# 2015 OLC Chelan FEMA


Data collected for:

Department of Geology and Mineral Industries

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Prepared by:

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# Contents



# Project Overview

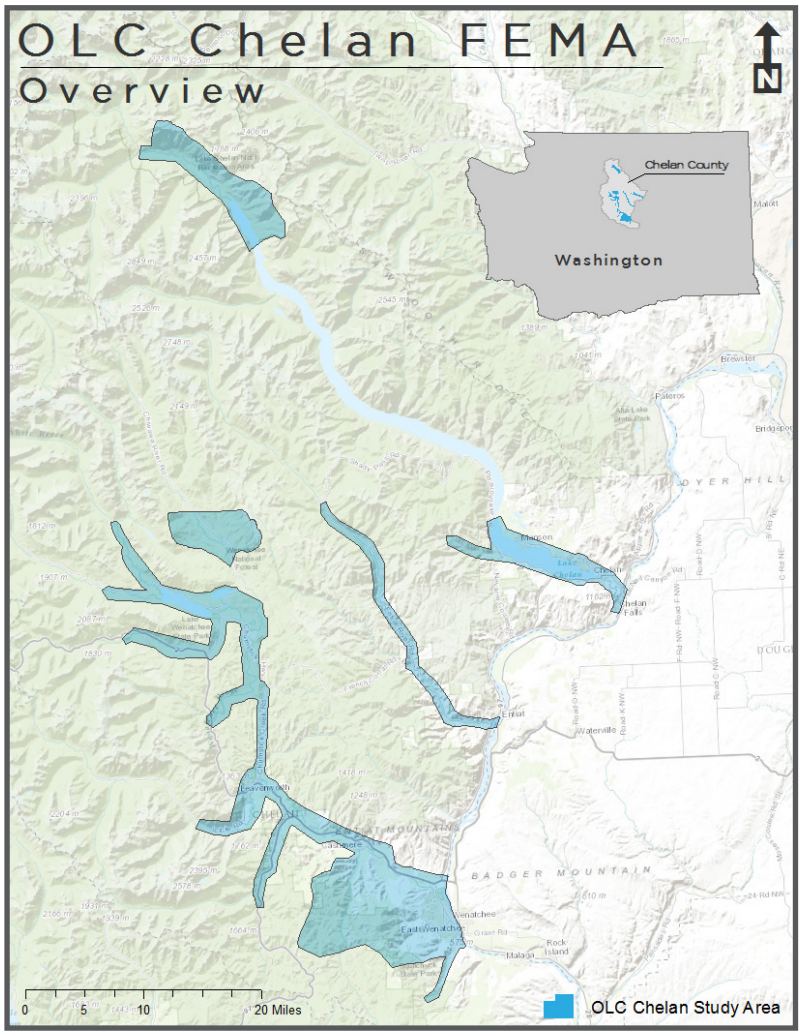
Quantum Spatial has collected Light Detection and Ranging (LiDAR) data for the Oregon LiDAR Consortium (OLC) Chelan FEMA study area. This study area is located in Chelan County, in central Washington.

The collection of high resolution geographic data is part of an ongoing pursuit to amass a library of information accessible to government agencies as well as the general public.

In July 2015 QSI employed remote-sensing lasers in order to obtain a total area flown of 215,029 acres. Settings for LiDAR data capture produced an average resolution of at least eight pulses per square meter.

Final products created include RGB extracted (from NAIP imagery) LiDAR point cloud data, one-meter digital elevation models of highest hit and bare earth ground models, one-meter density rasters, one-half-meter intensity rasters, study area vector shapes, and corresponding statistical data. Final deliverables are projected in UTM Zone 10.

| OLC Chelan FEMA Data | |
|---|---|
| LiDAR Acquisition Dates | 7/31/2015 - 10/15/2015 |
| Area of Interest | 201,078 acres |
| Date Extent | 215,029 acres |
| Projection | Universal Transverse Mercator (UTM) 10 North |
| Horizontal Datum<br>Vertical Datum | NAD83 (2011), Epoch 2010.00<br>NAVD88 (Geoid 12A) |
| Units | meters |




