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ASSESSMENT OF SUSPENDED SEDIMENT CONCENTRATION AND GRANULOMETRY USING AQUASCAT 1000S ON THE SULINA BRANCH OF THE DANUBE RIVER

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Abstract

This study presents an analysis of suspended sediment concentration and granulometric distribution along the Sulina branch of the Danube River, based on data collected using the AQUASCAT 1000S acoustic backscatter system. Measurements were conducted at six monitoring stations near or between the localities of Sulina, Gorgova, Crișan, Maliuc, Partizani, and an intermediate station between Sulina and Crișan. The AQUASCAT 1000S was employed to gather high-resolution acoustic data using its four frequency channels, ranging from kilohertz to megahertz, allowing for simultaneous observation of both fine and coarse sediment fractions. Data processing involved comparative analyses using different combinations of acoustic channels to evaluate their effectiveness in characterizing sediment concentration and size distribution across diverse hydrological and morphological conditions along the branch. Results reveal spatial variability in suspended sediment characteristics, influenced by local hydrodynamics and proximity to tributaries, human settlements, and natural channels. The study highlights the advantages and limitations of multi-frequency acoustic techniques in riverine sediment monitoring and contributes to the development of improved methodologies for sediment characterization in deltaic environments.

Key words*: AQUASCAT 1000S, Danube River, granulometry, multi-frequency analysis, Sulina branch, suspended sediment concentration.*

INTRODUCTION

The transport of suspended particulate matter (SPM) is a major problem for the aquatic environment, modifying the morphology of the seabed, marine habitats and the water quality index (WQI). In addition, there are also problems related to the health of aquatic flora and fauna because in the water, in addition to sand and silt, microplastics, heavy metals and even nuclear waste can be found as suspended matter, which can be consumed by fish and accumulate in their bodies.(Hunter et al., 2010; 2011; Iticescu et al., 2016; Popa et al., 2018; Arseni et al., 2020; Hussain et al., 2020; Călmuc et al., 2022; Lazăr et al., 2024). If people spend too much time in contact with such waters where the amounts of SPM are high or consume fish from these areas, the negative effects of these suspended matter can have negative effects on the human body (Falciola et al., 2022). In general, this toxic pollution is strictly anthropogenic, resulting from discharges of pollutants into waters and even naval transport. For such determinations related to the amount of SPM in water and sediment transport, modern acoustic technologies are becoming increasingly important in the assessment and monitoring of the aquatic environment, and equipment based on Acoustic Backscatter (ABS) technology, such as the AQUAscat 1000S, are essential for obtaining accurate data on SPM.(Smerdon & Thorne, 2008; Foote et al., 2010; Martini et al., 2010; Hunter et al., 2012a; 2012b; Bux et al., 2015; Divinsky & Kosyan, 2019; Fromant et al., 2017; 2021; Van Dijk et al., 2024; Zhu et al., 2024). This equipment uses high-frequency sound waves to evaluate the intensity of the signal reflected by suspended particles such as fine sediments, organic materials or microorganisms. The instrument measures the sound reflected by sediments or other materials suspended in water at precise intervals, which can be set between 2.5 mm and 4 cm. For depth measurements, this interval can be several tens of centimeters, and for monitoring suspended sediments, the typical distance is about 1-2 meters. In the case of dredging slab estimation, measurements can reach up to 10 meters (Bux, 2016; www.Aquatecsubsea.com). This study aims to highlight the advantages and limitations of multi-frequency acoustic techniques in river sediment monitoring and contribute to the development of improved methodologies for sediment characterization in deltaic environments.

MATERIALS AND METHODS

Study area and localization

The field measurements, made on 23 August 2023, targeted the Sulina branch of the Danube River located in Danube Delta, Romania. Monitoring stations were strategically positioned along this channel to capture spatial variability in hydrological and sedimentological conditions. Each station was named based on the nearest locality.

The geographic coordinates of the Aquascat measurement sites are:

- Partizani sampling station (Partizani): 45.19330° N, 28.95869° E
- Maliuc sampling station (Maliuc): 45.17459° N, 29.11427° E;
- Gorgova sampling station (Gorgova): 45.18153° N, 29.17888° E;
- Crisan sampling station (Crisan): 45.17358° N, 29.42541° E;
- Interim Sulina sampling station (near Sulina): 45.18125° N, 29.51804° E;
- Sulina sampling station (Sulina): 45.16208° N, 29.68527° E.

A map of the measurement sites where Aquascat observations were carried out is presented in Figure 1. The map was made using a Geographic Information System (GIS) providing spatial reference relative to key settlements and hydrological features of the Danube Delta.

