2015 OLC Upper Rogue Study Area

August 12, 2016

Data collected for:
Oregon Department of Geology and Mineral Industries

800 NE Oregon Street
Suite 965
Portland, OR 97232

Prepared by:
Quantum Spatial

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

Project Overview

QSI has completed the acquisition and processing of Light Detection and Ranging (LiDAR) data describing the Oregon LiDAR Consortium's (OLC) Upper Rogue Study Area. The Upper Rogue area of interest (AOI) shown in Figure 1 encompasses 1,397,140 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.

LiDAR data acquisition occured between March 12 and October 12, 2015. Settings for LiDAR data capture produced an average resolution of at least eight pulses per square meter. Final products are listed in page 3.

QSI acquires and processes data in the most current, NGS-approved datums and geoid. For Upper Rogue, 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.

Table 1: Upper Rogue delivery details

Upper Rogue	
Acquisition Dates	March 12 - October 12, 2015*
Buffered Area of Interest	1,397,140 acres
Projection	OGIC
Datum: horizontal & vertical	NAD83 (2011) NAVD88 (Geoid 12A)
Units	International Feet

*See page four for specific acquisition dates.

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

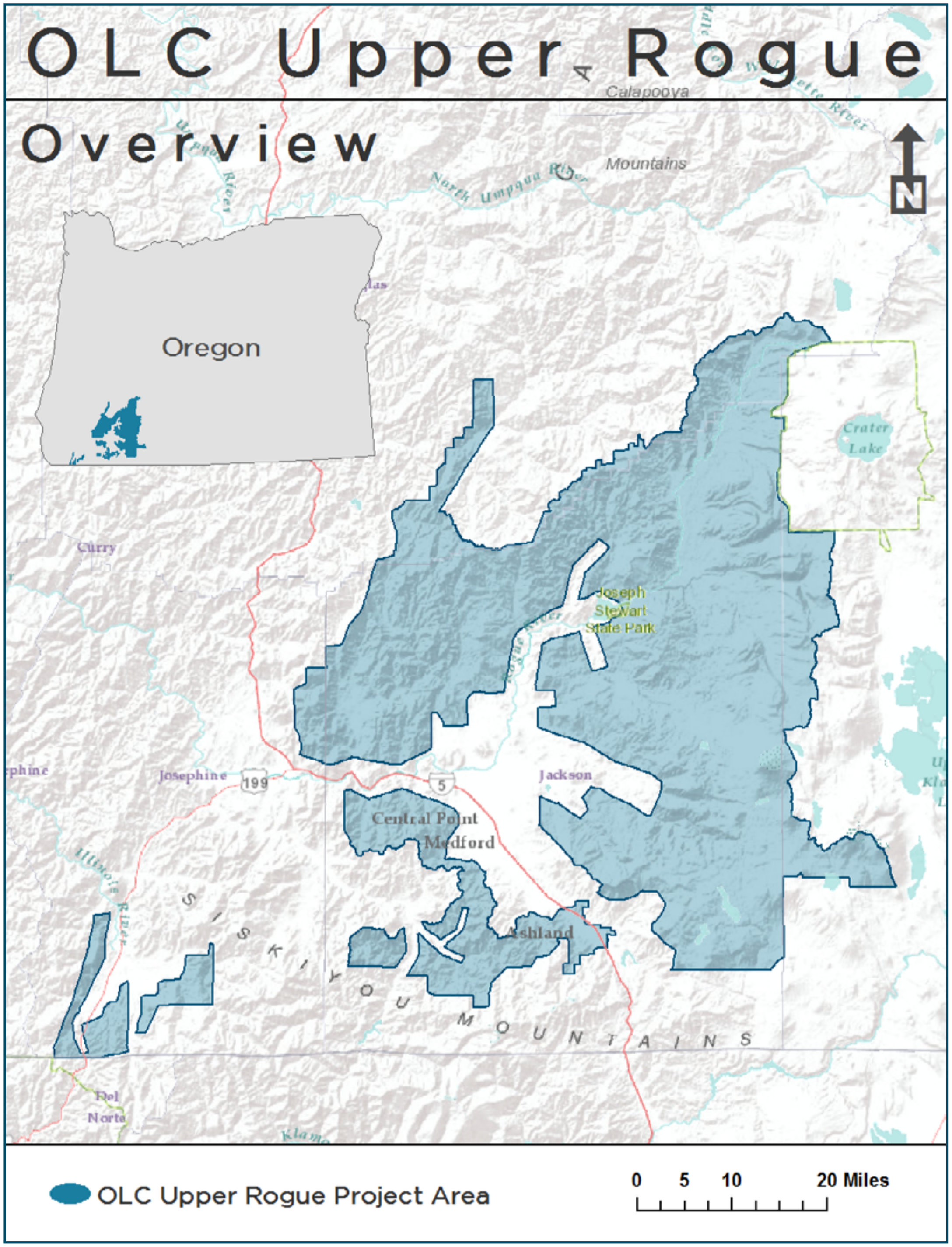

Figure 1: Upper Rogue study area location

Deliverable Products

Table 2: Products delivered for Upper Rogue study area.

