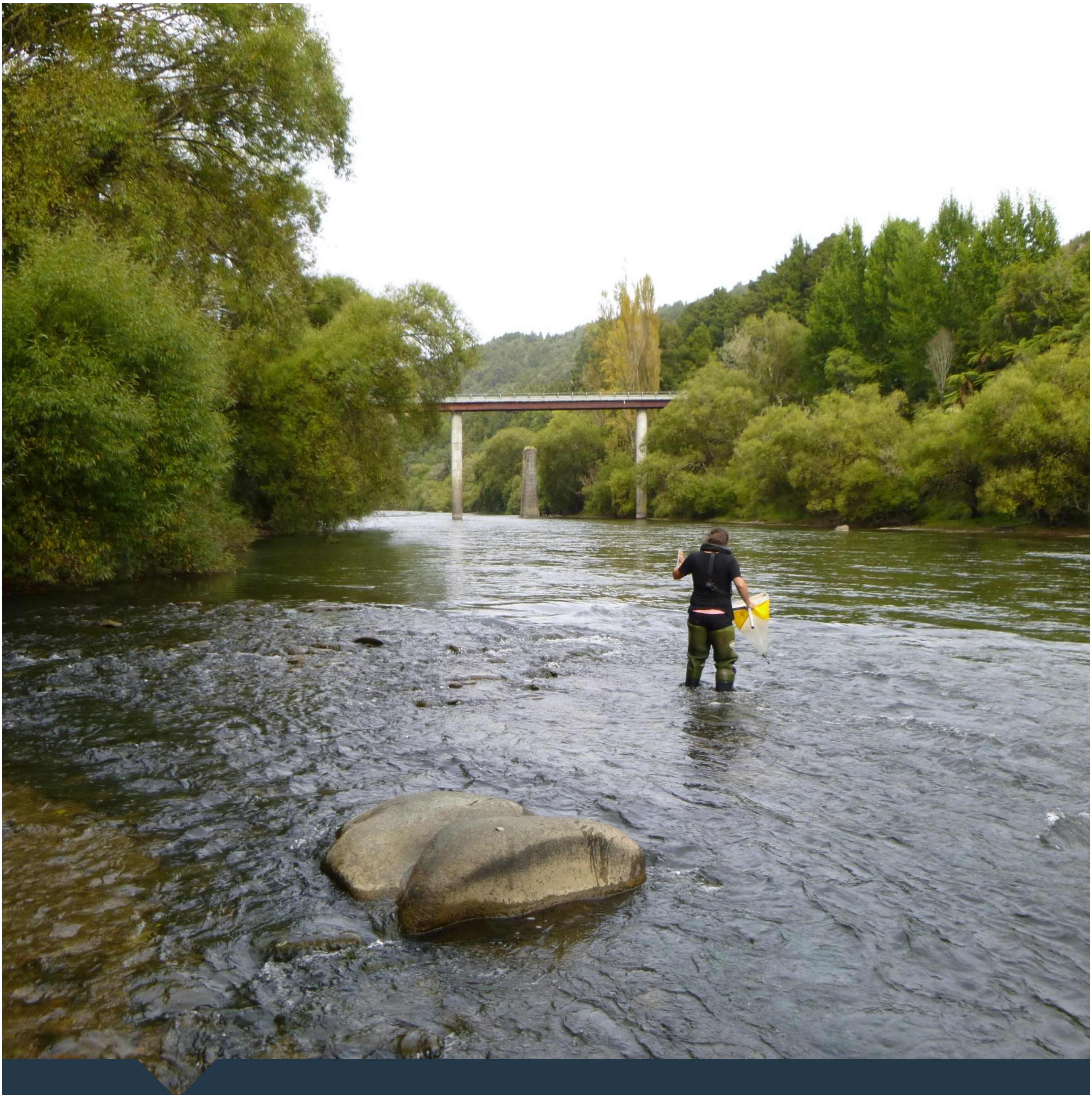

Manawatū Estuary
2026 broad-scale intertidal habitat mapping

June 2026

horizons REGIONAL COUNCIL

Prepared for:

Mike Patterson
Science Manager

June 2026
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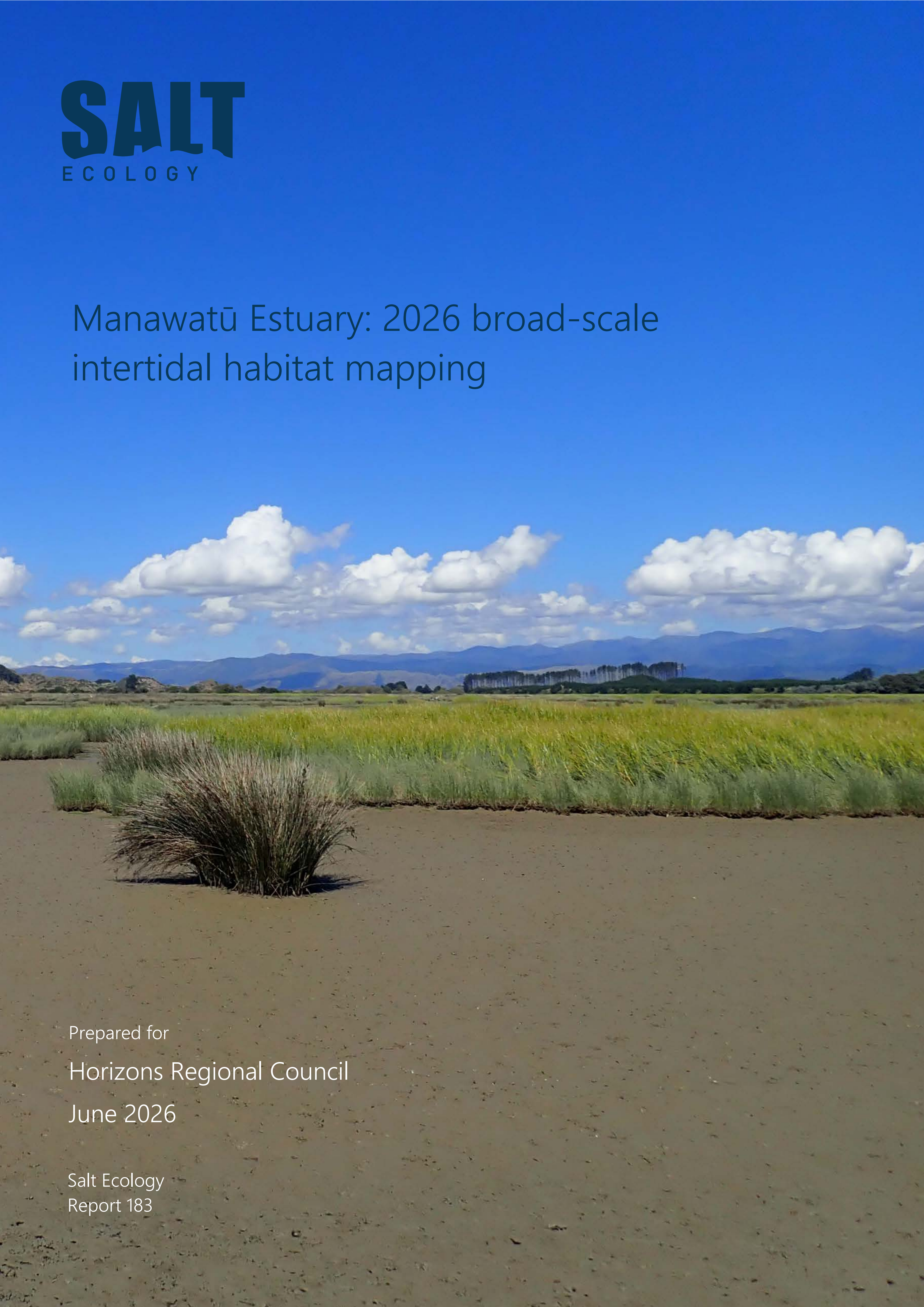

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ECOLOGY

Manawatū Estuary: 2026 broad-scale intertidal habitat mapping

Prepared for

Horizons Regional Council

June 2026

Salt Ecology
Report 183

Cover photo: Manawatū salt marsh including sea rush (*Juncus kraussii*), three square (*Schoenoplectus pungens*) and Caldwell's clubrush (*Bolboschoenus caldwellii*), January 2026.

All photos presented in the report are from the January 2026 survey unless specified otherwise.

RECOMMENDED CITATION

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For the environment
Mō te taiao

GLOSSARY

AA	Affected Area (OMBT metric)
AIH	Available Intertidal Habitat (OMBT metric)
aRPD	Apparent Redox Potential Discontinuity
CSR	Current Sedimentation Rate
DO	Dissolved Oxygen
EQR	Ecological Quality Rating (OMBT metric)
ETI	Estuary Trophic Index
HEC	High Enrichment Conditions
HRC	Horizons Regional Council
LCDB	Land Cover Data Base
NEMP	National Estuary Monitoring Protocol
NSR	Natural Sedimentation Rate
OMBT	Opportunistic Macroalgal Blooming Tool
QA/QC	Quality Assurance/Quality Control
SOE	State of the Environment (monitoring)
SSRTRE	Shallow, Short Residence-time Tidal River Estuary
TN	Total Nitrogen

ACKNOWLEDGEMENTS

Many thanks to Caitlin Wheeler of Horizons Regional Council (HRC) for reviewing the draft report. The tools used to QA/QC the GIS data and produce summaries and maps were developed by Megan Southwick of Salt Ecology.

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SUMMARY

In January 2026, broad-scale intertidal habitat mapping was undertaken in Manawatū Estuary, one of several estuaries in Horizons Regional Council's (HRCs) long-term State of the Environment (SOE) monitoring programme. This report describes dominant intertidal substrate (e.g., mud-elevated sediments) and vegetation (e.g., macroalgae, salt marsh), and compares findings with 2016 data. Key results are summarised below, and assessed against condition rating criteria in the table.

- Manawatū Estuary has high ecological values, but is degraded relative to most other estuaries in the region due to large areas of muddy sediment, and large historical losses of salt marsh and margin modification.
- Salt marsh extent was rated 'Very Good' in 2026 and comprised 57.8ha (49% of the intertidal area), consistent with 2016 results. The small apparent decline reflects more accurate mapping in 2026. Widespread hardened margins restrict landward migration of salt marsh in response to sea-level rise, which will result in future losses if space for passive or managed retreat is unavailable.
- Mud-elevated substrate (≥25% mud) was rated 'Very Poor' in 2026 and covered 70.3ha (48.5% of the Available Intertidal Habitat - AIH). There has been no meaningful change since the 2016 baseline (rated 'Very Good').
- Macroalgae was very sparse (0.38ha), and classified as absent or at trace levels (<1% cover) over 99.7% of the AIH. The OMBT EQR (0.999), and absence of High Enrichment Conditions, were both rated 'Very Good'. Although elevated nutrient inputs make the estuary highly susceptible to macroalgal blooms, physical factors appear to limit growth, i.e., high flow-speeds, flood-scouring, low salinities, high turbidity, rapid flushing.

Broad-scale indicators	Unit	2016*	2026
200m terrestrial margin	% densely vegetated	44	39
Salt marsh	% of intertidal area	56	49
	% loss from baseline	baseline	6%
	% loss from historic baseline[3]	Estimated >50%	Estimated >50%
Mud-elevated substrate	% AIH[1] area (≥25% mud)	53.3	48.5
	% increase from baseline in AIH	baseline	9.0(↓)
Macroalgae (OMBT-EQR[2])	Ecological Quality Rating (EQR)	0.985	0.999
High Enrichment Conditions	ha	0	0
Estuary-wide indicators[4]			
Sedimentation rate	CSR:NSR[5] ratio	-	2.3
Sedimentation rate	mm/yr	-	5.9

[1]Available Intertidal Habitat excludes salt marsh area; [2]Opportunistic Macroalgal Blooming Tool (OMBT) scores have been updated following QA/QC; [3]Natural extent estimate based on expert opinion; [4] Estuary-wide sedimentation indicators derived from catchment models (e.g., Hicks et al. 2019). [5]CSR=Current Sedimentation Rate, NSR=Natural Sedimentation Rate. dash=no data. *Existing GIS layers QA/QC checked in 2026 - values may differ slightly from original reports.

Very Good	Good	Fair	Poor	Very Poor

RECOMMENDATIONS

Monitoring

- Continue 10-yearly broad-scale monitoring to track major changes in habitat and pressures on the estuary.
- Conduct an annual visual check for conspicuous changes in mud extent, macroalgae, vehicle tracks, reclamation.

Management

- Continue ongoing efforts characterising catchment sediment and nutrient loads, and initiate targeted reductions where required.
- Develop an estuary restoration strategy for the managed retreat of salt marsh under sea-level rise where landform, hydrology, and land-use allow for salt marsh migration or re-establishment.

1. INTRODUCTION

Estuary monitoring is undertaken by most councils in Aotearoa New Zealand as part of their State of the Environment (SOE) programmes. The most widely-used monitoring framework is that outlined in a National Estuary Monitoring Protocol (Roberts et al. 2025b; Stevens et al. 2025). The NEMP is intended to provide resource managers with a scientifically defensible, cost-effective and standardised approach for monitoring the ecological status of estuaries in their region. The results establish a benchmark of estuarine health in order to better understand human influences, and against which future comparisons can be made. The NEMP approach involves two main types of survey:

- Broad-scale mapping of estuarine intertidal habitats - typically undertaken every 5 to 10 years.
- Fine-scale monitoring of estuary biota and sediment quality - typically conducted at 2-3 fixed sites in the dominant habitat of the estuary and commonly repeated at intervals of ~5 years after initially establishing a multi-year baseline.

The approaches are primarily intended to detect changes in habitat type (e.g., salt marsh or seagrass extent), delineate eutrophication symptoms (such as prolific macroalgal growth, organic enrichment, and anoxia), as well as assess changes within habitats from the input of nutrients, fine muds, and contaminants (e.g., metals pesticides), all of which are key drivers of degraded sediment condition.

Fig. 1. Manawatū Estuary at Foxton Beach, including the location of two fine-scale monitoring sites.

Horizons Regional Council (HRC) has undertaken SOE monitoring of selected estuaries in the region since 2016, with key west coast locations being Whanganui, Whangaehu, Rangitīkei, Manawatū, Ōhau, and Waikawa, and east coast locations being Tautāne, Wainui, Ākitio and Owāhanga. Smaller estuaries have been captured in region-wide assessments (Robertson & Stevens 2016; Roberts et al. 2025a).

In Manawatū Estuary (hereafter Manawatū), broad-scale NEMP monitoring commenced in 2016 (Stevens & Robertson 2016), and fine scale monitoring in 2017 (Robertson & Stevens 2017). The current report describes the methods and results of repeat intertidal broad-scale monitoring in Manawatū (Fig. 1), undertaken between 23-28 January 2026. The main purpose of the work was to characterise substrate, salt marsh, and the presence and extent of any seagrass or macroalgae, and to compare findings to the 2016 survey. As the field work required the use of a small boat, we also took the opportunity to collect some synoptic water quality measurements while moving among locations, adding to the knowledge gained in previous work.

