Kaipara Harbour sand extraction monitoring programme

2025 Bathymetry, Beach and Manukapua Island surveys

Prepared for Winstone Aggregates Group Lit and Mt Rex Shipping Ltd

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Climate, Freshwater & Ocean Science

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Executive summary

Winstone Aggregates Group Ltd and Mt Rex Shipping Ltd have been granted Coastal Permits (No. 29202 and 29193, respectively) that authorise the dredging and removal of sand and to disturb the seabed for the purpose of sand extraction in the entrance to the Kaipara Harbour. To meet resource consent monitoring conditions, NIWA was contracted to undertake the "Kaipara Harbour sand extraction monitoring programme" for 2024-25. The main purpose of the monitoring programme is to identify and quantify changes or trends of change in coastal morphology in parts of the Kaipara Inlet in the vicinity of sand extraction, by regularly measuring and comparing coastline and bathymetric features and to assess whether any changes are causatively related to sand extraction.

The 2025 sand extraction monitoring programme collected aerial survey and photographic records of Pouto Point, South Head and Manukapua Island. The latest surveys show that the study sites continue to evolve in a way that is consistent with morphological changes observed in past reports (e.g., Hume et al. 2003, Allis et al. 2017a, 2017b, 2019, Reeve et al. 2020, 2023, 2024).

As observed during the Kaipara Sand Study (Hume et al. 2003), Manukapua Island is highly mobile and there have been very large changes in island morphology over the last 150 years which are typical of a barrier island with little permanent vegetation adjacent to a tidal flood-delta with large sediment fluxes. The observed changes in 2025 include sand dune recession, dune migration, migration of nearshore channels, and change in extent of vegetation associated with the gradual movement of sediment.

The detailed analysis of Manukapua Island shows that sand is being lost from the western side of the island and is accumulating on the eastern side. This trend has been observed since the surveys began in 2008—suggesting that the island body is slowly migrating east with the prevailing aeolian (wind) transport of sand.

It will always be difficult to link morphological changes to sand extraction given the large sand movement volumes within the Kaipara Harbour, and the large natural changes in Manukapua Island which have been observed in the past and may be expected in future. The aerial and seabed survey programme has provided a considerable increase in coverage compared to previous ground-based beach profiling, and over time, will continue to gather robust information about changes in planform and sand storage volumes on Manukapua Island, and the sand banks within the Kaipara Harbour.

A memory drive supplied to the clients contains all survey information.

1 Introduction

Winstone Aggregates Group Ltd and Mt Rex Shipping Ltd have been granted Coastal Permits (No. 29202 and 29193, respectively) to authorise the dredging and removal of sand and to disturb the seabed for the purpose of sand extraction in the entrance to the Kaipara Harbour (Figure 1-1).

The extraction of sand from the inlet has the potential to result in a decrease in sand supply to nearby beaches. Hence the main purpose of the monitoring programme is to identify and where possible quantify changes or trends of change in coastal morphology in parts of the Kaipara Inlet in the vicinity of the sand extraction. The changes are investigated by regularly measuring and comparing coastline and bathymetric features and to assess whether any changes are causatively related to sand extraction.

The monitoring relates to the areas indicated in Figure 1-1:

- **Manukapua Island** (also known as Taporapora Island), which includes Tauhoa Channel and Tauhoa sandbank, immediately south of the island.
- **Kaipara South Head,** which includes Ocean beach, Papakanui Spit and Waionui Inlet.
- **Pouto Point**, extending north to Maori Bay and the outlet of South Tauhara Creek.

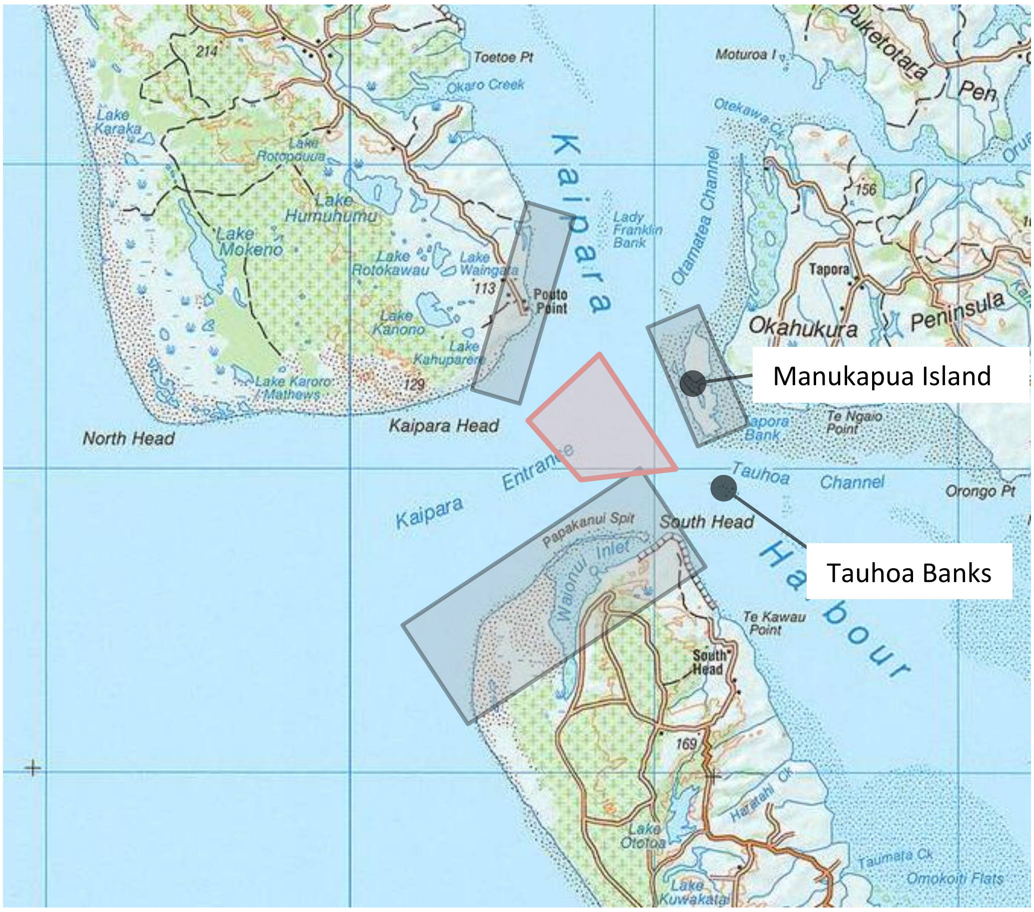


Figure 1-1: Layout of Kaipara Harbour entrance with monitoring areas. Shaded areas indicate approximate orthophoto coverage (grey) and consented sand extraction area (red). Scale: 10 km grid. [Source: LINZ 1:250,000 series].

During the Kaipara Sand Study, Hume et al. (2003) observed that Kaipara Harbour is a highly dynamic tidal inlet, which is characterised by large movements of sand on the seabed as shoals migrate and change shape. There are also large accompanying changes along the shorelines as beaches erode and accrete in response to local changes in tide and wave conditions and the effects on hydraulic processes as sand banks shift about. Manukapua Island is a barrier island that has been built entirely in the last 150 years from sand coming ashore by a combination of two process. Firstly, at high tide the water over the ebb-tidal delta is deep enough to allow ocean swell to drive in to Manukapua Island and move sand landward (Hume et al. 2003). Secondly, westerly winds blow sand up from the beach to form dunes.

Survey plans show vast changes in the Manukapua Island shoreline in historical times. In 1858 Manukapua Island was charted as a small 700 × 350 m sized feature. The 1914 cadastral surveys show the island comprised low sand hills and was 1200 × 600 m in size. Manukapua Island has built southward some 2 km since 1914 and in 2003 comprised about 16 million cubic metres of sand (Hume et al. 2003). This is strong evidence that large amounts of sand have come ashore in the vicinity of Manukapua Island (to build the island). This could be coming from the open coast. Alternatively, it could be a redistribution of sand within the harbour, perhaps, for instance, sand moving south from the eastern edge of Lady Franklin Bank or the Waikiri Creek shore (the inlet just north of Manukapua Island) (Hume et al. 2003).

Earlier beach-profiling studies show that the beach and seabed morphology around Manukapua Island is highly mobile, with large volumes of sand moving on an annual basis (Green et al. 2002, Edhouse et al. 2012, Kench et al. 2014). Sand accumulation (equivalent to net sand transport) of 1.5–2.1 M m^3/yr (1,500,000–2,100,000 cubic meters per year) is expected on the Manukapua Banks (Stephens and Reeve, 2010). Gross sand transport over the Manukapua Banks was estimated as 1.9–4.1 M m^3/yr (1,900,000–4,100,000 cubic meters per year). This compares to gross sand transport through the inlet entrance of 72 M m^3/yr (72,000,000 cubic meters per year), which is about 20–40 times that over the Manukapua Banks (Stephens and Reeve, 2010).

Stephens and Reeve (2010), modelled net sand accumulation in an area consented sand extraction area was in the range 1.0–1.8 M m^3/yr. Sustainable sand extraction rates were calculated based on the net sand accumulation in the practical extraction area. The volume of sustainable sand extraction was estimated to be 600,000 cubic metres per year (600,000 m^3/yr) (Stephens and Reeve, 2010). The consented maximum volume permitted for extraction for all consent holders in the first 5-years was 400,000 m^3/yr. The <u>average</u> volume extracted over the remaining 15 years of the consent cannot exceed 600,000 m^3/yr (sum of Winstone's 264,000 m^3/yr (Permit No. 29202) and Mt Rex's 336,000 m^3/yr (Permit No. 29193)). The consented <u>maximum</u> volume in any given year cannot exceed 700,000 m^3/yr (sum of Winstone's 308,000 m^3/yr and Mt Rex's 392,000 m^3/yr).

1.1 Background to monitoring programme

The work programme outlined herein is designed to meet the request for services specified in document "Kaipara Harbour sand extraction monitoring programme for resource consents – Auckland Council 41662 and 41663, November 2013", by Winstone Aggregates and Mt Rex Shipping Ltd.

The resource consent monitoring conditions that are the subject of this programme are:

20. The Consent Holder shall undertake an annual monitoring programme that provides remote sensing images and a digital topographic model for measuring and comparing changes in

coastal morphology of Taporapora (Manukapua Island). The monitoring programme shall produce beach profiles and topography that is appropriate for comparison with existing data collected using Differential GPS survey of the high tide line, the dune line and the low tide line and shall be approved by the Team Leader. The monitoring report shall provide an account of the net gain or loss of sand from areas of accretion and erosion on the western side of Taporapora Island.

21. The Consent Holder shall undertake aerial photography or other remote sensing imaging annually of an area comprising Kaipara South Head (Waionui Inlet, Ti Tree Island to mouth) and Papakanui Spit extending south to the ocean beach and also of an area of Pouto shoreline to Maori Bay (South Tauhara Creek). The aerial imaging record shall be assessed annually for changes in morphology by a suitably qualified person approved by Council and the assessment and findings shall be included in the annual coastal monitoring programme report provided to Auckland Council.

22A. The Consent Holder shall undertake a monitoring programme that will measure changes in seabed profiles on the Tapora Banks. This programme shall include at least 10 profiles, extending from low tide to 10 m water depth, 5 of which connect with beach Profiles 1 to 5 that have been established on the western shore of Taporapora Island (Manukapua Island) as described in condition 20 above and monitored at least two-yearly intervals. The monitoring programme shall be developed in consultation with the Team Leader and shall be approved by the Team Leader.

22B. The Consent Holder shall undertake a monitoring programme that will measure changes in seabed profiles on the western end of the Tauhoa Bank at least two-yearly intervals. This programme shall include at least three profiles, and shall be developed in consultation with the Team Leader and shall be approved by the Team Leader.

23. The monitoring programmes described in Conditions 20 and 21, above shall establish reference datum points for long-term consistency in survey. The number of profiles may need to be increased at some stage to take account of future shoreline and landform changes. Prior to commencement, the monitoring programmes shall be submitted to the Team Leader for approval.

24. The programmes shall be established by the Consent Holder and managed, analysed and reported upon by persons possessing appropriate expertise in the assessment of physical processes and beach behaviour.

25. Analysed results of the monitoring programmes shall be forwarded to the Minister, the Team Leader, the Department of Conservation, Oruawharo Marae, Royal Forest and Bird Protection Society and Ngati Whatua (Ngati Whatua o Kaipara and Te Uri o Hau), or alternatively the Kaipara Harbour Sand Extraction Monitoring Group annually.

26. The Consent Holder may comply with Conditions 18 to 21, by participating in, and contributing to a Kaipara Harbour Entrance Monitoring programme established on the following basis:

a) A working party being formed within one month of the date of commencement of consent consisting of representatives from the Consent Holder, the Auckland Council and Northland Regional Council, and any other party prepared to financially contribute to the monitoring programme.

b) The monitoring programme shall include, but not be limited to, the monitoring activities described in the Numerical Modelling conditions above (conditions 14 and 15) and the monitoring activities described in the Coastal and Seabed Monitoring Conditions above (conditions 20 to 23).

c) The working party shall engage the necessary experts to carry out the monitoring programme and in consultation with the experts will define the precise parameters of the monitoring.

d) The monitoring programme will be funded by the Consent Holder and any other party represented as shall be agreed between the parties.

1.2 Monitoring Programme

The primary objective of the sand extraction monitoring program is to collect monitoring data in a format suitable for analysis and comparison with historical data. This program also involves expert assessment and reporting of monitoring results. Surveys are conducted on both land and the adjacent seabed in the vicinity of where sand extraction occurs in the entrance of the Kaipara Harbour.

This report contains the results from the 2025 monitoring programme which collected orthorectified aerial photographs and beach transects within the required areas of Kaipara Harbour (see Figure 1-1).

NIWA was contracted to complete the following tasks for the 2025 monitoring:

1. Survey by aerial photogrammetry to produce fully orthorectified images of Manukapua Island, and approximately ortho-rectified images of Kaipara South Head, Ocean Beach and Pouto Point.
2. Compilation of 10 beach transects and topography on Manukapua Island for comparison with existing data (e.g., surface elevation profiles, dune line, high tide line and low tide line) and including some measurements for ground-truthing of aerial photogrammetry.
3. Subtidal profiling of 13 transects on the Tapora and Tauhoa Banks in and adjacent to the sand extraction area, which is to be integrated with the beach profiling.
4. Expert assessment and reporting of monitoring results, including identification of any significant changes in coastal morphology on Manukapua Island, Kaipara South Head and Pouto Point (North Head).
5. Presentation of the results to the Kaipara Harbour Sand Extraction Management Group (KHSEMG). Presentation location and time to be confirmed but prior to 30 June 2025.
6. An assessment of the satellite-derived bathymetry (SDB) and digital elevation model (DEM) trial was undertaken to evaluate the viability of these remote sensing products as alternatives to traditional survey methods.

NIWA managed the monitoring programme, completed tasks 4–5 and sub-contracted Interpine Innovation to undertake tasks 1 – 3.

The structure of this report is to outline the background to the monitoring in Section 1.1, and outline the method for aerial surveys in Section 2. The results of the monitoring programme are presented in Section 3 including the aerial orthophotos, beach transects, satellite data and seabed surveys. Section 4 discusses the results and provides a summary.

2 Monitoring methodology

2.1 Transect notation

The notation for the 13 transects surveyed on Manukapua Island are shown in Figure 2-1.

- Transects 1-10 are integrated beach-seabed transects lines extending from the eastern flank of the Manukapua Island, across the island body, and continuing approximately 5 km into the Kaipara Harbour entrance.
- Transects 11-13 are seabed-only surveys which traverse the Tauhoa Channel and Tauhoa Banks to the south of Manukapua Island.

Figure 2-1 also illustrates several no-longer surveyed seabed transects. See Allis et al. (2017a) for description of the transect surveys positions. Table A-1, Appendix A contains the coordinates for all shown transects.

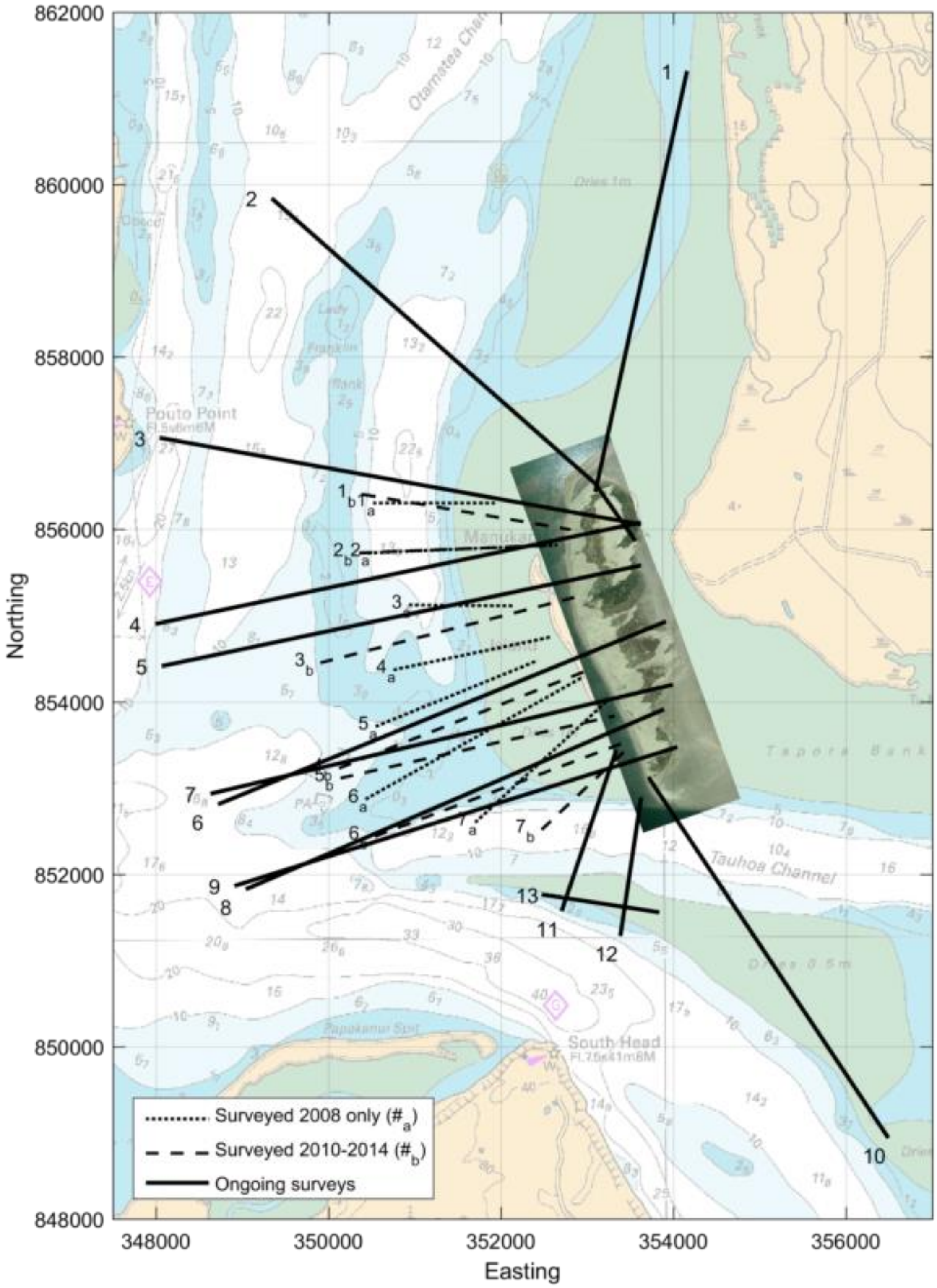


Figure 2-1: Location of beach and seabed survey transects. Transects 1-13 were surveyed in 2019, transects with subscript 'a' or 'b' refer to prior surveys. [Sources: LINZ hydrograph chart 4265 Kaipara Harbour, 2016 aerial photograph].

2.2 Aerial photography and LiDAR Survey

The aerial surveying for Manukapua Island was conducted on 11th January 2025. All data from the aerial LiDAR survey were processed into Mt Eden 2000 coordinates and New Zealand vertical datum 2016 (NZVD2016), and later converted into Auckland Vertical Datum 1946 (AVD-46)[1].

The survey flights were performed by Interpine as follows:

1. An aerial LiDAR (light detection and ranging) survey of Manukapua Island, undertaken using UAV LiDAR system flown 110 m above the island.
2. Ten beach transect lines (Figure 2-1) were mapped on Manukapua Island for comparison to historic monitoring using coordinates in Table A-1, Appendix A.
3. Manukapua Island aerial image was flown by drone at 110 m, while high-resolution satellite images were obtained for Kaipara South Head and Pouto Point.
4. A digital terrain model (DTM) was created from the LiDAR data covering the Manukapua Island utilising the ground control points which were established as part of the survey. Interpine have fixed the location of nine ground control points (GCP) on Manukapua Island using a survey grade decimetre GNSS (Trimble Geo6000XH). This was for the purposes of validation for subsequent LiDAR analysis (Figure 2-2).

Figure 2-2: Interpine have fixed the location of nine ground control points on Manukapua Island. [Credit Left: Susana Gonzalez (Interpine Group), Right: 0.25 m Aerial photo].

2.3 Digital Terrain Model Processing

Although a full analysis of the Digital Terrain Model (DTM) was not required for this monitoring round, a high-resolution LiDAR DTM was still collected. The use of LiDAR allows for data capture across the entire island with minimal disturbance—particularly important given limited access to the vegetated portions of Manukapua Island during the bird nesting season.

[1] Conversion from One Tree Point Vertical Datum 1964 to Auckland Vertical Datum 1946 = +0.24m

Prior to 2022, DTMs were obtained using plane-based aerial photogrammetry. From 2022 onwards, a drone-based LiDAR method has been adopted, providing improved spatial resolution and the ability to penetrate vegetation to measure the underlying ground surface.

While full DTM analyses were carried out for the 2014, 2015, 2017, 2019, and 2022 datasets, only the beach transect extraction was performed for the 2025 DTM dataset. Full geomorphic analysis of the DTM is planned for the 2025–2026 monitoring programme.

Key DTM collection and processing steps for previous years (2015, 2017, 2019, 2022, 2024) include:

- Acquisition of approximately 300 million individual ground points per survey at 0.1 m ground sample distance.
- Ground-truth validation with handheld GPS devices, confirming high vertical and horizontal accuracy.
- Manual filtering to remove vegetation artefacts, ensuring only bare-earth surfaces are retained.
- Interpolation of the filtered DTM to a 2 m resolution grid (~0.7 million points) to streamline data handling.

Estimated accuracy for these DTMs is ±0.15 m vertically and ±0.1 m horizontally. The largest errors typically occur in densely vegetated areas (Gonzalez, 2023).

Bi-annual DTM surveys now alternate with subtidal seabed mapping. The next full DTM analysis is scheduled for the 2025–2026 monitoring period.

2.4 Beach transects survey

The beach transect analysis is a continuation of the prior coastal monitoring programmes (e.g., Kench et al. 2013, 2014, Allis et al. 2014, 2015, 2017a, 2017b, 2019, Reeve 2023). Beach survey data were manually collected by the University of Auckland either once or twice per year ending in 2013, and beach surveying has been performed annually from 2014 with a change to aerial photogrammetry survey techniques[2]. While manual surveys were previously conducted up to 2013, and photogrammetry was used from 2014 onward, current transect data are now extracted directly from LiDAR-derived DTMs

For the 2025 monitoring round, although a full DTM analysis was not completed, the DTM dataset was used specifically to extract updated beach transects. This approach reduces the need for on-ground survey activity, particularly important given seasonal restrictions on accessing the vegetated areas of the island during bird nesting.

The on-land portion of Transects 4-7 and 9 have beach survey data from 1998 to present, while Transects 1-3, 8 and 10 have beach survey data from 2008 to present.

The following processing steps are adopted for each transect dataset:

[2] Allis et al. (2015) details a comparison of the two survey beach-profile techniques and adjusts the older surveys (1998-2008) to modern coordinate systems.

1. The complete profile set is presented to provide an overview of the range of profile positions since surveying began. These are shown as elevations and cross-shore positions for each survey date.
2. The datum 'zero' (0 m AVD-46) and the mean high water perigean springs tide level (MHWPS) is shown to indicate the upper range of the intertidal beach for Manukapua Island. A MHWPS elevation of 1.90 m AVD–46 was calculated from the 1.67 m MHWPS amplitude in Tauhoa channel (Stephens and Wadhwa 2012) plus the recent mean sea level (MSL) offset to AVD–46 = +0.23 m (Stephens et al. 2016).
3. An excursion distance plot is presented to show the beach position changing with time, which helps identify trends in erosion/accretion over the beach profile. This is shown as the cross-shore position of various elevations through time. For example, it shows how the position of the 2 m contour retreats/advances along the transect through time. See Kench et al. (2014, p.6) for further description of the excursion analysis.
4. The volume of sand contained under each profile is calculated for the area *seaward* of the zero-horizontal position (e.g., 0 m) and *above* a nominated vertical elevation (e.g., -1.5 m AVD-46). The nominated vertical elevation for each profile is the elevation selected by Kench et al. (2014) relative to AVD-46. The volume analysis is limited to the nominated part of the beach profile only and does not necessarily reflect island-wide changes in sand volume or distribution. At some transects, the profile has changed substantially since the original zero horizontal position was established by the University of Auckland, e.g., the erosion of an entire foredune.
5. A summary of observed geomorphic changes to the transect is presented. This identifies key profile features (e.g., foredune extent, dune crest, dune toe, intertidal beach), the consistency of each feature with prior surveys, approximate dimensions, and trend of change since the last survey and since surveying began, along with the appearance of any new trends or features.

Note that the 2015 monitoring report (Allis et al. 2015) corrected the elevation and horizontal position of the older University of Auckland beach surveys (1998-2008) to modern coordinate systems by comparing overlapping on-ground survey data. However, no on-ground survey data was available for the 2008-2013 beach profiles of Transect 8 and Transect 10. Consequently, Allis et al. (2015) manually adjusted these to modern coordinates with careful checking of profile alignment, profile features and trends, and comparison to previously reported volumes of Kench et al. (2014). Volumetric changes reported here for Transect 8 and Transect 10 include this adjustment.

2.5 Seabed survey

2.5.1 Survey methodology and results

Survey Overview

A single-beam hydrographic survey was undertaken on 14 May 2025 using NIWA's survey vessel *Whai II*. The survey followed 13 pre-defined transects, with start and end points shown in Figure 2-1 and listed in Appendix A, Table A-1. Prior to departure, transect coordinates were uploaded into the HYPACK hydrographic survey software, and all equipment was tested.

Equipment and Data Collection

The vessel was equipped with a Trimble R10 RTK GPS for real-time horizontal and vertical positioning, and a Tritech PA500 echo sounder (500 kHz, 6° beam angle, 0–50 m range) for depth measurements. Position and depth data were recorded via HYPACK. Soundings were taken at 1 Hz, with the vessel maintaining an approximate speed of 4 knots. Data were referenced to the NZGD2000 Mount Eden Circuit coordinate system and initially tied to NZVD2016 vertical datum, later converted to AVD-46.

HYPACK also calculated seabed elevations by integrating GPS elevation, echo sounder depth, and the draft of the transducer. A geoid model was not applied, allowing for consistent comparison between survey datasets.

Vertical errors associated with the use of RTK GPS are typically within ±1 cm horizontally and ±2 cm vertically. However, additional factors—such as the separation between base and rover stations and slight deviations in the vessel's actual track between survey years—can result in a cumulative repeatability error of up to ±20 cm (Hart et al. 2009). Therefore, changes in seabed elevation are not considered significant unless they exceed ±20 cm

GPS Validation and Accuracy

Previous surveys in the area used a local RTK base station (survey mark B5RA) to provide high-accuracy positioning. During the 2023 bathymetry survey, the Trimble "VRS now[3]" RTK service was trialled to assess its suitability as an alternative. The aim was twofold: (A) to confirm whether adequate cellular coverage existed across the survey area, and (B) to evaluate whether VRS Now could deliver comparable vertical accuracy to the base station approach.

A check shot to survey mark B5R9 (see Appendix A Table A-2) and comparison of bathymetry along transects T1 and T10 were used to evaluate performance. The results showed good agreement between methods, indicating that the VRS Now service was a suitable alternative for future surveys.

Survey Conditions and Observations

Weather during the survey was generally fine, with southwesterly winds around 10 knots in the morning easing to variable 5-knot winds in the afternoon. Patchy cloud persisted through an otherwise sunny day.

Some challenges were encountered with maintaining survey line alignment during the morning. Swell generated by opposing wind and tide conditions affected transects 4 and 5, and full coverage of transect 5 was not achieved. In the afternoon, conditions improved, although light chop and residual swell were present near the exposed southwestern end of the island and Tauhoa Bank.

[3] VRS (Virtual reference station) gives access to RTK correction services using a network of permanent, continuously operating reference stations.

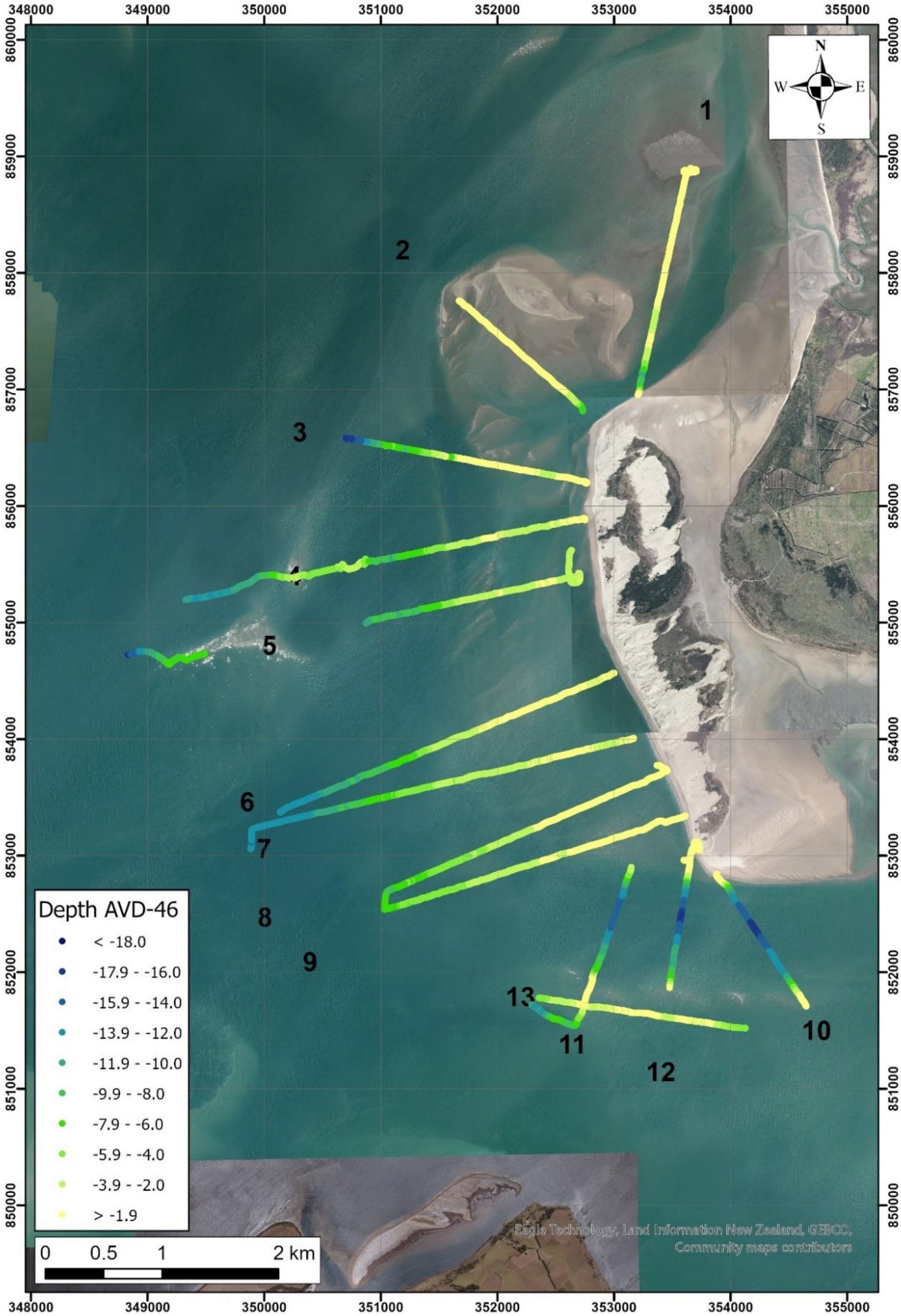


Figure 2-3: Seabed survey spatial distribution and depths (AVD-46) along the 13 surveyed transects in 2025. Coordinate grid is in NZGD2000 / Mount Eden Circuit.

