Sensitivity: General

Ecological and Water Quality Impact Assessment – Raglan Wastewater Discharge Options

Prepared for Watercare Services Ltd

Prepared by Beca Limited

2 September 2020

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Revision History

Revision Nº	Prepared By	Description	Date
1	Sarah Busbridge Gemma Wadworth	Draft for client review	30/06/20
2	Sarah Busbridge Gemma Wadworth	Final	2/09/2020

Document Acceptance

Action	Name	Signed	Date
Prepared by	**Sarah Busbridge** **Gemma Wadworth**		2/09/2020
Reviewed by	**Claire Webb**		2/09/2020
Approved by	**Garrett Hall**		2/09/2020
on behalf of	Beca Limited		

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Executive Summary

Watercare Services Ltd engaged Beca Ltd (Beca) to undertake an Ecological and Water Quality Impact Assessment of various wastewater discharge options in Raglan, Waikato.

Site visits were conducted on the 26th - 27th of May, and 22nd of July 2020 to take water quality measurements, macroinvertebrate samples and perform rapid ecological assessments of stream and riparian habitat. A desk-based review of information held by Waikato Regional Council and NIWA on the ecological values of the sample locations was also undertaken.

Twelve stream reaches were investigated at four sites (two locations at Wainui Stream, five locations at the Raglan Wastewater Treatment Plant (WWTP), one location at Te Aewa stream, and four locations at tributaries running through 15 Te Ahiawa Road to assess their suitability for wastewater discharge via stream recharge.

Based on the results of these investigations, Pond Tributary 2 at the WWTP was identified as the most suitable candidate location, and potential ecological effects were assessed based on the discharge of membrane bioreactor (MBR) treated wastewater in conjunction with ecological restoration at this location.

Potential adverse effects of wastewater discharge at this location include:

- Water quality effects;
- Ecotoxicity effects on aquatic organisms including freshwater fish and macroinvertebrates;
- Stimulatory nutrient-related effects on macrophyte and periphyton growth;
- Potential public health effects in the Whāingaroa Harbour;
- Streambank erosion due to increased flows;
- Temporarily increased sediment inputs.

Enhancement opportunities at this site include riparian restoration, infill and enrichment planting, and stream enhancement measures. Positive ecological effects expected to result from enhancement include:

- Decreased turbidity;
- Shading and temperature regulation of stream channel;
- Increased aquatic habitat heterogeneity;
- Filtration of surface runoff (reducing contaminant load discharge to streams);
- Long term bank stabilisation;
- Improved terrestrial habitat values for native fauna.

It is recommended that further investigations are undertaken to determine the magnitude of ecological and public health effects prior to confirming the site as the potential discharge location for treated wastewater. Recommended actions include:

- Fish surveys at the discharge location and various points between the discharge site and the harbour;
- Assessment of potential inanga spawning habitat at the Raglan WWTP;
- Stream flow assessment to enable determination of potential contaminant dilution;
- Further water quality monitoring to enable assessment of baseline conditions, including seasonal variability;
- Hydrodynamic modelling to understand potential dilution and effects of total nitrogen in the harbour, understood to be currently undertaken by DHI;
- Quantitative Microbial Risk Assessment (QMRA) to assess risk with respect to contact recreation and shellfish gathering at selected sites within the Wainui Inlet arm of the Whāingaroa Harbour.

1 Introduction

Wastewater in Raglan is collected and conveyed to the Raglan Wastewater Treatment Plant (WWTP) which is located to the south west of Raglan and operated by Waikato District Council (WDC). The current discharge point for treated wastewater from the WWTP is at the mouth of the Whāingaroa Harbour. This is a cause of concern for hapū and the local community.

The Raglan WWTP discharge consent expired in February 2020 and a short term (3 year) consent has been lodged with the Waikato Regional Council (WRC) to retain the status quo for discharge while long-term options are assessed. A list of potential treatment/discharge options was developed by Beca/WDC in 2019 and this options assessment is currently continuing.

One alternative wastewater discharge option, which was proposed for further investigation during the assessment of long-list options, is to upgrade the WWTP to a very high standard via the construction of a new membrane bioreactor (MBR) WWTP and to discharge a high quality tertiary treated wastewater to a local stream reach that has undergone ecological restoration.

Watercare Services Limited (Watercare) have engaged Beca Ltd (Beca) to further investigate the ecological and water quality constraints and benefits of this option. Locations near the WWTP potentially suitable for stream recharge with treated wastewater are identified in the report “Raglan Wastewater Treatment Plant Stream Recharge Concept”, prepared by Beca, dated 1 September 2020.

The objectives of the stream recharge option are to:

- Provide additional high-quality treated wastewater water flow into a local stream to enhance the ecosystem;
- Reduce adverse environmental effects from existing rural discharges near the WWTP;
- Avoid adverse effects on stream banks and ecosystems; and
- Provide long-term sustainable wastewater treatment and discharge.

1.1 Purpose and Scope

The purpose of this report is to identify potential ecological and water quality effects due to the discharge of treated wastewater to various streams reaches in the area surrounding the Raglan WWTP, and to assess opportunities for ecological enhancement at the same locations.

The scope of this assessment includes:

- Site walkovers conducted on the 26th - 27th of May 2020, and 22nd of July 2020 to take water quality measurements, macroinvertebrate samples and perform rapid habitat assessments of stream and riparian vegetation habitat at possible discharge sites;
- A desk-based review of the ecological values of the various stream reaches based on existing ecological information;
- An assessment of the ecological values of the sampled stream reaches;
- Recommendations on opportunities for ecological enhancement to address residual effects of the treated wastewater discharge; and
- An assessment of the potential ecological and water quality effects of the potential discharge of MBR treated wastewater.

This report has been prepared in general accordance with the EIANZ Ecological Impact Assessment Guidelines (Roper-Lindsay et al., 2018)

2 Site Description

Twelve stream reaches were investigated across four sites (Wainui Stream, Raglan WWTP, Te Aewa Stream, and 15 Te Ahiawa Road) to assess their suitability for stream recharge. All four sites are located in Raglan, which is part of the Whāingaroa catchment that drains into the Whāingaroa Harbour (Fig. 1). The greater Whāingaroa catchment covers 52,595ha of land. The area has an inherently unstable geology and many of the steep slopes are prone to erosion. Low-lying land in the catchment has been largely cleared of indigenous vegetation and developed for agriculture over the past 150 years (Environment Waikato, 2002). The cumulative effects of naturally unstable soils, and extensive farming results in many rivers in the catchment carrying high silt loads after high rainfall events and harmful bacteria (Environment Waikato, 2002). Whāingaroa Harbour is 'strongly flushed' which means that most of the water that comes into the harbour from the rivers goes out to sea in one tidal cycle. This means that sediment and bacteria are mostly taken out to sea. Nevertheless, when sediment loads are high some of it is deposited in the harbour (Environment Waikato, 2002).

Stream reaches assessed include two sites located along the downstream section of the Wainui Stream just past the confluence of Wainui Stream and Te Aewa Stream, five locations along the various watercourses that run past the Raglan WWTP and feed into the Wainui Stream, one location along the downstream reach of Te Aewa Stream, and four locations along tributaries of Te Aewa Stream that run through 15 Te Ahiawa Road (see Fig. 2 for locations). The Wainui Stream runs from the forested slopes of Karioi, through predominantly rural land to Whāingaroa Harbour. The downstream section of the stream is low gradient and relatively open, with riparian vegetation consisting of planted riparian species. Watercourses at the WWTP are un-named, low-order, low gradient streams surrounded by pastoral land use and recently planted (2007-2008) riparian scrub species. Small unnamed watercourses that run through 15 Te Ahiawa Road (pastoral land use) discharge into the downstream section of Te Aewa Stream, which in turn discharges into the Wainui Stream.

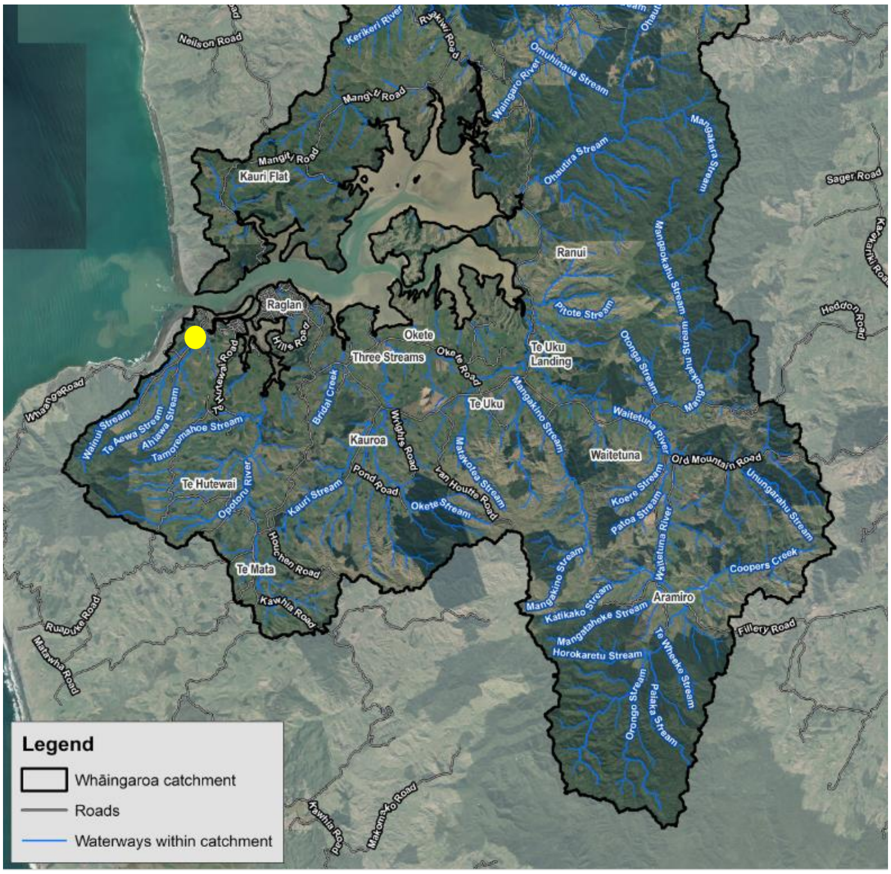

Figure 1 The Whāingaroa catchment (Source: Waikato District Council). Yellow point indicates the WWTP.

2.1 Proposed Activities

The Raglan population is expected to increase from 4,126 (2018) to 7,345 in 2055 as a result of anticipated development. Associated average daily wastewater flows are estimated to increase from 1,175 m^3/day to 2,335 m^3/day for the same time frame.

To treat the anticipated wastewater flows and discharge to a stream, a high level of treatment is assumed to be required. A membrane bioreactor (MBR) process with ultraviolet (UV) disinfection and alum dosing has been selected to achieve a high-quality treated wastewater with low nutrient and pathogen concentrations. The expected 90^{th} percentile treated wastewater quality is outlined in Table 1.

Table 1. Expected Treated Wastewater Quality (90 percentile)

TSS	$cBOD_5$	NH_4-N	TN	TP	E Coli	Virus
<5 mg/L	<5 mg/L	<1 mg/L	<8 mg/L	<1 mg/L	<10 no./100ml	4 log removal

A new inlet works would be required to protect the membranes from larger solids. One of the existing ponds would be reused as a wet weather buffer pond and the MBR sizing limited to 3,000 m^3/day. Wastewater would be pumped back to the MBR after a storm event.

A potential discharge method is via a rock gabion wall to distribute the flow along a length of the stream to create a diffuse discharge. Potential discharge locations are discussed in the below sections. The preferred discharge location and potential discharge option is discussed in Section 7.

3 Methods

3.1 Desktop Review

A desk based study was undertaken that sourced ecological information from the following sources:

- New Zealand Freshwater Fish Database (NZFFD, administered by NIWA);
- Waikato Regional Council biological and water quality monitoring records from Wainui Stream (2015-2019) and Whāingaroa Harbour (2012-2018); and
- Other publicly accessible reports or information.

Key findings of a previous baseline ecological and water quality assessment undertaken by Beca are also incorporated in this report. The purpose of the baseline assessment was to provide an initial indication of water quality and habitat values of streams located adjacent to the WWTP. Water quality sampling and habitat assessments were undertaken in September 2019 and reported on in 'Raglan Wastewater Treatment Plant – Water Quality and Ecology Baseline Assessment', prepared by Beca, dated 1 November 2019.

3.2 Site Visit

Site visits were undertaken to conduct habitat assessment, water quality field measurements, water quality and macroinvertebrate sampling at five WWTP sites, two Wainui stream sites, one Te Aewa stream site, and four sites along unnamed watercourses at 15 Te Ahiawa Road (shown in Fig. 2) to provide a high-level indication of baseline stream conditions and assess the potential effects of MBR treated wastewater discharge on downstream ecology and water quality.