2. OVERVIEW OF MANAWATŪ ESTUARY

Background information on Manawatū has been presented in previous reports (Robertson & Stevens 2016; Stevens & Robertson 2016; Roberts et al. 2025a), with this information summarised and added to below.

Manawatū is a large (470ha), shallow, short residence-time tidal river estuary (SSRTRE) that borders Foxton. The estuary mouth is always open to the sea and a tidal influence has been estimated to intrude 11-20km upstream (Robertson & Stevens 2016; Todd et al. 2016). The upper estuary is characterised by low salinity waters largely confined within defined river channels flanked by narrow bands of predominantly brackish aquatic plants, then pasture. In contrast, the middle and lower reaches have wide intertidal flats.

Despite extensive historical drainage and reclamation the estuary supports large areas of salt marsh, is a 'Site of Significance - Riparian', and is also classified as a Ramsar site, recognised internationally as an important wetland habitat and for its diverse bird population (Todd et al. 2016). Recreational use is high. Popular activities include walking, swimming, boating, fishing, duck shooting, whitebaiting, and birdwatching. Vehicle use in the lower estuary, beach & dune is also common.

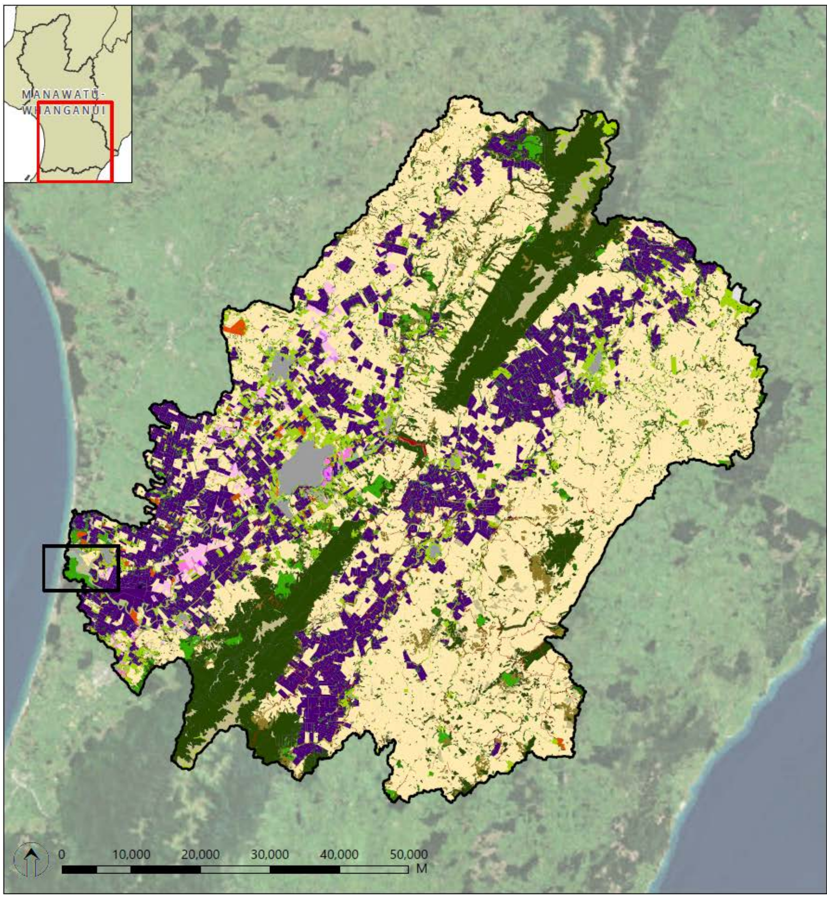
The river and/or estuary's hydrology have been modified by hydroelectric power, water abstraction, stormwater inputs, stopbanks, and drainage channels; however, the most significant change has been the creation of a flood control channel, the Whirokino Cut, completed in 1943 that bypassed a 7km loop of the lower river (the Foxton Loop), inadvertently cutting off and silting up the harbour. Historical data suggests that increased sediment has also altered the river course and the extent of the mud flats since the 1950's (Todd et al. 2016), with the river mouth variably migrating southward due to prevailing wave and wind conditions, and returning to the north under flood conditions.

Sheep and beef farming are the dominant catchment land uses (Fig. 2), with dairying also prominent, and exotic forestry present on the estuary margin. Several riverside towns are located in the catchment, including Dannevirke, Pahīatua, Eketāhuna, Woodville, Foxton and Palmerston North, the region's largest town.

Due to these upstream pressures, the estuary has high nutrient, sediment, and bacterial inputs (e.g., *E. coli*) with current water quality monitoring for these indicators in the Manawatū River rating it as 'Poor' (lawa.org.nz). Despite the urban presence in the catchment, estuary trace metal concentrations appear low (Forrest et al. 2026).

Based on its nutrient concentrations, Plew (2024) identified the estuary as vulnerable to macroalgal blooms, however physical scouring and the high flushing potential of the river appear to limit macroalgae establishment and persistence.

Lands & Survey map showing Manawatū River in 1929 prior to the Whirokino Cut, completed in 1943, that bypassed 7km of the lower river. Sourced from https://www.mapspast.org.nz/



Catchment Land Use*	ha	%
Built up area (urban)	7,470.3	1.3
Transport corridor	12,345.2	2.1
Non vegetated surfaces	5,033.8	0.9
Orchard or vineyard	135.6	0.02
Cropping (vegetable farms)	870.7	0.1
Cropping (horticulture/ lifestyle block)	733.2	0.1
Cropping (livestock farms)	5,026.4	0.9
Cropping (other land uses)	121.8	0.02
Pasture (sheep, beef and/or deer)	285,600.0	48.6
Pasture (dairy)	111,321.9	18.9
Pasture (specialist livestock)	2,062.5	0.4
Pasture (arable operations)	3,237.7	0.6
Grassland (low producing)	30,148.7	5.1
Exotic Forestry (commercial)	6,728.3	1.1
Exotic Forestry (other)	13,718.3	2.3
Mānuka and/or kānuka	10,206.1	1.7
Scrub & woody vegetation	12,715.0	2.2
Native forest	79,673.6	13.6
No data	450.4	0.1
TOTAL	587,599.5	100.0

*Land use data sourced from Horizons Regional Council's land-use mapping project (Herzig et al. 2020).

Fig. 2. Manawatū Estuary catchment land use classifications from HRC. Catchment boundary from CLUES (10.8).

3. METHODS

3.1 OVERVIEW

Broad-scale mapping of substrate and vegetation was carried out between 23-28 January 2026. Fig. 4 (next page) shows the estuary area surveyed. The survey approach and indicators are summarised below and in Table 1, with further detail of sampling methods and analyses provided in Appendix 1.

3.2 BROAD SCALE HABITAT MAPPING

Broad-scale mapping characterised the dominant intertidal substrates and vegetation types (Table 1), with the spatial extent and location of different habitat types, and temporal changes in features, providing valuable indicators of estuary condition. Mapping was based on updated NEMP methods (Roberts et al. 2025b), and additions by Salt Ecology described in Appendix 1.

The approach combined the use of aerial imagery, detailed field ground-truthing (e.g., annotation of aerial images, spot data on macroalgae and substrate type, and field photos), and post-field digital mapping using Geographic Information System (GIS) technology. Imagery used was ~0.3m/pixel resolution Manawatū Whanganui rural colour imagery flown by LINZ in 2022.

In 2026, QA/QC procedures described in Appendix 1, were applied through the phases of field data collection, digitising, and GIS data collation and processing. QA/QC procedures were also applied to existing GIS layers for 2016, with field codes, slivers, gaps, and overlapping polygons updated following the guidance provided in Roberts et al. (2025). These data have been provided to HRC as a separate electronic output, with updated summary data presented in the current report.

The main broad-scale survey elements were as follows:

- Substrate mapping qualitatively classified sediments (e.g., mud, sand, gravel, cobble, bedrock) according to the scheme described in Table A1.2 of Appendix 1. As mud is a key stressor on estuary habitats, an important focus was to map the spatial extent of soft-sediment (mud and sand), with validation samples collected for quantitative laboratory analyses of grain size at 10 locations, including the two fine scale monitoring sites (Appendix 2).
- Vegetation mapping characterised dominant features, namely salt marsh (e.g., rushland, herbfield, estuarine scrub) and seagrass (*Zostera muelleri*) where present, and also described the occurrence and extent of algae species that can be symptomatic of estuary degradation. Particularly important among the latter were nuisance 'opportunistic' macroalgae that can 'bloom' in response to conditions such as excess nutrient inputs (e.g., species of *Ulva* and *Gracilaria*).

To assist with percent cover estimates of seagrass and opportunistic macroalgae (when present), NEMP visual rating scales and field guides, as shown in Fig. 3, were used. For macroalgae, field data collection also included wet-weighing of macroalgal biomass, to enable calculation of Opportunistic Macroalgal Blooming Tool (OMBT) scores. The OMBT is a multi-metric index that combines different measures of opportunistic macroalgal proliferation to inform ecological condition (see Table 1; Appendix 1; WFD-UKTAG 2014; Stevens et al. 2022).

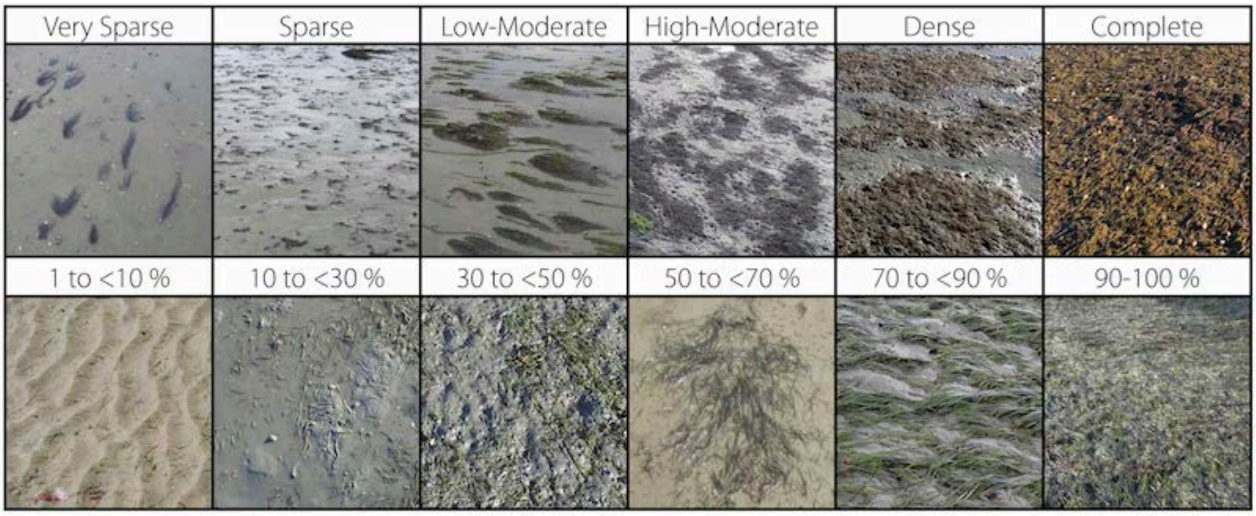


Fig. 3. Visual rating scale for % cover estimates of macroalgae and seagrass. Modified from FGDC (2012).

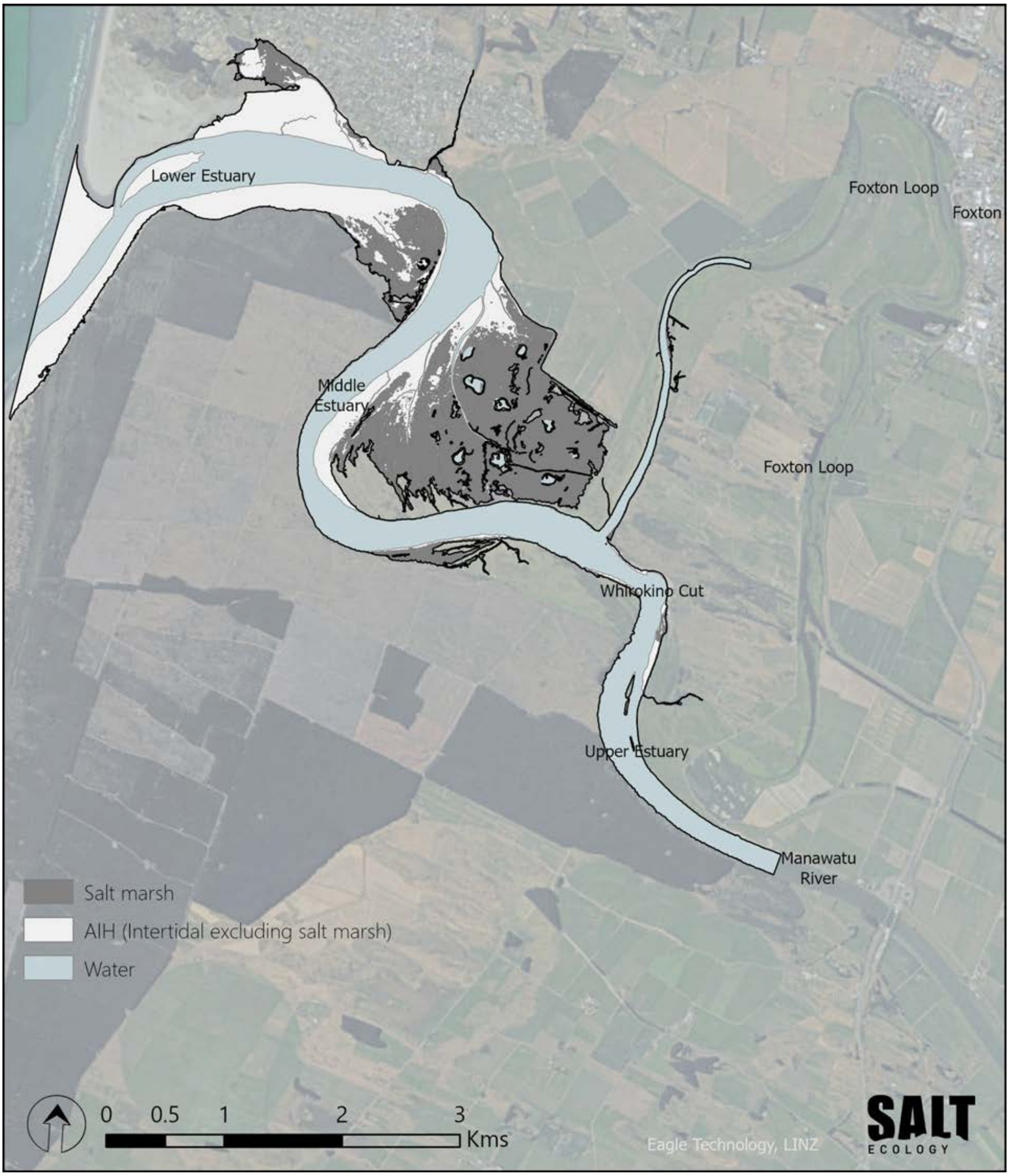


Fig. 4. Estuary survey area, defined by the area within the black outline. The location of sediment validation samples is shown in Appendix 2.

