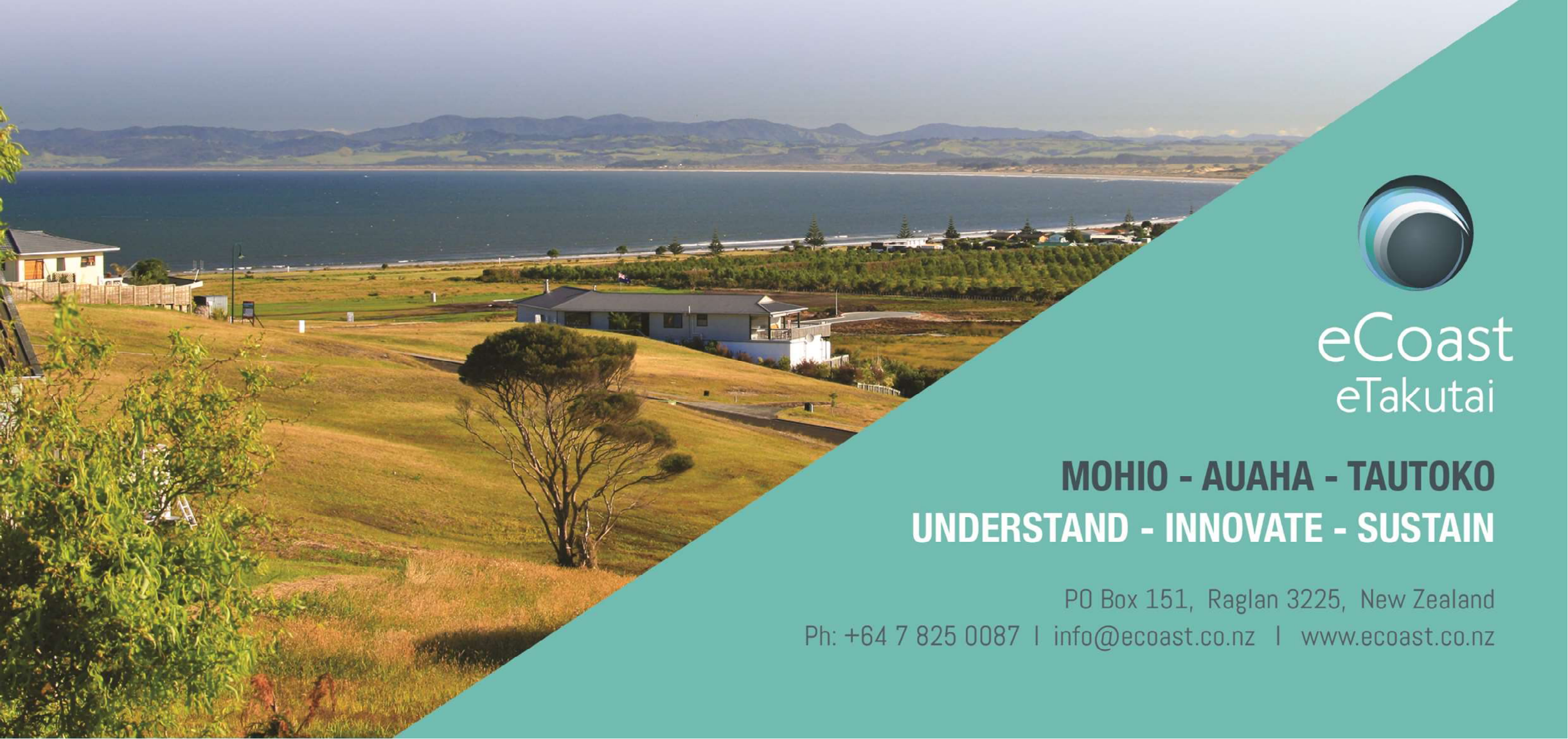
[eCoast, 2018:C5]

Wairoa Wastewater Treatment and Discharge – Assessment of Environmental Effects – Marine Ecology

Prepared for

Wairoa District Council



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Report Status

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Executive Summary

- This assessment of environmental effects relates to a 30 year resource consent renewal being sought by Wairoa District Council (WDC) as it relates to the discharge of treated wastewater into the lower Wairoa Estuary via subtidal outfall. The present-day environmental state of the Wairoa Estuary is degraded and widely impacted by sedimentation.
- Ecological effects relating to the existing sewage outfall have been assessed previously in a series of monitoring events and are used, in part, to support this current assessment of environmental effects. Collectively, these studies could find little evidence for negative environmental effects for sediment quality and benthic community composition associated with the existing wastewater discharge. This partly relates to the sampling design, but also the wider degraded environmental state of the Wairoa River and lower estuary.
- In an effort to reduce impacts associated with existing and future wastewater disposal into a degraded receiving environment, WDC has proposed a series of strategic modifications to land-based treatment processes, storage capacities, and disposal regimes (via the outfall). These will be implemented in stages.
- The strategic staged modifications will improve the wastewater quality and thus reduce the potential for negative impacts environmental which are likely to be negligible over the longer term. Improvements to the benthic ecology will also rely on improvements being made to upstream catchments to reduce sediment and other contaminants entering the Wairoa River that are transported to the lower estuary.
- An environmental monitoring programme is proposed that will provide essential data that can evaluate the extent and magnitude of both positive and negative effects to benthic ecology for current operations and future planned modifications.

