Army Bay Wastewater Treatment Plant

Receiving Environment Monitoring

Final - September 2025

Watercare

QUALITY INFORMATION

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REVISION HISTORY

Rev	Revision Date	Name	Position	Signature
1	29/09/2025	Michiel Jonker	Environmental Care Manager	
2	30/09/202	Gabriel Freitas De Almeida	Operations Controller	
3	30/09/2025	Jon Piggot	Head of Wastewater	

APPROVED

Date	Name	Position	Signature
29/09/2025	Michiel Jonker	Environmental Care Manager	

REMP CHANGE AND MONITORING HISTORY

Change type	Description	Effective date	Reference / condition	Reporting / monitoring implications
Discharge consent	To replace resource consents for the discharge of contaminants from Army Bay WWTP, and to enable staged upgrades to be constructed on site.	December 2019	Condition 18 of DIS60331146 & DIS60331113 under bundle BUN60331144	Requires preparation of a REMP to be submitted, and reviewed after 2 years, then every 5 years. REMP report to be provided annually.
REMP	REMP prepared detailing methodology of the monitoring plan	June 2019	Condition 18 of DIS60331146 & DIS60331113 under bundle BUN60331144	Monitoring includes, water quality, subtidal benthic ecology, intertidal macroalgae, sediment quality, shellfish
REMP review	Suggest improvements following two years of sampling	Submitted Sep 2022	Condition 21 of DIS60331146 & DIS60331113 under bundle BUN60331144	To include DO measurements, assess nutrient data in winter months and chlorophyll-a data in summer
REMP review	Suggests improvements to be made to the REMP methodology & annual reports	Submitted Sep 2025	Condition 21 of DIS60331146 & DIS60331113 under bundle BUN60331144	Once approved by AC, changes to be implemented

EXECUTIVE SUMMARY

This report presents the findings of the Receiving Environment Monitoring Programme (REMP) for the Army Bay Wastewater Treatment Plant, covering the period from March 2020 to June 2025. Monitoring included treated effluent quality, water quality in the receiving environment, and shellfish microbiology and heavy metals. The key findings of the report are summarised below.

Treated Effluent Quality

All discharge quality parameters met consent limits during the 2024–25 reporting period. Statistically significant trends over five years include:

- Increasing: nitrate, faecal coliforms, *Enterococci*, salinity
- Decreasing: ammoniacal nitrogen, $cBOD_5$, turbidity, total suspended solids
- Rising faecal coliforms and *Enterococci*

Water Quality Trends in the Receiving Environment

Most parameters were stable across sites with no widespread degradation observed. Significant spatial differences found for total oxidised nitrogen (TON), nitrate and pH.

TON and nitrate elevated at inner sites (200 m), indicating localised effluent impact, whereas pH differences extend to outer sites, but were not in line with effluent trends, suggesting broader environmental influences. Trend analysis also revealed decreasing $cBOD_5$ at inner sites, aligning with improved effluent quality.

Water Quality Effects on Receiving Environment Sites

There is no evidence of eutrophication or seasonal nutrient build-up at the outfall, as chlorophyll-*a* and nutrient levels show no significant seasonal variation. Some trends such as ammoniacal nitrogen and total phosphorus are likely driven by regional factors rather than effluent discharge.

Shellfish Microbiology

Food Standards Australia New Zealand limits *for Enterococci coli* exceeded at three of five shellfish sites in 2024–25, with the highest *E. coli* levels recorded at Army Bay and Te Haruhi Bay. Huaroa Point and Whangaparāoa Head consistently show low contamination, despite being the closest sites to the outfall. Spatial analysis therefore suggests contamination sources are unrelated to the outfall, likely linked to urban runoff and recreational land use.

Shellfish Heavy Metals

No heavy metal testing occurred in 2024–25 due to lab error (non-compliance with Condition 20e), but historical data (2020–2024) was presented and showed cadmium exceedances at four sites. However, as treated effluent cadmium levels are consistently below detection limits, other contamination sources are more likely to be the cause, including agricultural runoff and urban stormwater.

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1 INTRODUCTION

1.1 Background

Watercare Services Limited (Watercare) owns and operate a Wastewater Treatment Plant at Army Bay that services the Whangaparāoa Peninsula and Hatfields Beach, Orewa and Silverdale townships. This plant discharges treated wastewater via an outfall to the Hauraki Gulf.

Resource Consent DIS60331146 permits the discharge of treated wastewater, subject to conditions including maximum limits for contaminants of concern. The consent also requires regular reporting of water quality monitoring.

Condition 18 of the consent requires Watercare to design and implement a Receiving Environment Monitoring Plan (REMP). This plan includes the collection of monthly water quality and annual shellfish data. Water quality sampling began in March 2020 and has occurred since, contingent on COVID-19 restrictions.

Other aspects of the REMP include benthic ecological and sediment sampling. This work occurs annually, as detailed in a separate report (Bioresearches 2025[1]).

1.2 Scope

This report aims to summarise the water quality monitoring results collected between March 2020 to June 2025 inclusive. In doing so, this report includes:

- A description of the monitoring programme
- Sampling details
- Treated effluent quality for 2024-25
- An assessment of receiving water quality and shellfish results for 2024-2025
- Trend analysis of treated effluent quality
- Trend analysis of receiving water quality
- Trend analysis of shellfish microbiology and heavy metals.

This report does not include raw data. Raw data is available in a workable format on request.

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[1] Bioresearches (2025). Environmental Monitoring of the Benthos in the Whangaparāoa Passage (Autumn 2025)

2 SAMPLING PLAN/ METHOD STATEMENT

2.1 Locations

Figure 2-1- shows the treatment plant, outfall, and sampling locations. Water quality samples are collected from three sites north and three sites south of the outfall's diffuser. The REMP defines the sites at 2,000 m as reference sites, with the closer sites (200 m and 1,000 m) being effect sites. Treated effluent are collected from the WWTP discharge point, before it enters the outfall (immediately after the UV treatment). Shellfish samples are collected from five coastal sites, at each location, samplers collect five replicate samples for individual analysis.

2.2 Parameters

Table 2-1 lists the parameters that Watercare measures in treated effluent and receiving water samples. Field staff measure temperature, salinity, pH, and dissolved oxygen in situ using calibrated hand-held meters.

Table 2-1 Water quality parameters measured in Hauraki Gulf water quality samples

Parameter	Relevance
Physicochemical	
Temperature	Ecological health
Salinity	Seawater dilution indicator
pH	Ecological health
Dissolved oxygen	Ecological health
Total suspended solids	Ecological health/Recreational contact
Turbidity	Ecological health/Recreational contact (Hauraki Gulf only)
Chemicals and nutrients	
Ammoniacal nitrogen	Ecological health
Total oxidised nitrogen (nitrite + nitrate)	Ecological health
Total nitrogen	Eutrophication
Dissolved reactive phosphorus	Eutrophication
Total phosphorus	Eutrophication
Metals	
Arsenic	Ecological toxicity
Cadmium	Ecological toxicity
Lead	Ecological toxicity
Mercury	Ecological toxicity
Biological indicators	
Chlorophyll-a	Eutrophication
Enterococci spp.	Human health
Faecal coliforms	Human health

2.2.1 Frequencies

Watercare collects the Hauraki Gulf water samples each month, while shellfish sampling occurs annually over summer following a period of at least 5 days without rainfall greater than 5mm in 24 hours. Previously in April 2020 and again in August through to October 2021, sampling could not be taken due to COVID lockdowns preventing access.

Due to a lab error during this shellfish sampling round, only microbiological testing was conducted, while heavy metals testing was not.

2.3 Data processing

Monitoring data for treated effluent quality, receiving water quality and shellfish samples were compiled from Watercare's laboratory certificates. (Appendix C details specific data tags and sources used in preparing this report). Laboratory analyses were undertaken by Watercare Laboratory (IANZ accredited). Analysis of shellfish contamination uses standards set by Australia New Zealand Food Standards (FSANZ) guidelines for microbiological and heavy metal limits.

Statistical analyses were applied to assess both spatial differences and temporal trends in water quality and shellfish data. Non-parametric tests (Kruskal–Wallis with Dunn's post-hoc comparisons) were used to evaluate spatial variability across reference, inner and outer sites, while Mann–Kendall and Sen's slope estimators were applied to detect monotonic[2] trends over the 2020–2025 monitoring period. These methods were selected for their robustness to non-normal data distributions typical of environmental datasets. Significance was assessed at $p < 0.05$, with results presented in Appendix A and associated figures in Appendix B.