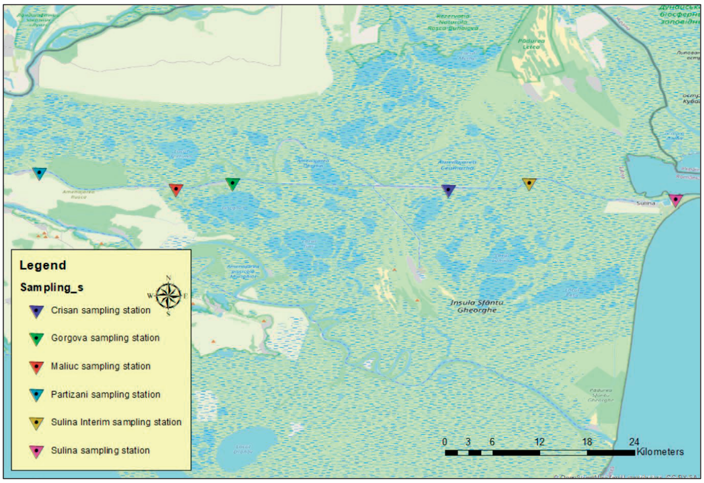


Figure 1. Location of the six sampling stations on Sulina branch located in Danube Delta

Equipment and data used

The AQUAscat 1000S is an advanced acoustic backscatter system designed for high-precision monitoring of suspended sediment concentrations (SSC) and particle dynamics in aquatic environments such as rivers, lakes, estuaries, and coastal waters. It operates by transmitting sound pulses at multiple frequencies (typically between 300 kHz and 5 MHz) into the water and recording the intensity of the backscattered signals. Unlike light, sound propagates more slowly and is less attenuated in water, enabling the AQUAscat to generate continuous backscatter profiles rather than discrete point measurements.

SSC estimation relies on the frequency-dependent scattering properties of suspended particles. By analyzing the backscatter from multiple transmitted frequencies, the system differentiates particle sizes within a sensitivity range of 20–500 µm (radius), enabling the derivation of both particle size distribution and sediment concentration along the profiling range.

Designed to meet the demand for enhanced accuracy and efficiency, the AQUAscat 1000S significantly improves understanding of sediment dynamics, which are critical for assessing ecological processes and potential impacts on water quality and human health. Built with marine-grade materials, the AQUAscat 1000S is suitable for deployment in harsh environments and supports flexible installation (e.g., moorings, frames, or vessels). For this study, a vessel-mounted configuration was used, with the instrument secured to maintain vertical orientation and prevent transducer obstruction it can be seen in Figure 2. In this study, the AQUAscat 1000S was deployed at six monitoring stations along the Sulina branch (Partizani, Maliuc, Gorgova, Crișan, Interim Sulina, and Sulina), as illustrated in Figure 2. The main specifications of the device are detailed in Table 1.

The AQUAscat 1000S frequency range enables detection of a broad spectrum of particle sizes, from fine silt to coarse sand. High frequencies enhance sensitivity to small particles, while lower frequencies penetrate denser sediment clouds, allowing effective differentiation of particle sizes and analysis of sediment composition and transport.

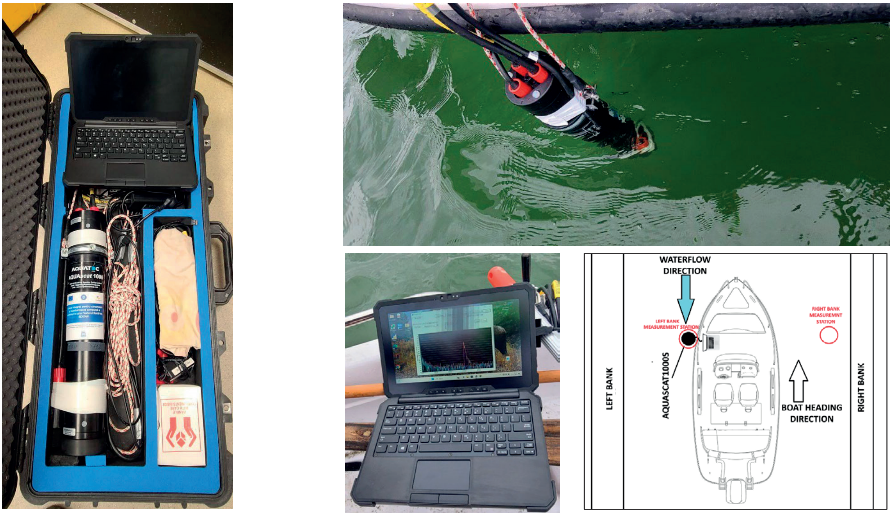
Using time-gated signal processing, the instrument divides the water column into depth bins to generate high-resolution vertical profiles of suspended sediment concentration (SSC) and particle size. Depth range and resolution are configurable to suit specific research needs.

Data analysis using AquaTalk toolkit software

Real-time data acquisition is supported through the AQUAscatTalk interface (Figure 3), which visualizes backscatter intensity per frequency. Post-processing, including calibration and application of acoustic scattering models, converts raw backscatter into SSC and particle size values.

Table 1. AQUAscat 1000S specifications (adapted after www.aquatecsubsea.com)

Specification	Description and ranges
Sediment range	Sensitive to a wide range of grain sizes Size inversion typically feasible for 20 µm to 500 µm radius Typically 0.01 g/l to 20 g/l over 1 m, or more over shorter range
Frequencies	4 frequencies - 500 kHz, 1 MHz, 2 MHz, 4 MHz
Transducers	Ø10-25mm ceramic discs (beam width according to frequency) 4 fixed transducers
Gain	Software controlled transmitter and receiver gain adjustment
Range	150 cm (typical), up to 10 m at frequencies below 2 MHz depending on options
Transmission rate	128 Hz max pulse rate for each frequency (i.e. 512 pulses per second for four), subject to acoustic range limits. Minimum rate 1 Hz for calibration
Range cells	256 cells. 2.5 mm, 5 mm, 10 mm, 20 mm and 40 mm at 1500 m/s speed of sound. Start/end range set by software
Burst duration and interval	Defined by number of profiles requested. The duration is internally generated from once every minute to once every 255 minutes, user definable start time of first burst
Trigger output	A digital output allows triggering of external instruments
Additional sensors	Built-in turbidity sensor
Data comms	RS232 up to 115 kbaud; USB 1.1 typically 2-3 Mbaud
Housing options	1000m rated aluminium alloy housing.
Software	AQUAtalk ® for AQUAscat ® for logger interaction AQUAscat ® toolkit for data processing



a) b)

