2016 OLC Milton Freewater

quantum SPATIAL

Data collected for:

Department of Geology and Mineral Industries

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Contents

Project Overview

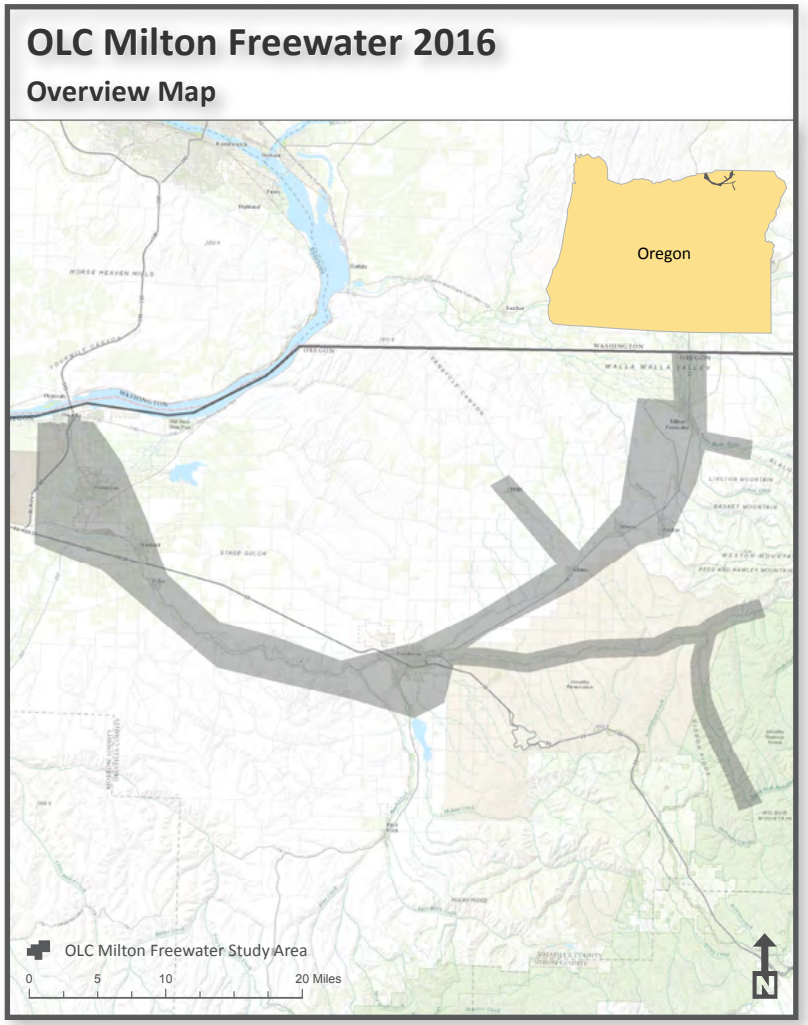
Quantum Spatial has collected Light Detection and Ranging (LiDAR) data for the Oregon LiDAR Consortium (OLC) Milton Freewater study area. This study area is located in Umatilla River, Oregon.

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 May and June of 2016 QSI employed remote-sensing lasers in order to obtain a total area flown of 206,834 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, three foot digital elevation models of highest hit and bare earth ground models, 1.5 foot intensity and ground density rasters, study area vector shapes, and corresponding statistical data. Final deliverables are projected in OGIC.

OLC Milton Freewater Data	
LiDAR Acquisition Dates	5/28/2016 - 6/5/2016
Area of Interest	197,093 acres
Bufered Area of Interest	206,834 acres
Projection	OGIC
Horizontal Datum Vertical Datum	NAD83 (2011) Epoch 2010.00 NAVD88 (Geoid 12A)
Units	International Feet



