

Supplementary Information

Supplementary Table 1

Summary of RTK-GNSS-surveyed aluminium benchmark plates (n = 15) installed across Paull Holme Strays in 2023 to evaluate LiDAR vertical accuracy and temporal stability.

Benchmark ID	Elevation Zone	Surface Type	RTK Change 2024→2025 (cm)	LiDAR Change 2024→2025 (cm)
Plate 01	Low	Bare mud	+0.5	+0.8
Plate 02	Low	Bare mud	-0.9	-2.0
Plate 03	Low	Sparse veg	+0.3	+1.0
Plate 04	Mid	Bare mud	+0.7	+1.5
Plate 05	Mid	Sparse veg	0.1	-2.0
Plate 06	Mid	Sparse veg	+0.2	+1.3
Plate 07	High	Bare mud	0.8	+2
Plate 08	High	Dense veg	+0.1	+1.0
Plate 09	High	Dense veg	-0.3	-1.8
Plate 10	Low	Mudflat	0.0	+1.2
Plate 11	Mid	Dense vegetation	+0.2	-1.0
Plate 12	High	Vegetated	0.0	+1.1
Plate 13	Mid	Bare mud	+2.1	+2.0
Plate 14	Low	Bare mud	-0.5	-1.1
Plate 15	High	Dense veg	+0.3	-1.1

Supplementary Figure 1

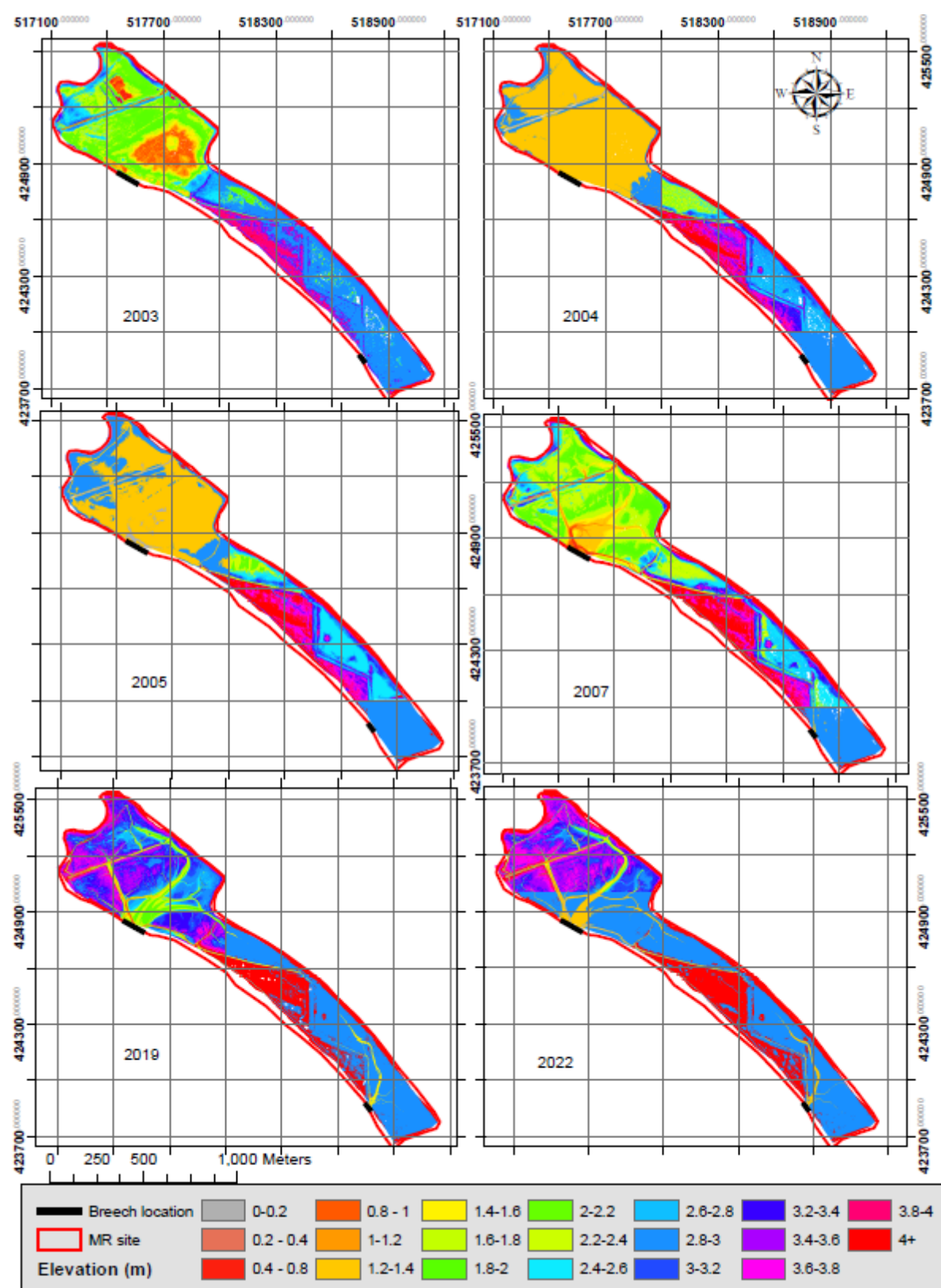


Figure S1. Cumulative elevation change (m) across Paull Holme Strays between 2003 and 2022 derived from Environment Agency LiDAR.

