WSI Applied Remote Sensing and Analysis

OLC Turnbull

August 26, 2013

Base station set up over control “TURN_03”

Data collected for:
Department of Geology and Mineral Industries

800 NE Oregon Street
Suite 965
Portland, OR 97232

Prepared by:
WSI

421 SW 6th Avenue
Suite 800
Portland, Oregon 97204
phone: (503) 505-5100
fax: (503) 546-6801

517 SW 2nd Street
Suite 400
Corvallis, OR 97333
phone: (541) 752-1204
fax: (541) 752-3770

Contents

Site of a prescribed burn that occured in the fall of 1992

Project Overview

WSI has completed the acquisition and processing of Light Detection and Ranging (LiDAR) data and orthoimagery for the Turnbull Study Area for the Oregon Department of Geology and Mineral Industries (DOGAMI). The Oregon LiDAR Consortium's Turnbull project area of interest (AOI) encompasses 176,454 acres in Lincoln and Spokane Counties in Washington.

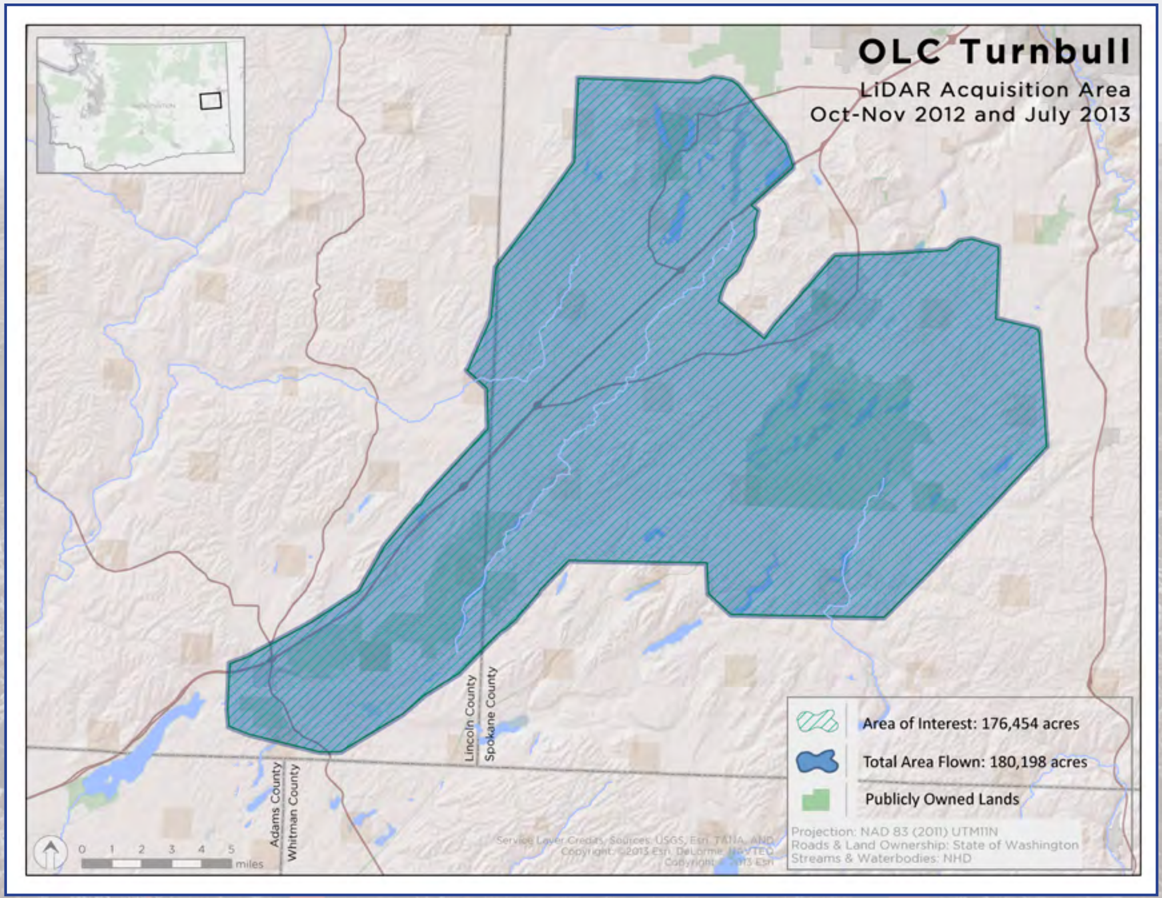
The collection of high resolution geographic data is part of an ongoing pursuit to amass a library of information accessible to government agencies as well as the general public.

