OLC Keno

WSI Applied Remote Sensing and Analysis

New Spencer Bridge spanning John C Boyle Reservoir

Data collected for:
Department of Geology and Mineral Industries

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Prepared by:
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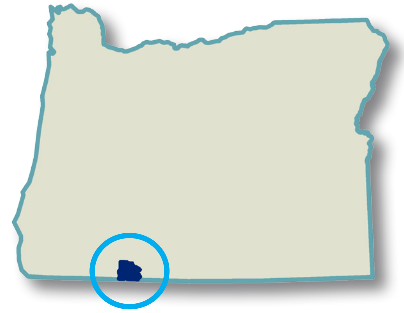


Project Overview

WSI has collected Light Detection and Ranging (LiDAR) data of the Oregon Keno Study Area for the Oregon Department of Geology and Mineral Industries (DOGAMI). The Oregon LiDAR Consortium's Keno project area encompasses approximately 200,000 acres in Klamath County near the Oregon-California state border and surrounds a portion of the Klamath River.

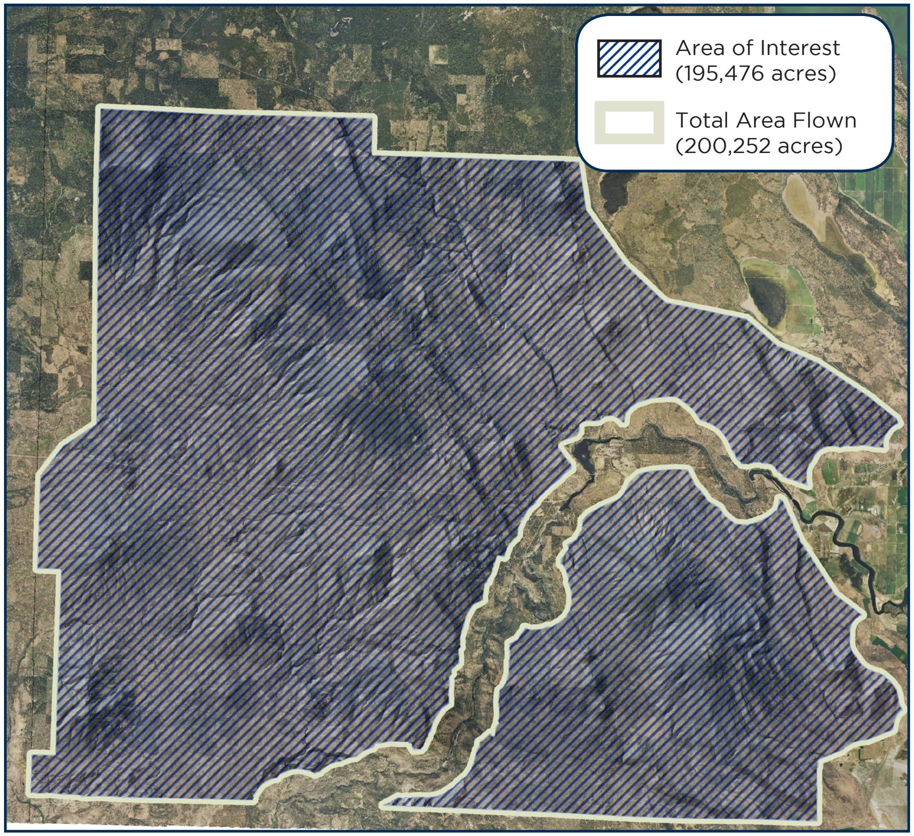
Data Delivered October 31st, 2012	
Acquisition Date	June 1st - Aug 17th, 2012
Area of Interest	195,476 acres
Total Area Flown	200,252 acres
Data	OGIC HARN
Projection	Oregon Statewide Lambert Conformal Conic
Datum: horizontal & vertical	NAD83 (HARN) NAVD88 (Geoid03)
Units	International Feet

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

Between June 1st and August 17th, 2012, WSI employed remote-sensing lasers in order to obtain a total of 200,252 acres of data with a resolution of eight pulses per square meter. Final products created include LiDAR point cloud data, 1 meter digital elevation models of bare earth ground model and highest-hit returns, area vector shapes, and corresponding statistical data.

Data for the Klamath River and surrounding area were acquired and processed; however, due to budgetary contraints these data were not requested for delivery.