OLC Chelan Project Overview Map

# Aerial Acquisition

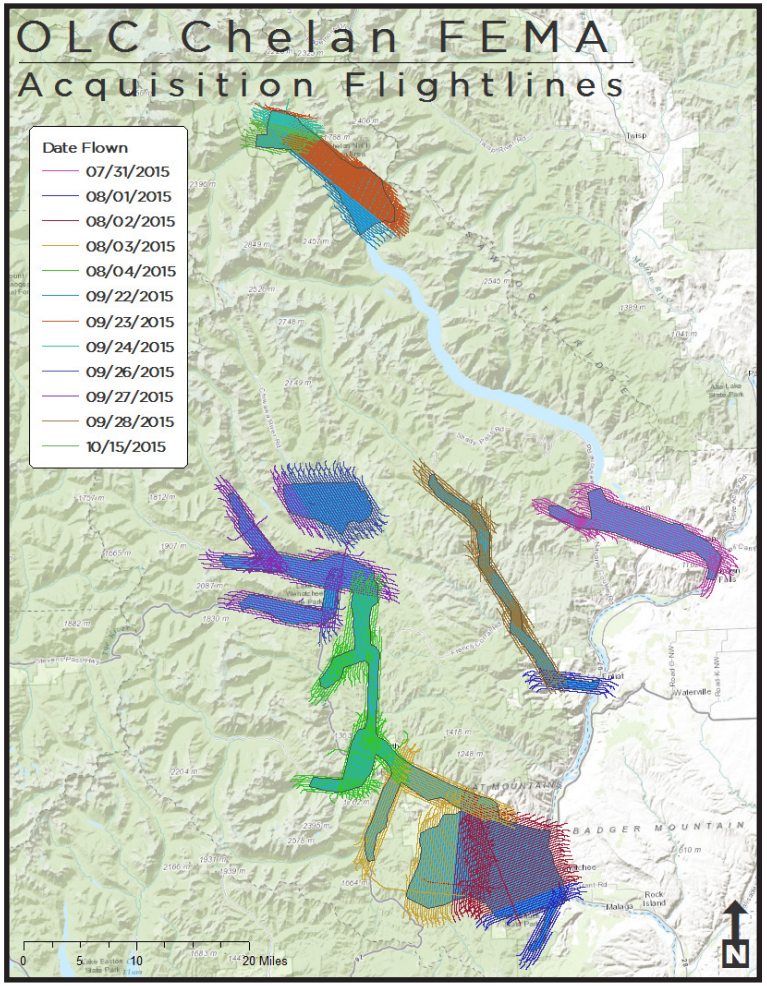
## LiDAR Survey

The LiDAR survey occurred between July 31, 2015 and October 15, 1015 utilizing a Leica ALS80 mounted in a Cessna Grand Caravan. The systems were programmed to emit single pulses at around 369 kHz and flown at 1,500 m AGL, capturing a scan angle of 15 degrees from nadir. These settings were developed to yield points with an average native density of greater than eight pulses per square meter over terrestrial surfaces.

To solve for laser point position, an accurate description of aircraft position and attitude is vital. Aircraft position is described as x, y, and z and was measured twice per second (two hertz) by an onboard differential GPS unit. Aircraft attitude is described as pitch, roll, and yaw (heading) and was measured 200 times per second (200 hertz) from an onboard inertial measurement unit (IMU).

The LiDAR sensor operators constantly monitored the data collection settings during acquisition of the data, including pulse rate, power setting, scan rate, gain, field of view, and pulse mode. For each flight, the crew performed airborne calibration maneuvers designed to improve the calibration results during the data processing stage. They were also in constant communication with the ground crew to ensure proper ground GPS coverage for data quality. The LiDAR coverage was completed with no data gaps or voids, barring non-reflective surfaces (e.g., open water, wet asphalt). All necessary measures were taken to acquire data under good conditions (e.g., minimum cloud decks) and in a manner (e.g., adherence to flight plans) that prevented the possibility of data gaps. All QSI LiDAR systems are calibrated per the manufacturer and our own specifications, and tested by QSI for internal consistency for every mission using proprietary methods.

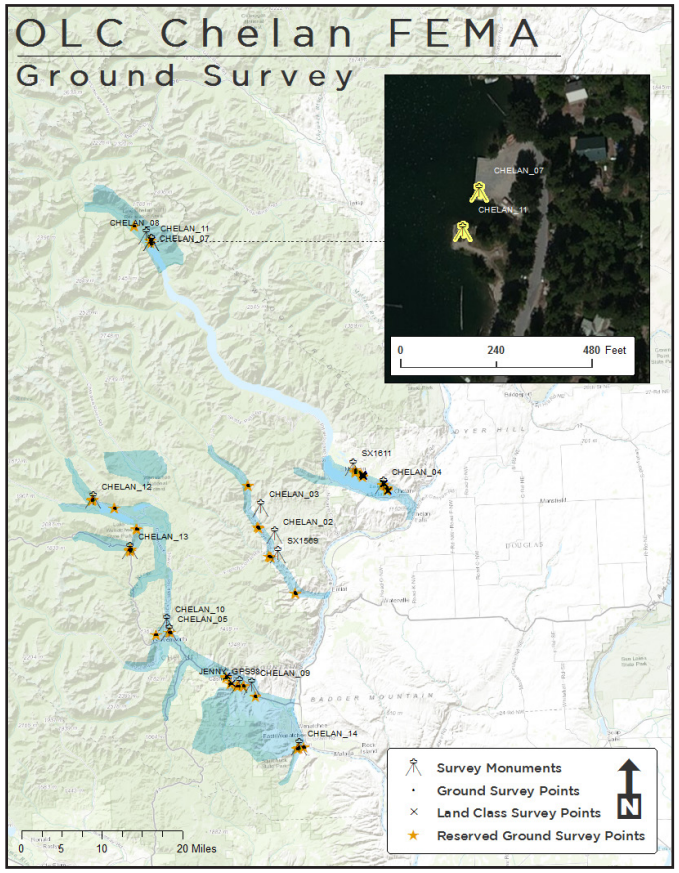
| OLC Chelan FEMA LiDAR Acquisition Specs | |
|---|---|
| Sensor | Leica ALS80 |
| Aircraft | Cessna Grand Caravan |
| Acquisition Date Range | 7/31/2015 - 10/15/2015 |
| Coverage | 100% Overlap with 60% Sidelap |
| Field of View (FOV) | 30 degrees |
| Targeted Pulse Density | ≥8 PPSM |
| Pulse Rate | 369 kHz |
| Speed | 140 kts |




Project Flightlines

# Ground Survey

Ground control surveys, including monumentation, aerial targets, and ground survey points (GSPs) were conducted to support the airborne acquisition. Ground control data are used to geospatially correct the aircraft positional coordinate data and to perform quality assurance checks on final LiDAR data products. See the table to the right for specifications of equipment used.




Ground survey map of the 2015 OLC Chelan FEMA study area.

| Monument Accuracy | |
|---|---|
| FGDC-STD-007.2-1998 Rating | |
| St Dev NE | 0.050 m |
| St Dev z | 0.050 m |

## Monumentation

Ground control surveys, including monumentation, and ground survey points (GSPs), were conducted to support the airborne acquisition. Ground control data were used to geospatially correct the aircraft positional coordinate data and to perform quality assurance checks on final LiDAR data.