Study Area

Aerial Acquisition

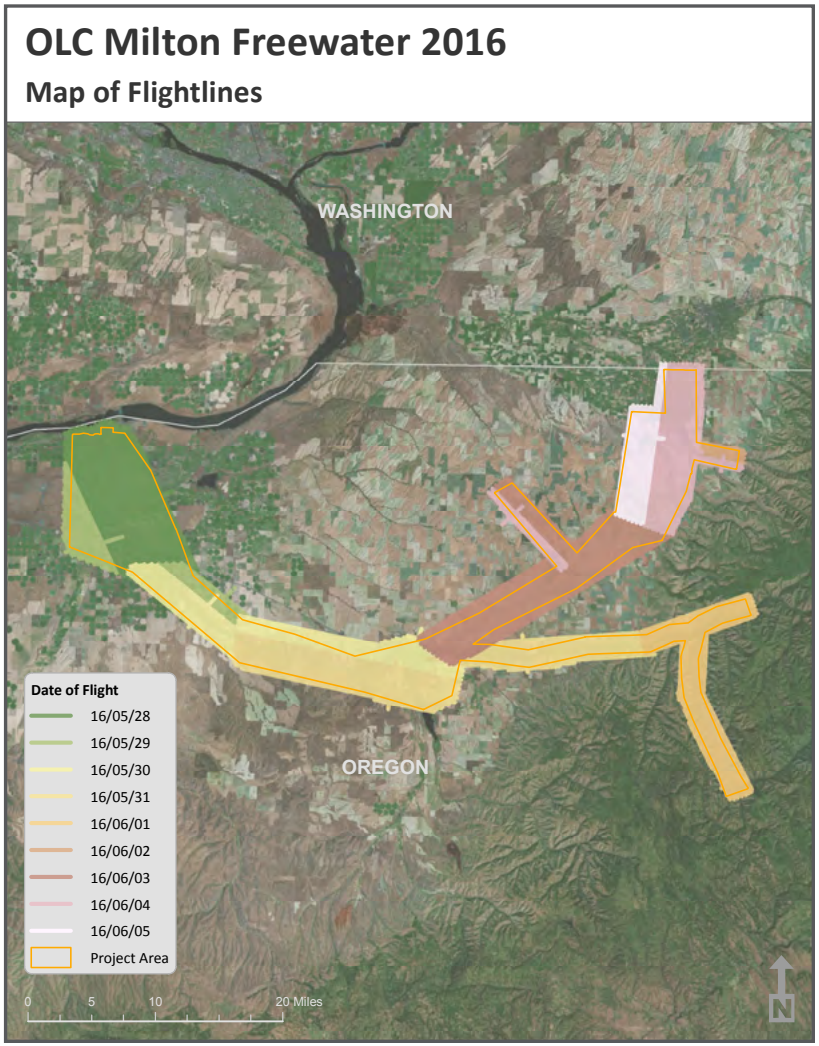
LiDAR Survey

The LiDAR survey occurred between May 28, 2016 and June 5, 2016 utilizing a Leica ALS80 mounted in a Cessna Grand Caravan. The systems were programmed to emit single pulses at around 191 kHz and flown at 1,400 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).

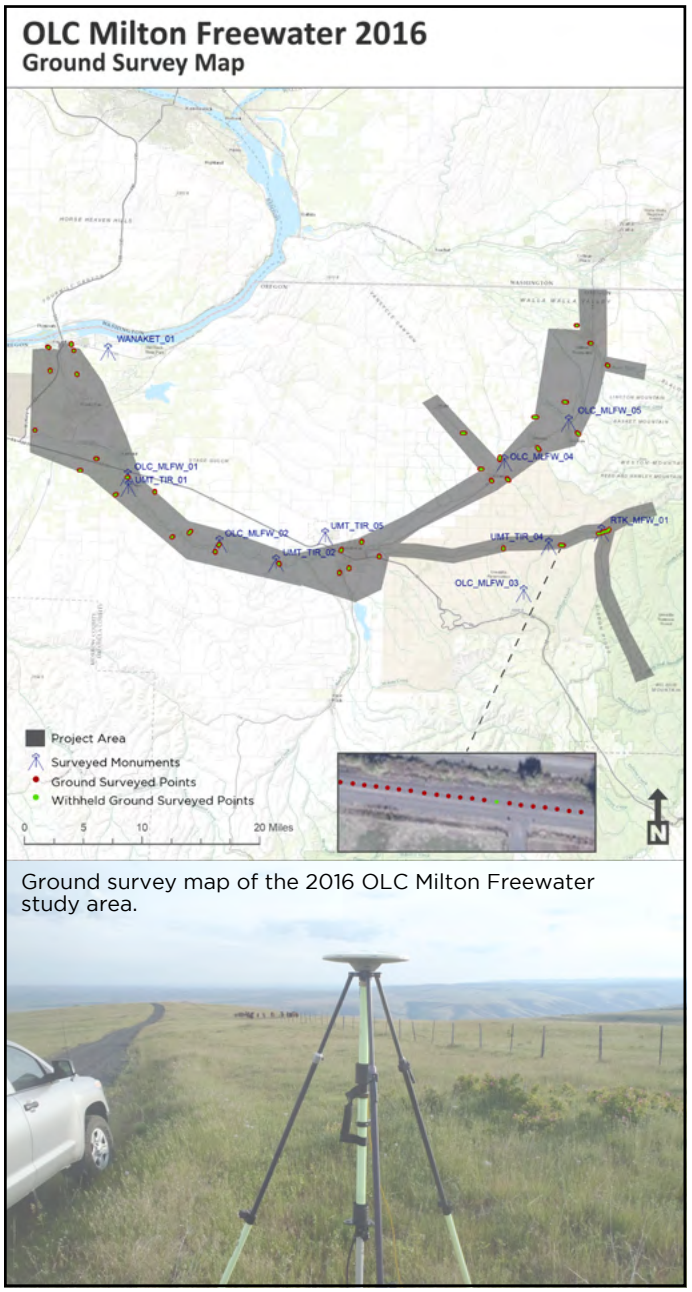
The LiDAR sensor operators constantly monitored the data collection settings during acquisition of the data, including pulse rate, power setting, scan rate, gain, field of view, and pulse mode. For each flight, the crew performed airborne calibration maneuvers designed to improve the calibration results 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 Milton Freewater LiDAR Acquisition Specs	
Sensor	Leica ALS80
Aircraft	Cessna Grand Caravan
Acquisition Date Range	5/28 /2016 - 6/5/2016
Coverage	100% Overlap with 60% Sidelap
Field of View (FOV)	30 degrees
Targeted Pulse Density	≥8 PPSM
Pulse Rate	191 kHz
Speed	105 kts



Map of Flightlines

Ground Survey



Ground survey map of the 2016 OLC Milton Freewater study area.

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.

Monumentation

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 five existing monuments and established six new monuments for the OLC Milton Freewater 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, Evon Silvia (OR PLS #81104) oversaw and certified the establishment of all monuments.