Note: Values reported as $<2 \times 10^{-16}$ are below the reporting precision of R.

Supplementary Table 2

Summary of generalized additive model results describing depth-dependent variation in bulk density, grain size, and sediment texture characteristics across elevation zones. Models were fitted using the *mgcv* package in R (v4.3.2). Statistical significance of smooth terms was assessed using approximate F-tests within the GAM framework. All tests were two-sided and no adjustment for multiple comparisons was applied. Exact p-values are reported where available.

Variable	Zone	edf	F	p-value	Depth trend
Bulk density	High	7.50	8.74	$<2 \times 10^{-16}$	Peaks near surface, then declines
	Mid	5.03	3.12	0.004426	Declines with depth
	Low	6.08	5.84	9.53×10^{-7}	Declines with depth
	Ref	2.45	3.68	0.010361	Slight decline
Grain size	High	3.77	8.65	5.83×10^{-7}	Gradual decline
	Mid	8.47	82.9	$<2 \times 10^{-16}$	Strong vertical structuring
	Low	2.91	7.04	3.33×10^{-5}	Coarser near surface
	Ref	2.44	1.73	0.144	Stable
Sand	High	6.45	4.37	5.12×10^{-5}	Nonlinear
Silt	Mid	10.65	6.82	0.00027	Nonlinear
Clay	High	8.95	3.72	5.62×10^{-5}	Nonlinear
	Mid	6.79	2.96	0.00205	Nonlinear

Supplementary Table 3

Summary of generalized additive models describing variation in total organic carbon, labile organic carbon and recalcitrant organic carbon with sediment depth and elevation zone. Statistical significance of parametric terms was assessed using t-tests and significance of smooth terms was assessed using approximate F-tests. All tests were two-sided and no adjustment for multiple comparisons was applied. Exact p-values are reported where available.

Model	Formula	Adjusted R ²	Deviance Explained (%)	Edf Range	F Range	p-value	K index	Concurvity (max)
Total OC	OC ~ s(depth, by = zone) + s(station, bs = 're')	0.631	65	2.9–5.9	12.06–45.12	$<2 \times 10^{-16}$	0.92	0.31
Labile OC	Labile_OC ~ s(depth, by = zone) + s(station, bs = 're')	0.962	96.4	9.7–12.5	15.2–42.6	4.06×10^{-7}	0.95	0.27
Recalcitrant OC	Recalcitrant_OC ~ s(depth, by = zone) + s(station, bs = 're')	0.822	83.3	8.1–11.9	7.9–21.3	2.03×10^{-13}	0.97	0.33
Drivers OC	OC ~ s(depth, by = zone) + s(bulk_density) + s(grain_size)	0.62	64.0	1.3–8.9	3.7–18.4	$<2 \times 10^{-16}$	0.93	0.4

Supplementary Table 4

Parametric coefficient estimates from the generalized additive model explaining variation in organic carbon content. Statistical significance was assessed using two-sided t-tests. Exact p-values are reported where available.

Term	Estimate	Standard Error	t value	p-value
(Intercept)	3.23908	0.07088	45.698	$<2 \times 10^{-16}$
zoneLow	-0.76749	0.09244	-8.302	$<2 \times 10^{-16}$
zoneMid	-0.59250	0.09015	-6.573	6.76×10^{-11}
zoneRef	-0.24340	0.14082	-1.728	0.0841

Supplementary Table 5

Smooth-term summaries from the generalized additive model explaining variation in organic carbon content. Statistical significance of smooth terms was assessed using approximate F-tests. All tests were two-sided and no adjustment for multiple comparisons was applied.

Smooth Term	edf	Ref df	F	p-value
s(depth)	3.055	3.562	2.095	0.0837
s(depth,zone)	11.797	76.000	1.243	3.27×10^{-6}
s(Bulk.density):zoneHigh	1.000	1.000	2.360	0.1246
s(Bulk.density):zoneLow	2.396	3.098	3.448	0.0153
s(Bulk.density):zoneMid	2.150	2.790	1.093	0.3856
s(Bulk.density):zoneRef	1.540	1.904	1.103	0.4077
s(Grain.size):zoneHigh	1.000	1.000	0.652	0.4197
s(Grain.size):zoneLow	1.000	1.000	2.428	0.1194
s(Grain.size):zoneMid	1.946	2.456	0.898	0.3844
s(Grain.size):zoneRef	1.000	1.000	0.349	0.5549