Appendix H:

Ecological Effects of Wastewater Overflows

Ecological effects of wastewater overflows

Gisborne District Council

Coast
&
Catchment Ltd
Environmental Consultants

Ecological effects of wastewater overflows

Gisborne District Council

Shane Kelly

Carina Sim-Smith

July 2019

Revised April 2020

Client report for Gisborne District Council

Report Number: 2019-06

Reviewed by: Geoff Mills

Disclaimer

This report has been prepared based on the information described to Coast and Catchment Ltd. by the client and its extent is limited to the scope of work agreed between these two parties. No responsibility is accepted by Coast and Catchment Ltd. or its directors, servants, agents, staff or employees for the accuracy of information provided by third parties, and/or for the use of any part of this report for purposes beyond those described in the scope of work. The information in this report is intended for use by the client and no responsibility is accepted for its use by other parties.

Contents

1 EXECUTIVE SUMMARY

Gisborne District Council (GDC) is seeking consent for controlled and uncontrolled discharges from its wastewater network. Controlled discharges have historically occurred from multiple engineered overflow points, spread around the network. The Council now plans to limit controlled discharges to four key outfalls. Dry weather overflows are unpredictable and could occur throughout the network. Coast and Catchment were commissioned to support the consent application by assessing the ecological effects of overflows on receiving waters. For clarity, this report does not address public health risks associated with wastewater overflows or cultural elements of water quality and ecology.

Separating the ecological effects of intermittent wastewater discharges from other stressors is difficult. Therefore, a “principles and data” driven approach was taken that combined our wider knowledge about wastewater effects on receiving water ecology, with specific information on the characteristics of Gisborne’s waterways, wastewater and river water quality, predictions of dispersal and dilution from key outfalls, and sediment quality and benthic ecological data.

Wastewater overflows have the potential to adversely affect receiving water, habitat quality and aquatic communities by increasing nutrient concentrations and productivity, through the deposition and decomposition of organic matter, and through the effects of toxic contaminants. However, the actual ecological effects caused by particular wastewater overflows depend on the nature of the discharges, discharge loads and frequency, whether overflows occur during dry or wet weather, and the values and assimilation capacity of the receiving environment.

A desktop review of Gisborne’s urban waterways indicated that they have a history of modification, with urban streams generally consisting of piped, channelised and open stream reaches, with narrow riparian margins and little vegetative cover. Available macroinvertebrate data indicates that the quality of Gisborne’s freshwater urban streams and rivers tends to be poor. However, they continue to support pollution-tolerant macroinvertebrates and fish. Estuarine sections of Gisborne’s rivers also support a range of fish and moderately diverse invertebrate communities.

The analysis of wastewater samples, and samples obtained from rivers and streams before, during, and after controlled discharge events indicated that wet weather discharges did not have a marked impact on estuarine water quality in Gisborne’s rivers. These results were consistent with model predictions, which suggest nitrogen, phosphorus and suspended solids concentrations from discharges will be rapidly diluted to levels well below those found in the receiving waters, as recorded in GDC’s river monitoring programme. Elevated concentrations of key metals (copper and zinc) were detected in some receiving water samples, but these were attributed to stormwater discharges rather than wastewater overflows. Dissolved oxygen levels were also low in the upper estuarine section of Taruheru River and in Waikanae Creek, but neither area was subjected to controlled discharges during the period analysed, and therefore, this effect was not attributable to wastewater inputs. Finally, sediment sampling directly below, and away from, key wastewater outfalls did not detect adverse ecological or sediment quality effects that could be linked to wastewater discharges.

GDC advice suggests that limiting discharges to the primary and secondary outfalls can be done without increasing discharge volumes at those outfalls. Based on that, and the results obtained in this study, we conclude that the ecological effects of the proposed wet weather discharges are likely to be minor, as no patterns were identified in benthic ecology, water quality or sediment quality that could be definitively linked to existing overflows. However, the potential for substantial (most likely short term) impacts from dry weather overflows cannot be discounted. Ensuring effective systems and processes are in place for preventing, detecting and responding to such events is therefore recommended.

2 BACKGROUND

The Water Utilities Department of Gisborne District Council (GDC) is seeking consent for intermittent wastewater discharges when heavy rainfall overwhelms the network (wet weather overflows) or when blockages, pump failures or other unpredictable events back up and overflow the sewer system (dry weather overflows). Wet weather overflows generally occur from engineered overflow points at specific sites, but the locations of dry weather overflows are unpredictable. Consequently, the receiving environments affected by dry weather overflows cannot be pre-determined.

Coast and Catchment were commissioned to provide an assessment of ecological effects on key waterways potentially affected by discharges from Primary and Secondary discharge points in the wastewater network (see below). For clarity, this report does not address public health risks associated with wastewater overflows, or cultural elements of water quality and ecology.

Gisborne District Council's wastewater network and associated operational procedures have been evolving since at least the 1970s. Mayhew (2019) summarises the history of changes as follows:

- *Historically, wet weather overflows occurred automatically when volumes/pressures in the wastewater network exceeded system capacity (surcharged). This resulted in widely dispersed and uncontrolled overflows, including on private property.*
- *From approximately 1995 to 2016, Council blocked all automatic overflows points and if a discharge point was to be retained a valve was installed which then required manual intervention to deliberately open the relief/scour valves – to direct overflows to Gisborne's main rivers in preference to overflows onto private property from gully traps or at toilets. While it is appreciated that overflows to rivers (and subsequently to the wider Bay) are not desirable, the health and social impacts are significantly less than would occur if the scour valves are not opened.*
- *From 2015, additional infrastructure and management improvements have been implemented to further reduce the number of overflow locations and the duration/volume of overflows including:*
- *A flowmeter was installed in 2015 to monitor flows from the complete Kaiti Catchment, which now assists in monitoring the network performance and assist when to open the Wainui Rd scour valve;*
- *The approach to opening scour valves is to only open those necessary to reduce overflows to private property and to close them as soon as possible to reduce the total discharge of diluted wastewater as far as practicable;*
- *Only two priority valves are opened, unless the magnitude of the rainfall event requires additional, secondary values to be opened. Priority is given to valves located lower in the*

catchment and as close to the sea as possible. This limits the extent of adverse effects to two locations, other than in extreme circumstances;

- *Additional emergency storage has been installed at Steel Rd (92m^3) to remove the requirement to overflow to the Kopuawhakapata Stream and to further reduce the risk of overflows to the Wainui Stream*
- *A new dedicated rising main from the Russell Street Pump station to reduce overflows from Russell Street, which is also supported by an existing emergency storage tank (100m^3);*
- *Diverting the Portside Pump Station rising main from the Hirini St manhole with the aim of reducing overflows during large wet weather events;*
- *Documenting all new procedures in an updated Operations Manual;*
- *Continuing to implement Council's 'Drainwise' programme to reduce SW inflow and infiltration as a primary means of reducing the frequency, volume and duration of overflows.*

The most recent changes are expected to limit controlled discharges to key outfalls at the following locations (Figure 2-2):

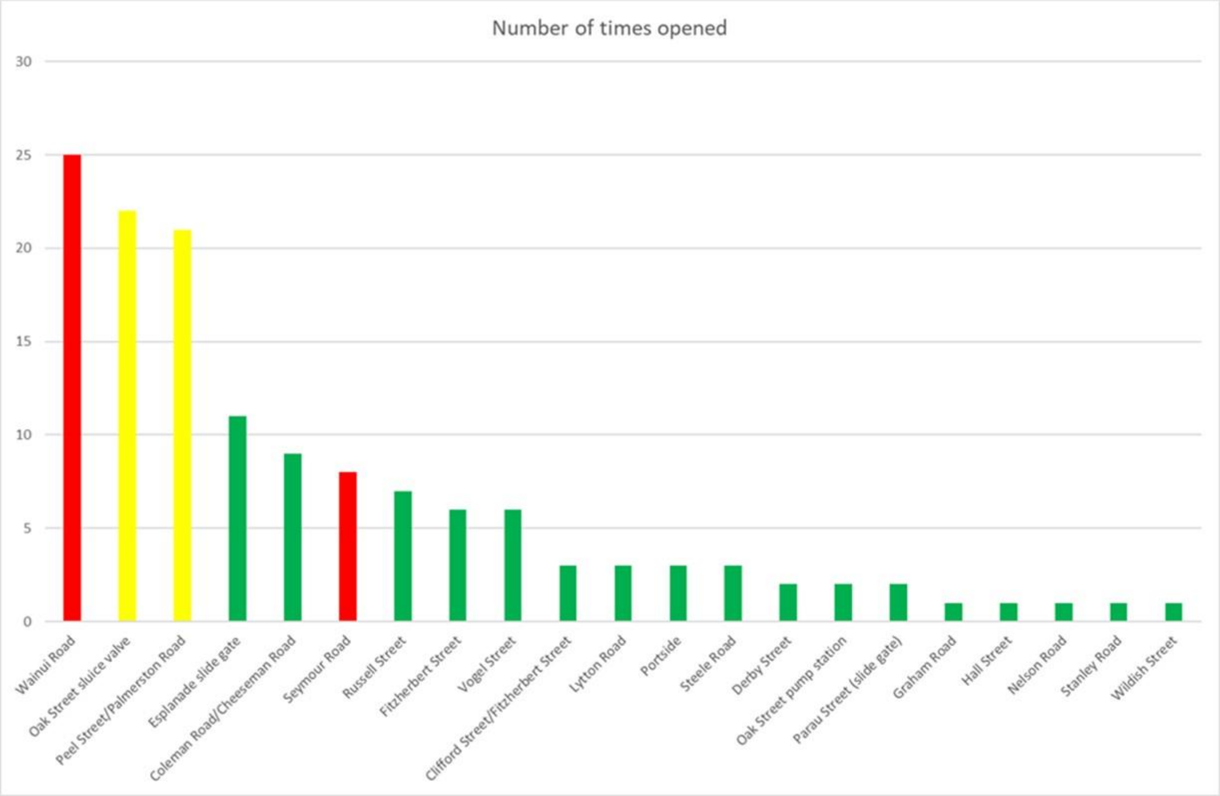
1. Primary (small and large rainfall events):
    a. Wainui Road
    b. Seymour/Turenne
2. Secondary (large events only):
    a. Oak Street
    b. Palmerston Road/Peel Street.

Routine controlled, wet weather overflows from tertiary overflow points have been phased out. However, it is recognised that in extreme events (larger than the 10-year ARI), overflows may occur from any controlled overflow point (including tertiary points) and from uncontrolled overflows (manholes/private property). Therefore, GDC is also seeking provision for such discharges through its consent application.

The frequency of overflows from various outfalls since 2006 is provided in Figure 2-1. In summary, since 2006:

- overflows have occurred on 34 events – an average of 2.5 events per year;
- discharges occurred from 21 different overflow locations, with most historical events involving more than one overflow valve being opened;
- the four primary and secondary overflow locations accounted for 55% of the total number of overflow discharge locations (information provided by Ian Mayhew, 4Sight Consulting based on Council's spreadsheet: Wastewater discharge volumes and river monitoring (vA2462687)).

Figure 2-1: Frequency of controlled wet-weather overflows since 2006 (provided by Ian Mayhew, 4Sight Consulting based on Council's spreadsheet: Wastewater discharge volumes and river monitoring (vA2462687)).



The Wainui Rd and Palmerston Road/Peel Street overflows discharge directly into estuarine sections of the lower Taruheru–Upper Turanganui river channels. The Oak St overflow discharges into a tidal section of a narrow creek, with the discharge point approximately 130 m up from the Taruheru River junction. The Seymour Rd/Turenne St overflow discharges into an approximately 500 m, intermittently flowing overland channel, which is fed by a combined stormwater and wastewater outfall (Figure 2-3). That channel joins the upper, tidal section of Waimata River. Most of the tertiary overflow points discharge into tidal sections of the main river systems. However, eight tertiary overflows discharge directly, or indirectly, to smaller streams.

Figure 2-2: Gisborne overflow points controlled by valves, slide gates and plugs. Primary, secondary and tertiary overflow points are shown, with the primary and secondary points labelled.

Sources: Esri, HERE, DeLorme, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), MapmyIndia, NGCC, © OpenStreetMap contributors, and the GIS User Community

Figure 2-3: Photos of the upper and lower sections of intermittently flowing overland channel that receives the Seymour Rd/Turenne St overflows. The top left photo shows the combined stormwater-wastewater outfall.

The complexity of Gisborne’s waterways means that it is difficult to separate and accurately quantify the ecological effects of intermittent wastewater discharges from:

- the co-occurring influences of other urban and rural activities that contribute contaminants and have altered the values and functioning of Gisborne’s waterways;
- the natural changes occurring in the complex transitional zones between coastal and freshwater habitats.

The lack of suitable reference sites unaffected by wastewater or other urban inputs, and quantitative data pre-dating wastewater discharges also confound separating the influence of wastewater inputs from other changes that have affected the values and quality of Gisborne’s waterways (such as the proliferation of the estuarine plant pest, *Spartina* spp.). A “principles and data” driven approach was therefore required to assess potential effects, by combining:

- a general understanding of potential wastewater effects on aquatic habitats and ecology;
- specific information on the characteristics of Gisborne’s waterways, and wastewater and river water quality;
- predictions of wastewater dispersal and dilution from key outfalls.
- an assessment of benthic habitat quality and ecology in Gisborne’s tidal rivers.

3 POTENTIAL EFFECTS OF WASTEWATER DISCHARGES

Wastewater discharges have the potential to affect aquatic habitats and ecology by:

- Promoting microalgal and nuisance macroalgae blooms by increasing the nutrients available for primary productivity.
- Reducing water clarity by promoting microalgae productivity (see above), increasing the concentrations of suspended solids, or the discharge of strongly coloured substances.
- Decreasing oxygen levels through the microbial decomposition of organic matter.
- Releasing toxic contaminants that reduce the condition or survival of aquatic organisms. The key toxicants in metropolitan wastewater are ammonia, nitrate, and oxygen demanding substances. Heavy metals, and toxic organic contaminants may also be present (although generally at relatively low concentrations).
- Affecting sediment quality and benthic communities through the deposition of organic matter and fine particulates that may accumulate in sediments causing anaerobic sediments and sulphide toxicity.
- Depositing biosolids and other gross pollutants that produce odours and adversely affect aesthetic values.
- Increasing the concentrations of microbial contaminants that pose a human health risk.

Actual effects depend on the nature of the discharges, discharge loads and frequency, whether overflows occur during dry or wet weather, and the values and assimilation capacity of the receiving environment.

3.1 Wet weather overflows

Wet weather overflows are caused by stormwater getting into the wastewater network during rainfall events, overwhelming the system capacity, and overflowing diluted wastewater through relief structures (engineered overflow points) designed reduce pipe pressure to prevent wastewater backing up and discharging into homes or at other locations where it would present a serious public nuisance and health risk. Engineered overflow points are commonly uncontrolled. However, in Gisborne, slide-gates or valves are purposefully opened to limit overflows to specific locations. This reduces the potential for overflows to occur in places where they would have an unduly adverse public health, nuisance, and/or ecological impact.

3.2 Dry weather overflows

Dry weather overflows are caused by blockages or pump failures that cause concentrated wastewater to back up and overflow from points throughout the sewer system. Dry weather overflow points potentially include homes, land and waterways. The concentrated nature of dry weather overflows and their occurrence during periods of low stream and river flows increases their potential to cause adverse ecological and habitat effects. However, the actual significance of effects depends on the site and overflow. The ecological effects of a small discharge of residential sewage directly into one of the main rivers are likely to be minor. Conversely, a large discharge over an extended period into a confined waterway could have a marked impact, particularly if the discharge included a large trade waste component containing significant contaminant loads. The incidence and impacts of dry weather overflows can be reduced by preventative measures (such as preventing materials that cause blockages from entering the wastewater system, regular inspections and maintenance), rapid detection, and fast and effective remedial actions.

4 GISBORNE WATERWAYS

Gisborne is built around the confluence of two rivers, the Waimata River and the Taruheru River, which combine to form the Turanganui River. To the southwest of the town, the smaller Waikanae Creek flows into the mouth of the Turanganui River. The combined catchment area for these three waterways is around 32,200 ha (Figure 4-1).

The Waimata River system has the largest catchment of approximately 22,700 ha. Predominant land covers in the Waimata catchment include steep grasslands, exotic forest and manuka/kanuka (Figure 4-2). Less than 3.5 km of the river runs through urban parts of Gisborne, of which, around 2 km is downstream of the only Primary outfall in its catchment (Seymour Rd/Turenne St). No secondary outfalls drain to the Waimata River system. Urban reaches of Waimata River are adjoined by a mix of public and private open space and residential development (see Appendix 3 for photographs).

The Taruheru River system is around 111 km in length and drains a catchment of around 8400 ha. The river system flows through a low-lying floodplain before reaching Gisborne township. Landuses in the catchment are dominated by cropping, orchards and grasslands, with urban development in the lower catchment (Figure 4-2; Gisborne District Council (2013)). The gradient of the river is very flat through the 5 km urban section (see Appendix 3 for photographs), and for 10 km upstream. As a consequence, water levels are strongly affected by sea levels, with tidal effects occurring over this distance (Poynter et al. 2016). A flood management scheme dating back to the 1960s including stopbanks, channel deepening and riverbank armouring enabled major changes in landuse from pastoral to horticultural. Despite this, low lying areas remain vulnerable to surface flooding (Peacock et al. 1997). The impacts of river modification and surrounding landuses have adversely affected the natural character of the river, which was scored as low by a River Expert Panel using the River Values Assessment System (RiVAS) (Booth et al. 2012). Two secondary outfalls discharge along Taruheru River (Oak St and Palmerston Rd/Peel St), while a Primary outfall is located in Turanganui River, just below the Waimata and Taruheru confluence.

The Waikanae Creek system is around 7.5 km in length and borders the southwestern edge of Gisborne township. It is a low gradient, groundwater fed stream that drains a catchment of around 1100 ha. The stream is tidally influenced, with the saline intrusion evident at least 4 km upstream from the sea. Landuse in the upper catchment is dominated by orchards and horticulture, while the mid to lower catchment is dominated by mixed urban (including industrial) development, though significant areas of urban parkland or open space are also present, including open space areas associated with closed landfills (Figure 4-2; Conn (2018)). The creek has been heavily impacted by human activities and was assessed as having low natural character (Booth et al. 2012). No primary or secondary outfalls discharge to Waikanae Creek.

Figure 4-1: Catchments of the Waimata and Taruheru Rivers and Waikanae Creek.

