Charlesworth Drain Water and Sediment Quality, and Īnanga Spawning

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Prepared for:
Christchurch City Council

Instream Consulting Limited
PO Box 1200
Christchurch 8140

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EXECUTIVE SUMMARY

This investigation assessed water quality, sediment quality, and īnanga (*Galaxias maculatus*) spawning habitat in waterways discharging from Linwood Paddocks, a Christchurch City Council–owned parcel of land bordering the Ihutai / Avon-Heathcote Estuary. The paddocks, historically modified for farming, are designated as a Site of Ecological Significance (SES/LP/14) in the District Plan, and there is interest in restoring them to a mosaic of wetland and dryland habitats. Charlesworth Drain originates in predominantly industrial catchment and is the main waterway traversing the paddocks. Concerns from Environment Canterbury prompted this study due to suspected impacts of industrial stormwater and legacy sediment contamination on estuarine water quality.

Water quality monitoring revealed multiple exceedances of national and regional guidelines for contaminants including ammoniacal nitrogen, *E. coli*, total phosphorus, copper, zinc, and biochemical oxygen demand (BOD). Contaminant concentrations were highest in Cuthberts Drain and in Charlesworth Drain at Francella Reserve. The proximity of these sites to Christchurch's oxidation ponds suggests the adjacent oxidation ponds contribute to the high organic and nutrient concentrations measured. Nitrogen-related contaminants were often diluted during wet weather. However, *E. coli* and total suspended solids frequently increased in wet conditions, especially in mid- and lower-catchment Charlesworth sites, reflecting industrial stormwater and faecal contamination sources.

Metal and hydrocarbon analyses of water and sediment confirmed spatially variable but localised contamination. While most metals and Polycyclic Aromatic Hydrocarbons were below ecological guidelines, exceedances of copper, zinc, and mercury were recorded in some Charlesworth Drain sites, potentially linked to both stormwater inputs and legacy soil contamination.

Biological surveys confirmed extensive īnanga spawning habitat in lower Charlesworth Drain; however, no eggs or adult īnanga were observed. This absence may be linked to degraded waterway conditions, sparse bank vegetation due to shading by willows, potential fish passage barriers at downstream tidal gates, or spawning occurring outside the normal timing.

The findings indicate that Charlesworth Drain – and by extension, parts of Linwood Paddocks – are contributing pollutants to the estuary. These results underscore the need for targeted mitigations and provide an evidence base to inform any future work in the Linwood Paddocks, with a focus on improving habitat quality, managing legacy contamination, and reducing upstream industrial stormwater impacts.

1. INTRODUCTION

Linwood Paddocks is an area of farmland owned by Christchurch City Council that borders the Ihutai / Avon-Heathcote Estuary. Although the paddocks have been drained for farming, they remain wet, support significant bird habitat, and form part of the estuary Site of Ecological Significance in the District Plan (SES/LP/14). There is a desire to naturalise Linwood Paddocks, by creating a mosaic of wetland and dryland habitats (see Appendix 1).

Charlesworth Drain is the main waterway that flows through the paddocks, and it drains an industrial catchment. Concerns have been raised by Environment Canterbury regarding the impacts of industrial stormwater entering Charlesworth Drain on water quality in the estuary. However, the paddocks themselves may be a source of contamination to the estuary. That is because the soils are contaminated with metals (copper, chromium, lead, and zinc) and Polycyclic Aromatic Hydrocarbons (PAHs) associated with historic biosolids application to land, dredge tailings, and landfills.

This report assesses the relative impact of upstream stormwater discharges and adjacent historic landuse on the water quality of drains discharging from the Linwood Paddocks. The report also assesses whether waterways within the Linwood Paddocks provide spawning habitat for īnanga (*Galaxias maculatus*), which are an At Risk species (Dunn *et al.* 2018). Results of these investigations may also be used to inform naturalisation plans for the Linwood Paddocks.

2. METHODS

2.1. Water Quality and Sediment Sampling

To assess the relative influence of historic landuse versus upstream stormwater discharges on water quality, surface water and sediment samples were collected from each of the nine locations listed in Table 1 and mapped in Figure 1. General habitat observations and photographs were also taken at each site. The rapid habitat assessment method described by Clapcott (2015) was not used, as it is not appropriate for tidal waterways.

All sampling was conducted during a low, outgoing tide to minimise dilution by seawater. Sediment sampling was carried out once, under baseflow conditions. Water quality sampling was performed on two occasions: once during baseflow and once following rainfall events, to capture the effects of stormwater runoff.

Sediment and surface water quality sampling methods generally followed those outlined in the Environmental Monitoring Plan (EMP), version 10, associated with the council's Comprehensive Stormwater Network Discharge Consent (CSNDC). Although not explicitly specified in the EMP, laboratory analyses were typically conducted to trace levels of detection, consistent with prior EMP monitoring. The only departure from the EMP methodology was the inclusion of additional analyses. For sediment samples, the additional analyses included total nitrogen, chromium, mercury, arsenic, cadmium, and nickel. For surface water samples, the additional analyses included total nitrogen, phosphorus, chromium, mercury, arsenic, cadmium, nickel, copper, lead, and zinc; dissolved chromium, mercury, arsenic, cadmium, and nickel; and total PAHs.

Total PAHs were calculated by summing the following 18 PAHs listed in the ANZG guidelines (ANZG 2025) for total PAH: naphthalene, acenaphthylene, acenaphthene, fluorene, anthracene, phenanthrene, fluoranthene, pyrene, benzo[a]anthracene, chrysene, benzo[a]pyrene, perylene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[e]pyrene, benzo[ghi]perylene, dibenz[a,h]anthracene, and indeno[1,2,3-cd]pyrene. Total sediment PAHs were normalised to 1% TOC, as recommended by ANZG (ANZG 2025). When a PAH compound was below the detection limit, half the detection limit was used in the calculation, which is consistent with NEMS (2023). Toxicity data for lead, nickel and zinc were normalised to a standard water hardness of 30 mg $CaCO_3$/L using the algorithms presented in Warne et al. (2018), whereas copper was normalised (i.e., becoming bioavailable copper) using the algorithms presented in Gadd et al. (2023). Ammoniacal-N concentrations were adjusted to pH 8 and 20°C to account for the strong influence of pH and temperature on the proportion of un-ionised ammonia, ensuring alignment with guideline conditions (ANZG 2025).

Sediment and water quality data from the nine sampling locations were summarised and tabulated for comparison against consent Attribute Target Levels and guideline conditions (Tables 2 & 3).

Figure 1: Location of water quality and sediment sampling sites. Section of Charlesworth Drain sampled for īnanga eggs occurred between the orange markers while the intertidal salt wedge occurred between the red markers.

Table 1: Sampling locations.