Between October 10, 2012 and July 23, 2013, WSI employed remote-sensing lasers in order to obtain a total area flown of 180,198 acres. 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, one meter digital elevation models of bare earth ground model and highest-hit returns, intensity rasters, 3-inch orthophotos, study area vector shapes, and corresponding statistical data.

Turnbull AOI Data Delivered August 31, 2013	
Acquisition Dates	October 10-11, 2012 November 6-8, 2012 July 21-23, 2013
Area of Interest	176,454 acres
Total Area Flown	180,198 acres
Projection	UTM 11 N
Datum: horizontal & vertical	NAD83 (2011) NAVD88 (Geoid 12A)
Units	Meters

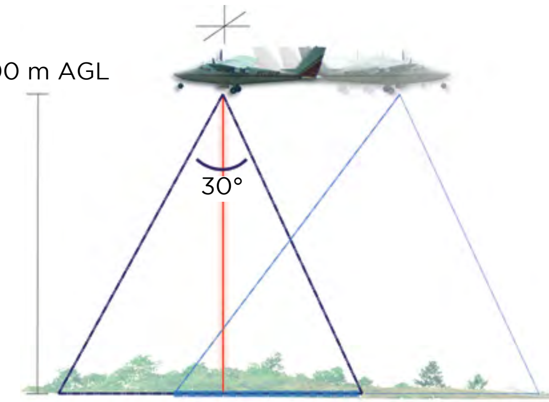
Study Area



Aerial Acquisition

Cessna Caravan

900 m AGL



LiDAR Survey

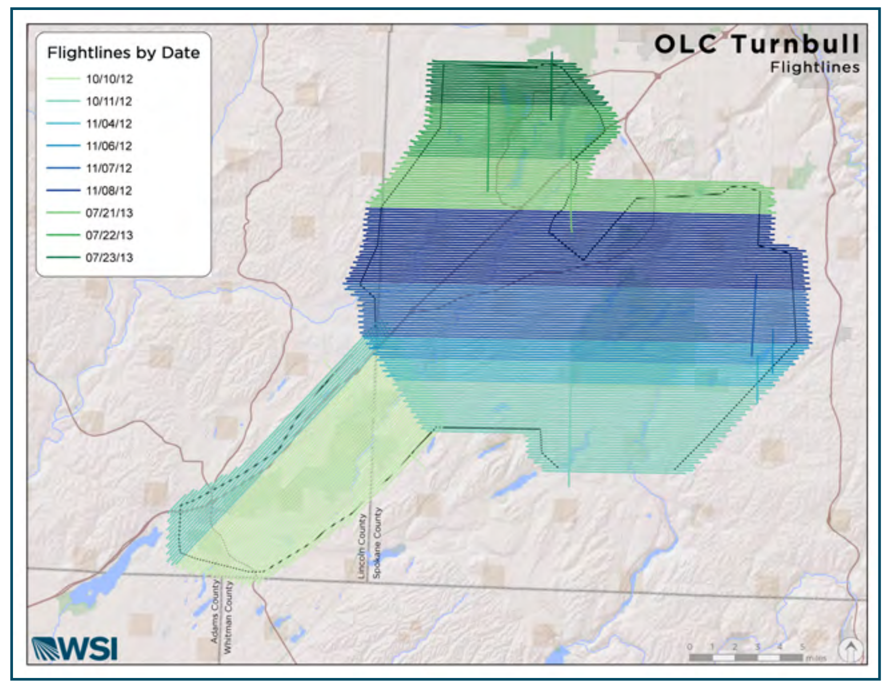
The LiDAR survey utilized a Leica ALS60 sensor mounted in a Cessna Caravan 208B. The system was programmed to emit single pulses at a rate of 96 to 106 kilohertz, and flown at 900 meters above ground level (AGL), capturing a scan angle of +/-15 degrees from nadir (field of view equal to 30 degrees). 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 60 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 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 (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, 221 flightlines provide coverage of the study area.

