Effects of Flood Protection Activities on Aquatic and Riparian Ecology in the Waikanae River

Prepared for Greater Wellington Regional Council (Flood Protection)

December 2016

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QUALITY STATEMENT

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Executive Summary

Greater Wellington Regional Council (GWRC) is seeking resource consents to allow for the continuation of its river management activities in the following parts of the Waikanae River and Waimeha Stream ("the application area"):

- the 7 km length of the Waikanae River between the Waikanae Water Treatment Plant weir and the coastal marine area (CMA), and
- the 1.8 km length of Waimeha Stream between Park Avenue and the CMA, and part of the estuary within the CMA.

The consent applications are described in detail in Tonkin and Taylor (2015). In parallel with preparation of these consent applications, GWRC has developed an Environmental Code of Practice (Code) and Monitoring Plan (EMP) which is intended to monitor and guide how all flood protection and erosion controls are undertaken (GWRC, working draft 2015).

The present report forms part of the consent application documentation. It describes the current state of watercourses within the application area, outlines the proposed flood protection activities, and provides an assessment of the potential effects of the proposed flood protection activities on river ecology. It also makes recommendations on measures that could potentially avoid or mitigate adverse effects, and environmental monitoring that should be undertaken to provide the ability to adaptively manage these activities and to provide for the maintenance or enhancement of aquatic ecosystem health. These recommendations have formed the basis for the monitoring proposed in GWRC's EMP.

The Waikanae River is a steep watercourse which drains the south-western foothills of the Tararua Ranges, and flows approximately 25 km westwards to the Tasman Sea. While steep, the upper catchment has a mature indigenous forest cover which minimises catchment erosion. The river passes through the coastal hills in a well-defined and entrenched channel, and is then bounded by low terraces before crossing a depositional fan and flowing around sand hills to the Waikanae Estuary. The lower reach crossing the depositional fan contains the application area. The Waikanae River within the application area supports a moderately diverse fish fauna including four species considered to be at risk (Declining)[1]. Brown trout are found throughout the river system and constitute a recreational trout fishery. The Waikanae Estuary has been identified as a site of value for native birds, including one of only two known populations of North Island Fernbird, and one of the largest nesting colonies of pied shags in the region.

GWRC proposes that the full 'tool box' of flood protection activities as described in the Code should be available for use in the application area. Many of the flood protection activities assessed here are identified as having potential adverse effects on the river ecology due to changes that they cause in water quality, riverine or riparian habitat, or due to direct impacts on river bird, benthic macroinvertebrate or fish communities. In many cases the adverse effects of individual works will be temporary, or can be avoided or mitigated by the application of good practice methods and by scheduling the works so as to avoid periods of peak sensitivity at specific locations, such as fish spawning and peak fish migrations, as specified in the Code.

It is this report's assessment that some practices such as the establishment of vegetative buffer zones, willow planting and layering, and construction of rock groynes, will have mostly positive effects on river ecology, while other activities involving a greater level of disruption to benthic habitats, such as gravel extraction and bed recontouring, will tend to have more negative effects.

Bed recontouring, channel re-alignment and gravel extraction are identified as having the greatest potential for adverse effects on river ecology in the short term. These activities involve major mechanical disturbance of benthic habitats, and create a visible discharge plume as well as increased rates of fine sediment deposition downstream. Research conducted on rivers in the northern Wairarapa Valley shows that individual works on short reaches (100m to 150m lineal length) do not have a lasting adverse effect on benthic ecology or fish communities, and that adverse effects are not likely to last much beyond the first fresh. Channel re-alignment works on a 220m reach of the Hutt River which resulted in a net loss of swift riffle habitat had a more lasting but localised effect of the fish community, probably requiring a series of freshes for full recovery. A key factor for speed of recovery appears to be

[1] Goodman et al, 2014: Conservation status of New Zealand Freshwater Fish.

the close availability of suitable habitat which acts as a nursery for recolonization. This habitat can be natural (i.e. other undisturbed parts of the river bed or could be artificially created).

The potential effects of larger scale works, for instance where mechanical disturbance of the river bed extends over river lengths of greater than 800m, are less well characterised, mainly because works on that scale occur infrequently and the opportunity to assess the effects of such activities has not arisen in recent years. It is assumed that the scale of effects might increase roughly in proportion with the scale of works, but that hypothesis is yet to be tested. For this reason a tiered ‘event’ monitoring approach is recommended by this report and proposed in the EMP, with increasing monitoring effort required for larger scale works sites.

It is recognised that information on the cumulative effect of multiple small works undertaken at different locations and at different times is currently limited. Effects of this type are more difficult to identify and will not necessarily be detected by monitoring focused on individual work sites. For this reason, in addition to the proposed event monitoring, an ongoing baseline monitoring programme is proposed to detect changes in geomorphological characteristics at specified river reaches over time, utilising a natural character index (NCI) to combine these various monitoring results. Baseline monitoring will also include biological variables and it is anticipated that, in the longer term, the monitoring programme will provide an improved understanding of the relationship between natural character and ecological health. The results of monitoring under the EMP will feed into a regular review of the activities and processes specified in the Code with the aim of improving environmental and other outcomes over time.

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1 Introduction

Greater Wellington Regional Council (GWRC) has a responsibility to manage the region's waterways for the minimisation and prevention of flood and erosion damage, as well as the maintenance of aquatic ecosystem health. GWRC's Flood Protection Department (Flood Protection) has lodged resource consent applications to undertake flood protection activities in a 7 km length of the Waikanae River, between the Waikanae Water Treatment Plant weir and the coastal marine area (CMA), and part of the river lying in the CMA. It will also cover parts Waimeha Stream. These reaches, shown on Figure 1-1 as a blue line, are referred to in this report as the "application area". Consent is sought for 35 years.

The new consents are intended to replace existing consents that currently allow for flood protection activities on these watercourses. The consent applications are described in detail in Tonkin and Taylor (2015).

The aim of this report is to describe, as far as is practicable based on available information, the current state of watercourses within these areas and at nearby reference locations (Section 3), to outline the proposed flood protection activities (Section 4), and to assess the potential effects of the proposed flood protection activities on river ecology (Sections 5 & 6). It makes recommendations on measures that could potentially avoid or mitigate adverse effects (Section 7), and environmental monitoring that should be undertaken to provide the ability to adaptively manage these activities and to provide for the maintenance or enhancement of aquatic ecosystem health (Section 8).

In parallel with this report GWRC has developed an Environmental Code of Practice (Code) and Monitoring Plan (EMP) which is intended to monitor and guide how all flood protection and erosion controls are undertaken (GWRC, working draft 2015). The recommendations of this report have been taken into consideration in the development of the Code and EMP.

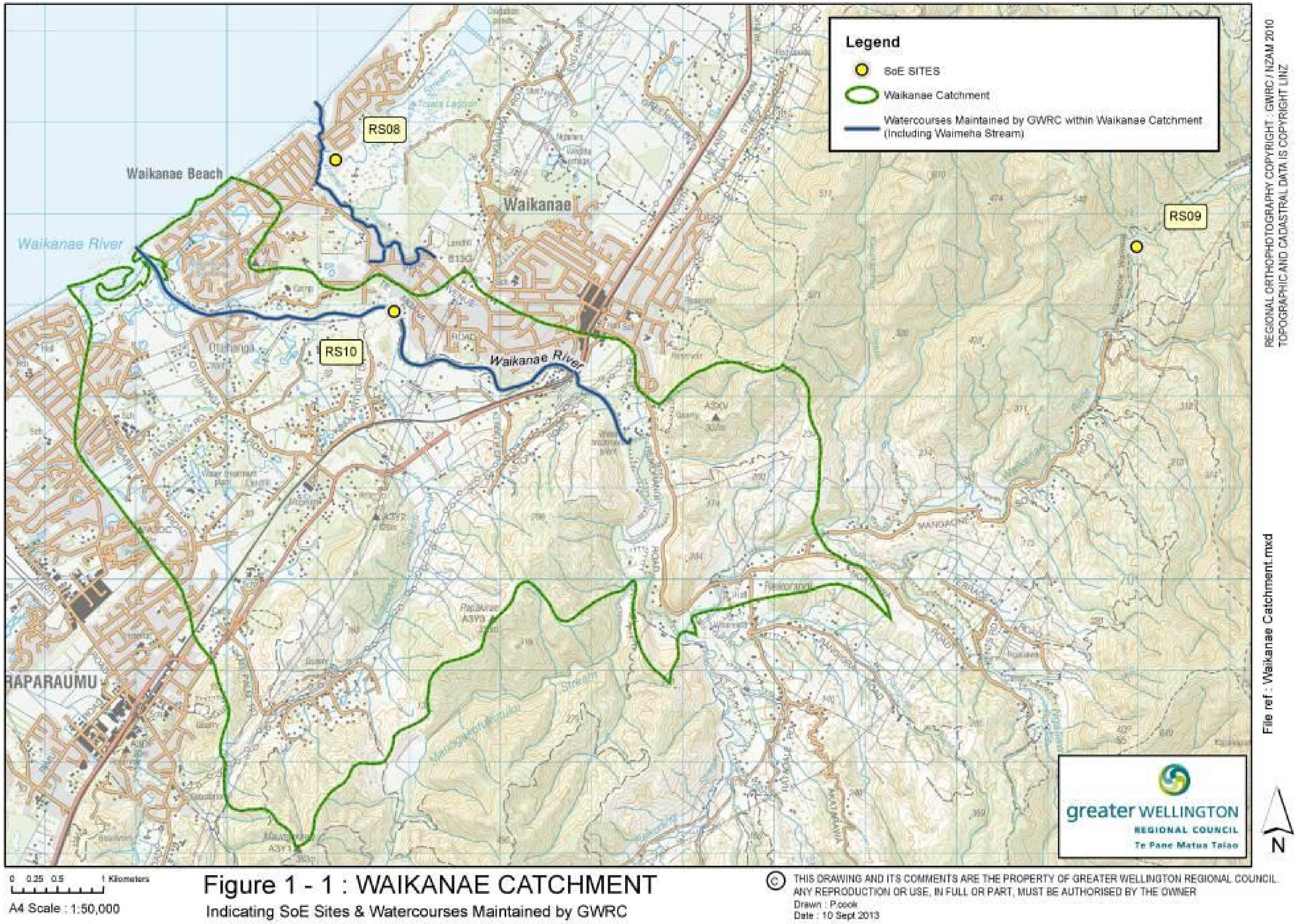

Figure 1 - 1 : WAIKANAE CATCHMENT
Indicating SoE Sites & Watercourses Maintained by GWRC

Drawn : P.cook
Date : 10 Sept 2013

2 Information Sources

Information on the water quality and biology of the Waikanae River and Waimeha Stream, and relevant information for other watercourses have been collected from a range of sources as summarised in Table 2-1.

Table 2-1: Information sources used in this report

Source	*Information*	*Sites sampled*	*Other details*
Cameron (2015a)	Habitat quality, water quality and fish	Three sites on the Hutt River	Before-After-Upstream-Control assessment of FP channel re-alignment works
Cameron (2015)	Habitat quality, aquatic vegetation, macroinvertebrates	Waimeha Stream	Site walkover, July 2015
Death & Death (2013)	Habitat quality, deposited sediment, periphyton macroinvertebrates and fish	Three sites on the Waiohine, Waingawa and Upper Ruamahanga Rivers	Before-After-Upstream-Control assessment of various FP river works
Department of Conservation BioWeb *Herpetofauna* database.	*Herpetofauna* distributions	1km wide river corridor around the Waikanae River application area	Database accessed August 2015 + Trent Bell, unpublished data
Fish & Game drift dive data	Trout	Five sites on Waikanae River	Drift dive data 1999 to 2014
Leathwick *et al* 2010	Freshwater Ecosystems of New Zealand (FENZ) Geodatabase	River of New Zealand	Predicted invertebrate and fish distributions
GWRC data	GWRC water quality, periphyton, macroinvertebrates, landcover, land use	Three SOE sites on the Waikanae River system	January 2004 to March 2015
GWRC maps	Application area, GWRC assets, RSoE sites, inanga spawning areas, riparian vegetation	Entire application area	
New Zealand Freshwater Fish Database (NZFFD)	Fish	35 sites within and upstream of the application area	Data 1960 to 2015
McArthur, Small and Govella (2015)	Birds	Otaki, Waikanae and Hutt Rivers	Baseline monitoring 2012, 2013 and 2014
McArthur, Robertson, Adams and Small (2015)	Birds	Wellington Region	Habitats of significance for indigenous birds
McArthur and Lawson (2013)	Birds	Review of sites with significance for rare or threatened birds	
Perrie *et al* (2012); Perrie and Conwell (2013); Morar and Perrie (2013); Heath *et al* (2014).	GWRC water quality, periphyton, macroinvertebrates, landcover, land use	3 SOE sites on the Waikanae River and Waimeha Stream/Ngarara Stream	Monthly data from July 2008 to June 2014.
Perrie (2009, unpublished draft)	Habitat quality, periphyton macroinvertebrates and fish	Four sites on the Waingawa River	Before-After-Upstream-Control assessment of FP activities (instream)
Perrie (2013); Cameron (2013)	Habitat quality, macroinvertebrates and fish	Three sites on the Hutt River at the Harcourt-Werry beaches	Before-After assessment of FP gravel extraction works

3 Description of Existing Environment

GWRC undertakes flood protection operations and maintenance activities on the Waikanae River between the KCDC Water Treatment Plant weir and the CMA boundary, a river length of 7 km, and on parts of Waimeha Stream. It is also responsible for management of the Waikanae River channel alignment through part of the Waikanae Estuary, the Waimeha Estuary and the mouth alignment of both watercourses.