<table>
<tr><th colspan="2">Upper Rogue
Projection: OGIC
Horizontal Datum: NAD83 (2011)
Vertical Datum: NAVD88 (GEOID12A)
Units: International Feet</th></tr>
<tr><td>Points</td><td>LAS v 1.2 tiled by 0.0375 minute USGS quadrangles
• Default (1), ground (2), and bridge (17) classfied points
• RGB color extracted from NAIP imagery
• Intensities</td></tr>
<tr><td>Rasters</td><td>3 foot ESRI GRID tiled by 7.5 minute USGS quadrangles
• Bare earth model
• Highest hit model
• LiDAR ground density images
1.5 foot GeoTiffs tiled by 7.5 minute USGS quadrangles
• Intensity images</td></tr>
<tr><td>Vectors</td><td>Shapefiles (*.shp)
• Data extent (TAF/BAOI)
• BAOI tile index of 0.0375 minute USGS quadrangles
• BAOI tile index of 7.5 minute USGS quadrangles</td></tr>
<tr><td>Metadata</td><td>• FGDC compliant metadata for all data products</td></tr>
<tr><th colspan="2">Projection: UTM Zone 10N
Horizontal Datum: NAD83 (2011)
Vertical Datum: NAVD88 (GEOID12A)
Units: Meters</th></tr>
<tr><td>Vectors</td><td>• Reserved ground survey points
• Reserved vegetated ground survey points for vegetated vertical accuracy (VVA) testing
• Ground survey points
• Monuments
• Acquisition flightlines</td></tr>
</table>

Aerial Acquisition

LiDAR Survey

The LiDAR survey utilized a Optech Orion H sensor mounted in a Partenavia P68, a Leica ALS 70 sensor mounted in a Cessna Caravan, and a Leica ALS 80 sensor mounted in a Cessna Grand Caravan. For system settings, please see Table 3. 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 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).

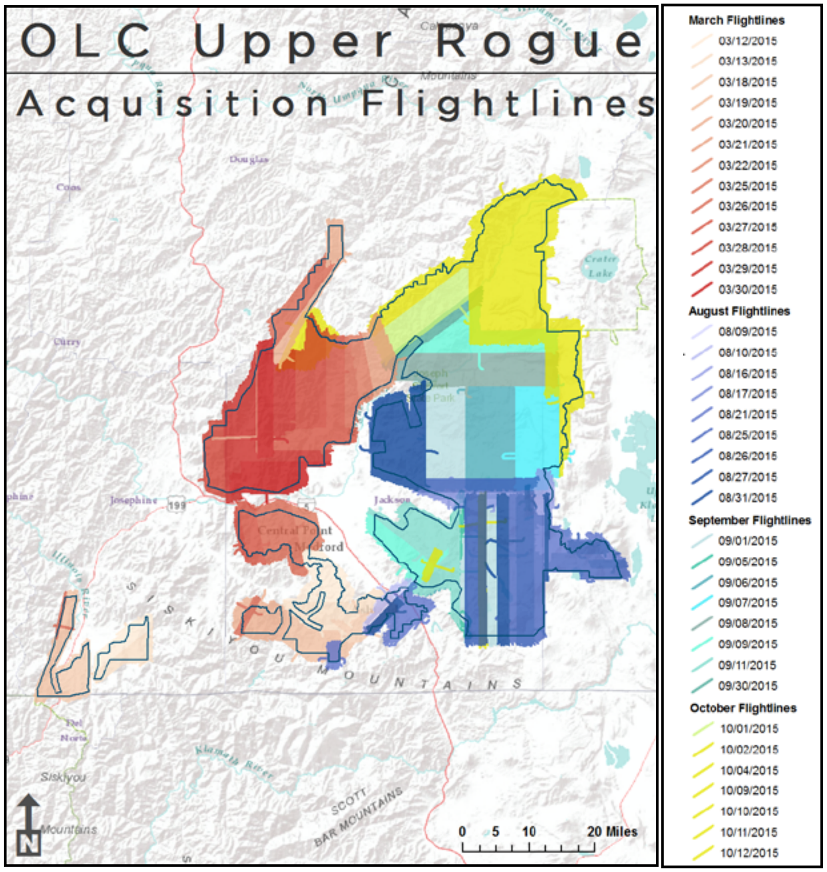

Figure 2: Upper Rogue aquisition specifications

Table 3: Upper Rogue aquisition specifications

OLC Upper Rogue			
Sensors Deployed	Optech Orion H	Leica ALS 70	Leica ALS 80
Aircraft	Partenavia P68	Cessna Caravan	Cessna Grand Caravan
Survey Altitude (AGL)	1,200 m	1,400 m	1,500 m
Pulse Rate	175 kHz	198 kHz	369.2 kHz
Pulse Mode	Multi (MPiA)	Single (SPiA)	Multi (MPiA)
Field of View (FOV)	30°	30°	30°
Scan Rate	66 Hz	55 Hz	55 Hz
Overlap	100% overlap with 60% sidelap	100% overlap with 60% sidelap	100% overlap with 60% sidelap

Ground Survey

Ground control surveys and ground survey points (GSPs) were collected 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.