In this monitoring programme, the reference sites are located 2,000 m from the outfall (N2000 and S2000), the outer sites are positioned 1,000 m from the diffuser (N1000 and S1000), and the inner sites are positioned 200 m from the diffuser (N200 and S200) (Figure 2-1). Comparisons between these groups provide a basis for determining whether conditions at the near-field sites (inner and outer) differ significantly from those at the reference sites, thereby helping to attribute observed changes to the wastewater discharge versus broader environmental influences.

2.4 Assumptions and limitations

Trend analyses presented in this report are based on a five-year dataset (March 2020–June 2025). While this duration aligns with the reporting cycle of the REMP, it represents a relatively short time series for detecting robust environmental trends. Natural variability in coastal systems — including climatic oscillations, storm events, and land-use pressures - can mask or exaggerate underlying changes within such a timeframe. As a result, observed trends should be interpreted cautiously, recognising that apparent increases or decreases may reflect short-term fluctuations rather than long-term directional change.

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[2] Meaning a trend that consistently moves in one direction over time — either always increasing or always decreasing.

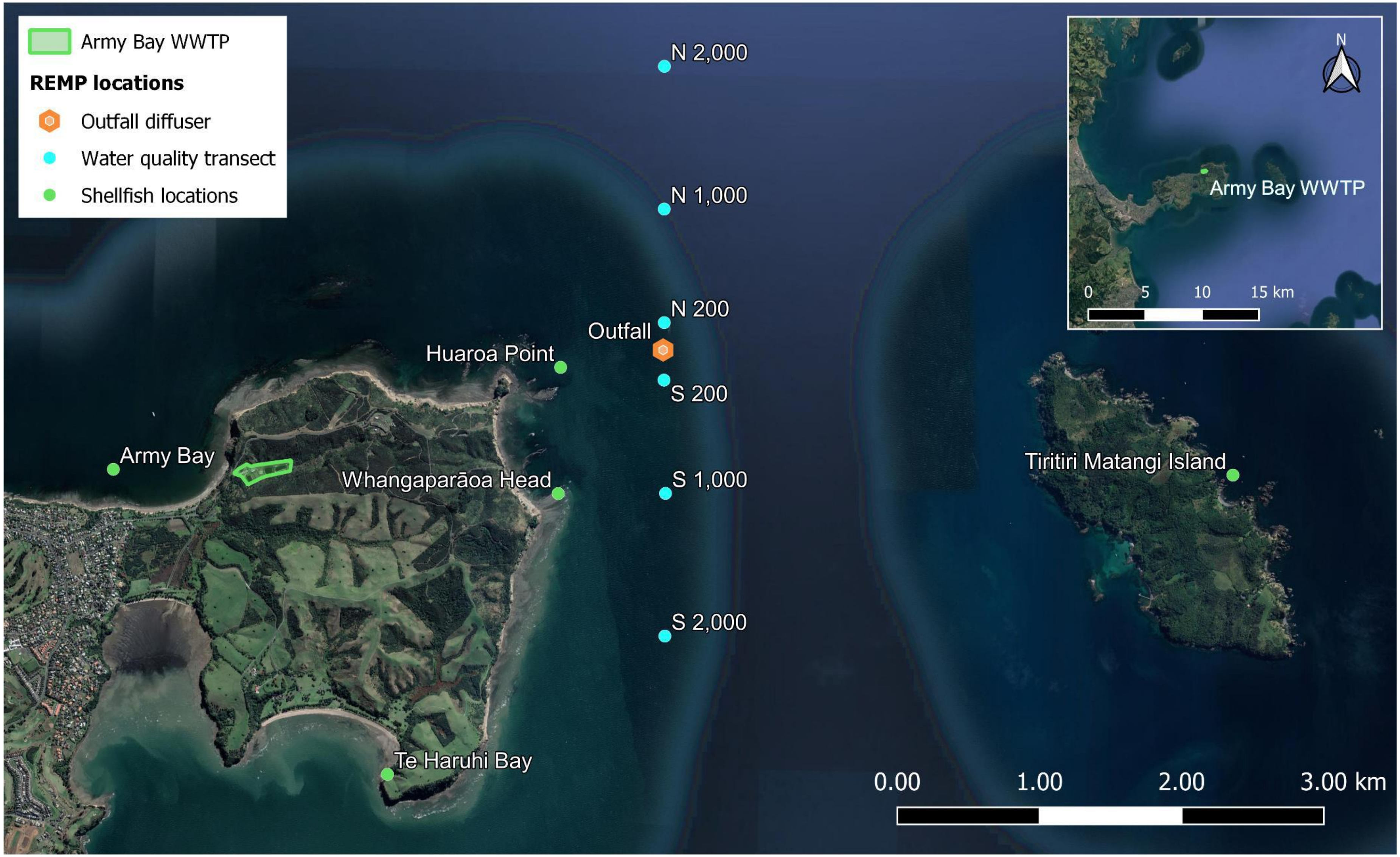


Figure 2-1 Army Bay REMP sampling locations.

3 TREATED EFFLUENT QUALITY

As reported in the annual performance report to Auckland Council, the WWTP discharge consistently met its consent requirements for effluent quality. Table 3-1 summarises the results.

Table 3-1 Army Bay WWTP treated effluent quality for the 2024-25 reporting period, arrows indicate change from 2023-24 reporting period based on median & 92nd %ile values

	Unit	n	Median	Min	92nd %ile	Max	Limit
Physicochemistry							
Flow rate -dry weather	m3/day	264	11,496	11,423	11,832	11,885	ave 13,500 m^3 max 39,825m^3
Temperature	˚C	55	19.7 ↓	17.40	24.38 ↑	24.70	-
pH	-	52	6.8 ↓	6.50	7.1 ↓	14.00	-
cBOD$_5$	mg O2/L	51	1.9 ↑	0.52	7.5 ↑	13.00	median 20
TSS	mg/L	52	4.6 ↑	1.00	14.16 ↑	38.00	median 35
Nutrients							
Ammonia	mg N/L	52	2.75 ↑	0.23	5.76 ↑	10.00	median 15
Nitrite	mg N/L	52	0.48 ↑	0.05	0.8364 ↑	1.28	-
Nitrate	mg N/L	47	15.0 ↑	8.63	17.67 ↑	24.00	-
Total N	mg N/L	52	21.1 ↑	17.40	43.30 ↑	63.60	-
DRP	mg P/L	52	5.36 ↑	2.41	7.43 ↑	9.80	-
Total P	mg P/L	52	5.7 ↑	2.52	8.79 ↑	9.51	-
Bacterial indicators							
Enterococci	cfu/100 mL	43	20 ↑	1.60	3056 ↑	8900	-
Faecal coliforms*	cfu/100 mL	52	94 ↑	1.60	7888 ↑	58000	-
Heavy metals (total)							
Arsenic	µg/L	2	-	-	-	0.0021 ↓	-
Cadmium	µg/L	2	-	-	-	0.00005 ↓	-
Lead	µg/L	2	-	-	-	0.0002 ↓	-
Mercury	µg/L	2	-	-	-	0.00005 ↓	-

Statistical analysis employing the Kruskal-Wallis test revealed significant differences in nine parameters over the 2020-2025 reporting period in the effluent discharge, these are presented in Figure 3-1. A strong increasing trend was measured in nitrate and faecal coliforms, and a weak, but significant increasing trend observed in total nitrogen, *Enterococci* and salinity. In comparison there are strong decreasing trends in ammoniacal nitrogen, cBOD$_5$, turbidity and total suspended solids.

Figure 3-1 Significant trends revealed in treated effluent over the 2020-2025 reporting period with blue denoting decrease and red increase Note: linear visualisation with 95% confidence interval, microbiological parameters use log10 scale.

The observed trends suggest a mixed picture of the plant's performance. Increasing faecal coliforms, alongside more frequent UV dosing requirement failures, strongly suggest reduced disinfection reliability, which is supported by the increase in *Enterococci*.

The decreasing ammoniacal nitrogen suggests the nitrification process within the WWTP is working well, but the increasing nitrate implies denitrification is not keeping up. This may be associated with short retention times caused by high flows, which is also the reason behind UV dosing requirements not being met. Following the first stage of UV bank upgrade next winter, we can start looking for improved performance in disinfection, which should increase further once the second UV channel is added.

The results of the statistical analysis are provided in Appendix A, and discussed further, in comparison to the trends observed at the receiving environment sites, in Section 5.