2.5.2 Bathymetric post-processing data analysis

Depth data were processed using HYPACK software and standard procedures, which included the removal of out-of-range points and smoothing of data spikes. The cleaned data were then imported into ArcPRO for spatial analysis.

Due to the influence of tidal currents and wind, the survey vessel occasionally deviates from the planned transect route (e.g., Figure 2-3, Transect 5). However, these deviations are generally constrained to within ±5 m using track guidance software. To ensure consistency and enable comparison between surveys, the ideal (planned) transect lines were digitized in ArcPRO and subdivided into points at 5 m intervals. Perpendicular lines were drawn through these points, and the elevation value of the nearest measured depth point was assigned to each. This process effectively interpolates depths along the planned survey track at 5 m intervals. As the same planned transect lines are used for all surveys, results from different dates can be directly compared.

2.6 Satellite digital elevation and bathymetry

For the 2025 monitoring programme, EOMAP (https://eomap.com) was subcontracted to undertake a satellite-derived digital elevation model (DEM) and satellite derived bathymetry (SDB) trial for the Manukapua Island and Tapora Banks area to evaluate its feasibility for future use within the monitoring programme. Figure 2-4 shows the EOMAP study area. The assessment utilised very-high-resolution (2 m) multispectral satellite datasets from Maxar's WorldView-2 satellites. These datasets were enhanced to a 0.5 m resolution using pansharpening algorithms that incorporate the satellite's panchromatic band, which is natively captured at 0.5 m resolution, full technical details can be found in Klinger,Russell (2025). Several archived optical satellite image datasets were used to derive the bathymetry, making the output a time-averaged surface rather than an instantaneous surface, as would be the case with a hydrographic survey. In this instance, the surface represents an average over several months, incorporating varying tidal and weather conditions, as well as different levels of solar illumination. From the available archive of satellite data, images were based on the following criteria:

1. minimal atmospheric interference (e.g., cloud, haze, or dust),
2. absence of floating substances or objects such as oil films, vegetation, or ice, maximum possible water clarity,
3. optimal illumination and sensor recording geometry to ensure radiometric consistency and minimise water surface effects such as sunglint (when sunlight reflects directly off the surface), and
4. minimal impact from waves or wave-breaking.

Figure 2-4: Manukapua Island and Tapora Bank of interest for satellite bathymetry and satellite digital elevation model. Red line represents the area of interest.

3 Monitoring results

3.1 Orthoimages

The aerial survey captured ortho-images of the Kaipara South Head, Pouto Point and Manukapua Island monitoring areas for qualitative morphodynamic analysis. Representative high water (2.034 m), low water (-0.79 m) and vegetation lines were also mapped for Manukapua Island.

Orthophotos were captured of the monitoring areas at several horizontal resolutions (Table 3-1). Full resolution orthophotos are included on the appended reference memory drive.

Table 3-1: Orthophoto resolution for monitored areas. The resolution shows the on-ground size of a pixel in each image, i.e., lower resolution value shows more detail in the orthophoto.

Location	Resolution
Manukapua Island	0.25 m
Pouto Point	0.5 m
Kaipara South Head	0.5 m

The aerial orthophotos of Manukapua Island, Pouto Point and Kaipara South Head are shown in Figure 3-1, Figure 3-2 and Figure 3-3 respectively. These are the eighth iteration of annual aerial orthophotos in these locations, all prior aerial photos are included on the appended reference memory drive.

A visual comparison of the high-resolution photos from 2014 to 2025 there are no major changes observed. At the scale of these photographs only large or abrupt morphological changes are expected to be visible when comparing prior years. The most notable features are:

- Minor changes in the position and shape of the nearshore channels, runnels and bedforms, vegetation extents and density, sand dune and valley extents, on Pouto Point, South Head and Manukapua Island.
- On Manukapua Island, there has been a continued slow easterly retreat of both the vegetation line and the high-water line. Vegetation retreat is most pronounced along the narrower southern half of the island. The sand spits extending eastward from the northern and southern tips of the island have remained consistent in size and orientation, aligning with the prevailing eastward littoral drift around the island's tips.
- On South Head, the pre-2012 breach—located approximately 4 km along the 6 km-long Papakanui Spit near the Waionui Inlet—has narrowed and shallowed, and the original channel now appears to have re-established as the primary flow path. The breach itself has been slowly migrating eastward. A small ebb tidal delta (less than 100 m in radius) has formed at the mouth of the breach and continues to extend northward into the harbour entrance.
- The wide sandy beach south of Pouto Point shows little change in the extent of sand and vegetation cover. The inner-harbour shoreline north of Pouto Point also appears stable, as does the stretch between Pouto Point and the mouth of Tauhara Creek. The

narrow barrier separating the Tauhara Creek estuary from Kaipara Harbour remains stable. A slight build-out of the beach at Pouto Point is evident when compared to 2023, returning to a similar extent observed in 2021.

The visual analysis of the aerial photographs indicates that the beaches and island are primarily shaped by natural sedimentation and transport processes. The observed patterns and changes have remained generally consistent over time, with no significant shifts in behaviour evident in the most recent data.

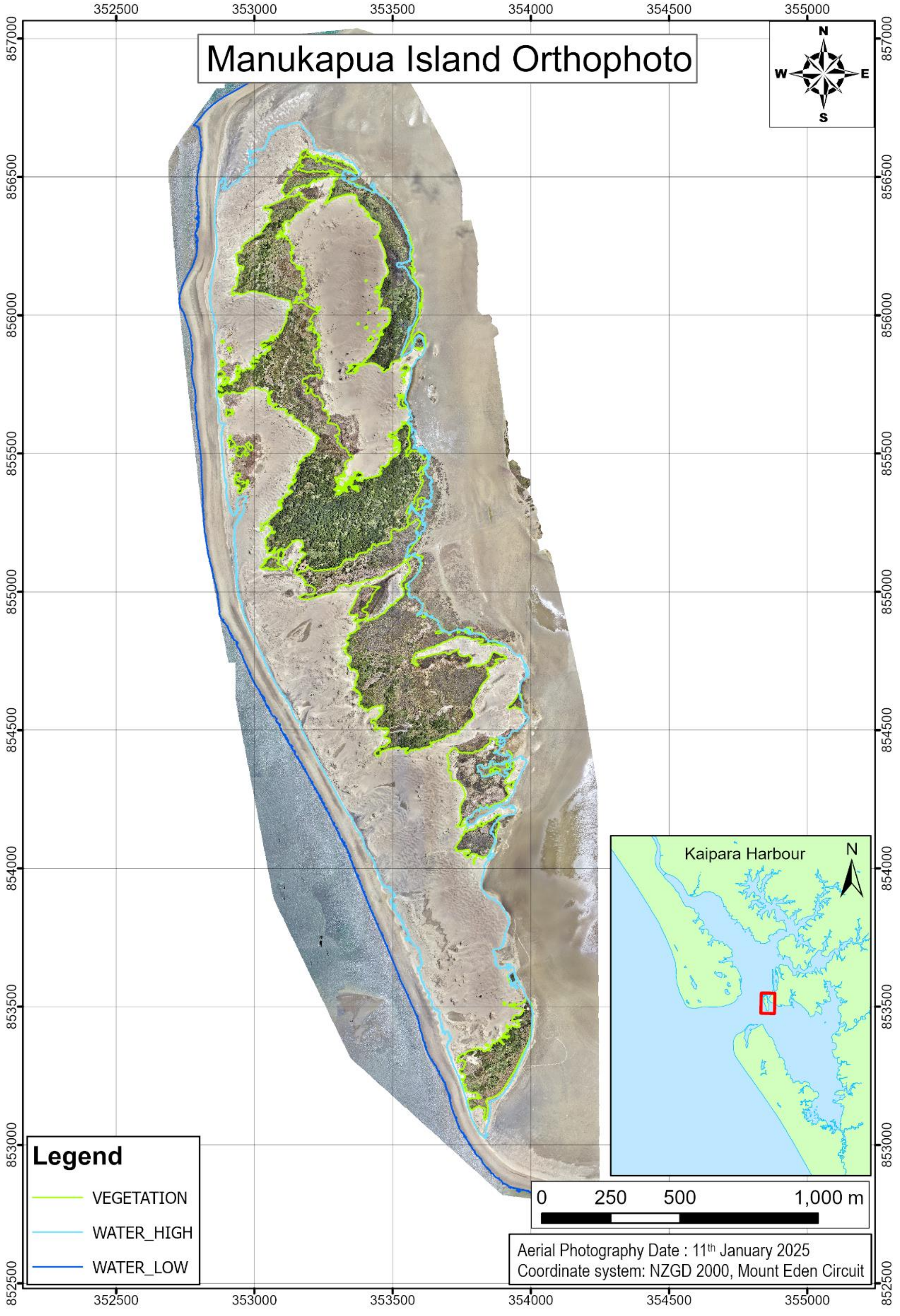


Figure 3-1: Manukapua Island aerial orthophoto. Line of high water = 2.034 m and low water = -0.79 m

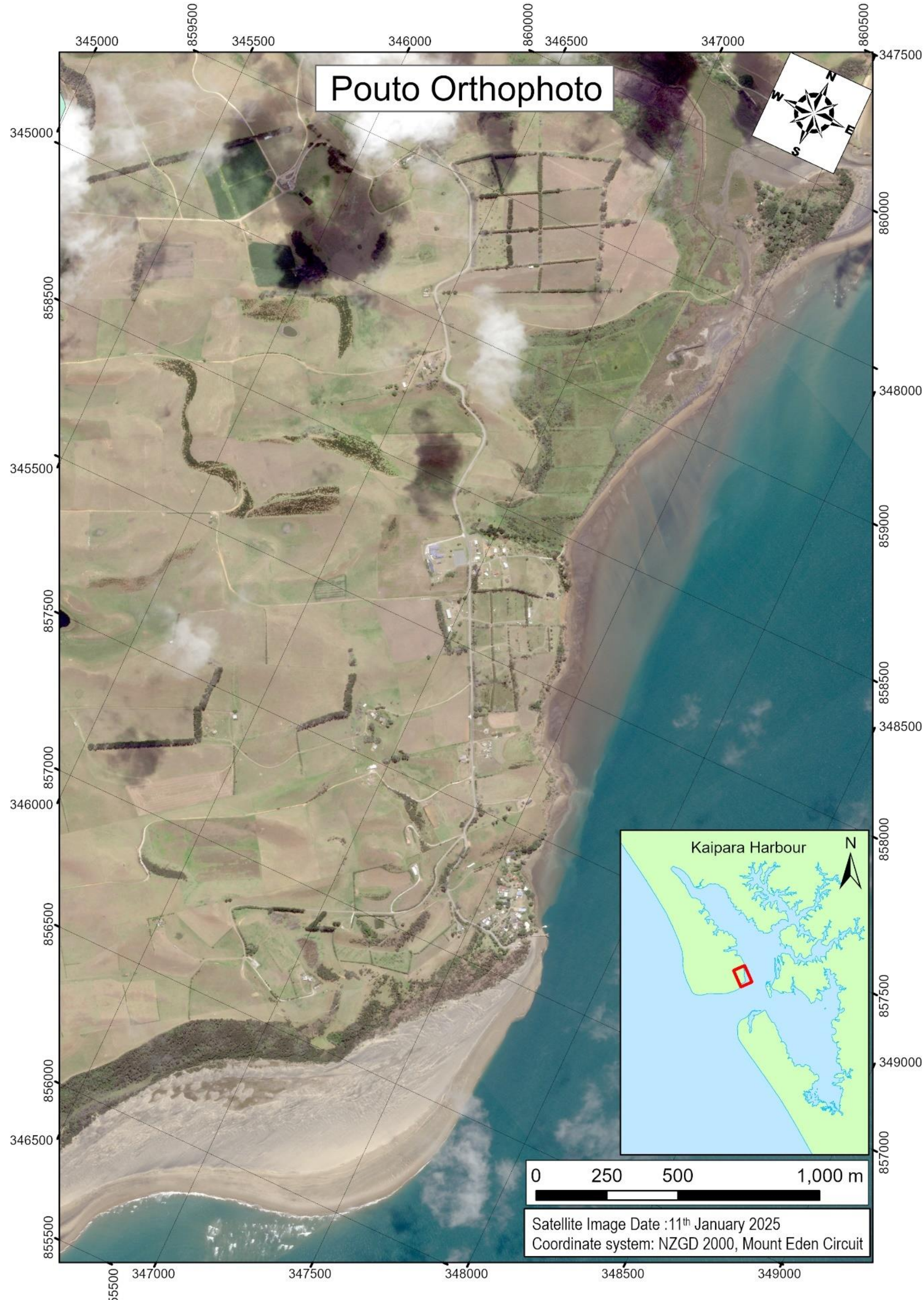


Figure 3-2: Pouto aerial orthophoto.

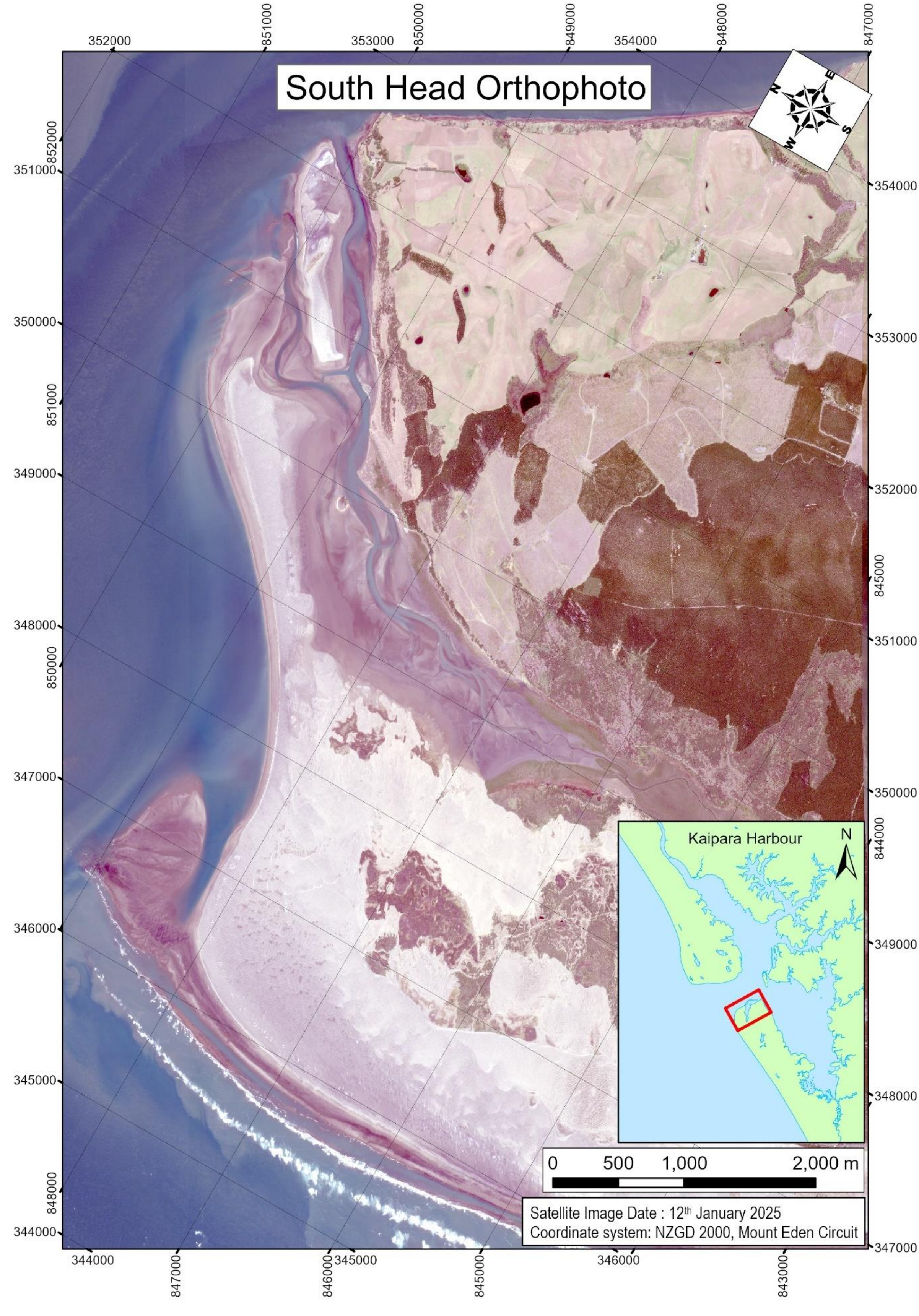


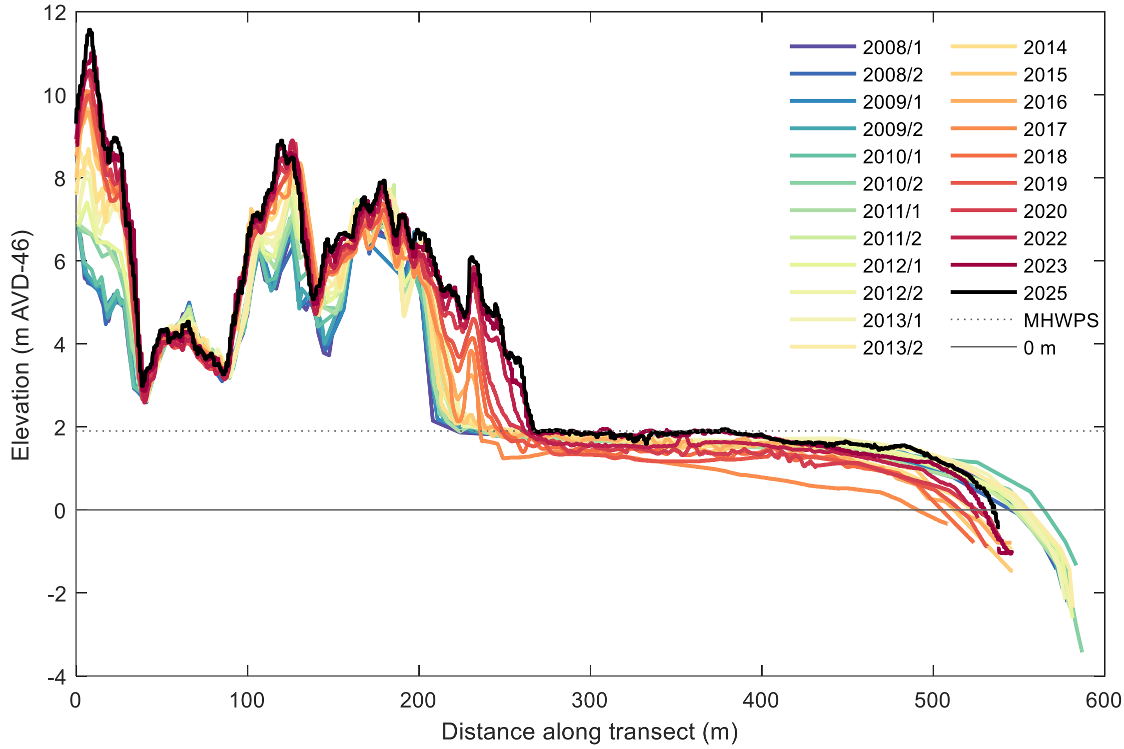
Figure 3-3: Kaipara South Head aerial orthophoto.

3.2 Beach transect surveys

The results from the beach portion of the LiDAR extracted survey transects along the western flank of Manukapua Island (see Figure 2-1) are shown in Figure 3-4 to Figure 3-12 in a north to south sequential order. Vertical elevations are specified relative to AVD-46 and horizontal distances are calculated as along-transect distance from the origin point (established by the University of Auckland when surveying began, see Appendix A Table A-1. Distances along-transect are presented as negative distances if they extend inland beyond the origin point.

Note that volumetric tables are only relative to the zero datum and due to migration of the sand dunes, the location of the beach profile over which the volume changes are calculated has changed over the years. Therefore, the volumetric changes are only relevant when comparing profiles sequentially i.e., when comparing the incremental or cumulative year-on-year change rather than comparing the first and last profile volumes.

3.2.1 Transect 1



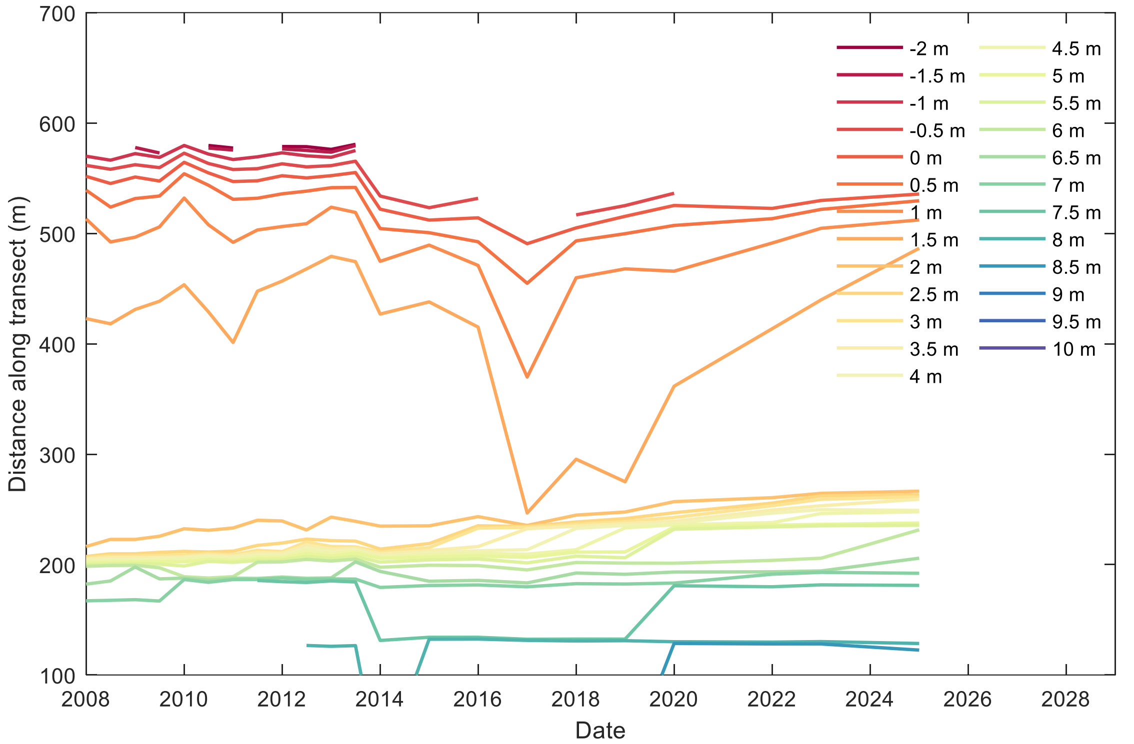


Figure 3-4: Beach profiles and excursion plots at Transect 1. Top: Beach profiles of distance along transect elevations for each survey date (colours), with MHWPS (dotted line) and 0 m elevation (thin solid line). Bottom: Excursion plot showing trend of distance along transect for various elevations through time (colours). Beach profile locations are shown in Figure 2-1.

Table 3-2: Beach volumes under Transect 1. Calculated as volume seaward of 0 m cross-shore distance and above -1.496 m elevation for each surveyed profile.

Survey ID	Volume m^3/m	Volume change m^3/m	Cumulative volume change m^3/m
2008/1	2371.4	0.0	0.0
2008/2	2348.4	-23.0	-23.0
2009/1	2372.7	24.3	1.3
2009/2	2395.3	22.6	23.9
2010/1	2454.2	59.0	82.8
2010/2	2467.8	13.6	96.4
2011/1	2428.4	-39.4	57.0
2011/2	2503.7	75.3	132.3
2012/1	2538.2	34.5	166.8
2012/2	2577.0	38.8	205.6
2013/1	2615.7	38.7	244.3
2013/2	2634.4	18.7	263.0
2014	2490.8	-143.6	119.4
2015	2524.2	33.4	152.8
2016	2550.4	26.3	179.0
2017	2330.5	-219.9	-40.9
2018	2503.2	172.7	131.8
2019	2487.5	-15.7	116.1
2020	2585.3	97.8	213.9
2022	2657.7	72.4	286.3
2023	2795.3	137.7	423.9
2025	2843.7	48.3	472.3

Extending north from the northern tip of Manukapua Island (see Figure 2-1), the 2025 survey of Transect 1 (Figure 3-4) shows an increase in sand volume of 48.3 m^3/m compared to 2023 (Table 3-2) which contributes to a total gain in volume of 472.3 m^3/m since 2008. The shape and elevation of the large foredune and secondary dune are consistent in shape to prior surveys, and the small (3 m height) incipient dune continues to develop at the toe of the foredune indicating the profile is prograding (advancing). The incipient dune has grown in height by 0.5 m since 2018 but remains relatively small (5 m high by 30 m wide) compared to the main foredune and may be short-lived like the small incipient dunes which formed and disappeared on Transect 3 and Transect 7. The elevation of the 300 m wide intertidal sandflat is consistent to 2018, but has gained approximately 0.7 m in elevation compared to 2020-2023 surveys. The edge of the channel remains stable at chainage 520 m, some 70 m inland from the 2008-2013 position. The excursion plot shows the transect has slow rates of progradation (4 m/year) in the +2 m to +7 m elevation and unsteady retreat of the -1 m to +1 m elevation.

3.2.2 Transect 2

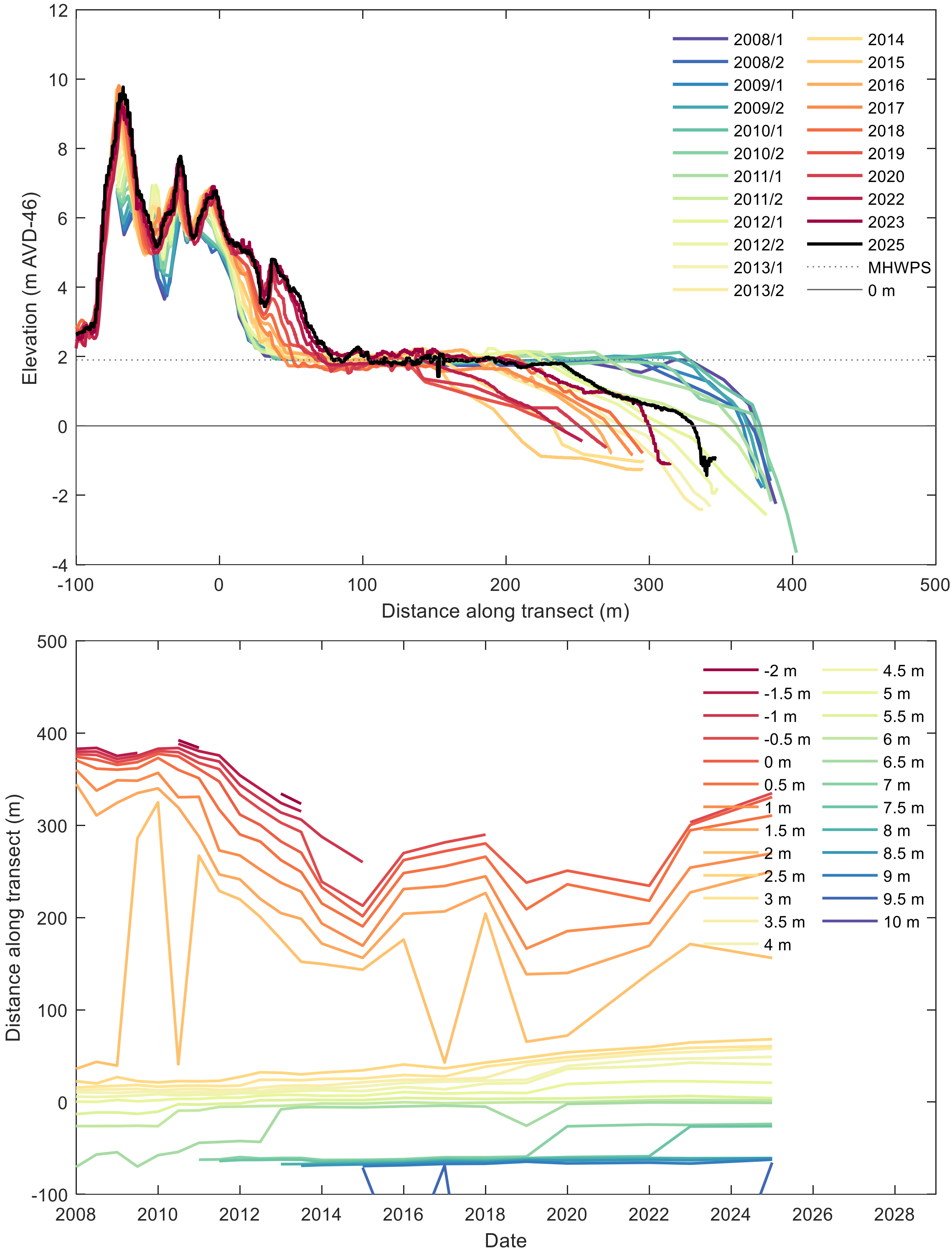


Figure 3-5: Beach profiles and excursion plots at Transect 2. Top: Beach profiles of distance along transect elevations for each survey date (colours), with MHWPS (dotted line) and 0 m elevation (thin solid line). Bottom: Excursion plot showing trend of distance along transect for various elevations through time (colours). Beach profile locations are shown in Figure 2-1.

Table 3-3: Beach volumes under Transect 2. Calculated as volume seaward of 0 m cross-shore distance and above -1.531 m for each surveyed profile.

Survey ID	Volume m^3/m	Volume change m^3/m	Cumulative volume change m^3/m
2008/1	1340.4	0.0	0.0
2008/2	1320.2	-20.2	-20.2
2009/1	1332.3	12.1	-8.1
2009/2	1352.4	20.1	12.0
2010/1	1389.7	37.3	49.3
2010/2	1339.5	-50.2	-0.9
2011/1	1322.6	-16.8	-17.7
2011/2	1231.6	-91.0	-108.8
2012/1	1174.2	-57.3	-166.1
2012/2	1135.6	-38.6	-204.7
2013/1	1089.7	-46.0	-250.7
2013/2	1048.5	-41.2	-291.9
2014	861.4	-109.0	-411.6
2015	772.3	-89.0	-500.6
2016	956.6	184.3	-314.9
2017	932.0	-24.6	-339.5
2018	955.0	63.0	-276.5
2019	813.0	-182.0	-458.5
2020	892.6	79.5	-378.9
2022	900.5	7.9	-371
2023	1154.7	254.1	-116.9
2025	1216.5	61.9	-55

Aligned northwest-southeast on the northern tip of Manukapua Island (see Figure 2-1), the 2025 survey of Transect 2 (Figure 3-5) shows the sand dunes, sandflats and intertidal beach are consistent in shape and height to prior surveys. The survey shows the transect increased in volume by 61.9 m^3/m (Table 3-3). This gain is a result of accumulation of the upper intertidal channel bank (located between 0 m and MHWPS elevation). The excursion plots show a similar pattern occurred in 2014-2015 (Figure 3-5) and review of aerial and satellite photos[4] confirm this pattern is associated with large scale sand waves migrating northeast along the channel edge. The cumulative volume change is −55 m^3/m since surveying began in 2008 and Figure 3-5 shows this loss is primarily results from the change in the width of the intertidal beach rather than from within the sand dunes which have retreated landward at a rate of 1 m/year from 2008 to 2014. Since 2014 there has been a reversal, and the intertidal beach has start to prograde (advancing seaward).