Instrumentation

All Global Navigation Satellite System (GNSS) static surveys utilized Trimble R7 GNSS receivers with Zephyr Geodetic Model 2 RoHS antennas and Trimble R8 and R10 GNSS receivers with internal antennas. Rover surveys for GSP collection were conducted with Trimble R6, R8, and R10 GNSS receivers. See Table 4 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. 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.

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. Table 6 provides the list of monuments used in the Upper Rogue study area.

Methodology

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.

Table 4: Ground survey instrumentation

Instrumentation			
Receiver Model	Antenna	OPUS Antenna ID	Use
Trimble R6	Integrated GNSS Antenna R6	TRM_R6	Rover
Trimble R7 GNSS	Zephyr GNSS Geodetic Model 2 RoHS	TRM57971.00	Static
Trimble R8 GNSS	Integrated Antenna R8 Model 2	TRMR8_GNSS	Static & Rover
Trimble R10 GNSS	Integrated GNSS Antenna R10	TRM_R10	Static & Rover

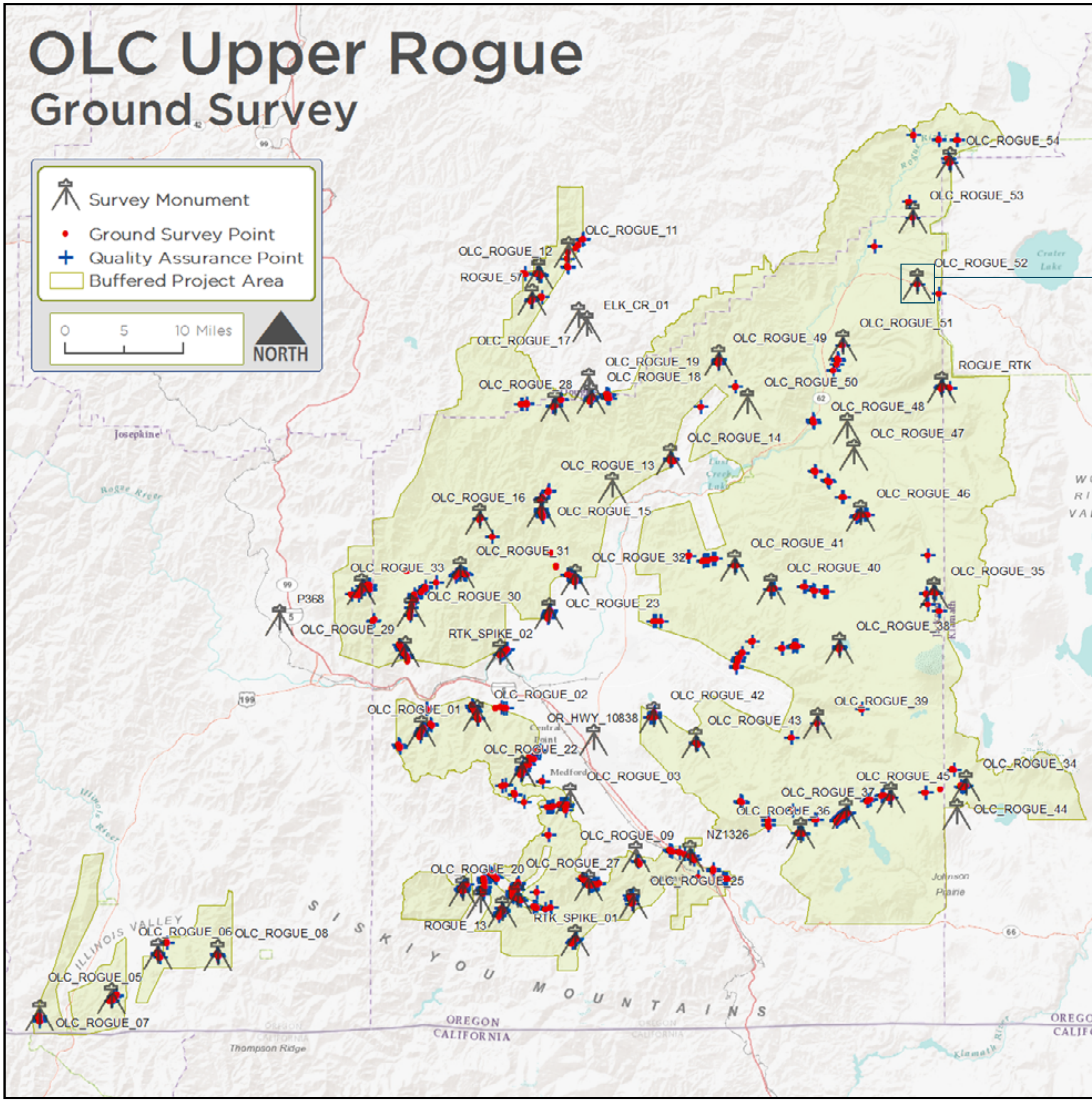

Figure 3: Upper Rogue study area ground control

Table 5: Monument accuracy

Monument Accuracy	
FGDC-STD-007.2-1998 Rating	
St Dev NE	0.05 m
St Dev z	0.05 m

Figure 4: OLC_Rogue_52 monument

Table 6: Upper Rogue monuments. Coordinates are on the NAD83 (2011) datum, epoch 2010.00. NAVD88 height referenced to Geoid12A

PID	Latitude	Longitude	Ellipsoid Height (m)	NAVD 88 Height (m)
ELK_CR_01	42° 51' 47.89427"	-122° 52' 29.96410"	429.503	453.050
NZ1326	42° 12' 56.39763"	-122° 42' 25.16969"	533.902	557.748
OLC_ROGUE_01	42° 22' 07.00310"	-123° 08' 53.91788"	367.532	391.620
OLC_ROGUE_02	42° 23' 15.01578"	-123° 03' 24.17445"	456.656	480.804
OLC_ROGUE_03	42° 17' 11.24224"	-122° 54' 11.54186"	480.129	504.240
OLC_ROGUE_04	42° 09' 51.58582"	-122° 59' 25.38937"	505.340	529.323
OLC_ROGUE_05	42° 02' 20.90011"	-123° 39' 24.33043"	758.815	784.108
OLC_ROGUE_06	42° 05' 42.15466"	-123° 34' 49.77393"	427.485	452.505