Study Area



Cessna Caravan

Aerial Acquisition

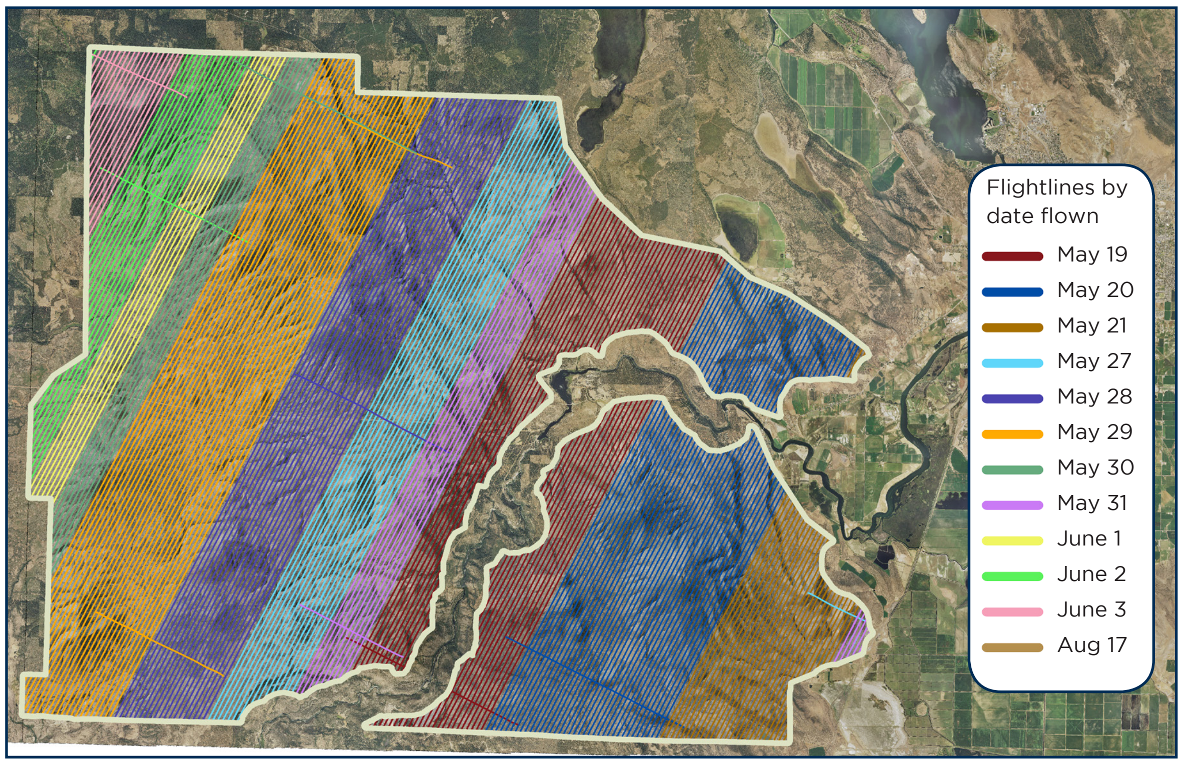
Airborne Survey

The LiDAR survey utilized Leica ALS50 and ALS60 sensors mounted in either Cessna Caravan 208B or Partenavia P.68 aircrafts. Depending on the pairing of sensor and aircraft, the systems were programmed to emit laser pulses at a rate between 96-105 kHz, and flown at 900 meters above ground level (AGL), capturing a scan angle of 30° from nadir. These settings are developed to yield points with an average native density of greater than eight points 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 variable according to distributions of terrain, land cover and water bodies. The study area was surveyed with opposing flight line side-lap of greater than 60% with at least 100% overlap to reduce laser shadowing and increase surface laser painting. The system allows up to four range measurements per pulse, and all discernable 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 (2 Hz) by an onboard differential GPS unit. Aircraft attitude is measured 200 times per second (200 Hz) as pitch, roll and yaw (heading) from an onboard inertial measurement unit (IMU). As illustrated in the figure below, 253 flightlines provide coverage for the area delivered to date.

Acquisition Specs	
Sensors Deployed	Leica ALS 50, Leica ALS 60
Aircraft	Partenavia P.68, Cessna Caravan 208B
Survey Altitude (AGL)	900m
Pulse Rate	96 - 105 Khz
Pulse Mode	Single (SPiA)
Field of View (FOV)	30°
Roll Compensated	Yes
Overlap	100% overlap with 60% sidelap
Pulse Emission Density	$\geq$ 8 pulse / m^2

Project Flightlines



Ground Survey

During the LiDAR survey, static (1 Hz recording frequency) ground surveys were conducted over 5 monuments with known coordinates. After the airborne survey, the static GPS data were processed using triangulation with CORS stations and checked against 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 GPS 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 5 seconds then calculating the pseudo range position from at least three epochs with the relative error under 1.5 cm horizontal and 2 cm vertical. All GPS measurements are made with dual frequency L1-L2 receivers with carrier-phase correction.