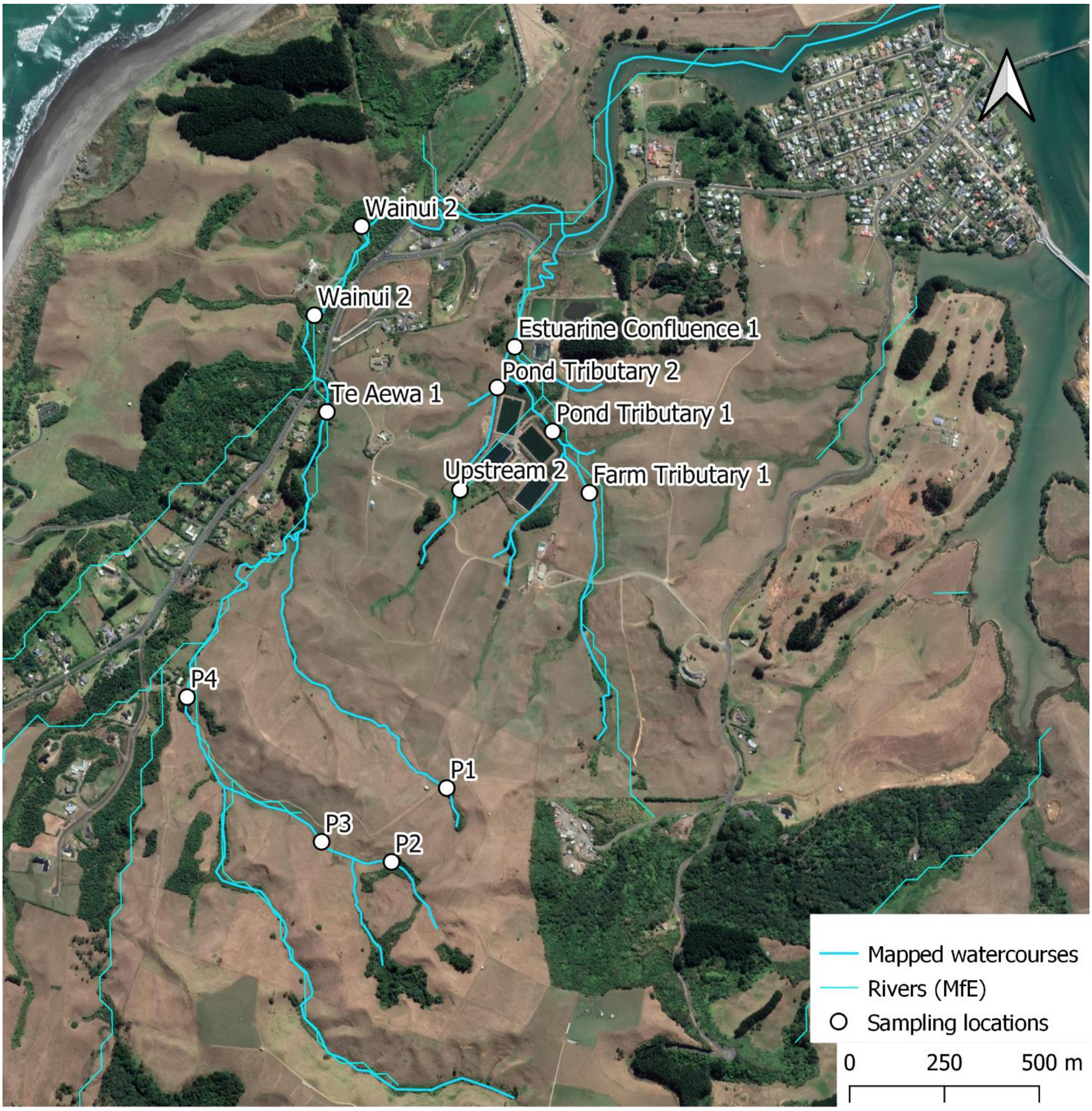

Figure 2. Sample locations at Raglan WWTP,Wainui stream, Te Aewa stream, and Te Ahiawa Road (P1 - P4).

3.2.1 Habitat Assessments

Watercourse assessments were completed on 26th and 27th of May 2020, and 22nd July following methods outlined in the Watercourse Assessment Methodology: Infrastructure and Ecology Document (Version 2.0) at each sampling location to assess the baseline condition of the existing watercourses (Lowe, Ingley, & Young, 2016). Data collected included: channel condition and morphology, bank and channel modification, stream bank erosion, debris jams, streambed substrate composition, channel shade and riparian vegetation.

Rapid habitat assessments were also completed at each site following Rapid Ecological Assessment methodology to capture the species composition and ecological value of riparian vegetation.

3.2.2 Water Quality Measurements

Field water quality measurements were recorded for pH, dissolved oxygen (DO), temperature and conductivity using a hand-held meter (YSI ProPlus during May visits and YSI ProDSS on July 22nd) at sample locations marked in Figure 2 (excluding P1 which was dry at the time of the site visit). Grab water samples were also collected from each of the locations, chilled, and delivered to R J Hill Laboratories Ltd (Hill Laboratories) at the end of each day for analysis of:

- Total Nitrogen;
- Total Ammoniacal Nitrogen;
- Nitrite-N;
- Nitrate-N;
- Nitrate-N + Nitrite N;
- Dissolved Reactive Phosphorus;
- Total Phosphorus; and
- E.coli.

3.2.3 Macroinvertebrate Sampling

Macroinvertebrate samples were collected sampling locations from the stream substrate and streambank vegetation using a kicknet (Macroinvertebrate samples were not taken from P1 which was dry at the time of the site visit, and P4 and Te Aewa 1 which were fast flowing due to recent heavy rainfall, making them unsuitable for sampling). Samples were preserved in ethanol and analysed by EIA Ltd for Macroinvertebrate Community Index (MCI) and Semi-Quantitative Macroinvertebrate Community Index (SQMCI). Both indices are used to measure stream health and organic enrichment. MCI is a presence-absence based index while the SQMCI uses a five-point scale of coded abundances (i.e. rare, common, abundant, very abundant, very very abundant) (Stark & Maxted, 2007). Higher MCI and SQMCI scores indicate high habitat and water quality. Consistent with best practice, the soft-bottomed version of the SQMCI (SQMCI-sb) was used for WWTP watercourses which had silt/mud substrates unlike the hard-bottomed Wainui stream. The percentage of EPT (*Ephemeroptera, Plecoptera* and *Trichoptera*) taxa were also calculated for each sample location. EPT taxa are highly sensitive to environmental perturbations, and samples with higher numbers of these taxa indicate high environmental quality.

3.3 Water Quality Effects Assessment

3.3.1 Adopted Guideline Values

Recognised water quality guidelines are adopted to provide an indication of whether contaminant concentrations in samples collected from possible receiving environment locations have potential to cause an adverse effect with respect to water quality and the health of aquatic organisms. The Waikato Regional Council (WRC) water quality guidelines are based on national standards and guidelines and are presented Table 2. Values from the National Policy Statement for Freshwater Management 2014 Appendix 2 Attribute States were also used (NPS-FM - amended 2017) and are presented in Table 3. Additionally, the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2018) 80th percentile default guideline values of 115 µs/cm for conductivity and 0.014 g/m^3 for filterable reactive phosphorus have been adopted. Water quality results are compared to the adopted guideline values in Section 4.

Table 2. Waikato Regional Council water quality guidelines

Water quality variable	WRC Categories		
	Excellent	Satisfactory	Unsatisfactory
Dissolved oxygen (% of saturation)	>90	80 – 90	<80
pH (acidity)	7 – 8	6.5 – 7 or 8 – 9	<6.5 or >9

Water quality variable	WRC Categories		
	Excellent	Satisfactory	Unsatisfactory
Turbidity (NTU)	<2	2 – 5	>5
Total ammonia (g NH_4-N/m^3)	<0.1	0.1 – 0.88	>0.88
Temperature (^oC)	<10	10 – 12	>12
	<16	16 – 20	>20
Total phosphorus (g/m^3)	<0.01	0.01 – 0.04	>0.04
Total nitrogen (g/m^3)	<0.1	0.1 – 0.5	>0.5
Baseflow water clarity (m)	>4	1.6 - 4	<1.6
Escherichia coli, single sample (no./100mL)	<55	55 - 550	>550

Table 3. Adopted NPS-FM Attribute States

Water quality variable	NPS-FM Attribute State		
	A	B	C
Dissolved Oxygen (g/m^3)[1]	≥8.0	≥7.0 and <8.0	≥5.0[2] and <7.0
Nitrate (g NO_3-N/m^3)	≤1.0	>1.0 and ≤2.4	>2.4 and ≤6.9[3]

[1]7-day mean minimum (Summer Period: 1 November to 30th April).

[2] 5.0 g/m^3 is the NPS-FM national bottom line for Dissolved Oxygen (7-day mean minimum).

[3] 6.9 g/m^3 is the NPS-FM national bottom line for nitrate (annual median).

3.4 Ecological Effects Assessment

Based on the results of ecological surveys and proximity to the WWTP, Pond Tributary 2 was identified as the most suitable candidate location for the discharge of MBR treated wastewater. Therefore, although the ecological values of all sampling locations are described, the potential ecological effects were assessed based on the discharge of treated wastewater at only this location.

The assessment of ecological effects was undertaken in accordance with the Ecological Impact Assessment. EIANZ guidelines for use in New Zealand: terrestrial and freshwater ecosystems, 2nd edition (Roper-Lindsay et al., 2018).

4 Water Quality Results

A results summary for the stream sites sampled at the Raglan WWTP, Wainui Stream and 15 Te Ahiawa Road / Te Aewa Stream are presented in Table 4,Table 5 and Table 6, respectively. The results are discussed in the subsequent sections and compared where relevant to results obtained during water quality sampling undertaken by Beca in September 2019 (which were reported on in the water quality and ecology baseline assessment report)[1].

Table 4. Results of water quality sampling in watercourses adjacent to the Raglan WWTP.

	Pond Trib 1	Upstream 2	Pond Trib 2	Farm Trib	Estuarine Confl.	Guideline Values[2]
Field Measurements						
Temperature (°C)	**13.1**	**13.9**	**14.2**	**15.8**	**14.0**	**<10 Excellent; 10–12 Satisfactory; >12 Unsatisfactory**
Dissolved Oxygen (g/m^3)	7.4	7.5	**5.4**	**6.1**	8.4	**>7.0[4]**
Dissolved Oxygen (%)	**77.8**	**64.2**	**52.7**	**62.0**	81.0	**>90 Excellent; 80–90 Satisfactory; <80 Unsatisfactory**
Specific Conductivity (µs/cm)	**392**	**622**	**265**	**398**	**403**	**<115[3]**
pH	6.34	6.72	5.76	6.56	5.35	**7-8 Excellent; 6.5-7 or 8-9 Satisfactory; <6.5 or >9 Unsatisfactory**
Laboratory Analysis[1]						
Total Nitrogen	**0.54**	0.20	**1.21**	0.39	**0.56**	**<0.1 Excellent; 0.1–0.5 Satisfactory; >0.5 Unsatisfactory**
Total Ammoniacal-N	<0.010	<0.010	0.119	0.013	0.022	**<0.1 Excellent; 0.1–0.88 Satisfactory; >0.88 Unsatisfactory**
Nitrite-N	0.002	<0.002	<0.002	<0.002	0.003	**-**
Nitrate-N	0.30	0.095	0.018	0.21	0.34	**≤ 2.4[4]**
Nitrate-N + Nitrite-N	0.30	0.096	0.018	0.21	0.34	**-**
Dissolved Reactive Phosphorus	<0.004	<0.004	<0.004	<0.004	<0.004	**<0.014[3]**
Total Phosphorus	0.01	**0.06**	**0.12**	0.01	**0.137**	**<0.01 Excellent; 0.01–0.04 Satisfactory; >0.04 Unsatisfactory**
Escherichia coli (MPN/100mL)	225	111	**>2,420**	435	219	**<55 Excellent; 55–550 Satisfactory; >550 Unsatisfactory**

Results in **Bold** denote exceedance of the WRS satisfactory guideline or other adopted guideline

[1]all units below are in g/m^3 unless otherwise specified

[2]Guideline values are from WRC (https://www.waikatoregion.govt.nz/Environment/Natural-

[1] Beca Ltd. Raglan Wastewater Treatment Plan – Water Quality and Ecology Baseline Assessment, 1 November 2019.

resources/Water/Rivers/healthyrivers/How-we-measure-quality/) unless otherwise noted

[3]Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2018) using the 80th percentile for warm-wet, low elevation

[4]National Policy Statement for Freshwater Management 2014 (amended 2017) Appendix 2 Attribute State B value

Table 5. Results of water quality sampling for the Wainui Stream.

	Wainui 1	Wainui 2	Guideline Values[2]
Temperature (°C)	**12.5**	**12.5**	**<10 Excellent; 10–12 Satisfactory; >12 Unsatisfactory**
Dissolved Oxygen (g/m^3)	11.5	10.4	**>7.0[4]**
Dissolved Oxygen (%)	108.0	94.9	**>90 Excellent; 80–90 Satisfactory; <80 Unsatisfactory**
Specific Conductivity (µs/cm)	**175.1**	**177.0**	**<115[3]**
pH	6.67	6.80	**7-8 Excellent; 6.5-7 or 8-9 Satisfactory; <6.5 or >9 Unsatisfactory**
Laboratory Analysis[1]			
Total Nitrogen	0.27	0.3	**<0.1 Excellent; 0.1–0.5 Satisfactory; >0.5 Unsatisfactory**
Total Ammoniacal-N	<0.010	<0.010	**<0.1 Excellent; 0.1–0.88 Satisfactory; >0.88 Unsatisfactory**
Nitrite-N	<0.002	<0.002	**-**
Nitrate-N	0.192	0.183	**≤ 2.4[4]**
Nitrate-N + Nitrite-N	0.193	0.184	**-**
Dissolved Reactive Phosphorus	0.005	0.005	**<0.014[3]**
Total Phosphorus	0.014	0.013	**<0.01 Excellent; 0.01–0.04 Satisfactory; >0.04 Unsatisfactory**
Escherichia coli (MPN/100mL)	225	249	**<55 Excellent; 55–550 Satisfactory; >550 Unsatisfactory**

Results in Bold denote exceedance of the WRC satisfactory guideline or other adopted guideline

[1]all units below are in g/m3 unless otherwise specified

[2]Guideline values are from WRC (https://www.waikatoregion.govt.nz/Environment/Natural-resources/Water/Rivers/healthyrivers/How-we-measure-quality/) unless otherwise noted

[3]Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2018) using the 80th percentile for warm-wet, low elevation

[4]National Policy Statement for Freshwater Management 2014 (amended 2017) Appendix 2 Attribute State B value

Table 6. Results of water quality sampling for the Te Aewa Stream and Tributaries.

