Appendix B

U.S. Geological Survey
McKenzie River Topobathymetric Lidar – Accuracy Assessment and Validation Field Survey Plan
(As of 7/12/2021)

Location: Eugene/Springfield, Oregon
Dates:

Arrive in Eugene, OR on July 18, 2021
Depart for Duty Station from Corvallis, OR on August 3, 2021
Actual Dates of McKenzie River Field Survey: July 26 – 31, 2021
NV5 / QSI Meeting on August 2, 2021 (Corvallis)

Statement of Problem and Objective:

The goal of this study is to evaluate and help define collection parameters (i.e. water clarity) for acquiring bathymetry from airborne commercial topobathymetric (TB) lidar systems in rivers. This study will test the Riegl VQ-880-G II topobathy lidar sensor in environmental conditions with varying degrees of bottom type, water clarity, and depth. The data collected will be useful in understanding lidar sensor performance and increase the general base of knowledge of this emerging technology within the USGS National Geospatial Program (NGP). The information gained from the study will help the 3D Elevation Program (3DEP) understand the potential viability of topobathymetric lidar as an effective technology for mapping bathymetry in rivers.

The Riegl VQ-880-G II is a short pulse length, high repetition rate lidar scanner. This topobathy laser scanning system includes an additional infrared (IR) channel, inertial measurement unit (IMU)– Global Navigation Satellite System (GNSS), and 29-Mpixel camera. The green channel (532 nm) of the VQ-880-G II performs a circular scan with an off-nadir angle of 20°. The IR channel provides the capability to detect the signal from the water surface, even under unfavorable conditions. The current flying height for the Riegl VQ-880-G II is 400m above ground level (AGL).

Riegl VQ-880-G II Topobathy Lidar

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USGS Oregon Water Science Center (WSC) – Science Plan Use for Topobathy Lidar Data Accurate bathymetry data is a critical component for developing reliable hydraulic models, which can be used to evaluate flood inundation, hazard analysis, or aquatic habitat evaluation. The ORWSC is currently mapping bathymetry on several Willamette tributaries including the McKenzie, North Santiam, and South Santiam Rivers to build the foundation for hydraulic modeling and endangered salmon and steelhead habitat modeling. Topobathy Lidar on the McKenzie River will provide a foundation for hydraulic modeling and post-fire geomorphic change detection. The topobathy Lidar will also provide a training and validation dataset to refine image derived bathymetric algorithms which will facilitate bathymetric on rivers beyond the current area of interest. A more spatially comprehensive bathymetric dataset of the McKenzie River would support studies that:

- Validate river-based satellite derived bathymetry (SDB)
- Fisheries – Endangered Steelhead / Trout habitat modeling
- River Restoration
- Dam Management
- Landslide Hazards / Sediment Transport
- Predict flow-routing as part of 2D / 3D hydrologic and hydraulic modeling

Study Area: (44° 6'3.15"N, 122°41'14.82"W)

The collection area encompasses the McKenzie River between Eugene, Oregon, and Trail Bridge Reservoir (Figure 1). The collection area also includes the South Fork of the McKenzie River from the confluence with the McKenzie River upstream to Cougar Dam and the Blue River Upstream to Blue River Dam. The McKenzie River is a 90-mile tributary of the Willamette River in western Oregon. The upper basin consists of granular, permeable igneous rocks, while most of the middle and lower McKenzie is made of the remnants of older, more weathered volcanic rocks. Annual base flows average around 1500 – 2000 cubic feet per second (cfs) in late July. Details about water clarity in the McKenzie River can be obtained through the USGS Stream Gage 14162500 near Vida, OR.

Ground-based Field Assessment:

At selected locations within the collection area, ground-based field data will be collected. Acoustic sonar, survey-grade GNSS, and ground-based lidar methods will be used to evaluate the accuracy and performance of the topobathymetric lidar system.

Figure 1. McKenzie River AOI

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Figure 3. McKenzie River Oxbow (Waded GNSS, Acoustic Sonar)
Secondary/Backup Site

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Figure 4. Deerhorn Landing Boat Ramp (Targets, GNSS Wading, and Acoustic Sonar) Coordinates: 44° 5'28.91"N, 122°42'56.72"W

Secondary/Backup Site

Figure 5a. Leaburg Reservoir (Old McKenzie Fish Hatchery and Lloyd Knox Park) Topo/Underwater Targets, GBL, Waded GNSS, Acoustic Sonar)
Coordinates: 44° 8'27.60"N, 122°36'39.26"W

Primary Site

Lloyd Knox Park is a park located in Lane County, OR at N44.13874° W122.60952° (NAD83) and at an elevation of 764 ft MSL.
It can be seen on the USGS 1:24K topographic map Vida, OR.