4 RECEIVING ENVIRONMENT WATER QUALITY

Table 4-1 presents a summary of water quality results from all receiving environment sampling sites for the 2024-2025 reporting period. Most physicochemical parameters, including $cBOD_5$, dissolved oxygen, pH, salinity, and temperature, were consistent across the sites, indicating stable conditions. Total suspended solids showed greater variation at the inner sites, although the lowest values were recorded there, suggesting no adverse impact from the treated effluent. *Enterococci* levels remained steady, implying that any challenges with UV disinfection at the WWTP are not affecting the receiving environment. Nitrate concentrations were elevated at the inner sites but showed little variation, while nitrite levels were uniformly low and consistent across all locations. Ammonia and dissolved reactive phosphorus varied between sites, although no clear spatial pattern was evident when comparing inner, outer, and reference locations.

Table 4-1 Average and standard error for water quality parameters at all sampling and reference points for the 2024-2025 reporting period

Parameter	N2000	S2000	N1000	S1000	N200	S200
Ammonia	0.0103 + 0.00356	0.0097 + 0.00316	0.0117 + 0.00441	0.0081 + 0.0031	0.0101 + 0.00328	0.0177 + 0.00706
cBOD5	0.5 + 0	0.63 + 0.13	0.5 + 0	0.5 + 0	0.51 + 0.01	0.5 + 0
Chlorophyll a	0.00102 + 0.000169	0.00216 + 0.000513	0.000978 + 0.000164	0.00137 + 0.000236	0.00117 + 0.000235	0.00274 + 0.00159
DO	7.91 + 0.137	7.82 + 0.129	7.94 + 0.151	7.82 + 0.14	7.94 + 0.146	7.84 + 0.133
DRP	0.009 + 0.000957	0.0099 + 0.000983	0.0109 + 0.00174	0.0098 + 0.000904	0.0104 + 0.00134	0.0107 + 0.00181
Enterococci	10 + 0	11 + 1	10 + 0	10 + 0	10 + 0	10 + 0
Nitrate	0.00384 + 0.000807	0.00341 + 0.000835	0.00678 + 0.00253	0.00368 + 0.000866	0.00637 + 0.00282	0.00828 + 0.00349
Nitrite	0.002 + 0	0.002 + 0	0.002 + 0	0.002 + 0	0.00204 + 4.44e-05	0.002 + 0
pH	8.1 + 0.0408	7.92 + 0.02	8.1 + 0.0408	8.04 + 0.0267	8.09 + 0.0423	8.06 + 0.034
Salinity	35 + 0.172	35 + 0.224	34.9 + 0.159	35.1 + 0.233	34.9 + 0.196	35.1 + 0.211
Temperature	17 + 0.965	17.2 + 0.882	16.9 + 0.93	17.2 + 0.891	16.9 + 0.929	17.2 + 0.887
Total N	0.0702 + 0.0124	0.0869 + 0.00774	0.0817 + 0.00823	0.0858 + 0.00917	0.0907 + 0.0108	0.0849 + 0.0105
TON	0.00384 + 0.000807	0.00341 + 0.000835	0.00703 + 0.00272	0.00368 + 0.000866	0.00667 + 0.0031	0.0083 + 0.00351
Total P	0.0109 + 0.00159	0.0124 + 0.00113	0.0127 + 0.0022	0.0121 + 0.00112	0.0123 + 0.00158	0.0146 + 0.00183
TSS	40.2 + 4.65	48.5 + 5.05	51.2 + 10.1	41.2 + 3.73	39.7 + 5.3	38.6 + 5.41
Turbidity	0.45 + 0.0507	0.65 + 0.106	0.494 + 0.0609	0.665 + 0.0928	0.511 + 0.0526	0.58 + 0.101

***Note**. Mean values presented ± standard error.*

5 WATER QUALITY TREND ANALYSIS

5.1 Ecological effects at the outfall

To assess whether the effluent discharge is contributing to eutrophication, characterised by excessive algal and phytoplankton growth, we examined seasonal patterns in primary production and nutrient accumulation for the reporting period 2020-2025. Chlorophyll *a* levels were used as an indicator of primary production during the warmer summer months, while nutrient concentrations (nitrate, total oxidised nitrogen [TON], dissolved reactive phosphorus [DRP]) and pH were assessed for potential build-up during winter.

Kruskal-Wallis tests revealed no statistically significant seasonal differences in any of the nutrient parameters (all p-values > 0.1), nor in chlorophyll *a* concentrations during summer (p = 0.827). These findings suggest that the discharge is not acting as a substantial source of nutrients, capable of driving increased primary production or seasonal nutrient enrichment, at the outfall site.

5.2 Water quality effects in the receiving environment

Statistical analysis employing the Kruskal-Wallis test revealed significant differences in total oxidised nitrogen (TON), nitrate and pH between sites over the 2020-2025 reporting period. No statistically significant differences were observed for the remaining parameters between sites (Table 5-1).

Table 5-1 Statistical results for quality parameters tested at the inner and outer sites compared to the reference sites

Component	H statistic	p-value	Significant ($p < 0.05$)
$cBOD_5$	0.095	0.954	No
Chlorophyll a	0.327	0.849	No
Enterococci	0.281	0.869	No
Ammoniacal nitrogen	0.912	0.634	No
Nitrite	0.965	0.617	No
Total oxidised nitrogen	**7.351**	**0.025**	**Yes**
Nitrate	**7.245**	**0.027**	**Yes**
Dissolved oxygen	0.171	0.918	No
pH	**10.473**	**0.005**	**Yes**
Dissolved reactive phosphorus	3.653	0.161	No
Total phosphorus	2.385	0.303	No
Salinity	0.038	0.981	No
Total suspended solids	3.582	0.167	No
Volatile solids	3.33	0.189	No
Temperature	0.003	0.998	No

Component	H statistic	p-value	Significant ($p < 0.05$)
Total nitrogen	1.298	0.522	No
Turbidity	0.693	0.707	No

Dunn's post-hoc test was then used to pinpoint which specific site comparisons showed statistically significant differences for the three affected parameters, helping to assess the extent of effluent impact on the receiving waters during the past five reporting periods.

Table 5-2 Statistical results for total oxidised nitrogen

Comparison	Z-score	Unadjusted p	Adjusted p	Interpretation
Inner vs Outer	1.63	0.104	0.155	Not significant
Inner vs Reference	**2.69**	**0.007**	**0.021**	**Significant**
Outer vs Reference	1.06	0.288	0.288	Not significant

The results indicate that TON is significantly higher at the inner sites (200 m from the discharge) compared to the reference sites, but not at the outer sites. This supports a localised influence of the effluent discharge on TON concentrations, with effects diminishing by 1,000 m.

Table 5-3 Statistical results for nitrate

Comparison	Z-score	Unadjusted p	Adjusted p	Interpretation
Inner vs Outer	1.61	0.107	0.161	Not significant
Inner vs Reference	**2.67**	**0.0075**	**0.023**	**Significant**
Outer vs Reference	1.06	0.288	0.288	Not significant

Results for nitrate concentrations were significantly different at the inner sites compared to the reference sites. This indicates a localised influence of the effluent on nitrate levels, with the effect diminishing to non-significant levels by the outer sites at 1,000 m.

Table 5-4 Statistical results for pH

Comparison	Z-score	Unadjusted p	Adjusted p	Interpretation
Inner vs Outer	0.65	0.518	0.518	Not significant
Inner vs Reference	**3.07**	**0.0021**	**0.0064**	**Significant**
Outer vs Reference	**2.42**	**0.0154**	**0.0231**	**Significant**

Both the inner (200 m) and outer (1,000 m) sites exhibited significantly different pH levels compared to the reference sites, indicating that the influence of the effluent discharge extends over a larger spatial range. This contrasts with the more localised effects observed for nitrate and total oxidised nitrogen (TON), which were only significantly elevated at the inner sites. The wider extent of pH alteration suggests that this parameter may be more sensitive to the discharge or influenced by additional factors contributing to its persistence over a larger area.

5.3 Trend analysis at receiving environment sites

Although previous testing has confirmed that only three water quality parameters show statistically significant differences between reference and sampling sites, we have extended our analysis to examine five-year trends (2020–2025) across all measured parameters, regardless of whether they are directly influenced by the WWTP discharge at all sampling sites. This broader approach allows us to identify any emerging patterns or shifts in the receiving environment, including those potentially driven by regional or natural factors, and to better understand the overall ecological trajectory of the Whangaparāoa Passage.