OLC_ROGUE_07	42° 01' 04.66723"	-123° 46' 28.24206"	717.223	742.878
OLC_ROGUE_08	42° 05' 36.81673"	-123° 28' 56.63990"	803.537	827.862
OLC_ROGUE_09	42° 12' 53.20064"	-122° 47' 44.04677"	587.585	611.452
OLC_ROGUE_11	42° 57' 17.74527"	-122° 54' 18.94647"	310.666	334.331
OLC_ROGUE_12	42° 55' 43.87705"	-122° 57' 15.45360"	293.171	316.875
OLC_ROGUE_13	42° 39' 59.63026"	-122° 49' 59.25091"	439.662	463.532
OLC_ROGUE_14	42° 42' 03.54891"	-122° 44' 08.86227"	509.166	532.958
OLC_ROGUE_15	42° 38' 14.31354"	-122° 57' 03.80141"	538.391	562.172
OLC_ROGUE_16	42° 37' 39.95742"	-123° 03' 08.27143"	630.468	654.201
OLC_ROGUE_17	42° 52' 25.49935"	-122° 53' 18.60968"	408.720	432.288
OLC_ROGUE_18	42° 46' 33.02411"	-122° 52' 06.86364"	998.598	1022.043
OLC_ROGUE_19	42° 47' 37.21365"	-122° 52' 19.79322"	955.973	979.422
OLC_ROGUE_20	42° 10' 22.71788"	-123° 04' 49.66498"	936.786	960.781
OLC_ROGUE_21	42° 08' 52.26538"	-123° 00' 52.78429"	1082.083	1106.019
OLC_ROGUE_22	42° 19' 10.20870"	-122° 58' 59.90736"	521.889	545.963
OLC_ROGUE_23	42° 30' 44.61326"	-122° 56' 18.23072"	391.583	415.750
OLC_ROGUE_25	42° 09' 30.87208"	-122° 47' 57.50260"	1181.392	1204.916
OLC_ROGUE_27	42° 10' 49.30490"	-122° 52' 24.79828"	1357.934	1381.660
OLC_ROGUE_28	42° 45' 58.82378"	-122° 55' 43.45972"	1258.505	1281.873
OLC_ROGUE_29	42° 27' 58.41703"	-123° 10' 30.95835"	292.225	316.365
OLC_ROGUE_30	42° 30' 56.85400"	-123° 09' 59.34774"	314.125	338.184
OLC_ROGUE_31	42° 33' 45.92488"	-123° 05' 06.68781"	375.690	399.664
OLC_ROGUE_32	42° 33' 15.20159"	-122° 53' 41.18139"	426.809	450.952
OLC_ROGUE_33	42° 32' 31.91539"	-123° 14' 52.94658"	1287.058	1310.898
OLC_ROGUE_34	42° 17' 58.74717"	-122° 15' 03.65322"	1559.908	1582.715
OLC_ROGUE_35	42° 32' 09.89278"	-122° 18' 03.13420"	1971.247	1993.991
OLC_ROGUE_36	42° 14' 35.30986"	-122° 31' 28.06861"	1380.053	1403.385
OLC_ROGUE_37	42° 15' 57.58498"	-122° 26' 55.89480"	1359.193	1382.434