Latitude:	N44.13874° (NAD83 datum)
Longitude:	W122.60952°
Elevation:	764 ft MSL
County:	Lane County, Oregon

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Figure 5b. Leaburg Reservoir / EWEB Boat Ramp (Waded GNSS, Acoustic Sonar)
Coordinates: 44° 8'41.63"N, 122°35'23.53"W
Primary Site

Figure 6. Finn Rock Boat Ramp (Topo/Underwater Targets, Waded GNSS, Acoustic Sonar)
Coordinates: 44° 7'42.89"N, 122°22'46.91"W
Primary Site

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Figure 7. McKenzie River Community School (GBL)
Coordinates: 44° 9'8.35"N, 122°21'44.97"W
Primary Site

Ground-based Field Assessment Methods

1. **Collect topographic information from land surfaces and shallow, wadable sections:** Acquire RTK-GPS depth profile information in the shallow sections (braided portions) of the river channel and, if possible, shore-normal transects of points of opportunity along the river edge. Position and survey topographic targets with a total station along river edge for point cloud 3D accuracy assessments. The absolute vertical accuracy of the lidar topo and bathymetry (depth) will be assessed with the profile data.
   a. RTK-GPS Horizontal Accuracy = +/- 1 cm + 1 part per million (ppm) RMS (2cm)
   b. RTK-GPS Vertical Accuracy = +/- 2 cm + 1 ppm RMS (3cm)
   c. SX10 Total Station Accuracy = Horizontal and vertical angular measurement accuracy (1 arc seconds) and distance measurement accuracy (± 2 mm + 1.5 ppm). The total station will be used to capture precise 3D coordinates on targets and invariant building/objects.

2. **Collect bathymetric information from non-wadable sections:** Collect transects of acoustic sonar data in the river channel using a series of comparable methods. The absolute vertical accuracy of the lidar bathymetry will be assessed with the sonar depth data (Oregon WSC).

   Approach: Seafloor Systems Hydrolite-DFX is a portable single frequency echosounder. The system operates at a frequency of 200 kHz for penetrating through soft sediments to detect both hard bottom classification and surface layers.

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Echosounder Specs:
Frequency: 200 kHz
Beam Width: 9 ° /20°
Ping Rate: 6 Hz w/ 2Hz output
Depth Accuracy: 1cm/ 0.1 % of depth
Output formats: NMEA, ASCII, ODOM, ATLAS
Range: 0.3 – 75m, noisy data in depths < 0.5m.

3. **Gather water clarity information**: Water clarity will be evaluated using a variety of approaches. This information will be used to help understand the performance of the airborne lidar system. Because the focus will be on collecting topographic and bathymetric information, water clarity will only be collected from a subset of points at a given site. Measurements will be made from boats, wading, and perhaps from bridges. Attempts will be made to collect a series of measurements along a lateral transect and, if possible, at discrete depths within a transect.
   a. USGS continuous water quality monitors record turbidity and other water quality metrics on the McKenzie River at Vida (14162500), McKenzie River near Walterville (14163900), McKenzie River Below Trail Bridge Dam (14158850), South Fork McKenzie River (14159500), and Blue River (14162200)
   b. Field turbidimeter: A field turbidimeter will be used for the majority of data collection. This will be from one of two turbidimeter models, both of which measure the reflection of a monochrome (780-900 nm wavelength) light beam on a single photoreceptor positioned at a 90^{o} angle to that beam:
      i. YSI EXO turbidity sensor: 0 – 4,000 Formazin Nephelometric Unit (FNU) range at +/-2% accuracy
      ii. YSI 6136 turbidity sensor:0 – 1,000 FNU range at +/-2% accuracy.
   c. Secchi disc/tube: Secchi depths will be measured in addition to (or in some cases, instead of) turbidity.
   d. Samples: If resources provide for it, it is possible that a subset of water samples will be collected to provide more information about clarity and sediment transport characteristics. Collected samples may be analyzed for clarity using benchtop turbidimeters or spectrophotometers but may also be sent to sediment laboratories for concentration and gradation analyses. Depth-integrating techniques (Edwards and Glysson, 1999) will be employed with an appropriately sized isokinetic sampler.

4. **Place land-based topo-targets:** Coincident with the lidar flight, place reflective topo targets along the river bank edge and features of opportunity to assess the 3D absolute horizontal and vertical accuracy of the lidar data.

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Reflective Topo Target (Example deployments from Kootenai in Idaho and Niobrara in Nebraska)

5. **Place underwater reflective targets:** Coincident with the lidar flight, place two to five underwater reflective targets on the river bottom in varying substrate conditions. The goal is to assess the underwater dispersion of the topobathymetric lidar system. An underwater target is logically placed and surveyed to create a spatially distributed range of known positions between the laser pulse and target.
   a. Given the highly dynamic nature of the streambed (in some reaches more than others), these targets will either need to be placed in slackwater or other low-velocity portions of the stream or will need to be placed and surveyed at nearly the same time (within 6 hours) as LiDAR flights are occurring.
   b. The potential deployment locations for these targets may also be limited by the fact that they will be installed using kayaks and canoes.
   c. The position of deployed targets will be determined using survey-grade GPS techniques.
   d. Underwater river targets – Use wide base to minimize sediment trapping and to help with target removal. Examine whether natural features (bedrock areas) could work for potential targets of opportunity.