3.2.3 Transect 3

Aligned approximately east-west on the northwestern side of Manukapua Island (see Figure 2-1), the 2025 survey of Transect 3 (Figure 3-6) shows the sand dunes, sandflats and intertidal beach are consistent in shape and height to prior surveys. The 2025 survey shows a volume loss of 82.6 m^3/m

[4] https://earthengine.google.com/timelapse#v=-36.39096,174.22186,11.599,latLng&t=3.03&ps=50&bt=19840101&et=20181231&startDwell=0&endDwell=0

contributing to a cumulative loss of 784.9 m^3/m. Notably, there is evidence of recession in the upper intertidal beach and dune toe. Some of this loss is offset by deposition on the landward (lee) side, as sand is transported inland by prevailing winds, leading to year-on-year increases in transect volume between the 0-100 m distance along the transect.

The excursion analysis indicates the rate of foredune recession (above MHWPS) has continued at 1–2 m/year since 2014 (Figure 3-6). The intertidal beach has remained nearly stationary (+/- 10 m change) throughout 2016–2025 which is a significant change from the -18 m/year average throughout 1998–2016. This slowing in the overall rate of shoreline (0 m contour) is attributed to erosion now undercutting 10 m high dunes, as opposed to earlier phases where retreat was primarily confined to the intertidal beach.

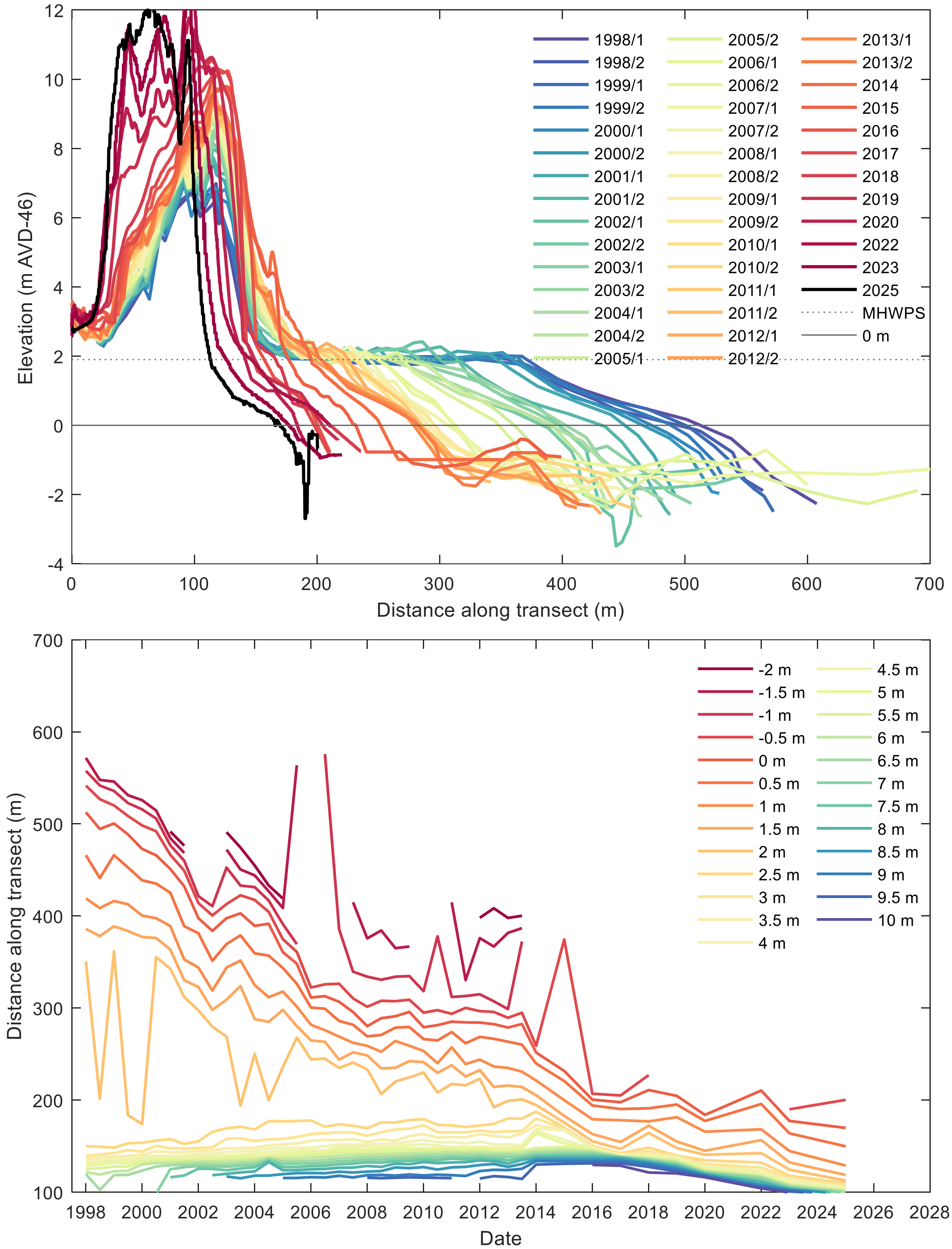
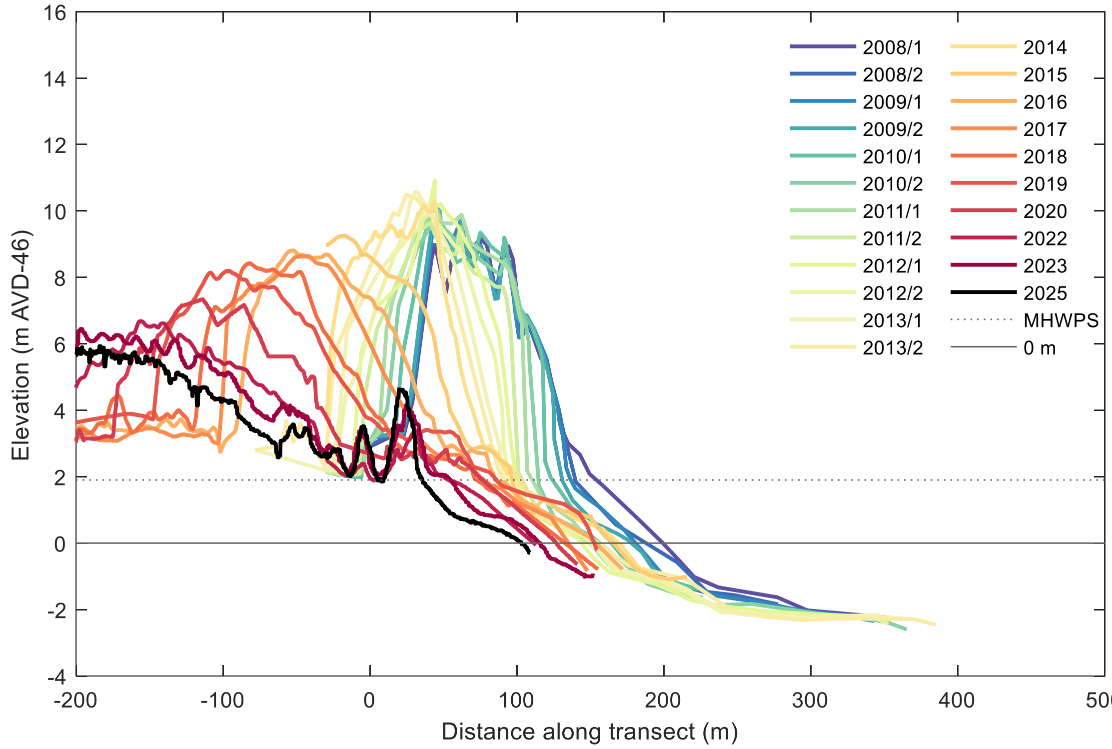


Figure 3-6: Beach profiles and excursion plots at Transect 3. Top: Beach profiles of distance along transect elevations for each survey date (colours), with MHWPS (dotted line) and 0 m elevation (thin solid line). Bottom: Excursion plot showing trend of distance along transect for various elevations through time (colours). Beach profile locations are shown in Figure 2-1.

Table 3-4: Beach volumes under Transect 3. Calculated as volume seaward of 0 m cross-shore distance and above -1.440 m for each surveyed profile.

Survey ID	Volume m^3/m	Volume change m^3/m	Cumulative volume change m^3/m
1998/1	1995.8	0.0	0.0
1998/2	1935.5	-60.3	-60.3
1999/1	1971.4	35.9	-24.4
1999/2	1945.2	-26.2	-50.6
2000/1	1927.0	-18.2	-68.8
2000/2	1923.5	-3.5	-72.3
2001/1	1901.8	-21.8	-94.0
2001/2	1817.3	-84.5	-178.5
2002/1	1723.3	-94.0	-272.5
2002/2	1657.0	-66.3	-338.8
2003/1	1783.3	126.3	-212.5
2003/2	1800.3	17.0	-195.5
2004/1	1757.1	-43.2	-238.7
2004/2	1754.8	-2.3	-241.0
2005/1	1711.3	-43.5	-284.5
2005/2	1660.4	-50.9	-335.4
2006/1	1622.2	-38.2	-373.7
2006/2	1665.7	43.6	-330.1
2007/1	1612.7	-53.1	-383.2
2007/2	1573.4	-39.3	-422.4
2008/1	1549.3	-24.1	-446.5
2008/2	1550.6	1.3	-445.2
2009/1	1582.3	31.7	-413.6
2009/2	1596.6	14.3	-399.3
2010/1	1577.0	-19.5	-418.8
2010/2	1578.4	1.3	-417.5
2011/1	1562.4	-15.9	-433.4
2011/2	1541.8	-20.6	-454.0
2012/1	1577.6	35.8	-418.2
2012/2	1540.3	-37.3	-455.5
2013/1	1532.2	-8.1	-463.7
2013/2	1557.9	25.8	-437.9
2014	1585.0	27.1	-410.8
2015	1537.7	-47.3	-458.1
2016	1328.5	-209.2	-667.4
2017	1292.0	-36.4	-703.8
2018	1393.5	101.4	-602.3
2019	1418.5	25.0	-577.3
2020	1341.1	-77.4	-654.7
2022	1403.7	62.6	-592.1
2023	1293.6	-110.2	-702.3
2025	1210.9	-82.6	-784.9

3.2.4 Transect 4



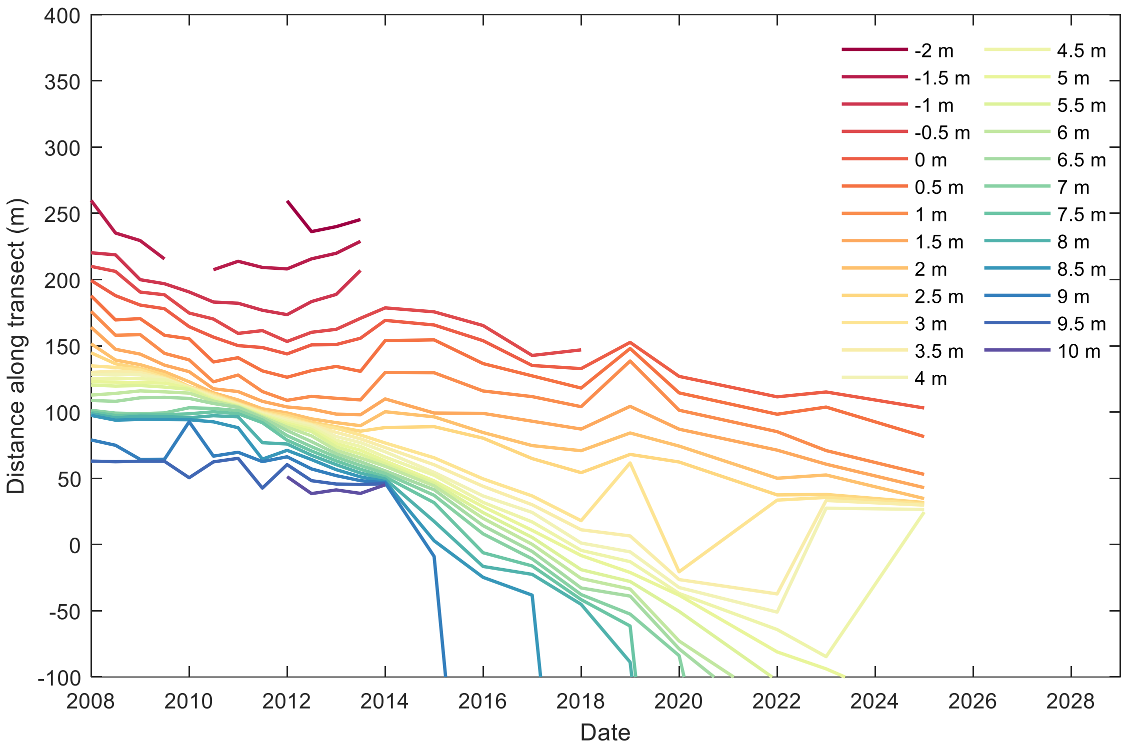


Figure 3-7: Beach profiles and excursion plots at Transect 4. Top: Beach profiles of distance along transect elevations for each survey date (colours), with MHWPS (dotted line) and 0 m elevation (thin solid line). Bottom: Excursion plot showing trend of distance along transect for various elevations through time (colours). Beach profile locations are shown in Figure 2-1.

Table 3-5: Beach volumes under Transect 4. Calculated as volume seaward of 0 m cross-shore distance and above -2.337 m elevation for each surveyed profile.

Survey ID	Volume m^3/m	Volume change m^3/m	Cumulative volume change m^3/m
2008/1	1536.4	0.0	0.0
2008/2	1468.3	-68.2	-68.2
2009/1	1452.8	-15.5	-83.6
2009/2	1376.6	-76.3	-159.9
2010/1	1390.0	13.5	-146.4
2010/2	1385.9	-4.1	-150.6
2011/1	1363.8	-22.0	-172.6
2011/2	1285.2	-78.7	-251.3
2012/1	1294.1	8.9	-242.3
2012/2	1269.9	-24.3	-266.6
2013/1	1240.0	-29.8	-296.4
2013/2	1239.7	-0.3	-296.7
2014	1174.8	-64.9	-361.6
2015	1039.5	-135.3	-496.9
2016	820.4	-219.1	-716.1
2017	670.6	-149.7	-865.8
2018	615.2	-55.4	-921.2
2019	707.1	91.9	-829.3
2020	569.0	-138.1	-967.4
2022	455.1	-114	-1081.4
2023	530.6	75.6	-1005.8
2025	412.3	-188.4	-1124.2

Aligned east-west on the north western side of Manukapua Island (200 m south of Transect 3, see Figure 2-1), the 2025 survey of Transect 4 (Figure 3-7) shows the foredune has continued to retreat landward and lower, with lesser changes to the intertidal beach elevation (located between 0 m and MHWPS). This survey shows that the ongoing recession of the dune (above MHWPS) continues at about 15 m/year but retreat of the intertidal beach has been <5 m/year since 2012. The steady inland migration of the foredune is characteristic of dune migration due to prevailing winds transporting sand from the stoss (front) face and deposition it on the lee (rear) face.

The calculated volumes show large cumulative losses of 1,124 m^3/m since 2008 (Table 3-5). However the volume changes are approximate as calculations are seaward of the nominated 0 m horizontal position (note how the 1998–2013 profiles stop at cross-shore distance of -80 m in Figure 3-7, when the dune crest and body have migrated landward but with small changes to shape.

3.2.5 Transect 5

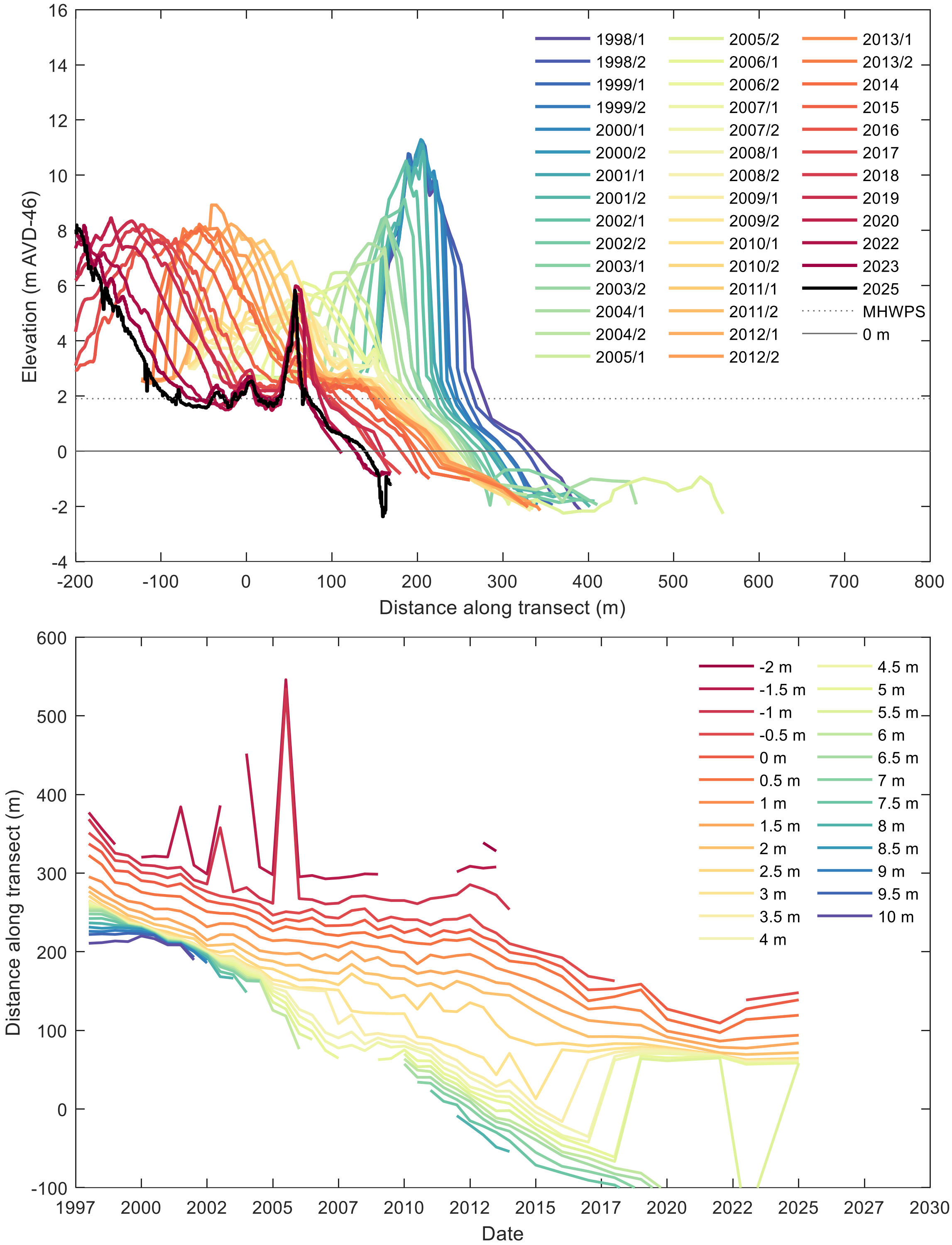


Figure 3-8: Beach profiles and excursion plots at Transect 5. Top: Beach profiles of distance along transect elevations for each survey date (colours), with MHWPS (dotted line) and 0 m elevation (thin solid line). Bottom: Excursion plot showing trend of distance along transect for various elevations through time (colours). Beach profile locations are shown in Figure 2-1.

Table 3-6: Beach volumes under Transect 5. Calculated as volume seaward of 0 m cross-shore distance and above -1.536 m elevation for each surveyed profile.

Survey ID	Volume m^3/m	Volume change m^3/m	Cumulative volume change m^3/m
1998/1	1307.2	0.0	0.0
1998/2	1238.7	-68.5	-68.5
1999/1	1140.4	-98.3	-166.8
1999/2	1064.9	-75.6	-242.4
2000/1	1006.5	-58.3	-300.7
2000/2	951.6	-55.0	-355.7
2001/1	877.3	-74.3	-430.0
2001/2	859.2	-18.1	-448.0
2002/1	832.0	-27.2	-475.2
2002/2	876.4	44.4	-430.8
2003/1	1030.0	153.6	-277.3
2003/2	966.4	-63.6	-340.9
2004/1	1001.3	35.0	-305.9
2004/2	1180.5	179.2	-126.7
2005/1	1203.1	22.6	-104.1
2005/2	1193.0	-10.1	-114.2
2006/1	1205.3	12.3	-101.9
2006/2	1195.8	-9.5	-111.4
2007/1	1151.2	-44.6	-156.0
2007/2	1135.9	-15.3	-171.3
2008/1	1147.5	11.6	-159.7
2008/2	1118.6	-28.9	-188.7
2009/1	1115.2	-3.4	-192.1
2009/2	1104.4	-10.7	-202.8
2010/1	1170.5	66.0	-136.8
2010/2	1146.6	-23.9	-160.6
2011/1	1163.2	16.6	-144.0
2011/2	1101.6	-61.6	-205.6
2012/1	1070.8	-30.8	-236.5
2012/2	1023.6	-47.2	-283.7
2013/1	959.2	-64.4	-348.1
2013/2	899.4	-59.8	-407.8
2014	849.2	-50.2	-458.0
2015	709.2	-140.0	-598.0
2016	659.4	-49.8	-647.8
2017	576.7	-82.7	-730.5
2018	581.5	4.8	-725.7
2019	615.1	33.5	-692.2
2020	500.8	-114.3	-806.5
2022	407.3	-93.5	-899.9
2023	464.8	57.6	-842.4
2025	467.7	2.9	-839.5

Aligned approximately east-west on the central-western side of Manukapua Island (see Figure 2-1), the 2025 survey of Transect 5 (Figure 3-8) shows steady continuation of trends from prior surveys. The large foredune has consistently receded at about 18 m/year since profiling started in 1998 with the crest of the foredune now over 300 m inland of the 1998 location. Similar to the 2023 survey, this year, the foredune migrated ~10 m landward. The incipient dune (at distances of 50-100 m) has decreased in height by ~0.75 m since the 2022 survey and remains relatively small (3–3.5 m high by 50 m wide) compared to the main foredune and may be short-lived like the small incipient dunes which formed and disappeared on Transect 3 and Transect 7. The excursion plot shows the surveyed foredunes are receding, and that the 2013-2025 surveys have captured a subtle reactivation of the intertidal beach retreat (located between 0 m and MHWPS elevation) which had stalled from 2005-2012.

The transect volume remained essentially unchanged from 2017-2025 (Table 3-6) but the cumulative trend is for a loss of 839.5m^3/m since 1998.

3.2.6 Transect 6

Aligned approximately east-west on the central-western side of Manukapua Island (see Figure 2-1), the 2025 survey of Transect 6 (Figure 3-9) generally shows similar trends to previous surveys, with gradual retreat of both the dunes and the intertidal beach (between the 0 m contour and MHWPS).

Notable morphological change has occurred in the foredune, which has undergone landward crest migration of approximately 150 m and a reduction in elevation of 3 m, indicating significant aeolian deflation and erosion. The foredune has now largely coalesced with the adjacent backdune system, resulting in a single, broader dune ridge rather than distinct fore- and backdune features.

Some of the sediment loss from the foredune appears to have been redistributed and deposited in the lee, leading to minor accretion behind the dune crest. Despite this localised reworking, the net volume change for 2025 shows a loss of 77.1 m^3/m in 2025.

Inland of the foredune, the secondary dune ridges and associated interdunal swales are undergoing gradual reshaping due to inland transport of wind-blown sand. The rearmost dune, located approximately 400 m inland, has remained relatively stable since the beginning of monitoring.

Despite the foredune losses, the cumulative volume change along this transect indicates an overall loss of -292.6 m^3/m of shoreline sediment (as indicated in Table 3-7), suggesting that while foredune retreat dominates the seaward edge, it is partially offset by sediment deposition further inland.

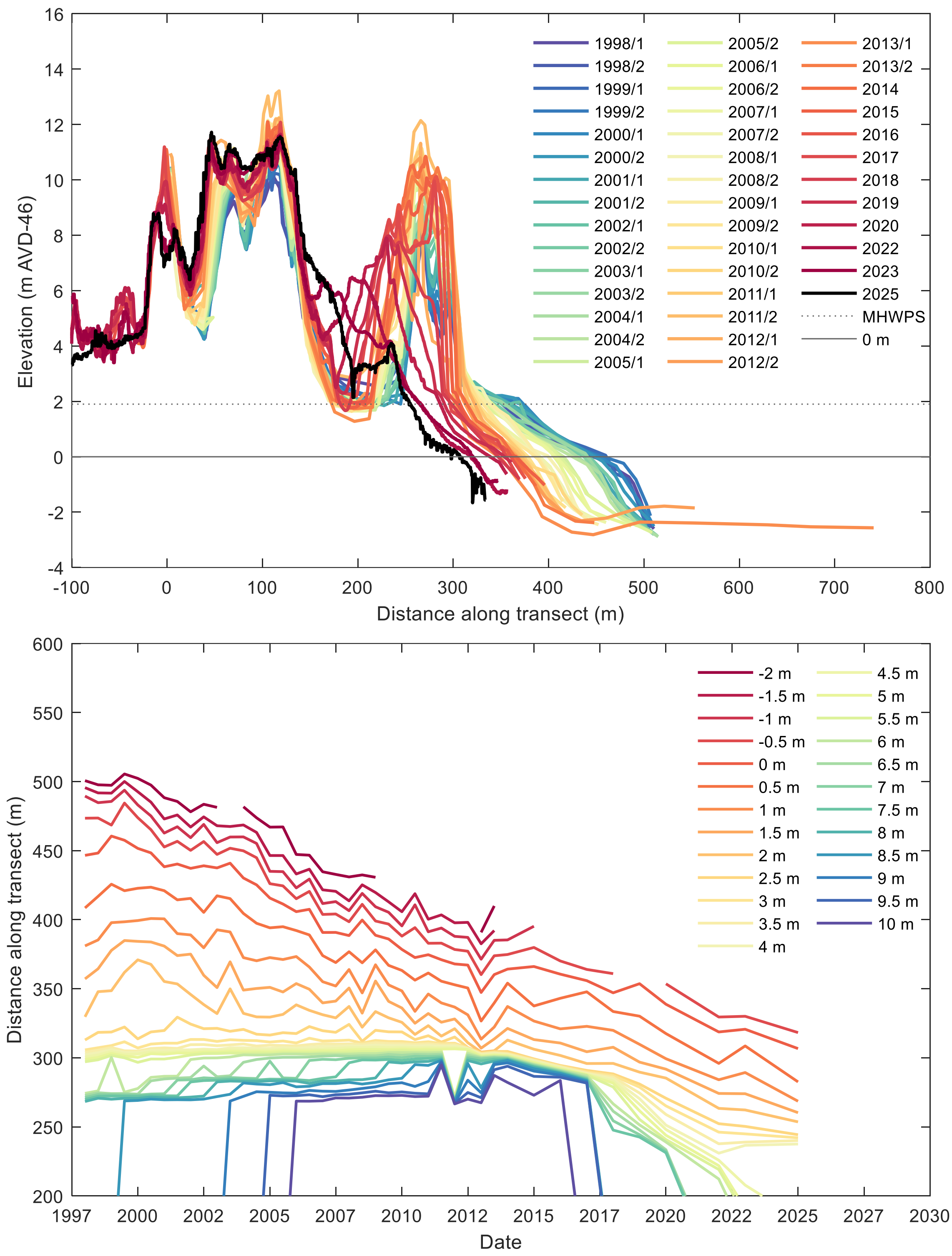


Figure 3-9: Beach profiles and excursion plots at Transect 6. Top: Beach profiles of distance along transect elevations for each survey date (colours), with MHWPS (dotted line) and 0 m elevation (thin solid line). Bottom: Excursion plot showing trend of distance along transect for various elevations through time (colours). Beach profile locations are shown in Figure 2-1.

Table 3-7: Beach volumes under Transect 6. Calculated as volume seaward of 0 m cross-shore distance and above -2.157 m elevation for each surveyed profile.

Survey ID	Volume m^3/m	Volume change m^3/m	Cumulative volume change m^3/m
1998/1	2920.6	0.0	0.0
1998/2	2955.4	34.9	34.9
1999/1	2969.2	13.8	48.7
1999/2	3011.7	42.5	91.1
2000/1	2962.2	-49.4	41.7
2000/2	2978.4	16.2	57.9
2001/1	2972.9	-5.5	52.4
2001/2	3020.7	47.8	100.2
2002/1	2996.1	-24.6	75.6
2002/2	2988.0	-8.2	67.4
2003/1	3007.9	19.9	87.3
2003/2	3047.5	39.6	127.0
2004/1	3058.2	10.7	137.6
2004/2	3033.2	-25.0	112.7
2005/1	3002.7	-30.5	82.2
2005/2	3014.2	11.5	93.7
2006/1	3002.0	-12.3	81.4
2006/2	3014.5	12.6	94.0
2007/1	2957.3	-57.3	36.7
2007/2	2978.0	20.7	57.4
2008/1	2974.1	-3.9	53.6
2008/2	2997.6	23.5	77.1
2009/1	3029.1	31.4	108.5
2009/2	3024.2	-4.8	103.7
2010/1	2377.5	-646.7	-543.1
2010/2	3073.2	695.7	152.7
2011/1	3101.3	28.1	180.7
2011/2	3355.0	253.7	434.4
2012/1	2872.7	-482.3	-47.9
2012/2	3117.0	244.3	196.4
2013/1	2909.5	-207.4	-11.0
2013/2	3046.6	137.1	126.1
2014	3169.8	123.1	249.2
2015	3103.6	-66.1	183.1
2016	3080.1	-23.5	159.5
2017	3063.5	-16.6	142.9
2018	2891.2	-172.2	-29.31
2019	2899.3	8.1	-21.2
2020	2826.1	-73.2	-94.5
2022	2672.9	-153.1	-247.6
2023	2705.058	32.1	-215.5
2025	2628	-77.1	-292.6

3.2.7 Transect 7

Aligned approximately east-west on the central-western side of Manukapua Island (see Figure 2-1), the 2025 survey of Transect 7 (Figure 3-10) shows further recession of the intertidal beach (located between 0 m and MHWPS elevation) and backshore/dune toe (below 4 m elevation) continues at about 5 m/year, contributing to a total of ~200 m of landward retreat since 1998.

In 2025, the upper foredune (above 6 m elevation) continues to erode, having lost ~4 m in crest elevation between the 2022 and 2023 surveys, a following 1 m of elevation has been lost since 2023.

Since 2010 the toe of the foredune (3 m elevation) has receded by 110 m. The onset of this recession began in 2010 as the intertidal beach had retreated sufficiently to allow waves to undercut the dune toe at high tide, thereby destabilising the foredune face and exposing more sediment to winds and currents to transport away from the beach face. Since the last survey this undermining led to oversteepening and collapse of foredune face. This collapse has allowed the retreat to accelerate, similar to that seen at Transects 4 and 6. The net loss for the 2025 survey was 182 m^3/m (Table 3-8), this has contributing to the overall loss of 1183.9 m^3/m from 1998-2025.

