Compass
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FEMA Region IX Technical Proposal for Task Order HSFE09-16-J-0001: LiDAR Data Acquisition and Processing Lake County, CA DR-4240

Contract HSFE60-15-D-0003
October 9, 2015

Prepared for:

Sherwin C. Turner
Contracting Officer/Team Leader
Disaster Acquisitions Response Team (DART)
FEMA Expeditionary Force Section (Expeditionary Branch)
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Submitted by:

Compass PTS JV
a JV led by AECOM and CDM Smith
3101 Wilson Boulevard, Suite 900
Arlington, VA 22201

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Subject: FEMA Region IX, Technical Proposal, Task Order HSFE09-16-J-0001, Contract HSFE60-15-D-0003: LiDAR Data Acquisition and Processing Lake County, CA

Dear Mr. Turner,

The Compass PTS Joint Venture (Compass) is excited to be selected to provide professional and technical services to execute Task Order HSFE09-16-J-0001 under Contract HSFE60-15-D-0003. With our experience on recent LiDAR projects for the USGS and other governmental agencies (meeting and exceeding QL2 specifications), as well as our experience providing rapid/emergency response mapping products and services, Compass is the ideal contractor for this work. We present to you this task order proposal and statement of our qualifications and experience that sets us aside from the competition and provides to FEMA a low risk solution to achieve all project goals effectively and efficiently.

As requested, this document serves as our technical proposal for this firm fixed price task order. Under this task order, Compass will conduct and provide the following services, as detailed in the provided Statement of Work (SOW) and in full conformance with USGS LiDAR Base Specification version 1.2.:

- Airborne LiDAR acquisition of Lake County, CA
- Generation of topographic data and products, to include:
  - The Bare Earth Digital Elevation Model (DEM) to be used for flood plain analysis.
    - Hydro-flattened DEM
    - Hydro-enforced DEM
  - Compliant metadata for digital deliverables
  - Technical Study Data Notebook (TSDN) narrative describing the scope of work, direction from FEMA, issues, information for next mapping partner, etc.;
  - Updates to the National Digital Elevation program (NDEP) project tracking and to the USGS 3DEP Seasketch LiDAR Data Tracking Websites

Any additional deliverables that are required under USGS LiDAR Base Specification version 1.2 will also be delivered.

Additionally, technical representatives and LiDAR analysts are available to address any question raised for delivered products during the independent Quality Assurance/Quality Control (QA/QC) review. If you have any questions regarding this proposal, please contact me at 703.682.9100 or our proposed Task Order Manager Mr. Richard McClellan, PLS, PMP, GISP, at 301.948.8550 ext. 227.

Thank you for the opportunity to work with you and the FEMA Region IX staff.

Yours sincerely,

Lillian Pitts Robison, PgMP, PMP, CFM
Project Director, Compass PTS A&E
lillian.robison@aecom.com

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01 Introduction

1.1 Purpose

This technical proposal for services under the U.S. Department of Homeland Security's Federal Emergency Management Agency (FEMA) Contract HSFE60-15-D-0003 is provided in response to Task Order Proposal Request (TOPR) No. HSFE09-16-J-0001 (issued on October 7, 2015) and the accompanying SOW for LiDAR Data Acquisition and Processing, Lake County, CA (DR-4240).

The objective of this task is to acquire county-wide LiDAR data for the generation of a range of topographic data and products. The area of interest is the extents of Lake County, CA. Products to be derived from the LiDAR data include Bare Earth product and DEMs for the purpose of performing flood plain analysis. In addition, Compass has a QA/QC team, independent from the LiDAR acquisition and processing team, to verify all requirements and specification are met.

1.2 Assumptions

For this proposal, Compass assumes the following:

General

- The project schedule is based on a four (4) month period of performance from the date of the Task Order award.
- Any change to the SOW described in this proposal will require a Change Request.
- All mapping data will be produced in North American Vertical Datum of 1988 (NAVD88). Compass will produce all products in compliance with FEMA Standards.
- Compass assumes that FEMA Region IX will provide timely review submissions.

Business Proposal

- It is understood that following the selection of the most highly qualified vendor based on technical proposals an RFP for a Performance Work Statement and business proposal will be sent by FEMA.

Schedule

- The Compass schedule and baseline is based on the date of the Task Order Award. If a change in scope, schedule, or budget is encountered, Compass will determine whether the change can be absorbed by the current task order, or a modification is needed. A modification will be documented via the Change Request process. If a Change Request is necessary, it will include justification on re-baselining the project schedule. Only upon approval of a Change Request will Compass update the MIP and Compass EVMS schedules.

FEMA Knowledge Sharing Site (KSS) (aka Guidelines and Standards)

- Compass will produce the deliverables for this task order based on the standards populated on the FEMA Knowledge Sharing Site (KSS) and in the FEMA Policy Memos, effective as of the date of Task Order award, or will seek approval for exceptions if needed.