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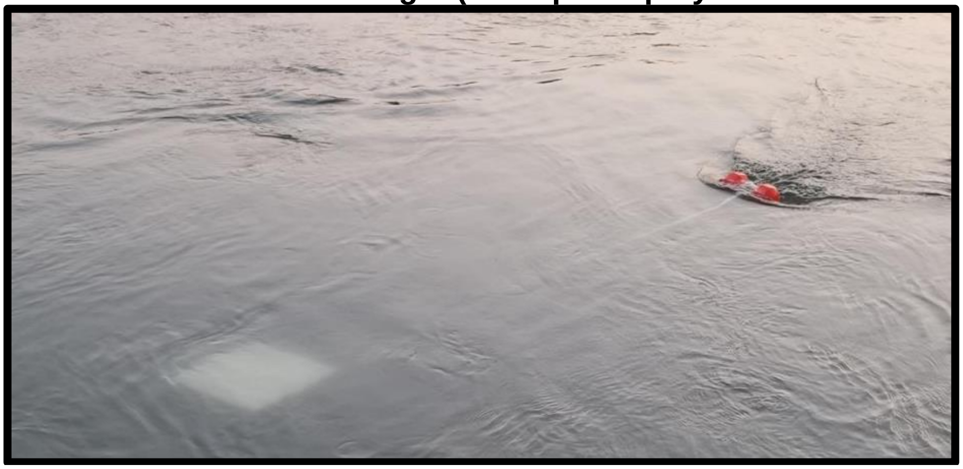
Reflective Underwater Target (Example deployment from Niobrara)



Reflective Underwater Target

6. **Collect Data on Structures:** Acquire Ground Based Lidar (GBL) data on structures (particularly structures with multiplanar roofs) located in the collection area to assess the 3D accuracy of the airborne lidar data.
    a. GBL Accuracy = 5 mm
    b. GBL Precision = 3 mm
    c. GBL Laser Wavelength = Near Infrared
    d. GBL Laser Beam Divergence = 0.35 mrad
    e. GBL Point Spacing = 10 to 20mm (Depends on average distance from the scan to area of interest)

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Field Survey and Airborne Lidar Data Collection Specifications:

- Projection = Oregon Statewide Lambert
- Horizontal Datum = NAD83 (2011)
- Horizontal Units = International Feet
- Vertical Datum = NAVD88 (Geoid18)
- Vertical Units = International Feet
- Lidar Data Format = LAS
- GNSS (Targets) Data Format = Shapefile, KML, CSV

Key Equipment List:

1. Seafloor Systems Hydrolite-DFX Dual Frequency Echosounder (Oregon WSC)
2. Trimble (R12 and R8) GNSS Receivers (Oregon WSC)
3. Secchi Disk(s) (USGS EROS)
4. Turbidity Meter(s)
5. 1 Riegl VZ-400i Ground-Based Terrestrial Laser Scanner (USGS EROS)
6. 9 Riegl Cylindrical Georeferencing/Alignment Targets (USGS EROS)
7. 3 Trimble (R10-2) GNSS Receivers with Trimble TDL-450H External Base Station Radio (USGS EROS)
8. 1 Trimble R8-3 GNSS Receiver (USGS EROS)
9. 1 GPS backpack, magnet to attach GPS antenna to vehicle (if required) (USGS EROS)

RTK-GNSS

10. 1 Trimble SX10 Robotic Total Station (USGS EROS)
11. Nikon AX-2s Automatic Level and level rod (USGS EROS)
12. Range Poles, Bipods, and Tripods (USGS EROS)
13. 4 Personal Flotation Devices, First Aid Kit (USGS EROS)
14. Waders (USGS EROS)
15. 60 Reflective topo targets with T-posts (USGS EROS)
16. Post pounder (USGS EROS)
17. 5 Underwater targets with support frames(USGS EROS)
18. Two-way radios (USGS EROS)

19. Cell phones (For safety, ensure containment in water proof case)
19. Sun and rain protection
20. Covid-19 (Preventive gear) – Cloth Face Coverings, Disinfecting Wipes, and Hand Sanitizer

Schedule / Work Plan:

Sunday, July 18th – Arrival in Eugene, OR (USGS EROS)
Monday, July 19th – Scout McKenzie River AOI (USGS EROS)

Tuesday, July 20th – Saturday, July 24th
Place and survey topo targets in boat ramps, park areas, and McKenzie River Community School. Scan planar features and trees with ground-based lidar, and establish validation control points (USGS EROS)

Sunday, July 25th – Scheduled Day Off

Monday, July 26th – Topobathymetric Lidar Collection in the AOI (NV5/QSI); Ground-based field validation activities at **Hayden Bridge Boat Ramp and Deerhorn Landing Boat Ramp** (USGS ORWSC and USGS EROS); Underwater Target Placement

Tuesday, July 27th – Topobathymetric Lidar Collection in the AOI; Ground-based field validation at **Leaburg Reservoir Area and *EWEB Boat Ramp*** (USGS ORWSC and USGS EROS); Underwater Target Placement

Wednesday, July 28th – Topobathymetric Lidar Collection in the AOI; Ground-based field validation at **Leaburg Reservoir Area and *EWEB Boat Ramp*** (USGS ORWSC and USGS EROS); Underwater Target Placement