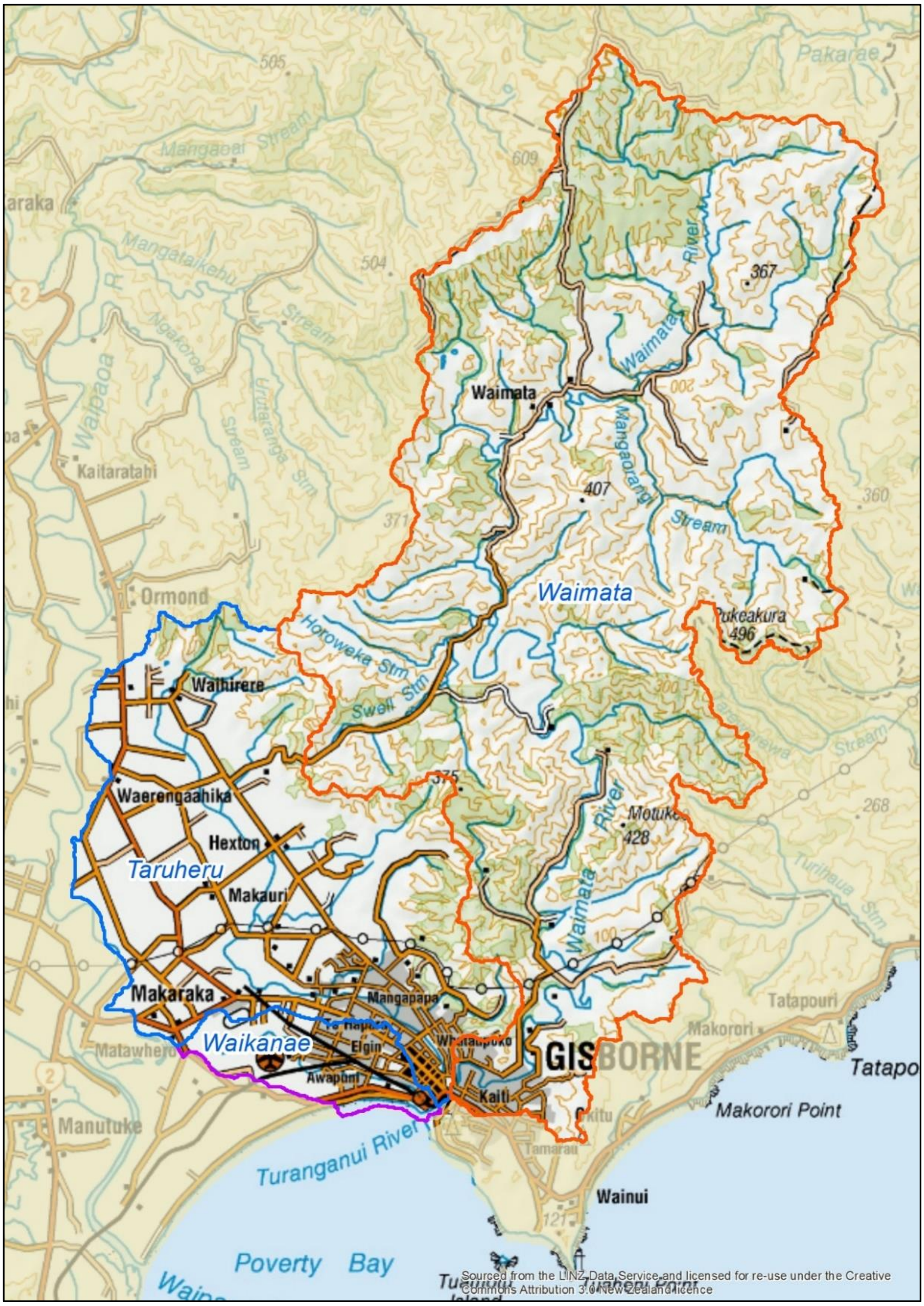
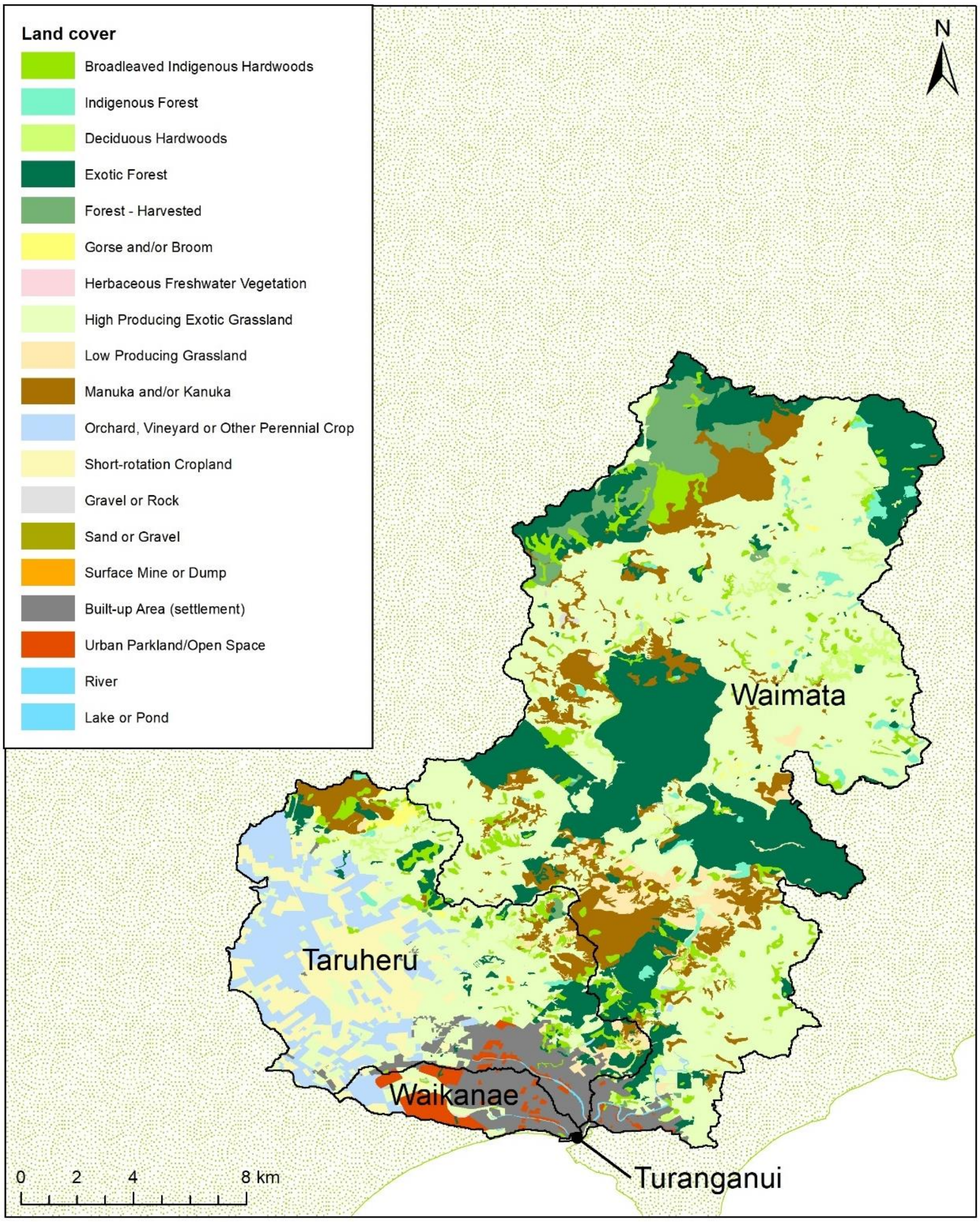


Figure 4-2. Land cover in the Waikanae, Taruheru, Waimata and Turanganui catchments. Data from New Zealand Land Cover Database version 4.1.



4.1 Riparian vegetation

Most of the native riparian vegetation along the Taruheru River has been removed and replaced with introduced grass, shrub and tree species, with large sections of the river simply edged with grass (Gisborne District Council 2013). The pest *Spartina* was planted in the lower river in the late 1950s and spread rapidly over the next 20 years, reaching densities of up to 100% coverage in some areas. *Spartina* traps silt, raising the level of estuarine mudflats. In areas where *Spartina* cover is incomplete, small patches of saltmarsh vegetation exist e.g., Raupo (*Typha orientalis*) *Juncus kraussii* subsp. *australiensis*, and oioi (*Apodasmia similis*) (Peacock et al. 1997).

Native riparian vegetation is scarce along the Waimata River downstream of the Goodwin Road Bridge[1]. Further upstream, the percentage of riparian vegetation increases, transitioning from weedy exotic species to pioneer species e.g., manuka/kanuka, to mature mixed canopy broadleaf species (Forbes et al. 2018).

Little riparian vegetation occurs along Waikanae Creek. The upper reaches of Waikanae Creek are mostly devoid of any woody riparian vegetation or shading, resulting in high summer water temperatures and low habitat value. Low value riparian vegetation is present along the majority of the middle reaches of the creek. However, a dense patch of raupo (*Typha orientalis*) has been planted adjacent to Te Kuri a Tauai Marae, which has begun to facilitate the development of brackish wetland and salt meadow habitats that include the 'At Risk–Naturally Uncommon' plant, native musk (*Thyridia repens*). Further downstream, large areas of the pest *Spartina* are present, that have encouraged sediment accumulation (Conn 2018).

A number of small, fragmented urban streams feed into the main rivers. In places, vegetated riparian margins bound these streams, but those sections are commonly interrupted by piped, lined and channelised sections, or reaches with no riparian cover. None of the primary or secondary overflow structures feed into continuously flowing, freshwater sections of these streams. However, several tertiary overflow points feed directly, or indirectly, into highly modified stream reaches (see Figure 4-3). Regularly wet weather overflows from these points are not expected, but the consent application does make provision for them to occur during extreme events.

---

[1] Goodwin Road Bridge is a GDC monitoring site – see Figure 5-1 for the location of that site.

Figure 4-3: Tertiary outfalls that drain directly or indirectly to smaller streams.

4.2 Freshwater instream values

4.2.1 Macroinvertebrate communities

A number of programmes/investigations have assessed macroinvertebrate communities in Gisborne's urban, and surrounding rural, streams and rivers, using the Macroinvertebrate Community Index (MCI) as a key indicator of river and stream health. The MCI uses the mix of macroinvertebrates at a site to classify stream health as poor, fair, good or excellent.

MCI scores for the GDC's rural freshwater monitoring sites closest to Gisborne township (Waimata River at Goodwins Road and Taruheru River at Tuckers Rd) are within the "poor" range. These two sites also have lower percentages of EPT taxa[2] (0–15%) and low abundances of EPT taxa (0–3%) (Roil & Death 2018).

---

[2] EPT (Ephemeroptera, Plecoptera and Trichoptera) taxa are highly sensitive to water quality and are therefore used as an indicator of stream health.

Similar results have been obtained from other urban and peri-urban streams. Palmer and Hardy (2015) assessed macroinvertebrate communities in a number of Gisborne's streams and rivers and obtained similarly low scores at a peri-urban Waikanae Creek (at Airport) site. MCI scores obtained at sites above and below Gisborne Port's upper logyard stormwater discharge to Kopuawhakapata Stream also showed that section of stream had very poor quality (Hamill 2012).

These results are consistent with those from other rural and urban areas where multiple, interacting stressors combine to produce relatively predictable outcomes for macroinvertebrates. In urban areas, a reduction in ecological condition typically occurs with increasing imperviousness. Multiple national and international studies have shown that ecological condition rapidly drops above a threshold in impervious cover, which typically falls between 6 and 20% total imperviousness (Klein 1979; Allibone et al. 2001; Walsh et al. 2001; Morse et al. 2003; Schueler et al. 2009). Accordingly, it would be reasonable to expect macroinvertebrate communities to be degraded in most (if not all) of Gisborne's urban streams, with slightly better condition possible in upper urban reaches with natural stream beds and riparian cover. No controlled overflows discharge into such areas.

As noted in Section 4.1, none of the primary or secondary overflow structures feed into smaller, continuously flowing urban streams, but several tertiary overflow points do feed directly, or indirectly into them (see Figure 4-3). Regularly wet weather overflows from these points are not expected, but the consent application does make provision for them to occur during extreme events. The lengths of those streams tend to be interrupted by piped, lined and channelised sections, and/or reaches with no riparian cover. Based on their highly modified nature and their surrounding landuses, the instream values of those streams are expected to be low with macroinvertebrate communities mainly, or wholly, comprised of tolerant species. The effects of rarely occurring wet weather overflows of predominantly domestic wastewater during extreme storm events, are likely to be indistinguishable from those already caused by other influences.

4.2.2 Fish

The most common freshwater fish reported to occur in the Taruheru and Turanganui River systems are eels (*Anguilla* spp.) and the common bully (*Gobiomorphus cotidianus*). Other species that have been occasionally reported include banded kokopu (*Galaxias fasciatus*), inanga (*Galaxias maculatus*), goldfish *(Carassius auratus*) and mosquitofish (*Gambusia affinis*), the latter two species being introduced (Peacock et al. 1997; Clapcott et al. 2012; Crow 2017). Other freshwater species may also occur.

A similar suite of fish has been recorded from the Waimata River including long and short-finned eels (*Anguilla dieffenbachia* and *A. australis*), common bully, torrentfish (*Cheimarrichthys fosteri*), inanga, Cran's bully (*Gobiomorphus basalis*), bluegill bully (*Gobiomorphus hubbsi*) and goldfish (Crow 2017).

Short and long-finned eels, inanga, common bully, giant bully (*Gobiomorphus gobioides*), mosquitofish and goldfish have been recorded from the upper reaches of Waikanae Creek (Crow 2017).

4.3 Coastal ecology

4.3.1 Benthic community

Cockles and pipis are present near the mouth of the Turanganui River (Gisborne District Council 2013), but sampling in the 1990s suggests that further upstream in the Taruheru River, the intertidal macrobenthic community is generally depauperate (Peacock et al. 1997). Twenty-four taxa were collected from sites between the confluence and 5 km upstream. The number of species progressively declined upstream, from 14 taxa at the confluence to 7 taxa at the upstream site. The community at the downstream site was dominated by polychaetes (capitellids, *Nicon aestuariensis*, and *Scolecolepides benhami*), mud snails (*Amphibola crenata*), estuarine snails (*Potamopyrgus estuarinus*), the bivalve *Arthritica* sp. and the mud crab (*Austrohelice crassa*). A mixture of freshwater (e.g., *Potamopyrgus antipodarum* and chironomid midges) and estuarine species were present at sites 4 km beyond the confluence, indicating that salinities in this area are low. Intertidal communities within *Spartina* beds had very low diversity, mainly comprising snails (*P. estuarinus* and *Pleuroloba costellaris*[3]).

4.3.2 Fish

Fish species recorded in saline areas of the Waimatea, Taruheru, Turanganui Rivers and Waikanae Creek include grey mullet (*Mugil cephalus*), common smelt (*Retropinna retropinna*), black flounder (*Rhombosolea retiaria*), kahawai (*Arripis trutta*) and kingfish (*Seriola lalandi lalandi*) (Gisborne District Council 2013; Crow 2017; Conn 2018). Other marine species also likely to be present including yellow eyed mullet, piper and snapper (Poynter et al. 2016).

4.3.3 Birds

Birds recorded from the lower reaches of the Taruheru River include weka (*Gallirallus australis*), white-faced heron (*Egretta novaehollandiae*), pied stilt (*Himantopus himantopus*), kingfisher (*Todiramphus sanctus*), little black shag (*Phalacrocorax sulcirostris*), little shag (*P. melanoleucos*) and mallard duck (*Anas platyrhynchos*) (Peacock et al. 1997). Other birds that are likely to be in the area include red billed gulls (*Larus novaehollandiae*), black backed gulls (*Larus dominicanus*) and variable oystercatchers (*Haematopus unicolor*) eBird 2019).

4.4 Water quality

Water quality data collected by GDC from Taruheru River and Waikanae Creek between 2010 and 2017 have previously been assessed by Kelly (2017). In Taruheru River, highest ammonia-N concentrations were recorded in upper rural areas of the catchment (at the Taruheru Kings monitoring site), but concentrations routinely exceeded the ANZECC (2000) trigger for the protection of NZ freshwater ecosystems and the SE Australian trigger for the protection of estuarine ecosystems at all of the Taruheru sites monitored. Ammonia-N toxicity guidelines, which are higher than those for ecosystem protection, were not exceeded during the monitoring periods examined.

Highest nitrate-N concentrations were regularly recorded at the Taruheru Lytton site, in the outer urban area. Nitrate-N concentrations routinely exceeded the ANZECC (2000) freshwater and SE Australian estuarine triggers for the protection of ecosystems at the three downstream sites in Taruheru River, but nitrate-N toxicity guidelines were not exceeded during the monitoring periods examined. Dissolved reactive phosphorus concentrations in Taruheru River displayed fairly similar patterns to nitrate-N concentrations.

Ammonia-N concentrations at the two Waikanae sites monitored routinely exceed the ANZECC (2000) trigger for the protection of NZ freshwater ecosystems and the SE Australian trigger for the protection

---

[3] Called *Ophicardelus costellaris* in Peacock et al. (1997).

of estuarine ecosystems. On one occasion, the ammonia-N toxicity guideline was exceeded during the period examined.

5 EFFECTS OF WASTEWATER ON RIVER WATER QUALITY

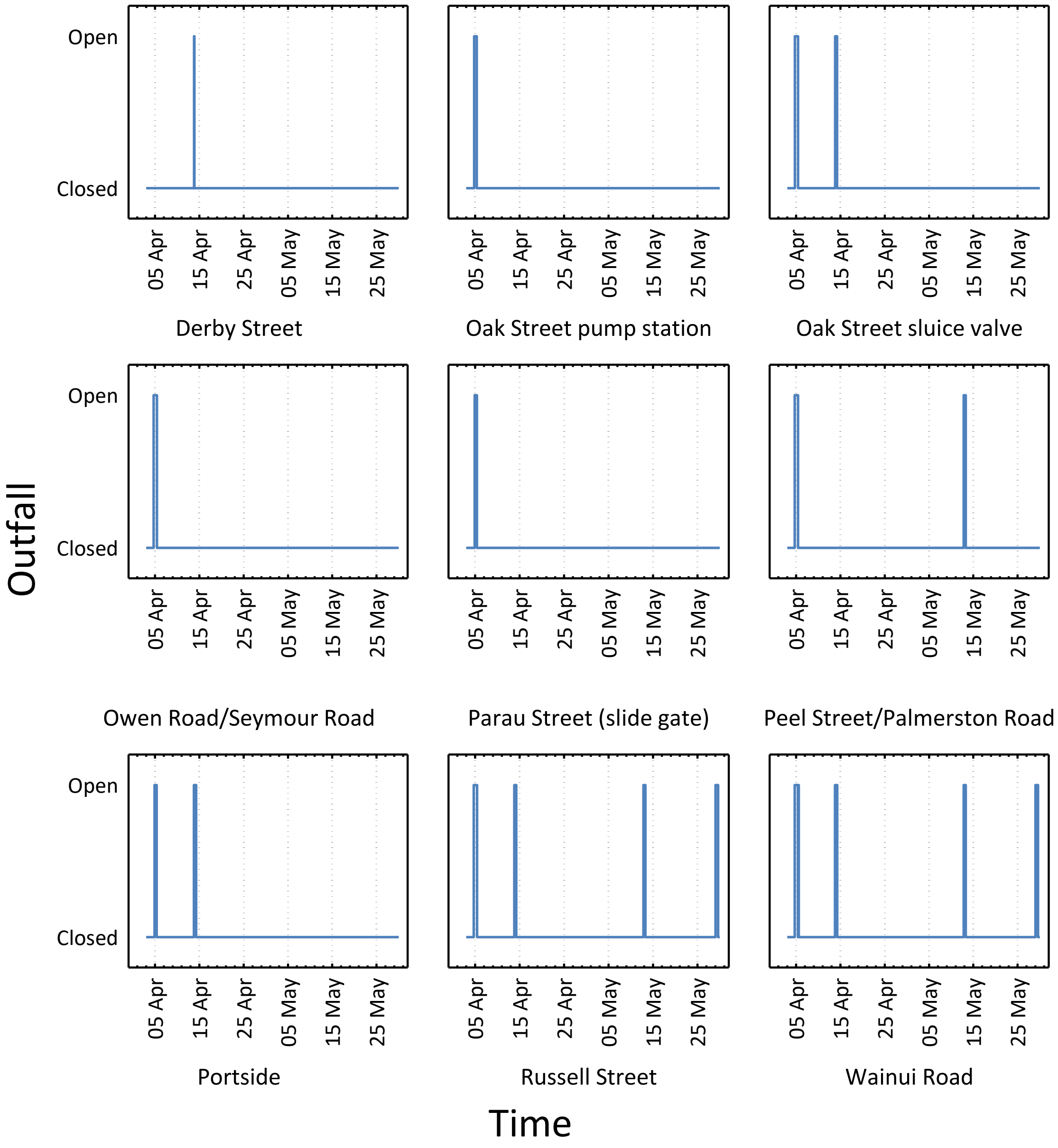
Gisborne District Council conducted river and wastewater sampling before, during and after discharge events by sampling 12 river/stream sites and three manholes between April and May 2017 (see Figure 5-1 for site locations). Nine controlled overflow points were opened during that period, with discharges lasting for between 1.42 and 17.78 hours (see Figure 5-2). Nakielski (2017) provides more details about the assessment, and an analysis of results. In summary, Nakielski (2017) concluded that:

- nitrogen and phosphorus appeared to increase over the period monitored, but this trend could not be conclusively linked to overflows;
- river sediment was dominated by upstream sources;
- overflows appeared to add to river ammonia-N levels, but did not cause large exceedances of guideline values or rise to levels above those observed during non-overflow rainfall events;
- metals in Gisborne's waterways were likely to be stormwater, rather than wastewater, related.

However, the methods Nakielski (2017) used to analyse and present water quality data potentially obscured the influence of wastewater overflows. Further analyses were therefore carried out using a combination of univariate and multivariate plots and analyses to obtain a clearer picture of relationships between wastewater discharges and river water quality.

Figure 5-1: Sites monitored before during and after controlled wastewater overflows in April-May 2017.

Figure 5-2: Controlled discharges between April and May 2017.



Box plots of salinity measurements indicated that eight of the 12 river sites were estuarine (Taruheru (Lytton, Wi Pere, and Peel), Turanganui (Gladstone and The Cut), Waimata (Grant, William Petty and Grey)), and four were freshwater (Taruheru (Tuckers), Waimata (Goodwins), Waikanae (Airport) and Kopuawhakapata (Hirini)) (Figure 5-3). Sites were therefore grouped as estuarine, freshwater or wastewater in subsequent analyses.

Principal Components Analysis (PCA) was used to obtain a better understanding of water quality at the estuarine and freshwater river sites, and to compare the composition of river water with that of wastewater (this excluded microbial indicators). Principal Components Analysis is a widely used method of combining multiple environmental variables and presenting them on along reduced dimensional axes (see Clarke and Gorley (2006) for a detailed description of this method). The first axis (PC1) explains the greatest proportion of variation in the combined variables, the second axis (PC2) explains the next largest proportion and so on. Principal Components Analysis plots allow:

- patterns in the values of multiple parameters among samples to be clearly visualised;
- the influence of individual parameters on those patterns to be identified.

Principal Components Analysis was carried out using normalised[4] concentrations of ammoniacal-N (NH_3-N and NH_4-N), nitrate-N, total nitrogen (TN), total phosphorus (TP), dissolved reactive phosphorus (DRP), total suspended solids (TSS) and dissolved copper (Cu) and zinc (Zn) from each site. Only samples containing data for all of those variables were used. Vector plots of individual parameters were also overlaid on PCA plots to identify the key parameters responsible for differences among sites. Note that a relatively high number of sites had copper and zinc concentrations that were below detection limits (DLs), and that DLs varied among sites and times. PCA's were therefore run on:

1. The full set of data, with data below DLs being replaced with the DLs.
2. A subset of the data with values below DLs being excluded.