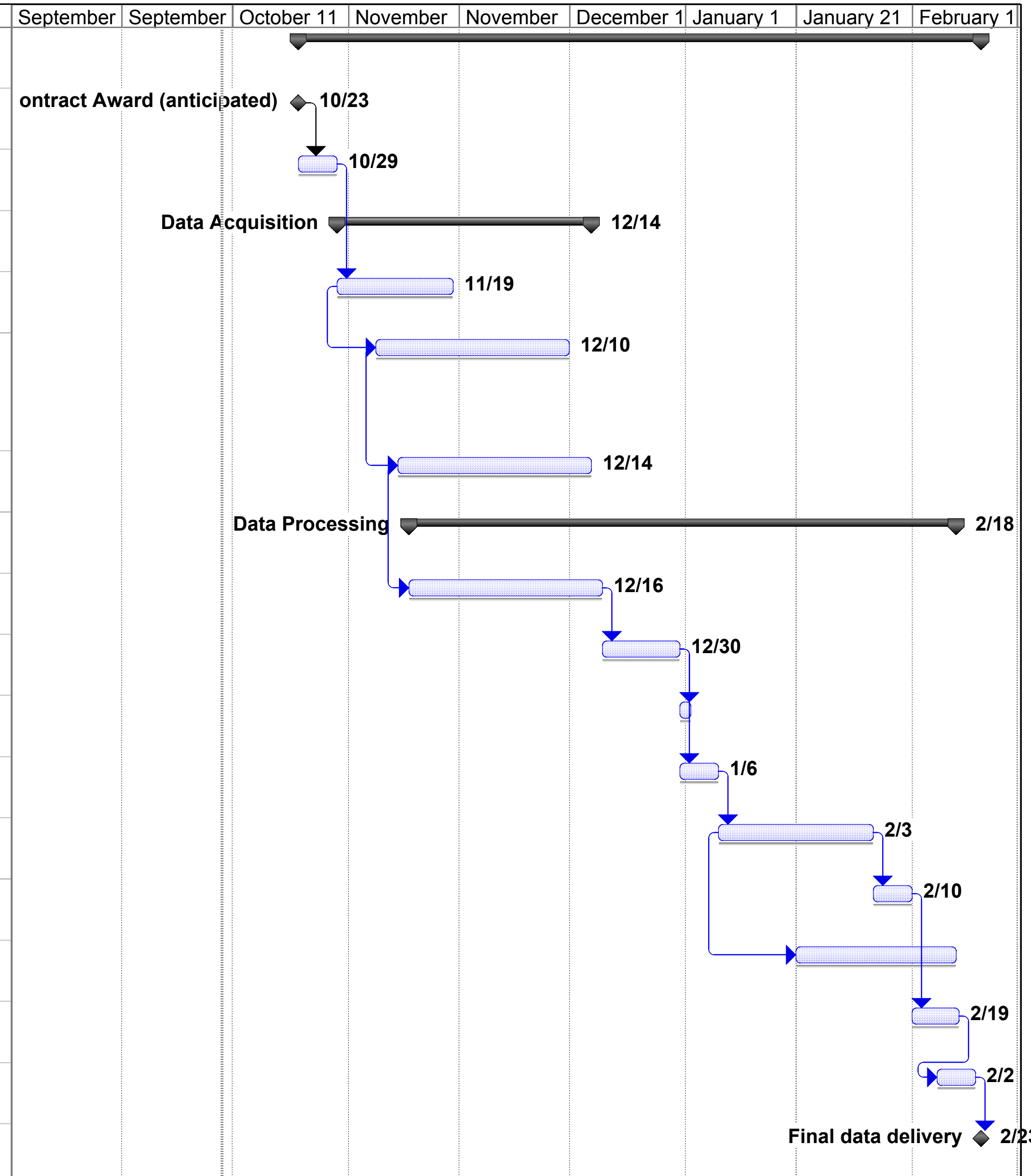
1.3 Deviations and Exceptions

Compass has reviewed the TOPR and SOW for Task Order HSFE09-16-J-0001. Compass takes no Deviations or Exceptions from the TOPR and SOW.

1.4 Schedule

The total period of performance for the work documented in this technical proposal is projected to be four (4) months from the date that FEMA issues a fully executed task order. The full project schedule is on the following page.

ID	Task Name
1	**Lake Valley, CA**
2	Contract Award (anticipated)
3	Project Planning
4	**Data Acquisition**
5	Ground control survey
6	Lidar data acquisition (weather and ground condition dependent)
7	Lidar data QC verification
8	**Data Processing**
9	GPS/IMU Data Processing
10	Boresighting
11	FVA QC Check
12	Lidar data pre- processing
13	Lidar data post-processing
14	Hydro flattening/enforcement
15	Independent QA/QC
16	Product Generation
17	Report and metadata generation
18	Final data delivery



Project: Lake Valley, CA
Date: Fri 10/9/15

Task		Summary		External MileTask	
Split		Project Summary		Progress	
Milestone		External Tasks		Split	

Page 1

1.5 Project Team

The project team consists of Compass with JV partner Fugro EarthData, Inc. (Fugro) as its exclusive LiDAR acquisition source. Fugro is an industry leader providing surveying and mapping solutions to clients who require acquisition, production, and analysis of high-resolution geospatial products. Fugro's flood and topographic experience includes regional mapping for FEMA and other federal agencies, including the United States Geological Survey (USGS), United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS), United States Army Corps of Engineers (USACE), National Oceanic and Atmospheric Administration (NOAA), and National Geospatial-Intelligence Agency (NGA). Fugro's skilled personnel are highly experienced and available to rapidly mobilize personnel and assets to Lake County upon Notice to Proceed (NTP).

Compass JV partner firm AECOM will serve as the independent QA/QC provider to Fugro's LiDAR products. AECOM has extensive experience across the nation independently assuring elevation data for use in FEMA flood insurance studies including a national task order for acquisitions in Regions IV, VIII, and IX, regional task orders in Regions IV, VI, and VIII, and for the North Carolina and Louisiana statewide acquisitions.

1.6 Task Order Approach Summary

In response to the TOPR, Compass is prepared to provide FEMA with planning, acquisition, processing, and derivative product generation from LiDAR data over the area of interest (AOI) defined as Lake County, CA. The data will be acquired to an aggregate nominal pulse spacing (ANPS) of 0.7 meters (2ppsm), including overlap, and processed according to NEEA QL2 LiDAR data meeting USGS standards. The total area of the AOI is approximately 1,330 sq. mi. LiDAR data and derivative products produced in compliance with this task order will be based on the USGS National Geospatial Program LiDAR Base Specification Version 1.2.

It is understood that this high resolution LiDAR data will support various risk analyses, as defined within the project's scope, including hydrologic analysis, hydraulic analysis, post fire debris flow, and non-regulatory products (e.g. depth grids and risk probability grids).

LiDAR data will be processed immediately after acquisition to ensure coverage, density, relative accuracy and NVA are met. LiDAR data will then be classified using TerraSolid processing and modeling software into ground and non-ground points. Classifications include 1) Processed, but unclassified; 2) Bare earth; 7) Low Noise; 9) Water; 10) Ignored ground (near a breakline); 17) Bridge decks; 18) High noise. Independent QA/QC will be performed on all data acquisition, processing, and final deliverables. The LiDAR point cloud and derivative DEMs are assured to meet vertical accuracy requirements.