A detailed aerial view of the application area in the Waikanae River is shown in GWRC Map Series W-271/1-8 included in Appendix A. The application area within Waimeha Stream is shown on GWRC map series W-271/9-11 in Appendix B. The portion of the application area affecting the Waikanae Estuary is shown on Figure 3-16. The Waimeha Estuary is shown in Figure 3-20.

3.1 Freshwater Habitats: Waikanae River & Waimeha Stream

3.1.1 Physical characteristics

3.1.1.1 Waikanae River

The Waikanae River is a steep watercourse which drains the south-western foothills of the Tararua Ranges, and flows approximately 25 km westwards to the Tasman Sea. The Waikanae catchment shares a drainage divide with the Hutt and Otaki catchments where elevations reach 1,100m in altitude. The catchment has a total area of 149 km^2 and has an average slope of 113m in 2 km. While steep, the upper catchment has a mature indigenous forest cover which minimises catchment erosion. The river passes through the coastal hills in a well-defined and entrenched channel, and is bounded by low terraces before crossing a depositional fan. The river then flows around sand hills to the estuary. (The application area includes the lower river on the depositional fan and the estuary.)

The earliest plan records (of 1890) show the Waikanae River with two separate branches below the SH1 Bridge, with one branch generally following the present river channel, and the other the present course of the Waimeha Stream. The river channels would have been relatively shallow, within a wetland and forest swamp environment (Williams 2013).

The gravel bed material of the Waikanae River is relatively fine compared with the Hutt or Otaki Rivers. Bed material transport capacity decreases with the lessening of the river grade below the bridges, and surface material on the bed becomes finer, with a sand bottom in the estuary. Generally there is a trend of bed aggradation from the river mouth upstream to Greenaway Road and bed degradation above that point. The change from aggradation to degradation coincides with a change in grade in the river. It is estimated that the annual sediment inflow rate at Greenaway Road is 6,000m^3.

The river has a median flow of 3.1 m^3/s at the Water Treatment Plant. The Waikanae's main tributaries are the Maungakotukutuku Stream, Reikorangi Stream, Rangiora River and Ngatiawa River. Mazengarb Stream is a low gradient, soft bottomed, minor tributary of the Waikanae River which drains low lying land between Otaihanga Road and Mazenbarb Road, and which flows into Waikanae Estuary some 700m upstream of the coast.

GWRC maintains two state of the environment river monitoring sites (RSoE) on the Waikanae River, one in the forested upper catchment at Mangaone Walkway (RS09) upstream of the application area, and a second on the lower river at Greenaway Road (RS10), within the application area. RS10 is located approximately three kilometres upstream of the river mouth (Figure 1-1). A third site (RS08) is located outside of the application area on Ngarara Stream (a tributary of Waimeha Stream lying to the north of the Waikanae River). Details of river characteristics at the RSOE sites within and upstream of the application area are included in Table 3-1. GWRC habitat grades are presented in Table 3-2.

Table 3-1: GWRC RSoE %Land-cover types in contributing catchment (from Perrie et al 2012)

Site no.	*Site name*	*Site type*	*Habitat grade*	*% Landcover types in upstream catchment*						
				Indigenous forest and scrub	*Exotic forest*	*Horticult ure*	*Pasture (high prod.)*	*Pasture (low prod.)*	*Urban (%)*	*Other (%)*
RS08	Ngarara Stream @Field W.	Impacted	poor	21.6	5.1	0.1	23.5	29.0	17.2	3.5
RS09	Waikanae R. @ Mangaone	Best avail	excellent	84.3	15.6	0.0	0.0	0.1	0.0	0.0

RS10	Waikanae R.@ Greenaway	Impacted	good	66.9	12.5	0.0	4.4	15.2	0.9	0.1

Note: sites within the area potentially affected GWRC flood protection activities (the application area) are shaded grey.

Table 3-2: Habitat scores for SOE sites assessed in summer/autumn 2014 (from Heath, et al,2014)

Site no.	*Site name*	*Fine sediment*	*Invert. habitat*	*Fish cover*	*Hydraulic hetergen-eity*	*Bank stability*	*Bank vege-tation*	*Riparian buffer*	*Riparian shade*	*Channel alteration*	*Total habitat score (of 220)*
RS08	Ngarara Stream @FW	1	2	10	1	10	5.25	6	3	8	46.25
RS09	Waikanae @Mangaone	19	40	40	20	18.5	20	19.5	20	20	217
RS10	Waikanae @Greenaway	20	30	20	15	18	11.5	12	9	15	150.5

3.1.1.2 Waimeha Stream

The Waimeha Stream and its tributary Ngarara Stream are spring-fed watercourses which drain low lying areas of land on the northern edge of Waikanae, including Te Harakiki Swamp, Totara Lagoon and surrounding farmland as well as the Waikanae township. The Waimeha Stream was formerly a tributary of the Waikanae River, but in the 1920's an artificial cut was made to create a new mouth for the Stream and separate it from the Waikanae River, to allow for subdivision of the original Waikanae Beach settlement.

The stream lies within an urban landscape with managed grass edges and exotic trees. The riparian vegetation mostly consists of long grasses with various native and exotic shrubs and weeds, and exotic trees (Figure 3-1 and 3-2).

The stream channel is weakly sinuous, set in sandy soil, with sharply cut edges resulting from silt/weed clearance for maintenance of drainage capacity. The lower reach adjacent to the golf course has an average width of 3 - 4m, centre channel depth of 0.4m (Figure 3-3). At this point the dominant substrate cover is silty sand, with abundant wood debris (some of which appears to drift wood carried upstream from the coast by tidal flows). Deposited sediment levels in the stream are relatively high as a result of agriculture and urban development in the surrounding catchment (see Table 3-3 and 3-4.).

Figure 3-1: View of Waimeha Stream below the Ngarara confluence

Figure 3-2: Waimeha Stream near Hona Street

Figure 3-3: Waimeha Stream within the golf course

Table 3-3: Stream channel characteristics of Waimeha Stream (MWH, 27/7/2015)

Habitat Parameter	*Sampling Site*	
	Waimeha Stream	*Waimeha Stream*
Location	Downstream Ngarara	Huiawa/Hona Streets
NZTM Ref	N5474763; E1771035	N5474476; E1771004
Channel shape	straight	Weakly sinuous
Flow conditions	Base flow	Base flow
Flow types	run	run
Mean wetted width (m)	4	3
Mean thalweg depth (cm)	0.4	0.4
%fine sediment cover	60	60
Dominant substrate	Silt/sand	Silt/sand
Periphyton %cover		
Filamentous >2cm long	None visible	None visible
Cyanobacteria >1mm thick	None visible	None visible
All mats >3mm thick	None visible	None visible
Wood	abundant	abundant

Table 3-4: Rapid habitat assessment results summary (using a protocol from Clapcott, 2015)

Habitat parameter	*Sampling Site*	
	Waimeha Stream (Downstream Ngarara)	*Waimeha Stream (Huiawa/Hona Streets)*
Deposited sediment	2	2
Invertebrate habitat diversity	3	3
Invertebrate habitat abundance	4	4
Fish cover diversity	3	3
Fish cover abundance	5	5
Hydraulic heterogeneity	3	3
Bank erosion	8	8
Bank vegetation	3	3
Riparian width	3	3
Riparian shade	4	5
Habitat quality score (of 100)	38	39

3.1.2 Water Quality

3.1.2.1 Waikanae River

Surface water quality is routinely monitored by GWRC at two RSoE sites on the Waikanae River, one in the forested upper catchment at Mangaone Walkway (RS09) upstream of the application area, and a second at Greenaway Road (RS10) within the application area and approximately three kilometres upstream of the river mouth (Figure 1-1). A third site (RS08) outside of the application area is located on Ngarara Stream, a tributary of Waimeha Stream.

GWRC uses a water quality index (WQI) to facilitate inter-site comparisons of the state of water quality in the Region's rivers and streams (Morar & Perrie, 2013). The WQI is derived from the median values of the following six variables: visual clarity (black disc), dissolved oxygen (%sat), dissolved reactive phosphorus, ammoniacal nitrogen, nitrate-nitrite nitrogen and *Escherichia coli (E. coli).* The WQI enables water quality at each site to be classified into one of four categories:

- Excellent: median value of all six variables comply with guideline values
- Good: median values for five of six variables comply with the guideline values, of which dissolved oxygen is one variable that must comply
- Fair: median values for three or four of the six variables comply with guideline values, of which dissolved oxygen is one variable that must comply
- Poor: median values of less than three of the six variables comply with the guideline values.

Guidelines and trigger values used by GWRC in the WQI assessment and more generally to assess the current state of water quality in rivers and streams in the Wellington Region are listed in Table 3-5. WQI grades for the year to June 2014 for RSoE sites located within and upstream of the application area are shown in Table 3-6 and water quality results for the five year period from January 2010 to March 2015 are summarised in Table 3-7.

Table 3-5: Guidelines and trigger values used by GWRC to assess current state of water quality in rivers and stream (after Perrie, et al, 2012)

Variable	Guideline value	Reference	GW WQI
Water temperature (°C)	≤19	Quinn and Hickey (1990) & Hay et al (2007	-
	≤25	Regional Freshwater Plan (RFP) (WRC 1999)	-
Dissolved oxygen (%sat)	≥80	RMA 1991 Third Schedule and WRC 1999 RFP 'bottom line'	✓
pH	6.5-9.0	ANZECC (1992)	-
Visual clarity (m)	≥1.6	MfE (1994) – guideline for recreation	✓
Turbidity (NTU)	≤5.6	ANZECC (2000) lowland TV	-
Nitrate-nitrogen (mg/L)	≤0.444	ANZECC (2000) lowland TV	✓
Ammoniacal nitrogen (mg/L)	≤0.021	ANZECC (2000) lowland TV	-
	Varies	ANZECC (2000) freshwater toxicity TV (95% protection level)	✓
Dissolved inorganic nitrogen (mg/L)	≤0.465	ANZECC (2000) by addition of the nitrate, nitrite and ammonia TVs	-
Total nitrogen (mg/L)	≤0.614	ANZECC (2000) lowland TV	-
Dissolved reactive phosphorus (mg/L)	≤0.10	ANZECC (2000) lowland TV	✓
Total phosphorus (mg/L)	≤0.033	ANZECC (2000) lowland TV	-
E. coli (cfu/100ml)	≤100	ANZECC (2000) stock water TV	✓
	≤550	MfE/MoH (2003) action level for recreation	

Table 3-6: Water Quality Index grades for RSoE sites in the application area (grey) and at upstream sites (unshaded) from monthly samples collected from July 2013 to June 2014 (Heath, et al, 2014)

Site	Site name	Water quality grade	Rank (of 55)	Guideline compliance (median values)					
				DO	Clarity	E. coli	NNN	Amm. N	DRP
RS08	Ngarara Stream @Field W.	poor	52	✗	✗	✗	✓	✗	✗
RS09	Waikanae R. @ Mangaone	good	23	✓	✓	✓	✓	✓	✗
RS10	Waikanae R.@ Greenaway	excellent	6	✓	✓	✓	✓	✓	✓

The annual monitoring report for the year to June 2014 (Heath, *et al*, 2014) graded RS10 (within the application area) as having "excellent" water quality while site RS09 (upstream of the application area) was rated as "good". The lower score at the upper catchment site was due to elevated dissolved reactive phosphorus (DRP) concentrations at that location, even at times of low flow, which may be a natural feature reflecting the underlying geology (a significant area of plantation forestry located immediately upstream of this monitoring site may also affect water quality in this reach). Sites RS10 and RS09 were ranked 6th and 23rd respectively, out of the 55 RSoE sites monitored in the Wellington Region.

Median water quality at the RSoE sites at times when the river flow is less than median are summarised in Table 3-8. These results are relevant to the extent that in-river flood protection works are most likely to be undertaken during moderate to low flows. Table 3-8 indicates that total suspended solids and turbidity values are lower and visual water clarity correspondingly higher when river flows are low.

Table 3-7: Summary of GWRC monthly water quality data at Waikanae River RSoE sites sampled monthly between Jan 2010 and March 2015 (n=69). Median values that did not meet a guideline are shown in bold font.

Determinand	*Waikanae River @ Mangaone Walkway (RS09) (upstream of application area)*			*Waikanae River @ Greenaway Road (RS10) (within application area)*			*Guideline value*
	median	*min*	*max*	*median*	*min*	*max*	
Water temp. (°C)	11.6	5.4	16.5	14.5	8.16	22.2	≤19
DO (%saturation)	98.4	80.8	112	102	65.4	117	≥80
pH	7.44	5.85	8.17	7.37	6.65	8.80	6.5-9.0
Visual clarity (m)	3.33	0.21	7.50	3.13	0.15	8.89	≥1.6
Turbidity (NTU)	0.7	0.28	22	0.55	0.21	42	≤5.6
Suspended solids (mg/L)	<1	<1	29	<1	<1	92	--
Conductivity (µS/cm)	86	62	98.4	103	78	158	--
TOC (mg/L)	1.57	0.71	9.8	1.50	0.67	8.9	--
NNN (mg/L)	0.117	0.031	0.280	0.220	0.020	0.480	≤0.444
Ammoniacal N (mg/L)	<0.005	<0.003	0.036	<0.005	<0.003	0.027	≤0.021
Total N (mg/L)	0.188	0.055	0.560	0.290	0.055	0.820	≤0.614
DRP (mg/L)	0.013	0.006	0.019	0.008	0.002	0.015	≤0.010
Total P (mg/L)	0.015	0.008	0.047	0.009	0.002	0.119	≤0.033
E. coli (cfu/100ml)	11	<1	1200	27	4	15000	≤550

Table 3-8: Median water quality values at Waikanae River sites at times when river flow is less than median, from monthly samples collected between 2004 and 2009 (n=31) provided by GWRC.