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1 Introduction

This report covers potential marine ecological effects in relation to renewal of a resource consent for the Wairoa District Council (WDC) to discharge treated wastewater emanating from the Wairoa wastewater treatment plant ("WWWTP"). The current permitted discharge is up to a maximum of 5,400 m^3 per day. The discharge consent authorising this activity expires in May 2019. As part of the renewal process a series of upgrades to the WWWTP, outfall, and discharge protocols are planned – these are summarised in Table 1.1 from LEI (2018); refer to LEI (2018) for supporting documentation. The rationale behind the modifications is to through time, reduce the likelihood for adverse impacts emanating from treated wastewater disposal on occur within the lower Wairoa Estuary. This will be achieved through a range of best practicable option and associated mitigation methods that include:

- wastewater irrigation to a series of farms;
- reticulation renewals and upgrades to reduce flows to WWWTP;
- reductions of reticulation leakage and pump station overflows;
- filtration and UV irradiation at the outlet of the WWWTP ponds to improve the discharge quality (remove pathogens and reduce algae);
- installation of treated wastewater storage facilities;
- reducing discharges (volumes and frequencies) to the Wairoa River as a direct result of progressively implementing irrigation to land and constructing additional storage facilities; and,
- support for wider Wairoa River catchment improvement projects.

These initiatives are presented in detail in LEI (2018). Sediment quality (geochemistry) and benthic ecology as it relates to the WWWTP outfall has been evaluated in a series of monitoring events that have focused on assessing levels of sediment contaminants (trace metals, nutrients and organic content) and invertebrate community composition. These abiotic and biotic parameters are used to underpin the assessment of environmental effects as it relates to the proposed changes to the WWWTP infrastructure and discharge regime over the next 30 years (Table 1.1).

The following sections in this report include: Section 2.0 – A summary of the present-day ecological condition surrounding the subtidal outfall and main findings from historic ecological monitoring of the lower Wairoa River and Estuary; 3.0 – An assessment of potential environmental effects on sediment geochemistry and benthic ecology in relation to the proposed modifications to the WWTP infrastructure and wastewater disposal; and, 4.0 a proposed ecological monitoring programme that can be implemented to evaluate ecological effects associated with WWWTP discharges through space and time. Recommended resource consent conditions are presented in Section 5.0, which is followed by suggested monitoring protocol (6.0).

Table 1.1. Summary of Wairoa's Future Treated Wastewater Discharge System.

Stage Timing	**Storage Capacity#**	**Irrigation Area#**	**River Discharge Parameters***	**Pump Station Overflows#**
Stage 1 0-5 years	No change (5,400 m^3 within the 2nd WWWTP pond).	Develop up to 50 ha	Below ½ median river flows: <1,600 m^3/d discharge on outgoing tide at night only. ½ median to median river flows: <3,000 m^3/d discharge on **any** outgoing tide. Median to 3 x median river flows: <5,000 m^3/d discharge on **any** outgoing tide. Above 3 x median river flows: unlimited discharge at any time.	Occur less often than now (<10 events/year). Triggered during larger storms.
Stage 2 6-10 years	Increase total to about 10,000 m^3	Expanded up to 100-150 ha total	Below ½ median river flows: <1,600 m^3/d discharge on outgoing tide at night only **but limited to no more than 30 days discharge in December to March**. ½ median to median river flows: <3,000 m^3/d discharge on any outgoing tide. Median to 3 x median river flows: <5,000 m^3/d) discharge on any outgoing tide. Above 3 x median river flows: unlimited discharge at any time.	Rare (<8 events/year); only during larger storms.
Stage 3 11-20 years	Increase total to 50-100,000 m^3	Expanded up to 300 ha total	Below ½ median river flows: **no discharge at any time**. ½ median to median river flows: <3,000 m^3/d discharge **only on outgoing tide at night**. Median to 3 x median river flows: <5,000 m^3/d discharge on any outgoing tide. Above 3 x median river flows: unlimited discharge at any time.	Very rare (<4 events/year); only during very large storms.
Stage 4 21-30 years	Increase total to 200-400,000 m^3	Expanded up to 600 ha total	Below **median** river flows: no discharge at any time. Median to 3 x median river flows: <5,000 m^3/d discharge **only on outgoing tide at night**. Above 3 x median river flows: unlimited discharge at any time.	Very rare (<4 events/year); only during unusually large storms.

Notes: * bold text highlights what is changing within each stage.
intended changes which depend on commitments outside resource consent processes.

2 Ecological condition and spatial/temporal trends in the Wairoa River receiving environment

2.1 Background Information

The Wairoa Estuary is a river mouth estuary approximately 9,700,000 m^3 in volume with two bar-built lagoons, the Whakamahi and Ngamotu lagoons, at its mobile entrance. The estuary marks the end point of Te Wairoa Hōpūpū Hōnengenenge Mātangi Rau awa which sits within a catchment area of 356,300 km^2 of which 264,547 km^2 is within the Hawke's Bay regional boundary – this is Hawke's Bay's largest catchment. The lower Wairoa Estuary has a wide range of estuarine habitats including sandspits, mudflats, lagoon and salt marsh habitat and the area comprising the lagoon, sandspit, and lower mudflats region is a Department of Conservation Wildlife management reserve (Cheyne and Addenbrook, 2002) and is designated by the Hawke's Bay Regional Council (HBRC) as a significant conservation area due to its biodiversity values. An early summary document of New Zealand's estuaries (McClay 1976) inferred that the environmental condition of the Wairoa Estuary had worsened between the period of 1965 and 1976 and in 1976 was classified as moderately polluted. This is still likely the case today (HBRC 2016).

Birds of significance associated with the estuary include Australasian Bittern (*Botaurus poiciloptilus*), Marsh Crake (*Porzana pusilla*) Spotless Crake (*Porzana tabuensis*) and the Royal Spoonbill (*Platalea regia*). The Wairoa Estuary, as for other estuarine areas within Hawke's Bay, serves as a nursery ground for flounder, short and long-finned eel, and inanga. Both cockles and pipi occur within the estuary proper and fresh water mussels (kakahi) were also historically abundant (Haggitt and Wade, 2016).

Hawke's Bay Regional Council (HBRC) established formal benthic monitoring within the estuary in 2011 at a site approximately 600m upstream of the outfall. Results from this monitoring suggest that sediment contaminants (trace metals, nutrients) are not problematic within the estuary, whereas impacts associated with sedimentation and recreational contact for the upper river adjacent Wairoa Water Ski Club, i.e., well beyond the zone of influence associated with the outfall were problematic (HBRC, 2016). Other stressors include storm water discharges and additional industrial discharges.