Thursday, July 29th – Topobathymetric Lidar Collection in the AOI; Ground-based field validation at **Finn Rock Boat Ramp** (USGS ORWSC and USGS EROS); Underwater Target Placement

Friday, July 30th – Topobathymetric Lidar Collection in the AOI; Ground-based field validation (USGS ORWSC and USGS EROS)

Saturday, July 31st –Survey Collection Wrap-up, Remove Field Targets, Clean and Pack Field Gear (USGS ORWSC and USGS EROS)

Sunday, August 1st – Scheduled Day Off

Monday, August 2nd – NV5 / QSI Technical Exchange Meeting (Corvallis)
Tuesday, August 3rd – Return to Duty Station

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General Permits Logistics Info:

1. Lane County Parks and Boat Ramps
    a. Old McKenzie Fish Hatchery Park
    b. Deerhorn Landing
    c. Hendricks Bridge
    d. Greenwood Landing
    e. Helfrich Landing
    f. Ben and Kay Dorris
    g. Forest Glen Park
2. Eugene Water and Electric Board sites
    A. Waterboard Park, Oregon
    B. EWEB Facility above Hayden Bridge
    C. Walterville Diversion between canal and river
    D. Leaburg canal lower power plant
    E. Leaburg canal . Access road between canal and river
    F. Leaburg diversion - access between canal and river (near fish screen?)
    G. Lloyd Knox Park
    H. Good Pasture Boat Landing
3. McKenzie River Trust sites
    a. Finn Rock
    b. McKenzie Oxbow
4. McKenzie River Community School

    Access Approved on 7/7/21 for July 20-24, 2021

    ***Upon arrival, check-in with the office prior to setting up.**

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at a glance **_RIEGL_ VZ-400i**

RIEGL VZ-400i Main Features

- ultra high speed data acquisition with up to 500,000 meas./sec, survey-grade accuracy ≤ 5 mm, up to 800 m measurement range
- high quality point cloud colorization based on Nikon® SLR camera image data taken simultaneouly during scanning, integration of various cameras possible
- orientation sensor for pose estimation
- advanced flexibility through support for external peripherals and accessories, e.g. external Bluetooth GNSS receiver on top
- cloud connectivity via Wi-Fi and 3G/4G LTE
- fully compatible with the _RIEGL_ VMZ Hybrid Mobile Laser Mapping System
- RiSCAN PRO standard processing software (included), RiSOLVE for fully automatic registration and colorization of scan data (optional)

Automatic On-board Registration

With two processors on-board, the _RIEGL_ VZ-400i is able to perform different processes in real-time such as automatic on-board registration in parallel to the scan data acquisition.

Processor 1	Processor 2
• **scan data acquisition** • simultanous acquisition of photographs during scanning • pose estimation (using GNSS/IMU/environment sensors)	• conversion of scan data into _RIEGL_ data base • on-board multiple time around resolution • **registration of scan data** as a background process

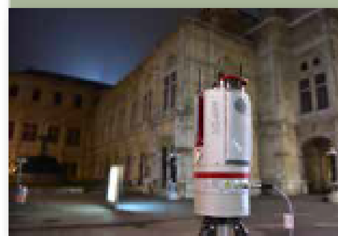
RIEGL VZ-400i Technical Data

- 800m max. measurement range
- 1.2MHz pulse repetition rate PRR
- online waveform processing
- Wi-Fi and 3G/4G LTE
- optional camera
- multiple target capability
- Laser Class 1

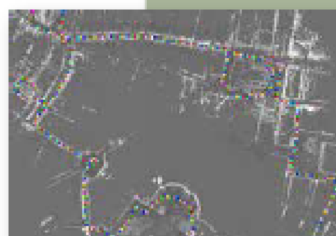
Laser Pulse Repetition Rate PRR (peak)	100 kHz	300 kHz	600 kHz	1,200 kHz
Max. Effective Measurement Rate (meas./sec)	42.000	125.000	250.000	500.000
Max. Measurement Range (ρ ≥ 90 %)	800 m	480 m	350 m	250 m
Max. Measurement Range (ρ ≥ 20 %)	400 m	230 m	160 m	120 m
Minimum Range	1.5 m	1.2 m	0.5 m	0.5 m
Accuracy / Precision	5 mm / 3 mm			
Field of View (FOV)	100° vertical / 360° horizontal			
Eye Safety Class	Laser Class 1 (eyesafe)			
Main Dimensions (width x height) / Weight	206 mm x 308 mm / 9.7 kg			

Further details to be found on the current _RIEGL_ VZ-400i Data Sheet.

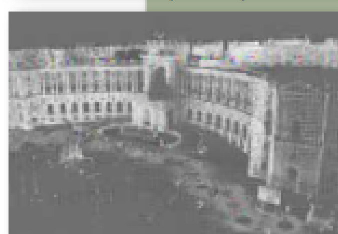
VZ-400i Field Experience:
One of the fastest scanners on the market:
500+ scans (50 mdeg) within 8 hours, handled by one operator!



