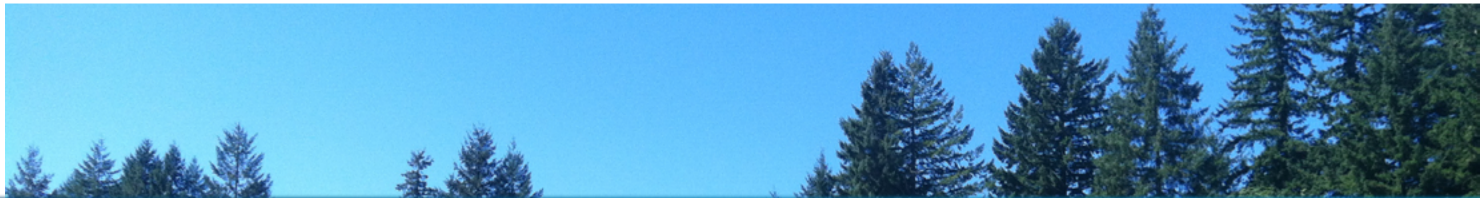
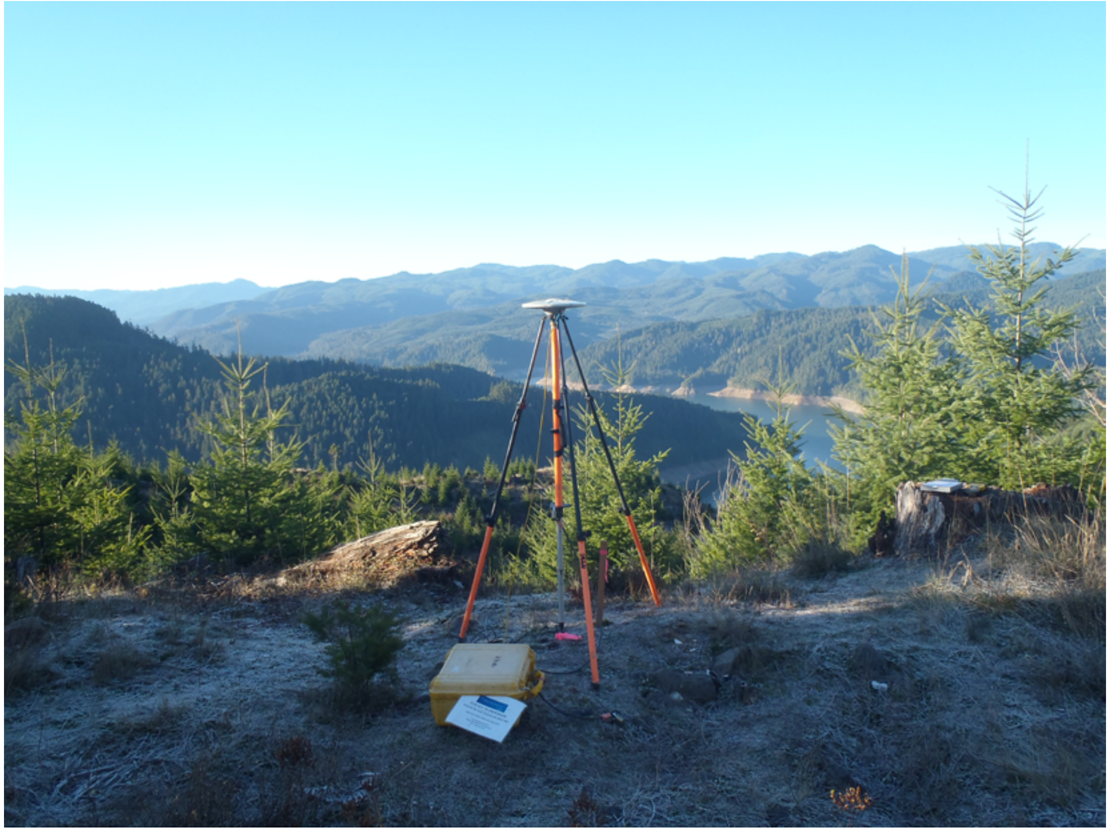
WSI Applied Remote Sensing and Analysis



OLC Lane County: Delivery 3

March 24, 2014



Base station set up over control “LANE 25”

Data collected for:
Oregon Department of Geology and Mineral Industries

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Prepared by:
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Contents

"Lane 24" survey cap

Project Overview

WSI has completed the acquisition and processing of Light Detection and Ranging (LiDAR) data and Four-Band Radio Metric Image Enhanced Survey (FRIES) of the OLC Lane County Delivery Area Three, for the Oregon Department of Geology and Mineral Industries (DOGAMI). The Oregon LiDAR Consortium's Lane County project area of interest (AOI) encompasses 1,611,890 acres. Delivery Area Three encompasses 132,012 acres.

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.

WSI began data collection on September 5, 2013 for the Lane County project and collection is currently ongoing contingent upon weather. Settings for LiDAR data capture produced an average resolution of at least eight pulses per square meter.

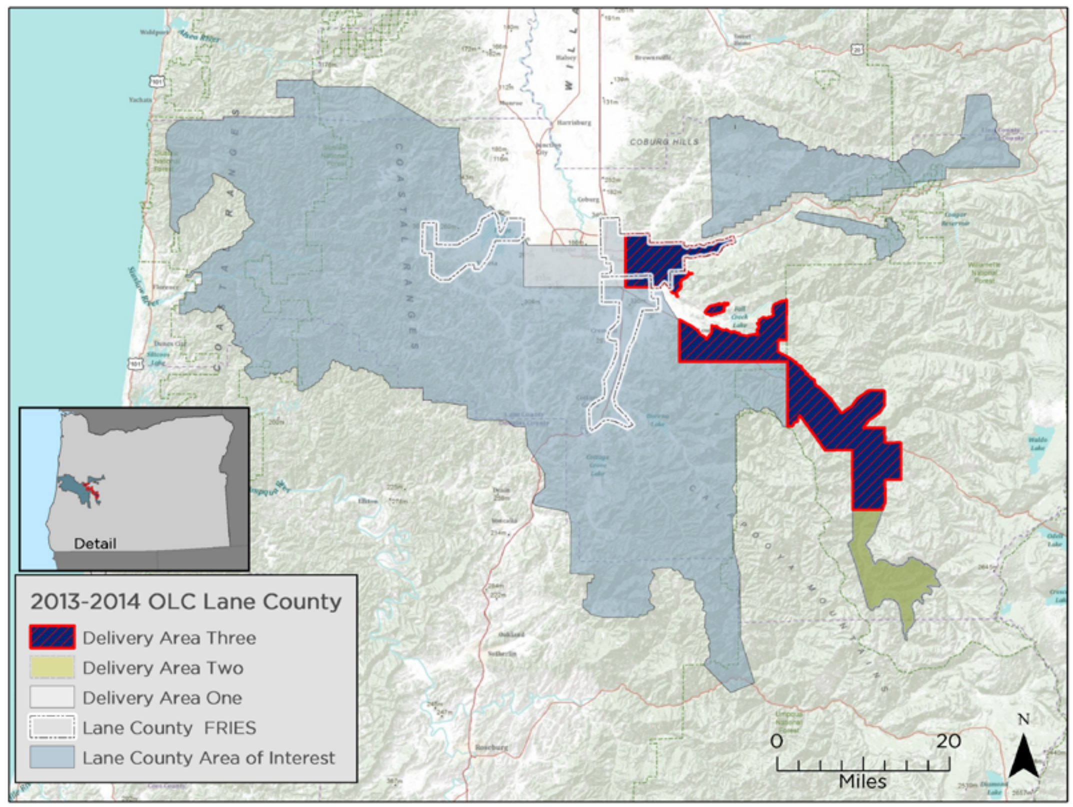
Final products created include LiDAR point cloud data, three-foot digital elevation models of bare earth ground model and highest-hit returns, 1.5-foot intensity rasters, 3-inch orthophotos, ground density rasters, study area vector shapes, and corresponding statistical data.