Manawatū River entrance, January 2026.

Table 1. Broad scale indicators of estuary condition that are assessed by field mapping and related methods.

Indicator	General rationale	Method description
Terrestrial margin vegetation	A densely vegetated terrestrial margin filters and assimilates sediment and nutrients, is a buffer to introduced grasses and weeds, is an important food source and habitat for a variety of species and, in waterway riparian zones, provides shade that moderates stream temperature fluctuations, and improves estuary biodiversity.	Mapped based on areal extent and classified using the LCDB5 classes, dominant species are also recorded as metadata where known.
Substrate type	High substrate heterogeneity generally supports high estuary biodiversity. Increases in fine sediment (i.e., mud <63µm) can reduce heterogeneity, concentrate contaminants, nutrients and organic matter, and lead to degradation of benthic communities by displacing sensitive species including shellfish. Enrichment of muddy sediments (i.e., high TOC and nutrients; Table 2) can additionally fuel algal growth and deplete sediment oxygen.	Mapped based on areal extent and classified using a modified version of the NEMP system (see Table A1.2, Appendix 1). The improved classification framework, developed by Salt Ecology, characterises substrate type based on mud content and is supported by grain size validation samples. Substrate type is also recorded beneath vegetation.
Salt marsh	Salt marsh (vegetation able to tolerate saline conditions where terrestrial plants are unable to survive) is important in estuaries as it is highly productive, naturally filters and assimilates sediment and nutrients, mitigates shoreline erosion, and provides an important habitat for a variety of species including insects, fish and birds.	Mapped based on areal extent. Dominant salt marsh species are recorded and categorised into sub-classes (e.g., rushland, herbfield). Pressures on salt marsh (e.g., drainage, grazing, erosion) are also recorded.
Seagrass	Seagrass (*Zostera muelleri*) beds enhance primary production and nutrient cycling, stabilise sediments, elevate biodiversity, and provide nursery and feeding grounds for invertebrates and fish. Seagrass is vulnerable to muddy sediments in the water column (reducing light), sediment smothering (burial), excessive nutrients (primarily secondary impacts from macroalgal smothering), and sediment quality (e.g., low oxygenation).	Mapped based on areal extent, and percent cover recorded within each seagrass patch. Pressures on seagrass beds (e.g., sediment or macroalgae smothering, leaf discolouration) are also recorded.
Opportunistic macroalgae	Opportunistic macroalgae (primarily species of *Gracilaria* and *Ulva*) are a symptom of estuary eutrophication (nutrient enrichment). At nuisance levels, these algae can form mats on the estuary surface that can adversely impact underlying sediments and fauna, other algae, fish, birds, seagrass, and salt marsh. The Opportunistic Macroalgal Blooming Tool (OMBT) is a multi-metric index that combines different measures of macroalgae (see text) and is calculated as an indicator of ecological condition.	Mapped based on areal extent. Species, percent cover, biomass and level of entrainment are recorded in each macroalgae patch to apply the OMBT (WFD-UKTAG 2014). The application of the OMBT incorporates New Zealand-based improvements described in Stevens et al. (2022).
High Enrichment Conditions	HECs characterise substrates with extreme levels of organic or nutrient enrichment (i.e., eutrophication). HECs are sediments depleted in (or devoid of) oxygen, which have a very shallow redox boundary (e.g., <10mm), an intense black colour in the sediment profile, and typically have a strong hydrogen sulfide (i.e., rotten egg) smell. Sediment samples are likely to have a quantitatively high nutrient or organic content (e.g., TOC >2%).	Mapped based on areal extent. The HEC metric is intended to highlight areas of severe enrichment that may require further investigation, e.g., sediment degradation within stable, entrained, high (≥50% cover) beds of opportunistic macroalgae, or within extensive surface microalgae or filamentous macroalgae growths.

3.3 ASSESSMENT OF ESTUARY CONDITION

In addition to the authors' expert interpretation of the data and summaries, results are assessed against 'condition ratings' for estuary health (Table 2), which are based on recent work conducted for the Ministry for the Environment (Stevens et al. 2024). These metrics assign different indicators to one of five colour-coded 'health status' bands, as shown in Table 2.

Salt marsh and seagrass rely on assessment of differences between current and baseline state, or natural historical salt marsh extent, if known. Data from Stevens and Robertson (2016) were used as baseline state. To date, the natural historical extent of the estuary has not been quantified, but could be assessed through a combined review of historical imagery, maps and paintings, oral histories, land elevation (i.e., LiDAR data), and expert judgement.

Herbfield growing in sandy mud in the lower estuary.

Extensive beds of salt marsh grow in the middle estuary.

Channelised backwater of the Foxton Loop.

Table 2. Indicators and condition ratings used to assess results in the current report. See Glossary for definitions.

Indicator	Unit	Very Good	Good	Fair	Poor	Very Poor
Mapped indicators						
200m terrestrial margin[1]	% densely vegetated	≥80 to 100	≥50 to <80	≥25 to <50	≥10 to <25	<10
Salt marsh	% of intertidal area[1]	≥20	≥10 to <20	≥5 to <10	>0 to <5	≤0
	% loss from baseline[2]	≤0	>0 to <5	≥5 to <10	≥10 to <20	≥20
	% loss from historic baseline[2]	<20	≥20 to <40	≥40 to <60	≥60 to <80	≥80
Mud-elevated substrate	% AIH[3] ≥25% mud[1]	<1	≥1 to <5	≥5 to <15	≥15 to <25	≥25
	% increase from baseline[2] within AIH[3]	≤0	>0 to <5	≥5 to <10	≥10 to <20	≥20
Seagrass	% AIH[3] (≥1% cover)	---------------------------- No rating ----------------------------				
	% loss from baseline[2] (≥50% cover)	≤0	>0 to <5	≥5 to <10	≥10 to <20	≥20
Macroalgae	OMBT[4] Ecological Quality Rating	≥0.8 to 1.0	≥0.6 to <0.8	≥0.4 to <0.6	≥0.2 to <0.4	<0.2
High Enrichment Conditions[1,5]	ha	<0.5	≥0.5 to <5	≥5 to <20	≥20 to <50	≥50
	% of AIH[3]	<1	≥1 to <5	≥5 to <10	≥10 to <20	≥20
Modelled indicators[6]						
Mean sedimentation ratio[1]	CSR:NSR[7] ratio	1 to 1.1	>1.1 to <2	≥2 to <5	≥5 to <10	>10
Sedimentation rate	mm/yr	<0.5	≥0.5 to <1	≥1 to <2	≥2 to <10	≥10

Ratings taken from Stevens et al. (2024) except where noted below.

1. General guidance from previous reports (e.g., Stevens & Robertson 2014; Robertson et al. 2016a; Robertson et al. 2017).
2. First measured baseline. Historic baseline estimated using expert opinion and sources like imagery, LiDAR, maps, and photos.
3. AIH = Available Intertidal Habitat - refers to the intertidal area outside of salt marsh.
4. OMBT = Opportunistic Macroalgal Blooming Tool.
5. The worse of the two ratings is used for High Enrichment Conditions.
6. Estuary-wide sedimentation indicators derived from catchment models (e.g., Hicks et al. 2019).
7. CSR = Current Sedimentation Rate; NSR = Natural Sedimentation Rate.

4. BROAD-SCALE RESULTS

A summary of the January 2026 broad-scale mapping survey is provided below. Supporting GIS files have been supplied electronically to HRC, with ground-truthing tracks and the location of field photos shown in Appendix 2. As no intertidal seagrass or areas of High Enrichment Conditions (HECs) were recorded in either 2016 or 2026, these are not discussed further.

4.1 TERRESTRIAL MARGIN

Table 3 and Fig. 5 summarise the 200m terrestrial margin land cover surrounding the estuary. Overall, dense vegetative cover accounted for 38.5% of the 200m terrestrial margin in 2026 and is rated 'Fair'. The margin is dominated by low and high producing exotic grassland (45.9%), primarily non-irrigated livestock grazing. This includes many areas that would have historically supported wetland or salt marsh habitat but have subsequently been infilled and/or drained for conversion to pasture, and are separated from the estuary by stop-banks to prevent flooding. Rip-rap armouring to protect stop-banks from erosion is common (see photos opposite). Terrestrial drainage is maintained through a mix of flap-gated culverts and pumps which restrict natural hydrological flow and allow for very limited tidal exchange into areas that were historically inundated.

Table 3. Summary of 200m terrestrial margin land cover, Manawatū Estuary, January 2026.

LCDB Class		%Margin
1	Built-up Area (settlement)	7.1
2	Urban Parkland/Open Space	1.7
5	Transport Infrastructure	1.1
10	Sand or Gravel	4.7
12	Landslide	0.2
20	Lake or Pond	0.1
21	River	0.6
40	High Producing Exotic Grassland	15.2
41	Low Producing Grassland	30.7
410	Duneland	1.1
45	Herbaceous Freshwater Vegetation	2.0
51	Gorse and/or Broom	0.3
54	Broadleaved Indigenous Hardwoods	7.3
56	Mixed Exotic Shrubland	2.6
58	Matagouri or Grey Scrub	0.8
64	Forest - Harvested	11.1
68	Deciduous Hardwoods	1.0
71	Exotic Forest	12.3
Grand Total		100.0
Total dense vegetated margin (LCDB5 classes 45-71)		38.5

Drainage channels are common in areas historically connected to the estuary, with wetland and salt marsh displaced by pasture.

Rip-rap armouring of flood stop-banks is extensive along the true right of the lower estuary.

Exotic forest (23.4%) is also a prominent feature on the true left of the estuary with approximately half of this recently harvested. On the true right is the built-up urban settlement and parklands of Foxton Beach (8.8%), where seawalls are common along the foreshore. The small areas of remaining native vegetation largely comprise broadleaved indigenous hardwoods (7.3%).

Near the estuary entrance, the coastal dune system is dominated by bare sand and duneland species, including the native sand-binder *Spinifex sericeus*. Historically mobile and extensive, the dunes have been stabilised over time through the introduction of exotic species, in particular marram grass and tree lupin, and the establishment of plantation pine forest.

The underlying sands remain prone to erosion, with historical changes in the location of the river channel previously documented by Woods and Kennedy (2008). In 2026, steep and eroding dune faces caused by river channel migration remain evident downstream of the Foxton Loop and opposite Fernbird Flat, with changes to these (and other) areas since 2016 highlighted in Fig. 6. As evident in Fig. 6 (and accompanying photo), bank erosion remains prominent on the outside of many river bends, with 50-80m of erosion over the past decade. Sediment deposition has also resulted in the localised 50-100m expansion of the terrestrial habitat at the western edge of Fernbird Flat (see Fig. 6).

Coastal dune dominated by introduced species including tree lupin and marram grass (top) and sheltered dune within the estuary dominated by the native sand-binder *Spinifex sericeus* (bottom).

While there are restrictions on vehicle access to the dune system, impacts from vehicle tracking are common.

The loss of historical wetland and salt marsh habitats around the estuary has greatly reduced the estuary's ability to filter nutrients and trap sediments. Shoreline armouring that prevents the landward migration of intertidal habitats in response to sea level rise in many areas is likely to result in coastal squeeze whereby existing salt marsh habitat is displaced and lost to increasing tidal inundation.

Armoured stop-banks prevent the landward migration of intertidal habitats in response to sea level rise.

Small tributaries to the estuary are channelised, often with flap-gates restricting tidal exchange.

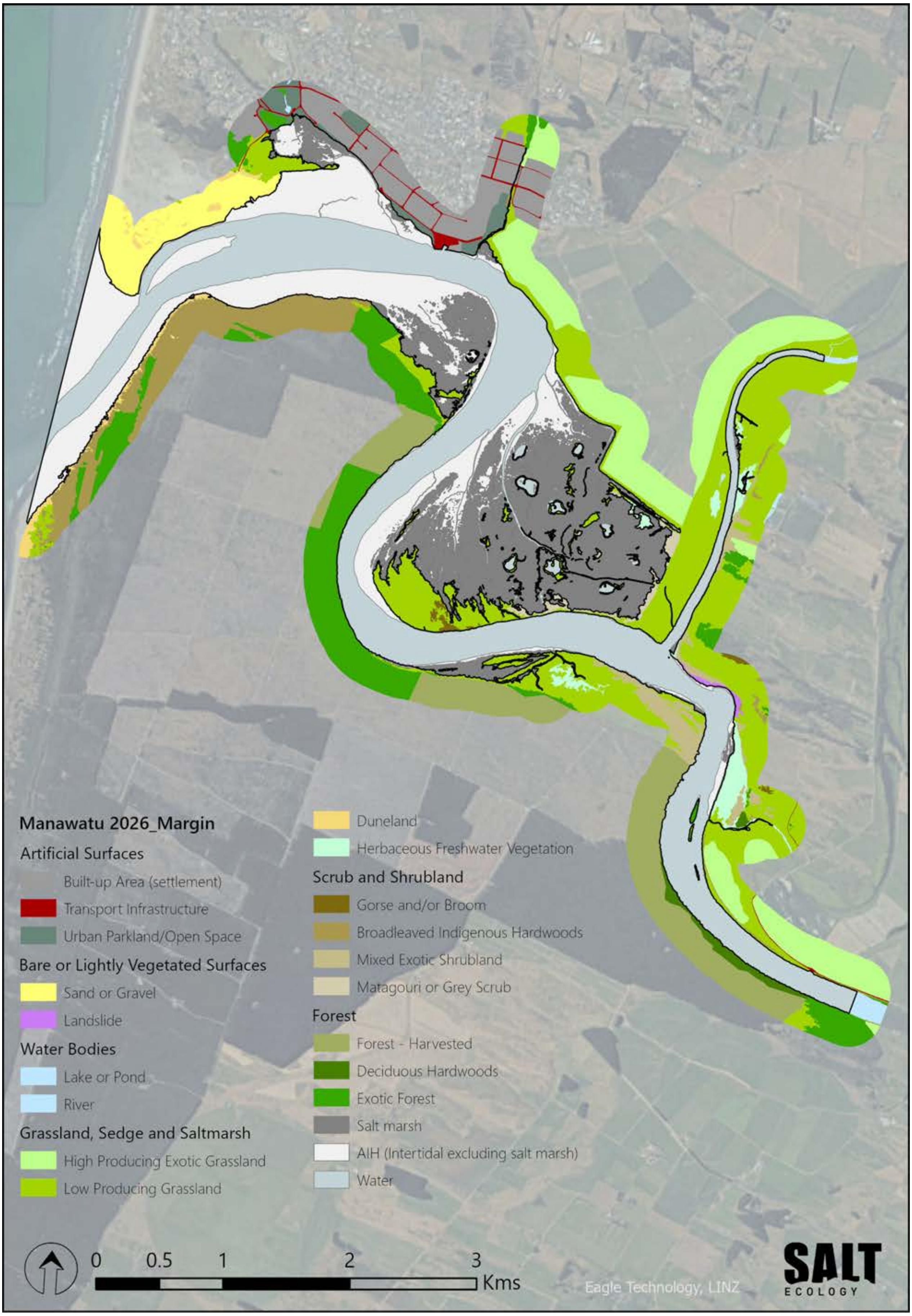


Fig. 5. Map of 200m terrestrial margin land cover, Manawatū Estuary, January 2026.

