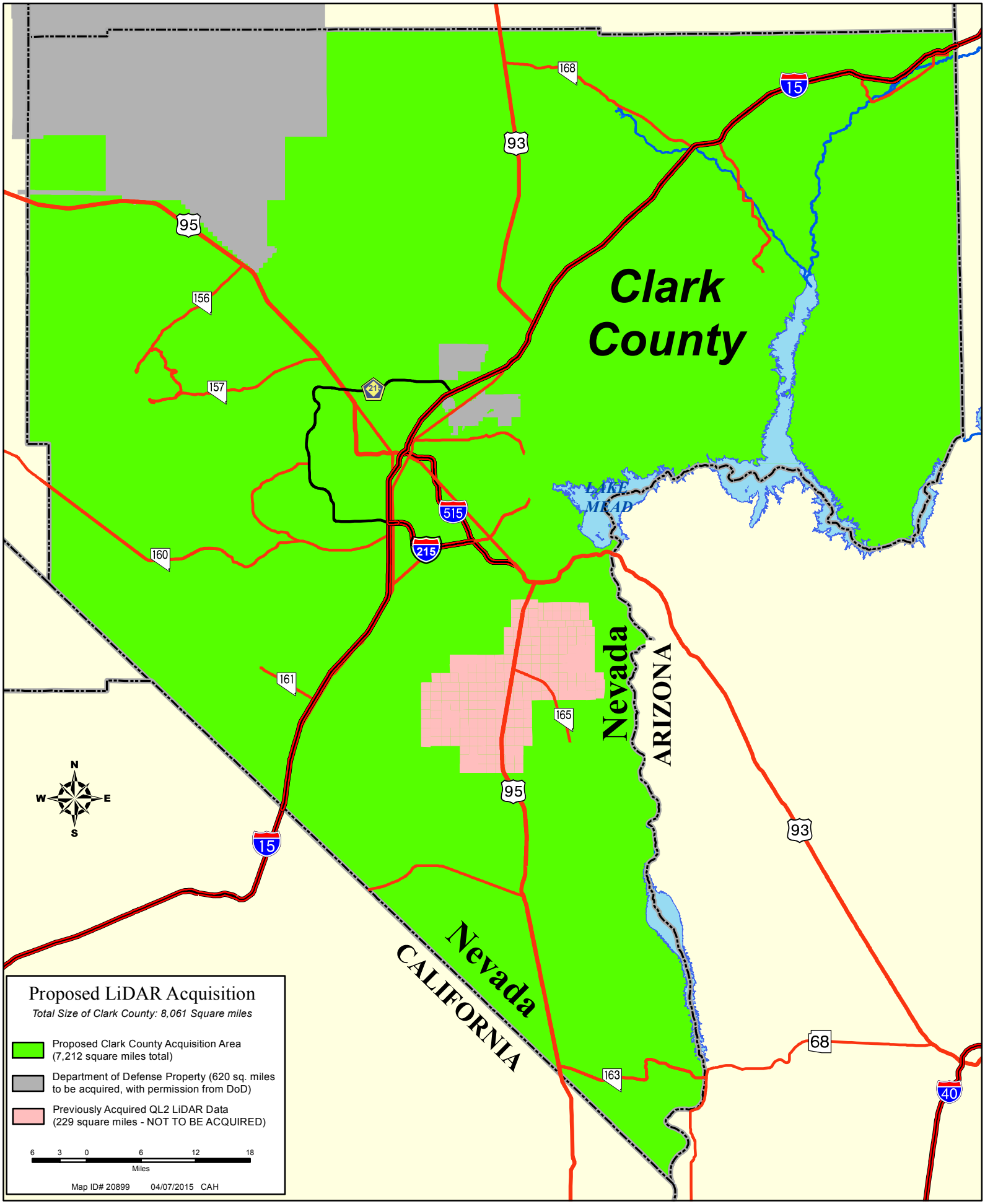
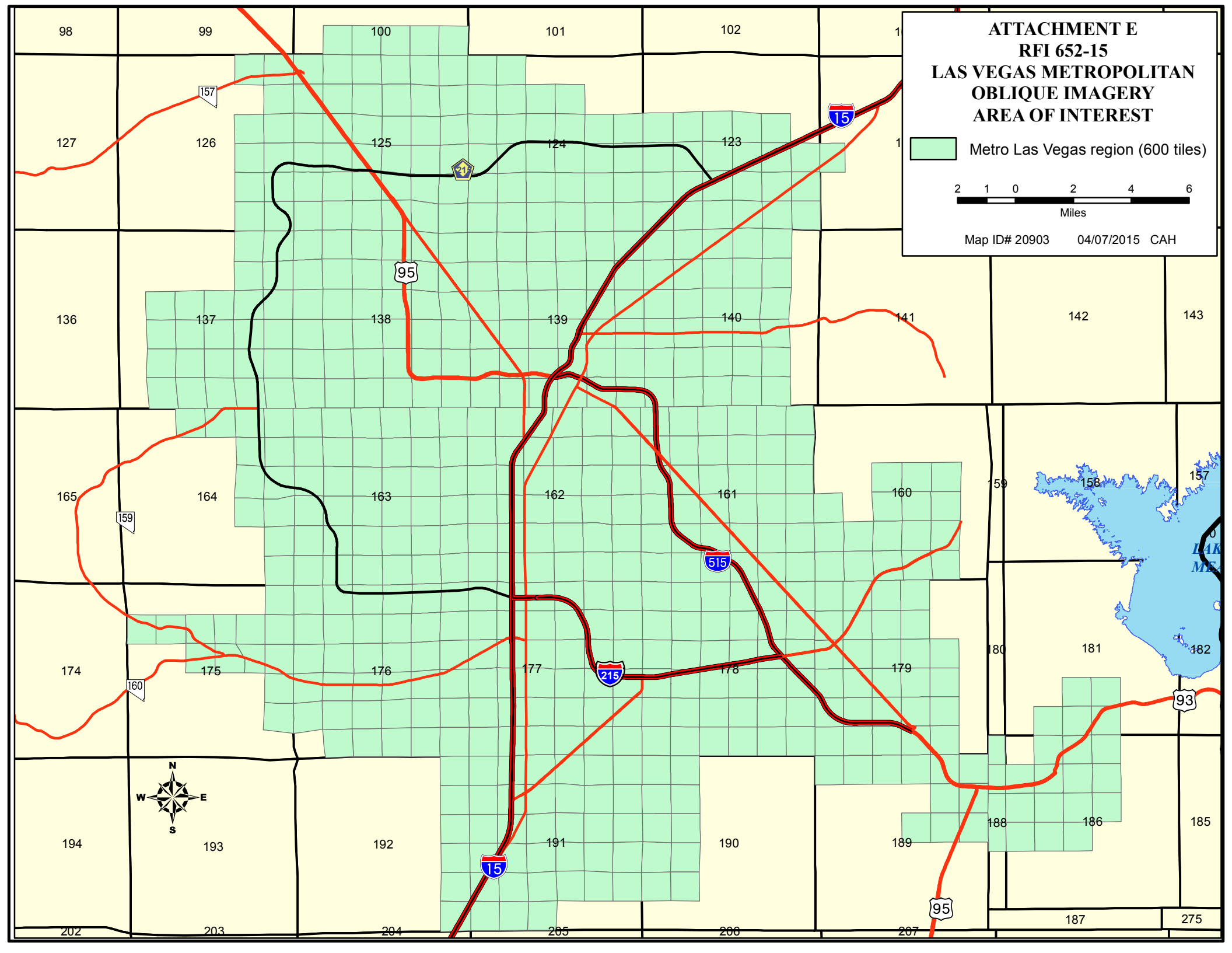
E
S
McCarran
International
Airport
215
176
177
178