WSI acquires and processes data in the most current, NGS-approved datums and geoid. For OLC Lane county, all final deliverables are projected in Oregon Lambert, endorsed by the Oregon Geographic Information Council (OGIC),[1] using the NAD83(2011) horizontal datum and the NAVD88 (Geoid 12a) vertical datum, with units in international feet.

1 http://www.oregon.gov/DAS/EISPD/GEO/pages/coordination/projections/projections.aspx

OLC Lane County AOI Data Delivered January 24, 2014	
Acquisition Dates	September 7, 2013- January 25, 2014
Delivery Area Three Area of Interest	132,012 acres
Lane County 2013/2014 Area of Interest	1,611,264 acres
Projection	Oregon Lambert
Datum: horizontal & vertical	NAD83 (2011) NAVD88 (Geoid 12A)
Units	International Feet

Study Area



Aerial Acquisition

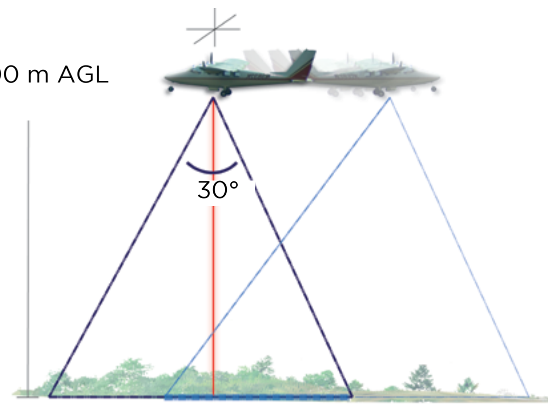
Cessna Caravan

LiDAR Survey

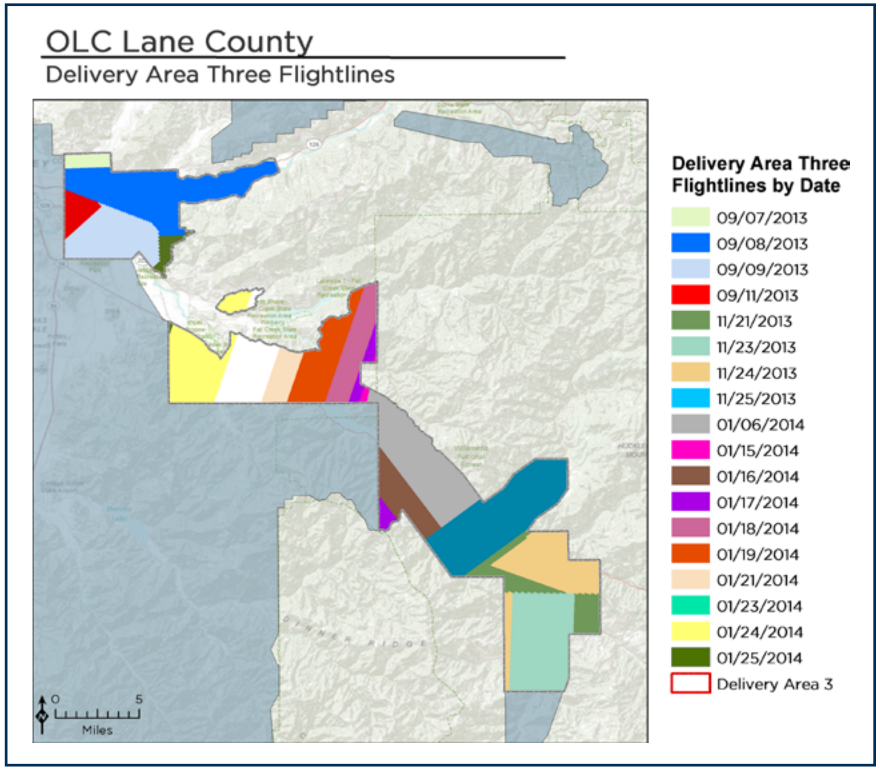
The LiDAR survey utilized both Leica ALS70 and ALS50 sensors mounted in a Cessna Caravan 208B and Piper PA-31 respectively. The systems were programmed to emit single pulses at a rate of 190 to 198 kilohertz, and flown at 1,400 meters or 900 meters above ground level (AGL), capturing a scan angle of +/-15 degrees from nadir (field of view equal to 30 degrees). These settings are developed to yield points with an average native density of greater than eight pulses per square meter over terrestrial surfaces.

The native pulse density is the number of pulses emitted by the LiDAR system. Some types of surfaces such as dense vegetation or water may return fewer pulses than the laser originally emitted. Therefore, the delivered density can be less than the native density and lightly vary according to distributions of terrain, land cover, and water bodies. The study area was surveyed with opposing flight line side-lap of greater than 65 percent with at least 100 percent overlap to reduce laser shadowing and increase surface laser painting. The system allows up to four range measurements per pulse, and all discernible laser returns were processed for the output dataset.

To solve for laser point position, it is vital to have an accurate description of aircraft position and attitude. Aircraft position is described as x, y, and z and measured twice per second (two hertz) by an onboard differential GPS unit. Aircraft attitude is measured 200 times per second (200 hertz) as pitch, roll, and yaw (heading) from an onboard inertial measurement unit (IMU). As illustrated in the accompanying map, 572 flightlines provide coverage of the study area.



