

Journal of Applied Hydrography

HYDROGRAPHISCHE NACHRICHTEN

06/2026

HN 134

Hydrographie
im Kontext der
Nachhaltigkeit



Beiträge vom
38. Hydrographentag
und DVW-Seminar



From above and below

Habitat mapping of an alpine lake in Austria

An article by ANNIKA L. WALTER, LUCAS DAMMERT, ELLEN HEFFNER, JAN RHOMBERG-KAUERT, HARALD STERNBERG and GOTTFRIED MANDLBURGER

habitat mapping | underwater LiDAR | bathymetric LiDAR | two-media photogrammetry
Habitatkartierung | Unterwasser-LiDAR | bathymetrisches LiDAR | Zweimedienphotogrammetrie

Authors

Annika L. Walter, Ellen Heffner and Prof. Dr. Harald Sternberg work at HafenCity University in Hamburg.

Lucas Dammert, Jan Rhomberg-Kauert and Prof. Dr. Gottfried Mandlbürger work at TU Wien.

annika.walter@hcu-hamburg.de

Introduction

High-resolution habitat mapping of freshwater ecosystems is essential for understanding biodiversity patterns, ecosystem functions and for guiding conservation efforts. In August 2025, the Lake Alm (Almsee) in Austria was surveyed in a joint survey campaign by TU Wien, RIEGL Laser Measurement Systems GmbH and HafenCity University Hamburg with shipborne and airborne sensors. The lake is characterised by an extremely clear water condition, fed by multiple freshwater spring funnels, which are clearly depictable as several metre deep depressions in the lake bottom, where the clear water furthermore allows the prosperous growth of macrophytes. Hence, this lake provides optimal conditions for evaluating the suitability of different optical remote sensing technologies for detailed habitat mapping, assessing their ability to capture the structural complexity of the lakebed and the prevailing aquatic vegetation. Lake Alm was surveyed using multiple remote sensing technologies, including an underwater laser scanner, a single-beam echo sounder, a side-scan sonar, a drone-based topo-bathymetric laser scanner as well as a drone equipped with a camera. The project scope and preliminary results will be presented.

Environment

Lake Alm is located within the municipality of Grünau im Almtal at approximately 47°45' north latitude and 13°57-58' east longitude. The lake was formed at the end of the Würm Ice Age 13,000 years ago by a late-glacial rockslide where about 0.5 km³ of rock material detached. As a result, the Alm River and the Weißeneggbach were dammed and Lake Alm was formed. Nowadays, Lake Alm has a size of 0.85 km², a volume of 2.1 Mio m³ and an average depth of 2.5 m (Land Oberösterreich 2021), whereas the deepest spot is a spring funnel with a depth of 9 m (Bergwelten 2022). With an exception of this spring funnel, the depth of the lake equals the maximum viewing depth and thus, the lake offers visibility to the ground throughout.

Due to the overall shallow water depth and the clarity of the water, the lake naturally offers sufficient light for photosynthesis (Land Oberösterreich 2010) resulting in large areas of the lake bottom being densely covered by macrophytes. *Charophyceae* and *Elodea* cover large areas of the lake bottom, building a dense low-grown vegetation layer. Additionally, patches of high-grown *Potamogeton* extend up to 2 m from the bottom (Blatterer 2020). Together with autotrophic plankton, the macrophytes provide the necessary foundation for life in the water and function as a source of food for waterfowl (Drack 1992).

Sensor technology and data acquisition

The survey took place in August 2025, with different shipborne (underwater laser scanner, single-beam echo sounder, side-scan sonar, handheld underwater camera) and airborne (bathymetric LiDAR and photo camera) sensor technologies. Extensive geometric reference data were also acquired in a small part of the survey area (Dammert et al. 2026). To increase the position accuracy of all GNSS-derived trajectories, a base station was set-up on the northern shoreline of Lake Alm for continuous recording over the entire survey day. For the scope of comparing optical sensing methods, the used sensors are described in detail in the following.

ULi

The underwater laser scanner ULi uses a green laser with a wavelength of 532 nm and two rotating wedge prisms, which allows for a 44°-field of view, to capture the scene with a beam divergence of 2 mrad and a pulse repetition rate of up to 100 kHz (Fraunhofer IPM 2026). For a dynamic application, the trajectory of the underwater laser scanner is tracked by an attached and calibrated inertial navigation system, which was connected with two GNSS antennas on a 96-cm baseline. The overall structure was pole-mounted on the starboard side of a 3.5 m long and 1.4 m wide aluminium vessel. There, the scanning unit of ULi was mounted pointing slightly off-nadir underneath the ship to

ensure a side-view capturing of the aquatic vegetation. For data acquisition a palmer scan pattern was chosen and, depending on the topography of the lake, the scanning distances varied between 50 cm and 9 m.