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

PID	Latitude	Longitude	Ellipsoid Height (m)	NAVD88 Height (m)
OLC_MLFW_01	45° 45' 18.56936"	-119° 12' 05.33412"	213.153	234.777
OLC_MLFW_02	45° 40' 34.20380"	-119° 02' 13.81275"	217.632	238.840
OLC_MLFW_03	45° 37' 23.18076"	-118° 30' 00.18161"	1066.919	1086.532
OLC_MLFW_04	45° 47' 01.54639"	-118° 32' 19.84698"	465.864	486.342
OLC_MLFW_05	45° 50' 02.65100"	-118° 25' 35.17334"	536.509	556.792
RTK_MFW_01	45° 41' 58.75191"	-118° 21' 55.33523"	514.808	534.369
UMT_TIR_01	45° 44' 30.77549"	-119° 11' 59.76564"	174.257	195.863
UMT_TIR_02	45° 39' 16.07479"	-118° 56' 12.17545"	254.080	275.081
UMT_TIR_04	45° 40' 56.73943"	-118° 27' 27.93252"	462.084	481.951
UMT_TIR_05	45° 41' 19.18429"	-118° 51' 06.11865"	431.272	452.222
WANAKET_01	45° 54' 32.63587"	-119° 14' 32.76374"	129.319	151.037

Monument Accuracy	
FGDC-STD-007.2-1998 Rating	
St Dev NE	0.020 m
St Dev Z	0.020 m

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) and Post-Processed Kinematic (PPK) survey techniques. For RTK surveys, a base receiver is positioned at a nearby monument to broadcast a kinematic correction to a roving receiver; for PPK surveys, however, these corrections are post-processed. 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.

Photo taken during ground survey - WANAKET_1 monument, R7 unit

Land cover descriptions of check points taken for the OLC Milton Freewater study area.

Land Cover Type	Land Cover Code	Description
Shrub	SHRUB	Areas dominated by shrubs
Tall Grass	TALL GRASS	Areas dominated by tall grass
Short Grass	SHORT GRASS	Areas dominated by short grass
Agriculture	AGRICULTURE	Areas dominated by agriculture lands
Urban	URBAN	Areas dominated by urban lands

Ground survey instrumentation

Instrumentation			
Receiver Model	Antenna	OPUS Antenna ID	Use
Trimble R7 GNSS	Zephyr GNSS Geodetic Model 2 RoHS	TRM57971.00	Static
Trimble R8	Integrated Antenna R8 Model 2	TRM_R8_GNSS	Static, Rover

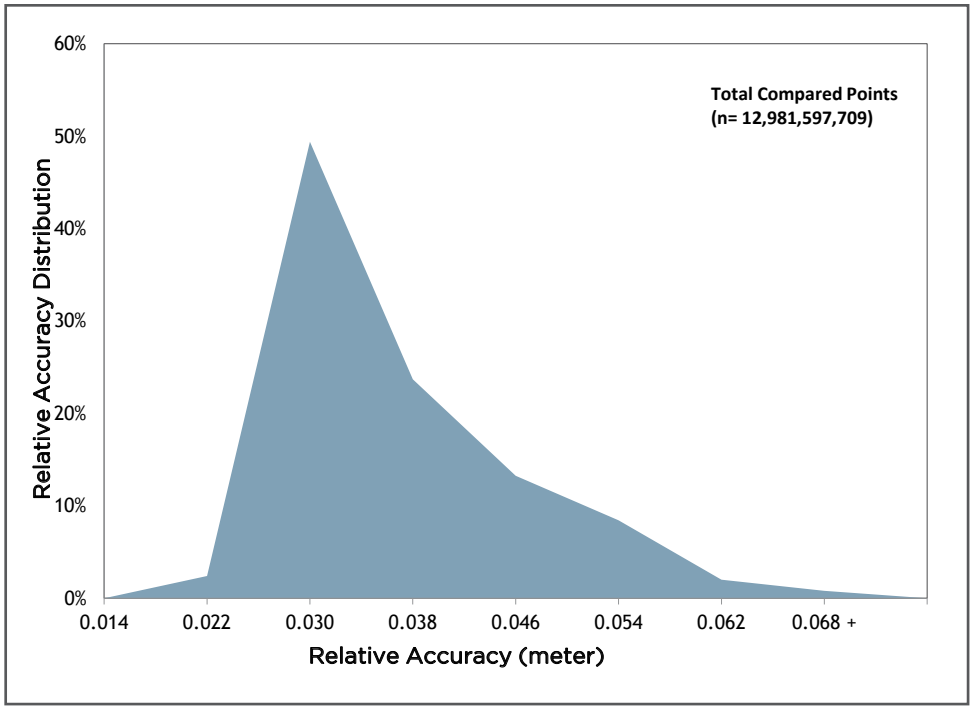
Accuracy

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 249 flightlines and 12,981,597,709 LiDAR points. Relative accuracy is reported for the entire study area.

Relative Accuracy Calibration Results	
Flightlines	249
Sample points	n = 12,981,597,709
Project Average	0.033 m 0.107 ft.
Median Relative Accuracy	0.029 m 0.098 ft.
1σ Relative Accuracy	0.034 m 0.113 ft.
2σ Relative Accuracy	0.050 m 0.165 ft.