The spatial configuration of ground survey monuments provided redundant control within 13 nautical miles of the mission areas for LiDAR flights. Monuments were also used for collection of ground survey points using real time kinematic (RTK) and post processed kinematic (PPK) survey techninques. Monument locations were selected with consideration for satellite visibility, field crew safety, and optimal location for GSP coverage. QSI utilized three existing monuments and established 12 new monuments for the OLC Chelan FEMA LiDAR project. New monumentation was set using 5/8" x 30" rebar topped with stamped 2-1/2" aluminum caps. QSI's professional land surveyor, Christopher Glantz (WA PLS #48755) oversaw and certified the establishment of all monuments.

Monuments utilized during the ground survey of the OLC Chelan FEMA project.

| PID | Latitude | Longitude | Ellipsoid Height (m) | NAVD88 Height (m) |
|---|---|---|---|---|
| CHELAN_02 | 47° 46' 30.17484" | -120° 21' 07.99430" | 727.357 | 746.088 |
| CHELAN_03 | 47° 49' 31.34566" | -120° 23' 08.44008" | 959.240 | 977.753 |
| CHELAN_04 | 47° 51' 28.98625" | -120° 03' 24.83358" | 406.772 | 425.923 |
| CHELAN_05 | 47° 36' 21.64406" | -120° 38' 27.89408" | 363.875 | 382.689 |
| CHELAN_07 | 48° 18' 38.94977" | -120° 39' 27.24987" | 319.073 | 336.646 |
| CHELAN_08 | 48° 19' 19.22772" | -120° 40' 17.57732" | 318.916 | 336.499 |
| CHELAN_09 | 47° 30' 15.14715" | -120° 25' 34.16611" | 219.715 | 239.085 |
| CHELAN_10 | 47° 37' 27.73931" | -120° 38' 48.83811" | 353.176 | 371.961 |
| CHELAN_11 | 48° 18' 38.31184" | -120° 39' 27.65298" | 318.866 | 336.440 |
| CHELAN_12 | 47° 50' 56.88530" | -120° 50' 06.83755" | 555.351 | 573.677 |
| CHELAN_13 | 47° 45' 22.56350" | -120° 44' 22.30126" | 587.397 | 605.951 |
| CHELAN_14 | 47° 23' 31.39259" | -120° 18' 17.28827" | 250.275 | 269.894 |
| JENNY_GPS98 | 47° 30' 27.32185" | -120° 27' 33.29900" | 361.305 | 380.628 |
| SX1569 | 47° 44' 26.23812" | -120° 20' 39.29344" | 768.144 | 786.968 |
| SX1611 | 47° 53' 36.07428" | -120° 08' 05.57169" | 353.580 | 372.517 |

Coordinates are on the NAD83 (2011) datum, epoch 2010.00. NAVD88 height referenced to Geoid12A.

To correct the continuously recorded onboard measurements of the aircraft position, QSI concurrently conducted multiple static Global Navigation Satellite System (GNSS) ground surveys (1 Hz recording frequency) over each monument. During post-processing, the static GPS data were triangulated with nearby Continuously Operating Reference Stations (CORS) using the Online Positioning User Service (OPUS) for precise positioning. Multiple independent sessions over the same monument were processed to confirm antenna height measurements and to refine position accuracy. The table on the previous page provides the list of monuments used.

## Ground Survey Points (GSPs)

Ground Survey Points (GSPs) are collected using Real Time Kinematic (RTK) survey techniques. For RTK surveys, a base receiver is positioned at a nearby monument to broadcast a kinematic correction to a roving receiver. All GSP measurements are made during periods with a Position Dilution of Precision (PDOP) no greater than 3.0 and in view of at least six satellites for both receivers. Relative errors for the position must be less than 1.5 centimeters horizontal and 2.0 centimeters vertical in order to be accepted.

In order to facilitate comparisons with high quality LiDAR data, GSP measurements are not taken on highly reflective surfaces such as center line stripes or lane markings on roads. GSPs are taken no closer than one meter to any nearby terrain breaks such as road edges or drop offs. GSPs were collected within as many flight lines as possible; however, the distribution depended on ground access constraints and may not be equitably distributed throughout the study area.

## Land Cover Class

In addition to ground survey points, land cover class control points were collected throughout the study area. Individual accuracies were calculated for each land cover type to assess confidence in the LiDAR derived ground models across land cover classes. Land cover types and descriptions are shown in the table below.

Field surveyor collecting land class RTK points.

Land cover descriptions of check points taken for the OLC Chelan FEMA study area.

| Land Cover Type | Land Cover Code | Description |
|---|---|---|
| Shrub | SHRUB | Areas dominated by shrubs |
| Short Grass | SHORT GRASS | Areas dominated by short grass |
| Tall Grass | TALL GRASS | Areas dominated by tall grass |

Ground survey instrumentation

| Instrumentation | | | |
|---|---|---|---|
| Receiver Model | Antenna | OPUS Antenna ID | Use |
| Trimble R7 GNSS | Zephyr GNSS Geodetic Model 2 RoHS | TRM57971.00 | Static |
| Trimble R10 | Integrated Antenna R10 | TRMR10 | Static, Rover |