For the full dataset, the first three PCA axes explained 83.7% of the variation in parameter concentrations (48.2%, 23.0% and 12.6% for PCA axes 1, 2 and 3, respectively). The PC1 axis was mainly aligned to variation in ammonia-N, TN, TP and DRP concentrations, PC2 aligned to variation in copper, zinc and nitrate-N concentrations, and PC3 aligned to TSS and nitrate-N. There was a clear pattern in the distribution of sites along PC1, with manhole samples separated from freshwater and estuarine samples (Figure 5-4). Estuarine and freshwater sites had similar ammoniacal-N, TP, and DRP concentrations.

Detection limits had a strong influence on the distribution of samples along the PC2 axis, but the general trend of PC2 explaining variation in copper, zinc and nitrate-N concentrations remained when samples with concentrations below detection limits were excluded (Figure 5-4 and Figure 5-5). Two samples from the Cut (Turanganui River) and Grey Street Bridge (lower Waikanae Creek) sites were outliers along PC2, due to high concentrations of zinc and copper. Wastewater samples did not cluster separately from estuarine and freshwater samples along the PC2 or PC3 axes (PC3 plot not shown).

5.1 What does this show?

In summary, the PCA analysis showed that wastewater (manhole) samples were clearly differentiated from the receiving waters by elevated concentrations of ammonia-N, DRP, TP and TN, but a clear wastewater signal was not apparent among river sites (a key indicator of such a signal would be freshwater and estuarine sites spreading out along PC1 rather than clustering at one end of the axis).

Concentrations of key metals (copper and zinc) and ammoniacal-N were also compared with ANZECC (2000) trigger values for the protection of 80% and 90% of species[5]. These triggers are appropriate for use in highly disturbed ecosystems. Metal trigger values were occasionally exceeded, but most estuarine samples were close to, or below, detection limits (which as noted above varied among

---

[4] Normalisation involves subtracting the variable's mean concentration from each data point and dividing by the standard deviation for that variable. This provides a mean of zero and standard deviation of one for each variable, thereby enabling data with different concentration ranges or units to be directly compared.

[5] The ammonia (NH_3-N) trigger was applied to NH_3-NH_4-N data. Comparisons against trigger values are therefore conservative.

sampling periods and were frequently high). Ammonia-N toxicity trigger values were not exceeded in estuarine or freshwater samples but were frequently exceeded in wastewater samples taken from manholes. Ammoniacal-N concentrations in samples obtained from wastewater manholes were 1.75 to 25 times the 90% trigger value for ammonia-N toxicity in marine water and 1.46 to 20.9 times the corresponding freshwater trigger.

Dissolved oxygen (DO) levels from estuary and freshwater sites were also plotted and compared with available reference values. In the estuary sites, lowest DO levels were obtained from the uppermost Taruheru site (Lytton Road), and from the Grey Street site on Waikanae Creek. This is significant because, the Lytton Road site was upstream of the controlled overflows[6] and no controlled overflows into Waikanae Creek occurred during the period monitored. In general, DO saturation increased down-river, but there also appeared to be a pattern of lower DO saturation during and/or after discharge events. A similar pattern occurred at freshwater sites around 4 km above the nearest outfall on Taruheru River (Tuckers) and around 7 km above the nearest outfall on Waimata River. This suggests that the DO sags were related to rainfall and associated storm flows rather than wastewater inputs (see Figure 5-12 and Figure 5-13).

Saturation levels at the Taruheru River Lytton Road, Peel Street and Wi Pere sites, and at the Waikanae Grey Street site frequently fell below the lower ANZECC (2000) chemical and physical stressor guideline value for Southeast Australia[7]. Dissolved oxygen concentrations and saturation at the freshwater sites also frequently fell below the ANZECC (2000) chemical and physical stressor guideline for lowland rivers[8]. However, DO concentrations at three of the four sites appeared to be in the “A” to “B” attribute state range for minimum concentrations in the National Policy Statement for Freshwater Management (Ministry for the Environment 2017). The exception was the Airport site in Waikanae Creek, where concentrations regularly fell below the national bottom line of 4 mg/L, putting this site into the “D” category.

5.2 Overall conclusions from the water quality analyses

Overall, the PCA and guideline comparisons indicated that:

- The key wastewater contaminants of concern were ammonia-N (in relation to toxicity and productivity effects) and phosphorus (in relation to productivity effects), but toxicity thresholds were not exceeded in the rivers.
- River metal concentrations appear to primarily be related to stormwater inputs, rather than wastewater, with trigger values for copper and zinc occasionally exceeding toxicity trigger values in the rivers.
- Dissolved oxygen levels were relatively low at upper estuary sites but saturation increased downstream, with sags in DO appearing to be related to rainfall events. Dissolved oxygen levels in Waikanae Creek were particularly low, but this appears to be unrelated to wastewater inputs.

---

[6] Upstream dispersal did not occur under any of the wet weather overflow scenarios hydrodynamically modelled, because flood flows overwhelmed tidal flows (see Section 6).

[7] Note that New Zealand does not have estuary guidelines for DO, and that the Southeast Australia guideline is currently being updated.

[8] ANZECC (2000) notes that the DO guideline is not that useful because of diurnal and seasonal variation.

Based on this, the overall conclusion drawn from the wastewater overflow assessment is that under the conditions prevailing over the period monitored, the effects of the wastewater on receiving waters were relatively minor. It is re-emphasised that this conclusion does not apply microbial contamination and associated risks to human health.

Figure 5-3: Boxplot of pooled salinity measurements in samples obtained from estuarine and freshwater sites before, during and after rainfall events.

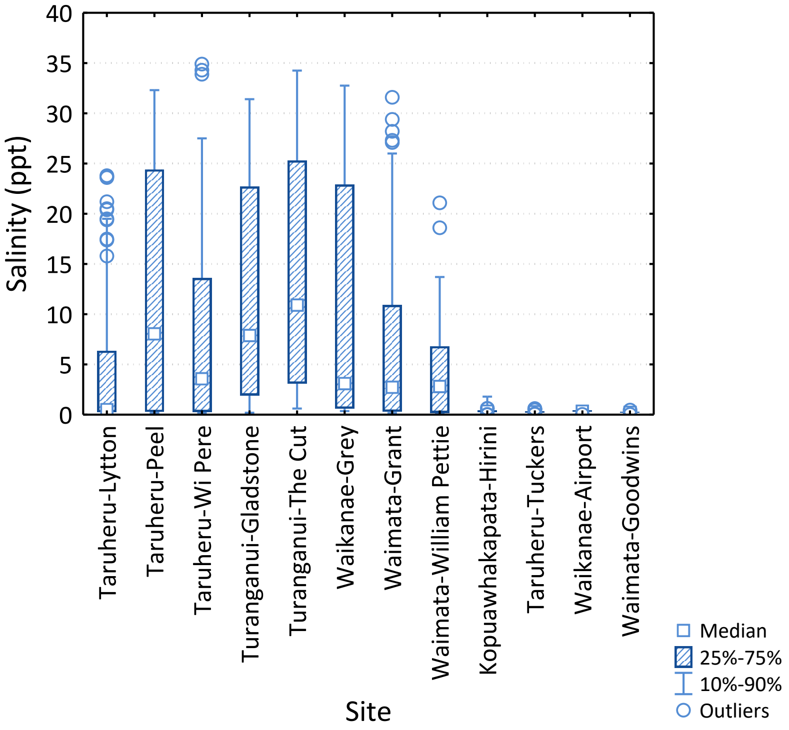


Figure 5-4: PCA of water quality indicators (ammoniacal-N, nitrate-N, TP, DRP, dissolved copper, and zinc) recorded in sewage (Munro, Ormond and Interceptor manholes), and in estuarine and freshwater samples between April and June 2017. Detection limits were used for samples with values with below those levels.

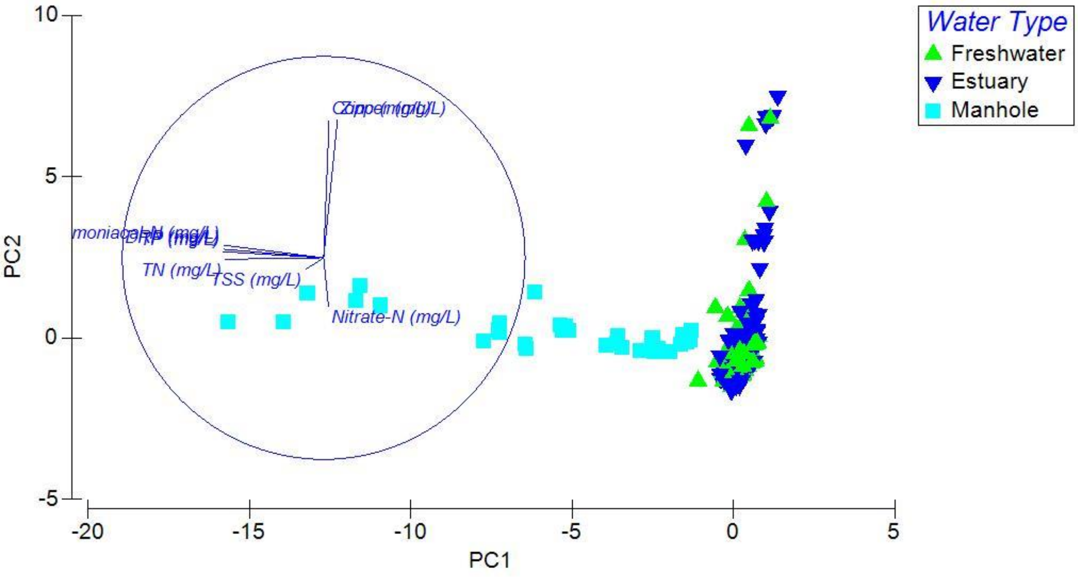


Figure 5-5: PCA of water quality indicators (ammoniacal-N, nitrate-N, TN, TP, DRP, TSS, dissolved copper, and zinc) recorded in sewage (Munro, Ormond and Interceptor manholes), and in estuarine and freshwater samples between April and June 2017. Samples with data below detection limits were excluded.

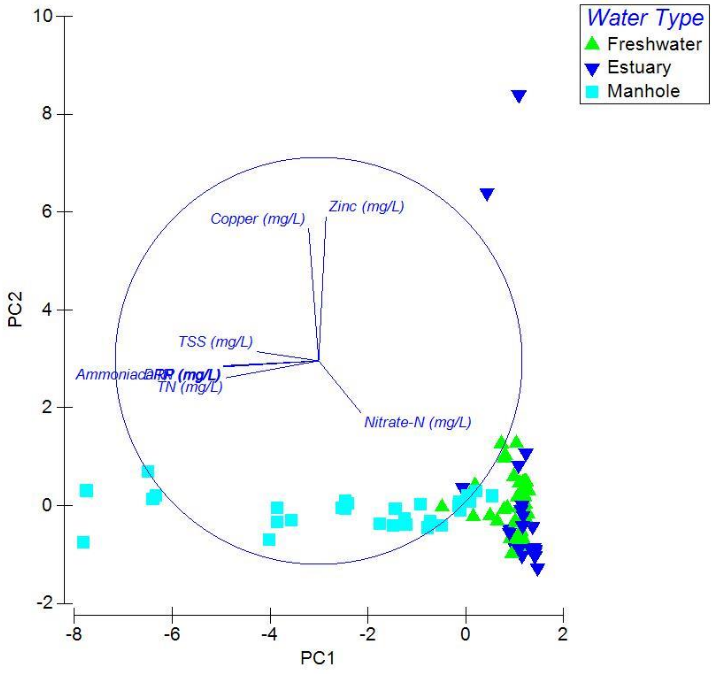


Figure 5-6: Total ammoniacal-N concentrations (dots) measured at estuarine sites before, during and after controlled wastewater discharges. ANZECC (2000) marine trigger values for the protection of 90% (red) and 95% (orange) of species are provided. The pooled, total duration of overflows is also provided for all sites (green line) even though individual sites may not be affected by those overflows. The coincidence of patterns among sites subject to, and not subject to overflow events would suggest that overflows are not the causal factor.

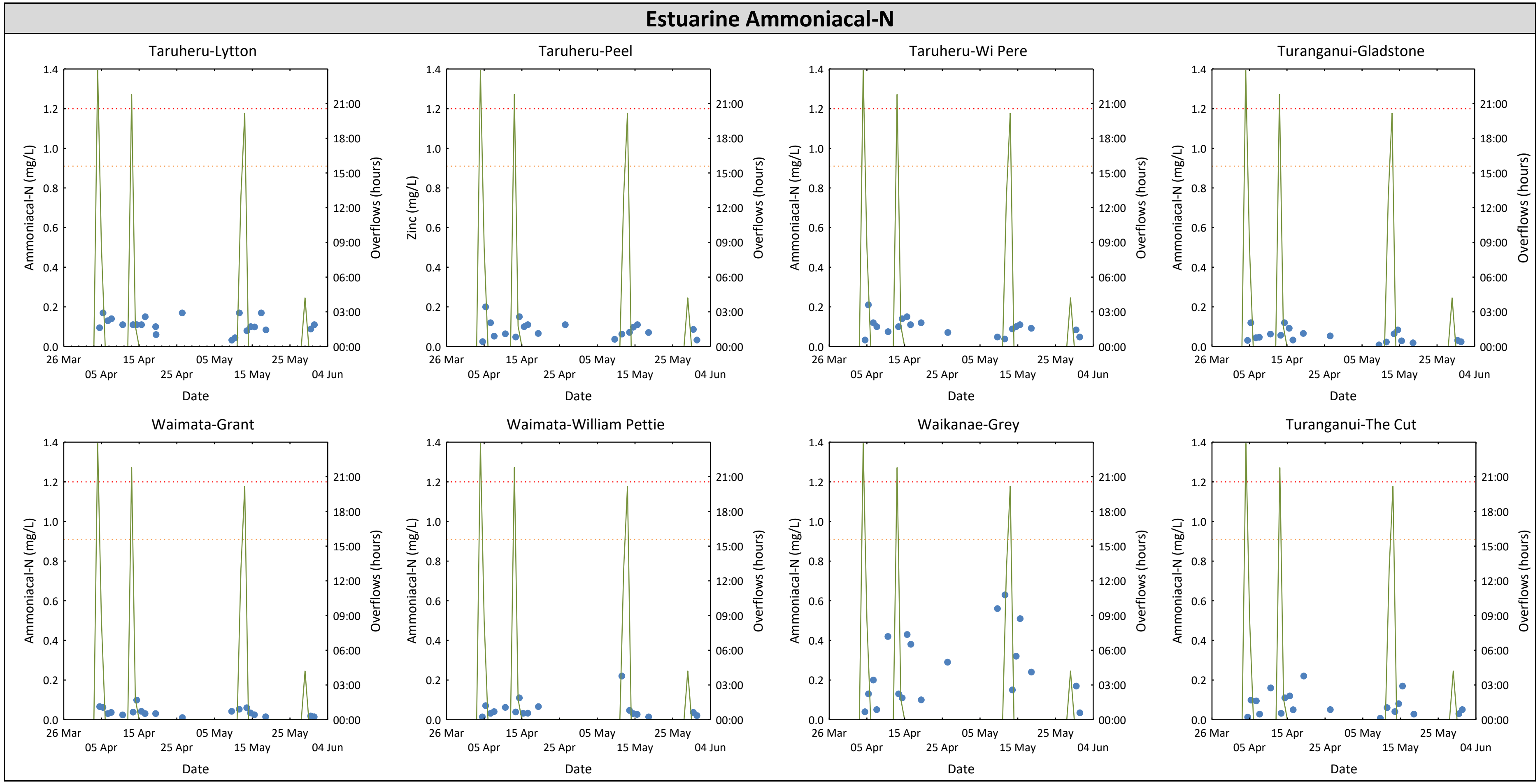
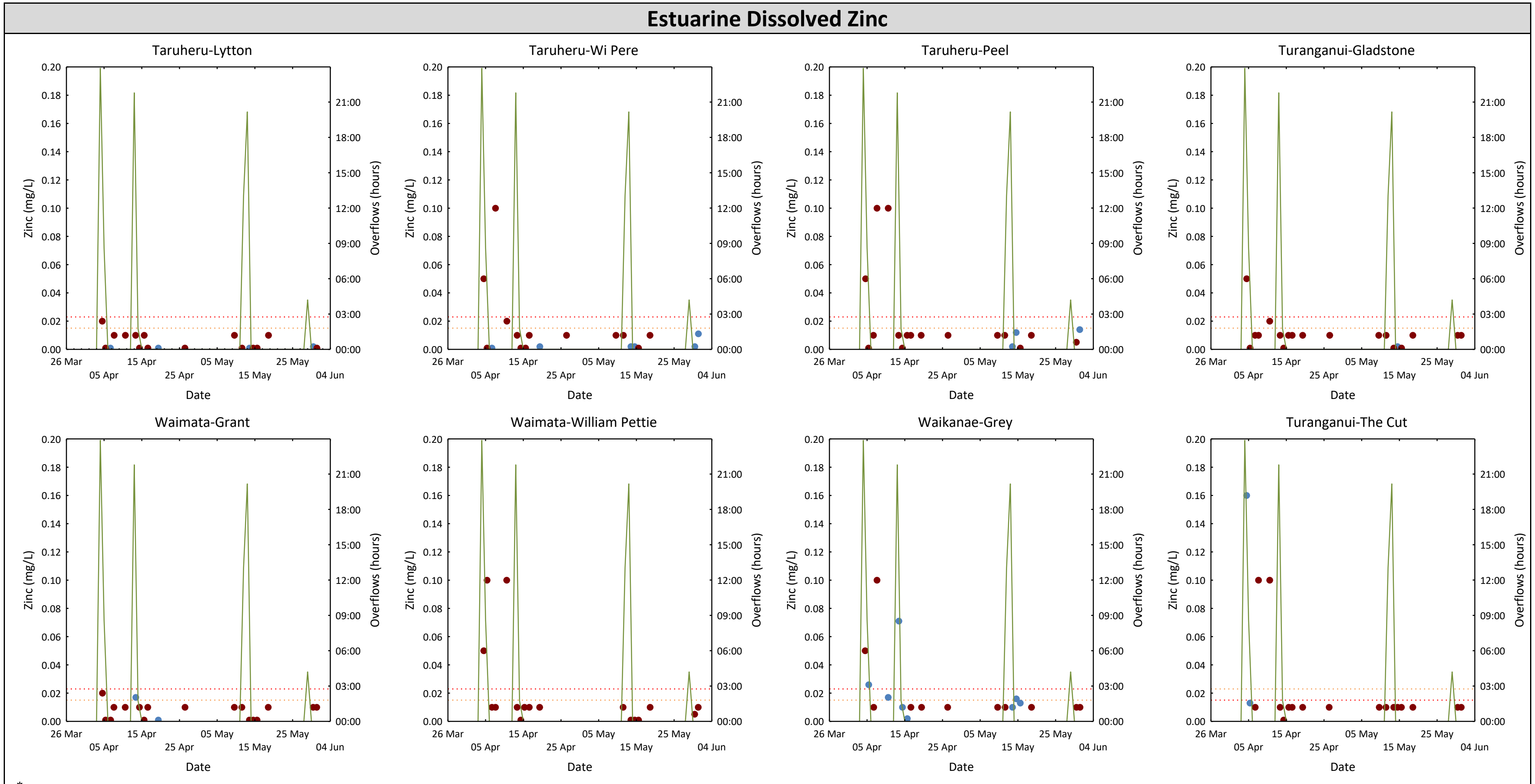
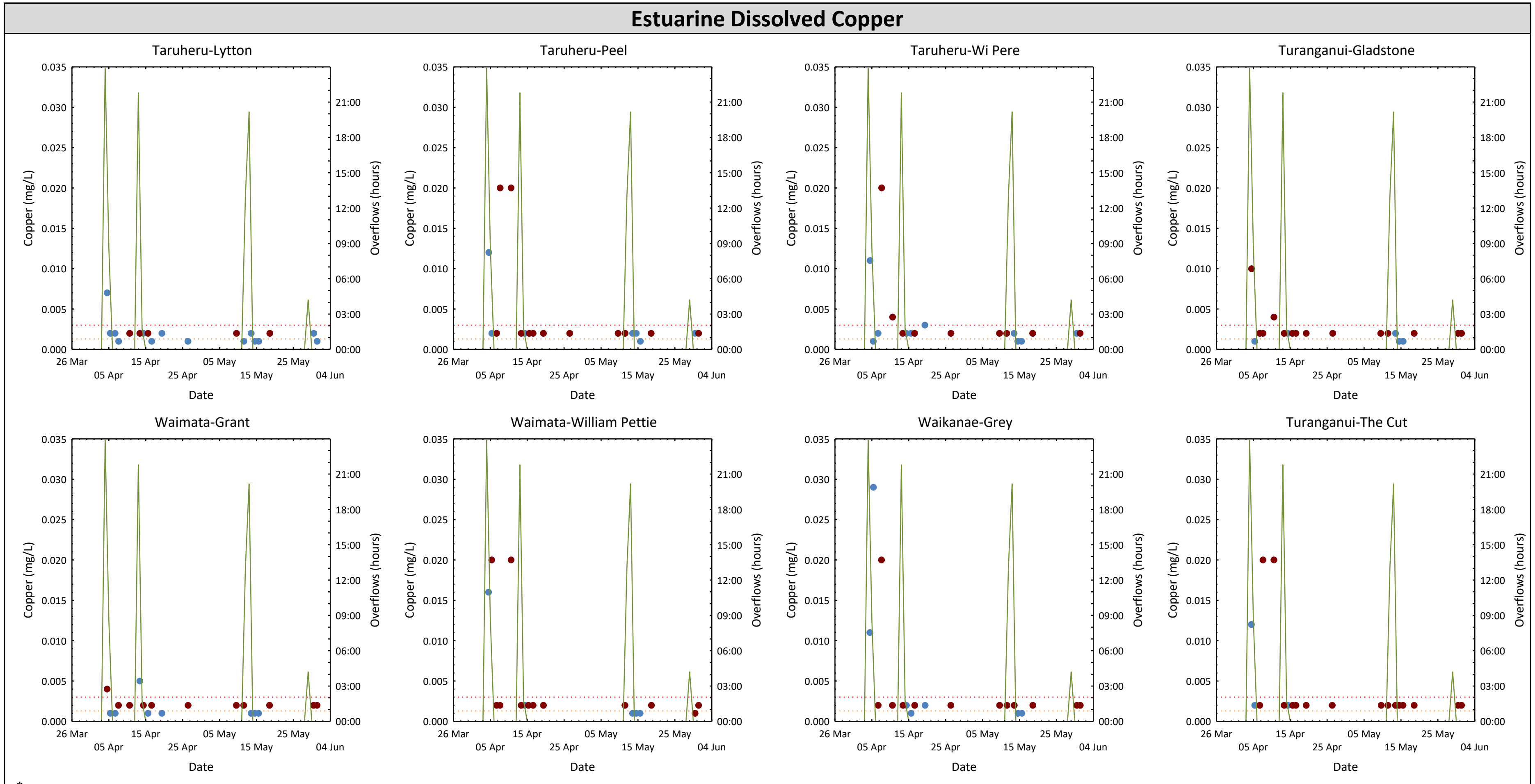


Figure 5-7: Dissolved zinc concentrations (blue dots >DL, brown dots <DL) measured at estuarine sites before, during and after controlled wastewater discharges. ANZECC (2000) marine trigger values for the protection of 90% (red) and 95% (orange) of species are provided*. The pooled, total duration of overflows is also provided for all sites (green line) even though individual sites may not be affected by those overflows. The coincidence of patterns among sites subject to, and not subject to overflow events would suggest that overflows are not the causal factor.