Code	Waterway	Location	Easting	Northing
L1	Lovetts Drain	Near mouth	1576204	5178246
L2	Lovetts Drain	Mid-paddocks	1575811	5178532
Ch1	Charlesworth Drain	Near mouth	1576530	5178373
Ch2	Charlesworth Drain	Mid-paddocks	1576123	5178673
Ch3	Charlesworth Drain Branch No. 1	Downstream of Dyers Road[1]	1575836	5178872
Ch4	Charlesworth Drain	Immediately upstream of paddocks	1576209	5179080
Ch5	Francella Reserve Pond	Francella Reserve	1575957	5179813
Ch6	Charlesworth Drain	Downstream of Maces Road	1575361	5179806
Cu1	Cuthberts Drain	Near mouth	1576970	5178546

Note: [1] Sample was taken downstream of confluence of two waterways draining the industrial catchment west of Dyers Road.

Table 2: Sediment quality guidelines used in this report, from the Australia and New Zealand Guidelines (ANZG 2025).

Sediment Parameter	DGV	GV-high
Antimony (mg/kg dry wt)	2	25
Cadmium (mg/kg dry wt)	1.5	10
Chromium (mg/kg dry wt)	80	370
Copper (mg/kg dry wt)	65	270
Lead (mg/kg dry wt)	50	220
Mercury (Inorganic) (mg/kg dry wt)	0.15	1
Nickel (mg/kg dry wt)	21	52
Zinc (mg/kg dry wt)	200	410
Arsenic (mg/kg dry wt)	20	70
Total PAHs (mg/kg dry weight, 1% OC)	10	50
TPHs (mg/kg dry wt)	280	550

Note: DGV = default guideline value; GV-high = additional upper guideline value; PAHs = polycyclic aromatic hydrocarbons; TPHs = total petroleum hydrocarbons; OC = organic carbon.

Table 3: Water quality guidelines used in this report, from the Australia and New Zealand Guidelines for freshwater (ANZG 2025), consent Attribute Target Levels (ATLs ; Kerr et al. 2025), Canterbury Land and Water Regional Plan (LWRP; Environment Canterbury 2018), Regional Coastal Environment Plan for the Canterbury Region (RCEP; Environment Canterbury 2020), and the National Policy Statement for Freshwater Management (NPS-FM; Ministry for the Environment 2020).

Water Quality Guidelines	DGV*1	GV-high*1	Consent ATLs	LWRP*1 (Discharge Standards)	LWRP*1 (Freshwater Outcomes)	RCEP	NPS-FM (bottom-line)
Dissolved copper (g/m^3)	0.0014		0.0013 (95th perc.)	0.0014		0.005	
Bioavailable copper (g/m^3)			0.47 (median)*2 0.73 (95th perc.)*2				
Dissolved lead (g/m^3)	0.0034		0.0044 (95th perc.)	0.0034		0.005	
Dissolved zinc (g/m^3)	0.008		0.008 (95th perc.)	0.008		0.050	
Dissolved nickel (g/m^3)	0.011			0.011		0.015	
Dissolved chromium (g/m^3)						0.050	
Dissolved arsenic (g/m^3)						0.050	
pH			7.0 - 8.5	6.5 – 8.5	6.5 – 8.5		
Total Suspended Solids (g/m^3)			17.7				
Dissolved oxygen (g/m^3)					7.0 (7-day mean min.) 5.0 (1-day min.)		5.0 (7-day mean min.) 4.0 (1-day min.)
Water temperature (°C)			25	Avg change ≤ 2	Avg change ≤ 2	25	
Biochemical Oxygen Demand (g/m^3)			2		2	2	
Dissolved reactive phosphorus (g/m^3)				0.010			
Dissolved inorganic nitrogen (g/m^3)				0.47			
Escherichia coli (CFU/100 ml)				550	130 (median) 1200 (95th perc.)		540
Ammoniacal-N (g/m^3)	0.9	0.32			0.03 (annual median)*3 0.05 (annual max.)*3		0.24 (median)*3 0.4 (95th perc.)*3
Nitrate-N							2.4 (median) 3.5 (95th perc.)

Note: '*1'ANZG and LWRP values (based on 'spring-fed lower basin') reflect a 95% level of species protection. '*2' recommended bottom-line by Gadd et al. (2023). '*3' Based on pH of 8 and temperature of 20°C. DGV = default guideline value; GV-high = additional upper guideline value.

2.2. Īnanga Spawning

Īnanga spawning surveys were conducted along Charlesworth Drain to identify the extent of suitable spawning habitat and egg production in the Linwood Paddocks. Cuthberts Drain and Lovetts Drain were also visited but were excluded from future monitoring due to there being no freshwater inputs into Lovetts Drain (evident at low tide) and a large weir structure near the downstream extent of Cuthberts Drain, which prevents fish passage, as well as any tidal ingress, thus inhibiting any spawning potential (Figure 2).

Figure 2: Weir preventing tidal ingress at Cuthberts Drain (top), a lack of freshwater inputs at Lovetts Drain (middle), and the suitable īnanga spawning survey reach at Charlesworth Drain (bottom).

Salinity was measured along Charlesworth Drain on 30 March, three days after the last spring tide, at regular intervals to delineate the upper extent of the saltwater wedge, an area where īnanga spawning is likely to occur. This informed the spatial extent of subsequent īnanga spawning surveys. Although the salinity survey did not coincide exactly with the peak of the spring tide, the surveyed area was extended to account for potential movement of the salt wedge. A salinity survey was also conducted in Lovetts Drain to confirm the absence of freshwater inputs.

Once the likely īnanga spawning zone was established, surveys began 10 m downstream of this point. Both banks were then surveyed at 5 m intervals, moving upstream for a total distance of 125 m (as indicated by the red line in Figure 1). Due to the absence of any spawning activity, a wider additional area was also surveyed either side of the salt wedge to ensure the occurrence of spawning was not missed (as indicated by the orange zone in Figure 1).

Spawning survey methods followed those recently used in Linwood Canal by Instream (in prep) and consisted of systematically searching both banks for īnanga eggs in March, April, and May 2025. Surveys were conducted within one week following spring tides, which correspond with peak spawning activity.

The survey approach was a simplified version of the method developed by Orchard (2018). It aimed to characterise the quality of potential spawning habitat, delineate the spatial extent of spawning, estimate the size of spawning sites, and provide a qualitative assessment of egg density. Each survey was completed by a two-person field team over a single day on each of the three survey dates.