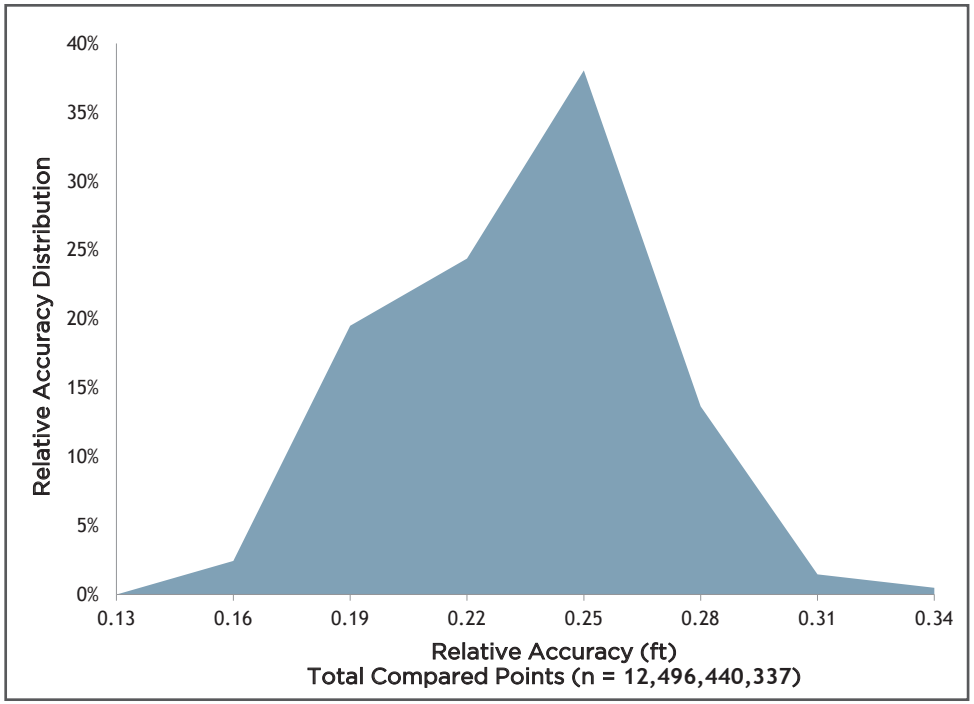
# Accuracy

## Relative Accuracy

Relative accuracy refers to the internal consistency of the data set and is measured as the divergence between points from different flightlines within an overlapping area. Divergence is most apparent when flightlines are opposing. When the LiDAR system is well calibrated the line to line divergence is low (<10 centimeters). Internal consistency is affected by system attitude offsets (pitch, roll, and heading), mirror flex (scale), and GPS/IMU drift.

Relative accuracy statistics are based on the comparison of 805 flightlines and over 12,496,440,337 LiDAR points. Relative accuracy is reported for the entire study area.

| Relative Accuracy Calibration Results | |
|---|---|
| Project Average | 0.056 m<br>0.185 ft. |
| Median Relative Accuracy | 0.053 m<br>0.175 ft. |
| 1σ Relative Accuracy | 0.060 m<br>0.197 ft. |
| 2σ Relative Accuracy | 0.085 m<br>0.279 ft. |