By testing for statistically significant increasing or decreasing trends at each site, we can:

- Identify ongoing or diminishing effects of the WWTP discharge, especially when these trends align with changes in effluent quality over time.
- Detect early signs of environmental degradation, where trends at near-field sites diverge from those at reference sites, potentially indicating emerging impacts not yet fully realised.
- Distinguish between discharge-related effects and broader environmental influences, by comparing trends at reference sites with those closer to the outfall. If similar trends are observed across all sites, this may suggest regional factors (e.g., climate variability, land-based inputs) are influencing water quality independently of the WWTP.

Inner sites (220 m from the outfall – N200 & S200)

Four water quality parameters show statistically significant trends at the inner sites, with two of these, CBOD$_5$, and pH, exhibiting the same trends at both the northern and southern inner sites (Figure 5-1). Comparison of these against trends observed in treated effluent, outer and reference sites are discussed below.

cBOD$_5$

A significant decreasing trend is observed at both inner sites and in the treated effluent. To the north, a moderate decreasing trend is evident at the outer site, while to the south, levels remain more consistent, with no significant trend. No significant trends are observed at the reference sites.

Although there is no statistical difference between the receiving environment sites, the matching decreasing trends at the inner sites, along with a continued but weakened trend at the N1000 site, suggest that the improved cBOD$_5$ levels in the effluent may be influencing water quality in the localised receiving environment.

pH

A moderate increasing trend is evident at both inner sites, which mirrors the trend at both outer sites and the northern reference site. No trend is observed at the southern reference site. In contrast, pH levels in the treated effluent have decreased over the five-year period.

This suggests that pH levels within the receiving environment are being influenced by environmental factors, despite the significant differences between inner and reference sites identified in earlier Kruskal–Wallis tests.

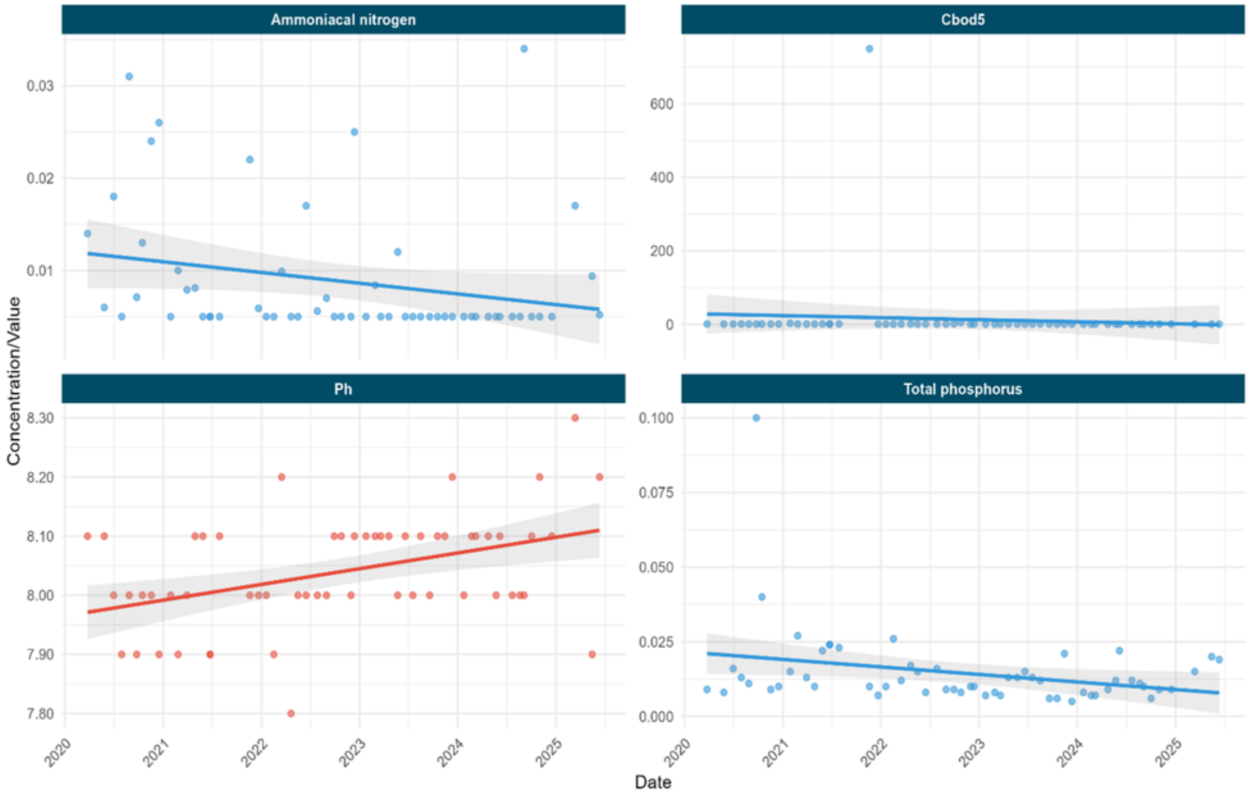


Figure 5-1 Plots showing significant trends in receiving water quality parameters at the inner sites (200m from outfall, with blue representing decreasing, and red, increasing trends [Note: linear visualisation with 95% confidence interval].

Ammoniacal nitrogen

Strong decreasing trends were observed at both outer sites and the northern reference site. In contrast, only moderately significant decreases were detected at the northern inner site and the southern reference site. Although the treated effluent also shows a strong decreasing trend, the absence of a significant trend, and only a moderate increase, at the inner sites suggests that these changes are unlikely to be directly linked to the treated effluent discharge. Instead, they are more likely influenced by other environmental or anthropogenic factors.

Total phosphorus

A weak but significant decreasing trend in total phosphorus is observed at the northern inner site. However, this is unlikely to be a direct influence of the outfall, as decreasing trends are also present at the reference sites, while no trend is observed in the treated effluent.

As such, any trends observed within the receiving environment are more likely the result of environmental or other anthropogenic factors.

Significant trend plots for the outer and reference sites can be found in 0.

5.4 Conclusion on water quality trends

The combined results of spatial comparisons and five-year trend analysis indicate that the treated effluent has a measurable but localised influence on water quality in the Whangaparāoa Passage.

Over the 2020-2025 reporting period, total oxidised nitrogen and nitrate were significantly elevated at the inner sites compared to reference sites, suggesting a clear influence from the effluent discharge, although no consistent trends over time were observed for these parameters. In contrast, pH showed both significant spatial differences and increasing trends at the inner sites, despite decreasing levels in the effluent, pointing to broader environmental influences. Improvements in $cBOD_5$ levels at the inner sites aligned with trends in the treated effluent, suggesting a positive effect of improved effluent quality on the receiving environment. For other parameters, such as ammoniacal nitrogen and total phosphorus, observed changes were more consistent with regional or environmental drivers, rather than direct discharge effects.

6 SHELLFISH – KAIMOANA

6.1 Microbiology

A summary of the microbiology monitoring of the shellfish at the five sampling sites is presented in Table 6-1, along with the results from the 2023-24 sampling for comparison. Notably, there were multiple instances where the FSANZ limit for *E.coli* in oysters was exceeded, with three of the five sites showing maximum levels greater than the 230 MPN/100 g limit.

The latest sampling results suggest that *E.coli* levels are lowest at Huaroa Point, which is the site closest to the outfall, followed by Te Haruhi and Army Bay. The poorest results were found at Whangaparāoa Head and Tiritiri Matangi, the latter of which recorded an extreme result of 350,000 MPN/ 100 g. These results are very different to the previous year, which recorded the highest *E.coli* level at the site closest to the outfall, Huaroa Point.

Table 6-1 E.coli and faecal coliform results from water and shellfish samples collected in December 2024, with shellfish results from previous monitoring period (December 2023)

	Huaroa Point			**Whangaparāoa Head**			**Te Haruhi Bay**			**Army Bay**			**Tiritiri Matangi**		
	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
E.coli (MPN/100 g)															
Water 2024-25	<1.7			3.3			<1.7			<1.7			9.8		
Shellfish 24-25	18	18	45	790	2300	7900	45	78	170	20	78	330	790	8078	35000
Shellfish 23-24	40	490	1300	18	20	45	18	20	78	490	790	790	18	18	45
Faecal coliforms (MPN/100 g)															
Water 2024-25	<1.7			3.3			<1.7			<1.7			25		
Shellfish 24-25	18	18	45	1100	35000	7900	45	120	230	20	110	330	1100	9440	35000
Shellfish 23-24	40	490	1300	18	18	170	18	45	45	490	790	790	18	40	78

6.1.1 Trend analysis of microbiology

To evaluate spatial differences in *E. coli* levels across the five shellfish monitoring sites during the 2020–2025 reporting period, a Kruskal-Wallis test was conducted. The test revealed a statistically significant variation in *E. coli* concentrations between sites, prompting a Dunn's post-hoc test to identify which specific site comparisons contributed to this result. These findings are illustrated in Figure 6-1, which maps the significant pairwise differences using directional arrows and Z-scores.