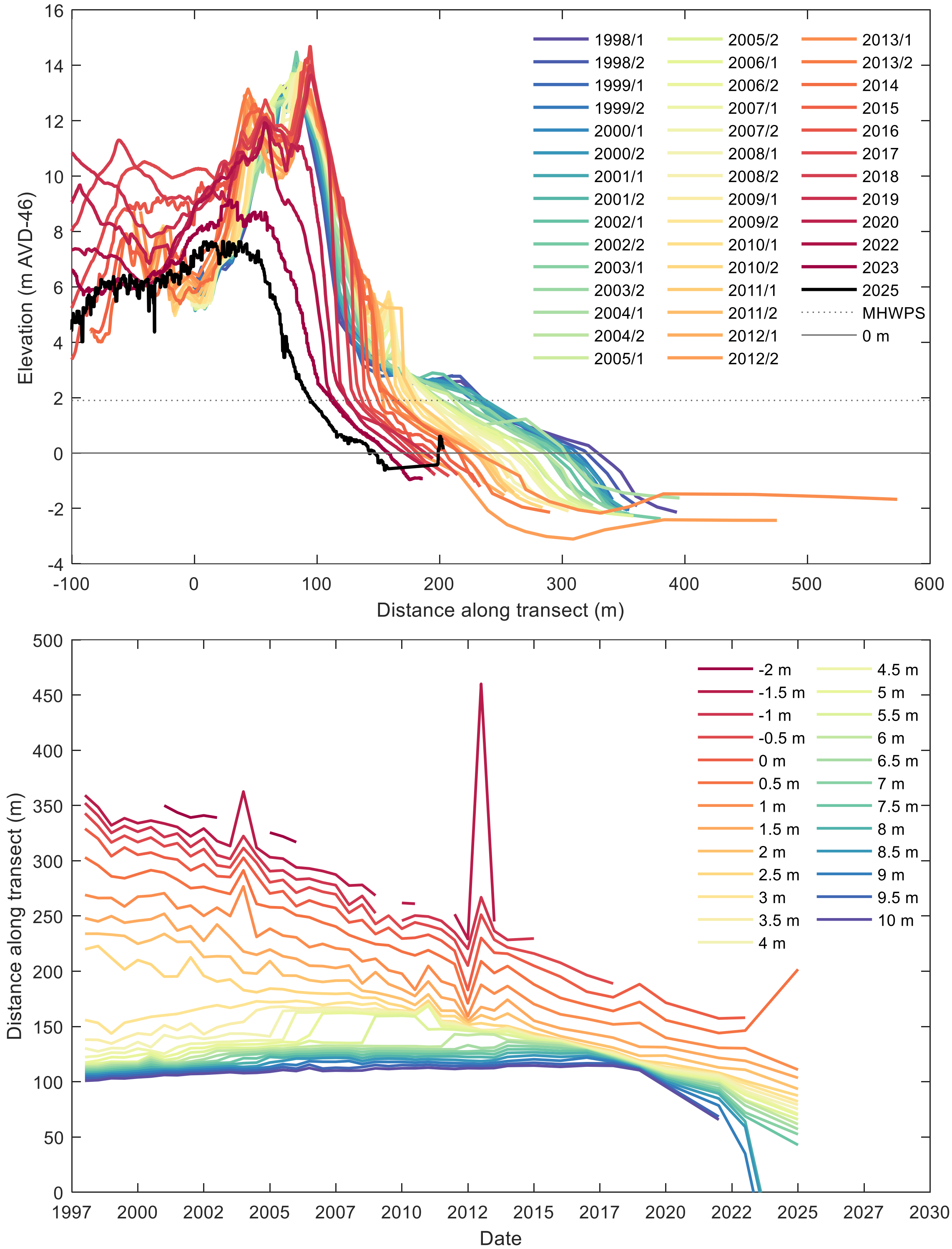


Figure 3-10: Beach profiles and excursion plots at Transect 7. Top: Beach profiles of distance along transect elevations for each survey date (colours), with MHWPS (dotted line) and 0 m elevation (thin solid line). Bottom: Excursion plot showing trend of distance along transect for various elevations through time (colours). Beach profile locations are shown in Figure 2-1.

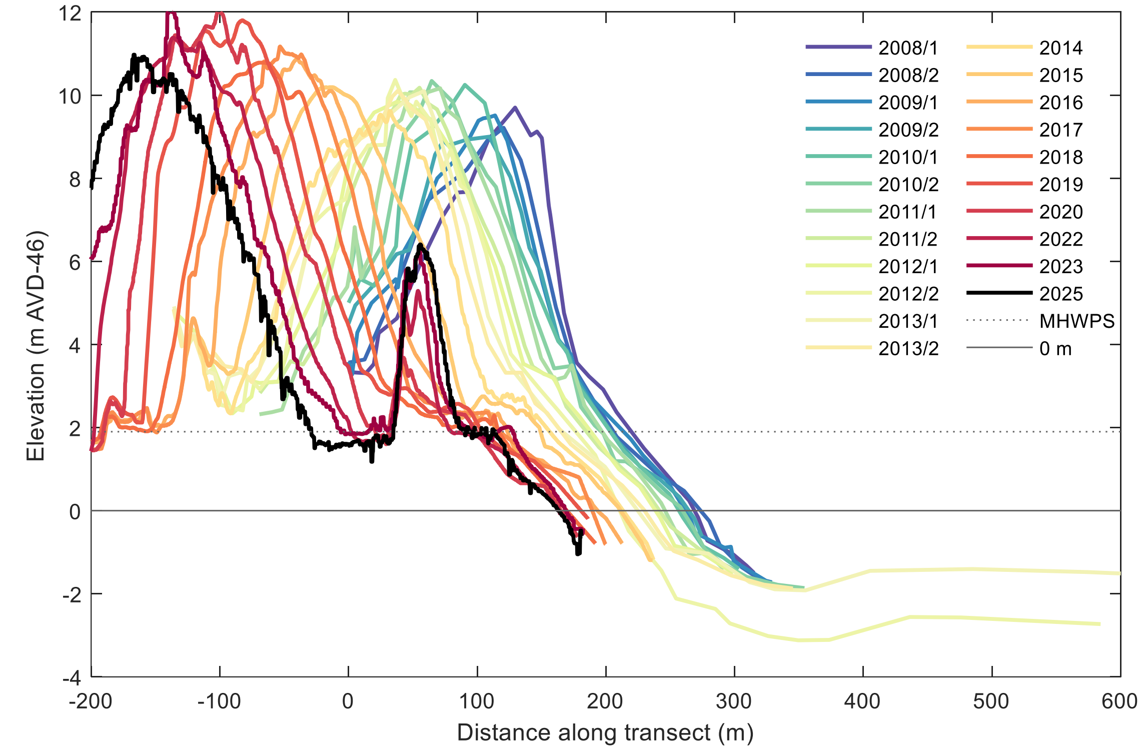
Table 3-8: Beach volumes under Transect 7. Calculated as volume seaward of 0 m cross-shore distance and above -1.682 m elevation for each surveyed profile.

Survey ID	Volume m^3/m	Volume change m^3/m	Cumulative volume change m^3/m
1998/1	2129.1	0.0	0.0
1998/2	2107.9	-21.3	-21.3
1999/1	2080.1	-27.8	-49.1
1999/2	2090.8	10.7	-38.4
2000/1	2089.1	-1.7	-40.1
2000/2	2112.9	23.8	-16.2
2001/1	2103.8	-9.1	-25.4
2001/2	2097.5	-6.2	-31.6
2002/1	2099.3	1.7	-29.9
2002/2	2091.3	-8.0	-37.8
2003/1	2090.0	-1.3	-39.1
2003/2	2079.0	-11.1	-50.2
2004/1	2145.8	66.8	16.7
2004/2	2064.4	-81.4	-64.8
2005/1	2073.5	9.1	-55.7
2005/2	2072.3	-1.1	-56.8
2006/1	2068.2	-4.1	-60.9
2006/2	2077.4	9.2	-51.7
2007/1	2046.8	-30.7	-82.4
2007/2	2039.1	-7.7	-90.1
2008/1	2004.7	-34.3	-124.4
2008/2	1982.6	-22.2	-146.6
2009/1	1984.7	2.2	-144.4
2009/2	1969.5	-15.2	-159.6
2010/1	1935.0	-34.4	-194.1
2010/2	1938.2	3.1	-191.0
2011/1	1994.0	55.9	-135.1
2011/2	1933.9	-60.2	-195.2
2012/1	1935.5	1.6	-193.6
2012/2	1840.7	-94.9	-288.5
2013/1	1962.4	121.7	-166.7
2013/2	1962.1	-0.3	-167.0
2014	1908.0	-54.1	-221.2
2015	1884.9	-23.1	-244.2
2016	1865.3	-19.6	-242.8
2017	1843.4	-21.9	-264.7
2018	1747.3	-96.1	-360.7
2019	1661.8	-85.5	-446.3
2020	1494.7	-167.1	-613.4
2022	1306.1	-188.5	-801.9
2023	1106.3	-199.8	-1001.8
2025	924.2	-182	-1183.9

3.2.8 Transect 8

Aligned southwest-northeast approximately 1 km from the southern tip of Manukapua Island (see Figure 2-1), the 2025 survey of Transect 8 (Figure 3-11) shows that there is erosion of the intertidal beach (located between 0 m and MHWPS elevation) and building of the dune. The differential recession rates have created a widening backshore area above the high-tide mark (2.5–3 m elevation) which has slowly widened at 5 m/year since 2012 and is now 100 m wide. The excursion plot shows that the latest observations are consistent with the recessional trends previously observed at this transect. The incipient dune which developed (at distances of 50-100 m) following the 2020 survey, is now ~6 m high by ~65 m wide. The beach ridge with a beach runnel (shallow depression usually filled with water at higher tides) between the incipient dune and foredune. Surprisingly, the ridge and runnel combination, which generally would prevent waves break further offshore and therefore less able to undermine the toe of the dune, has not slowed the foredune retreat.

The calculated volumes show a decrease in volume of 23.2 m^3/m in 2025 contributing to a total volume loss of 1192.5 m^3/m (Table 3-9) since 2008. However, this is a consequence of calculating changes seaward of the nominated 0 m horizontal datum, when the dune crest and body have migrated landward but with little change in shape or volume (see Figure 3-11).



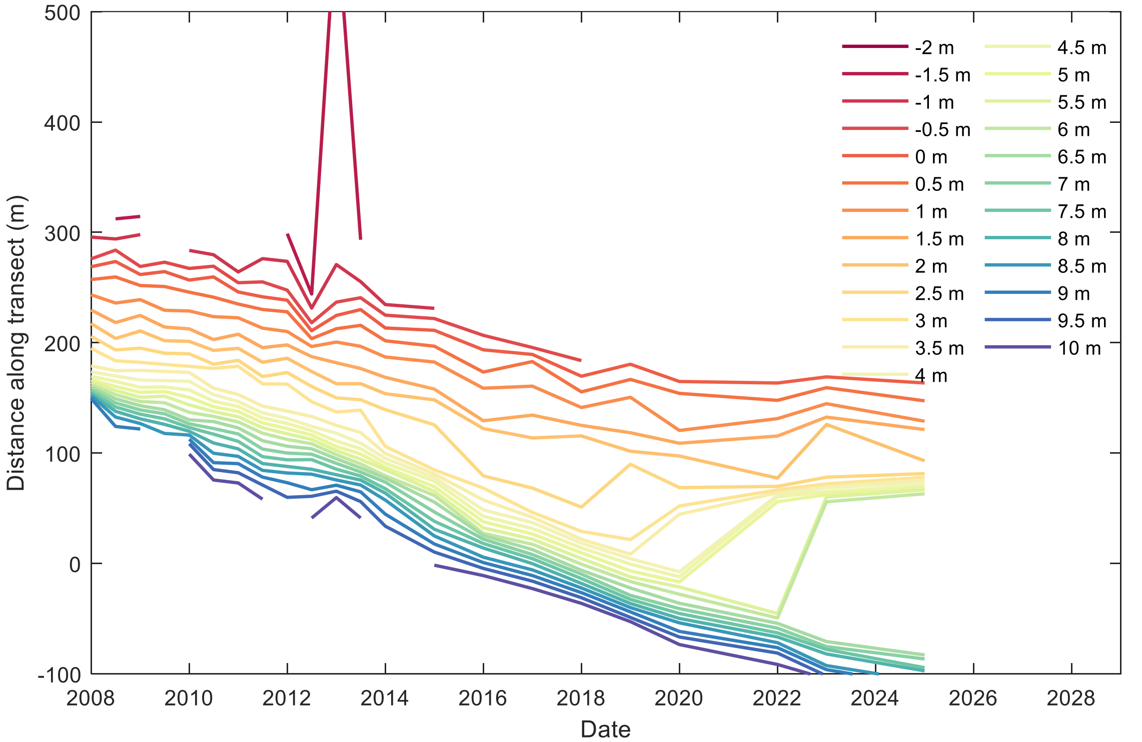


Figure 3-11: Beach profiles and excursion plots at Transect 8. Top: Beach profiles of distance along transect elevations for each survey date (colours), with MHWPS (dotted line) and 0 m elevation (thin solid line). Bottom: Excursion plot showing trend of distance along transect for various elevations through time (colours). Beach profile locations are shown in Figure 2-1. Note Allis et al. (2015) manually adjusted the elevation data of the 2008-2013 beach profiles to be consistent with the 2014-2022 data.

Table 3-9: Beach volumes under Transect 8. Calculated as volume seaward of 0 m cross-shore distance and above -2.0 m elevation for each surveyed profile.

Survey ID	Volume m^3/m	Volume change m^3/m	Cumulative volume change m^3/m
2008/1	1929.3	0.0	0.0
2008/2	1901.9	-27.4	-27.4
2009/1	1920.3	18.4	-9.0
2009/2	1876.7	-43.6	-52.6
2010/1	1957.4	80.7	28.1
2010/2	1938.9	-18.5	9.6
2011/1	1909.7	-29.3	-19.7
2011/2	1863.1	-46.6	-66.3
2012/1	1843.8	-19.3	-85.6
2012/2	1668.8	-175.0	-260.5
2013/1	1878.7	209.9	-50.7
2013/2	1666.1	-212.6	-263.2
2014	1453.4	-212.7	-475.9
2015	1279.1	-174.3	-650.2
2016	1001.0	-278.1	-928.3
2017	901.0	-100.0	-1028.3
2018	753.0	-148.0	-1176.3
2019	743.3	-9.7	-1186.0
2020	659.8	-83.5	-1269.5
2022	650.3	-9.5	-1279.0
2023	760	109.7	-1169.4
2025	736.8	-23.2	-1192.5

3.2.9 Transect 9

Aligned southwest-northeast at approximately 500 m from the southern tip of Manukapua Island (see Figure 2-1), the 2025 survey of Transect 9 (Figure 3-12) indicates a continuation of the long-term beach and dune recession at rates similar to recent years.

The period of rapid foredune retreat between 2013 and 2017—where the crest receded at rates of up to 40 m/year—has slowed markedly to 0–5 m/year in the years since. This deceleration, along with the stabilisation of the upper intertidal beach (between the 0 m and MHWPS elevations), has created an expanding backshore platform between elevations of 2–3 m. By 2025, this feature has widened to approximately 120 m and now supports the early development of a new foredune.

The historic foredune crest, which reached a height of ~14 m in 2005, has migrated landward by approximately 280 m and now stands at just 9.5 m elevation. However, the 2025 survey shows development of an incipient foredune approximately 50 m seaward of the current dune crest, reaching ~4.5 m elevation—suggesting renewed aeolian deposition and dune formation processes.

The upper intertidal beach has also retreated by ~190 m since 1998 but appears to have stabilised since 2018. The cumulative volumetric change along this transect is −936.7 m^3/m (Table 3-10), although this value only represents the volume change seaward of the fixed 0 m horizontal datum.

Because the entire beach and dune system has now migrated landward of this reference point (see Figure 3-11) the 2025 survey-derived change of −6.7 m³/m underrepresents the full extent of morphological change across the profile.

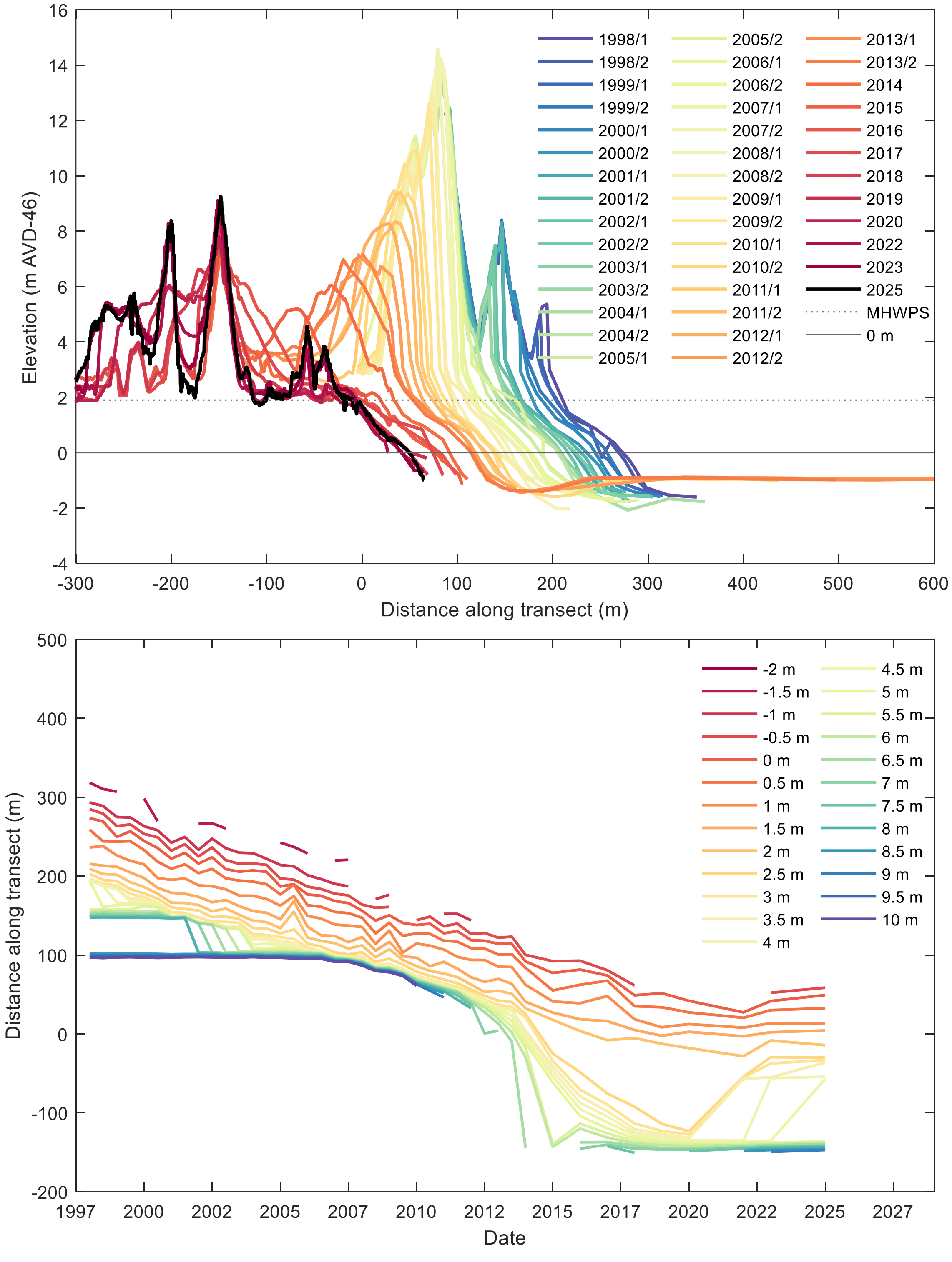


Figure 3-12: Beach profiles and excursion plots at Transect 9. Top: Beach profiles of distance along transect elevations for each survey date (colours), with MHWPS (dotted line) and 0 m elevation (thin solid line). Bottom: Excursion plot showing trend of distance along transect for various elevations through time (colours). Beach profile locations are shown in Figure 2-1.

Table 3-10: Beach volumes under Transect 9. Calculated as volume seaward of 0 m cross-shore distance and above -1.525 m elevation for each surveyed profile.

Survey ID	Volume m^3/m	Volume change m^3/m	Cumulative volume change m^3/m
1998/1	1064.3	0.0	0.0
1998/2	1027.5	-36.8	-36.8
1999/1	986.2	-41.3	-78.1
1999/1	447.1	-539.1	-617.2
1999/2	959.7	512.6	-104.6
2000/1	919.5	-40.2	-144.8
2000/2	870.1	-49.4	-194.2
2001/1	766.5	-103.6	-297.8
2001/2	784.1	17.6	-280.2
2002/1	700.6	-83.5	-363.8
2002/2	690.5	-10.1	-373.8
2003/1	641.9	-48.6	-422.4
2003/2	683.2	41.3	-381.1
2004/1	799.1	115.9	-265.2
2004/2	781.8	-17.3	-282.5
2005/1	968.1	186.3	-96.2
2005/2	996.5	28.4	-67.8
2006/1	889.7	-106.8	-174.6
2006/2	1302.9	413.2	238.5
2007/1	1196.0	-106.9	131.7
2007/2	1172.0	-24.0	107.7
2008/1	1119.8	-52.2	55.5
2008/2	996.2	-123.5	-68.1
2009/1	1004.6	8.4	-59.7
2009/2	893.9	-110.7	-170.4
2010/1	842.6	-51.3	-221.7
2010/2	956.3	113.7	-108.1
2011/1	806.0	-150.3	-258.3
2011/2	735.5	-70.5	-328.8
2012/1	663.3	-72.2	-401.0
2012/2	841.6	178.2	-222.8
2013/1	803.4	-38.2	-260.9
2013/2	647.6	-155.8	-416.7
2014	312.9	-334.8	-751.5
2015	233.9	-79.0	-830.4
2016	223.7	-10.2	-840.7
2017	208.9	-14.7	-855.4
2018	137.6	-71.3	-926.7
2019	133.9	-3.8	-930.4
2020	120.0	-13.9	-944.4
2022	62.8	-57.2	-1001.6
2023	120.9	58.2	-943.4
2025	127.7	6.7	-936.7

3.2.10 Transect 10

Extending southeast towards Tauhoa Channel from the southern tip of Manukapua Island (see Figure 2-1), the 2025 survey of Transect 10 (Figure 3-14) shows continued trends from prior surveys. The total 2025 volume change was (-419 m^3/m), contributing to a total volume loss of −572 m^3/m since surveys began.

Transect 10 lies at a highly dynamic location on the island's southern extremity, where the land narrows to less than 50 m in width (see Figure 2-1 This area is oriented perpendicular to the dominant west–southwest wind, wave, and tidal current conditions in the Tauhoa Channel. These forcing conditions promote both alongshore and cross-shore sediment transport, resulting in frequent reworking of the beach profile and high year-to-year variability in the surveyed transect. Volume changes of ±150 m^3/m between surveys are common, reflecting the inherently mobile nature of this sandspit environment.

Historically, a foredune up to 6 m high was present in 2014 but was eroded during 2018–2019, coinciding with a northward shift in the Tauhoa Channel. Since 1998, the southern tip of the island in this region has receded eastward by up to 300 m (as also shown in Transect 9, Figure 3-12). The beach and sandspit have now migrated well away from the original coordinates of Transect 10, which no longer intersects any established dune features. The transect now effectively intersects only the intertidal and subtidal beach profile, capturing the southern shoreline position and its interaction with the Tauhoa Channel.

The 2025 profile shows continued low, narrow morphology with limited vertical relief and no evidence of foredune re-establishment. These observations confirm that Transect 10, in its current position, no longer reflects the evolving dune–beach system of the island's southern tip.

With six biannual DTM surveys now available (from 2020–2025), we recommend repositioning Transect 10 approximately 150 m eastward along the same orientation. This would allow the transect to once again intersect the active shoreline and potentially capture any future foredune development or changes associated with further channel migration. A reanalysis of the full DTM dataset along the new transect alignment is also recommended to ensure consistency in long-term monitoring.

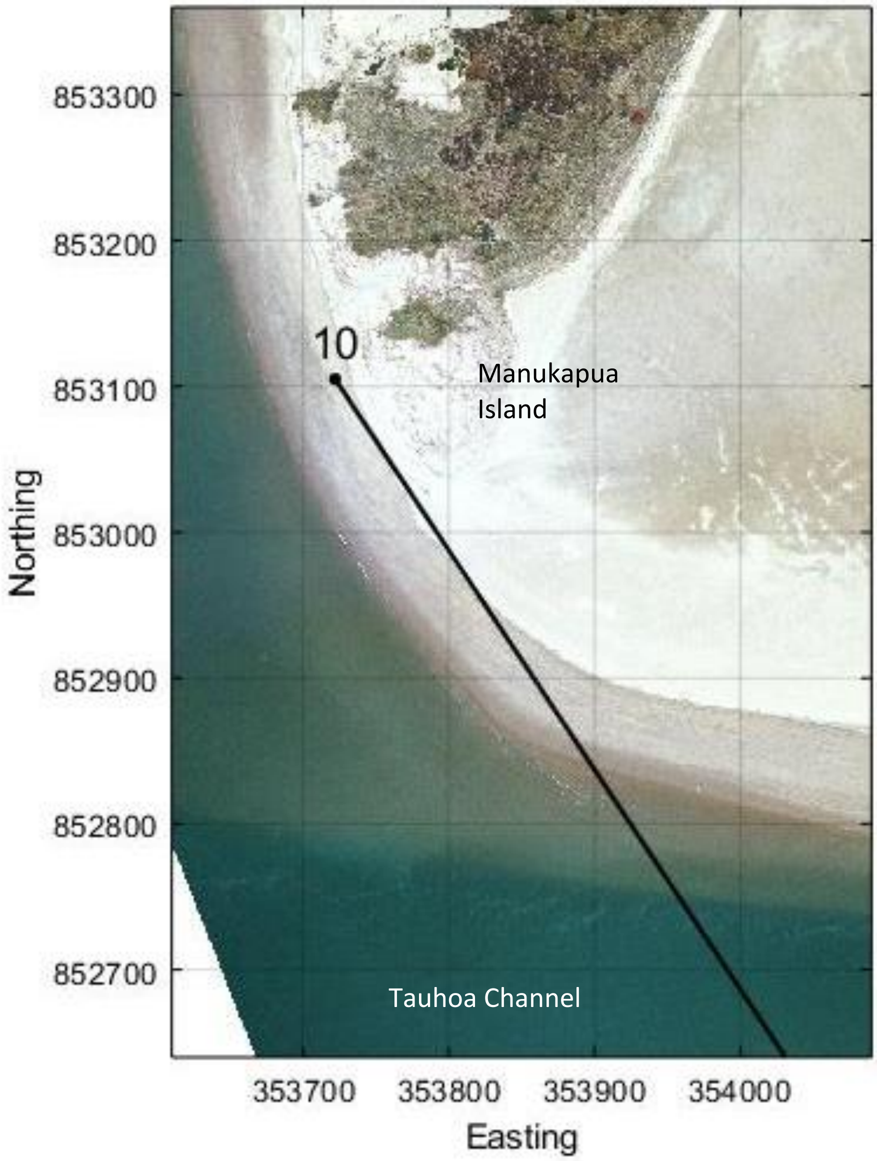


Figure 3-13: Close-up view of Transect 10 on southern tip of Manukapua Island with 2018 aerial photo. Black line indicates transect orientation. 100 m squares for scale.

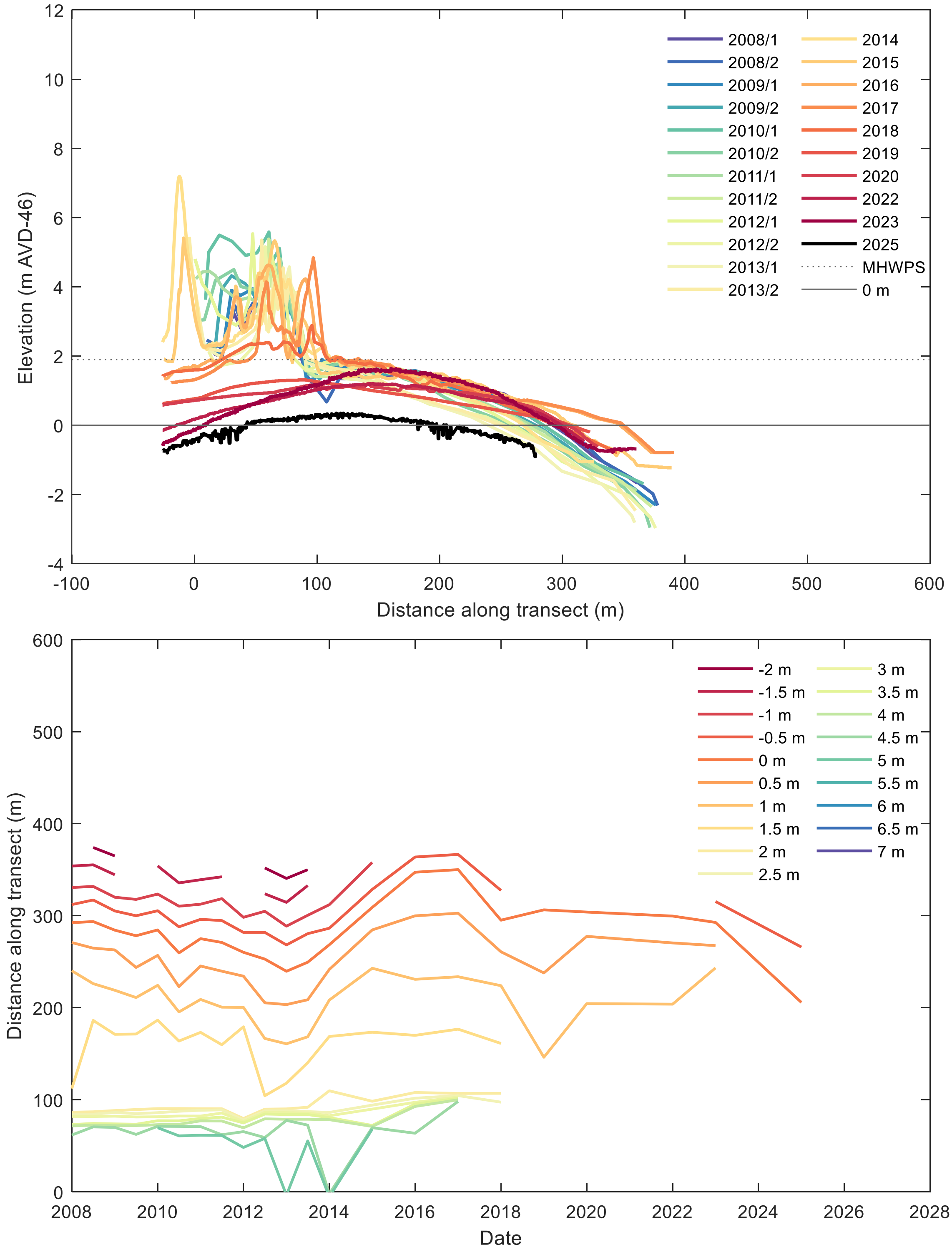


Figure 3-14: Beach profiles and excursion plots at Transect 10. Top: Beach profiles of distance along transect elevations for each survey date (colours), with MHWPS (dotted line) and 0 m elevation (thin solid line). Bottom: Excursion plot showing trend of distance along transect for various elevations through time (colours). Beach profile locations are shown in Figure 2-1.

Table 3-11: Beach volumes under Transect 10. Calculated as volume seaward of 0 m cross-shore distance and above -2.0 m elevation for each surveyed profile.

Survey ID	Volume m^3/m	Volume change m^3/m	Cumulative volume change m^3/m
2008/1	1122.5	0.0	0.0
2008/2	1127.6	5.1	5.1
2009/1	1120.8	-6.8	-1.6
2009/2	1106.3	-14.5	-16.1
2010/1	1256.8	150.5	134.3
2010/2	1157.1	-99.7	34.6
2011/1	1191.9	34.8	69.5
2011/2	1148.3	-43.6	25.9
2012/1	1120.0	-28.3	-2.5
2012/2	942.1	-177.9	-180.4
2013/1	978.2	36.1	-144.3
2013/2	1030.5	52.3	-91.9
2014	1104.4	73.9	-18.1
2015	1257.8	153.4	135.3
2016	1327.2	69.4	204.7
2017	1283.7	-43.5	161.2
2018	1109.6	-174.1	-12.9
2019	898.7	-210.9	-223.8
2020	920.1	21.4	-202.4
2022	868.4	-51.7	-254.0
2023	969.5	101.1	-152.9
2025	550.5	-419	-572

3.3 Island-wide trends

The data from excursion plots were converted into a timeseries of coordinates for each transect and overlaid on the 2025 orthophoto image (Figure 3-15 to Figure 3-19). Combining the geographic positions of the elevation contours on each transect generalises the survey results and illustrates the changing shape of the western flank of the Island.