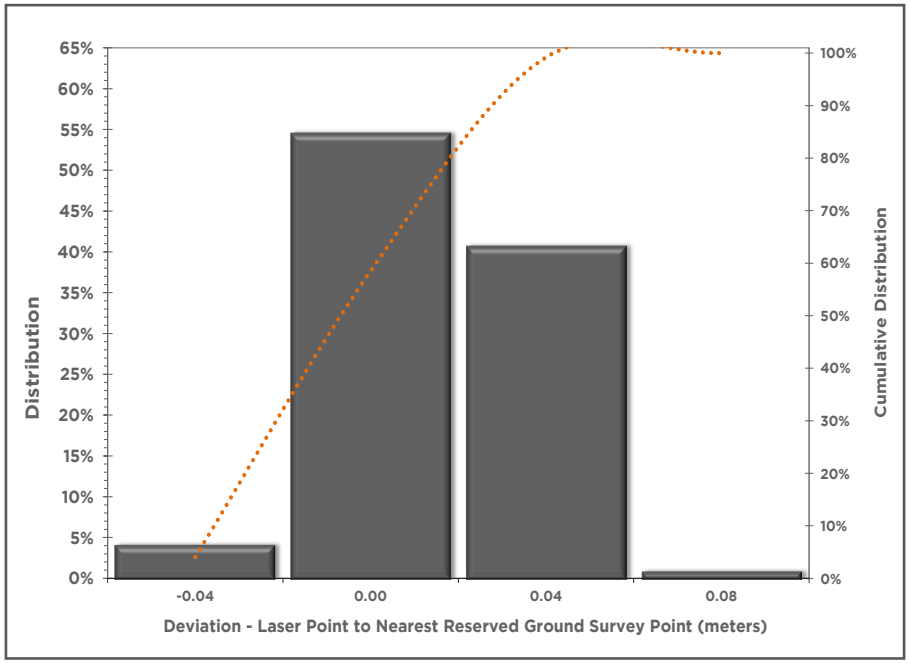
## Vertical Accuracy

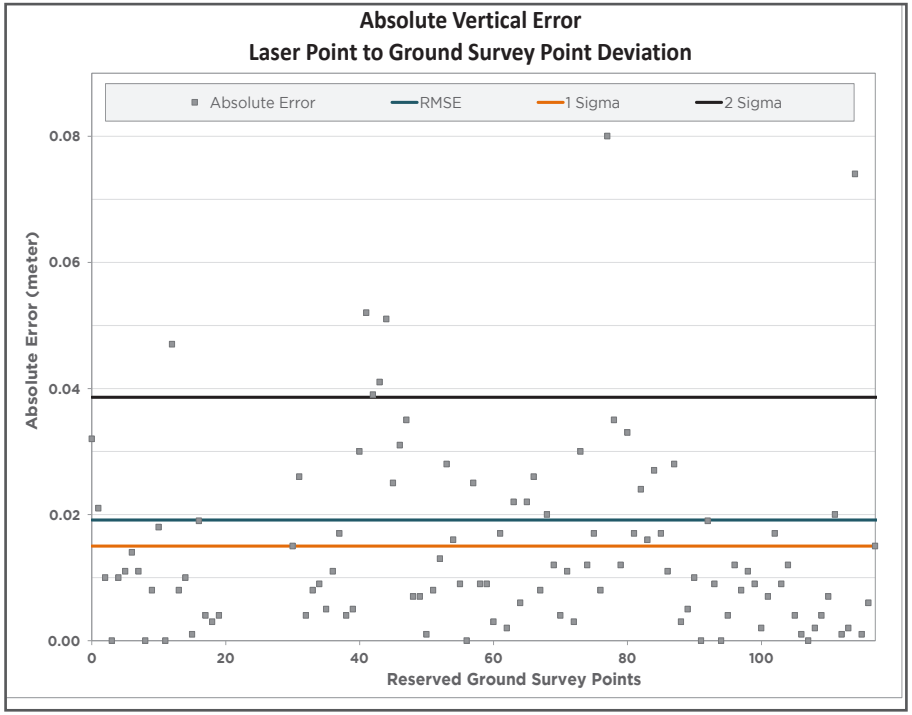
Vertical Accuracy reporting is designed to meet guidelines presented in the National Standard for Spatial Data Accuracy (NSSDA) (FGDC, 1998) and the ASPRS Guidelines for Vertical Accuracy Reporting for LiDAR Data V1.0 (ASPRS, 2004). The statistical model compares known ground survey points (GSPs) to the closest laser point. Vertical accuracy statistical analysis uses ground survey points in open areas where the LiDAR system has a "very high probability" that the sensor will measure the ground surface and reports the fundamental vertical accuracy value (FVA=1.96*RMSE).

For the OLC Chelan FEMA study area, a total of 2,230 GSPs were collected. An additional 123 reserved ground survey points were collected for independent verification, resulting in a fundamental vertical accuracy (FVA) of 0.038 meters.

| Vertical Accuracy Results | Hard Surface |
|---|---|
| Sample Size (n) | n = 123 GSPs |
| FVA (RMSE*1.96) | 0.038 m (0.123 ft.) |
| Root Mean Square Error | 0.019 m (0.063 ft.) |
| 1 Standard Deviation | 0.015 m (0.049 ft.) |
| 2 Standard Deviations | 0.039 m (0.127 ft.) |
| Average Deviation | 0.014 m (0.044 ft.) |
| Minimum Deviation | -0.080 m (-0.262 ft.) |
| Maximum Deviation | 0.052 m (0.171 ft.) |