2.2 Sediment geochemistry and benthic ecology

Since granting of the existing 20 year resource consent in 1999, ecological effects including sediment geochemistry adjacent to and at set distances away from the outfall been evaluated an additional four times as follows: EAM 2007 & 2011, Triplefin, 2018 and eCoast, 2018[1]. A baseline survey was undertaken in 1996 (Larcombe, 1996) and a dye dilution study was carried out in 2007 to evaluate mixing (Barter 2007). The ecological and sediment geochemistry surveys carried out between 1996 and 2018 have been predominantly focused on three sites that comprise two potential impact sites and one control (site Site C). These core monitoring sites are located as follows: Site A ~ 100 m south of the outfall discharge point; Site B ~ 100 m north of the outfall discharge point; and, Site C ~ 500 m north of the outfall discharge point (Figure 2.1). The 2017 survey (Triplefin 2018) added a further site (Site D) ~100m north-west, or inshore, of the outfall adding a 3rd potential "impact site" whereas the eCoast (2018:A3D3) study evaluated an additional 7 sites (Figure 2.2) in order to better describe the wider receiving environment of the Wairoa River and Estuary region and allow for additional control and impact data collection. Full details of the monitoring programmes including temporal and spatial trends have been detailed in the eCoast (2018:A3D3) report, while a brief summary of the findings are presented below.

Following on from the 1996 baseline survey (Larcombe, 1996) the majority of ecological surveys could find no strong evidence that wastewater discharges emanating from the outfall were impacting the immediate benthos or ecological communities in any more than a minor way. Strongest impacts were evident for sediment quality at Site A (2007, 2017) and occasionally Site B (2007, 2018) that reflect slight increase in organic material. In general, biodiversity was found to be low to moderate for all sites across surveys and while there was strong evidence for community composition to be statically different across surveys this was driven by changes in a few dominant species and tended to be consistent for all sites surveyed (A, B, and C), i.e., temporal variation more prominent than between site differences. This was unsurprising given the dynamic nature of the receiving environment concomitant with infrequency of sampling events. Numerically dominant species recorded at sites A, B, and C are typically considered to be synonymous with degraded/impacted environments (local nutrification). This was also true for the additional new sites, although abundances are lower than at Sites A-C and pipi were found to occur at much greater densities at sites further away from the outfall suggesting ecological impacts are mostly in close proximity to the outfall.

[1] The WDC is not formally required under the existing consent conditions of CD940404W to undertake ecological and sediment contaminant monitoring surrounding the outfall.

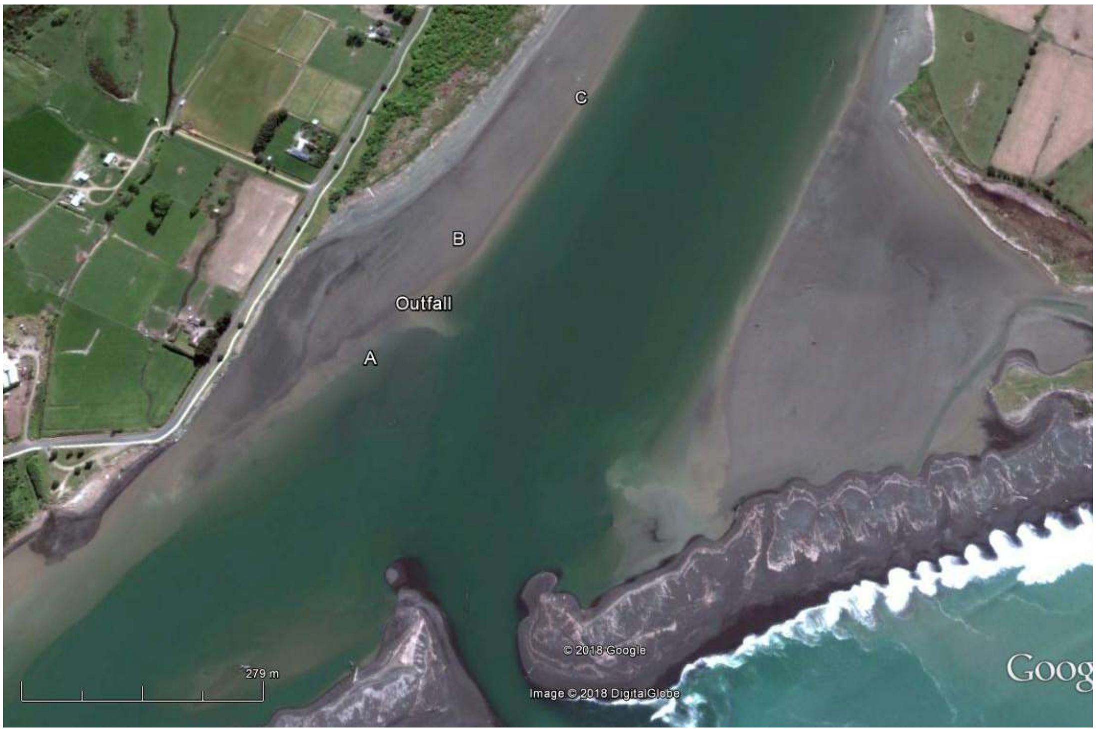

Figure 2.1. Historic sampling locations within the Wairoa estuary. A and B are potential impact sites located 100m north and south of the existing outfall. C is a control site.