*These are the same as the draft default guideline values (DGV) of the Australian and New Zealand guidelines for fresh and marine water quality.

Figure 5-8: Dissolved copper concentrations (blue dots >DL, brown dots <DL) measured at estuarine sites before, during and after controlled wastewater discharges. ANZECC (2000) marine trigger values for the protection of 90% (red) and 95% (orange) of species are provided*. The pooled, total duration of overflows is also provided for all sites (green line) even though individual sites may not be affected by those overflows. The coincidence of patterns among sites subject to, and not subject to overflow events would suggest that overflows are not the causal factor.



*These are the same as the draft default guideline values (DGV) of the Australian and New Zealand guidelines for fresh and marine water quality.

Figure 5-9: Ammonia-N concentrations (dots) measured in manholes (left) and freshwater (right) sites before, during and after controlled wastewater discharges. For comparison with the figures above, ANZECC (2000) trigger values for the protection of 90% (red) and 95% (orange) of species are provided. The pooled, total duration of overflows is also provided for all sites (green line) even though individual sites may not be affected by those overflows. The coincidence of patterns among sites subject to, and not subject to overflow events would suggest that overflows are not the causal factor.

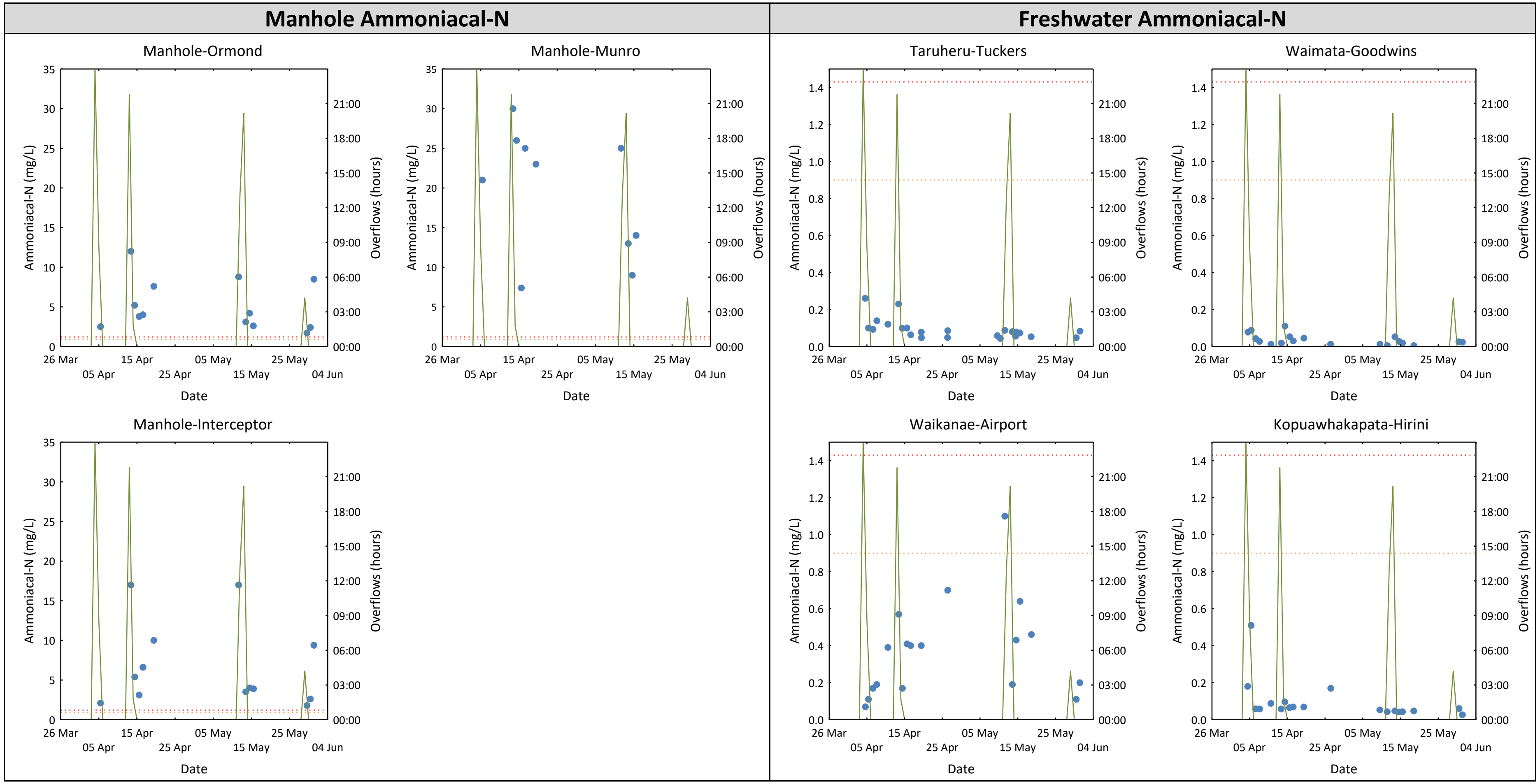


Figure 5-10: Dissolved zinc concentrations (blue dots >DL, brown dots <DL) measured in manholes (left) and freshwater (right) sites before, during and after controlled wastewater discharges. For comparison, trigger values for the protection of 90% (red) and 95% (orange) of species are provided. Estuary trigger values are used for the manhole sites and freshwater trigger values for streams. The pooled, total duration of overflows is also provided for all sites (green line) even though individual sites may not be affected by those overflows. The coincidence of patterns among sites subject to, and not subject to overflow events would suggest that overflows are not the causal factor.

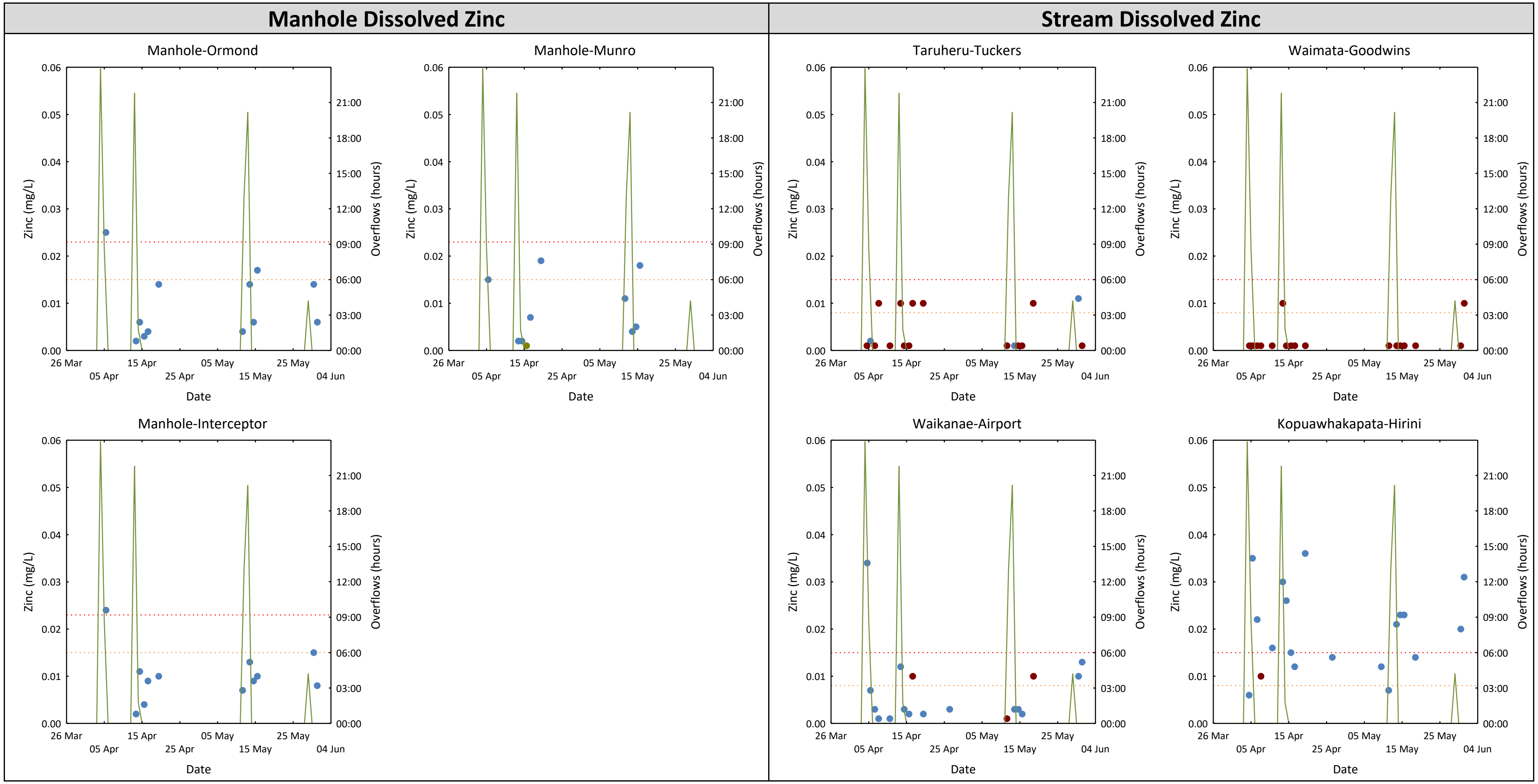


Figure 5-11: Dissolved copper concentrations (blue dots >DL, brown dots <DL) measured in manholes (left) and freshwater (right) sites before, during and after controlled wastewater discharges. For comparison with the figures above, trigger values for the protection of 90% (red) and 95% (orange) of species are provided. The pooled, total duration of overflows is also provided for all sites (green line) even though individual sites may not be affected by those overflows. The coincidence of patterns among sites subject to, and not subject to overflow events would suggest that overflows are not the causal factor.

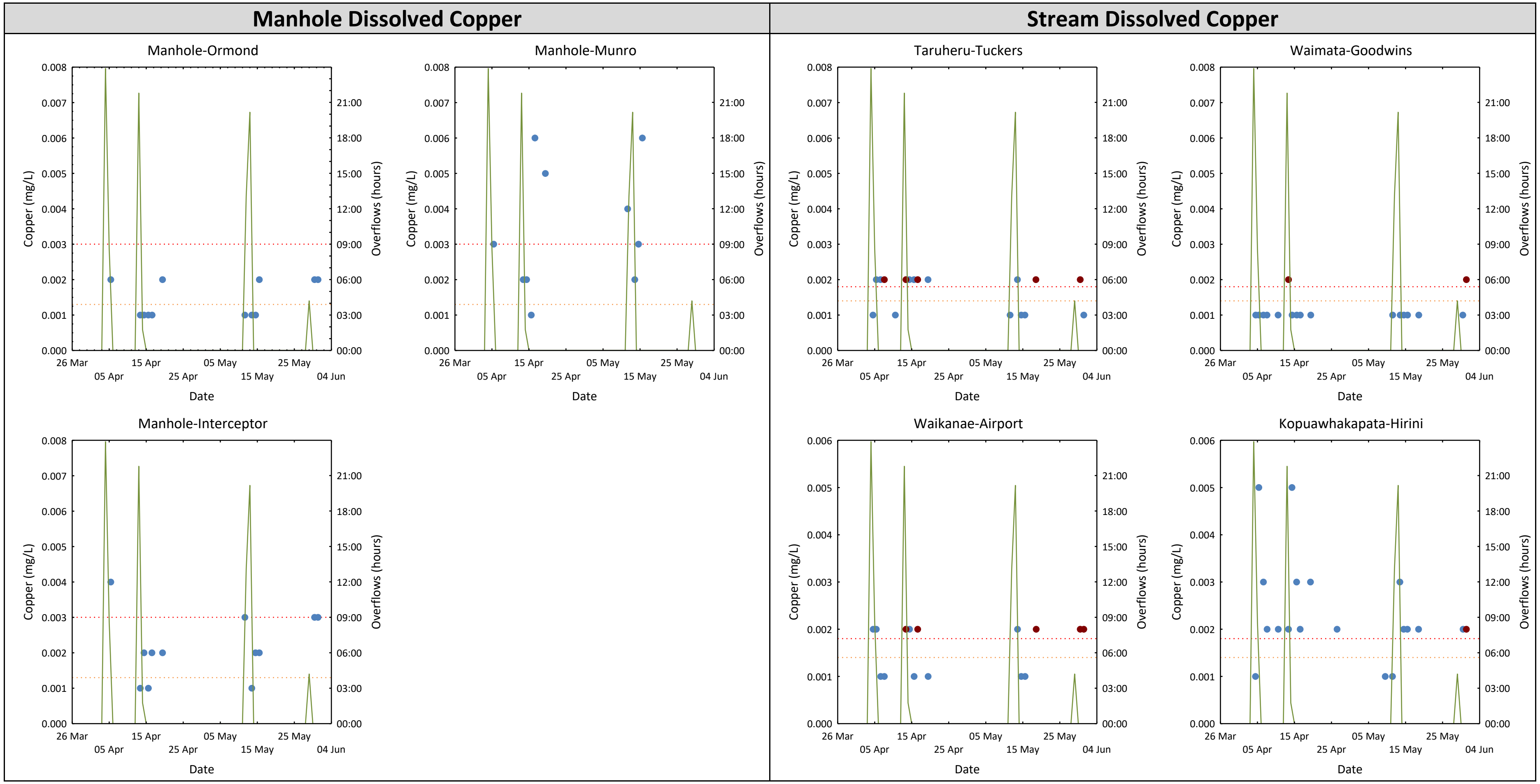


Figure 5-12: Dissolved oxygen saturation measured at estuarine sites before, during and after controlled wastewater discharges. ANZECC (2000) upper and lower, South-east Australia trigger values for physical and chemical stressors are provided. The pooled, total duration of overflows is also provided for all sites (green line) even though individual sites may not be affected by those overflows. The coincidence of patterns among sites subject to, and not subject to overflow events would suggest that overflows are not the causal factor.

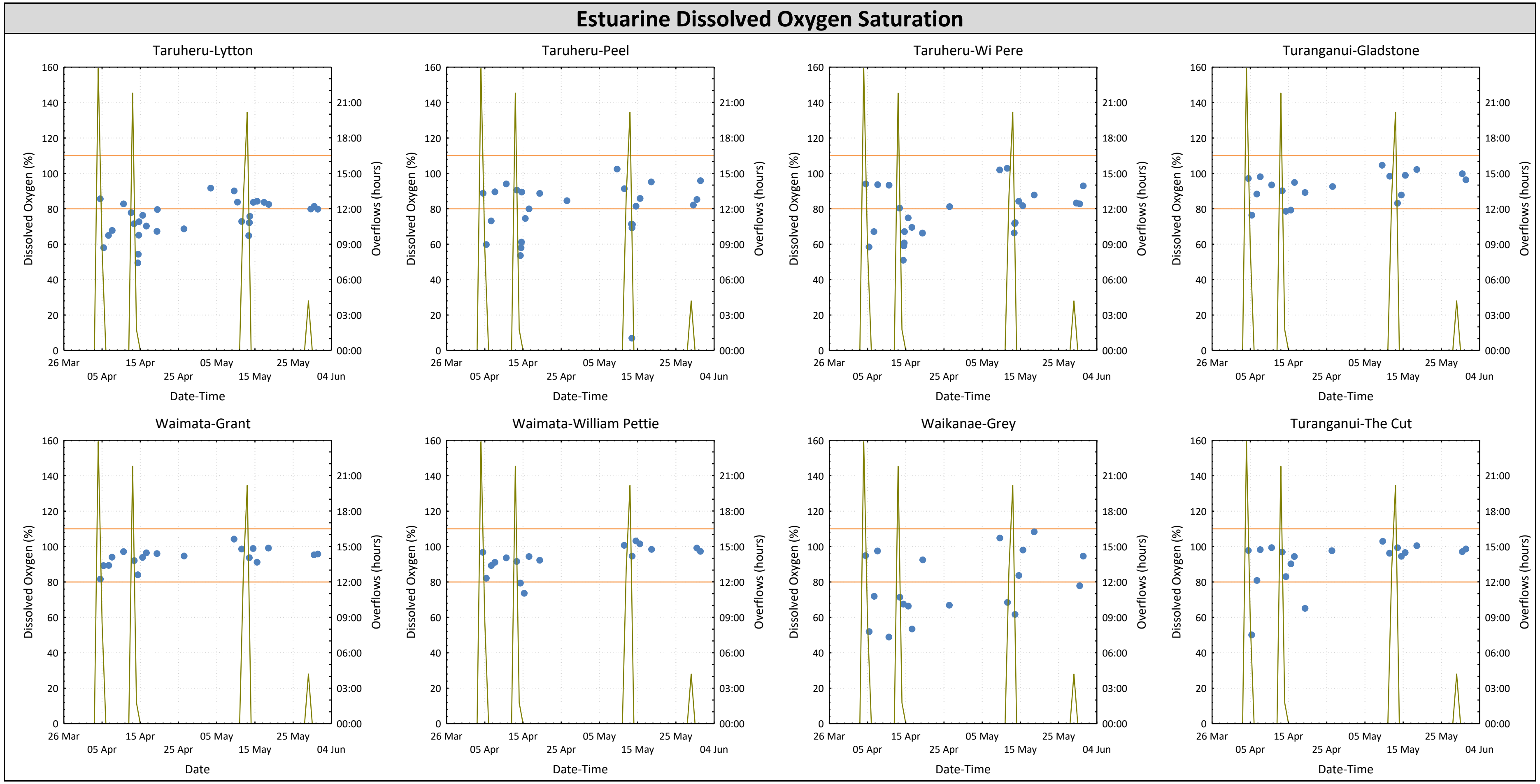
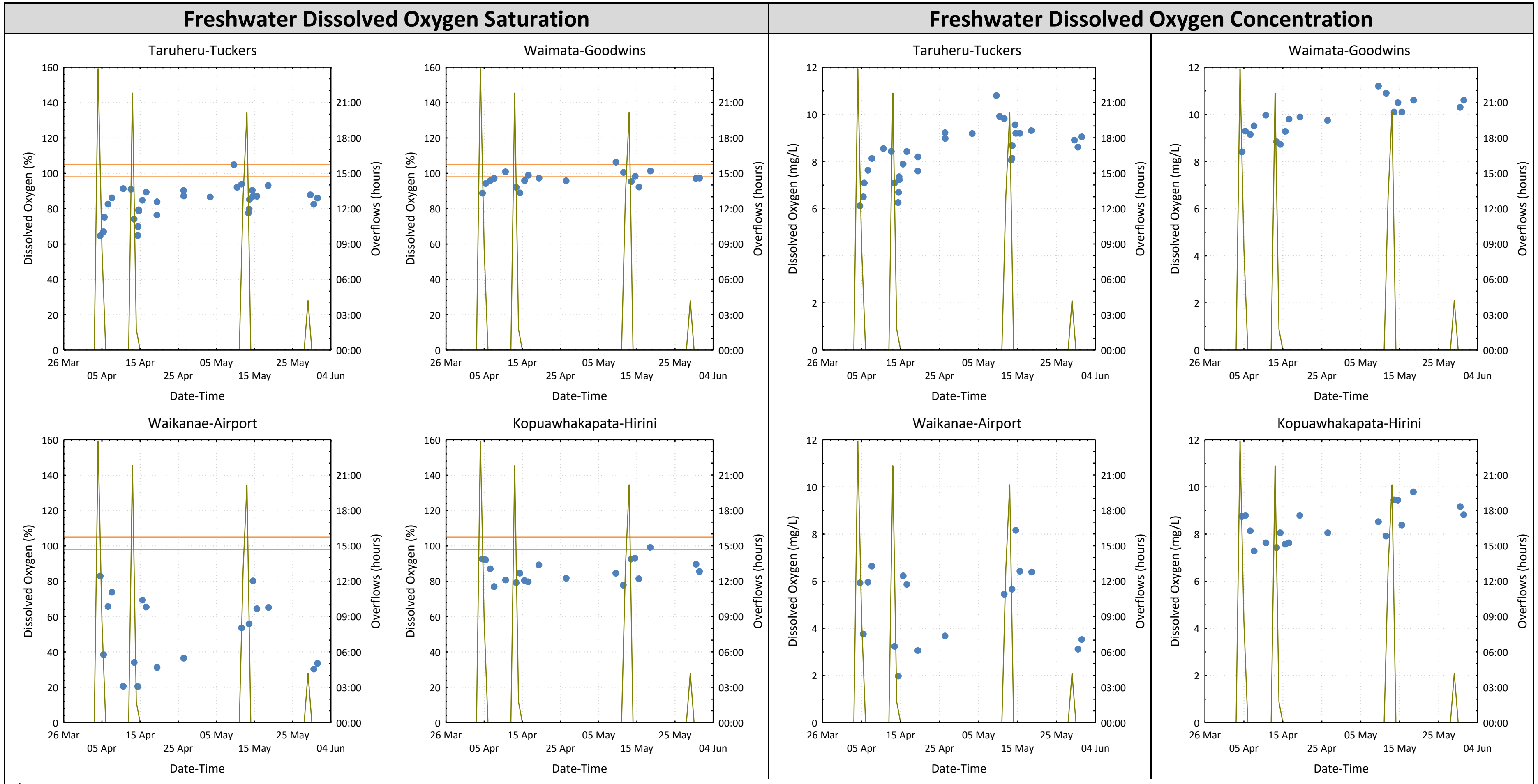


Figure 5-13: Dissolved oxygen levels measured at freshwater sites before, during and after controlled wastewater discharges. ANZECC (2000) upper and lower, trigger values for physical and chemical stressors are provided for saturation plots. NPS-FWM (Ministry for the Environment 2017) attribute states for dissolved oxygen concentrations in rivers are provided in Table 1. The pooled, total duration of overflows is also provided for all sites (green line) even though individual sites may not be affected by those overflows. The coincidence of patterns among sites subject to, and not subject to overflow events would suggest that overflows are not the causal factor.