	P 2	P 3	P 4	Te Aewa 1	Guideline Values[2]
Temperature (°C)	**12.3**	12.0	11.5	11.5	**<10 Excellent; 10–12 Satisfactory; >12 Unsatisfactory**
Dissolved Oxygen (g/m^3)	10.41	9.69	**6.46**	10.57	**>7.0[4]**
Dissolved Oxygen (%)	97.3	90.0	**60.0**	97.0	**>90 Excellent; 80–90 Satisfactory; <80 Unsatisfactory**
Specific Conductivity (µs/cm)	**229.2**	**191.8**	103.2	**159.9**	**<115[3]**
pH	7.71	6.75	**6.47**	7.24	**7-8 Excellent; 6.5-7 or 8-9 Satisfactory; <6.5 or >9 Unsatisfactory**
Turbidity (FNU)	16.15	25.30	245.20	34.17	**<2 Excellent; 2 – 5 Satisfactory; >5 Unsatisfactory**
Laboratory Analysis					
Total Nitrogen	**1.18**	**1.03**	**3.6**	**1.16**	**<0.1 Excellent; 0.1–0.5 Satisfactory; >0.5 Unsatisfactory**
Total Ammoniacal-N	<0.010	0.029	0.161	0.025	**<0.1 Excellent; 0.1–0.88 Satisfactory; >0.88 Unsatisfactory**
Nitrite-N	<0.002	<0.002	0.004	0.002	**-**
Nitrate-N	0.96	0.70	1.40	0.65	**≤ 2.4[4]**
Nitrate-N + Nitrite-N	0.96	0.70	1.40	0.65	**-**
Dissolved Reactive Phosphorus	0.020	<0.004	0.005	0.008	**<0.014[3]**
Total Phosphorus	**0.070**	**0.070**	**0.62**	**0.102**	**<0.01 Excellent; 0.01–0.04 Satisfactory; >0.04 Unsatisfactory**
Escherichia coli (MPN/100mL)	211	538	**19,860**	**5,480**	**<55 Excellent; 55–550 Satisfactory; >550 Unsatisfactory**

Results in Bold denote exceedance of the WRC satisfactory guideline or other adopted guideline

[1]all units below are in g/m3 unless otherwise specified

[2]Guideline values are from WRC (https://www.waikatoregion.govt.nz/Environment/Natural-resources/Water/Rivers/healthyrivers/How-we-measure-quality/) unless otherwise noted

[3]Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2018) using the 80th percentile for warm-wet, low elevation

[4]National Policy Statement for Freshwater Management 2014 (amended 2017) Appendix 2 Attribute State B value

4.1 WWTP Watercourses

4.1.1 Nitrogen Species

As was reported in the Water Quality and Ecology baseline assessment undertaken by Beca in September 2019 (Beca Ltd, 2019), elevated concentrations of Total nitrogen (TN) are typical of waterways around Waikato and are not unexpected at the WWTP watercourses given the surrounding pastoral land use and waterfowl roosting along the banks of the watercourses. However, not all sampling locations exceeded the WRC satisfactory guideline for TN in the May 2020 sampling event as they did in September 2019.

The TN concentration of 1.21 g/m^3 at Pond Trib 2 was higher than all other sites at the WWTP, including the upstream sampling location 'Upstream 2' where the TN concentration was 0.20 g/m^3. However, this differs to the September 2019 sampling round where TN was 1.19 g/m^3 at both Pond Trib 2 and Upstream 2. Oxidised nitrogen generally made up a higher proportion of TN in the September 2019 WWTP samples (64% to 84%) compared to May 2020 (approximately 1.5% at Pond Trib 2 to 62% at Estuarine confluence). Oxidised nitrogen was predominantly in the form of nitrate as opposed to nitrite.

The nitrate concentration of 0.018 g/m^3 at Pond Trib 2 was lower than the concentrations of the other sites, including the Upstream 2 site, though the nitrate concentration at Upstream 2 was still of a similar order of magnitude at 0.095 g/m^3. Concentrations at both these locations fall within the NPS-FM attribute state A for nitrate (<1.0 g/m^3).

The highest nitrate concentration from the May 2020 sampling round was at the Estuarine Confluence site (0.34 g/m^3). Nitrate concentrations from tributaries on the eastern side of the WWTP appear to have influenced this concentration as opposed to the western watercourse (nitrate concentrations at Farm Trib 1 and Pond Trib 1 were 0.21 g/m^3 and 0.30 g/m^3, respectively). Concentrations at these sites also fall within the NPS-FM attribute state A, as they did during the September 2019 sampling round.

The Pond Trib 2 total ammoniacal-nitrogen (NH_4-N) concentration of 0.119 g/m^3 was higher than all other WWTP sites, however, falls within the WRC satisfactory guideline category of 0.1 – 0.88 g/m^3. The NH_4-N concentrations of all other sites, including the Estuarine Confluence site downstream of Pond Trib 2, were within the WRC 'excellent' guideline category (<0.1 g/m^3). For the September sampling round, NH_4-N concentrations for all sites, including Pond Trib 2, were within the WRC 'excellent' guideline category (<0.1 g/m^3).

4.1.2 Phosphorus Species

The WRC satisfactory guideline value for Total Phosphorus (TP) of 0.04 g/m^3 was exceeded at Pond Trib 2 and Estuarine confluence where concentrations were 0.12 and 0.137 g/m^3, respectively. The TP concentration at Upstream 2 of 0.06 g/m^3 was also above the Satisfactory guideline but lower than the downstream locations. Total phosphorus concentrations at Farm Trib and Pond Trib 1 were both 0.01 g/m^3 and were within the WRC Satisfactory guideline category. Elevated TP concentrations at Pond Trib 2 and consequently, the downstream Estuarine Confluence location is likely due to the pastoral land directly adjacent to the Pond Trib 2 location and waterfowl faeces which was abundant at the site. The TP concentration at Pond Trib 2 was also above the WRC Satisfactory guideline in September 2019 as was the sample collected from Upstream 1. Upstream 1 was not able to be sampled in May 2020 as that reach of watercourse was dry. Total phosphorus concentrations at all other locations were below the WRC satisfactory guideline in September 2019 (Estuarine Confluence was not sampled in September 2019).

Dissolved reactive phosphorus was below the laboratory limit of detection in all samples collected in May 2020 at the WWTP watercourses (<0.004 g/m^3).

4.1.3 Microbiological Indicators

E. coli concentrations at Pond Trib 2 were elevated (>2,420 MPN/ 100 mL), similarly to. the September 2019 sample collected from Pond Trib 2 which had a concentration of 1,600 MPN/100 mL.

E. coli concentrations at the other WWTP watercourse locations were below the WRC satisfactory guideline value (550 MPN/100 mL).

4.1.4 Other Water Quality Parameters

Temperature and dissolved oxygen (DO) experience diurnal and seasonal fluctuations. A greater variability in temperature between sites was observed in May 2020 at the time of sampling (13.1 – 15.8°C) compared to September 2019 (14.3 – 14.9°C). On both occasions, temperatures were relatively warm creating unsatisfactory conditions for fish spawning. The WRC Satisfactory guideline category of 10 – 12°C is for fish spawning from May to September, when it is expected that temperatures would decrease compared to the May 2020 measurements over the subsequent winter months. Measured temperatures were low enough to maintain habitat quality for tolerant native fish species. As discussed in the Water Quality and Ecology Baseline assessment (Beca Ltd, 2019), it remains that the minimal riparian habitat of the stream reaches near the WWTP could result in temperatures that exceed thermal tolerances during the summer months, especially where channel depths are shallower.

Dissolved oxygen levels were generally lower than those measured in September 2019 and were below the WRC Satisfactory guideline of 80% at all locations except for the Estuarine Confluence. Concentrations were within Attribute State B of the NPS-FM for 7-day mean during the summer period at Pond Trib 1, Upstream 2 and Estuarine Confluence. Concentrations at Farm Trib 1 and Pond Trib 2 were within Attribute State C. During summer, DO diurnal fluctuations would be expected to be greater due to anticipated macrophyte growth and temperature changes.

4.2 Wainui Stream

Overall, water quality was better at the Wainui Stream locations compared to the WWTP adjacent watercourses. Water quality parameters analysed were similar at both sampling locations and either within excellent or satisfactory WRC guideline categories, or the NPS-FM attribute state A concentration range where applicable. Though the Wainui Stream runs through rural land use, riparian restoration planting in the catchment likely contributes to reduced contaminant loading and consequential good water quality compared to the WWTP watercourses which run directly adjacent to grazed pasture.

4.2.1 Nitrogen Species

Total nitrogen concentrations at both Wainui Stream sites were 0.27 and 0.30 g/m^3, respectively, and within the WRC satisfactory guideline category of 0.1 - 0.5 g/m^3. Total ammoniacal-nitrogen concentrations were both below the laboratory limit of detection (<0.010 g/m^3) so were within the WRC Excellent guideline category and fall within the NPS-FM attribute state A. Water quality was also good in terms of nitrate concentrations as the concentrations at Wainui 1 and Wainui 2 were 0.192 and 0.183 g/m^3, respectively, and are also within the NPS-FM attribute state A (<1.0 g/m^3).

4.2.2 Phosphorus Species

Total Phosphorus concentrations at Wainui 1 and Wainui 2 were 0.014 and 0.013 g/m^3, respectively, and within the WRC Satisfactory guideline category. Dissolved reactive phosphorus concentrations at both locations were 0.005 g/m^3 and below the adopted water quality guideline.

4.2.3 Microbiological Indicator

E. coli concentrations were also similar between sites, 225 and 249 MPN/100 mL, respectively, and within the WRC Satisfactory guideline category (55 – 550 MPN/100 mL).

4.2.4 Other Water Quality Parameters

Dissolved oxygen concentrations at both locations were within the WRC excellent guideline category, >90%, and therefore DO levels were likely to cause little to no stress on aquatic organisms at the time of sampling. As for the WWTP watercourses, during summer, DO diurnal fluctuations would be expected to be greater due to anticipated macrophyte growth and temperature changes.

Temperatures measured at both Wainui Stream locations were 12.5°C and therefore on the cusp of the satisfactory temperature range for fish spawning of 10 – 12°C (May – September) based on WRC guidelines.

4.3 Te Aewa Stream and Tributaries

Water quality of the 15 Te Ahiawa Road tributaries and the Te Aewa Stream was likely to be impacted by heavy rainfall occurring at the time of sampling and during the 24 hours prior. Consequently, the tributary of the Te Aewa Stream at the bottom of the 15 Te Ahiawa Road property was running very turbid, as was the reach of the Te Aewa Stream sampled from. Nutrients and E. coli were generally elevated at these noticeably turbid locations compared to the upper tributaries.

4.3.1 Nitrogen Species

Total nitrogen concentrations at all locations were an order of magnitude above the WRC satisfactory guideline category of 0.1 - 0.5 g/m^3, the highest concentration of 3.6 g/m^3 occurring at P4.

The total ammoniacal-nitrogen concentration at P2 was below the laboratory limit of detection (<0.010 g/m^3) and 0.029 g/m^3 at P3, both concentrations within the WRC Excellent guideline category and falling within the NPS-FM attribute state A. Nitrate concentrations were also within the NPS-FM attribute A band at P2 and P3, despite the heavy rainfall (0.96 and 0.71 g/m^3, respectively).

The nitrate concentration at P4 was comparatively elevated at 1.40 g/m^3, which is within the NPS-FM attribute state B (>1.0 - ≤ 2.4 g/m^3) but decreased downstream of the confluence with the Te Aewa Stream (at Te Aewa 1) to 0.65 g/m^3.

4.3.2 Phosphorus Species

Total Phosphorus concentrations at P2 and P3 were both 0.070 g/m^3, which is above the WRC Satisfactory guideline category. Downstream of these tributaries at P4 the total Phosphorus concentration was further elevated at 0.62 g/m^3.. Total phosphorus in the Te Aewa stream, downstream of the confluence with P4, remained above the WRC Satisfactory guideline category with a concentration of 0.102 g/m^3.

Dissolved reactive phosphorus concentrations at all locations were below the adopted 80th percentile Australian and New Zealand Guideline for Fresh and Marine Water (<0.014 g/m^3), except P2 where the concentration was 0.020 g/m^3.

4.3.3 Microbiological Indicator

The *E.coli* concentration at P2 was 211 MPN/ 100 mL (within the WRC Satisfactory category). The relatively low concentration is likely a result of good riparian planting adjacent to and upstream of the sampling location. Downstream at P3 the *E.coli* concentration was comparatively elevated but still within the WRC satisfactory category 538 MPN/ 100 mL.

At P4, the *E. coli* concentration was well above the WRC Satisfactory guideline at 19,860 MPN/ 100 mL. This location is most likely to have been impacted by increased runoff due to the heavy the rainfall.

At Te Aewa 1, the *E.coli* concentration remained elevated with a concentration of 5,480 MPN/100 mL, diluted by the main stem of the Te Aewa stream downstream of the confluence with the P4.

4.3.4 Other Water Quality Parameters

Dissolved oxygen concentrations were within the WRC excellent guideline category of >90% at all locations except for P4. Temperatures measured at the sampling locations ranged from 11.5 – 12.3 °C indicating that the streams can provide a suitable temperature range for fish spawning (the WRC satisfactory temperature range for fish spawning is 10 – 12°C).

Turbidity was above the WRC satisfactory guideline of 5 NTU at every location and was particularly elevated at P4 (245 FNU), which is not surprising based on visual observations of the site and heavy rainfall. The measurement of FNU signifies that the turbidity instrument measures scattered light at a 90 degree angle from the sample, as is the case for an instrument with the measurement unit NTU. However, the wavelength of light used is different between the instruments, and therefore measurements in FNU and NTU are not always directly comparable depending on sediment type. The measurements obtained however are substantially above that the WRC satisfactory guideline such that the streams can be considered to have had elevated turbidity. Total suspended solids were similarly elevated at P4 with a concentration of 310 g/m^3.

5 Ecological Values

5.1 Raglan WWTP

Bird surveys were not completed as part of the site visit, but kōtare (*Todiramphus sanctus*), dabchick (*Poliocephalus rufopectus;* At-Risk Recovering), fantail (*Rhipidura fuliginosa*) and pukeko (*Porphyrio melanotus*) were observed on site. A rabbit was also observed near Pond Tributary 2. No fish records were available for the site on the New Zealand Freshwater Fish Database (NZFFD) (Crow, 2017), however, an area of potential inanga spawning habitat was identified to the east of estuarine confluence 1 (Fig. 3). This area includes low gradient bank slopes with dense overgrown pasture grasses in close proximity to the marine environment.