PID	Latitude	Longitude	Ellipsoid Height (m)	NAVD 88 Height (m)
OLC_ROGUE_38	42° 28' 09.44668"	-122° 27' 28.30228"	901.625	925.030
OLC_ROGUE_39	42° 22' 38.70078"	-122° 29' 43.70178"	1231.497	1255.070
OLC_ROGUE_40	42° 32' 29.35735"	-122° 34' 16.62478"	752.518	776.251
OLC_ROGUE_41	42° 34' 15.34035"	-122° 37' 52.08966"	665.904	689.795
OLC_ROGUE_42	42° 23' 07.70498"	-122° 45' 55.73659"	483.741	507.926
OLC_ROGUE_43	42° 21' 16.29136"	-122° 41' 47.91787"	563.393	587.351
OLC_ROGUE_44	42° 15' 50.50819"	-122° 15' 59.51313"	1651.753	1674.631
OLC_ROGUE_45	42° 17' 08.11728"	-122° 22' 32.14687"	1390.615	1413.718
OLC_ROGUE_46	42° 37' 52.91385"	-122° 25' 21.20232"	1051.539	1074.693
OLC_ROGUE_47	42° 42' 18.83535"	-122° 25' 56.15625"	891.296	914.461
OLC_ROGUE_48	42° 44' 15.32619"	-122° 26' 39.10895"	778.248	801.458
OLC_ROGUE_49	42° 49' 19.67043"	-122° 39' 22.19108"	812.491	835.881
OLC_ROGUE_50	42° 46' 06.41415"	-122° 36' 28.81405"	829.097	852.595
OLC_ROGUE_51	42° 50' 23.71158"	-122° 26' 59.09894"	919.980	942.936
OLC_ROGUE_52	42° 54' 47.73535"	-122° 19' 28.93914"	1326.998	1349.352
OLC_ROGUE_53	42° 59' 42.26374"	-122° 19' 52.85224"	1416.157	1438.437
OLC_ROGUE_54	43° 03' 42.46739"	-122° 16' 09.13410"	1670.856	1692.916
OR_HWY_10838	42° 21' 27.34828"	-122° 51' 53.77031"	382.986	407.264
P368	42° 30' 12.67505"	-123° 23' 00.25554"	319.862	344.231
P784	41° 49' 50.92289"	-122° 25' 13.58557"	802.702	826.522
ROGUE_13	42° 09' 29.74350"	-123° 03' 01.75648"	455.048	479.072
ROGUE_57	42° 53' 49.96185"	-122° 57' 56.97488"	792.056	815.685
ROGUE_RTK	42° 47' 14.56519"	-122° 17' 11.69638"	1646.586	1668.874
RTK_SPIKE_01	42° 06' 46.35936"	-122° 53' 46.55316"	1072.285	1095.827
RTK_SPIKE_02	42° 27' 42.63554"	-123° 01' 07.26240"	312.773	336.943

LiDAR Accuracy Assessments

Table 7: Relative accuracy

Relative Accuracy Calibration Results		
Project Average	0.054 m	0.178 ft
Median Relative Accuracy	0.053 m	0.173 ft
1σ Relative Accuracy	0.058 m	0.190 ft
2σ Relative Accuracy	0.075 m	0.245 ft
Flightlines	1,839	
Sample points	21,190,480,423	

Relative Accuracy

Relative vertical 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, reported in Table 7 are based on the comparison of 1,839 full and partial flightlines and over 21 billion sample points.