Figure 2. AQUASCAT1000S: a) AQASCAT1000S equipament with all accesories and PC used for in field measurements; b) AQASCAT1000S equipment, PC and procedure (used for data recording) during deployment in measurement campaign on Sulina branch

The AQUAscatToolkit (Figures 3 and 4) is a MATLAB-based interface for processing and visualizing suspended sediment data from AQUAscat instruments.

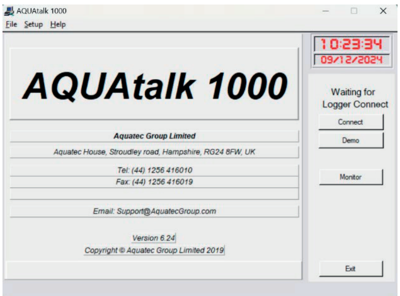


Figure 3. Software used for in-situ data measurement AQUAtalk 1000

It supports .aqa file handling, signal preprocessing, and SSC estimation.

Figure 3 shows first step of processing the raw data from the Partizani station, measured over a 10 m depth range during a 3-minute deployment. One-minute averaged profiles were generated by combining ~600 measurements per acoustic channel. Each channel targets specific sediment size ranges, enabling grain size distribution and concentration analysis. Final SSC values are computed by inverting backscatter data in the Calculated Suspended Sediment panel, providing an integrated sediment profile. Raw acoustic data from each 3-minute deployment was processed using the AQUAscatToolkit, with one-minute averaging and a 40 cm depth bin (Figure 5).

This initial preprocessing yields absolute backscatter (ABS) profiles, providing a first estimate of sediment distribution.

Suspended sediment data processing involved two main phases: (1) preprocessing, where backscatter profiles were averaged into one-minute intervals (~600 profiles per bin) to define vertical particle distribution from 40 to 1024 cm depth; and (2) post-processing, which included extensive averaging using ancillary data (temperature, pressure, salinity) to refine ABS profiles, followed by computational post-processing of raw data to derive high-resolution SSC and grain size profiles across the full 10.24 m water column.

Results were derived using the Calculated Suspended Sediment Profiles (SSCP) module, producing modeled grain size (µm) and concentration (g/L) for each 40 cm depth interval over a 10.24 m water column.

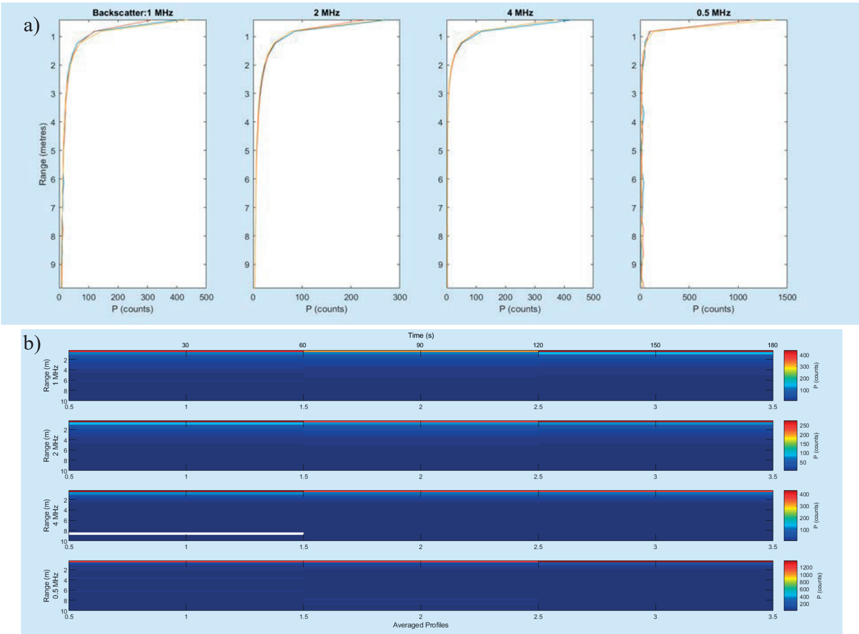


Figure 4. Measurement preprocessed results: a) Profiles of each channel recorded during monitoring campanin on 23 August 2023 at Partizani station, b) Backscater of each channel recorded during monitoring campanin on 23 August 2023 at Partizani station

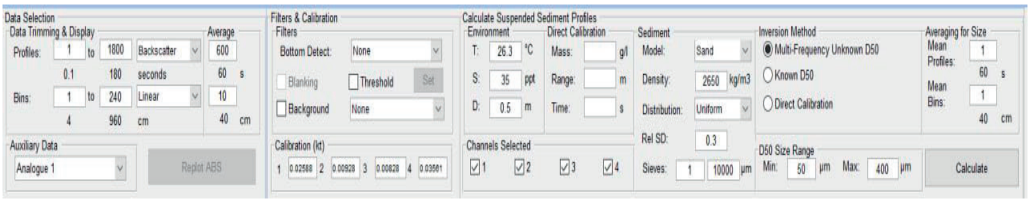


Figure 5 Settings used in AQUASCATToolkit for determining the average 1 minute grain size and concentrations

RESULTS AND DISCUSSIONS

The results obtained from AQUAscat1000S measurements at each of the six of the measurement stations on Sulina branch presented provide detailed insight into the vertical and temporal distribution of suspended sediment concentration (SSC) and particle size within the water column. The data reflects both the intensity of sediment transport processes and the stratification of grain sizes under varying hydrodynamic conditions.

