Annual Report 2019-2020

Kaituna River Re-Diversion and Te Awa o Ngatoroirangi/
Maketu Estuary Enhancement Project

Date: 30 August 2020

Contents

1. Introduction

This document is the annual report for the year ending 31 May 2020 for the Kaituna River Re-diversion and Te Awa o Ngatoroirangi / Maketu Estuary Enhancement project (the Project).

The first annual report was submitted in 2017 and covered early works that were undertaken that involved:

- Construction of Papahikahawai Bridge
- Re-contouring of Papahikahawai southern shoreline and re-planting with native plants
- Removal of two causeways blocking Papahikahawai Creek

The early works triggered a number of the conditions where monitoring and / or reporting was required. No further physical works were undertaken up until the 31st May 2018. However, cross section monitoring continued.

On the 12th June 2018, main construction commenced. Monitoring results have been taken annually since then. Results from 2018 did not show any significant changes from the 'before works' baseline.

Further monitoring was undertaken in 2019 in accordance with Conditions 31.1 to 31.4. Cross section surveys were carried out and a baseline established in April 2019 to meet the prior to Stage 1 commissioning requirement.

Stage 1 commissioning commenced on 12th February 2020 (opening and operation of 9 gates) which resulted increased flows from the Kaituna River into the estuary. This triggered a number of new conditions requiring monitoring prior to and from Stage 1. Full commissioning does not occur until all 12 gates are open sometime in 2021.

The current 2019-2020 report includes both data from ongoing ecological monitoring as well as additional monitoring required to meet consent conditions. Table 1 summarises the ecological monitoring for this period.

Table 1 Summary table of monitoring for the 2019-2020 period

Parameter	Requirement	Condition
Erosion and Bed Levels	Annually from commencement of construction until Stage 1, then twice a year for 3 years	Condition 31.1 – Papahikahawai Island
Erosion and Bed Levels	At least 1 month prior to Stage 1, then annually from Stage 1 for 5 years	Condition 31.2 – Maketu spit
Erosion and Bed Levels	At least 1 month prior to Stage 1, then annually from Stage 1 for 5 years	Condition 31.4 – Maketu township and Beach Road
Water quality	Once within 2 yrs of Stage 1, then annually for 5 years after Stage 1 (Jan-Mar).	Condition 32.1 – dissolved oxygen, temperature, salinity *Not required but data has been collected*
Ecology Flora	Transect 9, 10 and 11: No less than 1 month prior to Stage 1, within 6 months of Stage 1, then annually for 5 years.	Condition 34.1 – terrestrial and wetland vegetation

	Transect 1-6: within 6 months of Stage 1, then annually for 5 years.	
Ecology Flora	Prior to Stage 1, then 6 monthly got 2 years.	Condition 34.5 – vegetation composition and spatial extent
Sediment & algae	Once prior to Stage 1 commissioning, once within 2 yrs of Stage 1, once within 5 years of Stage 1.	Condition 35 – survey of algae & sediment

2. **Erosion and Bed Levels (Condition 31)**

2.1 Condition 31.1 & 31.2 – Papahikahawai Island & Maketu Spit

31.1 Prior to the commencement of works authorised under this resource consent, the Consent Holder shall undertake transect monitoring in the vicinity of Papahikahawai Island to monitor for any erosion as a result of the re-diversion, as follows:

(a) An initial survey of the full width of the bunds, extending 20 metres landward of the sand bund; and thereafter

(b) Permanently marked transects be located at four sites to the west and south of the island with each transect extending from the seaward face or toe of the existing sand bund to at least 50 metres offshore to pick up changes in near shore depths over time.

(c) The transects shall be undertaken using Real Time Kinematic Global Positioning System.

(d) Transects shall be measured as follows:

(i) ***Annually from the commencement of construction until Stage 1 commissioning of the diversion control structure****; and then*

(ii) Twice a year for three years following Commissioning and thereafter the frequency shall be assessed as part of the reporting requirements of Condition 29.3.

Surveys of ground and bed levels required by Condition 31.1 of the consent have already been undertaken and will continue annually until Stage 1 commissioning and thereafter twice a year following Commissioning. The requirement to establish and start monitoring was triggered by the early works ("*prior to the commencement of works*…"). The 2020 monitoring is the fourth year of annual transect monitoring at Papahikahawai Island.

31.2 The Consent Holder shall survey:

(a) The two transects (Maketu Spit 1 & 2) shown in the BOPRC Plan Number RC67958/12, with each survey of the transects to extend from at least mid-tide on the ocean side to at least low tide on the harbour side; and

(b) The seaward toe of the dune or eroding bank over the "Dune Toe Monitoring Area" shown in BOPRC Plan Number RC67958/12.

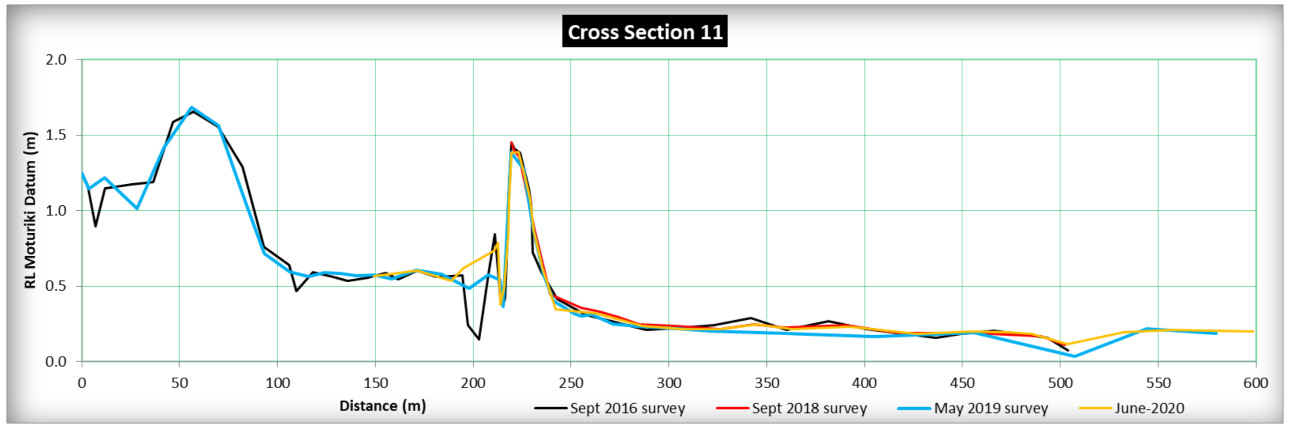
31.3. The first survey under condition 31.2 of this resource consent shall be undertaken at least one month prior to stage 1 commissioning and thereafter annually for a period of five years. After five years of annual surveys the frequency of the survey shall be assessed as part of the reporting requirements of Condition 29.3. The purpose of this survey is to monitor for any aggradation or erosion as a result of the re-diversion.

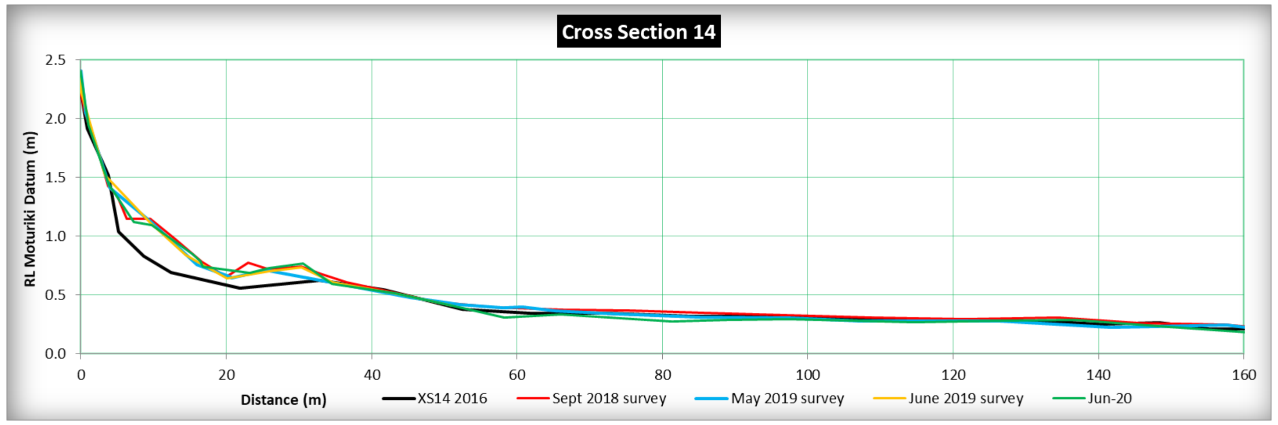
Surveys of ground and bed levels at the two transects Maketu Spit 1 & 2 required by Condition 31.2 of the consent have been undertaken annually since 2015 and will continue after Stage 1 commissioning annually for five years. Monitoring was not required to commence until just prior to Stage 1 commissioning.

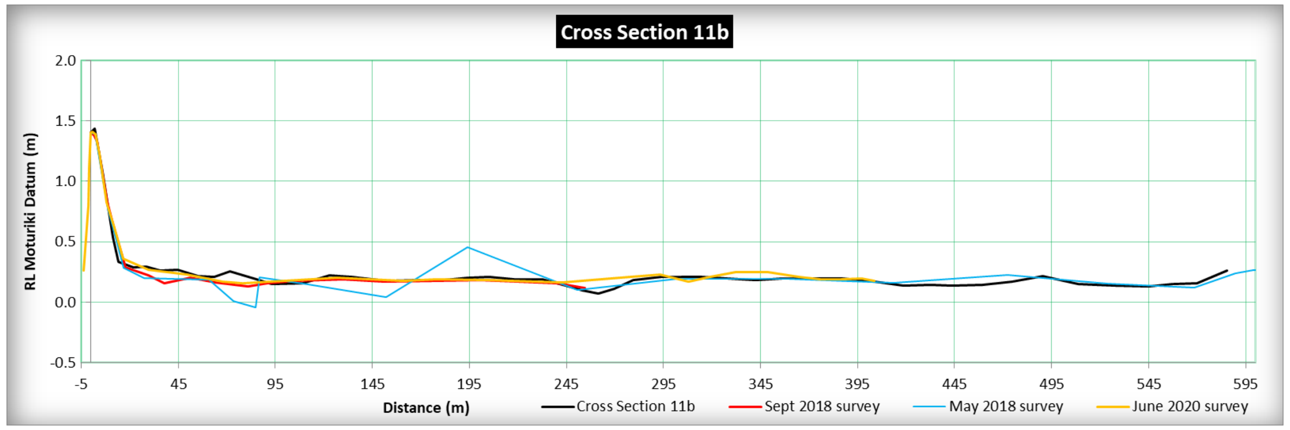
2.1.1 Results

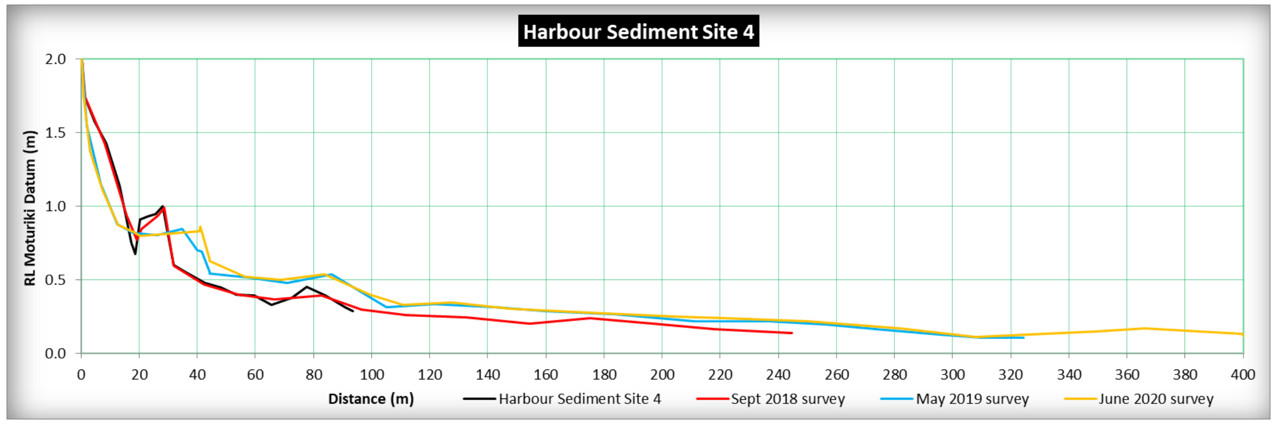
The location of the Papahikahawai transects are shown in Figure 1 along with the transect profiles in Figure 2 and 3. The 2020 monitoring results at Papahikahawai have been compared with 2016 to 2019 survey results.

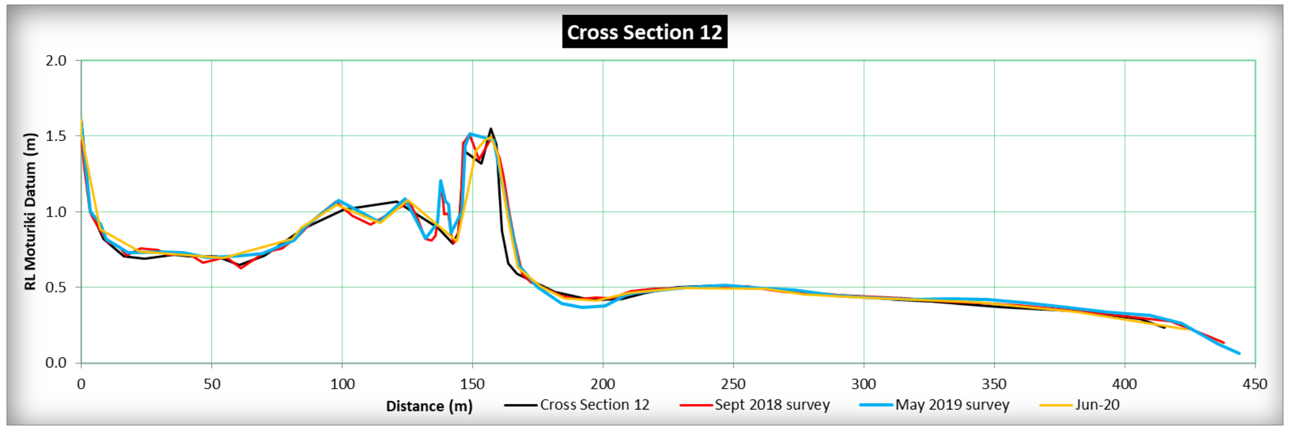
Figure 1 Papahikahawai Island survey locations

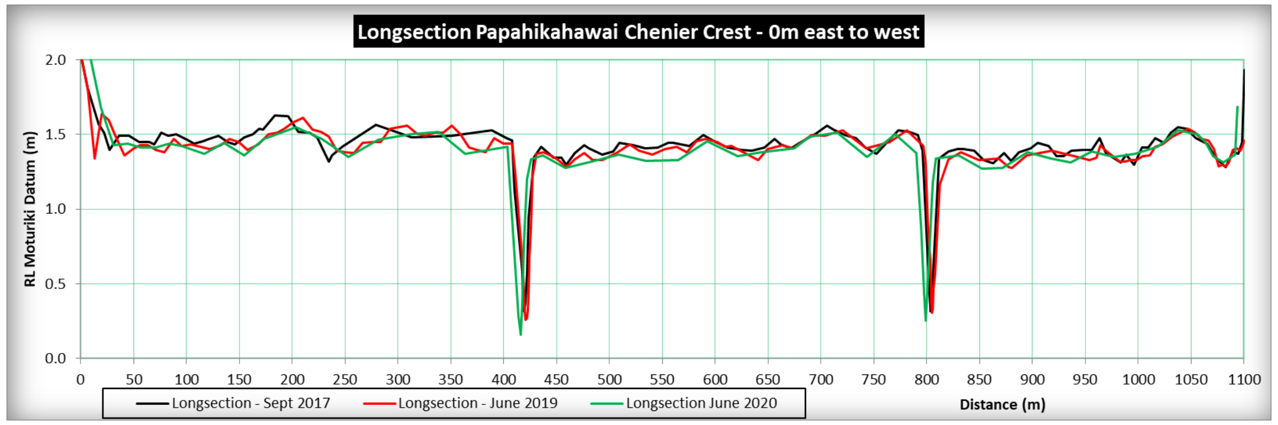












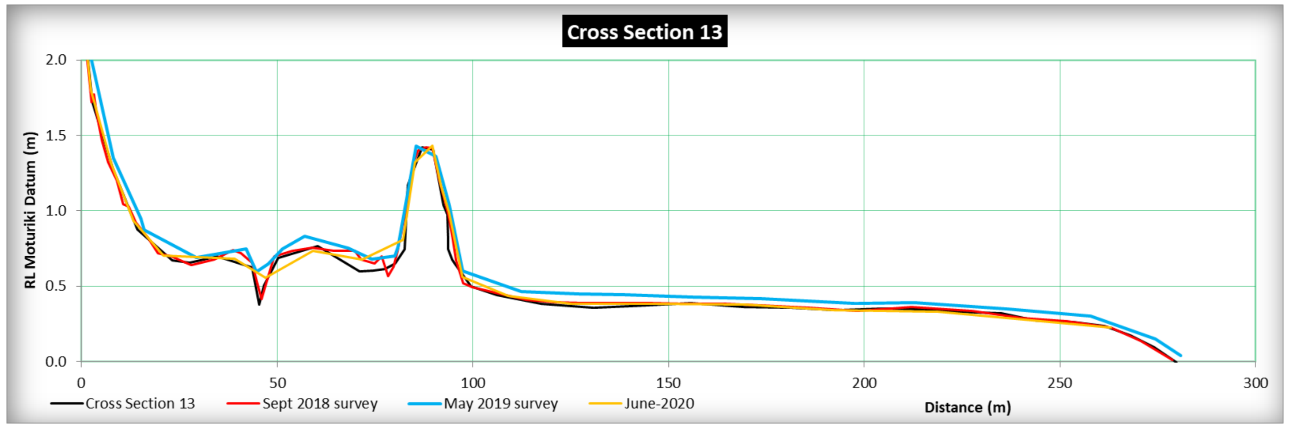


Figure 2 Papahikahawai Island Cross section monitoring results. Black line is the September 2016 survey, red line the September 2018 survey, blue line is the May 2019 survey and yellow line the June 2020 survey.