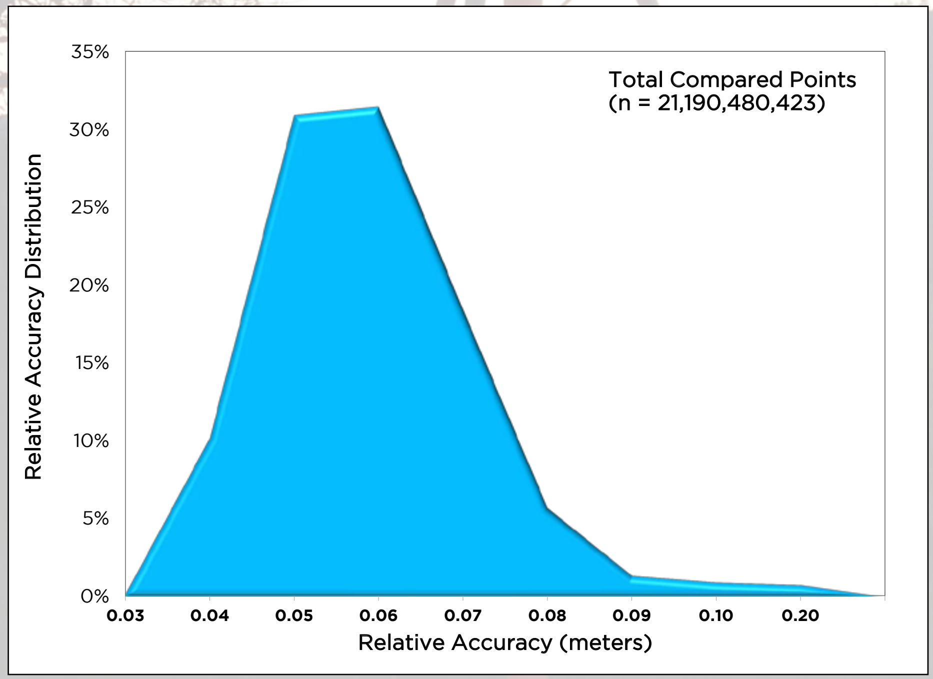

Figure 5: Relative accuracy based on 1,839 flightlines.

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 Positional Accuracy Standards for Digital Geospatial 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 Upper Rogue study area, a total of 14,623 GSPs were collected and used for calibration of the LiDAR data. An additional 773 reserved ground survey points were collected for independent verification, resulting in a non-vegetated vertical accuracy (NVA) of 0.091 meters, or 0.297 feet.

OLC will use quality assurance points (QAPs) acquired by OLC staff in representative areas of vegetated land cover to assess the vegetated vertical accuracy (VVA) of the OLC Upper Rogue dataset; results will be appended to this report.

Table 8: Vertical accuracy

Vertical Accuracy Results		
Sample Size (n)	773 Reserved Ground Survey Points	
NVA (RMSE*1.96)	0.091 m	0.297 ft
Root Mean Square Error	0.046 m	0.152 ft
1 Standard Deviation	0.038 m	0.125 ft
2 Standard Deviation	0.101 m	0.331 ft
Average Deviation	0.035 m	0.115 ft
Minimum Deviation	-0.327 m	-1.073 ft
Maximum Deviation	0.132 m	0.433 ft