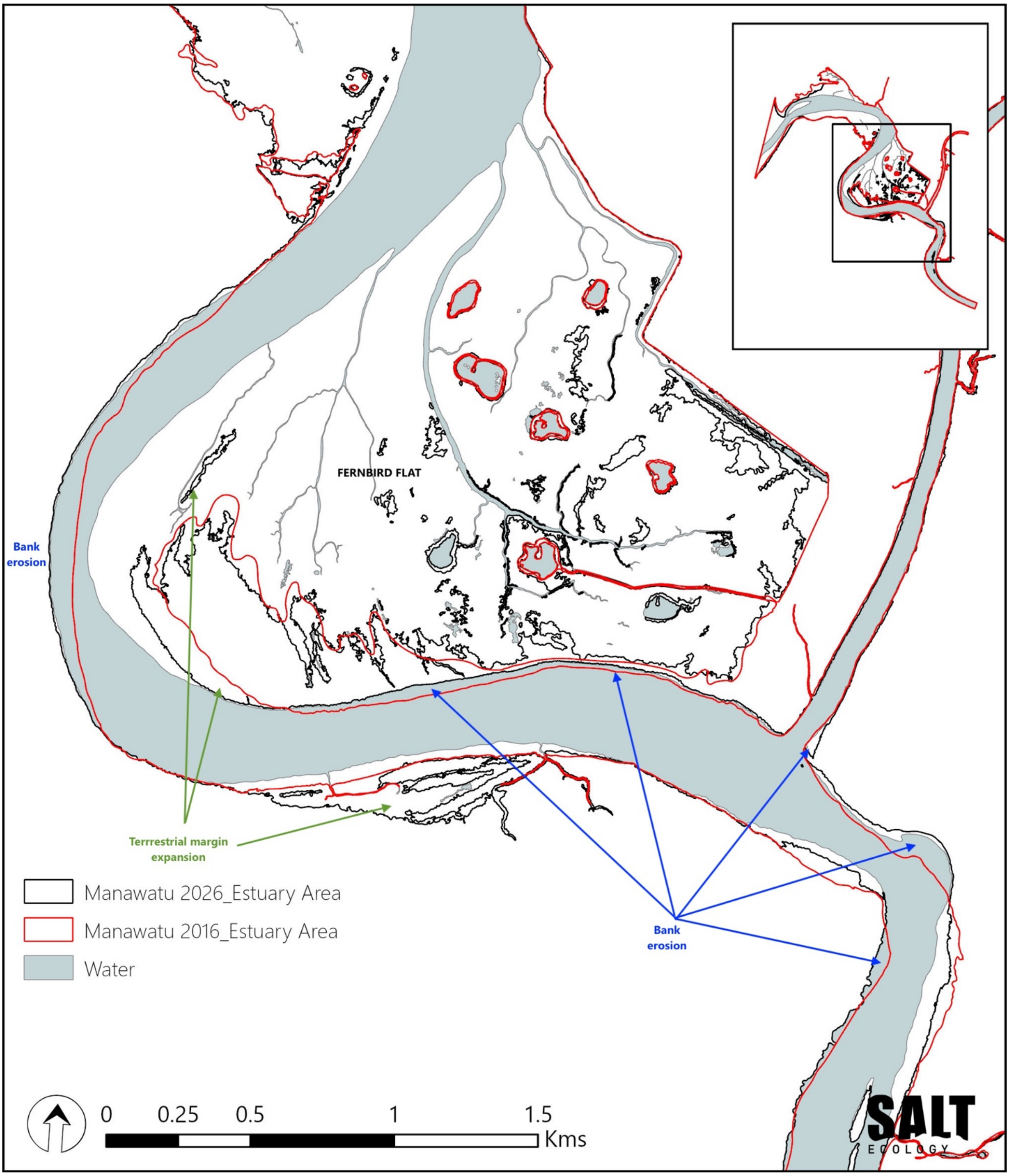


Fig. 6. Map highlighting key changes in the Manawatū Estuary boundary between 2016 and 2026.

Eroding channel margin adjacent to plantation pine forest opposite Fernbird Flat.

4.2 SALT MARSH

In January 2026, Manawatū Estuary supported 140.6ha of salt marsh, comprising 49% of the total mapped intertidal area of 286.1ha (Table 4; Fig. 7). Dominant vegetation types are summarised in Table 4, with sub-dominant species listed in Appendix 3 and additional detail in associated GIS layers.

Most of the salt marsh was located in the middle estuary and in a smaller pocket to the north, adjacent to Foxton Beach township (Fig. 7). Salt marsh was dominated by rushland (97ha; 69% of the salt marsh present), primarily comprising sea rush (*Juncus kraussii*), and the sharp flowered rush (*Juncus acutiflorus*). Large areas of sedgeland (31ha; 22%) were also present, dominated by three square (*Schoenoplectus pungens*) and Caldwell's clubrush (*Bolboschoenus caldwellii*), most commonly present along the seaward edge of rushland. Estuarine shrub, mainly salt marsh ribbonwood (*Plagianthus divaricatus*) was limited to elevated upper tidal reaches, while salt-tolerant herbfield tended to be the most seaward growing vegetation. Vehicle tracking was evident in a few localised areas (see photo below) but was not a widespread issue within salt marsh areas due to limited physical access.

Vehicle tracking on the true left of the lower estuary.

Table 4. Summary of salt marsh area (ha) and percent composition, Manawatū Estuary, January 2026.

Class	Dominant species*	ha	%
Estuarine Shrub	*Plagianthus divaricatus*	6.0	4.2
Sedgeland	*Schoenoplectus pungens*	31.5	22.3
Reedland	*Glyceria maxima*	0.03	0.02
Rushland	*Juncus kraussii*	97.3	68.9
Herbfield	*Sarcocornia quinqueflora*	5.8	4.1
Total		140.6	100

* See Appendix 3 for additional detail on sub-dominant species.

Extensive sedgeland (*Schoenoplectus pungens*) on the seaward edge of rushland (*Juncus kraussii*), in the north of the estuary.

Sarcocornia quinqueflora (glasswort) herbfield at the seaward edge of salt marsh in the middle estuary.

Salt marsh habitat naturally traps fine sediments, with 98% of the mapped salt marsh growing in substrate with elevated mud contents (≥25% mud; Appendix 4). Salt marsh zones are therefore excluded when assessing substrate condition ratings (see Table 2) to avoid skewing assessments due to salt marsh area.

Based on current extent, salt marsh condition is rated as 'Very Good', with the small reduction in area from 2016 attributed to improved classification of features rather than habitat losses. The natural salt marsh extent has not been quantified, and a direct comparison of historical and current extent is compromised by the impact of the Whirokino Cut and subsequent changes in the location of the river channel and entrance. Nevertheless, based on land elevations, current salt marsh appears likely to be <50% of the historical extent, predominantly in areas reclaimed and drained for pasture to the northeast of the middle estuary. The % loss from the historic baseline has therefore been given a condition rating of 'Fair' to 'Very Poor'.

Samolus repens (primrose) herbfield and, left of image, nationally vulnerable *Carex litorosa* (sea sedge) in the middle estuary.

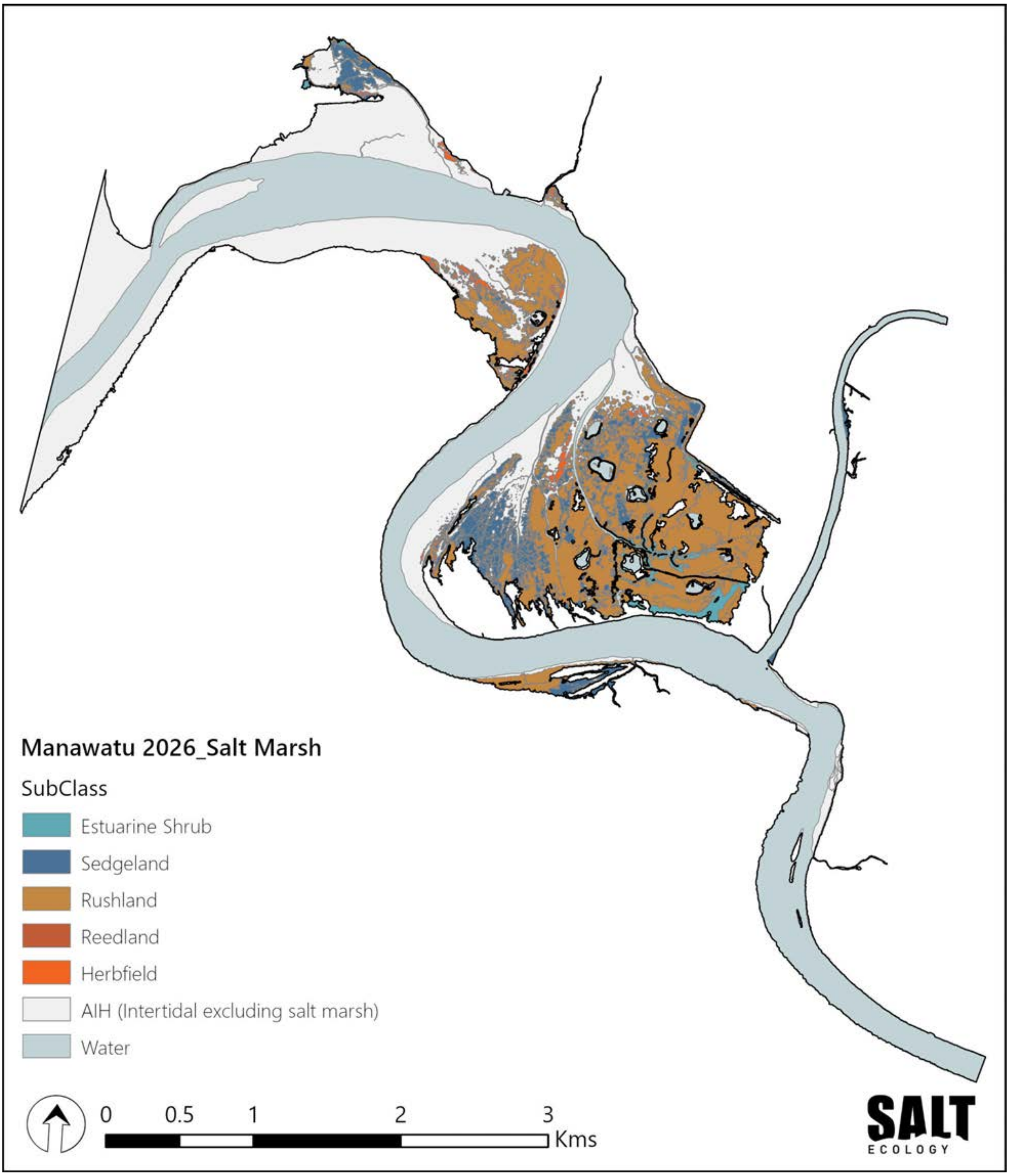


Fig. 7. Salt marsh sub-classes and their distribution, Manawatū Estuary, January 2026. The total salt marsh area of 140.6ha was ~49% of the total mapped intertidal area of 286.1ha.

Salt marsh in the middle estuary, January 2026.

4.3 SUBSTRATE

In 2026, qualitative substrate classifications were made throughout the 145ha available intertidal habitat (AIH; the intertidal area excluding salt marsh) (Table 5; Fig. 8), with classifications validated using sediment grain size analysis (see Appendix 2).

The estuary was predominantly composed of fine unconsolidated sediments, the most extensive being sand (<10% mud), followed by sandy mud (≥50–90% mud), and muddy sand (≥25–50% mud). There was a strong longitudinal pattern with marine sands dominating near the open coast, and catchment-derived muds further upstream, reflecting their proximity to input sources. Sandy sediments were generally well oxygenated, particularly near the estuary entrance, with apparent Redox Potential Discontinuity (aRPD) depth generally decreasing with increasing mud content, indicating reduced sediment oxygenation in finer substrates. The lower estuary appears to be subjected to episodic deposition events where relatively muddy sediments are deposited onto marine sands during flood events (see lower right photo), before being remobilised and redistributed to other parts of the estuary (including salt marsh and subtidal areas) or flushed out to sea.

Coarse substrates (cobble/gravel) were a relatively minor feature, as were artificial substrates and boulder fields used as shoreline armouring. Despite its small spatial extent, the latter however has a high relative impact on the estuary by preventing landward migration of the estuary in response to sea-level rise.

Table 5. Summary of dominant substrate in available intertidal habitat (AIH) outside areas of salt marsh, Manawatū Estuary, January 2026.

Substrate Class	Features	ha	% AIH
Artificial substrate	Artificial surfaces	0.04	0.03
	Artificial boulder field	0.6	0.4
Coarse substrate (>2mm)	Cobble field	0.3	0.2
	Gravel field	0.1	0.05
Sand (0-10% mud)	Firm sand	38.6	26.6
	Mobile sand	22.6	15.6
	Soft sand	0.2	0.2
Muddy Sand (≥10-25% mud)	Firm muddy sand	9.4	6.5
	Mobile muddy sand	2.8	1.9
Muddy Sand (≥25-50% mud)	Firm muddy sand	16.5	11.4
	Soft muddy sand	8.9	6.2
Sandy Mud (≥50-90% mud)	Firm sandy mud	15.7	10.9
	Soft sandy mud	26.5	18.3
	Very soft sandy mud	2.4	1.7
Mud (≥90% mud)	Soft mud	0.1	0.1
Total		144.9	100

Mobile muddy sand near the entrance.

Sandy mud (≥50-90% mud content) in the middle estuary.

Firm muddy sand (≥25-50% mud content) in the middle estuary.

Firm muddy sand (left of image) overlain with sandy mud (right of image) in the lower estuary.

