September 30, 2025

NOAA Ozarks

Riverine Shoreline Mapping Projects: MO2301-TB-C

Technical Data Report, NOAA Contract 1305M220DNCNL0064, Task Order 1305M223FNCNL0320

Prepared For:

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Cover Photo: This image depicts a view of the Gasconade River. The bare earth topobathymetric model is colored by elevation and overlaid by acquired orthoimagery.

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Introduction

This image depicts a southeast view over the Spring River. The bare earth topobathymetric model is colored by elevation and overlaid by orthoimagery acquired by NV5.

In July 2023, NV5 was contracted by the National Oceanic and Atmospheric Administration (NOAA) to collect topobathymetric Light Detection and Ranging (lidar) data and digital imagery from August 2023 to July 2024 for the NOAA Ozarks site. The NOAA Ozarks area of interest encompasses several river sections in Missouri, Arkansas, and Oklahoma. In total, the base project area of the NOAA Ozarks project (MO2301-TB-C) encompasses approximately 745 square statute miles. Data was collected to aid NOAA in modeling the topographic and geophysical properties of the study area to support accurate measurement and mapping of the national rivers and to support riverine resource management.

This report accompanies the delivered topobathymetric lidar data and documents contract specifications, data acquisition procedures, processing methods, and analysis of the final dataset including lidar accuracy, depth penetration, and density. Acquisition dates and acreage are shown in Table 1, a complete list of contracted deliverables provided to NOAA is shown in Table 3 with the coordinate reference system information for these deliverables shown in Table 2, the project extent is shown in Figure 1, and the project delivery areas are shown in Figure 2.

Table 1: Acquisition dates, acreage, and data types collected on the NOAA Ozarks site

Project Site	Contracted Acres	Buffered Acres	Aerial Acquisition Dates	Data Type
NOAA Ozarks	349,440	351,772	08/14/2023 – 09/04/2024	Topobathymetric - Lidar

*See Figure 21 through Figure 26 for more detailed flight dates for lidar acquisition

Deliverable Products

Table 2: Deliverable product coordinate reference system information

Product Type	Projection	Horizontal Datum	Vertical Datum	Units
Classified LAS	UTM Zone 15 North	NAD83(2011)	GRS80 (Ellipsoidal Height)	Meters
Classified LAS and Rasters	UTM Zone 15 North	NAD83(2011)	NAVD88(GEOID18)	Meters

Table 3: Lidar and imagery products delivered for the NOAA Ozarks site

Product Type	File Type	Product Details
Points	LAS v.1.4 (*.las), Point Format 6	• 500m x 500m tiled All Classified Returns
Rasters	1.0-meter Cloud Optimized GeoTIFFs (*.tif)	• 5000m x 5000m tiled Void-Clipped Topobathymetric Bare Earth Digital Elevation Models (DEM) • 5000m x 5000m tiled Normalized Bathymetric Bottom Intensity Rasters
Vectors	Shapefiles (*.shp)	• Delivery Boundary • Lidar Tile Index • DEM Tile Index • Bathymetric Void Shape • Feedback edits with Response • Ground Survey Points • Imagery Acquisition Flightlines • Imagery Footprints • Breaklines

Product Type	File Type	Product Details
Flightline & Sensor Trajectories	Trajectories (*.txt)	• Chiroptera 4X • Chiroptera 5
Digital Imagery	GeoTIFFs (*.tif)	• 3000m x 3000m tiled Imagery Mosaics
Metadata	Extensible Markup Language (*.xml)	• LAS Metadata • Bare Earth DEM Metadata • Normalized Seabed Intensity Metadata • Imagery Metadata • Project Boundary Metadata • Las Index Metadata • DEM Index Metadata • Breakline Metadata • Bathy Void Metadata • Feedback Shapefile Metadata
Reports	Adobe Acrobat (*.pdf)	• Imagery Reports • Field Data Collection Sheets • Ground Survey Report • Lidar Boresight and Calibration Reports • Lidar Technical Data Report

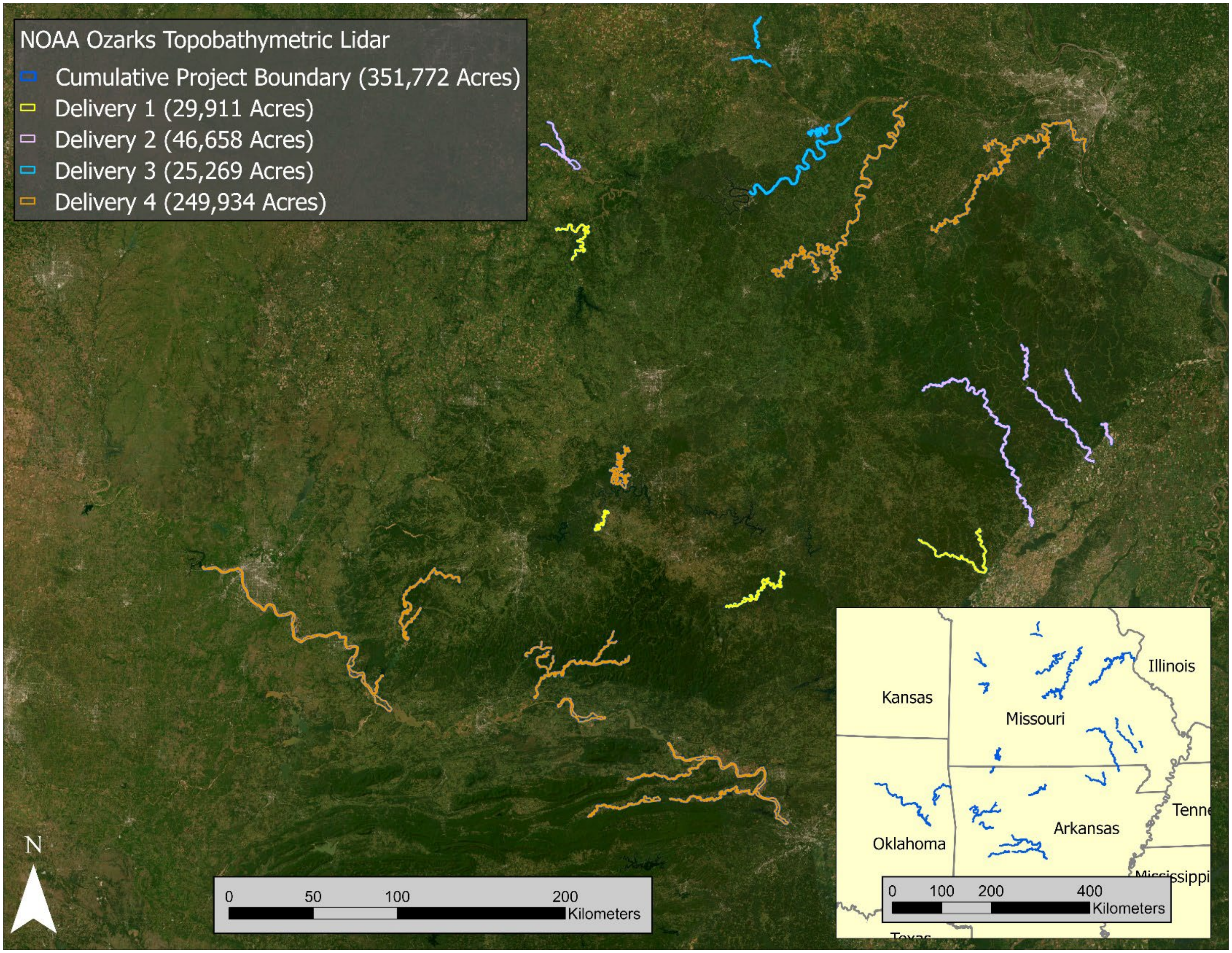


Figure 1: Delivery area location map of the NOAA Ozarks project areas.

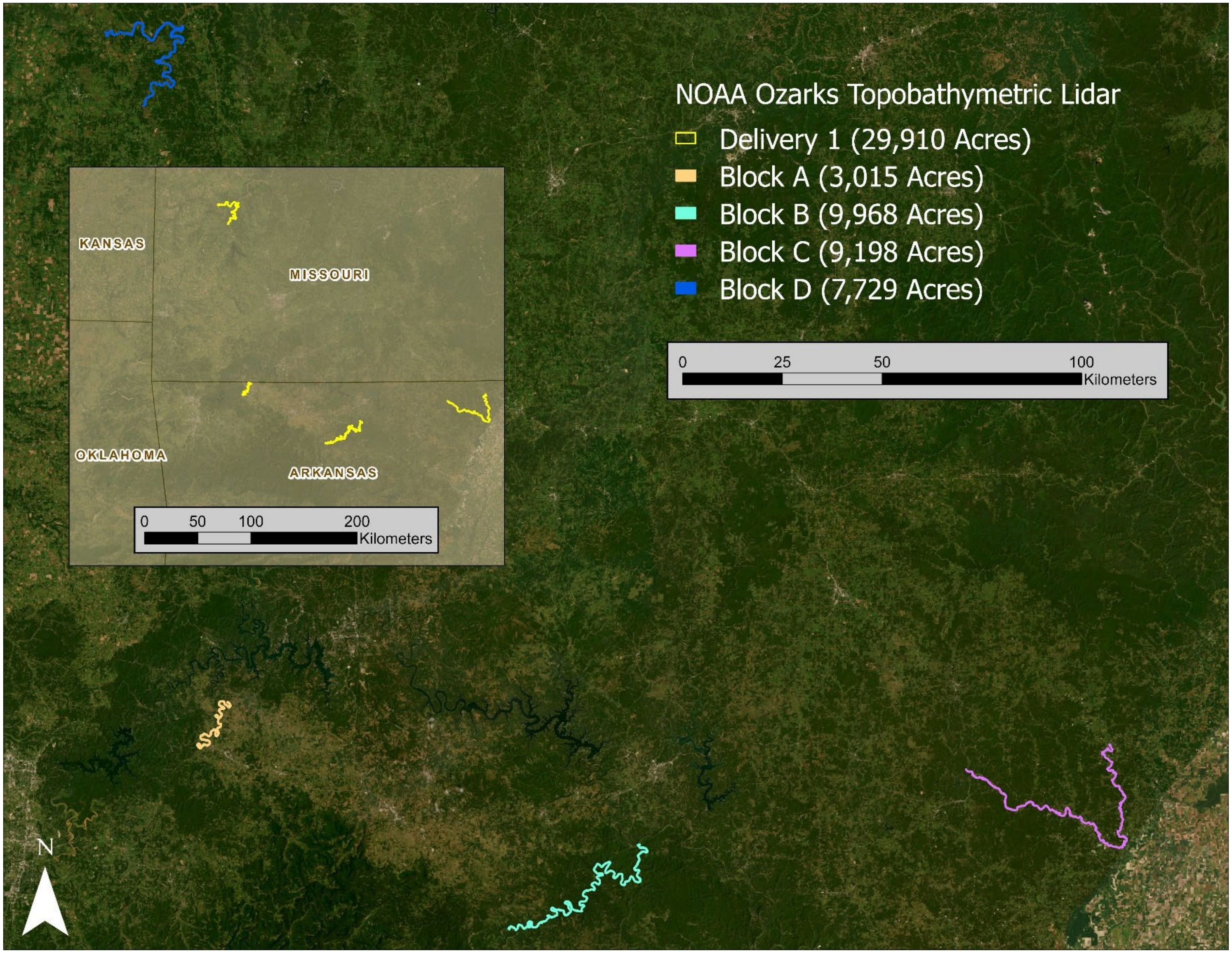


Figure 2: Location map of Delivery 1 divided into deliverable blocks (A, B, C, D) for the NOAA Ozarks project.

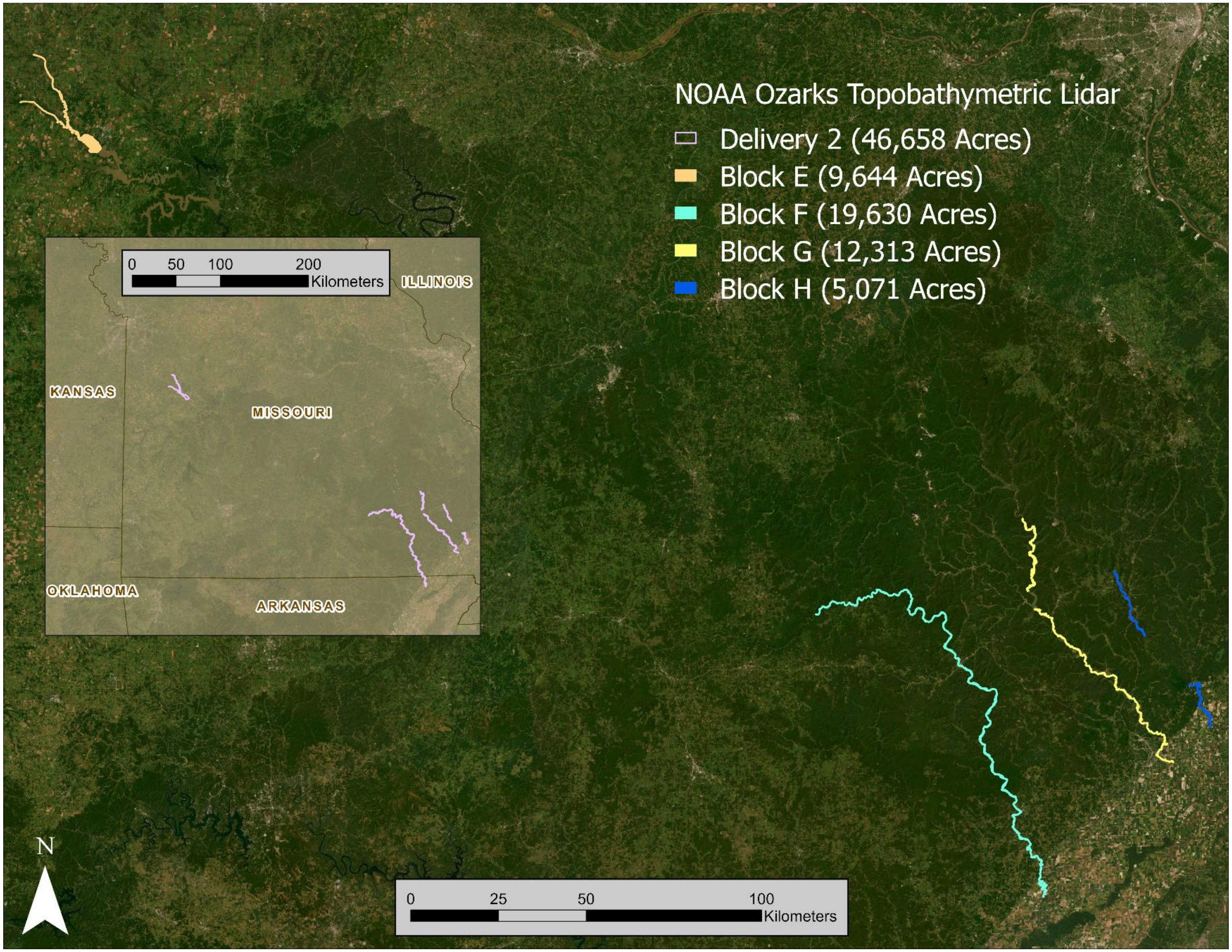


Figure 3: Location map of Delivery 2 divided into deliverable blocks (E, F, G, H) for the NOAA Ozarks project.

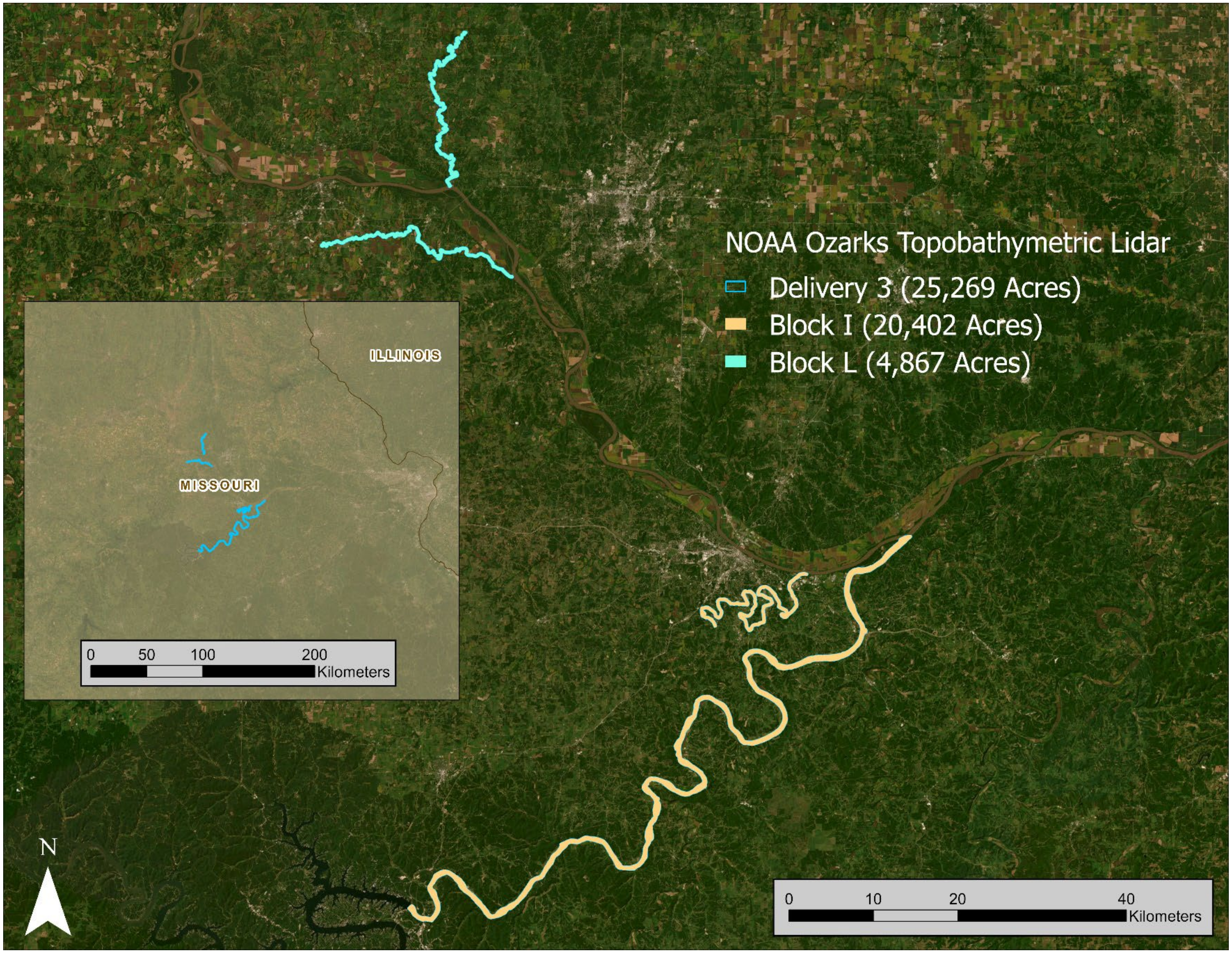


Figure 4: Location map of Delivery 3 divided into deliverable blocks (I and L) for the NOAA Ozarks project.

Docusign Envelope ID: A14F8124-CED6-4330-9298-FBE58D7C7D32

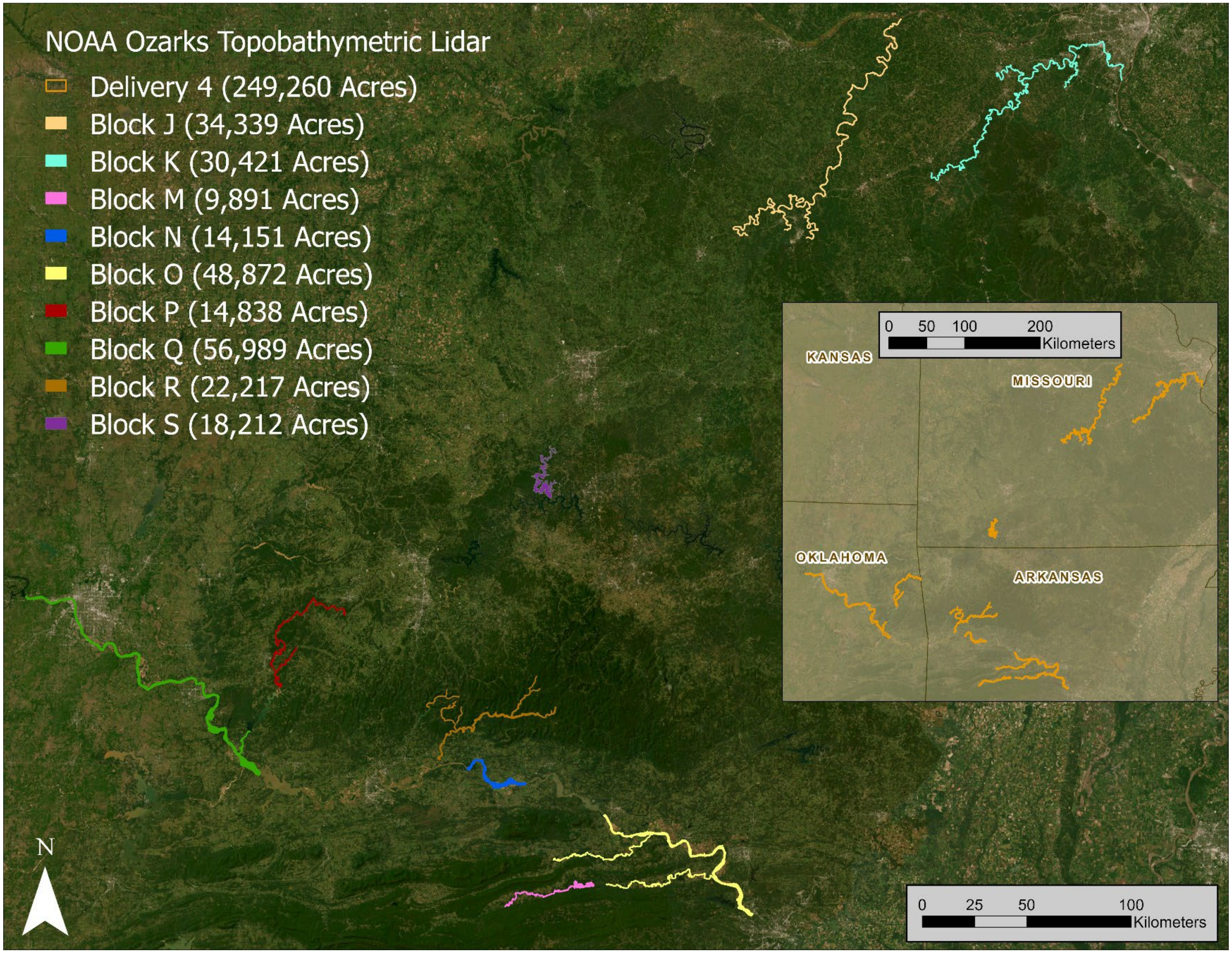


Figure 5: Location map of Delivery 4 divided into deliverable blocks (J, K, M, N, O, P, Q, R, S) for the NOAA Ozarks project.

ACQUISITION

This image depicts a northwest view of Bagnell Dam. The bare earth topobathymetric model is colored by elevation and overlaid by orthoimagery acquired by NV5.

Logistics Planning

In preparation for data collection, NV5 reviewed the project area and developed a specialized flight plan to ensure complete coverage of the NOAA Ozarks Lidar study area at the target combined point density of ≥3 points/m^2 for bathymetric areas and ≥8 points/m^2 for topographic areas. Acquisition parameters including orientation relative to terrain, flight altitude, pulse rate, scan angle, and ground speed were adapted to optimize flight paths and flight times while meeting all contract specifications. Figure 21 shows these optimized flight paths and dates.

Factors such as satellite constellation availability and weather windows must be considered during the planning stage. Any weather hazards or conditions affecting the flight were continuously monitored due to their potential impact on the daily success of airborne and ground operations. In addition, logistical considerations including private property access, potential air space restrictions, water clarity (Figure 6) , and flow conditions (Figure 7 through Figure 20) were reviewed.

Turbidity Measurements & Secchi Depth Readings

NV5's acquisition team considered several environmental conditions during the planning stage of the project to target the best possible windows for capturing bathymetric bottom returns. Water clarity was monitored daily using handheld Hach turbidity meters, Secchi disks, and semi-portable water quality data loggers operated by NV5 ground operations professionals. Readings were collected at 222 locations throughout the project site between August 13, 2023, and August 22, 2024. Turbidity observations were recorded three times to confirm measurements. Table 4 below provides turbidity and Secchi depth results per site on each day of data collection. Note that the latitude and longitude is an approximate location determined using ArcGIS and may not align with Google Earth or other location locaters. A true Secchi depth reading is where the Secchi depth reaches extinction. However, some of the Secchi depth readings were noted to have reached the bottom surface. Some locations were also inaccessible for Secchi and/or turbidity measurements.

Table 4: Water Clarity Observations for Lidar flights

Date	Time (UTC - 5)	Location	Latitude	Longitude	Turbidity Read 1 (NTU)	Turbidity Read 2 (NTU)	Turbidity Read 3 (NTU)	Secchi Depth (m)	Wind Speed (kt)
8/13/2023	8:47 AM	James River at Ralph Cox Memorial Access	36° 48' 21.36" N	93° 27' 41.56" W	4.03	3.84	4.14	*NA	NA
8/14/2023	10:39 AM	Docks at the End of Omega Ln at Lake of the Ozarks	36° 37' 16.52" N	93° 27' 38.92" W	2.83	2.63	2.25	1.97	NA
8/14/2023	2:24 PM	Hideaway Marina Dock A on Table Rock Lake	36° 39' 55.91" N	93° 29' 50.94" W	3.01	3.12	2.86	1.56	NA
8/15/2023	7:13 AM	3172 Long Bend Rd Galena, MO 65656 United States on the James River	36° 43' 19.00" N	93° 32' 22.48" W	4.24	4.63	4.89	**1.32	NA
8/15/2023	12:05 PM	Aunts Creek Swim Area	36° 40' 21.19" N	93° 27' 44.98" W	3.38	4.78	3.62	**1.32	NA
8/16/2023	11:56 AM	Rocky Beach at the End of Boat Dock Ln at Wooley Creek	36° 42' 38.86" N	93° 33' 41.79" W	4.67	4.52	5.51	*NA	NA
8/17/2023	12:49 PM	Shell Knob Boat Ramp, MO 65747 United States on Table Rock Lake	36° 42' 50.46" N	93° 30' 16.67" W	17.20	13.40	12.60	*NA	NA
8/17/2023	3:12 PM	222 Bywater Dr. Cape Fair, MO 65624. Dock Next to Boat Ramp on James River	36° 47' 4.91" N	93° 30' 48.55" W	10.50	8.64	9.77	1.05	NA

Date	Time (UTC - 5)	Location	Latitude	Longitude	Turbidity Read 1 (NTU)	Turbidity Read 2 (NTU)	Turbidity Read 3 (NTU)	Secchi Depth (m)	Wind Speed (kt)
8/18/2023	1:32 PM	James River at the End of County Road 173-45	36° 46' 57.98" N	93° 30' 20.11" W	8.13	8.15	7.76	*NA	NA
8/18/2023	2:28 PM	Horse Creek Boat Ramp on the James River	36° 49' 56.08" N	93° 26' 47.51" W	3.45	4.68	5.32	*NA	NA
8/19/2023	9:59 AM	Hunt Lane Boat Ramp on the James River	36° 42' 50.61" N	93° 30' 17.12" W	11.80	15.40	13.40	*NA	NA
8/20/2023	8:14 AM	2482–2574 County Road 411 Berryville, AR 72616 United States Kings River Access Point	36° 27' 44.16" N	93° 35' 44.03" W	3.27	2.40	3.21	*NA	NA
8/20/2023	10:30 AM	Hwy 143 Bridge Over Kings River	36° 25' 35.00" N	93° 37' 25.12" W	3.20	2.87	1.95	*NA	NA
8/20/2023	6:59 PM	US-62 Berryville, AR 72616 United States Kings River Access	36° 23' 38.94" N	93° 38' 13.75" W	2.57	3.59	2.11	*NA	NA
8/21/2023	11:34 AM	2497–2499 Tyler Bend Rd Marshall, AR 72650 United States Tyler Bend River Access	35° 59' 24.71" N	92° 45' 45.96" W	2.26	2.99	1.72	*NA	NA
8/21/2023	1:18 PM	3–7 Frost St Marshall, AR 72650 United States Buffalo River Access	35° 59' 10.45" N	92° 42' 53.40" W	2.77	2.36	1.63	**1.32	NA

Date	Time (UTC - 5)	Location	Latitude	Longitude	Turbidity Read 1 (NTU)	Turbidity Read 2 (NTU)	Turbidity Read 3 (NTU)	Secchi Depth (m)	Wind Speed (kt)
8/22/2023	10:48 AM	Spring Creek Rd. Buffalo River Access	36° 01' 49.65" N	92° 35' 6.27" W	1.05	2.24	2.05	**0.24	NA
8/22/2023	2:23 PM	County Road 6035 Yellville, AR 72687 United States Buffalo River Access	36° 07' 27.30" N	92° 32' 54.21" W	1.74	1.96	1.87	**1.32	NA
8/25/2023	12:30 PM	SITE 001: Spring Creek Campground Buffalo River Access at Terminus of the Searcy 99 Hwy, Harriet, AR 72639 South of Buffalo City, AR	36° 01' 50.19" N	92° 35' 5.62" W	1.46	1.28	1.38	**0.28	0.00
8/25/2023	2:30 PM	SITE 002: Buffalo City Access (Arkansas Game & Fish) Boat Ramp 05 miles West of the Confluence of the White and Buffalo Rivers in Buffalo City, AR	36° 09' 51.68" N	92° 26' 27.13" W	0.86	0.93	1.28	**0.50	0.00

Date	Time (UTC - 5)	Location	Latitude	Longitude	Turbidity Read 1 (NTU)	Turbidity Read 2 (NTU)	Turbidity Read 3 (NTU)	Secchi Depth (m)	Wind Speed (kt)
8/26/2023	11:30 AM	SITE 003: Spring Creek Campground Buffalo River Access at Terminus of the Searcy 99 Hwy, Harriet, AR 72639 South of Buffalo City, AR	36° 01' 50.75" N	92° 35' 5.04" W	1.20	1.34	1.41	**0.46	0.00
8/26/2023	1:00 PM	SITE 004: Terminus of Marion County Rd 6064 at the Confluence of Cedar Creek and the Buffalo River Five Miles Southeast of Buffalo City, AR	36° 07' 54.53" N	92° 30' 49.59" W	1.55	1.77	2.28	1.03	0.00
8/26/2023	2:45 PM	SITE 005: Spring Creek Campground Buffalo River Access at Terminus of the Searcy 99 Hwy, Harriet, AR 72639 South of Buffalo City, AR	36° 01' 49.65" N	92° 35' 6.27" W	1.97	2.31	1.66	**0.43	0.00