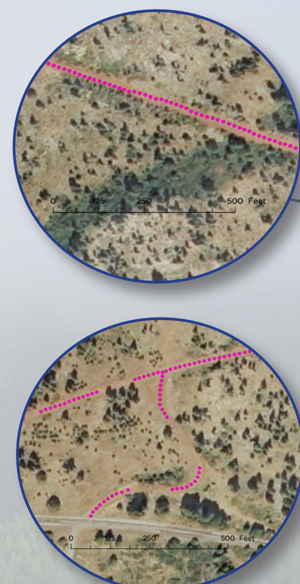
Monumentation

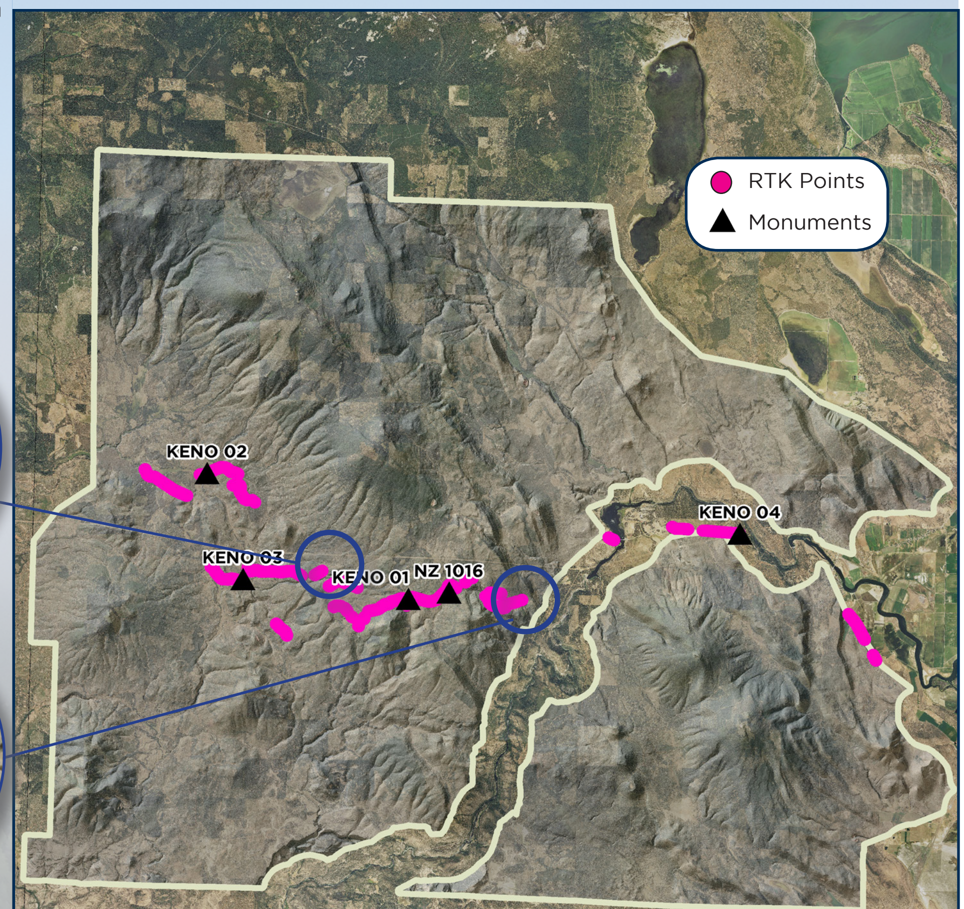
Existing and established survey benchmarks shall serve as control points during LiDAR acquisition including those previously set by WSI. NGS benchmarks are preferred for control points; however, in the absence of NGS benchmarks, WSI utilizes county surveys, department of transportation monumentation, or WSI produces its own monuments. These monuments are spaced at a minimum of one mile and every effort is made to keep these monuments within the public right of way or on public lands. If monuments are required on private property, consent from the owner is required. All monumentation is done with 5/8" x 30" rebar topped with a 2" diameter aluminum cap stamped "Watershed Sciences, Inc."