Determinand	*Waikanae River @ Mangaone Walkway (RS09)*	*Waikanae River @ Greenaway Road (RS10)*	*Guideline value*
Water temp. (°C)	12.3	15.9	≤19
DO (%saturation)	97.3	104	≥80
pH	7.55	7.35	6.5-9.0
Visual clarity (m)	4.51	2.61	≥1.6
Turbidity (NTU)	0.53	0.49	≤5.6
Suspended solids (mg/L)	<1	<1	--
Conductivity (µS/cm)	87.5	108	--
TOC (mg/L)	1.478	1.00	--
NNN (mg/L)	0.124	0.116	≤0.444
Ammoniacal N (mg/L)	<0.005	<0.005	≤0.021
Total N (mg/L)	0.189	0.190	≤0.614
DRP (mg/L)	0.013	0.008	≤0.010
Total P (mg/L)	0.021	0.010	≤0.033
E. coli (cfu/100ml)	45	25	≤550

Results of selected variables at sites RS09 and RS10 are summarised by annual boxplot for the years 2004 to 2015 to show trends over time (Appendix C). A Mann-Kendall Trend Test for Site RS10 results identified an increasing trend ($p<0.05$ and rate of change >1% per year) for water temperature and water clarity over that period, but no meaningful trends for other water quality variables.

3.1.2.1 Minor Streams

Mazengarb Stream (outside the application area, but flowing into it) receives treated wastewater from the Paraparaumu Wastewater Treatment Plant and historically has been a source of contaminant inputs to the Waikanae Estuary. However, Kapiti Coast District Council completed a major upgrade of the wastewater treatment plant during 2002, introducing nutrient removal and disinfection to the treatment process. The upgraded facility now achieves a high quality final wastewater, and appears to have reduced the adverse effects of the discharge on the water quality of the Waikanae River and estuary.

The Ngarara Stream (also outside the application area, but flowing into it) is a slow flowing, low elevation coastal stream which drains Te Harakiki Swamp and Totara Lagoon as well as production pasture to the north (and the now decommissioned Waikanae oxidation ponds). The Ngarara Stream is a tributary of the Waimeha Stream, flowing into the Waimeha immediately upstream of Field Way Road Bridge. Heath *et al* (2014) describes the Ngarara Stream as having “poor” water quality due to low dissolved oxygen content, low visual clarity and elevated nutrient content. This may be a consequence of a slow moving, low gradient watercourse within a predominantly agricultural catchment. Heath *et al* (2014) ranked site RS08 on Ngarara Stream 52nd of 55 RSoE sites.

The Waimeha Stream is the only minor water course included within the application area. Routine water quality data is not available for this site but it is noted that water clarity in Waimeha Stream is normally far greater than its tributary Ngarara Stream, and that the contrast can be striking when observed at the confluence (D Cameron, pers, obs.).

3.1.3 Periphyton

GWRC monitors periphyton cover and biomass at two RSoE monitoring sites, RS09 and RS10, on the Waikanae River. Two data sets are used: monthly observations of percent periphyton streambed cover and periphyton biomass (as indicated by chlorophyll *a* concentration) from annual surveys.

GWRC compares these data sets against the New Zealand periphyton guideline values which are summarised in Table 3-9. The results of periphyton biomass monitoring for the year to June 2010, 2011, 2012, 2013 and 2014 are summarised in Table 3-10. Monthly observations of filamentous and mat forming periphyton cover for the same period are summarised in Table 3-11.

Table 3-9: MfE guidelines used to assess periphyton stream bed cover and biomass (Biggs, 2000)

Instream value	Periphyton cover (%cover)		Periphyton biomass (mg/m^2)
	Mat >0.3 cm thick	Filamentous >2cm long	
Aesthetics/recreation	60%	30%	-
Benthic biodiversity	-	-	50
Trout habitat and angling	-	30%	120

Over the five year period from 2010 to 2014 inclusive, Site RS09 (upstream of the application area) complied with the MfE guidelines for periphyton cover and biomass on all sampling occasions. Over the same five year period Site RS10 (within the application area) also complied with the periphyton cover guideline on all monthly sampling occasions but exceeded the biomass guidelines on one occasion. Percent cover of cynobacteria mats was recorded only for the 2014 year during which both sites complied with the guideline on all monthly sampling occasions. These results show that excessive periphyton growth occurs rarely on the Waikanae River, which is consistent with the relatively low nutrient levels recorded in river water.

Table 3-10: Summary of streambed peripyton biomass at RSoE sites in the Waikanae River application area (grey) and upstream (unshaded), from 2009 to 2014 (after Perrie *et al,* 2011; Perrie and Conwell, 2013; and Morar and Perrie, 2013; and Heath, Perrie, & Morar, 2014). Non-compliance with MfE (2000) guidelines is highlighted in bold type

Site no.	*Site name*	*Chlorophyll a (mg/m^2)*				
		2010	*2011*	*2012*	*2013*	*2014*
RS09	Waikanae R. @ Mangaone	0.90	0.35	2.58	0.29	0.46
RS10	Waikanae R.@ Greenaway	9.7	19.1	**72.73**	14.02	4.95

Table 3-11: Summary of monthly observations of visible streambed filamentous and mat-forming periphyton cover in relation to exceedances of the MfE (2000) guidelines at RSoE sites within the application area (grey) and upstream (unshaded) for the years to June 2010, 2011, 2012, 2013 and 2014 (after Perrie and Conwell, 2013; Morar & Perrie, 2013; Heath, Perrie, & Morar, 2014).

Year	Site no.	Site name	*n*	Streambed cover (%)						
				Filamentous (>2 cm long)		Mats (>0.3 cm thick)		Cyanobacteria mats (>0.1cm thick)		
				Max	n>30% cover	Max	n>60% cover	Max	n 20-50 %	n>50 %
2010	RS09	Waikanae R. @ Mangaone	12	0	0	0	0	nt	nt	nt
	RS10	Waikanae R.@ Greenaway	12	15	0	43	0	nt	nt	nt
2011	RS09	Waikanae R. @ Mangaone	12	0	0	0	0	nt	nt	nt
	RS10	Waikanae R.@ Greenaway	10	13	0	31.5	0	nt	nt	nt
2012	RS09	Waikanae R. @ Mangaone	10	0	0	0	0	nt	nt	nt
	RS10	Waikanae R.@ Greenaway	10	5	0	23	0	nt	nt	nt
2013	RS09	Waikanae R. @ Mangaone	11	0	0	0	0	nt	nt	nt
	RS10	Waikanae R.@ Greenaway	10	30	0	32	0	nt	nt	nt
2014	RS09	Waikanae R. @ Mangaone	12	0	0	0	0	0	0	0
	RS10	Waikanae R.@ Greenaway	11	3	0	7	0	4	0	0

Nt = not tested

3.1.4 Macrophytes

3.1.4.1 Waikanae River

No nationally threatened aquatic or semi-aquatic plant species are known to be associated with the Waikanae River outside of the estuary (the vegetation of the estuarine margins is described in Section 3.2.3). Observations from bankside inspections of the river channel at Jim Cooke Memorial Park and Otaihanga Domain indicate that the River is virtually free of bottom-rooted aquatic macrophytes and that they are not an important feature of the river ecology (D. Cameron pers. obs.).

3.1.4.2 Waimeha Stream

Aquatic macrophytes are a dominant feature of the Waimeha Stream where they occupy up to 100% of the stream channel and can have a major influence on its flood capacity, and its ecology (see Figures 3-2 and 3-3). A survey of the aquatic vegetation of Waimeha Stream was conducted by MWH on 27 July 2015 in the reach between the stream mouth and the Waikanae Golf Club carpark (construction activity associated with the Mackays to Peka Peka Expressway prevented stream access much beyond that point). Vegetation percent-cover values and species recorded are summarised in Table 3-12. Aquatic vegetation maps are included in Appendix D.

In total seven species of bottom rooted macrophytes were identified, including two submerged species (*Lagarosiphon major* and *Aponogeton distachyos)*, four emergent species (*Persicaria hydropiper, Myriophyllum aquaticum, Typha orientalis* and *Apodasmia similis*), as well as the terrestrial *Cortaderia toetoe*, which was present at the stream margins.

Both *Lagarosiphon major* (oxygen weed) and *Aponogeton distachyos* (Cape pondweed) are introduced perennials which are recognised pest species in New Zealand; they often require management to control excess growth (Champion, *et al*, 2013). *Myriophyllum aquaticum* (parrots feather) is an introduced sprawling emergent weed, affecting a wide variety of habitats, with “unwanted organism” biosecurity status in New Zealand (Champion, *et al*, 2013). *Persicaria hydropiper* (water pepper) is an introduced emergent species which normally has relatively minor impacts in waterways. *Typha orientalis* (raupo) is an indigenous wetland plant which grows up to 4m tall, often in large colonies. It is found throughout New Zealand and although it is not threatened its abundance has declined due to the widespread draining wetlands. It provides habitat for eel, spawning inanga and other native fish. *Cortaderia toetoe* is an indigenous giant tussock grass found in swamps and wet ground in the North Island south of Tauranga. It is abundant and is not threatened.

In summary, both raupo and toetoe are native species which can potentially enhance fish habitat in Waimeha Stream, and which should be retained at locations where they do not unduly reduce channel capacity. The other species recorded in this reach are introduced pest species which are likely to require ongoing management to limit sprawl and maintain the channel capacity of Waimeha Stream.

Table 3-12: Vegetation cover (% wetted area) and species

Stream reach	*Submerged*	*Emergent*
Estuarine; downstream of Ngarara confluence	0% None	10% *Typha orientalis (raupo)* *Cortaderia spp. (toetoe)* *Apodasmia similis (jointed rush)*
Ngarara to Hona Street	10% *Lagarosiphon major (oxygen weed)* *Aponogeton distachyos (cape pondweed)*	20% *Persicaria hydropiper (water pepper)* *Myriophyllum aquaticum (parrots feather)* *Typha orientalis (raupo)*
Hona to Hemara	50% *Lagarosiphon major (oxygen weed)*	*10%* *Persicaria hydropiper (water pepper)*
Hemara to golf club carpark	50% *Lagarosiphon major (oxygen weed)*	*30%* *Persicaria hydropiper (water pepper)* *Myriophyllum aquaticum (parrots feather)*

3.1.5 Riparian Vegetation

3.1.5.1 Waikanae River

The Waikanae River's main stem is approximately 19km from the headwaters of the Tararua Forest Park to the coast, the lower 7km of which is within the application area. Riparian vegetation in the upper reaches consists of remnant and regenerating native forest and shrubs, which then transitions to open farmland with scattered tree and grasses providing variable riparian condition. The lower reaches, within the application area, are a mixture of rough pasture and treeland over pasture. Of the 14km of total river bank length within the application area (i.e. two banks of 7km) it is estimated that 7.4km (53%) has been planted with willows as vegetative bank protection. These plantings are mixed with scattered bush remnants in the urban area while the lower reach to the coast is buffered by KCDC reserve, which is grassland and treelands.

Wildland Consultants (2015) have conducted a detailed survey of the riparian edge vegetation at Jim Cooke Memorial Park (within the application area) and concluded that the area did not contain any significant vegetation values. Most of the vegetation in that area consists of exotic grassland while taller vegetation is dominated by exotic tree species, indigenous species not local to the Kapiti Coast, planted indigenous species up to about 40 years old, and some naturally regenerating indigenous shrubs and trees.

Vegetation within the Waikanae River riparian margins is shown in GWRC Map Series HR-5407 (Maps 1a to 41a), which are included in Appendix A. A GIS layer identifies area of planted willows and native vegetation, but does not provide further detail. GWRC has recognised that more detailed mapping of vegetation types within the riparian margins is desirable and has included this as a baseline monitoring item in the EMP, to be completed within three years of the consents being granted and repeated at 9-year intervals thereafter.

3.1.5.2 Waimeha Stream

The stream lies within an urban landscape with managed grass edges and exotic trees. The riparian vegetation mostly consists of long grasses with various native and exotic shrubs and weeds, and exotic trees (refer Figure 3-1 and 3-2, and map series W-271/9-11 in Appendix B).

3.1.6 Macroinvertebrate communities

3.1.6.1 Waikanae River and Waimeha Stream

GWRC undertakes annual macroinvertebrate monitoring at two RSoE sites in the Waikanae River (RS09 and RS10) and one site on the Ngarara Stream at Field Way (RS08). Of these three sites only site RS10 lies within the application area. Macroinvertebrate abundance results from the February 2014 sampling round, and from an additional site on Waimeha Stream (collected by MWH) are included in Appendix D. These results together with predictions from the FENZ database[2] were used to describe core macroinvertebrate communities of the Waikanae River and Waimeha Stream (Table 3-13). Macroinvertebrate composition by relative abundance is illustrated in Figure 3-4 and macroinvertebrate metric scores for the period 2010 to 2014 are summarised in Table 3-14.

The results show that the Waikanae River upstream of the application area at Site RS09 supports a diverse fauna dominated by sensitive EPT[3] taxa, especially the mayflies *Deleatidium* and *Coloburiscus,* the stonefly *Zelandoperla* and the caddisfly *Olinga.* Macroinvertebrate Community Index (MCI) and Quantitative Macroinvertebrate Community Index (QMCI) scores indicate “excellent” quality class in the upper river reflecting the high proportion of indigenous forest land cover, the small proportion of agricultural land-use and an absence of urban development.

The catchment area for lower/middle reach of the River at Site RS10 at Greenaway Road contains urban Waikanae, and nearly 20% in productive pasture. This difference in land-use compared with the upper river catchment is reflected in the macroinvertebrate community composition at Greenaway Road. *Deleatidium* remains the dominant taxa but *Coloburiscus* and *Zelandoperla* are rare and sensitive caddisflies such as *Olinga* are uncommon. The MCI and QMCI metrics indicate “good” quality in this reach, showing that the benthic fauna remains in relatively good condition despite the increased area of agricultural and urban land-use.