Figure 3 *Papahikahawai Cross Sections from 2019: A) Site 11a, B) Site 11b, C) Site 12, D) Site 13, E) Site 14, F) Site 4; Papahikahawai Chenier Crest: G) 2019 H) 2020*

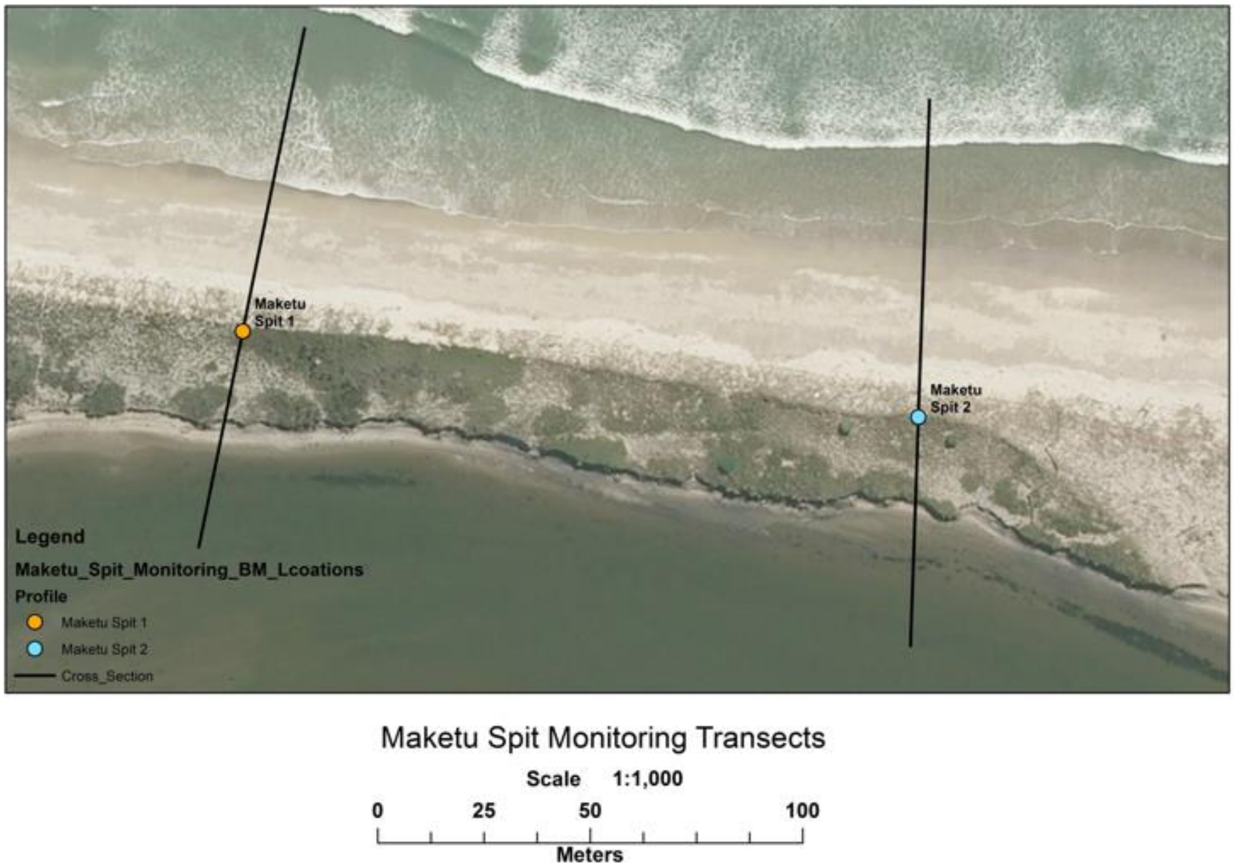
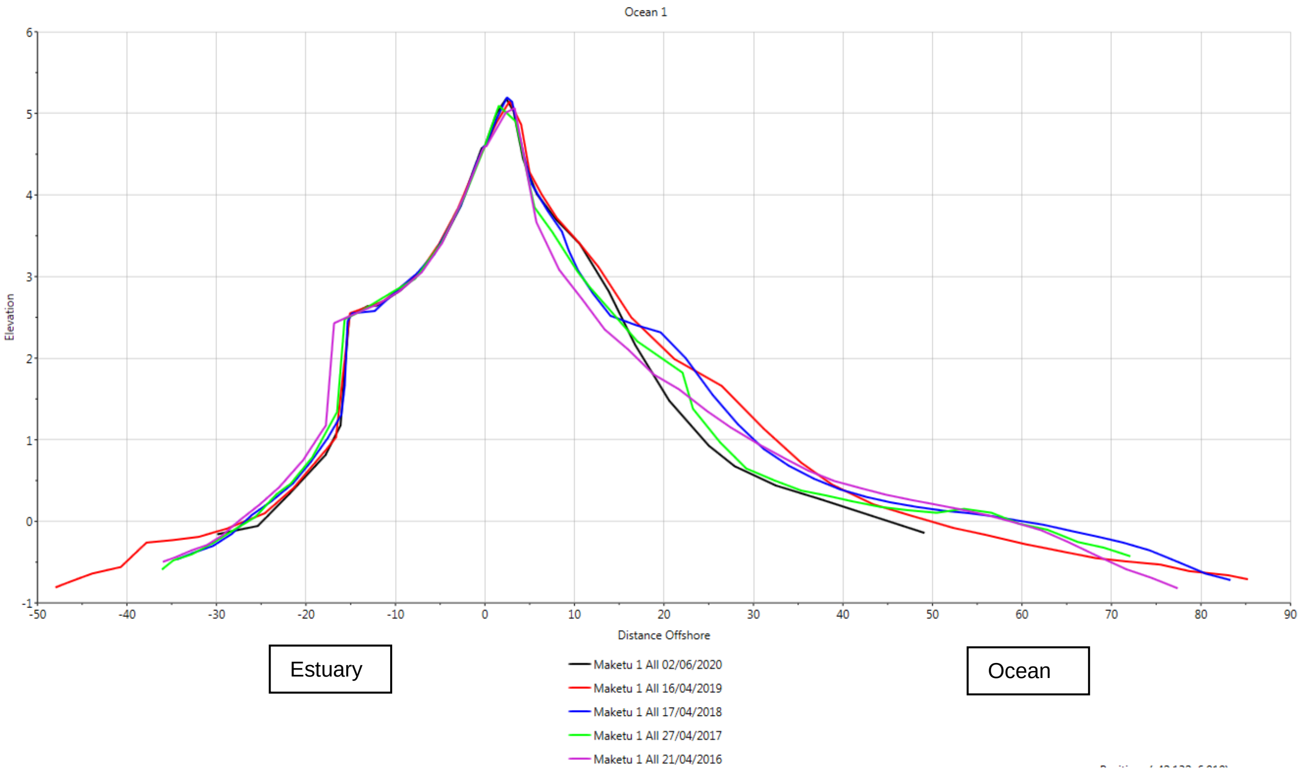


Figure 4 Maketu Spit Monitoring transects – Spit 1 and 2.



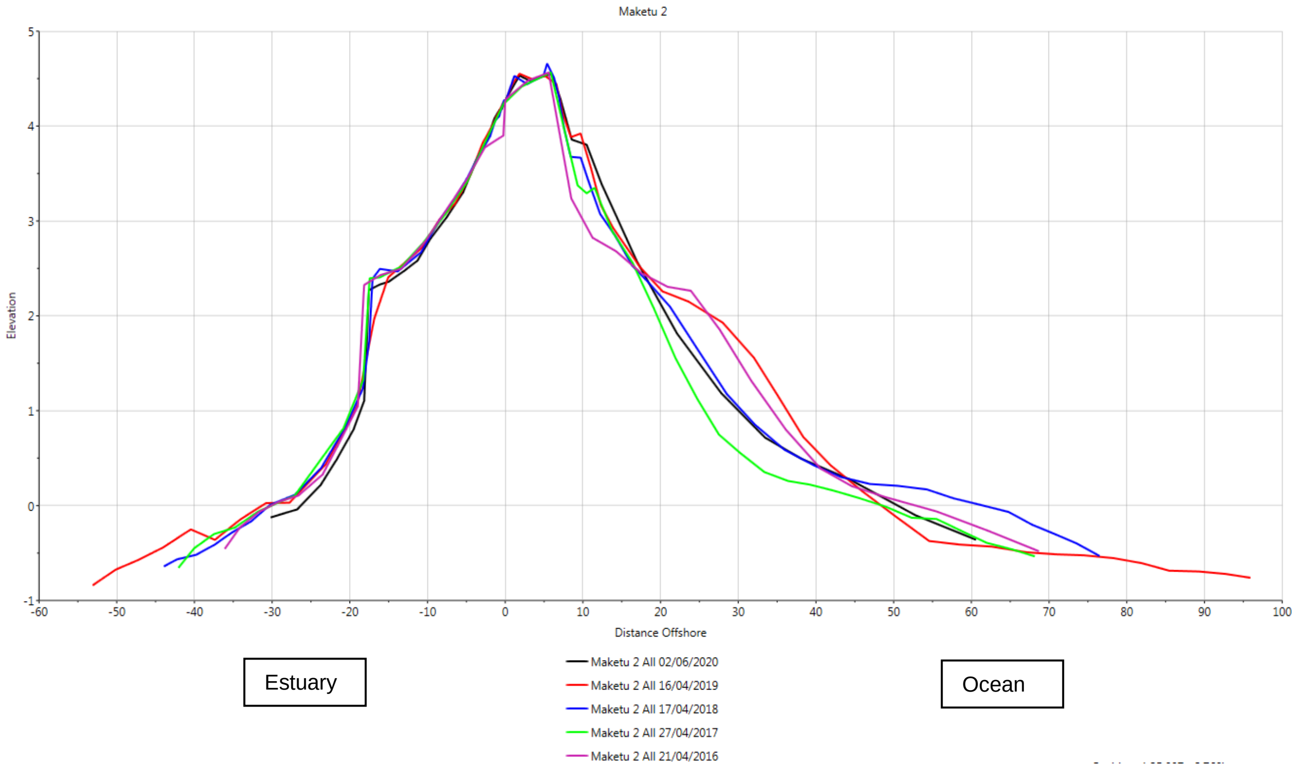


Figure 5 *Maketu spit surveying results. Spit 1 (top), Spit 2 (bottom). The red line represents the 2016 results, the blue line represents 2017 results, the green line represents 2018 results, the purple line represents 2019 results and the black line represents the 2020 results.*

The 2016 profiles at Papahikahawai established a ‘before works’ baseline to monitor against. The 2020 profiles were surveyed in June 2020.

There has been noticeable accretion at the 5-30 m section of profile XS14 since the 2016 survey. At site 4 there has been erosion in the upper section of the profile and considerable aggradation at the 30-100 m section since the 2018 survey. There has also been some aggradation at the 175-225 m section of profile XS11b since the 2018 survey.

A long section was taken at Papahikahawai Chenier Crest from east to west in June 2019 and June 2020. The location is shown in Figure 1 along with the long section profile in Figure 3. The results did not differ significantly from the 2017 and 2019 long section. From 25-600 m there has been variable minor erosion and aggradation.

The location of the Maketu Spit transects and the transect profiles are shown in Figure 4 and 5. The 2020 Maketu spit profiles have been compared against annual monitoring results since 2015.

At Maketu spit 1 and spit 2 the transect profiles have been reasonably consistent at the estuary side between years, however, at the ocean side the transect profiles show more variability with both aggradation and erosion between years.

2.2 Condition 31.4 – Maketu Township and Beach Road

31.4 The Consent Holder shall undertake surveys at Maketu Township and Beach Road to monitor for any erosion or aggradation as a result of the diversion as follows:

(a) A shoreline survey using Real Time Kinematic Global Positioning System in the area shown on BOPRC Plan Number RC67958/12 along the dune toe or seaward edge of the vegetation;

(b) A minimum of six cross sections in total with two along Beach Road and four distributed around Maketu township from Park Road foreshore to the marae. Each cross section shall extend to no less than 50 metres offshore;

(c) Bed and channel depths within the boat ramp access channel from Maketu Boat Ramp to 100 metres seaward; and

(d) The survey and transects shall be measured at least one month prior to Stage 1 commissioning and thereafter annually for five years. After five years of annual surveys the frequency of the survey shall be assessed as part of the reporting requirements of Condition 29.3.

Cross section surveys were carried out in April 2019 to meet the prior to Stage 1 commissioning requirement (ie. establish a baseline). The 2020 monitoring is the first year of annual monitoring post Stage 1 commissioning.

2.2.1 Results

The location of the Maketu transects is shown in Figure 6 along with the transect profiles in Figure 7. The 2020 monitoring results have been compared with 2016 to 2019 survey results.

Figure 6 *Survey Locations at Beach Road and Maketu township, including Maketu boat ramp, the Spit monitoring locations and the Dune Toe.*

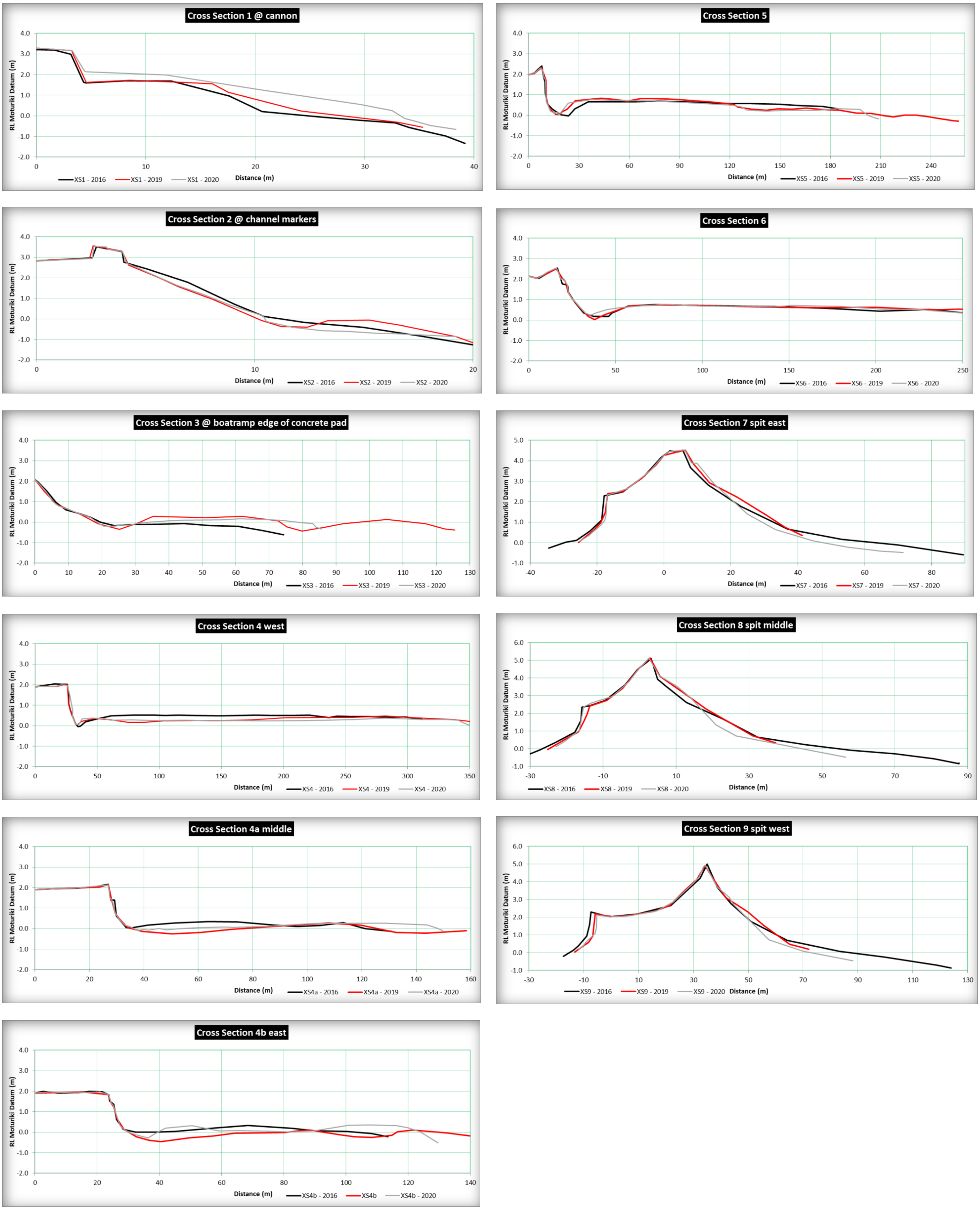


Figure 7 Maketu cross section monitoring results. Black line is the September 2016 survey, red line the September 2018 survey, red line is the May 2019 survey and grey line the June 2020 survey

The 2019 profiles along Beach Road, the Maketu township and the Maketu Boat Ramp established a 'before works' baseline to monitor against in future surveys.

The profiles at the spit monitoring locations were consistent between years but had some minor erosion on the ocean side at all three transects (profiles 7,8,9; Figure 7). Beach Road profile 1 had some aggradation from 4-40m and profile 2 some erosion between 13-18m. At the other locations within the Maketu estuary profiles 5 and 6 were reasonably consistent between years apart from profile 4a and 4b which had some aggradation at 50m and 130m (profile 4a) and 110m (profile 4b).

3. **Water Quality and Shellfish (Condition 32)**

3.1 Condition 32.1, 32.2 & 32.3 – Dissolved Oxygen, Temperature and Salinity

32.1 The Consent Holder shall use data loggers to measure dissolved oxygen, temperature and salinity in the Ongatoro/Maketu Estuary. Monitoring shall occur during the periods January to March (inclusive) with measurements made at intervals of 10 minutes (or less) for a period of at least 14 days.