The elevation contours shown in Figure 3-15 to Figure 3-17 represent the intertidal beach with AVD-46 contours of -1 m, 0 m and +2 m to approximate a low tide, MSL (0.23 m) and MHWPS (1.90 m). These contours encompass the elevations typically used to define land area, and also represent the part of the beach exposed to waves and nearshore currents over each tidal cycle. The results show the ongoing trend of landward retreat of the intertidal beach along the whole western flank of the Manukapua Island, however the northern end of the Island is migrating eastwards at the greatest rate (Transects 2 and 3) and the southern end is also migrating eastwards but at a slower rate (Transects 7-9), while the central section (e.g., Transects 5-6). is retreating at a rate slower than that observed at the northern and southern ends of the island. The intertidal beach over the northern and south tips of the Island (Transects 1 and 10) have remained relatively static over the period which surveys have been collected. However, it is not possible from the transects to determine if the whole island has decreased in area or volume as no survey information is available for the eastern flank of the island.

The elevation contours shown in Figure 3-18 and Figure 3-19 are +4 m and +7 m AVD-46, respectively representing the position of the mid and upper foredune face along the western flank of the island.

These contours indicate the areal extent of the dune systems which are largely subject only to wind-driven sand transport (i.e., above the wave-uprush limit). The figures show that dunes which grow to an elevation of 4 m are common across the island, but dunes growing past 7 m elevation are less common (the tallest dunes are typically 10 m elevation but have reached 14 m in the past on Transects 6, 7 and 9). Figure 3-18 also shows a near-stationary dune toe in the north and centre of the island (Transects 1-3, 6-7) contrasted with complete loss of a foredune in the mid-northern (Transects 4-5) and the southern sections (Transects 8-9). As previously mentioned, it is not possible to determine if the whole island has decreased in area or volume as no survey information is available for the eastern flank of the island.

Erosion and retreat of the foredunes at Transects 4 and 6 has resulted in a large landward movement of the +7 m contour in the 2022, 2023 and similarly in the recent 2025 survey. Comparing the island shape trends from the intertidal elevations (-1 m, 0 m and +2 m) with the dune elevations (+4), there is a contrast between the widespread intertidal beach retreat along the whole western flank and the localised retreat of the foredunes in the mid-northern and southern areas.

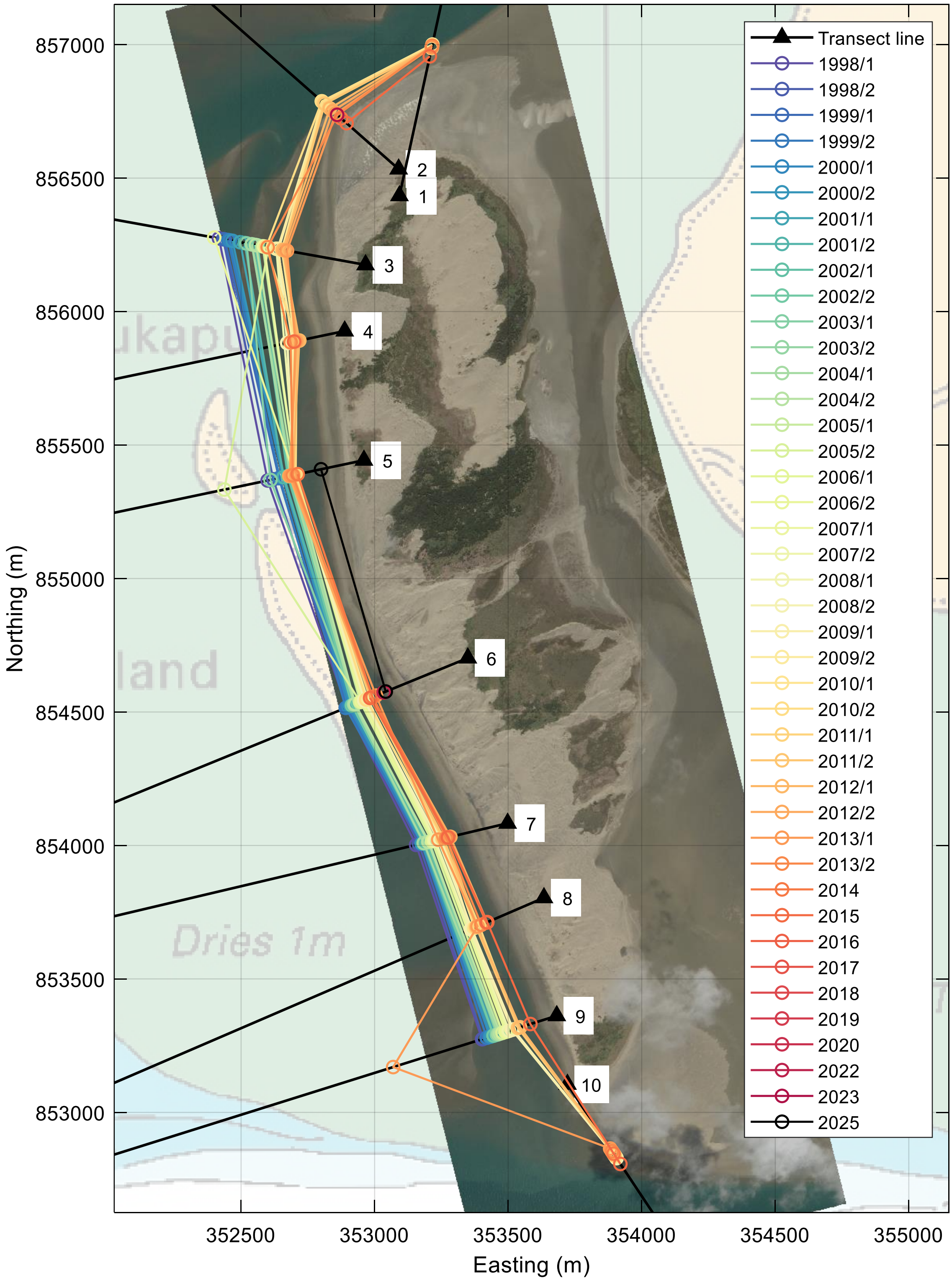


Figure 3-15: Location of the -1 m AVD-46 contour on western flank of Manukapua Island from beach profile surveys. The distance along transect from excursion plots (see beach profile figures above) were converted to Mt Eden 2000 coordinates and plotted for each survey date. Transects 3, 5-7 and 9 have data from 1998-2016, others from 2008-2016 only. Background aerial image dated 11-Jan-2025. Note the points offshore from the island are from surveyed sandbanks or shoals which have risen to above -1 m elevation. As with 2019, 2020, 2022 and 2023 the 2025 survey did not extend below -1 m elevation and is hence not plotted. Background bathymetric chart NZ4265 [Chart credit: LINZ].

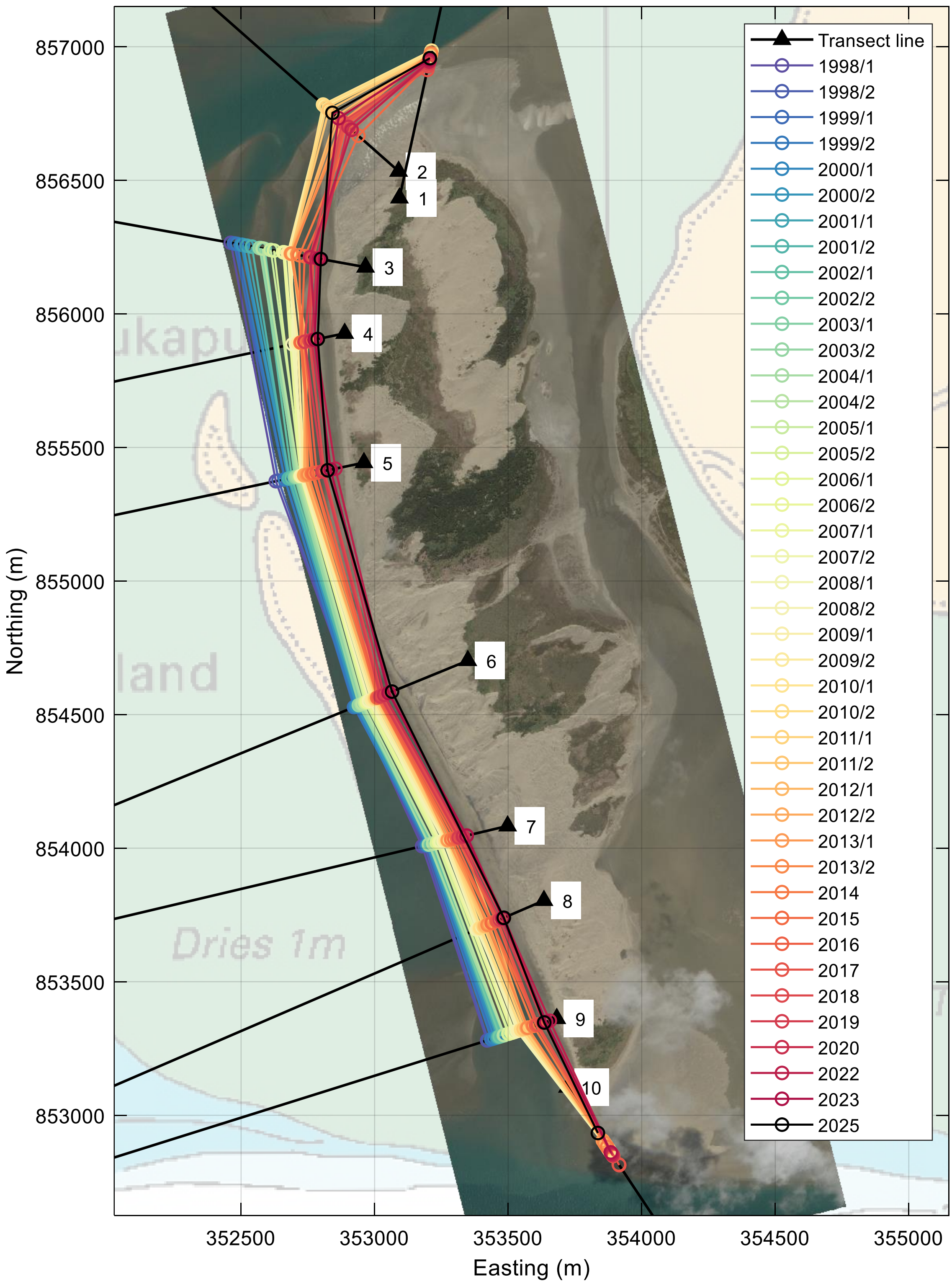


Figure 3-16: Location of the 0 m AVD-46 contour on western flank of Manukapua Island from beach profile surveys. The distance along transect from excursion plots (see beach profile figures above) were converted to Mt Eden 2000 coordinates and plotted for each survey date. Transects 3, 5-7 and 9 have data from 1998-2016, others from 2008-2016 only. Background aerial image dated 11-Jan-2025. Background bathymetric chart NZ4265 [Chart credit: LINZ].

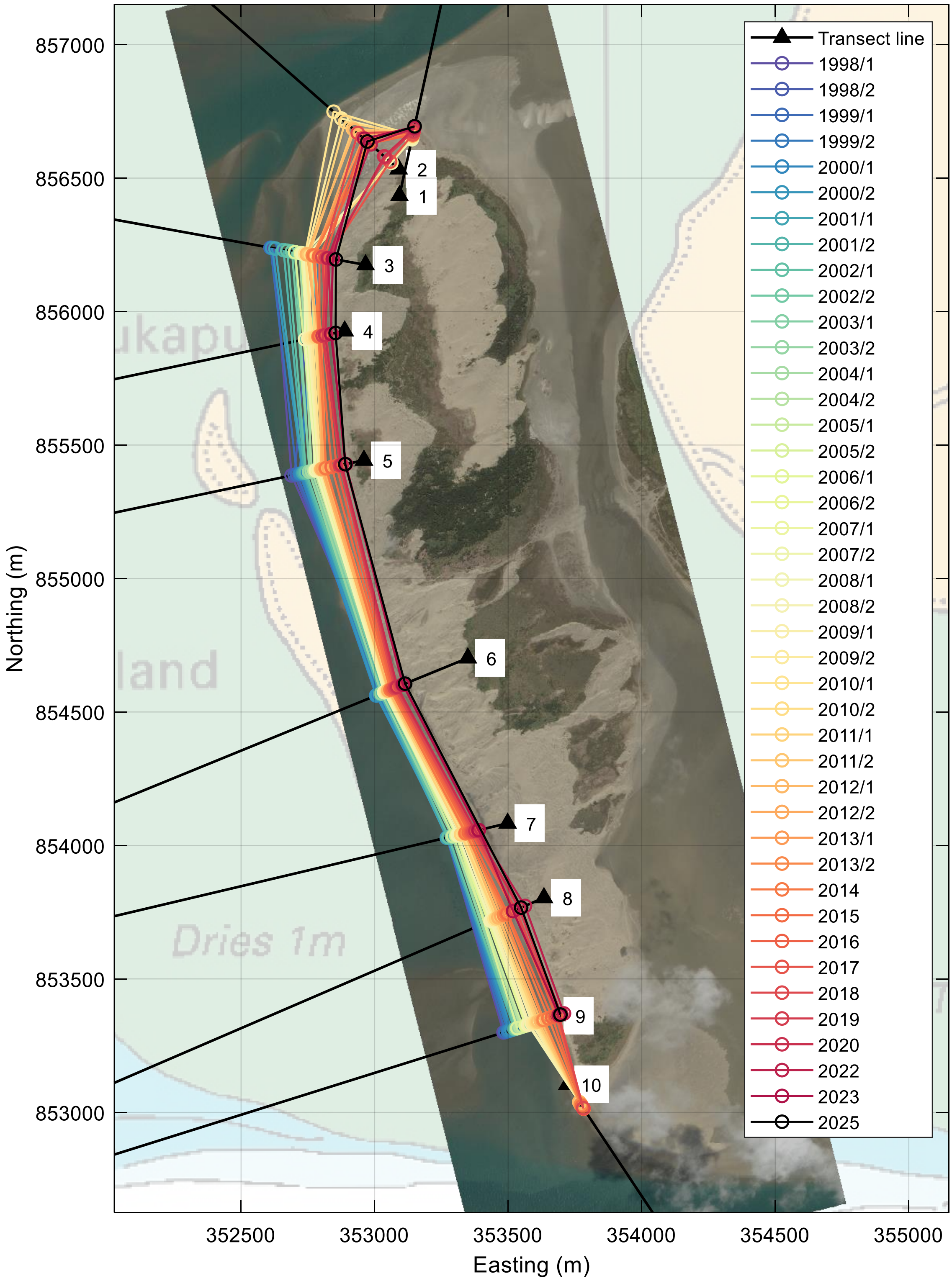


Figure 3-17: Location of the 2 m AVD-46 contour on western flank of Manukapua Island from beach profile surveys. The distance along transect from excursion plots (see beach profile figures above) were converted to Mt Eden 2000 coordinates and plotted for each survey date. Transects 3, 5-7 and 9 have data from 1998-2016, others from 2008-2016 only. Background aerial image dated 11-Jan-2025. Background bathymetric chart NZ4265 [Chart credit: LINZ].

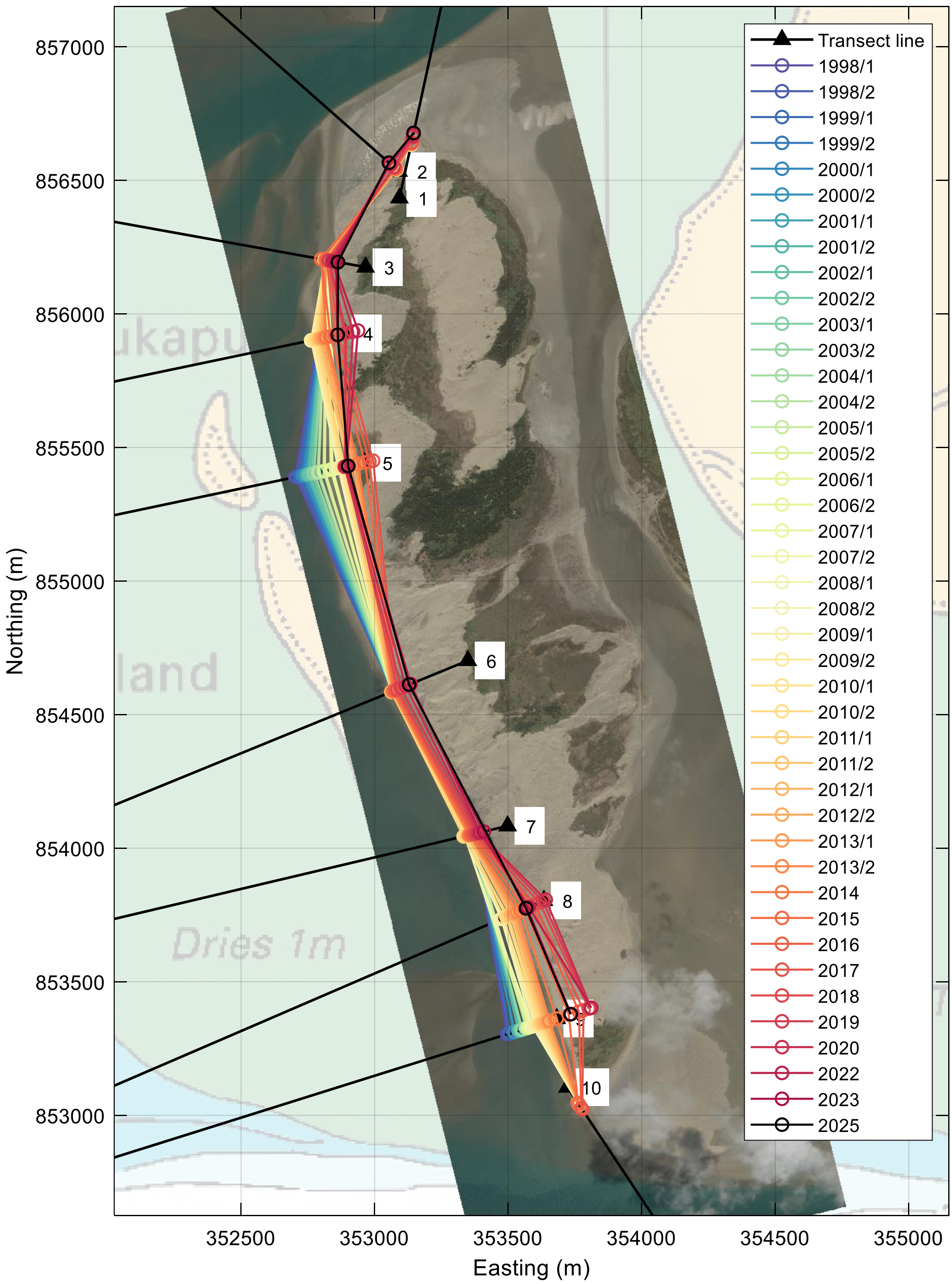


Figure 3-18: Location of the 4 m AVD-46 contour on western flank of Manukapua Island from beach profile surveys. The distance along transect from excursion plots (see beach profile figures above) were converted to Mt Eden 2000 coordinates and plotted for each survey date. Transects 3, 5-7 and 9 have data from 1998-2016, others from 2008-2016 only. Note the points offshore from the island are from surveyed sandbanks or shoals which have previously been to above 4 m elevation. Background aerial image dated 11-Jan-2025. Background bathymetric chart NZ4265 [Chart credit: LINZ].

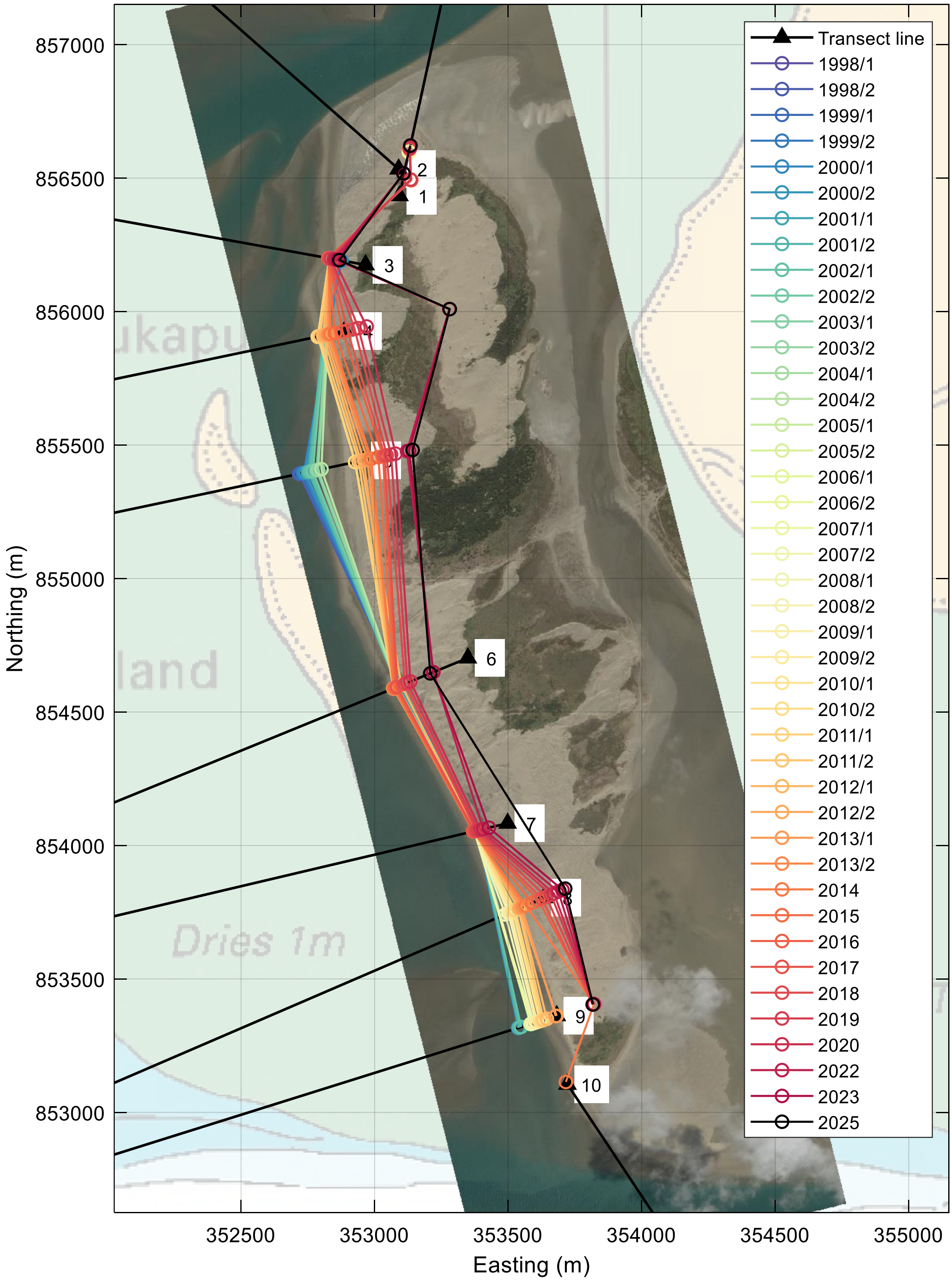


Figure 3-19: Location of the 7 m AVD-46 contour on western flank of Manukapua Island from beach profile surveys. The distance along transect from excursion plots (see beach profile figures above) were converted to Mt Eden 2000 coordinates and plotted for each survey date. Transects 3, 5-7 and 9 have data from 1998-2016, others from 2008-2016 only. Background aerial image dated 11-Jan-2025. Background bathymetric chart NZ4265 [Chart credit: LINZ].

3.4 Seabed transects

The 13 seabed transects surveys in 2025 are shown in Figure 3-20 to Figure 3-29. Vertical elevations are to AVD-46 datum and horizontal distances are calculated as along-transect distance from the each transects origin location (see Figure 2-1, coordinates of the transects are presented in Table A-1, Appendix A).

Survey results are presented in a north to south sequential order, with analysis and interpretation for each transect including:

1. The complete transect survey set to overview of the range of seabed positions since surveying began. These are shown as elevations and cross-shore positions for each survey date.

2. The volume of sand contained under each profile as calculated for the area *seaward* of the zero-horizontal position (e.g., 0 m) and *above* a nominated vertical elevation (e.g., -20 m AVD-46). The table shows calculated volumes and volume changes between survey dates, and cumulative changes over the whole survey period.

3. A descriptive evaluation of geomorphic changes to the transect. This identifies key transect features, the consistency of each feature with prior surveys and measured changes, along with the appearance of any new trends or features.

The seabed portion of Transects 1-10 have survey data from 2014-present, with Transects 11-13 having survey data from 2008-present. However, Transects 3-8 are closely aligned to older transects surveyed from 2008-2014 (near Transect 4) or 2010-2014 (near Transects 3, 5-8) which were replaced by the present transects as direct extensions to the beach transects. These older surveys are included in the following evaluation of seabed changes as they are approximately parallel to, and 150-250 m offset from the location of the current-day transects (see Figure 2-1).

The most recent (2025) beach profile survey is also included within the seabed transect figures as a link to the on-land portion of each transects (see Section 3.2 for the results, and Section 4.2 for the discussion of the beach profiles). Typically, beach and seabed transects are collected in close succession to ensure good spatial and temporal overlap. However, in this instance, weather conditions, tidal constraints, and equipment availability resulted in the beach transects and aerial imagery being collected in January, while the seabed surveys were conducted in May. Despite the timing difference between surveys, the subtidal portion of the beach transects, and seabed transects align reasonably well, indicating limited morphological change in the intervening period.

3.4.1 Transect 1

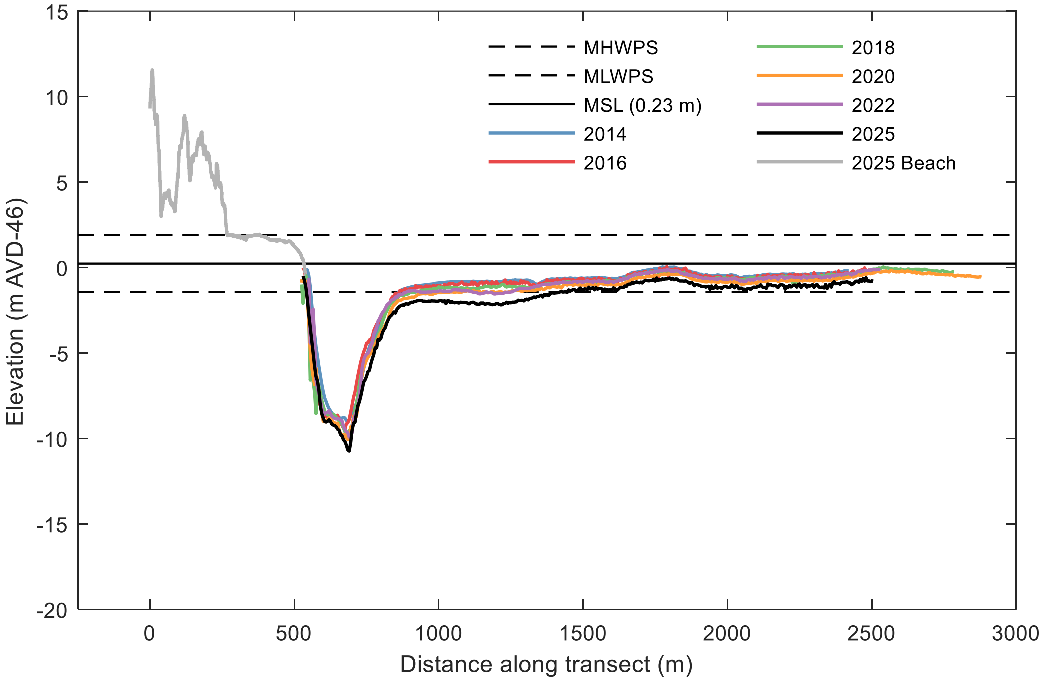


Figure 3-20: Beach and seabed profiles at Transect 1. Profile location shown in Figure 2-1 and transect coordinates in Table A-1.

Extending north from the northern tip of Manukapua Island (see Figure 2-1), the 2025 seabed survey of Transect 1 (Figure 3-20) shows the subtidal channel and intertidal sand banks are consistent in shape and depth to the 2014, 2016, 2018, 2020 and 2022 surveys. A loss of 1119 m3/m of seabed material has occurred which corresponds to a decrease in elevation of 57.2 cm over the 2 km transect (Table 3-12). A longer survey record would be required to explain these changes in context to the large-scale sediment movement within Kaipara Harbour.

Table 3-12: Seabed volumetric changes for Transect 1. Average depth change and total volume change as measured over the transect length for the specified survey interval.

Survey Interval	Transect length (m)	Average depth change (cm)	Total volume change (m^3/m)	Cumulative volume change (m^3/m)	Comments
2014-2016	1 880	-13.9	-261	-261	Surveys initiated 2014
2016-2018	1 980	-17.4	-345	-606	
2018-2020	2 260	-20.4	-461	-1067	
2020-2022	1 980	22.4	448	-619	
2022-2025	1 955	-57.2	-1119	-1738	

3.4.2 Transect 2

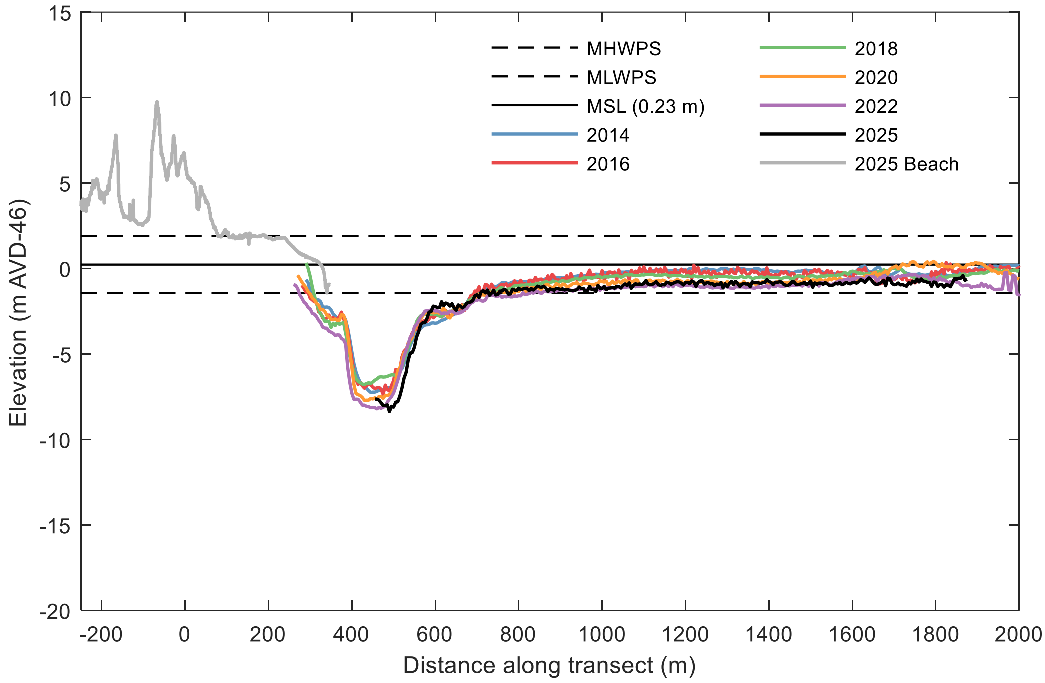


Figure 3-21: Beach and seabed profiles at Transect 2. Profile location shown in Figure 2-1 and transect coordinates in Table A-1. Aligned northwest-southeast on the northern tip of Manukapua Island (see Figure 2-1), the 2025 survey of Transect 2 (Figure 3-21) shows the subtidal channels and intertidal sand banks are consistent in shape and depth to the previous surveys. A loss of 699 m^3/m of seabed material has occurred since 2016 which corresponds to a decrease in elevation of 29.9 cm over the 1.7 km transect (Table 3-13). Some of the observed sediment loss may be partially attributed to a reduction in transect length during the most recent survey period. A longer survey record would be required to explain these changes in context to the large-scale sediment movement within Kaipara Harbour.