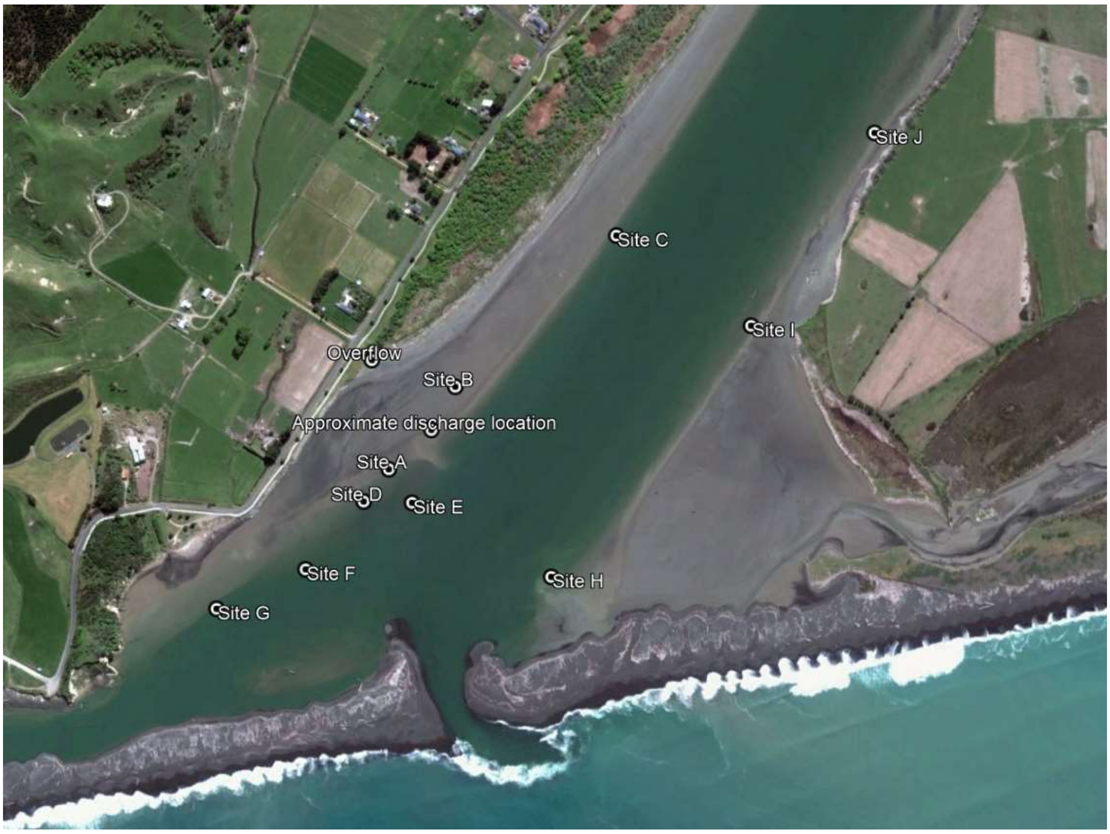

Figure 2.2. Sampling sites surveyed in 2018, eCoast (2018:A3D3).

Table 2.1. Summary of key findings from the monitoring studies undertaken to evaluate potential effects of the Wairoa Wastewater treatment plant on benthic ecology and sediment quality. The 1996 survey was a baseline study.

Survey	Findings
1996	The discharge was found to have no obvious effects on either benthic biology or sediment quality (Larcombe, 1996)
2007	There was evidence for discharge-related effects on sediment quality and community composition around the outfall (Sites A and B), although effects were not considered to be adverse (EAM, 2007). Trace metal concentrations were evaluated in flatfish from Wairoa estuary and compared to Mangawhio (reference) and other wastewater outfalls in Hawke's Bay. It was concluded that the concentration of the majority of trace metals were low and would not pose a health hazard.
2011	Examination of the sediment texture and chemistry results, combined with the benthic infaunal characteristics indicated that there was no evidence to suggest that the outfall was having large adverse effects on the receiving environment other than local changes (EAM, 2011) "*Given the decreased species diversity there is some evidence that overall conditions in the river estuary are deteriorating over time. Additionally, the WDC discharge is also a measurable contributing stressor to infaunal communities, particularly at the downstream "impact" site A, and this is in evidence as an increased level of variability among the summary indices compared to the other monitoring sites"*
2017	There was evidence for a persistent adverse effect on sediment quality from organic loading in the area 100m downstream of the outfall (Site A); however, this was not having any major adverse effect on benthic community health. The contribution of this effect to deterioration of estuary health was concluded to be no more than minor.
2018	Numerically dominant species enumerated at sites A, B, and C were considered to be synonymous with degraded/impacted environments. This was also true for the majority of the additional 7 "new sites", surveyed although abundance and diversity was found to be lower than at the sentinel Sites A-C. Pipi (an important indicator species of ecosystem health) were found to occur at greater densities with increasing distance away from the outfall, suggesting a local minor impact to the benthic ecology.

	For both sediment-bound contaminants and nutrient levels there was generally no consistent pattern across sites, the exception being Site B (100 m to the north of the outfall) that generally had higher sediment bound contaminants than other sampling sites. There was also a lack of a clear trend for both silt and organic content in relation to increasing or decreasing distance away from the outfall and thus no strong evidence that the outfall is impacting the immediate benthos in a major way. Hydrodynamic modelling of bed shear stress matched closely with sediment grain size analysis (eCoast, 2018 C1.1), which confirmed that the lack of distinct trends were due to the complex current patterns in the lower estuary.

The eCoast (2018:A3D3) study suggested that previous monitoring undertaken between 1996 and 2017 was insufficient to provide a useful indication of the magnitude and extent of the impacts of the outfall and the ecological health of the wider estuary associated with the discharge due to a combination of low site (spatial) replication and low temporal resolution (4 surveys done over a 20 year period). This is of particular importance when placed in the context of the dynamic nature of the receiving environment that has high variability in surficial sediment composition, i.e., alternating between periods of high mud, high sand/silt content and various combinations of the two. These findings suggest that activities taking place further upstream can often exert a strong influence on the lower Wairoa River estuary over and above impacts associated with the wastewater outfall. The 2018 eCoast survey was also limited by a lack of information to guide site selection (e.g. hydrodynamic modelling), however, through the increase in the number of sampling sites allowed for a greater evaluation of the environmental state of the lower estuary.