[*] The controlled overflow plot is provided to assist in the comparison of estuary sites. The only freshwater site actually affected by overflows during this period was the Hirinui site along Kopuwhakapata Stream on 4 and 5 April.

Table 1: NPS-FWM (Ministry for the Environment 2017) attribute states for dissolved oxygen in rivers.

Attribute State	Range		Description
	7-day mean minimum (Summer Period: 1 Nov to 30 Apr)	1-day minimum (Summer Period: 1 Nov to 30 Apr)	
A	≥8.0	>7.5	No stress caused by low dissolved oxygen on any aquatic organisms that are present at matched reference (near-pristine) sites.
B	>7.0 and <8.0	>5.0 and <7.5	Occasional minor stress on sensitive organisms caused by short periods (a few hours each day) of lower dissolved oxygen. Risk of reduced abundance of sensitive fish and macroinvertebrate species.
C	>5.0 and <7.0	>4.0 and <5	Moderate stress on a number of aquatic organisms caused by dissolved oxygen levels exceeding preference levels for periods of several hours each day. Risk of sensitive fish and macroinvertebrate species being lost.
National Bottom Line	5.0	4.0	
D	<5.0	<4.0	Significant, persistent stress on a range of aquatic organisms caused by dissolved oxygen exceeding tolerance levels. Likelihood of local extinctions of keystone species and loss of ecological integrity.

6 MODELLING

Hydrodynamic modelling has been used to examine the dispersal and dilution of wastewater from the primary outfalls (MetOcean Solutions 2019) with releases starting at mean high water and mean low water spring tides, with the following scenarios modelled:

- four wind velocity and direction (NW 15 m/s, NW 25m/s, SE 15m/s, SE 25m/s), and
- three river flow annual return intervals (ARI) (current 2-year, current 10-year, and future 10-year ARIs).

Discharge volumes and durations were adjusted for each of the ARIs modelled, with the largest volumes and durations associated with the current 10-year ARI. Specific model predictions were generated for total Kjeldahl nitrogen (TKN), total phosphorus and total suspended solids from the Peel and Wainui Street outfalls. Median concentrations based on inflow monitoring data from Gisborne wastewater treatment plant (Feb 2011 to Dec 2016) were modelled for these parameters (pers. comm. Wolfgang Kanz, GDC). Those medians were greater than the medians obtained from the manhole samples examined in Section 5 (see Table 2). Note that TKN provided a reasonable approximation for total nitrogen because measured nitrate-N and nitrite-N concentrations in

Gisborne's wastewater are relatively low compared with organic nitrogen and ammonia (the two TKN components)[9].

Upstream dispersal did not occur under any of the scenarios modelled (because flood flows overwhelmed tidal flows). Worst case predictions for TKN occurred under north-westerly winds of 25 $m.s^{-1}$, with the timing of the discharge relative to the tide having little influence on dispersal patterns (see Figure 6-1). Under those conditions, TKN concentrations between the Peel Street outfall and the confluence were predicted to exceed 0.04 mg/L (above concentrations without the modelled discharge), but they dropped sharply below the confluence and away from the Wainui outfall. Concentrations reached levels typically cited as minimum detection limits by commercial laboratories around the mouth of Turanganui River. In comparison, average total nitrogen concentrations measured by GDC at monitoring of sites in Taruheru, Turanganui and Waimata Rivers, and Waikanae Creek between 2014 and 2019 ranged from 0.513 to 3.117 mg/L (Table 3). Phosphorus and total suspended solids plumes were substantially smaller than the TKN plume (see MetOcean Solutions 2019).

Table 2: Median TKN, TP and TSS concentrations obtained from manholes sampled in April-May 2017 that were used for hydrodynamic modelling.

Source	Total Kjeldahl nitrogen (mg/L)	Total Phosphorus (mg/L)	Total Suspended Solids (mg/L)
Harris St WW interceptor manhole	14	1.25	69
Munro St WW interceptor manhole	36	4.8	190
Ormond Rd WW interceptor manhole	13	1.5	86
Modelled concentration	40	5.05	240

---

[9] Total nitrogen = TKN + nitrate-N + nitrite-N

Figure 6-1: Predictions of TKN dispersal using the current 10-year return interval (from MetOcean Solutions 2019). Plots show concentrations after 6 (left), 24 (middle) and 48 (right) hours, from release with 15 m/s (top) and 25 m/s (bottom) north westerly wind scenarios.

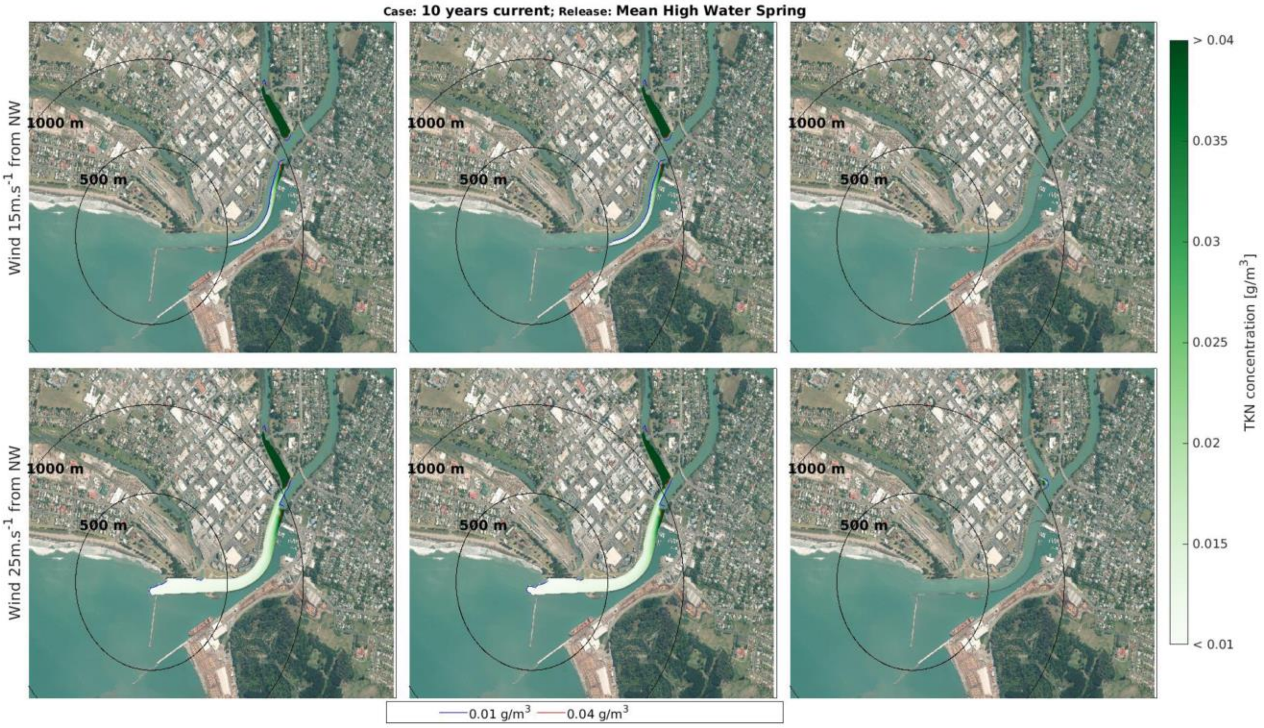


Table 3: Mean, maximum and minimum total nitrogen concentrations recorded in GDC's water quality monitoring programme between 2014 and 2019.

Monitoring Site	Mean Total N (mg/L)	Max Total N (mg/L)	Min Total N (mg/L)	Start Date	End Date	Number of samples
Taruheru River at Lytton Rd Bridge	2.835	8.8	0.13	Oct-14	Mar-19	64
Taruheru River at Peel St Bridge	1.34	7.4	0.01	Oct-14	Mar-19	65
Taruheru River at Tuckers Rd Bridge	3.117	14	0.38	Oct-14	Mar-19	66
Taruheru River at Wi Pere Pipe	1.968	8.4	0.031	Oct-14	Mar-19	65
Turanganui River at Gladstone Rd Bridge	0.744	5.7	0.031	Oct-14	Mar-19	65
Turanganui River at The Cut	0.635	3.6	0.033	Oct-14	Mar-19	64
Waikanae Creek at Grey St Bridge	0.859	2.8	0.021	Oct-14	Mar-19	64
Waikanae Creek at Stanley Rd Bridge	1.161	2.3	0.12	Oct-14	Mar-19	42
Waimata River at Goodwins Rd Bridge	0.57	2.5	0.11	Oct-14	Mar-19	64
Waimata River at Grant Rd	0.513	1.7	0.06	Oct-14	Mar-19	64

7 BENTHIC SURVEY

The potential habitat and ecological effects of discharges from the primary and secondary discharge points were assessed by surveying benthic communities and sediment quality in urban estuarine sections of the Taruheru, Waimata and Turanganui Rivers. Benthic communities and sediment quality are sensitive to the effects of multiple environmental stressors, including physical disturbance, sedimentation and smothering, toxic contaminants, and organic enrichment. As such, gradients in sediment quality and community composition commonly occur around wastewater outfalls. Relative to other areas, sediments in close proximity to wastewater outfalls could reasonably be expected to have elevated concentrations of nitrogen, phosphorus, total organic carbon and total organic matter (based on the general characteristics of wastewater).

As with water quality, other landuses also influence sediment quality. Rural landuses increase sediment and nutrient loads, while urban activities generate stormwater contaminants such as sediment and heavy metals. Sediments below urban stormwater outfalls are less likely to have elevated nutrient concentrations, but they commonly have elevated concentrations of heavy metals (particularly copper and zinc) and could have elevated total organic carbon and total organic matter concentrations (caused by inputs of organic matter, such as leaf litter). Zinc is a key urban stormwater contaminant, but it not a significant component of urban wastewater unless stormwater or significant trade waste inputs from zinc-related industries are present. Kennedy and Sutherland (2008) identified roofing materials, tyre wear, and atmospheric deposition (rain and dry deposition) as the major sources of zinc in Auckland’s stormwater. These are also likely to be the key sources in Gisborne.

The effects of these inputs are moderated by natural physical processes. Sediments, and any contaminants bound to them, tend to flocculate, settle out and accumulate in brackish, upper estuary areas, making them muddier than outer estuary and coastal zones. Having said that, the potential for sediment accumulation also depends on flushing characteristics and the available accommodation space for sediments (e.g., sediments are unlikely to accumulate in a well flushed channel with little intertidal margin). As noted earlier, disentangling all of these influences is difficult.

Wastewater effects on sediment quality and benthic ecology in Taruheru, Waimata and Turanganui Rivers was therefore assessed by measuring:

- mud content (measured as a percentage (%) of the total weight of sediment below 63 μm);
- total organic carbon (%);
- total organic matter (derived from ash free dry weight);
- total nitrogen and total recoverable phosphorus; and,
- total recoverable zinc (as an indicator of stormwater influences)

in samples obtained from 12 sites spread along tidal reaches of the rivers, together with benthic macrofauna at six sites in the lower sections of the rivers (Figure 7-1). A conservative (worst case) approach was taken to determining effects, by including two sites that were within 20 m of the Wainui Rd and Palmerston Rd/Peel St outfalls, and two within 20 m of the main-channel junctions of the tributaries into which the Oak St and Seymour Rd/Turenne St outfalls discharge. In accordance with the Resource Management Act (1991), an allowance is usually made for reasonable mixing to occur, but in this case, sampling close to the outfalls was done to maximise the likelihood that effects could be linked to discharges from the key wastewater outfalls.

At each site two composites, each made up from 3 subsamples, were obtained of the top 2 cm of sediment. The duplicate samples were transferred into sealed jars, chilled and delivered to Hill Laboratories the next day for the analysis of:

- sediment texture;
- total organic carbon;
- total organic matter (ash free dry weight);
- key nutrient concentrations (total nitrogen and total recoverable phosphorus); and,
- total recoverable zinc (as an indicator of stormwater influences).

Five ecological core samples (13 cm diameter by 15 cm deep) were also collected from each of the six sites in the lower section of the river system. These were sieved to 0.5 mm, preserved in isopropyl alcohol, and sent to an experienced taxonomist for sample sorting, taxa identification (to the lowest practicable level), and enumeration. Limiting the ecological sampling sites to the lower river was done to, as far as possible, minimise the potential for results to be confounded by the transition from marine to freshwater habitats.

Ecological data were analysed using diversity and abundance indicators including:

- number of taxa;
- total counts of individuals;
- Shannon’s Diversity; and,
- Pielou’s Evenness.

Indicator data were plotted and analysed using one-way ANOVA and Tukey’s Honest Significant Differences tests to detect statistically significant differences among sites, and the sites responsible for the differences identified. The assumptions of equal variance and normally distributed residuals were checked prior to analysis, with data being $\log_{10}$ transformed if raw data values violated those assumptions.

Non-metric multidimensional scaling (MDS) of square root transformed count data using Bray Curtis similarity was also used to look for differences in community composition among sites. Non-metric multidimensional scaling plots provide an easily interpretable representation of community data, with the composition of samples close together on an MDS plot being more similar than those further apart. The MDS analyses were also supported by cluster and similarity profile testing to identify statistically different groups of samples, and the taxa contributing to those differences. All multivariate analyses were carried out using Primer-E (version 6).

Explanation of Shannon and Pielou's Diversity Indices

Shannon's Diversity takes into account both the number of species (or taxa) and how evenly individuals are spread among those species (or taxa). It is a measure of the uncertainty associated with correctly predicting which species a randomly selected specimen belongs to. That uncertainty decreases as the number of taxa and evenness decreases. If nearly all individuals belong to a single species, Shannon diversity approaches zero (it equals zero if there is only one species). Conversely, Shannon diversity increases as the number of taxa and evenness increases, with the maximum value achieved when each taxon has the same number of individuals (the maximum value possible equals the log of the number of species). Shannon diversity values are sensitive to sampling effort and the logarithm base used. Therefore, results should only be compared among studies with similar sampling designs and for results using the same logarithm base (Clarke & Warwick 2001; Pla et al. 2012).

Pielou's Evenness is a measure of how even (i.e., similar) the abundances of individual species are at a site. Low index values indicate that the site is dominated by a single, or a few, species which occur in high abundance(s). The remaining species occur in relatively low abundances. In contrast, high index values indicate that the abundances of all species are similar. Pielou's Evenness is derived from the Shannon Diversity value of a sample divided by the maximum possible Shannon Diversity value of that sample (Clarke & Warwick 2001; Pla et al. 2012).

Figure 7-1: Sediment and ecological sampling sites. The locations of primary and secondary wastewater outfalls are also shown.

7.1 Results

7.1.1 Sediment quality

Sediment quality varied along and between river systems, but evidence of impacts in the immediate vicinity of the primary and secondary wastewater outfalls was limited. Key sediment quality findings are listed below.

- Averaged, total nitrogen concentrations in the two upper Taruheru sites (which includes the site below the Oak St. outfall) were at or above concentrations considered to cause moderate stress on a number of aquatic organisms (1000-2000 mg/kg). Concentrations at all other sites were in the range considered to cause minor stress on sensitive organisms (250–1000 mg/kg) (including sites below the Seymour/Turenne, Wainui and Palmerston/Peel outfalls) (Robertson et al. 2016; Figure 7-2). A general pattern of declining total nitrogen concentrations was observed down the urban section of Taruheru River (Figure 7-7), while relatively little variation was observed along Waimata and Turanganui Rivers.
- Highest averaged total recoverable phosphorus concentrations were recorded at the two upper Taruheru sites (which includes the site below the Oak St outfall) and from the site below the Palmerston/Peel outfall. However, concentrations at all sites were within the "good" range (200–500 mg/kg) proposed by Robertson and Stevens (2012) (Figure 7-3).
- Averaged, total organic carbon concentrations in the three upper Taruheru sites (which includes the site below the Oak St outfall) were at or above concentrations considered to cause moderate stress on a number of aquatic organisms (>1–2%), while concentrations at five sites were in the range considered to cause minor stress on sensitive organisms (0.5–1%) (including sites below the Seymour/Turenne, Wainui and Palmerston/Peel outfalls). Total organic carbon concentrations at four sites were in the range considered to cause no stress (Robertson et al. 2016; Figure 7-4). A general pattern of declining total organic carbon concentrations was observed down the urban section of Taruheru River. Relatively little variation was observed along Waimata and Turanganui Rivers. Very similar patterns were observed in total organic matter (Figure 7-7).
- Averaged, mud content at all sites was in the range considered to cause significant persistent stress on a range of aquatic organisms (>25%; Robertson et al. 2016; Figure 7-5). A general pattern of declining mud content was observed down the urban section of Taruheru River. Mud content was relatively high and variable in the Waimata and Turanganui Rivers (Figure 7-7).
- Averaged, zinc concentrations were below the low level (ISQG-L) ANZECC (2000) sediment quality guideline value, but concentrations were moderately elevated at the site below the Palmerston/Peel outfall where they exceeded the widely used ERL guideline value of Long & Morgan 1990 (Figure 7-6). With the exception of the spike in zinc concentrations below the Palmerston/Peel outfall, there was a general pattern of declining concentrations down the urban section of Taruheru and Turanganui Rivers. Zinc concentrations in Waimata River were consistently low along its urban reaches (Figure 7-7).

7.1.1.1 Overall conclusions from the sediment quality analyses

Overall, the results show an underlying pattern of declining levels of total nitrogen, total organic carbon, total organic matter and mud down the urban section of Taruheru River. The occurrence of relatively high concentrations of these parameters at the uppermost site (which is upstream of the most frequently overflowing outfalls) and relatively low concentrations at sites downstream of frequently overflowing outfalls (on all three rivers), suggests the observed trend is unrelated to wastewater overflows. The factor, or factors, causing these trends are uncertain, but rural runoff and natural sedimentation processes at the marine-freshwater interface may be involved.

Having said that, the influence of wastewater can potentially be seen as a spike in the sediment concentrations of phosphorus immediately below the Palmerston/Peel outfall (Site Taruheru 6). A similar spike in zinc concentrations at that location also suggests that stormwater runoff has a localised effect on that area. Concentrations of most parameters are also slightly higher below the Oak St outfall (Site Taruheru 2) compared with the adjoining upstream site (Site Taruheru 1, Lytton Rd).

Table 4: Averaged concentrations/percentages of total recoverable phosphorus (TP), total nitrogen (TN), total organic carbon (TOC), total organic matter (TOM), mud, and total recoverable zinc (Zinc) obtained from duplicate sediment samples. Coordinates are provided for the sampling sites.