RIEGL VZ-400i night scan in Vienna

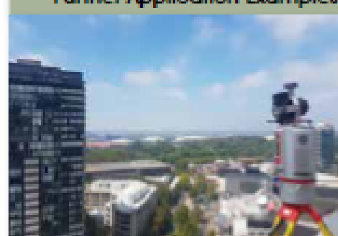


overview of scan positions (colored dots)

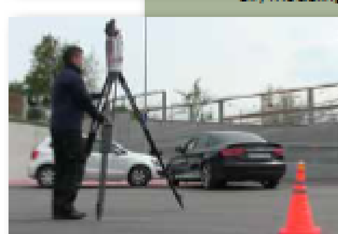


scan data detail, reflectance-scaled

Further Application Examples:



city modeling



forensics & investigation

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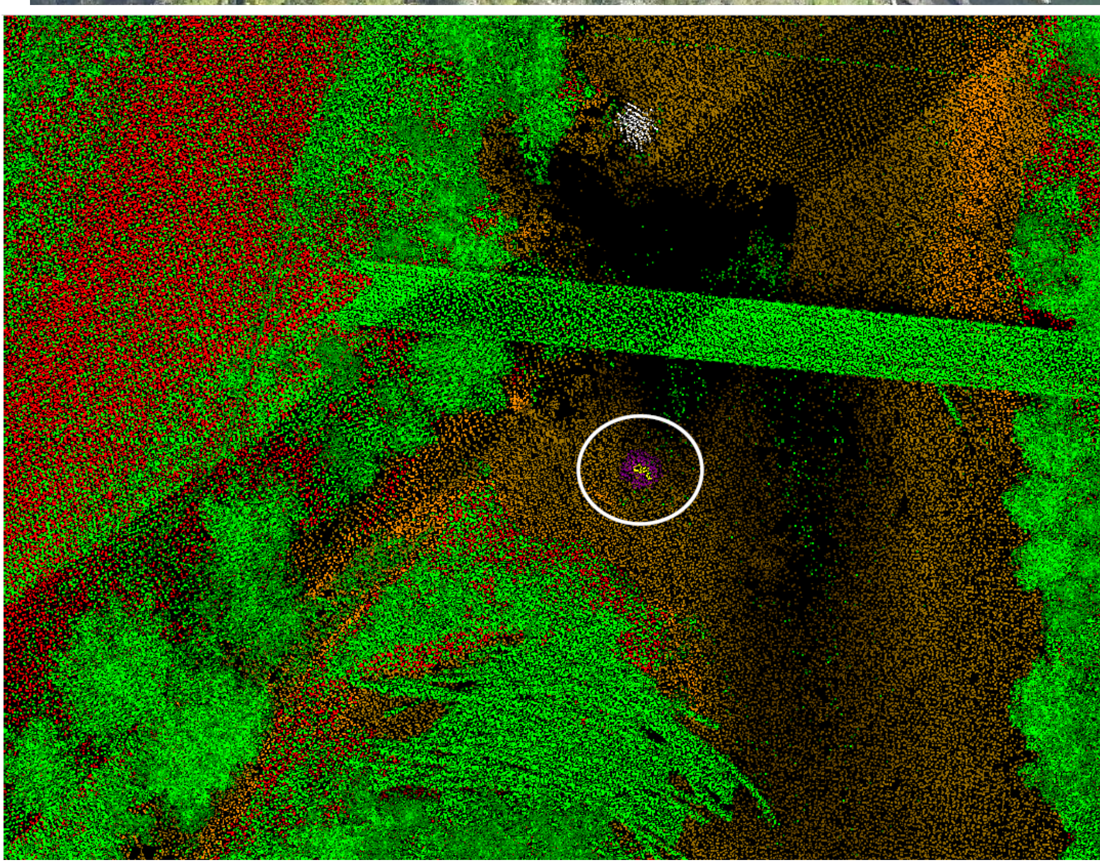
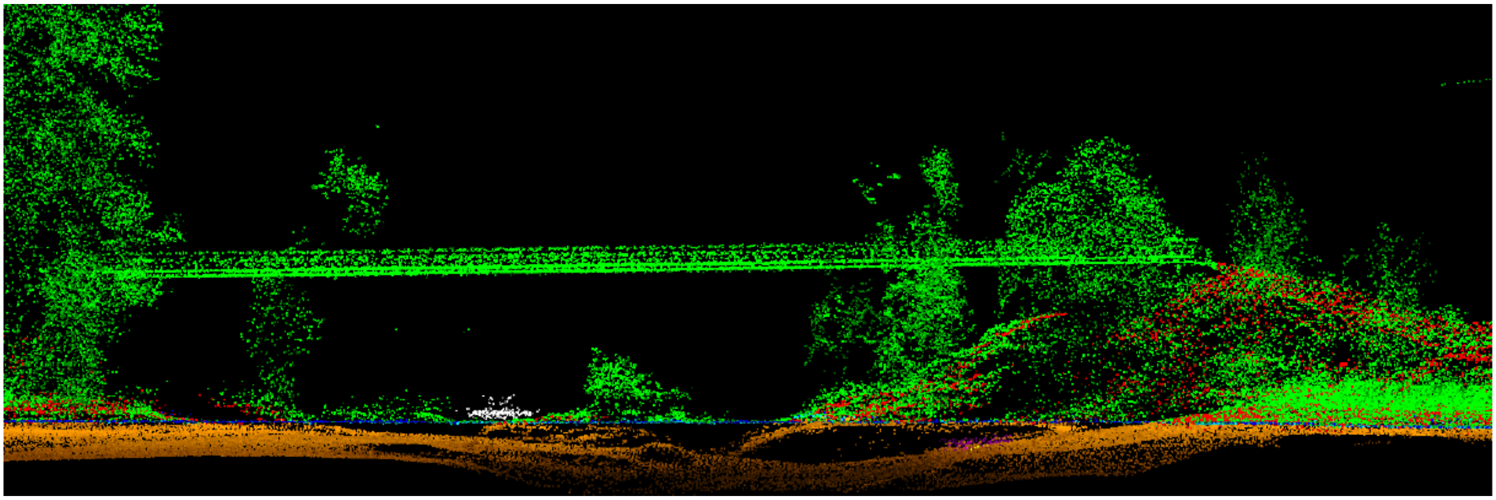
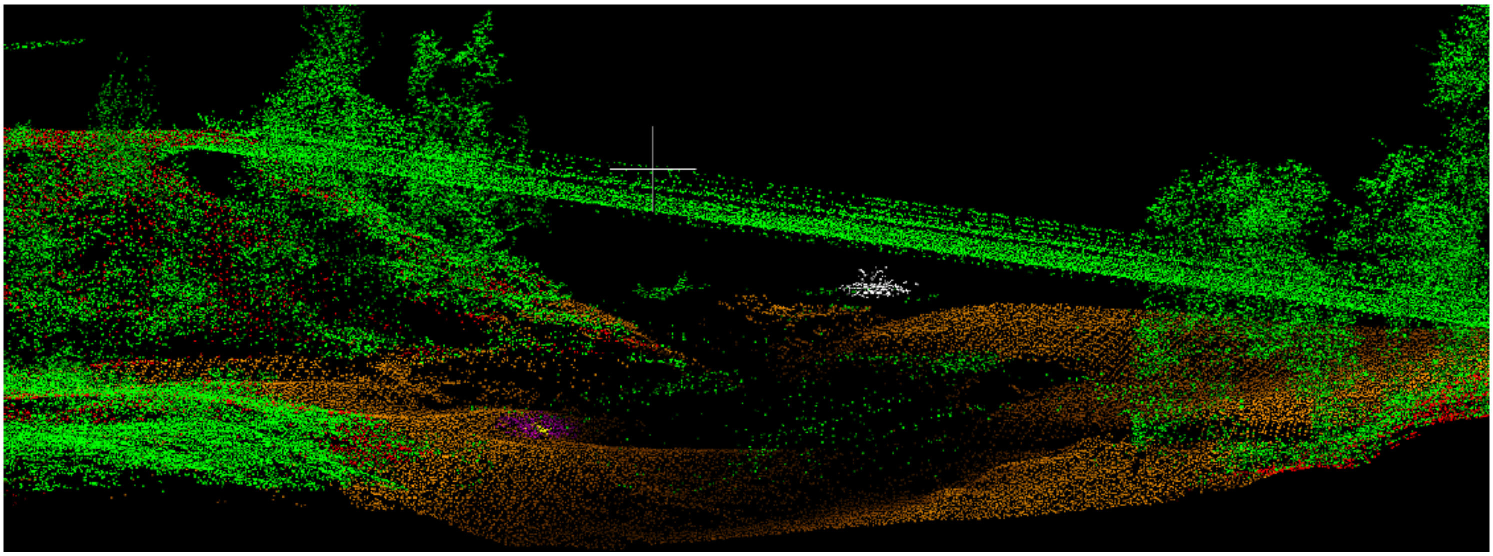
NV5 Observations of USGS Field Equipment