Species community composition in 2018 was found to differ among survey sites with historical sites A, B, and C having similar species composition and higher species diversity compared to the 7 new sites added to the programme. Numerically abundant species associated with sites A, B and C included the amphipod (*Paracorphium excavatum*) and polychaetes (*Scolelepis sp*. and *Nicon aestuariensis*). All are synonymous with degraded/muddy or impacted environments (see Hewitt *et al*. 2006; Rowden *et al*. 2012) with the high abundances a likely response to local organic enrichment typical of this region of the estuary. This was found to be also true for the new sites surveyed in 2018, although abundances were found to be lower than at Sites A-C. However, pipi (*Paphies australis*), an important indicator species of ecosystem health, were found to occur at much greater densities at sites further away from the outfall, suggesting a local minor impact to the benthic ecology.

Severity of impacts related to the wastewater treatment plant discharge are most likely to be greatest when the estuarine mouth is partially blocked or closed and when the WWTP storage capacity for effluent is exceeded and this effluent has to be discharged into the estuary during these 'restricted flow' conditions. In addition during some storm events the total daily volumes discharged can also exceed the consent limit of 5,400 m^3/d limit. No formal benthic monitoring has been undertaken during or following these periods to gauge the magnitude of impacts associated with such events. However, numerical modelling indicates that although discharge volumes are greater during high rainfall events, the associated increased river flow rates result in relatively fast dilution within 100 m of the outfall (eCoast, 2018:C1.1).

Evaluating impacts of the outfall on benthic effects is generally difficult given the low species diversity and wider degraded nature of the lower Wairoa Estuary, as well as the initial monitoring only having two potential impact sites within the outfall mixing zone (which is evident based on the 2018 survey and the differences found at Sites A-C in comparison to the rest of the new locations surveyed in 2018); and, sparse temporal resolution.

3 Assessment of Environmental Effects – Marine Ecology

Resource consent is being sought by Wairoa District Council for the discharge of treated sewage effluent emanating from the WWTP into the lower Wairoa River/Estuary via an existing subtidal outfall.

3.1 Impacts to sediment quality

Based on previous monitoring the high variability in trace metals, sediment nutrients, total volatile solids and organic content among sites through time is likely related to the highly dynamic nature of the receiving environment characteristic of the Wairoa River and lower estuary (eCoast, 2018:C1.1). For the most part, all components measured to gauge the magnitude of any impact have been routinely found to be either below ANZECC ISQG – Low sediment quality guidelines, or synonymous with low to moderate highly localised enrichment of sediments. The Wairoa Estuary is also comparable to other Hawkes Bay reference estuaries with sediment quality parameters measured not significantly elevated, and lies in the mid-range of values throughout New Zealand (eCoast 2018:A3D3). Of the three sites consistently evaluated, both site A and site B located 100 m up and downstream of the outfall (i.e. the closest monitoring sites to the outfall) are the ones that have exhibited signs of organic enrichment. While increased enrichment has the potential to invoke negative impacts on benthic ecology there is no strong evidence that this has translated into more than minor negative biological effects in terms of community composition or benthic diversity (Triplefin 2018; eCoast 2018:A3D3).

Therefore, with reference to historical monitoring information, should discharges remain in accordance with current discharge rates it would be expected that the spatial and temporal variation of constituents measured would likely persist and would be unlikely to worsen. As such the modifications to the wastewater treatment as outlined in (Table 1.1) is therefore likely to significantly reduce impacts associated with organic enrichment to the immediate benthos through time and therefore would be considered to be an improvement to the present-day discharge practises.

Given the planned staged approach to the WWWTP upgrade, negative effects (impacts) to the sediment geochemistry and thus sediment quality are likely to remain similar to those levels found for the short-term (0-5 years) and have the potential to even improve over the longer-term (> 10 years), assuming that upstream activities that deposit sediment and other contaminants into the lower estuary region do not worsen through time.

Resultantly, any adverse effects associated with the existing wastewater treatment and discharge (irrespective of planned improvements) will likely continue to be highly localised and be no more than minor. The planned improvements in terms of reducing discharges (volumes and frequencies) to the Wairoa River as a direct result of progressively implementing irrigation to land and constructing additional storage facilities will invariably reduce the scale of any potential adverse effects through time. An additional beneficial improvement is that the discharge quality can be improved so that it is analogous to or better than the river water quality it is discharged into. Through time the planned measures outlined in Table 1.1 have the potential to result in improved environmental quality with any potential negative effects associated with the outfall on sediment quality becoming negligible within the context of the mixing zone and wider receiving environment.

3.2 Impacts to benthic ecology

Because benthic (epifanual and infaunal) community composition is inextricably linked to the nature of sediment composition (grain size and organic content, contaminant levels, *etc.*) changes to these key parameters, particularly organic and mud contents will ultimately influence the assemblage structure and biodiversity through space and time. The high variability in species composition among sites through time to a degree reflect variation in physical parameters with the 2018 survey emphasising empirically the wider degraded nature of the lower region of the lower Wairoa river estuary. As such, Impacts associated with the outfall are difficult to establish, although appear negligible against the wider ecological state of the lower estuary region, particularly in terms of biodiversity and abundance. Therefore if no changes were made to the existing wastewater treatment plant it would be expected that community composition would remain similar to that quantified in previous surveys, i.e., low overall biodiversity and species abundances with minor local impacts.

Improving the discharge quality through time including reducing both volumes and discharge frequencies to the Wairoa River as a direct result of progressively implementing irrigation to land and constructing additional storage facilities certainly has the potential to improve environmental conditions within the zone of influence of the existing discharge plume. As such, we could expect species biodiversity and abundances of some species to increase through time, although this is unlikely to be immediate and again would be strongly contingent on other factors such as the channel dynamics (governed by hydrodynamic processese) and upstream influences, especially sedimentation. Potential effects associated with the staged upgrades are therefore likely to be positive rather than negative in outcomes.