Site	NZTM X	NZTM Y	TP (mg/kg)	TN (%)	TOC (%)	TOM (%)	Mud (%)	Zinc (mg/kg)
Taruheru 1	2035232	5710520	435	0.145	1.5	6	75.1	83.5
Taruheru 2	2036278	5709943	500	0.15	1.485	6.5	81.7	98.5
Taruheru 3	2037110	5709396	310	0.1	1.025	5.5	64.45	72
Taruheru 4	2037319	5709211	330	0.09	0.925	4.5	57.8	82
Taruheru 5	2037522	5708602	370	0.09	0.94	4.5	58.35	79
Taruheru 6	2037503	5708369	480	0.085	0.845	5	40.55	181.5
Turanganui 1	2037645	5708140	325	0.055	0.45	3	60.3	55
Turanganui 2	2037656	5707962	355	0.065	0.57	3.5	69.7	73
Turanganui 3	2037491	5707682	360	0.07	0.61	4	67.25	56.5
Waimata 1	2038684	5708216	295	0.05	0.45	3.5	47.45	45.5
Waimata 2	2038503	5708193	310	0.045	0.38	2.5	40.55	44.5
Waimata 3	2037952	5708452	320	0.055	0.445	3	66.1	49

Figure 7-2: Averaged total nitrogen concentrations obtained from duplicate sediment samples.

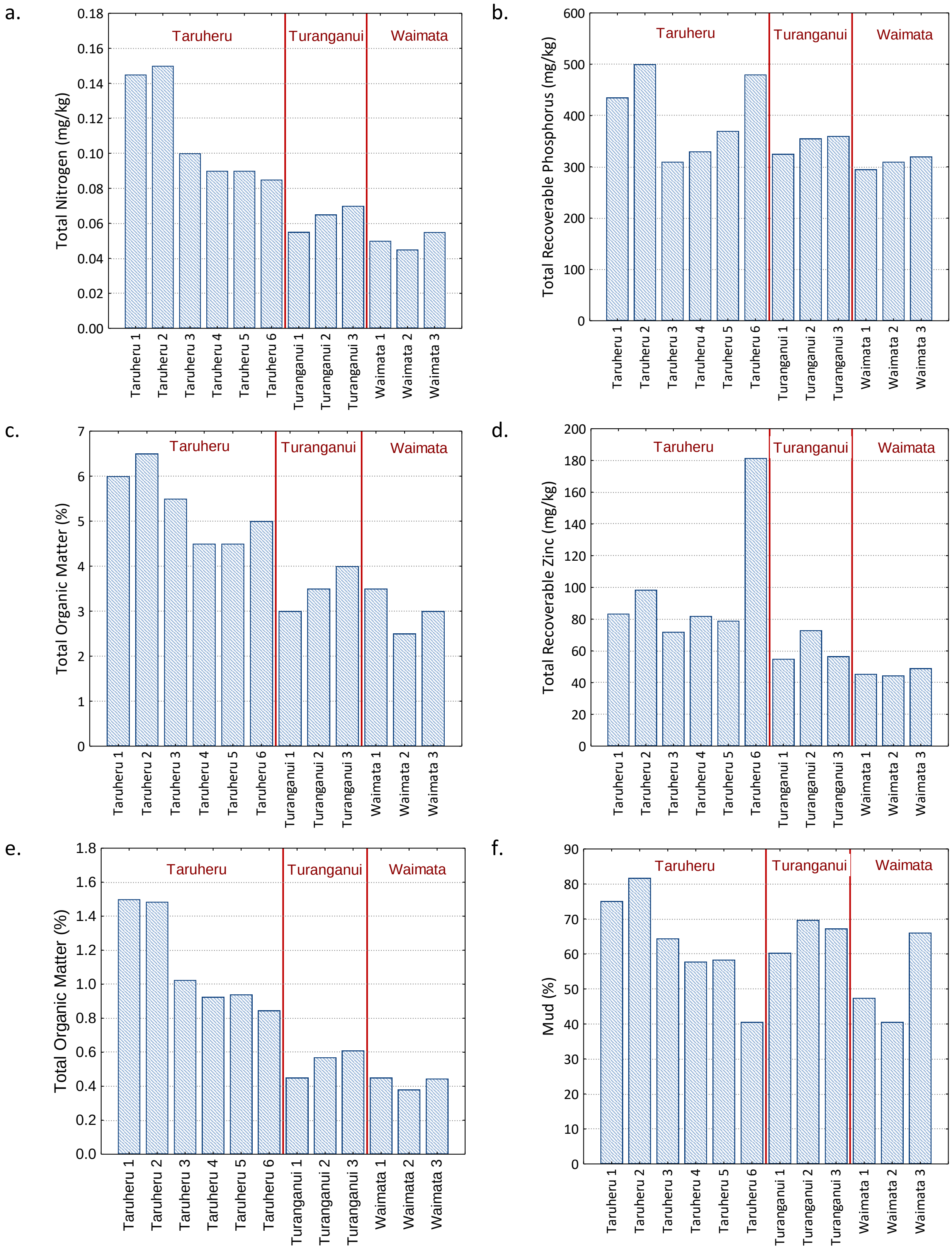
Figure 7-3: Averaged total recoverable phosphorus concentrations obtained from duplicate sediment samples.

Figure 7-4: Averaged total organic carbon concentrations obtained from duplicate sediment samples.

Figure 7-5: Averaged proportion of mud in duplicate sediment samples.

Figure 7-6: Averaged total recoverable zinc concentrations obtained from duplicate sediment samples.

Figure 7-7: Plots of averaged concentrations/percentages of a) total nitrogen b) total recoverable phosphorus, c) total organic matter, d) total recoverable zinc, e) total organic carbon, and f) sediment mud (<63 µm) content obtained from duplicate sediment samples down Taruheru, Turanganui, and Waimata Rivers.



7.1.2 Benthic Ecology

Benthic macrofaunal communities in benthic cores collected from sites around and below the confluence of Taruheru, Waimata and Turanganui Rivers contained moderate total numbers of taxa, ranging from:

- 14 taxa at the Taruheru 5 site;
- 17 taxa at the Taruheru 6 (below the Peel St outfall), Turanganui 2 (below the Wainui Rd outfall) and Waimata 3 sites; and,
- 20 taxa at the Turanganui 1 and Turanganui 3 sites.

However, a one-way ANOVA did not detect a significant difference in the average number of taxa in the core samples collected from each site. The Turanganui 3 site had the most individuals, with significant differences in average counts detected among samples from the Turanganui 3 and Turanganui 1/Taruheru 5 sites and Turanganui 2 (below the Wainui Rd outfall) and Turanganui 1 site. Few differences were detected in Pielou's evenness and Shannon diversity (Table 5, Figure 7-8 and Figure 7-9).

Overall, the same seven taxa made up between 91% and 97% of the total specimens counts at the six sites sampled: the polychaete *Heteromastus filiformis*; the small bivalve *Arthritica bifurca*; cockles *Austrovenus stutchburyi*; wedge shells *Macomona liliana*; and the polychaetes *Prionospio aucklandica* juvenile Nereidae, and *Scolecolepides benhami*. *Heteromastus filiformis* was the most abundant taxa all sites except the Waimata 3 site, where the small bivalve *A. bifurca* was more abundant. Plots of the abundance of the top six taxa (Figure 7-10 and Figure 7-11) indicated:

- samples obtained directly below the Peel St (Taruheru 6) and Wainui Rd (Turanganui 2) outfalls had high numbers of cockles (all small sizes);
- the Taruheru 5 and 6 and upper Turanganui 1 sites had relatively low abundances of the bivalve *A. bifurca* and nerid polychaetes.

Relatively high abundances of cockles and wedge shells are notable because both species are considered to be sensitive to fine sediment and contaminants (Gibbs & Hewitt 2004; Hewitt et al. 2009). However, the majority of cockles and wedge shells were small, with most cockles <5 mm in length (Figure 7-12).

Differences in community composition were further examined using multivariate analyses. Multidimensional scaling, cluster and similarity profile testing showed that the composition of taxa in samples from the Taruheru 5 and 6 and upper Turanganui 1 sites (which are mostly contained in cluster 'c' in Figure 7-13) differed from the composition in samples obtained from the lower Turanganui sites 2 and 3 (which are mostly contained in cluster 'a' in Figure 7-13) and the Waimata 3 site. Samples obtained from the Waimata 3 site were notable for being more variable than those from the other sites, with individual samples falling into clusters 'a', 'b' and 'd'.

These differences between the sites largely reflected variation in the relative abundance of individual taxa, rather than the presence or absence of those taxa. Similarity percentages indicated that key taxa involved in separating the communities from the 'a' and 'c' cluster in Figure 7-13 were the top seven taxa listed above, which together explained 68% of the dissimilarity between the clusters.

Note that cluster and similarity profile analyses did not separate samples obtained directly below the Peel St (Taruheru 6) and Wainui Rd (Turanganui 2) outfalls, from those obtained from more remote sites (Figure 7-13). The composition of samples obtained from below the Peel St outfall was more similar to the composition at other sites above the confluence, than it was to the Waimata site, or to sites below the confluence. Conversely, samples from the site directly below the Wainui Rd outfall were more similar to those from the lower Turanganui site 3 than those from sites above the confluence.

7.1.3 Overall conclusions from the benthic ecological analyses

Overall, the analyses of benthic ecological samples indicated that:

- intertidal communities of the lower Waimata, lower Taruheru and Turanganui differ from each other;
- benthic communities at sites directly below the two primary wastewater outfalls in the lower Taruheru and Turanganui zones, were largely indistinguishable from the communities at other sites within those zones; and,
- the assessment and analyses described suggest that the wastewater discharges had little effect of any practical significance on benthic ecology in the receiving environments sampled.

Table 5: Results of one-way ANOVA and Tukey's honestly significant difference tests of differences in ecological indicator values among benthic sampling sites.

Indicator	Sum of Squares	Degrees of Freedom	Mean Square	F value	P value	Tukey's honestly significant differences ($p<0.05$)
Number of taxa	30.167	5	6.033	1.0343	0.4202	
Number of Individuals	94277.1	5	18855.4	5.1894	**0.0023**	Turanganui 3 > Turanganui 1 Turanganui 3 > Taruheru 5 Turanganui 2 > Turanganui 1
Pielou's Evenness	0.13180	5	0.02636	3.194	**0.0238**	Waimata 3>Taruheru 6
Shannon Diversity	0.52084	5	0.10417	3.079	**0.0275**	Turanganui 1 > Taruheru 6

Figure 7-8: Mean (± S.E.) a) number of taxa, b) number of individuals, c) Pielou's evenness, and d) Shannon diversity in benthic cores collected from sites around and below the confluence of Taruheru, Waimata and Turanganui Rivers.

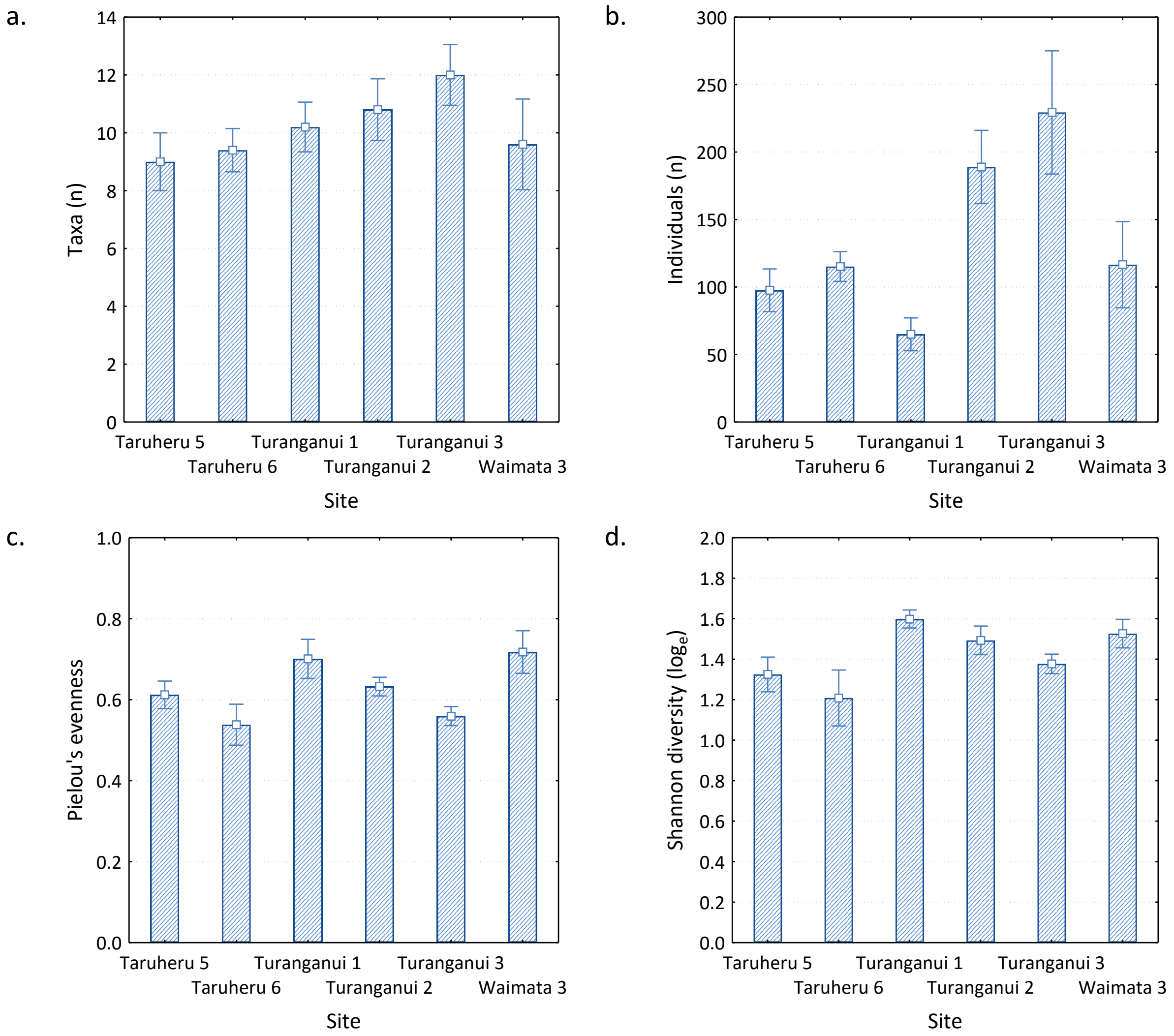


Figure 7-9: Bubbleplots of the mean a) number of taxa, b) number of individuals, c) Pielou's evenness, and d) Shannon diversity in benthic cores collected from sites around and below the confluence of Taruheru, Waimata and Turanganui Rivers.

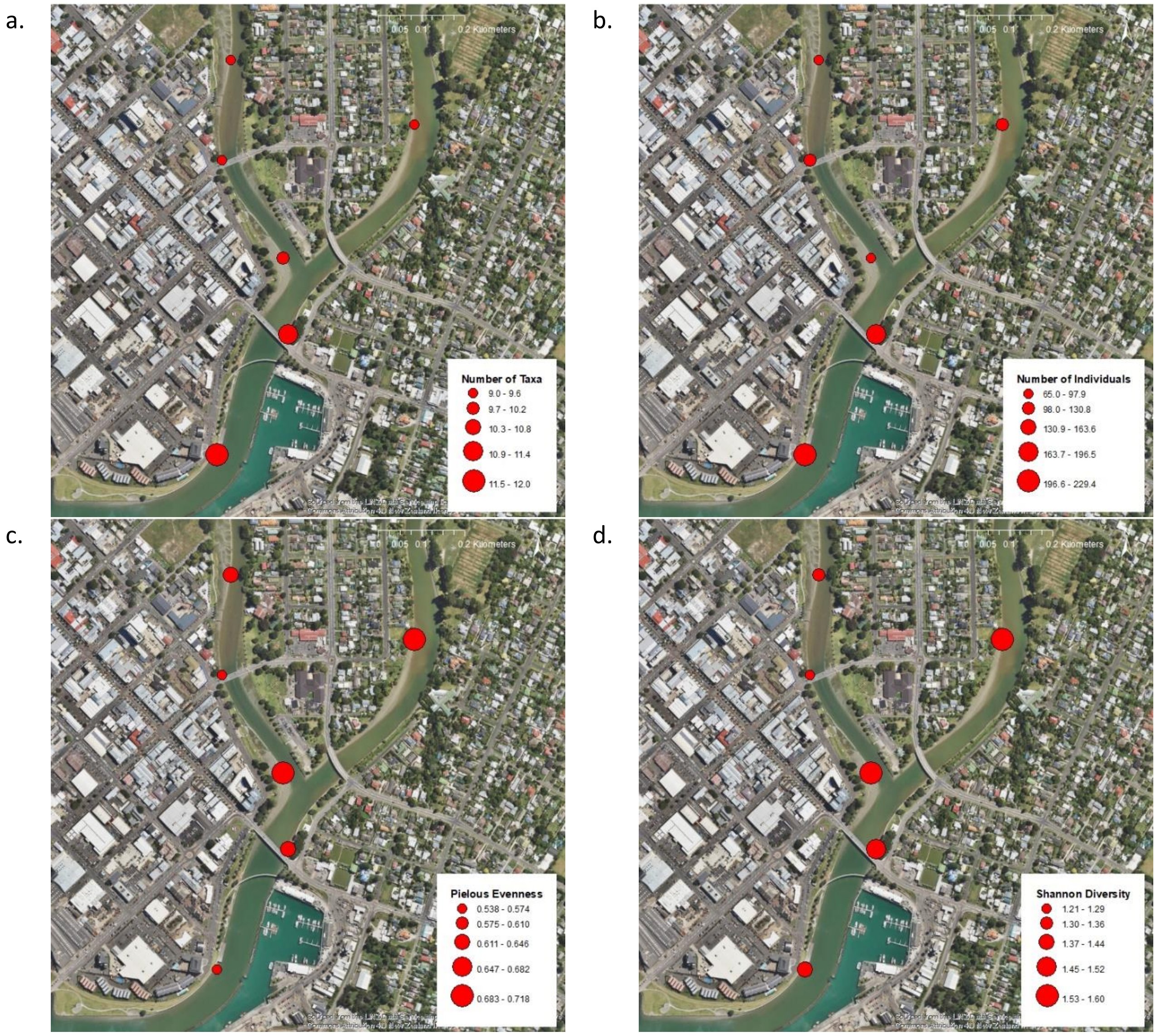


Figure 7-10: Mean (± S.E.) number of a) cockles *Austrovenus stutchburyi*, b) wedge shells *Macomona liliana* c) the small bivalve *Arthritica bifurca*, and the polychaetes d) *Heteromastus filiformis* e) juvenile Nereidae and f) *Prionospio aucklandica* in benthic cores collected from sites around and below the confluence of Taruheru, Waimata and Turanganui Rivers.

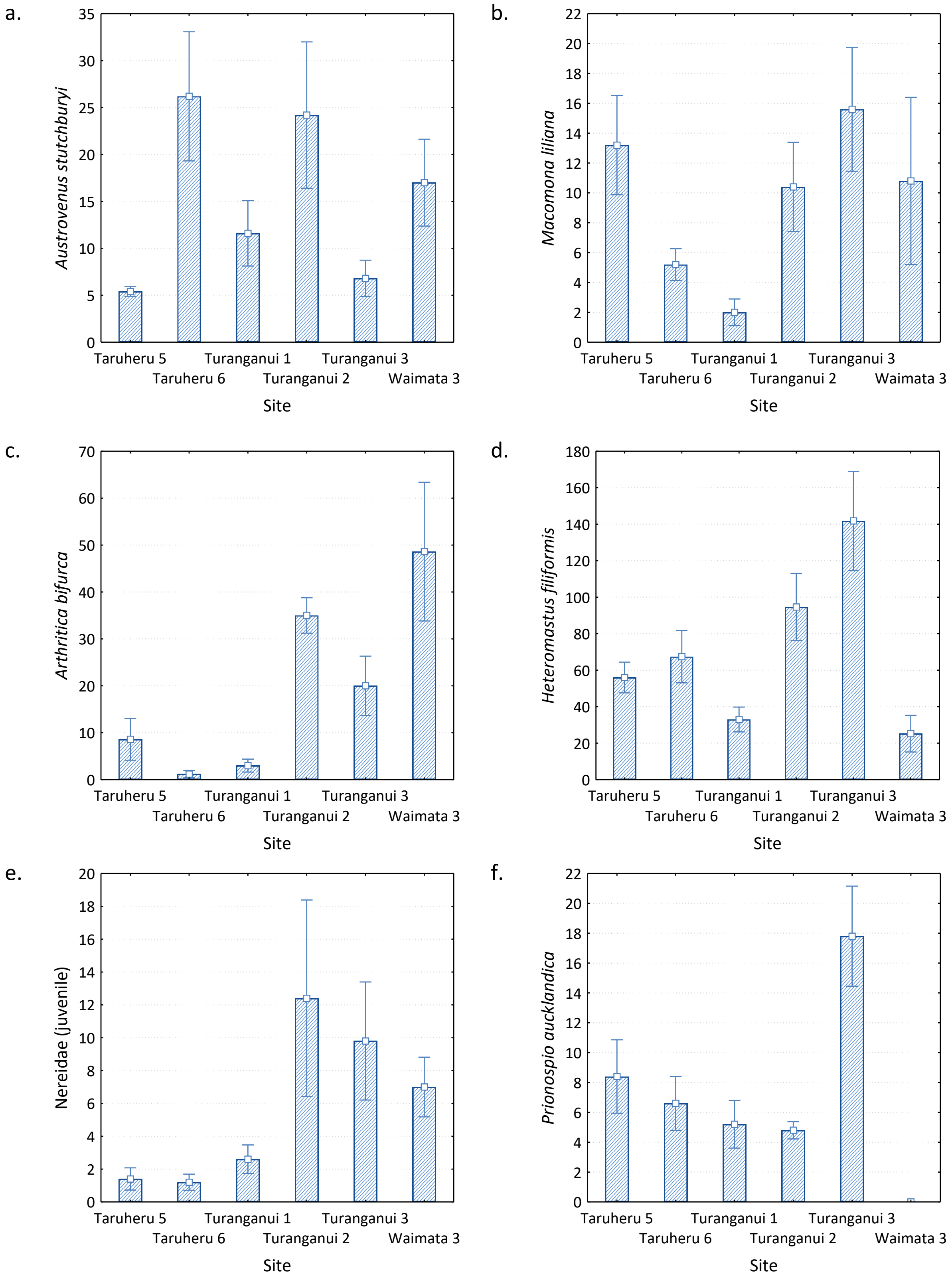


Figure 7-11. Bubbleplots of the mean number of a) cockles *Austrovenus stutchburyi*, b) wedge shells *Macomona liliana* c) the small bivalve *Arthritica bifurca*, and the polychaetes d) *Heteromastus filiformis* e) juvenile Nereidae and f) *Prionospio aucklandica* in benthic cores collected from sites around and below the confluence of Taruheru, Waimata and Turanganui Rivers.