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1.6.1 LiDAR Data Acquisition

Fugro will mobilize to the AOI and begin acquisition of LiDAR following NTP using twin engine aircraft modified for airborne data collection. Acquisition will be primarily controlled with strategic placement of ground control points, along with an airborne Global Positioning System (GPS), initial measurement unit (IMU) and attendant base stations for the project. Quality control (QC) checkpoints will additionally be surveyed in the acquisition areas to calculate non-vegetated vertical accuracy (NVA) and vegetated vertical accuracy (VVA) (ASPRS Positional Accuracy Standards, 2014). The flight plan developed for this task order considers acquisition area geometry and slope to minimize flight time and costs while maintaining a high accuracy standard for the data.

1.6.2 Data Accuracy and Reporting

The collected LiDAR data will meet or exceed the vertical accuracies in the table below:

Table 1: Vertical Accuracy

<table>
<tr><th colspan="3">VERTICAL ACCURACY REQUIREMENTS</th><td rowspan="5">Positional Accuracy Validation : The absolute and relative accuracy of the data, both horizontal and vertical, relative to known control, is verified <u>prior</u> to classification and subsequent product development. A detailed report of this validation is a required deliverable.
Relative Accuracy Requirements: Relative accuracy is ≤ 6 cm within individual swaths (smooth surface repeatability) and ≤ 8 cm RMSD within swath overlap (between adjacent swaths) with a maximum difference of ± 16 cm.</td></tr>
<tr><th></th><th>Accuracy</th><th>Confidence</th></tr>
<tr><td>$RMSE_Z$ (Non-Vegetated, LiDAR Swath, DEM)</td><td>≤ 10 cm</td><td>---</td></tr>
<tr><td>NVA (LiDAR Swath, DEM)</td><td>≤ 19.6 cm</td><td>95% Required</td></tr>
<tr><td>VVA (DEM)</td><td>≤ 29.4 cm</td><td>95^{th} Percentile Required</td></tr>
</table>

Reports are delivered to verify the project data meets/exceeds the above stated accuracy requirements:

1. **Accuracy of the LiDAR Point Cloud Data:** The NVA of the LiDAR point cloud data will be calculated against TINs derived from the final calibrated and controlled swath data, derived according to the National Standard for Spatial Database Accuracy (NSSDA).
2. **Accuracy of the Derived DEM:** The accuracy (ACC_z) of the derived DEM will be calculated and reported in the three (3) ways indicated in table 1.

1.6.3 Understanding of the Project AOI

To achieve a project scope with an ANPS of 0.7 meters over the project area (QL2), including the buffer, Fugro will design a custom flight plan for the Lake County AOI. The following page illustrates our understanding of the AOI and provides some additional acquisition specifications.

Use or disclosure of data contained on this sheet is subject to the restriction on the title page of this proposal.

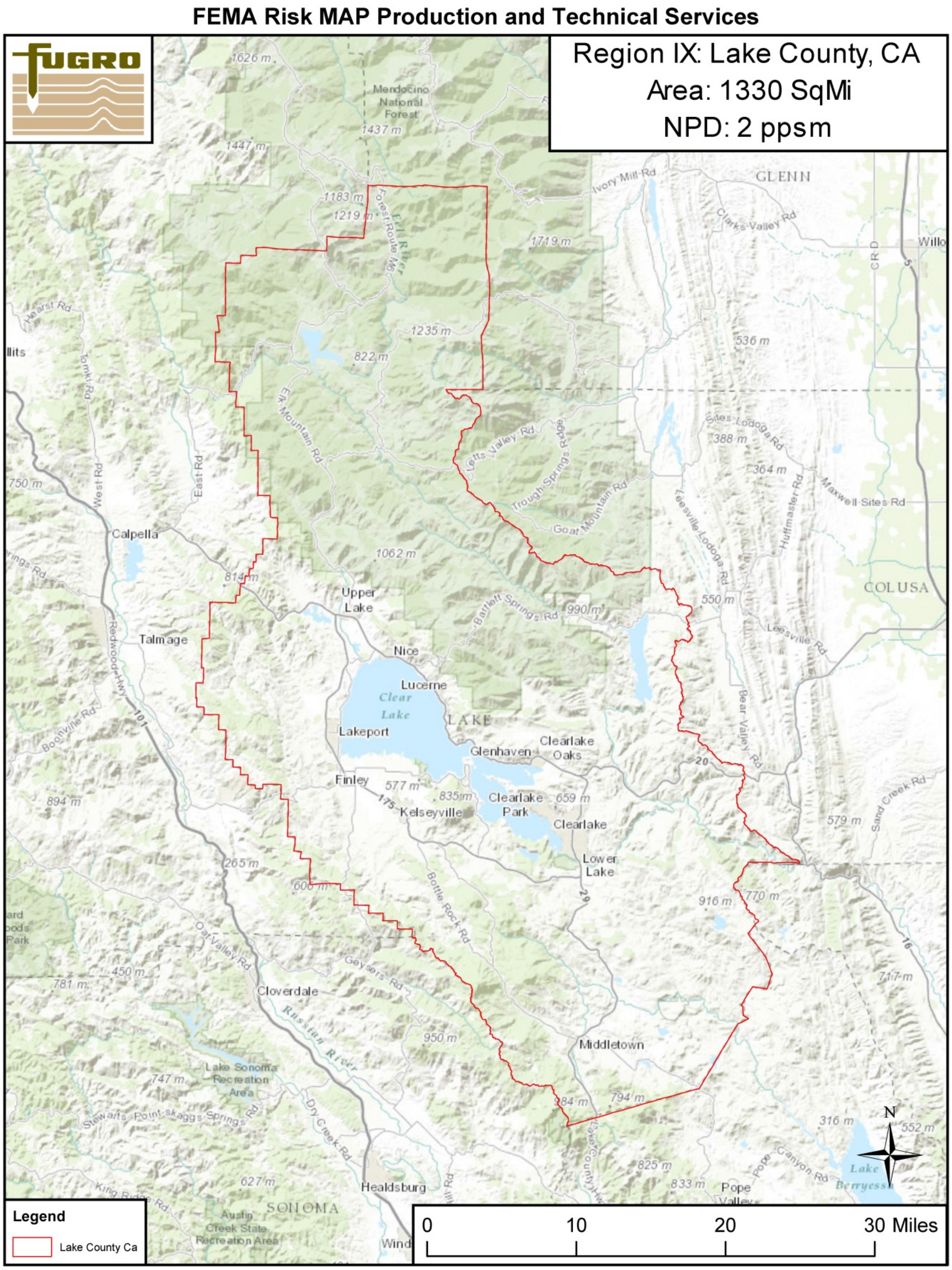

Figure 1-2: Lake County AOI

1.7 Verification of Data Usability / Raw Data Quality Control

All acquired LiDAR data goes through a preliminary review to assure that complete coverage is obtained and that there are no gaps between flight lines before the flight crew leaves the project site. Once back in the production center, the data is run through a complete iteration of processing to ensure that it is complete, uncorrupted, and that the entire project area has been covered without gaps between flight lines. There are essentially three steps to this processing as described in 1.7.1 – 1.7.3 below.