Ngarara and Waimeha Streams are both low gradient, spring-fed coastal streams with a soft sediment substrate, and a catchment dominated by agricultural and urban development. There is very little exposed gravel or cobble substrate in these streams; the primary habitat for invertebrates is aquatic plants, which grow very densely, and woody debris. The macroinvertebrate communities reflect these conditions, being dominated by the freshwater snail (*Potamopyrgus*) and crustaceans (copepods, ostrocods, *Paracalliope* and Cladocera). Sensitive EPT taxa are rare in the Ngarara and Waimeha Streams.

Table 3-13: Waikanae River monitoring locations and dominant macroinvertebrate taxa (data from GWRC RSoE, Feb 2014, Cameron, 2015; and FENZ predictions)

Site name	*Catchment land-use*	*Dominant invertebrate taxa (FENZ predictions in brackets)*
Ngarara Stream @Field Way (RS08)	Indigenous forest 21.6% Pasture 52.5% Urban 17.2% Upstream of application area	*Paracalliope>Potamopyrgus>Cladocera>Copepoda* *(Potamopyrgus>Oxythira>Elmidae>Austrosimulium>Orthocladiinae)*
Waimeha Stream W1 (MWH, 2015)	Within application area	*Potamopyrgus>Paracalliope>Amphipoda>Ostracoda* *(Potamopyrgus>Oxythira>Austrosimulium>Orthocladiinae)*
Waikanae River @ Mangaone Walkway (RS09)	Indigenous forest 84.3% Pasture 0.1% Urban 0.0% Upstream of application area	*Deleatidium>Olinga>Coloburiscus>Elmidae>Zelandoperla>Hydrobiosella* *(Deleatidium>Coloburiscus>Elmidae>Zelandoperla>Aoteapsyche>Aphrophila>Olinga)*
Waikanae River @ Greenaway (RS10)	Indigenous forest 66.9% Pasture 19.2% Urban 0.9% Within application area	*Deleatidium>Elmidae>Aoteapsyche>Orthocladiinae* *(Deleatidium>Elmidae>Aoteapsyche>Aphrophila>Coloburiscus)*

[2] Leathwick, et al , 2010: Freshwater ecosystems of New Zealand (FENZ) Geodatabase

[3] EPT includes sensitive taxa from the Ephemeroptera (mayfly) Plecoptera (stonefly) and Trichoptera (caddisfly) insect groups.

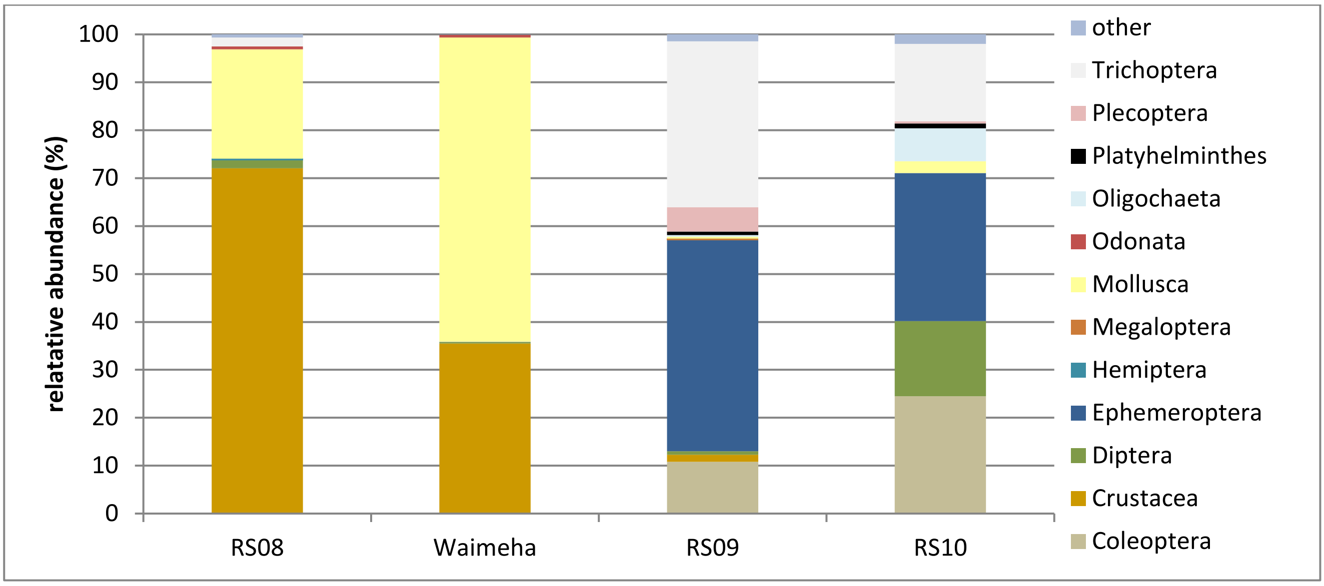

Figure 3-4: Macroinvertebrate community composition by relative abundance

Table 3-14: Mean macroinvertebrate metric scores (and standard deviation) at the Waikanae River and Ngarara Stream RSoE sites based on GWRC data collected annually in 2010, 2011, 2012, 2013 and 2014. MCI and QMCI quality classes (from Stark & Maxted 2007) are also included.

Site no.	*Site name*	*N*	*MCI*	*QMCI*	*N. Taxa*	*N. EPT taxa*	*%EPT taxa*
RS08	Ngarara Stream @ Field Way	5	72.1 (5.74) (Poor)	4.02 (1.30) (Poor/fair)	17.4 (3.51)	2 (1.8)	5.2 (4.57)
W1	Waimeha Stream @ Hona Street	1	76.1 (Poor)	4.79 (Fair)	16	2	13
RS09	Waikanae River @ Mangaone	5	138.5 (5.55) (Excellent)	8.01 (0.21) (Excellent)	28.4 (1.34)	17 (1.87)	65.3 (14.8)
RS10	Waikanae River @ Greenaway	5	113.2 (4.18) (Good)	5.35 (0.79) (Good)	26.4 (6.58)	12.4 (2.30)	48.2 (5.21)

Notes: [1]W1 Waimeha Stream data from MWH, July 2015.
[2]Sites within the FP application area are shaded grey.

3.1.6.2 Limitations of the data

All of the macroinvertebrate monitoring data assessed as part of this investigation have been collected from wadeable areas in riffle or fast-run habitat, in accordance with standard protocols for sampling macroinvertebrate in New Zealand (i.e. Stark, et al, 2001; Stark & Maxted, 2007). It is recognised that macroinvertebrate communities in pools and slow runs have not been described.

Similarly, we have not sighted any specific information on the macroinvertebrate fauna that live within the gravel substrate of the Waikanae River; that is the hyporheic invertebrates. Inhabitants of the hyporheic zone, defined as the water saturated sediment beneath the streambed, includes the “permanent hyporheos”, mainly small crustaceans, mites and worms that spend their entire life cycles there, as well as the “occasional hyporheos” which comprises insects, snails and other taxa more typically associated with surface sediments (Winterbourn & Wright-Stow, 2003). In the absence of specific information it has been assumed for the purpose of this assessment that flood protection activities which include mechanical disturbance of bed material, such as bed re-contouring and gravel extraction, will affect both habitat types, and that the effects on the hyporheos may be of a similar order to those documented for benthic fauna at the surface.

3.1.6.3 Comparison between the application area and upstream reaches

GWRC site RS09 upstream of the application area is characterised as "best available" with "excellent" habitat quality, 84% of the catchment in indigenous forest and 0.1% in production pasture. RS10, within the application area, is by contrast characterised as "impacted" with "good" habitat quality, 67% indigenous forest and 20% production pasture. As a result of these land-use differences the river water concentrations of nitrogen at RS10 are nearly twice those recorded at RS09. Although this does not often result in the development of nuisance level of algae production in the Waikanae River, it may have implications for the benthic fauna. Perrie *et al* (2012) found a strong positive relationship between MCI scores and the proportion of indigenous forest cover in the upstream catchment, and that nitrogen enrichment is strongly linked with macroinvertebrate community composition.

The observed differences in macroinvertebrate community composition between sites RS09 and RS10 are largely explained by the transition from indigenous forest cover of the upper river to the urban areas of Paraparaumu and Waikanae, and the increasing proportion of production pasture and urban land-use at the downstream sites. It is not possible to draw conclusions about the effects of flood protection activities on macroinvertebrate communities at RSoE sites because of these underlying differences in macroinvertebrate habitat. For that reason GWRC has instead undertaken a series of targeted investigations which are specifically focused on the effects of flood protection activities on macroinvertebrate communities (Perrie, 2013b; Death & Death, 2013), as discussed in Section 5 of this report.

3.1.7 Fish Communities

The New Zealand Freshwater Fish Database (NZFFD) was queried for records of sites sampled within the Waikanae River and Waimeha Stream catchments over the period 1960 to 2015 (45 records). In total, 11 NZFFD sites are located within the application area and a further 35 sites are located on watercourses outside (upstream) of the application area. The number of survey sites within and upstream of the application area is listed in Table 3-15.

Table 3-15: Number of NZFFD fish survey sites in each river sampled for freshwater fish (1960-2015)

Watercourse	Number of sites/records within application area	Number of sites/records upstream of application area	Sampling period
Waikanae River	8	23	1980 - 2012
Waimeha Stream	3	0	1990 - 2010
Ngarara Stream	0	12	1992 - 2010

3.1.7.1 Waikanae River

Sixteen species of fish have been recorded within the Waikanae River and tributaries, including fifteen native fish and the introduced brown trout (Table 3-16). The distributions of key species are shown in Figure 3-5 to 3-10. Two fish species recorded in the Waikanae River, the lamprey and shortjaw kokopu, are considered to be threatened (Nationally Vulnerable) and seven species are considered to be at risk due to declining numbers nationally (Goodman, *et al*., 2014).

Ten of these fish species have been recorded within the portion of the application area covering the Waikanae River, the most common of which are lonfin eel and redfin bully (at 100% of survey sites), brown trout and torrentfish (63%), as well as shortfin eel and common bully (50%). Predictions of fish species occurrence from the FENZ database (Leathwick, et al., 2010) based on geographical locations and physical attributes are generally consistent with recorded occurrence.

This analysis indicates that the core fish community of the Waikanae River application area consists of longfin eel, shortfin eel, redfin bully, common bully, torrentfish and brown trout. Other species such as inanga, koaro and banded kokopu are likely to be seasonally abundant but not necessarily resident within the application area.

Most of the indigenous fish species recorded in the catchment, except dwarf galaxias and brown mudfish, are diadromous, that is, they migrate to and from the sea at well-defined life stages, and in most cases the migrations are obligatory. Periods of peak sensitivity for upstream migrations from the sea into the lower river are shown in Appendix F and include the following:

- Peak periods of upstream migration of juvenile galaxiid species (whitebait), torrentfish, bluegill bully and redfin bully occur between August and December;
- Peak periods of upstream migration for juvenile longfin eel, shortfin eel and common bully are later during the summer, from December through to February.
- Juvenile lampreys migrate upstream during winter, from June to September.

Sea run brown trout migrate from the sea into the river during the autumn, moving up through the river and into headwater tributaries to spawn in the winter, however trout are not obliged to spend time in the sea and many trout in the Waikanae River may system move to spawning areas on the main-stem and headwater tributaries during May, June and July.

Downstream migration from the river into the sea occurs for most indigenous species during summer to late-winter and is undertaken by eels as adults and by galaxiids, and bullies as larvae. Downstream migratory activity is influenced by a number of environmental factors including rainfall, water temperature and phase of the moon but is generally assisted by increased river flows, which may make it less susceptible to disruption by in-channel river works.

Given the relatively dispersed character of upstream fish migrations, it is expected that some disturbance due to active-channel works can be tolerated during the migration period without serious disruption to fish recruitment, provided the active channel disturbance does not continue for more than a few days at any particular location or for more than a few weeks within the 7km long application area. Recommendations for the protection of indigenous fish are provided in Sections 7.4, 7.5 and 7.6. and have been incorporated into the Code.

Sensitive periods and locations for fish spawning are summarised in Appendix F and include:

- Inanga spawning habit is located in tidal estuary edge vegetation and occurs during March, April and May. Taylor & Kelly (2001) found suitable areas of inanga spawning habitat on the Waikanae River within and downstream of Otaihanga Reserve, predominantly on the true left (south) bank (see Appendix A). Recommendations for the protection of inanga spawning habitat are provided in Section 7.6 and have been incorporated into the Code.
- Other galaxiid species including koaro, banded kokopu and giant kokopu, spawn in vegetation or cobbles at the riparian margin between April and August. Spawning habitat is generally thought to occur near typical adult habitats (McDowell, 1990; Smith, 2015).
- Bullies spawn in riverbed substrate, often under large rocks, between August and February. Spawning habitat is thought to occur near or upstream of adult habitats (McDowell, 1990; Smith, 2015).
- Torrentfish spawn in riverbed substrate, probably in the lower river near the coast, mostly between January and April.
- Trout move into headwater tributaries, or suitable areas on the main-stem, to spawn during May and June. Development of brown trout eggs takes about four to six weeks, and after hatching the young alevins remain in the redd gravels for several weeks (McDowell, 1990). Trout spawning occurs throughout much of the Waikanae catchment, including parts of the main-stem of the river where habitat is suitable, potentially including some reaches within the application area (Strickland & Quarterman, 2001). Recommendations for the protection of trout spawning habitat are given in Section 7.6. and have been incorporated into the Code.