Table 3-13: Seabed volumetric changes for Transect 2. Average depth change and total volume change as measured over transect length for survey interval.

Survey Interval	Transect length (m)	Average depth change (cm)	Total volume change (m^3/m)	Cumulative volume change (m^3/m)	Comments
2014-2016	2 005	0	0	0	Surveys initiated 2014
2016-2018	2 005	-10	-199.9	-199.9	
2018-2020	2 020	-29.7	-600.1	-800	
2020-2022	1 970	-12.4	-244.9	-1044.9	
2022-2025	1 420	-29.9	-424.1	-699.0	transect shortened due to sea state

3.4.3 Transect 3

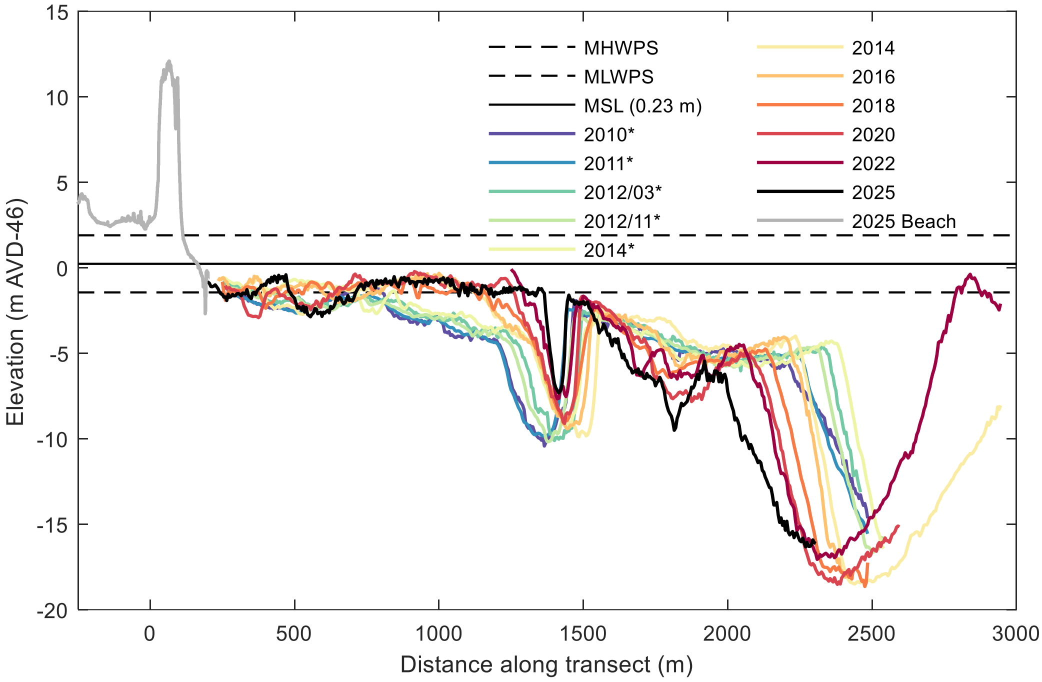


Figure 3-22: Beach and seabed profiles at Transect 3 with comparison to prior surveys on the closely aligned* Transect 1_b. Profile location shown in Figure 2-1 and transect coordinates in Table A-1. *Surveyed on Transect 1_b as approximately parallel to and 200 m south of Transect 3**.**

Aligned approximately east-west from the north western side of Manukapua Island (see Figure 2-1), the 2025 survey of Transect 3 (Figure 3-22) shows the steady continuation of seabed changes to the subtidal channels and intertidal sand banks since 2014, and since 2010 when taking into account prior surveys from the nearby Transect 1_b (2010-2014).

Approximately 1169 m^3/m of material has accumulated over 2022-2025 which corresponds to an average of -110.8 cm erosion across the 1.7 km transect (Table 3-14). The cumulative volume change since 2010 is -2052 m^3/m. The greatest contribution to the loss of volume over 2010-2025 is driven by the slow easterly (inshore) migration of the Otamatea Channel (chainage distance along transect >2300m) by ~250 m. Over this time the nearshore channel (Ch. 1250-1550m) has narrowed by ~160 m by infilling from the seaward side where the deposited sand appears to have eroded from the Otamatea Channel as it is transported by the prevailing onshore wave and current direction. The upper intertidal banks (within 1 km of the shore) have accumulated and built out since 2016 and are now well above MLWPS.

Table 3-14: Seabed volumetric changes for Transect 3. Average depth change and total volume change as measured over the transect length for the specified survey interval.

Survey Interval	Transect length (m)	Average depth change (cm)	Total volume change (m^3/m)	Cumulative volume change (m^3/m)	Comments
2010-2011	2 235	0.3	6	6	
2011-Mar 2012	2 135	3.0	64	71	
Mar 2012-Nov 2012	2 185	-3.8	-83	-13	
Nov 2012-2014	2 220	13.9	309	296	Alignment change from Transect 1_b
2014-2016	2 065	-10.7	-221	176	
2016-2018	2 160	-47.4	-1 024	-45	
2018-2020	2 225	-36.5	-813	-1 882	
2020-2022	1 345	74.3	1 000	-882	
2022-2025	1 055	-110.8	-1 169	-2 025	Too shallow to navigate full transect

3.4.4 Transect 4

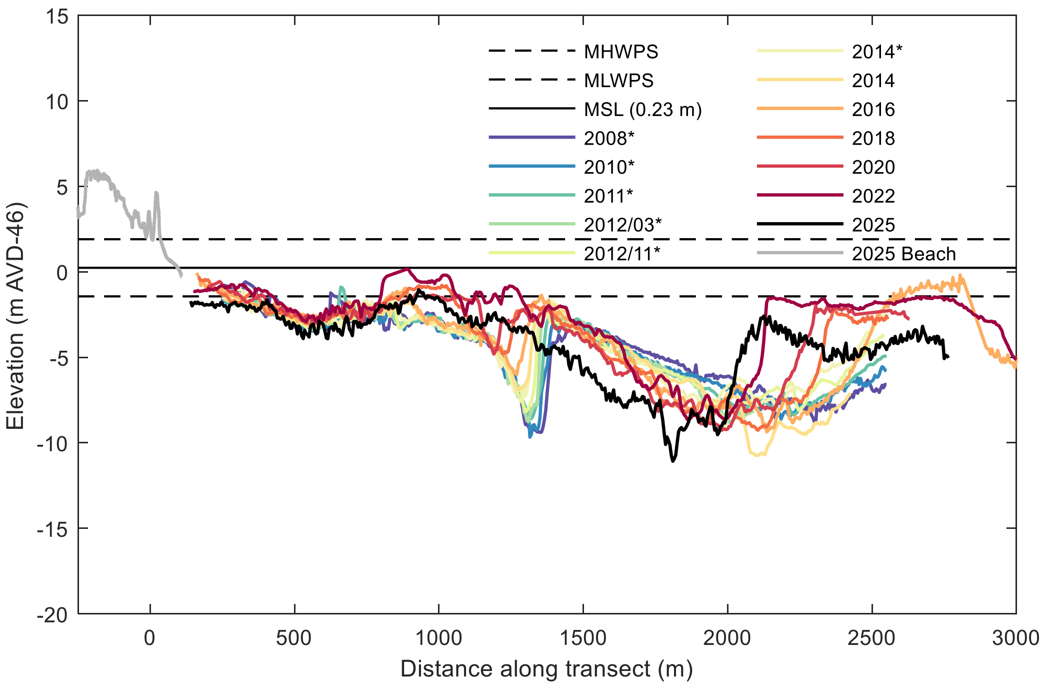


Figure 3-23: Beach and seabed profiles at Transect 4 with comparison to prior surveys on the closely aligned* Transect 2_a and 2_b. Profile location shown in Figure 2-1 and transect coordinates in Table A-1. *Surveyed on Transect 2_a and 2_b as approximately parallel to and 200 m north of Transect 4

Aligned east-west on the north western side of Manukapua Island (200 m south of Transect 3, see Figure 2-1), the 2025 survey of Transect 4 (Figure 3-23) shows the steady continuation of seabed changes to the subtidal channels and intertidal sand banks since 2014, and since 2008 if including prior surveys from the Transect 2_a and 2_b (2008-2014).

About 3,010 m^3/m material eroded from 2022-2025 which corresponds to an average of 128.9 cm elevation decrease across the 2.3 km transect (Table 3-15).

The inner subtidal channel (1,200 m) which was between the two sand shoals is now completely infilled. The central channel (Ch. 1,500-2,000) has decreased in width by 100 m and deepened. There is a shoreward migration of the entire profile, driven by the deposition of sand transported by the prevailing onshore waves and current.

Lady Franklin Banks (Ch. 2.5–3 km) showed signs of progradation and widening in the 2022 survey. This landward propagation continued in 2025 survey and was accompanied by a reduction in bank elevation. However, this apparent reduction may not reflect true morphological change, as wave breaking and rough sea conditions during the 2025 survey introduced significant uncertainty. These conditions likely affected vessel positioning and transect alignment, making it difficult to reliably capture the full elevation profile.

Table 3-15: Seabed volumetric changes for Transect 4. Average depth change and total volume change as measured over the transect length for the specified survey interval.

Survey Interval	Transect length (m)	Average depth change (cm)	Total volume change (m^3/m)	Cumulative volume change (m^3/m)	Comments
2008-2010	2 300	-9.9	-227	-227	
2010-2011	2,300	11.5	264	38	
2011-Mar 2012	1 840	-4.8	-89	-51	
Mar 2012-Nov 2012	1 515	17.7	268	217	
Nov 2012-2014	1 965	7.5	147	363	Alignment change from Transect 2_a and 2_b
2014-2016	2 175	24.0	523	886	
2016-2018	2 320	34.3	796	1 682	
2018-2020	2 240	17.0	380	2 062	
2020-2022	2 240	89	1 993	4 055	
2022-2025	2 335	-128.9	-3 010	1 045	rough sea conditions over Lady Franklin Bank

3.4.5 Transect 5

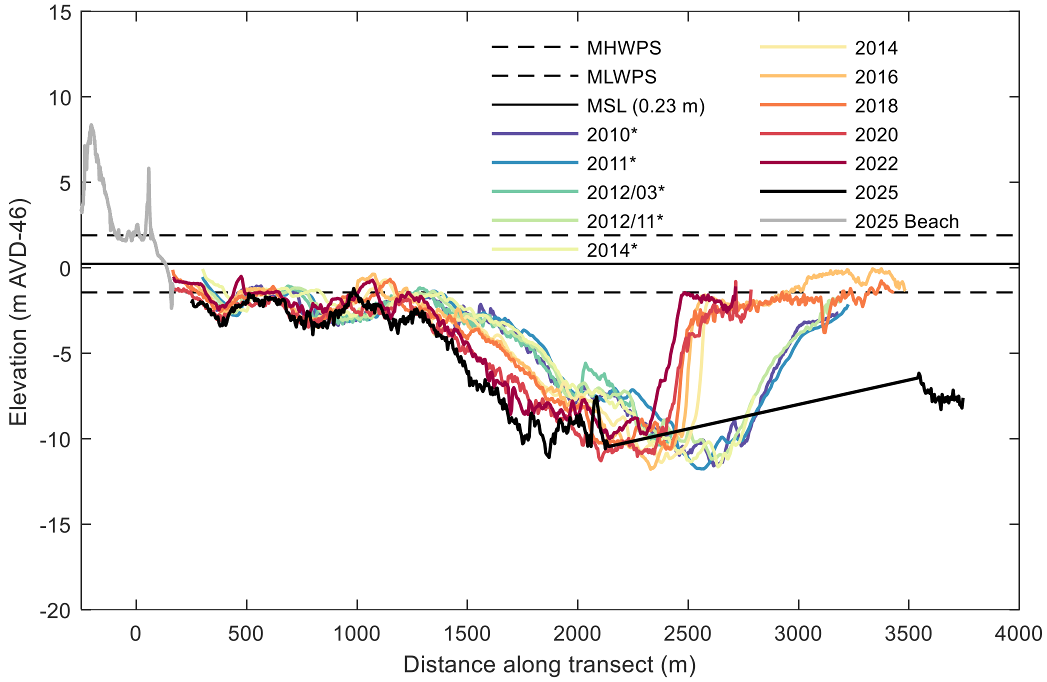


Figure 3-24: Beach and seabed profiles at Transect 5 with comparison to prior surveys on the closely aligned* Transect 3_b. Profile location shown in Figure 2-1 and transect coordinates in Table A-1. *Surveyed on Transect 3_b as approximately parallel to and 200 m south of Transect 5. Straight line in the 2025 profile data is due to the gap illustrated in Figure 2-3.

Aligned east-west on the central western side of Manukapua Island (250 m south of Transect 4, see Figure 2-1), the 2025 survey of Transect 5 (Figure 3-24) shows the steady continuation of seabed changes to the subtidal channels and intertidal sand banks since 2014, and since 2010 if including prior surveys from the nearby Transect 3_b (2010-2014).

Similar to Transect 4, Transect 5 could not be safely navigated across Lady Franklin Bank due to wave activity. As a result, no data were collected between 2000 m and 3500 m along the transect, creating a gap over the bank crest and upper slope.

Small localised bedform movement has occurred along the transect length with a general landward (eastward) migration of these bedform features, coinciding with the direction of the prevailing westerly winds.

Note that the alignment change, and 150 m offset from Transect 3_b to Transect 6 (2011 – 2014) resulted in the large volume change evident in Table 3-16, however the ongoing trend is readily apparent.

Table 3-16: Seabed volumetric changes for Transect 5. Average depth change and total volume change as measured over the transect length for the specified survey interval.

Survey Interval	Transect length (m)	Average depth change (cm)	Total volume change (m^3/m)	Cumulative volume change (m^3/m)	Comments
2010-2011	2 880	13.0	374	374	
2011-Mar 2012	2 125	-9.1	-192	182	
Mar 2012-Nov 2012	2 125	-3.8	-80	102	
Nov 2012-2014	2 445	-14.7	-360	-259	Alignment change from Transect 3_b
2014-2016	2 335	14.4	336	78	
2016-2018	3 165	-27.1	-857	-780	
2018-2020	2 620	-56.4	-1 479	-2 259	
2020-2022	2 550	77.4	1 973	-286	
2022-2025	2 465	-60.4	-1 490	-1 776	Too shallow to navigate full transect

3.4.6 Transect 6

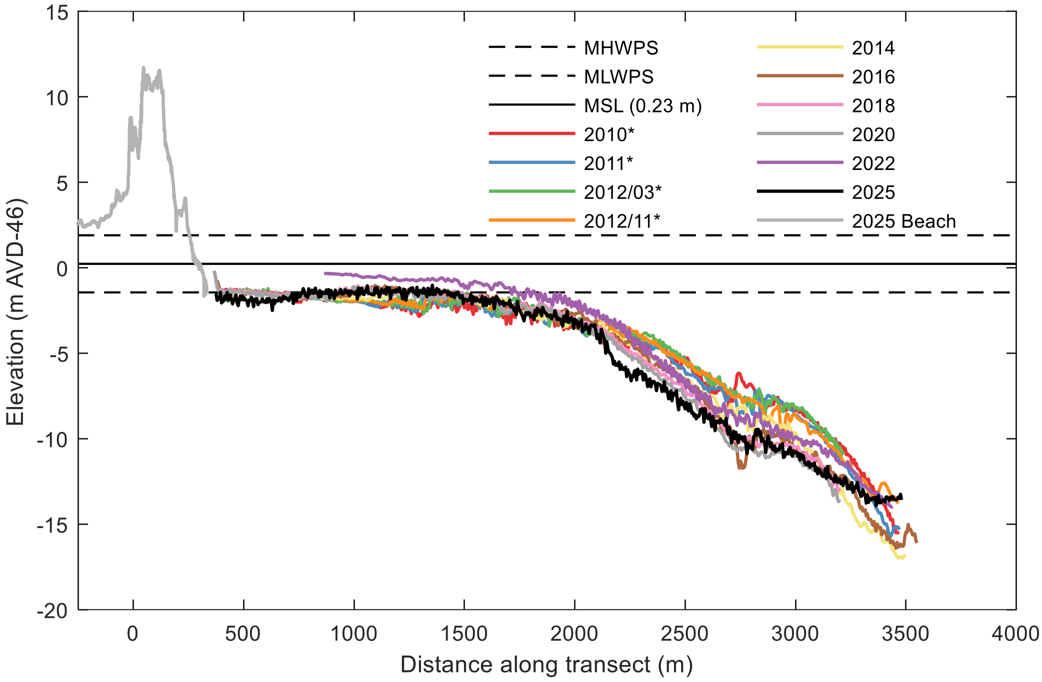


Figure 3-25: Beach and seabed profiles at Transect 6 with comparison to prior surveys on the closely aligned* Transect 4_b. Profile locations shown in Figure 2-1 and transect coordinates in Table A-1. *Surveyed on Transect 4_b as approximately parallel to and 150m south of Transect 6**.**

Aligned east-west on the central western side of Manukapua Island (400 m south of Transect 5, see Figure 2-1), the 2025 survey of Transect 6 (Figure 3-25) shows the steady continuation of seabed changes to the subtidal channel and intertidal sand banks since 2014, and since 2010 if including prior surveys from the nearby Transect 4_b (2010-2012).

A change in volume of -2719 m^3/m was observed from 2022-2025 which corresponds to an average change in depth of 105 cm along the 2.8 km transect (Table 3-17). The recent loss continues the trend since 2010 associated with the gradual inshore (easterly) migration of the main offshore channel (Ch. 2,000—3,500m) the prevailing sand transport direction. The annual migration is typically 50 m per year for depths greater than 4 m with minor changes at shallower depths.

Note that the alignment change and 150 m offset from Transect 4_b to Transect 6 (Nov 2012 – 2014) resulted in the large volume change evident in Table 3-17, however the ongoing trend is readily apparent.

Table 3-17: Seabed volumetric changes for Transect 6. Average depth change and total volume change as measured over the transect length for the specified survey interval.

Survey Interval	Transect length (m)	Average depth change (cm)	Total volume change (m^3/m)	Cumulative volume change (m^3/m)	Comments
2010-2011	3 070	-14.2	-436	-436	
2011-Mar 2012	2 740	-3.1	-85	-521	
Mar 2012-Nov 2012	2 820	-10.9	-309	-830	
Nov 2012-2014	2 710	-39.9	-1 081	-1 911	Alignment change from Transect 4_b
2014-2016	3 060	-2.4	-74	-1 985	
2016-2018	2 820	-8.4	-236	-2 221	
2018-2020	2 835	-21.7	-615	-2 836	
2020-2022	2 335	109.3	2 552	-284	
2022-2025	2 575	-105.6	-2 719	-3 004	

3.4.7 Transect 7

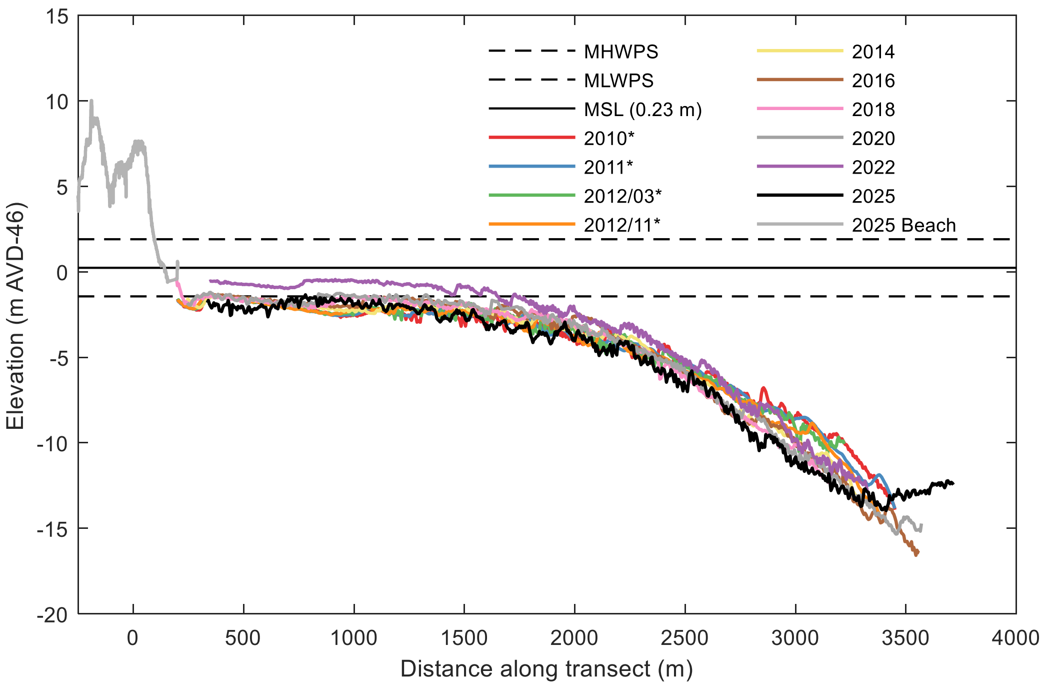


Figure 3-26: Beach and seabed profiles at Transect 7 with comparison to prior surveys on the closely aligned* Transect 5_b. Profile locations shown in Figure 2-1 and transect coordinates in Table A-1. *Surveyed on Transect 5_b as approximately parallel to and 150 m south of Transect 7.Aligned east-west on the southern half of Manukapua Island (600 m south of Transect 6, see Figure 2-1), the 2025 survey of Transect 7 (Figure 3-26) shows the steady continuation of seabed changes to the subtidal channel and intertidal sand banks since 2014, and since 2010 if including prior surveys from the nearby Transect 5_b (2010-2012).

Between 2022 and 2025, an estimated 3,981 m³ of sediment was lost along the 2.9 km transect, corresponding to an average change in the seabed elevation of approximately 133 cm (Table 3-18). This reduction in sand volume reflects changes to the offshore channel bank at depths greater than 5 m. While the main offshore channel continues to migrate landward (eastward), the rate of migration appears to have slowed in the most recent survey.

Note that the alignment change and 150 m offset from Transect 5_b to Transect 7 resulted in the large volume change in evident in Table 3-18.

Table 3-18: Seabed volumetric changes for Transect 7. Average depth change and total volume change as measured over the transect length for the specified survey interval.

Survey Interval	Transect length (m)	Average depth change (cm)	Total volume change (m^3/m)	Cumulative volume change (m^3/m)	Comments
2010-2011	3 250	-3.9	-127	-127	
2011-Mar 2012	3 010	-1.7	-51	-177	
Mar 2012-Nov 2012	3 020	-9.0	-271	-448	
Nov 2012-2014	3 020	-14.9	-449	-898	Alignment change from Transect 5_b
2014-2016	2 990	7.2	217	-681	
2016-2018	2 845	-14.0	-398	-1 078	
2018-2020	2 970	15.1	440	-638	
2020-2022	2 985	81.9	2 445	1 806	
2022-2025	2 985	-133.4	-3 981	-2 174	

3.4.8 Transect 8

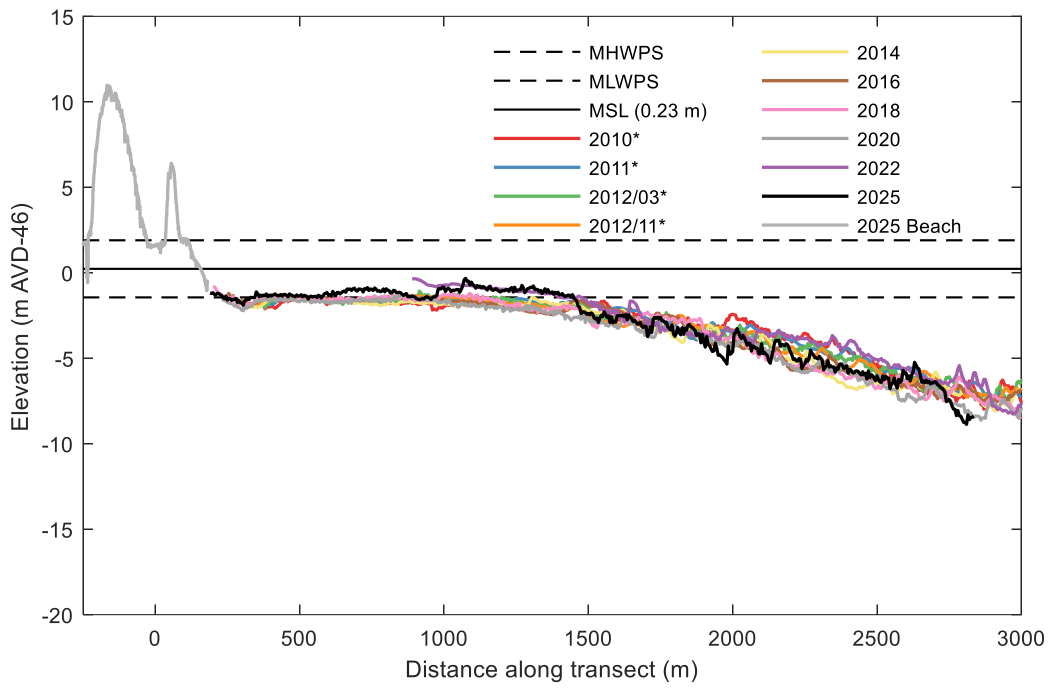


Figure 3-27: Beach and seabed profiles at Transect 8 with comparison to prior surveys on the closely aligned* Transect 6_b. Profile locations shown Figure 2-1 and transect coordinates in Table A-1. *Surveyed on Transect 6_b as approximately parallel to and 150m south of Transect 8.Aligned northeast-southwest at 1 km from the southern extent of Manukapua Island (400 m south of Transect 7, see Figure 2-1), the 2025 survey of Transect 8 (Figure 3-27) shows the steady continuation of seabed changes to the subtidal channel and intertidal sand banks since 2014, and since 2010 if including surveys from the nearby Transect 6_b (2010-2012).

A loss of 982 m³/m of sediment along the transect was observed between 2022 and 2025, corresponding to an average increase in the water depth of approximately 51 cm along the 3.3 km transect (Table 4.21). Similar to Transect 7, the decrease in sand volume is attributed to erosion of the offshore channel bank at depths below 5 m. Despite this recent loss, the cumulative increase in sand volume since 2010 remains positive, with a net gain of 843 m³/m

Note that the alignment change, and 150 m offset from Transect 6_b to Transect 8 resulted in the large volume change evident in Table 3-19.

Table 3-19: Seabed volumetric changes for Transect 8. Average depth change and total volume change as measured over the transect length for the specified survey interval.

Survey Interval	Transect length (m)	Average depth change (cm)	Total volume change (m³/m)	Cumulative volume change (m³/m)	Comments
2010-2011	3 060	6.5	200	200	
2011-Mar 2012	3 055	-1.4	-43	156	
Mar 2012-Nov 2012	3 045	-7.6	-231	-75	
Nov 2012-2014	2 780	-9.1	-254	-329	Alignment change from Transect 6_b
2014-2016	3 540	17.7	625	296	

Survey Interval	Transect length (m)	Average depth change (cm)	Total volume change (m³/m)	Cumulative volume change (m³/m)	Comments
2016-2018	3 300	-11.7	-387	-91	
2018-2020	3 320	-31.0	-1 031	-1 122	
2020-2022	2 895	103.8	2 938	1 816	
2022-2025	2 640	-51.7	-982	834	

3.4.9 Transect 9

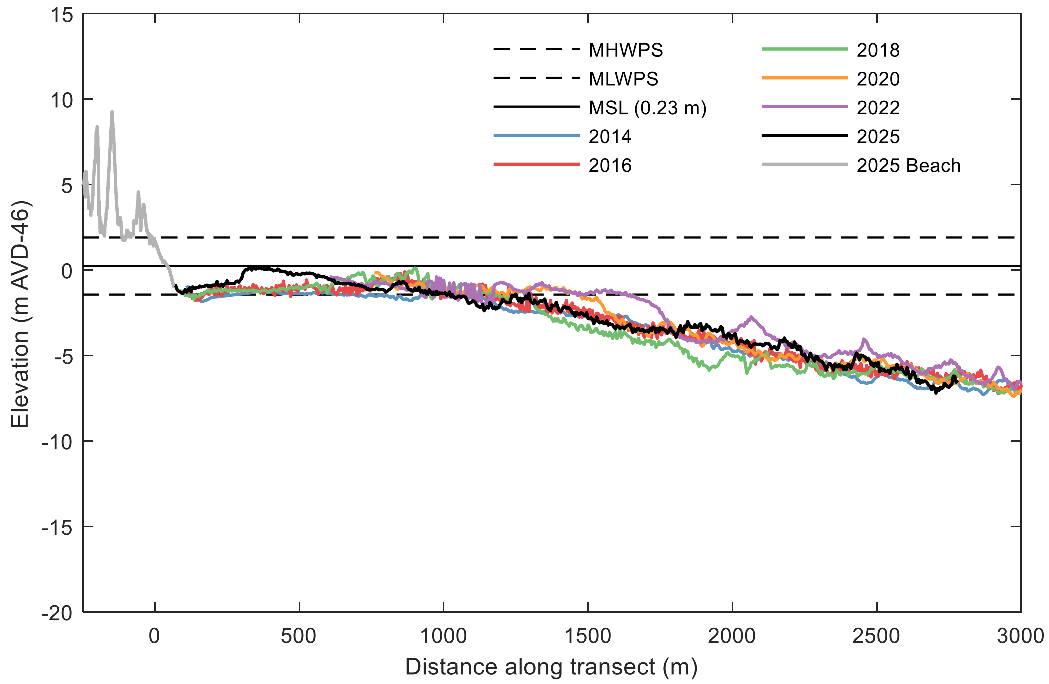


Figure 3-28: Beach and seabed profiles at Transect 9. Profile location shown in Figure 2-1 and transect coordinates in Table A-1. Aligned northeast–southwest and located approximately 500 m south of the southernmost extent of Manukapua Island (500 m south of Transect 8, see Figure 2-3), the 2025 survey of Transect 9 (Figure 3-28) indicates that the subtidal channel and intertidal sand banks remain consistent in shape and depth compared to previous surveys. A volume loss of 1,297 m³ between 2022 and 2025 offsets the 1,180 m³ gain recorded from 2020 to 2022, resulting in a cumulative volume change of 1,299 m³ since 2014 over the 3.3 km transect. The 2022–2025 loss corresponds to an average seabed elevation decrease of approximately 59 cm over the 3.44 km length (Table 3-20). This net volume reduction is largely attributed to changes on the subtidal flats, particularly between chainages 1,000 and 2,000 m.

Table 3-20: Seabed volumetric changes for Transect 9. Average depth change and total volume change as measured over the transect length for the specified survey interval.