Figure 6 displays the SSC and means grain radius profiles (top panels), as well as their corresponding time-series distributions (bottom panels). The vertical SSC profile shows a marked increase in concentration with depth, reaching values over 200 g/L between approximately 8.1 m and 9.5 m, indicating significant near-bed sediment presence. In contrast, concentrations decrease sharply above 6 m, with surface values below 50 g/L, likely due to strong surface flows inhibiting particle settling. The mean grain radius profile reveals coarser sediments near the surface, with values between 150-200 µm in the 0.5-4.5 m depth range. Grain size gradually decreases below this zone, reaching a minimum of around 50 µm between 6.7 m and 9 m. Notably, a secondary increase in grain size, again nearing 200 µm, is observed below 9.5 m, suggesting active sediment resuspension or bedload interaction at the channel bottom.

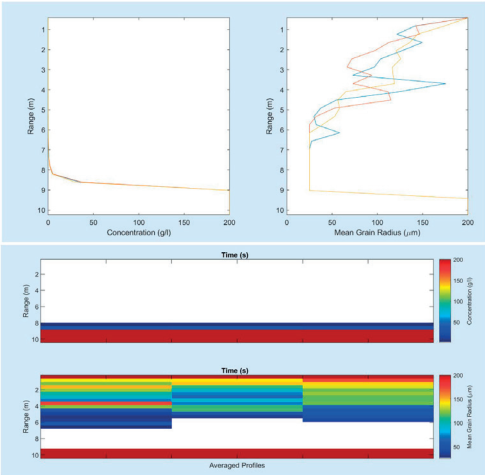


Figure 6. Profiles and time series of SSC grain size and concentration for Partizani station on 23.08.2023

These findings highlight a vertically stratified sediment structure, with finer particles suspended at mid-depths and coarse materials concentrated near the surface and bed. The distribution patterns reflect the interplay between flow velocity, sediment input, and depth-dependent turbulence, providing a representative snapshot of sediment dynamics in the Sulina branch at the time of measurement.

The measurements conducted at Maliuc station on 23 August 2024 reveal clear vertical stratification in both suspended sediment concentration (SSC) and particle size. As shown in Figure 7, SSC peaks near the channel bed, reaching values up to 200 g/L between 8.4 m and 10.2 m, while concentrations remain low (below 50 g/L) in the upper 8 m of the water column, consistent with enhanced surface flow limiting particle settling.

The grain size profile indicates coarser material near the surface, with mean grain radii reaching 200 µm in the top 0.5-2.5 m, followed by a mid-depth layer (2.5-5.7 m) of finer particles ranging from 50-120 µm. Below 5.7 m, grain sizes decrease significantly, dropping below 50 µm until approximately 9.2 m, where a second band of coarse particles (~200 µm) reappears near the bed (9.2-10.2 m), likely due to sediment resuspension or bedload interaction. These patterns show a typical two-layer structure, with coarse particles transported at the surface and near the bed, and finer sediments suspended in the mid-column, driven by local hydrodynamic conditions.

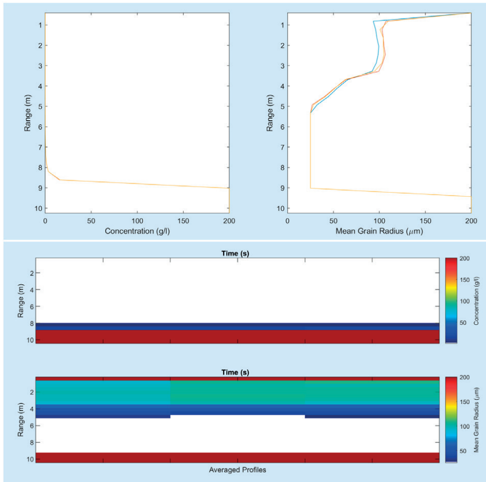


Figure 7. Profiles and timeseries of SSC grain size and concentration for Maliuc station on 23.08.2023

The vertical profiles and time-series recorded at Gorgova station (Figure 8) reveal a clear stratification of suspended sediment concentration (SSC) and grain size.

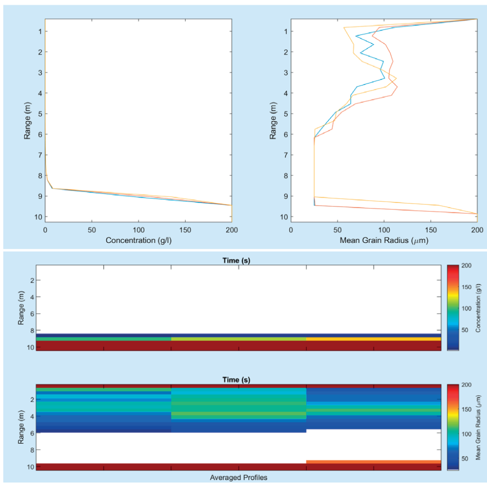


Figure 8. Profiles and timeseries of SSC grain size and concentration for Gorgova station on 23.08.2023

As shown in Figure 8, SSC values increase with depth, with concentrations of approximately 50 g/L observed between 8.5 m and 8.7 m, followed by a layer with concentrations between 100-130 g/L from 8.7 m to 9 m. The highest SSC, exceeding 200 g/L, is concentrated near the channel bed (below 9 m), indicating active sediment resuspension or accumulation. Grain size profiles show coarse particles at the surface, with values near 200 µm in the upper 0.5-2 m, transitioning to a mid-depth band (2-6 m) where particle radii range between 50-120 µm.