Stage 1 (0-5 years): The 5 year period governing Stage 1 for the most-part represents a "business as usual" scenario and, as such, effects associated with the proposed wastewater discharges are likely to remain negligible for the existing benthic ecology that is presently synonymous with a degraded environments; albeit supporting a higher biodiversity and abundances than at sites in other parts of the lower Wairoa Estuary. The present-day benthic community composition, diversity and individual species abundances would unlikely change dramatically over the first 5 year period. However, the adoption of the monitoring programme outlined in Section 6.0 is likely to provide better understanding on the likely impacts (positive and negative) that could be expected to occur in relation to the proposed WWWTP upgrade.

Stage 2 (6-10 years): The Stage 2 period will see the first major change to existing discharge protocols in terms of restricted discharge to the CMA due to increased provision for storage and disposal to land (Table 1.1). The restricted discharge over the summer periods is seen as a positive environmental outcome and should reduce any potential impacts associated with summer disposal – e.g., nuisance algal growth within the lower estuary. Any adverse effects associated with the disposal of wastewater over this period again is likely to be negligible.

Stage 3 (11-20) and 4 (21-30 years) The modifications to WWWTP associated with Stage 3 and Stage 4 have the potential to exert greatest positive effects on the lower estuary, particularly the elimination of wastewater disposal entirely when river flows are below ½ median flow (Stage 3) and for Stage 4 when the river is below median flow (Table 1.1). These measures combined with the other wastewater discharge options outlined for Stage 3 and 4 represent significant improvements to current practises, therefore negative effects to the benthic ecology in relation to wastewater disposal are likely to be insignificant.

Discharge of wastewater into the Wairoa River irrespective of the developmental stage are unlikely to have any impact on recreational activities associated with shellfish and gathering and fishing. This, in part, relates to the low abundance and size of species such as pipi enumerated within and outside the mixing zone (eCoast (2018:A3D3) and the EAM (2007) study that evaluated trace metal concentrations within flounder. Furthermore, impacts to the shallow coastal area beyond the Wairoa estuary mouth from the WWWTP wastewater disposal outlet have not been evaluated. This is largely due to the dynamic nature of this coastal area (high wave energy and tidal mixing) and difficulty in evaluating effects that relate to the outfall relative to other sources of potential impact.

In summary, when potential effects associated with the existing outfall are evaluated and placed in the context of historical marine survey results (limitations of these studies aside) the planned upgrades on balance are likely to have negligible negative impacts on sediment quality and benthic community composition over the next 30 years. Equally, the planned upgrades should be seen as a positive initiative for managing Wairoa townships current and potential future wastewater needs and represent a proactive and pragmatic approach to wastewater discharge into a presently degraded environment. Based on the Staged approach presented in Table 1.1, there is also potential for some longer-term improvements to species abundance(s) and benthic diversity; however, this will be largely contingent on reducing the effect of other stressors further upstream, particularly those responsible for increasing sedimentation.

4 Mitigation methods

The series of mitigations contained within the Table 1.1 (LEI, 2018) represent tangible solutions to existing and future wastewater needs of the Wairoa township. While these initiatives should go a long way to improving wastewater discharges into the Wairoa Estuary (quality and volume), additional mitigation in the form of restorative ecology could be undertaken in and around the lower estuary margins. Initiatives may potentially include, but not necessarily be limited to:

1. Removal of non-natural debris from intertidal margins around the estuary mouth;
2. Riparian planting around the lower estuary region, particularly in areas of active erosion;
3. Creation of wetland habitat in and around storm-water drains, to aid in stormwater filtration and contaminant removal prior to entering the Wairoa River, and;
4. Creation and enhancement of Inanga (whitebait) spawning habitat and bird roosting/wading habitat.

Collectively these mitigation methods would all help improve the ecological function of the lower estuarine regions of the Wairoa River and compliment the improvements being made to the WWWTP infrastructure and wastewater discharge protocol, as well as the wider Wairoa River catchment improvement projects.

5 Consent Conditions

Discharge requirements are to meet volumes and timings relative to river flow rates, tides and times depicted in Table 1.1.

Benthic, sediment quality and water quality monitoring should be undertaken to establish baseline conditions and thereafter to gauge the magnitude of impacts (positive and negative) associated with treated wastewater discharges.

Benthic surveys and water quality monitoring are required as part of an estuarine monitoring programme to be carried out by the permit holder: The initial baseline survey should be undertaken more than six months, but less than one year subsequent to granting of the resource consent. Subsequent monitoring surveys should be undertaken as outlined in Section 6.0.

The following parameters shall be sampled and analysed at each site:

- Sediment particle grain size
- Heavy metals (As, Cd, Cr, Cu, Hg, Ni, Pb, Zn)
- Organic content/matter (TVS)
- Nutrients (Total Recoverable P, Total N)
- Infauna

Results will be compared against national sediment quality guidelines (ANZECC 2000). These guidelines e.g., Interim Sediment Quality Guidelines (ISQG) consist of upper (ISQG-high) and lower (ISQG-low) thresholds above which biological impacts could be expected. Where concentrations are below ISQG-low values then adverse biological impacts would be expected rarely. Concentrations falling between ISQG-low and ISQG-high would be expected to cause adverse biological impacts occasionally, and concentrations above the ISQG-high would be expected to frequently cause adverse biological effects.

Water quality monitoring should be undertaken at five sites depicted in Figure 6.2 in order to establish conditions of the receiving environment (for both baseline and on-going monitoring). Monitoring should be done in accordance with the various river flow thresholds depicted in Table 1.1. Below ½ median river flows; ½ median river flows; and, 3 × median river flow.