ATTACHMENT C
RFP 652-15
LAS VEGAS METROPOLITAN
DIGITAL AERIAL IMAGERY
PROPOSED 3- or 4-INCH
RESOLUTION ACQUISITION
Metro Las Vegas region (600 tiles)
2 1 0 2 4 6
Miles
Map ID# 20901 04/07/2015 CAH
N
W
E
S
15
95
215
515
93
157
159
160

**ATTACHMENT D**
**RFP 652-15**
**PROPOSED LiDAR ACQUISITION**
**CLARK COUNTY, NV**




ATTACHMENT E
RFI 652-15
LAS VEGAS METROPOLITAN
OBLIQUE IMAGERY
AREA OF INTEREST
Metro Las Vegas region (600 tiles)
2 1 0 2 4 6
Miles
Map ID# 20903 04/07/2015 CAH
98
99
100
101
102
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126
125
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95
215
515
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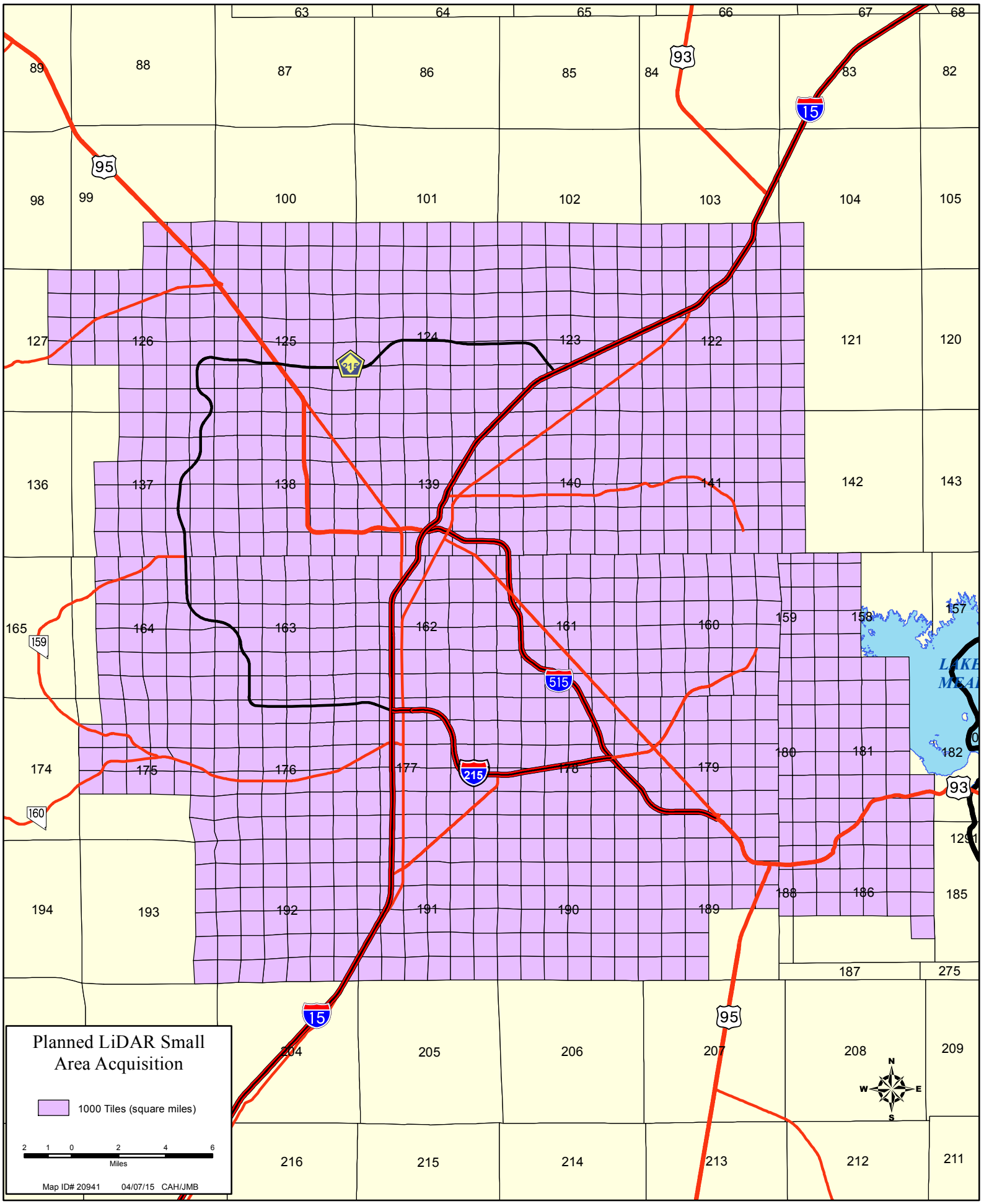
93
N
W
E
S