Below 6 m, particle sizes decrease further, falling below 50 µm until 9.4 m. A distinct increase in grain size, again nearing 200 µm, is evident in the bottom layer (9.4-10.2 m), consistent with bedload material or localized turbulence effects. The SSC and grain size profiles recorded at Crișan station during the late summer survey indicate a clear vertical structure in sediment transport (Figure 9).

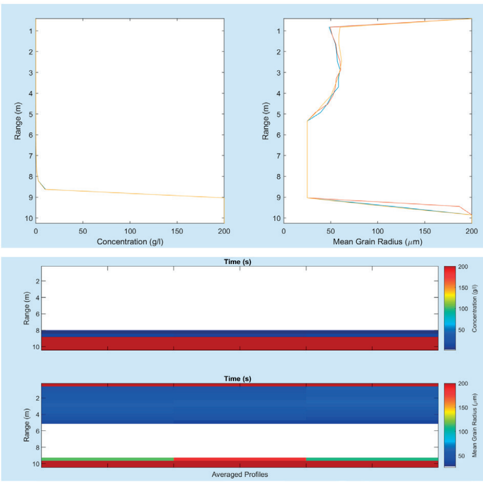


Figure 9. Profiles and timeseries of SSC grain size and concentration for Crișan station on 23.08.2023

SSC values begin to increase at depth, reaching ~50 g/L between 8.0 m and 8.7 m, with the highest concentrations exceeding 200 g/L near the channel bed (below 9 m). Near-surface concentrations remain low (below 50 g/L), likely due to higher surface flow velocities inhibiting particle settling. The anisys of calculated grain size profiles show the coarsest particles (~200 µm) at the surface in the 0-0.4 m depth bin, followed by a band of smaller particles (50-70 µm) between 0.4 m and 5.8 m. Below this, grain sizes decrease further, dropping below 50 µm between 5.8 m and 9 m, indicating a mid-column zone dominated by fine suspended sediments. A secondary increase in grain size is observed below 9 m, with values between 100-150 µm and peaking above 200 µm near the bed (9.0-9.8 m), suggesting active bedload transport or sediment resuspension in this deeper layer.

The profiles and time-series recorded at the Intermediary Crișan-Sulina station reveal pronounced vertical gradients in both suspended sediment concentration (SSC) and particle size (Figure 10).

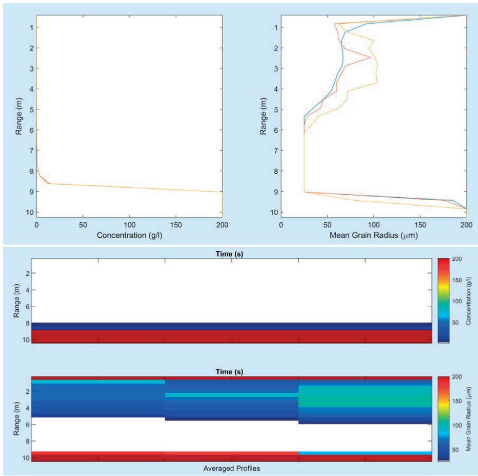


Figure 10. Profiles and time series of SSC grain size and concentration for Interim Sulina station on 23.08.2023

SSC values reach approximately 50 g/L between 8.7 m and 8.9 m, increasing to over 200 g/L near the channel bed (below 9 m), indicating significant sediment accumulation or resuspension in deeper layers. Surface concentrations remain low, under 50 g/L, likely due to enhanced turbulent mixing and flow velocity in the upper water column. Analysis on grain size distribution shows the coarsest material (~200 µm) at the surface within the 0-0.4 m bin. This is followed by a mid-layer (0.4-5.3 m) containing particles between 50-110 µm, and a further decrease below 5.7 m, where grain sizes drop below 50 µm, marking a zone dominated by fine sediments. At depths greater than 9 m, grain sizes increase again to 70-180 µm, with the bed layer exhibiting coarse material close to 200 µm, consistent with bedload transport dynamics.

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At Sulina station, the suspended sediment concentration (SSC) and particle size profiles exhibit well-defined vertical patterns (Figure 11).