Bathymetric LiDAR

The topo-bathymetric LiDAR and photogrammetric data acquisition were conducted using uncrewed aerial vehicles (UAVs). The UAV surveys were launched from the shore. For the topo-bathymetric data acquisition, a RIEGL VQ-840-GE was used to survey the entire lake at a flying altitude of approximately 120 m above ground, with a beam divergence of 1 mrad and 100 kHz pulse repetition rate. In addition, a RIEGL VUX-820 scanner was used to map the central part of the lake at a flying height of 100 m above ground, with a beam divergence of 2 mrad at 100 kHz pulse repetition rate.

Photogrammetry

The photogrammetric survey used a DJI P1 camera at 100 m altitude. About 2,500 images were acquired and ground control points were installed on the shore. Furthermore, a GoPro Hero 12 Black was operated from the vessel and used to acquire underwater footage of the aquatic vegetation. To allow for a localisation of the captured underwater images, the camera was operated on a handheld stick with a GNSS antenna on top.

Data processing

To compute a navigation solution for the laser sensors, i.e., ULi and bathymetric LiDAR, the trajectories were processed with correction data of the GNSS base station using the softwares Qinteria and PosPac, respectively. After processing of the trajectories, they were merged with their respective data.

For ULi, the acquired LiDAR waveform data was processed using the software Pulsalyzer, developed by the Fraunhofer IPM, to compute a coherent georeferenced point cloud. The derived point clouds were further processed and manually filtered in CloudCompare.

For the bathymetric LiDAR, the data were processed using RiPROCESS and the scientific point cloud processing software OPALS (Pfeifer et al. 2014) for integrated and refraction-aware georeferencing. The latter describes the integrated georeferencing, refraction correction and strip adjustment of the data in an iterative procedure (Mandlbürger et al. 2026).

The photogrammetric data was processed using Agisoft Metashape and the navigation data from the DJI UAV. While the refraction-induced effects can be corrected in the photogrammetric point cloud, the occurring distortion also impacts the bundle-block adjustment and thus orienta-

tion estimation of the images. This leads to a deformed photogrammetric block as effects caused by the refraction are compensated by other parameters estimated by the bundle-block adjustment. Consequently, the photogrammetric block is distorted due to the impact of refraction on the estimation of the exterior orientation parameters.

Results

As a preliminary result of the campaign, three exemplary datasets of a selected area of interest are presented and visually compared: two freshwater spring funnels located close to each other forming a kidney-shaped depression and the prevailing vegetation. A combined visualisation of the two kidney-shaped depressions captured by ULi, the VUX-820 and the photogrammetric dataset, can be seen in Fig. 1.

Hence, Fig. 1 highlights the differences between the optical sensing methods with regard to coverage, achieved data quality and resolution.

While ULi, operated from a water surface vehicle, captured single measurement strips across the depressions, the VUX-820 bathymetric LiDAR and the camera photos cover a much larger extent within a shorter acquisition time. Despite differences in sensor platforms, all three optical sensors achieve full depth penetration. The deepest points of the two kidney-shaped depressions show depths of 4.2 m and 4.6 m. The average water depth surrounding the depressions is 2.2 m, leading to a varying width of the measurement strips acquired by ULi from around 2.4 m to 4.7 m.