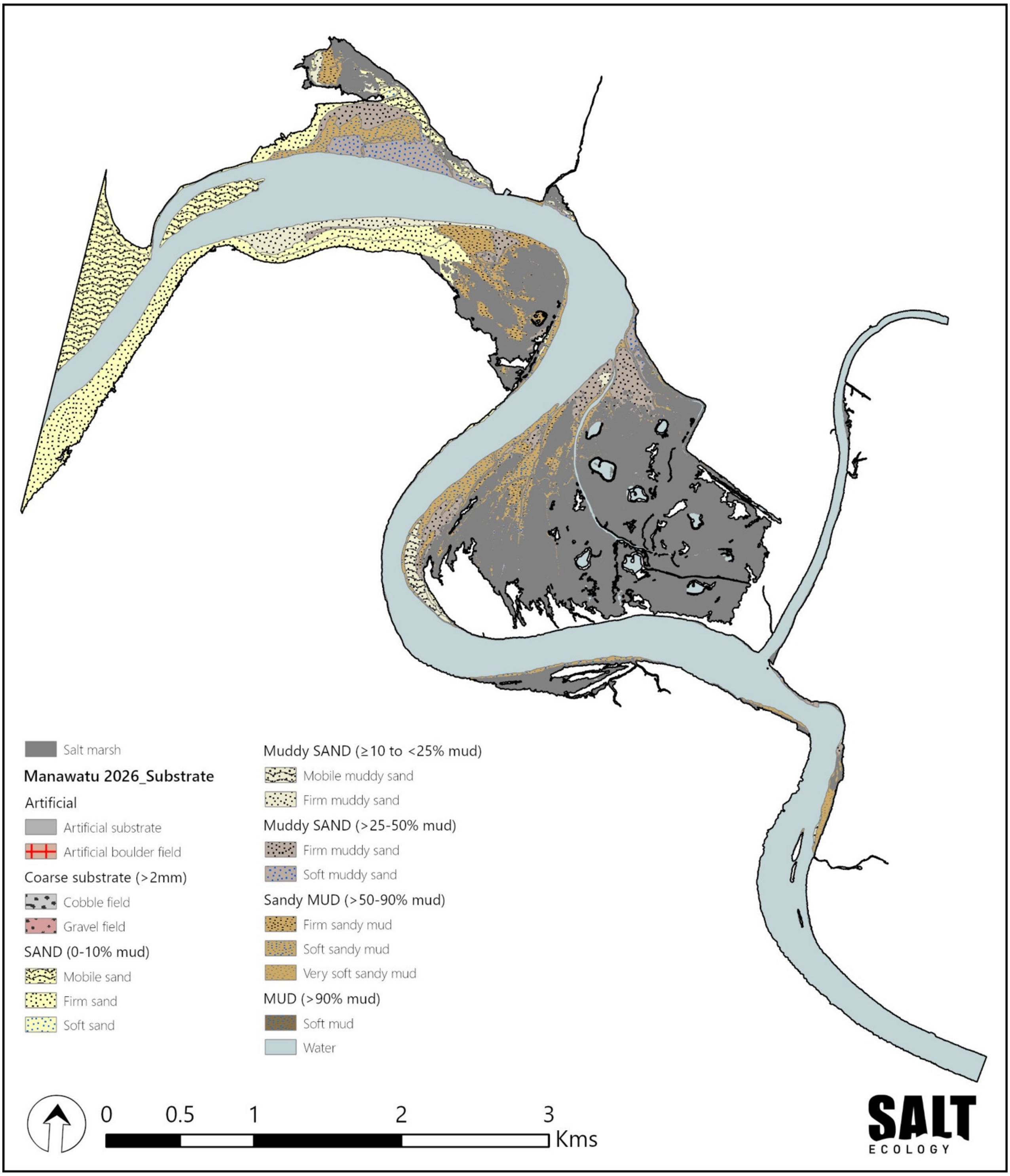


Fig. 8. Dominant intertidal substrate in the AIH (excluding salt marsh), Manawatū Estuary, January 2026.

Firm muddy sand (≥25-50%) among salt marsh in the lower estuary.

4.4 MACROALGAE

Opportunistic macroalgae species and biomass information is summarised in Table 6 and Fig. 9, with results detailed in Appendix 5.

Very little macroalgae was present in the estuary with 99.7% of the AIH classified as having macroalgae either absent or at trace levels (<1% cover). Only six discrete macroalgal patches were identified in 2026, comprising green algae from the *Ulva* genus and red algae from the *Gracilaria* genus. Five patches were classified as low (10 to 30%) cover, and a single patch as dense (70 to 90%) cover. These were all located within the middle estuary in sheltered areas among salt marsh.

In two patches, *Gracilaria* was growing in stable beds entrained in the sediment (see top photo opposite). However, the biomass of this macroalgae, and the other patches, was rated either low or moderate (Table 6), and below levels of concern.

Due to overall cover being <5% of the AIH, the OMBT score is based on the percent cover value using the method described in Stevens et al. (2022). This gave an OMBT-EQR score for Manawatū Estuary in 2026 of 0.999 (condition rating of 'Very Good').

Small patch of entrained low cover, moderate biomass, *Gracilaria* spp. in the middle estuary growing in mud-elevated sediment.

Sparse cover of *Ulva* spp. on rip-rap rock armouring.

Table 6. Summary of intertidal macroalgal cover (A) and biomass (B), Manawatū Estuary, January 2026.

A. Percent cover

Percent cover category	ha	% AIH
Sparse (1 to <10%)	-	-
Low (10 to <30%)	0.37	0.26
Moderate (30 to <50%)	-	-
High (50 to <70%)	-	-
Dense (70 to <90%)	0.01	0.004
Complete (≥90%)	-	-
Total	0.38	0.26

B. Biomass

Biomass category (g/m^2)	ha	% AIH
Very low (1 - 100)	0.3	0.22
Low (101 - 200)	-	-
Moderate (201 - 500)	0.1	0.04
High (501 - 1450)	-	-
Very high (>1450)	-	-
Total	0.4	0.24

A very sparse cover of microalgae (green tinge) was occasionally present on intertidal flats in the upper estuary.

The lower estuary had no macroalgal growth.

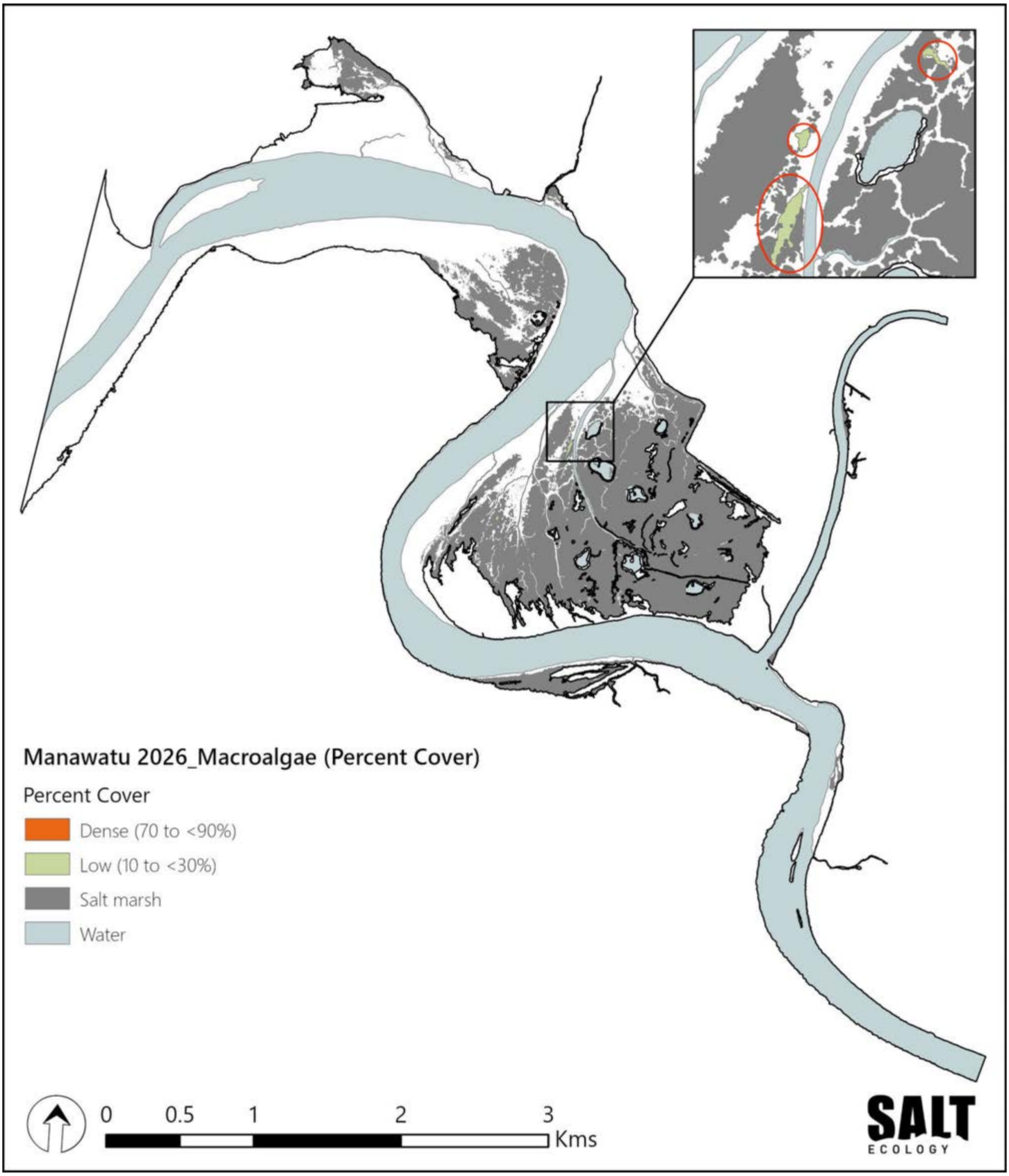


Fig. 9. Distribution and percent cover classes of macroalgae, Manawatū Estuary, January 2026.

Low cover of *Gracilaria* spp. in the middle estuary growing in mud-elevated sediment.

5. SYNTHESIS

A summary of key 2026 results is provided in Table 7, with results assessed relative to condition ratings, and the 2016 survey, in Table 8. Supporting data used to assess and interpret estuary condition were derived from catchment-scale nutrient and sedimentation models (CLUES 2018; Hicks et al. 2019) and are provided in Table 9.

Table 7. Summary of key broad scale features, Manawatū Estuary, January 2026.

a. Area summary	ha	% Estuary
Intertidal	286.1	56.1
Subtidal	224.2	43.9
Total	510.3	100
AIH (intertidal excluding salt marsh)	144.9	28.4
b. Key substrate features	**ha**	**% AIH**
Mud-elevated (≥25% mud)	70.3	48.5
c. Key habitat features	**ha**	**% Intertidal**
Salt marsh	141.2	49.4
d. Key enrichment features	**ha**	**% AIH**
Macroalgae (≥50% cover)	0.01	0.004
High Enrichment Conditions	0	0
e. Terrestrial margin	**ha**	**% Margin**
200m densely vegetated margin	219.0	38.5

Table 8 shows that Manawatū Estuary has been rated as 'Very Poor' for mud-elevated substrate over the last two surveys, 'Poor' for estimated estuary-wide mean annual sedimentation rate, 'Fair' for the densely vegetated 200m terrestrial margin, and 'Very Good' for the large area of salt marsh, the limited growth of macroalgae, and the absence of High Enrichment Conditions (HEC areas).

The condition of the estuary in a regional content was reflected in a recent limit-setting study for Horizons that characterised Manawatū as having high ecological values, but as being more degraded than most other estuaries in the region due to large areas of muddy sediment, considerable loss of salt marsh, and modification of the margin (Roberts et al. 2025c). We expand on these matters below, and also consider potential issues relating to elevated nutrient loads, which have been identified as a key pressure on the estuary.

5.1 SALT MARSH LOSS AND MARGIN MODIFICATION

Of the indicators assessed, the large extent of salt marsh is one of the most important ecological features of the estuary. It plays a critical role in estuarine health by filtering runoff, trapping fine sediments, assimilating nutrients, supporting biodiversity, and providing natural flood attenuation. The maintenance of existing salt marsh ensures these ecosystem services continue to be available, and reduces the estuary's vulnerability to future stressors.

Table 8. Summary of broad scale indicator ratings for Manawatū Estuary, 2016 and 2026.

Broad-scale indicators	Unit	2016*	2026
200m terrestrial margin	% densely vegetated	44	39
Salt marsh	% of intertidal area	56	49
	% loss from baseline	baseline	6%
	% loss from historic baseline[3]	Estimated >50%	Estimated >50%
Mud-elevated substrate	% AIH[1] area (≥25% mud)	53.3	48.5
	% increase from baseline in AIH	baseline	9.0(↓)
Macroalgae (OMBT-EQR[2])	Ecological Quality Rating (EQR)	0.985	0.999
High Enrichment Conditions	ha	0	0
Estuary-wide indicators[4]			
Sedimentation rate	CSR:NSR[5] ratio	-	2.3
Sedimentation rate	mm/yr	-	5.9

[1]Available Intertidal Habitat excludes salt marsh area; [2]Opportunistic Macroalgal Blooming Tool (OMBT) scores have been updated following QA/QC; [3]Natural extent estimate based on expert opinion; [4] Estuary-wide sedimentation indicators derived from catchment models (e.g., Hicks et al. 2019). [5]CSR=Current Sedimentation Rate, NSR=Natural Sedimentation Rate. dash=no data. *Existing GIS layers QA/QC checked in 2026 - values may differ slightly from original reports.

Very Good	Good	Fair	Poor	Very Poor

Table 9. Supporting data to assess estuary ecological condition in Manawatū Estuary, January 2026.

Supporting Condition Measure	
Mean freshwater flow (m^3/s)[1]	124
Catchment Area (Ha)[2]	587,600
Catchment nitrogen load (TN-t/yr)[1]	5018
Catchment phosphorus load (TP-t/yr)[1]	697
Catchment sediment load (KT/yr)[3]	2298
Estimated N areal load in estuary ($mg/m^2/d$)	2696
Estimated P areal load in estuary ($mg/m^2/d$)	374
CSR:NSR ratio[4]	2.3
Trap efficiency (sediment retained in estuary; %)[4]	2
Estimated rate of sedimentation (mm/yr)[4]	5.9

[1]Fraser (2021); [2]Herzig et al. (2020); [3]Vale and Smith (2023); [4]Hicks et al. (2019)

However, although extensive areas of salt marsh remain in Manawatū, we estimated that at least 50% has been lost relative to its natural extent, with substantial adjoining freshwater wetland habitat also likely drained and/or reclaimed. These past losses almost certainly contribute to increased adverse sediment deposition effects within the unvegetated intertidal part of the estuary, with studies showing that the amount of sediment trapped by salt marsh decreases exponentially as salt marsh area is reduced, resulting in greater sediment release to tidal flats (Donatelli et al. 2018). Furthermore, reclamation of salt marsh, particularly along the landward margin, can lead to infilling of the estuary itself due to a shift in hydrodynamics that may take centuries to reach a new equilibrium (van Maren et al. 2025).

The historical losses of salt marsh are closely associated with extensive modification around the estuary, displacing what would have naturally been a densely-vegetated margin with urban development, stop-banks, grazed pasture (predominantly on the northern side of the estuary including the lower reaches of the Foxton Loop), and forestry (predominantly on the southern side). This situation has facilitated the introduction of grasses and weeds into salt marsh areas.

Additionally, hardened margins and infrastructure will limit the potential for landward migration of salt marsh in response to sea-level rise, resulting in 'coastal squeeze'. As sea levels rise, progressive salt marsh loss can occur, particularly where space for passive or managed retreat is unavailable. Such losses could potentially be mitigated through targeted restoration in areas where landform, hydrology, and land-use allow for salt marsh migration or re-establishment. Around the Manawatū Estuary, achieving this outcome would likely require the retirement of marginal grazing land, re-establishment of tidal connections in previously drained areas, or improvement of tidal flushing in partially disconnected areas.