3. RESULTS AND DISCUSSION

3.1. Water Quality and Sediment Sampling

3.1.1. Site Conditions

The surveyed area comprised a range of modified and natural waterways, including estuarine margins, drainage channels, culverts, and shallow ponded areas. Substrates across all sites were predominantly soft sediments, often with an anoxic layer close to the surface, particularly in estuarine or low-flow sites. An orange precipitate, indicating iron flocculation, was noted at multiple sites, with a hydrocarbon sheen also observed at Site Ch3, and unusual foams present downstream of a culvert at Site Ch4.

Estuarine fauna such as crabs, gastropods, and bivalves were common in lower catchment areas (Sites Ch1, L1), while native rushes, sedges, and flax were intermixed with pastoral weeds, grasses, and exotic shrubs or trees in riparian zones. In some industrial and urban areas (Sites Ch5 and Ch6), macrophyte removal, artificial channelling, and timber lining were evident, reflecting recent infrastructure work.

Water levels varied, with some channels (e.g., Ch2) being deep with flowing water, while others (e.g., Cu1 and L2) had little-to-no baseflow, limiting water sampling opportunities. Surrounding landuse ranged from grazing paddocks in lower catchments, often with variable fencing and stock access, to fully industrial zones in upper and middle catchment areas. Some riparian sections, particularly those adjacent to wetlands or restoration sites, had more established native planting, although generally patchy.

3.1.2. Water Quality

Temperature, conductivity, and dissolved oxygen (DO) fluctuate diurnally, but the data also showed substantial variability linked to both site location and flow conditions (i.e., baseflow vs. wet weather). In particular, Sites L1 and L2 exhibited consistently elevated conductivity, indicating strong saline influence (Figure 3). This reach was confirmed as a predominantly tidal section with little to no freshwater input during baseflow conditions as part of the īnanga spawning survey (Section 3.2).

As expected, water temperatures were higher during baseflow conditions, likely due to increased solar exposure and reduced mixing. Conversely, DO levels were higher during the wet weather event, which can be attributed to both the cooler temperatures and increased flow velocities, enhancing aeration. This dynamic interplay suggests that event-driven flushing may temporarily improve water quality by reducing temperature and increasing oxygen availability.

However, under baseflow conditions, many sites exhibited a concerning combination of elevated temperatures and low dissolved oxygen, creating potentially stressful or unsuitable conditions for freshwater biota, particularly sensitive fish species such as common smelt (*Retropinna retropinna*), juvenile common bullies (*Gobiomorphus cotidianus*), and introduced brown trout (*Salmo trutta*). These patterns highlight the episodic nature of water quality improvements during flow events, and the potential for chronic habitat stress during low-flow periods, particularly in more enclosed or poorly connected sections of the catchment.

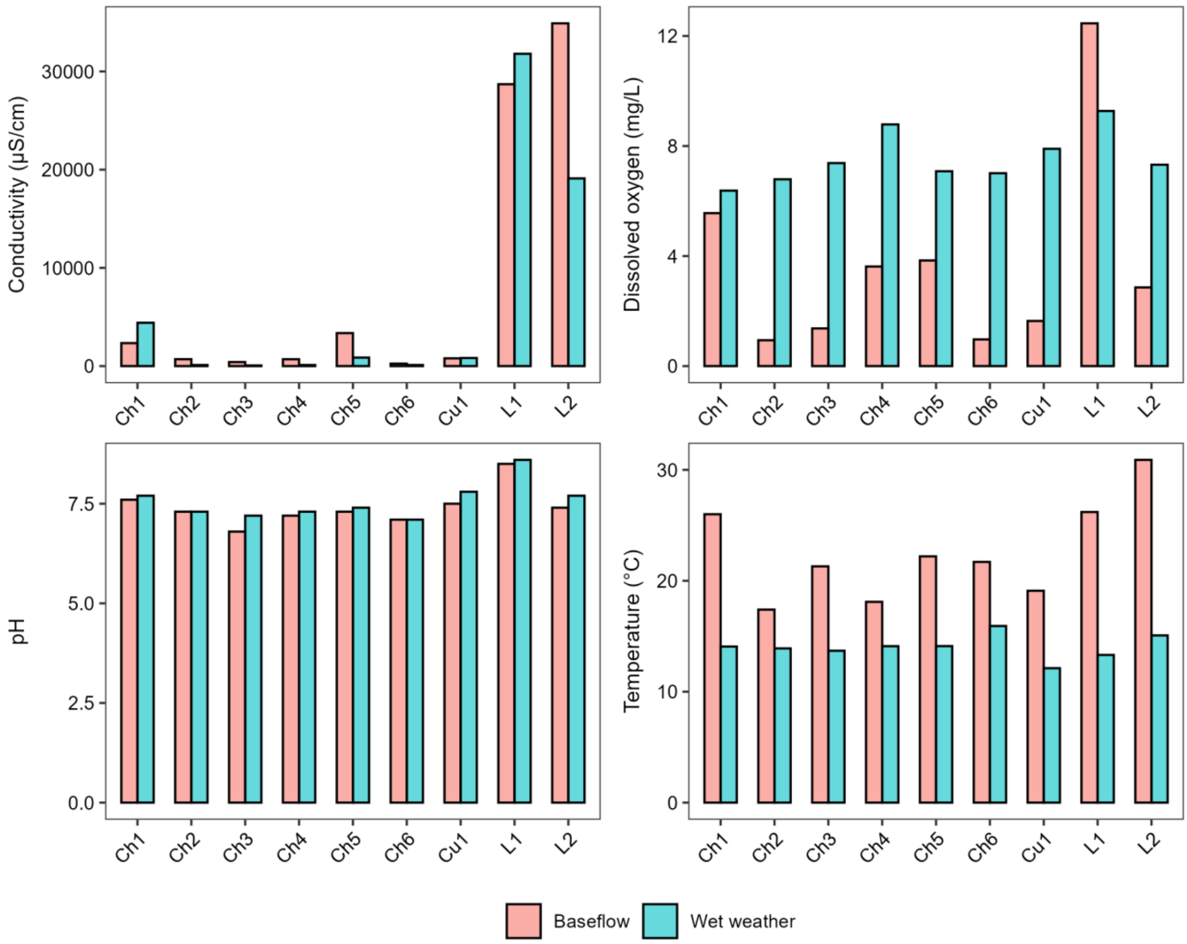

Figure 3: Basic water quality parameters during baseflow and wet weather conditions.

There was high spatial and temporal variability in nitrogen concentrations across the monitored sites (Figure 4). Sites L1 and L2 generally recorded the lowest concentrations, while Cu1 consistently showed elevated concentrations of both inorganic nitrogen (as ammoniacal-N) and organic nitrogen (as total Kjeldahl-N). Ammoniacal-N and organic nitrogen were also elevated at Ch1 and Ch5, to a lesser extent.