Monuments			
	Datum NAD 83 (HARN)		GRS 80
Name	Latitude	Longitude	Ellipsoid Height (m)
KENO 01	420647.52709	1220804.65847	1395.159
NZ 1016	420656.74245	1220653.47354	1391.89
KENO 02	420927.27103	1221359.56583	1185.301
KENO 03	420708.98587	1221253.11736	1229.015
KENO 04	42821.32323	1215828.84490	1273.215

Project Monuments & RTK points

Zoomed-in circles show detail of RTK point collection





Methodology

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 2 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 1Hz 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 3 CORS stations resulting in a fully adjusted position. Blue Marble Geographics Desktop v.2.5.0 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% confidence level (table, right).

Field employee collecting RTK

WSI collected 3,338 RTK points and utilized five monuments.

All RTK 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. RTK positions are collected on 20% 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 measurements, 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. In addition, it is desirable to include locations that can be readily identified and occupied during subsequent field visits in support of other quality control procedures described later. Examples of identifiable locations would include manhole and other flat utility structures that have clearly indicated center points or other measurement locations. In the absence of utility structures, a PK nail can be driven into asphalt or concrete and marked with paint.

Multiple differential GPS units are used in the ground based real-time kinematic (RTK) 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 cm).

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

R7 Receiver

Accuracy

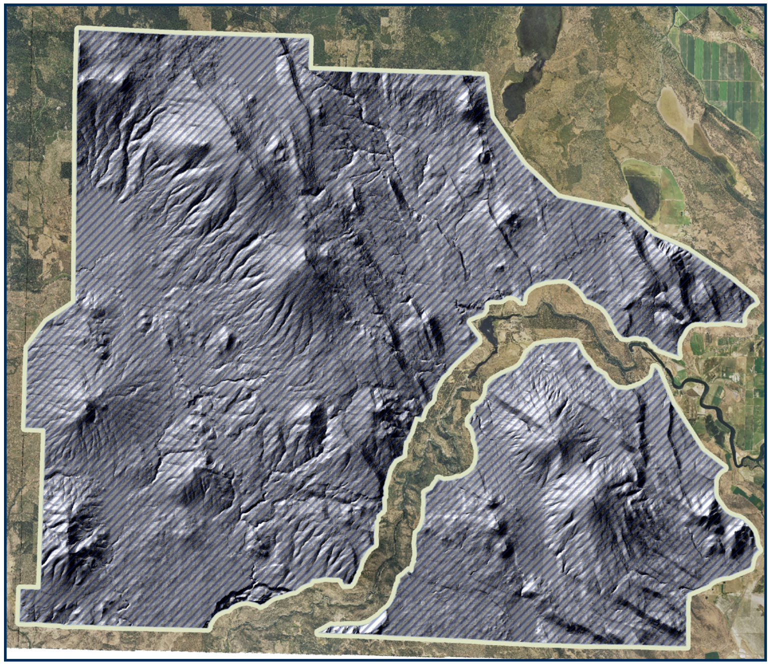
Relative Accuracy

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 cm). Internal consistency is affected by system attitude offsets (pitch, roll and heading), mirror flex (scale), and GPS/IMU drift.

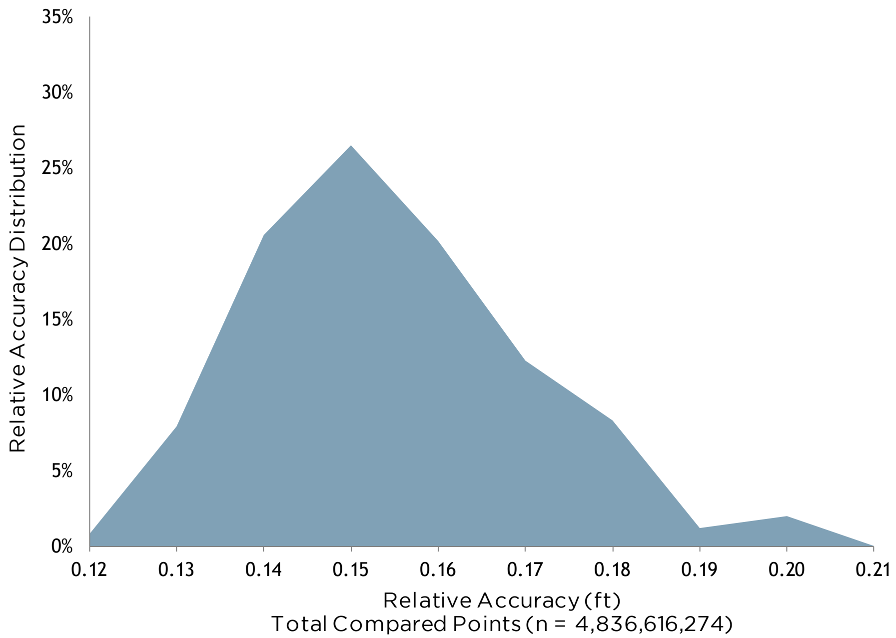
Relative accuracy statistics are based on the comparison of 253 flightlines and over 4 billion points. Relative accuracy is reported for the entire study area.