Table 3-16: Summary of the NZFFD records for the Waikanae River as of June 2015 (n=31). FENZ predictions of occurrence inside and outside of the application area are also provided (see Leathwick, et al., 2010).

Scientific name	Common name	%Occurrence			Migratory species	Threat status (Goodman *et al* 2014)
		Recorded within application area (n=8)	Recorded outside application area (n=23)	Predicted within/ upstream (FENZ)		
Aldrichetta foresteri	Yellow eyed mullet	0	4.3	n.d.	Marine/ estuarine	Not threatened
Anguilla australis	Shortfin eel	50	13	90/10	yes	Not threatened
Anguilla dieffenbachii	Longfin eel	100	100	100/100	yes	At risk (declining)
Cheimarrichthys fosteri	Torrentfish	63	17	20/10	yes	At risk (declining)
Galaxias postvectis	Shortjaw kokopu	0	22	0/90	yes	Threatened (Nationally Vulnerable)
Galaxias brevipinnis	Koaro	0	52	0/90	yes	At risk (declining)
Galaxias fasciatus	Banded kokopu	0	4.3	0/50	yes	Not threatened
Galaxias divergens	Dwarf galaxias	0	13	0/0	no	At risk (declining)
Galaxias maculatus	Inanga	38	4.3	100/10	yes	At risk (declining)
Geotria australis	Lamprey	38	4.3	10/10	yes	Threatened (Nationally Vulnerable)
Gobiomorphus hubbsi	Bluegill bully	0	8.6	10/10	yes	At risk (declining)
Gobiomorphus cotidianus	Common bully	50	13	90/20	yes	Not threatened
Gobiomorphus huttoni	Redfin bully	100	96	100/100	yes	At risk (declining)
Neochanna apoda	Brown mudfish	0	4.3*	n.d.	no	At risk (declining)
Retropinna retropinna	Common smelt	25	8.6	90/10	yes	Not threatened
Rhombosolea retiaria	Black flounder	25	4.3	10/10	yes	Not threatened
Salmo trutta	Brown trout	63	61	50/100	yes	Introduced/naturalised

Notes: n.d. = no data

*The NZFFD has a single record of brown mudfish in an unnamed wetland within the Waikanae catchment, but not directly associated with the Waikanae River

3.1.7.2 Waimeha Stream

Ten species of native fish have been recorded within the Waimeha/Ngarara Stream (Table 3-17). Four of these species (lonfin eel, inanga, giant kokopu and redfinned bully) are considered to be at risk due to declining numbers nationally (Goodman, *et al*., 2014).

Seven of these fish species have been recorded within the portion of the application area covering Waimeha Stream. The most commonly recorded fish species in this area are shortfin eel (at 75% of survey sites), longfin eel (50%), inanga (50%) and common bully (50%). Predictions of fish species occurrence from the FENZ database (Leathwick, et al., 2010) based on geographical locations and physical attributes are broadly consistent with recorded occurrence.

Based on NZFFD records the core fish community of Waimeha Stream application area consists of longfin eel, shortfin eel, inanga and common bully. This is consistent with the results a recent fish survey conducted in the Waimeha Stream as part of the Mackays to Peka Peka Expressway investigations, except that inanga were not recorded in that survey (Risi, 2012).

Taylor and Kelly (2010) identified potential areas of inanga spawning habitat on the Waimeha Stream downstream of the Ngarara confluence and mostly on the true left bank (south), as shown in Appendix B.

Table 3-17: Summary of the NZFFD records for the Waimeha/Ngarara Stream as of June 2015 (n=16). FENZ predictions of occurrence inside and outside of the application area are also provided (see Leathwick, et al., 2010).

Scientific name	Common name	%Occurrence			Migratory species	Threat status (Goodman *et al* 2014)
		Recorded within application area (n=4)	Recorded outside application area (n=12)	Predicted within/ upstream (FENZ)		
Anguilla australis	Shortfin eel	75	92	100/100	yes	Not threatened
Anguilla dieffenbachii	Longfin eel	50	83	60/100	yes	At risk (declining)
Galaxias fasciatus	Banded kokopu	0	17	40/50	yes	Not threatened
Galaxias maculatus	Inanga	50	67	100/100	yes	At risk (declining)
Galaxias argenteus	Giant kokopu	25*	8	10/10	yes	At risk (declining)
Gobiomorphus cotidianus	Common bully	50	58	10/100	yes	Not threatened
Gobiomorphus huttoni	Redfin bully	25	17	30/30	yes	At risk (declining)
Gobiomorphus basalis	Crans bully	0	8	0/0	no	Not threatened
Gobiomorphus gobiodes	Giant bully	25	0	10/10	yes	Not threatened
Retropinna retropinna	Common smelt	0	8	10/10	yes	Not threatened

*Not included in NZFFD but report by Ohau Plants Ltd (2009)

3.1.7.1 Comparison between the application area and upstream reaches

The application area in the Waikanae River begins at the sea and extends 7km through urban Waikanae, terminating upstream of the urban edge at the Water Treatment Plant weir, at an elevation of 29m above sea level. The application area contains the urban reach of the river, and is affected by the close proximity of the Paraparaumu and Waikanae Townships including roads, residential and commercial developments, water abstraction for town supply, and municipal landfill, wastewater treatment plant, etc, and by the loss of indigenous vegetation, with 20% of the contributing catchment in production pasture.

The Waikanae River upstream of the application area is also upstream of the urban area and, although it runs through production pasture in the Reikorangi Valley and production/exotic forestry further upstream, the steep upper catchment is covered by mature indigenous vegetation.

Based on the geographical and geomorphological differences between these areas, some difference in the fish community is to be expected. In particular, low elevation fish taxa such as inanga, smelt, shortfin eel and common bully are predicted to be rare or absent upstream of the application area while other taxa such as dwarf galaxias, koaro and banded kokopu are predicted to be more common at upstream locations. The records summarised in Table 3-16 are generally consistent with those predictions.

In addition to geographical changes, the transition from an indigenous forest catchment of upper catchment to the urban area of Waikanae has caused a range of habitat changes associated with the reduced integrity of riparian vegetation, increased inputs of nutrients (especially nitrogen), and increased occurrence of pest species.

While it would be possible to compare the fish data from application area with an upstream area unaffected by flood protection activities, such a comparison would be meaningless in the context of this assessment because of the geographical, geomorphological, and land-use differences between these areas. It would is not possible to draw any conclusions about the influence of flood protection activities on the distribution of fish on the basis of the NZFFD records. For that reason GWRC has undertaken a series of targeted investigations which are focused on the effects of flood protection activities (i.e., Cameron 2015; Death & Death, 2013; and Perrie, 2013a) as discussed in Section 5.

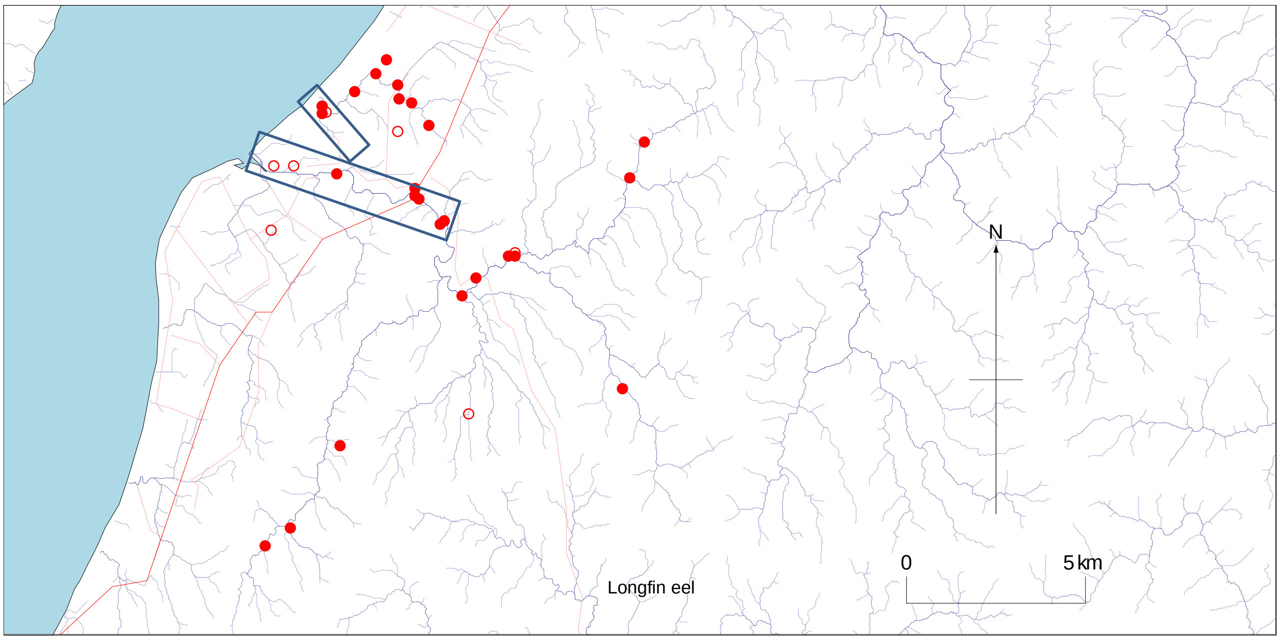

Figure 3-5: Longfin eel records for the Waikanae River and Waimeha Stream (presence indicated as red dots, absence by a circle). Data from NZFFD 1993-2013. The Waikanae and Waimeha application areas are shown indicatively as blue rectangles.

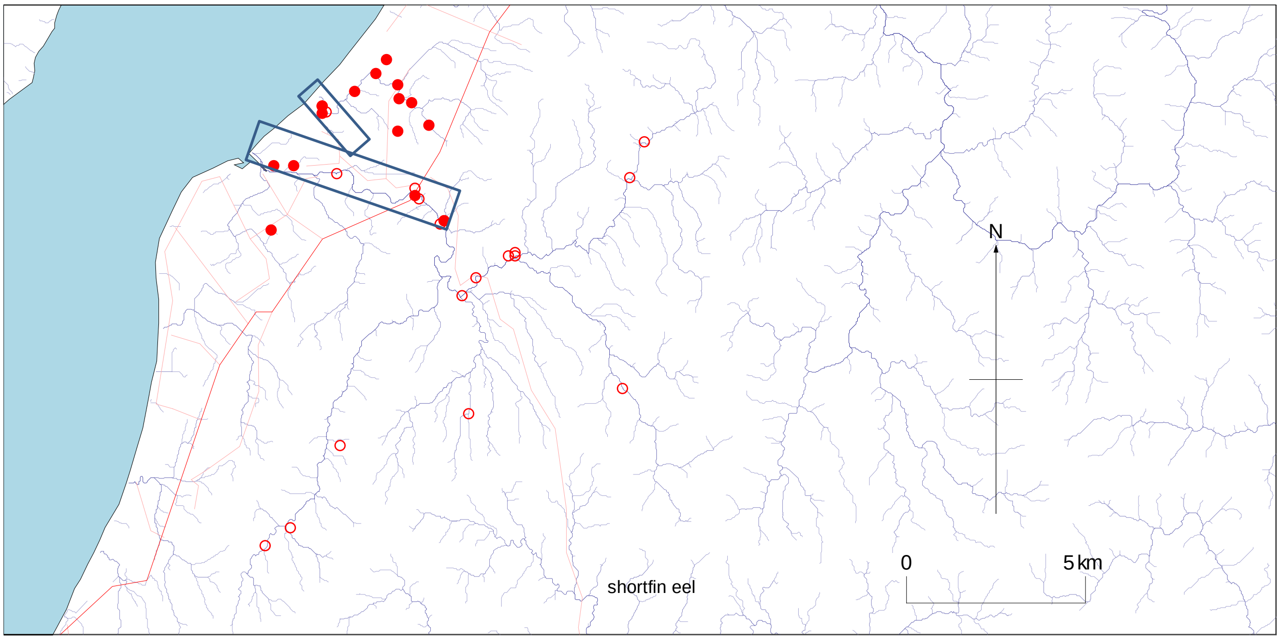

Figure 3-6: Shortfin eel records for the Waikanae River and Waimeha Stream (presence indicated as red dots, absence by a circle). Data from NZFFD 1993-2013. The Waikanae and Waimeha application areas are shown indicatively as blue rectangles.

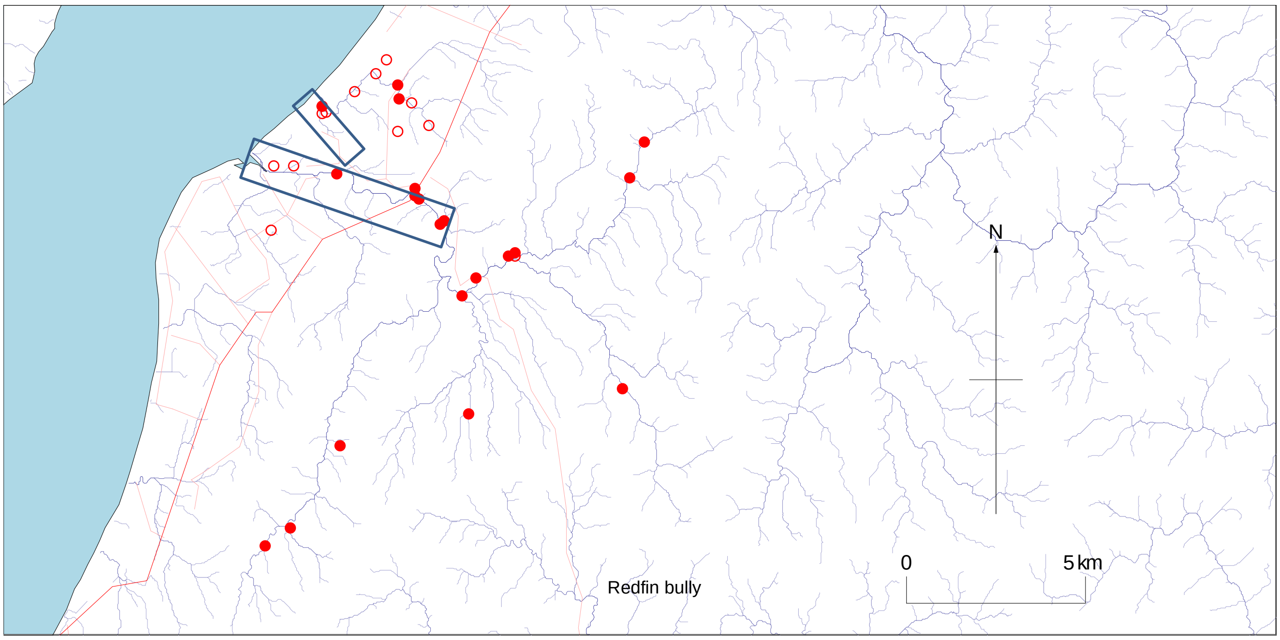

Figure 3-7: Redfin bully records for the Waikanae River and Waimeha Stream (presence indicated as red dots, absence by a circle). Data from NZFFD 1993-2013. The Waikanae and Waimeha application areas are shown indicatively as blue rectangles.