The analysis showed that *E. coli* levels at Army Bay were significantly higher than at three of the four other sites, with the exception of Te Haruhi Bay, which itself had significantly higher levels than both Huaroa Point and Whangaparāoa Head. These spatial patterns are further supported by the boxplot visualisation in Figure 6-2, which presents the distribution of *E. coli* levels at each site, including medians, interquartile ranges (IQR), and outliers.

Although Huaroa Point and Whangaparāoa Head are the closest shellfish sampling sites to the outfall, they consistently show low *E. coli* levels. This pattern is also observed at Tiritiri Matangi, which is both the furthest site and physically separated from the outfall by the island itself. In contrast, Army Bay and Te Haruhi Bay, which are slightly closer to the outfall than Tiritiri Matangi, show elevated *E. coli* levels, suggesting that other sources of contamination are contributing to the results at these locations.

The Army Bay site is the only location adjacent to an urbanised coastal suburb, where stormwater runoff, especially following rainfall, is likely a contributor to elevated *E. coli* levels. Te Haruhi Bay, located within Shakespear Regional Park, is likely influenced by the mixed land use including conservation areas, recreational facilities, and grazing livestock. High visitor numbers, including campers and swimmers, may contribute to faecal contamination via stormwater runoff, while grazing animals may also elevate E. coli levels in coastal waters here.

The boxplots in Figure 6-2 reinforce these findings. Army Bay and Te Haruhi Bay show the highest *E. coli* levels, as indicated by elevated medians and wider IQRs. Tiritiri Matangi displays a large IQR but a low median, suggesting that E. coli levels are usually low but subject to infrequent spikes, likely driven by episodic events. Huaroa Point has the most consistent and lowest E. coli levels, while Whangaparāoa Head also shows relatively stable and low concentrations.

Together, the spatial map and boxplot figures provide complementary evidence of site-specific differences in *E. coli* contamination, highlighting the influence of land use, proximity to urban areas, and potential non-outfall sources.

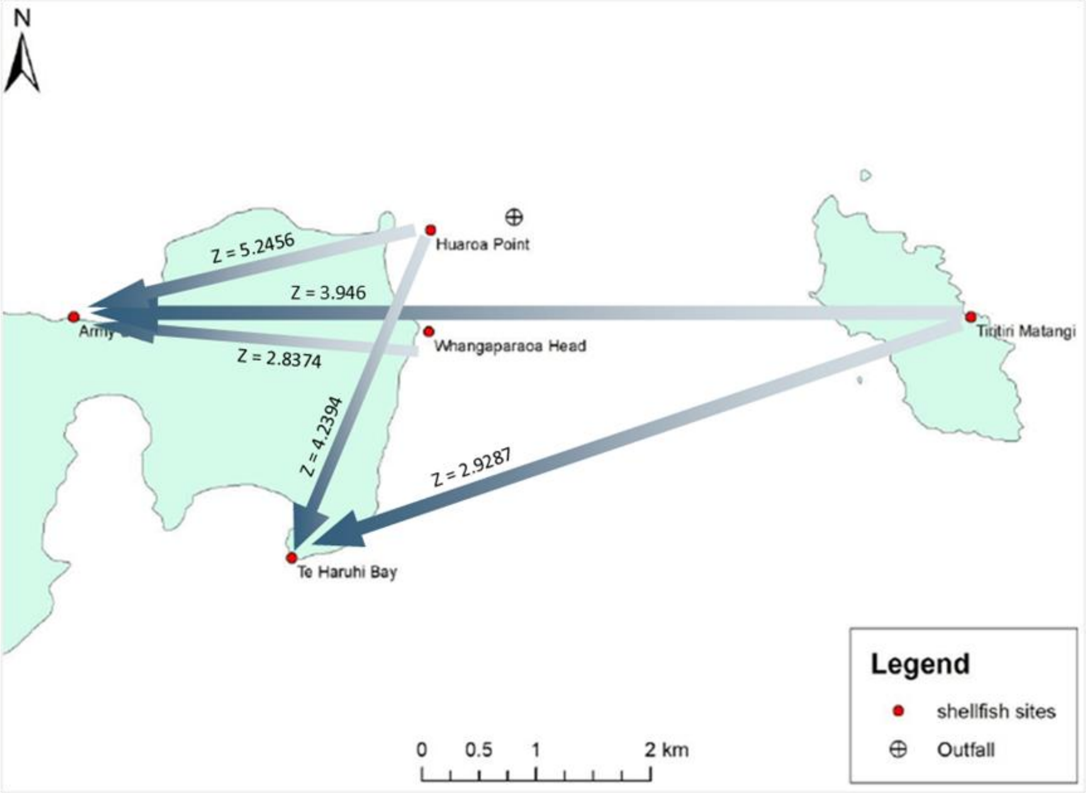


Figure 6-1 Map depicting significant differences between sampling sites with arrow heads pointed to higher E.coli levels, and the Z-score for each pairing.

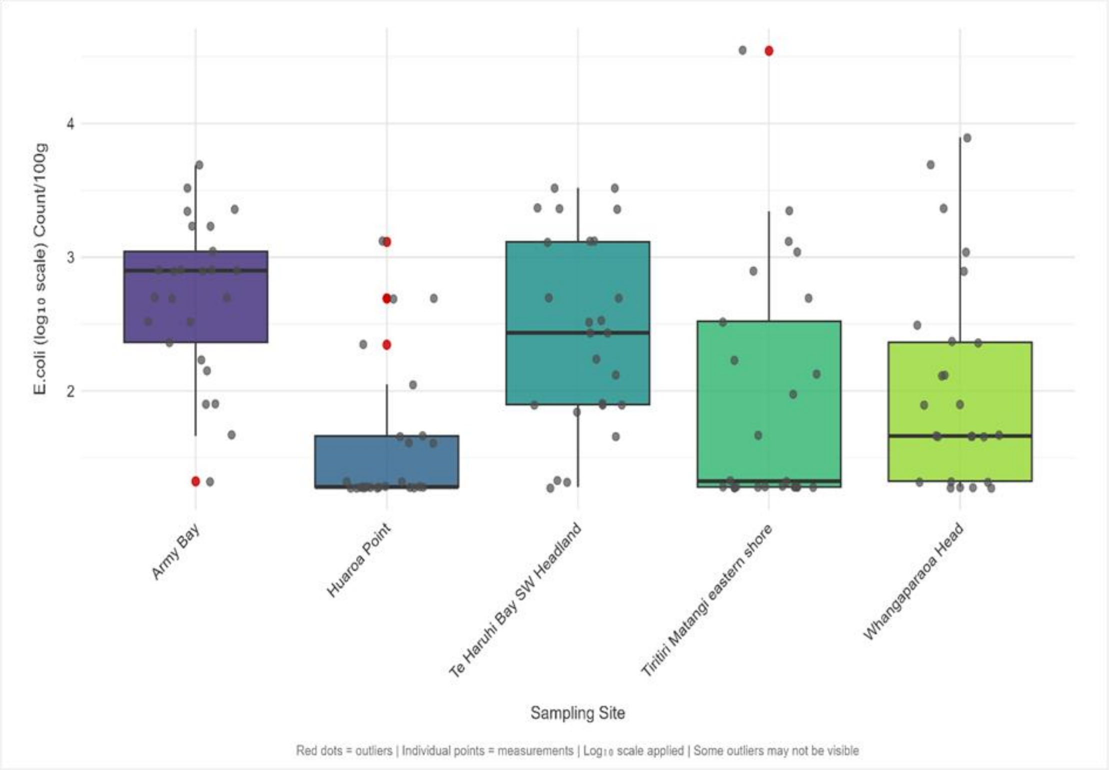


Figure 6-2 Boxplots of E.coli levels across the five sampling sites, presenting median, IQR and outlier results

6.2 Heavy metals trends

Shellfish were not tested for heavy metals during the 2024–25 sampling period due to a laboratory error, resulting in non-compliance with Condition 20e of the consent. However, all available heavy metal results from the 2020–2024 reporting period have been analysed and compared against the Australia New Zealand Food Standards Code (FSANZ).