Nitrate-N concentrations were consistently below the NPS-FM annual median bottom-line across sites, whereas several locations exceeded the NPS-FM annual median and 95th percentile bottom-lines for adjusted ammoniacal-N. Specifically, the NPS-FM adjusted ammoniacal-N 95th percentile was exceeded at Site Ch2 (baseflow) and at Sites Ch1, Ch5, and especially Cu1 during both sampling events. In addition, the NPS-FM median bottom-line was exceeded at Ch4 (baseflow) and L2 (wet weather). The substantially elevated ammoniacal-N concentrations observed at Cu1 reinforce the likelihood of an upstream source, such as the nearby oxidation ponds. The wet weather event did not consistently elevate nitrogen-related contaminants. Instead, a general dilution effect was observed, with lower nitrogen concentrations during wet weather at many sites. This indicates that elevated organic and inorganic nitrogen concentrations are primarily groundwater-sourced, with the nearby oxidation ponds the likely origin.

Biochemical oxygen demand (BOD) is a measure of organic enrichment and BOD levels were at or above the relevant LWRP/RCEP Freshwater Outcomes across all surveyed sites. BOD was particularly elevated at Ch5, especially during wet weather, indicating increased organic loading, presumably influenced by groundwater inputs from the nearby oxidation ponds. In contrast, downstream sites (Ch4 and Ch6) did not exhibit similar elevations, suggesting that organic inputs at Ch5 were diluted further along the Charlesworth Drain.

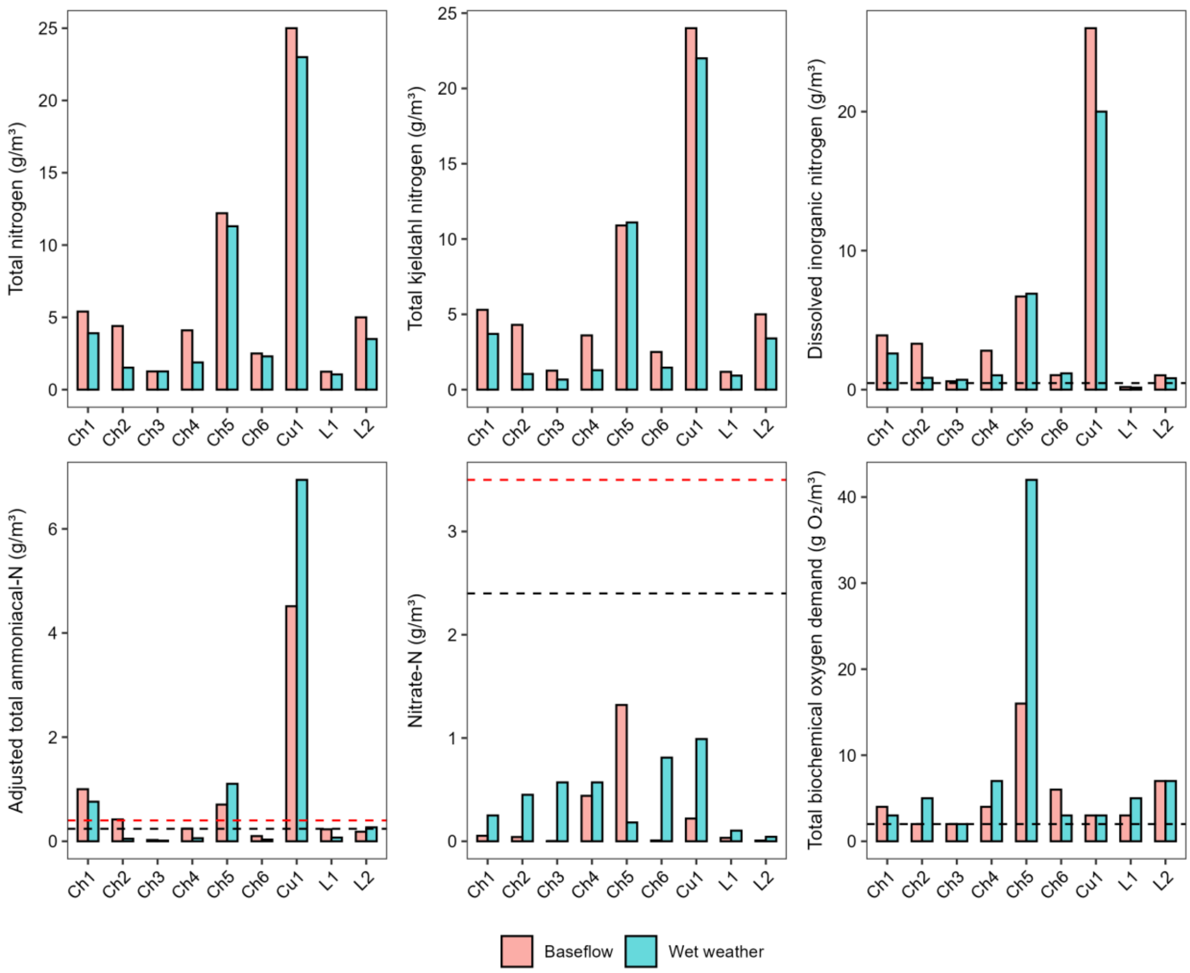

Figure 4: Nitrogen water quality parameters during baseflow and wet weather conditions. Adjusted total ammoniacal-N concentrations are based on pH 8 and temperature of 20°C to comply with guidelines. Dashed lines indicate relevant LWRP Discharge Standards for dissolved inorganic nitrogen; LWRP Freshwater Outcomes for total biochemical oxygen demand; and NPS-FM annual median (black) and 95th percentile (red) bottom-lines for ammonia and nitrate nitrogen.

Dissolved reactive phosphorus concentrations were generally low across most sites, except for Cu1, where phosphorus concentrations were very high on both sampling occasions (Figure 5). Total phosphorus during baseflow conditions was consistently equal to or exceeded those observed under wet weather conditions. Dissolved reactive phosphorus (DRP) concentrations exceeded the LWRP Discharge Standards – aligned with the NPS-FM Attribute Band ‘B’, which indicates at least slight ecological impact – at all sites except Ch2 during baseflow conditions. Site Cu1, in particular, was graded well below the lowest NPS-FM Attribute Band (‘D’: median > 0.018 g/m³; 95th percentile > 0.054 g/m³), with DRP concentrations of 3.4 g/m³ during wet weather and 4.6 g/m³ during baseflow.

Total suspended solids (TSS) concentrations were highly variable across sites and did not respond consistently to wet weather. Every site except Ch2 and Cu1 exceeded the TSS ATLs of 17.7 g/m³ in both events, with Cu1 being the only site to consistently remain below it. In Charlesworth Drain, all sites except Ch1 exhibited increased TSS in wet weather. In Lovetts Drain, Site L2 showed higher TSS concentrations under wet conditions, while L1 decreased following rain.