Date	Time (UTC - 5)	Location	Latitude	Longitude	Turbidity Read 1 (NTU)	Turbidity Read 2 (NTU)	Turbidity Read 3 (NTU)	Secchi Depth (m)	Wind Speed (kt)
8/26/2023	4:30 PM	SITE 006: Terminus of Marion County Rd 6064 at the Confluence of Cedar Creek and the Buffalo River Five Miles Southeast of Buffalo City, AR	36° 07' 54.51" N	92° 30' 48.68" W	2.23	2.66	2.68	**1.13	0.00
8/31/2023	11:45 AM	SITE 007: Sac River, Blackjack Access Ramp	37° 53' 9.61" N	93° 44' 37.10" W	8.74	8.49	8.63	0.84	NA
9/1/2023	12:00 PM	SITE 008: East side of Martinville Rd. Bridge, South Grand River	38° 20' 31.63" N	93° 49' 1.72" W	37.20	40.00	43.40	0.24	NA
9/1/2023	3:30 PM	SITE 009: West side of Martinville Rd Bridge, South Grand River	38° 20' 32.71" N	93° 49' 3.81" W	26.30	27.10	27.90	0.33	NA
9/2/2023	11:00 AM	SITE 010: Sac River Public Access	37° 59' 46.64" N	93° 44' 8.54" W	23.20	23.00	23.30	0.33	NA
9/3/2023	11:00 AM	SITE 011: Osage River Tributary, Sac River Offshoot Slough	38° 21' 45.57" N	93° 50' 3.29" W	97.30	96.50	96.70	0.10	NA
9/3/2023	3:00 PM	SITE 012: Sac River Public Access	38° 01' 15.64" N	93° 45' 4.75" W	21.80	20.90	21.10	0.42	NA

Date	Time (UTC - 5)	Location	Latitude	Longitude	Turbidity Read 1 (NTU)	Turbidity Read 2 (NTU)	Turbidity Read 3 (NTU)	Secchi Depth (m)	Wind Speed (kt)
9/4/2023	11:40 AM	SITE 013: Urich Public Access Ramp, South Grand River	38° 27' 9.51" N	94° 00' 13.25" W	14.90	15.30	15.50	0.46	NA
9/7/2023	5:51 PM	SITE 014: Roscoe Boat Ramp, Osage River	37° 59' 7.23" N	93° 48' 40.81" W	18.50	23.80	19.90	0.45	5.00
9/8/2023	12:05 PM	SITE 015: Muddy Bank of the Osage River	38° 01' 28.47" N	93° 50' 22.83" W	29.30	27.10	22.90	0.35	5.00
9/8/2023	12:56 PM	SITE 016: Rocky/Deep Bank of Osage River -	38° 00' 10.75" N	93° 56' 19.82" W	18.70	18.30	21.30	0.48	0.00
9/9/2023	11:04 AM	SITE 017: At the End of the Urich Public Access Ramp, South Grand River	38° 27' 8.10" N	94° 00' 13.35" W	30.50	26.10	58.80	0.35	0.00
9/9/2023	12:39 PM	SITE 018: Near Where State Route 7 Crosses Over Big Creek in MO	38° 25' 40.82" N	93° 54' 4.18" W	71.10	65.10	58.70	0.32	0.00
9/11/2023	12:32 PM	SITE 019: Gasconade River Boat Ramp.	37° 45' 33.65" N	92° 27' 8.83" W	9.75	8.11	7.60	**0.40	5.00

Date	Time (UTC - 5)	Location	Latitude	Longitude	Turbidity Read 1 (NTU)	Turbidity Read 2 (NTU)	Turbidity Read 3 (NTU)	Secchi Depth (m)	Wind Speed (kt)
9/11/2023	2:29 PM	SITE 020: Rocky River Bank on Bear Creek Near the Confluence with the Gasconade River	37° 47' 57.76" N	92° 24' 2.91" W	11.20	7.79	7.16	**0.40	5.00
9/11/2023	2:55 PM	SITE 022: Near Where State Route 87 Crosses Over Petite Saline Creek	38° 55' 4.57" N	92° 41' 9.87" W	4.85	3.96	3.77	**0.20	5.00
9/11/2023	3:23 PM	SITE 021: Boat Ramp off of Rio Rd. Near Gasconade River Bridge	37° 48' 3.21" N	92° 20' 27.63" W	6.29	11.40	7.11	**0.60	5.00
9/12/2023	5:10 PM	SITE 023: Gascozark River Boat Ramp	37° 54' 12.49" N	92° 17' 4.22" W	3.92	4.80	3.23	**0.80	0.00
9/12/2023	5:57 PM	SITE 025: Gascozark River Bridge Gravel Bar	37° 50' 15.63" N	92° 20' 24.90" W	4.42	3.89	3.66	**0.40	0.00
9/13/2023	12:06 PM	SITE 024: Moreau River Boat Ramp	38° 32' 30.77" N	92° 06' 23.35" W	32.00	34.50	23.90	0.30	NA
9/14/2023	1:04 PM	SITE 037: South of Roy Laughin Park at Roubideaux Creek	37° 49' 34.71" N	92° 12' 12.21" W	1.12	0.99	0.85	**0.30	0.00
9/14/2023	1:49 PM	SITE 027: Jack's Fork River Boat Ramp	37° 09' 10.04" N	91° 21' 11.64" W	1.48	1.43	1.14	**1.20	0.00

Date	Time (UTC - 5)	Location	Latitude	Longitude	Turbidity Read 1 (NTU)	Turbidity Read 2 (NTU)	Turbidity Read 3 (NTU)	Secchi Depth (m)	Wind Speed (kt)
9/14/2023	3:05 PM	SITE 029: Shawnee Creek Campground at Jack's Fork River	37° 10' 20.13" N	91° 18' 0.87" W	1.35	1.55	1.41	**1.00	0.00
9/14/2023	3:31 PM	SITE 031: Confluence of Current River and Jack's Fork	37° 11' 26.68" N	91° 16' 28.67" W	1.64	1.59	1.38	**0.40	0.00
9/14/2023	4:00 PM	SITE 033: Gasconade River Gravel Bar at End of Ruby’s Landing Dr.	37° 52' 6.72" N	92° 15' 40.35" W	4.61	4.55	5.37	**0.30	0.00
9/15/2023	11:08 AM	SITE 026: Gasconade River Boat Launch	38° 40' 5.18" N	91° 33' 17.22" W	17.80	28.60	30.20	0.40	0.00
9/15/2023	12:22 PM	SITE 035: Confluence of Gasconade River and Roubidoux Creek	37° 51' 3.51" N	092° 12' 48.13" W	3.37	4.12	3.41	**1.10	0.00
9/15/2023	2:10 PM	SITE 028: Petite Saline Creek off Connor Bridge Dr.	38° 55' 39.99" N	92° 36' 42.47" W	4.93	3.79	5.04	**0.50	0.00
9/15/2023	2:52 PM	SITE 030: Petite Saline Creek Near State Route V and Big Lick Rd.	38° 53' 55.68" N	92° 34' 45.33" W	8.98	8.91	13.60	**0.30	0.00

Date	Time (UTC - 5)	Location	Latitude	Longitude	Turbidity Read 1 (NTU)	Turbidity Read 2 (NTU)	Turbidity Read 3 (NTU)	Secchi Depth (m)	Wind Speed (kt)
9/15/2023	5:50 PM	SITE 032: Near Where Gravel Dr. Crosses Over Petite Saline Creek	38° 54' 3.93" N	92° 31' 29.34" W	15.60	13.60	12.50	0.40	0.00
9/16/2023	4:40 PM	SITE 034: Moniteau Creek. Country Rd. 406-Very Shallow/Dried up Creek in MO	39° 07' 15.04" N	92° 34' 3.29" W	2.72	2.94	3.41	**0.25	5.00
9/17/2023	11:26 AM	SITE 036: Near Where State Route W. Crosses Over Moniteau Creek in MO	39° 05' 1.22" N	92° 35' 22.51" W	14.90	16.20	16.90	**0.30	NA
9/17/2023	1:00 PM	SITE 039: Current River Gravel Bar at Powder Mill Campground	37° 10' 53.45" N	91° 10' 30.59" W	1.53	1.03	1.23	**0.40	0.00
9/17/2023	2:10 PM	SITE 038: Moniteau Creek Near Hwy 40 W.	38° 59' 18.60" N	92° 33' 19.21" W	21.90	20.80	19.40	0.42	NA
9/17/2023	3:51 PM	SITE 040: Boat Ramp Near the Confluence of Richland Creek and Gasconade River	38° 36' 13.25" N	91° 37' 59.13" W	11.70	11.40	11.60	0.64	NA
9/17/2023	5:05 PM	SITE 042: Gasconade River Boat Ramp	38° 33' 11.73" N	91° 35' 50.02" W	14.60	13.00	13.80	0.64	NA

Date	Time (UTC - 5)	Location	Latitude	Longitude	Turbidity Read 1 (NTU)	Turbidity Read 2 (NTU)	Turbidity Read 3 (NTU)	Secchi Depth (m)	Wind Speed (kt)
9/17/2023	6:23 PM	SITE 044: Osage River off Water St.	38° 33' 6.50" N	92° 01' 39.66" W	11.00	12.20	10.30	0.69	NA
9/18/2023	9:23 AM	SITE 046: Maria Osa Access Boat Ramp on Osage River	38° 29' 30.56" N	92° 00' 35.93" W	11.80	8.95	8.82	1.03	5.00
9/18/2023	11:22 AM	SITE 048: Gasconade River at the End of Helmig Ferry Rd.	38° 30' 10.49" N	91° 36' 49.77" W	11.90	12.90	11.00	0.61	NA
9/18/2023	12:05 PM	SITE 041: Current River Boat Ramp	37° 07' 38.00" N	91° 10' 23.14" W	1.33	1.30	1.23	**1.10	NA
9/18/2023	1:20 PM	SITE 043: Sandy Beach on Current River Near Logyard Campground Winona, MO 65588	37° 06' 51.30" N	91° 07' 49.32" W	1.64	1.34	1.39	**1.00	NA
9/18/2023	2:05 PM	SITE 050: Gasconade River Near Hwy 50	38° 28' 0.50" N	91° 37' 45.10" W	9.92	9.48	11.50	0.55	NA
9/18/2023	3:15 PM	SITE 052: Osage River Boat Ramp	38° 34' 27.61" N	91° 58' 24.11" W	7.81	7.14	8.19	0.78	NA
9/18/2023	5:30 PM	SITE 045: Current River Access Area	37° 02' 1.94" N	91° 03' 17.28" W	1.43	1.87	1.81	**0.90	0.00
9/19/2023	10:03 AM	SITE 056: Near Gooseberry Ln, Gasconade River	38° 29' 25.00" N	91° 40' 17.43" W	20.10	16.50	11.80	0.81	NA

Date	Time (UTC - 5)	Location	Latitude	Longitude	Turbidity Read 1 (NTU)	Turbidity Read 2 (NTU)	Turbidity Read 3 (NTU)	Secchi Depth (m)	Wind Speed (kt)
9/19/2023	10:52 AM	SITE 047: Salt River, Van Buren Boat Ramp	36° 59' 32.35" N	91° 00' 55.94" W	2.06	1.84	2.15	**1.20	5.00
9/19/2023	11:32 AM	SITE 049: Big Springs Boat Ramp on Current River	36° 57' 10.59" N	90° 59' 24.57" W	1.77	1.94	1.71	**1.00	5.00
9/19/2023	12:20 PM	SITE 051: Big Tree Campground at Current River	36° 55' 38.72" N	90° 54' 17.12" W	1.65	2.10	1.43	*NA	0.00
9/19/2023	1:00 PM	SITE 053: Current River Gravel Bar Across from Hickory Landing	36° 53' 22.24" N	90° 54' 48.14" W	1.40	1.78	1.87	**1.80	5.00
9/21/2023	12:40 PM	SITE 055: Osage River Near the Lock and Dam Spur	38° 28' 10.54" N	92° 02' 33.33" W	6.42	6.31	6.71	**0.90	NA
9/21/2023	1:25 PM	SITE 057: Osage River Near Pikes Camp Access	38° 28' 12.36" N	92° 10' 5.76" W	4.95	4.86	5.00	**1.60	NA
9/21/2023	3:40 PM	SITE 059: Boat Ramp at Pointers Creek Access Near the Gasconade River	38° 25' 28.86" N	91° 44' 31.28" W	10.70	11.20	11.10	0.80	NA
9/22/2023	4:45 PM	SITE 061: Rollins Ferry Access on the Gasconade River	38° 23' 33.47" N	91° 49' 13.65" W	8.00	7.95	7.80	1.60	NA

Date	Time (UTC - 5)	Location	Latitude	Longitude	Turbidity Read 1 (NTU)	Turbidity Read 2 (NTU)	Turbidity Read 3 (NTU)	Secchi Depth (m)	Wind Speed (kt)
9/22/2023	6:15 PM	SITE 063: St. Thomas Ferry Access on the Osage River	38° 25' 19.68" N	92° 12' 29.51" W	4.78	4.41	4.73	2.00	NA
9/23/2023	11:30 AM	SITE 065: Muddy Beach on Tavern Creek, Split Off of Osage River	38° 19' 3.72" N	92° 17' 23.58" W	9.90	10.00	10.20	1.30	NA
9/24/2023	11:00 AM	SITE 067: Boat Ramp at Pay Down Access Park on the Gasconade River	38° 13' 48.69" N	91° 48' 49.09" W	7.68	7.43	7.95	**1.70	NA
9/25/2023	12:00 PM	SITE 069: East Bank of Gasconade River at the End of State Route 335	38° 11' 17.21" N	91° 54' 25.55" W	3.90	4.20	4.27	**1.70	NA
9/25/2023	4:30 PM	SITE 071: Boat Ramp on East Bank of the Current River at the End of Jefferson St.	36° 36' 49.85" N	90° 49' 54.27" W	1.92	1.84	2.07	**1.50	NA
9/26/2023	2:00 PM	SITE 073: Current River Near Border of Missouri and Arkansas	36° 29' 55.82" N	90° 46' 58.49" W	1.60	1.12	1.21	**2.50	NA
9/27/2023	3:00 PM	SITE 075: Near Where US Bicycle Route 66 Crosses Over Roubidoux Creek and Spring Rd.	37° 49' 2.46" N	92° 11' 33.1" W	9.68	10.20	9.74	**0.70	NA

Date	Time (UTC - 5)	Location	Latitude	Longitude	Turbidity Read 1 (NTU)	Turbidity Read 2 (NTU)	Turbidity Read 3 (NTU)	Secchi Depth (m)	Wind Speed (kt)
9/27/2023	6:42 PM	SITE 058: Hwy 62 Bridge Over the Eleven Point River	36° 14' 42.78" N	91° 05' 4.49" W	12.00	11.30	9.81	**0.60	0.00
9/28/2023	9:00 AM	SITE 077: West Bank of Osage River Near Bagnell Dam	38° 12' 4.21" N	92° 37' 29.79" W	3.68	3.63	3.66	**1.50	NA
9/28/2023	10:42 AM	SITE 060: Imboden Boat Ramp on the Spring River	36° 12' 12.78" N	91° 10' 11.37" W	11.90	12.90	12.00	**0.60	0.00
9/28/2023	12:15 PM	SITE 062: Boat Ramp off Lawrence Rd. on the Spring River Near the Town of Ravenden, AR	36° 13' 29.14" N	91° 15' 1.75" W	11.00	10.40	9.63	0.60	0.00
9/28/2023	2:01 PM	SITE 064: Hardy Beach Boat Ramp on the Spring River	36° 18' 44.44" N	91° 28' 20.73" W	6.68	6.50	5.97	0.60	0.00
9/28/2023	4:15 PM	SITE 081: Confluence of Little Piney Creek and Gasconade River	37° 55' 13.69" N	91° 58' 30.97" W	3.40	3.21	2.99	**1.30	NA
9/29/2023	9:30 AM	SITE 079: Tuscumbia Access at the Osage River	38° 13' 56.07" N	92° 27' 31.54" W	2.69	3.02	2.51	**1.40	NA
9/29/2023	11:30 AM	SITE 083: Boat Ramp in Kings Bluff Access off Hwy 8A on the Osage River	38° 16' 37.57" N	92° 23' 14.36" W	3.50	3.74	3.51	**1.30	NA

Date	Time (UTC - 5)	Location	Latitude	Longitude	Turbidity Read 1 (NTU)	Turbidity Read 2 (NTU)	Turbidity Read 3 (NTU)	Secchi Depth (m)	Wind Speed (kt)
9/29/2023	3:20 PM	SITE 085: Near Where Eastgate Rd. Crosses Over Big Piney River	37° 45' 37.18" N	92° 03' 29.68" W	1.75	1.81	1.49	**1.50	NA
9/30/2023	9:58 AM	SITE 066: Markham Spring Boat Ramp on the Black River	36° 58' 34.82" N	90° 35' 58.22" W	5.00	4.77	4.81	**0.65	0.00
9/30/2023	5:57 PM	SITE 068: Underneath the Bridge Off of County Road 459 A on the Black River	37° 04' 45.15" N	90° 42' 50.75" W	6.49	6.44	5.75	*NA	0.00
10/1/2023	1:00 PM	SITE 087: Near Where Hwy 28 Crosses Over the Gasconade River	37° 53' 32.29" N	92° 04' 49.94" W	2.57	2.49	2.48	**1.50	NA
10/1/2023	2:48 PM	SITE 070: Old Greenville Rec Area Boat Ramp on the St. Francis River	37° 05' 45.22" N	90° 27' 12.18" W	13.80	13.60	13.30	0.50	0.00
10/2/2023	10:00 AM	SITE 089: Near Where US Bicycle Route 66 Crosses Over Big Piney River	37° 51' 14.81" N	92° 04' 36.17" W	1.34	1.22	1.39	**0.60	NA
10/2/2023	10:34 AM	SITE 072: Beach Near RV Camp Where Highway K Crosses Over the Black River	37° 19' 29.03" N	90° 45' 53.67" W	2.73	2.62	2.48	*NA	0.00

Date	Time (UTC - 5)	Location	Latitude	Longitude	Turbidity Read 1 (NTU)	Turbidity Read 2 (NTU)	Turbidity Read 3 (NTU)	Secchi Depth (m)	Wind Speed (kt)
10/2/2023	12:15 PM	SITE 091: Riddle Bridge Access Over the Gasconade River	37° 54' 34.03" N	92° 07' 56.50" W	3.75	3.72	3.91	**2.50	NA
10/2/2023	12:41 PM	SITE 074: Boat Docks / Rec Area at the Confluence of the Black River and Clearwater Lake	37° 10' 47.6" N	90° 47' 25.37" W	12.70	12.50	12.30	0.40	0.00
10/2/2023	2:30 PM	SITE 093: Boat Ramp at Shady Beach Campground at the Meramec River	38° 16' 30.42" N	90° 56' 23.04" W	6.03	6.73	6.78	**1.00	NA
10/3/2023	8:55 AM	SITE 076: Beneath Lake Clearwater Dam at the Black River	37° 07' 56.38" N	90° 46' 8.87" W	9.40	8.67	9.22	**0.50	0.00
10/3/2023	11:30 AM	SITE 095: Bird's Nest Beach Park at the Meramec River	37° 59' 46.70" N	91° 21' 37.54" W	4.00	4.11	4.08	**1.20	NA
10/3/2023	1:00 PM	SITE 097: Meramec River Beach Near Onondaga Canoe/Kayak Ramp	38° 03' 34.64" N	91° 13' 18.44" W	3.68	3.50	3.70	*NA	NA

Date	Time (UTC - 5)	Location	Latitude	Longitude	Turbidity Read 1 (NTU)	Turbidity Read 2 (NTU)	Turbidity Read 3 (NTU)	Secchi Depth (m)	Wind Speed (kt)
10/3/2023	1:03 pm	SITE 080: Boat Ramp at the River Bend in Poplar Bluff on the Black River	36° 45' 6.37" N	90° 23' 34.22" W	14.20	13.60	13.80	0.40	0.00
10/3/2023	3:30 PM	SITE 099: River Round Conservation Area on the Meramec River	38° 21' 22.63" N	90° 52' 22.86" W	8.52	8.42	8.11	**1.70	NA
10/4/2023	12:15 PM	SITE 078: Missouri W. Bridge Boat Ramp on the Black River	36° 49' 16.81" N	90° 25' 22.40" W	5.24	5.26	5.35	**0.75	0.00
10/6/2023	2:03 PM	SITE 082: Beach Near Where Plum Ford Rd Crosses Over the Meramec River	38° 16' 40.76" N	90° 59' 50.13" W	8.04	6.46	7.27	**0.61	NA
10/6/2023	4:24 PM	SITE 084: Sand Ford Boat Ramp on the Meramec River	38° 15' 8.61" N	91° 04' 49.31" W	4.78	5.21	8.10	**1.00	NA
10/7/2023	11:06 AM	SITE 086: Meramec Caverns at the Meramec River	38° 14' 32.18" N	91° 05' 25.59" W	4.53	8.27	5.84	**0.61	NA
10/7/2023	11:23 AM	SITE 101: River Road Park at the Black River	37° 07' 56.75" N	90° 46' 1.48" W	9.79	9.69	9.14	**0.89	5.00

Date	Time (UTC - 5)	Location	Latitude	Longitude	Turbidity Read 1 (NTU)	Turbidity Read 2 (NTU)	Turbidity Read 3 (NTU)	Secchi Depth (m)	Wind Speed (kt)
10/7/2023	12:32 PM	SITE 088: Boat Ramp in Meramec State Park on the Meramec River	38° 12' 10.56" N	91° 05' 53.82" W	7.40	4.86	5.78	**1.00	NA
10/7/2023	1:06 PM	SITE 103: Cedar Bay Near Where Missouri Route 34 Crosses Over the Black River	37° 04' 45.45" N	90° 42' 51.6" W	6.84	7.07	6.46	**0.45	5.00
10/7/2023	2:05 PM	SITE 090: Boat Ramp Near Where Sappington Bridge Crosses Over the Meramec River	38° 09' 29.43" N	91° 06' 32.15" W	4.70	4.28	7.47	**0.80	NA
10/7/2023	4:30 PM	SITE 092: Flamm City Boat Ramp on the Meramec River	38° 25' 2.46" N	90° 20' 49.61" W	11.10	9.22	10.80	0.85	NA
10/8/2023	10:15 AM	SITE 094: Near Where Jeffco Blvd Crosses Over the Meramec River	38° 27' 24.1" N	90° 21' 36.64" W	16.80	13.40	13.10	0.65	NA
10/8/2023	10:27 AM	SITE 105: North Side of Ray Clinton Park Poplar Bluff, MO on the Black River	36° 45' 9.31" N	90° 23' 38.38" W	7.11	5.36	5.82	0.76	5.00

Date	Time (UTC - 5)	Location	Latitude	Longitude	Turbidity Read 1 (NTU)	Turbidity Read 2 (NTU)	Turbidity Read 3 (NTU)	Secchi Depth (m)	Wind Speed (kt)
10/8/2023	10:56 AM	SITE 107: Sportsman Park on a Boat Ramp in Poplar Bluff, MO on the Black River	36° 45' 50.35" N	90° 22' 40.47" W	6.87	9.33	6.22	0.78	5.00
10/8/2023	2:59 PM	SITE 096: Meramec River Near Lucky Clover Lakeside River Resort	37° 59' 22.1" N	91° 23' 4.04" W	2.83	3.38	2.08	**0.40	NA
10/9/2023	10:20 AM	SITE 109: Hilliard Public Fishing Access Underneath 526 Bridge on the Black River	36° 49' 17.47" N	90° 25' 21.71" W	6.82	5.51	5.16	**0.88	5.00
10/9/2023	10:54 PM	SITE 098: Near Where Hwy 50 Crosses Over the Bourbeuse River	38° 26' 35.24" N	90° 59' 47.32" W	7.83	8.61	5.35	0.50	NA
10/9/2023	12:22 PM	SITE 108: Boat Ramp Near Confluence of Bourbeuse River and Meramec River	38° 23' 56.62" N	90° 53' 27.69" W	11.70	8.34	9.23	1.10	NA
10/9/2023	12:34 PM	SITE 100: Henry A and Amalia Uhlemeyer Public Fishing and Boat Access Boat Ramp	38° 26' 21.72" N	90° 54' 27.35" W	5.64	7.16	7.56	**0.80	NA

Date	Time (UTC - 5)	Location	Latitude	Longitude	Turbidity Read 1 (NTU)	Turbidity Read 2 (NTU)	Turbidity Read 3 (NTU)	Secchi Depth (m)	Wind Speed (kt)
10/9/2023	2:43 PM	SITE 102: Near Where State Hwy 30 Crosses Over the Meramec River	38° 30' 55.28" N	90° 26' 6.61" W	11.50	9.91	8.53	0.90	NA
10/9/2023	3:28 PM	SITE 104: Boat Ramp in George Winter Park on the Meramec River	38° 30' 6.13" N	90° 25' 14.75" W	68.50	66.20	65.10	0.30	NA
10/9/2023	3:54 PM	SITE 110: Boat Ramp in Robertsville State Park on the Meramec River	38° 26' 10.3" N	90° 49' 5.89" W	6.45	4.29	4.87	**0.90	NA
10/9/2023	4:36 PM	SITE 106: Boat Ramp in Emmenegger Nature Park on the Meramec River	38° 32' 42.46" N	90° 26' 2.39" W	18.60	16.10	15.20	0.67	NA
10/10/2023	12:25 PM	SITE 112: Boat Ramp in Meramec Levee Recreational Park on the Meramec River	38° 32' 46.25" N	90° 29' 3.64" W	8.85	7.00	8.38	**0.60	NA
10/10/2023	1:15 PM	SITE 114: Greentree Park Boat Ramp on the Meramec River	38° 33' 29.96" N	90° 26' 52.37" W	8.81	6.48	9.42	1.20	NA

Date	Time (UTC - 5)	Location	Latitude	Longitude	Turbidity Read 1 (NTU)	Turbidity Read 2 (NTU)	Turbidity Read 3 (NTU)	Secchi Depth (m)	Wind Speed (kt)
10/10/2023	3:10 PM	SITE 116: Allenton Boat Ramp on the Meramec River	38° 28' 28.45" N	90° 39' 36.13" W	6.81	6.16	4.89	**0.90	NA
10/10/2023	3:42 PM	SITE 111: Lake Access off of Missouri T Road Near the St. Francis River	36° 55' 32.96" N	90° 16' 43.88" W	14.90	14.10	15.20	0.51	5.00
10/10/2023	4:56 PM	SITE 113: Pull off next to Highway 34 between Silva and Patterson MO on the St. Francis River	37° 11' 40.59" N	90° 30' 8.61" W	5.50	4.65	5.04	0.71	5.00
10/10/2023	4:58 PM	SITE 118: Pacific Palisades Boat Ramp on the Meramec River	38° 28' 37.3" N	90° 42' 56.26" W	7.11	4.89	6.90	**1.00	NA
10/11/2023	10:44 AM	SITE 115: Greenville Recreation Area Boat Ramp St. on the Francis River	37° 05' 45.8" N	90° 27' 11.69" W	9.69	7.51	7.86	0.99	5.00
10/12/2023	10:43 AM	SITE 120: Sherman Beach on the Meramec River	38° 32' 6.01" N	90° 35' 20.66" W	5.90	7.76	6.88	**0.80	NA
10/12/2023	2:45 PM	SITE 122: Rockford Park Near Rockford Beach on the Big River	38° 25' 14.28" N	90° 35' 21.5" W	8.40	9.01	9.73	1.00	NA

Date	Time (UTC - 5)	Location	Latitude	Longitude	Turbidity Read 1 (NTU)	Turbidity Read 2 (NTU)	Turbidity Read 3 (NTU)	Secchi Depth (m)	Wind Speed (kt)
10/12/2023	4:08 PM	SITE 124: Route 66 State Park Boat Ramp on the Meramec River	38° 30' 7.41" N	90° 35' 29.04" W	7.91	6.95	8.15	**0.65	NA
10/15/2023	10:13 AM	SITE 126: Byrnes Mill Park on the Big River	38° 26' 16.85" N	90° 35' 1.6" W	8.09	6.32	9.02	**0.65	NA
10/15/2023	11:15 AM	SITE 122: Rockford Park Near Rockford Beach Recollected After Rain on the Big River	38° 25' 16.92" N	90° 35' 20.37" W	8.40	9.65	8.22	0.60	NA
10/17/2023	9:50 AM	SITE 128: Petit Jean Boat Ramp on the Petit Jean River	35° 04' 28.18" N	93° 12' 0.87" W	24.20	23.20	21.50	0.55	NA
10/19/2023	7:00 AM	SITE 202: Maumelle Park Arkansas River Boat Launch	34° 49' 51.17" N	92° 25' 48.98" W	9.40	8.57	9.01	0.71	3.50
10/19/2023	9:00 AM	SITE 203: The Confluence of Palarm Creek and Arkansas River	34° 54' 14.02" N	92° 26' 57.32" W	8.81	8.81	8.92	0.66	7.80
10/19/2023	11:06 AM	SITE 213: Just Up River Close to Confluence of Taylor Creek and Arkansas River	34° 59' 31.92" N	92° 36' 11.32" W	11.70	11.00	11.40	0.46	1.00

Date	Time (UTC - 5)	Location	Latitude	Longitude	Turbidity Read 1 (NTU)	Turbidity Read 2 (NTU)	Turbidity Read 3 (NTU)	Secchi Depth (m)	Wind Speed (kt)
10/20/2023	8:48 AM	SITE 215: Sandy Shore on Arkansas River Bank	35° 04' 19.75" N	92° 32' 38.38" W	7.84	7.58	7.56	0.64	1.00
10/20/2023	10:24 AM	SITE 216: Boat Ramp at the End of Cadron Settlement Park Rd. Near the Confluence of Cadron Creek and Arkansas River	35° 06' 13.99" N	92° 32' 43.58" W	8.23	8.06	8.06	0.58	1.00
10/20/2023	12:38 PM	SITE 210: Cobble on Bank of Fourche La Fave River Near Where AR-216 Hwy Crosses Over	35° 00' 45.0" N	92° 43' 24.45" W	10.20	10.00	10.00	0.73	1.00
10/20/2023	2:00 PM	SITE 209: Boat Ramp Near Where S. Fourche Ave. Crosses Over Fourche La Fave River	34° 59' 46.63" N	92° 47' 39.77" W	8.27	8.29	8.23	0.69	0.00
10/21/2023	8:49 AM	SITE 218: Boat Ramp Near Whillock Hydroelectric Plant on the Arkansas River	35° 07' 48.07" N	92° 46' 52.17" W	9.73	9.60	9.58	0.58	1.00
10/21/2023	10:02 AM	SITE 217: Boat Ramp at Confluence of Cypress Creek and Arkansas River	35° 04' 13.05" N	92° 42' 56.88" W	12.30	12.30	12.30	0.50	0.00