1.7.1 GPS/IMU Processing

Airborne GPS and IMU data is immediately processed using the airport GPS base station data, which is available to the flight crew upon landing the plane. This ensures the integrity of all the mission data. These results are used to perform the initial LiDAR system calibration test.

1.7.2 Raw LiDAR Data Processing

The technicians process the raw data to LAS format flight lines with full resolution output before performing QC. A starting configuration file is used in this process, which contains the latest calibration parameters for the sensor. The technicians also generate flight line trajectories for each of the flight lines during this process.

1.7.3 Verification of Coverage and Data Quality

The following steps and quality control measures are performed by highly qualified LiDAR technicians and supervisors, and verify complete coverage and ensure data quality:

- ✓ Trajectory files are checked to ensure completeness of acquisition for the flight lines, calibration lines, and cross flight lines.
- ✓ Intensity images are generated for the entire lift at the required 0.7 m aggregate nominal post spacing. Visual checks of the intensity images against the project boundary are performed to ensure full coverage to the 100m buffer beyond the project boundary.
- ✓ The intensity histogram will be analyzed to ensure the quality of the intensity values.
- ✓ Thorough review of the data is performed to identify any data gaps in project area. Data voids [areas => 4($ANPS^2$)] measured using first returns only within a single swath are not acceptable, except where caused by water bodies, by areas of low near infra-red (NIR) reflectivity such as asphalt or composition roofing, or where appropriately filled-in by another swath.
- ✓ A sample TIN surface is generated to ensure no anomalies are present in the data.
- ✓ Turbulence is inspected for each flight line. If any adverse quality issues are discovered, the flight line is rejected and re-flown.
- ✓ The achieved post spacing will be evaluated against project specified 0.7 m ANPS, and also checked to make sure there is no clustering in point distribution.

1.7.4 LiDAR Data Processing

Data processing includes the following four (4) production steps for generating the final deliverables:

1. Raw data processing and boresight
2. Pre-processing
3. Post-processing
4. Product development

Quality control steps are incorporated throughout each step, and are described in the following sections.

Raw Data Processing and Boresight: Raw data processing is the reduction of raw LiDAR, IMU, and GPS data into XYZ points. This is a hardware-specific, vendor-proprietary process. The raw LiDAR data processing algorithms use the sensor's complex set of electronic timing signals to compute ranges or distances to a reflective surface. The ranges must be combined with positional information from the GPS/IMU system to orient those ranges in 3D space and to produce XYZ points. As with any such electronic measuring system, systematic errors can be introduced from a variety of internal and external sources – instrument timing errors, effects of the atmosphere, initialization errors and so on.

The boresight for each lift is done individually as the solution may change slightly from lift to lift. The following steps describe the Raw Data Processing and Boresight process:

- Technicians process the raw data to LAS format flight lines using the final GPS/IMU solution. This LAS data set is used as source data for boresight.
- Technicians first use Fugro proprietary and commercial software to calculate initial boresight adjustment angles based on sample areas within the lift. These areas cover calibration flight lines collected in the lift, cross tie and production flight lines. These areas are well distributed in the lift coverage, and cover multiple terrain types that are necessary for boresight angle calculation. The technician analyzes the results and makes any necessary additional adjustment until it is acceptable for the selected areas. The boresight angle adjustment process will ensure proper alignment between different look angles, as well as between flight line overlaps.
- Once the boresight angle calculation is complete for the selected areas, the adjusted settings are applied to all of the flight lines of the lift and checked for consistency. Technicians utilize commercial and proprietary software packages to analyze the matching between flight line overlaps for the entire lift and adjust as necessary until the results meet the project specifications.

Once all lifts are completed with boresight adjustment individually, the technician will check and correct the vertical misalignment of all flight lines and also the matching between data and ground truth. The following criteria will be used:

- Relative accuracy ≤ 6 cm within individual swaths (smooth surface repeatability)
- Swath overlap difference, RMSDZ, ≤ 8 cm between adjacent swaths
- Swath overlap maximum difference ± 16 cm

The technician will run a final vertical accuracy check of the boresighted flight lines against the surveyed NVA check points after the z correction to ensure meeting the requirement of $RMSE_Z$ (non-vegetated) ≤ 10 cm, NVA ≤ 19.6 cm 95% Confidence Level (Required Accuracy). The accuracy validation report will be delivered to FEMA and AECOM.

Pre-processing: The project will be set up for filtering once boresighting is complete for the project and all lifts are tied to ground control. The LiDAR data will be cut to production tiles.

Post-Processing: Fugro has developed a unique, time efficient, and cost effective method for processing LiDAR data.

The automated classification routines will be applied to the tiled data first. The low noise points, high noise points and ground points will be classified automatically in this process. We utilize commercial software, as well as proprietary, in-house developed software for automatic filtering. The parameters used in the process are customized for each terrain type per project to obtain optimum results. The algorithm has the ability to process large amounts of elevation point data in batch mode. Conceptually, the goal of automated processing is to classify the points to their proper classification as accurate as possible automatically, thereby reducing the amount of manual editing that is required.