E. coli counts exceeded the LWRP annual median Freshwater Outcome at nearly all sites during both sampling events, except at L1, which only exceeded the Outcome under baseflow conditions. In Charlesworth Drain, lower catchment sites (Ch1, Ch2) consistently exceeded the maximum *E. coli* LWRP Freshwater Outcome in both events, while mid-catchment sites (Ch3, Ch4, Ch6) only did so during wet weather. In contrast, the upper catchment site Ch5 exceeded the LWRP annual maximum Outcome under baseflow but not wet conditions. Although not entirely uniform, these patterns suggest a general increase in *E. coli* concentrations during wet weather, particularly at mid- and lower-catchment sites. This suggests a greater source of faecal contamination within Linwood Paddocks than upstream.

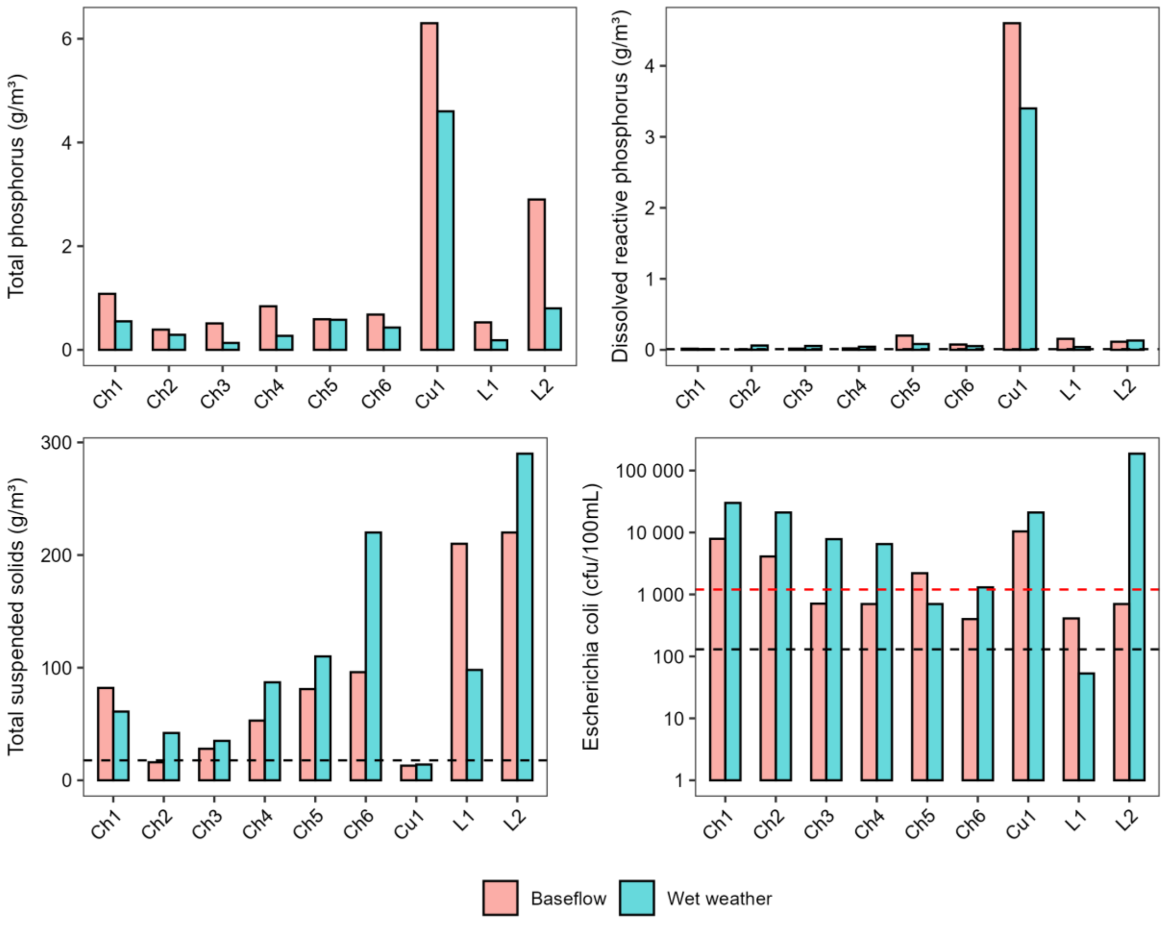

Figure 5: Phosphorus, suspended solids, and E. coli water quality parameters during baseflow and wet weather conditions. Note that the E. coli y axis is non-linear. Dashed lines denote LWRP Discharge Standards for dissolved reactive phosphorous; LWRP Freshwater Outcomes for annual median (black) and annual maximum (red) E. coli.; and ATLs for total suspended solids.

Metal concentrations showed clear spatial and temporal variation, with multiple exceedances of ANZG default and bioavailability-adjusted guidelines observed across sites and sampling conditions (Figure 6). Zinc concentrations were the most elevated of all metals measured, had the highest concentrations of all metals, with copper and nickel also elevated, but much less so.

Zinc concentrations were elevated across sites regardless of being hardness-normalised, with particularly high values at mid-catchment Charlesworth Drain sites during wet weather, especially at Ch3. Under baseflow conditions, Ch6 was the only site to exceed the zinc ANZG guideline. In contrast, normalised nickel concentrations showed far fewer guideline exceedances, with only Ch4 (wet weather) and Ch6 (both events) exceeding the ANZG guideline.

All sites except Cu1 exceeded the ANZG default guideline for dissolved copper in at least one sampling event. During wet weather, all Charlesworth Drain sites exceeded this guideline except Ch5, which – despite recording the highest copper concentration overall during baseflow – showed a substantial decrease under wet conditions. Exceedances of the median bottom-line guideline recommended by Gadd et al. (2023) for bioavailable copper were observed at Ch2, Ch3, Ch4, and Ch6 during baseflow, with Ch3 also exceeding their 95th percentile bottom-line. Ch5 exceeded both the median and 95th percentile guideline during baseflow only. In contrast, Cu1 and L2 consistently remained below the bioavailable copper guidelines, while L1 exceeded the 95th percentile in baseflow and the median guideline during wet weather.

Dissolved lead, arsenic, and chromium remained consistently below their respective ANZG default guideline values across all sites and sampling periods.