As summarised in Table 6-2, cadmium levels have exceeded FSANZ limits in the past at four of the five monitoring sites. Notably, cadmium concentrations in the treated effluent have consistently remained below the detection limit of 0.00005 mg/L, indicating that the effluent is not the source of cadmium contamination in shellfish. Likely contributors include agricultural runoff and urban stormwater inputs.

Table 6-2 Heavy metal data from shellfish samples collected (2020-2024)

	Arsenic (mg/kg)		***Inorganic Arsenic (mg/kg)**		**Cadmium (mg/kg)**		**Lead (mg/kg)**		**Mercury (mg/kg)**	
	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max
FSANZ limit			2		2		2		0.5	1
Huaroa Point	3.84	5.37	0.38	0.5	1.35	2.19	0.05	0.08	0.03	0.05
Whangaparāoa Head	3.26	7.14	0.33	0.7	1.10	3.06	0.05	0.09	0.03	0.08
Te Haruhi Bay	2.98	4.09	0.30	0.4	1.17	1.78	0.06	0.14	0.03	0.05
Army Bay	3.62	5.67	0.36	0.6	1.32	2.30	0.04	0.07	0.03	0.04
Tiritiri Matangi	3.35	7.64	0.33	0.8	1.52	3.00	0.05	0.10	0.01	0.02

To further explore spatial variation in heavy metal contamination,

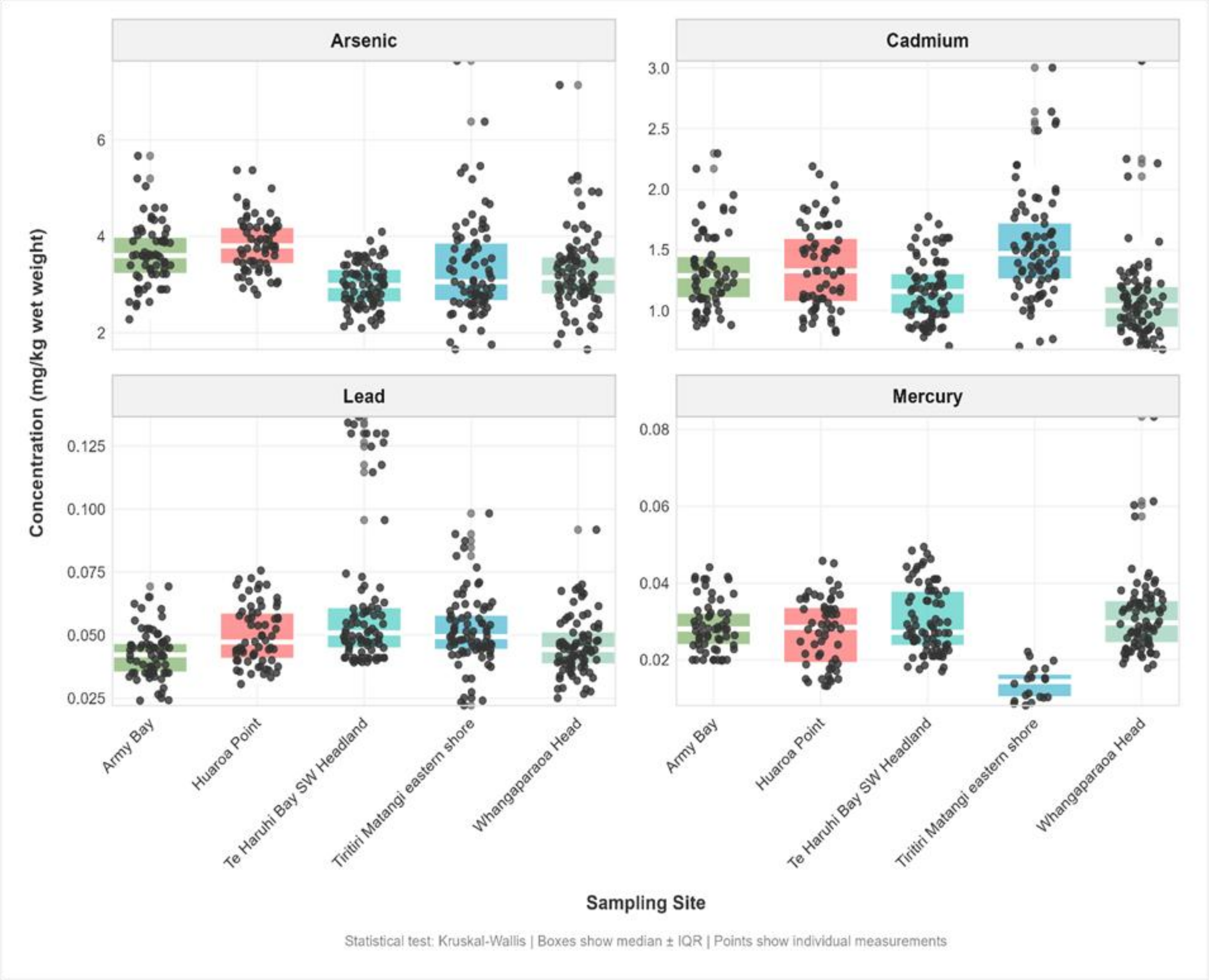


Figure 6-3 presents boxplots of arsenic, cadmium, lead, and mercury concentrations across the five sampling sites. Each plot shows the distribution of measured values, with medians, IQR, and individual data points. Statistically significant differences between sites were identified using the Kruskal-Wallis test ($p < 0.05$).

- Cadmium shows the most pronounced spatial variation, with elevated levels and outliers at several sites, supporting the earlier finding of FSANZ exceedances.
- Arsenic concentrations also vary across sites, with some locations showing notably higher values.
- Lead and mercury concentrations are generally low, with both displays distinct site-specific differences.

These results highlight the influence of local environmental factors, such as land use, catchment characteristics, and hydrodynamics, on heavy metal accumulation in shellfish. The elevated cadmium levels, in particular, suggest that further investigation into non-effluent sources of contamination may be warranted. While this falls outside the scope of the Watercare’s responsibilities, it is our view that identifying and addressing these alternative sources would be beneficial for understanding and managing broader environmental risks.