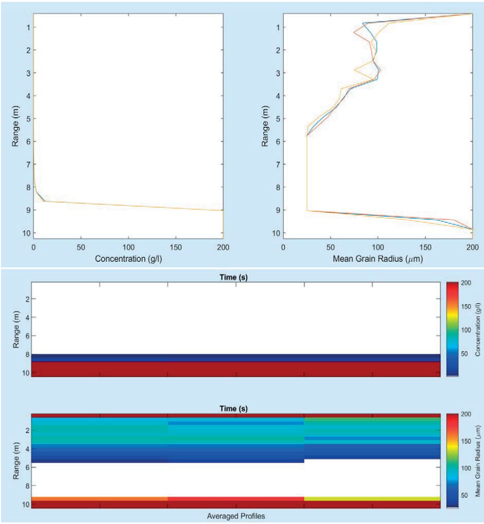

Figure 11. Profiles and time series of SSC grain size and concentration for Sulina station on 23.08.2023

SSC values begin to rise at depth, reaching approximately 50 g/L between 8.7 m and 9.0 m, and peak above 200 g/L near the channel bed (below 9 m), suggesting sediment accumulation in the deeper zone. In contrast, surface concentrations remain very low, under 50 g/L, likely due to stronger surface currents maintaining sediment in suspension or transporting it downstream. The grain size distribution reveals coarse particles (~200 μm) at the water surface within the 0-0.4 m layer, followed by a band of 50-110 μm particles in the 0.4-5.7 m depth range. Below this, grain sizes drop below 50 μm, indicating the dominance of fine sediment between 5.7 m and 9 m. At depths greater than 9 m, particle size increases again to 140-180 μm, with the bed layer (~10 m) showing grain sizes of ~200 μm, indicative of bedload transport or deposition.

These results confirm a vertically stratified sediment structure at Sulina, with coarse sediment layers at both the surface and bed, and a mid-column zone dominated by finer particles, shaped by local hydrodynamic conditions and channel morphology.

Statistical analysis of the sediment profile and transport dynamics

The Sulina branch, the only fully regulated and navigable channel of the Danube River in the Danube Delta, plays a key role in sediment transport and hydrodynamics. To assess sediment behavior along this branch, acoustic backscatter data from six stations were analyzed using Python. The analysis included vertical profiling of particle size and suspended sediment concentration (SSC), inter-station statistical comparisons, grain-size-based sediment classification (clay, silt, sand), and transport indicators such as cumulative mass and near-bed concentration, collectively offering insights into sediment distribution, flow intensity, and transport dynamics shaped by both natural and engineered conditions. Figure 12 presents overlaid line plots representing the vertical variation in particle size (μm) and suspended sediment concentration (g/l) for all six stations.

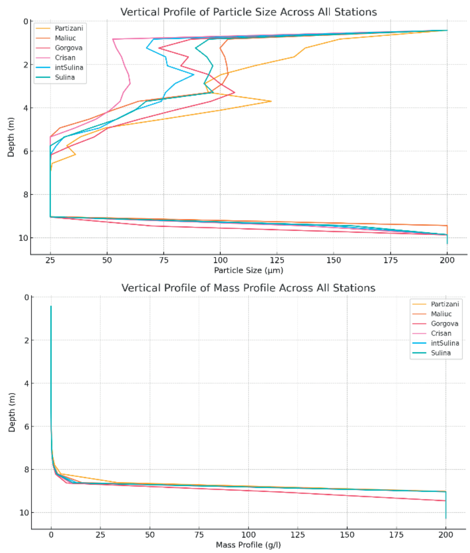

Figure 12. Vertical profiles of (a) particle size and (b) suspended sediment concentration (mass profile) across all six stations along the Sulina branch of the Danube River

Depth profiles are shown from surface to near-bed, revealing structural layering of sediment. Particle size tends to be coarser near the surface and bed, while SSC peaks at greater depths, especially below 8 m, where near-bed resuspension is evident. The vertical separation between size and concentration layers reflects complex sediment transport regimes influenced by both turbulence and flow regulation. Partizani and Crișan show the most pronounced layering, suggesting localized energy gradients or bedload interactions.

To evaluate sediment variability along the Sulina branch, descriptive and inferential statistics were computed for each station, including measures of central tendency, dispersion, and depth correlations for both particle size and suspended sediment concentration (SSC). This statistical assessment offers insight into sediment heterogeneity, vertical structuring, and transport intensity under regulated flow conditions.

The results presented in Table 2 reveal that mean particle sizes ranged from approximately 63 to 90 µm, with highest variability observed at Partizani and Maliuc, suggesting greater sediment heterogeneity upstream. Suspended sediment concentrations (MP) exhibited large standard deviations and maximum values of 200 g/L at all stations, indicating the presence of high-density near-bed sediment layers.

Correlation analysis shows strong positive relationships between SSC and depth at all stations ($r \approx 0.64$-0.66, $p < 0.001$), consistent with typical stratified sediment profiles in energetic fluvial systems. In contrast, particle size-depth correlations were weaker and less consistent, reflecting more complex sediment sorting influenced by flow velocity gradients and local morphology. These statistical indicators support the presence of depth-dependent sediment stratification and highlight upstream-to-downstream shifts in sediment composition and concentration patterns along the Sulina branch. Classifying suspended sediments by grain size in our dataset allowed us to evaluate flow energy conditions, dominant sediment transport modes, and potential depositional environments along the Sulina branch.

Table 2. Statistical summary of suspended sediment parameters by station

Station	Mean Size (µm)	Std Size (µm)	Min Size (µm)	Max Size (µm)	Mean MP (g/l)	Std MP (g/l)	Min MP (g/l)	Max MP (g/l)	r(S,D)*	p(S,D)*	r(MP,D)*	p(MP,D)*
Partizani	90.23	64.08	25.00	200.00	33.67	74.39	0.0004	200.00	-0.224	0.2818	0.6637	0.0003
Maliuc	77.82	63.21	25.00	200.00	32.86	74.52	0.0002	200.00	-0.079	0.7074	0.6504	0.0004
Gorgova	74.71	55.15	25.00	200.00	29.10	68.37	0.0007	200.00	-0.173	0.4095	0.6398	0.0006
Crișan	62.90	56.93	25.00	200.00	32.59	74.60	0.0015	200.00	0.104	0.6224	0.6457	0.0005
Int. Sulina	71.09	56.86	25.00	200.00	32.74	74.55	0.0006	200.00	-0.006	0.9784	0.6483	0.0005

*D - Water column depth or depth; MP - mass profile or concentration sediment particles; S - Size of the sediment particles.