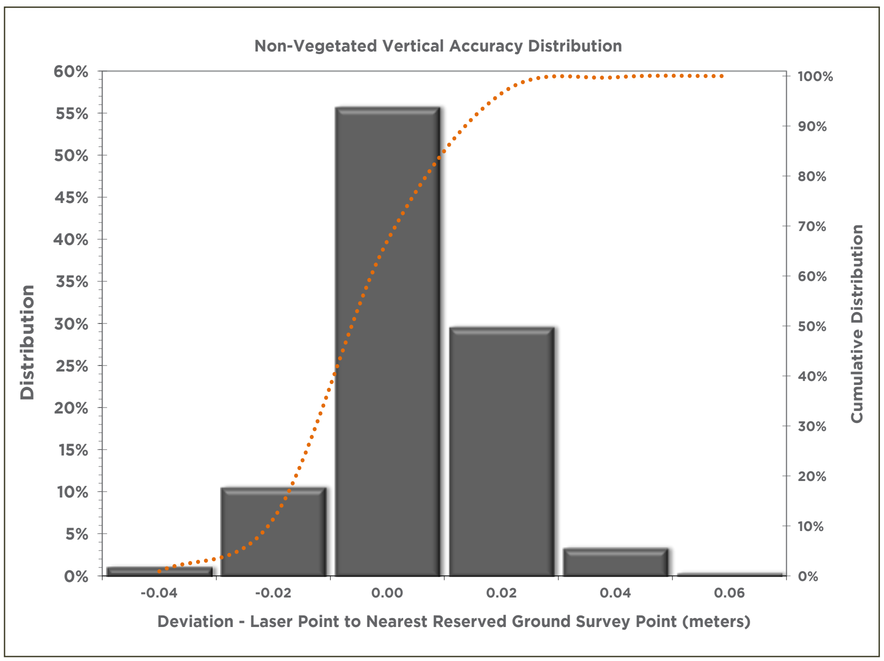

Figure 6: Vertical Accuracy distribution

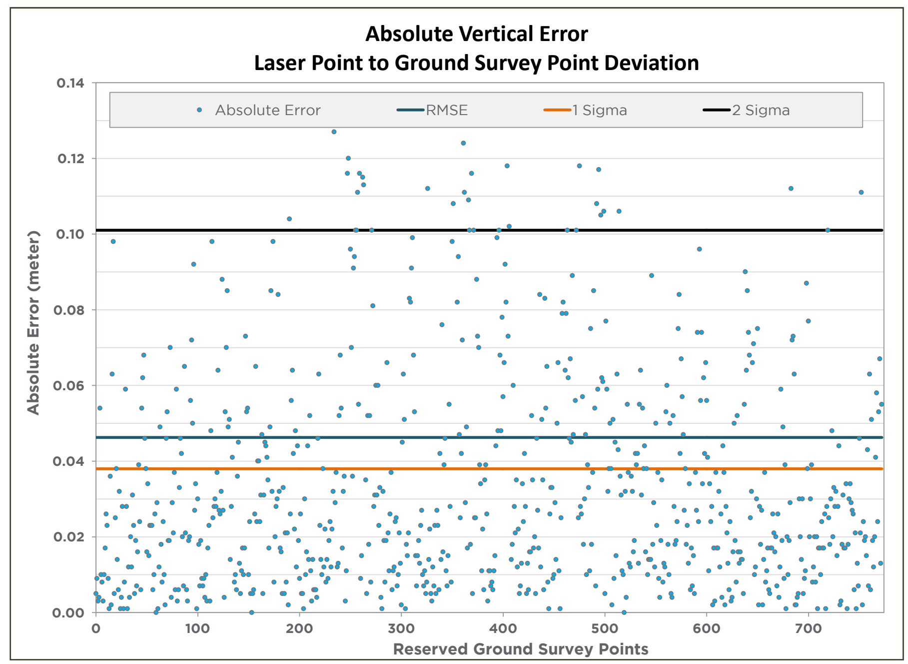

Figure 7: GSP absolute error

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. Densities are reported for the delivery area.

Table 9: Average pulse density

	pulses per square meter	pulses per square foot
Average Pulse Density	12.24	1.14

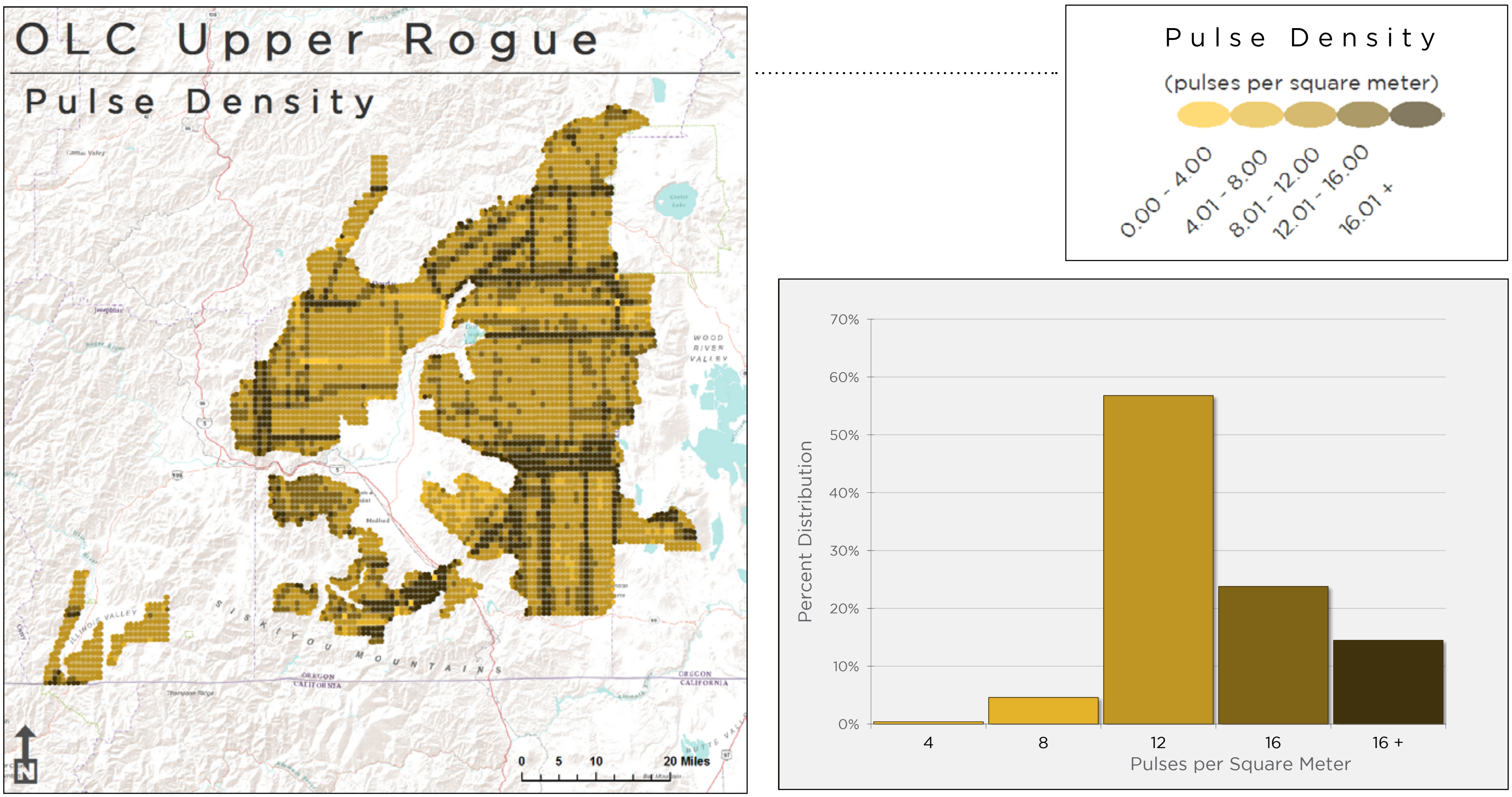

Figure 8: Average pulse density per 0.75' USGS Quad (color scheme aligns with density chart).