Date	Time (UTC - 5)	Location	Latitude	Longitude	Turbidity Read 1 (NTU)	Turbidity Read 2 (NTU)	Turbidity Read 3 (NTU)	Secchi Depth (m)	Wind Speed (kt)
10/21/2023	11:26 AM	SITE 226: Sweeden Island Boat Launch in Arkansas River	35° 10' 3.13" N	93° 00' 40.18" W	15.10	14.70	15.00	0.50	1.00
10/21/2023	1:09 PM	SITE 227: Boat Ramp in River Front Park near the Arkansas River Bridge Over the Arkansas River	35° 13' 26.56" N	93° 09' 7.04" W	9.26	9.54	9.41	0.64	4.00
10/22/2023	9:25 AM	SITE 224: Cobble River Bank of Petit Jean River Near Petit Jean Boat Ramp	35° 04' 27.9" N	93° 12' 0.48" W	13.60	13.50	13.60	0.48	3.00
10/22/2023	10:29 AM	SITE 225: Cobble River Bank Where Dale Bend Rd Crosses Over Petit Jean River	35° 04' 37.43" N	93° 14' 28.0" W	17.60	17.60	17.30	0.48	2.00
10/22/2023	11:31 AM	Site 222: Creek Just Below Low Dam Entering Petit Jean River	35° 03' 32.62" N	93° 23' 44.34" W	11.90	12.10	11.90	0.60	0.50
10/22/2023	1:46 PM	SITE 204: Shoreline Above Nimrod Dam, Which Lies Between Nimrod Lake and Fourche La Fave River	34° 57' 8.33" N	93° 09' 36.54" W	13.60	13.50	13.60	0.57	1.00

Date	Time (UTC - 5)	Location	Latitude	Longitude	Turbidity Read 1 (NTU)	Turbidity Read 2 (NTU)	Turbidity Read 3 (NTU)	Secchi Depth (m)	Wind Speed (kt)
10/22/2023	2:48 PM	SITE 207: Creek Next to Highway 155 S. Bridge Entering the Fourche la Fave River	34° 57' 25.29" N	92° 59' 6.27" W	2.19	2.19	2.16	0.30	0.00
10/23/2023	10:39 AM	SITE 233: Downstream of S. Highway 307 Bridge Near the Confluence of Hopper Creek and Fourche la Fave River	34° 54' 11.56" N	93° 29' 51.33" W	3.05	3.00	3.06	0.88	1.00
10/23/2023	1:18 PM	SITE 235: Downstream of W. Highway 28 Bridge Over Fourche Fave River	34° 52' 20.31" N	93° 39' 23.15" W	5.11	5.19	5.12	0.81	1.00
10/23/2023	2:30 PM	SITE 230: Boat Ramp in Porter Creek Near Sunlight Bay Campground	34° 57' 10.86" N	93° 18' 15.34" W	27.70	26.20	26.80	0.35	2.00
10/24/2023	10:57 AM	SITE 229: Sandy Shore Near 236 Boat Ramp in the Carter Cove Recreation Area Near Nimrod Lake	34° 57' 34.3" N	93° 14' 17.54" W	36.50	34.80	36.10	0.43	5.00
10/24/2023	12:31 PM	SITE 231: Boat Ramp Near Where County Road 9 (River Road) Crosses Over Porter Creek	34° 57' 1.62" N	93° 19' 25.1" W	21.80	21.80	22.10	0.35	1.00

Date	Time (UTC - 5)	Location	Latitude	Longitude	Turbidity Read 1 (NTU)	Turbidity Read 2 (NTU)	Turbidity Read 3 (NTU)	Secchi Depth (m)	Wind Speed (kt)
10/25/2023	8:44 AM	SITE 236: Boat Ramp in Cedar Creek at the End of County Road 2091	35° 24' 18.55" N	93° 39' 37.28" W	12.10	12.00	12.60	0.46	1.00
10/25/2023	10:05 AM	SITE 241: Boat Ramp in East Side City Park Near Where E. Commercial St. Crosses Over Gar Creek	35° 29' 13.17" N	93° 49' 16.21" W	12.90	12.50	12.80	0.45	2.00
10/25/2023	11:04 AM	SITE 236: Boat Ramp in O'Kane Park on the Sixmile Creek	35° 22' 8.00" N	93° 45' 28.33" W	21.90	22.20	22.30	0.40	1.50
10/25/2023	1:22 PM	Boat Ramp on the Southern Bank of the Arkansas River in Citadel Bluff Park	35° 27' 57.68" N	93° 56' 11.86" W	9.90	9.82	9.83	0.53	1.00
10/26/2023	9:47 AM	Upstream from Adams Road Bridge and the Missouri Pacific Railroad and Downstream of the North Cecil Gas Field on the Northern Bank of the Arkansas River in the Citadel Bluff Park	35° 28' 35.03" N	93° 57' 55.42" W	22.40	22.40	22.50	0.40	0.00

Date	Time (UTC - 5)	Location	Latitude	Longitude	Turbidity Read 1 (NTU)	Turbidity Read 2 (NTU)	Turbidity Read 3 (NTU)	Secchi Depth (m)	Wind Speed (kt)
10/26/2023	10:58 AM	Boat Ramp in Mulberry River in Vine Prairie Public Use Area	35° 29' 1.31" N	94° 03' 37.12" W	32.20	31.60	32.00	0.27	1.00
10/26/2023	12:10 PM	Cobble Creekside Near the Confluence of Simpson Branch and Mulberry River	35° 32' 40.36" N	94° 02' 9.84" W	2.07	2.05	1.99	0.86	0.00
10/26/2023	12:35 PM	SITE 247: Sandy Creekside at the Confluence of Mill Creek and Mulberry River	35° 34' 9.67" N	94° 01' 14.3" W	2.02	1.94	1.98	**1.06	1.00
10/30/2023	1:48 PM	SITE 317: Boat Ramp at Carters Park on the Illinois River	35° 47' 54.31" N	94° 53' 30.88" W	23.80	23.60	24.00	0.35	8.00
10/30/2023	3:31 PM	SITE 315: Boat Ramp at Horseshoe Bend Public Use Area on Illinois River	35° 49' 16.29" N	94° 54' 11.27" W	1.52	1.33	1.34	**1.17	3.00
10/31/2023	12:37 PM	SITE 318: Downstream of S. Welling Bridge Over Baron Fork, a Tributary of the Illinois River	35° 52' 6.09" N	94° 53' 52.81" W	0.82	0.57	0.48	**1.12	8.00

Date	Time (UTC - 5)	Location	Latitude	Longitude	Turbidity Read 1 (NTU)	Turbidity Read 2 (NTU)	Turbidity Read 3 (NTU)	Secchi Depth (m)	Wind Speed (kt)
10/31/2023	1:44 PM	SITE 319: Just Downstream of Highway 51 Bridge Over Baron Fork, a Tributary of the Illinois River	35° 55' 18.07" N	94° 50' 14.26" W	0.99	0.76	0.86	**1.12	5.00
10/31/2023	2:39 PM	SITE 312: Gravel Boat Launch at Todd Public Access Area on Illinois River	35° 57' 31.01" N	94° 52' 9.14" W	1.99	2.16	1.86	**1.12	4.00
11/1/2023	9:16 AM	SITE 314: Near US Hwy 62 Bridge at the End of S. 540 Rd on the Illinois River	35° 55' 21.68" N	94° 55' 26.16" W	1.51	1.52	1.56	**1.14	5.00
11/1/2023	10:20 AM	SITE 308: Gravel Boat Launch at the Edmondson Public Access Area on the Illinois River	36° 01' 55.58" N	94° 54' 44.93" W	1.97	2.08	1.97	**1.04	4.00
11/1/2023	2:13 PM	SITE 304: Illinois River Near Hampton Bridge	36° 06' 17.08" N	94° 46' 59.41" W	1.39	1.42	1.43	**1.14	3.00
11/5/2023	1:21 PM	Cobble Beach on Illinois River Between S. Hwy 59 and Kansas City Southern Railroad	36° 07' 47.01" N	94° 34' 17.72" W	5.52	5.45	5.86	**1.15	2.20

Date	Time (UTC - 5)	Location	Latitude	Longitude	Turbidity Read 1 (NTU)	Turbidity Read 2 (NTU)	Turbidity Read 3 (NTU)	Secchi Depth (m)	Wind Speed (kt)
11/6/2023	9:03 AM	Swift Park Boat Launch on Arkansas River	36° 08' 19.56" N	96° 14' 17.92" W	11.40	10.90	13.50	0.60	0.80
11/6/2023	10:28 AM	Boat Ramp along Braided Channel of Arkansas River Near the Wilson Ave. Bridge	36° 07' 37.84" N	96° 07' 31.8" W	10.60	11.50	10.80	0.70	0.30
11/6/2023	12:13 PM	Beach at River Parks along Braided Channel of Arkansas River	36° 04' 57.12" N	95° 59' 8.46" W	13.70	12.30	12.80	0.50	1.20
11/6/2023	1:08 PM	Beach along Braided Channels of Arkansas River Near E. 96th St. Bridge	36° 01' 25.65" N	95° 57' 23.03" W	7.17	7.28	7.49	**0.50	1.60
11/7/2023	8:32 AM	Beach- Deep Channel on Side of Arkansas River Near Harmony Bridge	35° 57' 26.46" N	95° 53' 24.5" W	6.12	5.76	6.78	0.75	2.20
11/7/2023	3:06 PM	Beach along Braided Channel of Arkansas River Near Riverview Sod Ranch	35° 55' 46.77" N	95° 46' 11.4" W	36.40	35.70	37.70	0.30	1.10
11/8/2023	8:56 AM	Boat Ramp/Dock On the Arkansas River Along the Port Trail	35° 46' 5.02" N	95° 17' 53.81" W	18.30	19.50	17.00	0.50	3.80

Date	Time (UTC - 5)	Location	Latitude	Longitude	Turbidity Read 1 (NTU)	Turbidity Read 2 (NTU)	Turbidity Read 3 (NTU)	Secchi Depth (m)	Wind Speed (kt)
11/24/2023	10:29 AM	SITE 290: Ernest Childers Bridge Over the Arkansas River	35° 55' 4.05" N	95° 39' 27.39" W	8.72	8.98	8.41	**0.29	NA
11/24/2023	12:56 PM	SITE 284: Hopewell Park Public Boat Ramp on Arkansas River	35° 42' 24.18" N	95° 13' 58.63" W	22.30	24.60	23.70	0.36	NA
11/24/2023	1:55 PM	SITE 288: Shallow/ Almost Dried up Section of Arkansas River	35° 47' 29.05" N	95° 33' 10.32" W	6.93	10.30	12.20	**0.26	NA
11/25/2023	3:03 PM	SITE 279: Summers Ferry Park Boat Ramp on Arkansas River	35° 31' 20.38" N	95° 07' 28.96" W	19.20	17.70	16.60	0.38	NA
11/26/2023	9:11 AM	SITE 283: Spaniard Creek Boat Ramp at Spaniard Creek	35° 35' 44.0" N	95° 15' 44.88" W	21.30	28.30	27.70	0.31	NA
11/26/2023	12:34 PM	SITE 273: Eikes Landing on Arkansas River	35° 24' 46.23" N	95° 00' 32.94" W	12.50	20.60	18.40	0.27	NA
11/27/2023	10:28 AM	SITE 277: Lower Illinois River Public Access	35° 35' 29.83" N	95° 03' 34.1" W	5.62	7.84	6.45	**0.39	NA
11/27/2023	2:55 PM	SITE 303: Carnes Ford Public Access at Illinois River	36° 08' 27.28" N	94° 40' 3.92" W	2.36	3.23	3.41	**0.86	NA

Date	Time (UTC - 5)	Location	Latitude	Longitude	Turbidity Read 1 (NTU)	Turbidity Read 2 (NTU)	Turbidity Read 3 (NTU)	Secchi Depth (m)	Wind Speed (kt)
8/14/2024	12:35 PM	SITE 403: Byrd's Adventure Center, 7037 Cass Oark Rd, Ozark, AR 72949.	35° 40' 46.32" N	93° 44' 23.28" W	4.82	5.14	4.94	**0.54	NA
8/15/2024	12:15 PM	SITE 404: Mulberry River Where Forest Service Roads 9311a and 1418 Converge	35° 41' 43.63" N	93° 26' 18.27" W	32.00	23.40	26.60	**0.50	NA
8/15/2024	1:26 PM	SITE 405: Mulberry River South of the Confluence with Bowen Creek and North of the State Route 103 Bridge	35° 41' 3.78" N	93° 36' 0.14" W	9.05	7.67	6.96	**0.50	NA
8/16/2024	3:50 PM	SITE 406: Mayberry River Private Access - Oark, AR	35° 40' 50.37" N	93° 34' 48.0" W	8.25	11.90	8.42	**1.50	NA
8/17/2024	1:26 PM	SITE 407: Frog Bayou off Bidville Rd Bridge	35° 44' 11.07" N	94° 04' 27.13" W	17.60	16.40	16.40	**0.50	NA
8/17/2024	2:10 PM	SITE 408: Hurricane Creek Bridge Over Hurricane Creek	35° 42' 22.97" N	94° 01' 39.57" W	28.00	27.30	30.00	*NA	NA

Date	Time (UTC - 5)	Location	Latitude	Longitude	Turbidity Read 1 (NTU)	Turbidity Read 2 (NTU)	Turbidity Read 3 (NTU)	Secchi Depth (m)	Wind Speed (kt)
8/18/2024	10:45 AM	SITE 409: Mulberry River at Hignite Hollow Bridge	35° 41' 9.11" N	93° 27' 15.74" W	12.50	13.70	12.00	**0.50	NA
8/18/2024	1:30 PM	SITE 410: Little Mulberry Creek at Spoke Plant Hollow	35° 45' 57.57" N	93° 35' 28.93" W	3.34	7.95	8.18	**1.00	NA
8/19/2024	11:03 AM	SITE 408: Hurricane Creek Bridge at Dockerys Gap Over Hurricane Creek	35° 42' 22.97" N	94° 01' 39.57" W	13.40	15.20	16.20	**0.50	NA
8/19/2024	4:33 PM	SITE 411: Hurricane Creek Bridge at Shores Lake Over Hurricane Creek	35° 37' 47.59" N	93° 57' 54.71" W	10.60	10.20	9.76	**1.00	NA
8/20/2024	11:30 AM	SITE 412: Pig Trail Bridge/Mulberry River at River Outfitter Private Access in Cass	35° 40' 11.31" N	93° 49' 41.97" W	12.2	9.49	9.71	**1.20	NA
8/20/2024	1:03 PM	SITE 413: Mulberry River at Big Eddy Hollow	35° 39' 17.55" N	93° 51' 25.30" W	5.96	6.85	7.33	**0.80	NA
8/20/2024	2:56 PM	SITE 414: Mulberry River at Nix Hollow	35° 37' 34.63" N	93° 55' 5.70" W	4.80	3.47	2.94	**0.50	NA

Date	Time (UTC - 5)	Location	Latitude	Longitude	Turbidity Read 1 (NTU)	Turbidity Read 2 (NTU)	Turbidity Read 3 (NTU)	Secchi Depth (m)	Wind Speed (kt)
8/21/2024	12:15 PM	SITE 415: Mulberry River at Campbell Cemetery	35° 37' 24.11" N	93° 54' 39.44" W	2.88	7.05	4.71	**0.50	NA
8/21/2024	2:45 PM	SITE 416: Indian Creek Public Access	35° 40' 59.88" N	93° 42' 42.31" W	5.34	5.96	4.31	**0.50	NA
8/22/2024	1:42 PM	SITE 417: Salt Fork Creek at County Road 76	35° 41' 36.52" N	93° 55' 49.05" W	14.10	16.10	12.60	**0.50	NA

** The current is too swift and shallow or the site is otherwise unsuitable for a Secchi reading*
*** Measurement is depth to the bottom surface due to observational depth limitations*

Figure 6: These photos taken by NV5 acquisition staff display water clarity conditions in four different locations within the NOAA Ozarks site.

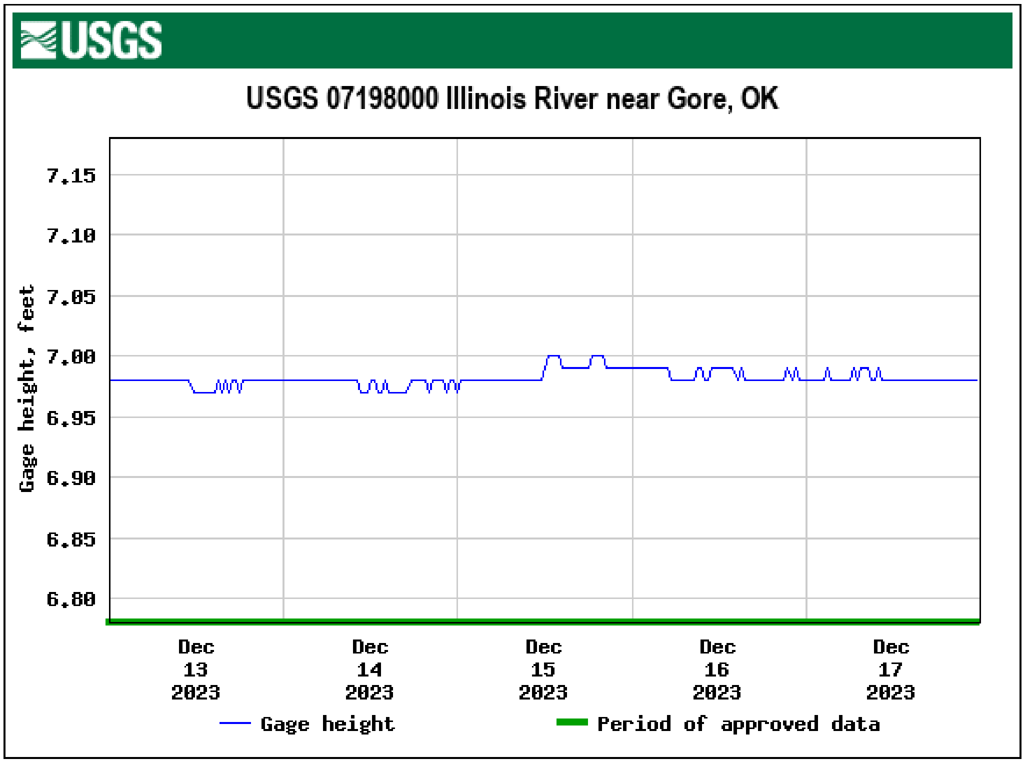


Figure 7: USGS Station 07198000 gage height along the Illinois River at the time of lidar acquisition (December 13 – 17, 2023).

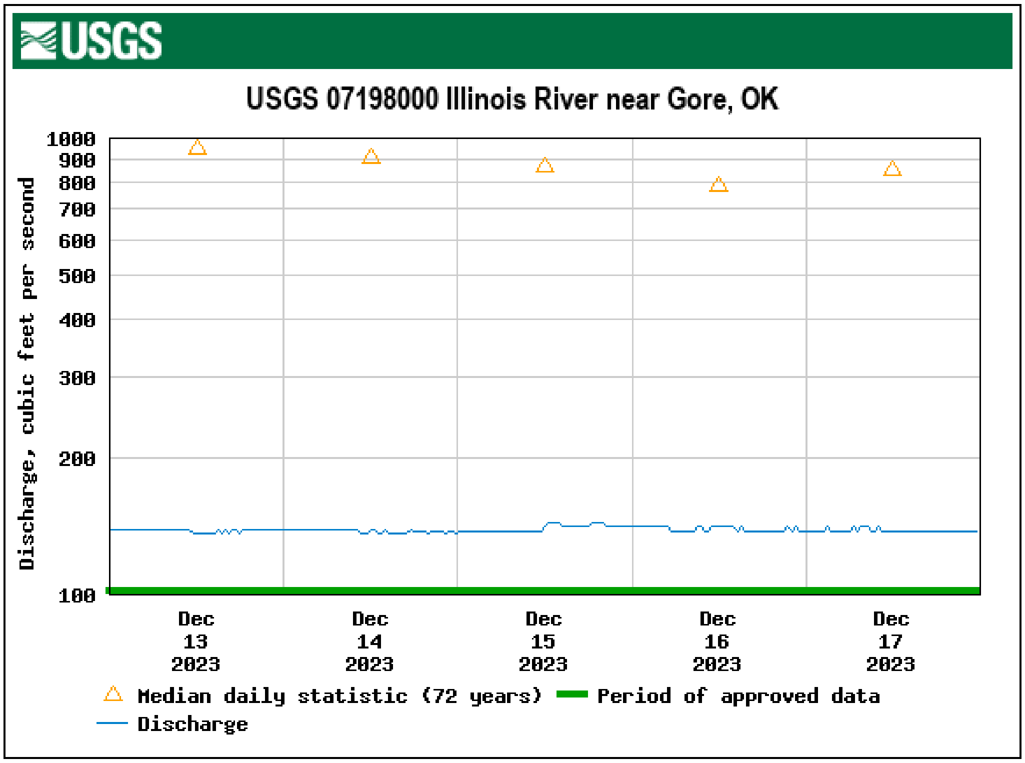


Figure 8: USGS Station 07198000 flow rates along the Illinois River at the time of lidar acquisition (December 13 – 17, 2023).

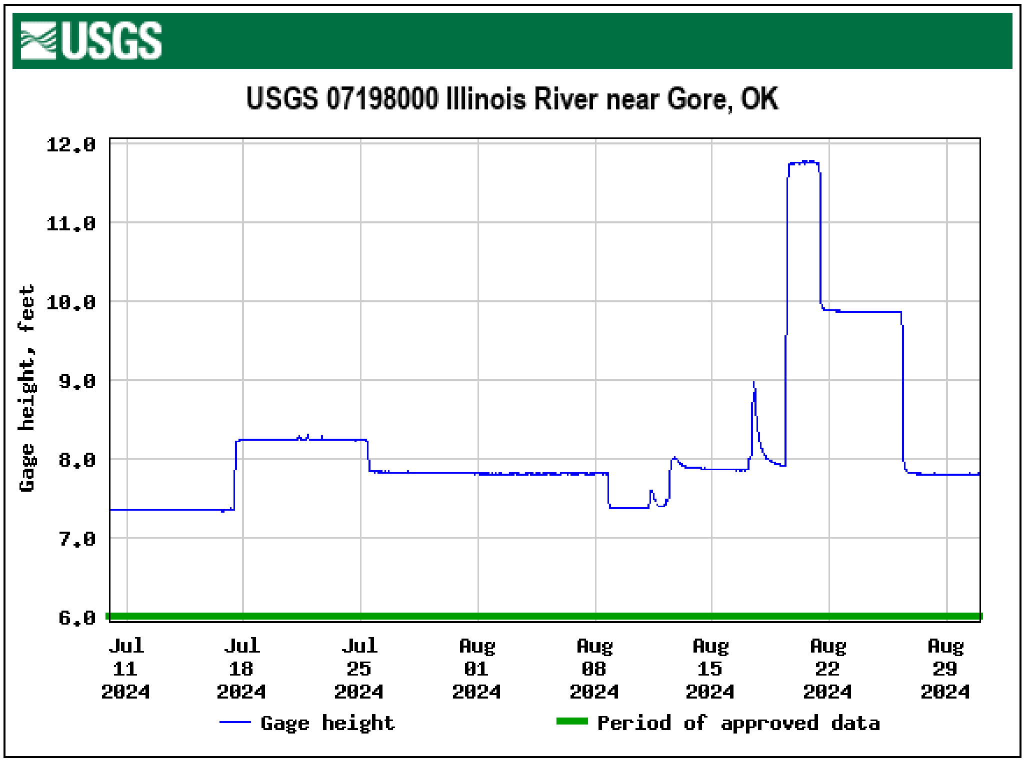


Figure 9: USGS Station 07198000 gage height along the Illinois River at the time of lidar acquisition (July 10 – August 30, 2024).

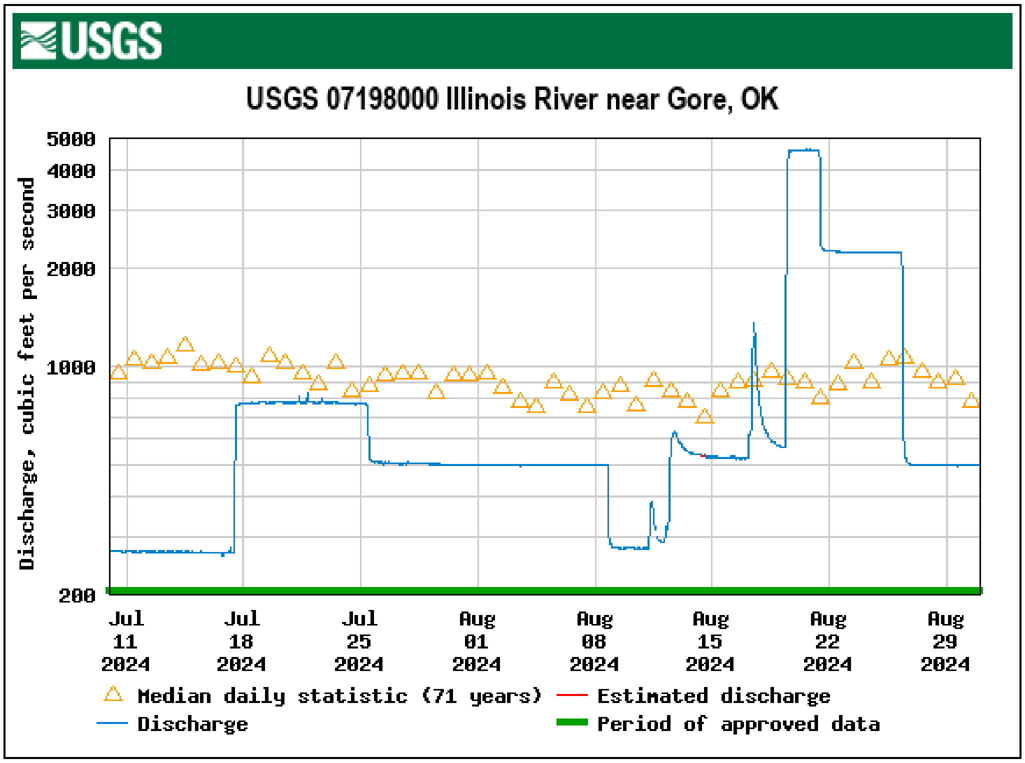


Figure 10: USGS Station 07198000 flow rates along the Illinois River at the time of lidar acquisition (July 10 – August 30, 2024).

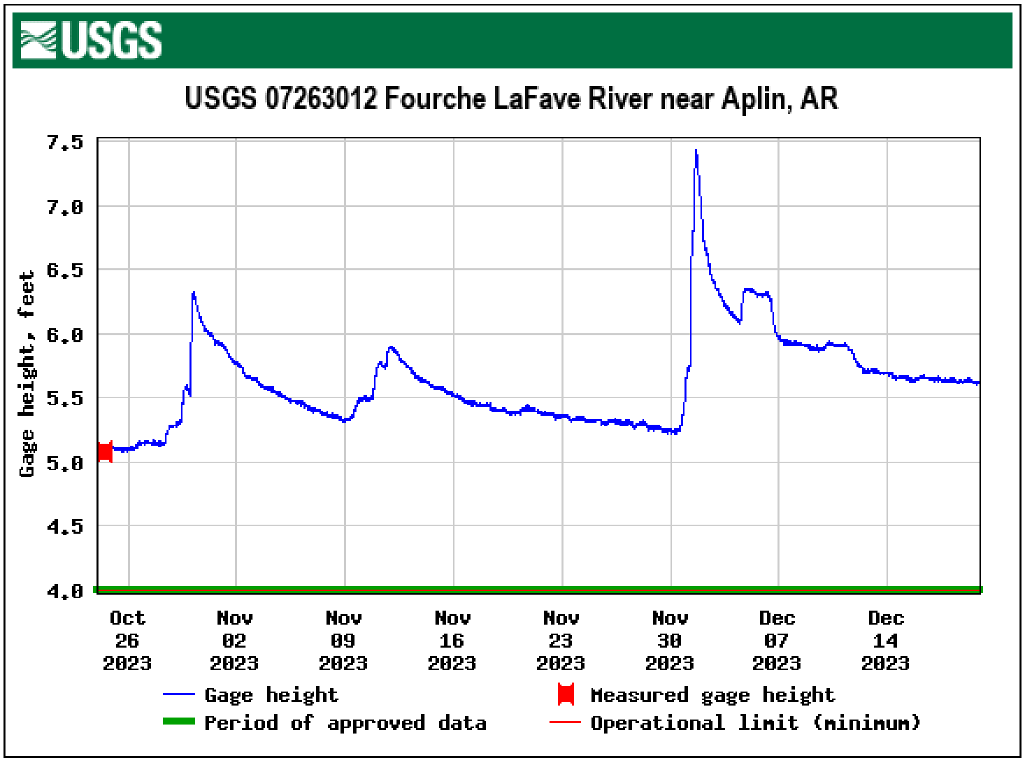


Figure 11: USGS Station 07263012 gage height along the Fourche LaFave River at the time of lidar acquisition (October 24 – December 19, 2024).