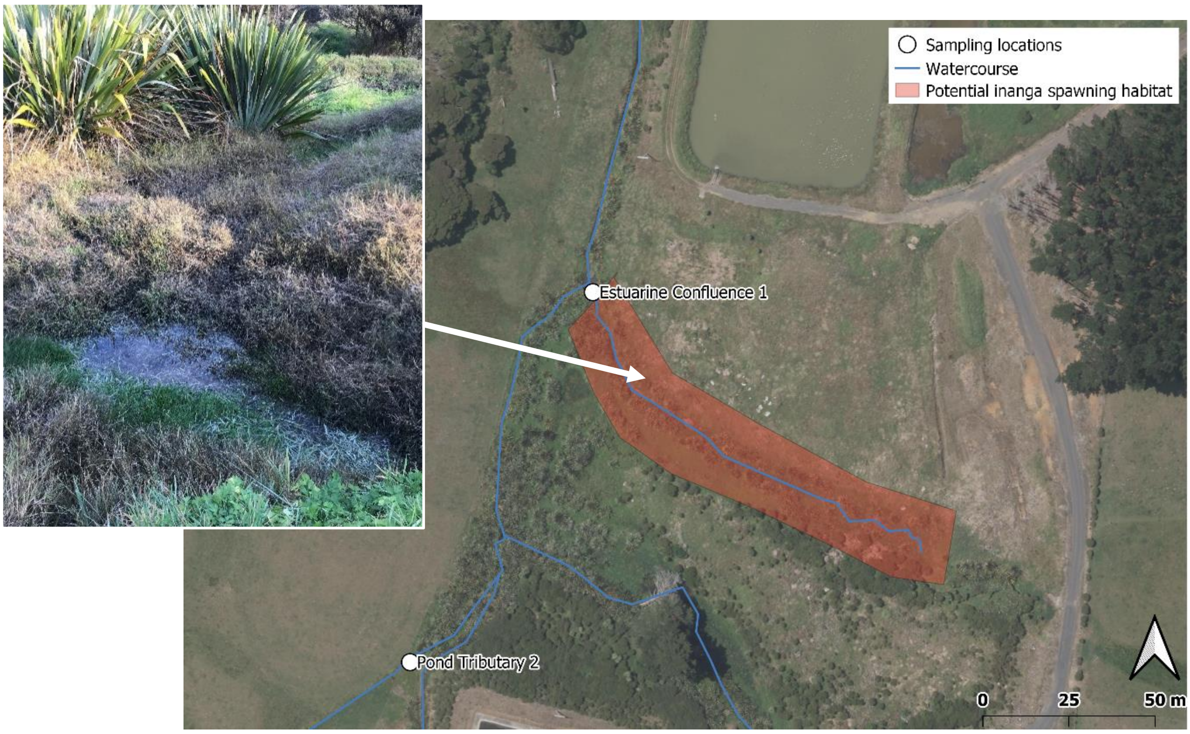

Figure 3. Potential inanga spawning habitat at the WWTP.

5.1.1 Raglan WWTP – Pond Tributary 1

The subject reach is a permanent stream that runs from grazed pasture to the east of the WWTP (see Fig. 4) through a restoration planting on the WWTP property. The stream has a wetted channel width ranging from 0.5m – 2m. Stream depth ranges from 0.2m – 0.6m and bank height from 0.45m – 1m. The bank has a low gradient (<30°) and no signs of erosion or mass wasting. The substrate consists of silt and mud.

There is a large amount of emergent and free-floating macrophyte growth along the subject reach including duckweed (*Lemna minor*) and mercer grass (*Paspalum distichum*). Some periphyton growth is present near the bridge downstream of the sampling location. The stream is slow flowing and has poor habitat heterogeneity consisting of run habitat and a small amount of pool habitat.

Stream banks have good vegetation cover, although this consists mostly of harakeke (*Phormium tenax*), overgrown kikuyu (*Pennisetum clandestinum)* and creeping buttercup (*Ranunculus repens*) that provide limited shading (~30%). Approximately 5m from the stream, manuka (*Leptospermum scoparium)* is dominant with interspersed karamu (*Coprosma robusta)*, *Coprosma propinqua*, and tī kōuka (*Cordyline australis*).

Woody weed species present include woolly nightshade (*Solanum mauritianum)* and blackberry (*Rubus fruticosus)*.

The Macroinvertebrate community index returned a SQMCI-sb score of 2.44 which is scored as poor quality according to Stark and Maxted (2007). Macroinvertebrate communities had low diversity (15 taxa) with no EPT taxa present, indicating severe pollution.

Overall the value of the subject reach is assessed as low based on poor aquatic habitat quality, low MCI values, and the potential for continued nutrient inputs from upstream farming activities. Riparian vegetation provides some ecological value, but species diversity is low and botanical values are compromised by the presence of weed species.

Figure 4. Pond Tributary 1. From left: grazed pasture and patch of raupō upstream of subject reach; stream channel with emergent macrophyte growth; view looking upstream towards subject reach and restoration planting.

5.1.2 Raglan WWTP – Pond tributary 2

The subject reach runs through grazed pasture to the west of the WWTP and then through a young restoration planting along the western edge of the WWTP property. The stream is fenced to prevent stock access, but the fence is located very close (~1m) to the channel and signs of previous stock access are evident. Upstream, little riparian vegetation is present apart from two tree ferns, rushes (*Juncus* sp.) and exotic herbaceous species (Fig. 5). On the downstream side of the fence at the sampling location, the subject reach has a wetted channel width of 0.5 (reaching 1.5m at its widest point) and a depth of approximately 30cm. The bank height is 1.2m. The stream substrate consists of silt and mud and the stream banks have a steep gradient but few erosions scars (<20%) and are generally stable. Upstream there is some bank slumping which is attributed to stock previously having access to the area. Habitat heterogeneity is low with the subject reach consisting only of slow flowing run habitat.

The true right bank has a wet ground area spanning approximately 8m from the stream and 10m from the fence that is vegetated with overgrown pasture grass and weed species. The remainder of the subject reach runs through a restoration planting (planted approx. 2007-2008). Mānuka and harakeke are the dominant species with interspersed karamū, māhoe (*Melicytus ramiflorus*), and kawakawa (*Piper excelsum*). Small patches of bracken fern are present, and in high light areas weed species include: pampas (*Cortaderia selloana*), kikuyu, *Solanum nigrum, Consyza* sp., and creeping buttercup. Shading ranges from non-existent upstream to ~60% downstream. Emergent macrophytes are present in the upstream section of the channel.

The Macroinvertebrate community index returned a SQMCI-sb score of 3.70 which is scored as poor quality according to Stark and Maxted (2007). Macroinvertebrate communities were depauperate (8 taxa) with no EPT taxa present, indicating severe pollution.

Overall the value of the subject reach is assessed as low based on poor aquatic habitat quality, low MCI values, and the likelihood of continued nutrient inputs from adjacent farming activities.

Figure 5. Pond tributary 2. From left: upstream reach of watercourse running through grazed pasture; sampling location near the western edge of the WWTP property; upstream wetland/gully area.

5.1.3 Raglan WWTP – Upstream 2

The subject reach is a small low-flow stream that has a wetted channel width of 1m - 1.5m and a depth of 0.2 - 0.4m. The stream banks have moderate erosion scars (~20%) and some bank slumping is evident. Some debris is present in the channel but it mostly consists of small branches and leaves. The substrate consists of silt/mud and run and pool habitat types are present.

The upstream section is well-shaded and runs through a patch of dense mixed native-exotic vegetation with a considerable understory including seedling regeneration and ground ferns (Fig. 6). Species present include māhoe, kawakawa, and ponga. Downstream the watercourse runs through a relatively young restoration planting consisting of harakeke, umbrella sedge (*Cyperus ustulatus*), karamū, and karo (*Pittosporum crassifolium*) that provides little shading (Fig. 6). The width of the riparian buffer is narrow in places (~3m). Weed species present at the site include gorse, creeping buttercup, grass species and *Persicaria*.

Figure 6. Upstream two. Section of the subject reach under the dense patch of established vegetation (left), and the establishing riparian planting that the downstream section of the subject reach runs through (right).

The Macroinvertebrate community index returned a SQMCI-sb score of 2.68 which is scored as poor quality according to Stark and Maxted (2007). Macroinvertebrate communities were lacking diversity(9 taxa) with no EPT taxa present, indicating severe pollution.

Overall the value of the subject reach is assessed as low based on poor aquatic habitat quality, presence of weed species, and low MCI values. Riparian vegetation is likely to improve the ecological value of the watercourse in the future, but currently provides little shading and the buffer width is relatively narrow.

5.1.4 Raglan WWTP – Farm Tributary 1

The subject reach is a small, low-flow stream that runs through grazed pasture area. The channel is steeply incised with substantial erosion and bank slumping (Fig. 7). The stream has a wetted channel width of 0.3-0.5m and a depth of 10cm. The substrate consists of silt and mud and the subject reach consists of run habitat. Although the stream is fenced to exclude stock access, the fence is located very close to the channel (~1-2m) and riparian vegetation consists predominantly of herbaceous species such as pasture grass, gorse, *Juncus* spp., pampas, and thistles that provide little to no shading (Fig. 7).

Figure 7. Farm tributary 1. Subject reach looking downstream (left), and channel showing evidence of bank slumping and stock presence close to stream (right).

The Macroinvertebrate community index returned a SQMCI-sb score of 2.48 which is scored as poor quality according to Stark and Maxted (2007). Macroinvertebrate communities had a low diversity (10 taxa) with no EPT taxa present, indicating the watercourse is adversely impacted by pollution.

Overall the value of the subject reach is assessed as very low based on poor water and habitat quality, absence of shading and low riparian vegetation values, erosion, and the likelihood of continued nutrient inputs from adjacent farming activities.

5.1.5 Raglan WWTP – Estuarine confluence

The subject site is located at the confluence two small streams. The tributary on the true right is very shallow (~10cm) and overgrown grassy vegetation grows across the entirety of the channel, providing potential inanga spawning habitat (see Fig. 3 above). The tributary on the true left is faster flowing. The subject reach includes run habitat, and a small extent of riffle and pool habitat.

The watercourse has a wetted channel width of approximately 0.5m and depth ranging from 10-40cm. The substrate consists of silt and mud. Upstream the banks have a low gradient, but downstream the banks are highly incised and at risk of erosion and mass slumping (Fig. 8).

Bank vegetation provides little shading and consists of low density planted harakeke, sedges and overgrown grass with interspersed karamu, *Coprosma propinqua* and patches of blackberry.

Figure 8. Estuarine confluence 2 sampling location (left), and downstream channel (right).

The Macroinvertebrate community index returned a SQMCI-sb score of 2.79 which is scored as poor quality according to Stark and Maxted (2007). Macroinvertebrate communities had a low diversity (13 taxa) with 7.69% EPT taxa present, indicating pollutants are present but levels are slightly improved compared to upstream sites. The proximity of the sampling location to the tidal reach of the Wainui Stream indicates that the subject reach could be subject to some tidal influence, potentially altering the macroinvertebrate community from a typical freshwater stream. However, at the time of sampling, undertaken approximately at mid-tide, the conductivity of the stream was not indicative of saline influence, therefore tidal influence on the stream was not confirmed.

Overall the value of the subject reach is assessed as moderate based on the potential inanga spawning habitat and connectivity to the estuarine environment. A more thorough assessment of the inanga spawning values of the site should be undertaken to inform future decision making.

5.2 Wainui Stream

Fish surveys were not undertaken but according to the New Zealand Freshwater Fish Database (NZFFD) (Crow, 2017), the following freshwater fish species are present upstream of the sample locations in Wainui stream. During the site visit, one juvenile *Gobiomorphus* sp. was identified during macroinvertebrate sampling at site one.

Table 7. Freshwater fish recorded in the NZFFD upstream of sample locations in Wainui stream (within 500m). Conservation status assigned according to Dunn, et al., (2018) and Grainger et al., (2018)..

Species	Conservation Status
Shortfin eel (*Anguilla australis*)	Not Threatened
Longfin eel (*Anguilla dieffenbachii*)	At Risk - Declining
Giant kokopu (*Galaxias argenteus*)	At Risk - Declining
Banded kokopu (*Galaxias fasciatus)*	Not Threatened
Inanga (*Galaxias maculatus)*	At Risk - Declining
Redfin bully (*Gobiomorphus huttoni*)	Not Threatened
Freshwater crayfish/Kōura (*Paranephrops* spp.)	At Risk – Declining
Freshwater shrimp (*Paratya curvirostris)*	Not Threatened

5.2.1 Wainui stream – Site one

The subject reach is a natural, permanent stream with a wetted channel width ranging from 1.5m – 4m and a depth ranging from 0.3m – 1.6m. The sampling site is located adjacent to grazed farmland and appears to be used for recreational purposes and the stream bank has been modified with steps cut into the bank on the true left. There are signs that horses have recently been grazing on the grassy bank on the true left and a rabbit burrow is present, but the area is generally fenced to exclude stock.

The stream banks have a steep gradient but are generally stable with less than 20% of the banks showing erosion scars. The stream is hard bottomed with the substrate consisting of boulder and cobble with a small amount of sediment deposition. There is very little evidence of mass wasting and debris is limited to small twigs and branches. There true right has good riparian vegetation cover (70-90%) while the left has more patchy vegetation and large areas of grass. A number of trees in the riparian zone are deciduous and as a result, shading was low at the time of the site visit (10-30%). The stream has good habitat heterogeneity with run, riffle, cascade, and pool habitat (Fig. 9).

Riparian vegetation consists of willow (salix spp.), mānuka (*Leptospermum scoparium*), karamū (*Coprosma robusta*), tī kōuka (*Cordyline australis*), harakeke (*Phormium tenax*), Kiokio (*Blechnum novae-zelandiae*), sedges (Carex spp.) with some scattered blackberry (*Rubus fruticosus*) and patches of grass and creeping buttercup (*Ranunculus repens*).

Figure 9. Wainui stream site one. Cascade habitat (left), and riparian vegetation and grassed area along the subject reach (right)

The Macroinvertebrate community index returned a MCI score of 92.17 and a SQMCI score of 4.42 which is scored as fair quality according to Stark and Maxted (2007). Macroinvertebrate communities were moderately diverse (23 taxa) with 34.78% EPT taxa. The MCI values recorded for the stream reach are consistent with LAWA results from macroinvertebrate sampling and slightly below the 5 year median of 99[2].

[2] https://www.lawa.org.nz/explore-data/waikato-region/river-quality/wainui-stream/wainui-stream-raglan-at-wainui-mci/

Overall the value of the subject reach is moderate-high based on habitat heterogeneity, presence of EPT taxa, connectivity with high-quality upstream habitat, and the likelihood that At Risk – Declining freshwater fish species are present.