32.2 The monitoring required by condition 32.1 shall occur at the following two locations shown in Figure 4.1, page 51 of Hamill (2014) "Kaituna River Re-diversion Project: Ongatoro/Maketu Estuary condition and potential ecological effects" attached to the application material:

(a) Mid-estuary; and

(b) Papahikahawai Lagoon 2.

32.3 The monitoring required by condition 32.1 shall be carried out as follows:

(a) Once within two years of Commissioning of the diversion control structure; and

(b) Once at five years after Commissioning.

3.1.1 Results

Dissolved oxygen, salinity and temperature have been measured since 2007 by Bay of Plenty Regional Council (BOPRC, 2020; Appendix 1) as part of their wider ecological monitoring programme which will help better understand how the hydrological changes to the Kaituna River and Maketu Estuary have impacted the estuarine ecosystem. This is the first year monitoring of these parameters were required to be measured in the Maketu Estuary and Papahikahawai Creek as part of Condition 32.1.

In Figure 8 below the results of dissolved oxygen measurements are shown for the deployments made from 2017 up to 2020 at the Causeway 2 site in Papahikahawai Creek. The 2017 oxygen levels (% saturation) stand out as having consistently far lower levels of oxygen present in the water column. These levels of oxygen are very poor and will severely limit the species that could survive in this environment. The 2017 measurements were taken before the restoration of tidal flows to this area and measurements since then, all show some improvement, but remain at poor levels that will continue to have degree of impairment to the full life supporting capacity of this area. It is expected that levels of dissolved oxygen will tend to improve over time as the area continues to recover from all the changes that have occurred. In particular, the northern block of previous farmland has only been exposed to the tides since June 2019 and will likely contribute to increased oxygen fluctuations for several years (BOPRC, 2020; Appendix 1).

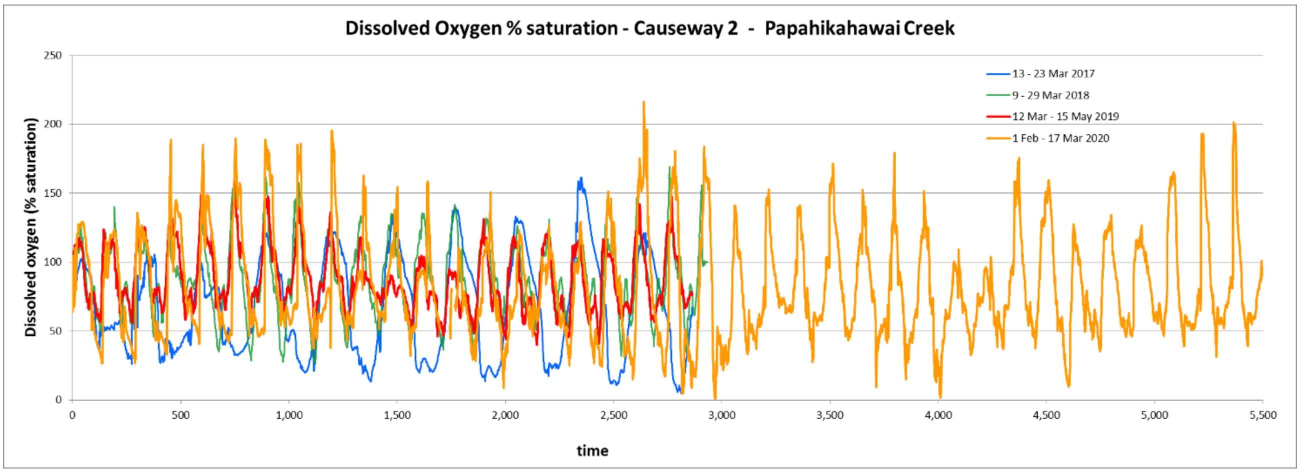


Figure 8 *Dissolved oxygen levels (% saturation) recorded for short periods at the Causeway 2 site in Papahikahawai Creek from 2017 to 2020 (graph replicated from the BOP RC 2020 Maketu Estuary Benthic Ecology Monitoring Report; Appendix 1).*

In the 2020 results, the change in diversion flow from 150,000 to 400,000 m^3 occurs at 1,600 on the time axis of Figure 16. It is apparent that drops in dissolved oxygen occur after this point, but given the changes taking place with increased movement of sediment and macroalgal beds that would occur with the increased current flows, the effect on dissolved oxygen appears to have been very minor. The results also indicate that the lower minimum dissolved oxygen values return to the same levels as prior the increased flow within three weeks (BOPRC, 2020; Appendix 1).

In Figure 9 below, results are shown for dissolved oxygen levels measured in the water column at the mid-estuary WQ 5 site. As with the Causeway 2 site results in Papahikahawai Creek, there is an apparent drop in DO minimums observed after the increase in river flow on the 12th February 2020. There was also some concern that the sensor had been placed too close to the bottom in the February deployment and suffered from smothering by drifting algae. The data that clearly showed such effects has been removed from the data set. Then a re-deployment at this site in April 2020 at a slightly higher level above the bottom resulted in far less variable levels of oxygen than the earlier February measurements and show improvement in conditions compared to the exact same time of year in 2019 (BOPRC, 2020; Appendix 1).

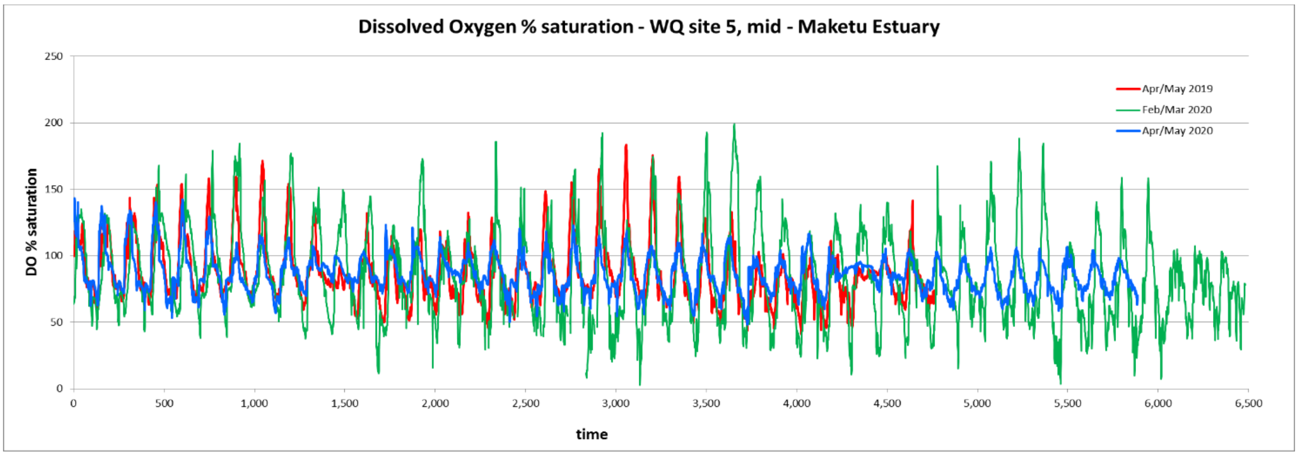


Figure 9 *Dissolved oxygen levels (% saturation) recorded for short periods at the WQ 5 site in the upper mid area of Maketu Estuary in 2019 and 2020 (graph replicated from the BOPRC 2020 Maketu Estuary Benthic Ecology Monitoring Report; Appendix 1).*

Changes to salinity levels at the mid estuary WQ 5 and Causeway 2 site in Papahikahawai Creek are shown in Figures 10 and 11 below. The 2019 measurements at both sites were made while there was no river flow occurring and shows the marked drop in salinity being achieved with the re-diversion of the Kaituna River. Modelling (DHI, 2014) shows that with the full flow (600,000 m^3 per tidal cycle) it is expected that salinity levels at the Causeway 2 site would be around a salinity of 10 on average. In Figure 10 it can be seen that after the re-diversion flows increased from 150,000 to 400,000 m^3 (about 1,600 on time axis), salinity has dropped to this level for brief periods of time. Similar results are shown in Figure 11 for the WQ 5 site in the mid estuary at which modelling predicts salinities to sit around an average of 15 -20 for full flow (BOPRC, 2020; Appendix 1).

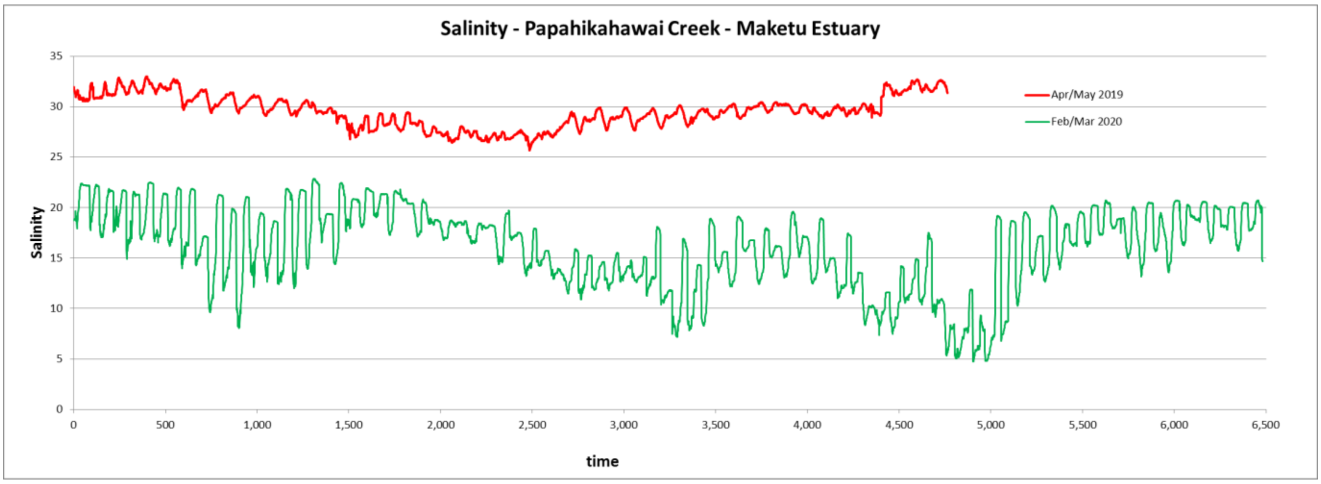


Figure 10 Salinity levels (ppt) recorded for short periods in Papahikahawai Creek in 2019 and 2020 (graph replicated from the BOP RC 2020 Maketū Estuary Benthic Ecology Monitoring Report; Appendix 1).

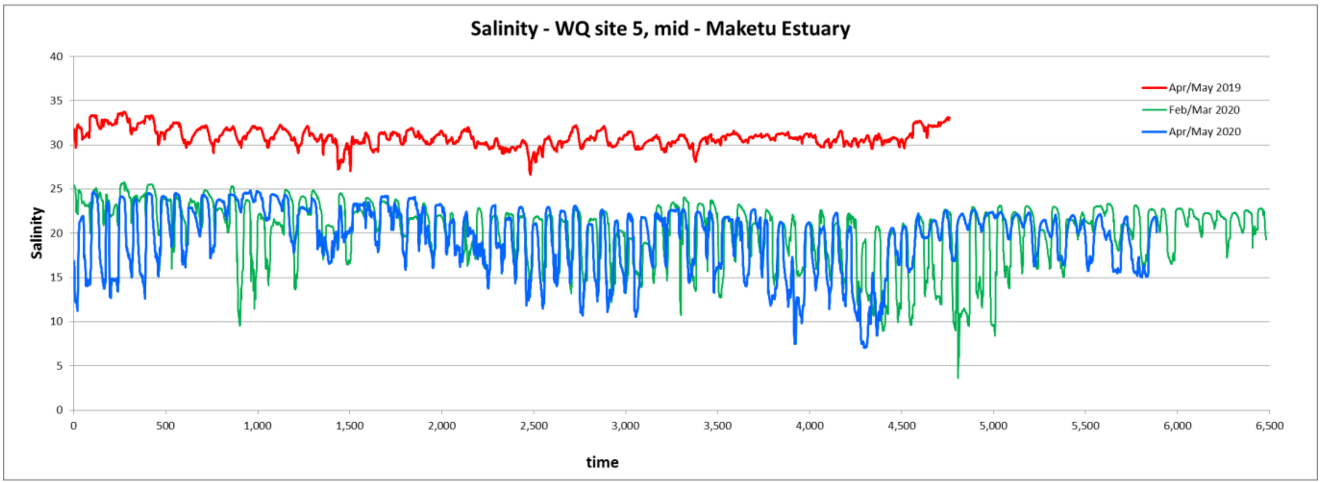


Figure 11 Salinity levels (ppt) recorded for short periods at the WQ 5 site in the upper mid area of Maketu Estuary in 2019 and 2020 (graph replicated from the BOPRC 2020 Maketu Estuary Benthic Ecology Monitoring Report; Appendix 1).

Changes to temperature levels at the mid estuary WQ 5 and Causeway 2 site in Papahikahawai Creek are shown in Figures 12 and 13 below. In 2019 temperature levels from both sites were much lower compared to the 2020 measurements after the re-diversion of the Kaituna River. At the Papahikahawai Creek site the maximum temperature recorded was 31.6ºC in 2020 compared to 21.6 ºC in 2019. After the re-diversion flows increased from 150,000 to 400,000 m^3 (about 1,600 on time axis), temperature levels dropped for a brief period of time at both sites. High temperatures in this part of the estuary are not unknow given the shallow water particularly at low tide.

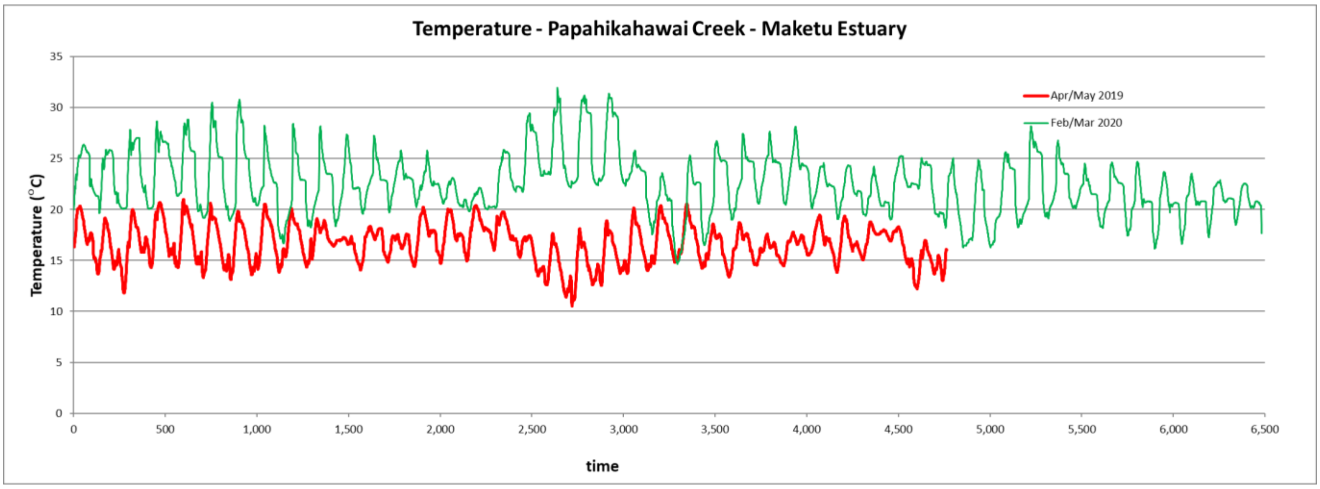


Figure 12 Temperature levels (ºC) recorded for short periods in Papahikahawai Creek in 2019 and 2020.

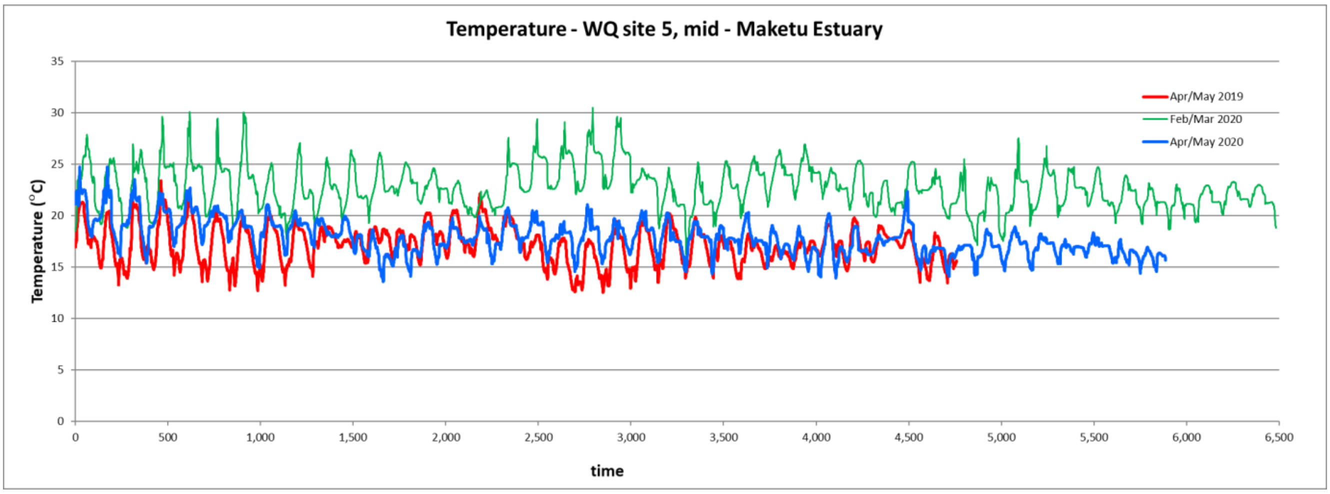


Figure 13 Temperature levels (ºC) recorded for short periods at the WQ 5 site in the upper mid area of Maketū Estuary in 2019 and 2020.