The following parameters shall be sampled and analysed at each site:

- Dissolved oxygen
- pH
- Dissolved reactive phosphorus (*DRP)*
- Soluble inorganic nitrogen (SIN)

- Ammoniacal nitrogen (NH_4-N)
- *Escherichia coli* (E. coli) and faecal coliforms.

6 Estuarine Monitoring Programme

The purpose of the environmental monitoring programme detailed below is to establish a survey protocol that will enable an assessment of benthic health in relation to the discharge of wastewater into the Wairoa Estuary as the 4 stages outlined in Table 1.1 are progressively established. To date this has been difficult to appraise due to low site replication of historical surveys and a lack of robust hydrodynamic modelling to designate sampling sites.

6.1 Benthic Survey

Initially a baseline survey will be required to evaluate any impacts relating to the existing outfall. It is recommended that a total of 12 sites – 9 potential impact and 3 control developed from the results of the 2018 monitoring and hydrodynamic modelling– should be established at increasing distances away from the subtidal outfall. Sites should be orientated in a North, South and Easterly direction (refer to Table 6.1 and Figure 6.1) that aligns with the mixing scenarios based on hydrodynamic modelling. Sites should be designated at distances 50 m, 100 m and 200 m away from the outfall terminus. The historic sites A, B, and C will be retained as they contain useful historical information. The monitoring protocol will incorporate 3 components – sediment quality, benthic ecology and water quality monitoring, the latter of which has been lacking from previous surveys. Additional statistical analyses that evaluate the importance of physical parameters in explaining biological variation will also be incorporated into the programme.

Table 6.1. Monitoring site locations

Site	Lat	Long	Comment
1	39° 3'30.73"S	177°25'12.81"E	50 m northeast of outfall
2	39° 3'29.58"S	177°25'14.16"E	100 m northeast - original B
3	39° 3'32.98"S	177°25'10.07"E	50 m southwest
4	39° 3'34.14"S	177°25'8.58"E	100 m southwest - original A
5	39° 3'33.05"S	177°25'13.10"E	50 m southeast
6	39° 3'27.25"S	177°25'17.43"E	200 m northeast
7	39° 3'36.23"S	177°25'5.55"E	200 m southwest
8	39° 3'20.54"S	177°25'25.34"E	500 m northeast - original Control site C
9	39° 3'13.82"S	177°25'46.71"E	1 km northeast Control - 2018 site J
10	39° 3'40.64"S	177°24'58.48"E	350 m southwest - deposition site between 2018 GF & G
11	39° 3'46.01"S	177°24'49.92"E	680 m southwest - deposition site
12	39° 3'37.70"S	177°25'26.85"E	450 m southeast Control - deposition site between 2018 H & I

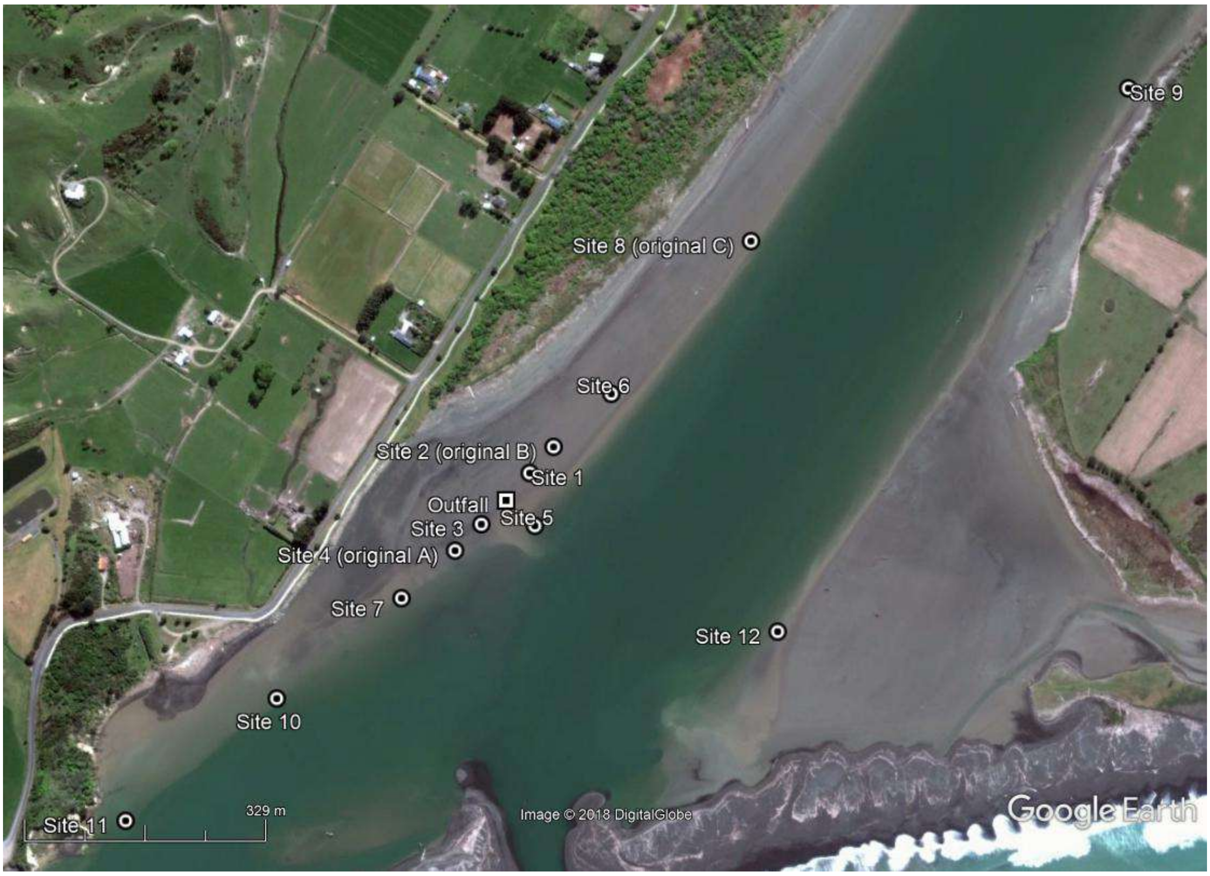

Figure 6.1. Recommended monitoring sites.