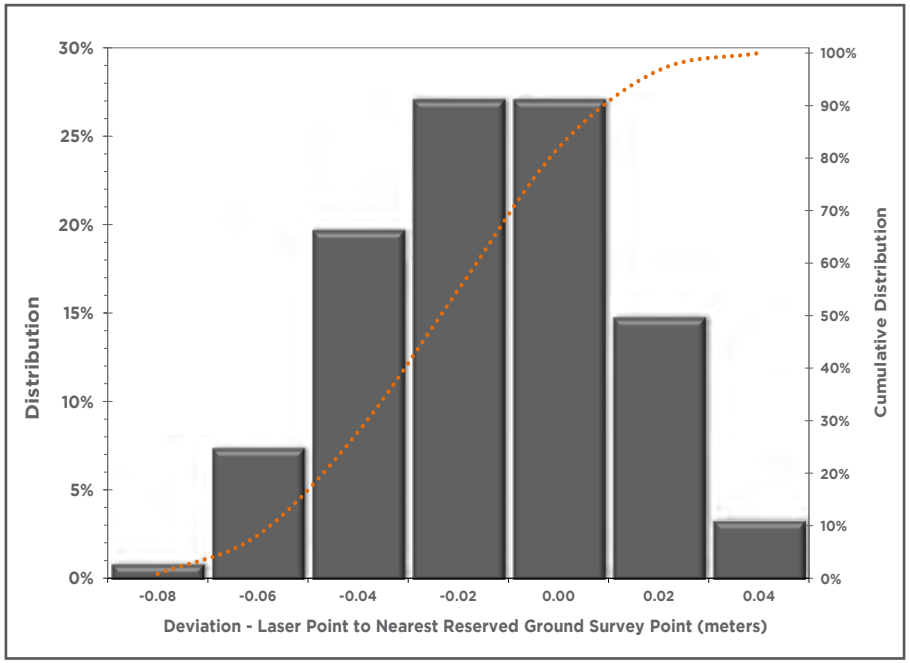
Vertical Accuracy

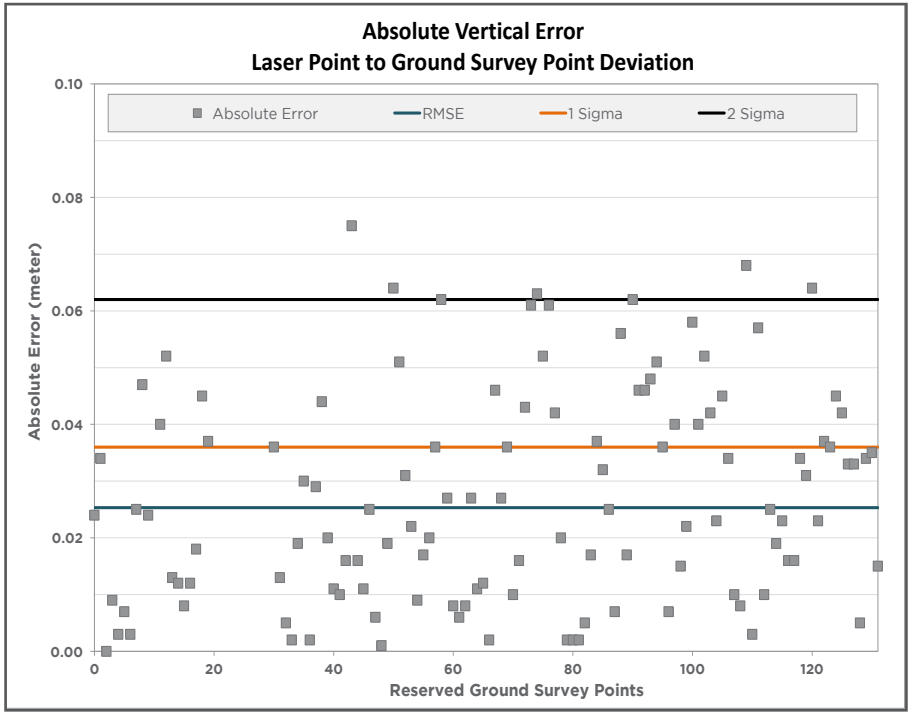
Vertical Accuracy reporting is designed to meet guidelines presented in the National Standard for Spatial Data Accuracy (NSSDA) (FGDC, 1998) and the ASPRS Guidelines for Vertical Accuracy Reporting for LiDAR Data V1.0 (ASPRS, 2014). The statistical model compares known ground survey points (GSPs) to 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 is evaluated at the 95th percentile.

For the OLC Milton Freewater study area, a total of 2,351 GSPs were collected. An additional 122 reserved ground survey points were collected for independent verification, resulting in a fundamental vertical accuracy (FVA) of 0.050 meters.

Vertical Accuracy Results	Hard Surface
Sample Size (n)	n = 122 GSPs
FVA (RMSE*1.96)	0.050 m (0.163 ft.)
Root Mean Square Error	0.025 m (0.083 ft.)
1 Standard Deviation	0.036 m (0.118 ft.)
2 Standard Deviations	0.062 m (0.203 ft.)
Average Deviation	0.028 m (0.091 ft.)
Minimum Deviation	-0.094 m (-0.308 ft.)
Maximum Deviation	0.036 m (0.118 ft.)