Project Flightlines



Lane County Acquisition Specifications	
Sensors Deployed	Leica ALS 50 and Leica ALS 70
Aircraft	Cessna Caravan 208B, Piper-PA
Survey Altitude (AGL)	1400 m / 900 m
Pulse Rate	190-198 kHz
Pulse Mode	Single (SPiA)
Field of View (FOV)	30°
Roll Compensated	Yes
Overlap	100% overlap with 65% sidelap
Pulse Emission Density	≥ 8 pulses per square meter

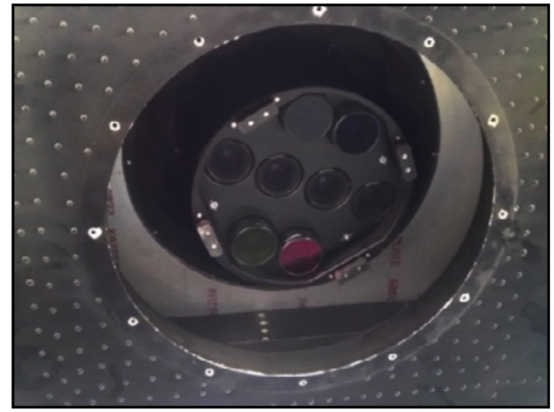
Aerial Acquisition

Photography

The photography or Four-Band Radio Metric Image Enhanced Survey (FRIES) utilized an UltraCam Eagle 260 megapixel camera mounted in a Cessna 208B Caravan. The UltraCam Eagle is an 80 mm, 260 megapixel large format digital aerial camera manufactured by the Microsoft Corporation. The system is gyro-stabilized and contains a fully integrated UltraNav flight management system with a POS-AV 510 IMU embedded within the body of the camera unit.

The Eagle was designed with high efficiency, high resolution, and high accuracy in mind. With a physical pixel size of 5.2 microns, the Eagle captures a 6.5 cm ground sample distance (GSD) at a flying height of 1,000 meters AGL. This sensor size of the camera is 20,010 x 13,080 pixels in size, which allows for total ground coverage of 1300 x 850 meters within a single captured image frame at 1,000 meters AGL. This large footprint coupled with a fast frame rate (1.8 seconds per frame) allows for highly efficient acquisition. The precise integrated UltraNav system is accurate enough for direct georeferencing in many applications.

The UltraCam Eagle simultaneously collects panchromatic and multispectral (RGB, NIR) imagery in 14 bit format. The spectral sensitivity of the panchromatic charged coupled device (CCD) array ranges from 400-720 nm, with 16,000 grey values per pixel. Four separate 27 mm lenses collect red (590-720 nm), green (490-660 nm), blue (410-590 nm) and near infrared (690-990 nm) light. Panchromatic lenses collect high resolution imagery by illuminating nine CCD arrays, writing nine raw image files. RGB and NIR lenses collect lower resolution imagery, written as four individual raw image files. Level 2 images are created by stitching together raw image data from the nine panchromatic CCDs, and ultimately combined with the multispectral image data to yield Level 3 pan-sharpened TIFFs in either 8 bit format.



Above: UltraCam Eagle lens configuration as viewed from the Cessna Caravan.

Above: A Cessna Grand Caravan 208B was employed in the collection of all orthoimagery.

Below: UltraCam Eagle installed in the aircraft.

Orthophoto Processing

Within the UltraMap software suite, raw acquired images are radiometrically and geometrically corrected using the camera's calibration files and output as Level 2 images. The resulting radiometry is then manually edited to ensure each image has the appropriate tone, no pixels are clipped, and to blend each image with its neighbors. Once radiometry has been edited, separate RGBI and Panchromatic images are blended together to form single level 3 pan-sharpened 4 band TIFF images.

The kinematic GPS positional data is post-processed in office, using static monument coordinates from base stations that were occupied for a minimum of 6 hours, and were running during the time of acquisition. Photo position and orientation are calculated by linking the time of image capture, the corresponding aircraft position and attitude, and the smoothed best estimate of trajectory (SBET) data in POSPacMMS, and outputting an initial Exterior Orientations (EO) file.

The EO file is combined with level 3 TIFFs within the Inpho software suite to place the images frames spatially. Aerial triangulation is performed to tie the image frames to each other, and to align them with surveyed ground control coordinates. A point cloud ground model is generated from the image frames by finding matching pixels between images and calculating the coordinates of each extracted point. Triangulated image frames are then draped onto a DEM, derived from the extracted point cloud and orthorectified. Individual orthorectified tiffs are blended together to remove seams and corrected for any remaining radiometric differences between images using Inpho's OrthoVista. The 4-Band image mosaic is tiled to create a usable GeoTIFF raster product.

The 4-band GeoTIFF format allows for flexibility in image analysis and display. By adjusting the image band setup to display the near infrared spectral band as red (this display is known as color-infrared), vegetation stands out extremely vividly in the orthophoto mosaic.

Digital Orthophotography Survey Specifications	
Aircraft	Cessna 208-B Grand Caravan
Sensor	UltraCam Eagle
Altitude	1,846 m AGL
GPS Satellite Constellation	6
GPS PDOP	3.0
GPS Baselines	≤ 13nm
Image	8-bit GeoTIFF
Along Track Overlap	60%
Spectral Bands	Red, Green, Blue, NIR
Resolution	3 in. pixel size

Below: Trimble R7 set up over Lane_19

Ground Survey

During the LiDAR survey, static (one hertz recording frequency) ground surveys were conducted over three monuments with known coordinates. After the airborne survey, the static GPS data were processed using triangulation with CORS stations and using the Online Positioning User Service (OPUS) to quantify daily variance. Multiple sessions were processed over the same monument to confirm antenna height measurements and reported position accuracy.