Turnbull Acquisition Specs	
Sensors Deployed	Leica ALS 50 and Leica ALS 60
Aircraft	Cessna Caravan 208B
Survey Altitude (AGL)	900 m
Pulse Rate	96-106 kHz
Pulse Mode	Single (SPiA)
Field of View (FOV)	30°
Roll Compensated	Yes
Overlap	100% overlap with 60% sidelap
Pulse Emission Density	≥ 8 pulses per square meter

Sensor ALS 60

Project Flightlines



Aerial Acquisition

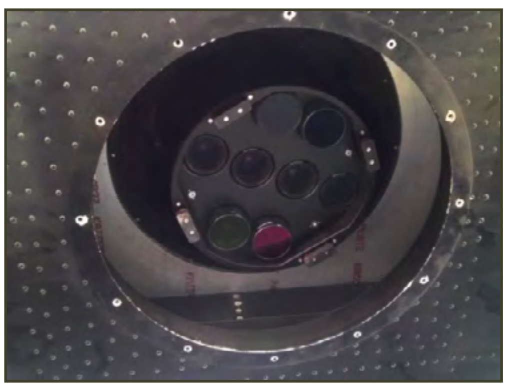
Photography

The photography survey utilized an UltraCam Eagle 260 megapixel camera mounted in a Cessna 208-B Grand Caravan. The UltraCam-Eagle is a large format digital aerial camera manufactured by the Microsoft Corporation. The system is gyro-stabilized and simultaneously collects panchromatic and multispectral (RGB, NIR) imagery.

Panchromatic lenses collect high resolution imagery by illuminating nine CCD (charged coupled device) arrays, writing nine raw image files. RGB and NIR lenses collect lower resolution imagery, written as four individual raw image files.

Level 02 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 03 pan-sharpened tiffs.

Digital Orthophotography Survey Specifications	
Aircraft	Cessna 208-B Grand Caravan
Sensor	UltraCam Eagle
Altitude	1,846 m AGL
GPS Satelite 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



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

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

UltraCam Eagle installed in the aircraft.

Ground Survey

During the LiDAR survey, static (one hertz recording frequency) ground surveys were conducted over four 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.

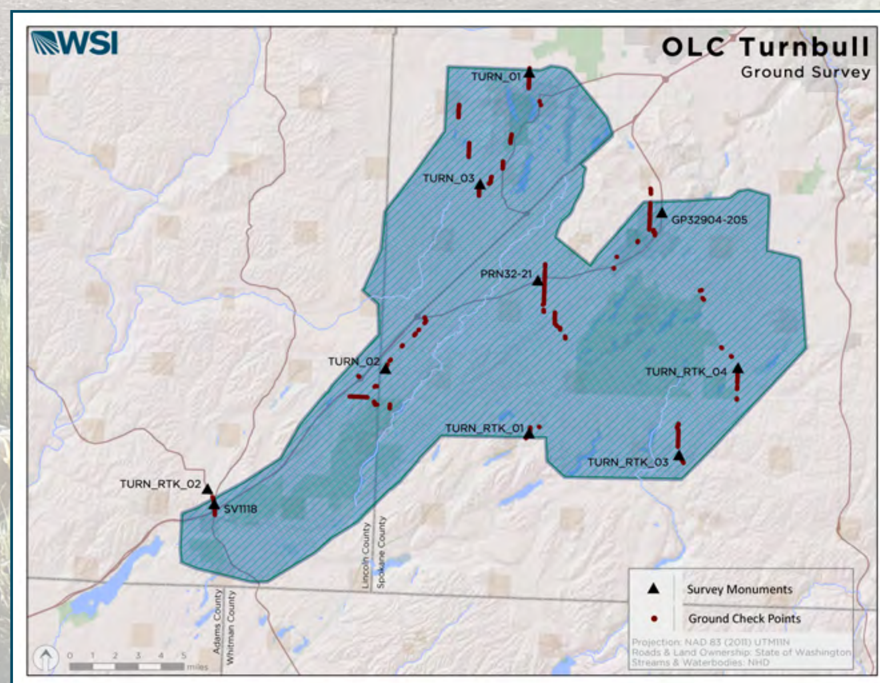
Instrumentation

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 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 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.