Given the high-energy, regulated nature of this channel, we used standard granulometric thresholds - clay (<4 µm), silt (4-63 µm), and sand (>63 µm) - to distinguish between suspended, wash load, and bedload transport regimes.

Based on the measured particle size values at each depth, we categorized sediment samples into these three classes. For each station, we calculated the percentage contribution of clay, silt, and sand within the water column, enabling a clear assessment of the dominant sediment fractions and their vertical distribution across the branch. The results can be seen in Table 3.

The results confirm that sand-sized particles dominate the suspended load at all stations (>89%), indicative of a high-energy, turbulent regime capable of mobilizing and suspending coarse material. The low clay and silt content further suggests that fine sediments are either scoured or flushed downstream, consistent with the artificially regulated and navigable nature of the Sulina branch.

Table 3. Sediment classification by grain size

Station	Clay (%)	Silt (%)	Sand (%)
Partizani	1.52	4.55	93.94
Maliuc	1.52	4.55	93.94
Gorgova	1.52	7.58	90.91
Crișan	1.52	9.09	89.39
Int. Sulina	1.52	7.58	90.91

Slightly higher silt content at downstream stations may signal reduced turbulence or localized deposition zones, but these remain minor. To assess sediment mobility and deposition potential along the Sulina branch, we calculated three key indicators based on our data: cumulative sediment mass (g/l) as a proxy for total load, near-bed average suspended sediment concentration (SSC) to identify potential resuspension zones, and the correlation between particle size and SSC to evaluate the relationship between sediment coarseness and concentration. These metrics enabled comparative analysis between stations, highlighting differences in transport energy, vertical sediment structure, and the contribution of coarser particles to the suspended load (Tabel 4).

Table 4. Sediment transport indicators

Station	Cumulative Mass (g/l)	Near-Bed Avg MP (g/l)	Size-MP Correlation
Partizani	841.86	166.74	0.438
Maliuc	821.48	163.14	0.545
Gorgova	727.59	144.64	0.473
Crișan	814.66	161.98	0.604
Int. Sulina	818.41	162.61	0.558

The upstream stations Partizani and Maliuc register the highest cumulative sediment loads, likely due to greater sediment input or upstream scouring. Near-bed concentrations exceeding 160 g/l across all stations confirm the presence of dense sediment layers at depth, characteristic of bedload interaction or resuspension zones. Moreover, the moderate-to-strong positive correlations (r = 0.44-0.60) between particle size and SSC suggest that coarser particles are frequently suspended when concentrations are high, pointing to intense turbulent mixing and localized energy peaks within the flow.

CONCLUSIONS

This study provided a detailed assessment of suspended sediment dynamics along the Sulina branch, the only fully regulated and navigable distributary of the Danube River. Using high-resolution acoustic backscatter data from six monitoring stations, we analyzed vertical profiles of suspended sediment concentration (SSC) and particle size, supported by statistical classification and transport indicators.

The results revealed a clear vertical stratification of sediments, with SSC peaking near the riverbed (often exceeding 160 g/l) and particle sizes ranging from fine silts to coarse sands. Statistical analysis showed strong positive correlations between SSC and depth, confirming concentrated sediment layers at depth across all stations. In contrast, particle size showed more variable vertical patterns, suggesting localized flow effects.

Sediment classification based on grain size demonstrated a clear dominance of sand (>63 µm) at all stations, consistent with the high-energy, engineered channel environment. Fine sediment fractions (clay and silt) were minimal, indicating efficient downstream flushing and limited deposition zones.

Transport indicators further supported these findings, with upstream stations exhibiting higher cumulative sediment loads, and moderate to strong correlations between particle size and SSC indicating the frequent suspension of coarse material under energetic flow conditions.

Together, these analyses confirm that the Sulina branch functions as a high-capacity sediment transport corridor, where flow regulation enhances both sediment throughput and vertical stratification. The findings have important implications for navigation management, dredging operations, and understanding sedimentary processes in modified deltaic systems.

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REFERENCES

Arseni, M., Rosu, A., Calmuc, M., Calmuc, V. A., Iticescu, C., & Georgescu, L. P. (2020). Development of flood risk and hazard maps for the lower course of the Siret River, Romania. *Sustainability, 12*(16), 6588. https://doi.org/10.3390/su12166588

Bux, J., Peakall, J., & Biggs, S. (2015). *In situ* characterisation of a concentrated colloidal titanium dioxide settling suspension and associated bed development. *Powder Technology.* https://www.sciencedirect.com/science/article/pii/S0032591015005604

Bux, J. (2016). *Novel characterisation of concentrated dispersions by in situ acoustic backscatter systems* [Doctoral thesis, University of Leeds]. White Rose eTheses Online. https://etheses.whiterose.ac.uk/id/eprint/14306/