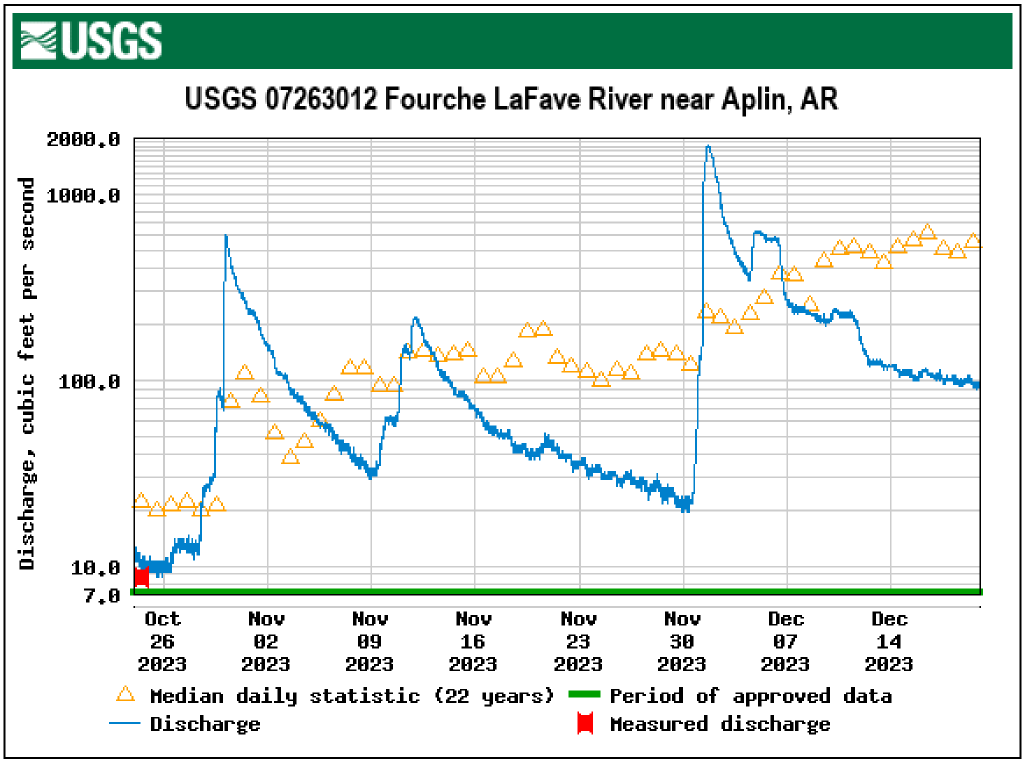


Figure 12: USGS Station 07263012 flow rates along the Fourche LaFave River at the time of lidar acquisition (October 24 – December 19, 2024).

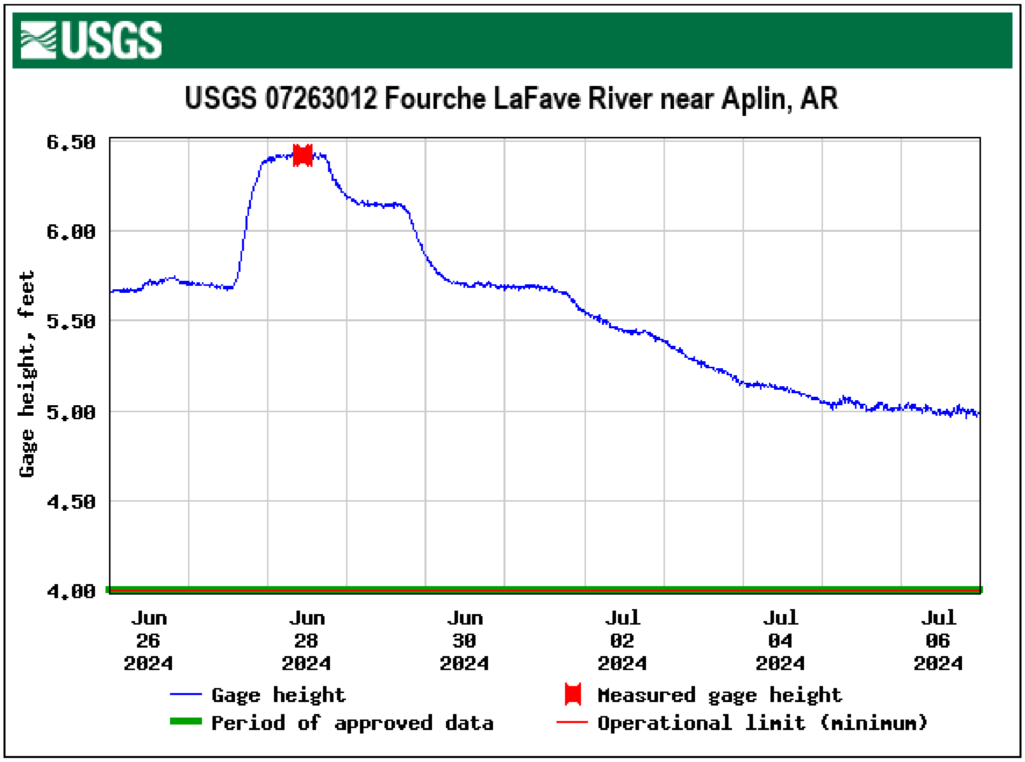


Figure 13: USGS Station 07263012 gage height along the Fourche LaFave River at the time of lidar acquisition (June 26 – July 06, 2024).

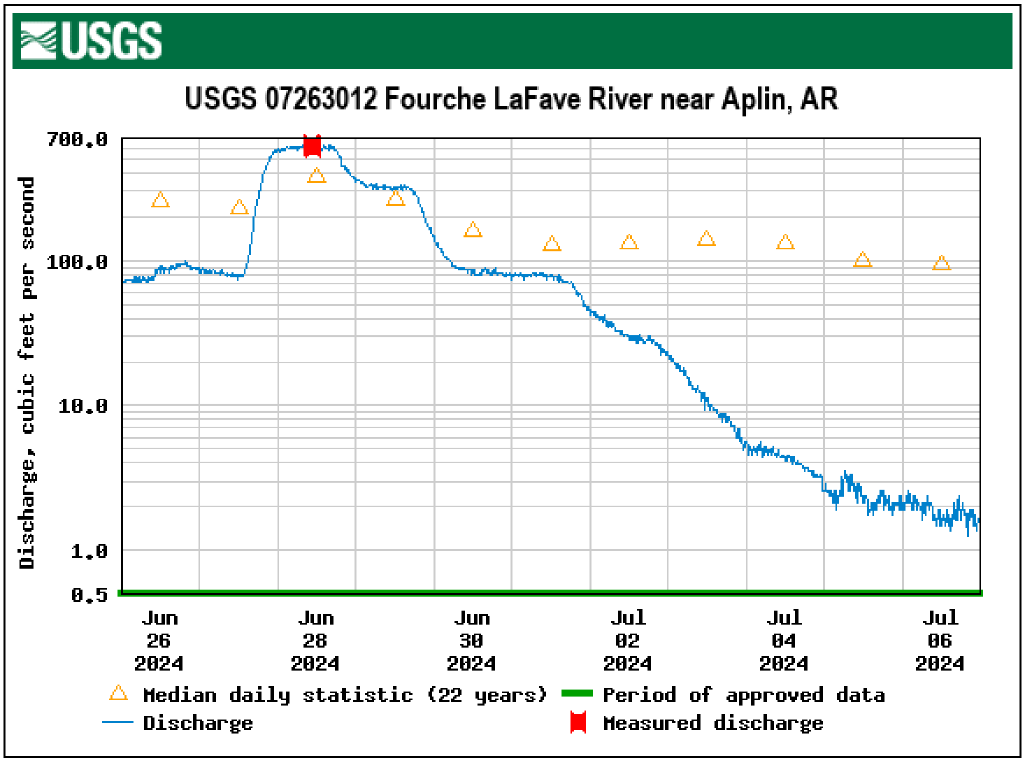


Figure 14: USGS Station 07263012 flow rates along the Fourche LaFave River at the time of lidar acquisition (June 26 – July 06, 2024).

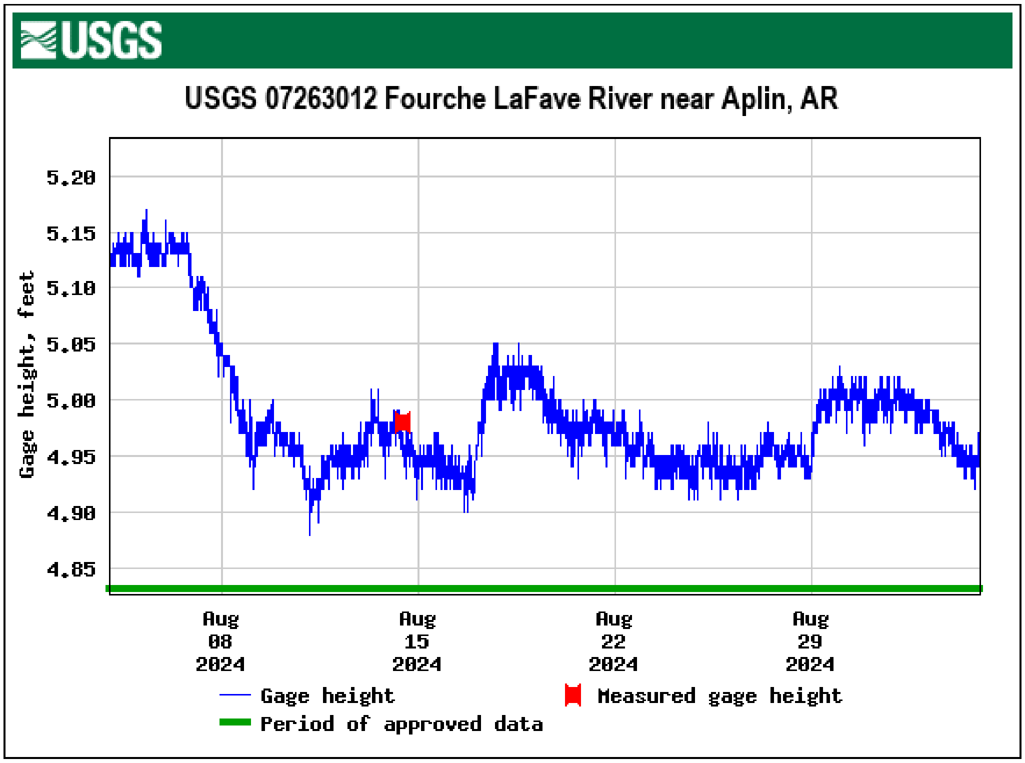


Figure 15: USGS Station 07263012 gage height along the Fourche LaFave River at the time of lidar acquisition (August 04 – September 03, 2024).

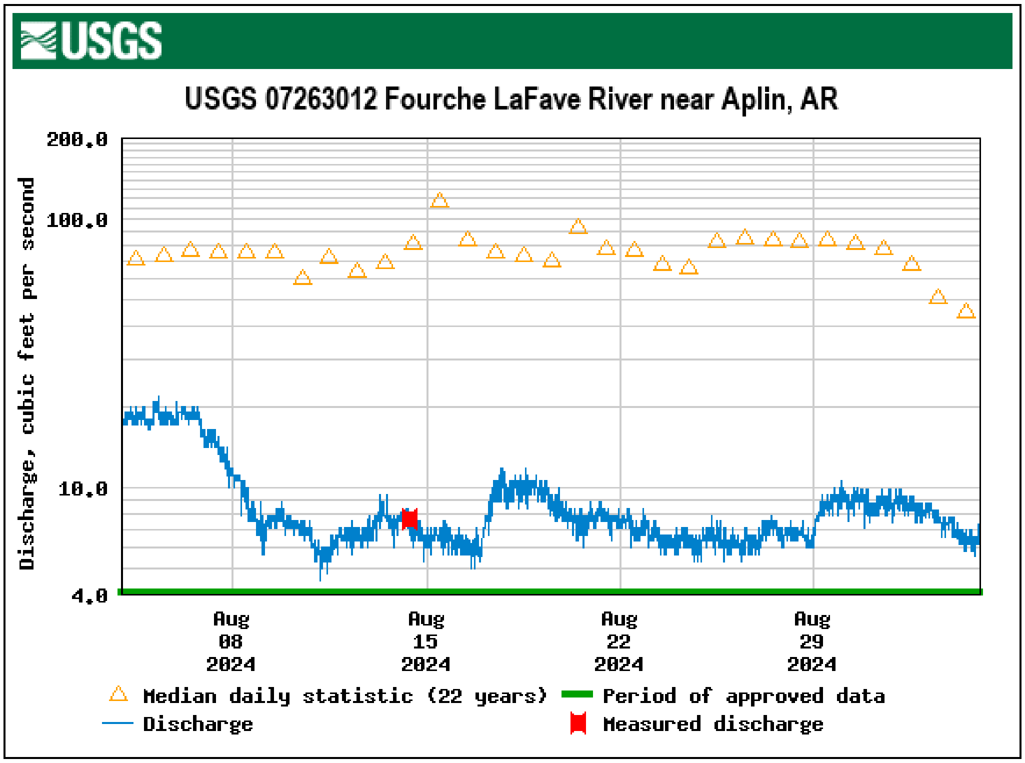


Figure 16: USGS Station 07263012 flow rates along the Fourche LaFave River at the time of lidar acquisition (August 04 – September 03, 2024).

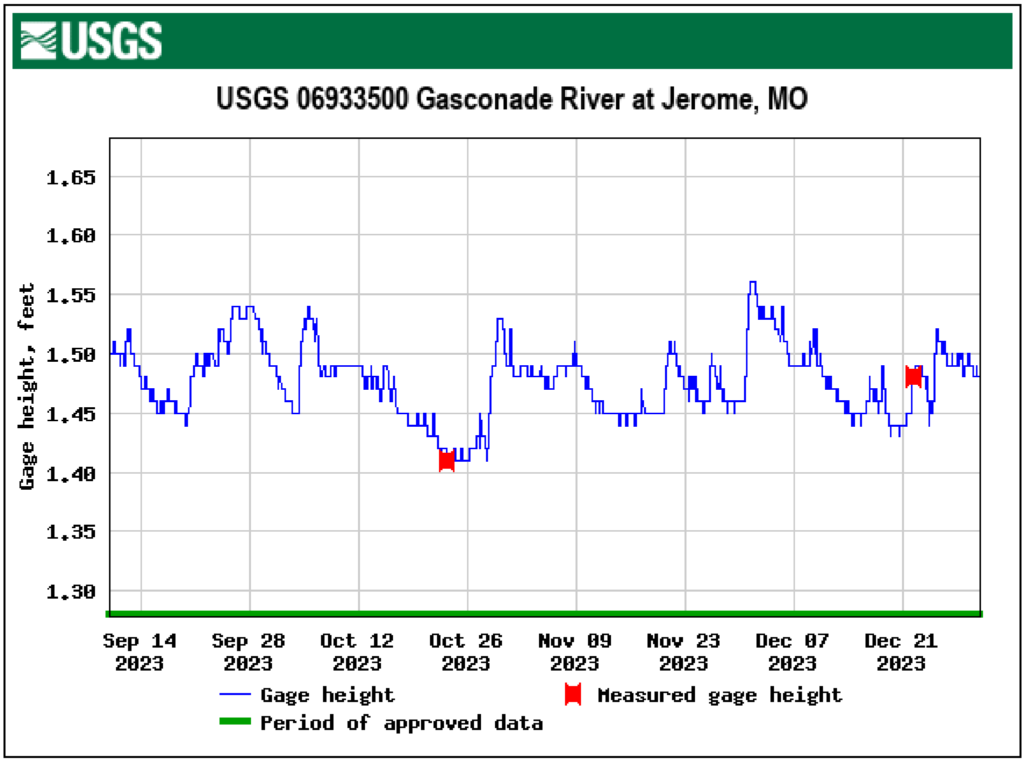


Figure 17: USGS Station 06933500 gage height along the Gasconade River at the time of lidar acquisition (September 10 – December 30, 2024).

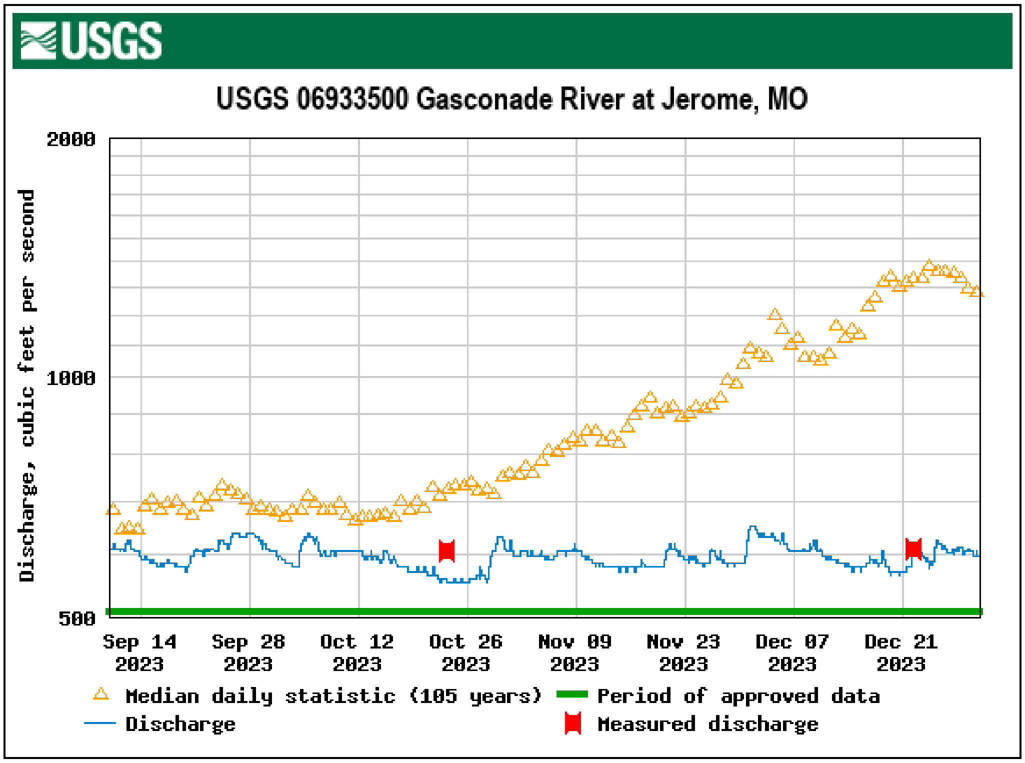


Figure 18: USGS Station 06933500 flow rates along the Gasconade River at the time of lidar acquisition (September 10 – December 30, 2024).

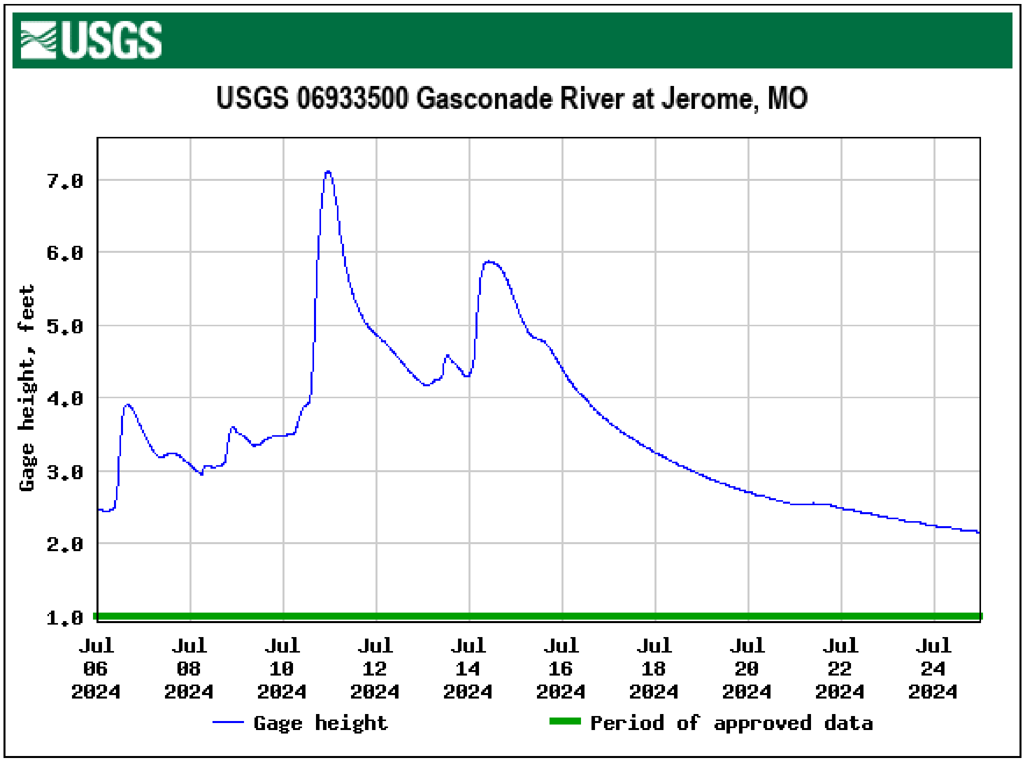


Figure 19: USGS Station 06933500 gage height along the Gasconade River at the time of lidar acquisition (July 6 – July 24, 2024).

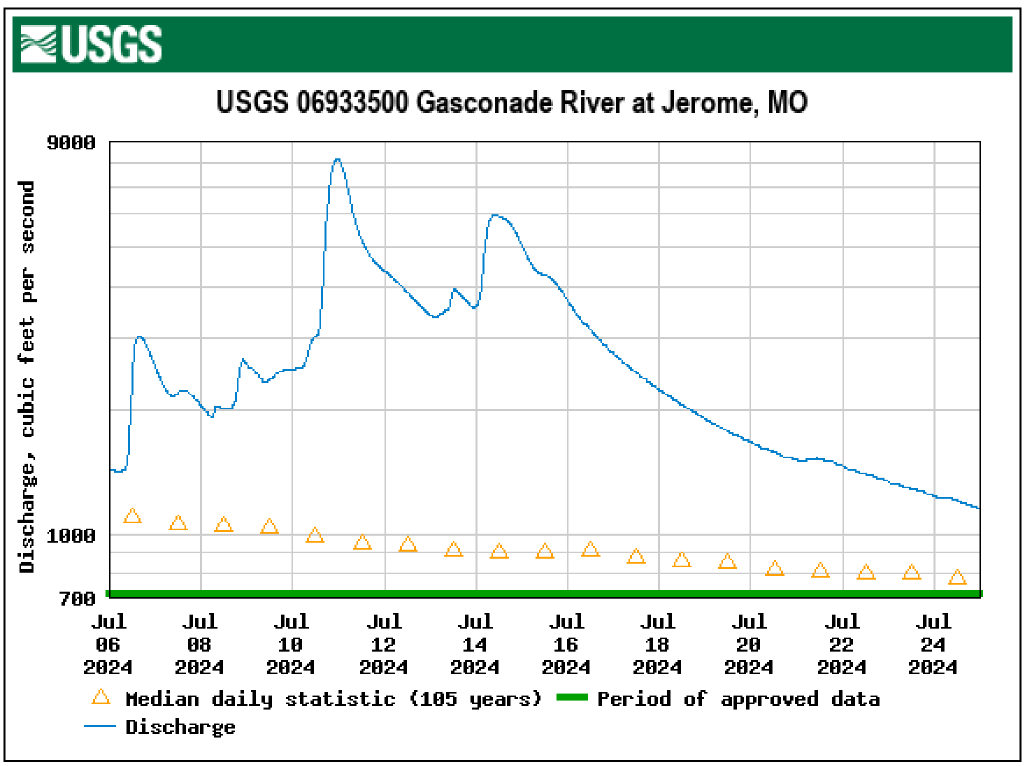


Figure 20: USGS Station 06933500 flow rates along the Gasconade River at the time of lidar acquisition (July 6 – July 24, 2024).

Airborne Lidar Survey

The lidar survey was accomplished using Chiroptera 4X (CH4X) and Chiroptera 5 (CH5) dual green and NIR laser systems mounted in Cessna Grand Caravans. The CH4X and CH5 sensors allow for a depth penetration of K*Dmax=2.7/k and 3.2/k at 15% seabed reflectance, respectively. Chiroptera shallow green laser sensors perform well in both shallow and deep waters with dynamic surfaces and automatically correct for water refraction making them useful in collecting riverine data. These sensors detect obstructions, such as vegetation and anthropogenic features, with oblique lidar. This means they can provide additional information from multiple positions that more closely resemble the actual features and can allow for further analyses compared to traditional imagery. These systems provide seamless integration between the NIR and green channels. Sensor specifications and settings for the NOAA Ozarks acquisitions are displayed in Table 5.

Chiroptera systems acquire full waveform data for every pulse. The recorded waveform enables range measurements for all discernible targets for a given pulse. It is not uncommon for some types of surfaces (e.g., dense vegetation or water) to return fewer pulses to the lidar sensor than the laser originally emitted. The discrepancy between first return and overall delivered density will vary depending on terrain, land cover, and the prevalence of water bodies. All discernible laser returns were processed for the output dataset. Table 5 summarizes the settings used to yield an average pulse density of ≥3 and ≥8 pulses/m^2 for bathymetric and NIR returns, respectively, over the NOAA Ozarks project area. Figure 21 through Figure 26 show the flightlines acquired over each state using these lidar specifications.

Leica Chiroptera CH4X Sensor

Table 5: Lidar specifications and aerial survey settings

Parameter	NIR Sensor	Shallow Green Sensor
Acquisition Dates	08/14/2023 – 09/04/2024	08/14/2023 – 09/04/2024
Aircraft Used	Cessna Grand Caravan	Cessna Grand Caravan
Sensors	Leica Chiroptera 4x Leica Chiroptera 5	Leica Chiroptera 4x Leica Chiroptera 5
Laser Channel	NIR	Green (shallow)
Maximum Returns	6	15
Resolution/Density	Average 8 points/m²	Average 8 points/m²
Nominal Pulse Spacing	0.35 m	0.35 m
Survey Altitude (AGL)	400 – 600 m	400 – 600 m
Survey speed	140 knots	140 knots
Field of View	40°	40°
Mirror Scan Rate	4200 RPM	3500 – 4200 RPM
Target Pulse Rate	250 – 425 kHz	35 – 50 kHz
Pulse Length	2.5 ns	2.5 ns
Laser Pulse Footprint Diameter	10 – 30 cm	160 – 285 cm
Central Wavelength	1030 nm	515 nm
Pulse Mode	Continuous Multipulse	Continuous Multipulse
Beam Divergence	0.50 mrad	4.0 – 4.75 mrad
Swath Width	291 - 437 m	291 - 437 m
Swath Overlap	60 %	60 %
Intensity	16-bit	16-bit

All areas were surveyed with an opposing flightline side-lap of ≥60% (≥100% overlap) to reduce laser shadowing and increase surface laser painting. To accurately solve for laser point position (geographic coordinates x, y, and z), the positional coordinates of the airborne sensor and the orientation of the aircraft to the horizon (attitude) were recorded continuously throughout the lidar data collection mission. Position of the aircraft was measured twice per second (2 Hz) by an onboard differential GPS unit, and aircraft attitude was measured 200 times per second (200 Hz) as pitch, roll, and yaw (heading) from an onboard inertial measurement unit (IMU). To allow for post-processing correction and calibration, aircraft and sensor position and attitude data are indexed by GPS time.