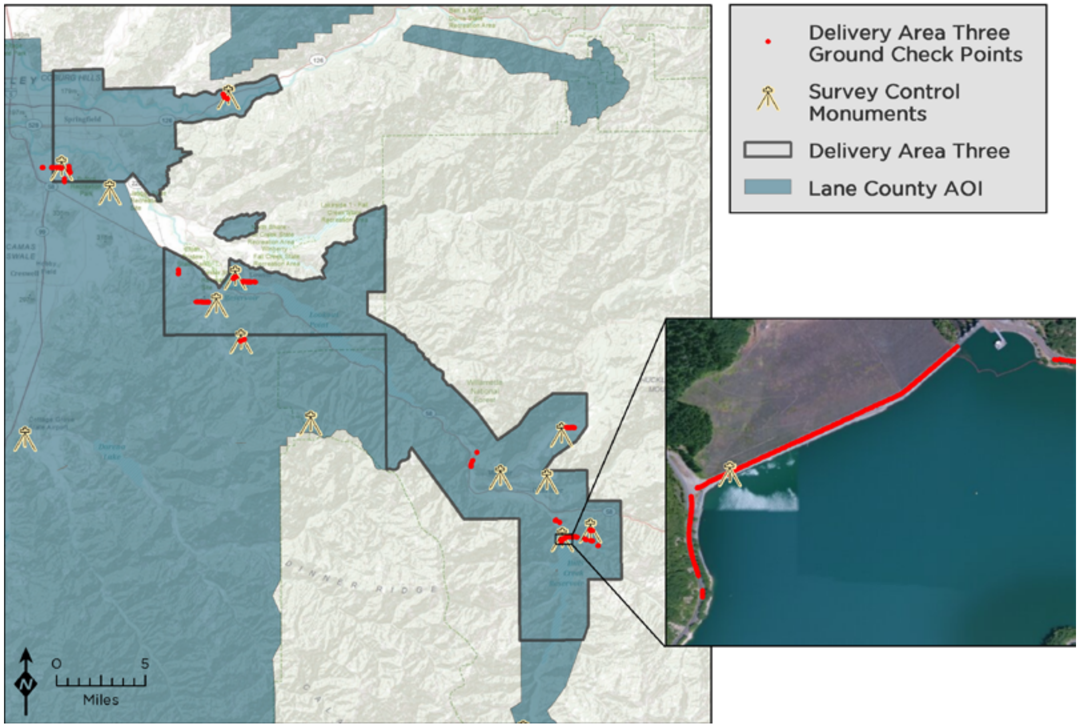
Instrumentation

For this study area all Global Navigation Satellite System (GNSS) survey work utilizes a Trimble GNSS receiver model R7 with a Zephyr Geodetic Antenna Model 2 for static control points. The Trimble GNSS R8 unit is used primarily for real time kinematic (RTK) work but can also be used as a static receiver. For RTK data, the collector begins recording after remaining stationary for five seconds then calculating the pseudo range position from at least three epochs with the relative error under 1.5 centimeters horizontal and 2.0 centimeters vertical. All GPS measurements are made with dual frequency L1-L2 receivers with carrier-phase correction.

Monuments			
Name	Latitude	Longitude	Ellipse
	Datum NAD 83 (2011)		GRS 80
AI2001	43° 55' 19.20493"	-122°4 7' 41.08223"	195.963
LANE_11	44° 04' 08.74341"	-122° 48' 06.59661"	161.587
LANE_13	44° 00' 41.08475"	-122° 59' 27.48519"	119.047
LANE_15	43° 59' 28.97732"	-122° 56' 10.19436"	139.378
LANE_24	43° 42' 26.18996"	-122° 25' 40.56001"	450.794
LANE_25	43° 42' 51.38283"	-122° 23' 45.43363"	792.318
LANE_28	43° 53' 58.92454"	-122° 48' 59.17889"	194.478
LANE_29	43° 52' 12.08177"	-122° 47' 18.45224"	420.38
LANE_29A	43° 52' 12.08161"	-122° 47' 18.45256"	420.361
LANE_31	43° 45' 16.82389"	-122° 26' 41.15314"	492.053
LANE_32	43° 47' 33.82161"	-122° 25' 40.76291"	677.205
LANE_34	43° 45' 30.54400"	-122° 29' 48.47559"	308.081
LANE_35	43° 48' 11.57911"	-122° 42' 37.56859"	1041.596

OLC Lane County

Delivery Area Three Ground Control



Monumentation

Existing and established survey benchmarks serve as control points during LiDAR acquisition, including those previously set by WSI. NGS benchmarks are preferred for control points; however, in the absence of NGS benchmarks, WSI produces our own monuments. These monuments are spaced at a minimum of one mile and every effort is made to keep them within the public right of way or on public lands. If monuments are necessary on private property, consent from the owner is required. All monumentation is done with 5/8" x 30" rebar topped with a two-inch diameter aluminum cap stamped "Watershed Sciences, Inc. Control." Twelve new monuments were established and one NGS monument was occupied for the Lane County study area (see Monument table at bottom left).

Methodology

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

Each aircraft is assigned a ground crew member with two R7 receivers and an R8 receiver. The ground crew vehicles are equipped with standard field survey supplies and equipment including safety materials. All control points are observed for a minimum of two survey sessions lasting no fewer than two hours. At the beginning of every session the tripod and antenna are reset, resulting in two independent instrument heights and data files. Data are collected at a rate of one hertz, using a 10 degree mask on the antenna.

The ground crew uploads the GPS data to the Dropbox website on a daily basis to be returned to the office for Professional Land Surveyor (PLS) oversight, Quality Assurance/Quality Control (QA/QC) review, and processing. OPUS processing triangulates the monument position using three CORS stations resulting in a fully adjusted position. Blue Marble Geographics Calculator 2013 SP1 is used to convert the geodetic positions from the OPUS reports. After multiple days of data have been collected at each monument, accuracy and error ellipses are calculated. This information leads to a rating of the monument based on FGDC-STD-007.2-1998 Part 2 at the 95 percent confidence level (see monument accuracy table).

WSI collected 1,618 GCP points, established 12 new monuments and occupied one NGS monument for Delivery Area Three.

All Ground Check Point (GCP) measurements are made during periods with a Position Dilution of Precision (PDOP) of less than 3.0 and in view of at least six satellites by the stationary reference and roving receiver. For collecting GCPs, WSI uses two methods; Real Time Kinematic (RTK) and Post Processed Kinematic (PPK). GCP positions are collected on 20 percent of the flight lines and on bare earth locations such as paved, gravel or stable dirt roads, and other locations where the ground is clearly visible (and is likely to remain visible) from the sky during the data acquisition and RTK measurement period(s). In order to facilitate comparisons with LiDAR survey points, RTK measurements are not taken on highly reflective surfaces such as center line stripes or lane markings on roads. RTK points are taken no closer than one meter to any nearby terrain breaks such as road edges or drop offs. Examples of identifiable locations would include manhole and other flat utility structures that have clearly indicated center points or other measurement locations.

Multiple differential GPS units are used in the ground based real-time kinematic portion of the survey. To collect accurate ground surveyed points, a GPS base unit is set up over monuments to broadcast a kinematic correction to a roving GPS unit. The ground crew uses a roving unit to receive radio-relayed kinematic corrected positions from the base unit. This RTK survey allows precise location measurement (≤1.5 centimeters).