**ATTACHMENT F**
**RFP 652-15**
**CLARK COUNTY LiDAR PROJECT**
**PROPOSED SMALL AREA ACQUISITION**



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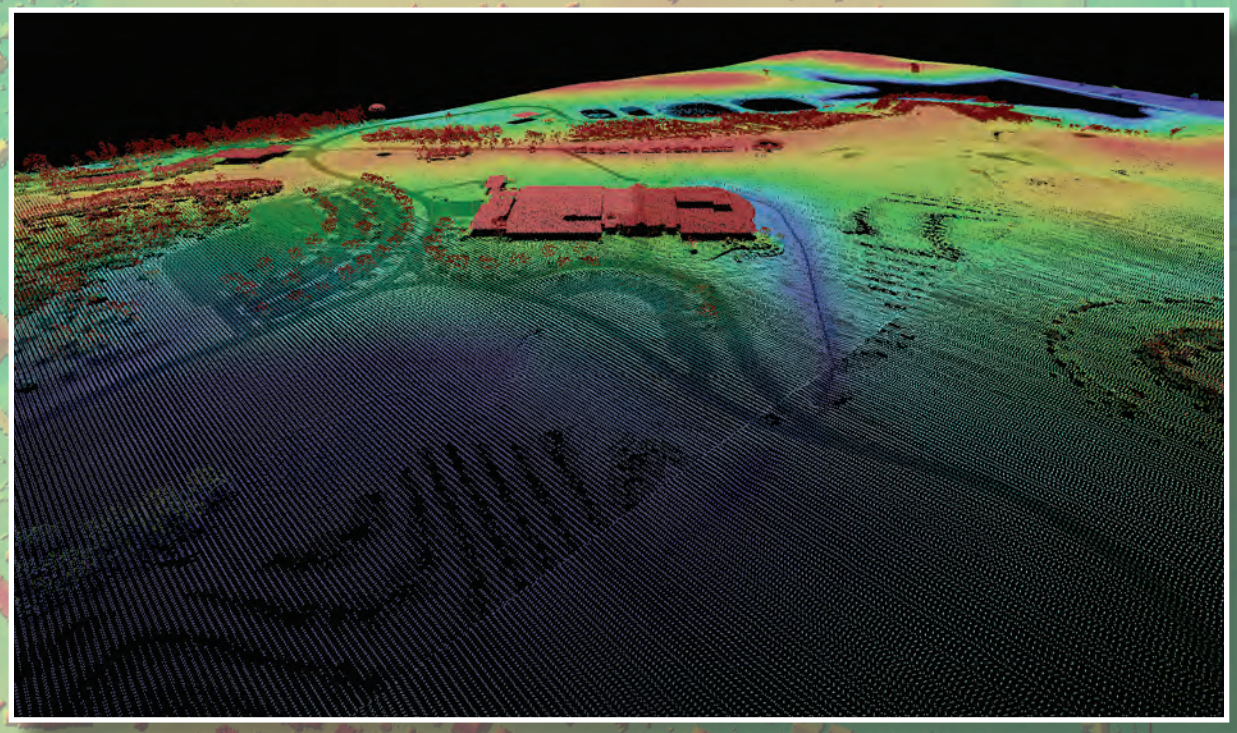
National Geospatial Program

# 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

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National Geospatial Program

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**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
Revised: October 2014 (ver. 1.1)
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ISSN 2328-7055 (online)

# 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]

| Class number | Land cover class or description | Previous reporting group | Current reporting group |
|---|---|---|---|
| 1 | Clear or open, bare earth, low grass; for example, sand, rock, dirt, plowed fields, lawns, golf courses | FVA | NVA |
| 2 | Urban areas; for example, tall, dense man-made structures | SVA | |
| 3 | Tall grass, tall weeds, and crops; for example, hay, corn, and wheat fields | SVA | VVA |
| 4 | Brush lands and short trees; for example, chaparrals, mesquite | SVA | |
| 5 | Forested areas, fully covered by trees; for example, hardwoods, conifers, mixed forests | SVA | |
| 6 | Sawgrass | n/a | n/a |
| 7 | Mangrove and swamps | n/a | |

**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.

# References Cited

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American Society for Photogrammetry and Remote Sensing (ASPRS), 1990, Accuracy standards for large-scale maps: Bethesda, Md., American Society for Photogrammetry and Remote Sensing, 3 p. [Also available at *http://www.asprs.org/a/society/committees/standards/1990_jul_1068-1070.pdf*.]

Dewberry, 2012, National enhanced elevation assessment: Fairfax, Va., Dewberry, 871 p. [Also available at *http://www.dewberry.com/Consultants/GeospatialMapping/FinalReport-NationalEnhancedElevationAssessment*.]