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 2 inch diameter aluminum cap stamped "Watershed Sciences, Inc. Control." Four new monuments were established and occupied for the Turnbull study area (see Monument table at bottom left).

Monuments			
	Datum NAD 83 (2011)		GRS 80
Name	Latitude	Longitute	Ellipsoid Height (m)
GP32904-205	47 30 27.99306	-117 33 51.46982	706.552
PRN32-21	47 27 43.71374	-117 40 42.25761	695.341
SV1118	47 18 45.93196	-117 58 23.10912	598.266
TURN_01	47 35 37.70119	-117 41 35.25287	715.073
TURN_02	47 24 09.64108	-117 49 04.73574	674.837
TURN_03	47 31 18.43492	-117 44 07.90194	724.038
TURN_RTK_01	47 21 53.90310	-117 40 54.05451	691.027
TURN_RTK_02	47 19 19.86277	-117 58 48.04213	600.439
TURN_RTK_03	47 21 15.36986	-117 32 27.05129	704.650
TURN_RTK_04	47 24 38.90308	-117 29 17.99638	708.788



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 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 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 percent confidence level (see monument accuracy table).


Ground professional collecting RTK

WSI collected 3,381 RTK points and utilized 10 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 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.

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

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).

R7 Receiver

Accuracy

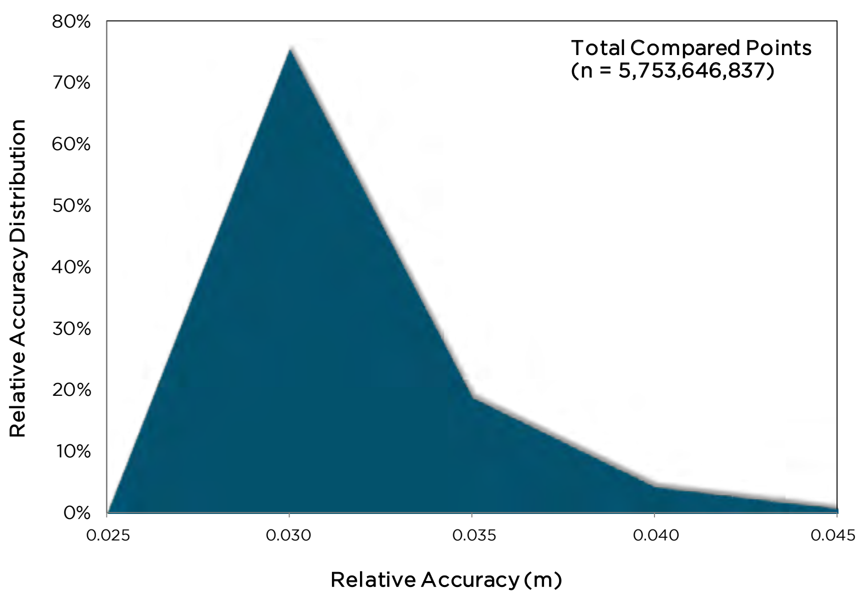
Relative Accuracy

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 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 221 flightlines and over 5.7 billion points. Relative accuracy is reported for the entire study area.

Relative Accuracy Calibration Results	
Project Average	0.10 ft. (0.03 m)
Median Relative Accuracy	0.09 ft. (0.03 m)
1σ Relative Accuracy	0.10 ft. (0.03 m)
2σ Relative Accuracy	0.12 ft. (0.04 m)