Ground professional collecting RTK

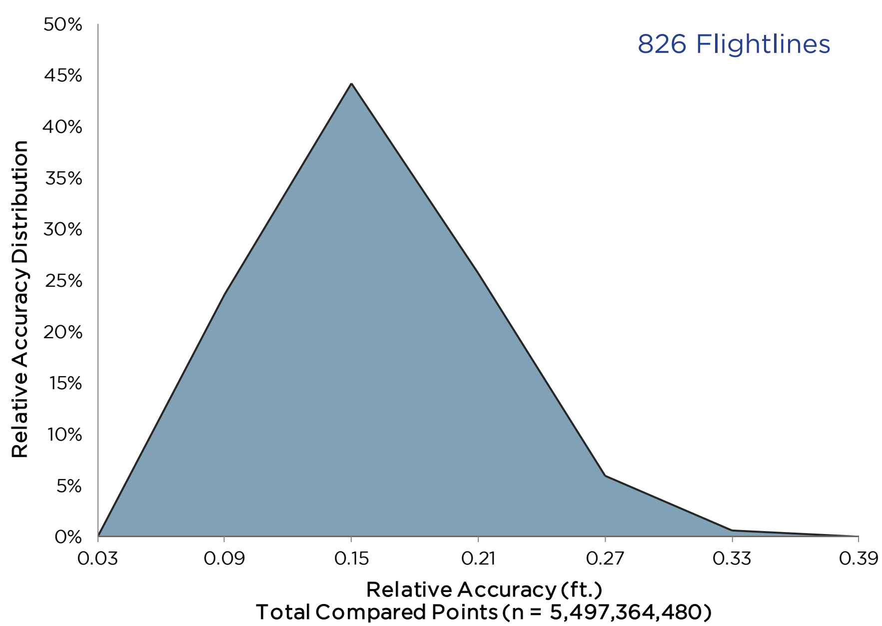
LiDAR Accuracy

Relative Accuracy

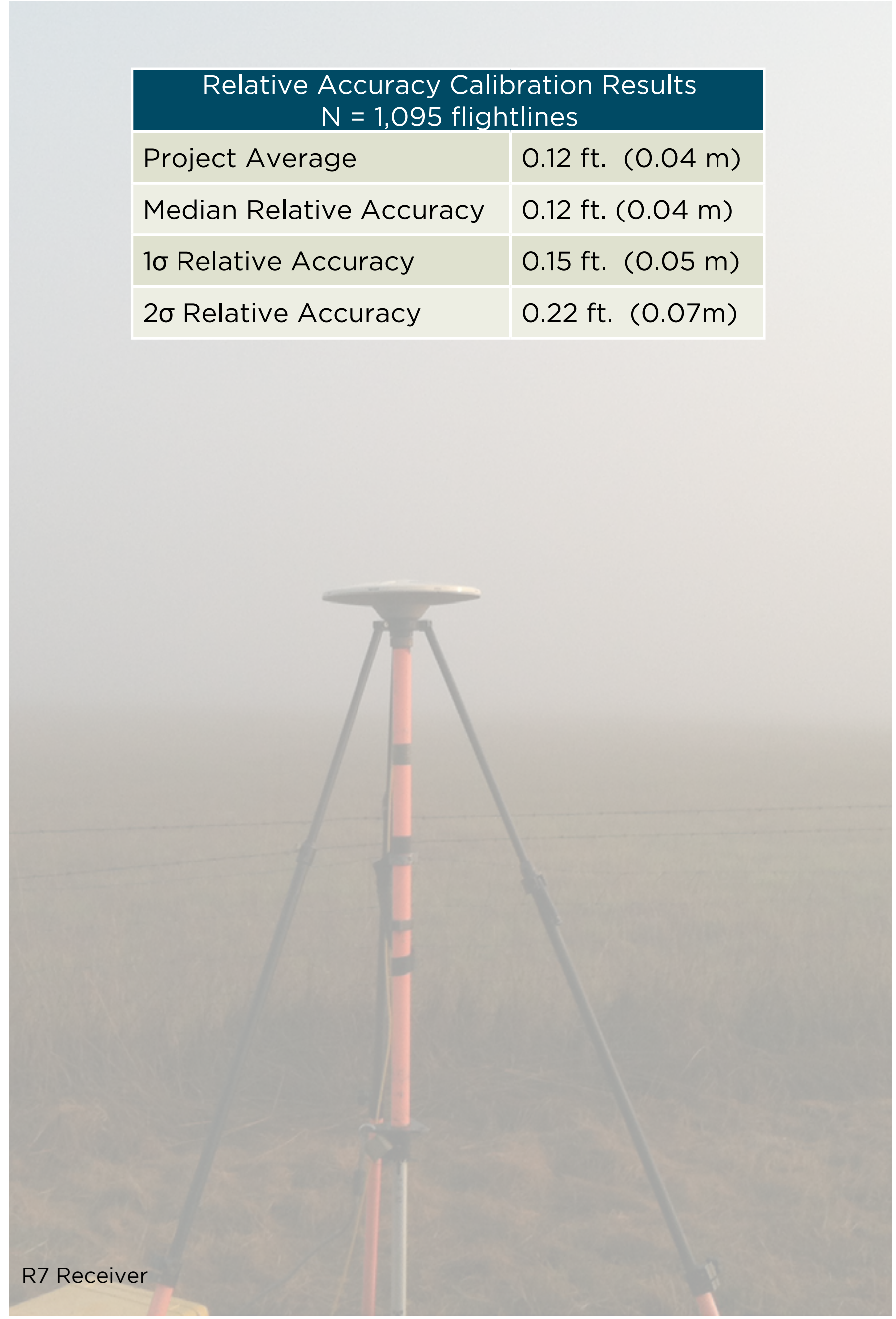
Relative accuracy refers to the internal consistency of the data set and is measured as the divergence between points from different flightlines within an overlapping area. Divergence is most apparent when flightlines are opposing. When the LiDAR system is well calibrated the line to line divergence 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 826 flightlines (572 full and partial flightlines from Delivery Area Three) and over 5 billion points. Relative accuracy is reported for the cumulative delivered portions of the study area.

Relative Accuracy Distribution



Relative Accuracy Calibration Results N = 1,095 flightlines	
Project Average	0.12 ft. (0.04 m)
Median Relative Accuracy	0.12 ft. (0.04 m)
1σ Relative Accuracy	0.15 ft. (0.05 m)
2σ Relative Accuracy	0.22 ft. (0.07m)



R7 Receiver

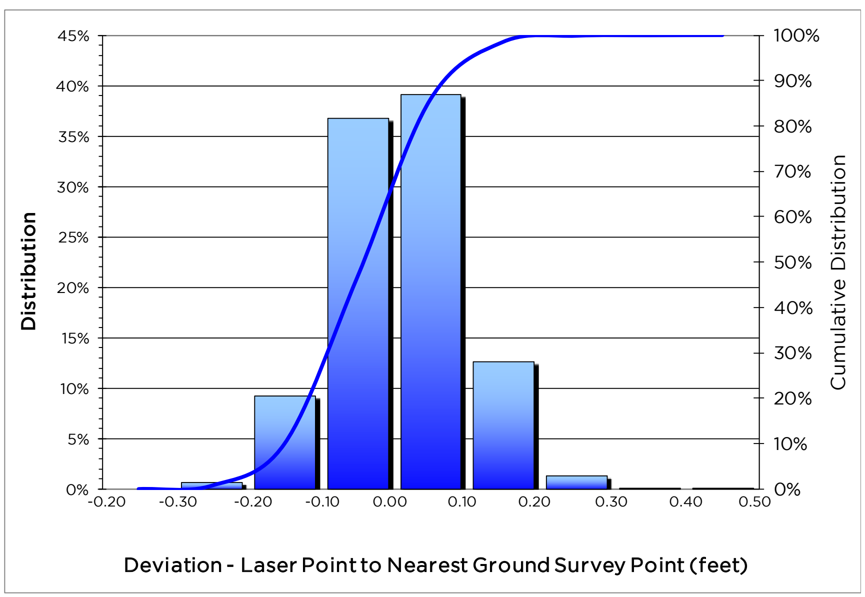
Vertical Accuracy

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 check points to the closest laser point. Vertical accuracy statistical analysis uses ground control 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 Lane County Delivery Three study area, 1,618 RTK points were collected. Statistics are calculated on the cumulative sum of all points collected for all deliveries.