Protecting and enhancing the remaining salt marsh, alongside restoring vegetated buffer zones and improving hydrological connectivity, will be critical to supporting long-term estuarine resilience and maintaining the essential ecosystem services salt marsh provides.

On a positive note, there have been no meaningful reductions in the area of salt marsh, or the extent of densely vegetated 200m terrestrial margin, relative to the 2016 baseline. The small changes summarised in Table 8 primarily reflect better quality aerial photographs available in 2026, enabling more accurate mapping and classification of these features than was possible in 2016. For salt marsh, the 6% (9ha) reduction relative to the 2016 baseline is almost entirely due to reclassification of 2016 salt marsh to terrestrial habitat in 2026. For the 200m terrestrial margin, the changes capture recent harvesting of pine forest on the southern side of the estuary. This likely represents a short-term alteration of the current cover, with replanting expected to relatively quickly be re-established.

An example of pasture adjacent to the estuary with a residual drainage channel connecting to a salt marsh filled drain landward of the stop-bank. Such areas are potentially suitable for future expansion of salt marsh with sea level rise.

5.2 MUDDY SEDIMENT

Encouragingly, there was no meaningful change in the spatial extent of mud-elevated sediments between 2016 and 2026 (see Table 8). However, of ongoing concern is the persistence of mud-elevated sediments in the upper tidal flats. Muddy substrates degrade benthic habitat quality, can displace seagrass and sensitive species such as cockles, and increase the retention of nutrients and contaminants. Such changes could have flow-on effects for other species such as fish and shorebirds that depend on these habitats for feeding and nursery areas.

Table 9 shows catchment models estimate the current sediment load to the estuary to be 2.3 times higher than the pre-human load. Due to the current large total catchment sediment load (2298kT/yr), the predicted estuary-wide sedimentation rate is 5.9 mm/year (a condition rating of 'Poor'), despite the estuary's very low predicted trapping efficiency (2%). The impact of sediment inputs were evident during the 2026 survey, with 'fresh' mud deposition along many of the upper estuary intertidal flats and within salt marsh, and high turbidity in the water column.

Turbid muddy waters of the Manawatū River, and fresh intertidal mud deposits, 28 January 2026.

Observations during previous broad-scale and fine-scale estuary surveys has also revealed what appears to be regular event-related sediment deposition on tidal flats of the lower estuary, with mud-elevated sediments being deposited on top of sand-dominated sediments, before subsequent remobilisation and redistribution to other parts of the estuary, or export to the open coast. Event-driven deposition and export of fine sediments has been recorded in other estuaries nationally (Davidson 2018; Stevens & Roberts 2022).

Similarly, large deposits of driftwood are evident in many parts of Manawatū Estuary. These deposits, most commonly found in the upper tidal margins, cause spatially and temporally variable impacts by smothering salt marsh. While much of this material in 2026 appeared to be naturally sourced from the catchment, there is a potential risk of forestry slash compounding existing problems if it is not managed appropriately.

Deposit of driftwood smothering salt marsh in the upper tidal margin of the lower estuary.

5.3 NUTRIENTS

Several recent reports (i.e., Plew 2024; Roberts et al. 2025a; Roberts et al. 2025c) have considered the potential susceptibility of estuaries in the region to nutrients, and assessed how they may respond to changes in input loads under different management scenarios. Although the Estuary Trophic Index (ETI) Tool 1 (Robertson et al. 2016b) would predict Manawatū to be highly susceptible to macroalgal blooms based on current nutrient inputs, its susceptibility is likely over-estimated. In tidal river estuaries like Manawatū, algal growth is limited by several factors, including strong currents, flood-scouring, low salinities, limited available intertidal habitat, and high water turbidity (Plew 2024).

This scenario is consistent with the findings of the two broad-scale surveys, which show limited macroalgae growth, and OMBT-EQR scores consistent with a 'Very Good' condition rating (Table 8). Similarly, the absence of High Enrichment Conditions areas, where sediments become organically enriched and are poorly oxygenated, indicates that algal biomass is not accumulating and rotting within the intertidal reaches of the estuary. High Enrichment Conditions areas are generally persistent and are likely to be evident if there are regular blooms of opportunistic macroalgae, even if the algae are subsequently washed from the estuary.

5.4 WATER QUALITY

Even though Manawatū does not appear susceptible to developing problems with opportunistic macroalgae, in river-dominated estuaries excess nutrient inputs can lead to phytoplankton blooms in the water column

(Forrest et al. 2024). This situation primarily arises where there is prolonged water column stratification, whereby tidal seawater flows into an estuary (and may become trapped in deeper pools) beneath outflowing river water.

In the case of the Manawatū, the development of strong or sustained stratification and phytoplankton blooms is considered unlikely, except perhaps in the Foxton Loop. In the main channel, the risk is mitigated by the estuary's relatively rapid flushing time as a consequence of the large river flow and the entrance remaining continuously open. Although previous assessments have reported a tidal influence up to 20km upstream (Todd et al. 2016), there are no data to indicate that a salt wedge penetrates that far. Further, opportunistic water column measurements made during the 2016 broad-scale survey (not included in the survey report) did not identify any significant salinity stratification issues.

To add to the limited existing information, during the January 2026 broad-scale mapping, synoptic water quality measurements were made of salinity, temperature, dissolved oxygen (DO), and chlorophyll-a (the latter being an indicator of phytoplankton biomass). Summary data and site locations are presented in Appendix 6. The purpose was to assess potential stratification within the water column of the upper estuary, the presence of phytoplankton blooms, and any obvious water quality degradation. As the measurements were made immediately after a flood event (see Fig. 10), they do not represent the worst-case conditions likely to be encountered under prolonged summer low-flow, but nevertheless adds a useful point-in-time record of post-flood conditions. Data were logged at five representative sites, with additional measurements made at multiple locations between the sites, but not logged given there was no appreciable change in values.

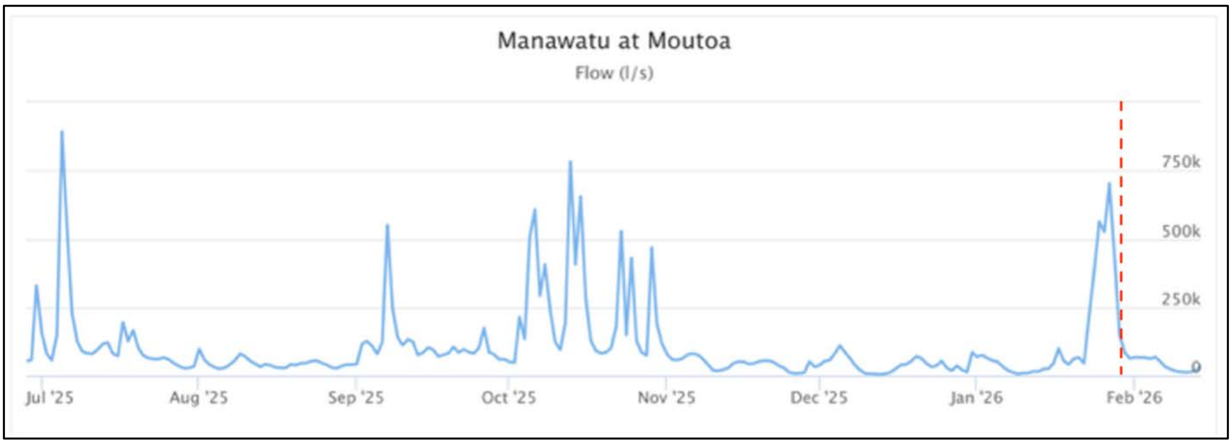
The survey found no indications of temperature or salinity stratification within estuary waters, indicating strong vertical mixing as was expected after the recent flood. However, also as expected, there was limited mixing between the Foxton Loop and the Manawatū River, as evident in the photo opposite. In general terms, the turbid Manawatū River flow was well oxygenated upstream of the Foxton Loop (Site 2; DO concentrations >9g/m^3), whereas measurements within the freshwater-dominated Foxton Loop were much lower (Sites 3-5; DO range 2.98-4.98g/m^3). At the confluence of the downstream end of the Foxton Loop and Manawatū River (Site 1; see top photo opposite), turbid bottom water remained well oxygenated but tannin-rich surface waters were poorly oxygenated.

This indicates a high level of oxygen consumption within the Foxton Loop. With chlorophyll-a indicating there were no phytoplankton blooms present, this suggests the low DO is most likely to be driven by macrophytes and freshwater algae. While subtidal features were not surveyed, the presence of macrophyte communities was noted (see photo below), with invasive Hornwort (*Ceratophyllum demersum*) present drifting in the river and deposited on shorelines.

Macrophytes and freshwater algae produce oxygen during the day via photosynthesis, and consume it at night, leading to large diurnal fluctuations in concentrations. In the Foxton Loop, this process is likely exacerbated by poor flushing, and by inputs of sediments and nutrients from farm run-off, stormwater, and discharges from the Foxton wastewater treatment plant, among others. The impact of these types of stressors significantly degrades the ecological quality of the Foxton Loop, but are only expected to have a relatively minor impact on the wider estuary because of the highly flushed nature of the main river system.

Tannin-rich waters of the Foxton Loop (left) and turbid waters of the Manawatū River, 28 January 2026.

The native macrophyte *Ruppia* spp. (Horse's mane weed) is extensive in the subtidal reaches of the lower Foxton Loop (left), and invasive Hornwort (*Ceratophyllum demersum*) (right).



Source: https://envirodata.horizons.govt.nz/?siteName=Manawatu%20at%20Moutoa&collectionName=Flow

Fig. 10. Manawatū River daily mean flows in the 6-months before the broad-scale survey. The timing of the survey (28 January 2026) relative to a preceding flood event is indicated by the dashed red line.

6. CONCLUSIONS AND RECOMMENDATIONS

Overall, Manawatū Estuary is primarily exhibiting signs of ecological stress through the large extent of muddy sediment, and the historical loss of salt marsh habitat. Ongoing catchment sediment inputs, in particular flood-related deposition events, are likely compounded by the historical loss of extensive salt marsh and marginal wetland habitat, which would once have played a crucial role in trapping and filtering fine sediments before they reached the estuary. The predicted ongoing loss of high value salt marsh habitat by 'coastal squeeze' due to physical barriers to natural migration (in response to sea level rise) will further increase the estuary's susceptibility to sediment stressors in future.

Based on the monitoring results described above it is recommended HRC consider the following:

Monitoring

- Continue full broad-scale monitoring on a 10-year cycle to track major long-term changes in habitat and pressures on the estuary.
- When conducting any other on-water work in the estuary, collect opportunistic water quality measurements (including depth profiling) to improve understanding of estuary susceptibility. When conducting terrestrial work, carry out an estuary walkover (see Stevens et al. 2025) to quickly check on the status of changeable features (e.g., mud extent and macroalgae) and any other manageable pressures (e.g., vehicle impacts, reclamation, weeds).

Management

- HRC have well-established work programmes characterising catchment sediment and nutrient loads and sources. Continuation of ongoing efforts are recommended, alongside targeted reductions of inputs of nutrients and sediments in particular, where required.
- Any management actions should be cognisant of the overarching non-statutory management plan for Papangaio – Te Wharangi – Manawatū Estuary 2025-2035 that has been developed to maintain and enhance the values of the site, with the collaboration and endorsement from hapū and iwi of the area, namely Ngāti Raukawa, Muaūpoko and Rangitāne o Manawatū, community and ecological groups, and territorial, regional and central government statutory agencies (see Manawatū Estuary Management Team (2025) for further details).
- Recognising the above, it is recommended that HRC further explore development of a specific estuary restoration strategy for the managed retreat of salt marsh under sea-level rise where landform, hydrology, and land-use allow for salt marsh migration or re-establishment. A first stage to consider would be simple inundation modelling to assess potential salt marsh losses/gains and barriers to retreat (e.g., Crawshaw et al. 2022; Stevens 2023; Bulmer et al. 2024; Stevens 2024).

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APPENDIX 1. SAMPLING METHODS, MANAWATŪ, JANUARY 2026

The broad-scale habitat mapping methods largely follow the National Estuary Monitoring Protocol (NEMP) (Roberts et al. 2025b). The NEMP outlines a tiered monitoring approach for each indicator; the level of monitoring; and improvements to assessment, analysis and QA/QC elements. Any adjustments or additions to the NEMP are described in Table A1.1 and this appendix.

Table A1.1. Summary of broad-scale methods used in this report.

Indicator	Method
Substrate	Substrate was assessed using the intermediate level of monitoring described in the NEMP, incorporating additional substrate descriptors (e.g., texture – firm, soft, very soft) and classes (e.g., sandy mud and mud), which are aggregated in the NEMP. The changes, and a full list of substrate codes, is provided in Section A1.1 and Table A1.2. Substrate validation is required for fine unconsolidated substrate types (e.g., MS10, MS25). Briefly, a validation sample is collected from the surface 2cm and analysed for grainsize, and the qualitative classification compared with the mud fraction from the grainsize analysis (see Appendix 2 in Roberts et al. 2025b).
Salt marsh	Salt marsh was assessed using the comprehensive level of monitoring described in the NEMP, with measurements of salt marsh extent, sub-classes, and dominant species.
Seagrass	Seagrass, where present, is assessed using the intermediate level of monitoring described in the NEMP, with measurements of seagrass extent and percent cover.
Macroalgae	Macroalgae was assessed using the comprehensive level of monitoring described in the NEMP, with measurements of macroalgae extent, percent cover, biomass and entrainment.
High Enrichment Conditions (HEC)	Mapped based on areal extent where there are obvious low sediment oxygen conditions (e.g., black sediments with rotten egg smell), conspicuous surface growths of sulfur-oxidising bacteria, stable, entrained, dense (>50% cover) beds of opportunistic macroalgae, or the extensive presence of surface microalgae or filamentous-algae.
200m Terrestrial margin	Described in Section A1.2.
Catchment land cover	Described in Section A1.2.

A1.1 Estuary substrate classification and mapping

The NEMP designates substrate based on the dominant surface features present (e.g., rock, boulder, cobble, gravel, sand, muddy sand, sandy mud), with associated substrate codes and classification descriptors. Salt Ecology uses these classifications with one exception: the Sandy Mud (SM50; 50-100% mud) class is divided into two sub-classes – Sandy Mud (SM; ≥50-90%) and Mud (M; ≥90% mud). For national reporting these two sub-classes can be aggregated.

Salt Ecology also use lower-case abbreviations to designate sediment 'firmness' based on how much a person sinks:

- firm (f) - Sink 0 to <2cm "to sole of shoes"
- soft (s) - Sink 2 to <5cm "sole of shoes to ankles"
- very soft (vs) - Sink ≥5cm "above ankles"

Because this measure is highly variable between observers, it is only used as a supporting narrative descriptor of substrate type. Mobile (m) and artificial (a) substrate are classified separately.