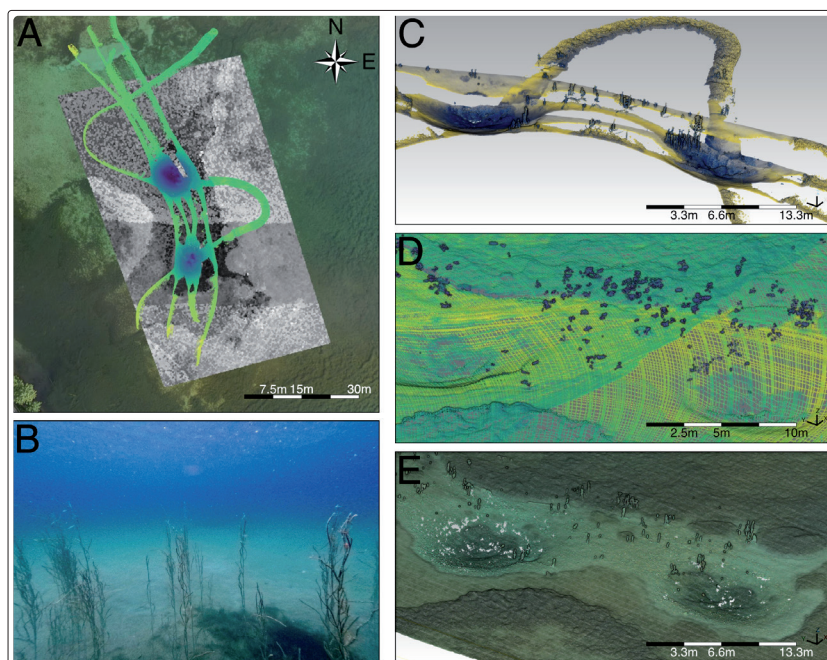
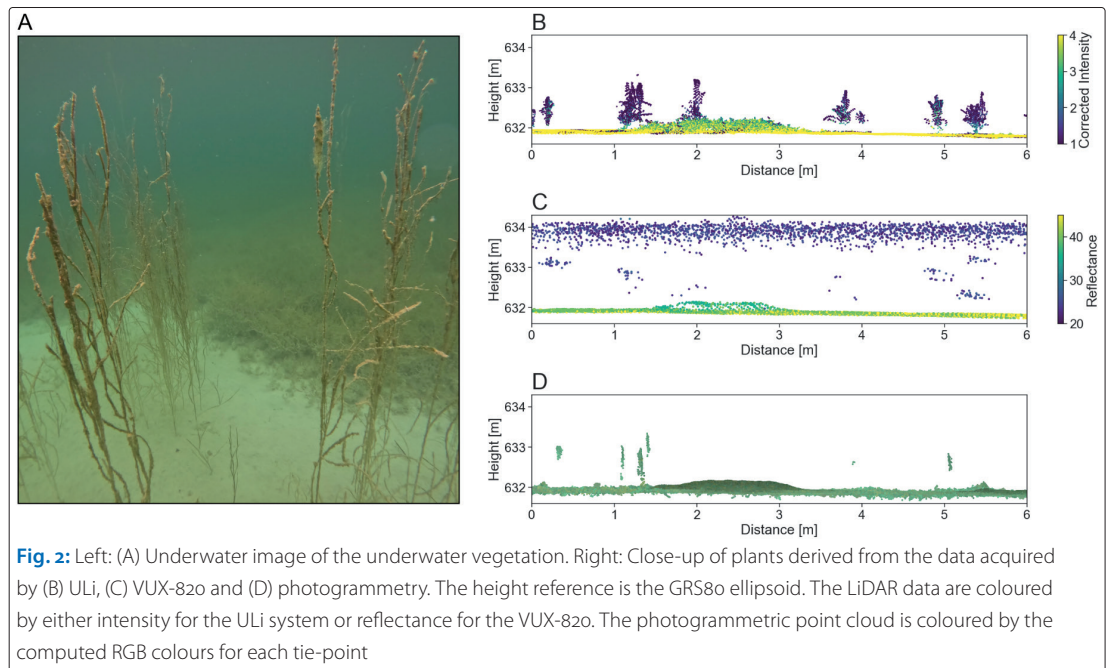


Fig. 1: Left: (A) Combined top-view visualisation of the three datasets acquired during the Lake Alm measurement together with (B) an underwater image of the presumable *Potamogeton* present in the area of interest. Right: Oblique visualisation of the spring funnel depressions derived from the data acquired by (C) ULi, (D) the VUX-820 and (E) photogrammetry



The oblique view visualisation of all three datasets further emphasises that all datasets are able to resolve point-wise elevations, in this case single plants in the water column. However, those features are less distinct in the point cloud derived from the bathymetric LiDAR VUX-820. Thus, the individual datasets highlight the resolution capability of ULi and the photogrammetric captured data.

A close-up view of underwater vegetation captured by ULi, the bathymetric LiDAR VUX-820 and the photogrammetric approach in Fig. 2 (right) further outlines the achievable level of detail of each sensor. While ULi reveals the most detailed representation of the plants, the other two methods display singular detections. In the depicted figure, two different kinds of macrophytes are visible: A fully ground covering, densely grown vegetation, where none of the optical sensors are able to penetrate through and another type of vegetation, where plants singularly protrude in the water column, some up to 2 m high, to the water surface. Images of the respective plants taken with the GoPro are shown in Fig. 2 (left). The high-grown vegetation refers most likely to *Potamogeton* and the low-grown vegetation to *Charophyceae*.