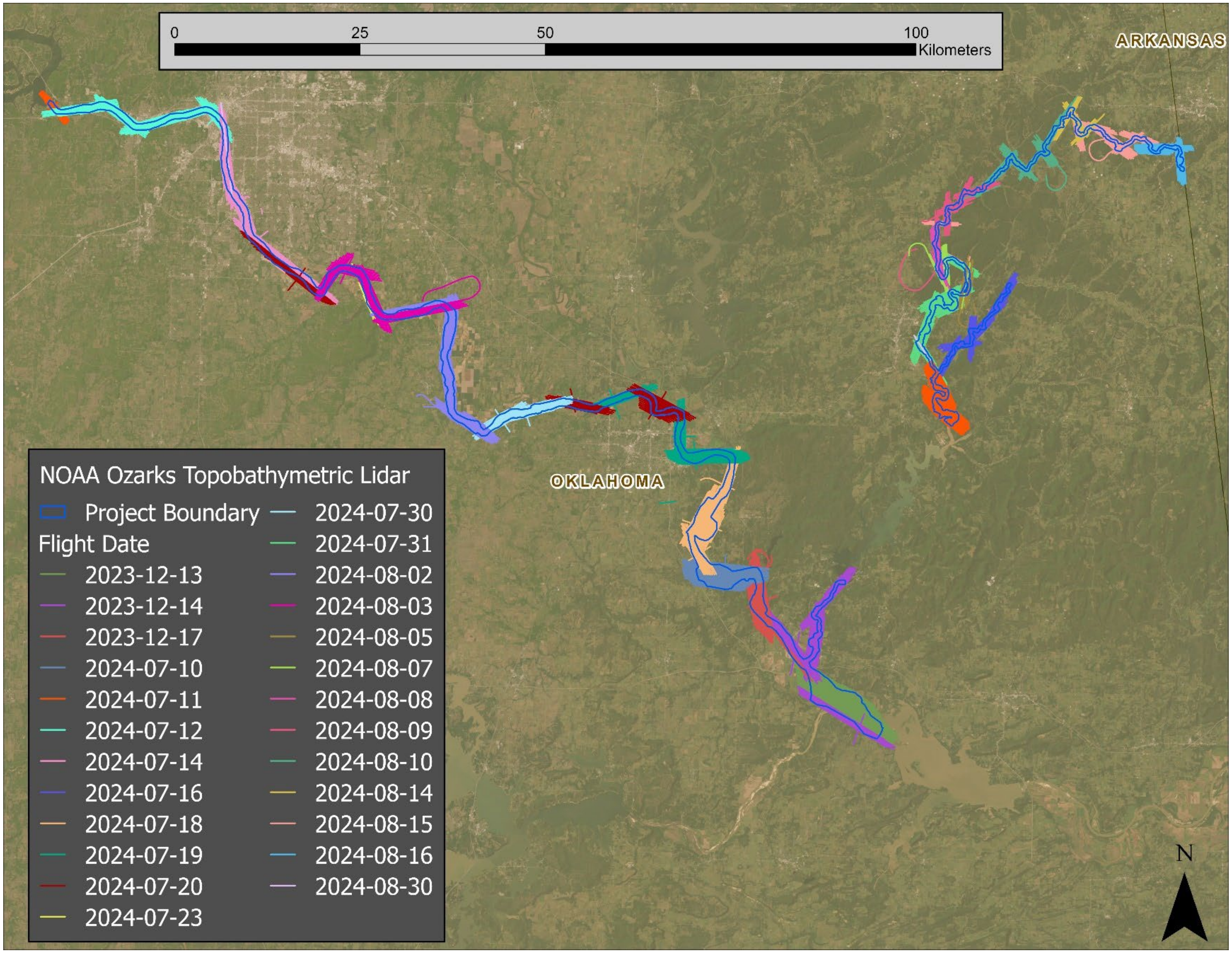


Figure 21: Flightlines map showing the acquisition of the sites in Oklahoma

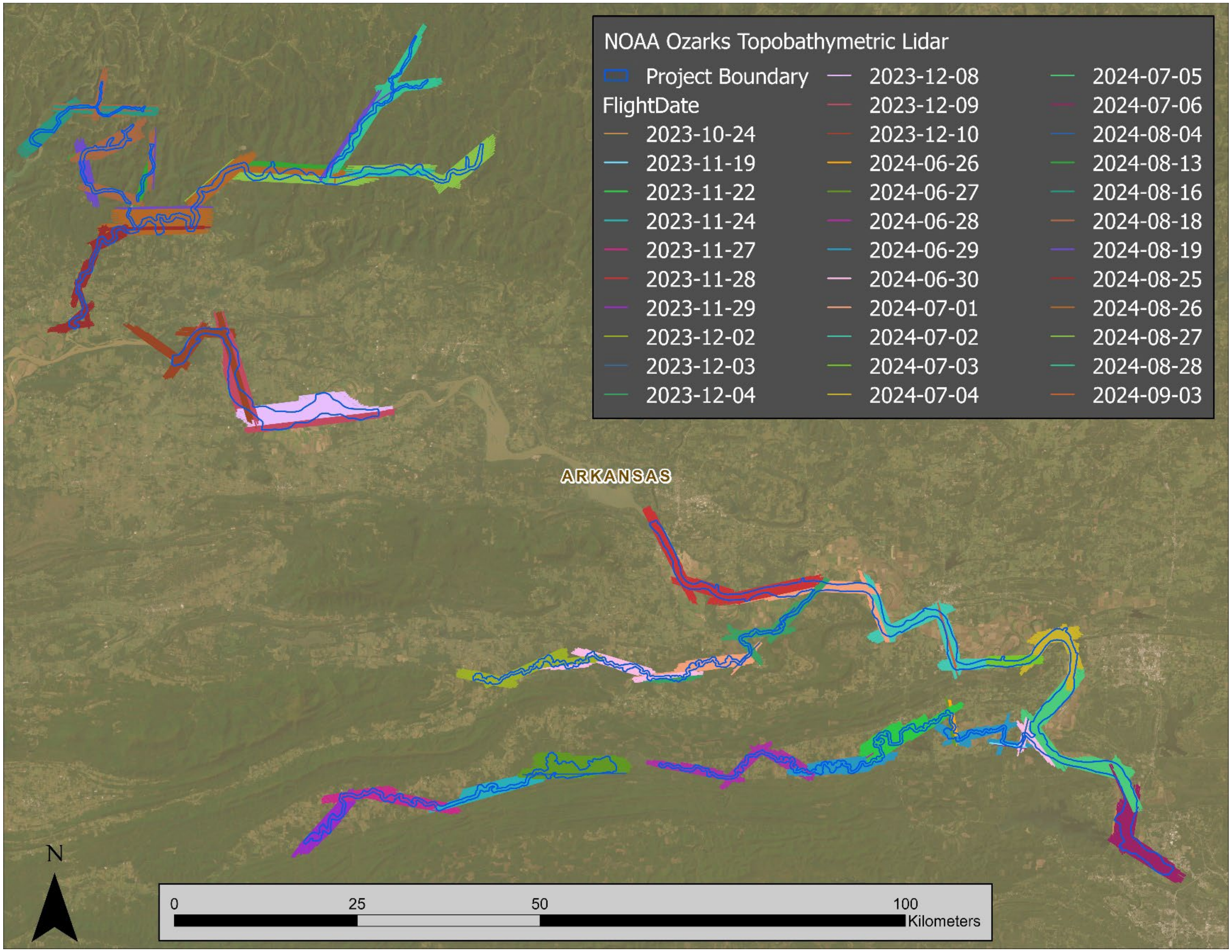


Figure 22: Flightlines map showing the acquisition of the sites in eastern and central Arkansas

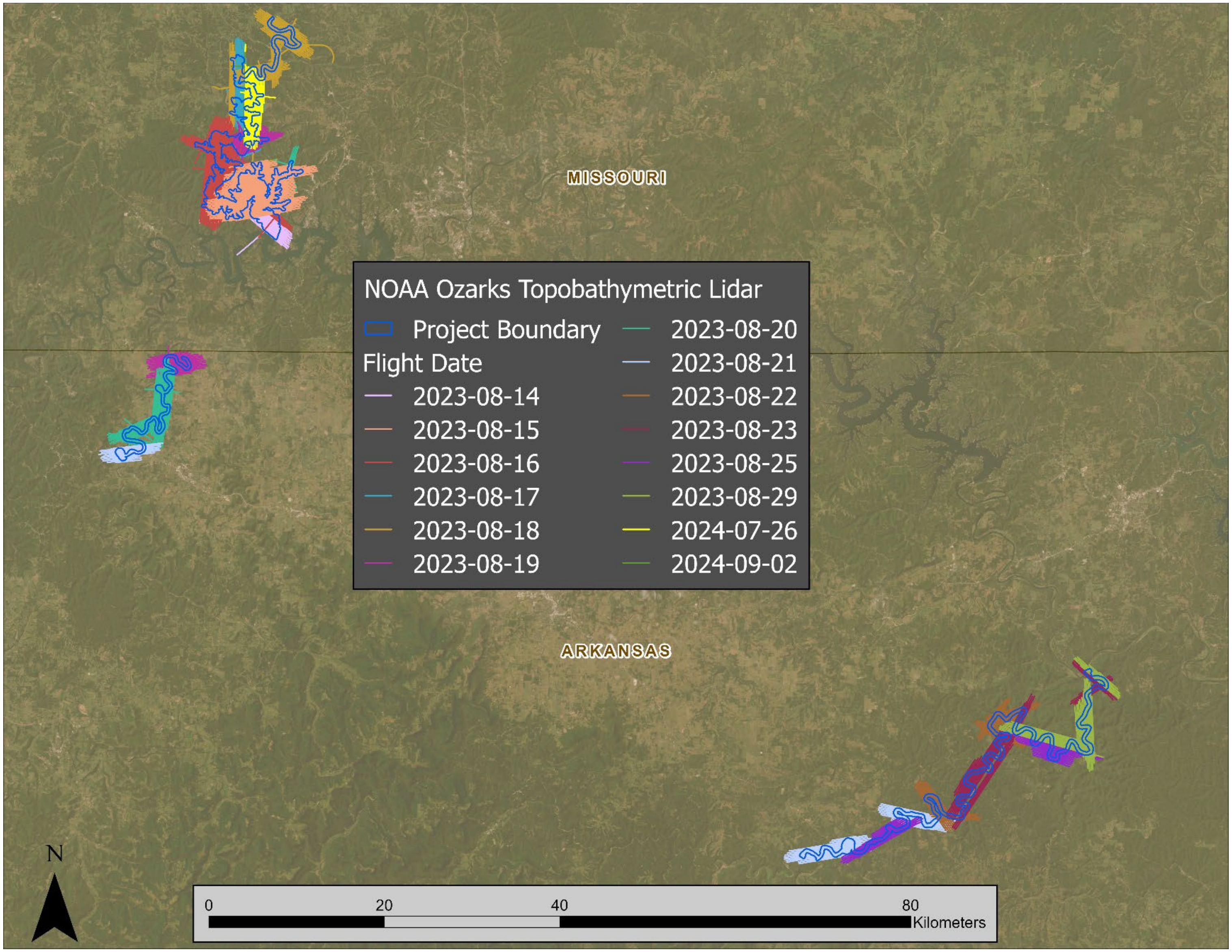


Figure 23: Flightlines map showing the acquisition of the sites near the western Arkansas and Missouri border

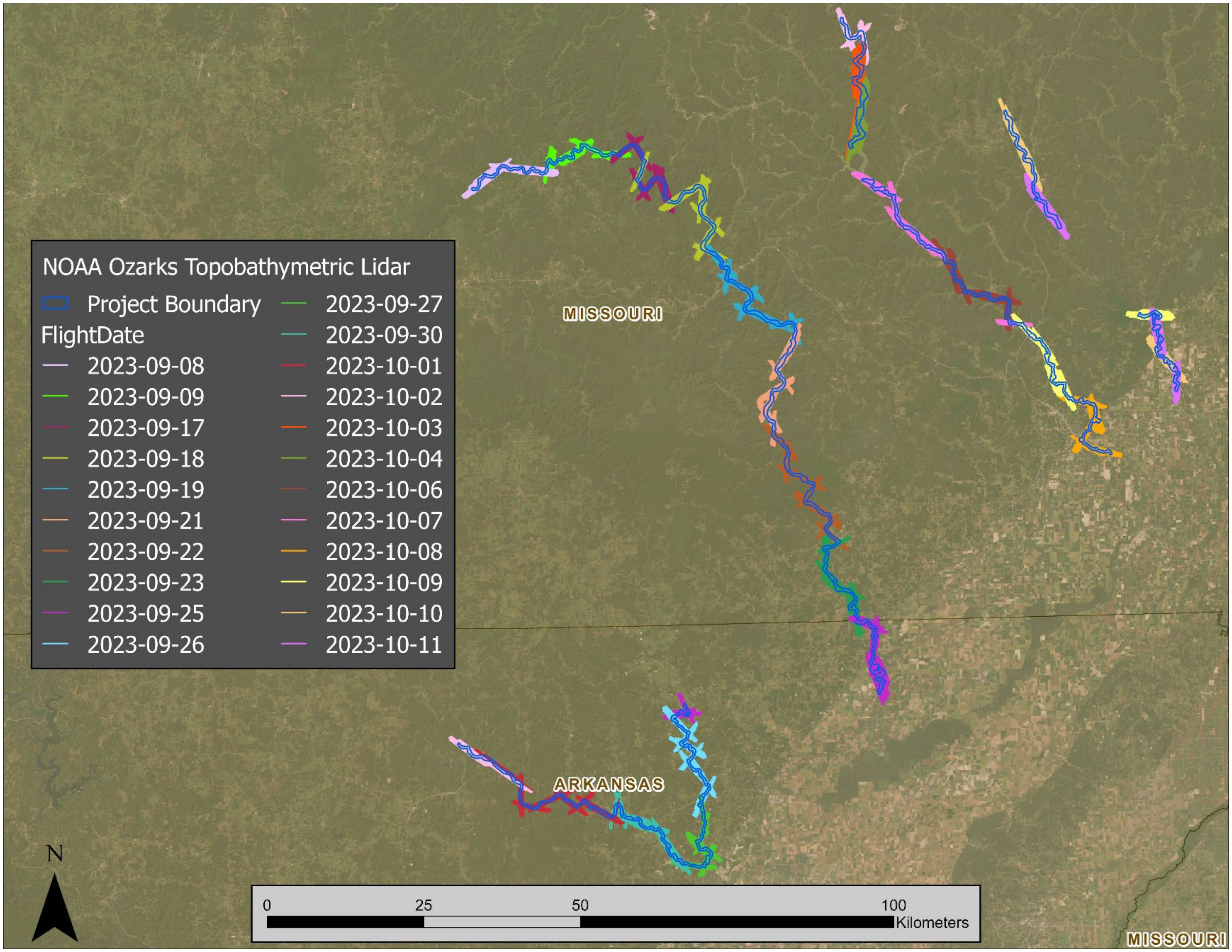


Figure 24: Flightlines map showing the acquisition of the sites near the eastern Arkansas and Missouri border

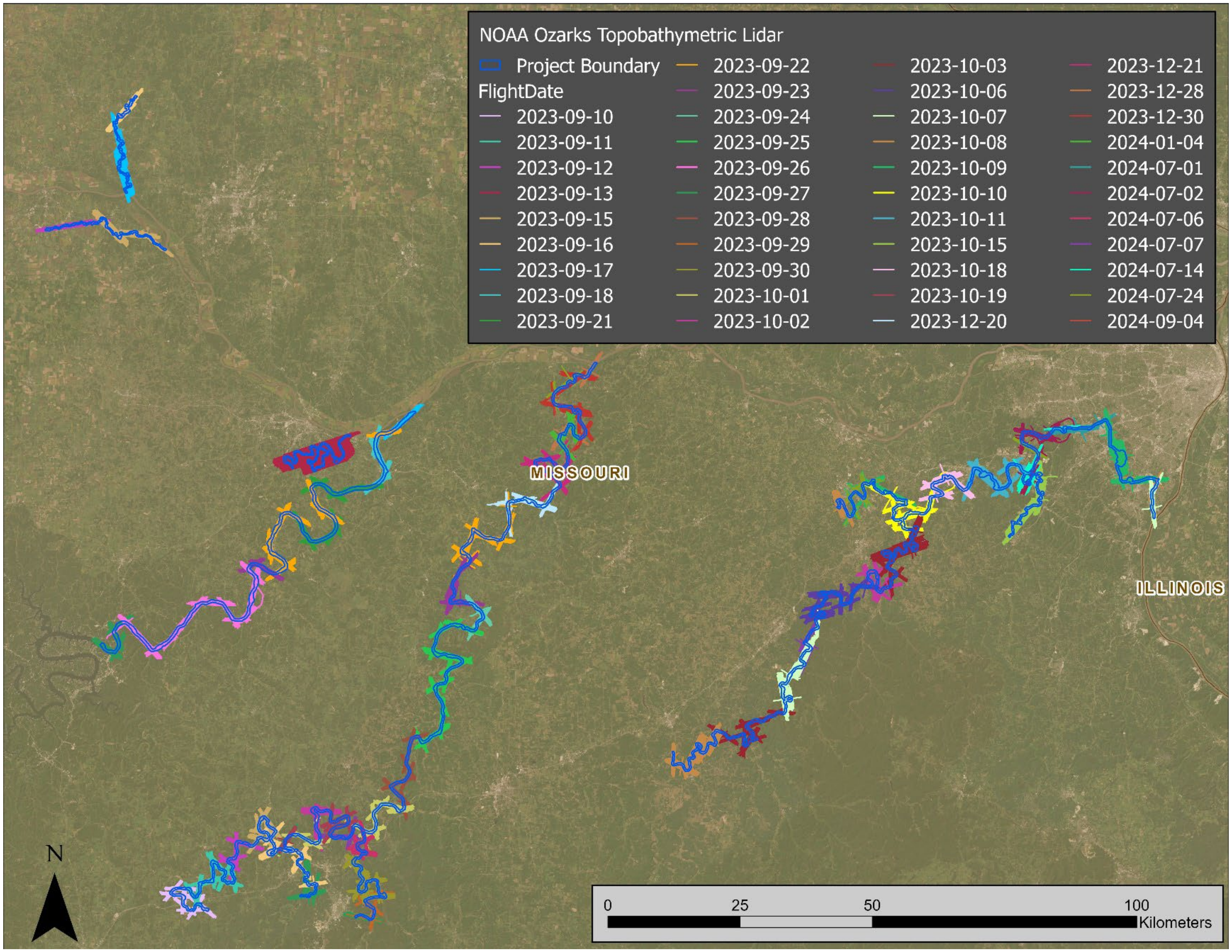


Figure 25: Flightlines map showing the acquisition of the sites in eastern Missouri

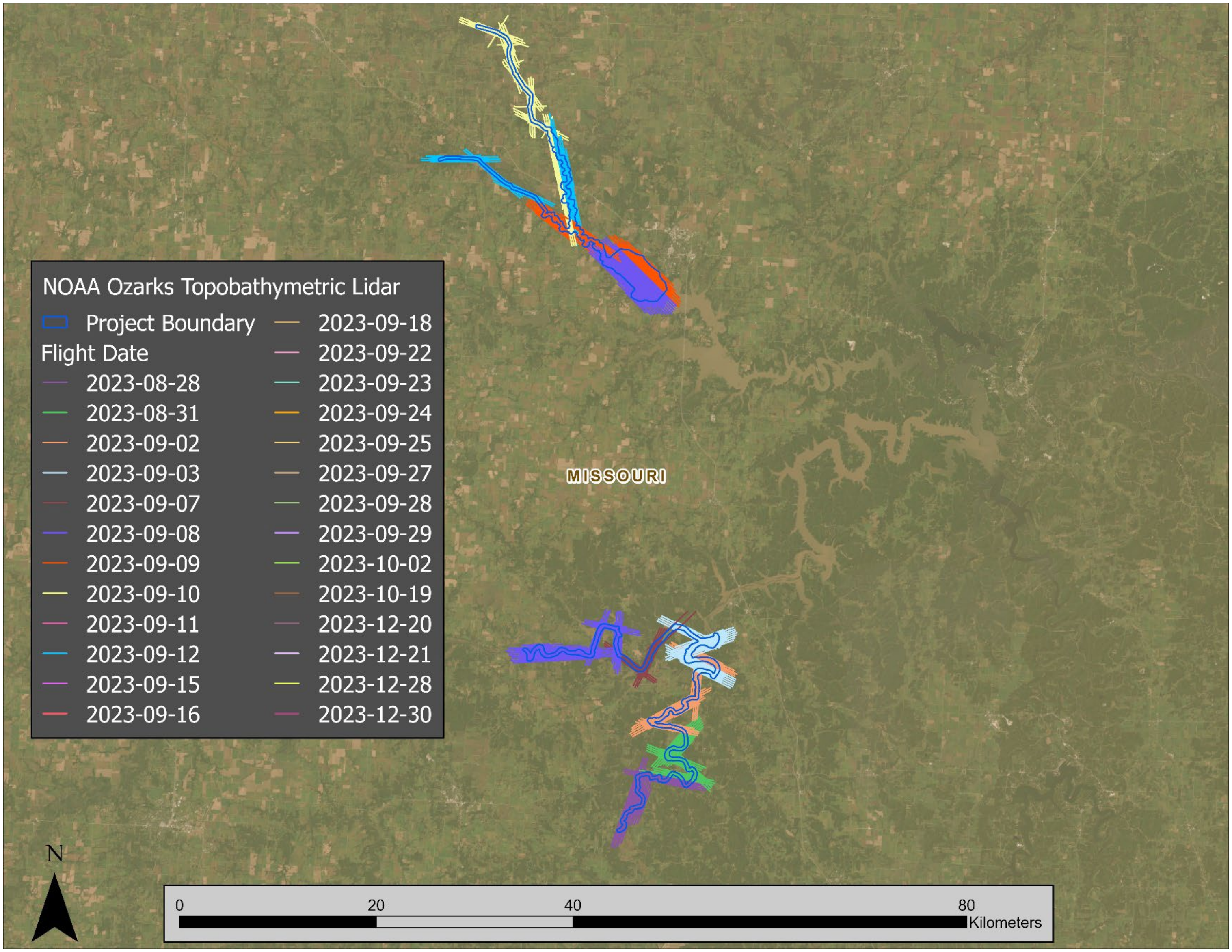


Figure 26: Flightlines map showing the acquisition of the sites in western Missouri

Ground Survey

Ground control surveys, including monumentation, aerial targets and ground survey points (GSPs), were conducted from August of 2023 through January of 2024 and June of 2024 through September of 2024 to support the airborne acquisition. Ground control data were used to geospatially correct the aircraft positional coordinate data and to perform quality assurance checks on final lidar data and orthoimagery products.

Base Stations

Base stations were used for collecting ground survey points using real time kinematic (RTK), post processed kinematic (PPK), fast static (FS), and total station (TS) survey techniques.

Base station locations were selected with consideration for satellite visibility, field crew safety, and optimal location for GSP coverage. NV5 utilized 44 permanent real-time network (RTN) base stations including 16 from the Hexagon SmartNet[1] network, 20 from Missouri Department of Transportation Real Time Network (MODOT), and 8 from the Arkansas Department of Transportation Real Time Network (ARDOT). Two (2) existing NV5 monuments and four (4) new monuments were also established for the NOAA Ozarks Lidar project (Table 6, Figure 27). New monumentation was set using 5/8” x 30” rebar topped with stamped 2 ½ " aluminum caps. NV5’s professional land surveyor, Steven J. Hyde (ARPLS#1767, MOPLS#2016000164, OKPLS#1856), oversaw and certified the ground survey.

Table 6: Base station positions for the NOAA Ozarks acquisition. Coordinates are on the NAD83 (2011) datum, epoch 2010.00

Monument ID	Latitude	Longitude	Ellipsoid (meters)	State	Network
ARBA	35° 46' 19.10610"	-91° 38' 58.79208"	90.014	Arkansas	SMARTNET
ARBY	36° 21' 21.53616"	-93° 34' 49.29481"	323.382	Arkansas	SMARTNET
ARCL	35° 28' 10.30440"	-93° 28' 46.51331"	106.891	Arkansas	SMARTNET
ARCW_DOT	35° 05' 13.23651"	-92° 21' 48.40895"	78.956	Arkansas	ARDOT
ARCW_SMARTNET	35° 06' 49.07677"	-92° 30' 20.45448"	75.005	Arkansas	SMARTNET
ARDV	35° 05' 35.16533"	-93° 22' 48.34348"	88.948	Arkansas	ARDOT
ARFS	35° 19' 18.22383"	-94° 18' 16.14665"	112.341	Arkansas	ARDOT
ARHL	36° 15' 36.19245"	-91° 32' 35.57285"	191.359	Arkansas	ARDOT
ARJO	35° 50' 21.62370"	-90° 42' 15.50636"	78.925	Arkansas	SMARTNET
ARLR	34° 40' 21.44393"	-92° 22' 57.18150"	74.419	Arkansas	ARDOT
ARMA	35° 54' 23.10035"	-92° 38' 00.56156"	294.744	Arkansas	SMARTNET

[1] https://hxgnsmartnet.com/0000000

Monument ID	Latitude	Longitude	Ellipsoid (meters)	State	Network
AROZ	35° 29' 46.17178"	-93° 50' 38.04921"	122.379	Arkansas	ARDOT
ARPG	36° 03' 32.78722"	-90° 31' 07.62505"	69.603	Arkansas	ARDOT
ARRV	35° 18' 22.61410"	-93° 07' 51.34678"	90.978	Arkansas	ARDOT
ARSM	35° 21' 48.46514"	-94° 22' 08.96872"	128.485	Arkansas	SMARTNET
ARSS	36° 11' 27.63110"	-94° 33' 44.73026"	324.726	Arkansas	SMARTNET
MOBE	37° 27' 19.28714"	-91° 12' 56.71473"	389.106	Missouri	MODOT
MOBO	38° 55' 52.53367"	-92° 46' 43.65919"	206.708	Missouri	MODOT
MOBR	36° 42' 35.20127"	-93° 13' 23.59214"	289.897	Missouri	MODOT
MOCL	38° 23' 19.74350"	-93° 45' 21.33532"	208.104	Missouri	MODOT
MOCO	38° 59' 32.00211"	-92° 17' 04.88566"	207.716	Missouri	MODOT
MODP	36° 38' 42.39207"	-90° 47' 52.77641"	148.608	Missouri	MODOT
MODR	38° 27' 45.47416"	-91° 27' 54.94360"	238.253	Missouri	MODOT
MODX	36° 48' 24.82023"	-89° 58' 42.95873"	89.104	Missouri	MODOT
MOEG	37° 52' 37.77791"	-94° 01' 23.62392"	227.469	Missouri	SMARTNET
MOEL	38° 20' 49.67807"	-92° 35' 43.33476"	262.488	Missouri	MODOT
MOIT	37° 35' 56.39381"	-90° 37' 40.66589"	259.42	Missouri	SMARTNET
MOJC	38° 34' 47.29654"	-92° 17' 40.74731"	201.083	Missouri	MODOT
MONF	37° 34' 19.54018"	-92° 20' 33.30401"	312.599	Missouri	MODOT
MOOA	38° 02' 29.61628"	-93° 41' 06.70146"	234.923	Missouri	MODOT
MOPB	36° 45' 37.38437"	-90° 23' 31.12782"	101.41	Missouri	SMARTNET
MOS2	38° 20' 21.14367"	-91° 00' 22.18573"	215.063	Missouri	MODOT
MOS9	37° 12' 40.05753"	-93° 13' 56.93241"	394.825	Missouri	SMARTNET
MOSI	38° 33' 44.23066"	-90° 27' 40.90251"	109.133	Missouri	MODOT
MOSL	37° 10' 38.14513"	-90° 27' 52.44434"	98.257	Missouri	MODOT
MOSR	37° 49' 14.66192"	-92° 09' 15.38868"	311.338	Missouri	MODOT
MOST	37° 58' 13.44534"	-91° 20' 33.15310"	196.802	Missouri	MODOT
MOVB	36° 57' 36.45557"	-91° 03' 37.81009"	136.839	Missouri	MODOT
MOVE	38° 11' 29.10968"	-91° 56' 55.26052"	241.223	Missouri	MODOT
MOW2	36° 43' 27.67214"	-91° 50' 05.73807"	268.809	Missouri	SMARTNET
MOWW	38° 15' 12.09648"	-93° 21' 42.33069"	192.855	Missouri	MODOT

Monument ID	Latitude	Longitude	Ellipsoid (meters)	State	Network
OKME	35° 44' 32.79003"	-95° 20' 39.16190"	161.134	Oklahoma	SMARTNET
OKOE	35° 39' 58.88911"	-95° 57' 49.24783"	181.205	Oklahoma	SMARTNET
OKSP	36° 02' 49.58269"	-96° 05' 13.86791"	204.132	Oklahoma	SMARTNET
OZARKS_01	38° 14' 19.08891"	-92° 27' 06.78746"	143.744	Missouri	NV5
OZARKS_02	34° 54' 30.48870"	-93° 35' 41.12957"	102.119	Arkansas	NV5
OZARK_01	35° 41' 21.80827"	-93° 34' 25.88489"	283.377	Arkansas	NV5
OZARK_02	35° 44' 12.06788"	-94° 04' 28.86707"	287.622	Arkansas	NV5
OZARK_03	35° 38' 20.73511"	-93° 57' 12.60107"	252.115	Arkansas	NV5
OZARK_04	35° 41' 16.42457"	-93° 49' 10.74425"	199.984	Arkansas	NV5

NV5 utilized static Global Navigation Satellite System (GNSS) data collected at 1 Hz recording frequency for each base station. During post-processing, the static GNSS data was triangulated with nearby Continuously Operating Reference Stations (CORS) using the Online Positioning User Service (OPUS[2]) for precise positioning. Multiple independent sessions over the same monument were processed to confirm antenna height measurements and to refine position accuracy.

Monuments were established according to the national standard for geodetic control networks, as specified in the Federal Geographic Data Committee (FGDC) Geospatial Positioning Accuracy Standards for geodetic networks.[3] This standard provides guidelines for classification of monument quality at the 95% confidence interval as a basis for comparing the quality of one control network to another. The monument rating for this project is shown in Table 7.

Table 7: Federal Geographic Data Committee monument rating for network accuracy

Direction	Rating
1.96 * St Dev $_{NE}$:	0.020 m
1.96 * St Dev $_{z}$:	0.020 m

For the NOAA Ozarks Lidar project, the monument coordinates contributed no more than 2.8 cm of positional error to the geolocation of the final ground survey points and lidar, with 95% confidence.

[2] OPUS is a free service provided by the National Geodetic Survey to process corrected monument positions: OPUS website

[3] Federal Geographic Data Committee, Geospatial Positioning Accuracy Standards (FGDC-STD-007.2-1998). Part 2: Standards for Geodetic Networks, Table 2.1, page 2-3: FGDC Standards Website

Ground Survey Points (GSPs)

Ground survey points were collected using real time kinematic (RTK), post-processed kinematic (PPK), fast-static (FS), and total station (TS) survey techniques. For RTK surveys, a roving receiver receives corrections from a nearby base station or Real-Time Network (RTN) via radio or cellular network, enabling rapid collection of points with relative errors less than 1.5 cm horizontal and 2.0 cm vertical. PPK and FS surveys compute these corrections during post-processing to achieve comparable accuracy. RTK and PPK surveys record data while stationary for at least five seconds, calculating the position using at least three one-second epochs. FS surveys record observations for up to fifteen minutes on each GSP in order to support longer baselines. All GSP measurements were made during periods with a Position Dilution of Precision (PDOP) of ≤ 3.0 with at least six satellites in view of the stationary and roving receivers. See Table 8 for NV5 ground survey equipment information.

Forested checkpoints are collected using total stations to measure positions under dense canopy. Total station backsight and setup points are established using GNSS survey techniques.

GSPs were collected in areas where good satellite visibility was achieved on paved roads and other hard surfaces such as gravel or packed dirt roads. GSP measurements were not taken on highly reflective surfaces such as center line stripes or lane markings on roads due to the increased noise seen in the laser returns over these surfaces. GSPs were collected within as many flightlines as possible; however, the distribution of GSPs depended on ground access constraints and monument locations and may not be equably distributed throughout the study area (Figure 27).

Table 8: NV5 ground survey equipment identification

Receiver Model	Antenna	OPUS Antenna ID	Use
Trimble R750	Zephyr Model 3 GNSS	TRM115000.10	Trimble R750
Trimble R12	Integrated Antenna	TRMR12	Rover/Static
Trimble M3 Total Station	N/A	N/A	VVA

Land Cover Class

In addition to ground survey points, land cover class checkpoints were collected throughout the study area to evaluate vertical accuracy. Vertical accuracy statistics were calculated for all land cover types to assess confidence in the lidar derived ground models across land cover classes (Table 9, see Lidar Accuracy Assessments, page 77).