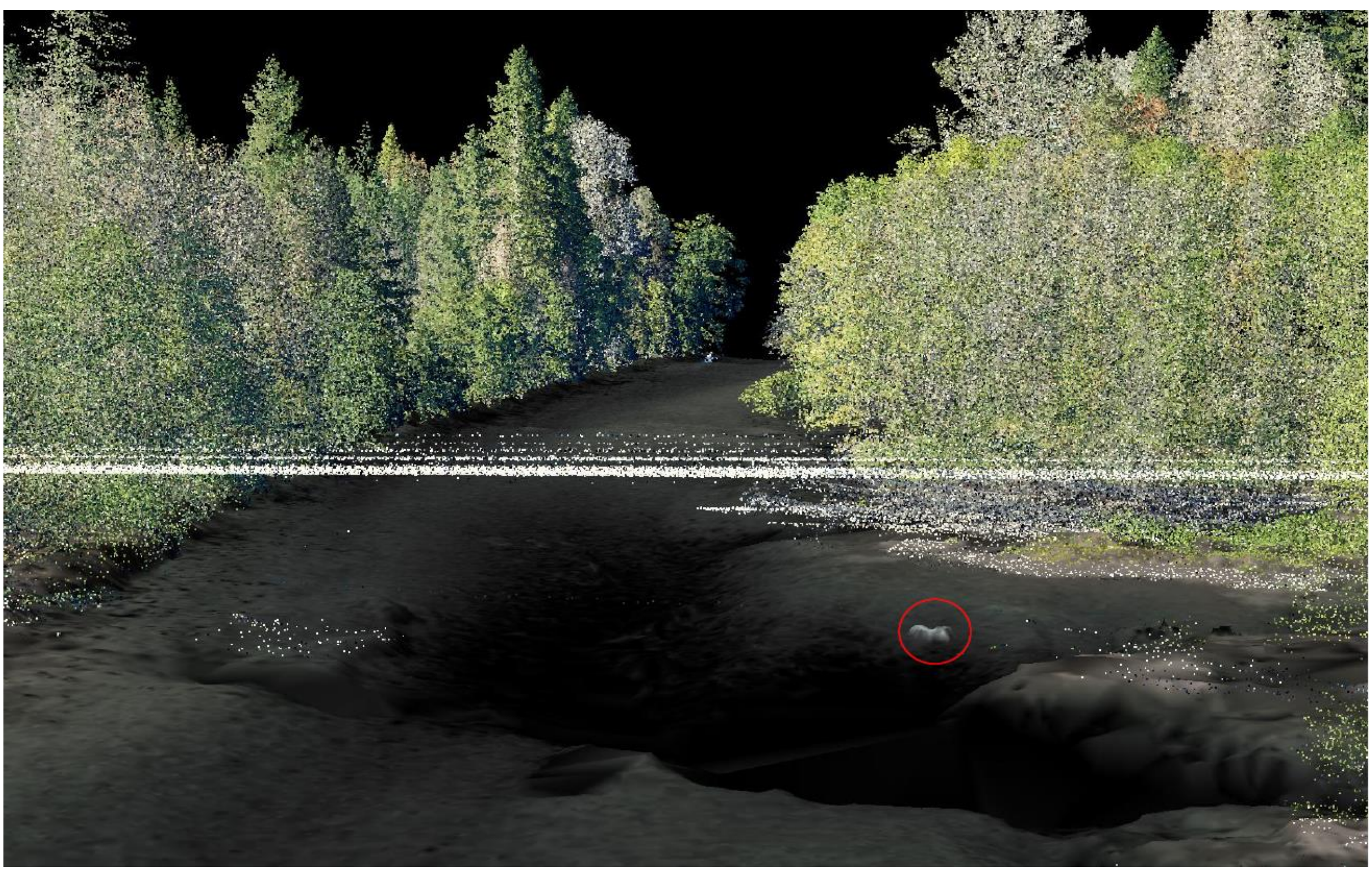


Prelim class codes in LAS file

- 1 default
- 2 ground
- 5 targets
- 6 boat
- 7 topo noise
- 8 high intensity backscatter surrounding target
- 9 NIR water surface
- 40 riverbed
- 41 green channel water surface
- 45 water column (back scatter between water surface and perceived bathy bottom)
- 47 bathy noise







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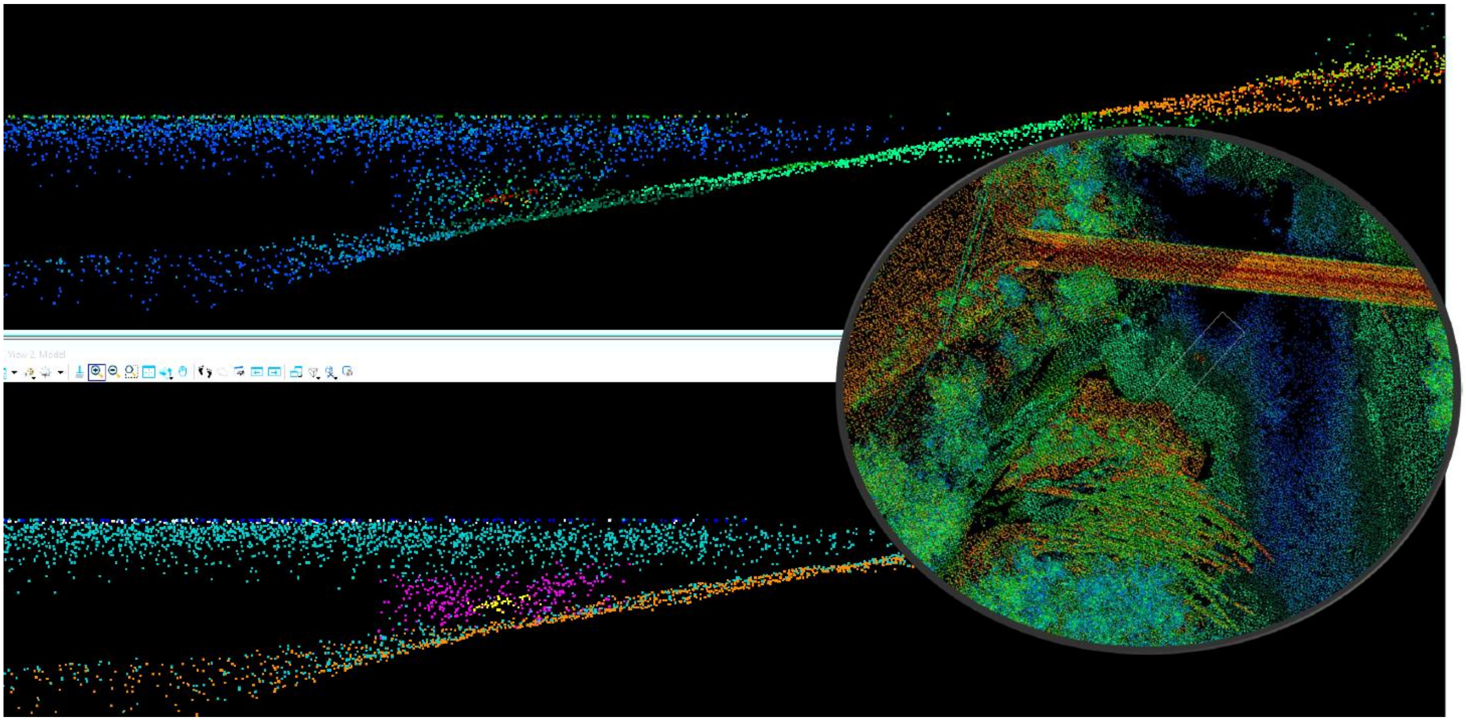