Relative Accuracy Distribution



LiDAR point cloud of South Badger Lake Road with RGB extraction

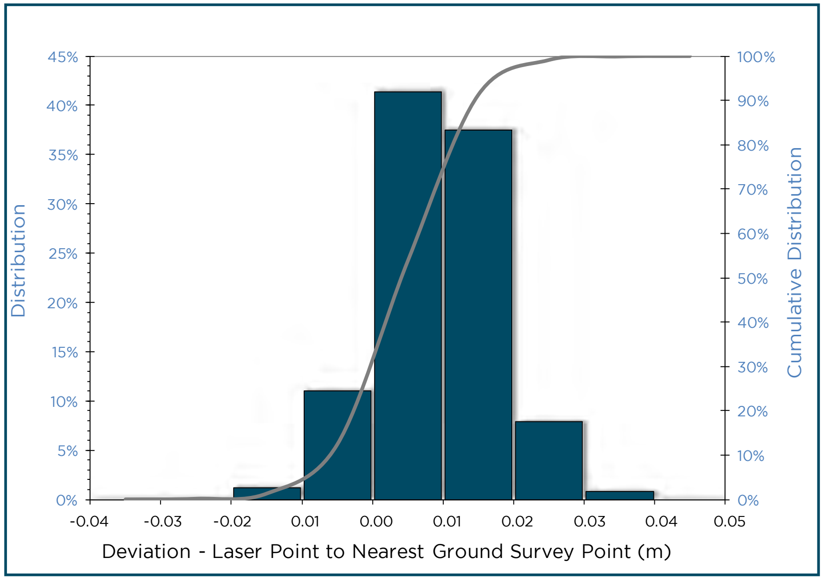
Vertical Accuracy

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 RTK ground survey 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 Turnbull study area, 3,381 RTK points were collected.

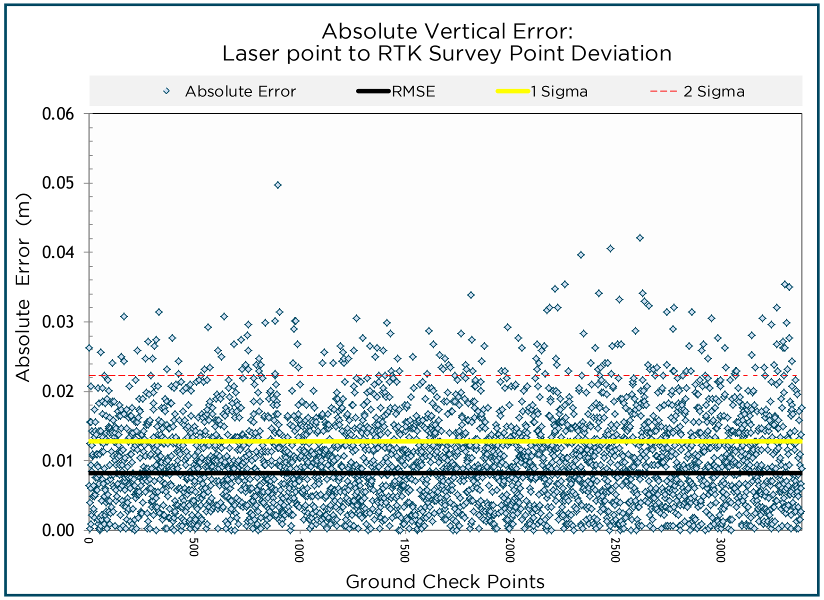
For this project, no independent survey data were collected, nor were reserved points collected for testing. As such, vertical accuracy statistics are reported as "Compiled to Meet." Vertical Accuracy is reported for the entire study area and reported in the table below. Histogram and absolute deviation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

Vertical Accuracy Results	
Sample Size (n)	3,381
Root Mean Square Error	0.03 ft (0.01 m)
1 Standard Deviation	0.04 ft (0.01 m)
2 Standard Deviation	0.07 ft (0.02 m)
Average Deviation	0.03 ft (0.01 m)
Minimum Deviation	-0.11 ft (-0.03 m)
Maximum Deviation	0.16 ft (0.05 m)