Federal Emergency Management Agency (FEMA), 2002, Guidelines and specifications for flood hazard mapping partners, appendix A—Guidance for aerial mapping and surveying (revised April 2003): Federal Emergency Management Agency, 57 p., accessed June 2, 2014, at *http://www.fema.gov/media-library-data/1387814416677-caa613eeca53246cb7a7dcbf342a7197/Guidelines+and+Specifications+for+Flood+Hazard+Mapping+Partners+Appendix+A-Guidance+for+Aerial+Mapping+and+Surveying+(Apr+2003).pdf*.

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Gesch, D.B., 2007, The national elevation dataset, chap. 4, *in* Maune, D.F., ed., Digital elevation model technologies and applications—the DEM users manual (2nd ed.): Bethesda, Md., American Society for Photogrammetry and Remote Sensing, p. 99–118. [Also available at *http://topotools.cr.usgs.gov/pdfs/Gesch_Chp_4_Nat_Elev_Data_2007.pdf*.]

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National Digital Elevation Program (NDEP), 2004, Guidelines for digital elevation data, version 1: National Digital Elevation Program, 93 p. [Also available at *http://www.ndep.gov/NDEP_Elevation_Guidelines_Ver1_10May2004.pdf*.]

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**EXHIBIT B**

**SCHEDULE OF PRICING**

| Item No. | LiDAR Digital Elevation Data (1-year project) | Estimated No. of Tiles | Cost per Tile / Unit | Total Estimated Cost |
|---|---|---|---|---|
| **1.** | Quality Level 2 (QL2) LiDAR Digital Elevation Data of Clark County, including:<br>- Metadata<br>- Raw Point Cloud<br>- Classified Point Cloud<br>- Bare-Earth Surface (Raster DEM)<br>- Breaklines | 7,832 | $ _____ | $ _____ |

| Item No. | LiDAR Digital Elevation Data (2-year project) | Estimated No. of Tiles | Cost per Tile / Unit | Total Estimated Cost |
|---|---|---|---|---|
| **2.** | Quality Level 2 (QL2) LiDAR Digital Elevation Data of Clark County, including:<br>- Metadata<br>- Raw Point Cloud<br>- Classified Point Cloud<br>- Bare-Earth Surface (Raster DEM)<br>- Breaklines | 3,900 (per year) | $ _____ | $ _____ |

| Item No. | LiDAR Digital Elevation Data (2-year project) | Estimated No. of Tiles | Cost per Tile / Unit | Total Estimated Cost |
|---|---|---|---|---|
| **3.** | Quality Level 2 (QL2) LiDAR Digital Elevation Data of Clark County, including:<br>- Metadata<br>- Raw Point Cloud<br>- Classified Point Cloud<br>- Bare-Earth Surface (Raster DEM)<br>- Breaklines | 1,000 (See Attachment F for area) | $ _____ | $ _____ |

| Item No. | OPTIONAL<br>LiDAR Digital Elevation Data | Estimated No. of Tiles | Cost per Tile / Unit | Total Estimated Cost |
|---|---|---|---|---|
| **4.** | Quality Level 1 (QL1) LiDAR Digital Elevation Data of the LV Valley, including:<br>- Metadata<br>- Raw Point Cloud<br>- Classified Point Cloud<br>- Bare-Earth Surface (Raster DEM)<br>- Breaklines | 600 | $ _____ | $ _____ |

| Item No. | OPTIONAL<br>Contour Data | Estimated No. of Tiles | Cost per Tile / Unit | Total Estimated Cost |
|---|---|---|---|---|
| **5.** | 2-foot Elevation Contours | 600 | $ | $ |
| **6.** | 1-foot Elevation Contours | 600 | $ | $ |

| Item No. | Digital Aerial Imagery Type | Estimated No. of Tiles | Cost per Tile / Unit | Total Estimated Cost |
|---|---|---|---|---|
| **7.** | One- (1) 6-Inch Resolution 4-band imagery product combined natural color imagery (RGB), and color Infrared imagery (CIR) | 1,491 | $ _____ | $ _____ |

| Item No. | BLOCKS 1 & 2<br>Digital Aerial Imagery Types | Estimated No. of Tiles | Cost per Tile / Unit | Total Estimated Cost |
|---|---|---|---|---|
| **8.** | One- (1) 6-Inch Resolution 4-band imagery product combined natural color imagery (RGB), and color Infrared imagery (CIR) | 891 | $ _____ | $ _____ |
| **9.** | One- (1) 4-Inch Resolution 4-band imagery product combined natural color imagery (RGB), and color Infrared | 600 | $ _____ | $ _____ |