Table A1.2. Modified NEMP substrate classes and field codes.

Consolidated substrate			Code	NEMP equivalent (depth of sinking)	
Bedrock		Rock field "solid bedrock"	RF	RF	Rockland
Coarse Unconsolidated Substrate (>2mm)					
Boulder	>256mm	Boulder field "bigger than your head"	BF	BF	Boulder field
Cobble	64 to <256mm	Cobble field "hand to head sized"	CF	CF	Cobble field
Gravel	2 to <64mm	Gravel field "smaller than palm of hand"	GF	GF	Gravel field
Shell	2 to <64mm	Shell "smaller than palm of hand"	Shel	Shell	Shell
Fine Unconsolidated Substrate (<2mm) – see footnotes					
SAND (S)	Low mud (0-10%)	Mobile sand	mS	MS	Mobile sand (<1cm)
		Firm shell/sand	fShS	FSS	Firm shell/sand (<1cm)
		Firm sand	fS	FS	Firm sand (<1cm)
		Soft sand	sS	SS	Soft sand (>2cm)
		Very soft sand	vsS	SS	Soft sand (>2cm)
Muddy SAND10 (MS10)	Moderate mud (≥10-25%)	Mobile muddy sand	mMS10	MS	Mobile sand (<1cm)
		Firm muddy shell/sand	fMShS10	FSS	Firm shell/sand (<1cm)
		Firm muddy sand	fMS10	FMS	Firm mud/sand (<2cm)
		Soft muddy sand	sMS10	SM	Soft mud/sand (2-5cm)
		Very soft muddy sand	vsMS10	VSM	Very soft mud/sand (>5cm)
Muddy SAND25 (MS25)	High mud (≥25-50%)	Mobile muddy sand	mMS25	MS	Mobile sand (<1cm)
		Firm muddy shell/sand	fMShS25	FSS	Firm shell/sand (<1cm)
		Firm muddy sand	fMS25	FMS	Firm mud/sand (<2cm)
		Soft muddy sand	sMS25	SM	Soft mud/sand (2-5cm)
		Very soft muddy sand	vsMS25	VSM	Very soft mud/sand (>5cm)
Sandy Mud (SM)	Very high mud (≥50-90%)	Firm sandy mud	fSM	FMS	Firm mud/sand (<2cm)
		Soft sandy mud	sSM	SM	Soft mud/sand (2-5cm)
		Very soft sandy mud	vsSM	VSM	Very soft mud/sand (>5cm)
Mud (M)	Mud (≥90%)	Firm mud	fM90	FMS	Firm mud/sand (<2cm)
		Soft mud	sM90	SM	Soft mud/sand (2-5cm)
		Very soft mud	vsM90	VSM	Very soft mud/sand (>5cm)
Zoogenic (living)					
Areas dominated (≥50% cover) by mussel, oyster or calcareous tubeworms.		Mussel reef	MUSS		Mussel
		Oyster reef	OYST		Oyster
		Tubeworm reef	TUBE		Calcareous tubeworms
Artificial Substrate					
Introduced natural or human-made materials that modify the environment. Includes rip-rap, rock walls, wharf piles, bridge supports, walkways, boat ramps, groynes, flood control banks, flap-gates.		Solid Feature (e.g., boat ramp, seawall)	SF		
		Boulder field	aBF		Boulder field
		Cobble field	aCF		Cobble field
		Gravel field	aGF		Gravel field
		Sand field	aSF		Firm/Soft sand

Sediment firmness: Subjectively classified as 'firm' if you sink 0-<2cm, 'soft' if you sink 2-5cm, or 'very soft' if you sink >5cm.
Mobile: Sediment is firm but routinely moved by tidal currents or waves. Commonly characterised by having a rippled surface layer.
Sand: Sandy sediment that is granular when rubbed between the fingers and releases no conspicuous fines when sediment is disturbed.
Shell/Sand: Mixed sand and shell hash. See muddy sand sub-classes below for field guidance on estimating mud content.
Muddy Sand: Sand-dominated sediment that is mostly granular when rubbed between the fingers but has a smoother consistency than sand. Sub-divided into two sub-classes based on estimated mud content (commonly validated by laboratory analysis of representative substrate);

i. Moderate mud (≥10-25%) content: Muddy fines evident when sediment is disturbed. Sediments generally firm to walk on.
ii. High mud (≥25-50%) content): Muddy fines conspicuous when sediment is disturbed. Sediments generally soft to walk on.

Sandy Mud (≥50-90% mud content): Mud-dominated sediment primarily smooth/silken when rubbed between the fingers, but retains a granular component. Sediments generally soft or very soft and only firm if dried out, or another component (e.g., gravel) prevents sinking.
Mud (≥90% mud content): Mud-dominated sediment with no obvious sand component. Smooth/silken when rubbed between the fingers. Sediments generally only firm if dried out, or another component (e.g., gravel underneath mud) prevents sinking.

A1.2 Catchment description and terrestrial margin mapping

Catchment land cover maps are constructed from the most recent Landcare Research Land Cover Data Base (currently LCDB5 2018/2019) using the catchment boundary from CLUES 10.8 (ESNZ). The dominant land cover has been classified based on the codes described in Table A1.3. Using the same broad-scale approach described in Section 6.2 of the NEMP, these same LCDB5 classes are used to "ground-truth" and categorise features within the 200m terrestrial margin of an estuary. The one exception is the addition by Salt Ecology of a new sub-class (410 – Duneland) to delineate coastal duneland from low producing grassland, due to the high value of duneland habitat.

Table A1.3. Landcare Land Cover Database (LCDB5) classes used in the mapping of terrestrial features.

Artificial Surfaces		Grassland, Sedge and Saltmarsh	
1	Built-up Area (settlement)	40	High Producing Exotic Grassland
2	Urban Parkland/Open Space	41	Low Producing Grassland
5	Transport Infrastructure	410*	Duneland
6	Surface Mines and Dumps	43	Tussockland
Bare or Lightly Vegetated Surfaces		45	Herbaceous Freshwater Vegetation
10	Sand and Gravel	46	Herbaceous Saline Vegetation
12	Landslide	Scrub and Shrubland	
14	Permanent Snow and Ice	47	Flaxland
15	Alpine Grass/Herbfield	50	Fernland
16	Gravel and Rock	51	Gorse and/or Broom
Water Bodies		52	Manuka and/or Kanuka
20	Lake or Pond	54	Broadleaved Indigenous Hardwoods
21	River	55	Sub Alpine Shrubland
22	Estuarine water	56	Mixed Exotic Shrubland
Cropland		58	Matagouri or Grey Scrub Forest
30	Short-rotation Cropland	Forest	
33	Orchard Vineyard & Other Perennial Crops	64	Forest - Harvested
		68	Deciduous Hardwoods
		69	Indigenous Forest
		71	Exotic Forest

*Duneland is an additional category to the LCDB classes to differentiate between "Low Producing Grassland" and "Duneland".

A1.3. METHOD REFERENCES

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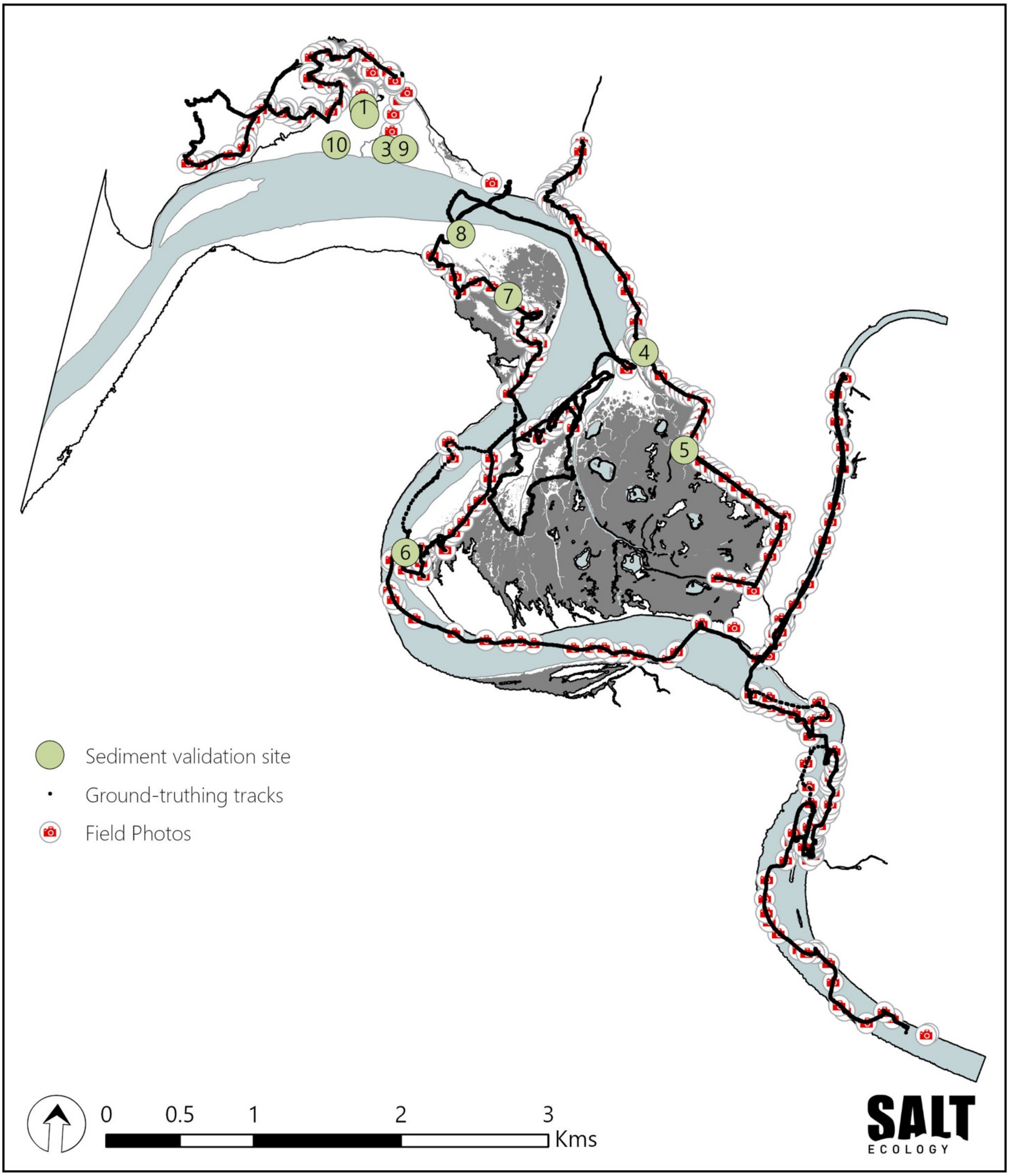
APPENDIX 2. GROUND-TRUTHING AND SEDIMENT VALIDATION, JANUARY 2026



Sediment validation sampling was undertaken at 10 sites (see figure above) to validate qualitative field estimates of sediment type (with respect to mud content) against laboratory grain size analysis of mud content. For this method, an acceptance tolerance of '±5% mud' difference from the broad substrate class has been adopted, unless field notes specify the sample was taken because the substrate could not be accurately determined in the field (e.g., flood deposits overlying and/ or integrating into firm substrates). For any samples with differences >5%, photos of the sample site and field notes are revisited to assess the disparity and determine whether to change the field classification.

Of the 10 sediment validation samples, eight matched the original field mud content estimates (unshaded), one was within the 5% tolerance (shaded yellow), and one was slightly above the 5% tolerance (shaded yellow with red text).

The non-match at Site 1 was at a transition between two substrate types. Following a review of field photos and notes, the mapped boundary was adjusted to reflect the slightly higher mud content at the sample point.

Overall, the high degree of concordance between field estimates and laboratory validation samples provides strong validation of the classifications applied.

2026 sediment validation sample results.

Site	NZTM East	NZTM North	Sed firmness	Field code	Qualitative % mud	Mud (%)	Sand (%)	Gravel (%)	Result	Change made [1]
1	1788862	5517832	firm	MS10_25	10 to <25%	31.7	68.1	0.1	Non match	Boundary adjusted[1]
2	1788871	5517793	firm	MS25_50	25 to <50%	30.7	69.0	0.3	Match	
3	1788987	5517618	soft	MS25_50	25 to <50%	28.8	70.7	0.5	Match	
4	1790356	5516619	firm	MS10_25	10 to <25%	18.9	76.0	5.2	Match	
5	1790580	5516125	firm	SM50_90	50 to 90%	91.8	4.1	4.1	Within 5%	
6	1789158	5515550	mobile	MS10_25	10 to <25%	11.2	88.8	< 0.1	Match	
7	1789646	5516884	soft	SM50_90	50 to 90%	87.7	12.0	0.4	Match	
8	1789388	5517197	mobile	S0_10	<10%	4.8	95.0	0.2	Match	
A	1788728	5517633	firm	MS25_50	25 to <50%	31.7	68.1	0.1	Match	
B	1789077	5517624	firm	MS25_50	25 to <50%	33.6	66.3	< 0.1	Match	

1. Change made following a review of field photos and notes

APPENDIX 3. SALT MARSH RAW DATA, JANUARY 2026

Salt marsh Class, and dominant and sub-dominant taxa extent (ha). '-' indicates no sub-dominant taxa recorded.