6.1.1 Sediment quality

At each site, three replicate sediment cores will be collected using a PVC 60 mm (internal Φ) x 150 mm long corer (sleeve). Individual cores sill be sampled by pushing individual cores into the sediment to a depth of 150mm, digging around the outside of the corer and placing a hand over the bottom of the corer when extracting the core from the surrounding sediment. This will ensure the integrity of the core profile is maintained. Following removal, individual cores will be split vertically and visually assessed for the presence/absence of anoxic layers and areas within the core with redox potential discontinuity layer (RPDL) measured to +/- 1mm. The top 5 cm from each core will then be combined to form a composite sample. Specific analyses (tests) will be run on composite samples that will include organic matter; particle size analysis (by weight); total recoverable phosphorus, total nitrogen, and trace metals As, Cd, Cr, Cu, Ni, Pb, Zn, and Hg, and faecal coliforms and *Escherichia coli* (E. coli). There will be 12 samples for each monitoring event.

6.1.2 Benthic sampling

Infaunal samples (cores) will be collected using a circular PVC 130mm (internal Φ) x 200mm long core (total area 0.013 m^2). Sample acquisition will again be done by manually pushing the core into the sediment to a depth of 150 mm and digging down the outside of the core, placing a hand over the bottom, and extracting the core and intact sample. Each sample will then be removed from the core sleeve and immediately washed into a 0.5 mm sieve. Biological material retained on the sieve will be further washed into labelled (time, site #) jars containing 70% isopropyl alcohol in seawater. Rose Bengal solution will be added to each sample, and left for several hours for the stain to be absorbed by the biological material. There will be 60 individual samples for each monitoring event.

Biological material will be identified to the lowest possible taxonomic level. The size of bivalves should be measured to ± 1mm. Data generated will consist of counts as well as size which should be compiled into MS Excel and checked for accuracy using QA/QC procedures.

6.1.3 Water quality

A total of 5 water quality sites will be established (Figure 6.2). Initial monitoring will be used to establish baseline water quality conditions at different flow rates as depicted in Table 1.1. At each site a water samples will be obtained and analysed for *dissolved reactive phosphorus (*DRP), soluble inorganic nitrogen (SIN), ammoniacal nitrogen (NH_4-N) and *Escherichia coli* (E. coli).

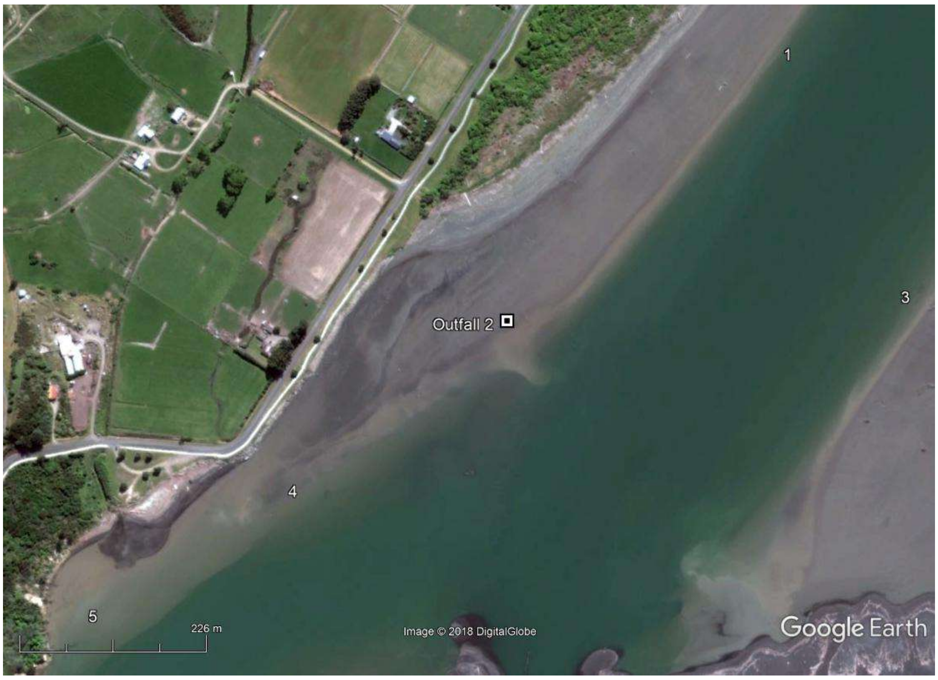

Figure 6.2. Potential sites to evaluate water quality within the Wairoa Estuary.

6.1.4 Data analysis

Data will be presented as plots of diversity, abundance, and community composition. A combination of multivariate and univariate statistical tests will be used to analyse the various datasets generated. Statistical programmes such as PRIMER-E statistical software (Clarke and Warwick 2001) and associated routines, particularly PERMANOVA (Anderson *et al*., 2008) or R statistical software (R core developmental team, 1995) will be used. In recent years PERMANOVA has become increasingly popular in the analysis of both univariate and multivariate datasets relating to environmental impact assessments. Central univariate and multivariate hypothesise that underpin the statistical analyses will be established.

6.1.5 Outputs

The key outputs of the monitoring programme will be a technical report and associated raw data files for archiving.

6.1.6 Timing

It is recommended that monitoring is staggered in accordance with the proposed stages outlined in Table 1.1. A baseline survey should be undertaken in summer 2019/20 followed by successive monitoring events every 2 years up to the completion of Stage 2. Baseline and impact monitoring should be undertaken at the same time of year each time, preferable in late summer when river flow is usually at its lowest. Thereafter, monitoring should be undertaken every 5 years.

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