4. Ecology - Flora (Condition 34)

4.1 Condition 34.1, 34.4, 34.5 and – Terrestrial and Wetland Vegetation

34.1 The Consent Holder shall undertake vegetation transect monitoring to determine the effects of the re-diversion on terrestrial and wetland vegetation as follows:

	Location	Frequency
Transects 1-8	As shown on BOPRC Plan Number RC67958/12 with Transect 7 being extended to the waters edge of the new re-diversion channel	no later than 6 months after full commissioning and thereafter annually for 5 years
Transect 9	1 new transect to be established on land in the general location shown in BOPRC Plan Number RC67958/12	No less than 1 month prior to Stage 1 commissioning and then no later than 6 months after full commissioning and thereafter annually for 5 years
Transect 10 and 11	1 north-south and 1 east-west transect to be established on the land north of Fords Cut using paired plot methodology	No less than 1 month prior to Stage 1 commissioning and then within 6 months of each planting stage and then annually for 5 years

34.2 Transects should be measured using the methodology from section 3.1.5.1, on pages 18 to 20, of MacGibbon (2014) 'Kaituna River Re-diversion Project: Ongatoro/Maketu Estuary Enhancement Project – Terrestrial, Avian and Wetland Ecology' provided as part of the application material in the locations shown on BOPRC Plan Number RC67958/12.

34.3 In the event that access to Transects 6 and 8 cannot be gained from the landowner, there is no requirement to monitor. The Consent Holder shall notify the Regional Council in writing within 10 working days of access being denied identifying the attempts made to gain access.

34.4 The salt marsh remnants and the small Sacocornia patch in Papahikahawai Creek shall be monitored using photopoint monitoring. Surveys shall be carried out annually from Stage 1 commissioning for a period of five years.

34.5 The vegetation composition and spatial extent along the true left bank of the re-diversion channel shall be surveyed prior to river re-diversion and monitored 6 monthly for a period of two years following Commissioning. In the event that any die back is observed, the dead plants shall be replaced with alternative salt tolerant plants as soon as practicable.

34.6 Any observed die back and subsequent replacement planting shall be reported on under sub-clause 29.1(vi) of this resource consent.

Note: condition 34.4 is not required to be undertaken until after Stage 1 commissioning. The first round of monitoring will be reported in the 2021 annual report.

4.1.1 Results

Terrestrial and wetland vegetation assessments are required to be monitored to understand the effects of the Kaituna re-diversion. There are 8 established transects in the Maketū Estuary Lower Katiuna River (transects 1-8; MacGibbon, 2014) that will be monitored from full commissioning.

Three new transects were required to be established prior to commissioning (transect 9-11). Wildlands (2018)[1] established new transects and quadrats (transect 10 and 11) on the land north of Fords Cut to provide baseline data to compare ongoing changes in vegetation cover across all vegetation sites (Figure 12). The vegetation assessment for these transects was carried out on 8th and 11th June 2018 (Wildlands, 2018). Transect 9 was not established until June 2020[2] - this is later than was required by the conditions but will still provide a suitable baseline.

For transects 10 and 11 all quadrats had some level of vegetation cover. Indigenous plant species occurred in 18 of the quadrats, while naturalised plants occurred in 20 of the quadrats. In total, six indigenous and 37 naturalised vascular plant species were recorded within the quadrats. All of the vascular plants that were recorded were dicotyledonous herbs, monocotyledonous herbs, rushes, or grasses. Two quadrats also contained unidentified algae. Dead leaf litter, animal faeces, and bare ground were present in all but one of the quadrats and collectively had 37% mean coverage across all quadrats. Standing water was present in 13 of the 24 quadrats.

Table 2 summarises the mean cover of the most common indigenous and naturalised species recorded in the quadrats.

Table 2 Mean cover, cover range, and frequency of the 11 most common plant species recorded within quadrats at Te Paika Wetland.

Height Class	Common Name	Species Name	Mean Cover (%)	Cover Range (%)	Number of Quadrats Present
<30 cm	Arrow grass	*Triglochin striata*	13	0-67.5	15
	Bachelor's button	*Cotula coronopifolia*	4	0-27	15
	Glasswort	*Salicornia quinqueflora*	1.2	0-28	1
	Indian doab*	*Cynodon dactylon*	8.5	0-80	6
	Sea spurrey	*Spergularia tasmanica*	5.5	0-27	13
	Buck's horn plantain*	*Plantago coronopus*	1.9	0-25	12
	Creeping bent*	*Agrostis stolonifera*	1.7	0-40	5
	Kikuyu grass*	*Cenchrus clandestinus*	7.6	0-92	5
	Crested dogstail*	*Cynosurus cristatus*	2.1	0-35	3
30-100 cm	Sea rush	*Juncus kraussii* subsp. *australiensis*	7.4	0-70	5
100-200 cm	Sea rush	*Juncus kraussii* subsp. *australiensis*	3.0	0-50	2

[1] Wildlands (2018) Te Paika Wetland Monitoring: Establishment, June 2018. Prepared for Bay of Plenty Regional Council August 2018. Contract Report No. 4695

[2] Wildlands (2020) Vegetation Monitoring at Ford Island, Lower Kaituna River, Maketu: June 2020. Prepared for Bay of Plenty Regional Council July 2020. Contract Report No. 4695b

All quadrats had vegetation cover that occurred in the 0-30 cm height class. The mean cover of vegetation across all quadrats within the 0-30 cm height class was 51%. Sixty one percent of the total vegetation cover within this height class comprised indigenous plant species. Within the 0-30 cm height class, arrow grass (*Triglochin striata*) had the highest mean cover of the indigenous plant species (13%), followed by sea spurrey (*Spergularia tasmanica*). Arrow grass and bachelor's button were the most common species in terms of the number of quadrats they were recorded in (15 for each species) (Table 1). Within this height class, Indian doab (*Cynodon dactylon**1) had the highest mean cover of naturalised species recorded within the quadrats (8.5%), followed by kikuyu grass (*Cenchrus clandestinus**) (7.6%). Buck's horn plantain (*Plantago coronopus**) was the most frequently recorded naturalised species, occurring in 12 of the quadrats (Table 2).

Ten of the quadrats had vegetation cover that occurred in the 30-100 cm height class. The five species in this height class were either indigenous or naturalised rushes or grasses. In six of the quadrats, the cover within this height class entirely comprised indigenous species, while in three quadrats the cover was entirely composed of naturalised species. Only one quadrat had both indigenous and naturalised species present (one species of each) in this height class. The mean cover of vegetation within the 30-100cm height class for all quadrats was 8%.

Three of the quadrats had vegetation that occurred in the 100-200 cm height class that had a mean cover of 3%. The vegetation within this height class comprised two rush species; soft rush (*Juncus effusus var. effusus**) and sea rush.

The average cover of indigenous species was lower in dryland quadrats (mean: 11.3%) compared to the wetland quadrats (mean: 82%). Naturalised grasses were the common cover species in dryland quadrats while arrow grass, bachelor's button, sea spurrey, and sea rush were generally the dominant species in the wetland sites (Wildlands, 2014).

For transect 9 all of the quadrats were located on dryland habitats, with an elevation of less than five metres above sea level. Four quadrats were predominantly covered in bare ground and one plot was covered in leaf litter. Of the remaining three plots that contained >5% vegetation cover, one contained no cover of indigenous plants, while another contained <5% cover of the indigenous rush wīwī. Only one plot contained vegetation cover that was dominated by the indigenous fern, rārahu (bracken; *Pteridium esculentum*) (Table 3).

Vegetation cover ranged from 0-98%, with bare ground and litter making up the remainder. Only two indigenous species were recorded: rārahu (bracken) and wīwī (*Juncus pallidus*), and they only occurred in one quadrat each. The 14 exotic plant species recorded occurred in seven out of eight quadrats. All of the vascular plant species that were recorded were shrubs, dicotyledonous herbs, ferns, rushes, or grasses. Dead plants were observed in two quadrats and covered 30-51% of the *quadrat.* Leaf litter was present in all quadrats, and bare ground present in six of the eight quadrats, with overall mean cover of 21% and 54% respectively. Maximum vegetation height ranged from 0-1.1 metres, and mean vegetation height ranged from 0-0.6 metres.

Table 3 summarises the mean cover of the most common indigenous and naturalised species recorded in the quadrats.

Table 3 Mean cover, cover range, and frequency of the plant species and ground cover recorded within the eight quadrats along transect 9, Ford Island

Height Class (cm)	Common Name (Species Name)	Mean Cover (%)	Cover Range (%)	Number of Quadrats Present In
<29	Bare ground	54.4	0-99	6
	Litter	21.1	0.5-100	8
	Black nightshade (*Solanum nigrum*)	0.1	0-0.5	1
	Blackberry (*Rubus fruticosus* agg.) (dead)	0.1	0-1	1
	Catsear (*Hypochaeris radicata*)	0.4	0-3	1
	Cocksfoot (*Dactylis glomerata*)	0.8	0-5	3
	Gorse (*Ulex europaeus*)	1.9	0-15	1
	Indian doab (*Cynodon dactylon*)	0.6	0-5	1
	Indian doab (*Cynodon dactylon*) (dead)	4.4	0-20	2
	Inkweed (*Phytolacca octandra*)	4.0	0-30	2
	Kikuyu grass (*Cenchrus clandestinus*)	0.2	0-1	2
	Kikuyu grass (*Cenchrus clandestinus*) (dead)	3.8	0-30	1
	Lotus (*Lotus pedunculatus*)	0.1	0-0.5	1
	Narrow-leaved plantain (*Plantago lanceolata*)	0.3	0-2	1
	Pampas (*Cortaderia selloana*)	0.1	0-1	1
	Pampas (*Cortaderia selloana*) (dead)	1.9	0-15	1
	Paspalum (*Paspalum dilatatum*)	3.3	0-15	3
	Rārahu (bracken; *Pteridium esculentum*)	6.3	0-50	1
	Tall fescue (*Lolium arundinaceum* subsp. *arundinaceum*)	0.6	0-5	1
	Unidentified seedling	0.1	0-0.5	1
	Wīwī (*Juncus pallidus*)	0.4	0-3	1
	Yorkshire fog (*Holcus lanatus*)	0.3	0-2	1
30-99	Cocksfoot (*Dactylis glomerata*)	0.1	0-1	1
	Gorse (*Ulex europaeus*)	1.3	0-10	1
	Inkweed (*Phytolacca octandra*)	5	0-40	1
	Pampas (*Cortaderia selloana*)	0.4	0-3	1
	Paspalum (*Paspalum dilatatum*)	0.6	0-5	1
	Rārahu (bracken; *Pteridium esculentum*)	3.8	0-30	1
	Wīwī (*Juncus pallidus*)	0.1	0-1	1
>100	Inkweed (*Phytolacca octandra*)	0.1	0-1	1

Figure 12 Locations of transect lines and quadrats at Te Paika Wetland: transect 10 (left) transect 11 (right) (map replicated from the Wildlands 2018 Te Paika Wetland Monitoring Establishment Report).

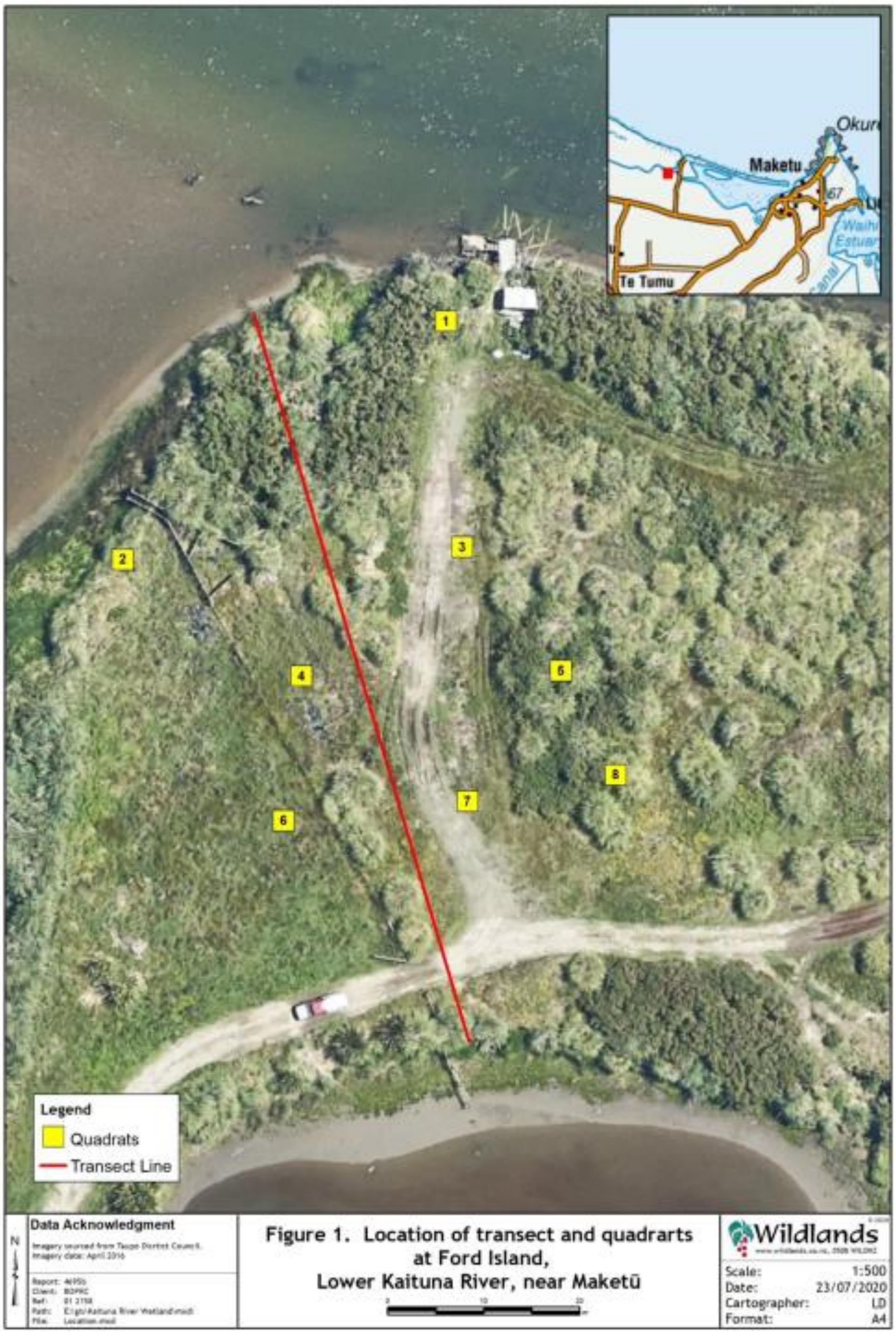


Figure 13 Locations of transect line 9 (map replicated from the Wildlands 2020 Ford Island Report).

5. **Sediment and Algae (Condition 35)**

5.1 Condition 35 – Sediment and Algae Survey

35.1 The Consent Holder shall undertake a survey of sediment and algae in the estuary as follows:

(a) Along a minimum of three transects in the upper estuary;

(b) Along a minimum of three transects in the mid-estuary, (including one at the downstream end of Papahikahawai Creek); and

(c) Along a minimum of one transect in the lower estuary.

35.2 The sediment survey shall be undertaken:

(a) Once prior to the Stage 1 commissioning of the diversion control structure;

(b) Once within one year of the Stage 1 commissioning of the diversion control structure;

(c) Once within two years of the Commissioning of the diversion control structure; and

(d) Once within five years of the Commissioning of the diversion control structure.

35.3 Variables assessed during the sediment survey shall include:

(a) Algae cover and type;

(b) Per cent cover of mud/silt;

(c) Depth of mud/silt; and

(d) Anoxic depth (that is, depth of RPD (redox potential discontinuity).

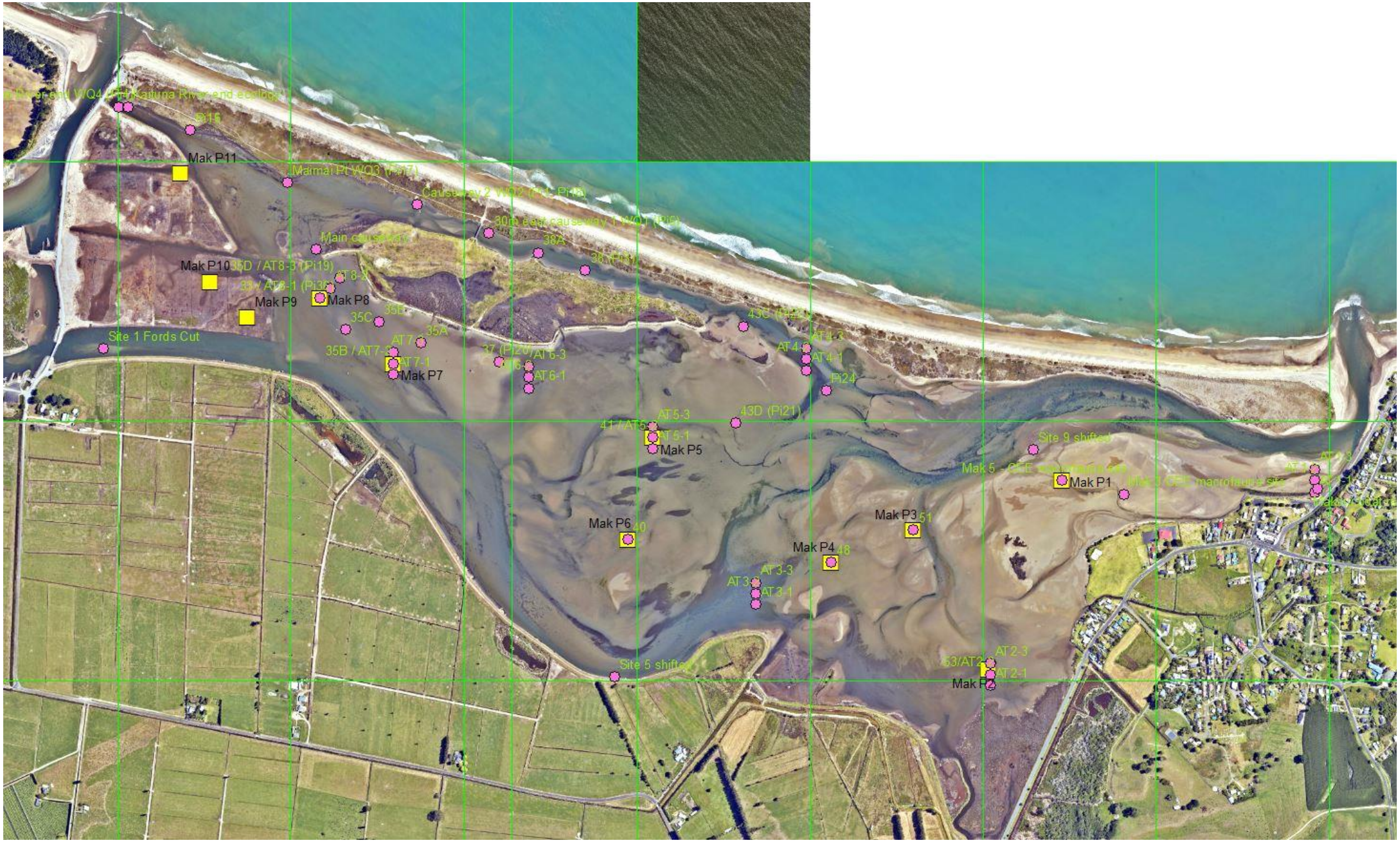


Figure 13 Location of ecological (pink circles) and sediment sites (yellow squares) throughout Maketu Estuary

5.1.1 Results

Algae

Algae monitoring has been undertaken by Bay of Plenty Regional Council in the Maketū Estuary since 2011 as part of compliance and state of the environment monitoring. There are 8 long term transects along which the cover and biomass of macroalgae has been recorded which have been used to meet the surveying prior to Stage 1 commissioning requirements. Transects AT-1 and AT-2 can be defined as the lower estuary, transects AT-3, AT-4 and AT-5 as the mid-estuary, and transects AT-6, AT-7 and AT-8 as the lower estuary (Appendix 1).