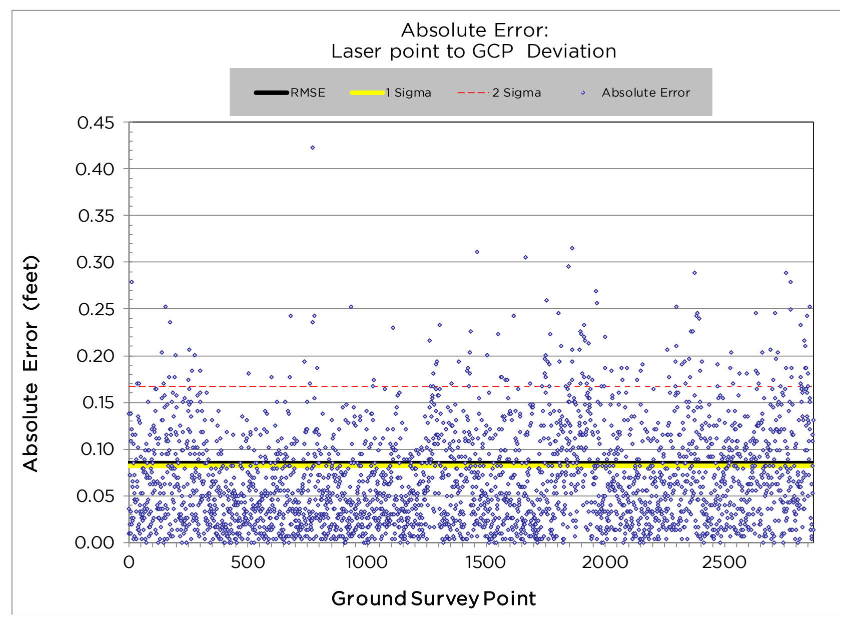
For this project, no independent survey data were collected, nor were reserved points collected for testing. As such, vertical accuracy statistics are reported as "Compiled to Meet." Vertical Accuracy is reported for the entire study area and reported in the table below. Histogram and absolute deviation statistics displayed below.

Vertical Accuracy Results	
Sample Size (n)	2,874 Ground check points
Root Mean Square Error	0.09 ft. (0.03 m)
1 Standard Deviation	0.08 ft. (0.03 m)
2 Standard Deviation	0.17 ft. (0.05 m)
Average Deviation	0.01 ft. (0.00 m)
Minimum Deviation	-0.29 ft. (-0.09 m)
Maximum Deviation	0.42 ft. (0.13 m)