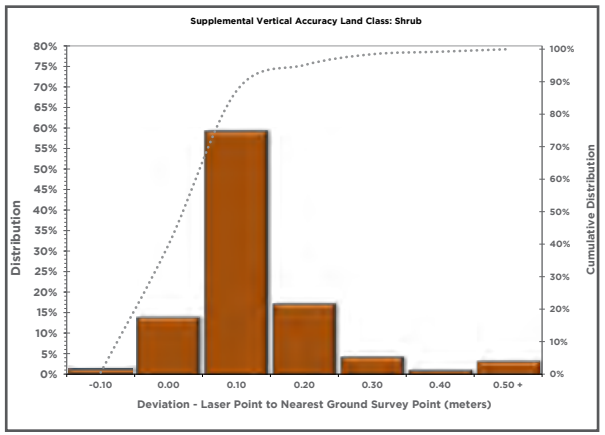
Vertical Accuracy Distribution

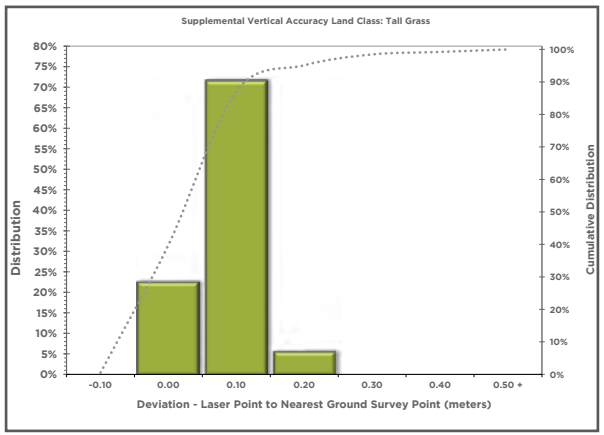


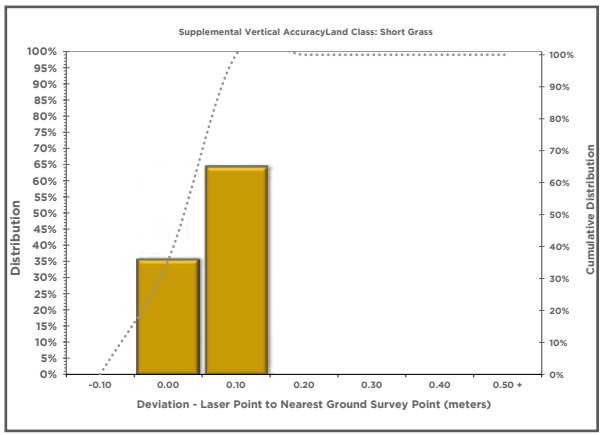


Supplemental and Consolidated Vertical Accuracies

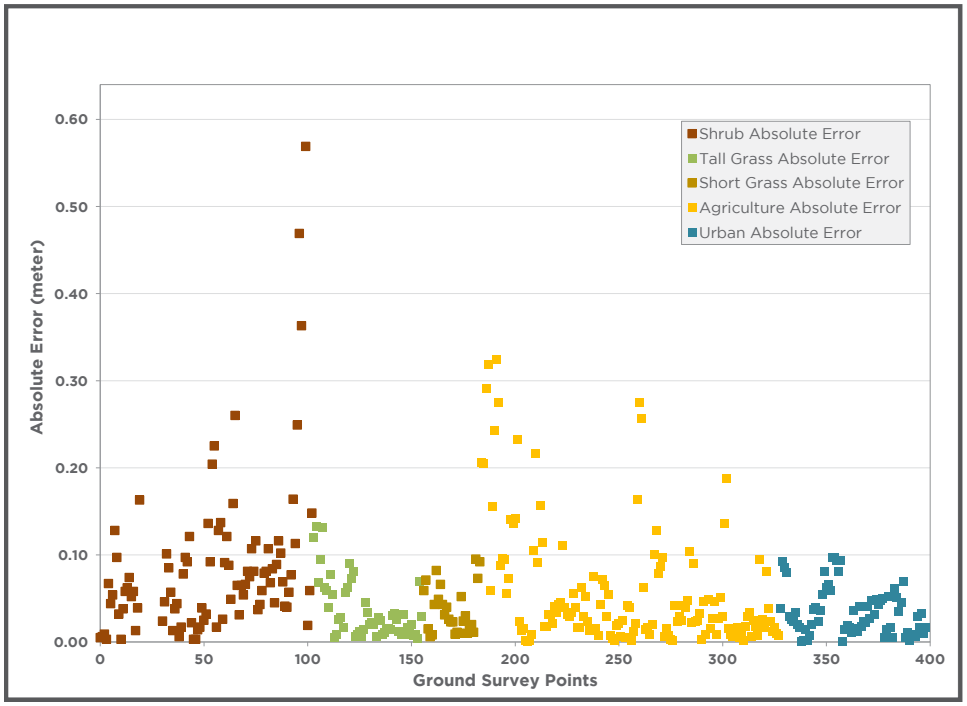
QSI also assessed absolute vertical accuracy for the OLC Milton Freewater study area, using Supplemental Vertical Accuracy (SVA) and Consolidated Vertical Accuracy (CVA) reporting. SVA compares known ground survey point data within individual land cover class categories to the triangulated ground surface 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.