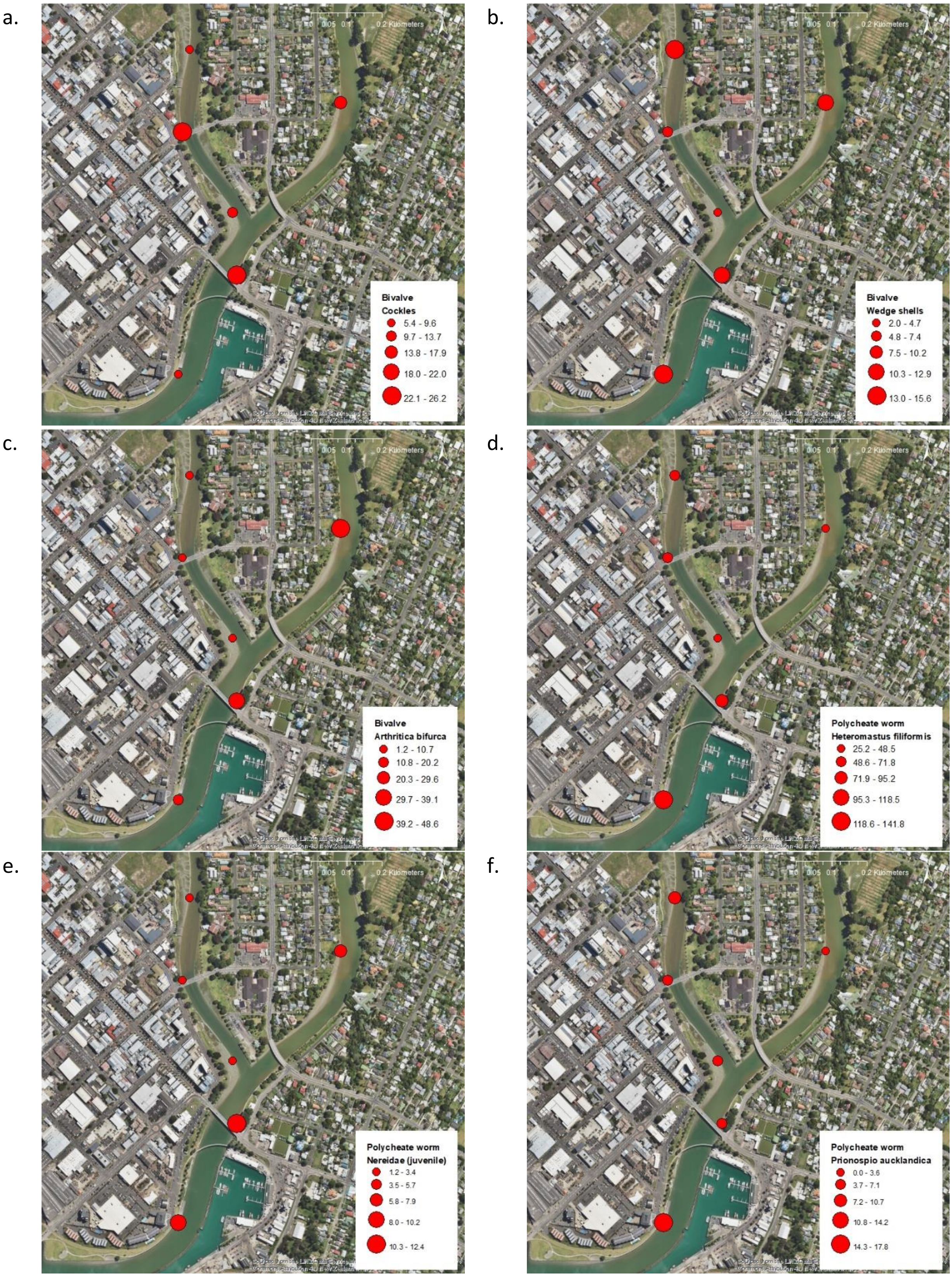


Figure 7-12: Size distribution of cockles, *Austrovenus stutchburyi*, obtained from the six ecological sampling sites.

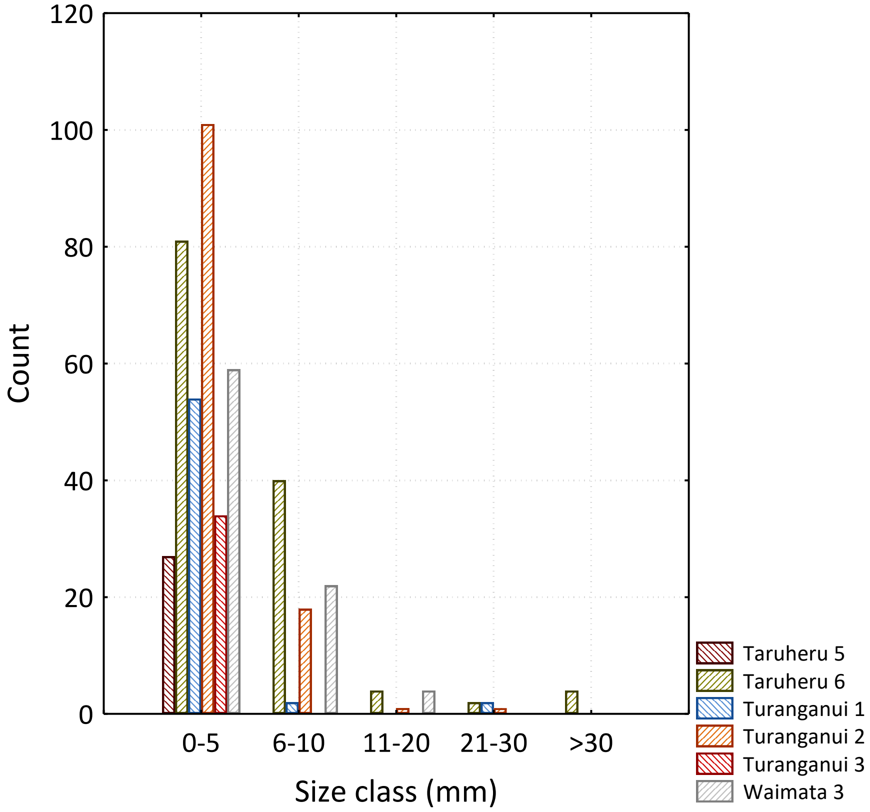
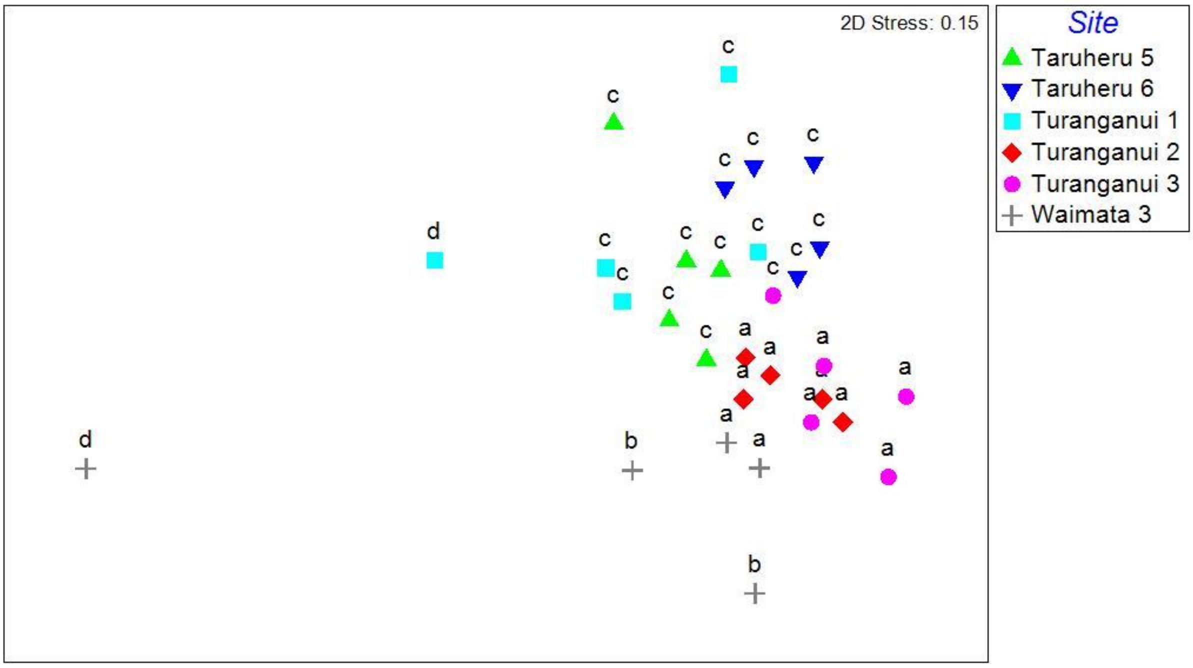


Figure 7-13: Multidimensional scaling plot of benthic community composition in benthic cores collected from sites around and below the confluence of Taruheru, Waimata and Turanganui Rivers. Individual samples are coloured by site. Letters indicate statistically significant clusters identified using similarity profile analysis (p<0.05).



8 SUMMARY AND CONCLUSIONS

Gisborne's urban waterways have been modified by rural and urban landuses, and flood controls. Its urban streams generally consist of piped, channelised and open reaches, with narrow riparian margins and little cover. Unsurprisingly, macroinvertebrate surveys have shown that the quality of urban streams and rivers tends to be poor. However, they do continue to support tolerant macroinvertebrates and fish, including eels. Estuarine sections of Gisborne's rivers also support a range of fish species that are targeted by fishers, and support moderately diverse invertebrate communities.

Wastewater overflows have the potential to adversely affect water quality and aquatic communities:

- by increasing nutrient concentrations and productivity;
- through the deposition and decomposition of organic matter; and,
- through the effects of toxic contaminants.

However, the actual ecological effects caused by wastewater overflows depend on the nature of the discharges, discharge loads and frequency, whether overflows occur during dry or wet weather, and the values and assimilation capacity of the receiving environment (note that cultural elements of water quality, and microbial contaminants and human health effects are outside the scope of this assessment and have not been considered here).

Dry weather overflows are unpredictable, in terms of when and where they occur, and their magnitude of effect. While they have the potential to cause significant adverse effects, actual impacts are site and discharge specific. Small discharges of residential sewage directly into Gisborne's main rivers are likely to be minor. Conversely, a large discharge over an extended period into a confined waterway could have a marked impact, particularly if the discharge included a large trade waste component. Having effective systems and processes for preventing, detecting and responding to such events is therefore recommended.

Our analyses suggest that wet weather discharges do not have a substantial impact on water quality or benthic ecology in estuarine sections of Gisborne's rivers (cultural and microbial considerations excluded). This conclusion is based on the following reasons:

- overflow and corresponding river water quality analyses suggested that the effects of the monitored, wet weather discharges on urban river water quality, were below levels of ecological concern;
- the results of water quality monitoring were consistent with model predictions that suggest nitrogen, phosphorus and suspended solids concentrations from discharges will rapidly be diluted to levels well below those recorded in GDC's river monitoring programme;
- only minor changes in sediment quality were detected directly below two of the primary and secondary outfalls;
- adverse ecological effects were not apparent immediately below primary and secondary outfalls in lower river sections.

GDC advice suggests that limiting discharges to the primary and secondary outfalls can be done without increasing discharge volumes at those outfalls. Based on that, and the results obtained in this study, we conclude that the ecological effects of the proposed wet weather discharges are likely to be minor, as wet weather overflows are episodic, dispersal and dilution is predicted to be rapid, and no patterns were identified in benthic ecology, water quality or sediment quality that could be definitively linked to existing overflows. However, the potential for substantial (most likely short term) impacts from dry weather overflows cannot be discounted. Ensuring effective systems and processes are in place for preventing, detecting and rapidly responding to such events is therefore recommended.

9 REFERENCES

Allibone, R., Horrax, J., Parkyn, S. (2001) Stream classification and instream objectives for Auckland's urban streams. Auckland Regional Council Technical report 2008/002, Auckland Regional Council, Auckland. 76 pp.

ANZECC (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Environment & Conservation Council, and Agriculture and Resource Management Councils of Australia & New Zealand. , Canberra, Australia. 316 pp.

Booth, K., Callis, J., Cave, H., Fogle, S., Gaddum, M., Hudson, K., Warmenhoven, T. (2012) Natural character in the Gisborne District: application of the River Values Assessment System (RiVAS). Lincoln University, Canterbury. 21 pp.

Clapcott, J., West, D., Goodman, J., Goodwin, E., Lander, R., Lucas, J., Crone, D., Murphy, P., Palmer, M.A., Hughey, K.F.D. (2012) Native fish: development and application of the River Values Assessment System (RiVAS and RiVAS+) method to the Gisborne District Council Region. Lincoln University, Canterbury, New Zealand. 32 pp.

Clarke, K.R., Gorley, R.N. (2006) PRIMER v6: User manual/tutorial. Primer-E Ltd., Plymouth, UK. 190 pp.

Clarke, K.R., Warwick, R.M. (2001) Changes in marine communities: an approach to statistical analysis and interpretation. Primer-E Ltd, Plymouth, UK.

Conn, S. (2018) Te Whakamatutu o Te Hane Me Te Whenua o Waikanae Ecological Assessment. Tonkin & Taylor Ltd, Gisborne, New Zealand. 43 pp.

Crow, S. (2017) New Zealand Freshwater Fish Database. Version 1.2. National Institute of Water and Atmospheric Research Ltd. Available at: https://nzffdms.niwa.co.nz/search [Accessed: June 2019]

eBird (2019) New Zealand Bird Atlas. Available at: https://ebird.org/atlasnz/home [Accessed: June 2019]

Forbes, A., Norton, D., Marshall, G. (2018) Waimata River riparian zone description and guidance for restoration. University of Canterbury, Christchurch, New Zealand. 26 pp.

Gibbs, M., Hewitt, J. (2004) Effects of sedimentation on macrofaunal communities: a synthesis of research studies for ARC. ARC Technical Publication TP264, Auckland Regional Council, Auckland. 48 pp.

Gisborne District Council (2013) Gisborne regional freshwater values framework. Gisborne, New Zealand.

Hamill, K. (2012) Baseline Survey of Kopuawhakapata Stream, Gisborne, March 2012. Client report for Port of Gisborne, Opus International Consultants Ltd., Whakatane. 16 pp.

Hewitt, J.E., Anderson, M.J., Hickey, C.W., Kelly, S., Thrush, S.F. (2009) Enhancing the ecological significance of sediment contamination guidelines through integration with community analysis. *Environmental Science and Technology,* 43: pp. 2118–2123

Kelly, S. (2017) Gisborne Wastewater Treatment Plant wetland options: Water quality considerations. Client report for Gisborne District Council 2017-08, Coast and Catchment, Auckland. 18 pp.

Kennedy, P., Sutherland, S. (2008) Urban sources of copper, lead and zinc. ARC Technical Report TR 2008/023, Auckland Regional Council, Auckland.

Klein, R.D. (1979) Urbanisation and stream quality impairment. *Water Resources Bulletin,* 15: pp. 948-963

Long, E.R., Morgan, L.G. (1990) The potential for biological effects of sediment-sorbed contaminants tested in the National Status and Trends Program. National Oceanic and Atmospheric Adminstration, Seattle, Washington. 175 pp.

Mayhew, I. (2019) Gisborne wastewater network overflow discharges resource consent: Application and assessment of effects on the environment (draft in prep). 4Sight Consulting, Auckland.

MetOcean Solutions (2019) Scour event modelling: Poverty Bay. Report prepared for Gisborne District Council, MetOcean Solutions,, Raglan.

Ministry for the Environment (2017) National Policy Statement for Freshwater Management 2014 (amended 2017). Ministry for the Environment, Wellington. 47 pp.

Morse, C.C., Huryn, A.D., Cronan, C. (2003) Impervious surface area as a predictor of the effects of urbanization on stream insect communities in Maine, U.S.A. *Environmental Monitoring and Assessment,* 89: pp. 95-127

Nakielski, M. (2017) Wastewater overflow assessment initial river monitoring report. 4Sight Ltd, Auckland. 58 pp.

Palmer, M., Hardy, A.R. (2015) Summer bio-monitoring survey for the Waipaoa and associated river catchments February 2015, Gisborne District, Te Turanganui a Kiwa. Report for Gisborne District Council, Nga Mahi Te Taiao Consultants. 39 pp.

Peacock, D.H., Ward, C., Stephenson, G. (1997) Physical and ecological changes to the Taruheru Estuary, Gisborne. Gisborne District Council, Gisborne, New Zealand. 32 pp.

Pla, L., Casanoves, F., Di Rienzo, J. (2012) Quantifying Functional Biodiversity. Springer, Berlin, Germnay. 98 pp.

Poynter, M., Everitt, S., Mayhew, I. (2016) Taruheru river weir - review for Gisborne District Council. 4 Sight Consulting Ltd. 57 pp.

Robertson, B., Stevens, L. (2012) Hutt Estuary: Fine scale monitoring 2011/12. Client report prepared for Greater Wellington Regional Council, Wriggle Limited, Nelson.

Robertson, B.M., Stevens, L., Robertson, B.P., Zeldis, J., Green, M., Madarasz-Smith, A., Plew, D., Storey, R., Oliver, M. (2016) NZ estuary trophic index screening tool 2: Determining monitoring indicators and assessing estuary trophic state. Client report prepared for Envirolink Tools Project: Estuarine Trophic Index, MBIE/NIWA Contract No: C01X1420, Wriggle Limited, Nelson. 68 pp.

Roil, H., Death, R. (2018) SOE Report 2015–2018 Aquatic ecosystems in Gisborne: macroinvertebrate communities. Gisborne District Council, Gisborne, New Zealand. 46 pp.