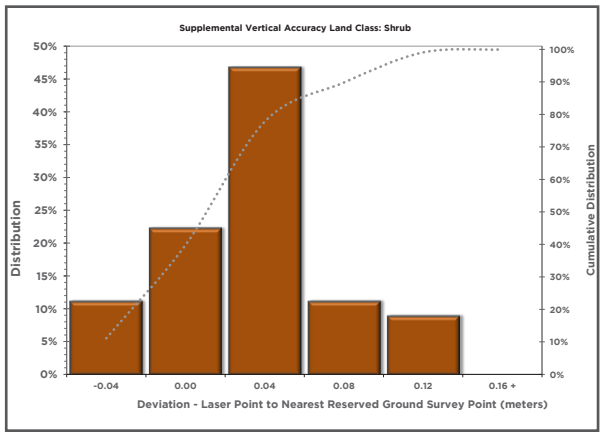
Vertical Accuracy Distribution

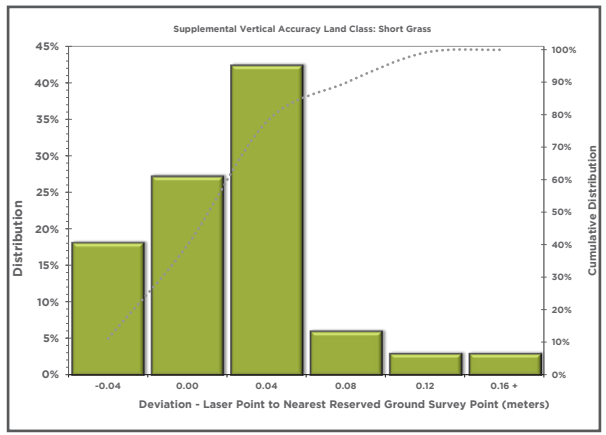


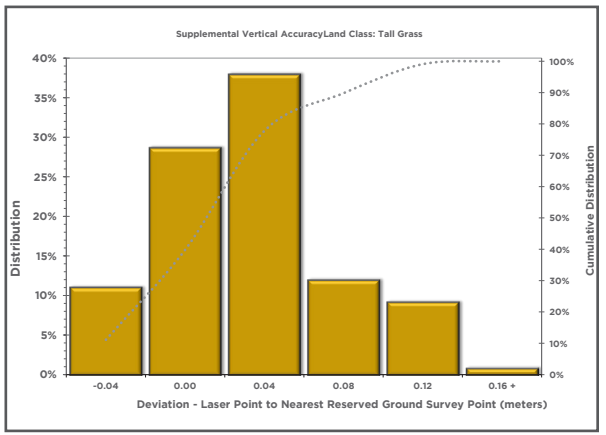



## Supplemental and Consolidated Vertical Accuracies

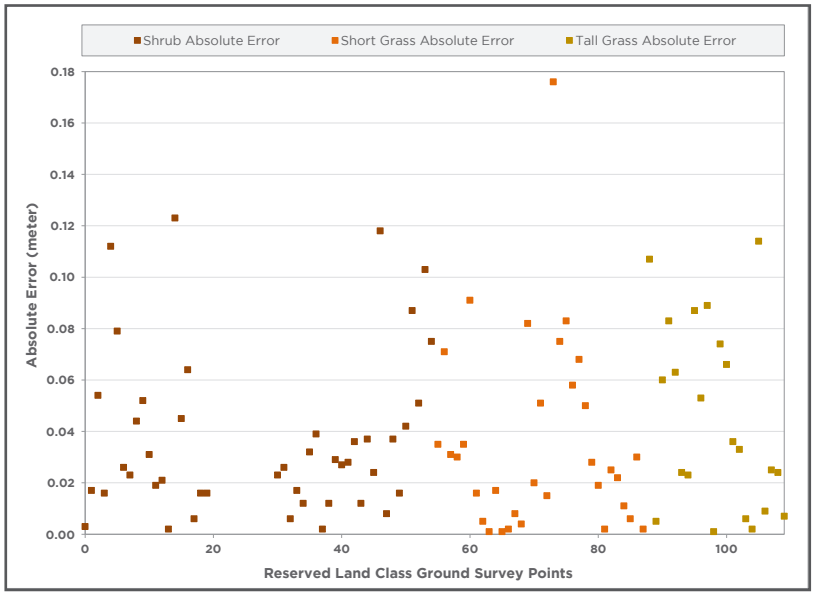
QSI also assessed absolute vertical accuracy for the OLC Chelan FEMA study area, using Supplemental Vertical Accuracy (SVA) and Consolidated Vertical Accuracy (CVA) reporting. SVA compares known ground survey point data within individual land cover class categories to the triangulated ground surface generated by the LiDAR points. CVA, rather, compares known ground survey points within all land cover classes to the triangulated ground surface generated by LiDAR points. SVA and CVA are measures of the accuracy of LiDAR point data in various land cover classes where the LiDAR system has a high probability of measuring the ground surface and is evaluated at the 95th percentile, as shown in the table below.



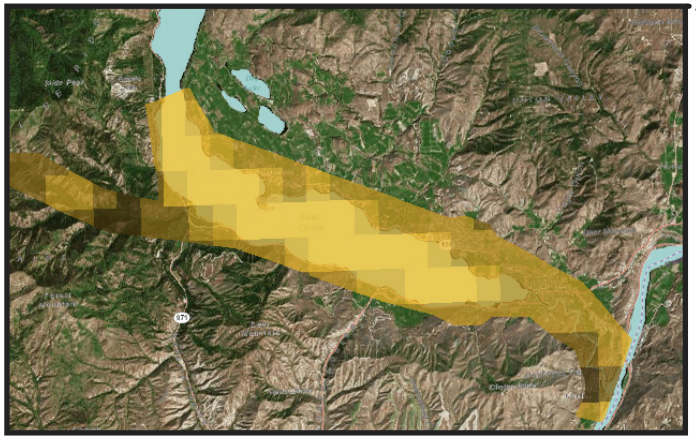

| Vertical Accuracy Results | SVA | | | CVA |
|---|---|---|---|---|
| | Shrub | Short Grass | Tall Grass | All Land Cover Classes |
| Sample Size | n = 45 | n = 33 | n = 30 | n = 231 |
| 1 Standard Deviation | 0.038 m<br>0.125 ft. | 0.035 m<br>0.115 ft. | 0.053 m<br>0.175 ft. | 0.025 m<br>0.082 ft. |
| 2 Standard Deviations | 0.110 m<br>0.362 ft. | 0.086 m<br>0.283 ft. | 0.099 m<br>0.324 ft. | 0.083 m<br>0.272 ft. |
| Average Deviation | 0.037 m<br>0.122 ft. | 0.035 m<br>0.116 ft. | 0.039 m<br>0.127 ft. | 0.025 m<br>0.080 ft. |
| Minimum Deviation | -0.123 m<br>-0.404 ft. | -0.083 m<br>-0.272 ft. | -0.052 m<br>-0.171 ft. | -0.123 m<br>-0.404 ft. |
| Maximum Deviation | 0.118 m<br>0.387 ft. | 0.176 m<br>0.577 ft. | 0.114 m<br>0.374 ft. | 0.176 m<br>0.577 ft. |