Once the automated filtering has been completed, the files are run through a visual inspection to ensure that the filtering was not too aggressive or not aggressive enough. In cases where the filtering is too aggressive and important terrain have been filtered out, the data is either run through a different filter within the local area or is corrected during the manual filtering process. Bridge deck points are classified as well during the interactive editing process. The interactive editing is completed in visualization software that provides manual and automatic point classification tools. Fugro utilizes commercial and proprietary software for this process. All manually inspected tiles will then go through a peer review to ensure proper editing and consistency.

After the manual editing and peer review, all tiles will go through another final automated classification routine. This process ensures only the required classifications are used in the final product (all points classified into any temporary classed during manual editing will be re-classified into proper customer specified classifications).

1.7.5 Deliverable Product Development

After the LiDAR has been through all initial processing and checked for quality, we begin the process of derivative product development to the requirements and specification detailed in the task order and USGS LiDAR Base Specification version 1.2.

Raw Point Cloud Data: All collected flight lines are included in generating this product after the boresight is completed and the adjustment is made to match data to the ground control. The flight lines will go through the following processes:

- Assign flight line ID to each point and file source ID to each flight line based upon the flight line trajectory.
- Re-project flight lines files to deliverable projection/datum and unit.
- Package final LAS 1.4 format deliverable and QC.

The raw point cloud data will be delivered in fully compliant LAS v1.4 format, Point Record Format 6 with Adjusted Standard GPS Time. The flight lines will include all collected points, and will be fully calibrated, georeferenced, and adjusted to ground. Correct and properly formatted georeference information as Open Geospatial Consortium (OGC) well known text (WKT) will be assigned in all LAS file headers. Intensity values are included for each point, normalized to 16-bit. This deliverable will be organized and delivered in their original swath, one file per swath, one swath per file.

Classified Point Cloud Data: Once manual inspection, QC and final autofilter are complete for the LiDAR tiles, the LAS data will be packaged to the project specified tiling scheme, clipped to project boundary including the 100 meter buffer and LAS v1.4 format. It will also be reprojected to project specified projection, datum and unit. The file header will be formated to meet project specification with File Source ID assigned. This Classified Point Cloud product will be used for the generation of derived products. Water points will be classified to Class 9 and Ignored groud points are classified to Class 10, using the collected hydro breaklines.

This product will be delivered in fully compliant LAS v1.4 format, Point Record Format 6, with Adjusted Standard GPS Time at a precision sufficient to allow unique timestamps for each pulse. Correct and properly formatted georeference information as Open Geospatial Consortium (OGC) well known text (WKT) will be assigned in all LAS file headers. Each tile will have unique File Source ID assigned. The

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Point Source ID will match to the flight line ID in flight trajectory files. Intensity values are included for each point, normalized to 16-bit. The following classification scheme will be included:

1. Class 1 Processed, but Unclassified
2. Class 2 Bare Earth Ground
3. Class 7 Low Noise (low, manually identified, if necessary)
4. Class 9 Water
5. Class 10 Ignored Ground (Breakline Proximity)
6. Class 17 Bridge Decks
7. Class 18 High Noise (high, manually identified, if necessary)

The classified point cloud data will be delivered in tiles, without overlap, using the project tiling scheme.

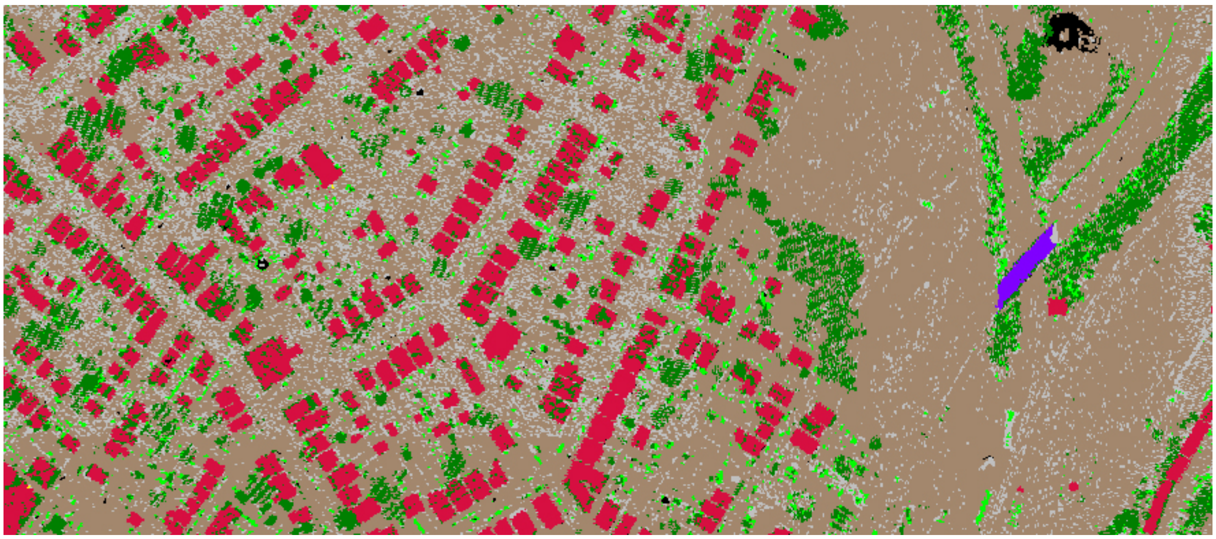

Figure 1-3: Classified Point Cloud

LiDAR Hydro Flattened Breaklines: Hydro breaklines are collected and produced based on USGS LiDAR Base Specification version 1.2. The following hydro features are included:

- Inland Ponds and Lakes
- Inland Streams and Rivers
- Non-tidal Boundary Water
- Tidal Water

The hydro-flattened breaklines will be delivered in ESRI geodatabase format meeting FEMA's breakline topology rules standard.

LiDAR Hydro Enforced Breaklines: In order to support FEMA's need for various risk analyses, as defined within the project's scope, including hydrologic analysis, hydraulic analysis, post fire debris flow, and non-regulatory products, we will collect and deliver hydro enhanced breaklines for the project including:

- Additional Inland Ponds and Lakes
- Additional Inland Streams and Rivers
- Single line streams and culverts

Gridded Digital Elevation Model data – Hydro Flattened DEM: The Hydro Flattened DEM will be generated using the LiDAR bare earth points and 3D hydro flattening polygons to a resolution of 1.0 meter.