| Item No. | BLOCKS 1 & 2<br>Digital Aerial Imagery<br>Types | Estimated No. of Tiles | Cost per Tile / Unit | Total Estimated Cost |
|---|---|---|---|---|
| **10.** | One- (1) 6-Inch Resolution 4-band imagery product combined natural color imagery (RGB), and color Infrared imagery (CIR) | 891 | $ | $ |
| **11.** | One- (1) 3-Inch Resolution 4-band imagery product combined natural color imagery (RGB), and color Infrared imagery (CIR) | 600 | $ | $ |

**EXHIBIT C**

**REQUEST FOR INFORMATION**
**OBLIQUE IMAGERY**
**TECHNICAL SPECIFICATIONS**

This Exhibit describes the technical and other details the OWNER has drafted to acquire oblique imagery. The PROPONENTS are invited to comment on the proposed requirements and offer what capabilities they currently have or plan to acquire. The ability to provide these services will not affect the PROPONENTS standing and will not be considered during the proposal evaluation process.

The purpose of this section is to aid the OWNER in planning future operations and gaining budgetary information to help define the scope of any future operations. PROPONENTS are encouraged to address any impediments to acquiring this technology if not already in place, and any other factors that the OWNER should consider.

1. PRODUCT ACQUISITION SPECIFICATIONS

   a) Acquisition and Delivery Requirements

      i. Oblique imagery should be flown in similar timeframe as current orthoimagery acquisition, which is from March 1 – April 15. Describe if this timeframe can be met, or what your acquisition timeframe would be for the oblique imagery acquisition.

      ii. Describe in detail the processing workflow of oblique imagery, including expected availability and delivery dates for product. Keep in mind that the orthoimagery deliverables deadline is August 15. Can you meet this timeframe? If not, please outline, in detail, what the timeline would be for ultimate acceptance of oblique imagery product (pilot imagery delivery & availability, up through project completion).

   b) Camera/Sensor Type

      All image data must be collected using proven oblique camera system that can meet the specifications in this document.

   c) Conditions During Imagery Acquisition

      Digital imagery will not be captured when the sun elevation angle is less than thirty (30) degrees above the horizon. Photography will take place when atmospheric conditions are such that clear and well-defined images of physical features (e.g. buildings, trees, and other ground cover) can be obtained. Photography will not be acquired during photogrammetric obstruction conditions (e.g. clouds, cloud shadows, fog, rain, snow, smog, smoke, haze, or dust. In areas of the Las Vegas Strip & Downtown Las Vegas (Attachment B), the sun angle should be no less than forty-five (45) degrees above the horizon during acquisition to minimize shadows. Additionally, areas in Attachment B should be acquired to ensure that transportation corridors are visible in their entirety, not obscured by nearby buildings or other structures, such as signs.

   d) Flight Height Restrictions and Permissions

      Collection of this imagery will comprise of most of the populated areas of the county. Total area covered for oblique imagery contains approximately 600 square miles of urban areas

of the Las Vegas Valley metropolitan area (see Attachment E). The Federal Aviation Administration (FAA) has set a minimum flight height of 7500' above Mean Sea Level (MSL) for imagery acquisition in the Las Vegas Valley over the past several years for orthoimagery acquisition. Note that the surface elevation for the Las Vegas Valley region varies from 1200' above MSL in the eastern part of the Valley to over 3200' above MSL in the Western side. Are you able to fly at an adequate level to obtain the product as specified (either 4-inch or 9-inch)?

2. PRODUCTS AVAILABLE FOR PROPONENT

OWNER will provide the PROPONENT access to available datasets, including the following:

a) Ability to tie into SNWA CORS sites in the Las Vegas Valley and surrounding region

b) Any digital imagery previously collected by OWNER

c) Professional-surveyed control data in the area of interest (implementing PROPONENT's ground control plan)

d) Any other geospatial data that is available that may assist the PROPONENT

e) Any LiDAR elevation data of the area of interest, collected through separate RFP / 3DEP funding, will be available upon completion of collection.