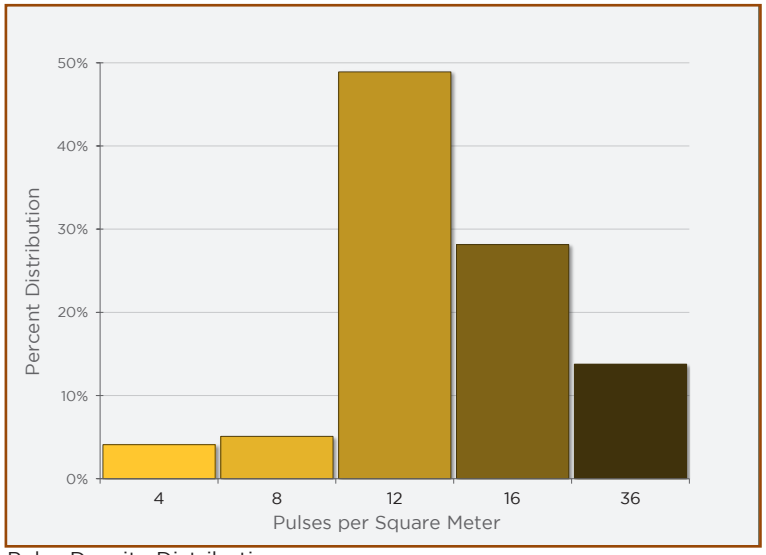


Density

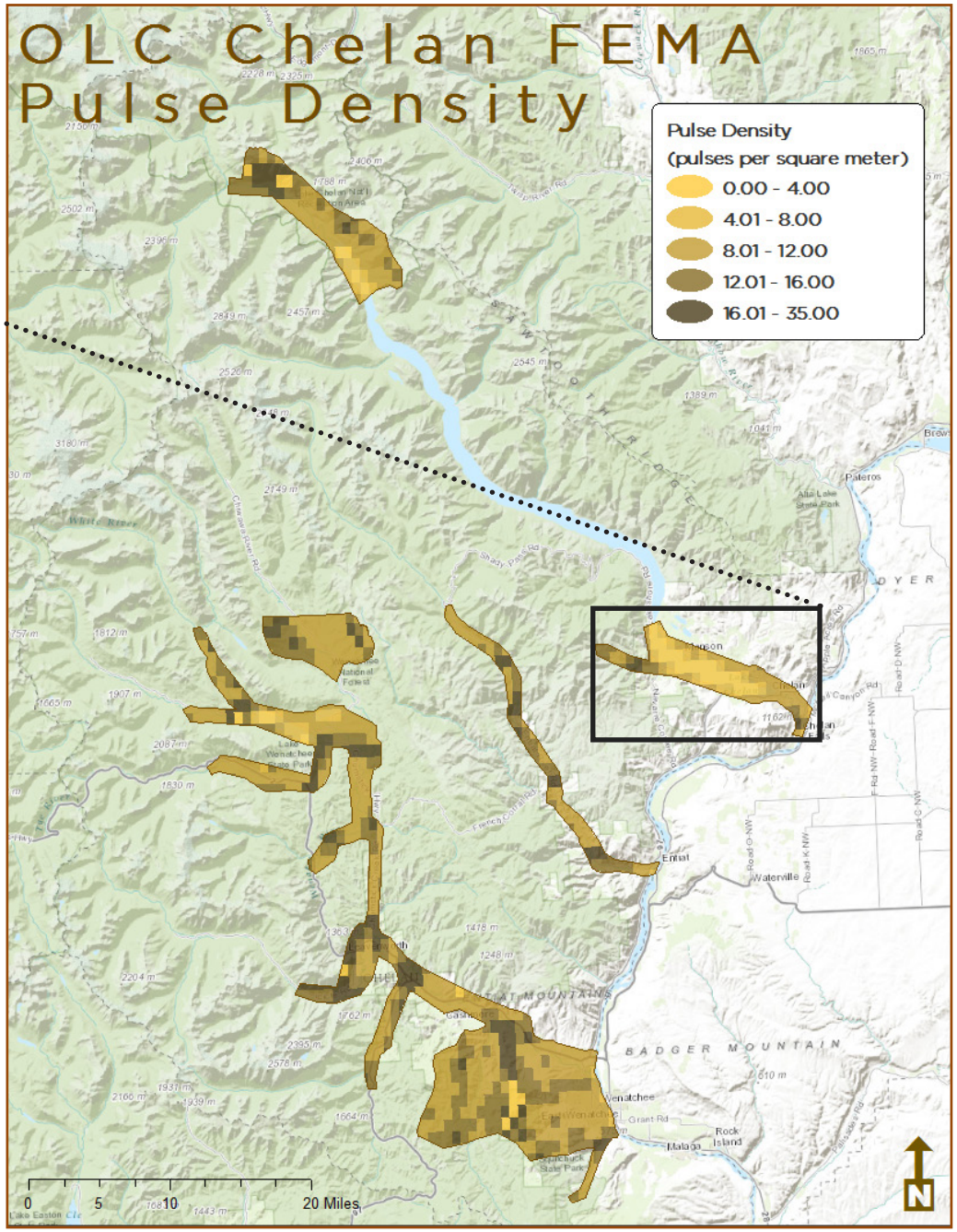
## Pulse Density

Some types of surfaces (e.g., dense vegetation, water) may return fewer pulses than the laser originally emitted. Therefore, the delivered density can be less than the native density and vary according to terrain, land cover, and water bodies. Density histograms and maps have been calculated based on first return laser pulse density and ground-classified laser point density.






Pulse Density Distribution

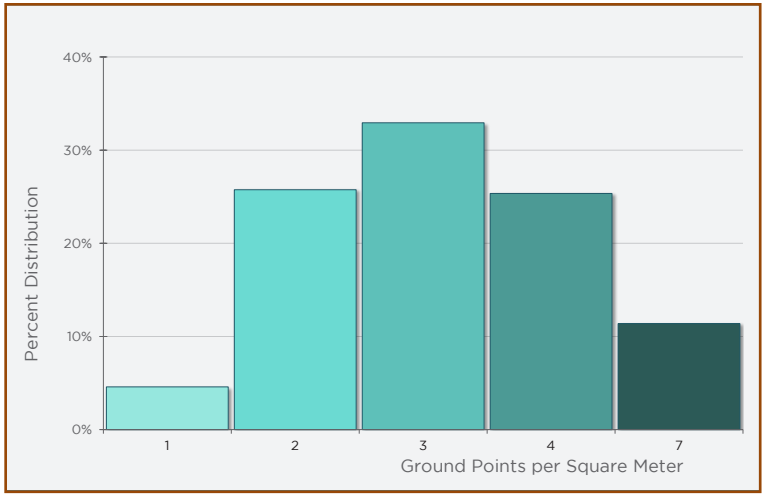



Average Pulse Density per 0.75' USGS Quad (color scheme aligns with density chart).