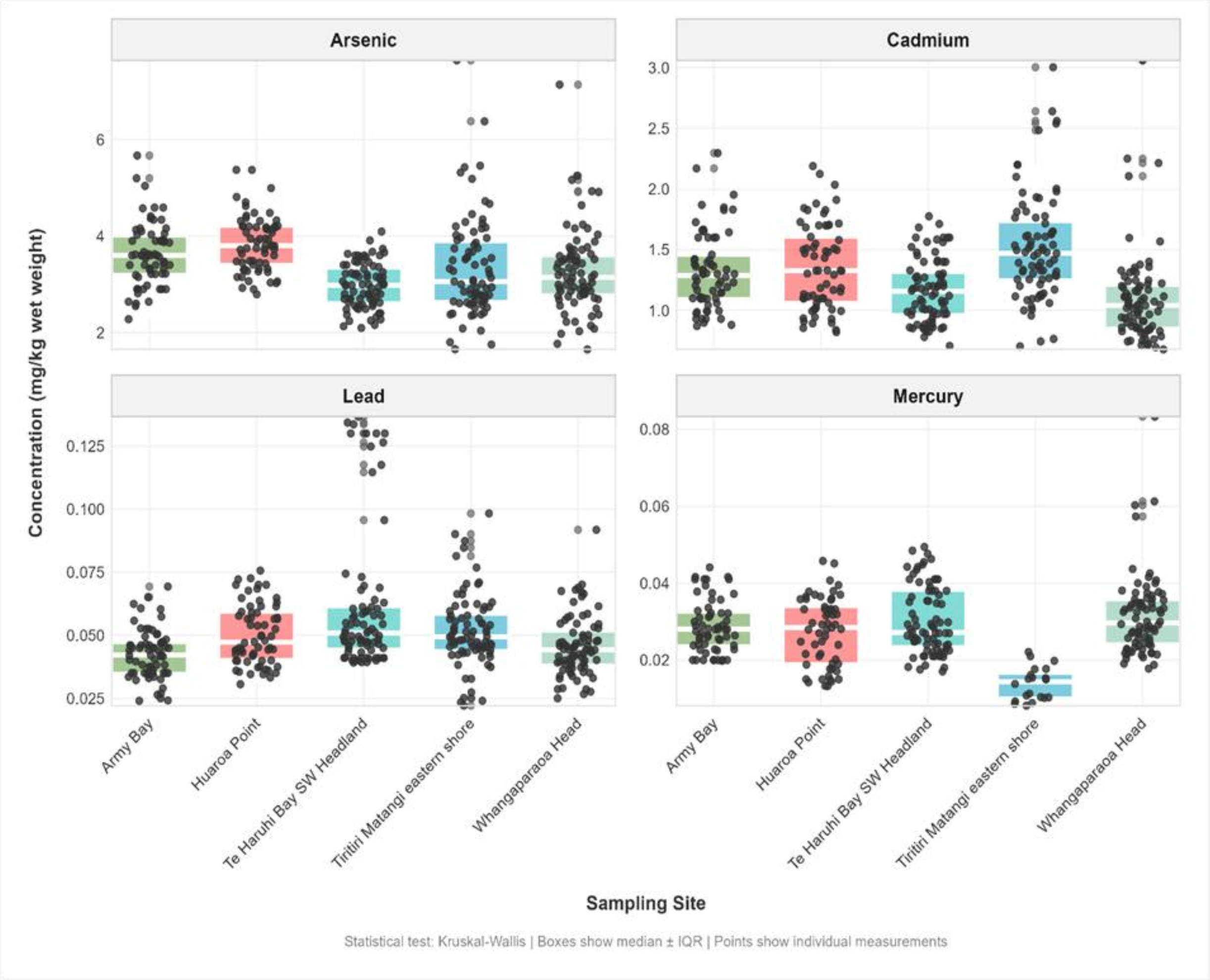


Figure 6-3 Boxplots of heavy metal levels across the five sampling sites, presenting median and interquartile range.

7 CONCLUSION

Effluent discharge quality consistently met consent limits throughout the reporting period. However, upward trends in faecal coliforms and nitrate point to potential challenges with disinfection reliability and denitrification efficiency. Despite this, water quality in the receiving environment remains generally stable, with only localised effects observed for nitrate and total oxidised nitrogen near the outfall.

Shellfish microbiology monitoring identified elevated *E. coli* levels at Army Bay and Te Haruhi Bay, likely influenced by urban runoff and recreational land use rather than the wastewater discharge. Historical heavy metal data revealed cadmium exceedances at several sites, though treated effluent concentrations remained below detection limits.

Overall, the monitoring results suggest that the Army Bay WWTP is performing effectively in safeguarding the receiving environment. Localised improvements in water quality, such as reduced $cBOD_5$ and suspended solids, align with enhancements in effluent treatment, indicating that ongoing optimisation of plant operations is yielding positive environmental outcomes. Continued monitoring will be important to track these relationships and ensure compliance with consent conditions while supporting broader environmental protection efforts.

Appendix A. Statistical Results

Kruskal-Wallace test results for nutrient build-up in winter and chlorophyll-a build-up in summer

Component	Chi-squared	p-value	Interpretation
Nitrate	3.28	0.194	Not significant
Total Oxidised Nitrogen	3.39	0.183	Not significant
Dissolved Reactive Phosphorus	3.79	0.15	Not significant
pH	1.83	0.401	Not significant
Chlorophyll-a	3.28	0.194	Not significant

Mann-Kendall test results presenting significant quality trends at the receiving environment sites, where p-value < 0.05 = significant, Tau reflects strength and direction of the trend (positive is increasing), and Sens' slope estimates rate of change per time unit

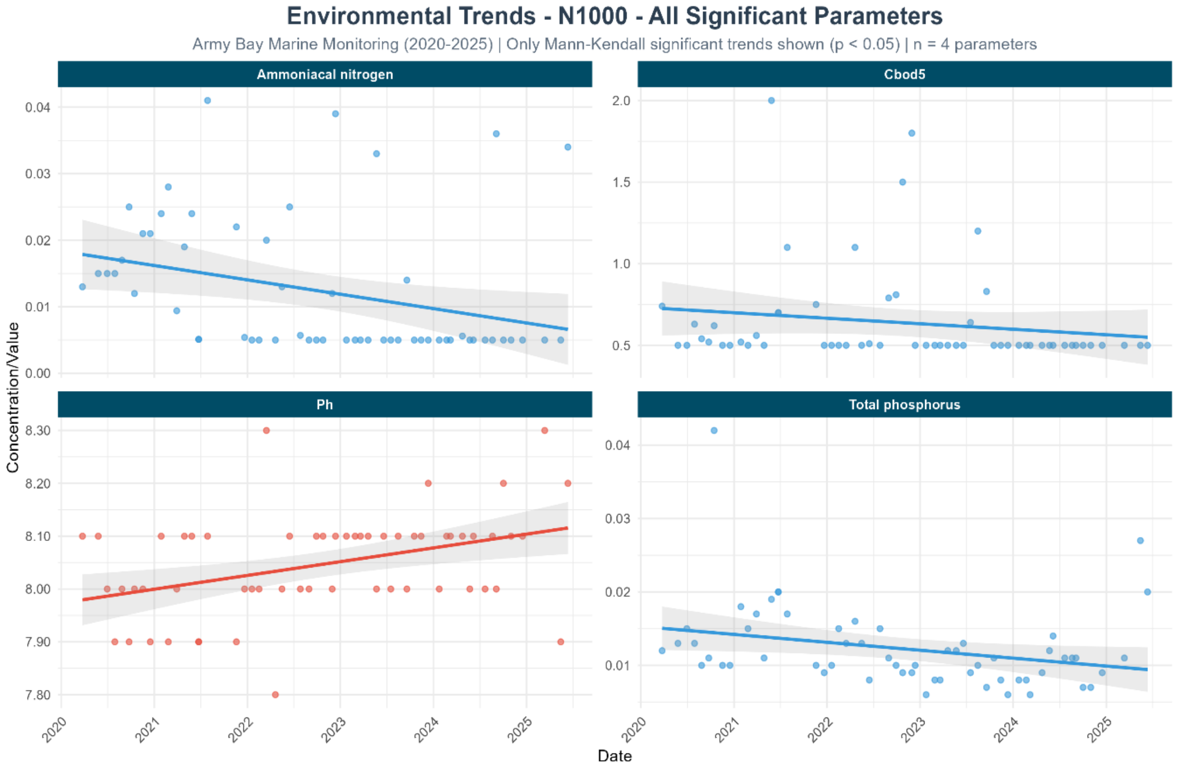
Site	Component	P-value	Tau	Sen slope	Trend direction
N200	Ammoniacal nitrogen	0.00564	-0.223	0	Moderate decreasing trend
N200	Cbod5	0.01088	-0.195	0	Significant decreasing trend
S200	Cbod5	0.04714	-0.142	0	Significant decreasing trend
N200	Ph	0.00146	0.27	0	Moderate increasing trend
S200	Ph	0.00201	0.259	0	Moderate increasing trend
N200	Total phosphorus	0.04701	-0.179	-0.000002	Significant decreasing trend
N1000	Ammoniacal nitrogen	0.00008	-0.334	-0.000001	Strong decreasing trend
S1000	Ammoniacal nitrogen	0.00011	-0.313	0	Strong decreasing trend
N1000	Total phosphorus	0.00314	-0.266	-0.000003	Moderate decreasing trend
N1000	$cBOD_5$	0.00609	-0.213	0	Moderate decreasing trend
S1000	Total phosphorus	0.03385	-0.189	-0.000002	Significant decreasing trend
S1000	Ph	0.00894	0.223	0	Moderate increasing trend
N1000	Ph	0.00167	0.266	0	Moderate increasing trend
N2000	Ammoniacal nitrogen	0.00025	-0.312	-0.000001	Strong decreasing trend
S2000	Ammoniacal nitrogen	0.00152	-0.243	0	Moderate decreasing trend
S2000	Total phosphorus	0.00695	-0.24	-0.000002	Moderate decreasing trend
N2000	Total phosphorus	0.02727	-0.198	-0.000002	Significant decreasing trend
N2000	Ph	0.00357	0.247	0	Moderate increasing trend

Dunn test results for shellfish microbiological pairwise comparisons for E. coli

Comparison	Z or t score	P-value	P adjusted	Significant
Army Bay - Huaroa Point	5.2456	0	0.000001	Yes
Army Bay - Te Haruhi Bay	1.0062	0.15716	1	No
Army Bay - Tiritiri Matangi	3.946	0.00004	0.000397	Yes
Army Bay - Whangaparāoa Head	2.8374	0.002274	0.022738	Yes
Huaroa Point - Te Haruhi Bay	-4.2394	0.000011	0.000112	Yes
Huaroa Point - Tiritiri Matangi	-1.2996	0.09687	0.968702	No
Huaroa Point - Whangaparāoa Head	-2.4082	0.008016	0.08016	No
Te Haruhi Bay - Tiritiri Matangi	2.9398	0.001642	0.016419	Yes
Te Haruhi Bay - Whangaparāoa Head	1.8312	0.033532	0.33532	No
Tiritiri Matangi - Whangaparāoa Head	-1.1086	0.133803	1	No