5.2.2 Wainui stream – Site two

The subject reach is located downstream of site one and has a wetted channel width ranging from 2m – 3.5m and a depth ranging from 0.3m – 0.8m. The substrate consists of silt/mud/sand, cobble, gravel and a small amount of boulder. On the true left, a small overland flow path discharges into the stream just prior to a sharp bend in the channel. The banks on the true left side are steeply incised (Fig. 10) with erosion scars and some evidence of mass wasting while the stream banks on the true right side have a lower gradient. Bank height ranges 1m - 2m. Some organic matter is present in the channel, but this predominantly consists of small twigs and tī kōuka leaf litter. The watercourse consists of run and riffle habitat with some pool habitat.

A high proportion of the streambanks are covered in vegetation, although around 50% of this is herbaceous weed cover. The latitudinal extent of riparian vegetation is smaller on the true left, with the narrowest point extending approximately 5m from the stream before reaching fenced pasture. Woody vegetation at the site is well established (estimated 20-30 years since planting). Tī kōuka is dominant in the canopy with other species including karamū, kawakawa, mahoe, black mamaku (*Cyathea medullaris*), and interspersed exotic tree species including walnut sp. and poplars. Understorey species include *Veronica* sp., Harakeke, juvenile tree ferns, shrubby toatoa (*Haloragis erecta*), sedges, blackberry and arun lily.

The area to the true right of the stream is highly invaded by tradescantia with some small patches of creeping butter cup and bindweed. The large amount of weedy ground cover appears to be supressing regeneration and there are very few seedlings or saplings.

Figure 10. Wainui stream – site two. From left: incised bank; stream channel looking downstream showing tradescantia invasion on the right bank; stream channel looking upstream showing riffle habitat

The Macroinvertebrate community index returned a MCI score of 97.14 and a SQMCI score of 4.36 which is scored as fair quality according to Stark and Maxted (2007). Macroinvertebrate communities were moderately diverse (21 taxa) with 33.33% EPT taxa. The MCI values recorded for the stream reach are consistent with LAWA results from macroinvertebrate sampling and slightly below the 5 year median of 99[3].

Overall the value of the subject reach is moderate-high based on habitat heterogeneity, presence of EPT taxa, connectivity with high-quality upstream habitat, and the likelihood that At Risk – Declining freshwater fish species are present.

5.3 Te Aewa Stream

Fish surveys were not undertaken but according to the New Zealand Freshwater Fish Database (NZFFD) (Crow, 2017), the following freshwater fish species are present in the downstream section of the Te Aewa Stream.

Table 8. Freshwater fish recorded in the NZFFD upstream of sample locations in Wainui stream (within 500m). Conservation status assigned according to Dunn, et al., (2018) and Grainger et al., (2018).

Species	Conservation Status
Shortfin eel (*Anguilla australis*)	Not Threatened
Longfin eel (*Anguilla dieffenbachii*)	At Risk - Declining
Banded kokopu (*Galaxias fasciatus)*	Not Threatened
Inanga (*Galaxias maculatus)*	At Risk - Declining
Redfin bully (*Gobiomorphus huttoni*)	Not Threatened
Common bully (*Gobiomorphus cotidianus*)	Not Threatened
Smelt (*Retropinna retropinna*)	Not Threatened
Lamprey (*Geotria australis*)	Threatened - Nationally Vulnerable
Freshwater crayfish/Kōura (*Paranephrops* spp.)	At Risk – Declining
Freshwater shrimp (*Paratya curvirostris)*	Not Threatened
Freshwater mussel/Kākahi (*Echyridella menziesi*)	At Risk - Declining

5.3.1 Te Aewa Stream – site one

The subject reach is a permanent stream located downstream of the confluence of the 15 Te Ahiawa Road watercourses and Te Aewa Stream. The site was visited immediately after a heavy rainfall event and water was turbid and fast-flowing. The stream has a wetted channel width of approximately 2m and a depth of 45cm. The substrate was not visible due to high turbidity. The majority of the reach is fenced to exclude stock, but the fence at the sampling location has collapsed and stock are able to access the river. Although, at the time of the site visit, no evidence of recent stock access was present.

The streambanks have a height of 1-1.5m and a gradient of 30-45° with some previous signs of erosion and bank slumping. Large trees have fallen across the channel but are suspended above water level and are not blocking flow. Some organic matter is present in the channel, consisting of small twigs and leaves. The watercourse consists of run and riffle habitat with some pool habitat. Some (~30%) stable bank undercut areas are present and the stream has good meander.

The subject reach had moderate shading (~30%) at the time of the site visit, although this is likely higher during spring/summer months when the large deciduous trees along the upstream section of the reach have foliage. Other riparian vegetation consists of large Pinus radiata, tarata, tī kouka, arun lily, karamū,

[3] https://www.lawa.org.nz/explore-data/waikato-region/river-quality/wainui-stream/wainui-stream-raglan-at-wainui-mci/

hangehange, large leaved privet, tōtara, inkweed, and woolly nightshade. Ground cover includes kiokio, onion weed, creeping buttercup, *Juncus effusus*, ladder fern, clover, and pasture grasses.

Overall the value of the subject reach is assessed as moderate based on good habitat heterogeneity, and the likelihood that At Risk – Declining and Nationally Threatened freshwater fish species are potentially present based on the NZFFD. However, riparian vegetation was relatively limited.

Figure 11. Te Aewa stream sampling location, downstream of confluence with 15 Te Ahiawa Road tributaries.

5.4 15 Te Ahiawa Road

Fish surveys were not undertaken and no records are available for the unnamed watercourses that run through 15 Te Ahiawa Road. Fish species are expected to be similar to those recorded in Te Aewa stream, at least as far upstream as the P3 sampling location where there is a culvert perched approximately 40cm above water level. This may impede the passage of swimming fish species. During the site visit, one juvenile Kōura (*Paranephrops* spp.; At Risk - Declining) was identified during macroinvertebrate sampling at P3.

Two Significant Natural Areas (SNA 1 and 2) are located within the boundaries of the farm (Fig. 12). These consist of wetland and bush habitat and have been fenced.

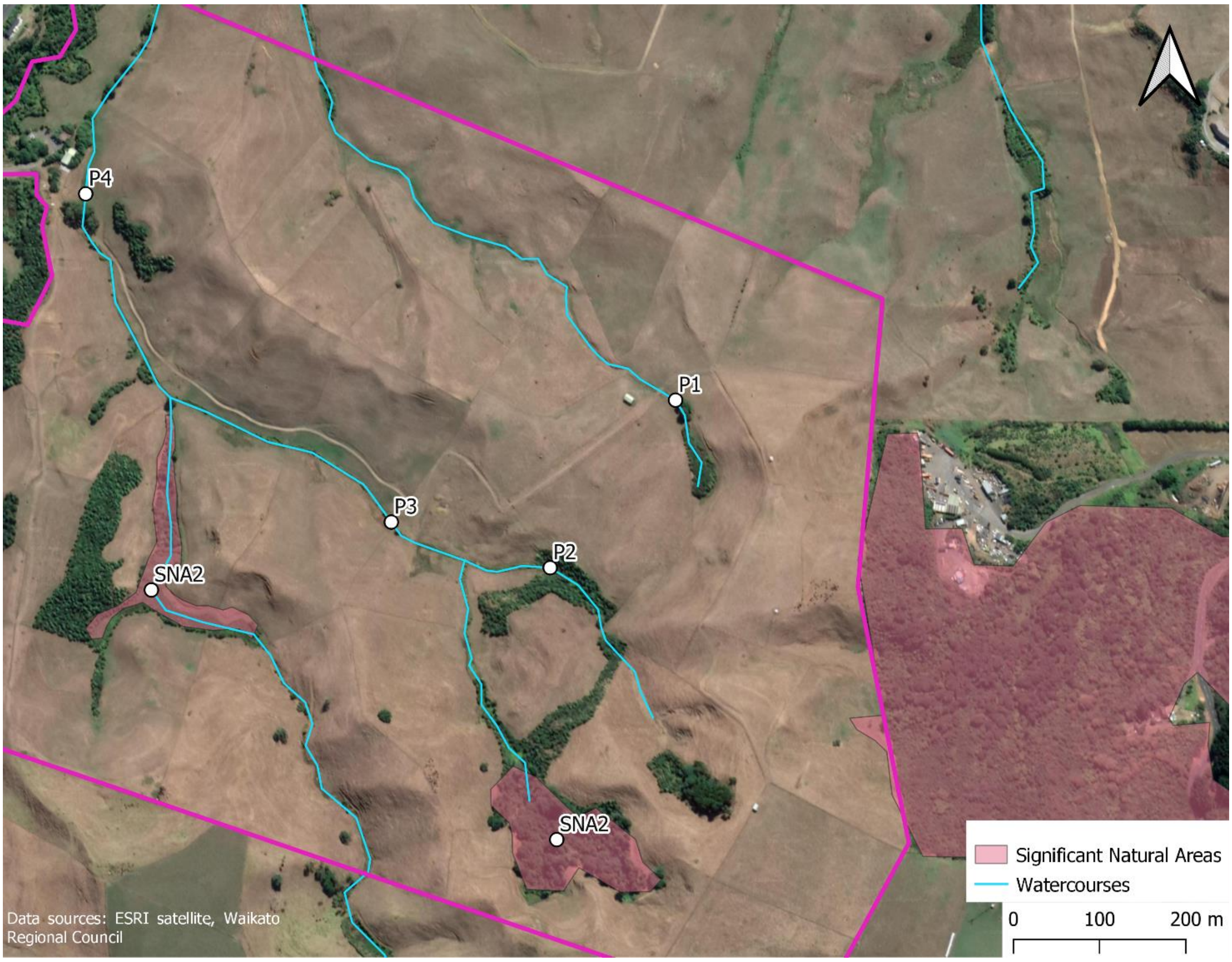

Figure 12. Significant Natural Areas at 15 Te Ahiawa Road.

5.4.1 15 Te Ahiawa Road Tributary 1 (P1)

At the sampling location, no water was present, but the channel was well defined with a bank height of approximately 2m. The watercourse is classified as an intermittent stream (Lowe, Ingley, & Young, 2016). Just upstream of the sampling location, a small revegetation planting is present that provides an estimated 70m of shading. Plant species present include: kawakawa, akeake, karamū, mānuka, pōhutukawa, inkweed, large leaved privet, and woolly nightshade. Downstream, very little riparian vegetation is present.

The value of the subject reach is assessed as low based on its intermittent nature and the limited amount of riparian vegetation.

Figure 13. Photos of intermittent stream (15 Te Ahiawa Road tributary 1) (left), and riparian vegetation along the upper section (right).

5.4.2 15 Te Ahiawa Road Tributary 2 (P3)

The subject reach is a permanent stream that runs from a patch (0.66ha) of replanted indigenous forest and wetland vegetation (see Fig. 14) through pasture where it is bordered by a narrow (~2m width) strip of mostly herbaceous riparian vegetation. The stream has a wetted channel width ranging from 0.3m – 0.6m and a depth ranging from 0.1m – 0.2m. At the sampling location, the stream is deeply incised with a bank height of 2-5m. The bank has a steep gradient (>50°) and some signs of erosion, but banks are well-vegetated and generally appear stable. The substrate consists of clay/mud, with small amounts of cobble and gravel. The stream consists of run, cascade and pool habitat. Undercut banks with overhanging vegetation are present along approximately 50% of the reach. Debris jams are present in the form of occasional large tree limbs and numerous twigs, leaves, and fern fronds. The stream is fenced to exclude stock.

Upstream vegetation provides good shading >80% and consists of a canopy of tī kouka, karo, tarata, ponga, karamū, and mānuka. The understory consists of *Paesia scaberula,* harakeke, inkweed, kawakawa, woolly nightshade and sparse Himalayan honeysuckle. Ground cover consists of creeping buttercup, pasture grass, *Paesia scaberula, Carex germinata*, kiokio and sparse *Juncus effusus*. Indigenous vegetation is dominant.

Downstream vegetation provides some (<30%) shading and consists of Carex germinate, pasture grasses and sparse whekī ponga.

The Macroinvertebrate community index returned a QMCI-sb score of 6.48 which is scored as excellent quality according to Stark and Maxted (2007). Macroinvertebrate communities had low diversity (13 taxa) with 23.1% EPT taxa present.

Overall, the value of the subject reach is assessed as moderate based on the reasonable riparian vegetation and habitat heterogeneity, and high QMCI-sb score. However, a low proportion of EPT taxa were present and the macroinvertebrate community had low diversity.

Figure 14. 15 Te Ahiawa Road tributary 2 - Photos from left: looking upstream at planted gully, looking downstream, and incised stream banks.

5.4.3 15 Te Ahiawa Road Tributary 3 (P3)

The subject reach is a permanent stream downstream of a confluence. The stream is fenced 1.5-2m from the channel to exclude stock and is culverted under a bridge. The culvert on the downstream side is perched approximately 40cm above water level.

Upstream of the bridge the stream has very little shading, and a substrate of mud/silt/clay. The wetted channel width ranges from 0.3-1m and the stream has a depth of approximately 10cm. Stream banks have a low gradient and shallow banks (~50cm) until they reach the bridge where they have a steep gradient, height of 1.5m and evidence of erosion/bank slumping. The upstream section of the reach consists of run and cascade habitat. Bank vegetation consists of pasture grasses, Juncus effusus, kiokio, creeping buttercup and occasional whekī ponga.

Downstream of the bridge, vegetation provides improved shading (~80%). Here, the stream has a wetted channel width of 1.5m and is approximately 20cm deep. The streambanks are highly incised and 1.5-2m high. The substrate consists of clay, mud and occasional boulders, and run and riffle habitat are present. Riparian vegetation consists of black mamaku, whekī ponga, kōhūhū, *Paesia scaberula, Carex germinate,* inkweed, Galium sp., and pasture grasses.

The Macroinvertebrate community index returned a QMCI-sb score of 5.18 which is scored as good quality according to Stark and Maxted (2007). Macroinvertebrate communities had low diversity (9 taxa) with 11% EPT taxa present. The sample at this site only included 9 individuals and it's likely the sample was affected by recent rainfall reducing invertebrate numbers.

Overall, the value of the subject reach is assessed as moderate - high due to the presence of the At Risk – Declining Kōura species. Nevertheless, the ecological values of the reach are compromised by limited riparian vegetation and the culvert which likely prevents freshwater fish species that are poor climbers from accessing upstream habitat.

Figure 15. 15 Te Ahiawa Road tributary 3 - Photos from left: upstream of the bridge, downstream of bridge, perched culvert.