Relative Accuracy Calibration Results	
Project Average	0.14 ft (0.04 m)
Median Relative Accuracy	0.14 ft (0.04 m)
1σ Relative Accuracy	0.14 ft (0.04 m)
2σ Relative Accuracy	0.16 ft (0.05 m)

Accuracy Coverage Area (100% Coverage)



Relative Accuracy Distribution

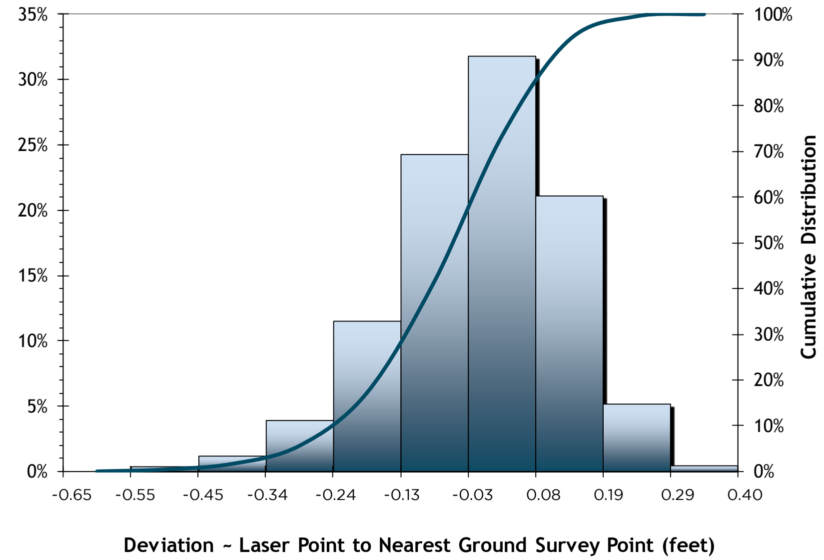


Fundamental Vertical Accuracy

FVA accuracy reporting is designed to meet guidelines presented in the National Standard for Spatial Data Accuracy (NSSDA) (FGDC, 1998). FVA compares known RTK ground survey points to the closest laser point. FVA 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 95% percentile of RMSEZ. For the Central Coast Study Area, 3,338 RTK points were collected.

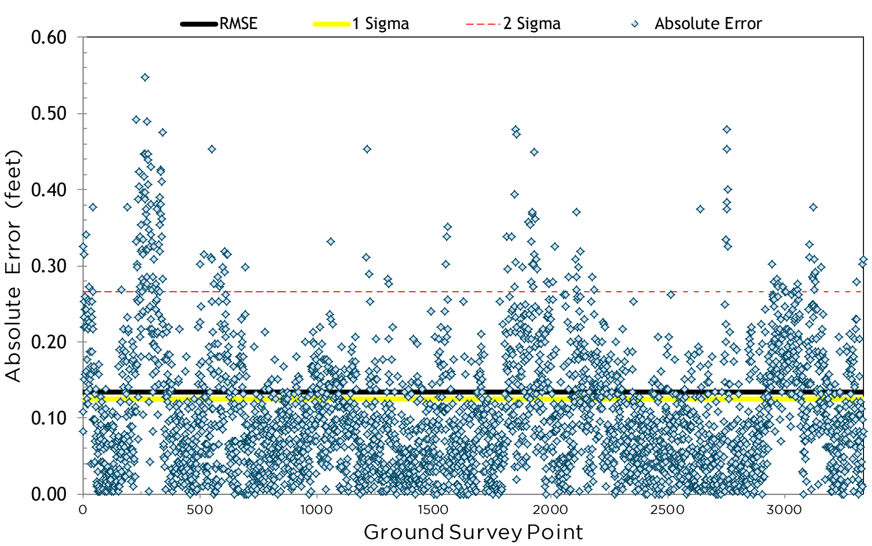
For this project, no independent survey data were collected, nor were reserved points collected for testing. As such, vertical accuracy statistics are reported as "Compiled to Meet," in accordance with the ASPRS Guidelines for Vertical Accuracy Reporting for LiDAR Data V1.0 (ASPRS, 2004). Fundamental Vertical Accuracy is reported for the entire study area and reported in the table below. Histogram and absolute deviation statistics displayed to the right.