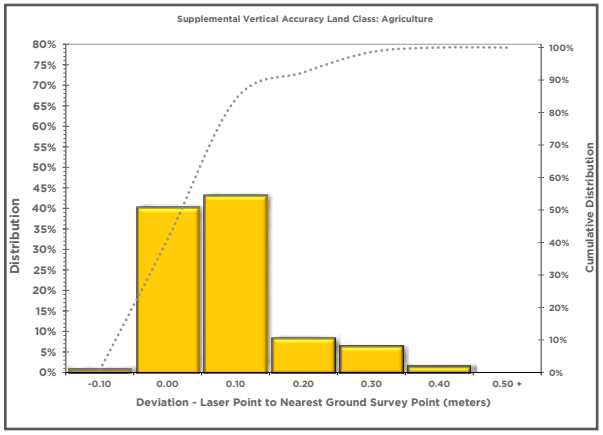


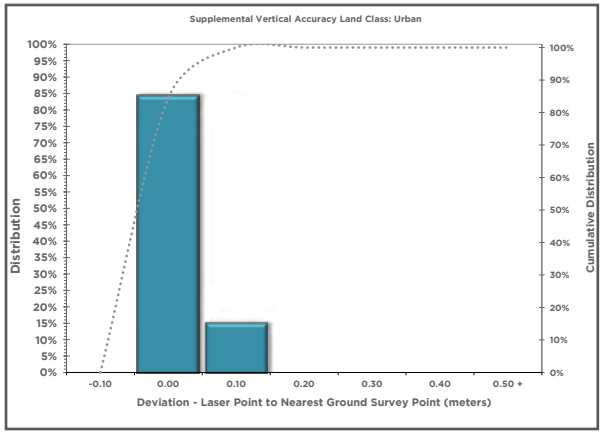


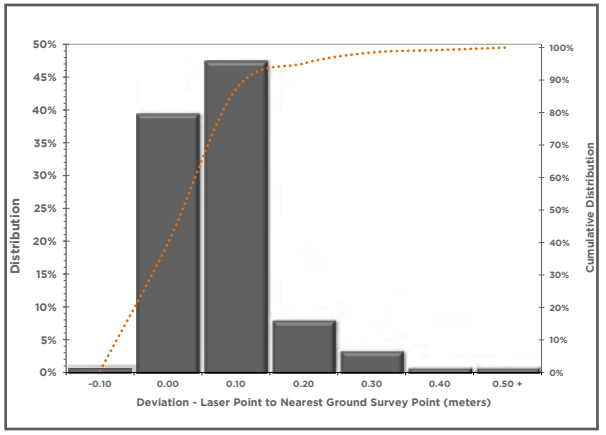
Vertical Accuracy Results	SVA					CVA
	Shrub	Tall Grass	Short Grass	Agriculture	Urban	All Land Cover Classes
Sample Size	n = 93	n = 53	n = 28	n = 144	n = 71	n = 389
1 Standard Deviation	0.089 m 0.291 ft.	0.034 m 0.111 ft.	0.044 m 0.143 ft.	0.049 m 0.160 ft.	0.041 m 0.135 ft.	0.058 m 0.190 ft.
2 Standard Deviations	0.253 m 0.831 ft.	0.105 m 0.344 ft.	0.089 m 0.290 ft.	0.230 m 0.753 ft.	0.093 m 0.303 ft.	0.178 m 0.585 ft.
Average Deviation	0.091 m 0.298 ft.	0.036 m 0.118 ft.	0.037 m 0.121 ft.	0.058 m 0.190 ft.	0.035 m 0.114 ft.	0.057 m 0.187 ft.
Minimum Deviation	-0.107 m -0.351 ft.	-0.033 m -0.108 ft.	-0.040 m -0.131 ft.	-0.111 m -0.364 ft.	-0.097 m -0.318 ft.	-0.111 m -0.364 ft.
Maximum Deviation	0.643 m 2.110 ft.	0.133 m 0.436 ft.	0.095 m 0.312 ft.	0.324 m 1.063 ft.	0.033 m 0.108 ft.	0.643 m 2.110 ft.