As a general overall trend most sites peaked in macroalgae cover in 2014 and in 2019 the majority of sites had the lowest levels seen for some time. In 2020 transects AT-1, -3, -4 and -5 all showed some increase of macroalgal cover in 2020 compared to 2019 (Figure 14).

Several sites around the estuary have for a number of years had consistently high cover and biomass of macroalgae. Transect AT-2 is in the southern most region of the estuary and has, as shown in Figure 14, had a very high cover of macroalgae from 2011 up to 2018. Since 2018 this site has largely cleared of macroalgae allowing improvement of sediment conditions and recovery of macrofaunal diversity. A similar trend has been observed at AT-8 which is the western most transect in the upper estuary. This site had a very high biomass of *Gracilaria chilensis* with patches of cyanobacteria which in the 2020 monitoring had cleared to near zero cover. The change in condition of this site between 2018 and 2020 is shown in the photos below (Figure 15) with abundant titiko present in 2020.

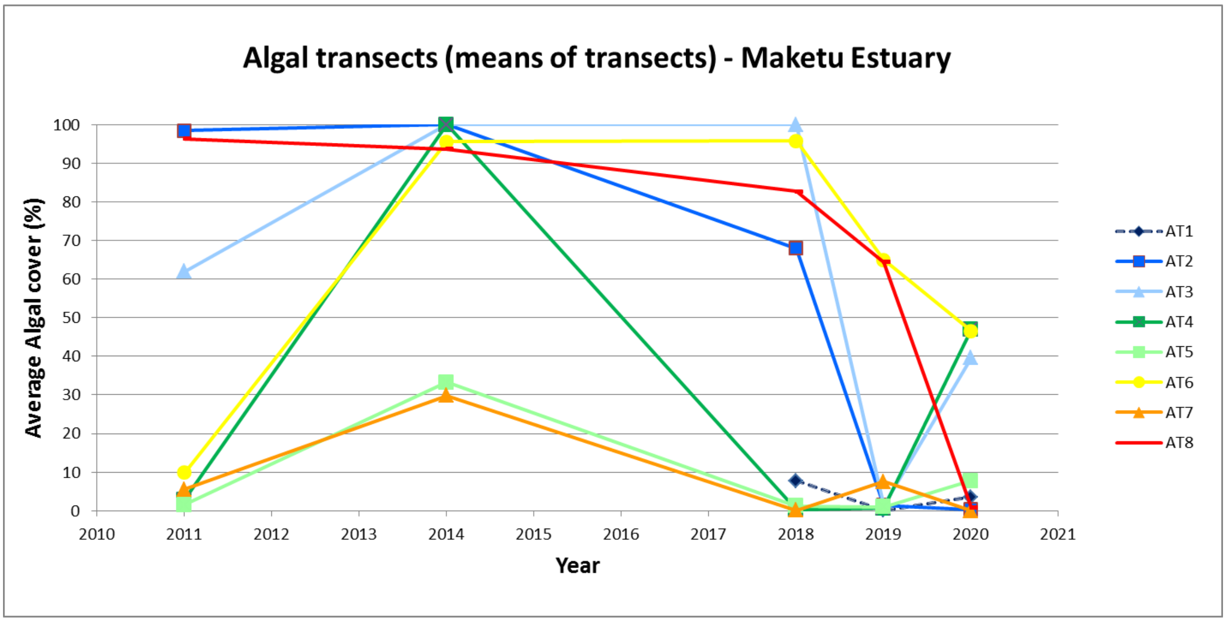


Figure 14 Mean macroalgal cover measured along transects throughout Maketū Estuary from 2011 to 2020. Lower estuary: AT-1 and AT-2, mid-estuary: AT-3, AT-4 and AT-5, upper estuary AT-6, AT-7 and AT-8.

Figure 15 Photographs of site AT-8 in the upper estuary in January 2018 (left) with macroalgal and cyanbacterial cover and in 2020 with no macroalgae or cyanobacteria and titiko (mud snails) present.

Another marked change that has occurred in Maketu estuary outside of the impounded area of Papahikahawai Creek, is in the same channel to the east of where the causeway had blocked it. The removal of the causeway increased the tidal flows along this channel which had several effects. One change was a reduction in the amount of macroalgae that was present in the channel. At site 38 in this channel, the macroalgal cover dropped from an average of 96% in 2017 just prior to the removal of the causeway, down to 0% in 2018 seven months after. A similar change also occurred further along at site 43c dropping from 78% to 0% (Appendix 1).

Sediment

Sediment monitoring of grain size, redox potential discontinuity (RPD) and heavy metals have been undertaken consistently by Bay of Plenty Regional Council in the Maketu Estuary since 2017 as part of a wider environmental monitoring programme. Sediment grain size and RPD are required to be surveyed prior to Stage 1 commissioning from the lower, mid and upper estuary. Transects AT-1 and AT-2 can be defined as the lower estuary, transects AT-3, AT-4 and AT-5 as the mid-estuary, and transects AT-6, AT-7 and AT-8 as the lower estuary (Appendix 1). Figure 16 presents the proportion of sediment grain size fraction and depth of anoxic sediment from the 2019/2020 sampling period which will act as baseline for future monitoring.

In the 2019/2020 sampling period the dominant fraction was sand at all sites with an average proportion of 71.9%, followed by mud with an average proportion of 28.1% and there were no sites that consisted of gravel. The proportion of sand was highest at AT1 in the lower estuary (98.1%) while proportions of mud were highest at some sites in the mid and upper estuary (AT3, AT4 and AT6; Figure 16).

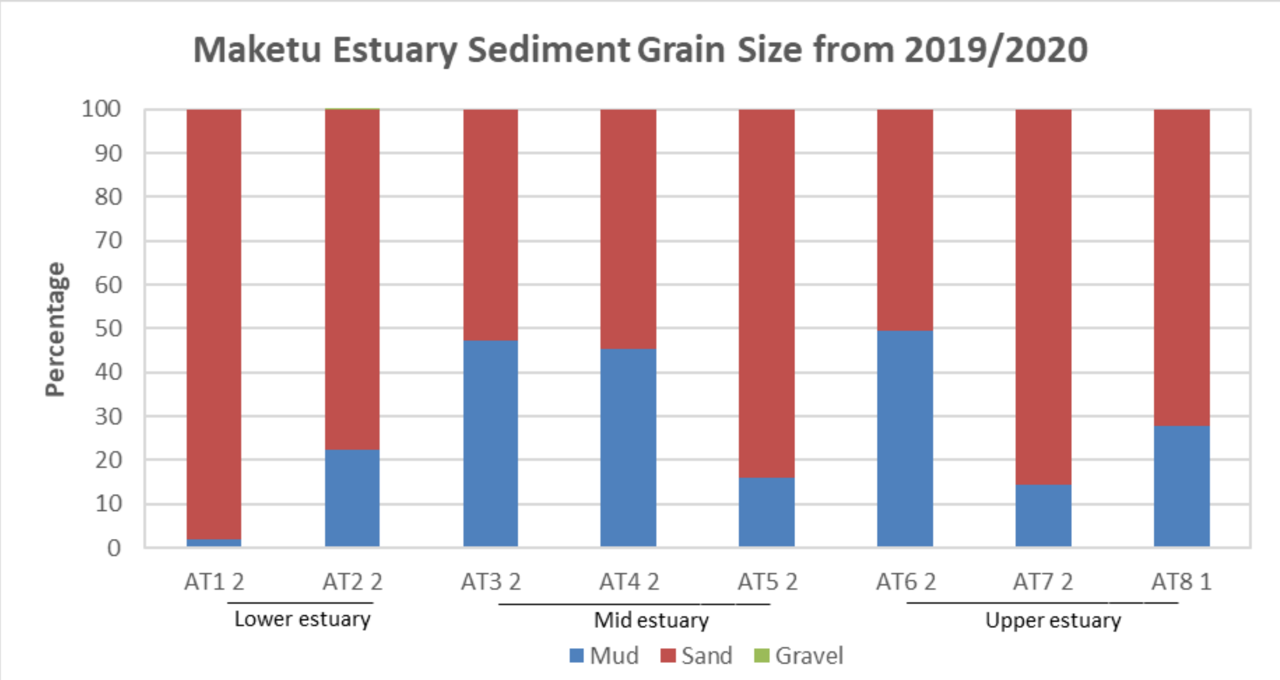


Figure 16 Proportion of gravel, sand and mud in sediments on the sandbanks of the Maketū Estuary.

The depth of anoxic sediment (redox potential discontinuity layer) was consistency small across sites ranging from 2-4mm, apart from transect AT1 in the lower estuary which was much greater at 26mm (Figure 17).

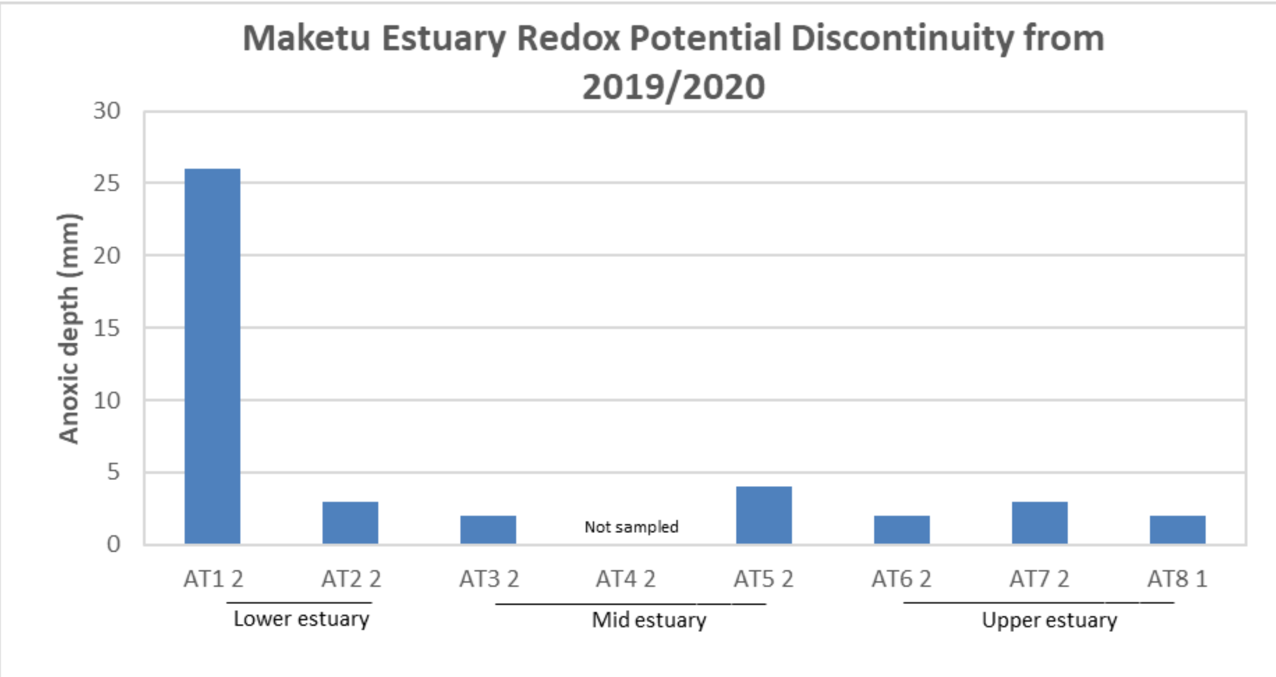


Figure 17 Depth of anoxic sediment (Redox Potential Discontinuity) from 2019/2020 monitoring prior to Stage 1 commissioning.

6. **Reporting Requirements (Condition 29)**

6.1 Condition 29 – Reporting

29.1(f) Identify instances where the Consent Holder has provided opportunities for Tangata Whenua involvement under condition 28.2(i) and Condition 8A.

29.1(g) Identifies any recommendations made by any of the Tangata Whenua groups under condition 8B.7 and, where the recommendations have not been adopted by the consent holder, the reasons for not adopting those recommendations.

28.2(i) Identify and provide opportunities for tangata whenua and the community to be involved in developing education or research projects associated with the Project, particularly around incorporating elements of Matauranga Maori, and in wetland restoration and ecological monitoring.

8A.3(g) A process for Tangata Whenua to have input into and provide feedback on the annual report prepared under Condition 29 prior to its lodgement with the Regional Council.

6.1.1 Discussion

The following opportunities have been identified and actioned:

Opportunity	Action taken	Outcome
Mural for control building	Te Toko Whitu (Tangata whenua working group) developed a brief for an artist to design a mural for 2 walls of the control building. Applications were received and a sub-group appointed the artist. The draft concept was provided for comment at a hui, following which minor changes were made.	Completed mural that tells a story about the values of the area
Involvement with monitoring	Assistance with sampling work required as part of consent conditions	ahi kā employed to assist with shellfish sampling Maketu locals paid to undertake regular spit cross section profile monitoring
Education and research projects	Waikato University, School of Science – various research underway looking at estuary flushing and mixing Te Waata ran a three day Wānanga for school students on Papahikahawai to instruct them in various cultural matters in May 2020	Various monitoring projects by university students and staff
Other	Support for Te Maru o Kaituna River Authority - Action Planning and Implementation Waka Ama – relocation and advocacy	Inclusion of projects in the Kaituna Action Plan, eg. Project 6: A work programme will be developed with tangata whenua, environmental care groups and the Maketu community to identify and prioritise restoration tasks. This may include continued wetland and/or estuarine margin planting as well as saltmarsh and seagrass restoration Return of club including a new launching area

On 21 July 2020 the results of the annual monitoring were presented at a tangata whenua hui in Maketu. Key feedback on the monitoring results were:

- Maketu locals have informally commented on the positive changes they have seen to the estuary and this is reflected in the results that have been presented
- If requirements can be met, there was support to move from 9 to 12 culverts being open earlier.

The presentation used at the hui was used by Te Rūnanga o Ngāti Whakaue ki Maketū at their own runanga meeting to update members.

6.2 Condition 29.2 Recommended changes to monitoring

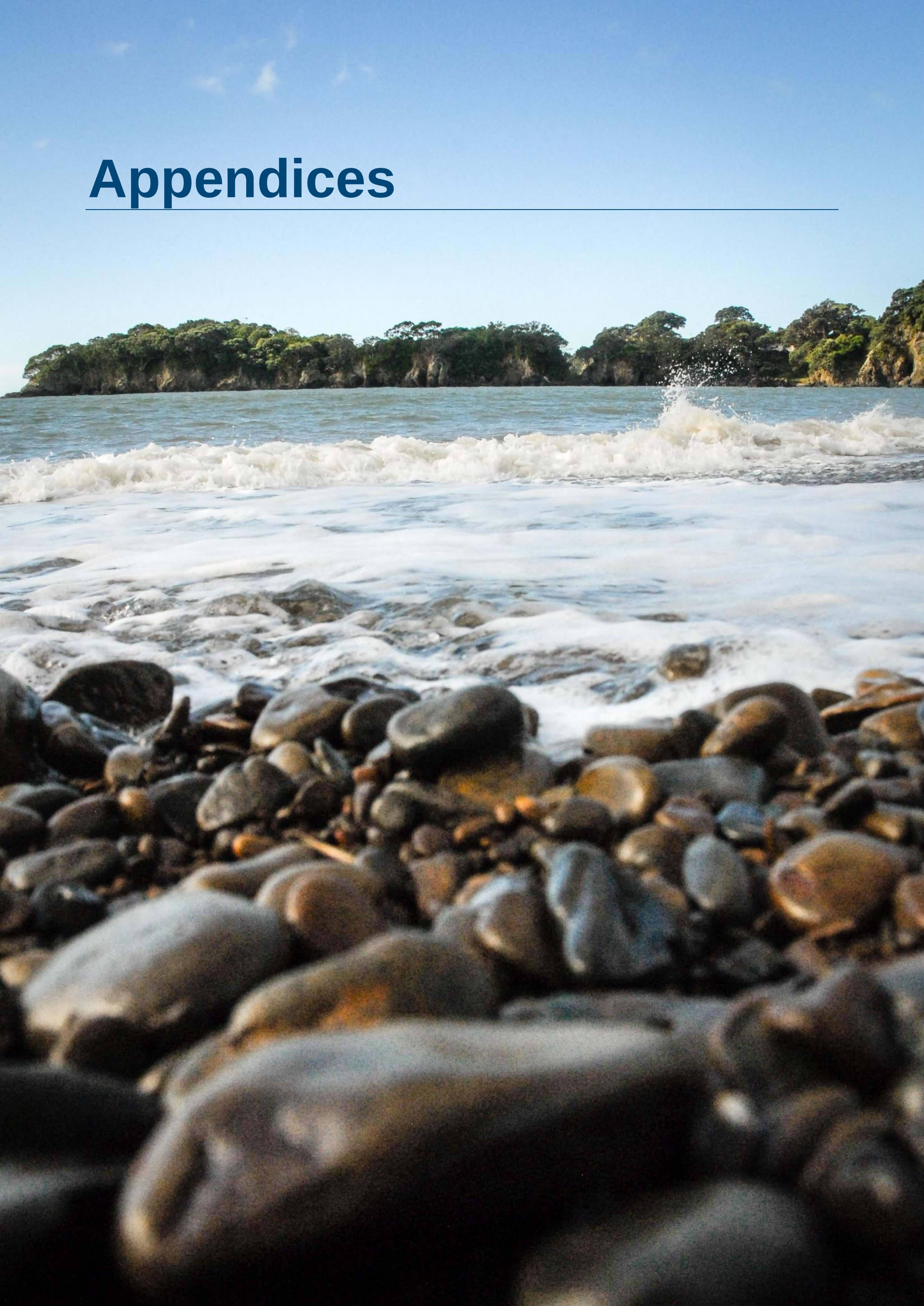
29.2 The monitoring parameters, site locations and frequency of sampling outlined in the Environmental Monitoring Programme and any other alterations may be reviewed as part of each monitoring report.