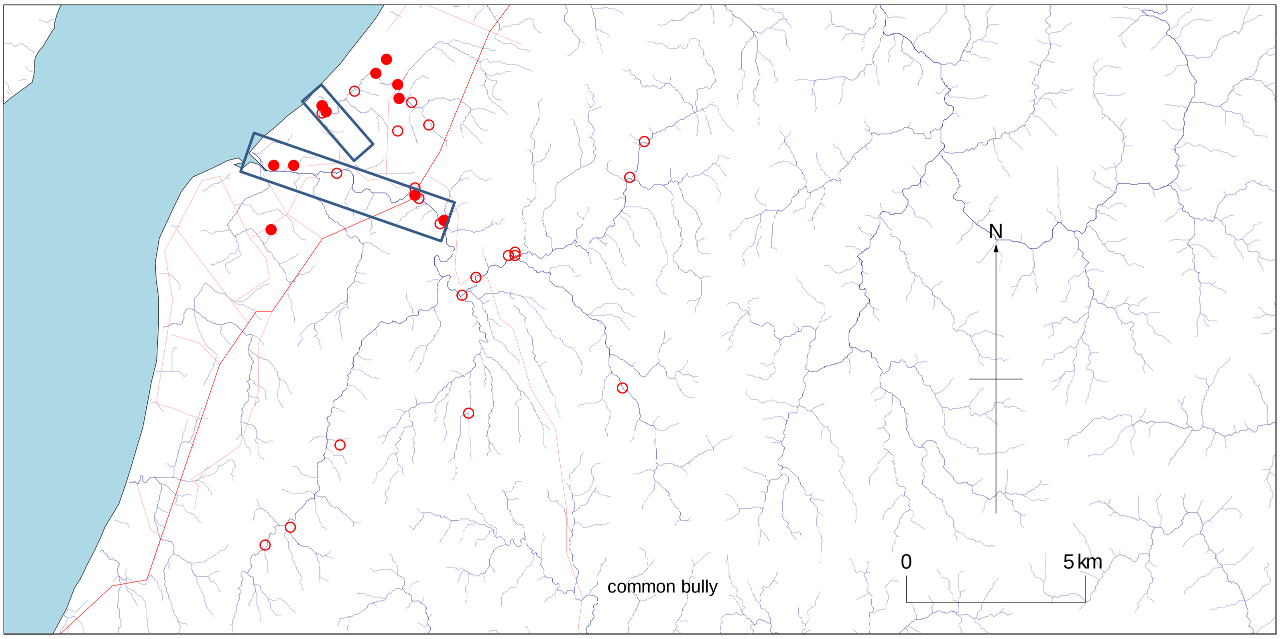

Figure 3-8: Common bully records for the Waikanae River and Waimeha Stream (presence indicated as red dots, absence by a circle). Data from NZFFD 1993-2013. The Waikanae and Waimeha application areas are shown indicatively as blue rectangles.

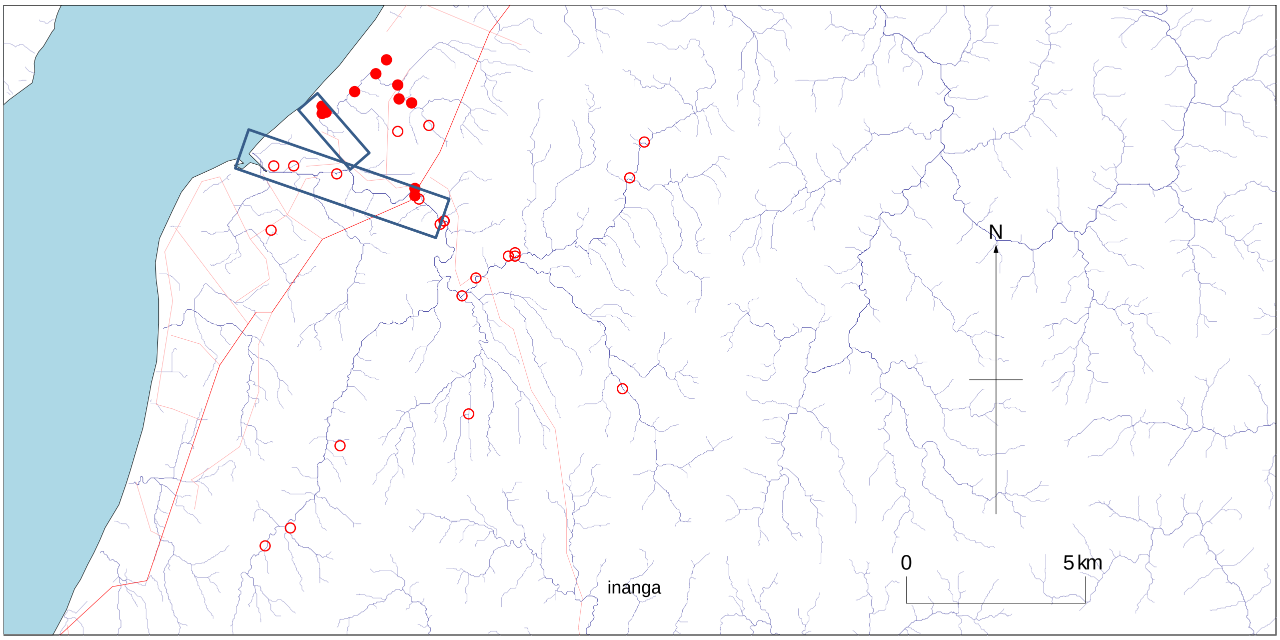

Figure 3-9: Inanga records for the Waikanae River and Waimeha Stream (presence indicated as red dots, absence by a circle). Data from NZFFD 1993-2013. The Waikanae and Waimeha application areas are shown indicatively as blue rectangles.

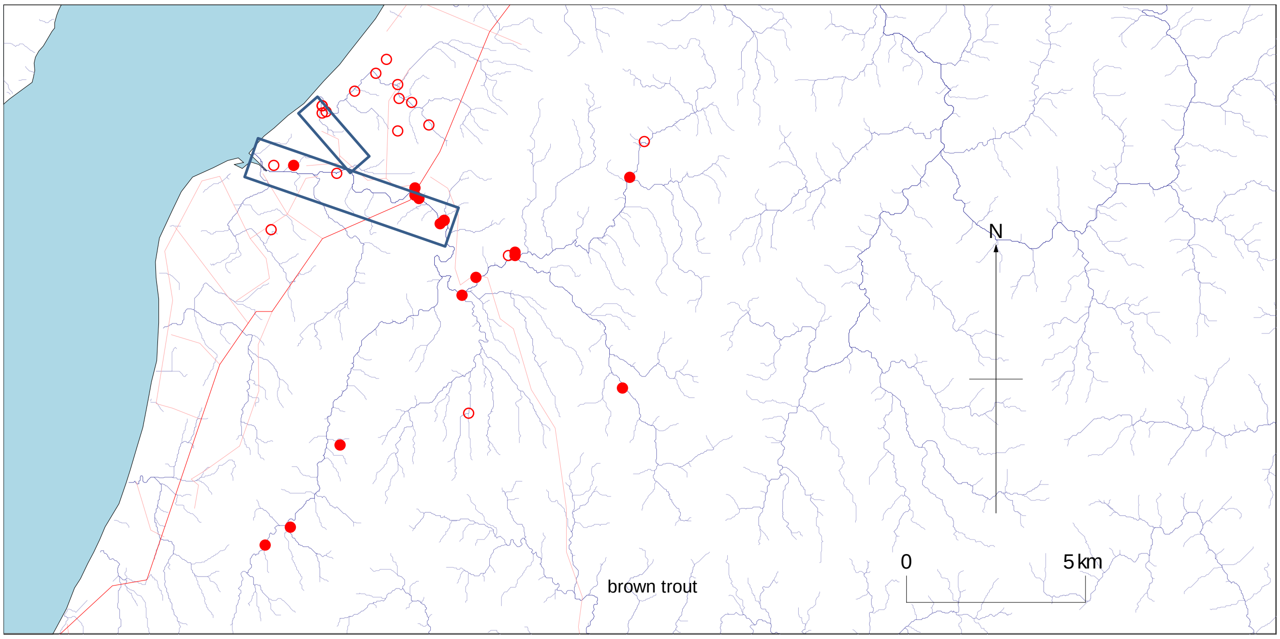

Figure 3-10: Brown trout records for the Waikanae River and Waimeha Stream (presence indicated as red dots, absence by a circle). Data from NZFFD 1993-2013. The Waikanae and Waimeha application areas are shown indicatively as blue rectangles.

3.1.8 Recreational fisheries

3.1.8.1 Trout

Wellington Acclimatisation Society first liberated brown trout into the Waikanae River in 1886 and continued this practice almost annually until 1974 when artificial stocking ceased (Maxwell and Smith 1992). Angler use had been light up until the 1990's but NZ Fish and Game reports that it has since escalated to become a significant fishery for anglers. The river is normally closed for angler use during the trout spawning period between May and September (Pilkington, 2014). The abundance of trout has been monitored annually by Fish and Game NZ since 1999 in order to explore the relationship between trout abundance and the frequency and extent of river control works. GWRC agreed, via a Memorandum of Understanding (MOU), to fund the annual survey in the Waikanae River (and also Hutt River) over the fifteen year term of the resource consents granted in 1998, in recognition of concerns by Fish and Game that some flood protection activities may compromise the preferred habitat requirements of brown trout.

Monitoring results reported by Pilkington (2014) in relation to the three survey reaches (located at water treatment plant 1, water treatment plant 2, and Jim Cooke Park) show that:

- The mean number of trout per kilometre observed in 2014 was 13.8 (standard error 4.7) compared with 34.3 (standard error 16.2) in 2013 (refer Figure 3-11).
- The sixteen year trend is neutral showing on average neither increase nor decrease of trout numbers overall.
- Trout numbers were variable at all sites but were typically higher within the application area (Cooke Park & Treatment 2) than upstream of it (Treatment 1) (refer Figure 3-12).

To date the data has not identified any significant negative effects on trout that can be attributed to flood protection activities in the Waikanae River.

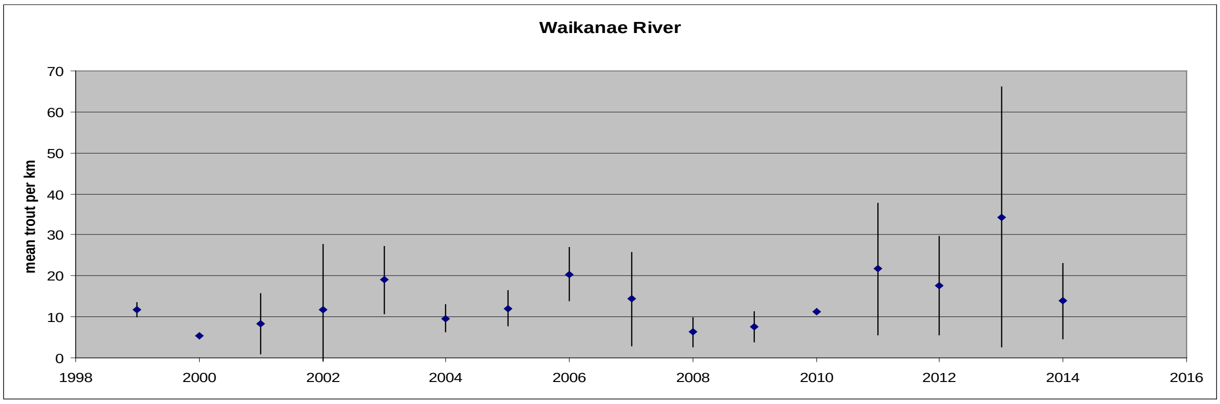

Figure 3-11: Mean large and medium trout per km, Waikanae River (from Pilkington, 2014)

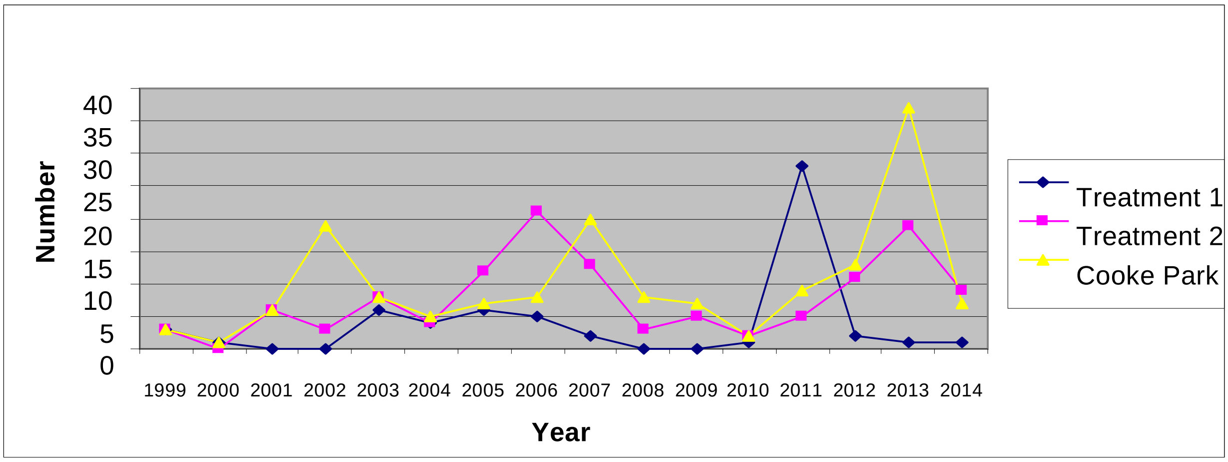

Figure 3-12: Number of trout over each individual drift dive (from Pilkington, 2014)

3.1.8.2 Whitebait

Both the Waikanae River and Ngarara/Waimeha Stream support a popular recreational whitebait fishery, at times attracting over 20 fishers during the whitebait run. Six galaxiid species (whitebait) have been recorded in the two watercourses.