Table 9: Land Cover Types and Descriptions

Land cover type	Land cover code	Example	Description	Accuracy Assessment Type
Shrub	SH		Low growth shrub	VVA
Tall Grass	TG		Herbaceous grasslands in advanced stages of growth	VVA
Forest	FR		Forested areas	VVA
Bare Earth	BE		Areas of bare earth surface	NVA
Urban	UA		Areas dominated by urban development, including parks	NVA

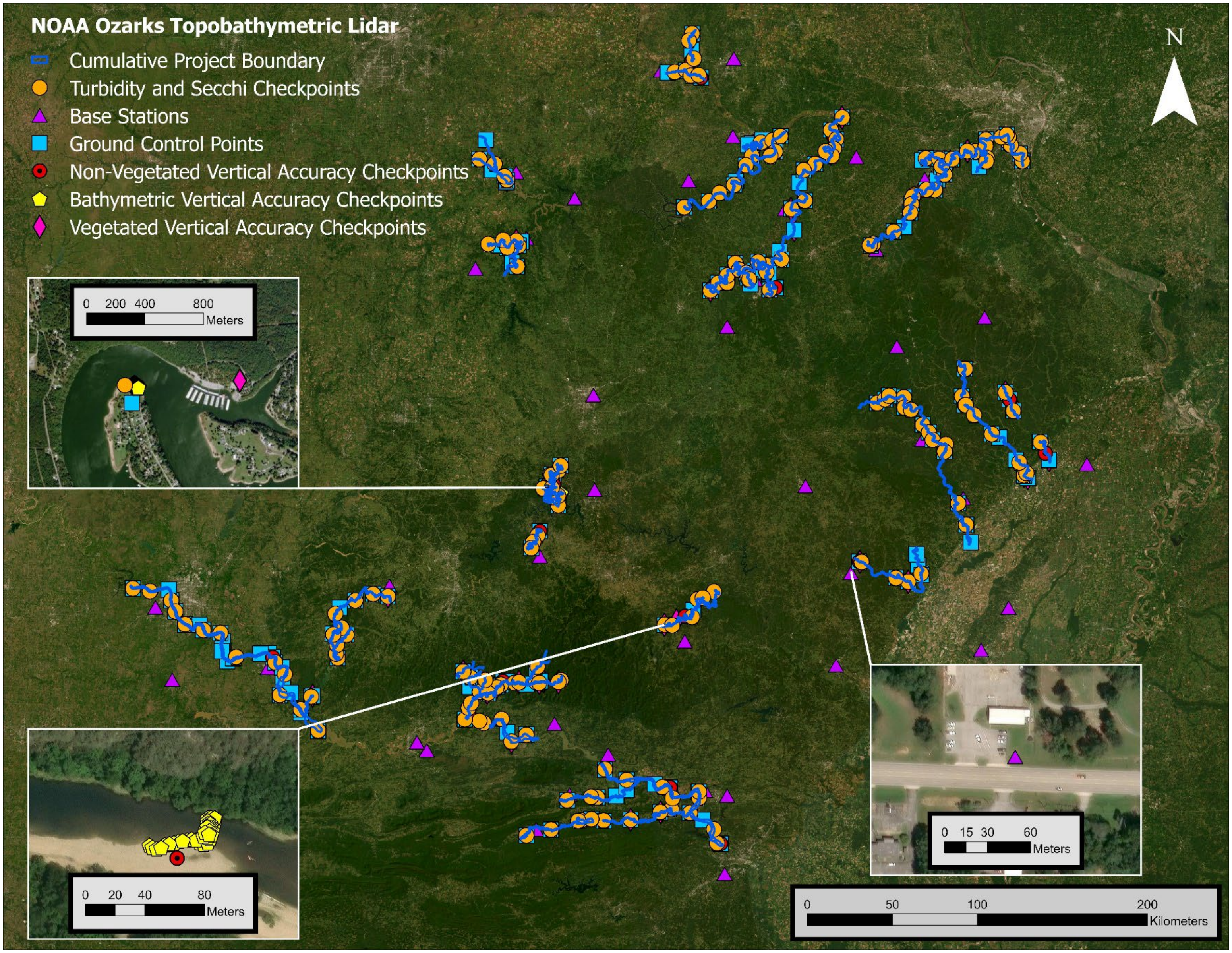
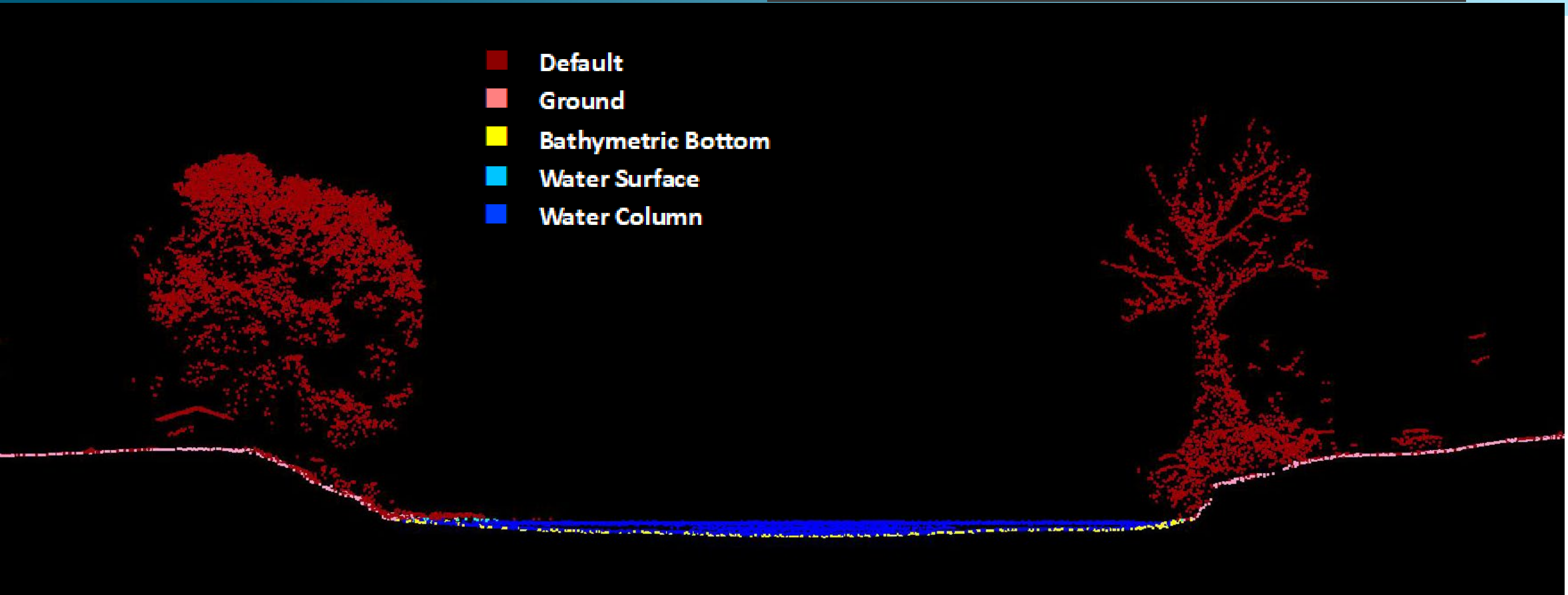


Figure 27: Ground survey location map



This 2-meter lidar cross section shows a view of the Spring River in northern Arkansas, in the NOAA Ozarks project area, symbolized by point classification.

Topobathymetric Lidar Data

Sensor calibration was performed for each system installation to minimize systematic errors. Upon lidar data acquisition, NV5 processing staff initiated a suite of automated and manual techniques to validate the data and create the contracted project deliverables. Processing tasks included GPS control computations, kinematic corrections, smoothed best estimate trajectory (SBET) calculations, laser point positioning, data calibration and adjustment for optimal relative and absolute accuracy, and lidar point classification, as shown in Table 10.

Bathymetric Lidar Data

Lidar Survey Studio (LSS) was used to perform bathymetric return processing. Synthetic water surface points were derived automatically by LSS based topographic channel information. Bathymetric returns were differentiated based on their location relative to the water surface model, then were spatially corrected for refraction through the water column based on the angle of incidence of the laser and the refractive index of the water. Additionally, a water scatter compensation factor was applied as described in the Lidar Boresight and Calibration reports.

The refracted returns were reviewed for errors, and the resulting point cloud was classified using both manual and automated techniques. Processing methodologies were tailored to the Ozarks landscape. Brief descriptions of these tasks are shown in Table 11, and example raster layers for processing and review can be visualized in Figure 28.

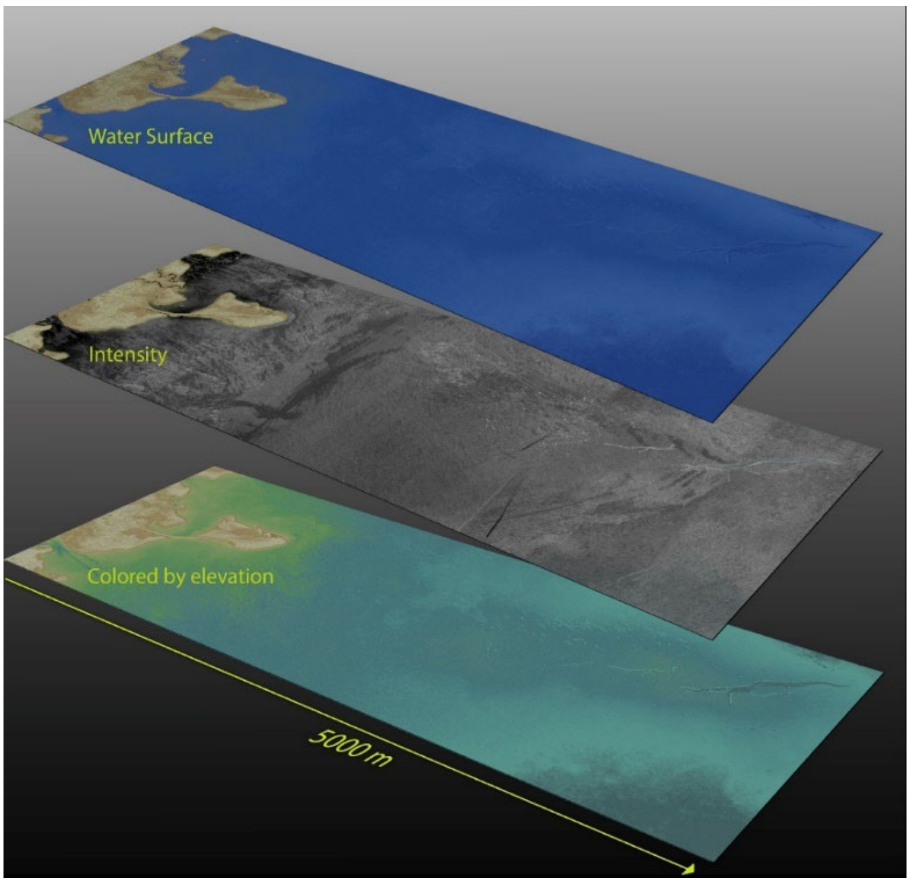


Figure 28: Example processing data layers

Table 10: ASPRS LAS classification standards applied to the NOAA Ozarks dataset

Classification Number	Classification Name	Classification Description
1	Unclassified	Processed, but unclassified
2	Ground	Bare-earth ground
7 Withheld	Low Noise	Noise (low manually identified)
18 Withheld	High Noise	Noise (high manually identified)
22	Temporal Exclusion	Consolidated adjacent lift unclassified and ground associated with areas where temporal differences are present
40	Bathymetric Bottom	Bathymetric point (e.g., seafloor or riverbed; also known as submerged topography)
41	Water Surface	Water's surface (sea/river/lake surface from topographic-bathymetric lidar.
42- Synthetic	Derived Water Surface	Synthetic water surface location used in computing refraction at water surface
43	Submerged Feature	Submerged object, not otherwise specified (e.g., wreck, rock, submerged piling)
44	S-57 Object	International Hydrographic Organization (IHO) S-57 object, not otherwise specified
45	Water Column	Refracted returns not determined to be water surface or bathymetric bottom
48	Overlap Water Surface and Water Column	Consolidated adjacent lift water surface and water column associated with areas where temporal differences are present
64	Submerged Aquatic Vegetation	Benthic vegetation in submerged, refracted areas
65	Overlap Bathymetric Bottom	Denotes bathymetric bottom temporal changes from varying lifts, not utilized in the bathymetric point class
1-Withheld	Edge Clip	Noise (low manually identified)

Classification Number	Classification Name	Classification Description
1-Overlap Withheld	Unrefracted Green Chiroptera	Noise (high manually identified)

Original SOW classification scheme	Delivered in LAS files
Additional classification codes	Delivered in LAS files
Original SOW classification code not used	Not delivered in LAS files
Deleted points	Not delivered in LAS files

Table 11: Lidar processing workflow

Lidar Processing Step	Software Used
Resolve kinematic corrections for aircraft position data using kinematic aircraft GPS and static ground GPS data. Develop a smoothed best estimate of trajectory (SBET) file that blends post-processed aircraft position with sensor head position and attitude recorded throughout the survey.	Inertial Explorer v.8.9
Calculate laser point position by associating SBET position to each laser point return time, scan angle, intensity, etc. Create raw laser point cloud data for the entire survey in *.las (ASPRS v. 1.4) format. Convert data to orthometric elevations by applying a geoid correction.	Lidar Survey Studio v.3.4.0 Las Projector 1.3 (NV5 proprietary software)
Import raw laser points into manageable blocks to perform manual relative accuracy calibration and filter erroneous points. Classify ground points for individual flightlines.	TerraScan v.19.005
Using ground classified points per each flightline, test the relative accuracy. Perform automated line-to-line calibrations for system attitude parameters (pitch, roll, heading), mirror flex (scale), and GPS/IMU drift. Calculate calibrations on ground classified points from paired flightlines and apply results to all points in a flightline. Use every flightline for relative accuracy calibration.	Lidar Survey Studio v.3.4.0
Apply refraction correction to all subsurface returns.	Lidar Survey Studio v.3.4.0
Classify resulting data to ground and other client designated ASPRS classifications (Table 10). Assess statistical absolute accuracy via direct comparisons of ground classified points to ground control survey data.	TerraScan v.19.005 TerraModeler v.19.003
Generate bare earth models as triangulated surfaces. Export all surface models as Cloud-Optimized GeoTIFFs 1-meter pixel resolution.	LasTools Software Suite Las Product Creator 4.0 (NV5 proprietary software) ArcMap v. 10.8
Normalize seabed intensity values for angle of incidence and depth and export intensity images as cloud optimized GeoTIFFs at a 1-meter pixel resolution.	Las Monkey v.2.6.8 (NV5 proprietary) Inpho OrthoVista v.14.0.3 Las Product Creator 4.0 (NV5 proprietary software)
Output standard deviation raster mosaics of ground, bathymetric bottom, and submerged objects as cloud optimized GeoTIFF format at a 1-meter pixel resolution.	LasTools Software Suite

Lidar-Derived Products

Because hydrographic laser scanners penetrate the water surface to map submerged topography, this affects how the data should be processed and presented in derived products from the lidar point cloud. The following section discusses certain derived products that vary from the traditional (NIR) specification and delivery format.

Topobathymetric DEMs

Bathymetric bottom returns can be limited by depth, water clarity, and bottom surface reflectivity. Water clarity and turbidity affect the depth penetration capability of the green wavelength laser by returning laser energy diminishing by scattering throughout the water column. Additionally, the bottom surface must be reflective enough to return the remaining laser energy back to the sensor at a detectable level. The predicted depth penetration range of the CH4X and CH5 sensors are 1.5- and 1.8-times the recorded Secchi depth, respectively. Therefore, it is not unexpected to have no bathymetric bottom returns in turbid or non-reflective areas.

As a result, creating digital elevation models (DEMs) presents a challenge with respect to interpolation of bathymetric areas without returns. Traditional DEMs are “unclipped,” meaning areas lacking ground returns are interpolated from neighboring ground or bathymetric bottom returns, with the assumption that the interpolation is close to reality. In bathymetric modeling, these assumptions are prone to error because a lack of bathymetric returns can indicate an increase in depth that the sensor cannot detect. The resulting bathymetric void areas may suggest greater depths, rather than similar elevations from neighboring bathymetric bottom returns. Therefore, a shapefile delineating bathymetric voids was created to control the extent of the delivered bare earth topobathymetric model to avoid false triangulation (interpolation from TIN’ing) across areas without mapped bathymetry.

Normalized Bathymetric Bottom Intensity

A lidar echo return signal has a recorded amplitude associated for each point and is logged in LAS files as an Intensity record. Laser return intensity is generally a unitless measure of discrete return signal strength, stored as a 16-bit integer value (0 to 65,535). Intensity values roughly correspond to the reflectivity of the surface, which is a function of surface material composition. The magnitude of intensity values can vary across similar surfaces due to variability in atmospherics, water clarity, range, submerged depth, and the angle of incidence on the object. The result is inconsistencies within the images that can reduce the utility of these data for analytics.

When a laser pulse enters the water column, the return signal fades exponentially with depth (Figure 29, Figure 30); the diminishing rate depends on water properties such as turbidity and composition. This exponential decay can be corrected after determining the rate of decline by comparing similar substrates across multiple flightlines and varying depths. The bathymetric intensity values for this dataset have been normalized for depth, angle of incidence, and absolute flying altitude (Figure 31). Please note that intensity values are still subject to localized changes of water properties within the water column across a water body.

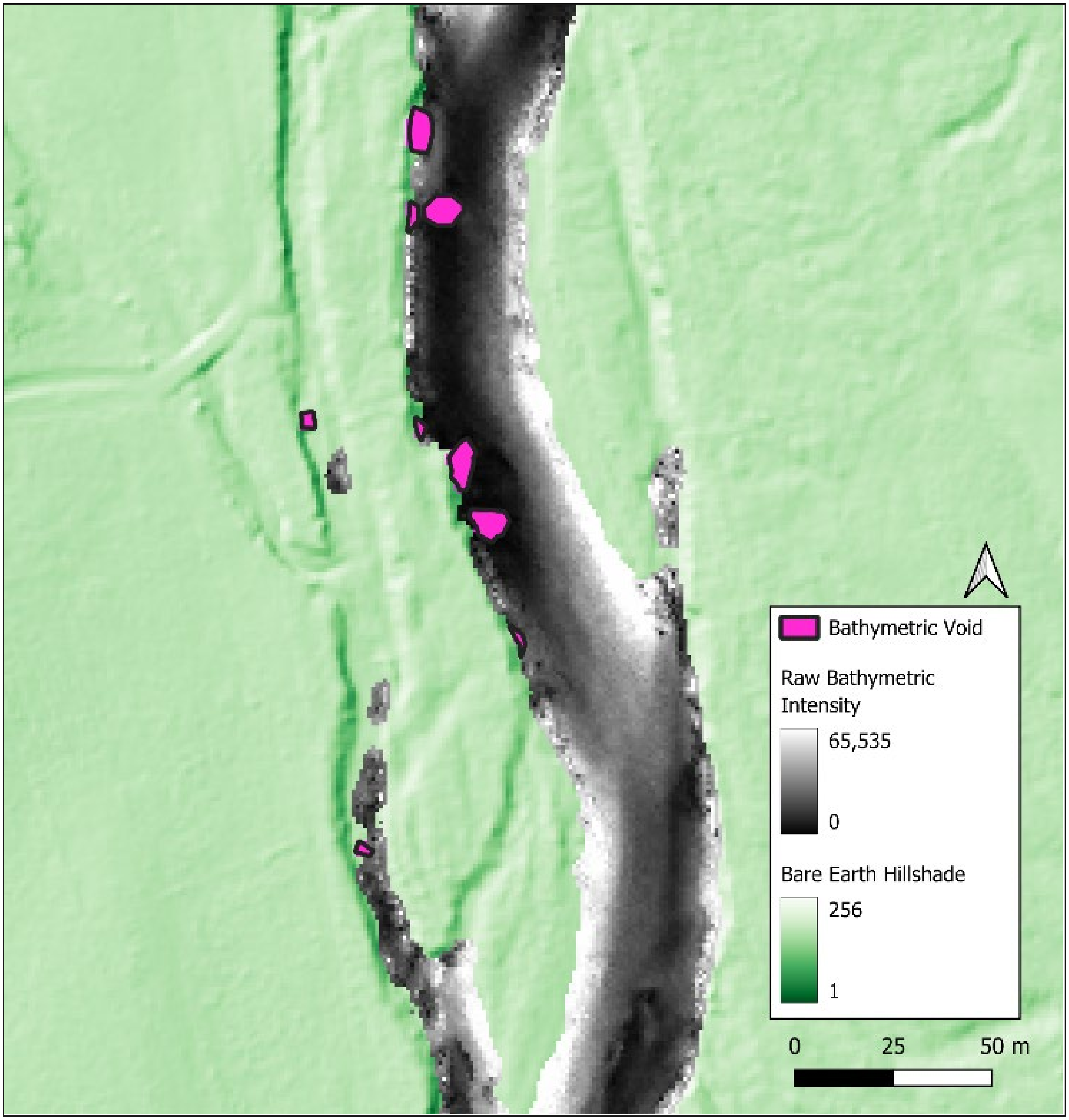


Figure 29: An example of Raw Bathymetric Bottom Intensity values

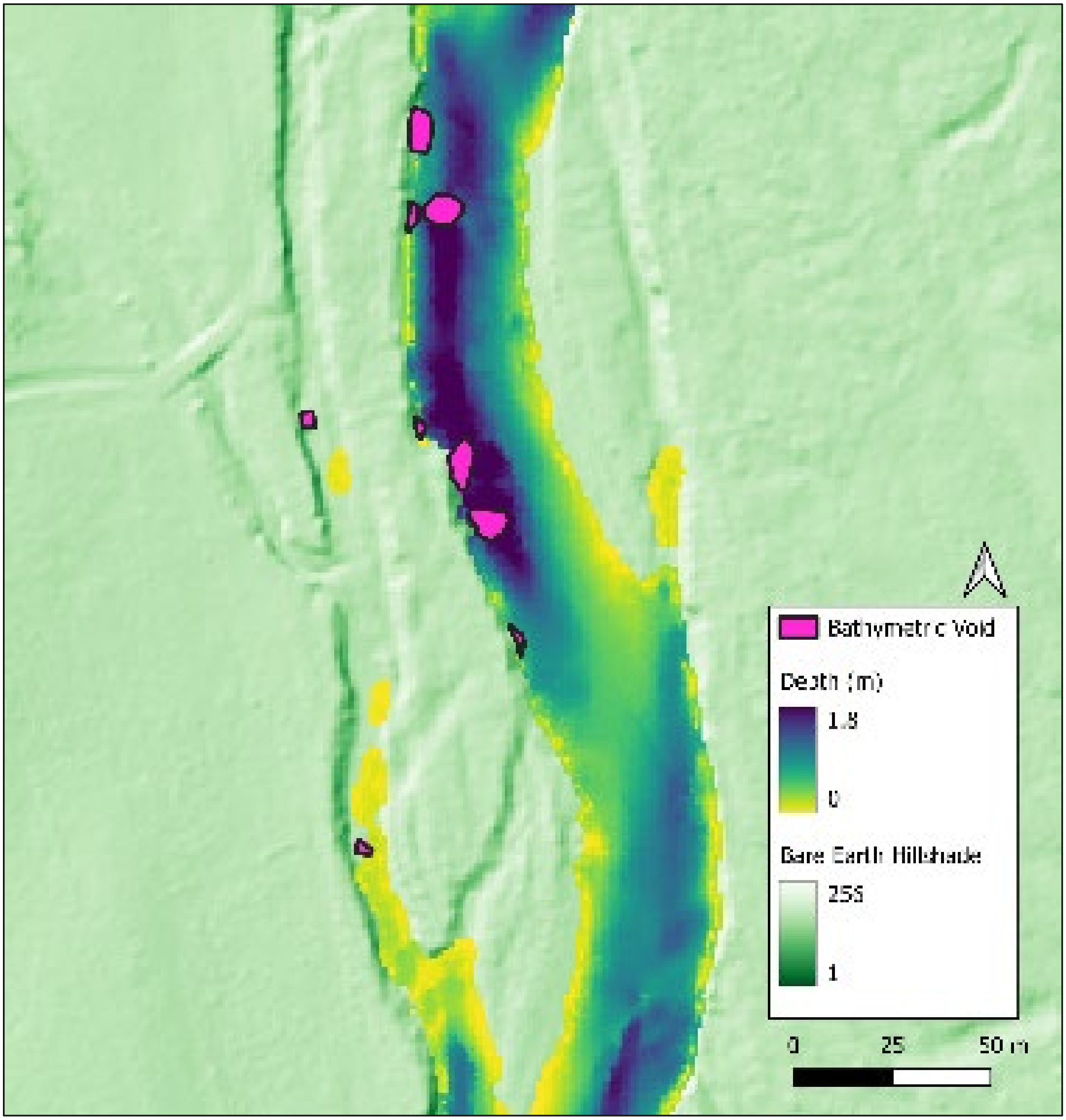


Figure 30: Depth raster shows an example of areas of deeper bathymetry which correlated to diminished bathymetric bottom intensity values.

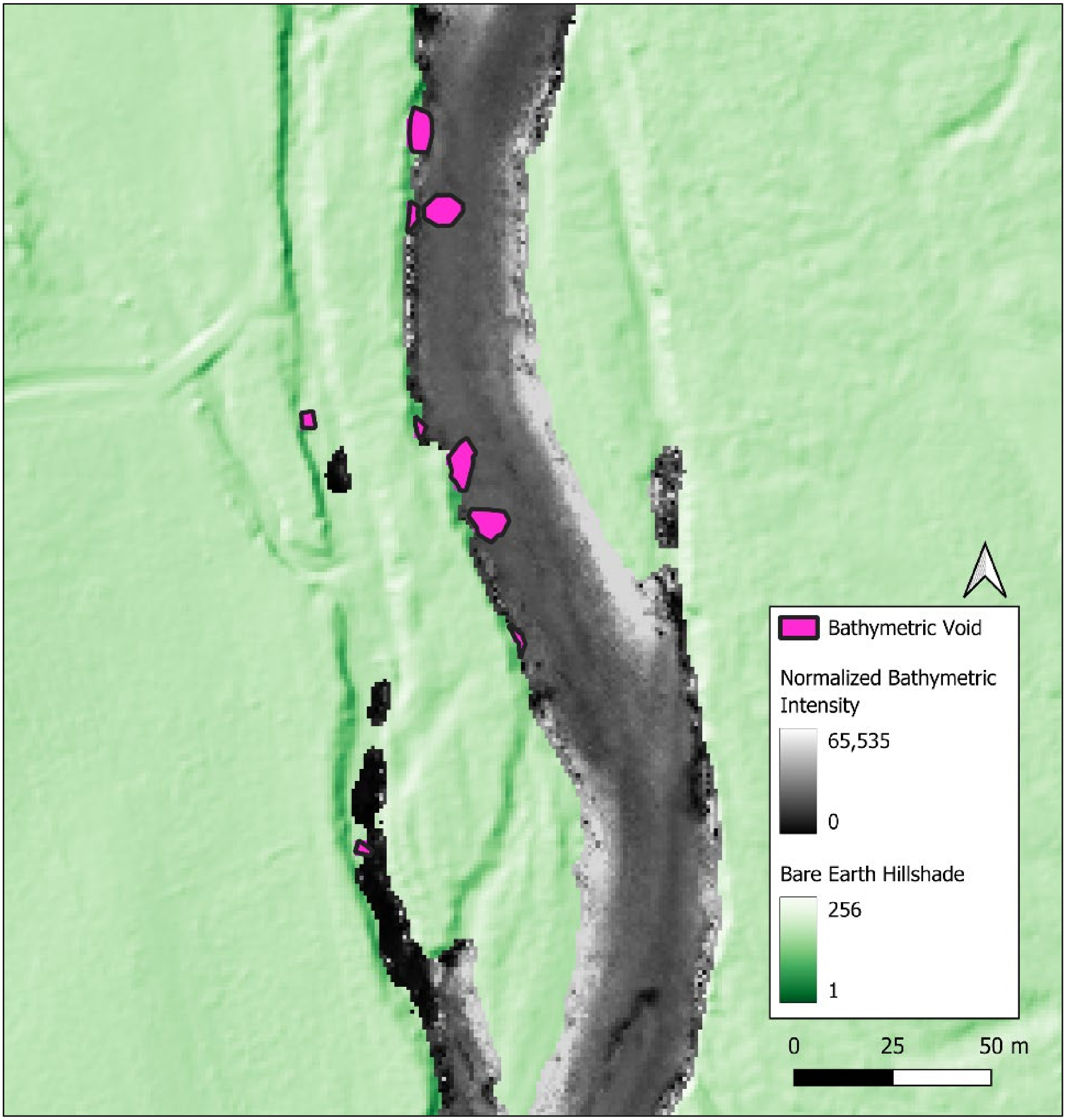
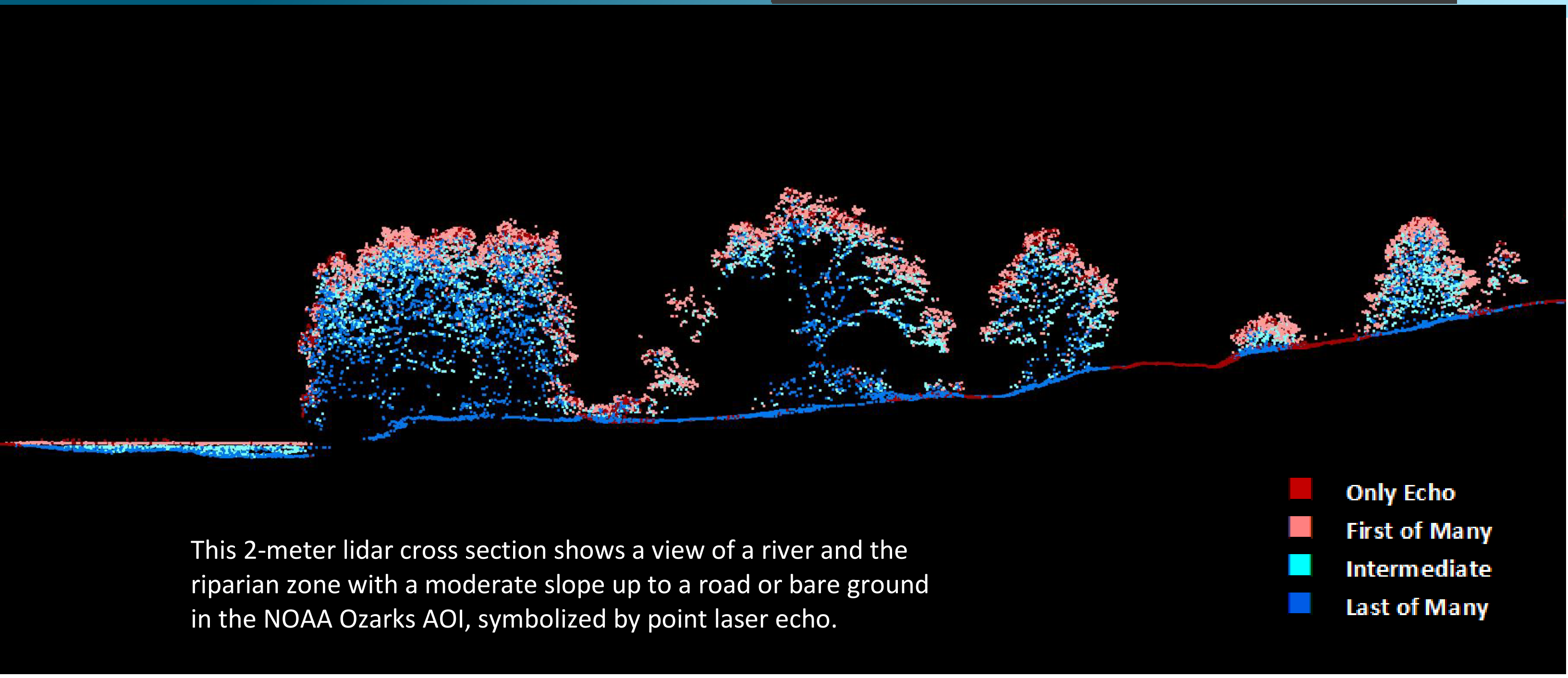


Figure 31: An example of bathymetric bottom Intensity values, which were normalized for depth, angle of incidence, and absolute flying altitude.



This 2-meter lidar cross section shows a view of a river and the riparian zone with a moderate slope up to a road or bare ground in the NOAA Ozarks AOI, symbolized by point laser echo.

Bathymetric Lidar

An underlying principle for collecting hydrographic lidar data is to survey near-shore areas that can be difficult to collect with other methods, such as multi-beam sonar, particularly over large areas. The capability and effectiveness of the bathymetric lidar is impacted by several parameters including depth penetration below the water surface, bathymetric return density, and spatial accuracy.