Where needed, supplemental breaklines will also be collected and used in DEM generation under the bridges to ensure a logical terrain surface below a bridge. This will be delivered in a separate shape file.

The bare earth points that fall within 1*ANPS along the hydro breaklines (points in Class 10) will be excluded from the DEM generation process. This is analogous to the removal of mass points for the same reason in a traditional photogrammetrically compiled DTM. This process will be done in batch, using proprietary software.

The technicians will use Fugro proprietary software for the production of LiDAR-derived hydro-flattened bare earth DEM surface using TIN model in initial grid format at 1m GSD. Water bodies (inland ponds and lakes), inland streams and rivers, and other non-tidal water bodies will be hydro-flattened within the DEM. Hydro-flattening will be applied to all water impoundments, natural or man-made, that are larger than ~2 acres in area, to all streams that are nominally wider than 100’, and to all non-tidal boundary waters bordering the project area, regardless of size. This process will be done in batch.

Once the initial, hydro-flattened bare earth DEM is generated, the technicians will check the tiles to ensure that the grid spacing meets specifications. The technicians will also check the surface to ensure proper hydro-flattening. The entire data set will be checked for completed project coverage. The tiles are then converted to ERDAS Imagine format. Georeference information will be included in raster files. Void areas (i.e., areas outside the project boundary but within the tiling scheme) will be coded using a unique “NODATA” value.

Gridded Digital Elevation Model data – Hydro Enforced DEM: The Hydro Enforced DEM will be generated using the LiDAR bare earth points and 3D hydro enforced breaklines to a resolution of 1.0 meter.

Where needed supplemental breaklines will also be collected and used in DEM generation under the bridges to ensure a logical terrain surface below a bridge. This will be delivered in a separate shape file.

The bare earth points that fall within 1*ANPS along the hydro breaklines (points in Class 10) will be excluded from the DEM generation process. The hydro enforced DEM depicts the terrain beneath specific drainage structures, such as bridges and culverts, to maintain the continuous water flow.

The technicians will use Fugro proprietary software for the production of LiDAR-derived hydro-enforced bare earth DEM surface using TIN model in initial grid format at 1m GSD in batch.

Once the initial, hydro-enforced bare earth DEM is generated, the technicians will check the tiles to ensure that the grid spacing meets specifications. The technicians will also check the surface to ensure proper hydro-enforcement. The entire data set will be checked for completed project coverage. The tiles are then converted to ERDAS Imagine format. Georeference information will be included in raster files. Void areas (i.e., areas outside the project boundary, but within the tiling scheme) will be coded using a unique “NODATA” value.

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02 Technical Evaluation Factors (TEF) and Subfactors.

Fugro has provided LiDAR acquisition and production services for over 18 years. Their investment in LiDAR technology dates back to the early 1990s when they teamed with a hardware expert to design and build the first operational, wide-area commercial airborne LiDAR mapping system. This early R&D effort provided a solid foundation for Fugro to grow into the successful LiDAR mapping operation it is today, with demonstrated expertise planning and executing successful LiDAR mapping programs throughout the world. Fugro provides the technology, experience, and resources to produce a full range of LiDAR data that meets the requirements for both emergency/rapid response and non-emergency applications all in full compliance with USGS QL2 / 3DEP requirements and specification.

Fugro is one of the selected vendors for the USGS contract for providing QL2 LiDAR services to support the 3DEP program. Fugro has continued to invest in and contribute to the LiDAR community by creating efficient data collection and processing techniques, publishing technical documents and performing 3rd party QAQC services on LiDAR projects to be sure data collection and processing procedures meet industry and client expectations.

For this project, Fugro understands it is required to meet the USGS Quality Level 2 (QL2) as specified in the 'Lidar Base Specifications' document, Version 1.2, published November 2014

Vast Capacity for Standard, Surge and Rapid / Emergency Response Requirements:

Fugro's large pool of skilled personnel and equipment resources provides ability to work on task orders with very little notice. We have demonstrated this ability on many emergency response mapping projects. Fugro's history includes supporting federal and local government agencies to accelerate project schedules by adding additional equipment and personnel for data acquisition and processing.

Figure 2-1: Fugro Emergency Response Resource Capacity

One example of our success delivering accurate and precise bare earth LiDAR is the an emergency LiDAR task order issued from the USACE St Louis District, which requiried rapid deployment to areas of damage caused by Hurricane Sandy covering the Connecticut coastline.

Officials and first responders quickly sought updated geospatial data to verify and assess storm damage. With more than 11 years of experience providing emergency response mapping, Fugro was contacted to provide LiDAR mapping over the entire stretch of the Connecticut coastline.

Fugro mobilized within 24 hours of NTP, and acquired the data during low tide windows and optimal weather conditions over the next several days. The initial data products were delivered within 48 hours of completion of acquisition. The final bare earth digital elevation model was delivered in mid-December 2012.

This response lasted over three weeks and required 12-16 hours/day to meet acquisition requirements.

Figure 2-2: Extent of Acquisition for Post-Sandy Airborne LiDAR Survey Effort.

Another example, local to Region IX, is a mapping project that required mobilization within 48 hours of NTP to acquire over 3,140 sq. mi. of color infrared orthoimagery to delineate burn areas following wildfires in California. Additionally a 2m DEM was generated to model mudslides.

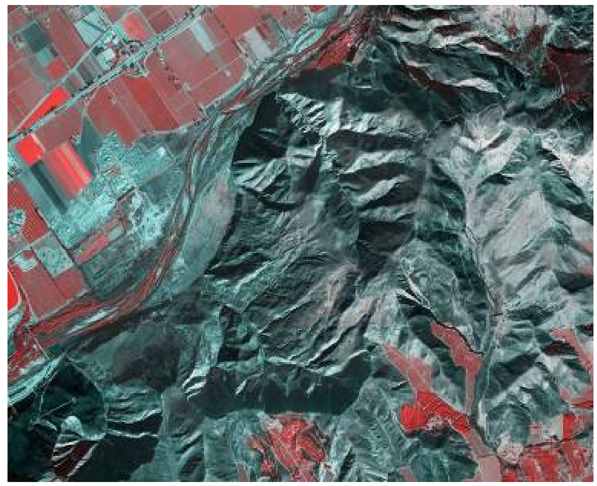

Figure 2-3: California Wildfire Orthoimagery and DEM Project

2.1 Specialized Experience and Technical Competence

Compass and JV team members are very familiar with all nationally recognized map accuracy standards and guidelines for topographic products, including USGS LiDAR Base Specification version 1.2. We have met this specification many times on task orders through the USGS Geospatial Products and Services (GPSC) Contract. Additionally we delivered thousands of topographic mapping products that meet FEMA, American Society of Photogrammetry and Remote Sensing (ASPRS), National Map Accuracy Standards (NMAS), and other specifications.