The peak period of upstream galaxiid migration is from the beginning of August to the end of December (the whitebait fishing season opens on 15 August and runs until November 30).

3.1.9 Birds of Waikanae River

3.1.9.1 Introduction

GWRC has recognised that there is potential for flood protection activities to have both positive and negative impacts in bird populations present in the river corridors. In response to this, GWRC's Code and EMP (GWRC, Working Draft, March 2015) has committed to a bird monitoring programme that involves carrying out annual surveys on a three year on, five year off cycle on most of the major rivers affected by flood protection activities. The first three-year series of annual bird surveys on the western sector rivers, including the Waikanae River, commenced in late 2012, with three consecutive annual surveys having being completed in the summers of 2012/13, 2013/14 and 2014/15. The results these surveys are reported by McArthur, Small, & Govella (2015).

The river bird surveys are specifically designed to provide estimates of the local population sizes of four shorebird species that are known to breed on the open gravels of rivers subject to flood protection activities (McArthur et al, 2015). Because these four species are largely restricted to these riverine gravel habitats in the Wellington Region, they are considered to be at relatively high risk of being adversely impacted by these activities. Furthermore, three of these four species are of relatively high conservation concern nationally. The banded dotterel (*Charadrius bicinctus*) is ranked as Nationally Vulnerable under the New Zealand Threat Classification System, with a predicted national rate of decline of 30-70% over the next decade. The black-billed gull (*Larus bulleri*) is ranked as Nationally Endangered, with a predicted national rate of decline of >70% over the same period. Pied stilt (*Himantopus hinantopus*) is ranked as 'At Risk', Declining, with a predicted rate of decline of 10-50% over 10 years. The final species is black-fronted dotterel (*Elseyornis melonops*), a recent addition to the New Zealand avifauna, having self-colonised from Australia in the early 1950s. The southern North Island is currently a stronghold for this species in New Zealand, however the black-fronted dotterel is not ranked as either Threatened or 'At Risk.

In contrast to the locally-breeding shorebird species that provide the focus for this monitoring, the majority of the remaining bird species recorded in the river corridor are terrestrial species that are common and widespread in the surrounding landscape, and are considered unlikely to be adversely impacted by the localised effects of flood protection activities occurring in the bed of the river itself (McArthur, Playle, & Govella, 2013; McArthur *et al*, 2015). A number of additional shorebird and waterfowl species do make use of the lower reaches of the river and estuary during certain stages of their life cycle however, so in addition to monitoring trends in population sizes of the four most vulnerable locally breeding shorebird species, numbers of non-breeding shorebirds, waterfowl and terrestrial bird species are also undertaken during these surveys. This will enable broad trends in both the diversity and distribution of these species to be monitored over time.

3.1.9.2 Riverbed nesting shorebirds

McArthur, *et al*, (2015) reported that no shorebirds were observed breeding on the exposed gravel beaches of the Waikanae River during the 2012-2015 surveys, however a pair of variable oystercatchers (*Haematopus unicolor*) was seen with a downy chick at the Waikanae Estuary during the 2014/2015 survey. Pied stilts and banded dotterels have also been recorded nesting at the Waikanae Estuary in the past (Kirk & Wodzicki 1943; Wodzicki 1946). The morphology of the Waikanae River between the SH 1 bridge and the Waikanae Estuary, particularly the narrow channel width and relatively small areas of open, dry gravel habitat, means that there is very little (if any) suitable habitat to support riverbed nesting shorebirds upstream of the Estuary (N. McArthur pers. obs).

3.1.9.3 Spatial patterns in bird species diversity

McArthur *et al,* (2015) recorded a total of 45 bird species during the 2012-2015 surveys, including 27 native species and 18 introduced species. Of the native species, nine species are ranked as Nationally Threatened or 'At Risk' under the New Zealand Threat Classification System (Robertson *et al*, 2012). In addition to the 45 species recorded during the 2012-2015 surveys, a further 45 species (42 native and three introduced) have been recorded on the Waikanae River (the majority at the Waikanae Estuary) since 1927 (Appendix 5, McArthur *et al*, 2015), bringing the total number of bird species so far recorded on the Waikanae River to 90. Both the total number of species and the ratio of native to introduced species encountered within each 1 km survey section varied little upstream of XS155. However, the total number of species, the proportion of native species, and the proportion of Nationally Threatened and 'At Risk' species encountered gradually increased downstream from this point, with the highest number of species being detected at the Waikanae River mouth (Figure 3-13). A list of bird species recorded on the Waikanae River during the 2012-2015 surveys is included in Appendix G.

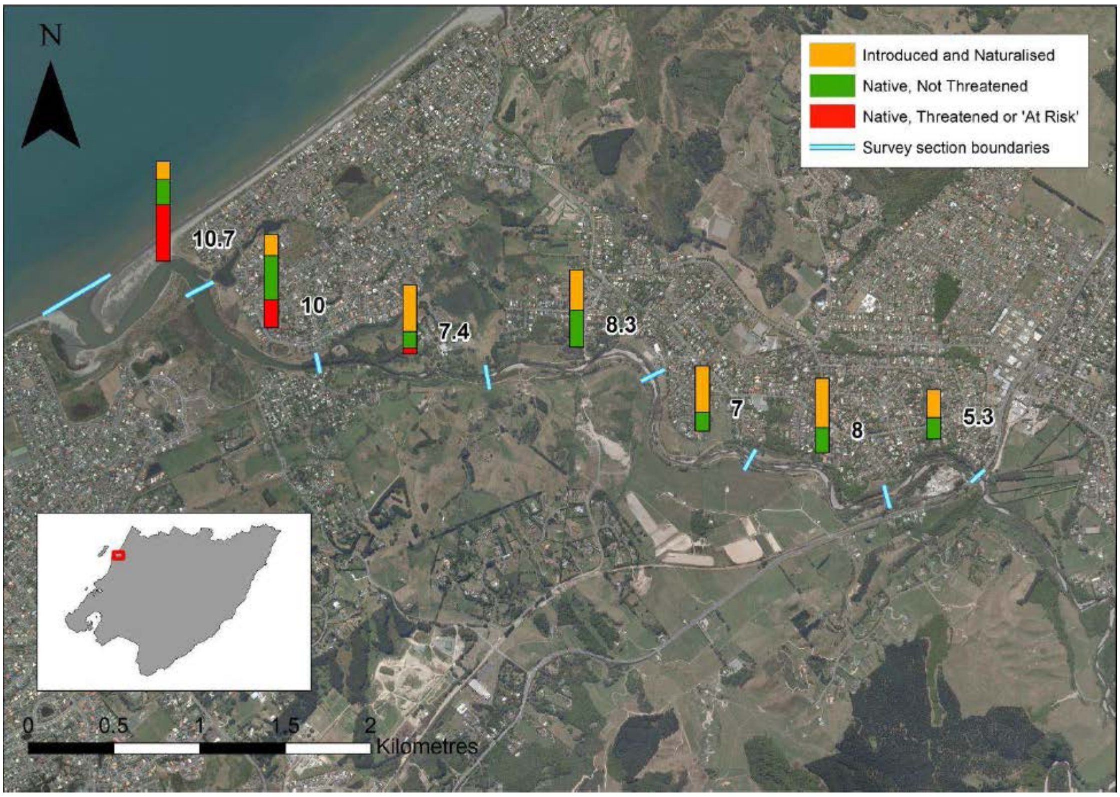

Figure 3-13: Map of the Waikanae River showing spatial patterns in bird species diversity (from McArthur, et al, 2015). Coloured bars and adjacent values represent the mean number of species detected along each 1km survey section during three annual surveys between 2012 and 2015

3.1.9.4 Sites of Value for Indigenous Birds

McArthur *et al*, 2015, identified one site of value for native birds on the Waikanae River based on the data collected during these surveys, and this was the Waikanae Estuary and its associated wetlands and ponds (Figure 3-14).

This site supports a relatively high total number of bird species, a relatively high number of Nationally Threatened and 'At Risk' species, and a higher ratio of native to introduced bird species than any other reach of the Waikanae River. In addition, the wetlands associated with the Waikanae River mouth support one of only two known populations of North Island fernbird (*Bowdleria punctata*) in the Wellington Region, and one of the largest nesting colonies of pied shags (*Phalacrocorax varius*) in the region. As well as supporting a relatively high diversity of resident native bird species, this estuary is also a regionally important stop-over site for several migrant shorebird species including South Island pied oystercatcher (*Haematopus finschi*), bar-tailed godwit (*Limosa lapponica*) and black-fronted tern (*Chlidonias albostriatus*).

3.1.10 Birds of Waimeha Stream

McArthur (2015a) described the bird values of the Waimeha Stream based on a site visit carried out on 16th February 2014 and a destop analysis of the available 'citizen science' data for the site, together with systematic bird data collected from the nearby Waikanae River. Sixteen species of birds have been recorded at the mouth of the Waimeha Stream, including 12 native species and four introduced species. Of the native species, six are ranked as ‘At Risk’ or Threatened under the New Zealand Threat Classification System. A species list is provided in Appendix H. Those six species that have threat rankings of ‘at risk’ or higher are by definition those that should be considered of most concern when assessing the impacts of activities described in this consent application. McArthur (2015a), observed however that:

“the very small area of habitat at the Waimeha Stream mouth, the transitory nature of bird populations using this small area of habitat and the proximity of the much larger Waikanae Estuary a few kilometres to the south leads me to believe the effects on these species of concern are likely to be negligible.

Furthermore, as a result of the site visit I carried out on the 16th February 2014, together with an examination of aerial imagery of the Waimeha Stream, I’m satisfied that with the exception of the stream mouth, no suitable shorebird habitat exists along the length of this stream due to the narrow channel width and lack of open gravel beaches. The riparian habitat on either side of the Waimeha Stream appears to be extremely similar to that found along the nearby Waikanae River (a mixture of suburban, parkland and semi-rural habitats), so I believe it would be reasonable to assume that the Waimeha Stream supports a very similar bird community to that found along the Waikanae River. A list of the bird species detected along the Waikanae River during annual surveys carried out between 2012 and 2015 can be found in Appendix 4 of McArthur et al (2015) [included here as Appendix G]*. With the exception of those shorebird species recorded at the mouth of the Waikanae River, the remaining bird species detected are all relatively common and widespread in the surrounding landscape and are ranked as either “Not Threatened” or “Introduced and Naturalised” under the New Zealand Threat Classification System (Robertson et al, 2013). As a consequence, it’s my view that the activities described in this consent application are likely to have a negligible impact on the bird species known or likely to be present along the Waimeha Stream*.”

Figure 3-14: Map of the Waikanae River showing the location of the Waikanae Estuary ‘bird site of value’

3.1.11 Herpetofauna

A search of lizard and frog records in the Department of Conservation BioWeb Herpetofauna database relevant to a corridor extending 1km either side of the Waikanae River and Waimeha Stream channels and running the length of the application area was undertaken (Trent Bell, Ecogecko). Additional *Mokopirirakau* "southern North Island" and *Oligosoma polychroma* records were sourced from unpublished data (Trent Bell, unpub. data, trent@ecogecko.co.nz).

Only one lizard species is recorded within this area: the northern grass skink. It's likely presence within the corridor is indicated as 'moderate' where rank grassland and scrubland occurs in areas infrequently inundated by the river (Table 3-18, Figure 3-15). The likelihood of lizard presence is low in those areas frequently flooded by the river.

Table 3-18: Herpetofauna records within a 1km radius of the Waikanae application area. Reptile threat classification obtained from Hitchmough *et al.* (2012). Herpetofauna records obtained from Department of Conservation BioWeb *Herpetofauna* database, accessed 08-08-2015.