Vertical Accuracy Distribution



GCP Absolute Error

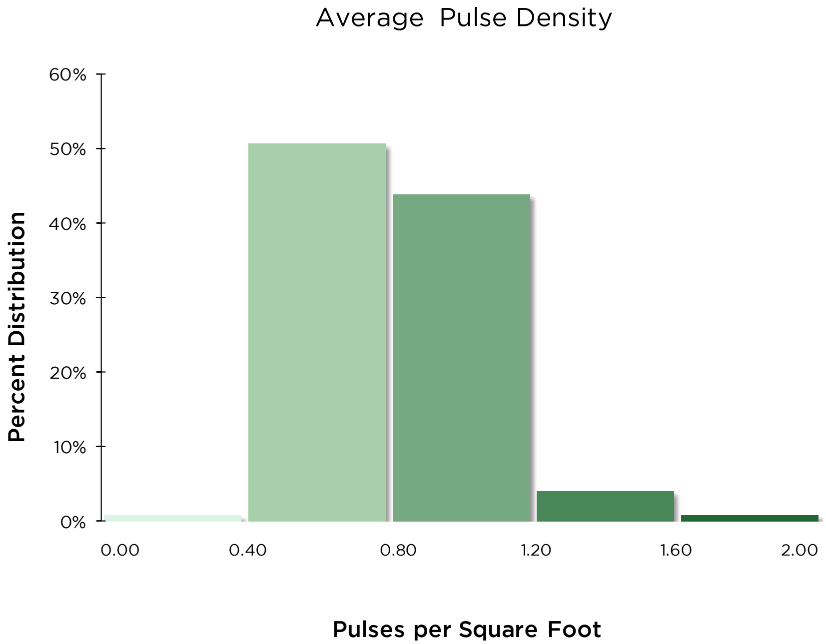


Density

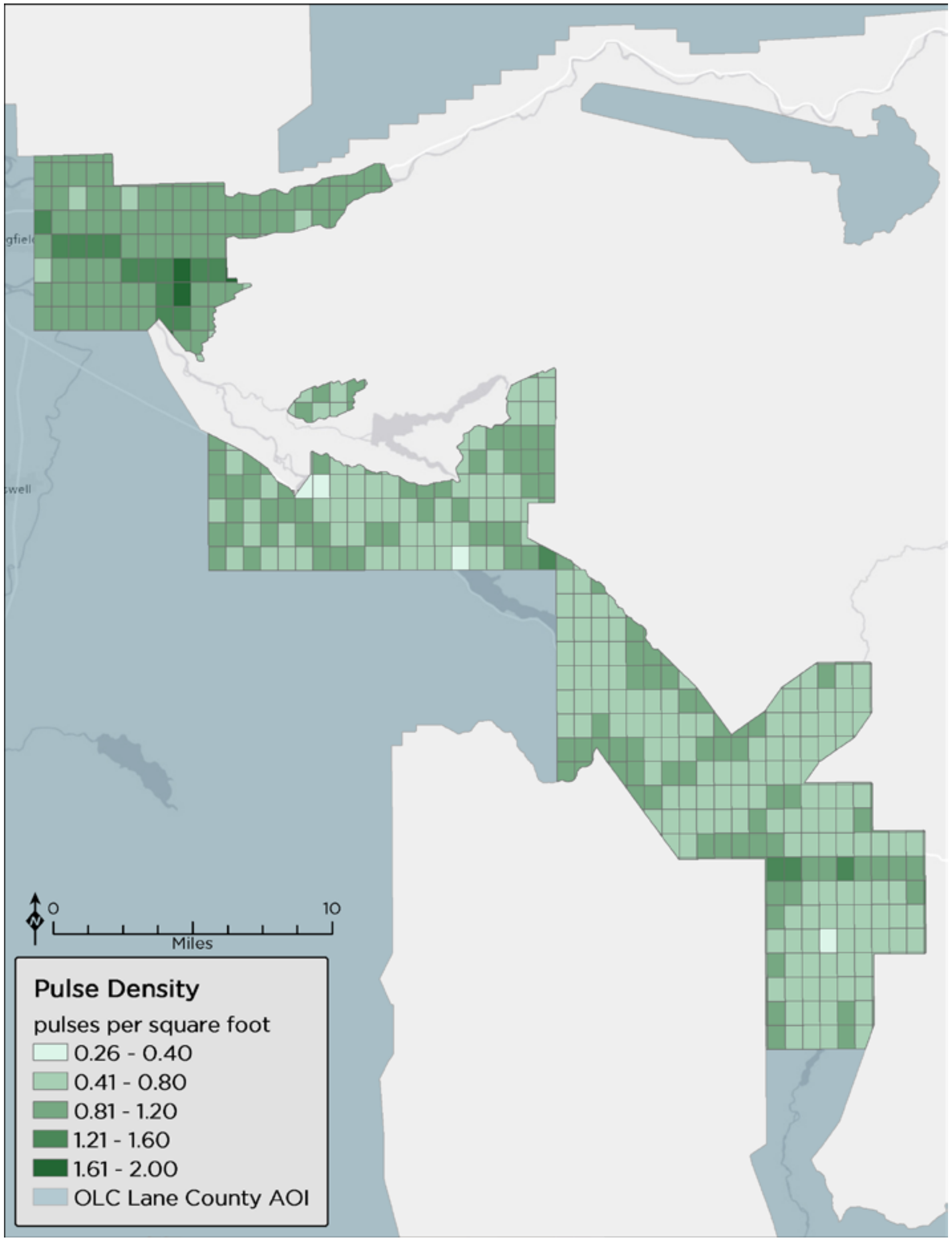
Pulse Density

Final pulse density is calculated after processing and is a measure of first returns per sampled area. 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	pulses per square meter	pulses per square foot
	8.79	0.82



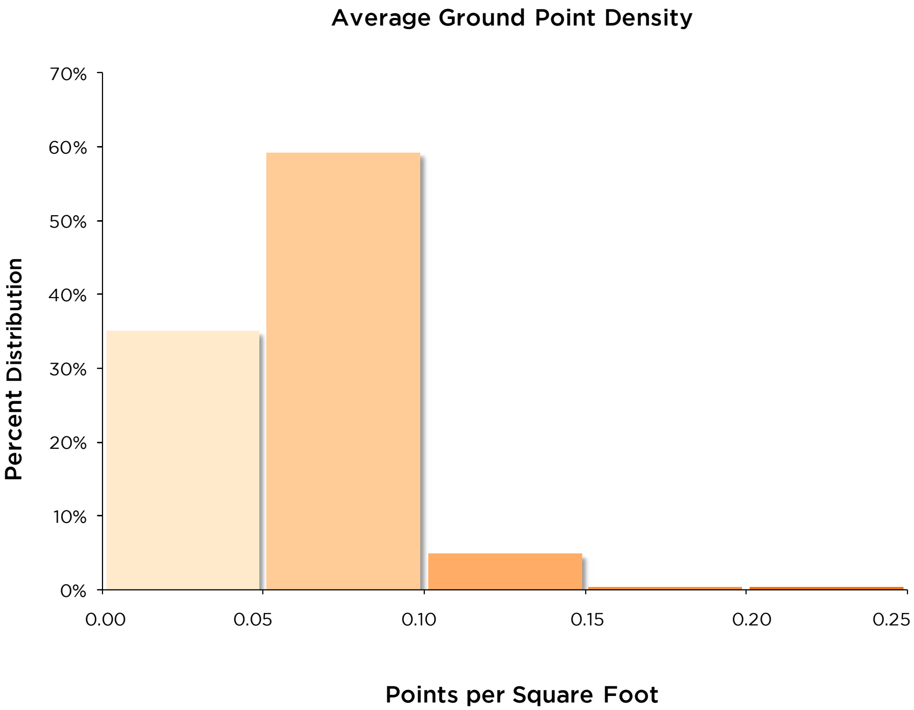
Average Pulse Density per 0.75' USGS Quad (color scheme aligns with density chart)



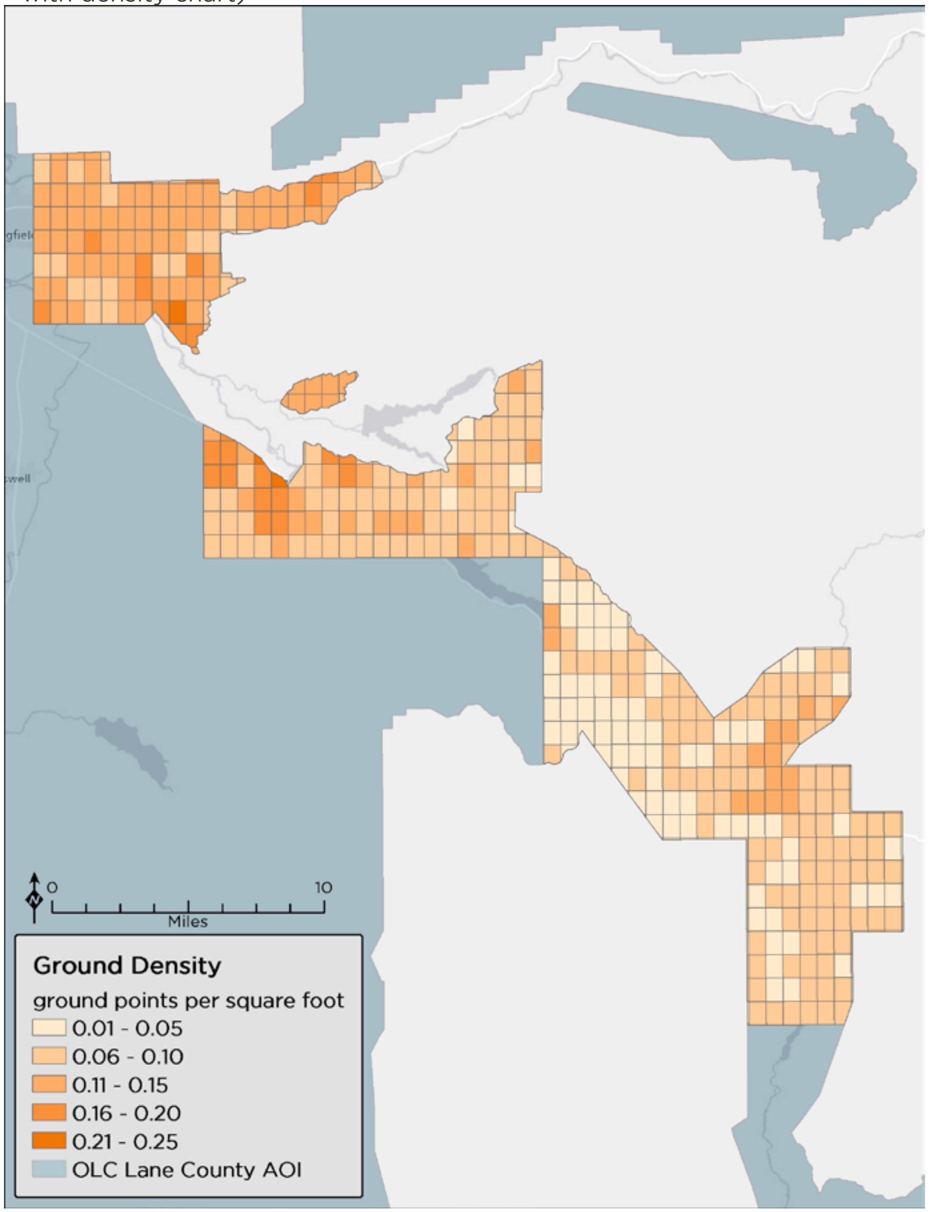
Ground Density

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. The classifications are influenced by terrain and grounding parameters that are adjusted for the dataset. The reported ground density is a measure of ground-classified point data.