Mapped Bathymetry

Under optimal conditions, the specified depth penetration range of the CH4X and CH5 sensors are about 1.5 and 1.8 Secchi depths, respectively; therefore, bathymetry data below these depths at the time of acquisition are not to be expected. To assist in evaluating performance results of the sensor, a polygon layer was created to delineate areas where bathymetry was successfully mapped.

This shapefile was used to control the extent of the delivered clipped topobathymetric model and to avoid false triangulation across areas in the water with no returns. Insufficiently mapped areas were identified by triangulating bathymetric bottom points with an edge length maximum of 4.56 meters. This ensured all areas of no returns (> 9 m^2), were identified as data voids. Overall, NV5 mapped 38.06% of the entire NOAA Ozarks project, 96.67% of D1A, 98.59% of D1B, 85.88% of D1C, 31.34% of D1D, 12.92% of D1E, 97.14% of D2F, 84.70% of D2G, 59.87% of D2H, 61.66% of D2I, 63.20% of D3L, 91.91% of D4J, 64.31% of D4K, 32.96% of D4M, 7.64% of D4N, 6.54% of D4O, 53.73% of D4P, 31.90% of D4Q, 89.01% of D4R, and 12.69% of D4S.

Lidar Point Density

First Return Point Density

The acquisition parameters were designed to acquire an average first-return density of 8 points/m^2 in terrestrial areas and 3 points/m^2 for bathymetric areas. First return density describes the density of pulses emitted from the laser that return at least one echo to the system. Multiple returns from a single pulse were not considered in the first return density analysis. Some types of surfaces (e.g., breaks in terrain, water, and steep slopes) may have returned fewer pulses than originally emitted by the laser.

First returns typically reflect off the highest feature on the landscape within the footprint of the pulse. In forested or urban areas, the highest feature could be a tree, building, or power line, while in areas of unobstructed ground, the first return will be the only echo and represents the bare earth surface.

The average first-return density for the NOAA Ozarks Lidar project was 25.97 points/m^2 for the NIR sensor and 3.61 points/m^2 for the green sensors (Table 12). The statistical distributions of all first return densities per 100 m x 100 m cell are portrayed in Figure 32 through Figure 34.

Bathymetric and Ground Classified Point Densities

The density of ground classified lidar returns and bathymetric bottom returns were also analyzed for this project. Terrain character, land cover, and ground surface reflectivity all influenced the density of ground surface returns. In vegetated areas, fewer pulses may have penetrated the tree canopy, resulting in lower ground density. Similarly, the density of bathymetric bottom returns was influenced by turbidity, depth, and bottom surface reflectivity. In turbid areas, fewer pulses may have penetrated the water surface, resulting in lower bathymetric density.

The ground and bathymetric bottom classified density of lidar data for the NOAA Ozarks project was 8.46 points/m^2. The return density for each delivery is shown in Table 12. The statistical distributions per 100 m x 100 m cell of the ground and bathymetric bottom classified return densities are portrayed in Figure 35.

Additionally, for the NOAA Ozarks project, density values of only bathymetric bottom returns were calculated for areas containing at least one bathymetric bottom return. Areas lacking bathymetric returns (voids) were not considered in calculating an average density value. Within the successfully mapped area, a bathymetric bottom return density of 5.16 points/m^2 was achieved.

Table 12: Average lidar point densities

Delivery	Block	NIR First Returns	Green First Returns	Combined First Returns	Ground and Bathymetric Bottom Classified Returns	Bathymetric Bottom Classified Returns
D1	A	27.99 points/m^2	1.04 points/m^2	29.03 points/m^2	9.69 points/m^2	8.05 points/m^2
D1	B	28.83 points/m^2	1.30 points/m^2	30.14 points/m^2	6.99 points/m^2	8.17 points/m^2
D1	C	27.68 points/m^2	1.53 points/m^2	29.21 points/m^2	11.68 points/m^2	5.08 points/m^2
D1	D	27.73 points/m^2	2.01 points/m^2	29.74 points/m^2	7.96points/m^2	5.63points/m^2
D2	E	27.40 points/m^2	0.47 points/m^2	27.88 points/m^2	5.86 points/m^2	1.10 points/m^2
D2	F	27.91 points/m^2	1.90 points/m^2	29.81 points/m^2	8.19 points/m^2	8.44 points/m^2
D2	G	27.70 points/m^2	1.23 points/m^2	28.93 points/m^2	10.14 points/m^2	6.20 points/m^2
D2	H	23.96 points/m^2	1.48 points/m^2	25.44 points/m^2	8.47 points/m^2	4.82 points/m^2
D3	I	27.71 points/m^2	2.22 points/m^2	29.93 points/m^2	9.38 points/m^2	5.95 points/m^2
D3	L	48.72 points/m^2	0.22 points/m^2	48.95 points/m^2	9.83 points/m^2	2.60 points/m^2
D4	J	29.72 points/m^2	2.33 points/m^2	32.05 points/m^2	10.86 points/m^2	8.29 points/m^2
D4	K	28.07 points/m^2	1.89 points/m^2	29.96 points/m^2	9.47 points/m^2	7.07 points/m^2
D4	M	24.95 points/m^2	2.08 points/m^2	27.03 points/m^2	10.34 points/m^2	7.11 points/m^2
D4	N	19.45 points/m^2	6.64 points/m^2	26.09 points/m^2	10.64 points/m^2	6.10 points/m^2
D4	O	19.84 points/m^2	6.80 points/m^2	26.64 points/m^2	6.70 points/m^2	5.67 points/m^2
D4	P	28.63 points/m^2	2.49 points/m^2	31.12 points/m^2	7.64 points/m^2	6.60 points/m^2
D4	Q	18.78 points/m^2	7.22 points/m^2	26.01 points/m^2	8.35 points/m^2	5.80 points/m^2
D4	R	40.22 points/m^2	0.51 points/m^2	40.73 points/m^2	5.89 points/m^2	4.54 points/m^2
D4	S	19.73 points/m^2	6.79 points/m^2	26.52 points/m^2	5.73 points/m^2	6.91 points/m^2
Cumulative	A-S	25.96 points/m^2	3.62 points/m^2	29.58 points/m^2	8.45 points/m^2	5.16 points/m^2

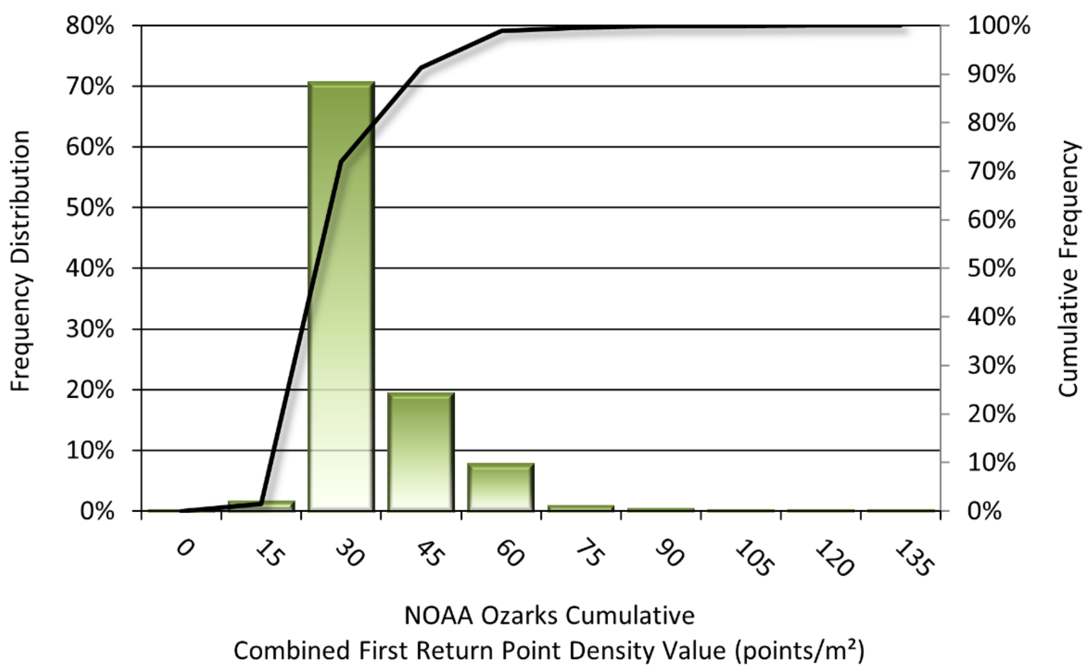


Figure 32: Frequency distribution of first return densities per 100 x 100 m cell for all the sensors

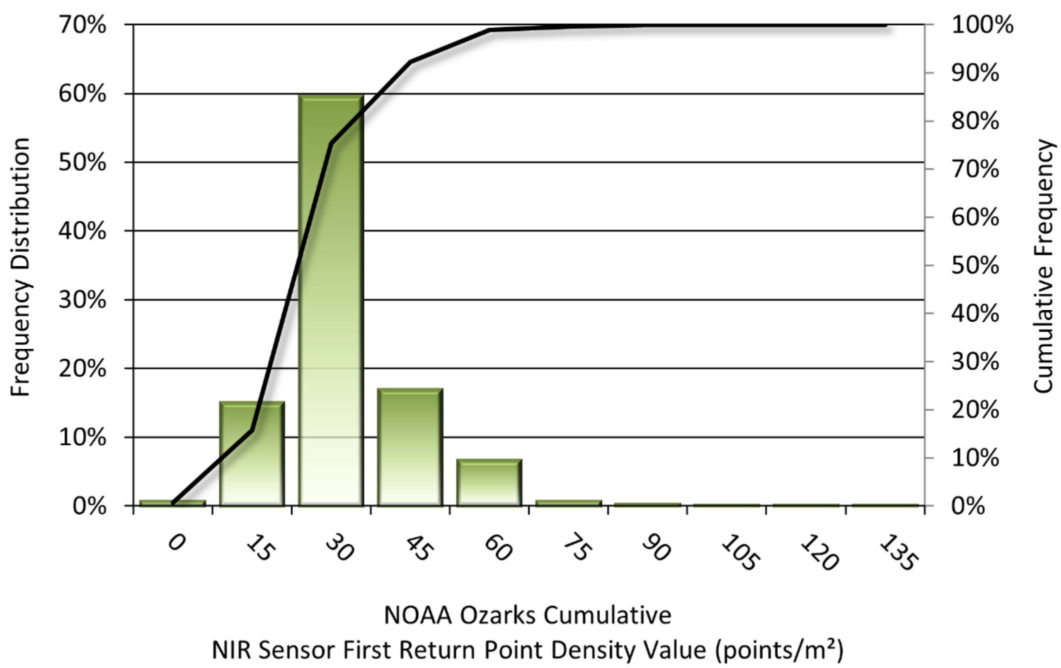


Figure 33: Frequency distribution of NIR sensor first return densities per 100 x 100 m cell for the NIR sensor

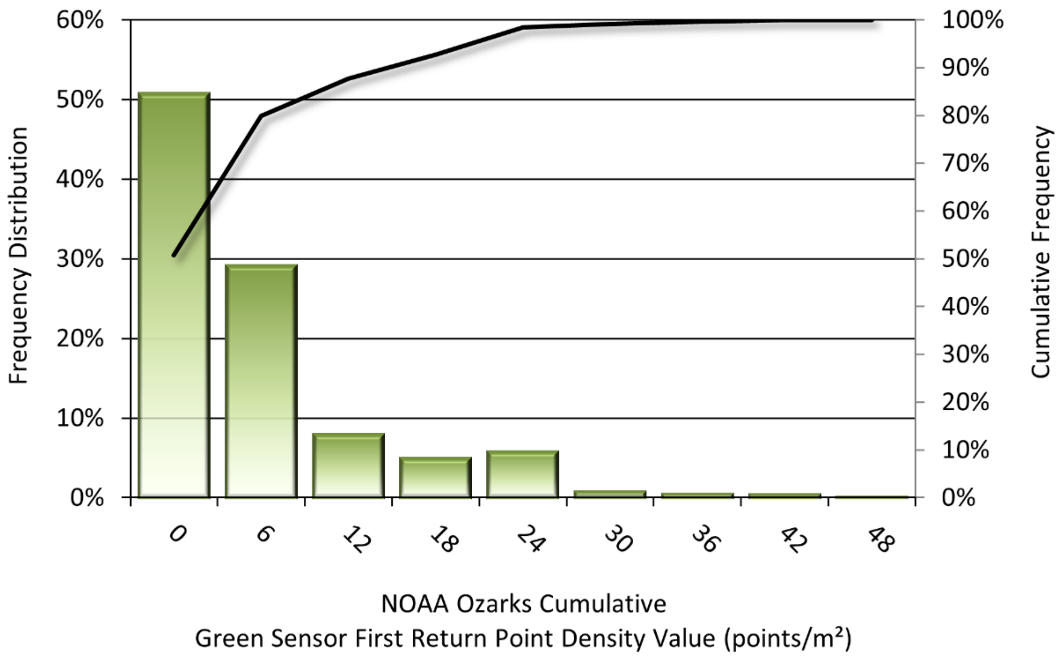


Figure 34: Frequency distribution of Green sensor first return densities per 100 x 100 m cell for the green sensor

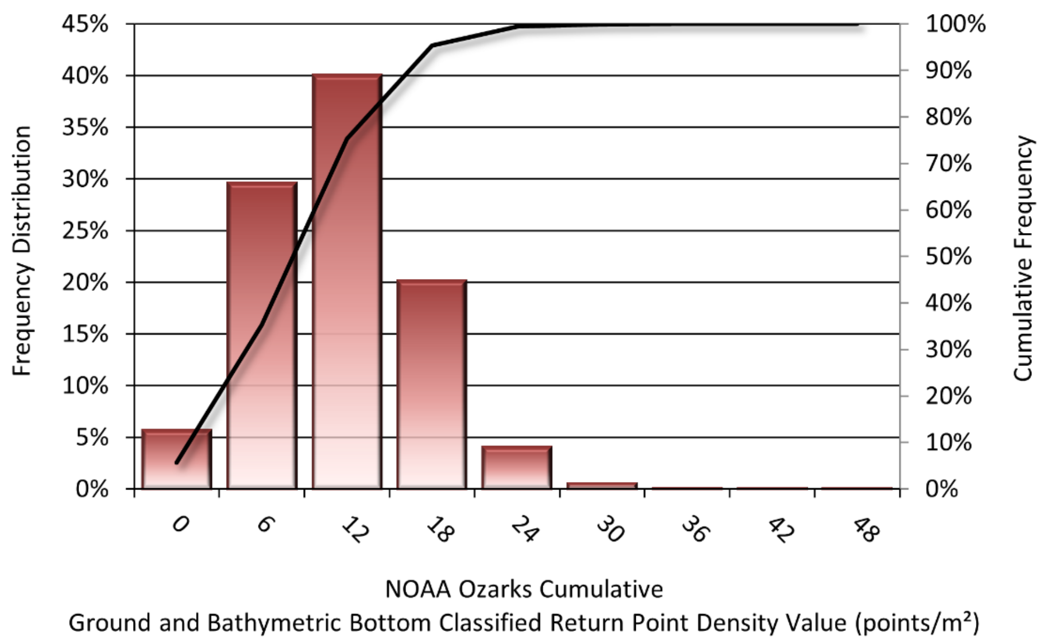


Figure 35: Frequency distribution of ground and bathymetric bottom classified return densities per 100 x 100 m cell for all the sensors

Lidar Accuracy Assessments

The accuracy of the lidar data collection can be described in terms of absolute accuracy (the consistency of the data with external data sources) and relative accuracy (the consistency of the dataset with itself). See Appendix A for further information on sources of error and operational measures used to improve relative accuracy.

Lidar Non-Vegetated Vertical Accuracy

Absolute accuracy was assessed using Non-vegetated Vertical Accuracy (NVA) reporting designed to meet guidelines presented in the FGDC National Standard for Spatial Data Accuracy.[4] NVA compares known ground checkpoint data that were withheld from the calibration and post-processing of the lidar point cloud to the triangulated surface generated by the classified lidar point cloud as well as the derived gridded bare earth DEM. NVA is a measure of the accuracy of lidar point data in open areas where the lidar system has a high probability of measuring the ground surface. This dataset was tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data, Edition 2, Version 2 (2024) for a 10.0 cm $RMSE_V$ Vertical Accuracy Class (Table 13 and Table 14).

The mean and standard deviation (sigma σ) of divergence of the ground surface model from ground checkpoint coordinates are also considered during accuracy assessment. These statistics assume the error for x, y, and z is normally distributed, and therefore the skew and kurtosis of distributions are also considered when evaluating error statistics. For the NOAA Ozarks survey, 56 ground checkpoints were withheld from the calibration and post-processing of the lidar point cloud. The Non-Vegetated Vertical Accuracy (NVA) was found to be RMSE = 0.031 meters as compared to classified LAS, and RMSE = 0.034 meters as compared to the bare earth DEM (Figure 36 and Figure 37).

NV5 also assessed absolute accuracy using a total of 189 ground control points. Although these points were used in the calibration and post-processing of the lidar point cloud, they still provide a good indication of the overall accuracy of the lidar dataset and have therefore been provided in Table 15 and Figure 38.

[4] Federal Geographic Data Committee, ASPRS POSITIONAL ACCURACY STANDARDS FOR DIGITAL GEOSPATIAL DATA Edition 2, Version 2, 2024. https://asprsorg.sharepoint.com/sites/PublicAccess/Shared%20Documents/Forms/AllItems.aspx?id=%2Fsites%2FPublicAccess%2FShared%20Documents%2FPublic%5FDocuments%2FStandards%2F2024%5FASPRS%5FPositional%5FAccuracy%5FStandards%5FEdition2%5FVersion2%2E0%2Epdf&parent=%2Fsites%2FPublicAccess%2FShared%20Documents%2FPublic%5FDocuments%2FStandards&p=true&ga=1

Table 13: NVA, as compared to Classified LAS

Delivery	Block	Sample	95% Confidence (1.96*RMSE)	Average	Median	RMSE	Standard Deviation (1σ)
D1	**A**	2	0.015 m	0.006 m	0.006 m	0.008 m	0.011 m
D1	**B**	3	0.035 m	-0.016 m	-0.018 m	0.018 m	0.009 m
D1	**C**	1	0.025 m	0.013 m	0.013 m	0.013 m	NA
D1	**D**	1	0.061 m	-0.031 m	-0.031 m	0.031 m	NA
D2	**E**	1	0.022 m	0.016 m	0.016 m	0.011 m	NA
D2	**F**	4	0.094 m	0.007 m	0.004 m	0.048 m	0.055 m
D2	**G**	3	0.031 m	-0.016 m	-0.016 m	0.016 m	0.001 m
D2	**H**	3	0.071 m	-0.021 m	-0.033 m	0.036 m	0.036 m
D3	**I**	1	0.027 m	-0.014 m	-0.014 m	0.014 m	NA
D3	**L**	2	0.032 m	0.011 m	0.011 m	0.016 m	0.017 m
D4	**J**	6	0.064 m	-0.017 m	-0.023 m	0.033 m	0.031 m
D4	**K**	8	0.068 m	0.001 m	0.000 m	0.035 m	0.037 m
D4	**M**	1	0.047 m	0.024 m	0.024 m	0.024 m	NA
D4	**N**	0	NA	NA	NA	NA	NA
D4	**O**	4	0.047 m	-0.003 m	-0.003 m	0.024 m	0.027 m
D4	**P**	1	0.120 m	-0.061 m	-0.061 m	0.061 m	NA
D4	**Q**	4	0.049 m	-0.016 m	-0.018 m	0.025 m	0.023 m
D4	**R**	9	0.068 m	-0.016 m	-0.009 m	0.034 m	0.032 m
D4	**S**	2	0.021 m	0.010 m	0.010 m	0.011 m	0.006 m
Cumulative	**A-S**	56	0.060 m	-0.008 m	-0.010 m	0.031 m	0.030 m

Table 14: NVA, as compared to Bare Earth DEM

Delivery	Block	Sample	95% Confidence (1.96*RMSE)	Average	Median	RMSE	Standard Deviation (1σ)
D1	**A**	2	0.025 m	0.000 m	0.000 m	0.013 m	0.018 m
D1	**B**	3	0.040 m	-0.013 m	-0.008 m	0.020 m	0.019 m
D1	**C**	1	0.006 m	0.003 m	0.003 m	0.003 m	NA
D1	**D**	1	0.041 m	-0.021 m	-0.021 m	0.021 m	NA
D2	**E**	1	0.036 m	0.026 m	0.026 m	0.018 m	NA
D2	**F**	4	0.127 m	-0.008 m	-0.024 m	0.065 m	0.074 m
D2	**G**	3	0.036 m	-0.016 m	-0.017 m	0.018 m	0.011 m
D2	**H**	3	0.078 m	-0.025 m	-0.043 m	0.040 m	0.038 m
D3	**I**	1	0.047 m	-0.024 m	-0.024 m	0.024 m	NA
D3	L	2	0.060 m	0.021 m	0.021 m	0.030 m	0.031 m
D4	**J**	6	0.079 m	-0.022 m	-0.032 m	0.041 m	0.037 m
D4	**K**	8	0.060 m	0.003 m	-0.002 m	0.030 m	0.032 m
D4	**M**	1	0.047 m	0.024 m	0.024 m	0.024 m	NA
D4	**N**	0	NA	NA	NA	NA	NA
D4	**O**	4	0.054 m	-0.007 m	-0.008 m	0.027 m	0.030 m
D4	**P**	1	0.129 m	-0.066 m	-0.066 m	0.066 m	NA
D4	**Q**	4	0.058 m	-0.019 m	-0.018 m	0.030 m	0.027 m
D4	**R**	9	0.070 m	-0.020 m	-0.016 m	0.036 m	0.031 m
D4	**S**	2	0.019 m	0.007 m	0.007 m	0.010 m	0.010 m
Cumulative	**A-S**	56	0.068 m	-0.010 m	-0.011 m	0.034 m	0.034 m

Table 15: Ground Control Points

Delivery	Block	Sample	95% Confidence (1.96*RMSE)	Average	Median	RMSE	Standard Deviation (1σ)
D1	A	2	0.003 m	0.001 m	0.001 m	0.001 m	0.002 m
D1	B	2	0.010 m	0.000 m	0.000 m	0.005 m	0.007 m
D1	C	7	0.066 m	-0.001 m	0.007 m	0.034 m	0.036 m
D1	D	6	0.048 m	0.003 m	0.006 m	0.024 m	0.026 m
D2	E	6	0.040 m	0.003 m	0.011 m	0.021 m	0.024 m
D2	F	12	0.083 m	0.001 m	-0.015 m	0.042 m	0.044 m
D2	G	9	0.044 m	-0.002 m	-0.015 m	0.023 m	0.024 m
D2	H	5	0.072 m	-0.005 m	0.007 m	0.037 m	0.040 m
D3	I	13	0.045 m	-0.004 m	0.006 m	0.023 m	0.024 m
D3	L	6	0.046 m	0.003 m	0.009 m	0.023 m	0.025 m
D4	J	24	0.095 m	0.000 m	0.001 m	0.049 m	0.050 m
D4	K	23	0.049 m	-0.002 m	0.001 m	0.025 m	0.025 m
D4	M	3	0.047 m	-0.006 m	-0.008 m	0.024 m	0.029 m
D4	N	2	0.063 m	0.011 m	0.011 m	0.032 m	0.043 m
D4	O	15	0.060 m	-0.001 m	-0.003 m	0.030 m	0.031 m
D4	P	7	0.054 m	0.000 m	0.002 m	0.027 m	0.030 m
D4	Q	26	0.070 m	-0.001 m	0.002 m	0.036 m	0.036 m
D4	R	15	0.063 m	-0.005 m	0.002 m	0.032 m	0.033 m
D4	S	6	0.053 m	0.003 m	-0.011 m	0.027 m	0.030 m
Cumulative	A-S	189	0.064 m	-0.001 m	0.002 m	0.033 m	0.033 m

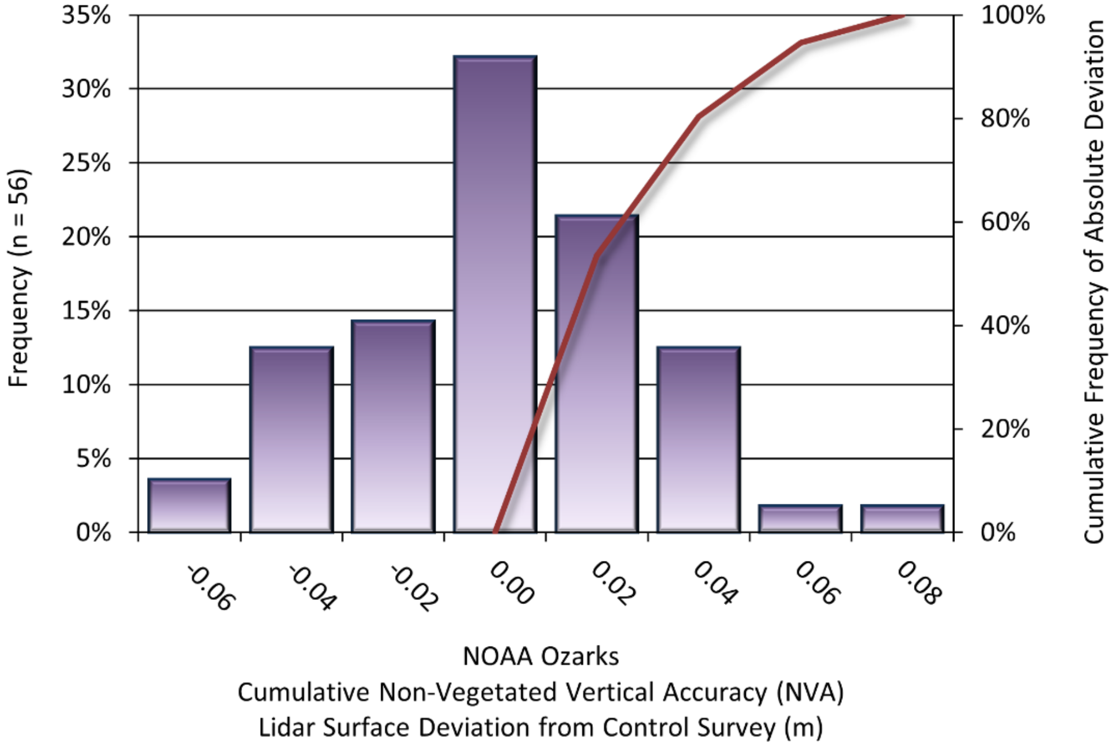


Figure 36: Frequency histogram for classified LAS deviation from ground checkpoint values

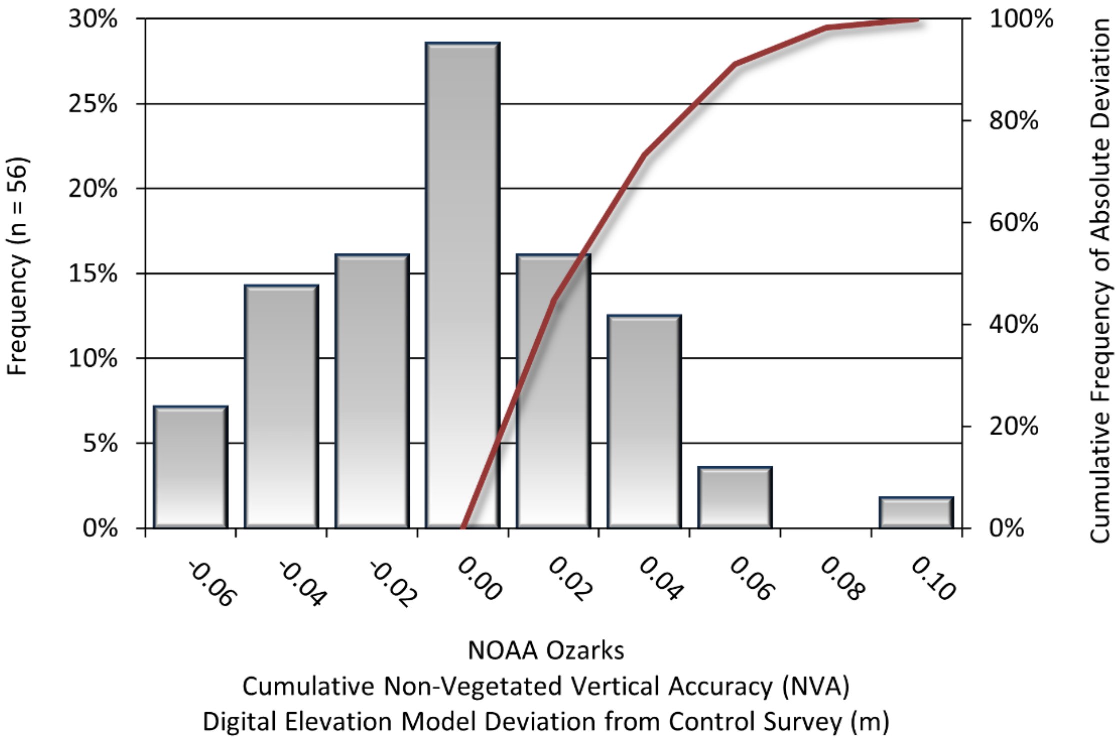


Figure 37: Frequency histogram for lidar bare earth DEM deviation from ground checkpoint values

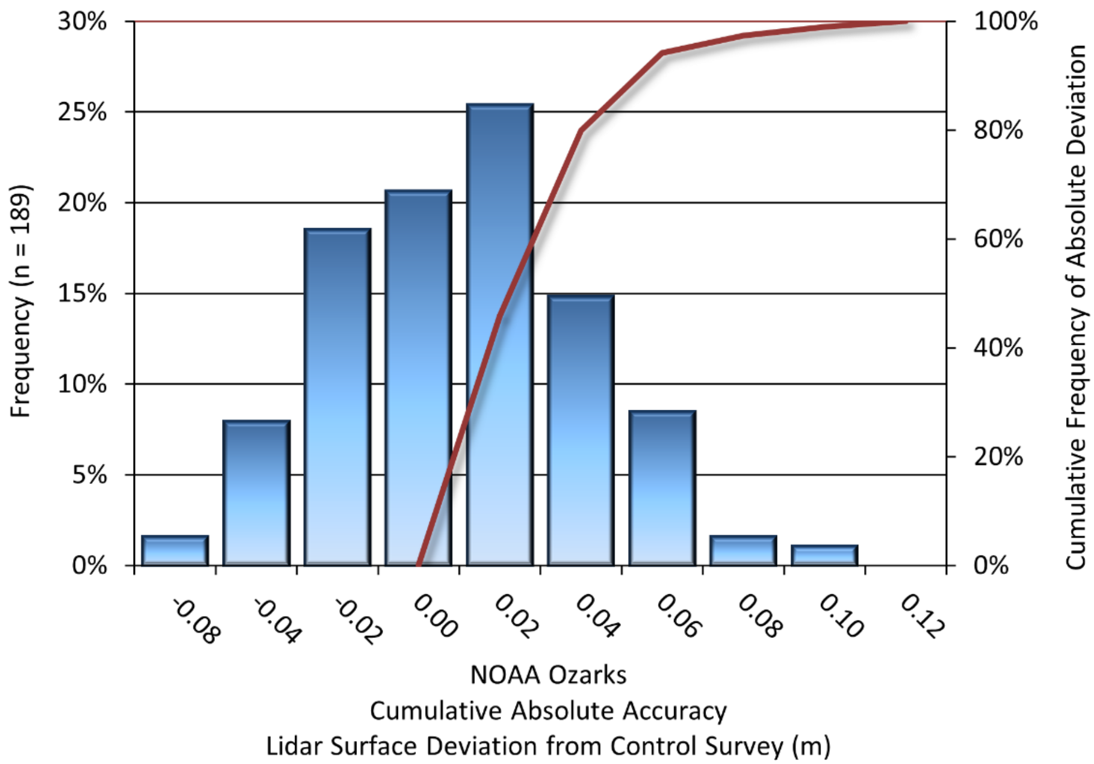


Figure 38: Frequency histogram for lidar surface deviation ground control point values

Lidar Vegetated Vertical Accuracies

NV5 also assessed vertical accuracy using Vegetated Vertical Accuracy (VVA) reporting. VVA compares known ground checkpoint data collected over vegetated surfaces using land class descriptions to the triangulated ground surface generated by the ground classified lidar points. Unlike in non-vegetated areas, the errors associated with data collected in vegetated areas cannot be assumed to approximate a normal distribution. This dataset was tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data, Edition 2, Version 2 (2024) for an 8 cm $RMSE_V$ Vertical Accuracy Class. The Vegetated Vertical Accuracy (VVA) was found to be RMSE = 0.116 meters as compared to the classified LAS, and RMSE = 0.116 meters as compared to the bare earth DEM (Table 16, Table 17, Figure 39, and Figure 40).