A review of the monitoring parameters, site locations and frequency of sampling has been undertaken.

The following monitoring location changes are recommended:

Condition	Proposed change	Reasons for change
34.1 Transects 10 and 11	The condition requires one transect be north-south and the other east-west. The recommendation is for both to run north-south	The Transects were relocated to better reflect the Wetland Restoration Plan and planting

Appendices



Appendix 1: Maketu Estuary benthic ecology monitoring 2020

MEMORANDUM

To:	Pim De Monchy **Coastal Catchments Manager**
From:	Stephen Park **Senior Environmental Scientist**
	Date: 10 June 2020
File Ref:	
Subject:	**Maketu Estuary benthic ecology monitoring 2020**

Introduction

This memo is for the purpose of providing an overview of the more salient ecological changes or responses that have been noted in Maketū Estuary following a number of restoration projects completed prior to the last round of Bay of Plenty Regional Council environmental monitoring undertaken over the summer of 2019/20. As such the ecological changes noted do not include effects from increased flows from the Kaituna River which commenced on 12th February 2020 after the latest round of ecological monitoring. However the results of monitoring salinity and oxygen at two sites over the period in which increased river flow commenced, is included.

The relevant key restoration projects within Maketū Estuary which have potential ecological effects include;

- removal of the causeway on the northern side of Papahikahawai Island to open Papahikahawai Creek back up to the estuary on 6th June 2017.
- removal of the reclamation bund around the southern margin of Papahikahawai Island to open this area back up to the estuary and restore it as intertidal wetland in July 2017.
- removal of the causeway linking the former Brain farmland (now Te Pā Ika wetland) to Papahikahawai Island in September 2018 and the removal of the reclamation bunds around the southern half of farmland in October 2018 and the northern half in June 2019.

These three projects have returned a total of around 45 ha back to the intertidal zone of Maketū Estuary (Papahikahawai Creek – 15.5 ha, Papahikahawai Island - 7 ha and Te Pā Ika - 22.5 ha). In terms of total estuary area, this represents a significant increase of around 19% on the previous extent of 230 ha.

Background

There have been numerous changes to Maketū Estuary as a result of both natural events and impacts occurring as a result of wetland reclamation and flood mitigation works. The Kaituna River historically entered Maketū Estuary in the northwest close to the spit and sea. Some river flow passed the northern side of Paphikahawai Island via Papahikahawai Creek, but the majority flowed around the western and southern sides of the Island. The river had at times breeched the spit and entered directly out to sea at Te tumu as it did in 1907. Between 1925-28 Fords Cut was excavated upstream of this breech to encourage flows through the estuary. However a later flood event in 1928 caused another breech of the spit. A decision was then made in 1954 by the Kaituna River Board to open a permanent cut out to sea at Te tumu which was completed in 1957. Fords Cut was then closed off so that only a very small amount of water entered the estuary on spring tides. The result of these flood protection schemes and reclamation of the wetlands around the estuary had a significant impact on the health of the estuary (KRTA, 1986).

Since the diversion of the river, the local community had strongly advocated the return of the river and in 1983 the Minister for the Environment ordered a report into the issues and options for Maketū Estuary. The report was critical of the initial decision to divert the river out of the estuary and recommended re-diversion of the river to the estuary. In 1991 the Department of Conservation made an application for diversion of up to 200,000 m^3 per tidal cycle and dredging of the estuary. In 1994 consent was granted for up to 100,000 m^3 of river flow to be diverted back to the estuary on each tidal cycle. Although the diversion structure was completed in 1995, it was not until 1998 that the full flow occurred on a permanent basis. A later gauging of the flows and assessment by modelling showed that flows were estimated to be up to 150,000 m^3 per tidal cycle (DHI 2009).

Then more recently in 2009, the Bay of Plenty Regional Council established the Kaituna and Ōngātoro/Maketū Strategy Implementation project and in 2011 the hearing panel for the Strategy recommended full re-diversion of the river. Following further assessments of issues and options consent was sought by the Bay of Plenty Regional Council in 2014 for the diversion of up 600,000 m^3 per tidal cycle along with other changes aimed at improving the estuaries ecological health. Consent was granted for the 600,000 m^3 per tidal cycle with conditions that flow starts at 400,000 m^3 (stage 1) for the first year and going to full flow once monitoring confirms there are no water quality issues. Initial flow through the gates commenced at 400,000 m^3 per tidal cycle on the 12th February 2020. During construction of the new diversion structure, there was a period between September 2018 and June 2019 when the flows from the river were stopped altogether.

Some of the key changes to the estuary as a result of the loss in river inflows included infilling of the lower estuary with sand from the open coast. Gauging of estuary volume showed a 34% reduction between 1972 and 1985 (Rutherford et al., 1989) and a further reduction of 17.3% up to 1996 (Domijan et al., 1996). The reduction in tidal volume and shallowing of benthic habitat has had adverse impacts on shellfish beds. When these hydrological impacts are combined with the reported a loss of 160 ha (95%) of maritime marsh between 1939 and 1979 (KRTA, 1986) the impacts on the benthic ecology are extensive. The latest assessment of the ecological health of Maketū Estuary showed it to be in poor condition (Park, 2018) primarily due to the extensive macroalgal beds and extent of muddy sediments.

Monitoring programmes

Environmental monitoring of Maketū Estuary is conducted by various groups including local Iwi, the University of Waikato and the Bay of Plenty Regional Council. The monitoring information presented in this memo comes from that currently being undertaken by the Bay of Plenty Regional Council as part of its state of the environment programme, compliance monitoring for the re-diversion consent (RC 67-958) and project monitoring to track ecological changes associated with some of the wetland restoration projects. There is a range of monitoring undertaken for compliance of Consent 67-958, but this memo only covers the benthic ecology and water quality component of the consent monitoring.

Figure 1, location of monitoring sites in Maketū Estuary (pink circles). Yellow squares are sites measuring sediment accumulation rate.

Ecological changes in the Papahikahawai Creek area

Background

The Paphikahawai Creek area originally formed part of the Kaituna River mouth channel system flowing into Maketū Estuary. As set out in the background information above, a number of major flood mitigation changes resulted in this area having reduced freshwater flows from 1957 onwards. In 1964 tidal flows in and around Papahikahawai Creek were severely reduced by construction of a causeway on the northern side of Papahikahawai Island and reclamation of tidal areas to the north of Fords Cut for farmland. In 1971 the reclaimed area north of Fords Cut was joined to Papahikahawai Island by construction of another large causeway. This effectively separated the north-western portion of the estuary resulting in a stagnant water body that had no tidal fluctuations. As shown in Figure 2 below it became highly degraded over the years developing poor water quality and a 100% cover of macroalgae and cyanobacteria (blue-green algae). Salinity levels were fairly constant over time and varied spatially from around 28 in the eastern part of Papahikahawai Creek to 20 near Fords Road.

Following the restoration of tidal flows to the Papahikahawai Creek area in June 2017 recovery of the area has progressed well. As shown in Figure 3, the cover of algae has substantially reduced now that tidal flows occur. The following sections present some of the key representative results from the various sites that have been monitored in this area.

Figure 2, looking west from Papahikahawai Island (December 2016) showing former Kaituna River inflow channels in Maketū Estuary.

Figure 3, looking west from Papahikahawai Island (January 2020) showing former Kaituna River inflow channels in Maketū Estuary after June 2017 return of tidal flows.

Changes to macroalgal extents in Papahikahawai Creek area

There are a number of sites around the margins of the previously cut-off area of Papahikahawai Creek at which the percentage cover and biomass of macroalgae has been monitored up to the summer of 2019/20. The results from that monitoring are shown in Figure 4 below with macroalgal cover at all sites reducing from 100% down to 0%. Those sites with the strongest tidal current exposure such as Causeway 2 in Paphikahawai Creek cleared within a year, while other sites have taken several years to clear. There are still some areas of macroalgae that haven't cleared but these are relatively small in extent. Figure 4 also shows the average macroalgal cover from all sites monitored in Maketū Estuary, which shows that estuary wide there has been some improvement since 2014, but not the marked reduction seen in Papahikahawai Creek.

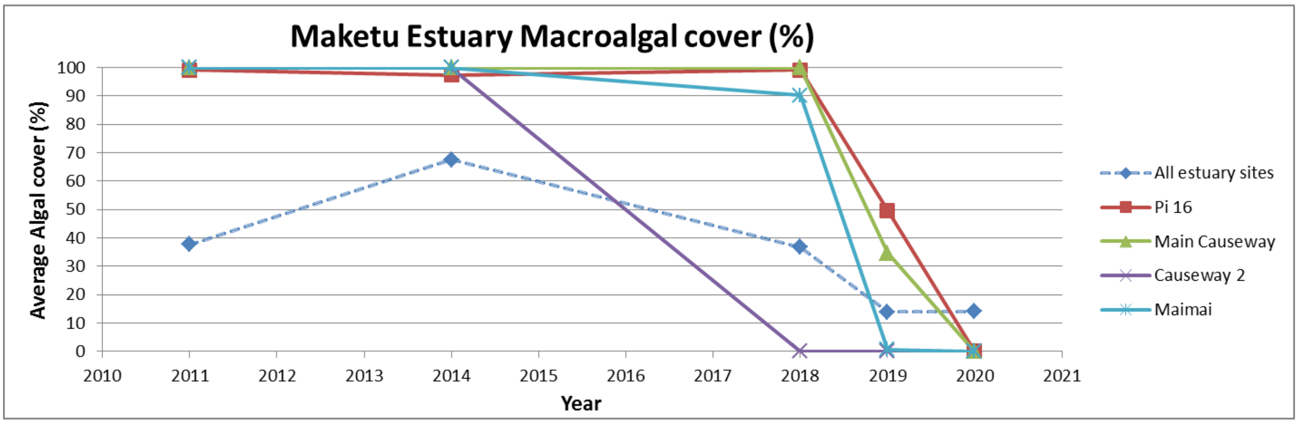


Figure 4, Macroalgal cover at sites in the previously cut-off area of Papahikahawai Creek.

Changes to sediment parameters in Papahikahawai Creek area

Some key indicators of sediment health have been monitored at sites in the Papahikahawai Creek area following the return of tidal flows. In Figure 5 below the mud content is shown for several sites with the most consistent trend seen at the Causeway 2 site in an area where tidal currents have increased the most and the mud content has reduced. An initial moderate increase in mud content was evident at the main causeway site, likely due to initial mobilisation of sediment from higher up in the estuary onto that site, however is now reducing in line with the two other sites.

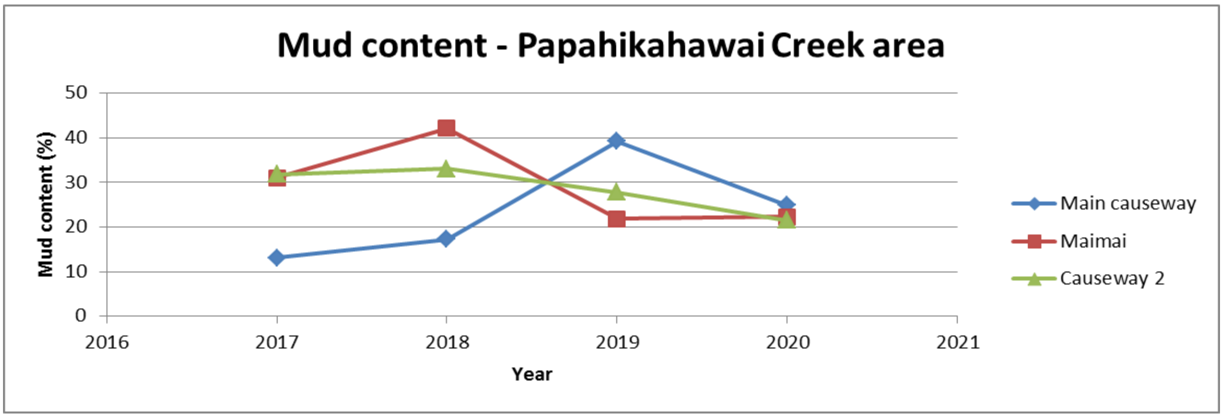


Figure 5, mud content (%) of the sediments at sites in the Papahikahawai Creek area from 2017 to 2020.

The amount of total organic carbon (TOC) measured in the sediments of sites in the Papahikahawai Creek area is shown for some sites in Figure 6. In general TOC has shown a consistent decline at all the sites which will be linked to the reduction in macroalgal cover at the sites. Some of the previous TOC levels measured at the main causeway and Maimai site were at very high levels which causes deoxygenation of the sediments, making them unsuitable for macrofauna.

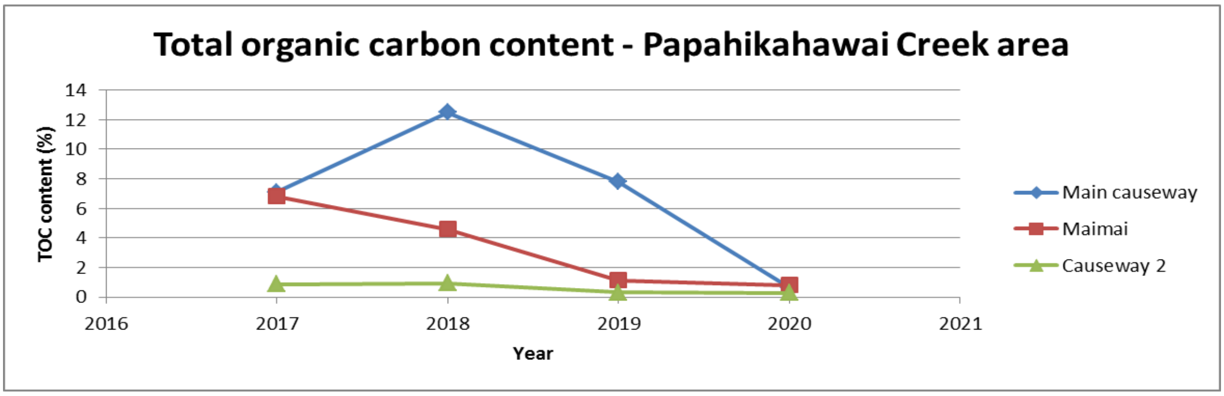


Figure 6, Total Organic content (TOC %) of the sediments at sites in the Papahikahawai Creek area from 2017 to 2020.

Changes to benthic macrofauna communities in Papahikahawai Creek area

With the restoration of tidal flows and a re-connection to the sea, marine life has been able to recolonise the Papahikahawai Creek area as benthic habitat conditions have improved. Figures 7 & 8 below are examples of the changes that taken place. The Causeway 2 site (Figure 7) has shown the greatest degree of change having reached an average of 7 species per sample. The Maimai site (Figure 8) is reasonably representative of other areas around the margins of the Papahikahawai Creek area with a mean 4 species per sample.

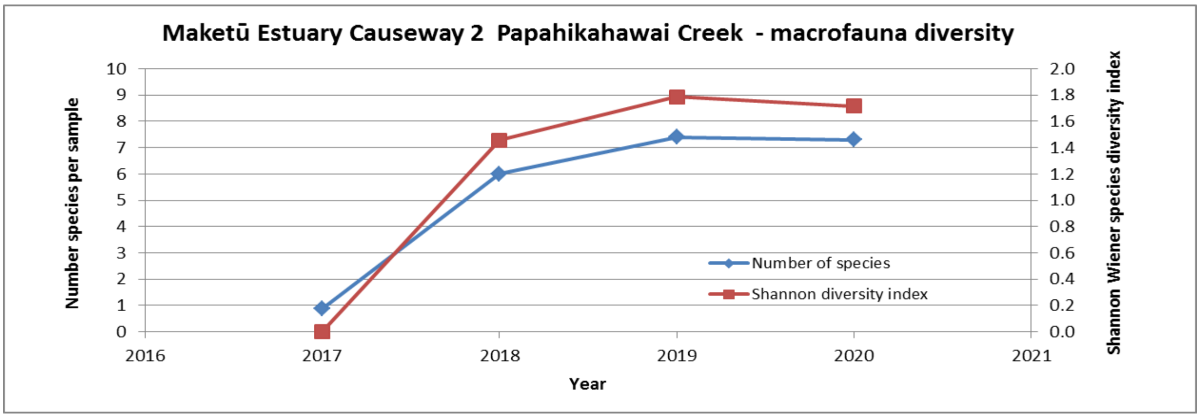


Figure 7, Mean number of species and Shannon diversity index for the Causeway 2 site in the Papahikahawai Creek area from 2017 to 2020.