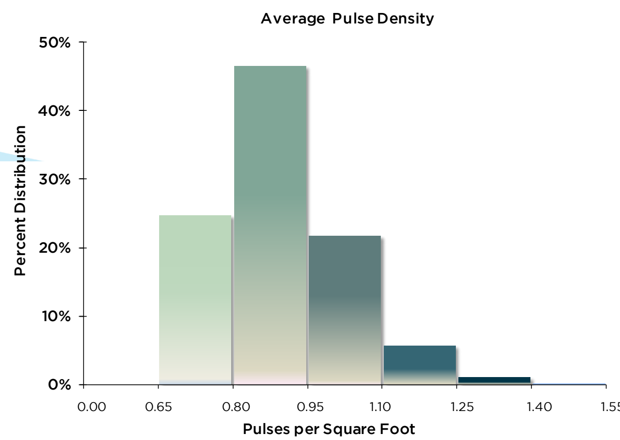
Vertical Accuracy Distribution

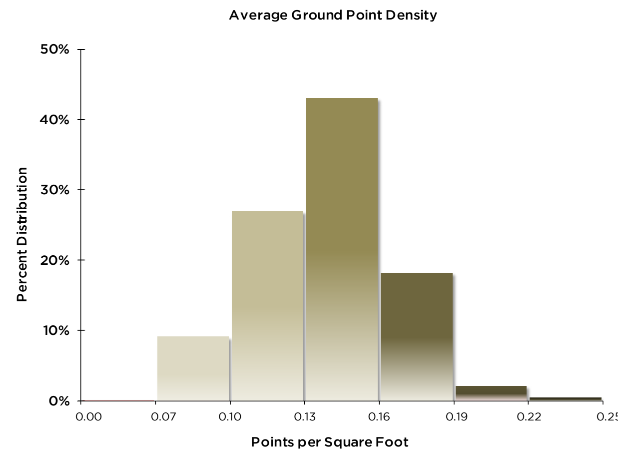


Vertical Accuracy Results	
Compiled to meet 0.24 ft. (0.07m) accuracy at 95% confidence level in open terrain	
Sample Size (n)	3,338
Root Mean Square Error	0.13 ft (0.04 m)
1 Standard Deviation	0.12 ft (0.04 m)
2 Standard Deviation (FVA)	0.27 ft (0.08 m)
Average Deviation	-0.01 ft (0.00 m)
Minimum Deviation	-0.55 ft (-0.17 m)
Maximum Deviation	0.38 ft (0.12 m)

RTK Absolute Error







Density

Pulse Density

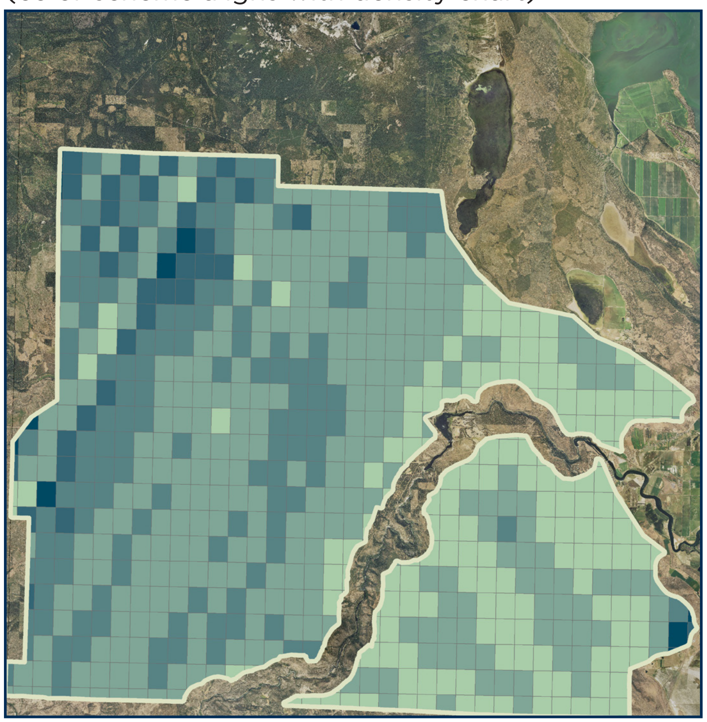
Some types of surfaces (i.e. dense vegetation or water) may return fewer pulses than the laser originally emitted. Therefore, the delivered density can be less than the native density and vary according to terrain, land cover and water bodies. Density histograms and maps have been calculated based on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