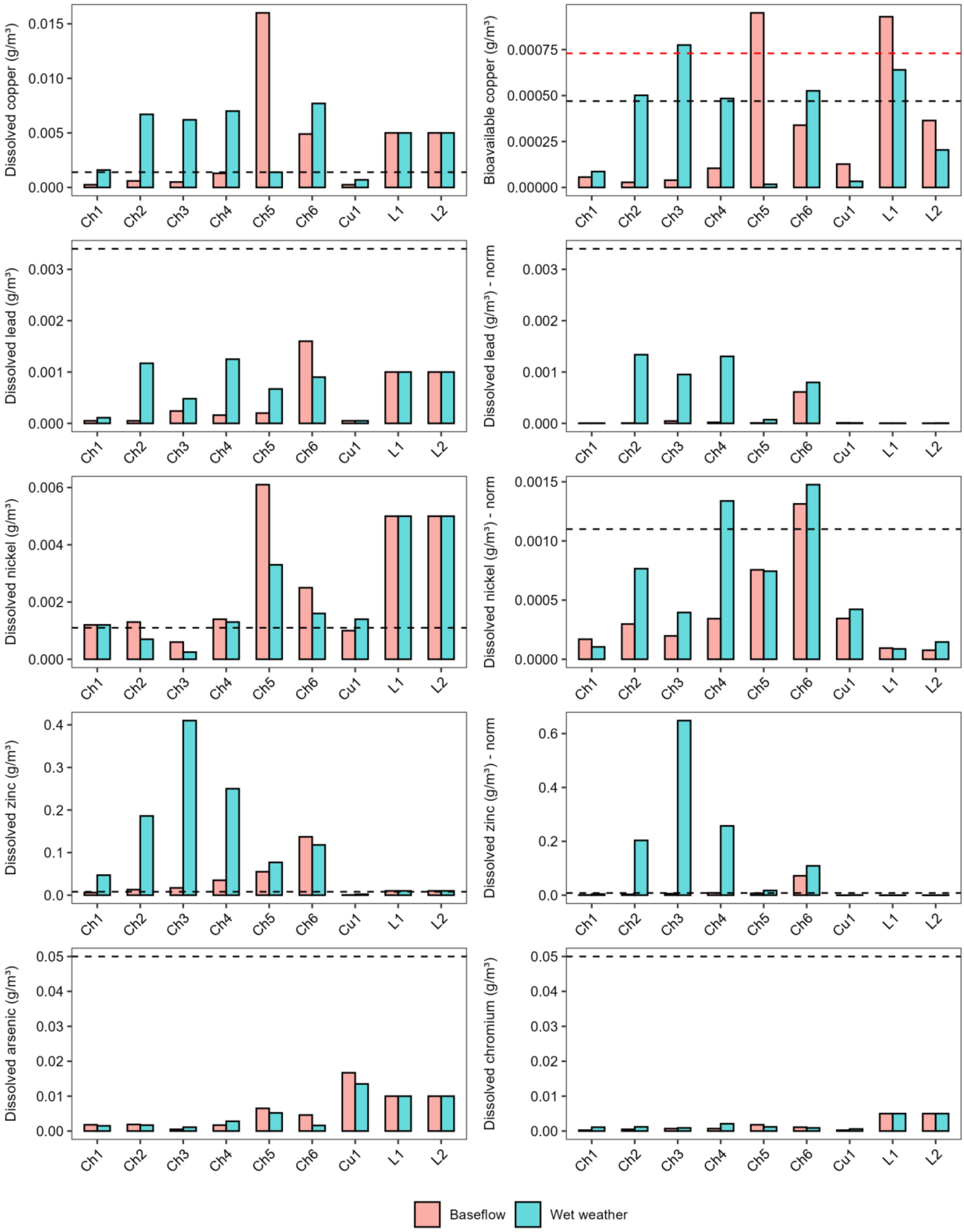

Figure 6: Heavy metal water quality parameters during baseflow and wet weather conditions. Dashed lines indicate relevant ANZG default guidelines for dissolved copper, lead, nickel, and zinc; RCEP guidelines for dissolved arsenic and chromium; and Gadd et al. (2023) recommended median (black line) and 95th percentile (red line) bottom-lines for bioavailable copper.

3.1.3. Sediment

Most sites met the relevant ANZG default guideline values for the measured metal and metalloid contaminants (Figure 7). However, Site Ch5 exceeded the default guidelines for both arsenic and mercury, indicating potential localised contamination at that location. Zinc was the only parameter to exceed guidelines at multiple sites, with all sites within the Charlesworth Drain catchment (Ch1 to Ch5) recording zinc concentrations above the ANZG default guideline. Furthermore, the more downstream sites (Ch1 to Ch3) also exceeded the higher ANZG upper guideline, suggesting elevated zinc levels associated with sediment deposition closer to the outlet and estuarine interface.