Monument OLC_MLFW_02 established for OLC Milton Freewater project







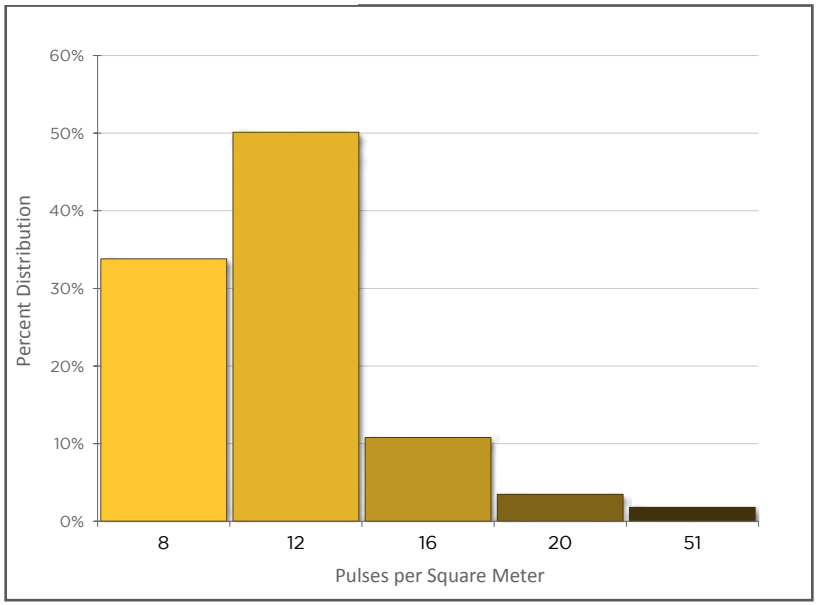
Density

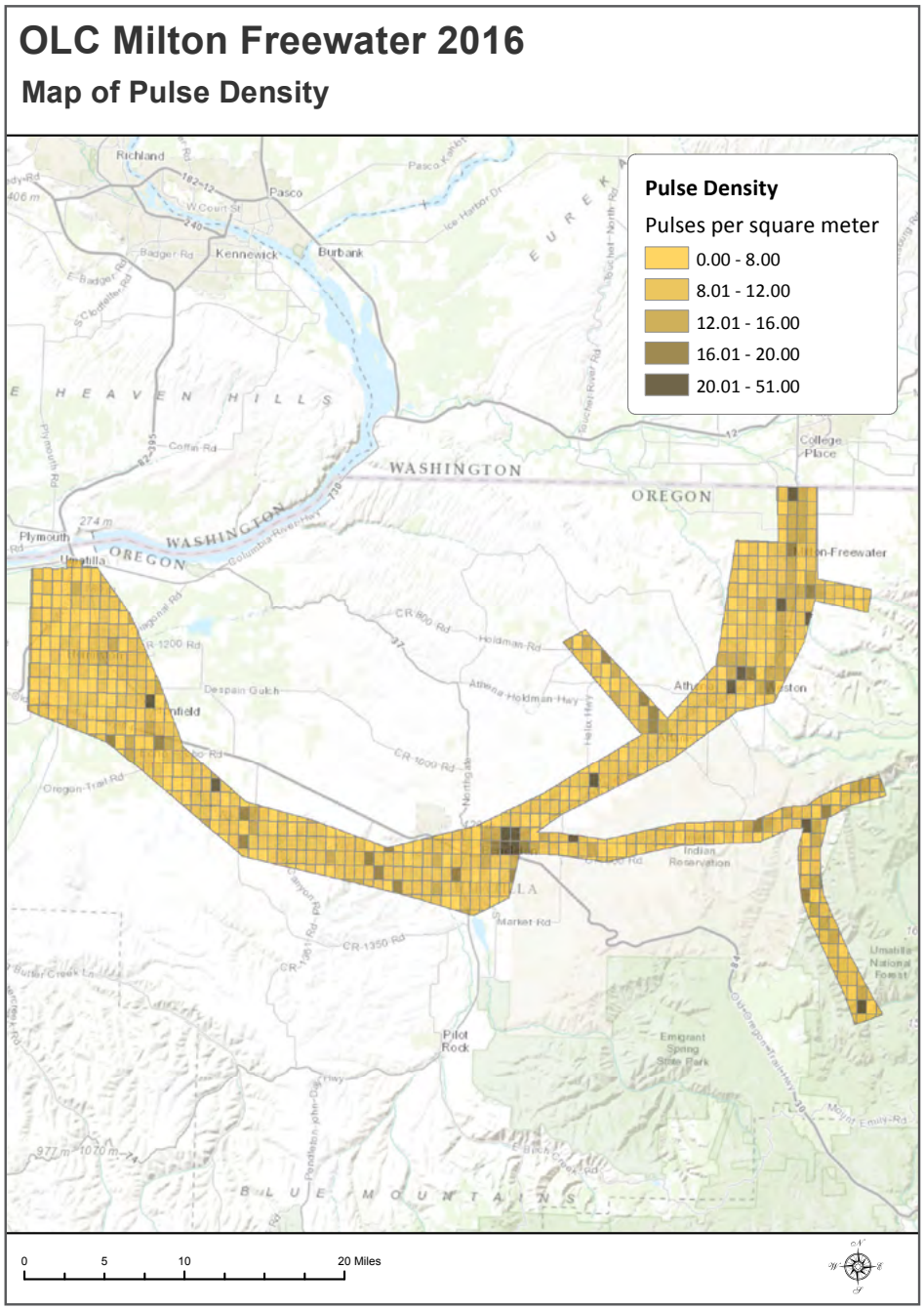
Pulse Density

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.

Average Point Densities			
Pulses per square meter	Pulses per square foot	Ground points per square meter	Ground points per square foot
8.69	0.81	2.11	0.20