Ground Density	points per square meter	points per square foot
	0.91	0.08



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



Orthophoto Accuracy

Orthophoto Accuracy Assessment

To assess the spatial accuracy of the orthophotographs, artificial check points were established. 18 check points, distributed evenly across the total acquired area, were generated on surface features such as painted road lines and fixed high-contrast objects on the ground surface. They were then compared against check points identified from the LiDAR intensity images. The accuracy of the final mosaic was calculated in relation to the LiDAR-derived check points and is listed below.

Orthophotos are not in Delivery Area 2, though are part of the project. Assessment recorded here coincides with Delivery Area One, and will be updated as the project progresses.

Above: Example of co-registration of color images with LiDAR intensity images. **Below:** Examples of permanent air targets located within Lane County project area

Orthophoto horizontal accuracy results

Orthophoto Horizontal Accuracy (n=18)	WSI Achieved (m)	WSI Achieved (ft.)
RMSE	0.169	0.554
1 Sigma	0.168	0.552
2 Sigma	0.328	1.075

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Appendix

PLS Certificate

WSI provided LiDAR and Orthometric Photo Services for OLC's Lane County project as described in this report.

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

Matthew Boyd
Principle
WSI

I, Christopher W. Brown, being duly registered as a Professional Land Surveyor in the state of Oregon, say that I hereby certify the methodologies and results of the attached LiDAR, and the Static GPS occupations on the Base Stations during airborne flights and RTK survey on hard-surface, and GCP's were performed using commonly accepted Standard Practices. Field work conducted for this report was conducted between September 27, 2013 and January 25, 2014.

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".

Christopher W. Brown, PLS Oregon & Washington
WSI
Portland, OR 97204

REGISTERED
PROFESSIONAL
LAND SURVEYOR

3/24/2014

OREGON
JULY 13, 2004
CHRISTOPHER W. BROWN
60438LS

RENEWS: 12/31/2015

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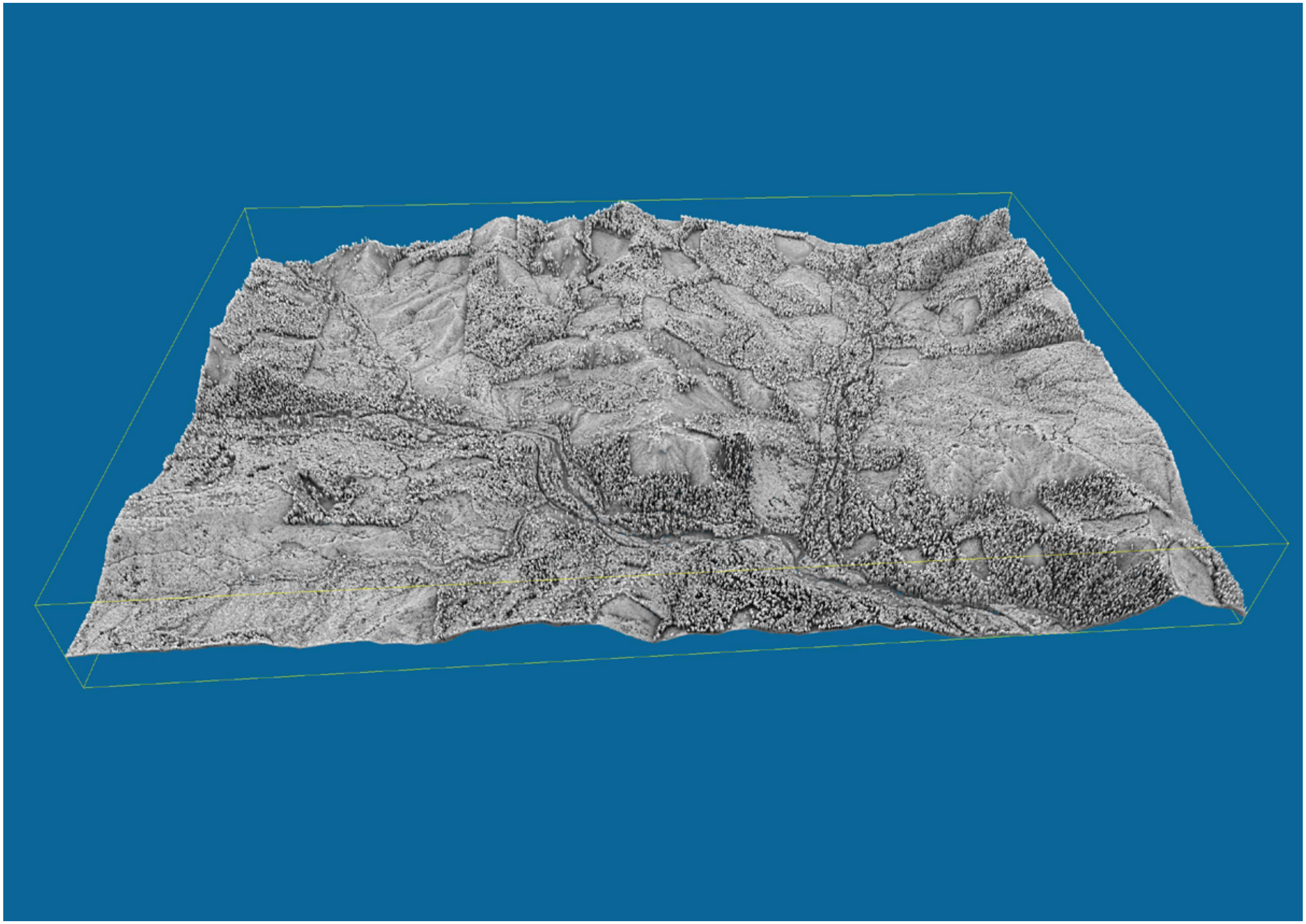
Selected Imagery

Orthophotos: **Top Left:** Main Street Bridge, Springfield, Oregon. **Top Right:** McKenzie View Drive, south of Coburg, Oregon. **Bottom Left:** Kellogg Road, Springfield, Oregon **Bottom Right:** Island Park along the Willamette River, Spring-field, Oregon.



Highest Hit DEM of section of Delivery Area Two

LiDAR derived DEM's: **Above** highest hit DEM and **Below:** bare earth DEM. Both areas depicted are within delivery area three.