5.4.4 15 Te Ahiawa Road Tributary 4

The subject reach is a permanent stream upstream of a confluence with Te Aewa Stream. The stream is fenced ~2m from the channel to exclude stock. The site was visited immediately after a heavy rainfall event and water was turbid and fast-flowing. The substrate was not visible but is expected to be mud/silt. The subject reach has a wetted channel width ranging from 0.5-1.5m, and a depth of 10cm. A road/track has been recently cut into the true left bank. The streambanks range from 0.5-1.5m and have a low gradient, becoming steeper downstream. Run, riffle and pool habitat are present.

Riparian vegetation provides little shading along the majority of the reach and consists of large eucalyptus trees, creeping buttercup, mercer grass, blackberry, and sparse carex and kiokio.

No information is available on the NZFFD for this unnamed stream. However, the presence of at risk – declining species both upstream at P3, and downstream of the reach in the Te Aewa Stream indicate that they are likely to be present.

Based on the likely presence of at risk species, the value of the subject reach is assessed as moderate. Nevertheless, the stream has low ecological function values based on a to lack of riparian vegetation, low habitat complexity and poor water quality, impacted by the up-catchment pastoral land use.

Figure 16. 15 Te Ahiawa Road tributary 4 - Photos of sampling location looking downstream (left) and upstream (right).

6 Summary of Stream Ecological Values

Ecological values were assigned to aquatic habitat and riparian vegetation based on EIANZ guidelines (Roper-Lindsay, Fuller, Hooson, Saunders, & Ussher, 2018). MCI values were assigned according to (Stark & Maxted, 2007), and water quality values were assigned based on the number of contaminant concentrations that were above adopted guideline values. Overall value was then assigned using the criteria presented in Table 9 below. A summary of stream ecological values is presented in Table 10.

Table 9. Rating system for assessing ecological value of terrestrial and freshwater systems (Roper-Lindsay *et al*. 2018).

Description	Value
Feature rates Very Low for at least three assessment attributes and Low to Moderate for the remaining attribute(s).	Negligible
Feature rates Very Low to Low for most assessment attributes and moderate for one. Limited ecological value other than providing habitat for introduced or tolerant indigenous species.	Low
Feature rates High for one assessment attribute and Low to Moderate for the remainder, OR The Project area rates Moderate for at least two attributes and Very Low to Low for the rest. Likely to be important at the level of the Ecological District.	Moderate
Feature rates High for at least two assessment attributes and Low to Moderate for the remainder, OR The Project area rates High for one attribute and Moderate for the rest. Likely to be regionally important.	High
Feature rates High for at least three assessment attributes. Likely to be nationally important.	Very High

Table 10. Summary of stream ecological values at each sampling location.

Watercourse	Aquatic habitat	Riparian vegetation	Water quality	MCI	Overall ecological value
Upstream 2	Low	Low	Low - Moderate	Low	Low
Farm Trib 1	Very low	Negligible	Moderate	Low	Low
Pond Trib 1	Low	Low	Low	Low	Low
Pond Trib 2	Low	Low	Low	Low	Low
Estuarine confluence	High	Low	Low	Low	Moderate
Wainui 1	High	Low	Moderate - High	Moderate	Moderate – High
Wainui 2	High	Moderate	Moderate - High	Moderate	Moderate - High
Te Aewa 1	Very High	Low	Low	NA	Moderate
P1 (intermittent stream)	NA - dry	Low	NA	NA	Low
P2	Moderate	Moderate	Low - Moderate	High	Moderate
P3	High	Low	Low - Moderate	High*	Moderate - High
P4	High	Very low	Low	NA	Moderate

*May not provide an accurate representation of macroinvertebrate communities due to rain at the time of sampling.

Macroinvertebrate communities at all WWTP watercourses had MCI and SQMCI scores indicative of severe pollution or nutrient enrichment. Despite riparian replanting, the soft-bottomed streams sampled generally had low habitat heterogeneity and low shading.

Sampling locations at Wainui Stream had more heterogeneous habitat and diverse macroinvertebrate communities with EPT taxa present. The downstream sites at Wainui Stream are assessed as having improved baseline conditions compared to the watercourses at WWTP. The Wainui Stream is considered a more sensitive receiving environment and the magnitude of effect of wastewater being discharged at this location is expected to be higher than at the WWTP.

Sampling locations at 15 Te Ahiawa Road and Te Aewa Stream had patchy riparian vegetation and were surrounded by agricultural land. Although MCI samples were not able to be taken at all sites, QMCI-sb scores were the highest of all sites sampled. The freshwater fish database also shows that threatened and at-risk species are present in Te Aewa Stream near the sampling location, and downstream of the 15 Te Ahiawa Road watercourses, indicating these streams have high aquatic habitat value. Although no fish surveys have been undertaken at 15 Te Ahiawa Road, it is likely that the perched culvert at the P3 sampling location limits upstream migration of swimming species. These watercourses have high restoration potential, but like Wainui Stream, have improved baseline conditions compared to the watercourses at WWTP. Therefore, they are considered to be more sensitive receiving environments, and wastewater discharge is likely to have a higher magnitude of potential effect.

Where more than water quality result exceeded the WRC Satisfactory guideline category in either the September 2019 or May 2020 sampling round, the water quality has been considered low at the WWTP site. Watercourses where contaminant concentrations were predominantly within the WRC Satisfactory guideline category, but some concentrations were within the excellent category or NPS-FM Attribute State A are considered to have Moderate to High water quality. It is important to note that samples were only collected on 1-2 occasions, and a longer-term monitoring programme would be required to ascertain more representative water quality values. Stated water quality values are therefore indicative only.

There is no data available on freshwater fish species at the WWTP or 15 Te Ahiawa Road watercourses, therefore at these locations there is some uncertainty with assigning ecological values.

7 Preferred Potential Discharge Option

From an ecological perspective, the degraded baseline condition of Pond Trib 2 and the downstream environment minimises the potential for adverse ecological effects from treated wastewater discharges. Macroinvertebrate and freshwater fish communities at Wainui and Te Aewa Streams are expected to be more sensitive to adverse effects associated with treated wastewater discharges. Discharge at these locations is expected to alter baseline conditions and may exclude aquatic organisms from otherwise high-quality habitat. Furthermore, in comparison to the Wainui Stream sites, discharge at Pond Trib 2 provides increased opportunities for ecological enhancement (see Section 9). Due to the proximity of Pond Trib 2 to the WWTP, this location is also considered a potentially viable option from an engineering perspective. Following the MBR and UV processes, the treated wastewater would be able to discharge via gravity to the stream (Beca Ltd, 2020). At the edge of the stream, a rock gabion wall or other discharge mechanism could be constructed to distribute the flow along a length of the stream to create a diffuse discharge. Prior to the design of a potential diffuse discharge mechanism being confirmed, appropriate consultation should be undertaken to confirm that the design is acceptable to key stakeholders, including hapū.

Potential water quality and ecological effects are discussed below on the basis of Pond Trib 2 being the potential stream recharge location.

8 Water Quality and Ecological Effects Assessment

8.1 Potential Water Quality and Ecotoxicity effects

The wastewater treatment concept design involves an MBR process with UV disinfection and alum dosing to provide a high level of treatment. The expected 90th percentile treated wastewater quality is reproduced below for reference.

Table 11 - Expected Treated Wastewater Quality (90th percentile)

TSS	$cBOD_5$	NH_4-N	TN	NO_3-N	TP	E Coli	Virus
<5 g/m³	<5 g/m³	<1 g/m³	<8 g/m³	<7 g/m³	<1 g/m³	<10 no./100ml	4 log removal

An assessment of baseline hydraulic flow for the watercourses has not been undertaken, therefore resulting concentrations due to dilution in the receiving environment cannot yet be attained for discharged contaminants. Potential effects on water quality and associated adverse toxicity effects by comparison of 90th percentile discharge concentrations to measured concentrations in the receiving environment and relevant guideline values are commented on below. Further water quality monitoring of identified contaminants would be required to better understand baseline water quality.

Fish surveys in the area will be required to confirm presence or absence and whether any fish species are present that would be particularly sensitive to the contaminants discharged at predicted concentrations.

8.1.1 Potential Water Quality Improvements

The expected 90th percentile TSS discharge concentration is generally lower than concentrations measured in the WWTP adjacent watercourses. Temporarily increased sediment inputs can be expected once planted riparian vegetation shades out grass cover along stream reaches, resulting in natural stream bank erosion and channel widening until the stream channel stabilises (Parkyn, Davies-Colley, Cooper, & Stroud, 2005). Nevertheless, at the preferred discharge location, Pond Trib 2, and downstream reach, water quality with respect to TSS concentrations would be expected to improve long term.

Likewise, the 90th percentile *E.coli* discharge concentration is lower than concentrations measured at Pond Trib 2 and the downstream Estuarine Confluence location. The discharge is therefore not expected to have adverse effect on *E.coli* concentrations in the receiving environment.

8.1.2 Total Nitrogen and Nitrate

The contaminants with the greatest difference between baseline receiving environment concentrations and expected 90th percentile discharge concentrations are TN and nitrate. Total nitrogen and nitrate concentrations at the preferred discharge option location in May 2020 were 1.21 and 0.018 g/m^3, respectively. The discharge with a 90th percentile TN concentration of <8 g/m^3 is therefore likely to have some effect on TN concentrations in the watercourse, and at times the WRC satisfactory guideline for TN with respect to nuisance macrophyte growth may not be achieved.

The 90th percentile nitrate discharge concentration of <7 g/m^3 is lower than the NPS-FM National Bottom Line annual 95th percentile concentration of 9.8 g/m^3, and similar to the National Bottom Line annual median concentration of 6.9 g/m^3 where growth effects on up to 20% of species are stated to occur. Dilution would be required to achieve higher NPS-FM attribute states (A, B or C) where toxicity effects would be expected to occur on fewer species compared to the national bottom line values.

The derivation of the NPS-FM attribute states was undertaken by NIWA (NIWA, 2013). The most sensitive species used in the NPS-FM chronic nitrate toxicity attribute state derivation was lake trout with a no observable effects concentration (NOEC) of 1.6 mg/L for growth and development endpoints. Lake trout are not expected to be found in the receiving environment habitat and are generally not resident in New Zealand Rivers (NIWA, 2013).

Sub-adult and juvenile inanga (*Galaxias maculatus*) were included in the derivation of the NPS-FM attribute states. The growth of juvenile inanga was the most sensitive chronic measure, with a NOEC of 6.0 mg/L in low hardness water and 20.8 mg/L in moderate hardness water. Some dilution of the discharge would therefore be required to protect juvenile inanga in the receiving watercourse based on the 90th percentile concentration. However, the typical discharge concentration is expected to be lower than the 90th percentile concentration and under those circumstances, growth effects would be less likely to occur based on the NOEC data. Invertebrates were found to be less sensitive to nitrate toxicity than fish. The most sensitive invertebrate NOEC was >14 mg/L for a freshwater crayfish, *Astacus astacus* for mortality (NIWA, 2013), which is appreciably greater than the 90th percentile discharge concentration.

NIWA have also recommended native species that may be suitable for future nitrate toxicity testing, including fish and invertebrates, to cover a representative range of freshwater species. NIWA suggest that priority species would include the common bully and eel elvas. As nitrate toxicity data for these species is not currently available, and if they are found in the receiving environment through fishing surveys, it may be appropriate to take a precautionary approach with respect to the NPS-FM attribute state used in future effects assessment. The amphipod species *Parcalliope fluviatalus* was also listed by NIWA as a species suitable for further nitrate toxicity testing (NIWA, 2013). An organism of the same genus was identified at the Estuarine Confluence site.

Dilution in the receiving watercourse will reduce the discharge concentration, though further assessment of stream flow rates is required to inform the extent of dilution and consequential chronic nitrate toxicity effects. Acute nitrate toxicity effects for sensitive species occur at higher concentrations (>20 g/m^3) and would therefore not be expected to occur as a result of the discharge based on the NPS-FM guidance.

8.1.3 Total ammoniacal-nitrogen

Total ammoniacal-nitrogen concentrations in samples collected from Pond Trib 2 and the downstream Estuarine Confluence location in May 2020 were comparatively low compared to expected discharge concentrations. The 90th percentile NH_4-N discharge concentration of <1 g/m^3 is greater than the WRC

Satisfactory guideline value of 0.88 g/m^3 for toxicity to fish. With dilution in the receiving watercourse the resulting concentration may meet this guideline value, however, hydraulic assessment is required to ascertain the likely level of dilution. Additionally, toxicity guidelines published by the USEPA (USEPA, 2013) are lower than 0.88 mg/L to account for the presence of early life stage fish and freshwater mussels, which are particularly sensitive to NH_4-N toxicity. For early life stage fish and freshwater mussel presence, the USEPA chronic criteria concentration (CCC) is 0.78 g/m^3 at pH 8 and a temperature of 20°C. Without mussel presence, the CCC at pH 8 and 20°C is 2.7 mg/L to protect early life stage fish. Generally, NH_4-N toxicity increases with increasing pH and temperature. Therefore, under certain pH and temperature conditions, toxicity effects have the potential to occur as a result of the discharge in the receiving stream, depending on dilution and the presence of sensitive species.

The pH of Pond Trib 2 in September 2019 was 7.5, while in May 2020 the pH of Pond Trib 2 was 5.76 and the downstream Estuarine Confluence pH measured was 5.35, demonstrating that variable pH can occur in the stream. Temperature in the watercourse may also increase in summer low flow conditions. Longer-term monitoring is required to understand a representative temperature and pH range for the receiving environment, and implications for NH_4-N toxicity. It is noted that USEPA CCC are chronic 30-day rolling average (not to exceed 2.5 times the CCC as a four-day average within the 30 days, more than once in three years as an average).

Other studies have found sensitive native invertebrate species, freshwater mussels and mayflies (*Deleatidium sp*) can exhibit chronic toxicity effects at lower concentrations (such as those used in the derivation of the NPS-FM attribute states where the attribute state B concentration range for annual 95th percentile is 0.05 – 0.40 mg/L) (NIWA, 2014). It is noted that the guidelines developed by NIWA are described as indicative and it was stated by NIWA that a thorough literature review of the ANZECC (2000) freshwater database was not undertaken in the review of the guidelines. Other guidelines for NH_4-N toxicity such as those produced by the USEPA may therefore be more appropriate to use in future assessments. During the May 2020 investigations, freshwater mussels and mayflies were not recorded in the receiving stream, however, depending on dilution, wastewater discharges may constrain their ability to colonize following stream recharge.