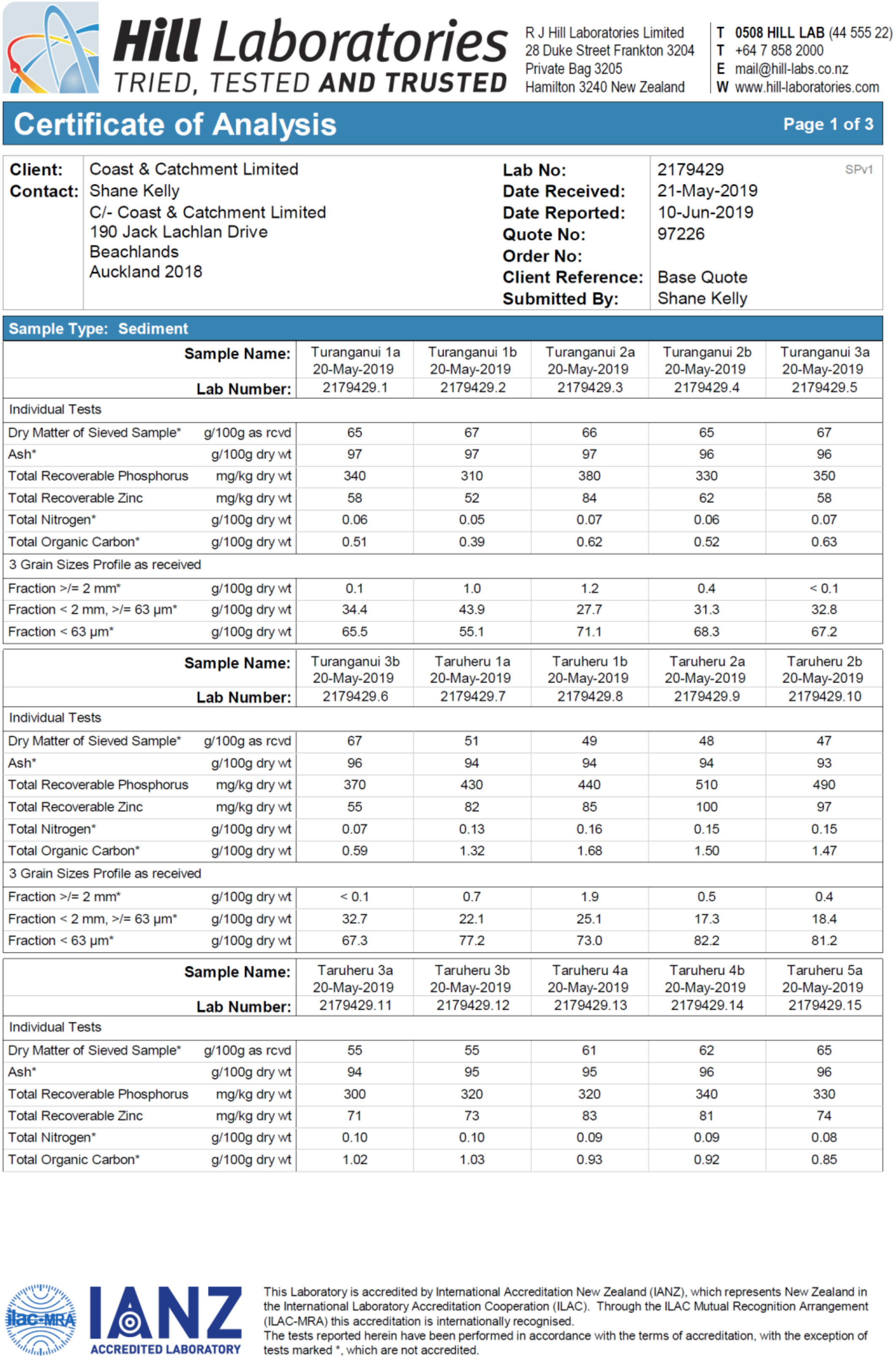
Schueler, T.R., Fraley-McNeal, L., Cappiella, K. (2009) Is impervious cover still important? Review of recent research. *Journal of Hydrologic Engineering,* 14: pp. 309-315

Walsh, C.J., Sharpe, A.K., Breen, P.F., Sonneman, J.A. (2001) Effects of urbanization on streams of the Melbourne region, Victoria, Australia. I. Benthic macroinvertebrate communities. *Freshwater Biology,* 46: pp. 535

10 ACKNOWLEDGEMENTS

Data and information were provided by staff from GDC, 4Sight Consulting and MetOcean Solutions. John McMeeking assisted with benthic sample collection, while sample analyses were carried out by Hill Laboratories and Biolive.

11 APPENDIX 1: SEDIMENT QUALITY RESULTS



Hill Laboratories
TRIED, TESTED AND TRUSTED

R J Hill Laboratories Limited
28 Duke Street Frankton 3204
Private Bag 3205
Hamilton 3240 New Zealand

T 0508 HILL LAB (44 555 22)
T +64 7 858 2000
E mail@hill-labs.co.nz
W www.hill-laboratories.com

Certificate of Analysis

Page 1 of 3

SPv1

Client:	Coast & Catchment Limited	**Lab No:**	2179429
Contact:	Shane Kelly C/- Coast & Catchment Limited 190 Jack Lachlan Drive Beachlands Auckland 2018	**Date Received:**	21-May-2019
		Date Reported:	10-Jun-2019
		Quote No:	97226
		Order No:	
		Client Reference:	Base Quote
		Submitted By:	Shane Kelly

Sample Type: Sediment

Sample Name:		Turanganui 1a 20-May-2019	Turanganui 1b 20-May-2019	Turanganui 2a 20-May-2019	Turanganui 2b 20-May-2019	Turanganui 3a 20-May-2019
Lab Number:		2179429.1	2179429.2	2179429.3	2179429.4	2179429.5
Individual Tests						
Dry Matter of Sieved Sample*	g/100g as rcvd	65	67	66	65	67
Ash*	g/100g dry wt	97	97	97	96	96
Total Recoverable Phosphorus	mg/kg dry wt	340	310	380	330	350
Total Recoverable Zinc	mg/kg dry wt	58	52	84	62	58
Total Nitrogen*	g/100g dry wt	0.06	0.05	0.07	0.06	0.07
Total Organic Carbon*	g/100g dry wt	0.51	0.39	0.62	0.52	0.63
3 Grain Sizes Profile as received						
Fraction >/= 2 mm*	g/100g dry wt	0.1	1.0	1.2	0.4	< 0.1
Fraction < 2 mm, >/= 63 µm*	g/100g dry wt	34.4	43.9	27.7	31.3	32.8
Fraction < 63 µm*	g/100g dry wt	65.5	55.1	71.1	68.3	67.2

Sample Name:		Turanganui 3b 20-May-2019	Taruheru 1a 20-May-2019	Taruheru 1b 20-May-2019	Taruheru 2a 20-May-2019	Taruheru 2b 20-May-2019
Lab Number:		2179429.6	2179429.7	2179429.8	2179429.9	2179429.10
Individual Tests						
Dry Matter of Sieved Sample*	g/100g as rcvd	67	51	49	48	47
Ash*	g/100g dry wt	96	94	94	94	93
Total Recoverable Phosphorus	mg/kg dry wt	370	430	440	510	490
Total Recoverable Zinc	mg/kg dry wt	55	82	85	100	97
Total Nitrogen*	g/100g dry wt	0.07	0.13	0.16	0.15	0.15
Total Organic Carbon*	g/100g dry wt	0.59	1.32	1.68	1.50	1.47
3 Grain Sizes Profile as received						
Fraction >/= 2 mm*	g/100g dry wt	< 0.1	0.7	1.9	0.5	0.4
Fraction < 2 mm, >/= 63 µm*	g/100g dry wt	32.7	22.1	25.1	17.3	18.4
Fraction < 63 µm*	g/100g dry wt	67.3	77.2	73.0	82.2	81.2

Sample Name:		Taruheru 3a 20-May-2019	Taruheru 3b 20-May-2019	Taruheru 4a 20-May-2019	Taruheru 4b 20-May-2019	Taruheru 5a 20-May-2019
Lab Number:		2179429.11	2179429.12	2179429.13	2179429.14	2179429.15
Individual Tests						
Dry Matter of Sieved Sample*	g/100g as rcvd	55	55	61	62	65
Ash*	g/100g dry wt	94	95	95	96	96
Total Recoverable Phosphorus	mg/kg dry wt	300	320	320	340	330
Total Recoverable Zinc	mg/kg dry wt	71	73	83	81	74
Total Nitrogen*	g/100g dry wt	0.10	0.10	0.09	0.09	0.08
Total Organic Carbon*	g/100g dry wt	1.02	1.03	0.93	0.92	0.85

IANZ
ACCREDITED LABORATORY

This Laboratory is accredited by International Accreditation New Zealand (IANZ), which represents New Zealand in the International Laboratory Accreditation Cooperation (ILAC). Through the ILAC Mutual Recognition Arrangement (ILAC-MRA) this accreditation is internationally recognised.
The tests reported herein have been performed in accordance with the terms of accreditation, with the exception of tests marked *, which are not accredited.

Sample Type: Sediment

Sample Name:		Taruheru 3a 20-May-2019	Taruheru 3b 20-May-2019	Taruheru 4a 20-May-2019	Taruheru 4b 20-May-2019	Taruheru 5a 20-May-2019
Lab Number:		2179429.11	2179429.12	2179429.13	2179429.14	2179429.15
3 Grain Sizes Profile as received						
Fraction >/= 2 mm*	g/100g dry wt	0.2	0.5	0.9	0.7	0.6
Fraction < 2 mm, >/= 63 µm*	g/100g dry wt	36.1	34.3	40.0	42.8	41.4
Fraction < 63 µm*	g/100g dry wt	63.7	65.2	59.1	56.5	58.0

Sample Name:		Taruheru 5b 20-May-2019	Taruheru 6a 20-May-2019	Taruheru 6b 20-May-2019	Waimata 1a 20-May-2019	Waimata 1b 20-May-2019
Lab Number:		2179429.16	2179429.17	2179429.18	2179429.19	2179429.20
Individual Tests						
Dry Matter of Sieved Sample*	g/100g as rcvd	62	67	70	73	66
Ash*	g/100g dry wt	95	95	95	97	96
Total Recoverable Phosphorus	mg/kg dry wt	410	540	420	300	290
Total Recoverable Zinc	mg/kg dry wt	84	173	190	44	47
Total Nitrogen*	g/100g dry wt	0.10	0.09	0.08	0.05	0.05
Total Organic Carbon*	g/100g dry wt	1.03	0.87	0.82	0.41	0.49
3 Grain Sizes Profile as received						
Fraction >/= 2 mm*	g/100g dry wt	0.5	28.3	15.3	< 0.1	< 0.1
Fraction < 2 mm, >/= 63 µm*	g/100g dry wt	40.8	29.9	45.5	58.0	47.1
Fraction < 63 µm*	g/100g dry wt	58.7	41.9	39.2	42.0	52.9

Sample Name:		Waimata 2a 20-May-2019	Waimata 2b 20-May-2019	Waimata 3a 20-May-2019	Waimata 3b 20-May-2019	
Lab Number:		2179429.21	2179429.22	2179429.23	2179429.24	
Individual Tests						
Dry Matter of Sieved Sample*	g/100g as rcvd	70	73	69	70	-
Ash*	g/100g dry wt	97	98	97	97	-
Total Recoverable Phosphorus	mg/kg dry wt	330	290	330	310	-
Total Recoverable Zinc	mg/kg dry wt	48	41	51	47	-
Total Nitrogen*	g/100g dry wt	0.05	0.04	0.06	0.05	-
Total Organic Carbon*	g/100g dry wt	0.42	0.34	0.50	0.39	-
3 Grain Sizes Profile as received						
Fraction >/= 2 mm*	g/100g dry wt	0.2	< 0.1	< 0.1	0.3	-
Fraction < 2 mm, >/= 63 µm*	g/100g dry wt	56.7	62.0	32.6	34.9	-
Fraction < 63 µm*	g/100g dry wt	43.2	37.9	67.4	64.8	-

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.
Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Sediment

Test	Method Description	Default Detection Limit	Sample No
Individual Tests			
Environmental Solids Sample Drying*	Air dried at 35°C Used for sample preparation. May contain a residual moisture content of 2-5%.	-	1-24
Environmental Solids Sample Preparation	Air dried at 35°C and sieved, <2mm fraction. Used for sample preparation. May contain a residual moisture content of 2-5%.	-	1-24
Dry Matter for Grainsize samples (sieved as received)*	Drying for 16 hours at 103°C, gravimetry (Free water removed before analysis).	0.10 g/100g as rcvd	1-24
Total Recoverable digestion	Nitric / hydrochloric acid digestion. US EPA 200.2.	-	1-24
Ash*	Ignition in muffle furnace 550°C, 6hr, gravimetric. APHA 2540 G 23rd ed. 2017.	0.04 g/100g dry wt	1-24
Total Recoverable Phosphorus	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, screen level. US EPA 200.2.	40 mg/kg dry wt	1-24
Total Recoverable Zinc	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, trace level. US EPA 200.2.	0.4 mg/kg dry wt	1-24
Total Nitrogen*	Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.02 g/100g dry wt	1-24

Sample Type: Sediment			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Total Organic Carbon*	Acid pretreatment to remove carbonates present followed by Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.05 g/100g dry wt	1-24
3 Grain Sizes Profile as received			
Fraction >/= 2 mm*	Wet sieving with dispersant, as received, 2.00 mm sieve, gravimetry.	0.1 g/100g dry wt	1-24
Fraction < 2 mm, >/= 63 µm*	Wet sieving using dispersant, as received, 2.00 mm and 63 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-24
Fraction < 63 µm*	Wet sieving with dispersant, as received, 63 µm sieve, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-24

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

This certificate of analysis must not be reproduced, except in full, without the written consent of the signatory.

Ara Heron BSc (Tech)
Client Services Manager - Environmental

12 APPENDIX 2: ECOLOGICAL RESULTS

Sample	***Edwardsia* sp.**	**Nemertea**	***Amphibola crenata***	***Cominella glandiformis***	***Notoacmea* sp.**	***Potamopyrgus estuarinus***	***Turbonilla* sp.**	***Zeacumantus lutulentus***
Taruheru 5a	1	-	-	-	-	-	1	-
Taruheru 5b	-	-	-	1	-	-	-	-
Taruheru 5c	-	1	-	-	-	-	-	-
Taruheru 5d	1	1	-	2	-	-	-	-
Taruheru 5e	-	1	-	-	-	-	-	-
Taruheru 6a	-	2	-	1	-	-	-	-
Taruheru 6b	-	-	-	1	-	-	-	-
Taruheru 6c	-	-	1	-	-	-	-	-
Taruheru 6d	-	-	-	-	1	-	-	-
Taruheru 6e	-	-	-	-	-	-	-	-
Turanganui 1a	-	-	-	-	-	-	-	-
Turanganui 1b	-	2	-	1	1	-	-	1
Turanganui 1c	1	1	-	-	-	-	-	-
Turanganui 1d	-	-	-	-	-	-	-	-
Turanganui 1e	-	-	-	-	1	-	-	2
Turanganui 2a	-	1	-	-	-	-	1	-
Turanganui 2b	-	1	-	-	-	-	-	-

Sample	***Edwardsia* sp.**	**Nemertea**	***Amphibola crenata***	***Cominella glandiformis***	***Notoacmea* sp.**	***Potamopyrgus estuarinus***	***Turbonilla* sp.**	***Zeacumantus lutulentus***
Turanganui 2c	-	-	-	-	-	-	-	-
Turanganui 2d	-	-	-	-	-	1	2	-
Turanganui 2e	-	1	-	-	-	-	1	-
Turanganui 3a	-	-	-	-	-	-	-	-
Turanganui 3b	-	1	-	-	-	-	1	-
Turanganui 3c	-	1	-	-	-	-	-	-
Turanganui 3d	-	1	-	-	-	-	-	-
Turanganui 3e	-	1	-	-	-	1	1	-
Waimata 3a	-	1	-	-	-	-	1	-
Waimata 3b	-	-	-	-	-	-	-	-
Waimata 3c	-	1	-	1	-	-	1	-
Waimata 3d	-	1	1	1	-	-	1	-
Waimata 3e	-	1	-	-	-	-	-	-

Sample	***Zeacumantus subcarinatus***	***Arthritica bifurca***	***Austrovenus stutchburyi***	***Leptomya retiaria retiaria***	***Macomona liliana***	***Paphies australis***	***Saccostrea glomerata***	***Theora lubrica***
Taruheru 5a	-	15	7	-	5	-	-	-
Taruheru 5b	-	-	5	-	17	1	-	-
Taruheru 5c	-	23	4	-	24	1	-	-
Taruheru 5d	-	3	5	-	11	1	-	-
Taruheru 5e	-	2	6	-	9	2	-	-
Taruheru 6a	1	-	47	-	7	-	-	-
Taruheru 6b	-	-	32	-	5	-	-	-
Taruheru 6c	-	-	7	-	2	-	-	-
Taruheru 6d	1	2	29	-	4	-	-	-
Taruheru 6e	-	4	16	-	8	-	-	-
Turanganui 1a	-	3	4	-	3	-	-	-
Turanganui 1b	-	8	23	-	5	-	-	-
Turanganui 1c	-	1	11	-	1	-	-	-
Turanganui 1d	-	3	5	-	-	-	-	-
Turanganui 1e	-	-	15	-	1	-	-	-
Turanganui 2a	-	22	13	-	6	-	-	-
Turanganui 2b	-	45	8	-	8	-	-	-
Turanganui 2c	-	39	16	-	6	-	-	-

Sample	***Zeacumantus subcarinatus***	***Arthritica bifurca***	***Austrovenus stutchburyi***	***Leptomya retiaria retiaria***	***Macomona liliana***	***Paphies australis***	***Saccostrea glomerata***	***Theora lubrica***
Turanganui 2d	-	35	50	-	22	-	-	-
Turanganui 2e	-	34	34	-	10	-	-	-
Turanganui 3a	-	18	4	-	10	-	1	1
Turanganui 3b	1	12	13	-	22	1	-	5
Turanganui 3c	-	2	6	-	5	-	-	-
Turanganui 3d	-	31	2	1	13	-	-	1
Turanganui 3e	-	37	9	-	28	-	-	-
Waimata 3a	-	48	17	-	7	-	-	-
Waimata 3b	-	3	4	-	-	1	-	-
Waimata 3c	-	35	12	-	4	4	-	-
Waimata 3d	-	91	20	3	11	-	-	-
Waimata 3e	-	66	32	1	32	-	-	-

Sample	*Aonides trifida*	*Boccardia* sp.	*Prionospio aucklandica*	*Scolecolepides benhami*	*Heteromastus filiformis*	*Armandia maculata*	Nereidae (juvenile)	*Nicon aestuariensis*	*Perinereis vallata*
Taruheru 5a	-	-	12	-	38	-	1	-	-
Taruheru 5b	-	-	1	-	36	-	-	-	-
Taruheru 5c	1	4	12	-	80	-	4	-	-
Taruheru 5d	1	-	13	1	66	-	1	-	-
Taruheru 5e	2	-	4	-	60	-	1	-	-
Taruheru 6a	8	-	11	2	32	-	1	-	-
Taruheru 6b	1	-	3	2	40	-	1	-	-
Taruheru 6c	1	-	7	1	80	-	-	-	1
Taruheru 6d	-	-	10	3	74	-	1	1	-
Taruheru 6e	4	-	2	-	111	-	3	1	-
Turanganui 1a	-	-	10	3	32	-	4	-	2
Turanganui 1b	-	1	8	3	57	-	-	-	-
Turanganui 1c	-	-	3	1	33	-	4	-	-
Turanganui 1d	-	3	3	-	15	-	4	-	-
Turanganui 1e	2	1	2	3	28	-	1	-	-
Turanganui 2a	-	-	5	1	66	2	5	-	-
Turanganui 2b	-	-	6	4	88	-	4	-	-
Turanganui 2c	1	-	3	5	159	-	36	-	1

Sample	***Aonides trifida***	***Boccardia* sp.**	***Prionospio aucklandica***	***Scolecolepides benhami***	***Heteromastus filiformis***	***Armandia maculata***	**Nereidae (juvenile)**	***Nicon aestuariensis***	***Perinereis vallata***
Turanganui 2d	-	-	6	2	106	1	7	1	1
Turanganui 2e	-	-	4	1	54	-	10	-	-
Turanganui 3a	-	-	20	6	98	-	10	-	-
Turanganui 3b	-	-	24	11	199	-	5	-	-
Turanganui 3c	-	-	5	5	76	3	2	-	-
Turanganui 3d	-	-	18	8	124	-	9	-	-
Turanganui 3e	-	-	22	19	212	1	23	-	2
Waimata 3a	-	-	-	3	45	-	7	1	-
Waimata 3b	-	-	-	-	-	-	5	-	-
Waimata 3c	-	-	-	1	19	-	2	1	-
Waimata 3d	-	-	-	7	10	-	13	-	1
Waimata 3e	-	-	-	3	52	-	8	-	-

Sample	***Pectinaria australis***	**Cumacea**	***Exosphaeroma planulum***	***Austrohelice crassa***	***Halicarcinus* sp. Juvenile**	***Halicarcinus whitei***	***Hemiplax hirtipes***
Taruheru 5a	-	-	-	-	-	-	-
Taruheru 5b	-	-	-	-	-	-	-
Taruheru 5c	-	-	-	-	-	-	-
Taruheru 5d	-	-	-	-	-	-	-
Taruheru 5e	-	-	-	-	-	-	-
Taruheru 6a	-	-	-	-	-	-	-
Taruheru 6b	-	-	-	-	-	-	1
Taruheru 6c	-	-	-	-	-	-	-
Taruheru 6d	-	-	-	-	-	1	2
Taruheru 6e	-	-	-	-	-	-	-
Turanganui 1a	-	1	-	1	-	-	-
Turanganui 1b	-	-	-	-	-	-	-
Turanganui 1c	-	-	-	1	-	-	1
Turanganui 1d	-	-	-	3	-	-	-
Turanganui 1e	1	-	1	-	-	-	-
Turanganui 2a	-	-	-	-	-	-	-
Turanganui 2b	1	-	-	-	-	-	3
Turanganui 2c	-	-	-	-	-	-	-

Sample	***Pectinaria australis***	**Cumacea**	***Exosphaeroma planulum***	***Austrohelice crassa***	***Halicarcinus* sp. Juvenile**	***Halicarcinus whitei***	***Hemiplax hirtipes***
Turanganui 2d	1	1	-	-	-	-	2
Turanganui 2e	-	2	-	-	-	-	-
Turanganui 3a	-	1	-	-	-	-	-
Turanganui 3b	4	1	-	-	2	-	-
Turanganui 3c	-	1	-	-	1	-	-
Turanganui 3d	-	-	-	-	-	-	-
Turanganui 3e	2	3	-	-	-	-	-
Waimata 3a	-	-	-	-	-	-	1
Waimata 3b	-	-	-	-	-	-	-
Waimata 3c	1	-	-	-	-	-	-
Waimata 3d	-	-	-	-	-	-	1
Waimata 3e	-	1	-	-	-	-	-

13 APPENDIX 3: SITE PHOTOGRAPHS

Waimata 1

Waimata 2 No photo

Waimata 3

Taruheru 1

Taruheru 2

Taruheru 3

Taruheru 4

Taruheru 5

Taruheru 6

Turanganui 1

Turanganui 2

Turanganui 3