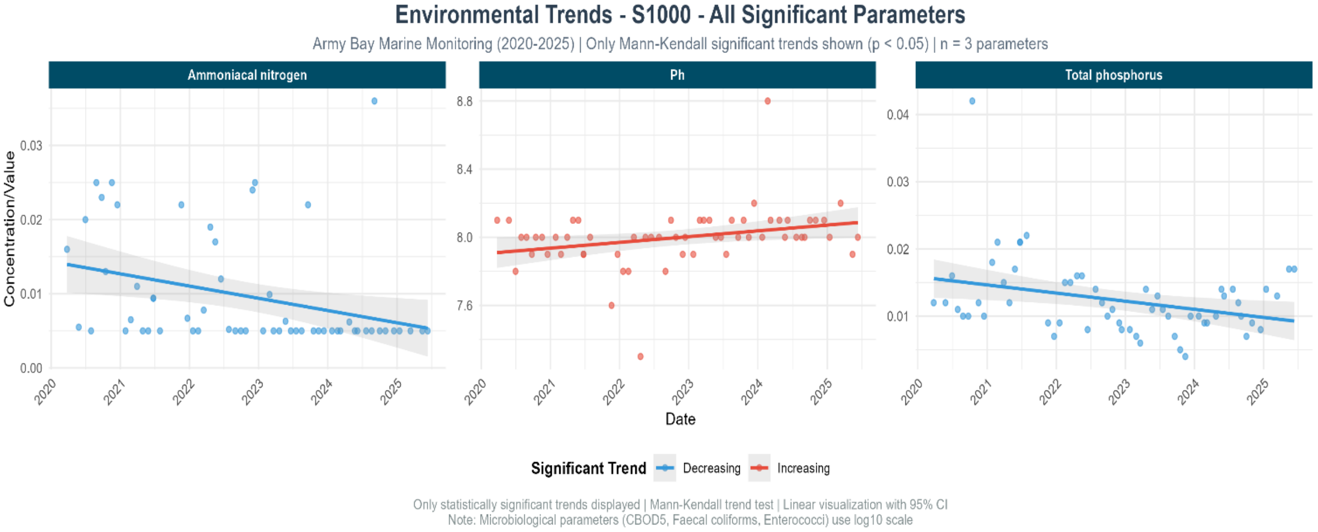
Appendix B. Trend plots

Plots for significant trends in water quality parameters at the outer and reference sites for the 2020-2025 reporting period



Environmental Trends - N1000 - All Significant Parameters

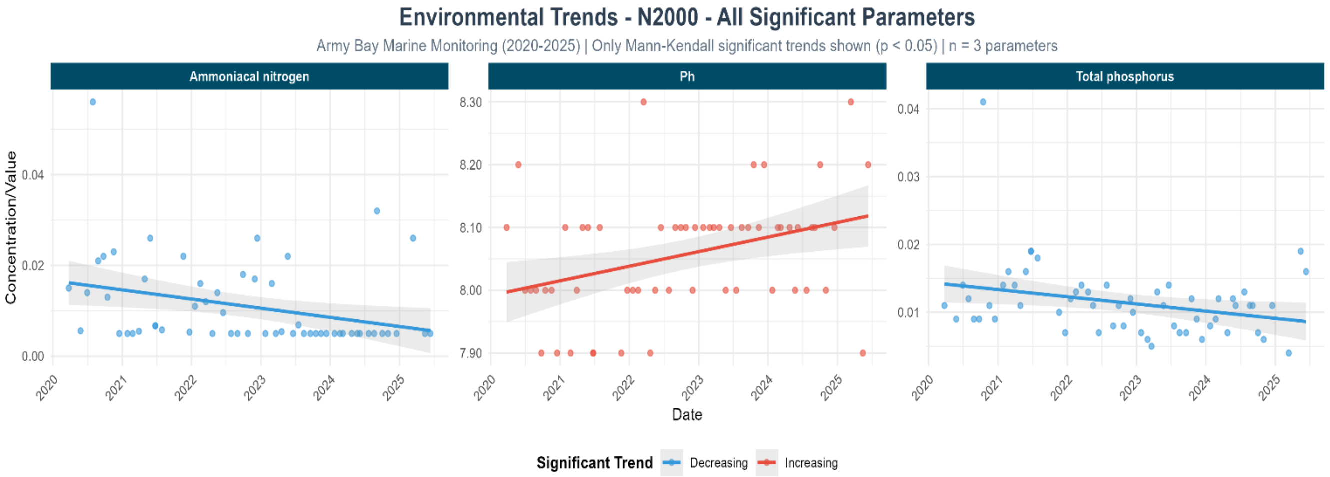
Army Bay Marine Monitoring (2020-2025) | Only Mann-Kendall significant trends shown ($p < 0.05$) | n = 4 parameters



Environmental Trends - S1000 - All Significant Parameters

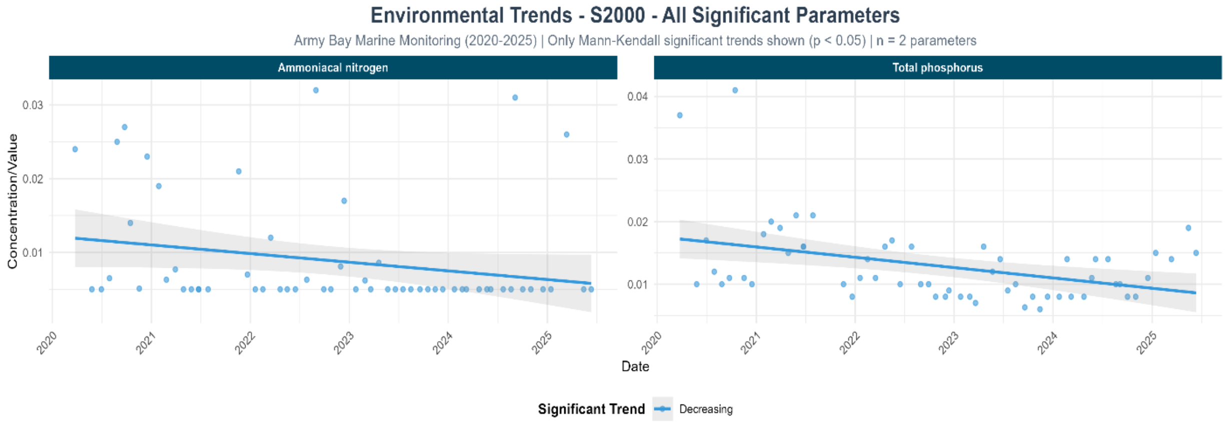
Army Bay Marine Monitoring (2020-2025) | Only Mann-Kendall significant trends shown ($p < 0.05$) | n = 3 parameters

Only statistically significant trends displayed | Mann-Kendall trend test | Linear visualization with 95% CI
Note: Microbiological parameters (CBOD5, Faecal coliforms, Enterococci) use log10 scale



Environmental Trends - N2000 - All Significant Parameters

Army Bay Marine Monitoring (2020-2025) | Only Mann-Kendall significant trends shown ($p < 0.05$) | n = 3 parameters



Environmental Trends - S2000 - All Significant Parameters

Army Bay Marine Monitoring (2020-2025) | Only Mann-Kendall significant trends shown ($p < 0.05$) | n = 2 parameters

Only statistically significant trends displayed | Mann-Kendall trend test | Linear visualization with 95% CI
Note: Microbiological parameters (CBOD5, Faecal coliforms, Enterococci) use log10 scale

Appendix C. Data Sources

Download location of environmental monitoring data used in this report.

Category	Parameter	Source platform	Tag/ID
Treated effluent quality	Physicochemical, nutrients, microbiology, heavy metals	Labware ID	WSL_AB_STP_PUV_EFF_C DTARB-Field Data
Receiving environment water quality	Physicochemical, nutrients, microbiology, heavy metals	Labware	N200, S200, N1000, S1000, N2000, S2000
Shellfish	Metals and microbiology	Labware	Shellfish -1 to Shellfish 5