Average Point Densities			
Pulse Density (sq ft)	Pulse Density (sq m)	Ground Density (sq ft)	Ground Density (sq m)
0.74	8.02	0.13	1.88

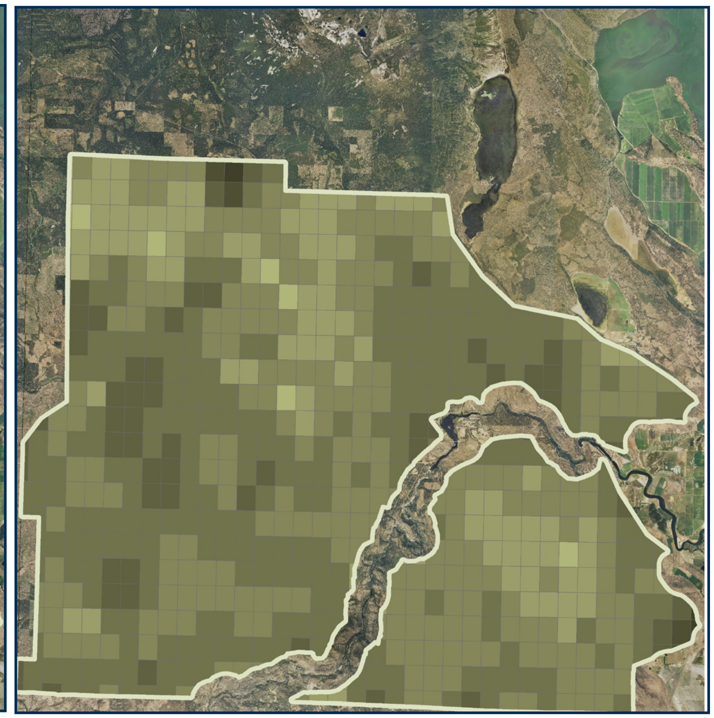
Ground Density

Ground classifications were derived from ground surface modeling. 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 bin boundaries.

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



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



Appendix

Certifications

WSI provided LiDAR services for the Keno study area as described in this report.
I, Mathew Boyd, have reviewed the attached report for completeness and hereby state that it is a complete and accurate report of this project.

Mathew Boyd
Principal
WSI

I, Christopher W. Yotter-Brown, being first dully sworn, say that as described in the Ground Survey subsection of the Acquisition section of this report was completed by me or under my direct supervision and was completed using commonly accepted standard practices. Accuracy statistics shown in the Accuracy Section have been reviewed by me to meet National Standard for Spatial Data Accuracy.