3. IMAGERY TECHNICAL SPECIFICATIONS

The Oblique images should:

a) Be in natural color

b) Have a Ground Sample Distance to ensure it meets the specified pixel resolution (either 4-inch or 9-inch resolution).

c) Be acquired using an acknowledged Oblique camera system, describing if sensor can acquire natural color only or multispectral oblique imagery

d) Be geo-referenced in State Plane NAD 83 Nevada East FIPS 2701 in US Survey feet

e) Include orthogonal views

f) Include oblique views in at least four directions (north, south, east, west)

g) Be collected with cameras or sensors that accommodate the motions of the aircraft for a seamless aerial

h) Be collected with the same Oblique camera system regardless of aircraft used

i) Have the ability to accurately measure bearings, distances, areas, depths and heights on the oblique imagery, while taking into account change in terrain and elevation

j) Have the ability to precisely measure the width and height of structures and their features such as windows, doors, overhangs, decks, etc.

k) Be compressed and delivered as JPEG or other industry standard format compression. If PROPONENT's compression is non-industry standard or proprietary, provide details of the product to be delivered

l) Include metadata that shall conform to the International Organization of Standards (ISO)

19115-1:2014 or as amended and current FGDC content standards for Digital Geospatial Metadata describing the aerial production process shall be submitted in extensible markup language (.xml) format for each tile. Information can be found at the following websites:

- http://www.fgdc.gov/metadata/geospatial-metadata-standards
- http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=53798

Please enclose typical metadata delivered for similar types of oblique imagery projects.

4. SERVICE DELIVERY APPROACH

PROPONENT shall:

a) Develop an efficient flight plan, including dates and timelines for the completion of each flight area;

b) Provide a ground control plan;

c) Coordinate flying in different parts of the region (i.e. simultaneous capture);

d) Complete each flight area within a reasonable time frame, to be discussed with PROPONENT;

e) Complete processing of photographs in a reasonable time frame;

f) Ensure the quality of the deliverables;

g) Manage project issues and risks;

h) Communicate regularly with OWNER on the status of each project (flight area) and any issues/constraints encountered;

i) Manage any changes / alterations to the approved project plan.

j) The distribution of products, such as oblique imagery and supporting data, shall be the responsibility of the PROPONENT. The PROPONENT will provide a portable hard drive that will be used to transfer the deliverables and will become a part of the final delivery. The hard drives will be shipped containing the final deliverable as the project is completed.

5. PROPONENT QUALIFICATION AND EXPERIENCE

OWNER expects PROPONENT to have successfully completed projects of similar scope and complexity.

a) Provide the client name and reference contact information.

b) Provide the project start and completion dates (month / year).

c) Describe in detail projects you have completed that are similar in scope and complexity to OWNER’s requirements.

d) Was the project completed on time and within budget? Provide details and explanations if not completed on time and within budget.

6. INTEGRATION OF OBLIQUE IMAGERY INTO EXISTING SOFTWARE & APPLICATIONS

   Provide information regarding ability to integrate oblique imagery in standard industry software products, as well as standard internet protocols and applications, including:

   a) Integration with ESRI® application suite of products;

   b) Provide information pertaining to delivering oblique imagery via a hosted cloud based web application;

   c) Software used to view oblique images must include measurement tools, specific to the photo viewer, in determining distances, heights and areas;

   d) Provide information pertaining to integration with ESRI® ArcGIS Desktop that will enable users to access the oblique imagery with measurement tools inside of ESRI's latest ArcGIS desktop software (ArcMap version 10.2 or later).

   e) Provide information pertaining to integration with other software such as Autodesk, Intergraph, or any other industry geospatial software platforms.

   f) Describe in detail integrations with various web API's, or if PROPONENT offers custom-built API

   g) Provide detail on working integration with mainstream CAMA systems.

   h) List current working integration with mainstream public safety and emergency dispatch applications.

   i) Describe the PROPONENT's ability to utilize the OWNER's existing GIS data (such as parcels and other vector based data) within desktop software and any web/cloud solution.

   j) Describe the PROPONENT's ability to integrate software into mobile field device with assessment gathering tools and data fields.

   k) Describe any additional tools PROPONENT can provide.

7. LICENSING

   OWNER expects details on licensing requirements or options. OWNER intends the aerials to be used for the betterment, protection and safety of the entire county, and as such will make the oblique images available to other governmental agencies in Clark County that will work collectively with the OWNER to serve that goal.

   a) Describe the licensing structure and terms available. Can the data be shared with other local agencies and/or federal government, or contractors working on behalf of an agency? Please outline any limitations to data usage.

   b) Describe any restrictions on publishing the Licensed Data or any portion thereof by making them available on general access network, including the external agency Internet applications, and local and wide area networks within an agency, including the Intranet.