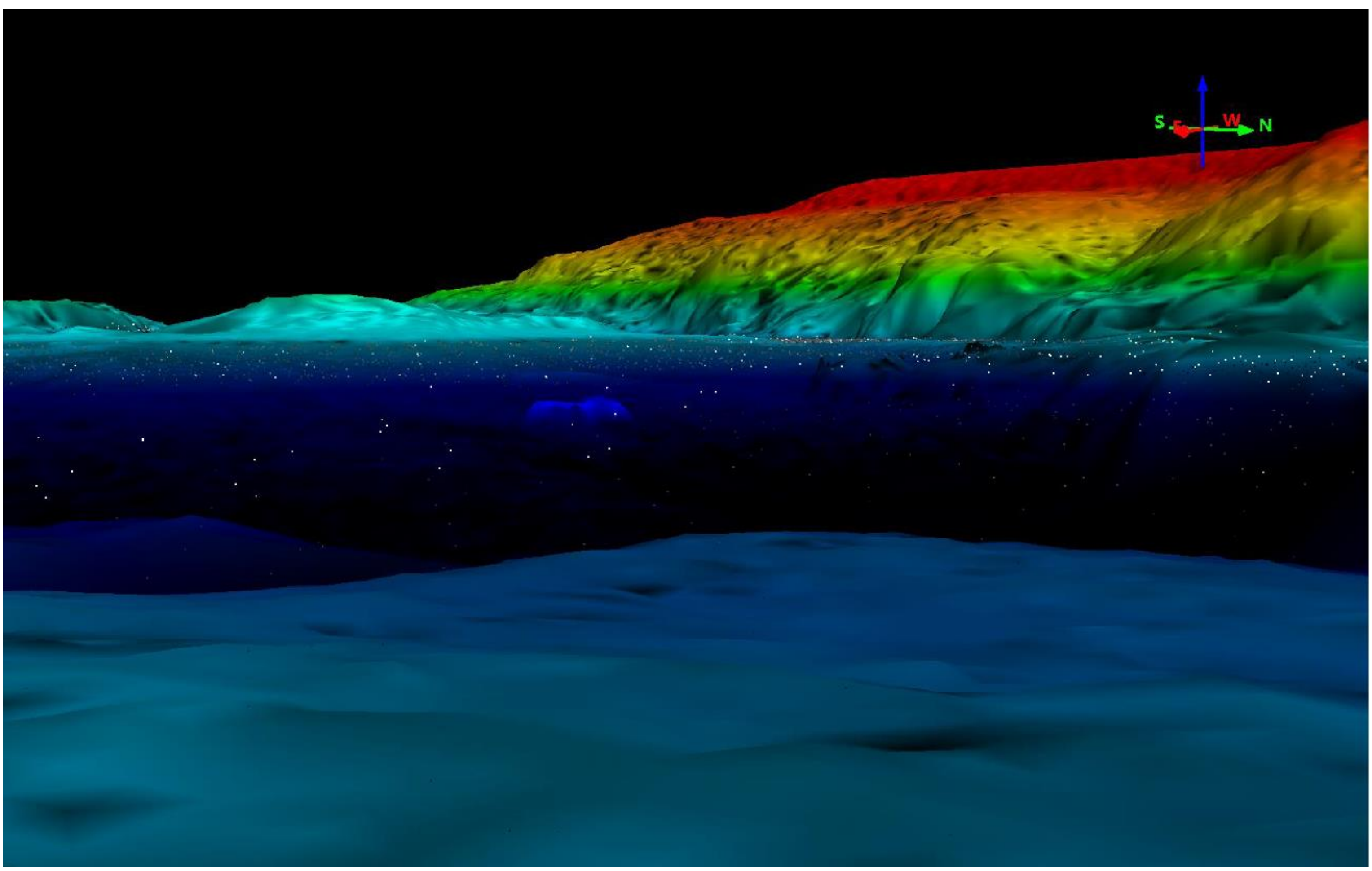


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