2.1.1 TEF Subfactor 1: Experience and Efficiency in Delivering Accurate and Precise Bare Earth LiDAR data.

Fugro has extensive experience delivering bare earth data that conforms to USGS LiDAR Base Specification version 1.2. We have been a USGS Geospatial Products and Services Contract (GPSC) holder for over 10 years, and have developed a highly efficient, streamlined that maintains the high quality required for this type of delivery.

The bare earth data is filtered from the LiDAR point cloud first by an automated process where the filtering parameters are customized for the specific terrain types in the project AOI. The goal for the automated filtering is to optimize the classification result and get the bare earth points classified as accurate as possible. Then visual inspection and peer review ensures misclassified areas are corrected before the delivery.

09/15/2015: From Kathryn Yoder, USGS: PA Sandy LiDAR task order evaluation:

"Fugro dealt with issues found in QA in a timely manner. They met with USGS to determine how to best meet our needs and to ensure their adherence to USGS Specifications on this task order and in the future."

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Figure 2-4: Bare-Earth Surface (Raster Digital Elevation Model)

2.1.2 TEF Subfactor 2: Proven and Efficient Methods of Generating Triangulated Irregular Networks (Tins) and Digital Elevation Models (Dems) From Bare Earth Lidar Data.

Fugro has acquired hundreds of thousands of square miles (sq. mi.) of Lidar data over the last 10 years, and nearly all of this work has required the generation of elevation models and TIN surface data. One specific project is the **James River Watershed**, which the runs through North Dakota and South Dakota. Over the last five (5) years we have acquired over 35,000 sq. mi. of surface elevation data. The delivered surface elevation data of the James River Watershed and surrounding watersheds in North Dakota and South Dakota for use in conservation planning, design, research, delivery, floodplain mapping, and hydrologic modeling.

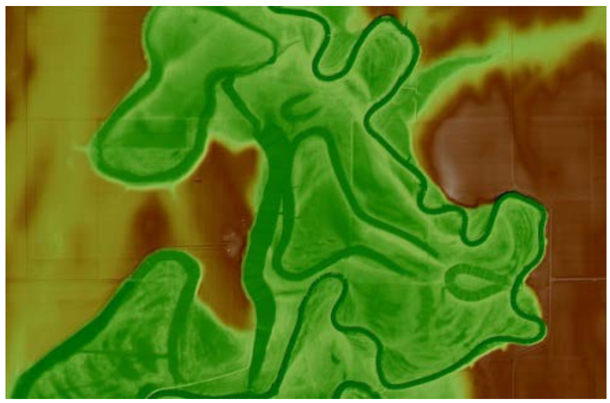

Figure 2-5: James River DEM Surface

Another recent example of a project closer in size to the Lake County, CA project is a task order we delivered to **Fort Bend County, TX** in 2014. The project area of interest covered approximately 917 sq. mi. over Fort Bend County. Fugro provided project management, airborne LiDAR acquired at a density of 4 points per square meter, with the product deliverables including the all-return fully classified point cloud, hydrologic breaklines, 1-meter hydro-flattened DEM, and 1-meter intensity images.

Figure 2-6: Digital Elevation Model w/ Hydroflattened Breaklines

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2.2 Capacity to Accomplish the Work in the Required Time.

Fugro owns and maintains a fleet of aircraft and LiDAR sensors configured for aerial data acquisition. Our staff of professionals and flight operations personnel includes registered Professional Engineers, Professional Land Surveyors, ASPRS Certified Photogrammetrists and Mapping Scientists, Federal Aviation Administration (FAA) certified pilots, aerial acquisition specialists and sensor operators, geographical information system (GIS) specialists, and other additional support personnel. Our capacity allows us to have multiple redundant systems in place should any unforeseen issues arise that could affect the project schedule.

09/02/2015: From Kathryn Yoder, USGS: In response to the final delivery for Kidder County, ND LiDAR Project: "This deliverable was completed over a month ahead of schedule and with no issues found in QA. Fugro did an excellent job of communicating throughout the entire process."

Figure 2-7: Fugro Base of Flight Operations

2.2.1 Personnel Resource Capacity

Table 2: Key Personnel Availability and Experience

PERSONNEL	% AVAILABILITY	YEARS WITH THE COMPANY / TOTAL YEARS	ROLE / AREA OF EXPERTISE	RELEVANT CERTIFICATIONS
Brian Wegner	10%	28 / 28	Principal In Charge	CP, PSM
Richard McClellan	75%	9 /9	Project Manager	-
Dave Holm	50%	16 / 17	Project Quality Manager	CP, SP, GISP
Guy Meiron	25%	23 / 24	Project Engineer, Tech Sup	PE
Andy Weathers	25%	7 / 28	Flight Operations Manager	FAA Pilot license
Douglas Johnson	25%	22 / 31	Raw Data QA/QC	CP
Jerry Halvorson	25%	21 / 21	Airborne GPS Specialist	-
Tian Wang	75%	13 / 13	Lidar Data Processing Manager	-
Nora May	25%	7/7	Geodetic Scientist	CP, PhD

Table 3: Compass Production Staff Capacity

PRODUCTION STAFF DISCIPLINE	PERSONNEL
Acquisition (Flight Operations, Pilots, Sensor Technicians)	26
DEM Edit/ Programming (LiDAR and Elevation Technicians/Analysts)	24
Ortho-production (AT, Finishing, Quality Control) Many cross trained with LiDAR processing expertise.	36
Project Management / Administrative Staff (Executive, Finance, Sales/Marketing, IT)	55
Independent QA/QC Personnel	**50**