Pulse Density Distribution



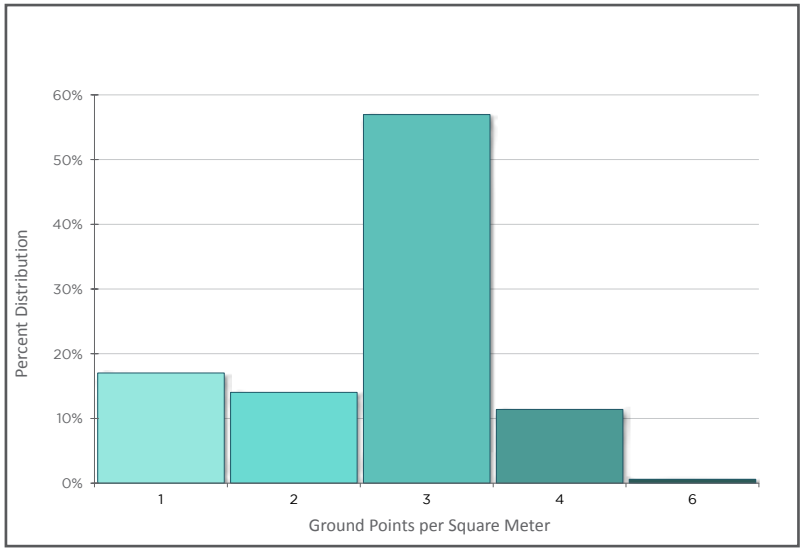


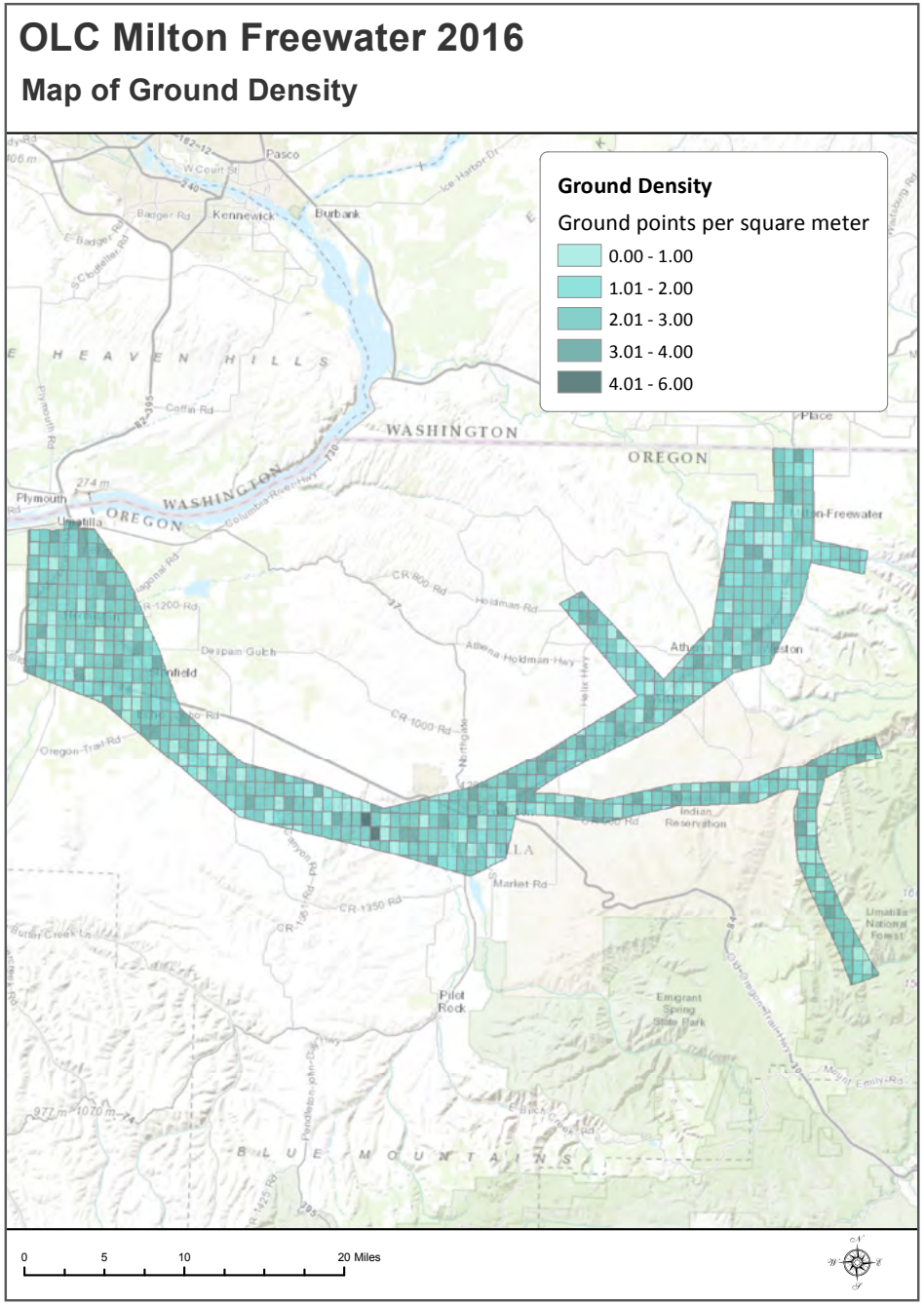
Average Pulse Density per 0.75' USGS Quad (color scheme aligns with density chart).

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

Quantum Spatial, Inc. provided LiDAR services for the 2016 OLC Milton Freewater project as described in this report.

I, Evon P. Silvia, being duly registered as a Professional Land Surveyor in and by the state of Oregon, hereby certify that the methodologies, static GNSS occupations used during airborne flights, and ground survey point collection were performed using commonly accepted Standard Practices. Field work conducted for this report was conducted between May 24, 2016 and June 21, 2016.

Accuracy statistics shown in the Accuracy Section of this Report have been reviewed by me and found to meet the "National Standard for Spatial Data Accuracy".

Evon P. Silvia 2016.09.13 10:14:56 -07'00'

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