Călmuc, M., Călmuc, V. A., Arseni, M., Simionov, I. A., Antache, A., Apetrei, C., & Georgescu, P. L. (2022). Identification and characterization of plastic particles found in the Lower Danube River. *Scientific Papers. Series E. Land Reclamation.* https://landreclamationjournal.usamv.ro/pdf/2022/Art40.pdf

Divinsky, B. V., & Kosyan, R. D. (2019). Bottom sediment suspension under irregular surface wave conditions. *Oceanology, 59*(4), 482–490. https://doi.org/10.1134/S0001437019040039

Falciola, L., Ancona, V., Zlati, M. L., Georgescu, L. P., Iticescu, C., Ionescu, R. V., & Antohi, V. M. (2022). New approach to modelling the impact of heavy metals on the European Union's water resources. *International Journal of Environmental Research and Public Health, 20*(1), 45. https://doi.org/10.3390/ijerph20010045

Foote, K., & Martini, M. A. (2010). Standard-target calibration of an acoustic backscatter system. In *OCEANS 2010 MTS/IEEE Seattle*. IEEE. https://ieeexplore.ieee.org/abstract/document/5664362/

Fromant, G., Le Dantec, N., & Perrot, Y. (2021). Suspended sediment concentration field quantified from a calibrated MultiBeam EchoSounder. *Applied Acoustics.* https://www.sciencedirect.com/science/article/pii/S0003682X21002000

Fromant, G., Floc'h, F., Lebourges-Dhaussy, A., Jourdin, F., Perrot, Y., Le Dantec, N., & Delacourt, C. (2017). In situ quantification of the suspended load of estuarine aggregates from multifrequency acoustic inversions. *Journal of Atmospheric and Oceanic Technology, 34*(8), 1703–1717. https://journals.ametsoc.org/view/journals/atot/34/8/jtech-d-16-0079.1.xml

Hunter, T., Biggs, S., & Peakall, J. (2010). An acoustic backscatter system (ABS) for the characterisation of legacy waste dispersions. In *DIAMOND Annual Conference*. https://www.researchgate.net/publication/267684290

Hunter, T., Biggs, S., Young, J., Fairweather, M., & Peakall, J. (2011). Ultrasonic techniques for the in situ characterization of nuclear waste sludges. In *WM Symposia*. https://archivedproceedings.econference.io/wmsym/2011/papers/11275.pdf

Hunter, T., Darlison, L., Peakall, J., & Biggs, S. (2012a). Using a multi-frequency acoustic backscatter system as an in situ high concentration dispersion monitor. *Chemical Engineering Science.* https://www.sciencedirect.com/science/article/pii/S0009250912003946

Hunter, T., Peakall, J., & Biggs, S. (2012b). An acoustic backscatter system for in situ concentration profiling of settling flocculated dispersions. *Minerals Engineering.* https://www.sciencedirect.com/science/article/pii/S0892687511004298

Hussain, S. T., Hunter, T. N., Peakall, J., & Barnes, M. (2020). Utilisation of underwater acoustic backscatter systems to characterise nuclear waste suspensions remotely. *Proceedings of Meetings on Acoustics, 40*(1), 070005. https://doi.org/10.1121/2.0001303

Iticescu, C., Murariu, G., Georgescu, L. P., Burada, A., & Topa, C. M. (2016). Seasonal variation of the physico-chemical parameters and Water Quality Index (WQI) of Danube water in the transborder Lower Danube area. *Revista de Chimie, 67*(9), 1772–1779. http://bch.ro/pdfRC/ITICESCU%20C%209%2016.pdf

Lazăr, N. N., Simionov, I. A., Petrea, Ș. M., Iticescu, C., Georgescu, P. L., Dima, F., & Antache, A. (2024). The influence of climate changes on heavy metals accumulation in *Alosa immaculata* from the Danube River Basin. *Marine Pollution Bulletin, 200,* 116145. https://doi.org/10.1016/j.marpolbul.2024.116145

Martini, M. A., & Foote, K. G. (2010). Measurements of echo stability of an acoustic backscatter system. In *OCEANS 2010 MTS/IEEE Seattle*. IEEE. https://ieeexplore.ieee.org/abstract/document/5664356/

Popa, P., Murariu, G., Timofti, M., & Georgescu, L. P. (2018). Multivariate statistical analyses of water quality of Danube River at Galati, Romania. *Environmental Engineering and Management Journal.* https://www.researchgate.net/publication/307955477

Smerdon, A. M., & Thorne, P. D. (2008). A coastal deployment of a commercial multiple frequency acoustic backscatter sediment profiler. https://nora.nerc.ac.uk/id/eprint/6491/

Van Dijk, T. A. G. P., Roche, M., Lurton, X., Fezzani, R., Simmons, S. M., Gastauer, S., Mesdag, C., Berger, L., Klein Breteler, M., & Parsons, D. R. (2024). Bottom and suspended sediment backscatter measurements in a flume—Towards quantitative bed and water column properties. *Journal of Marine Science and Engineering, 12*(4), 609. https://doi.org/10.3390/jmse12040609

Zhu, Q., Xing, F., Wang, Y. P., Syvitski, J., Overeem, I., Guo, J., Li, Y., Tang, J., Yu, Q., Gao, J., & Gao, S. (2024). Hidden delta degradation due to fluvial sediment decline and intensified marine storms. *Science Advances, 10*(18), eADK1698. https://doi.org/10.1126/sciadv.adk1698