The USEPA have also published acute toxicity criteria which are not to be exceeded more than once every three years on average. Where sensitive species are present, at pH 7 and 20°C, the acute criterion is 17 mg/L. This criterion varies with pH and temperature, for example, at pH 8 and a temperature of 20°C the acute criterion decreases to 3.9 mg/L. Again, further monitoring of pH and temperature is required to more fully understand the potential for acute toxicity effects to occur.

8.1.4 Total Phosphorus

The 90th percentile TP concentration (<1 g/m^3) is low due to proposed alum dosing, however, may still result in increased TP concentrations in the receiving environment. The TP concentration measured at Pond Trib 2 in May 2020 was 0.12 g/m^3 which is already above the WRC Satisfactory guideline of 0.04 g/m^3, therefore the discharge may contribute further to TP concentrations above the guideline value.

8.1.5 Temperature

The temperature of the discharge may be able to be controlled to minimise effects on the receiving stream. Longer term monitoring of the identified potential receiving stream is recommended to understand seasonal fluctuations in temperature and consequential requirements for the temperature of the discharge, so that the stream may achieve a satisfactory temperature range with respect to fish health and potential spawning habitat.

Riparian revegetation is also expected to decrease maximum stream temperatures by ~4-5°C within 15 years if a full canopy successfully develops along the length of the stream (Collier et al., 2001).

8.1.6 Dissolved Oxygen

Dissolved oxygen field measurements varied between September 2019 and May 2020 sampling events, and in May 2020 the measurement was below the WRC satisfactory guideline. Wastewater discharges have the potential to affect DO levels therefore further monitoring is required, particularly of baseline monitoring in the receiving environment to be able to compare results to the NPS-FM Appendix 2 attribute states. Like temperature, dissolved oxygen concentrations control habitat quality for fish and thus influence fish population distribution and ability to migrate in watercourses (Franklin, 2014). The DO levels in Pond Trib 2 were almost 30% below the Resource Management Act (1991) dissolved oxygen standard of at least 80% saturation for the protection of aquatic ecosystems, and at 5.4g/L, also below the 7-day mean guideline value of 8.0 g/L defined by Franklin (2014).

8.2 Stimulatory Nutrient-related Effects on Macrophytes and Periphyton

Total nitrogen and total phosphorus concentrations in treated wastewater discharges are expected to be above the current baseline levels in the stream. An increase in nutrient concentrations has the potential to cause a proliferation of aquatic macrophytes and algal biomass. During winter months, dilution may be sufficient for the effects of nutrient inputs to become negligible, however an assessment of baseline hydraulic flow would be required to confirm this. During summer months, with increased temperatures and lower water depths, macrophytes are more likely to proliferate. Riparian restoration may mitigate adverse effects as once riparian vegetation is well established, this will reduce temperature and light availability and limit the growth of macrophytes and periphyton.

The increase in nutrient inputs and potential stimulatory effect on macrophyte and periphyton is a key issue that requires further investigation of the expected dilution of wastewater discharges.

8.3 Streambank Erosion

At the time of the site visit, the watercourse had low flow levels. The discharge of MBR treated wastewater will increase flow to a maximum of 3000m³/day. This is likely to increase the risk of erosion and mass slumping downstream where the channel is already steeply incised. Riparian revegetation will provide some protection against this but is unlikely to be well established enough to minimise adverse effects by the time wastewater discharges commence. The installation of natural erosion protection solutions (i.e. Green Terramesh) in conjunction with riparian restoration should be considered prior to beginning discharges to minimise adverse ecological effects.

8.4 Riparian Revegetation

Riparian restoration will have a positive effect on water quality and stream habitat value that will increase as the vegetation matures. Potential long-term effects will include:

- Increased dissolved oxygen and decreased turbidity;
- Increased organic matter and woody debris inputs (provision of aquatic habitat for fish and macroinvertebrates);
- Shading and temperature regulation of stream channel;
- Filtration of surface runoff (reduced contaminant load discharge to streams);
- Long term bank stabilisation.

The positive effects of riparian revegetation will also help mitigate some of the adverse effects of existing rural land use near the WWTP.

8.5 Whāingaroa Harbour

Treated wastewater will eventually flow into the Whāingaroa Harbour. Five sites in the harbour are routinely monitored using an estuarine health index called the Traits Based Index (TBI). According to data from 2012-2018, sites are evaluated as moderately healthy (Waikato Regional Council, 2020).

As noted in Section 2, the Whāingaroa Harbour has a large catchment and contaminants generated from land uses such as the extensive farming in the catchment can be transported via rivers to discharge in the harbour. Hydrodynamic modelling has previously been undertaken to elucidate the contribution of faecal coliforms from the existing WWTP compared to inputs from inflowing rivers (Greer, 2015). The modelling study concluded that rivers entering the harbour have a large-scale influence on water quality relative to the existing WWTP discharge. The upgrade of the WWTP is expected to improve concentrations of microbes and pathogens in the discharge so that contributions to the harbour are further reduced.

Nutrient inputs from the WWTP discharge also have the potential to effect the harbour with respect to phytoplankton and macrophyte growth.

Residence times have an impact on the fate of contaminants discharged to the harbour (eCoast, 2016). Through hydrodynamic modelling, residence times of 35 to 45 days in the harbour have been observed (in the upper estuary during medium river flow conditions). In particular, the Waituna and Waingaro Rivers drain approximately 60% of the Harbour Catchment area and flow into the harbour head where residence times can be up to 45 days during low river flows (eCoast, 2016). Conversely, lower residence times are predicted to occur in the lower harbour where the WWTP discharge would enter the harbour via the stream. Overall, it is considered that, in drowned river valley estuaries such as the Whāingaroa Harbour, residence times exhibit an increasing gradient from the mouth to the head of the estuary (eCoast, 2016). Water quality of the harbour may therefore be more influenced by river flows into the head of the estuary compared to the WWTP discharge.

Due to comparatively short residence times in the area of ther harbour where the treated wastewater will discharge to, phytoplankton blooms may be less likely to occur as a result of nutrient inputs. The relatively large intertidal area however, means that the harbour is generally suitable for macrophyte growth (NIWA, 2018). Due to the high level of treatment provided by the proposed MBR process, nutrient inputs to the harbour are expected to be less than from the existing WWTP. Nevertheless, as the potential discharge location is different to the existing, mixing into the harbour will differ and it is recommeded that further assessment is undertaken of potential adverse effects on harbour water quality. It is understood that DHI are undertaking hydrodynamic modelling to understand potential contaminant dilution in the harbour and potential for nitrogen related water quality and ecological effects.

Though the upgrade is expected to reduce inputs of microbes and pathogens into the harbour, it is also recommended that a Quantitative Microbial Risk Assessment (QMRA) be undertaken to assess public health risk with respect to contact recreation and shellfish gathering at selected sites within the Wainui Inlet arm of the Whāingaroa Harbour.

9 Enhancement Opportunities

Key enhancement opportunities at the WWTP site include riparian planting, enrichment and infill planting, weed control and stream enhancement within the WWTP designation (see Figure 17). Further restoration planting could extend adjacent to the tributary on land to the west of the WWTP (subject to landowner discussion and confirmation of ability; indicative diagram provided in Appendix C).

Riparian planting should take place, upstream of Pond Tributary 2 and along the unvegetated section of the watercourse running from Estuarine Confluence 1 towards the harbour. A riparian buffer width of 10m is the recommended minimum to meet restorative functions (Collins, Doscher, Rennie, & Ross, 2012). This would ensure that the entire reach was vegetated and improve stream channel shading. Ideally, the pasture that the upstream section of the watercourse runs through would be retired to minimise the cumulative effect of wastewater and farm-related nutrient inputs. The downstream streambanks which are currently steeply incised and at risk from erosion would also benefit from the installation of natural erosion protection solutions and planting of species with deep, soil binding roots (see Marden, Rowan, & Phillips, 2005 for candidate species).

The extent of the watercourse that is already planted would also benefit from infill planting where gaps have developed, and enrichment planting using mid-late successional species to improve species diversity and ensure successional progression. All planting activities should take place in conjunction with the removal of weed vegetation species to ensure these plants do not outcompete native species. Once a canopy is established, herbaceous weed species will be naturally shaded out. Planting larger seedlings at higher densities (1 plant per m^2) and investing in larger seedlings would fast track the development of a canopy over the stream channel.

Long-term, these planting activities will greatly enhance the terrestrial habitat values of the site for indigenous fauna, increase the riparian buffer length and width, reduce water temperature in the stream, increase woody debris inputs to the stream, and assist in mitigating any residual effects of nutrient inputs from wastewater discharges through increased filtration.

Stream enhancement opportunities include increasing habitat heterogeneity in the stream by creating a more diverse range of water depths and velocities. This could include adding rock formations to create pools and riffle zones within the stream channel, and/or adding deadwood to improve habitat complexity.

Figure 17. Ecological enhancement opportunities at the Raglan WWTP.

10 Conclusions and Recommendations

The overall ecological value of the candidate location (Pond Trib 2) for MBR treated wastewater discharges at the Raglan WWTP is assessed as low. The channel is largely unshaded and water quality measurements show high turbidity and nutrient concentrations compared with adopted guidelines. Macroinvertebrate communities in the receiving environments can be generally characterised as tolerant and stream habitat heterogeneity is low.

Enhancement opportunities identified at the site include riparian revegetation, infill and enrichment planting, stream channel enhancements, and bank stabilization.

Based on ecological assessments and preliminary information available, the discharge of MBR treated wastewater in conjunction with stream restoration activities is expected to result in increased nutrient inputs downstream of the discharge point, but improved overall instream habitat, terrestrial habitat, and provide restorative riparian functions once vegetation is established.

Some further work is required to be able to assess the overall level of effect of treated wastewater discharges on the ecological and water quality values of the receiving environment. This should include fish surveys to confirm the presence/absence of fish species at the site, an assessment/evaluation of potential inanga spawning habitat, and flow assessments of the stream to inform the potential level of dilution of discharged contaminants. Longer-term water quality monitoring would also be required to better ascertain baseline water quality conditions, including any seasonal variability. Based on this investigation, key considerations for any future assessment may include but are not limited to:

- Potential toxicity effects from nitrate and total ammoniacal-nitrogen;
- Stimulatory nutrient related effects from total nitrogen and total phosphorus in the receiving stream and Whāingaroa harbour;
- Understanding public health risk associated with contact recreation and shellfish gathering at selected sites in the Wainui Inlet arm of the Whāingaroa harbour using Quantitative Microbial Risk Assessment; and
- Streambank erosion.

11 Limitations

This report has been prepared by Beca Ltd (Beca) solely for Watercare Services Ltd (the client). This report is prepared solely for the purpose of the assessment of potential ecological effects of the proposed works (Scope). The contents of this report may not be used by the Client for any purpose other than in accordance with the stated Scope.

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This report should be read in full, having regard to all stated assumptions, limitations and disclaimers.

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A

Appendix A – EIA Ltd Macroinvertebrate Sampling Results

Table 12. Macroinvertebrate community indices for sampled reaches. Macroinvertebrate samples were processed by EIA Ltd.

Sampling location	Upstream 2	Farm Trib 1	Pond Trib 1	Pond Trib 2	Estuarine confluence	Wainui 1	Wainui 2	P2	P3
Substrate type	Silt/mud	Silt/mud	Silt/mud	Silt/mud	Silt/mud	Cobble/ Boulder	Cobble	Clay/mud/ cobble	Clay/mud/silt
MCI value	80.00	72.00	78.67	85.00	90.77	92.17	97.14	117.08	103.56
MCI interpretation	Fair – probable moderate pollution	Poor – probable severe pollution	Poor – probable severe pollution	Fair – probable moderate pollution	Fair – probable moderate pollution	Fair – probable moderate pollution	Fair – probable moderate pollution	Good – Possible mild pollution	Good – Possible mild pollution
SQMCI value	NA	NA	NA	NA	NA	4.42	4.36	NA	NA
SQMCI interpretation	NA	NA	NA	NA	NA	Fair – probable moderate pollution	Fair – probable moderate pollution	NA	NA
SQMCI-sb value	2.68	2.48	2.44	3.70	2.79	NA	NA	6.48 (QMCI-sb)	5.18 (QMCI-sb)
SQMCI-sb interpretation	Poor – probable severe pollution	Poor – probable severe pollution	Poor – probable severe pollution	Poor – probable severe pollution	Poor – probable severe pollution	NA	NA	Excellent – Clean water	Good – Possible mild pollution
Number of Taxa	9	10	15	8	13	23	21	13	9
Number of individuals	154	136	130	35	143	62	171	55	9
% EPT Taxa	0.0	0.0	0.0	0.0	7.69	34.78	33.33	23.08	11.11

B

Appendix B – Hill Laboratories Analysis Reports

Hill Laboratories
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Certificate of Analysis

Client:	Beca Limited	**Lab No:**	2373280 SPv1
Contact:	Gemma Wadworth	**Date Received:**	26-May-2020
	C/- Beca Limited	**Date Reported:**	02-Jun-2020
	PO Box 6345	**Quote No:**	104750
	Wellesley Street	**Order No:**	20:070
	Auckland 1141	**Client Reference:**	20:070
		Submitted By:	Gemma Wadworth

Sample Type: Aqueous

Sample Name:		Farm Trib 1 26-May-2020 1:36 pm	Pond Trib 2 26-May-2020 10:50 am	Pond Trib 1 26-May-2020 12:00 pm	Upstream 1 26-May-2020 2:10 pm	Duplicate 26-May-2020 4:15 pm
Lab Number:		2373280.1	2373280.2	2373280.3	2373280.4	2373280.5
Individual Tests						
Total Suspended Solids	g/m³	< 3	34	12	23	21
Total Nitrogen	g/m³	0.39	1.21	0.54	0.20	0.55
Total Kjeldahl Nitrogen (TKN)	g/m³	0.19	1.20	0.24	0.11	0.21
Total Phosphorus	g/m³	0.010	0.120	0.010	0.060	0.046
Carbonaceous Biochemical Oxygen Demand ($cBOD_5$)	g O_2/m^3	< 2	< 2	< 2	< 2	< 2
Escherichia coli	MPN / 100mL	435	> 2,420	225	111	261
Nutrient Profile						
Total Ammoniacal-N	g/m³	0.013	0.119	< 0.010	< 0.010	0.019
Nitrite-N	g/m³	< 0.002	< 0.002	0.002	< 0.002	0.002
Nitrate-N	g/m³	0.21	0.018	0.30	0.095	0.34
Nitrate-N + Nitrite-N	g/m³	0.21	0.018	0.30	0.096	0.34
Dissolved Reactive Phosphorus	g/m³	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004