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2.2.2 LiDAR Sensor Capacity

Table 4: Compass LiDAR Sensor Capacity

SENSOR NAME	QTY	TYPE
Leica ALS60	2	Topographic LiDAR
Riegl LMS Q680i	8	Topographic LiDAR
FLI-MAP Fx	1	Topographic LiDAR
Riegl LMS Q780i	2	Topographic LiDAR
Riegl LMS Q1560	1	Topographic LiDAR
FLI-MAP 400	7	Topographic LiDAR

2.3 Knowledge of the General Geographic Area of the Project.

Fugro has 12 offices distributed throughout the Region IX boundary. We have extensive knowledge and experience in floodplain mapping, hazard analysis, and related services; this experience includes numerous programs that support the development of integrated flood management, coastal management systems, and emergency response. Over the past decade we have acquired remotely sensed airborne data throughout the region in support of programs such as Central Valley Floodplain Evaluation and Delineation Program (CVFED), National Coastal Mapping Program (NCMP), California Coastal Mapping Program (CCMP), among others. We have included a summary of a portion of these projects in the tables below. In addition to topographic and bathymetric LiDAR, we have supported imagery programs such as the USDA's National Agricultural Imagery Program (NAIP). Under this program we have captured Nevada (once); New Mexico (twice); and California (six times), and we are again flying Nevada this year (2015).

These acquisitions provide us with knowledge of the atmospheric and terrain conditions in this region, which can be less than ideal for airborne acquisition. Knowing the difficulties of the region allows us to maximize available flight windows and cost-effectively plan for and mitigate issues before they cause problems for a particular task order.

Proposed Task Order manager Mr. Richard McClellan has managed the majority of the projects listed below in his 29 year career in the surveying and mapping industry.

Table 5: Task Order Manager Experience

Project	Completion Date	Size (Sq. Mi.)	Resolution
CA Central Valley Floodplain Evaluation and delineation program (CA CVFED)	2012	2,133	1m NPS
Description: Under this program Fugro acquired and processed 1-meter nominal post spacing LiDAR processed to bare earth. Data was processed according to FEMA standards, and delivered in .las and ASCII formats. Fugro also developed an Esri-compatible digital elevation model (DEM) as part of the final deliverable. The resulting data is incorporated into hydraulic modeling systems used by engineering firms, local authorities, and government agencies (i.e. FEMA, US ACE, DNR, etc.) to analyze, assess, and plan for flood management, prevention and response activity in and around the Central Valley area.			

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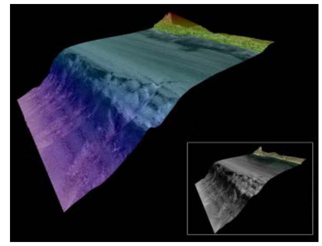
Project	Completion Date	Size (Sq. Mi.)	Resolution
California Coastal Mapping Program (CCMP)	2012	1,200	1m NPS
Description: This project included collecting tide-coordinated, high-resolution topographic LiDAR and airborne bathymetric LiDAR from 500 meters inland to one (1) kilometer offshore that was merged into a seamless dataset. Both onshore and offshore components also included simultaneous collection of orthoimagery and hyperspectral data. This project was part of a California statewide which included the California Ocean Protection Council (OPC) effort to develop a climate change strategy to address and mitigate potential impacts of sea level change on coastal communities. 			
National Coastal Mapping Program (NCMP)	2012	468	1m NPS
Description: In 2010, the USACE extended the survey limits from California up the coast to include OR and WA in support of the Joint Airborne LiDAR Bathymetry Technical Center of Expertise (JALBTCX) NCMP. This project was performed to the same specification as the CCMP project above.			
California Coastal Structure Mapping	2012	N/A	N/A
Description: Fugro collected high resolution topographic LiDAR data along the open coast and inland bays of CA for the CCMP. The processed LiDAR data meets FEMA's specifications for use in flood plain mapping. California Ocean Protection Council (OPC) initiated restudy of coastal flood risk along the California open coast and provided the processed data to FEMA Region IX for use as base map data for the recently. Using this data, FEMA tasked Fugro to reclassify portions of the LiDAR data along the CA coast to identify man-made structures including buildings, seawalls, floodwalls, bulkheads, and revetments to determine flood risk. Following the reclassification process, the LiDAR LAS tiles and polygons (Esri shapefile format) for the areas where coastal protection structures are located were delivered to FEMA.			
USACE St. Louis District Survey and Mapping TOs:	Ongoing	N/A	30cm
Description: Fugro has completed numerous survey and mapping projects in the Region in the past 5 years. Under our USACE St. Louis District IDIQ contract we have completed delivery orders for geospatial acquisition and mapping of military installations as noted here:			

USACE MILITARY INSTALLATIONS – FEMA REGION IX DISTRICT			
Installation Name	State	Acq. Date(S)	Date
Florence	AZ	4/4/2013	8/2/2013
Buckeye	AZ	4/4/2013	7/26/2013
Papago	AZ	6/18/2012	9/19/2012
Navajo	AZ	7/11/2012	8/27/2012
Camp Roberts	CA	8/18/2011	9/28/2011
Camp San Luis Obispo	CA	8/18-19/2011	9/28/2011
Camel Tracks TNG Site	NM	7/13/2012	9/28/2012
TS Camp Luna	NM	7/13/2012	9/28/2012
Santa Fe	NM	7/13/2012	9/28/2012
NG Deming (Black Mtn) FR	NM	6/19/2012	9/27/2012
Springer	NM	7/12/2012	9/24/2012
Las Cruces	NM	6/19/2012	9/19/2012
NOAA SF Bay – Hydrographic/ Topographic Survey	On Going	453	1m NPS
This project was developed by the NOAA Office of Coastal Management to collect and deliver topographic and bathymetric elevation point data derived from LiDAR data. Data are used for coastal management decision-making, including such applications as sea level rise. Additionally, the project provides accurately positioned sonar imagery data of San Francisco Bay coastal and near shore waters to delineate marine habitat types and provides OPC and NOAA with bathymetric survey data from a combination of multi-beam and interferometric sonar data.			

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