Vertical Accuracy Distribution



RTK Absolute Error



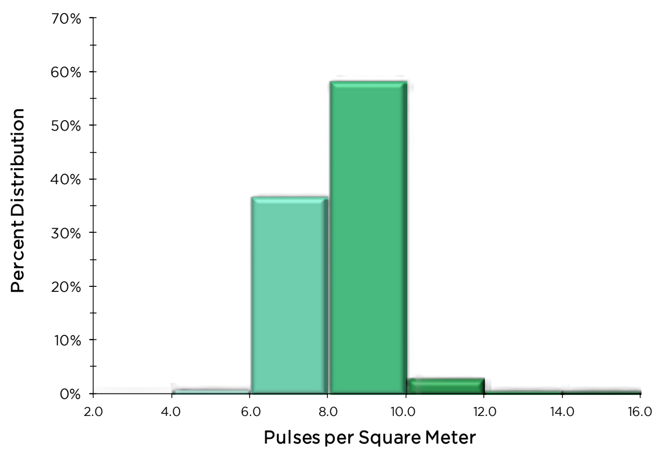
Density

Pulse Density

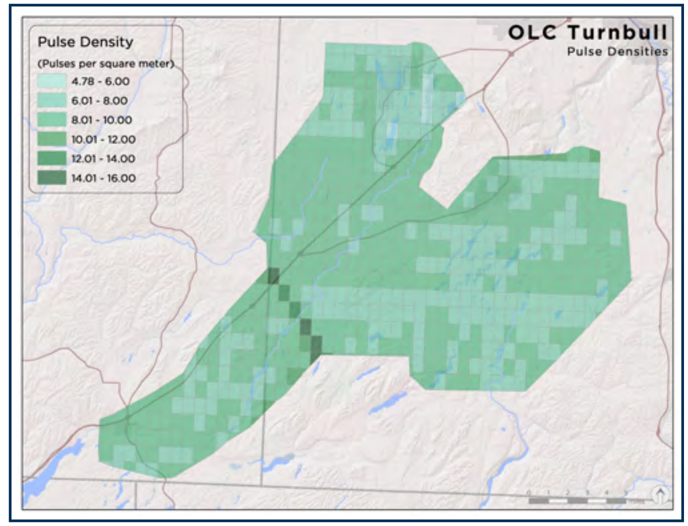
Some types of surfaces (e.g., dense vegetation, water) may return fewer pulses than the laser originally emitted. Therefore, the delivered density can be less than the native density and vary according to terrain, land cover, and water bodies. Density histograms and maps have been calculated based on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

Average LiDAR Point Density Results			
Pulses per square foot	Pulses per square meter	Ground points per square foot	Ground points per square meter
0.77	8.26	0.20	2.17

Pulse Density Distribution



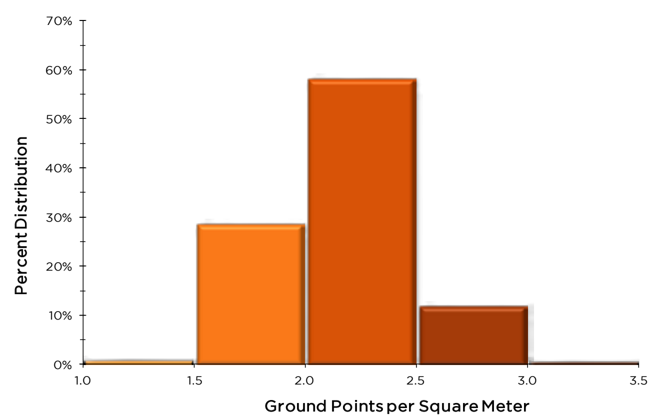
Average Pulse Density per 0.75' USGS Quad (color scheme aligns with density chart)