Sample Name:		Esturine Confluence 26-May-2020 4:15 pm				
Lab Number:		2373280.6				
Individual Tests						
Total Suspended Solids	g/m³	68	-	-	-	-
Total Nitrogen	g/m³	0.56	-	-	-	-
Total Kjeldahl Nitrogen (TKN)	g/m³	0.22	-	-	-	-
Total Phosphorus	g/m³	0.137	-	-	-	-
Carbonaceous Biochemical Oxygen Demand ($cBOD_5$)	g O_2/m^3	< 2	-	-	-	-
Escherichia coli	MPN / 100mL	219	-	-	-	-
Nutrient Profile						
Total Ammoniacal-N	g/m³	0.022	-	-	-	-
Nitrite-N	g/m³	0.003	-	-	-	-
Nitrate-N	g/m³	0.34	-	-	-	-
Nitrate-N + Nitrite-N	g/m³	0.34	-	-	-	-
Dissolved Reactive Phosphorus	g/m³	< 0.004	-	-	-	-

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 simple 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. A detection limit range indicates the lowest and highest detection limits in the associated suite of analytes. A full listing of compounds and detection limits are available from the laboratory upon request.
Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Nutrient Profile		0.0010 - 0.010 g/m^3	1-6
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1-6
Total Suspended Solids	Filtration using Whatman 934 AH, Advantec GC-50 or equivalent filters (nominal pore size 1.2 - 1.5µm), gravimetric determination. APHA 2540 D (modified) 23rd ed. 2017.	3 g/m^3	1-6
Total Nitrogen	Calculation: TKN + Nitrate-N + Nitrite-N. Please note: The Default Detection Limit of 0.05 g/m^3 is only attainable when the TKN has been determined using a trace method utilising duplicate analyses. In cases where the Detection Limit for TKN is 0.10 g/m^3, the Default Detection Limit for Total Nitrogen will be 0.11 g/m^3.	0.05 g/m^3	1-6
Total Ammoniacal-N	Phenol/hypochlorite colourimetry. Flow injection analyser. (NH_4-N = NH_4^+-N + NH_3-N). APHA 4500-NH_3 H (modified) 23rd ed. 2017.	0.010 g/m^3	1-6
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.002 g/m^3	1-6
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m^3	1-6
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.002 g/m^3	1-6
Total Kjeldahl Nitrogen (TKN)	Total Kjeldahl digestion, phenol/hypochlorite colorimetry. Discrete Analyser. APHA 4500-N_{org} D (modified) 4500 NH_3 F (modified) 23rd ed. 2017.	0.10 g/m^3	1-6
Dissolved Reactive Phosphorus	Filtered sample. Molybdenum blue colourimetry. Flow injection analyser. APHA 4500-P G (modified) 23rd ed. 2017.	0.004 g/m^3	1-6
Total Phosphorus	Total phosphorus digestion, ascorbic acid colorimetry. Discrete Analyser. APHA 4500-P B & E (modified from manual analysis and also modified to include a reductant to reduce interference from any arsenic present in the sample) 23rd ed. 2017. NWASCO, Water & soil Miscellaneous Publication No. 38, 1982.	0.004 g/m^3	1-6
Carbonaceous Biochemical Oxygen Demand ($cBOD_5$)	Incubation 5 days, DO meter, nitrification inhibitor added, dilutions, seeded. APHA 5210 B (modified) 23rd ed. 2017.	2 g O_2/m^3	1-6
Escherichia coli	MPN count using Colilert (Incubated at 35°C for 24 hours), or Colilert 18 (Incubated at 35°C for 18 hours). APHA 9223 B 23rd ed. 2017.	1 MPN / 100mL	1-6

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

Dates of testing are available on request. Please contact the laboratory for more information.

Samples are held at the laboratory after reporting for a length of time based on the stability of the samples and analytes being tested (considering any preservation used), and the storage space available. Once the storage period is completed, the samples are discarded unless otherwise agreed with the customer. Extended storage times may incur additional charges.

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Kim Harrison MSc
Client Services Manager - Environmental

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Certificate of Analysis

SPv1

Client:	Beca Limited	**Lab No:**	2373908
Contact:	Gemma Wadworth	**Date Received:**	27-May-2020
	C/- Beca Limited	**Date Reported:**	02-Jun-2020
	PO Box 6345	**Quote No:**	104750
	Wellesley Street	**Order No:**	20:070
	Auckland 1141	**Client Reference:**	20:070
		Submitted By:	Gemma Wadworth

Sample Type: Aqueous

Sample Name:		W1 27-May-2020 9:40 am	W2 27-May-2020 10:30 am	Duplicate 27-May-2020 10:30 am		
Lab Number:		2373908.1	2373908.2	2373908.3		
Individual Tests						
Total Suspended Solids	g/m³	< 3	< 3	< 3	-	-
Total Nitrogen	g/m³	0.27	0.30	0.30	-	-
Total Kjeldahl Nitrogen (TKN)	g/m³	< 0.10	0.12	0.12	-	-
Total Phosphorus	g/m³	0.014	0.013	0.016	-	-
Carbonaceous Biochemical Oxygen Demand ($cBOD_5$)	g O_2/m³	< 2	< 2	< 2	-	-
Escherichia coli	MPN / 100mL	225	249	210	-	-
Nutrient Profile						
Total Ammoniacal-N	g/m³	< 0.010	< 0.010	0.014	-	-
Nitrite-N	g/m³	< 0.002	< 0.002	< 0.002	-	-
Nitrate-N	g/m³	0.192	0.183	0.182	-	-
Nitrate-N + Nitrite-N	g/m³	0.193	0.184	0.184	-	-
Dissolved Reactive Phosphorus	g/m³	0.005	0.005	0.005	-	-

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 simple 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. A detection limit range indicates the lowest and highest detection limits in the associated suite of analytes. A full listing of compounds and detection limits are available from the laboratory upon request.
Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Nutrient Profile		0.0010 - 0.010 g/m³	1-3
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1-3
Total Suspended Solids	Filtration using Whatman 934 AH, Advantec GC-50 or equivalent filters (nominal pore size 1.2 - 1.5µm), gravimetric determination. APHA 2540 D (modified) 23rd ed. 2017.	3 g/m³	1-3
Total Nitrogen	Calculation: TKN + Nitrate-N + Nitrite-N. Please note: The Default Detection Limit of 0.05 g/m³ is only attainable when the TKN has been determined using a trace method utilising duplicate analyses. In cases where the Detection Limit for TKN is 0.10 g/m³, the Default Detection Limit for Total Nitrogen will be 0.11 g/m³.	0.05 g/m³	1-3
Total Ammoniacal-N	Phenol/hypochlorite colourimetry. Flow injection analyser. (NH_4-N = NH_4^+-N + NH_3-N). APHA 4500-NH_3 H (modified) 23rd ed. 2017.	0.010 g/m³	1-3
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.002 g/m³	1-3
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m³	1-3
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.002 g/m³	1-3

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Total Kjeldahl Nitrogen (TKN)	Total Kjeldahl digestion, phenol/hypochlorite colorimetry. Discrete Analyser. APHA 4500-N_{org} D (modified) 4500 NH_3 F (modified) 23rd ed. 2017.	0.10 g/m^3	1-3
Dissolved Reactive Phosphorus	Filtered sample. Molybdenum blue colourimetry. Flow injection analyser. APHA 4500-P G (modified) 23rd ed. 2017.	0.004 g/m^3	1-3
Total Phosphorus	Total phosphorus digestion, ascorbic acid colorimetry. Discrete Analyser. APHA 4500-P B & E (modified from manual analysis and also modified to include a reductant to reduce interference from any arsenic present in the sample) 23rd ed. 2017. NWASCO, Water & soil Miscellaneous Publication No. 38, 1982.	0.004 g/m^3	1-3
Carbonaceous Biochemical Oxygen Demand ($cBOD_5$)	Incubation 5 days, DO meter, nitrification inhibitor added, dilutions, seeded. APHA 5210 B (modified) 23rd ed. 2017.	2 g O_2/m^3	1-3
Escherichia coli	MPN count using Colilert (Incubated at 35°C for 24 hours), or Colilert 18 (Incubated at 35°C for 18 hours). APHA 9223 B 23rd ed. 2017.	1 MPN / 100mL	1-3

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

Dates of testing are available on request. Please contact the laboratory for more information.

Samples are held at the laboratory after reporting for a length of time based on the stability of the samples and analytes being tested (considering any preservation used), and the storage space available. Once the storage period is completed, the samples are discarded unless otherwise agreed with the customer. Extended storage times may incur additional charges.

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Certificate of Analysis

SPv1

Client:	Beca Limited	**Lab No:**	2405623
Contact:	Gemma Wadworth C/- Beca Limited PO Box 6345 Wellesley Street Auckland 1141	**Date Received:**	22-Jul-2020
		Date Reported:	28-Jul-2020
		Quote No:	104750
		Order No:	20:104
		Client Reference:	4288629/V01/1C
		Submitted By:	Gemma Wadworth

Sample Type: Aqueous

Sample Name:		TA2 22-Jul-2020 11:05 am	TA3 22-Jul-2020 11:30 am	TA4 22-Jul-2020 1:50 pm	TA5 22-Jul-2020 2:15 pm	
Lab Number:		2405623.1	2405623.2	2405623.3	2405623.4	
Individual Tests						
Total Suspended Solids	g/m^3	24	28	43	310	-
Total Nitrogen	g/m^3	1.18	1.03	1.16	3.6	-
Total Kjeldahl Nitrogen (TKN)	g/m^3	0.22	0.32	0.51	2.2	-
Total Phosphorus	g/m^3	0.070	0.070	0.102	0.62	-
Carbonaceous Biochemical Oxygen Demand ($cBOD_5$)	$g\ O_2/m^3$	< 2	< 2	< 2	< 2	-
Escherichia coli	MPN / 100mL	211 #1	538 #1	5,480 #1	19,860 #1	-
Nutrient Profile						
Total Ammoniacal-N	g/m^3	< 0.010	0.029	0.025	0.161	-
Nitrite-N	g/m^3	< 0.002	< 0.002	0.002	0.004	-
Nitrate-N	g/m^3	0.96	0.70	0.65	1.40	-
Nitrate-N + Nitrite-N	g/m^3	0.96	0.71	0.65	1.40	-
Dissolved Reactive Phosphorus	g/m^3	0.020	< 0.004	0.008	0.005	-

Analyst's Comments

#1 Please interpret this result with caution as the sample was > 10 °C on receipt at the lab. The sample temperature is recommended by the laboratory's reference methods to be less than 10 °C on receipt at the laboratory (but not frozen). However, it is acknowledged that samples that are transported quickly to the laboratory after sampling, may not have been cooled to this temperature.

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 simple 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. A detection limit range indicates the lowest and highest detection limits in the associated suite of analytes. A full listing of compounds and detection limits are available from the laboratory upon request. Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Aqueous

Test	**Method Description**	**Default Detection Limit**	**Sample No**
Nutrient Profile		0.0010 - 0.010 g/m^3	1-4
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1-4
Total Suspended Solids	Filtration using Whatman 934 AH, Advantec GC-50 or equivalent filters (nominal pore size 1.2 - 1.5µm), gravimetric determination. APHA 2540 D (modified) 23rd ed. 2017.	3 g/m^3	1-4
Total Nitrogen	Calculation: TKN + Nitrate-N + Nitrite-N. Please note: The Default Detection Limit of 0.05 g/m^3 is only attainable when the TKN has been determined using a trace method utilising duplicate analyses. In cases where the Detection Limit for TKN is 0.10 g/m^3, the Default Detection Limit for Total Nitrogen will be 0.11 g/m^3.	0.05 g/m^3	1-4
Total Ammoniacal-N	Phenol/hypochlorite colourimetry. Flow injection analyser. (NH_4-N = NH_4^+-N + NH_3-N). APHA 4500-NH_3 H (modified) 23rd ed. 2017.	0.010 g/m^3	1-4
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.002 g/m^3	1-4

ilac-MRA 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: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m^3	1-4
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.002 g/m^3	1-4
Total Kjeldahl Nitrogen (TKN)	Total Kjeldahl digestion, phenol/hypochlorite colorimetry. Discrete Analyser. APHA 4500-N_{org} D (modified) 4500 NH_3 F (modified) 23rd ed. 2017.	0.10 g/m^3	1-4
Dissolved Reactive Phosphorus	Filtered sample. Molybdenum blue colourimetry. Flow injection analyser. APHA 4500-P G (modified) 23rd ed. 2017.	0.004 g/m^3	1-4
Total Phosphorus	Total phosphorus digestion, ascorbic acid colorimetry. Discrete Analyser. APHA 4500-P B & E (modified from manual analysis and also modified to include a reductant to reduce interference from any arsenic present in the sample) 23rd ed. 2017. NWASCO, Water & soil Miscellaneous Publication No. 38, 1982.	0.004 g/m^3	1-4
Carbonaceous Biochemical Oxygen Demand ($cBOD_5$)	Incubation 5 days, DO meter, nitrification inhibitor added, seeded. APHA 5210 B (modified) 23rd ed. 2017.	2 g O_2/m^3	1-4
Escherichia coli	MPN count using Colilert (Incubated at 35°C for 24 hours), or Colilert 18 (Incubated at 35°C for 18 hours). APHA 9223 B 23rd ed. 2017.	1 MPN / 100mL	1-4

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

Dates of testing are available on request. Please contact the laboratory for more information.

Samples are held at the laboratory after reporting for a length of time based on the stability of the samples and analytes being tested (considering any preservation used), and the storage space available. Once the storage period is completed, the samples are discarded unless otherwise agreed with the customer. Extended storage times may incur additional charges.

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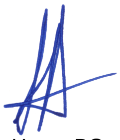

Ara Heron BSc (Tech)
Client Services Manager - Environmental

C

Appendix C – Possible Restoration Planting Outside Designation

Figure C-1: Potential restoration planting opportunities, including to the west of the WWTP designation (dark green shaded; subject to landowner discussion and confirmation of availability).