Survey Interval	Transect length (m)	Average depth change (cm)	Total volume change (m^3/m)	Cumulative volume change (m^3/m)	Comments
2014-2016	3 440	30.9	1 063	1 063	Surveys initiated 2014
2016-2018	3 345	-29.4	-982	81	
2018-2020	2 710	49.2	1 334	1 415	
2020-2022	2 820	41.8	1 180	2 595	
2022-2025	2175	-59.6	-1 297	1 299	

3.4.10 Transect 10

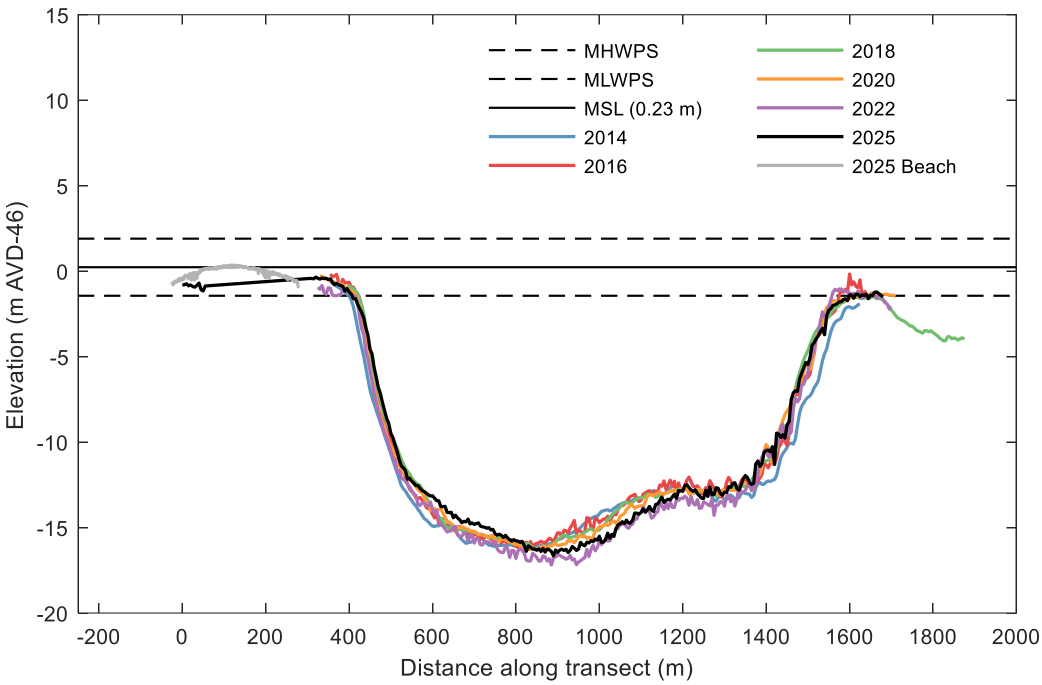


Figure 3-29: Beach and seabed profiles at Transect 10. Profile location shown in Figure 2-1 and transect coordinates in Table A-1. Extending southeast from the southernmost extent of Manukapua Island (see Figure 2-1), the 2025 survey of Transect 10 (Figure 3-29) shows that the channel and bank morphology remain consistent in shape and depth compared to previous surveys. The deep channel separating Manukapua Island from Tauhoa Banks has remained stable in both depth and width since the initial survey in 2014. A small net increase in volume of 610 m³ was recorded between 2022 and 2025 (Table 3-21). A longer survey record will help place these short-term changes in the context of broader sediment dynamics and large-scale movement within Kaipara Harbour.

Table 3-21: Seabed volumetric changes for Transect 10. Average depth change and total volume change as measured over the transect length for the specified survey interval.

Survey Interval	Transect length (m)	Average depth change (cm)	Total volume change (m^3/m)	Cumulative volume change (m^3/m)	Comments
2014-2016	1 275	61.3	781	781	Surveys initiated 2014
2016-2018	1 250	6.1	77	858	
2018-2020	1 320	-13.4	-176	682	
2020-2022	1 375	-49.7	-683	-1	
2022-2025	1 360	44.9	611	610	

3.4.11 Transect 11

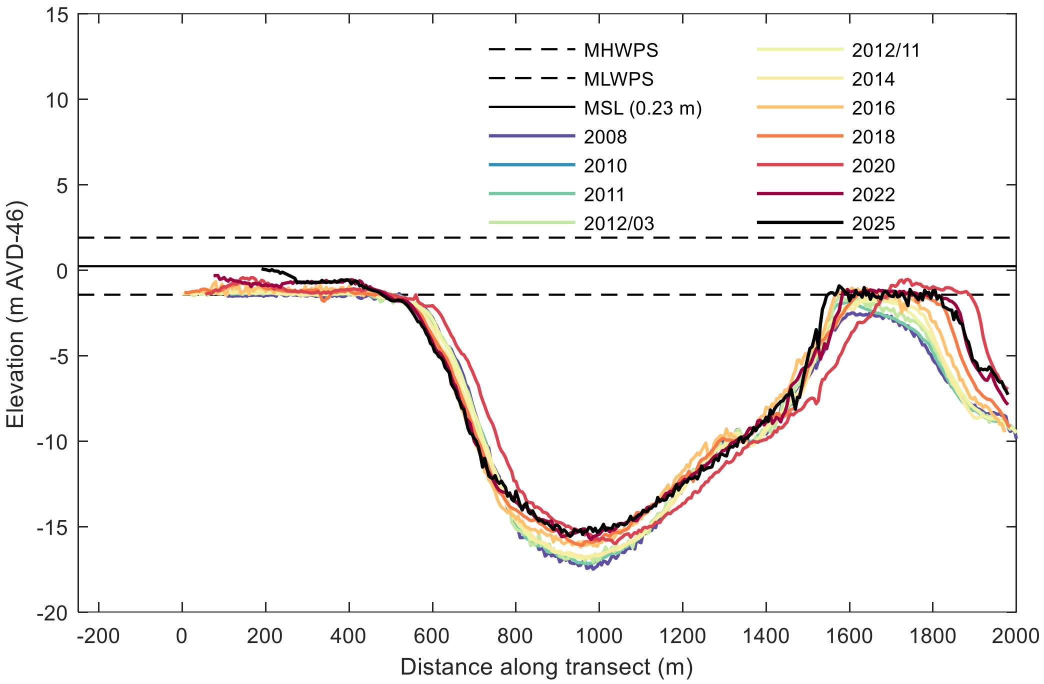


Figure 3-30: Seabed profiles at Transect 11 (Tauhoa Banks). Profile location shown in Figure 2-1 and transect coordinates in Table A-1.

To the south of Manukapua Island and crossing the Tauhoa Channel to Tauhoa Banks, the 2025 survey of Transect 11 (Figure 3-30) displays a consistent seabed profile to that of prior surveys and nearby transects.

The 2025 survey shows an overall small amount of shallowing of the Tauhoa Channel and Tauhoa Banks with a volume gain of 117 m^3/m since 2022, an average accumulation of 6.5 cm. Since 2008 over the 1.9 km transect (Table 3-22) the net volume accumulation is 1,590 m^3. The sand has predominantly accumulated on the southern flank of Tauhoa Banks (Ch. 1,900) and within the main channel (Ch. 750-1,550), with smaller losses on the inshore flank (Manukapua Island side) of the main channel. Overall, the Tauhoa Channel dimensions are consistent at a maximum depth of 15 m and the channel is approximately 1 km wide (relative to mean sea level). The Tauhoa Banks rise to -1.0 m (AVD-46) and therefore will be exposed during spring low tides.

Table 3-22: Seabed volumetric changes for Transect 11. Average depth change and total volume change as measured over the transect length for the specified survey interval.

Survey Interval	Transect length (m)	Average depth change (cm)	Total volume change (m^3/m)	Cumulative volume change (m^3/m)	Comments
2008-2010	1 195	6.3	120	120	2008-2010 for depths < 10m only
2010-2011	1 885	4.1	77	197	
2011-Mar 2012	1 885	11.3	214	411	
Mar 2012-Nov 2012	1 980	1.4	27	438	
Nov 2012-2014	1 900	-4.0	-76	361	
2014-2016	1 865	40.3	822	1 183	
2016-2018	1 930	5.7	110	1 226	
2018-2020	1 925	12.5	241	1 467	
2020-2022	1 905	0.3	7	1 473	
2022-2025	1 790	6.5	117	1 590	

3.4.12 Transect 12

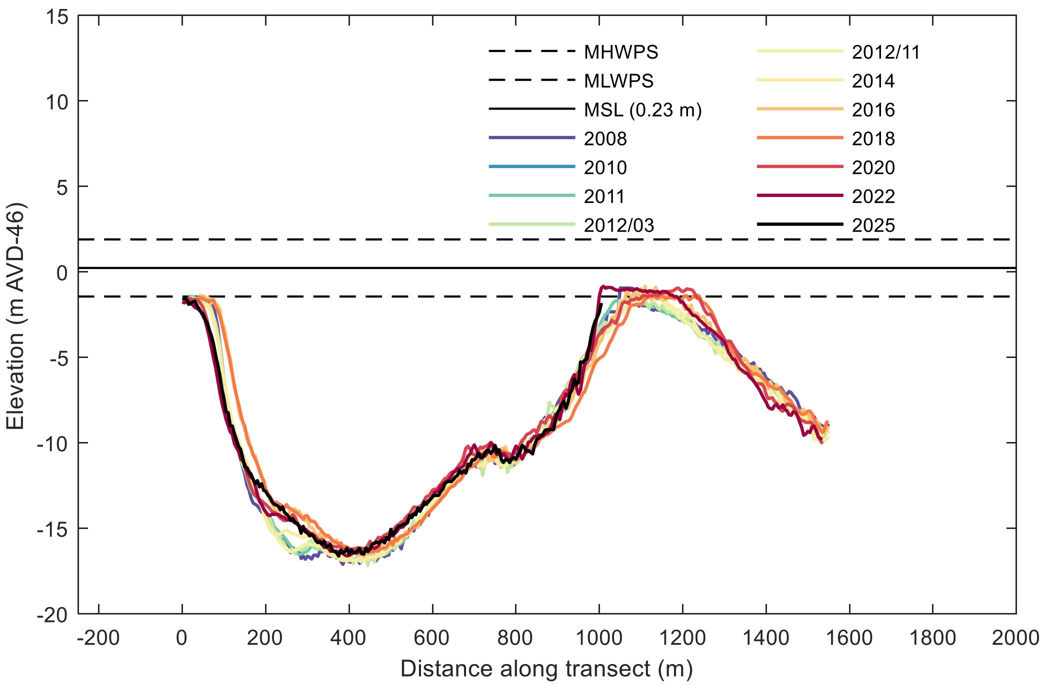


Figure 3-31: Seabed profiles at Transect 12 (Tauhoa Banks). Profile location shown in Figure 2-1 and transect coordinates in Table A-1. To the south of Manukapua Island and crossing the Tauhoa Channel to Tauhoa Banks, the 2025 survey of Transect 12 (Figure 3-31) displays consistent characteristics to prior surveys and to the adjacent transects. The 2025 survey shows an overall increase in the volume of Transect 12 of 77 m3/m which corresponds to an 8 cm increase in depth over the 1.5 km transect. The net volume gain since 2008 is 602 m3. The main shifts in sand volume are slight reduction in volume from the northern flank of Tauhoa Banks (Ch. 800-1,100) and an increase on the southern flank (Ch. 1,200-1,600). These changes are also consistent with Transect 11 which also extends across Tauhoa Banks (Table 3-23).

The maximum width of the Tauhoa Channel of around 1 km has remained largely consistent over the survey period, as has the maximum depth a 17 m. The small 'step' feature observed at a depth of 14 m (Ch. 250 m) within the channel in 2014 has since infilled. The Tauhoa Banks rise to - 1.5 m AVD-46 and therefore will be exposed during spring low tides. (while not shown here google earth image shows Tauhoa Banks exposed at low tide).

Table 3-23: Seabed volumetric changes for Transect 12. Average depth change and total volume change as measured over the transect length for the specified survey interval.

Survey Interval	Transect length (m)	Average depth change (cm)	Total volume change (m^3/m)	Cumulative volume change (m^3/m)	Comments
2008-2010	800	-0.9	-14	-14	2008-2010 for depths < 10m only
2010-2011	1 535	-6.7	-104	-117	
2011-Mar 2012	1 535	2.6	40	-77	
Mar 2012-Nov 2012	1 535	-4.0	-61	-139	
Nov 2012-2014	1 535	-3.6	-56	-195	
2014-2016	1 510	52.8	797	602	
2016-2018	1 510	-8.0	-121	482	
2018-2020	1 515	18.9	125	768	
2020-2022	1 535	-15.9	-243	525	
2022-2025	1 005	7.7	77	602	

3.4.13 Transect 13

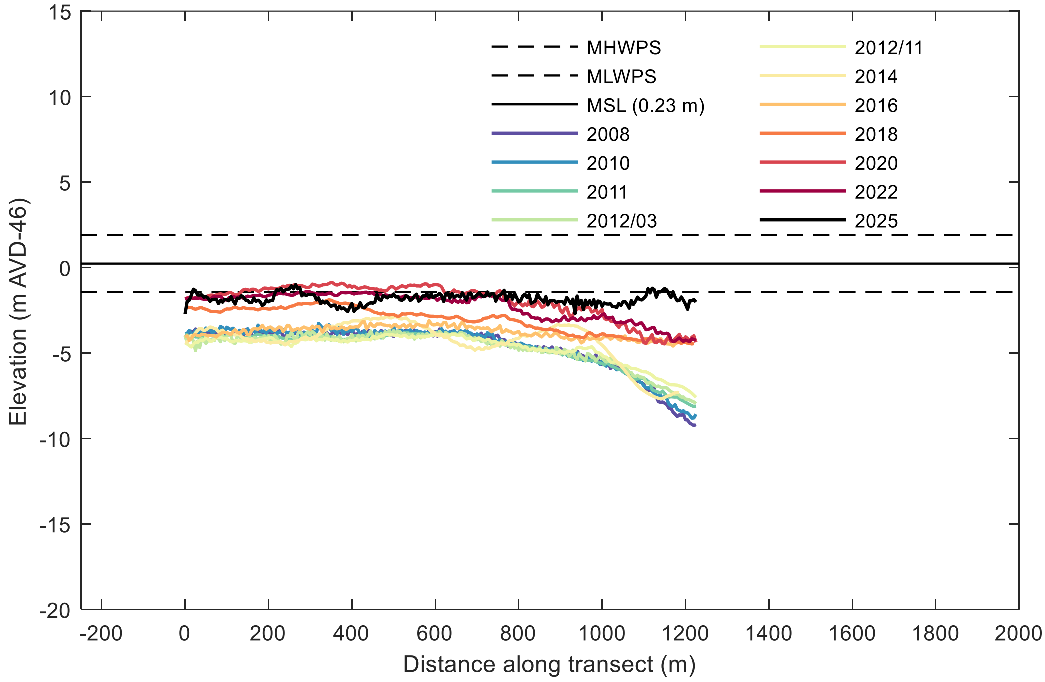


Figure 3-32: Seabed profiles at Transect 13 (Tauhoa Banks). Profile location shown in Figure 2-1 and transect coordinates in Table A-1. The variation in elevation for 2014 is due to tidal currents and winds deflecting the survey vessel as illustrated in Figure 2-3.

South of Manukapua Island along Tauhoa Banks, the 2025 survey of Transect 13 (Figure 3-32) indicates an overall seabed shallowing of 43 cm since the 2022 survey. Accumulation has occurred along most of the transect, with the greatest shallowing observed at the eastern end between chainages 1000 and 1200 m. The total volume change since 2008 is 3,352 m³, equivalent to an average of approximately 16 cm of vertical accumulation per year if evenly distributed across the 1.2 km transect (Table 3-24). This pattern of sedimentation is also reflected at the seaward ends of Transects 11 and 12, which intersect Transect 13 at chainages 130 m and 800 m, respectively (see Figure 2-1).

Table 3-24: Seabed volumetric changes for Transect 13. Average depth change and total volume change as measured over the transect length for the specified survey interval.

Survey Interval	Transect length (m)	Average depth change (cm)	Total volume change (m³/m)	Cumulative volume change (m³/m)	Comments
2008-2010	1 215	7.5	91	91	2008-2010 for depths < 10m only
2010-2011	1 215	-13.6	-165	-74	
2011-Mar 2012	1 215	1.9	23	-51	
Mar 2012-Nov 2012	1 215	3.2	38	-13	
Nov 2012-2014	1 175	32.4	380	368	Survey vessel influenced by waves/currents (2014 only)
2014-2016	1 175	51.1	600	968	
2016-2018	1 215	73.8	897	1 865	
2018-2020	1 215	109.8	1335	3 229	
2020-2022	1 215	-30.5	-370	2 829	

Survey Interval	Transect length (m)	Average depth change (cm)	Total volume change (m^3/m)	Cumulative volume change (m^3/m)	Comments
2022-2025	1 215	43	523	3 352	

3.5 Satellite Bathymetry and Digital Elevation Model Results

3.5.1 Satellite derived bathymetry

Satellite-derived bathymetry, shown in Figure 4-33, provides good coverage for depths less than 6 meters, however, data beyond this depth was found to be unreliable.

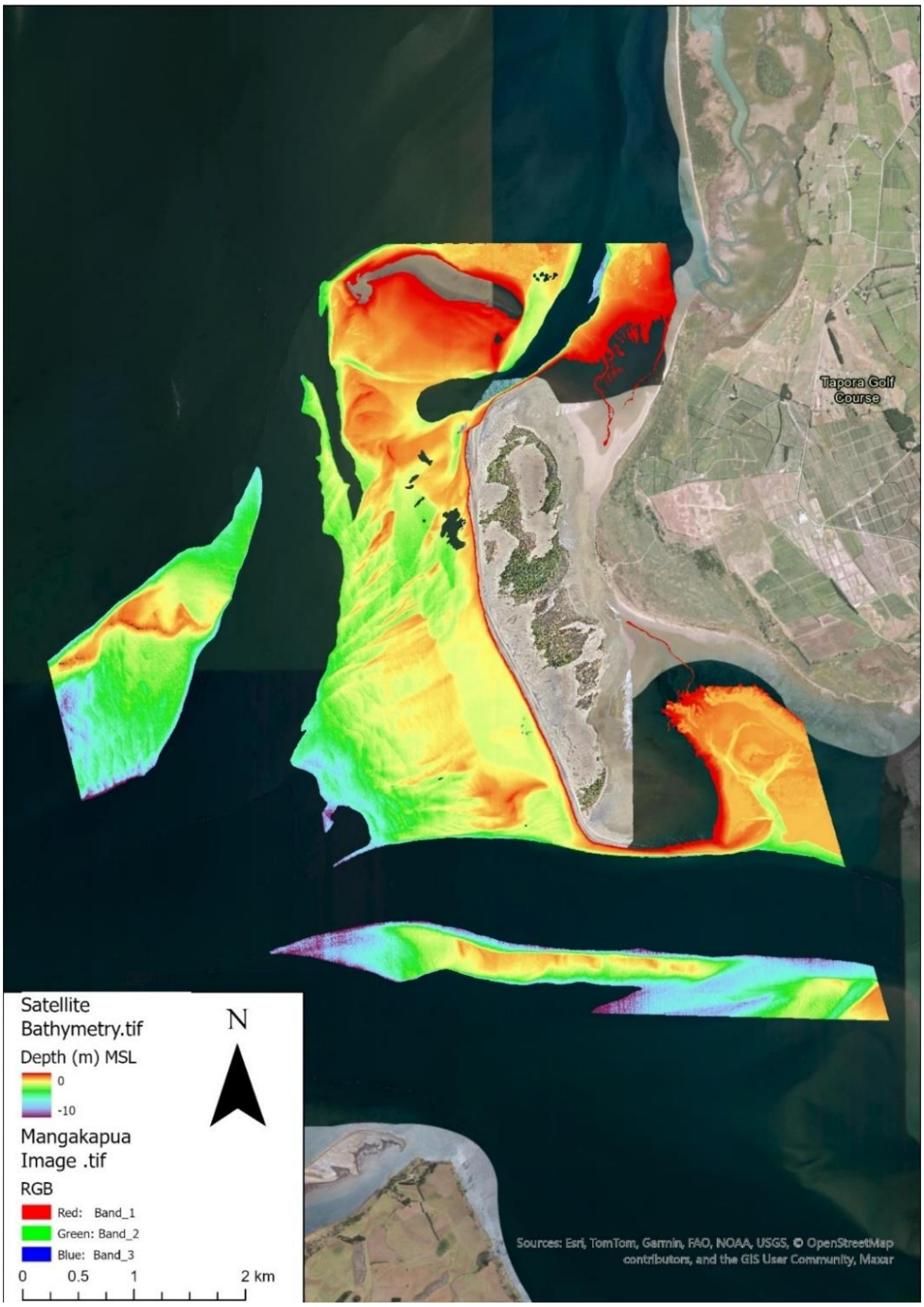
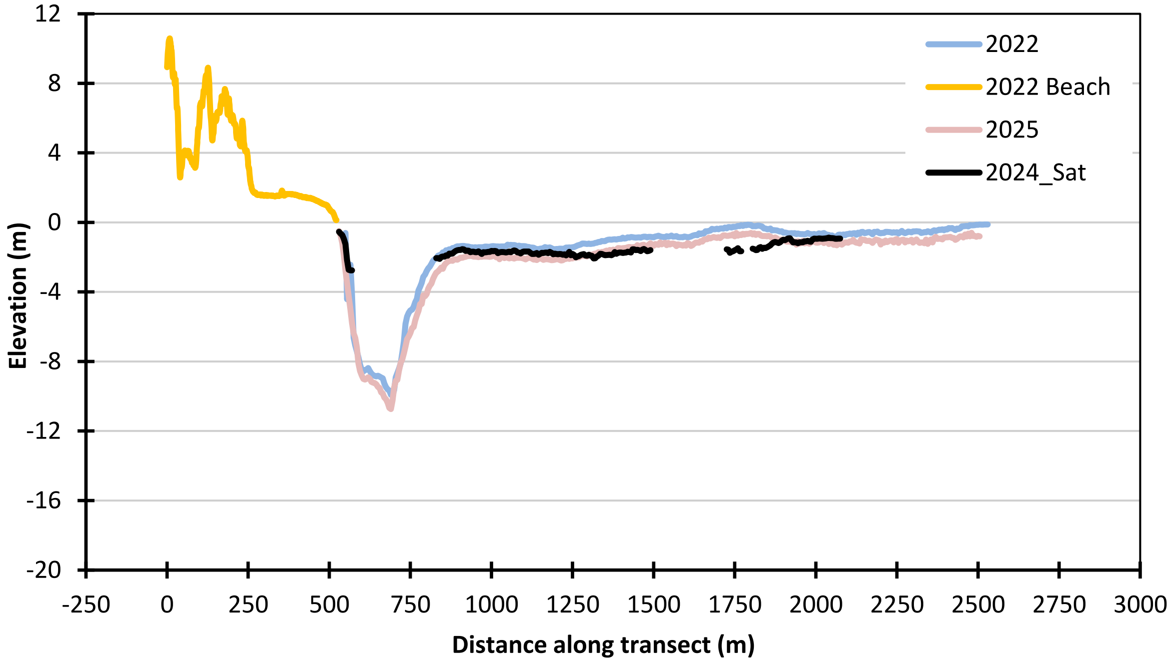


Figure 3-33: Satellite derived bathymetry for the sub-tidal area around Manukapua Island. Colour scale represents depths relative to MSL derived from the Pouto Point tide gauge.



, shows a comparison between satellite-derived bathymetry and single-beam survey data along Transect 1 single-beam data from both the 2022and 2025 is presented. The satellite-derived data generally aligns well with the survey measurements in shallow areas. However, no data were collected below depths of 3 m between the 500–800 m chainage, and similarly, no data were available in the intertidal zone around the 1500-1750 m mark where the seabed dries at low tide.

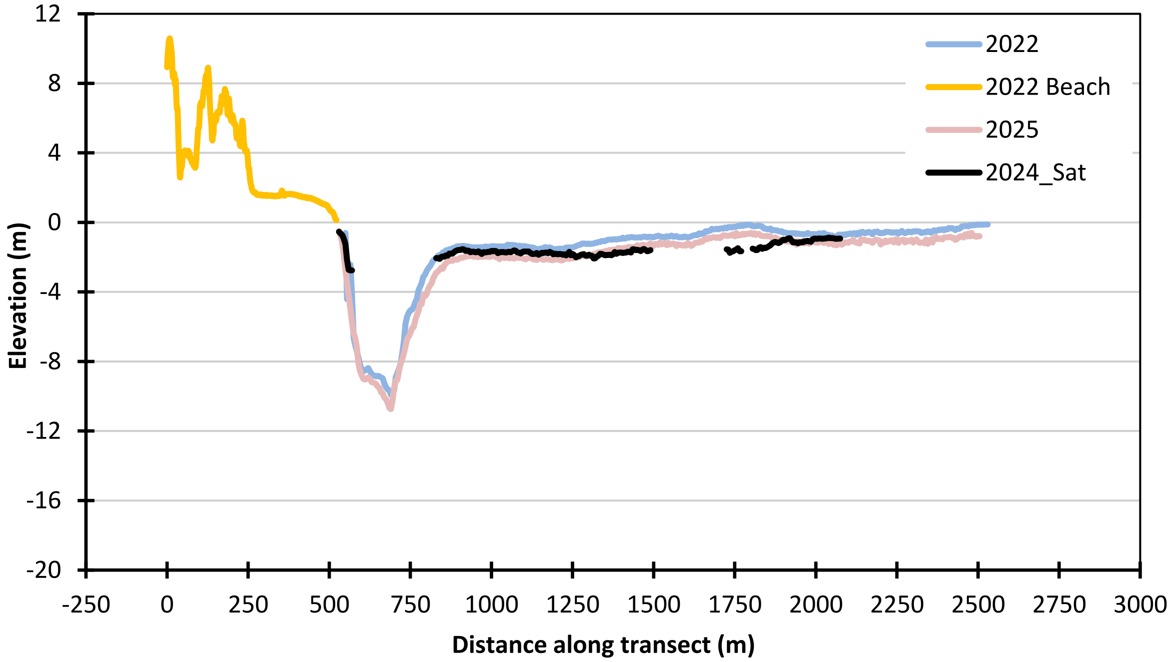


Figure 3-34: Satellite derived bathymetry data extracted along bathymetry transect 1. The black line represents the satellite-derived bathymetry, while the pink and blue lines show the single-beam bathymetry data from the 2025 and 2022 surveys, respectively.

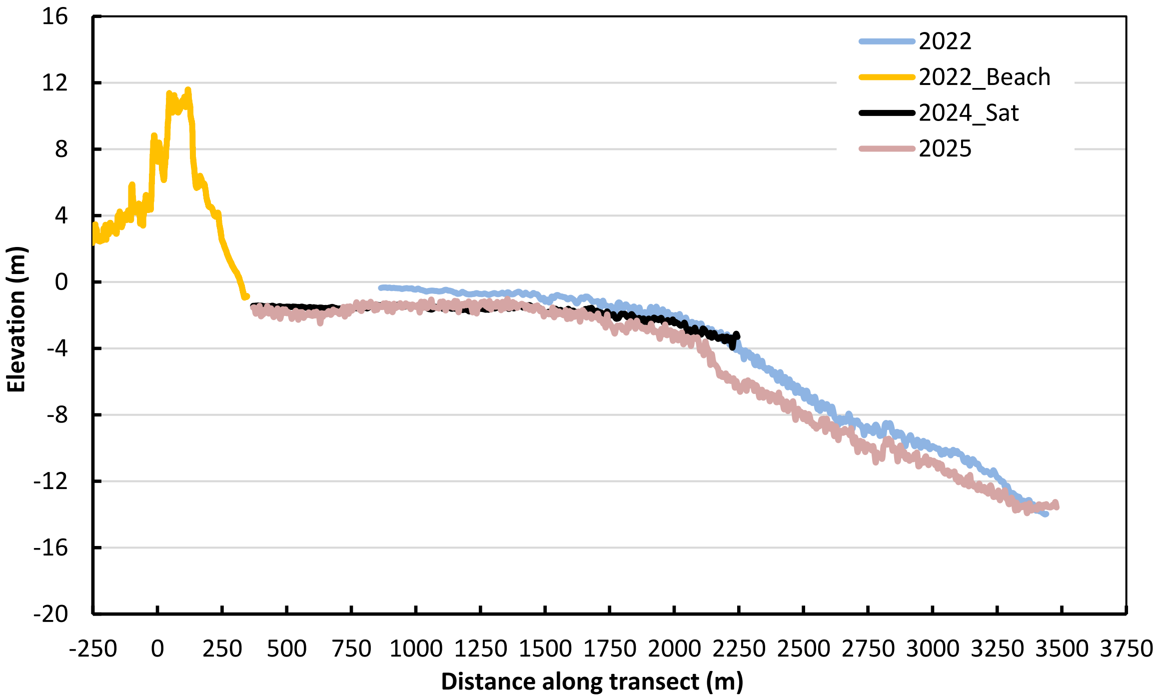


Figure 3-35, presents the comparison along Transect 6, covering the range from 250–2000 m. The satellite-derived bathymetry closely aligns with the survey data in shallow areas but starts to diverge as the depth increases.

Figure 3-36, illustrates satellite-derived bathymetry along Transect 13. In shallow water between 500–1250 m chainage, there is close agreement between satellite-derived and single-beam bathymetry, this is particularly evident when the satellite-derived bathymetry is compared to the 2022 single-beam survey. However, between chainages 100 and 500 m distances along the transect, where the seafloor is deeper than -3 m, the satellite-derived data show poorer correspondence with the surveyed bathymetry.

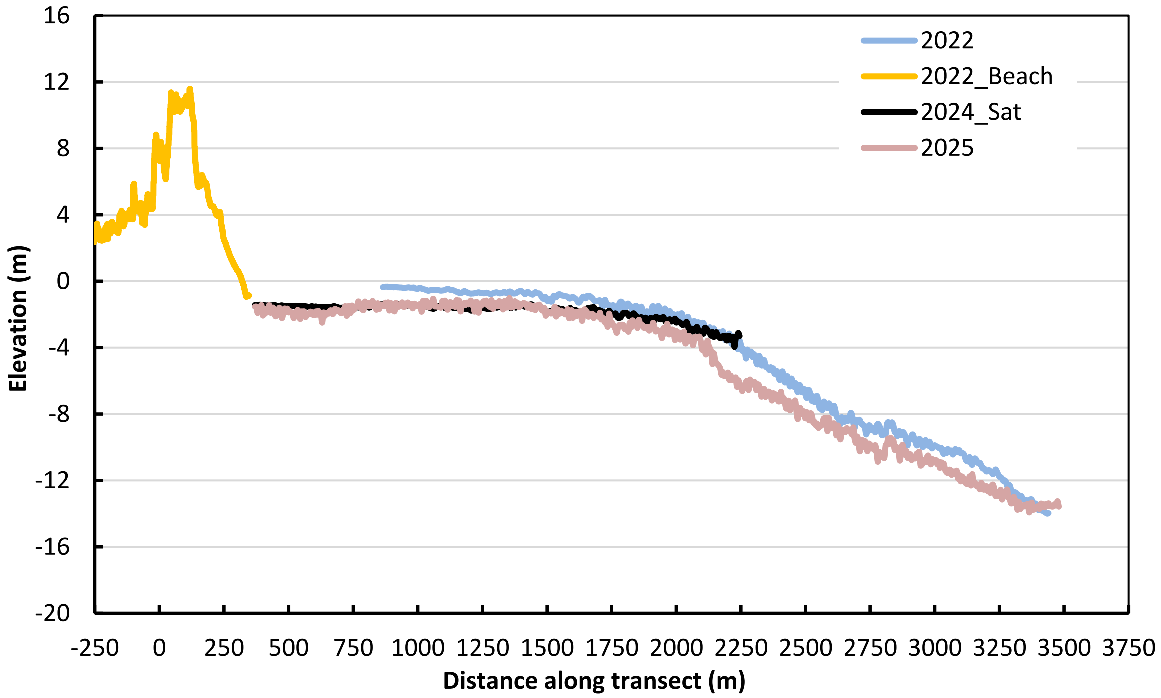


Figure 3-35: Satellite derived bathymetry data extracted along bathymetry Transect 6. The black line represents the satellite-derived bathymetry, while the pink and blue lines show the single-beam bathymetry data from the 2025 and 2022 surveys, respectively.