REGISTERED PROFESSIONAL LAND SURVEYOR 10/16/2012

OREGON
JULY 13, 2004
Christopher W. Yotter - Brown
60438 LS

RENEWAL DATE: 6/30/2014

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

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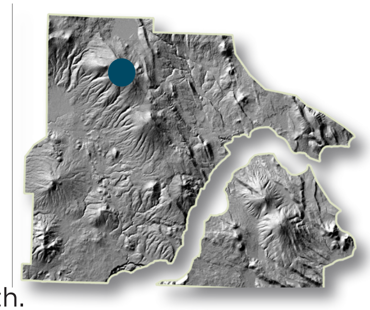
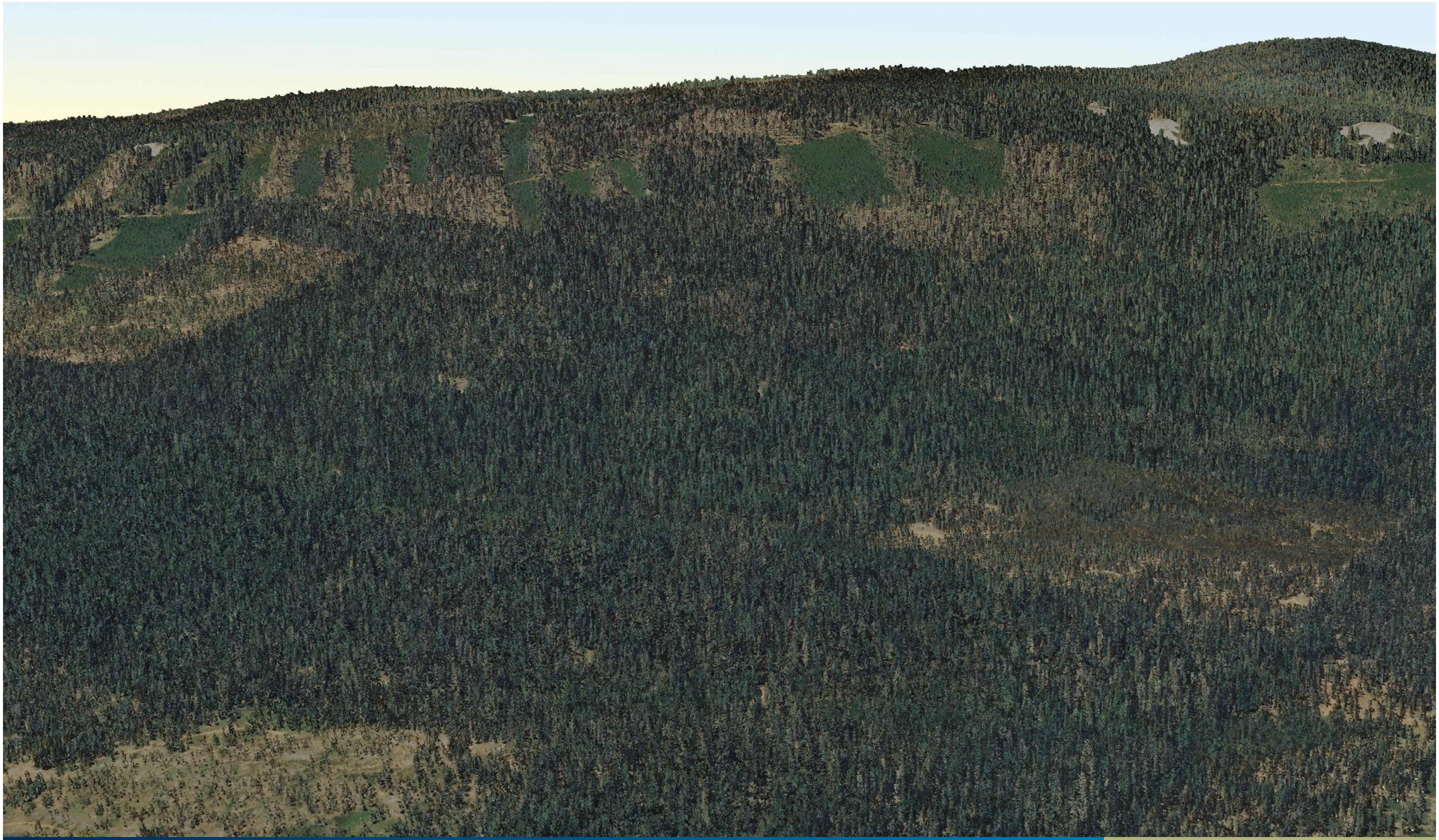
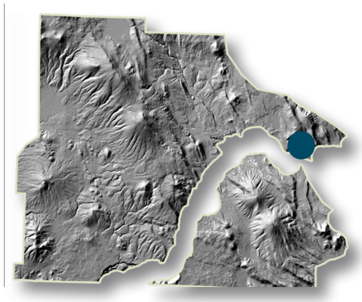


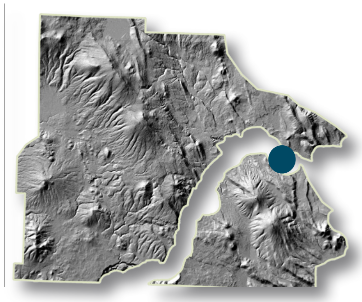
LiDAR-derived Imagery

LiDAR point cloud with RGB extraction from 2011 NAIP imagery. Forested hills of Surveyor Mountain. View to the South.





LiDAR point cloud with RGB extraction from 2011 NAIP imagery. Klamath River and Keno, OR. View to the West.



LiDAR point cloud with RGB extraction from 2011 NAIP imagery. Keno Dam on the Klamath River. View to the West.