Conclusion and outlook

The preliminary results of the joint research campaign of different optical sensing technologies at Lake Alm already show the high potential of the integrated datasets. Due to the optimal visibility conditions in the lake, Lake Alm appears as a suitable environment for comparing optical sensing methods.

As outlined, all three optical sensors achieve full depth penetration of the lake. While the shipborne underwater laser scanner ULi offers, due to

its much smaller distance to the measured objects and therewith its smaller footprint size, the highest potential in terms of resolution and detailed datasets, it is still limited in coverage to small survey strips. Meanwhile, the airborne systems (bathymetric LiDAR and camera data) collected from UAV flight campaigns provide full coverage, but are not able to resolve plants at the same level of detail. Finally, at least two different species of macrophytes are detected in the (underwater and airborne) LiDAR and photogrammetric datasets, and therefore enhance the ability to capture diverse aquatic vegetation.

Until now, the lake Alm data is being assessed in three studies addressing the bathymetric LiDAR data. The studies investigate (i) integrated refraction-aware georeferencing of bathymetric LiDAR data (Mandlbürger et al. 2026), (ii) the accuracy analysis of bathymetric LiDAR (Dammert et al. 2026) and (iii) the classification of vegetation using bathymetric LiDAR data. Further analysis of the data will concentrate on enhancing for example the photogrammetric data by implementing a refraction-aware bundle-block adjustment to derive a correct underwater model for the airborne photogrammetric data. In addition, the collected ULi data will be further evaluated, taking environmental parameters such as temperature into account. Besides, the achievable data quality will be optimised by enhancing the refraction correction. The ULi and photo datasets will be used for a detailed comparative plant detection analysis. For a joint assessment of the varying sensor technologies, the penetration depth of the individual sensors, in areas where the lake floor is covered by dense mats of macrophytes, will be analysed and difference models will be computed. //

References

Bergwelten (2022): Der Almsee in Grünau im Portrait. www.bergwelten.com/a/der-almsee-im-portraet

Blatterer, Hubert (2020): Algen im Almsee. www.land-oberoesterreich.gv.at/Mediendateien/Formulare/Dokumente%20UWD%20Abt_WW/Web_Infotafel%20Almsee.pdf

Dammert, Lucas; Jan Rhomberg-Kauert; Philipp Amon; Hans-Berndt Neuner; Gottfried Mandlbürger (2026): Accuracy assessment of bathymetric LiDAR using planar reference geometries and total station measurements. ISPRS Archives, Toronto [submitted]

Drack, Gertrude (1992): Die Bedeutung des Almsees als Lebensraum einer Wasservogelgemeinschaft. www.zobodat.at/pdf/OEKO_1992_3_0017-0022.pdf

Fraunhofer IPM (2026): Underwater LiDAR System. Optical inspection of underwater infrastructure. www.ipm.fraunhofer.de/de/gf/objekterfassung-laserscanning/anw/unterwasser-laserscanning/unterwasser-infrastruktur.html

Land Oberösterreich (2010): Gewässerschutzbericht Seenaufsicht in Oberösterreich, Gewässerschutzbericht 43. www.land-oberoesterreich.gv.at/files/publikationen/uwd_ogw_seenaufsicht.pdf

Land Oberösterreich (2021): Seeprofil Almsee. www.land-oberoesterreich.gv.at/Mediendateien/Formulare/Dokumente%20UWD%20Abt_WW/Almsee-2021.pdf

Mandlbürger, Gottfried; Lucas Dammert; Jan Rhomberg-Kauert; Florian Pöppel; Martin Pfennigbauer (2026): Refraction-aware integrated Georeferencing of bathymetric Laser Scanning Data. ISPRS Archives, Toronto [submitted]

Pfeifer, Norbert; Gottfried Mandlbürger; Johannes Otepka; Wilfried Karel (2014): OPALS – A framework for Airborne Laser Scanning data analysis. Computers, Environment and Urban Systems, DOI: 10.1016/j.compenvurbsys.2013.11.002



Obtain comprehensive hydrographic data in deep water and coastal regions

Our hydrographic survey services, including our lidar bathymetry, acoustic surveys, satellite imagery analysis, and subsurface mapping, are used by both government and private sector clients for various applications along the coastline and offshore to support nautical charting, cable route surveys and coastal zone management.

Hydrography also has significant applications in supporting the blue economy and underpins our climate and nature activities, providing essential data for sustainable development and environmental conservation.



Scan the QR code to find out more about our hydrographic surveys