Table 16: VVA, as compared to Classified LAS

Delivery	Block	Sample	95th Percentile	Average	Median	RMSE	Standard Deviation (1σ)
D1	**A**	0	NA	NA	NA	NA	NA
D1	**B**	2	0.151 m	0.123 m	0.123 m	0.127 m	0.044 m
D1	**C**	2	0.177 m	0.116 m	0.116 m	0.134 m	0.096 m
D1	**D**	1	0.119 m	0.119 m	0.119 m	0.119 m	NA
D2	**E**	2	0.123 m	0.076 m	0.076 m	0.075 m	0.074 m
D2	**F**	1	0.043 m	-0.043 m	-0.043 m	0.043 m	NA
D2	**G**	2	0.187 m	0.078 m	0.078 m	0.141 m	0.166 m
D2	**H**	3	0.232 m	0.079 m	0.032 m	0.150 m	0.156 m
D3	**I**	1	0.058 m	0.058 m	0.058 m	0.058 m	NA
D3	**L**	1	0.239 m	0.239 m	0.239 m	0.239 m	NA
D4	**J**	6	0.178 m	0.069 m	0.042 m	0.105 m	0.087 m
D4	**K**	3	0.181 m	0.013 m	0.003 m	0.137 m	0.167 m
D4	**M**	0	NA	NA	NA	NA	NA
D4	**N**	1	0.019 m	-0.019 m	-0.019 m	0.019 m	NA
D4	**O**	2	0.055 m	0.052 m	0.052 m	0.052 m	0.004 m
D4	**P**	2	0.125 m	0.105 m	0.105 m	0.107 m	0.032 m
D4	**Q**	3	0.163 m	0.131 m	0.117 m	0.134 m	0.032 m
D4	**R**	9	0.172 m	0.083 m	0.091 m	0.107 m	0.072 m
D4	**S**	3	0.135 m	0.057 m	0.086 m	0.100 m	0.100 m
Cumulative	**A-S**	44	0.193 m	0.078 m	0.084 m	0.116 m	0.088 m

Table 17: VVA, as compared to Bare Earth DEM

Delivery	Block	Sample	95th Percentile	Average	Median	RMSE	Standard Deviation (1σ)
D1	**A**	0	NA	NA	NA	NA	NA
D1	**B**	2	0.160 m	0.128 m	0.128 m	0.133 m	0.051 m
D1	**C**	2	0.130 m	0.096 m	0.096 m	0.103 m	0.054 m
D1	**D**	1	0.169 m	0.169 m	0.169 m	0.169 m	NA
D2	**E**	2	0.123 m	0.075 m	0.075 m	0.075 m	0.074 m
D2	**F**	1	0.053 m	-0.053 m	-0.053 m	0.053 m	NA
D2	**G**	2	0.196 m	0.087 m	0.087 m	0.146 m	0.166 m
D2	**H**	3	0.243 m	0.093 m	0.062 m	0.158 m	0.157 m
D3	**I**	1	0.058 m	0.058 m	0.058 m	0.058 m	NA
D3	**L**	1	0.219 m	0.219 m	0.219 m	0.219 m	NA
D4	**J**	6	0.188 m	0.069 m	0.041 m	0.106 m	0.089 m
D4	**K**	3	0.172 m	0.010 m	0.003 m	0.132 m	0.162 m
D4	**M**	0	NA	NA	NA	NA	NA
D4	**N**	1	0.019 m	-0.019 m	-0.019 m	0.019 m	NA
D4	**O**	2	0.064 m	0.057 m	0.057 m	0.058 m	0.011 m
D4	**P**	2	0.127 m	0.107 m	0.107 m	0.109 m	0.031 m
D4	**Q**	3	0.157 m	0.128 m	0.147 m	0.133 m	0.043 m
D4	**R**	9	0.182 m	0.082 m	0.087 m	0.106 m	0.071 m
D4	**S**	3	0.136 m	0.027 m	-0.014 m	0.089 m	0.104 m
Cumulative	**A-S**	44	0.205 m	0.077 m	0.074 m	0.116 m	0.089 m

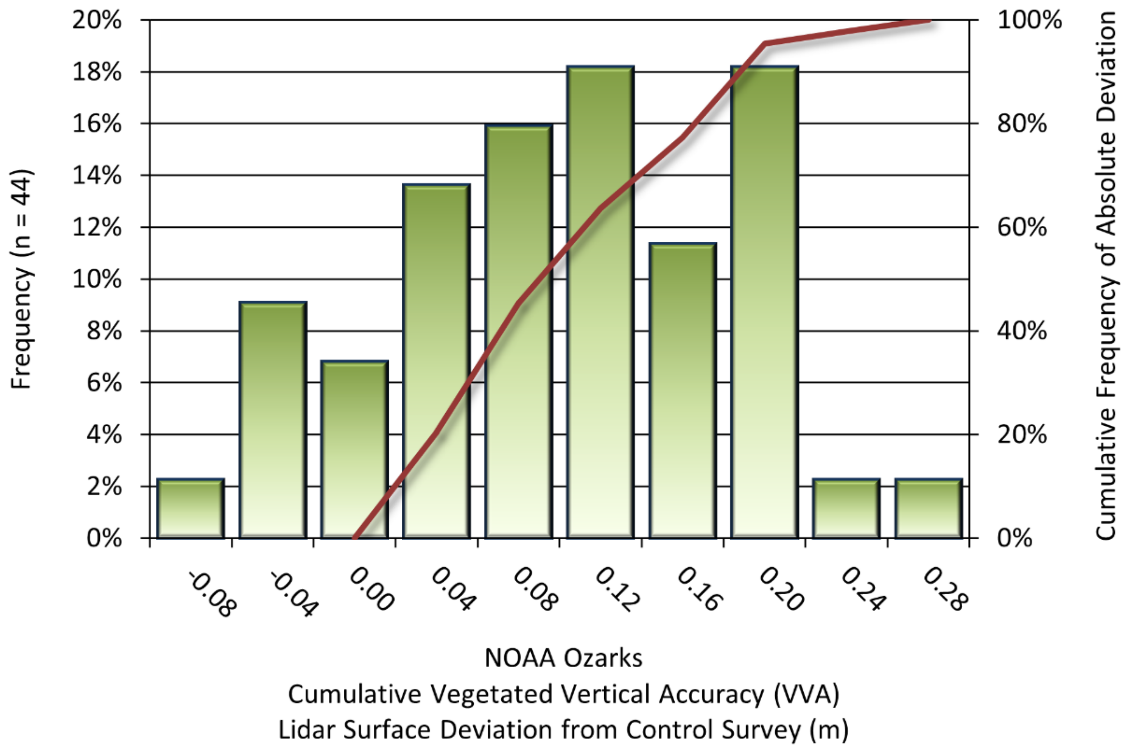


Figure 39: Frequency histogram for lidar surface deviation from all land cover class point values (VVA)

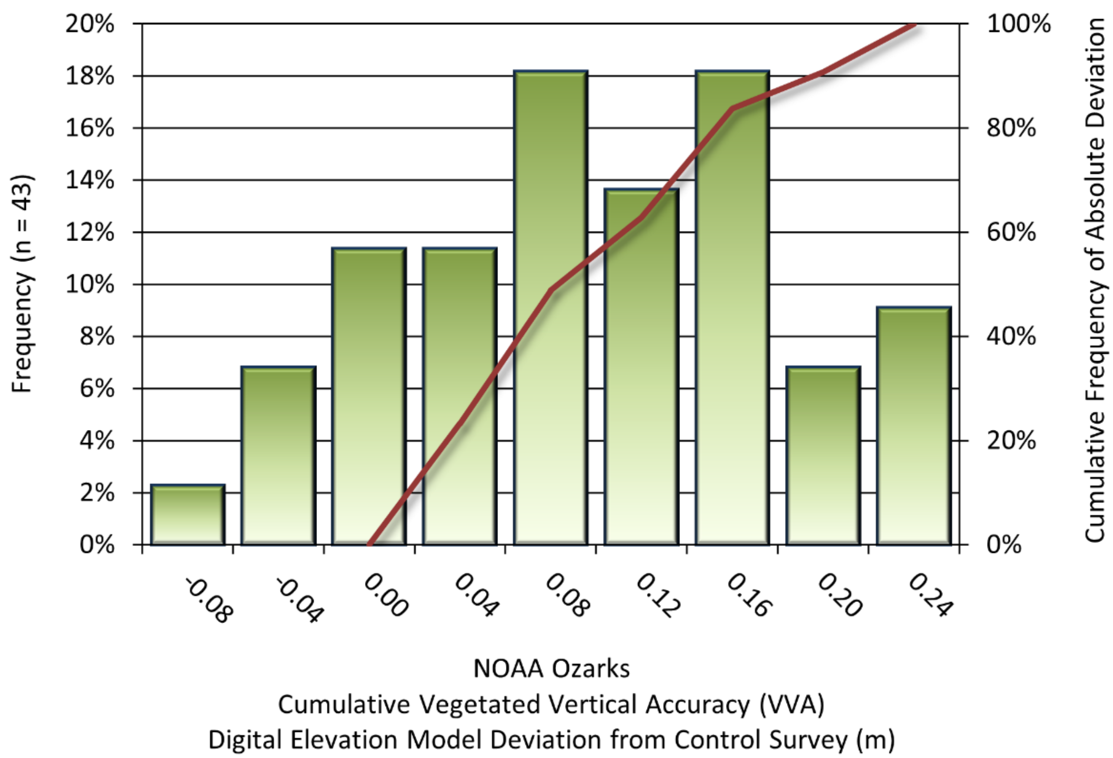


Figure 40: Frequency histogram for the lidar bare earth DEM deviation from vegetated checkpoint values (VVA)

Lidar Bathymetric Vertical Accuracies

Bathymetric (submerged) checkpoints were also collected in order to assess the submerged surface vertical accuracy. In accessing a total of 3,409 submerged points, the Bathymetric Vertical Accuracy was found to be RMSE = 0.069 meters.

Table 18: Bathymetric accuracy

Delivery	Block	Sample	95% Confidence (1.96*RMSE)	Average	Median	RMSE	Standard Deviation (1σ)
D1	**A**	62	0.085 m	-0.025 m	-0.024 m	0.043 m	0.036 m
D1	**B**	114	0.075 m	0.017 m	0.016 m	0.038 m	0.035 m
D1	**C**	35	0.127 m	0.037 m	0.030 m	0.065 m	0.054 m
D1	**D**	48	0.084 m	0.026 m	0.023 m	0.043 m	0.034 m
D2	**E**	25	0.084 m	0.026 m	0.025 m	0.043 m	0.036 m
D2	**F**	306	0.088 m	0.012 m	0.012 m	0.045 m	0.043 m
D2	**G**	238	0.145 m	-0.004 m	-0.016 m	0.074 m	0.074 m
D2	**H**	77	0.132 m	0.035 m	0.031 m	0.067 m	0.058 m
D3	**I**	301	0.114 m	0.004 m	0.007 m	0.058 m	0.058 m
D3	**L**	48	0.164 m	0.060 m	0.050 m	0.084 m	0.059 m
D4	**J**	559	0.138 m	0.000 m	0.008 m	0.070 m	0.070 m
D4	**K**	525	0.142 m	-0.006 m	0.005 m	0.072 m	0.072 m
D4	**M**	83	0.097 m	-0.014 m	-0.010 m	0.050 m	0.048 m
D4	**N**	34	0.211 m	-0.075 m	-0.052 m	0.107 m	0.078 m
D4	**O**	113	0.149 m	-0.015 m	-0.008 m	0.076 m	0.075 m
D4	**P**	141	0.147 m	-0.012 m	-0.009 m	0.075 m	0.074 m
D4	**Q**	74	0.273 m	0.022 m	0.028 m	0.139 m	0.138 m
D4	**R**	239	0.172 m	-0.030 m	-0.031 m	0.088 m	0.082 m
D4	**S**	387	0.102 m	0.007 m	0.007 m	0.052 m	0.051 m
Cumulative	**A-S**	3,409	0.134 m	0.000 m	0.004 m	0.069 m	0.069 m

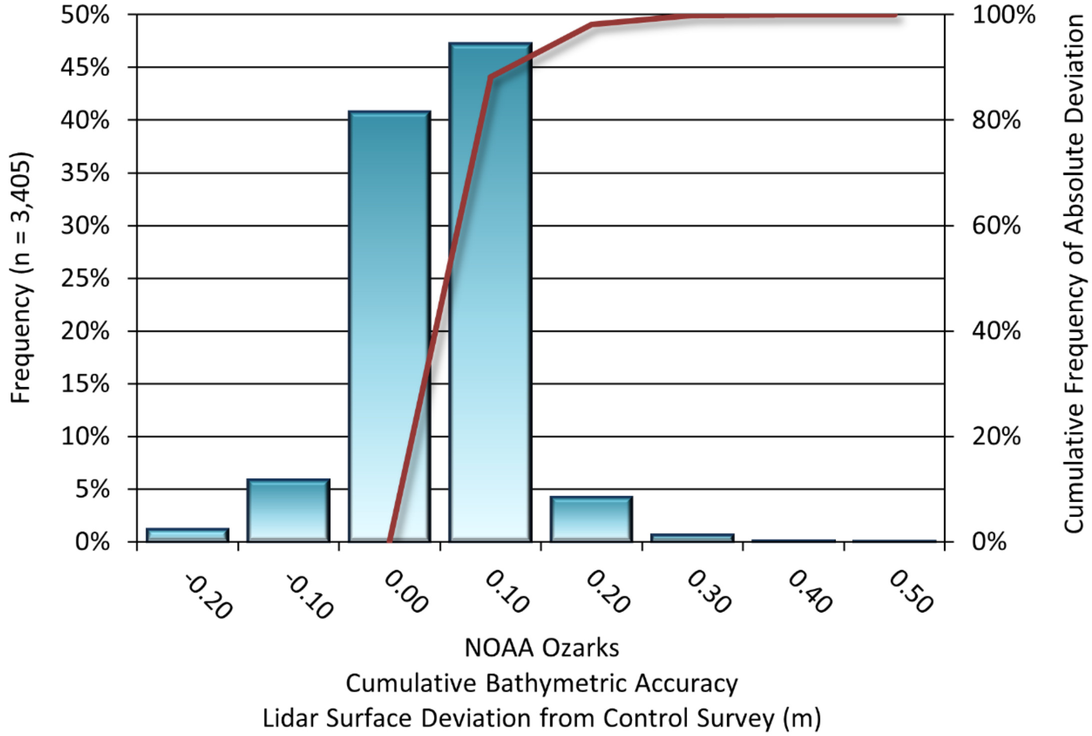


Figure 41: Frequency histogram for lidar surface deviation from submerged checkpoint values

Lidar Relative Vertical Accuracy

Relative vertical accuracy refers to the internal consistency of the dataset as a whole: the ability to place an object in the same location given multiple flightlines, GPS conditions, and aircraft attitudes. When the lidar system is well calibrated, the swath-to-swath vertical divergence is low (<0.10 meters). The relative vertical accuracy was computed by comparing the ground surface model of each individual flightline with its neighbors in overlapping regions. The average (mean) line to line relative vertical accuracy for the NOAA Ozarks Lidar project was 0.024 meters (Table 19, Figure 42).

Table 19: Relative Accuracy

Delivery	Block	Sample	95% Confidence (1.96*RMSE)	Average	Median	RMSE	Standard Deviation (1σ)
D1	**A**	172	0.018 m	0.023 m	0.024 m	0.007 m	0.014 m
D1	**B**	424	0.019 m	0.026 m	0.027 m	0.013 m	0.026 m
D1	**C**	486	0.017 m	0.026 m	0.037 m	0.018 m	0.035 m
D1	**D**	377	0.023 m	0.030 m	0.082 m	0.056 m	0.109 m
D2	**E**	246	0.028 m	0.033 m	0.053 m	0.028 m	0.056 m
D2	**F**	953	0.019 m	0.027 m	0.029 m	0.013 m	0.026 m
D2	**G**	514	0.017 m	0.024 m	0.037 m	0.021 m	0.042 m
D2	**H**	176	0.023 m	0.030 m	0.054 m	0.030 m	0.058 m
D3	**I**	818	0.015 m	0.017 m	0.018 m	0.005 m	0.010 m
D3	**L**	179	0.023 m	0.031 m	0.062 m	0.035 m	0.069 m
D4	**J**	2110	0.021 m	0.027 m	0.045 m	0.028 m	0.055 m
D4	**K**	1623	0.022 m	0.031 m	0.050 m	0.031 m	0.061 m
D4	**M**	103	0.018 m	0.017 m	0.023 m	0.012 m	0.023 m
D4	**N**	111	0.012 m	0.012 m	0.013 m	0.002 m	0.004 m
D4	**O**	1168	0.025 m	0.032 m	0.086 m	0.059 m	0.116 m
D4	**P**	391	0.017 m	0.017 m	0.018 m	0.004 m	0.009 m
D4	**Q**	1031	0.023 m	0.034 m	0.076 m	0.051 m	0.100 m
D4	**R**	636	0.020 m	0.045 m	0.060 m	0.033 m	0.065 m
D4	**S**	528	0.025 m	0.026 m	0.053 m	0.033 m	0.066 m
Cumulative	**A-S**	11920	0.021 m	0.024 m	0.053 m	0.036 m	0.070 m

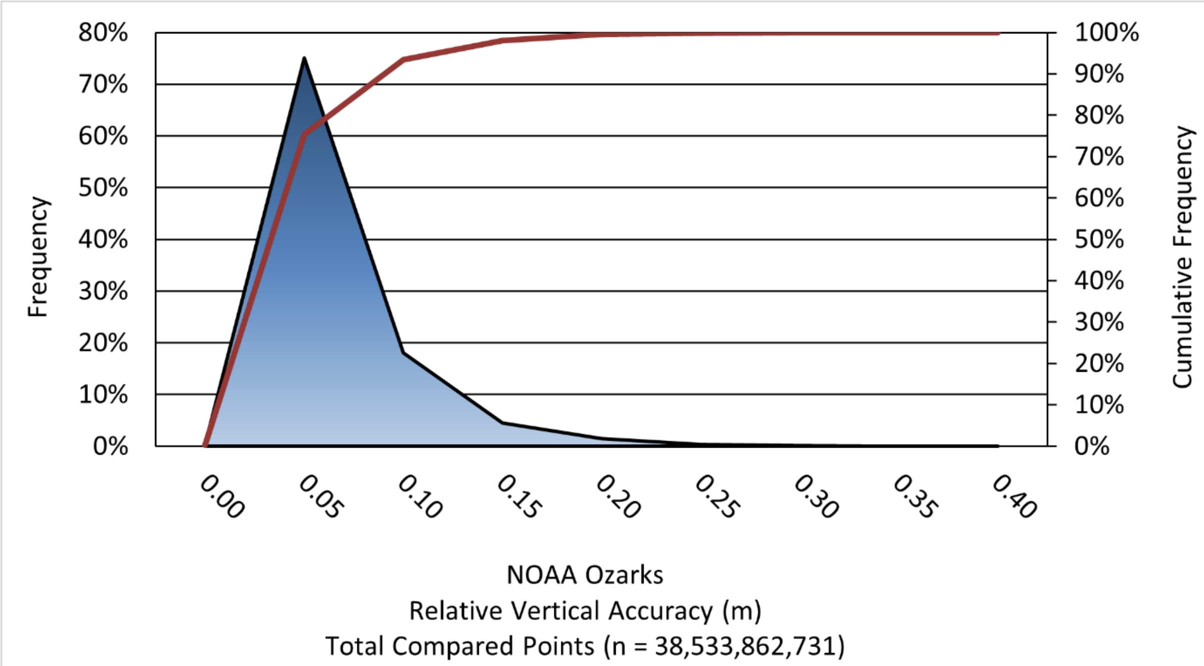


Figure 42: Frequency plot for relative vertical accuracy between flightlines

Lidar Horizontal Accuracy

Lidar horizontal accuracy is a function of Global Navigation Satellite System (GNSS) derived positional error, flying altitude, and inertial navigation system (INS) derived attitude error. The obtained $RMSE_r$ value is multiplied by a conversion factor of 1.7308 to yield the horizontal component of the National Standards for Spatial Data Accuracy (NSSDA) reporting standard where a theoretical point will fall within the obtained radius 95 percent of the time. Based on the parameters described in Table 20, summarized by sensor and flying altitude, this project was produced to meet 0.026 meters horizontal accuracy at the 95% confidence level.

Table 20: Cumulative horizontal accuracy

Parameter	Green Sensor 400 m	NIR Sensor 400 m
IMU Error	0.002 degrees	0.005 degrees
GNSS Error	0.008 m	0.008 m
RMSEr	0.026 m	0.026 m

CERTIFICATIONS

NV5 provided lidar services for the NOAA Ozarks project as described in this report.

I, Alex McManus, have reviewed the attached report for completeness and hereby state that it is a complete and accurate report of this project.

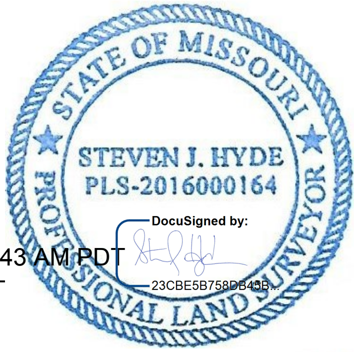
Signed by:
Alex McManus
1D65E3271523487... 9/30/2025 | 6:02 PM PDT

Alex McManus
Project Manager
NV5

I, Steven J. Hyde, PLS, being duly registered as a Professional Land Surveyor in and by the state of Missouri, Arkansas, and Oklahoma 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 August 13, 2023 and September 04, 2024.

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".

DocuSigned by:
23CBE5B758DB45B... 10/1/2025 | 5:43 AM PDT



Steven J. Hyde, PLS
NV5
Corvallis, OR 97330

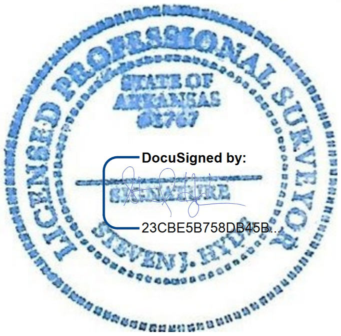


Figure 43: **This image depicts a view of the Gasconade River and Big Piney River, the smaller offshoot. The bare earth topobathymetric model is overlaid by acquired orthoimagery**

Figure 44: **This image depicts a northwest view overlooking the Buffalo River. The bare earth topobathymetric model is overlaid by acquired orthoimagery**

GLOSSARY

1-sigma (σ) Absolute Deviation: Value for which the data are within one standard deviation (approximately 68th percentile) of a normally distributed dataset.

1.96 * RMSE Absolute Deviation: Value for which the data are within two standard deviations (approximately 95th percentile) of a normally distributed dataset, based on the FGDC standards for Non-vegetated Vertical Accuracy (NVA) reporting.

Accuracy: The statistical comparison between known (surveyed) points and laser points. Typically measured as the standard deviation (sigma σ) and root mean square error (RMSE).

> **Absolute Accuracy:** The vertical accuracy of lidar data is described as the mean and standard deviation (sigma σ) of divergence of lidar point coordinates from ground survey point coordinates. To provide a sense of the model predictive power of the dataset, the root mean square error (RMSE) for vertical accuracy is also provided. These statistics assume the error distributions for x, y and z are normally distributed, and thus we also consider the skew and kurtosis of distributions when evaluating error statistics.
>
> **Relative Accuracy:** Relative accuracy refers to the internal consistency of the dataset; i.e., the ability to place a laser point in the same location over multiple flightlines, GPS conditions and aircraft attitudes. Affected by system attitude offsets, scale and GPS/IMU drift, internal consistency 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).
>
> **Root Mean Square Error (RMSE):** A statistic used to approximate the difference between real-world points and the lidar points. It is calculated by squaring all the values, then taking the average of the squares and taking the square root of the average.

Data Density: A common measure of lidar resolution, measured as points per square meter.

Digital Elevation Model (DEM): File or database made from surveyed points, containing elevation points over a contiguous area. Digital terrain models (DTM) and digital surface models (DSM) are types of DEMs. DTMs consist solely of the bare earth surface (ground points), while DSMs include information about all surfaces, including vegetation and man-made structures.

Intensity Values: The peak power ratio of the laser return to the emitted laser, calculated as a function of surface reflectivity.

Nadir: A single point or locus of points on the surface of the earth directly below a sensor as it progresses along its flightline.

Overlap: The area shared between flightlines, typically measured in percent. 100% overlap is essential to ensure complete coverage and reduce laser shadows.

Pulse Rate (PR): The rate at which laser pulses are emitted from the sensor; typically measured in thousands of pulses per second (kHz).

Pulse Returns: For every laser pulse emitted, the number of wave forms (i.e., echoes) reflected back to the sensor. Portions of the wave form that return first are the highest element in multi-tiered surfaces such as vegetation. Portions of the wave form that return last are the lowest element in multi-tiered surfaces.

Real-Time Kinematic (RTK) Survey: A type of surveying conducted with a GPS base station deployed over a known monument with a radio connection to a GPS rover. Both the base station and rover receive differential GPS data and the baseline correction is solved between the two. This type of ground survey is accurate to 1.5 cm or less.

Post-Processed Kinematic (PPK) Survey: GPS surveying is conducted with a GPS rover collecting concurrently with a GPS base station set up over a known monument. Differential corrections and precisions for the GNSS baselines are computed and applied after the fact during processing. This type of ground survey is accurate to 1.5 cm or less.

Scan Angle: The angle from nadir to the edge of the scan, measured in degrees. Laser point accuracy typically decreases as scan angles increase.

Native Lidar Density: The number of pulses emitted by the lidar system, commonly expressed as pulses per square meter.

Appendix A - Accuracy Controls

Relative Accuracy Calibration Methodology:

Manual System Calibration: Calibration procedures for each mission require solving geometric relationships that relate measured swath-to-swath deviations to misalignments of system attitude parameters. Corrected scale, pitch, roll and heading offsets were calculated and applied to resolve misalignments. The raw divergence between lines was computed after the manual calibration was completed and reported for each survey area.

Automated Attitude Calibration: All data was tested and calibrated using TerraMatch automated sampling routines. Ground points were classified for each individual flightline and used for line-to-line testing. System misalignment offsets (pitch, roll and heading) and scale were solved for each individual mission and applied to respective mission datasets. The data from each mission were then blended when imported together to form the entire area of interest.

Automated Z Calibration: Ground points per line were used to calculate the vertical divergence between lines caused by vertical GPS drift. Automated Z calibration was the final step employed for relative accuracy calibration.

Lidar accuracy error sources and solutions:

Source	Type	Post Processing Solution
Long Base Lines	GPS	None
Poor Satellite Constellation	GPS	None
Poor Antenna Visibility	GPS	Reduce Visibility Mask
Poor System Calibration	System	Recalibrate IMU and sensor offsets/settings
Inaccurate System	System	None
Poor Laser Timing	Laser Noise	None
Poor Laser Reception	Laser Noise	None
Poor Laser Power	Laser Noise	None
Irregular Laser Shape	Laser Noise	None

Operational measures taken to improve relative accuracy:

Focus Laser Power at narrow beam footprint: A laser return must be received by the system above a power threshold to accurately record a measurement. The strength of the laser return (i.e., intensity) is a function of laser emission power, laser footprint, flight altitude and the reflectivity of the target. While surface reflectivity cannot be controlled, laser power can be increased and low flight altitudes can be maintained.

Reduced Scan Angle: Edge-of-scan data can become inaccurate. The scan angle was reduced to a maximum of ±20° from nadir, creating a narrow swath width and greatly reducing laser shadows from trees and buildings.

Quality GPS: Flights took place during optimal GPS conditions (e.g., 6 or more satellites and PDOP [Position Dilution of Precision] less than 3.0). Before each flight, the PDOP was determined for the survey day.

Ground Survey: Ground survey point accuracy (<1.5 cm RMSE) occurs during optimal PDOP ranges and targets a minimal baseline distance of 4 miles between GPS rover and base. Robust statistics are, in part, a function of sample size (n) and distribution. Ground survey points are distributed to the extent possible throughout multiple flightlines and across the survey area.

50% Side-Lap (100% Overlap): Overlapping areas are optimized for relative accuracy testing. Laser shadowing is minimized to help increase target acquisition from multiple scan angles. Ideally, with a 50% side-lap, the nadir portion of one flightline coincides with the swath edge portion of overlapping flightlines. A minimum of 50% side-lap with terrain-followed acquisition prevents data gaps.

Opposing Flightlines: All overlapping flightlines have opposing directions. Pitch, roll and heading errors are amplified by a factor of two relative to the adjacent flightline(s), making misalignments easier to detect and resolve.