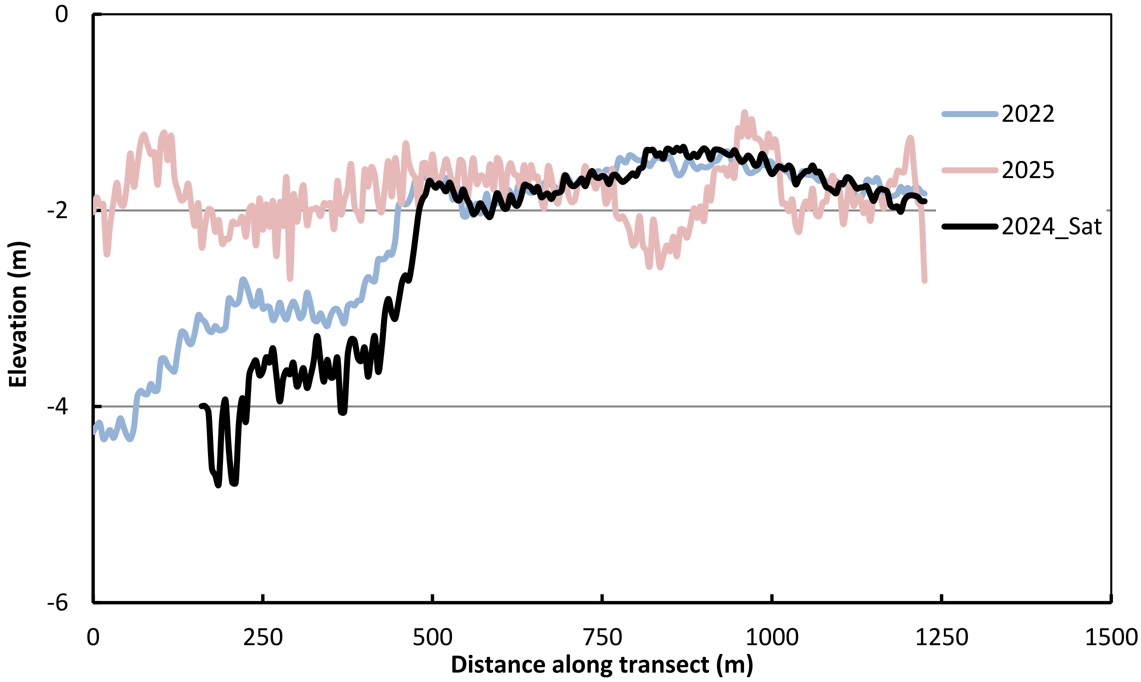


Figure 3-36: Satellite derived bathymetry data extracted along bathymetry Transect 13. The black line represents the satellite-derived bathymetry, while the pink and blue lines show the single-beam bathymetry data from the 2025 and 2022 surveys, respectively.

3.5.2 Satellite derived DEM

Figure 3-37, shows the satellite-derived DEM for Manukapua Island. Similar to the satellite bathymetry, it provides good spatial coverage, capturing most of the intertidal area that separates the island from the mainland.

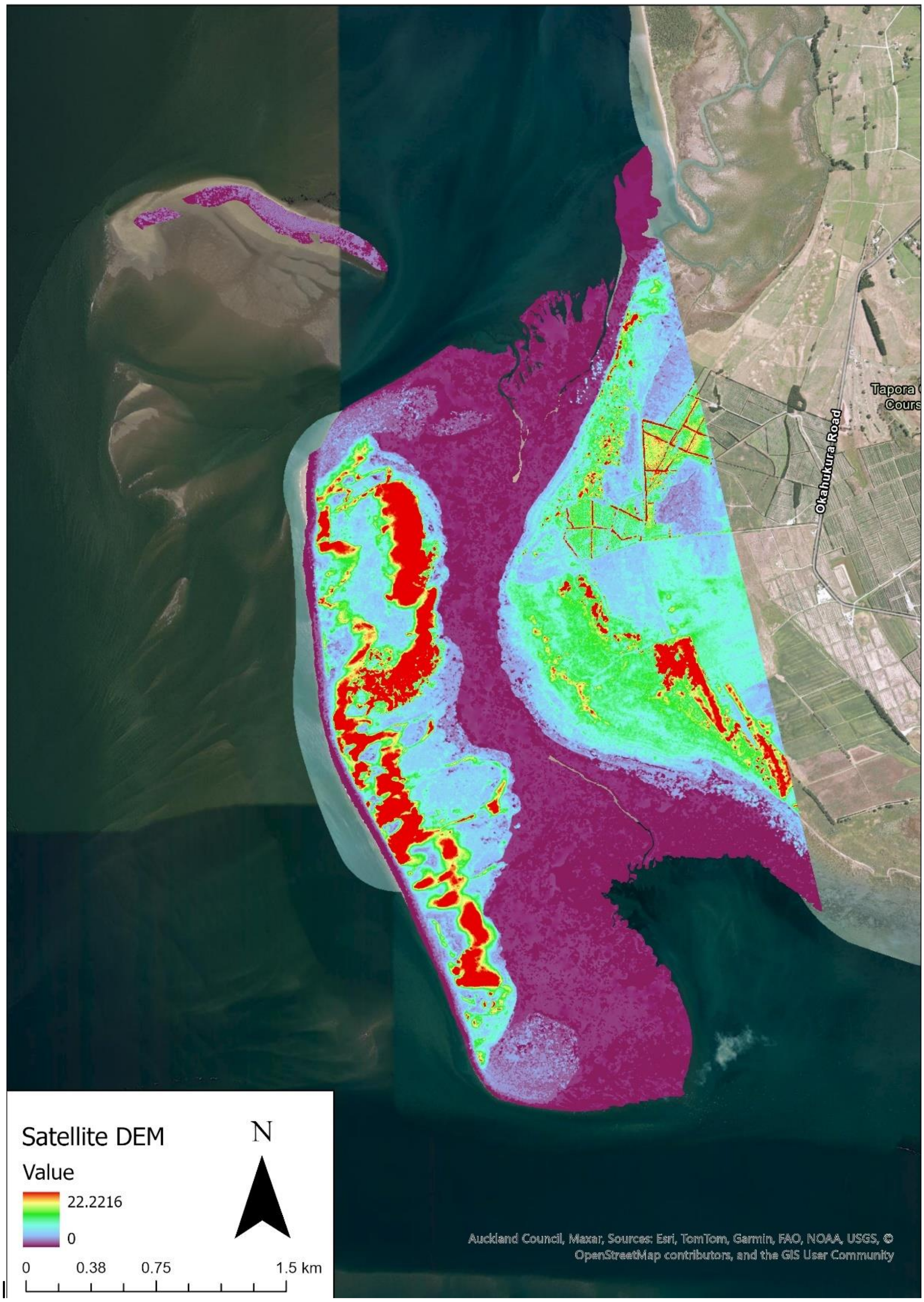


Figure 3-37: Satellite Digital Elevation Model (DEM) for Manukapua Island. Colour scale represents elevation relative to NZVD2016.

Figure 3-38 illustrates the satellite-derived elevation profile for Transect 1. The satellite data underpredicts elevation across much of the transect when compared to the 2023 and 2025 LiDAR surveys, which are in strong agreement with each other. This suggests a systematic offset issue in the satellite-derived elevation at this location. The largest discrepancies occur in the upper intertidal and dune toe zones, highlighting the need for further correction or calibration when using satellite data in this region.

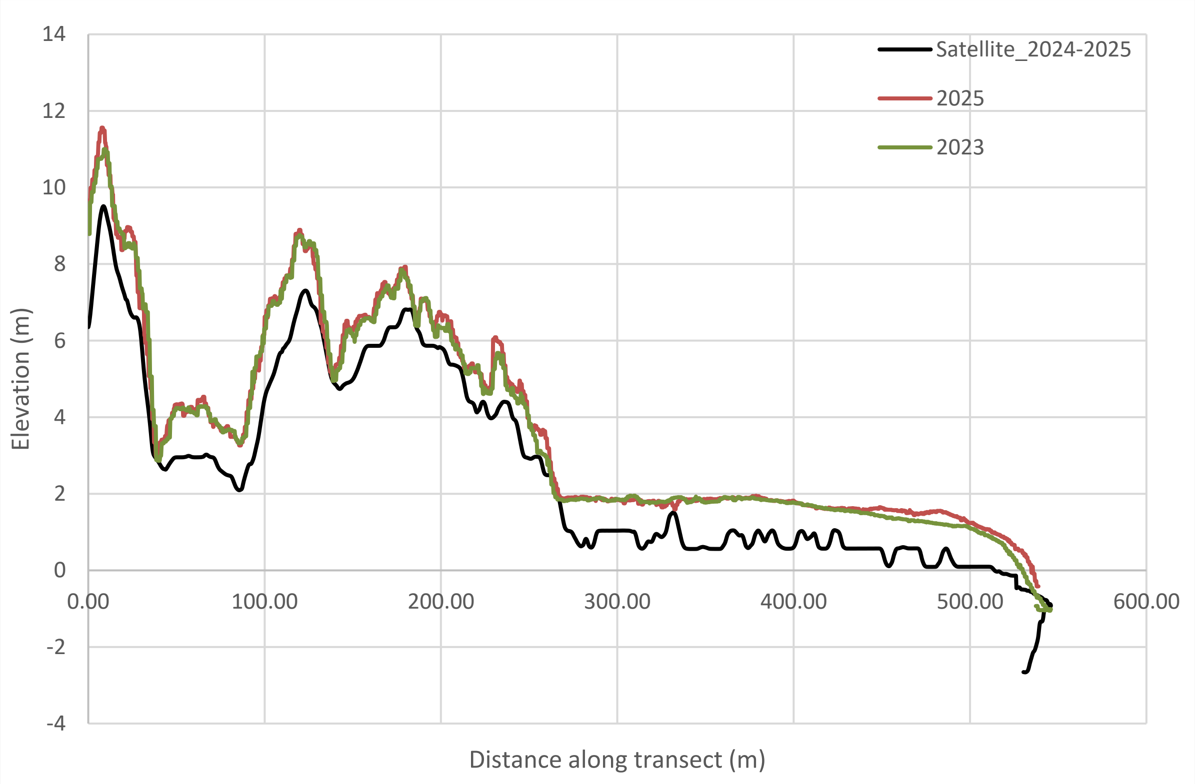


Figure 3-38: Satellite elevation extracted from beach Transect 1. The black line represents the satellite DEM, while the green and red lines show LiDAR-derived elevation profiles from the 2023 and 2025 surveys, respectively.

For Transect 5 (Figure 3-39), the satellite-derived elevation performs reasonably well overall, particularly through the intertidal beach and lower foredune. However, there is a slight underprediction in elevation between –400 and –500 m along the transect—corresponding to the front of the main dune. Despite this, the general shape and slope of the dune system are captured well.

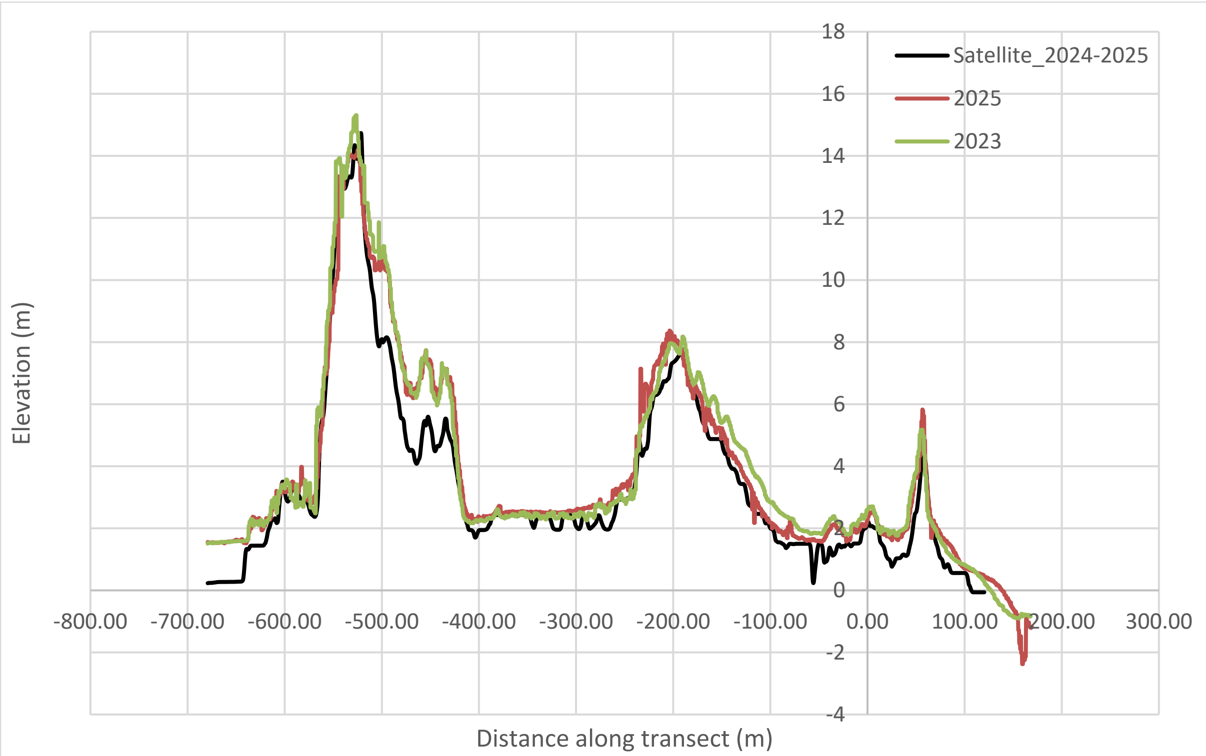


Figure 3-39: Satellite elevation extracted from beach Transect 5. The black line represents the satellite DEM, while the green and red lines show LiDAR-derived elevation profiles from the 2023 and 2025 surveys, respectively.

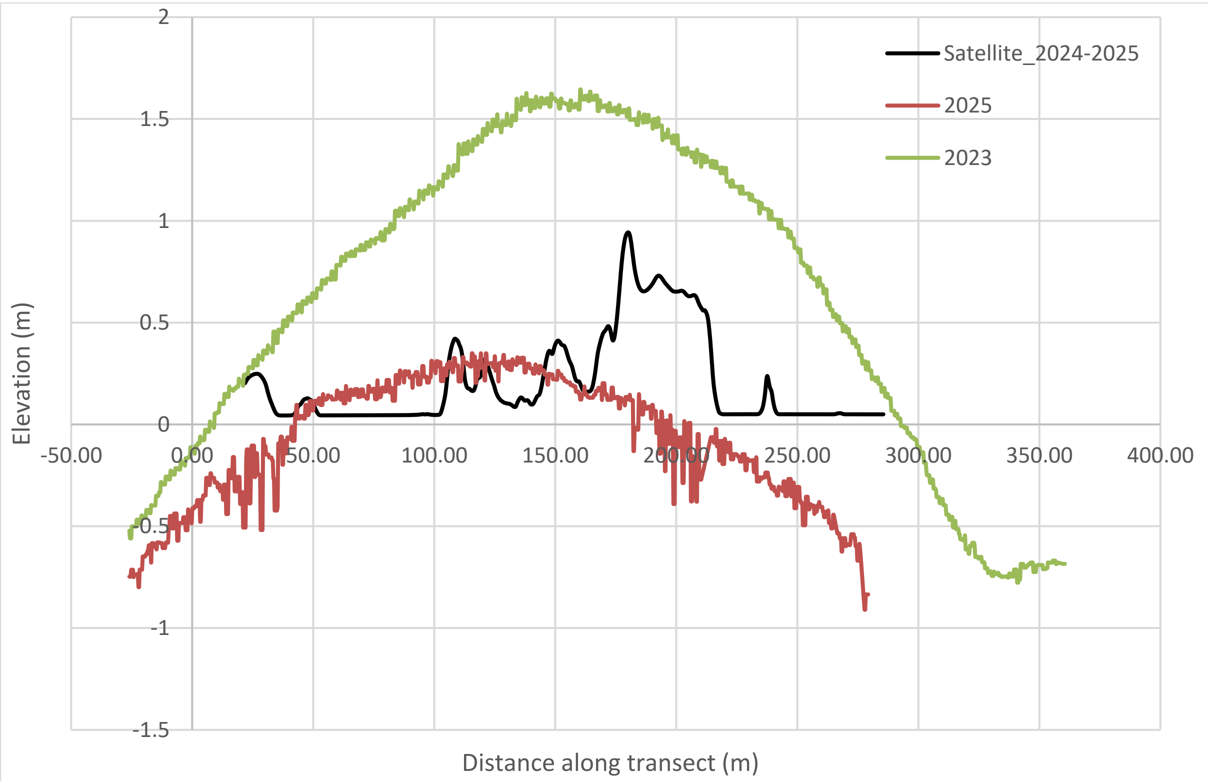


Figure 3-40: Satellite elevation extracted from beach Transect 10. The black line represents the satellite DEM, while the green and red lines show LiDAR-derived elevation profiles from the 2023 and 2025 surveys, respectively.

Figure 3-40 illustrates the satellite-derived elevation profile for Transect 10, the satellite profile generally falls between the two LiDAR datasets, consistent with the time-averaged nature of satellite-derived elevation products. However, in the intertidal portion of the transect, the satellite elevation returns zero values, likely due to water coverage or low reflectance in shallow submerged areas limiting elevation retrieval.

4 Discussion and summary

4.1 Aerial photographs

Consent Condition 21 requires that aerial imagery be assessed annually for morphological changes. In accordance with this condition, aerial photography was undertaken in 2025 for Kaipara South Head (covering Waionui Inlet, Ti Tree Island to the harbour mouth), Papakanui Spit extending to the ocean beach, and the Pouto shoreline south to Māori Bay (South Tauhara Creek). As the 2025 images represent the eighth in the orthophoto time series, only large or abrupt morphological changes are readily visible, with most areas showing only minor year-to-year variation. The observed changes include gradual migration of nearshore channels, lagoon and inlet adjustments, and vegetation shifts at Pouto Point, South Head, and Manukapua Island. These changes are consistent with the ongoing redistribution of sediment at the Kaipara Harbour Entrance.

4.2 Beach transects

Consent condition 20 requires comparison with existing transect data and an account of the net gain or loss of sand from areas of accretion and erosion on the western side of Manukapua Island.

The 10 beach transects surveyed in 2025 on the western flank of Manukapua Island were compared to the 1998-2022 surveys and show consistent morphological changes to those reported previously (Kench et al. 2014, Allis et al. 2014, 2015, 2017a, 2017b, 2019, Reeve et al. 2020, 2023).

The 2025 analysis of surveyed beach transects shows:

- The general trend in beach transect volume since monitoring began is for erosion, with most transects (9 of 10) showing overall recession of the beach and foredune, and only Transect 1 shows net sediment accumulation. The same trend was observed in previous beach surveys.
- With the exception of Transect 1 and 2 all others transects show some easterly migration of the foredune (above 4 m elevation) reflecting active wind transport of sand promoting elevation changes within the dunes across the island. The largest observed foredune change is the 300 m retreat and gradual disappearance of a 14 m high dune , observed at Transects 5, 7 and 9 and evident from 1998-2018. In contrast, Transect 1 and 2 are nearly unchanged from their 2008 position.
- All profiles show changes to the intertidal beach (between the 0 and MHWPS elevations), which are related to the inshore migration of subtidal channels adjacent to Manukapua Island, as observed in the seabed surveys. The changes may also indicate change in the rate of sand transported to and from the intertidal beach by wind, waves and currents. The largest retreat of the intertidal beach was approximately 250 m since 1998 and occurred at Transect 9.
- Several Transects (3, 4, 6 and 7) show the dune toe (2-3 m elevation) is receding at rates between 5 to 10 m/year. The onset of this recession coincides with the timing of intertidal beach retreat allowing waves to undercut the dune toe at high tide, thereby destabilising the foredune face and exposing more sediment for wind and waves to transport away from the beach face.

Comparing the observed trends in island shape between the intertidal elevations (-1 m, 0 m and +2 m) and the dune elevations (+4, +7 m), there is a contrast between the widespread intertidal beach retreat along the whole western flank and the localised retreat of the foredunes in the mid-northern and southern areas. This is possibly related to the inshore migration of offshore channels adjacent to Manukapua Island (Section 4.3), with the deeper water near to the island allowing larger waves to reach and erode the sand on a high tide, along with increased potential for subtidal currents to transport sand away from the shoreline.

4.3 Seabed transects

Consent condition 22A and 22B required a monitoring programme to measure changes in 13 seabed profiles on the Tapora Banks and Tauhoa Banks at two yearly intervals.

The 13 seabed transects surveyed in 2025 surveys on Manukapua Island and Tauhoa Banks were compared to the 2008–2022 surveys and show consistent morphological changes to those reported previously (e.g., Allis et al. 2014, 2017a, 2019, Reeve et al. 2021, 2023). The transects aligned east-west (Transects 2-9) all show gradual inshore (easterly) migration of the main offshore channel with the prevailing sand transport direction. The annual migration amount is typically 50 m per year for depths greater than 4 m with minor changes at shallower depths.

Over the whole survey period to 2025, Transects 4 and 8-12 show net volume gain while the remaining transects (1-3 and 5-7) show net loss of volume. The accreting transects gained an average of ~40 cm in elevation and the eroding transects lost ~60 cm elevation from 2023–2025. Transects across the Tauhoa Banks (Transects 11–13) consistently show accretion of sand material, generally in excess of 30 cm elevation per unit length along the transect, and up to 103 cm (Transect 8).

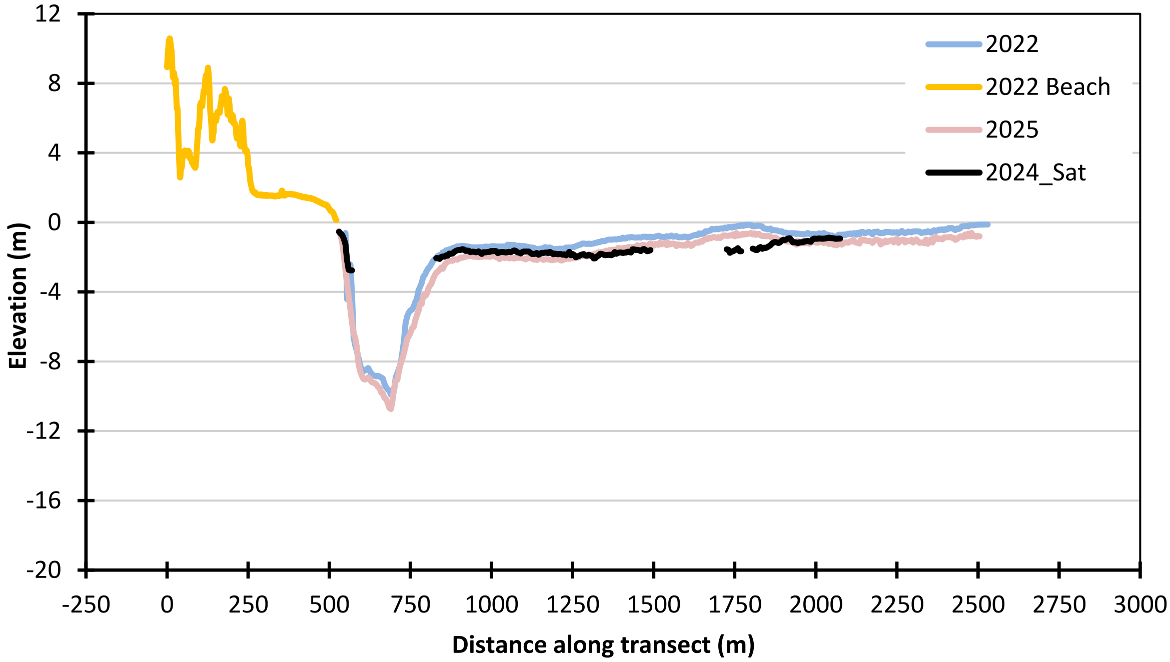
The next bi-annual seabed surveys are scheduled in 2026-27.

4.4 Satellite bathymetry and digital elevation model

As part of the 2025 monitoring programme, a satellite-derived bathymetry (SDB) and digital elevation model (DEM) trial was undertaken to evaluate the viability of these remote sensing products as alternatives to traditional survey methods such as LiDAR and single-beam bathymetry. This assessment was carried out with limited ground truthing, in order to evaluate the standalone performance of satellite-derived products.

Bathymetry Performance

Satellite-derived bathymetry was evaluated against single-beam survey data along Transects 1, 6, and 13 (



to Figure 3-36). Results show good agreement in shallow water, particularly for depths shallower than approximately –3 m, where satellite data captured both the general bathymetric profile and variability well.

However, in water depth great than 3m, the accuracy of satellite bathymetry decreases significantly. Discrepancies exceeding 1 m were common, and no usable data was returned below –6 m. These deeper regions—where much of the sand extraction activity occurs on Tapora Banks—remain inaccessible to this technique. Additionally, intertidal flats and areas with steep bathymetric gradients displayed data gaps or spurious values due to limitations in optical penetration and water clarity.

Advantages of Satellite-Derived Bathymetry

- Good spatial coverage in shallow coastal and intertidal zones.
- Cost-effective alternative to hydrographic surveys for baseline or reconnaissance work.
- Reasonably accurate above –3 m, supporting initial site characterisation or model boundary setup.

Limitations

- No usable data beyond –6 m depth.
- Accuracy declines rapidly with depth (errors ≥1 m by –4 m).
- Incomplete coverage in drying flats and steep terrain transitions.

In summary, satellite-derived bathymetry is not currently suitable for bi-annual monitoring of deep channels or extraction areas, as the depth limitations and vertical inaccuracies preclude its use in volume change assessments or navigational analyses. However, it shows promise for long-term, large-scale trend analysis in intertidal and shallow subtidal zones, especially where conventional surveys are constrained by access or cost. A 5–6 year interval may be more appropriate for using satellite data to detect general patterns of sediment movement, erosion, or accretion.

The satellite-derived DEM was compared to LiDAR-based profiles from the 2023 and 2025 surveys along three beach transects (Figures 4-38 to 4-40). Results were mixed:

- Transect 1 showed a systematic underprediction of elevation across the entire profile, suggesting a vertical offset issue in the satellite data. This undermines its use for detecting subtle morphological change.
- Transect 5 showed reasonable agreement, particularly through the intertidal beach and lower foredune, although elevations were underestimated along the face of the main dune (–400 to –500 m chainage).
- Transect 10 performed the best, with the satellite-derived elevation falling between the 2023 and 2025 LiDAR surveys, consistent with the time-averaged nature of satellite products. However, zero values were returned in intertidal areas likely due to shallow water coverage.

While spatially comprehensive, the vertical accuracy of satellite elevation data was insufficient to quantify beach volume change at the profile scale. Consequently, it is not recommended as a substitute for the LiDAR systems that is currently being used, particularly where accurate volume comparisons are required.

4.5 Summary

The 2025 sand extraction monitoring programme for Kaipara Harbour included aerial LiDAR surveys and photographic records at Pouto Point, South Head, and Manukapua Island, along with seabed surveys near the active extraction area adjacent to Manukapua Island. In addition, the potential application of satellite-derived data for ongoing monitoring was assessed.

The 2025 survey marks 22 years of beach profiling and 12 years of seabed surveying. Results indicate that the three study sites continue to evolve in line with morphological changes reported in previous assessments (e.g., Hume et al. 2003, Allis et al. 2017b, Reeve et al. 2020, 2023). These changes include the ongoing migration of nearshore subtidal channels, shifting vegetation boundaries, and the reconfiguration of lagoons and inlets—reflecting the dynamic redistribution of sediment within the Kaipara Harbour entrance.

As observed during the Kaipara sand study (Hume et al. 2003), Manukapua Island remains highly mobile, having experienced significant island and seabed morphological change over the past 150 years. This is characteristic of a barrier island with limited stabilising vegetation, situated adjacent to a tidal flood-delta system with high sediment throughput.

It will always be difficult to link morphological changes to sand extraction given the sand movement volumes within the Kaipara Harbour and the large natural changes in Manukapua Island which have been observed in the past and can be expected in future. Over the monitoring period, volume changes over the seabed transects and over the whole of Manukapua Island are a fraction of a percentage of the background sediment supply and storage (Hume et al. 2003).

Satellite-derived bathymetry and elevation data offer useful reconnaissance-level insights, particularly in shallow, intertidal, and hard-to-access zones. However, they are not currently robust enough—either in vertical accuracy or depth coverage—to replace LiDAR or single-beam survey techniques for annual or bi-annual monitoring of sand extraction impacts in Kaipara Harbour.

These data products may be more effectively deployed for low-frequency monitoring (e.g., every 5–6 years), to identify long-term geomorphic trends such as:

- Migration or reshaping of Manukapua Island.
- Changes in intertidal sand flat extent.
- General shoreline retreat or dune migration.
- Model boundary updates in shallow zones.

When integrated alongside conventional survey methods and numerical modelling, satellite-derived datasets can serve as a complementary layer, providing cost-effective spatial context and supporting broader environmental assessments.

Given the significant landward retreat of the shoreline at Manutapua Island—particularly evident where the recent transects (e.g., Transect 4 and 5) lie predominantly inland of the original 1998 Transect origins, consequently that the existing baseline may no longer be appropriate. We suggest a revised methodology should be adopted that involves redefining the transect origins. This would require recalculating all historical transect data relative to the new baseline to ensure consistent analysis of shoreline change and volume trends over time.

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Appendix A Survey details

Table A-1: Survey profile start and end points (Mount Eden 2000).

Transect	Offshore point		Onshore point		Origin point (0 m chainage)		Transect length (m)
	Northing (m)	Easting (m)	Northing (m)	Easting (m)	Northing (m)	Easting (m)	
Ongoing survey transects (2014 - present)							
1	856434.1	353093.4	861319.5	354156.2	856433.8	856434.1	4999.6
2	855866.0	353559.5	859842.1	349341.0	856533.8	855866.0	5797.0
3	856057.1	353624.5	857062.4	348045.6	856175.0	856057.1	5668.7
4	856080.1	353621.0	854903.3	347994.2	855927.0	856080.1	5748.5
5	855583.0	353624.7	854414.0	348067.3	855443.0	855583.0	5679.0
6	854932.3	353912.2	852810.5	348720.0	854702.0	854932.3	5609.0
7	854199.6	353991.7	852933.3	348632.1	854083.0	854199.6	5507.1
8	853913.4	353889.3	851825.1	349042.1	853804.0	853913.4	5277.9
9	853474.8	354043.3	851864.7	348911.3	853362.0	853474.8	5378.6
10	853130.1	353715.3	848940.4	356489.8	853105.0	853130.1	5025.1
11	851571.6	352701.9	853440.3	353336.0			1973.4
12	851283.7	353383.6	852891.9	353624.3			1626.1
13	851764.8	352471.4	851558.4	353834.6			1378.7
Transects (2010- 2014)							
1_b	856305.2	350517.3	856305.2	351928.6	-	-	1411.3
2_b	855726.5	350454.8	855818.3	352654.6	-	-	2201.7
3_b	855123.7	350933.0	855112.7	352147.4	-	-	1214.4
4_b	854370.6	350753.2	854751.4	352575.8	-	-	1862.0
5_b	853713.5	350547.1	854478.5	352423.7	-	-	2026.5
6_b	852870.0	350429.8	854292.2	352957.0	-	-	2899.9
7_b	852599.5	351699.6	854014.3	353233.6	-	-	2086.8
8_b	851571.6	352701.9	853440.3	353336.0	-	-	1973.4
9_b	851283.7	353383.6	852891.9	353624.3	-	-	1626.1
10_b	851764.8	352471.4	851558.4	353834.6	-	-	1378.7
Transects (2008)							
1_a	856405.7	350398.8	855996.3	352807.9	-	-	2443.6
2_a	855726.8	350356.5	855819.2	352651.0	-	-	2296.4
3_a	854451.8	349906.4	855211.1	352850.6	-	-	3040.5
4_a	853229.3	350121.7	854383.2	353050.4	-	-	3147.8
5_a	853114.1	350139.9	853836.3	353316.3	-	-	3257.5
6_a	852438.8	350537.8	853513.9	353393.2	-	-	3051.1
7_a	852516.1	352470.9	853434.5	353439.5	-	-	1334.8
8_a	851572.4	352691.6	853439.8	353339.7	-	-	1976.7
9_a	851342.2	353384.4	852856.2	353635.3	-	-	1534.6
10_a	851739.6	352616.6	851560.8	353827.8	-	-	1224.3

Table A-2: Details of survey marks.

Survey mark	Easting (m) (Mount Eden 2000)	Northing (m) (Mount Eden 2000)	Orthometric height (One Tree Point datum 1964)
B5R9	347 726.15 m	857 203.94 m	3.17m
B5RA	347 714.12 m	857 202.40 m	8.15m

Conversion from One Tree Point Vertical Datum 1964 to Auckland Vertical Datum 1946 = +0.24m.