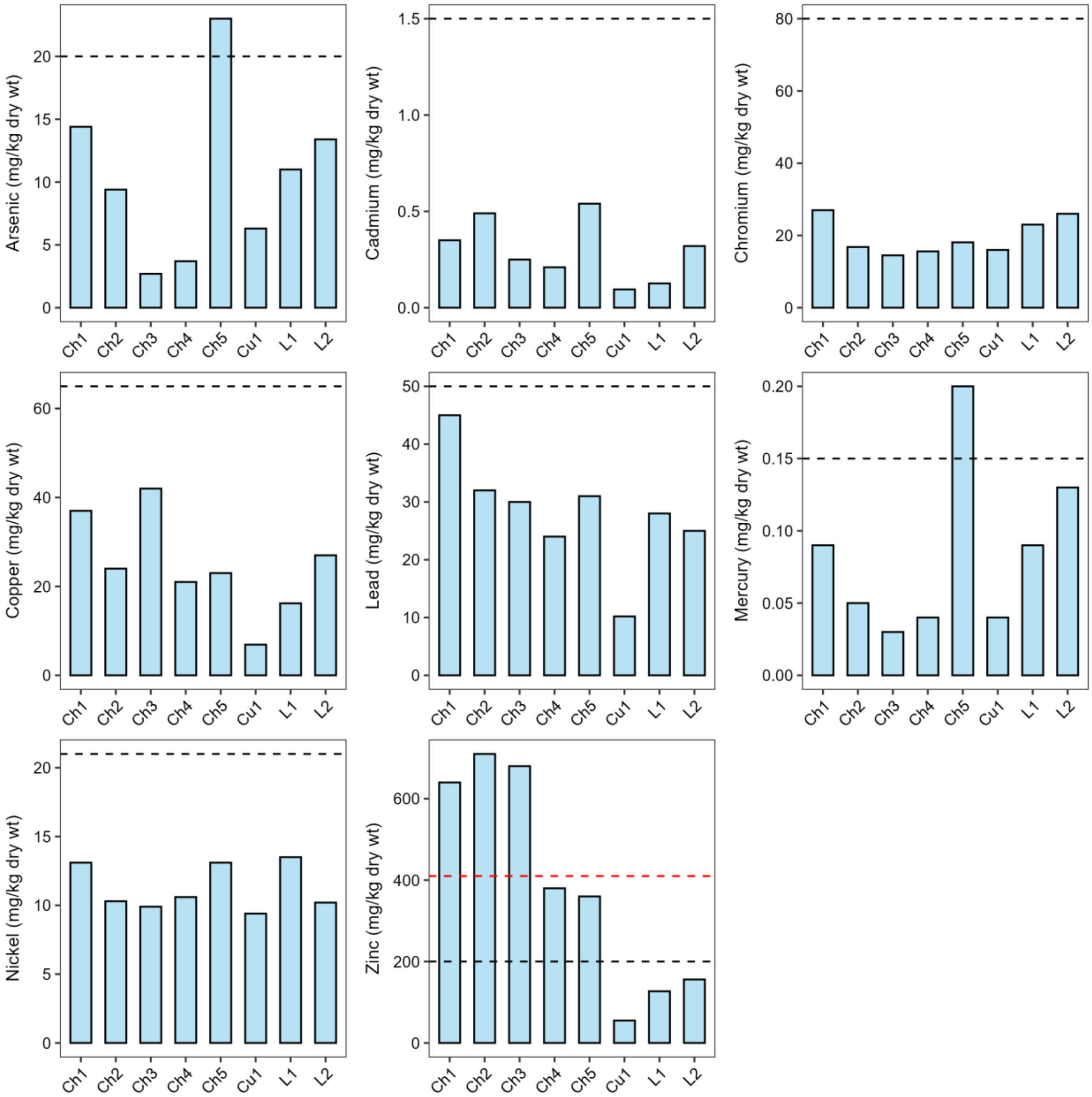

Figure 7: Sediment concentrations of metals and metalloids. Dashed lines indicate relevant ANZG default guideline values (black) and upper guideline values (red).

Although there was notable site-to-site variability in sediment concentrations of organic contaminants, including polycyclic aromatic hydrocarbons (PAHs) and total petroleum hydrocarbons (TPH), none of the measured values exceeded the relevant ANZG sediment quality guideline values (Figure 8). This suggests that, while contamination is present, it remains below concentrations considered likely to pose ecological risks.

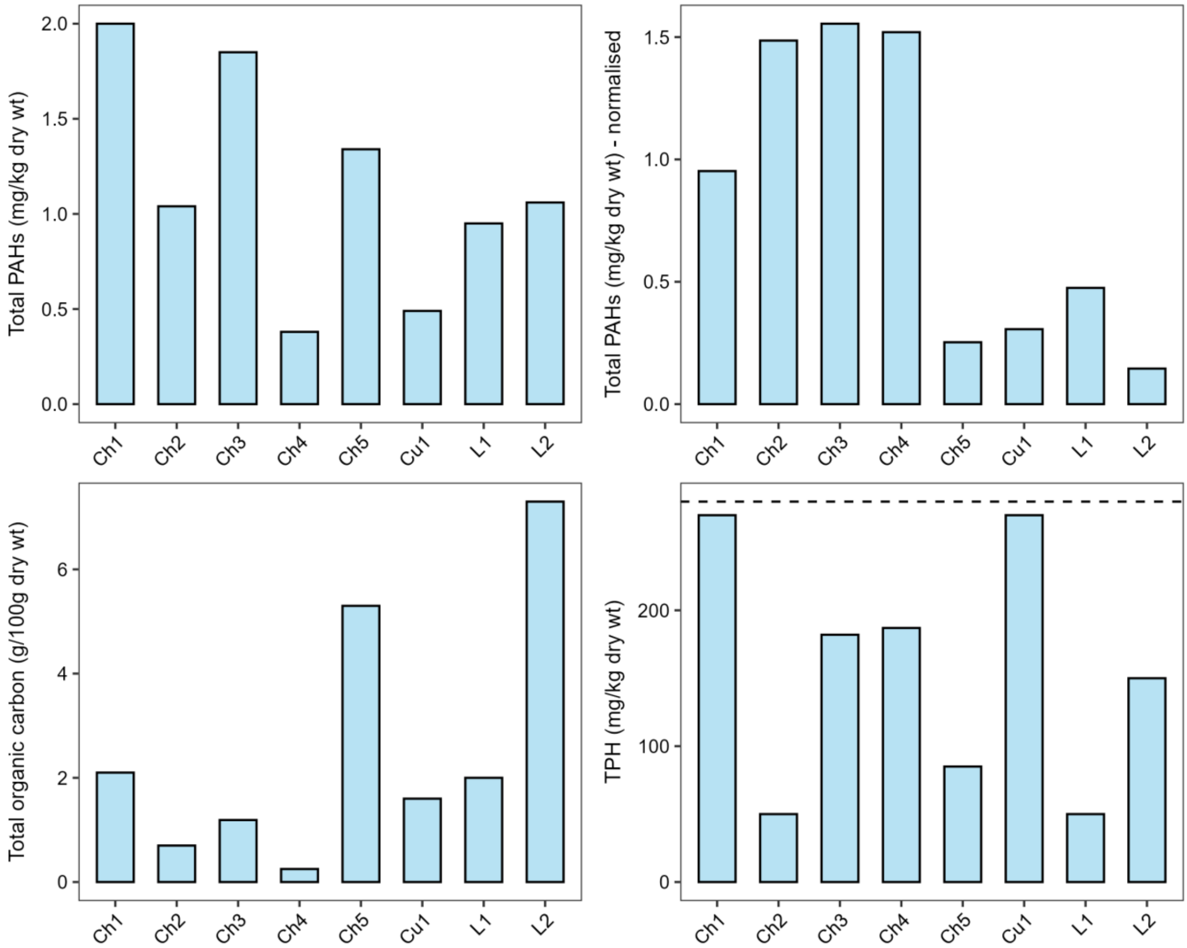

Figure 8: Sediment concentrations of organics, including hydrocarbons. Note total PAHs were normalised to 1% TOC. Dashed line indicates relevant ANZG default guideline values for TPH.

3.2. Īnanga Spawning

No īnanga eggs, nor any adult īnanga, were observed in Charlesworth Drain during any sampling period despite extensive searching. Despite the absence of observed īnanga spawning, Charlesworth Drain contained extensive areas of suitable spawning habitat, particularly in the lower sections of the survey area downstream of the main farm road. These lower areas were dominated by long grasses, while the upper sections featured buttercup with scattered flaxes. However, suitable habitat was limited immediately upstream of the farm road culvert, where groundcover was often sparse due to shading from willows (Figure 9). Areas dominated by buttercup and grasses offered high-quality spawning conditions, with dense stems and root mats that retained moisture well. In contrast, sections shaded by willows lacked adequate ground vegetation, making them unsuitable for īnanga spawning.

Figure 9: Riparian conditions within īnanga spawning range, including dense grasses downstream of road (top left), absence of spawning vegetation under willows immediately upstream of farm road (top right), and dense bushels of buttercup (Ranunculus sp.) (bottom). Note sedimentation and suspended orange iron floc in water column.