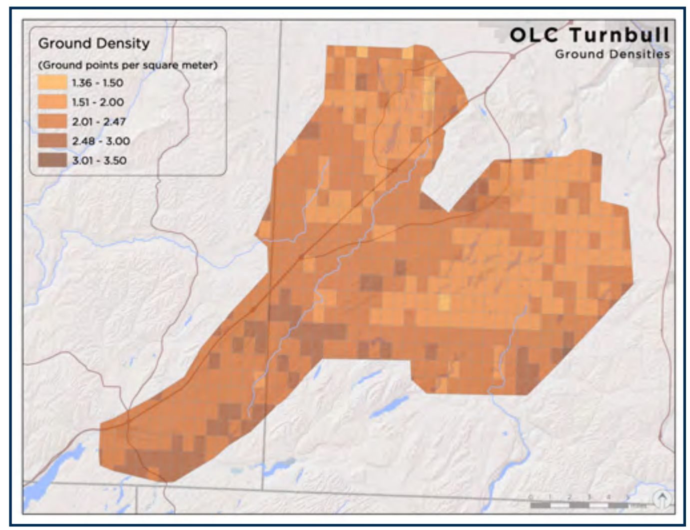
Ground Density

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



Orthophoto Accuracy

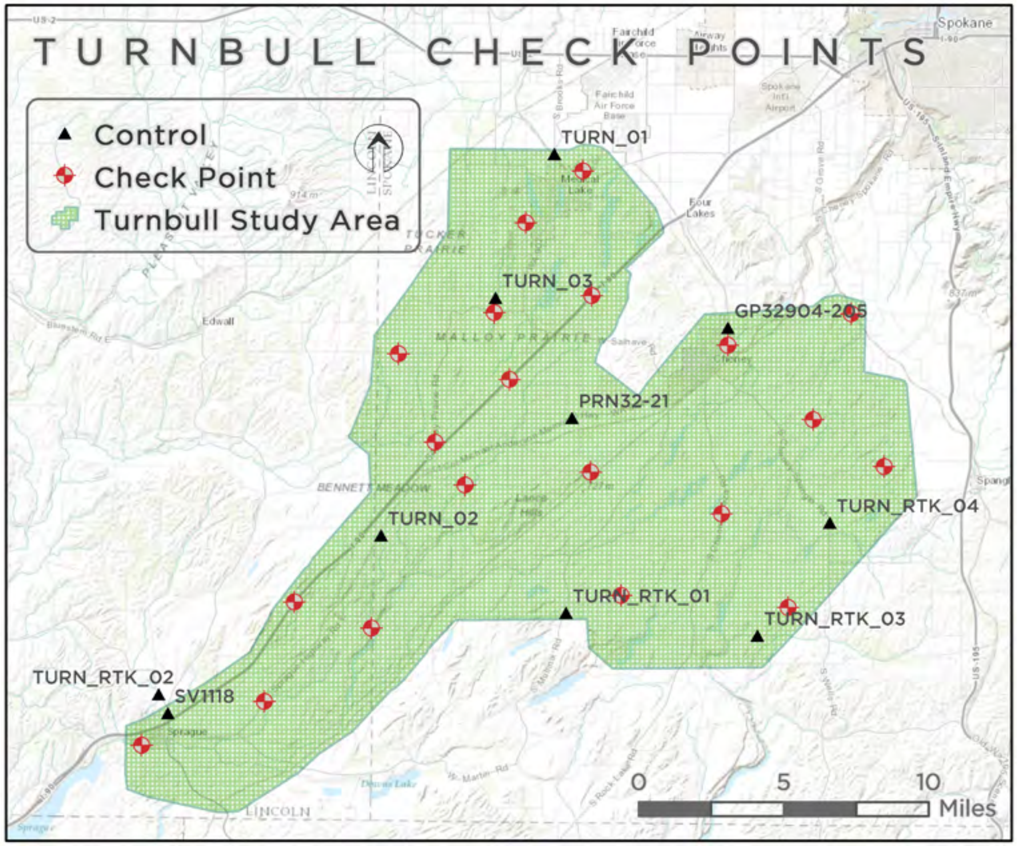
Orthophoto Accuracy Assessment

To assess the spatial accuracy of the orthophotographs, artificial check points were established. Five 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.

Orthophoto horizontal accuracy results

Orthophoto Horizontal Accuracy (=20)	WSI Achieved (m)	WSI Achieved (ft.)
RMSE	0.170	0.558
1 Sigma	0.154	0.505
2 Sigma	0.277	0.906