8. TECHNICAL SUPPORT

   a) Describe your technical support options, including if there are any supporting or maintenance fees for such support.

b) Describe the licensing structure and terms available.

9. TRAINING

a) Describe initial on-site training provided during implementation.

b) Describe available training documentation or resources provided to the OWNER.

c) Describe available on-going training options, including cost for training services.

10. SERVICE DELIVERY APPROACH

a) Describe how PROPONENT is able to logistically capture photos from different areas of the region simultaneously.

a) Describe the minimum square mileage area of each flight path.

b) Describe any limitations to flying at high altitudes, including pixel resolution.

c) Describe how PROPONENT will manage the flight plan(s) including field and rest stops, and areas where flight restrictions may occur, like the Las Vegas metropolitan area.

d) Describe how PROPONENT will ensure that each flight area is completed within a reasonable timeframe.

e) Describe the time required to process photographs. This is the time from end of aerial collection to delivery. Include the rate of processing time required per square mile of photos collected. If processing time is not dependent on area or quantity of photos captured, then include processing time only.

f) Describe the Quality Control and Quality Assurance procedure(s) through the stages of processing the imagery, ensuring a quality, delivered product.

g) Describe how PROPONENT will manage any project issues / risks.

h) Describe how PROPONENT will communicate with OWNER on the status of each project (flight area) and any issues / constraints encountered.

i) Describe how PROPONENT will manage any changes / alterations to the project plan, and how you would communicate those changes to OWNER.

11. DESKTOP AND TOOLS AVAILABLE or DESIRED

Oblique imagery will be used in Desktop Software and embedded in custom applications, both desktop and web based (ESRI, Autodesk, other geospatial software, and web development kits or APIs). Some of the tools that would be used with oblique imagery include:

a) Distance Tool – measure lengths, widths, and perimeters

b) Height Tool – determine the height of any feature.

c) Location Tool – obtain geo-coordinates of items in the image

d) Area Tool – Measure acreage or square footage of any area

e) Elevation Tool – Access ground elevation

f) Bearing Tool – Determine directional (from True North) location

g) Select Tool – locate by client supplied data such a street address, tax account number or

coordinates

h) Link Tool – link an unlimited amount of additional data/text per image

i) Text Annotation Tool – describe features within an image

j) Line Drawing Tool – draw straight or free-form lines to highlight a feature

k) Circle Drawing Tool – create circular boundaries/perimeters from specific locations

l) Navigate Tool – allows for easy navigation through your image warehouse by opening next adjacent image in approximate scale and same direction.

m) Search by Address Tool – ability to search from pre-defined queries of parcel address data.

n) Zoom – zoom in and out of all images

o) Search – search GIS data and address information and zoom to features that have been found.

p) GIS Data Overlay - display GIS shapefile format data on top of oblique imagery.

q) Export – export oblique imagery for use for display other purposes.

r) Export to GIS - export orthogonal images with corresponding coordinate mapping files for use with GIS.

## PRICING FORM

This Pricing Form is submitted in response to the Owner's Request for Information and is in accordance with all conditions and specifications in this document. Please include the estimated cost to acquire either 4-inch resolution or 9-inch resolution oblique imagery, and any other high-resolution options. If there are added costs for any associated software products, APIs, or fees separate from what is listed below, please include them on a separate attachment.

The OWNER will view any pricing information as budgetary estimates given the specifications and quantity estimates in this Request for Information and not firm offers. The PROPONENT is encouraged to provide information regarding cost drivers that the OWNER may mitigate through timing and duration of service, quantity or other factors within its control.

| Item No. | Oblique Imagery | No. of Tiles | Cost per Tile / Unit | Total Cost |
|---|---|---|---|---|
| **1.** | 4-direction Oblique Imagery, 4-inch resolution (include any maintenance and/or support costs) | 600 | $ _____ | $ _____ |
| **2.** | 4-direction Oblique Imagery, 9-inch resolution (include any maintenance and/or support costs) | 600 | $ _____ | $ _____ |
| **3.** | Other resolution options<br><br>---------- | 600 | $ _____ | $ _____ |