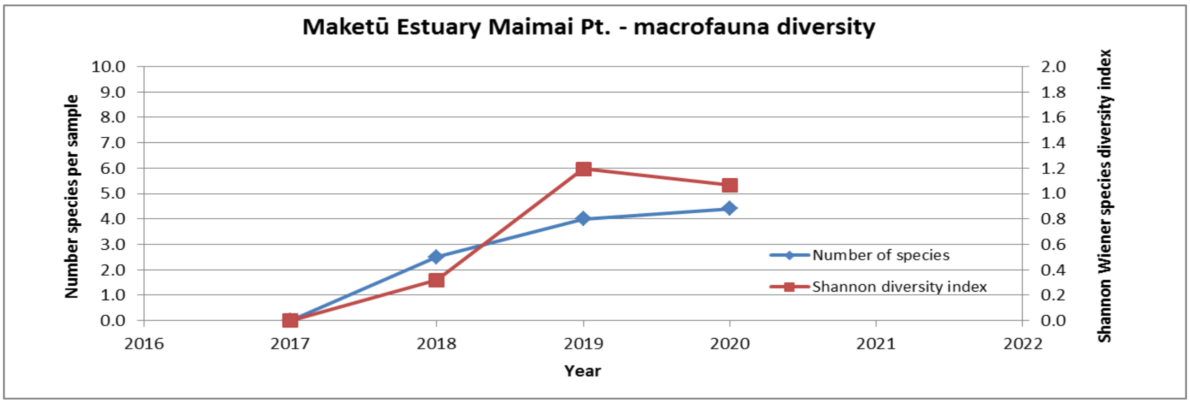


Figure 8, Mean number of species and Shannon diversity index for the Maimai site in the Papahikahawai Creek area from 2017 to 2020.

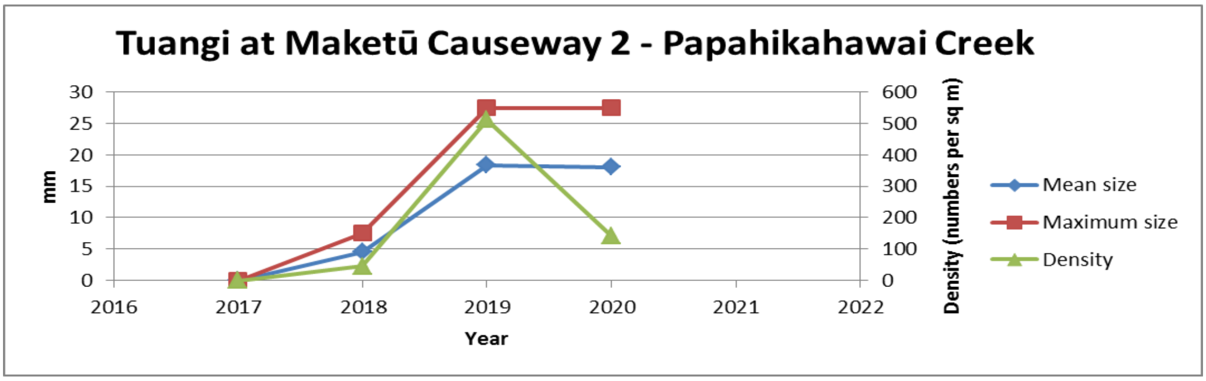


Figure 9, Density, mean size and maximum size of tuangi (cockles) at the Causeway 2 site from 2017 to 2020 in the Papahikahawai Creek area.

The tuangi (cockle) density and size recorded at the Causeway 2 site in Papahikahawai Creek (Figure 9) has shown that recruitment occurred within the first year of being re-opened. After just two years some tuangi had already reached a size of 25-30mm and mean size of 18mm. Other sites around the margins of Papahikahawai Creek have also recorded some recruitment of tuangi but not to the same extent as the habitat is not as suitable.

Other prominent macrofauna changes to the Papahikahawai Creek area is the recruitment and increase in the number of crabs which have shown consistently high increases across this area. In Figure 10 below the numbers of crab holes recorded at the main causeway and Maimai sites are shown and these sites are representative of much of the intertidal habitat in this area.

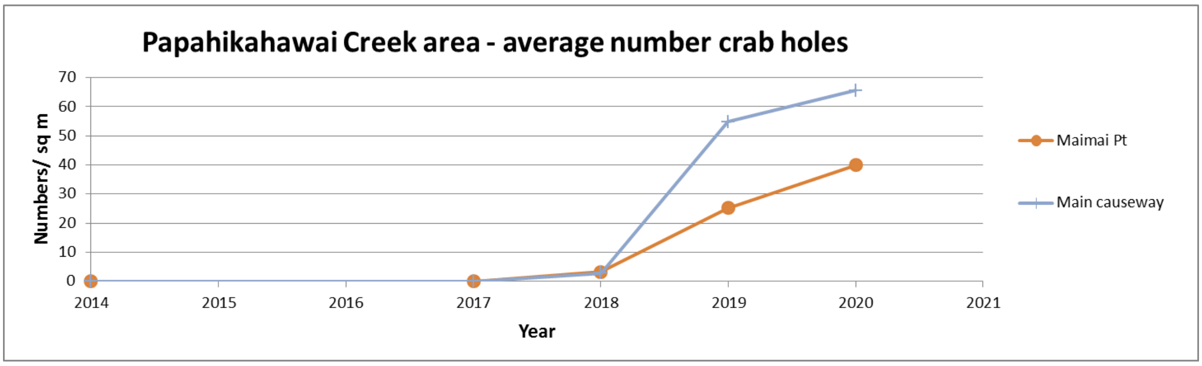


Figure 10, Density of crab holes recorded at the Main causeway and Maimai sites in the Papahikahawai Creek area from 2014 to 2020.

Some sites such as the Main Causeway have also shown good recruitment of titiko (mud snails) with density at this site having reached average numbers around 25 per square meter since the June 2017 restoration of tidal flows. In Figure 3 which is a photo overlooking this monitoring site, the numerous small white dots further out on the flats towards the water are titiko.

Summary – Papahikahawai Creek area

Before the re-opening of the impounded Papahikahawai Creek area, it was in a very poor degraded ecological state. Restoration of tidal flows has produced a dramatic reduction in the extent of the previous 100% macroalgal cover to near zero in most areas. Some improvement in the sediment condition has also been noted which is often linked to the reduction in macroalgal cover, or at sites where tidal flows are higher. However the extensive accumulation of mud and organic matter in the sediments does mean that improvements may take place slowly over a very long period and in some areas may not change much at all.

Despite the expected lag in improvement of sediment conditions for much of the Papahikahawai Creek area, it has shown a significant recruitment and increase in macrofaunal diversity over most of this area. Some areas such as the Causeway 2 site, already has numbers of species as high as would be expected for such a location.

The Papahikahawai Creek area now supports a range of polychaete, bivalve, crustaceans and gastropods which should continue to increase in density and diversity slowly over time. The renewed productivity of this area is also very obvious to the casual observer in terms of supporting vastly increased numbers of fish and birds which can now be seen in this area.

As expected, the only adverse impact that has occurred in the Papahikahawai Creek area is a die-back of rush around the margins. Prior to restoration of tidal flows the rushes had grown down to the mean tide level. Over time the surviving rush will likely expand upwards to higher tidal levels.

Changes noted in the wider estuary

As part of compliance and state of the environment monitoring there are 8 transects along which the cover and biomass of macroalgae has been recorded in Maketū Estuary and the results are shown in Figure 11 below. As a general overall trend most sites peaked in macroalgae cover in 2014 and in 2019 the majority of sites had the lowest levels seen for some time. In 2020 transects AT-1, -3, -4 and -5 all showed some increase of macroalgal cover in 2020 compared to 2019.

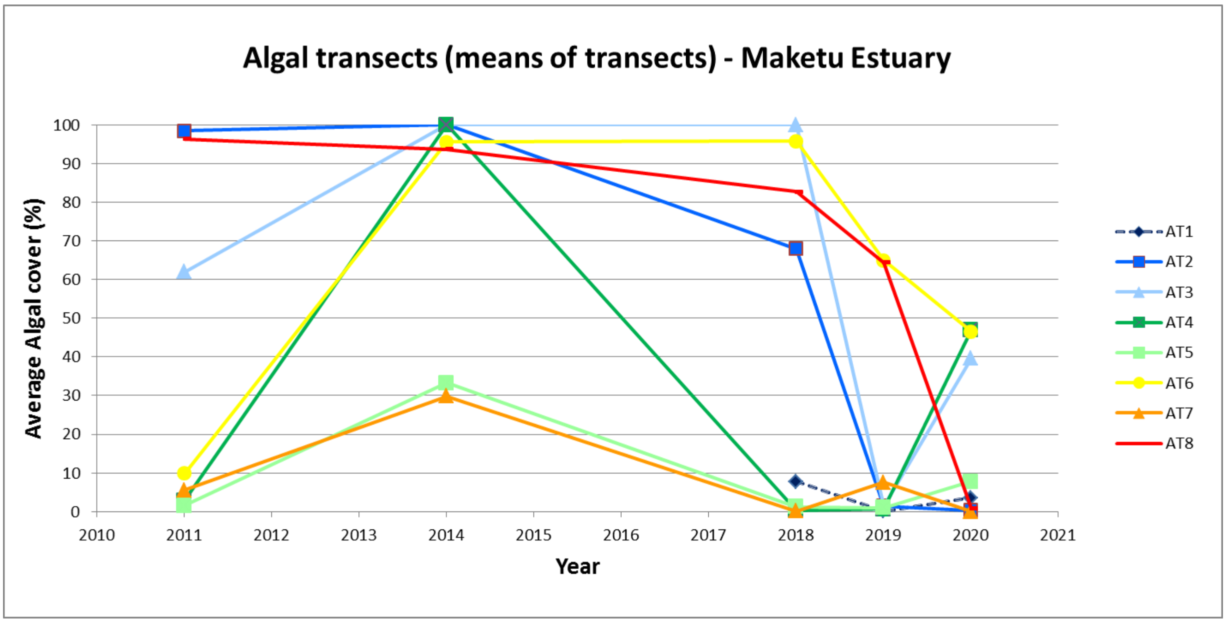


Figure 11, Mean macroalgal cover measured along transects throughout Maketū Estuary from 2011 to 2020.

Several sites around the estuary have for a number of years had consistently high cover and biomass of macroalgae. Transect AT2 is in the southern most region of the estuary and has, as shown in Figure 11, had a very high cover of macroalgae from 2011 up to 2018. Since 2018 this sites has largely cleared of macroalgae allowing improvement of sediment conditions and recovery of macrofaunal diversity (see Figure 12 below). A similar trend has been observed at AT8 which is the western most transect in the upper estuary. This site had a very high biomass of *Gracilaria chilensis* with patches of cyanobacteria which in the 2020 monitoring had cleared to near zero cover. The change in condition of this site between 2018 and 2020 is shown in the photos below (Figure 13) with abundant titiko present in 2020.

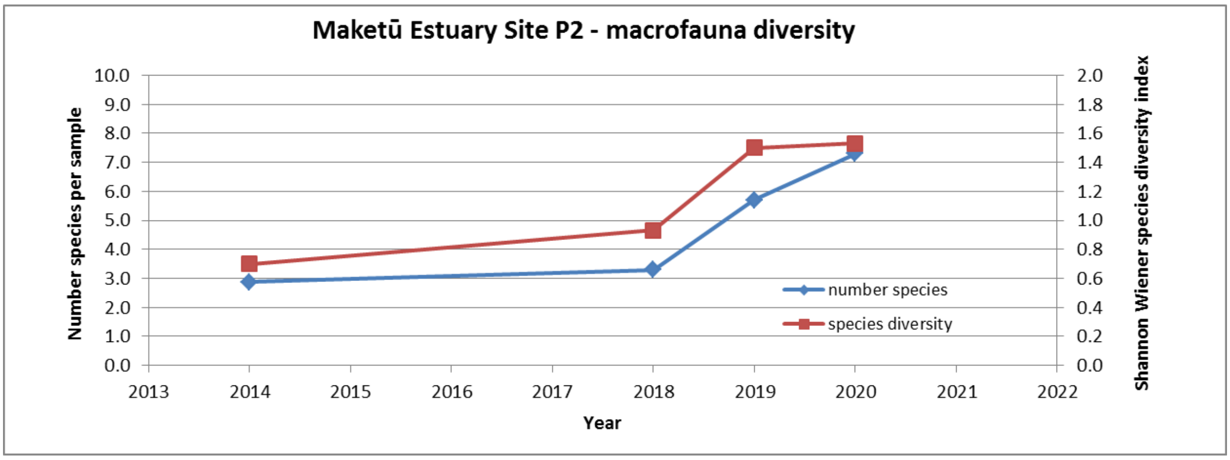


Figure 12, Mean number of macrofauna species and Shannon diversity index for Maketū P2 site from 2014 to 2020.

Figure 13, Photographs of site AT8 in the upper estuary in January 2018 (left) with macroalgal and cyanbacterial cover and in 2020 with no macroalgae or cyanobacteria and titiko present.

Another marked change that has occurred in Maketū estuary outside of the impounded area of Papahikahawai Creek, is in the same channel to the east of where the causeway had blocked it. The removal of the causeway increased the tidal flows along this channel which had several effects. One change was a reduction in the amount of macroalgae that was present in the channel. At site 38 in this channel, the macroalgal cover dropped from an average of 96% in 2017 just prior to the removal of the causeway, down to 0% in 2018 seven months after. A similar change also occurred further along at site 43c dropping from 78% to 0%.

Associated with the loss of macroalgae and the increased current flows in the open eastern section of Paphikahawai Creek has been an increase in shellfish numbers. This increase has been most notable at sites 38 and 38a further up the channel which most likely benefitted more from increased current flows. Figures 14 and 15 below show the increase in density of tuangi at each of these two sites. The drop in mean size of tuangi at site S38a between 2017 and 2019 is due to the large number of new tuangi recruiting to the population.

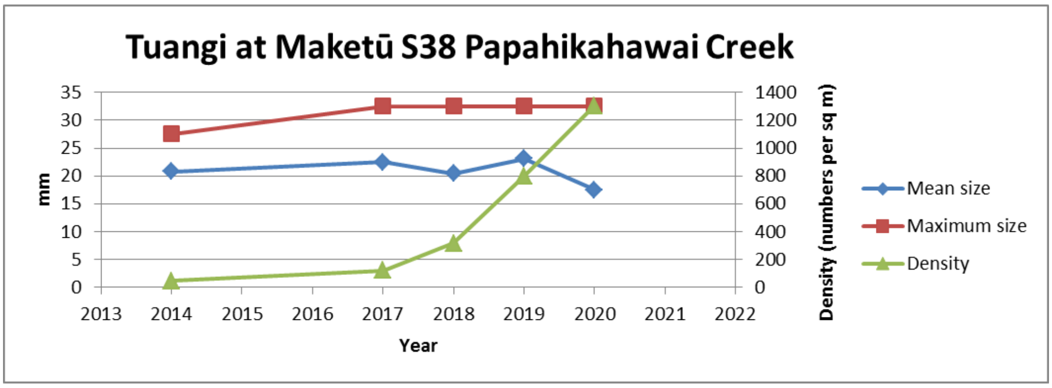


Figure 14, Density, mean size and maximum size of tuangi (cockles) at site S38 from 2017 to 2020 in the Papahikahawai Creek channel.

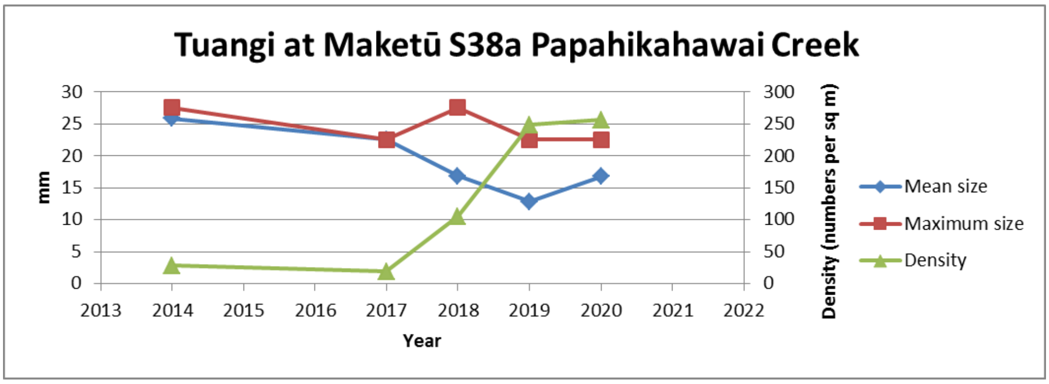


Figure 15, Density, mean size and maximum size of tuangi (cockles) at site S38a from 2017 to 2020 in the Papahikahawai Creek channel.

Results from DO and Salinity measurements

As set out in the background information, there have been a number of major hydrological changes to the Kaituna River and Maketū Estuary that will change the nature of the estuarine ecosystem. To monitor changes in dissolved oxygen and salinity levels in the upper estuary, loggers have been deployed for short periods at sites in the mid-upper estuary (water quality site 5) and in the Papahikahawai Creek area since 2017. As part of the Consent 67 958, these two sites will also be used for compliance monitoring as set by condition 32.1-3. These conditions require that dissolved oxygen and salinity are measured at these two sites for at least 14 days in the period from January to March, once within the first two years after commissioning, and once more within five years of commissioning. As the diversion flows were commissioned on the 12th February 2020, the logging measurements made at the two sites from 1st February to 17th March, 2020 also covers those compliance requirements for the first set of data logging.

In Figure 16 below the results of dissolved oxygen measurements are shown for the deployments made from 2017 up to 2020 at the Causeway 2 site in Papahikahawai Creek. The 2017 oxygen levels (% saturation) stand out as having consistently far lower levels of oxygen present in the water column. These levels of oxygen are very poor and will severely limit the species that could survive in this environment. The 2017 measurements were taken before the restoration of tidal flows to this area and measurements since then, all show some improvement, but remain at poor levels that will continue to have degree of impairment to the full life supporting capacity of this area. It is expected that levels of dissolved oxygen will tend to improve over time as the area continues to recover from all the changes that have occurred. In particular the northern block of previous farmland has only been exposed to the tides since June 2019 and will likely contribute to increased oxygen fluctuations for several years.