Class, dominant taxa + primary subdominant taxa	Area (ha)	Total
Estuarine Shrub		**5.95**
Plagianthus divaricatus (Salt marsh ribbonwood)		
-	0.34	
Apodasmia similis (Jointed wirerush)	1.76	
Festuca arundinacea (Tall fescue)	0.35	
Juncus acutiflorus (Sharp flowered rush)	2.81	
Juncus kraussii (Searush)	0.69	
Sedgeland		**31.46**
Bolboschoenus caldwellii (Caldwell's clubrush)		
-	2.32	
Festuca arundinacea (Tall fescue)	0.50	
Juncus acutiflorus (Sharp flowered rush)	0.07	
Juncus kraussii (Searush)	1.13	
Leptinella dioica	0.00	
Schoenoplectus pungens (Three square)	8.02	
Schoenoplectus tabernaemontani (Lake clubrush)	0.61	
Cyperus ustulatus (Giant umbrella sedge)		
-	0.03	
Juncus edgariae (Wiwi)	0.02	
Eleocharis acuta (Spike sedge)		
-	1.73	
Isolepis prolifera (Budding clubrush)	0.33	
Limosella lineata (Mudwort)	0.04	
Isolepis cernua (Slender clubrush)		
Schoenoplectus pungens (Three square)	0.001	
Schoenoplectus pungens (Three square)		
-	2.79	
Bolboschoenus caldwellii (Caldwell's clubrush)	4.53	
Juncus kraussii (Searush)	8.99	
Leptinella dioica	0.00	
Samolus repens (Primrose)	0.01	
Sarcocornia quinqueflora (Glasswort)	0.32	
Rushland		**97.31**
Apodasmia similis (Jointed wirerush)		
-	0.10	
Bolboschoenus caldwellii (Caldwell's clubrush)	0.65	
Juncus kraussii (Searush)	3.72	
Plagianthus divaricatus (Salt marsh ribbonwood)	0.36	
Schoenoplectus pungens (Three square)	0.43	
Juncus acutiflorus (Sharp flowered rush)		
Bolboschoenus caldwellii (Caldwell's clubrush)	0.36	
Juncus kraussii (Searush)	4.82	
Plagianthus divaricatus (Salt marsh ribbonwood)	7.47	
Sarcocornia quinqueflora (Glasswort)	0.09	
Rushland (continued)		
Juncus kraussii (Searush)		
-	1.98	
Apodasmia similis (Jointed wirerush)	24.42	
Bolboschoenus caldwellii (Caldwell's clubrush)	0.86	
Festuca arundinacea (Tall fescue)	0.64	
Juncus acutiflorus (Sharp flowered rush)	19.34	
Plagianthus divaricatus (Salt marsh ribbonwood)	12.57	
Samolus repens (Primrose)	0.30	
Sarcocornia quinqueflora (Glasswort)	13.12	
Schoenoplectus pungens (Three square)	2.12	
Selliera radicans (Remuremu)	0.32	
Schoenoplectus tabernaemontani (Lake clubrush)		
Bolboschoenus caldwellii (Caldwell's clubrush)	0.24	
Eleocharis acuta (Spike sedge)	3.40	
Herbfield		**5.82**
Leptinella dioica		
-	0.01	
Samolus repens (Primrose)	0.50	
Samolus repens (Primrose)		
-	0.56	
Leptinella dioica	1.11	
Sarcocornia quinqueflora (Glasswort)	0.37	
Sarcocornia quinqueflora (Glasswort)		
-	0.24	
Juncus acutiflorus (Sharp flowered rush)	0.04	
Juncus kraussii (Searush)	0.57	
Samolus repens (Primrose)	0.70	
Selliera radicans (Remuremu)	1.32	
Selliera radicans (Remuremu)		
Samolus repens (Primrose)	0.15	
Sarcocornia quinqueflora (Glasswort)	0.25	
Reedland		**0.03**
Glyceria maxima (Reed sweetgrass)	0.03	
Total		**140.60**

Turf Plant		
Limosella lineata (Mudwort)		
-	0.49	
Cotula coronopifolia (Bachelor's button)	0.11	
Isolepis prolifera (Budding clubrush)	0.02	
Total		**0.62**

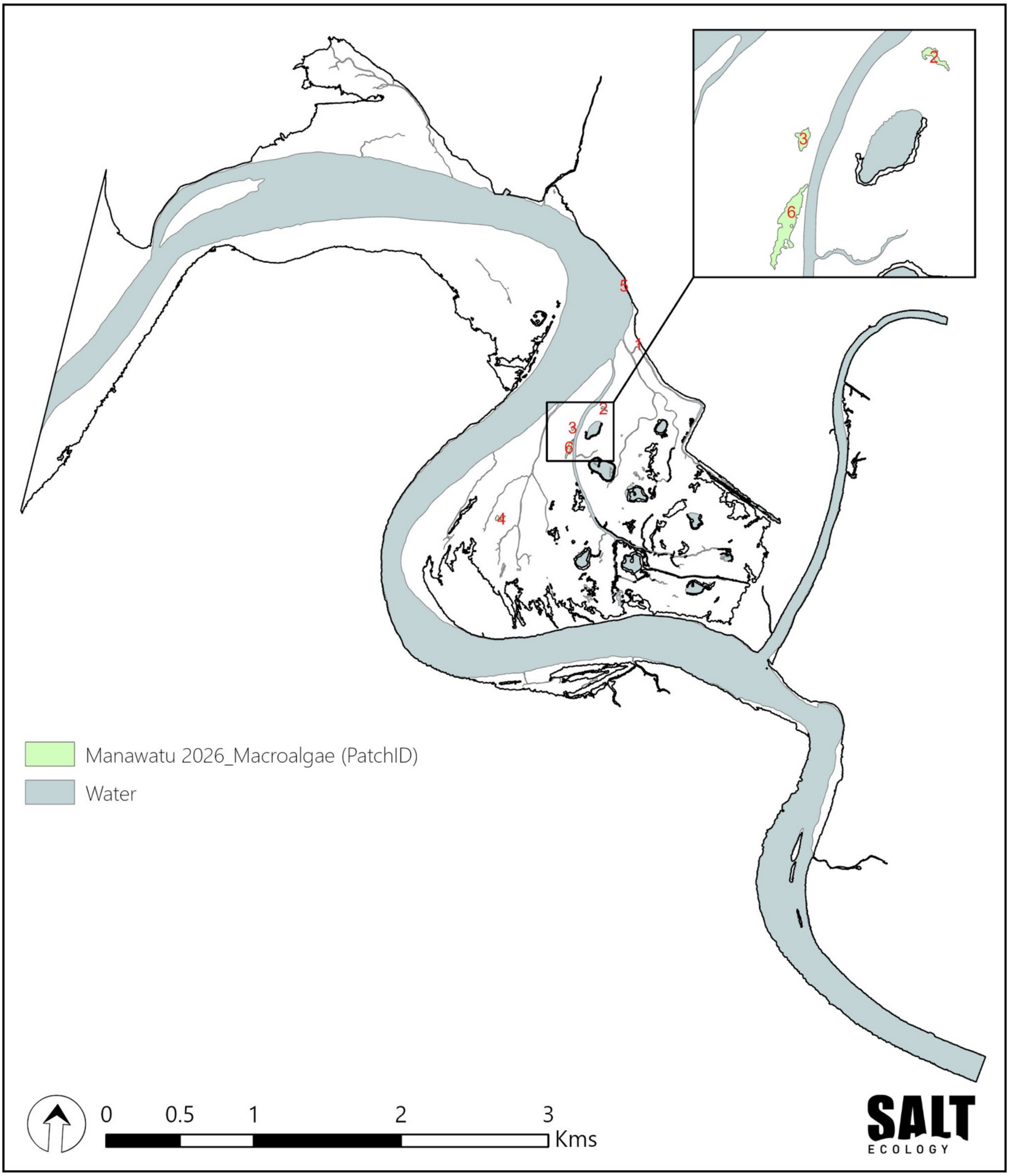
APPENDIX 4. SUBSTRATE RAW DATA, JANUARY 2026

Total estuary substrate, and substrate within salt marsh and macroalgae.

		Intertidal		AIH		Salt marsh		Macroalgae	
Sub-class	**Feature**	**ha**	**%**	**ha**	**%**	**ha**	**%**	**ha**	**%**
Artificial	Artificial surfaces	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Boulder field	0.6	0.2	0.6	0.4	0.0	0.0	0.1	31.4
Coarse substrate (>2mm)	Cobble field	0.3	0.1	0.3	0.2	0.0	0.0	0.0	0.0
	Gravel field	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0
SAND (<10% mud)	Mobile sand	22.6	7.9	22.6	15.6	0.0	0.0	0.0	0.0
	Firm sand	38.9	13.6	38.6	26.6	0.3	0.2	0.0	0.0
	Soft sand	0.2	0.1	0.2	0.2	0.0	0.0	0.0	0.0
Muddy SAND (≥10 to <25% mud)	Mobile muddy sand	2.8	1.0	2.8	1.9	0.0	0.0	0.0	0.0
	Firm muddy sand	11.6	4.0	9.4	6.5	2.1	1.5	0.0	0.0
Muddy SAND (≥25 to <50% mud)	Firm muddy sand	26.4	9.2	16.5	11.4	9.8	7.0	0.0	0.0
	Soft muddy sand	9.0	3.1	8.9	6.2	0.0	0.0	0.0	0.0
Sandy MUD (≥50 to <90% mud)	Firm sandy mud	141.5	49.5	15.7	10.9	125.8	89.1	0.0	1.4
	Soft sandy mud	29.6	10.3	26.5	18.3	3.0	2.1	0.3	67.2
	Very soft sandy mud	2.4	0.8	2.4	1.7	0.0	0.0	0.0	0.0
MUD (≥90% mud)	Soft mud	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0
		286	100	145	100	141	100	0	100

APPENDIX 5. MACROALGAE PATCH INFORMATION AND EQR

A. Macroalgae patch locations, January 2026



EQR raw data and ratings, 2026

Patch ID	Dominant Species	% Cover	% Cover Category	Biomass (g/m^2)	Biomass Category	Entrained	Substrate	Area (ha)
1	*Ulva* spp. (Sea lettuce)	70	Dense (70 to <90%)	100	Very low (1 - 100)	0	fSM	0.01
2	*Gracilaria* spp. (Agar weed)	25	Low (10 to <30%)	400	Moderate (201 - 500)	0	sSM	0.03
3	*Gracilaria* spp. (Agar weed)	25	Low (10 to <30%)	400	Moderate (201 - 500)	1	sSM	0.03
4	*Ulva* spp. (Sea lettuce)	15	Low (10 to <30%)	80	Very low (1 - 100)	0	sSM	0.07
5	*Ulva* spp. (Sea lettuce)	10	Low (10 to <30%)	20	Very low (1 - 100)	1	aBF	0.12
6	*Gracilaria* spp. (Agar weed)	10	Low (10 to <30%)	80	Very low (1 - 100)	1	sSM	0.13

2026 Metric	Face value	FEDS	Environmental Quality Class
% cover in AIH	0.04	0.999	High
Average biomass (g/m^2) in AIH	0.3	0.999	High
Average biomass (g/m^2) in AA	109	0.783	Good
%entrained in AA	42.7	0.249	Poor
Worst of AA (ha) and AA (% of AIH)		0.990	High
AA (ha)	0.38	0.992	High
AA (% of AIH)	0.26	0.990	High
Survey EQR		0.999	High (Very Good)

Notes: AA=Affected Area, AIH=Available Intertidal Habitat, FEDS=Final Equidistant Score, EQR=Ecological Quality Rating.

The EQR Score is the average of the 5 scaled metric scores (using the lower of AA or AA/AIH). However, if there is ≤5% cover on the AIH, the % cover EQR score = the EQR.

EQR raw data and ratings, 2016

Patch ID	Dominant Species	% Cover	% Cover Category	Biomass (g/m^2)	Biomass Category	Entrained	Substrate	Area (ha)
1	*Ulva* spp. (Sea lettuce)	50	High (50 to <70%)	155	Moderate (201 - 500)	0	aBF	0.31
2	*Ulva* spp. (Sea lettuce)	80	Dense (70 to <90%)	126	Moderate (201 - 500)	0	aBF	0.16
3	*Ulva* spp. (Sea lettuce)	80	Dense (70 to <90%)	78	Very low (1 - 100)	0	sSM	0.1
4	*Gracilaria* spp. (Agar weed)	50	High (50 to <70%)	75	Very low (1 - 100)	0	RF	0.15
5	*Gracilaria* spp. (Agar weed)	20	Low (10 to <30%)	2	Very low (1 - 100)	1	sSM	0.01

2016 Metric	Face value	FEDS	Environmental Quality Class
% cover in AIH	0.38	0.985	High
Average biomass (g/m^2) in AIH	0.75	0.999	High
Average biomass (g/m^2) in AA	120	0.761	Good
%entrained in AA	1.4	0.782	Good
Worst of AA (ha) and AA (% of AIH)		0.975	High
AA (ha)	0.73	0.985	High
AA (% of AIH)	0.63	0.975	High
Survey EQR		0.985	High (Very Good)

Notes: AA=Affected Area, AIH=Available Intertidal Habitat, FEDS=Final Equidistant Score, EQR=Ecological Quality Rating.

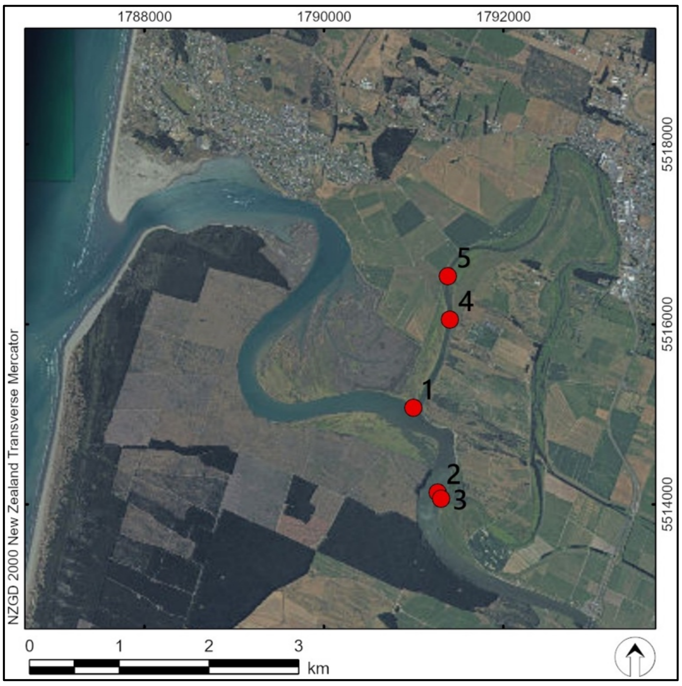
The EQR Score is the average of the 5 scaled metric scores (using the lower of AA or AA/AIH). However, if there is ≤5% cover on the AIH, the % cover EQR score = the EQR.

APPENDIX 6. SYNOPTIC WATER QUALITY DATA, 28 JANUARY 2026.

Condition rating is the one-day minimum criterion from Robertson et al. (2016a).

	Site 1	Site 2	Site 3	Site 4	Site 5
Easting (NZTM)	1791000	1791400	1791379	1791301	1791266
Northing (NZTM)	5515072	5516055	5516533	5514063	5514133
Distance from mouth (km)	6.5	7.4	7.5	7.6	8.0
Surface water					
Depth (m)	0.2	0.2	0.2	0.2	0.2
Temp (^oC)	21.1	17.2	19.8	21.8	22.1
DO saturation (%)	50.2	101.1	49.0	45.3	41.8
DO conc (g/m^3)	4.41	9.53	4.40	4.01	3.54
Salinity (ppt)	0.37	0.06	0.12	0.39	0.37
Chl a (mg/m^3)	6.7	2.2	4.3	7.6	7.6
Bottom water					
Depth (m)	5.3	0.8	1.8	3.2	5.0
Temp (^oC)	18.2	17.2	17.9	19.9	19.9
DO saturation (%)	79.0	99.5	52.5	36.2	31.3
DO conc (g/m^3)	7.28	9.47	4.98	3.30	2.98
Salinity (ppt)	0.17	0.06	0.06	0.41	0.38
Chl a (mg/m^3)	5.1	3.2	3.3	9.8	10.2
General					
Secchi depth (m)	0.55	0.06	0.28	0.80	0.95
Maximum depth (m)	7.1	0.9	2.5	3.3	6.0
Channel width (m)	75	50	15	50	30

Site 1: Manawatū River opposite seaward end of Foxton Loop
Site2: Manawatū River opposite upstream end of Foxton Loop
Site 3: Foxton Loop upstream discharge to main river
Site 4: Foxton Loop downstream discharge to main river
Site 5: Foxton Loop mid-section

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