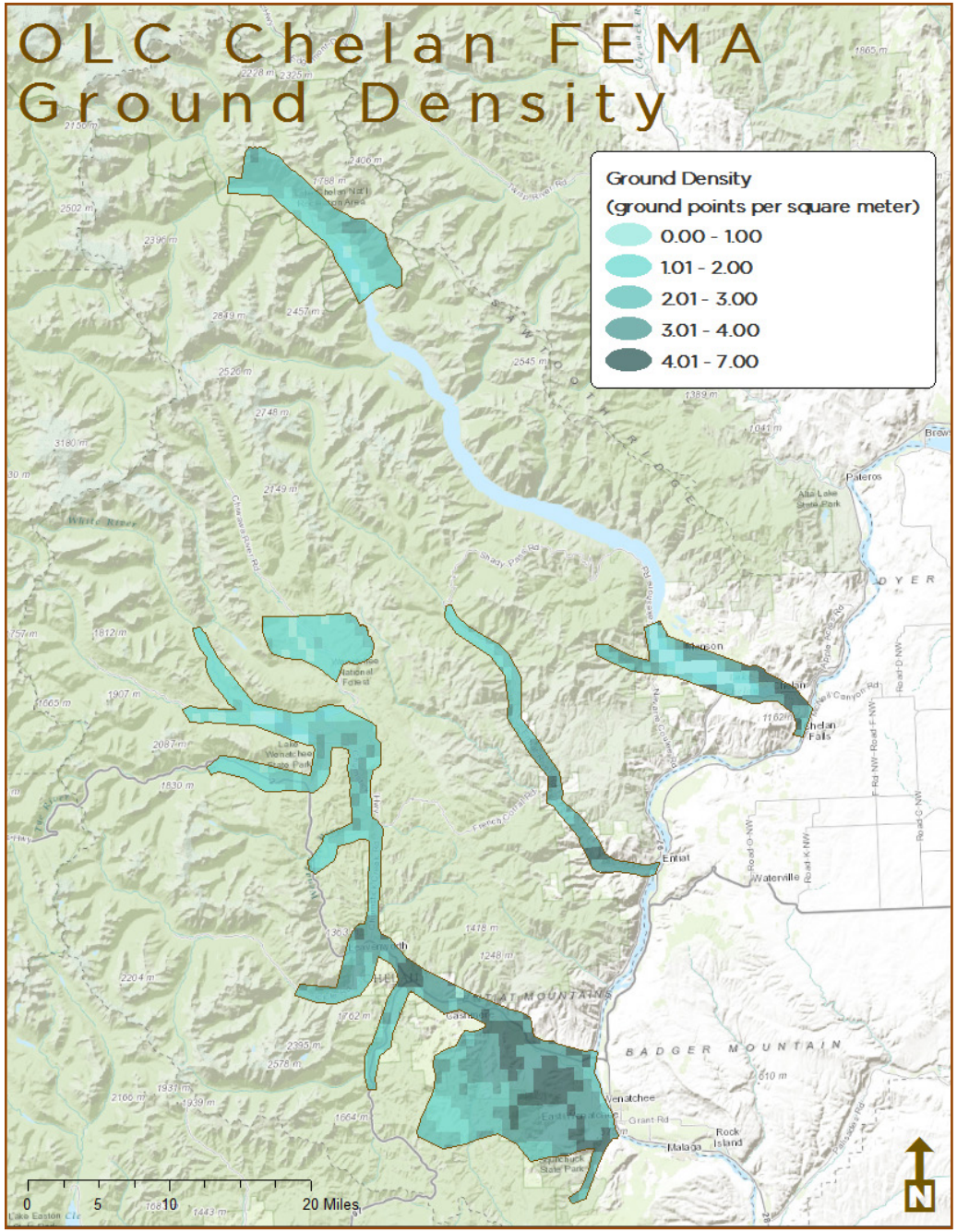
| Average Pulse Density | Average Ground Density |
|---|---|
| Pulses per square meter | Ground points per square meter |
| 12.34 | 2.65 0 |
| Pulses per square foot | Ground points per square foot |
| 1.15 | 0.25 |

## Ground Density

Ground classifications were derived from ground surface modeling. Further classifications were performed by reseeding of the ground model where it was determined that the ground model failed, usually under dense vegetation and/or at breaks in terrain, steep slopes, and at tile boundaries.




Ground Density Distribution




Average Ground Point Density per 0.75' USGS Quad (color scheme aligns with density chart).

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# Appendix
# PLS Certification

WSI, a Quantum Spatial company, provided LiDAR Services for OLC Chelan project as described in this report.

I, John English, have reviewed the attached report for completeness and herby state that it is a complete and accurate report of this project.

John T English 3/18/2016

John English
Project Manager
WSI, a Quantum Spatial Company

I, Christopher Glantz, being duly registered as a Professional Land Surveyor in the state of Washington, say that I hereby certify the methodologies and results of the attached LiDAR project, and that Static GNSS occupations on the Base Stations during airborne flights and RTK survey on hard-surface and GSP's were performed using commonly accepted Standard Practices. Field work conducted for this report was conducted between July 14, 2015 and October 15, 2015. Accuracy statistics shown in the Accuracy Section of this Report have been review by me and found to meet the "National Standard for Spatial Data Accuracy".

3/18/2016

Christopher Glantz, PLS
Land Survey Manager
WSI, a Quantum Spatial Company