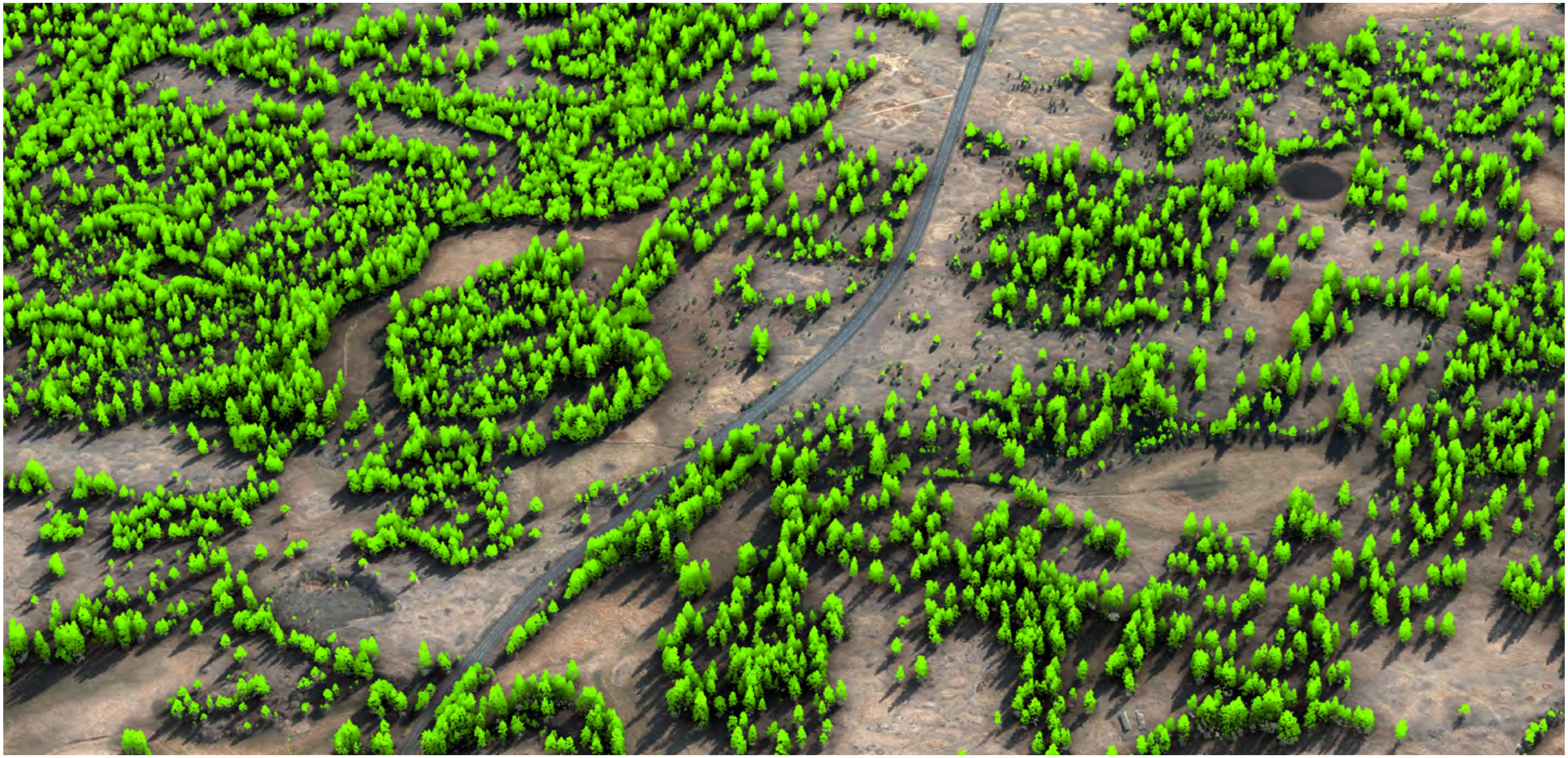
Above: Example of co-registration of color images with LiDAR intensity images.



Appendix

LiDAR-derived Imagery

LiDAR point cloud with RGB extraction from orthoimages of South Badger Lake Road in the southeastern portion of the study area.



[Page Intentionally Blank]

Certification

Watershed Sciences provided LiDAR services for the OLC Turnbull 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
Portland, OR 97204

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.

8/26/2013

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

CHRISTOPHER W. YOTTER-BROWN
STATE OF WASHINGTON
46328
REGISTERED
PROFESSIONAL LAND SURVEYOR

Renews: 12/21/2014