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 in Table 10 is a measure of ground-classified point data for the delivery area.

Table 10: Average ground density

Ground Density	points per square meter	points per square foot
	1.81	0.17

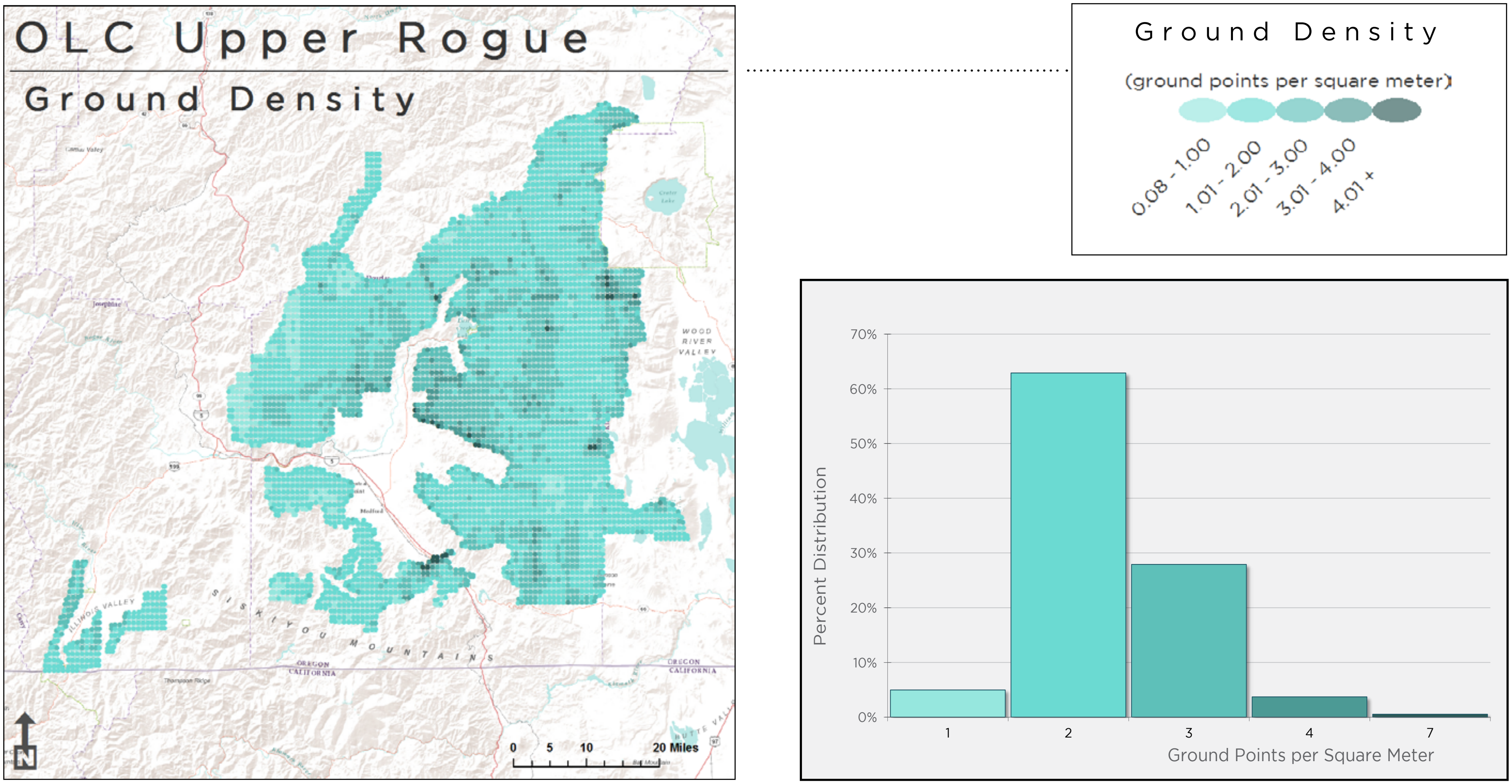

Figure 9: Average ground density per 0.75' USGS Quad (color scheme aligns with density chart).

[Page Intentionally Blank]

Appendix A : PLS Certification

Certifications

Quantum Spatial, Inc. provided LiDAR services for the 2015 OLC Upper Rogue 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 March 12, 2015 and April 28, 2015 and between August 9, 2015 and October 14, 2015.

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, PLS
Quantum Spatial, Inc.
Corvallis, OR 97333

REGISTERED
PROFESSIONAL
LAND SURVEYOR

OREGON
JUNE 10, 2014
EVON P. SILVIA
81104LS

EXPIRES: 06/30/2018