The absence of observed īnanga spawning in Charlesworth Drain may be due to multiple contributing factors. One possibility is that spawning activity was missed during surveys, particularly if peak spawning occurred outside the monitoring window. However, several site-specific issues suggest broader limitations on īnanga presence and spawning suitability.

The downstream tide gate at Charlesworth Drain poses a significant barrier to fish passage throughout the tidal cycle. Its heavy, top-hung design – combined with the drain's limited baseflow – means the gate remains almost entirely closed most of the time. Although the structure includes an adjacent culvert intended to allow fish passage (Pers. Comm., Colin Hill, CCC, October 2024), this culvert has collapsed, become filled with gravel, and is no longer functional. This likely restricts access for īnanga and other diadromous species.

Additional ecological constraints are also apparent. The drain appears highly degraded, with substantial sedimentation, visible hydrocarbons, and accumulations of iron floc. These conditions suggest poor habitat quality for adult īnanga. Moreover, a high abundance of slugs and their eggs was observed (Figure 10), indicating that egg predation by slugs may be a further factor limiting successful spawning.

Given these multiple constraints – poor habitat quality, potential barriers to fish movement, and egg predation – it is plausible that there are few or no adult īnanga currently inhabiting Charlesworth Drain. We recommend targeted sampling for adult īnanga during summer months to confirm their presence or absence and better understand the species' habitat use in this system.

Figure 10: Slug eggs observed in Charlesworth Drain (top) and example of comparison between īnanga and slug eggs (bottom) from Jung (2022). Red arrows indicate slug eggs and yellow arrows indicate īnanga eggs. Slug eggs are typically larger (≥2 mm) than īnanga eggs (0.8 to 1.2 mm) and often oval and opaque.

A nearby, previously documented īnanga spawning site at Linwood Canal was also revisited to check for spawning activity on each monthly sampling occasion (~20 minutes by two people). The grass berm on the true left bank had been freshly mowed in March; however, a vegetated buffer was left intact near the edge of the waterway. Despite a thorough search effort along both banks, particularly in areas that had previously supported high spawning activity (Orchard 2018; Instream in prep), no eggs were found. Several viable spawning habitats were still present. On the true right bank, vegetation appeared sparse, with grasses often outcompeted by dense sedge growth. Although vegetation on the true left bank was recovering from mowing undertaken the previous month, root structures remained relatively sparse.

The absence of īnanga eggs at both Charlesworth Drain and the previously known spawning site at Linwood Canal suggests that a spawning event may have been missed. It is possible that spawning was triggered by a significant rainfall event occurring between the scheduled surveys (e.g., the wet weather event on 8 April 2025). However, given that īnanga populations typically spawn multiple times within a season in response to successive spring tides and associated environmental cues, at least some egg deposition would still be expected to be observed if multiple spawning pulses had occurred.

4. CONCLUSIONS AND RECOMMENDATIONS

This report identified multiple water quality stressors in waterways flowing through the Linwood Paddocks that may affect ecological health within the waterways themselves and contribute to impacts on the Avon-Heathcote Estuary. Contaminant sources likely include upstream industrial stormwater discharges, the adjacent oxidation ponds, and possibly also legacy landuse within the paddocks. Although not all parameters exceeded water quality guidelines, elevated nutrient, microbial, and metal concentrations were frequently observed – particularly in Charlesworth and Cuthberts Drains – raising concerns about cumulative impacts on estuarine ecological health.

Very high concentrations of ammoniacal-N at Cu1 and Ch5 strongly suggest the oxidation ponds are the source. High BOD levels at Ch5 also indicate organic enrichment from the oxidation ponds.

E. coli levels exceeded LWRP Freshwater Outcomes across nearly all sites, indicating significant faecal contamination, particularly at downstream Charlesworth sites during both wet and dry conditions. This highlights the likelihood of a combination of persistent inputs from stock and birds in the paddocks and wider catchment sources such as stormwater, wastewater overflows, or failing infrastructure.

Several sites exceeded ANZG guidelines for copper, zinc, and occasionally nickel, with bioavailable copper concentrations frequently elevated across sites. Zinc was consistently elevated at Charlesworth Drain sites in both sediment and water, especially during the wet weather sampling and in low-mid catchment sites, likely due to deposition from up-catchment sources. Hydrocarbon contaminants (PAHs and TPHs) were detected in sediment at several sites but remained below guidelines.

Biological surveys revealed suitable īnanga spawning habitat in lower Charlesworth Drain, yet no eggs or adults were observed. While it is possible that peak spawning was missed during surveys, site-specific issues suggest more fundamental constraints. The downstream tide gate remains mostly closed, significantly limiting fish passage, whereas a nearby culvert intended to support fish movement has collapsed and is no longer functional. The drain itself appears highly degraded, with sedimentation, hydrocarbons, and iron floc affecting habitat quality, and a high abundance of slugs suggests egg predation may also be an issue. Together, these factors suggest limited or no adult īnanga presence.

Overall, the results suggest that contaminants entering the estuary originate from a combination of persistent sources, including livestock and bird activity in paddocks, as well as wider catchment inputs such as industrial stormwater, wastewater overflows, and discharges from oxidation ponds. Metals deposited within Charlesworth Drain (from upstream stormwater sources) may also become mobilised during very high flows and enter the estuary. To protect the ecological integrity of this sensitive receiving environment, targeted management of these upstream sources is recommended. The following actions are proposed to guide this process.

To protect and enhance aquatic ecological values

- Remove dense willow canopy along the intertidal salt-wedge zone of Charlesworth Drain to promote groundcover vegetation and support īnanga spawning habitat.
- Assess and, if necessary, modify the downstream tidal gates at the mouths of Charlesworth Drain and Lovetts Drain to improve fish passage and connectivity between the estuary and upstream habitat.
- Undertake fish surveys to confirm whether īnanga or other migratory species are using Charlesworth Drain.
- Avoid mowing of known or potential īnanga spawning areas (especially lower Charlesworth Drain and Linwood Canal) prior to and during the spawning season (January to May).
- Undertake further water quality monitoring to better understand trends in key parameters (e.g., ammoniacal-N, BOD, E. coli, copper, and zinc).

To address contaminant sources

- Conduct targeted investigations into the oxidation ponds' influence on Cu1 and Ch5 water quality, particularly nitrogen and BOD loading.
- Evaluate and enhance stormwater management infrastructure, including filtration or treatment systems, particularly in industrial areas.
- Continue sediment monitoring for metals to assess long-term contaminant trends and potential legacy effects.

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APPENDIX 1: LINWOOD PADDOCKS CONCEPT PLAN

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