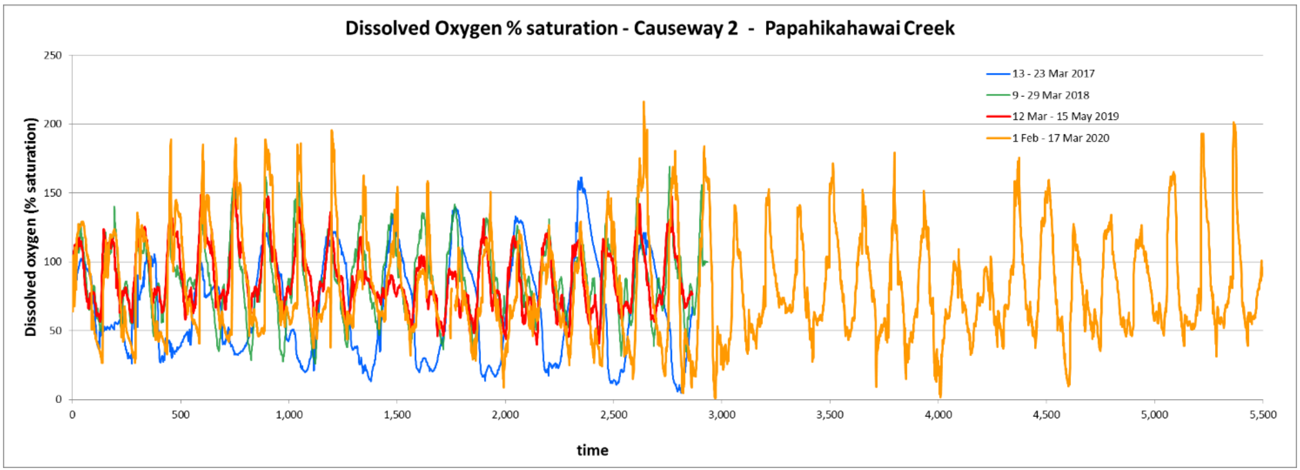


Figure 16, Dissolved oxygen levels (% saturation) recorded for short periods at the Causeway 2 site in Papahikahawai Creek from 2017 to 2020.

In the 2020 results, the change in diversion flow from 150,000 to 400,000 m^3 occurs at 1,600 on the time axis of Figure 16. It is apparent that drops in dissolved oxygen occur after this point, but given the changes taking place with increased movement of sediment and macroalgal beds that would occur with the increased current flows, the effect on dissolved oxygen appears to have been very minor. The results also indicate that the lower minimum dissolved oxygen values return to the same levels as prior the increased flow within three weeks.

In Figure 17 below, results are shown for dissolved oxygen levels measured in the water column at the mid-estuary WQ 5 site. As with the Causeway 2 site results in Papahikahawai Creek, there is an apparent drop in DO minimums observed after the increase in river flow on the 12th February 2020. There was also some concern that the sensor had been placed too close to the bottom in the February deployment and suffered from smothering by drifting algae. The data that clearly showed such effects has been removed from the data set. Then a re-deployment at this site in April 2020 at a slightly higher level above the bottom resulted in far less variable levels of oxygen than the earlier February measurements and show improvement in conditions compared to the exact same time of year in 2019.

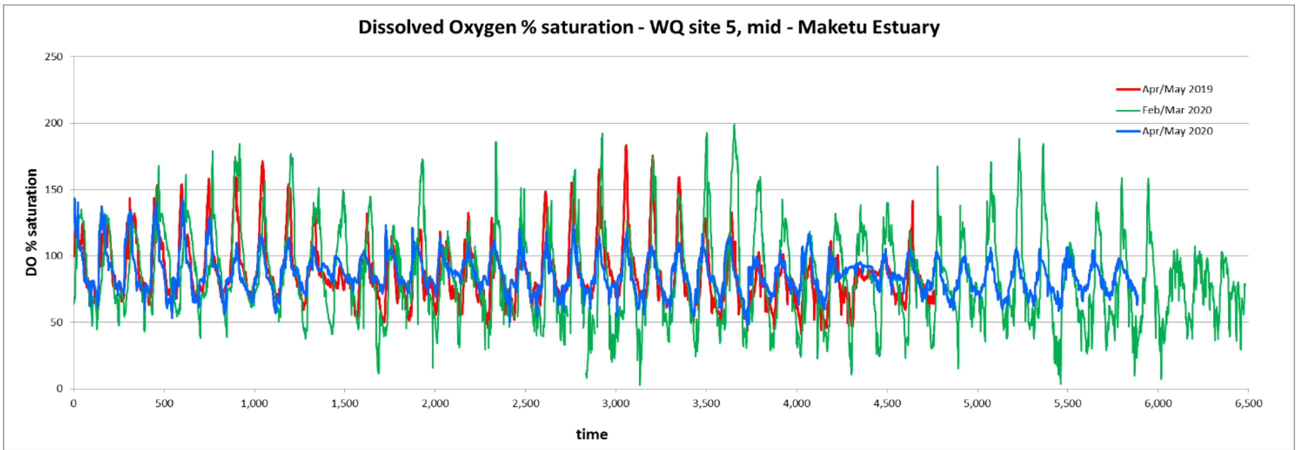


Figure 17, Dissolved oxygen levels (% saturation) recorded for short periods at the WQ 5 site in the upper mid area of Maketū Estuary in 2019 and 2020.

Changes to salinity levels at the mid estuary WQ 5 and Causeway 2 site in Papahikahawai Creek are shown in Figures 18 and 19 below. The 2019 measurements at both sites were made while there was no river flow occurring and shows the marked drop in salinity being achieved with the re-diversion of the Kaituna River. Modelling (DHI, 2014) shows that with the full flow (600,000 m^3 per tidal cycle) it is expected that salinity levels at the Causeway 2 site would be around a salinity of 10 on average. In Figure 18 it can be seen that after the re-diversion flows increased from 150,000 to 400,000 m^3 (about 1,600 on time axis), salinity has dropped to this level for brief periods of time. Similar results are shown in Figure 19 for the WQ 5 site in the mid estuary at which modelling predicts salinities to sit around an average of 15 -20 for full flow.

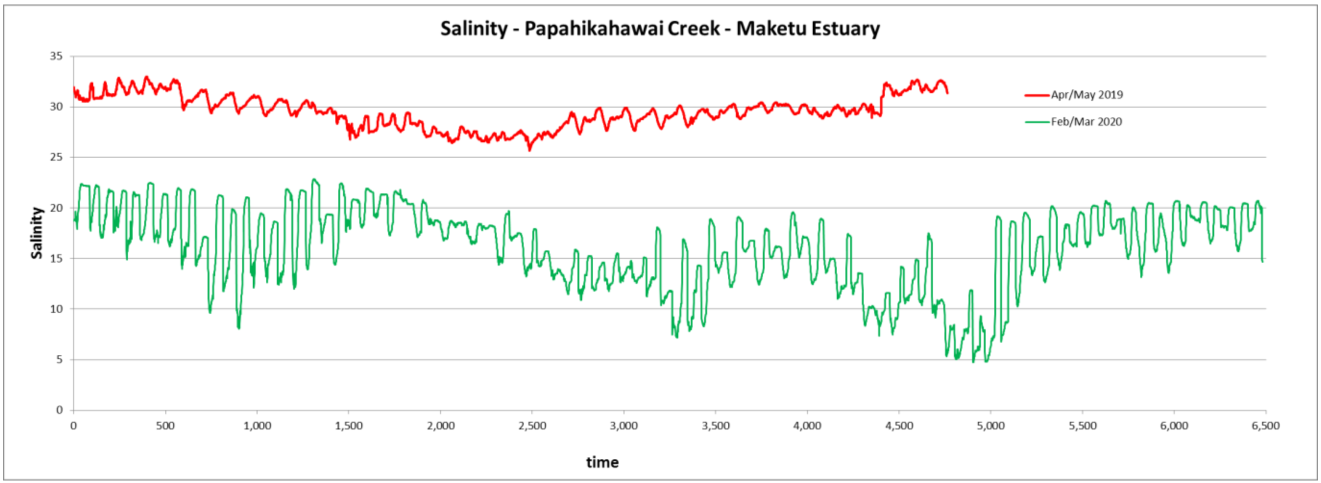


Figure 18, Dissolved oxygen levels (% saturation) recorded for short periods at the WQ 5 site in the upper mid area of Maketū Estuary in 2019 and 2020.

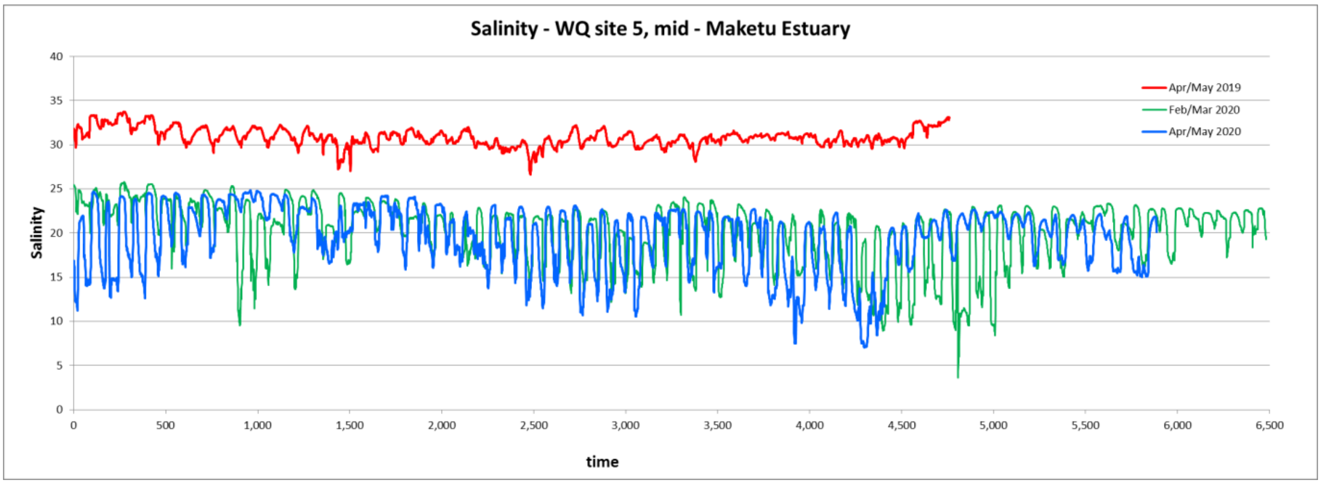


Figure 19, Dissolved oxygen levels (% saturation) recorded for short periods at the WQ 5 site in the upper mid area of Maketū Estuary in 2019 and 2020.

Te Pā Ika wetland

The restoration of tidal flows into the former reclaimed farmland now called Te Pā Ika (adjacent and east of Ford Road) has been quite recent with the southern half having been open to the estuary since September 2018. Two monitoring sites (P9 & P10) established in this area and monitored for macrofauna in 2020 show that recruitment of estuarine macrofauna has occurred. Both these sites had around 3 species recorded in each sample taken. Polychaete worms, amphipods and crabs being the predominant macrofauna groups present at both sites. The northern half of Te Pā Ika was only opened to the sea in Jun 2019. Results of January 2020 macrofauna monitoring in this area (site P11), showed results very similar to the mean number of species and composition as that of the southern Te Pā Ika area.

Sediments at the Te Pā Ika sites (P9-P11) are currently quite muddy (28 – 46% mud content) and have moderate levels of nutrient and organic content (TOC) present. The nutrient and TOC levels are however lower than some nearby estuary sites covered by macroalgae. It is expected that the sediments are likely to show some degree of change over the next decade as parameters settle to new equilibrium states. Hence some improvement may be possible, although conditions are already similar to what might be expected in this type of upper estuary, high tide level environment.

Papahikahawai Island wetland

There are no monitoring sites in this restored intertidal wetland area. However casual inspection of the area in January 2020 showed that rush present before being opened back up to the sea has survived and that some additional estuarine plant recruitment is taking place. As with the Te Pā Ika wetland area, there is notable crab recruitment taking place and wading birds are seen feeding in the area.

Changes in sediment Accumulation Rates

It is too early to pick up changes in sediment accumulation rates monitored in Maketū Estuary in relation to the increased flows from Kaituna River as monitoring occurred prior to that change. It may also take several years to reliably detect any effects on sedimentation even at sites that will be influenced by changes in current speeds and sediment transport. There is however one site that has shown a response to changes in current flows. That is the Maketū P8 site in the upper estuary located just to the south of the main causeway that was removed in September 2018. The removal of this causeway and the opening up to the sea of the former farmland has resulted in increased currents across this site. Prior to these changes the site had little water flow across it and had been accumulating sediment at a rate of 11 mm per year up to July 2019 since being installed (Jan 2017) as shown in Figure 20 below. In the period between July 2019 and January 2020, 69 mm of sediment have been lost. This area of the estuary is quite sheltered and there were no signs of disturbance to the site, so it is clear that there has been a loss of sediment across this area. The sediments that were accumulating on the site were very fine and muddy, so would have been quite easily eroded with any increase of current speeds.

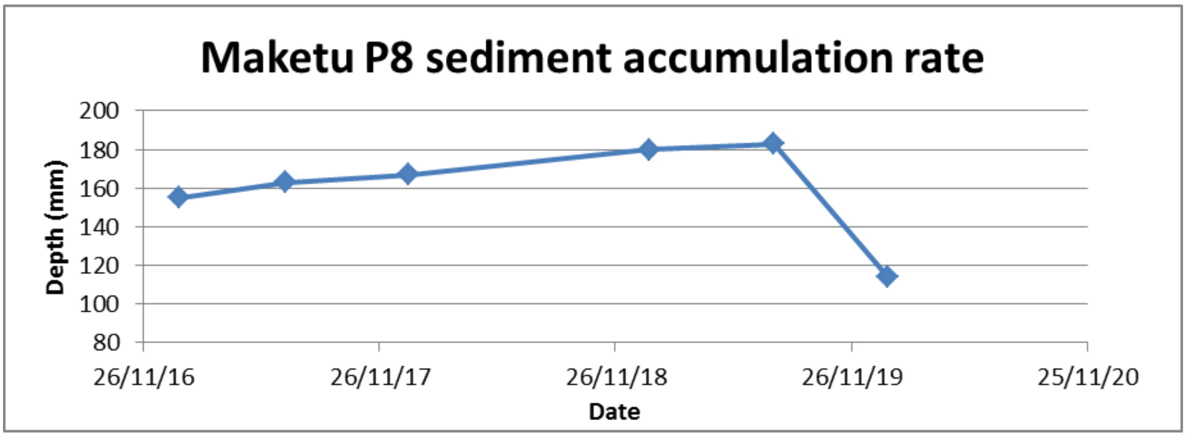


Figure 20, Sediment accumulation rate measured at the Maketū Estuary P8 site between 2017 and 2020.

Other sediment parameters measured at the Maketū P8 site also show an associated marked change and support the result shown in the sedimentation monitoring. The average value of the previous three years (2017-2019) is compared to 2020 results for the following parameters; Mud (%) 55 / 28, Total Organic Carbon (%) 1.8 / 0.48, Total Nitrogen (g/100g) 0.21 / 0.05 and Total Phosphorus (mg/kg) 387 / 179. Site P8 is also shown in Figure 13 comparing the differences seen in the reduction of macroalgal cover and increase in macrofauna. Sites that lose thick macroalgal cover do tend to lose some sediment, such as P2 which has recently lost 5 mm of sediment. Hence, some of the sediment loss at P8 could be attributed to this mechanism alone, but it is unlikely that the loss would have been anywhere near the extent seen without the change in current speeds.

Conclusions

The restoration projects that are taking place around Maketū Estuary are being monitored for a range of physical and biological parameters that can be used to evaluate the health of the ecosystem. As covered in this memo there is a very obvious improvement to the previously cut-off section of Papahikahawai Creek. Since having tidal flows restored it has cleared of nearly all the macroalgae and cyanobacterial mats that were previously covering this area. The sediments in this area were in a very poor state and those areas where there are now good current flows have shown marked and consistent improvement to levels that might be expected from an equivalent estuarine site in fair condition. However much of this area has low current flows and is showing improvement, but will take a longer period to recover to the full potential.

Restoration of tidal flows, clearance of macroalgae and improvement in the quality of the sediments has resulted in the Papahikahawai Creek area being colonised by a range of estuarine species. One of the more prominent early colonisers has been the crabs and titiko. The level of productivity now occurring supports an obvious increase in the numbers and species of fish and bird life feeding in this area.

The opening of the former farmland to the sea (now referred to as Te Pā Ika wetland) is a recently completed project and monitoring has only occurred once this last summer. However that monitoring has shown that colonisation of the area by estuarine macrofauna has been relatively rapid, especially for the northern half which had only been restored to the sea six month prior to sampling. Therefore it was surprising to see the number macrofauna species and composition to be very similar to the southern area of Te Pā Ika. The Papahikahawai Island wetland restoration area is not monitored, but inspection of the area shows that most of the same changes appear to be taking place.

In parts of the upper estuary outside of the previously cut-off Papahikahawai Creek area there have been improvements noted as a result of increased current flows. This includes improved sediment conditions in the upper estuary around site P8 and increased numbers of tuangi in the Papahikahawai Creek channel.

In the mid and lower Maketū Estuary some changes in ecology have been observed but these are more likely the result of natural cycles of change. There has been a reduction in overall extent of macroalgal cover since 2014, but several sites have shown a slight increase over the last year, especially in the abundance of sea lettuce. The expectation of increased river flows into the estuary is that it may export and reduce the overall extent of macroalgae and this may become apparent in future surveys.

Overall, the monitoring results show that changes made in opening back up a number of areas to the estuary has not had any notable adverse consequences for the ecology of the ecosystem and that restoration is occurring throughout all these areas with visible positive improvements in the whole ecosystem.

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