Species	Common name	Threat Classification	Number of records	Species habitat preference	Likelihood of presence
Oligosoma polychroma	Northern grass skink	Not Threatened	4	Macro: Grassland and scrubland. Micro: Dense rank grass, wood piles, rock piles.	Moderate

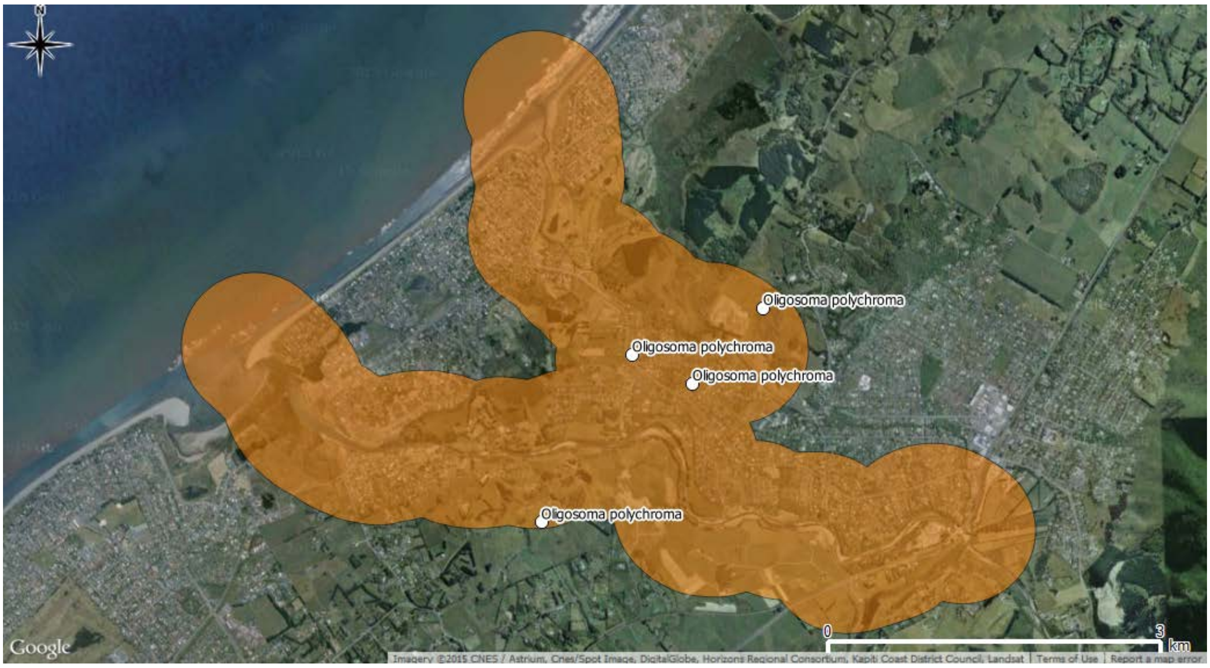

Figure 3-15: Area searched for Herpetofauna records, within a 1km radius of the Hutt River application area

A field search for terrestrial and arboreal lizards was conducted alongside the Waikanae River at Jim Cooke Memorial Park on 26 July 2015 (day/night survey) as part of a separate consent application by GWRC for stopbank improvements. That search, conducted in optimal conditions, failed to detect any lizards or their sign (Wildland Consultants, 2015). The authors concluded that "*Overall, the habitat availability at the site is considered to be of low significance for lizards*".

It is noted that the likelihood of lizard presence in those areas frequently flooded by the river is low, and that the majority of flood protection activities occur in areas frequently affected by flood waters.

3.1.12 Natural Character Index

A natural character index (NCI) developed by Massey University has been used to assess the degree of departure from the reference condition of geomorphological characteristics for the Hutt, Otaki and Waikanae rivers. The NCI is determined from physical features including bed width ratios (i.e., active, bank-full and permitted channel widths compared with 'natural' channel width), channel sinuosity and pool-riffle sequence. These characteristics are measured from aerial photography and LiDAR imagery surveying. The NCI provides a proxy measure for the environmental condition and health of these waterways. In particular it provides a repeatable method for assessing changes in condition over time for defined reaches of each river. The first NCI assessment was completed in 2013 and referenced against the earliest available aerial photographs for these rivers (1953 for the Waikanae River) and is reported in Williams (2013). A summary of results for the Waikanae River is provided in Table 3-19. The locations of the six NCI reaches are shown in Appendix A.

The NCI values are the ratios of the present to historic (reference) measurements, where a value of 1 means no change over the assessment period. Results for the Jim Cooke Park and Greenaway Road reaches (XS 300 - XS 240 and XS 230 – XS 175) show the greatest degree of departure from the reference condition, whereas reaches upstream of Jim Cooke Part show very little change.

Table 3-19: NCI assessment for the Waikanae River (from Williams 2012)

Reach Cross section	Sinuosity	Pools	Natural Floodplain width to:			Overall NCI
			Active	Bank-full	Permitted	
XS 550 – XS 430	0.96	1.00	1.10	1.00	1.22	**1.06**
XS 429 – XS 350	0.97	0.83	1.28	1.17	1.13	**1.08**
XS 345 – XS 310	0.79	1.52	1.22	0.99	0.73	**1.05**
XS 300 – XS 240	0.98	0.00	0.79	1.00	0.41	**0.64**
XS 230 – XS 175	0.98	0.26	0.76	0.99	0.52	**0.70**
XS 155 – XS 80	0.74	0.83	1.03	1.00	0.82	**0.88**
Average	*0.90*	*0.74*	*1.03*	*1.03*	*0.81*	***0.90***

Death, et al, (2015) describes a modification of the NCI to assess the geomorphological change of individual engineering activities and to give some indication of where mitigation activities should be directed. This is discussed further in Section 8.2.10.

3.2 Waikanae Estuary

3.2.1 Physical characteristics

The Waikanae Estuary is a moderate-sized (40-50m wide, 1-2m deep, 2km long) “tidal river mouth” type estuary which drains onto a broad flat beach just north of Paraparaumu. The majority of the estuary area consists of a long, shallow lagoon type estuary running along the back of the beach parallel to the sea (Robertson & Stevens, 2012). Longshore drift along the Kapiti Coast tends to cause the formation of a sand-spit which results in the mouth migrating to the south (Williams, 1992). The channel is periodically artificially opened to the sea at the north end to protect land to the south, but this is a relatively infrequent event which last occurred in December 2001. High flow events in the River occasionally have the power to open the channel naturally, depending on the condition of the sand spit and state of the tide. It is also noted that high spring tides and storm surges occasionally submerge and/or erode the sand spit.

The estuary is usually freshwater dominated at low tide and at high tide consists of a freshwater layer on top of saline bottom water. Plant and animal life is therefore restricted to those that tolerate such regular salinity extremes (Robertson and Stevens, 2012). The application area extends through the upper estuary to the sand spit, as shown in Figure 3-16.

3.2.2 Human and Ecological values

Human and ecological use of the estuary is high. It is one of the few estuary/wetland areas of any size in the south-western North Island, and is a Nationally Significant Wetland habitat for waders, seabirds and waterfowl, both local and migratory (Department of Conservation, WERI database). More wild birds visit the Waikanae Estuary and associated wetlands than any other area in the Wellington region (Robertson & Stevens, 2012).

The Waikanae Estuary Scientific Reserve was established in 1987 and is administered by the Department of Conservation. This reserve protects a natural mosaic of freshwater lakelets, saltwater lagoons and marshes, tidal sand flats and a sandy beach at the mouth of the Waikanae River. The reserve covers an area of 58.5 hectares immediately south of the application area (see Figure 3-17).

Figure 3-16: View of the application area (dashed blue lines) and design channel alignment (dashed red lines) within the Waikanae Estuary (hatched)

3.2.3 Marginal Vegetation

The Waikanae Estuary includes large areas of bare sand flats, periodically inundated by the sea; areas of fixed dune with lupin-marram-blackberry/grasses shrubland; smaller areas of fixed dune with marram-lupin/grass shrubland; smaller areas of shore primrose (*Salmolus repens*)-Scirpus-batchelors button (*Cotula coronopifolia*) herb field on low saltmarsh; areas of sea rush (*Juncus kraussii*)-Leptocarpus rushland on high salt marsh; a few patches of raupo swamp in freshwater lakelets; and a lagoon with horse's mane weed (*Ruppia megacarpa*) (Boffa Miskell Partners, 1992).

Carpets of remuremu (*Selliera radicans*) grow in the firm mud along the waters of the estuary. The mosaic of tidal sand flats, sand dunes, salt marshes and lakelets also provide a home for two regionally rare carex species; *Carex litorosa* and *C. dipsacea* (Jeremy Rolfe, pers.com.). The threatened (Nationally Endangered) species *Centipeda minima subsp. Minima* has been recorded within the Waikanae Estuary Scientific Reserve (Philippa Crisp, *pers comm*.).

Within the application area, along the true left bank of the estuary, salt marsh species including marsh ribbonwood (*Plagianthus divaricatus*), sea rush, and jointed wire rush or oioi (*Apodasmia similis*) have been recorded (Boffa Miskell Partners, 1992). Robertson & Stevens (2007) estimate that the total area of salt marsh/dune associated with the Waikanae Estuary is 10 - 20 ha.

3.2.4 Fine Scale Monitoring and Condition Ratings

Recent fine scale monitoring of the Waikanae Estuary by Robertson & Stevens (2012) addressed sedimentation, eutrophication and toxicity. The authors concluded that the estuary was in a fair condition, but in a more degraded state than the previous year. Since 2011, metal concentrations had increased, and sediment oxygenation had declined from a Redox Potential Discontinuity (RPD)[4] depth of 3-10cm to 1-3cm.

The likely explanation for this declining condition was an increase in suspended sediment loads in 2012 to the estuary, which resulted in nutrient and metal concentration increases. They noted that the source of the nutrient rich fine sediments was uncertain, but was possibly exacerbated by recent forest harvesting in the upper catchment. The condition ratings for 2010, 2011 and 2012 are summarised in Table 3-20.

Table 3-20: Waikanae Estuary condition ratings (from Robertson & Stevens, 2012).

CONDITION RATINGS	2010	2011	2012
Sedimentation Rate	Plates Deployed	Very High	Very High
Invertebrates: Mud Tolerance	Moderate	Moderate	Moderate
Sediment Oxygenation (RPD)	Fair-Good	Good	Fair
Total Organic Carbon (TOC)	Very Good	Very Good	Good
Total Phosphorus (TP)	Good	Good	Fair
Total Nitrogen (TN)	Good	Good	Good
Invertebrates: Organic Enrichment Tolerance	Low to Moderate	Low	Low
Metals (Cd, Cr, Cu)	Very Good	Very Good	Very Good
Metals (Ni, Pb, Zn)	Good	Good	Good
DDT	Very Good	Not Tested	Not Tested

3.2.5 Sedimentation

Because estuaries are a sink for sediments, their natural cycle is to slowly infill with fine muds and clays. Prior to European settlement they were dominated by sandy sediments and had low sedimentation rates (<1mm/year). In the last 150 years, with catchment clearance, wetland drainage, and land development for agriculture and settlements, New Zealand's estuaries have begun to infill more rapidly. Today,

[4] The RPD is the grey layer between the oxygenated yellow-brown sediments near the surface and the deeper anoxic black sediments. It is an effective ecological barrier for most but not all sediment-dwelling species. A rising RPD will force most macrofauna towards the surface to where oxygen is available.

average sedimentation rates in our estuaries are typically 10 times or more higher than before humans arrived (Robertson & Stevens, 2012).

Stevens & Robertson (2014) have tracked changes to sediment indicators in the Waikanae Estuary for the period 2010 to 2014. They report that the overall mean sedimentation rate across the four years of monitoring is an increase of 26.4mm/yr. The authors concluded that although the lower estuary near the open coast remains dominated by clean sands, these results, combined with observations of fresh mud deposits, highlight rapid recent sedimentation infilling of the upper estuary flats. Sediment mud content was 31.7%, reflecting soft mud overlying firm muddy sands. Average RPD depth was 1.5cm and has declined since 2010. These results show rapid sediment deposition from 2010 to 2014. The elevated sediment mud content and shallow RPD depth indicate the upper estuary is at high risk of sediment related impacts from poor clarity and muddy intertidal substrates.

3.2.6 Macroalgae

Macroalgae is an important feature of estuaries, contributing to their high productivity and biodiversity. However when high nutrient inputs combine with suitable growing conditions, nuisance blooms of rapidly growing algae can occur. At nuisance levels such growths can deprive seagrass of light, causing its eventual decline, while decaying macroalgae can accumulate on shore-lines causing local depletion of sediment oxygen, and nuisance odours (Stevens & Robertson, 2013).

The results of four annual intertidal macroalgal cover surveys of Waikanae River Estuary are summarised by (Stevens & Robertson, 2013). Percentage cover of macroalgae was broadly mapped throughout all intertidal habitats in the estuary, using a 7 category percent cover rating scale to describe density. The 2013 percent cover results of macroalgae within the estuary are presented in Figure 3-17 and a summary of condition ratings and results from 2010 to 2013 is provided in Table 3-22. The results show that macroalgae is absent from the vast majority of the estuary but that minor localised nuisance conditions (rotting macroalgae, poorly oxygenated and sulphide rich sediments) occurred in one small part of the estuary, in the flap-gate embayment.

Table 3-21: Summary of condition rating and macroalgal cover results, 2010-13 (from Stevens & Robertson, 2013).

Year	Low Density Rating	High Density Rating	Result
2010	0.01	VERY LOW	Macroalgae absent from the vast majority of the estuary. Very low cover of *Ulva intestinalis* along the lower true left bank. Dense macroalgal cover = <1%.
2011	0.01	LOW	Macroalgae absent from the vast majority of the estuary. Very low cover of *Ulva intestinalis* along the true left bank. Increase in nuisance conditions near flapgate. Dense macroalgal cover = 2.3%.
2012	0.04	LOW	Macroalgae absent from the vast majority of the estuary. Low cover of *Ulva intestinalis* along the lower true left bank. Increase in nuisance conditions near flapgate. Dense macroalgal cover = 2.8%.
2013	0.16	LOW	Macroalgae absent from the vast majority of the estuary. Increased cover of *Ulva intestinalis* along the lower true left bank. Minor nuisance conditions near flapgate. Dense macroalgal cover = 2.8%.

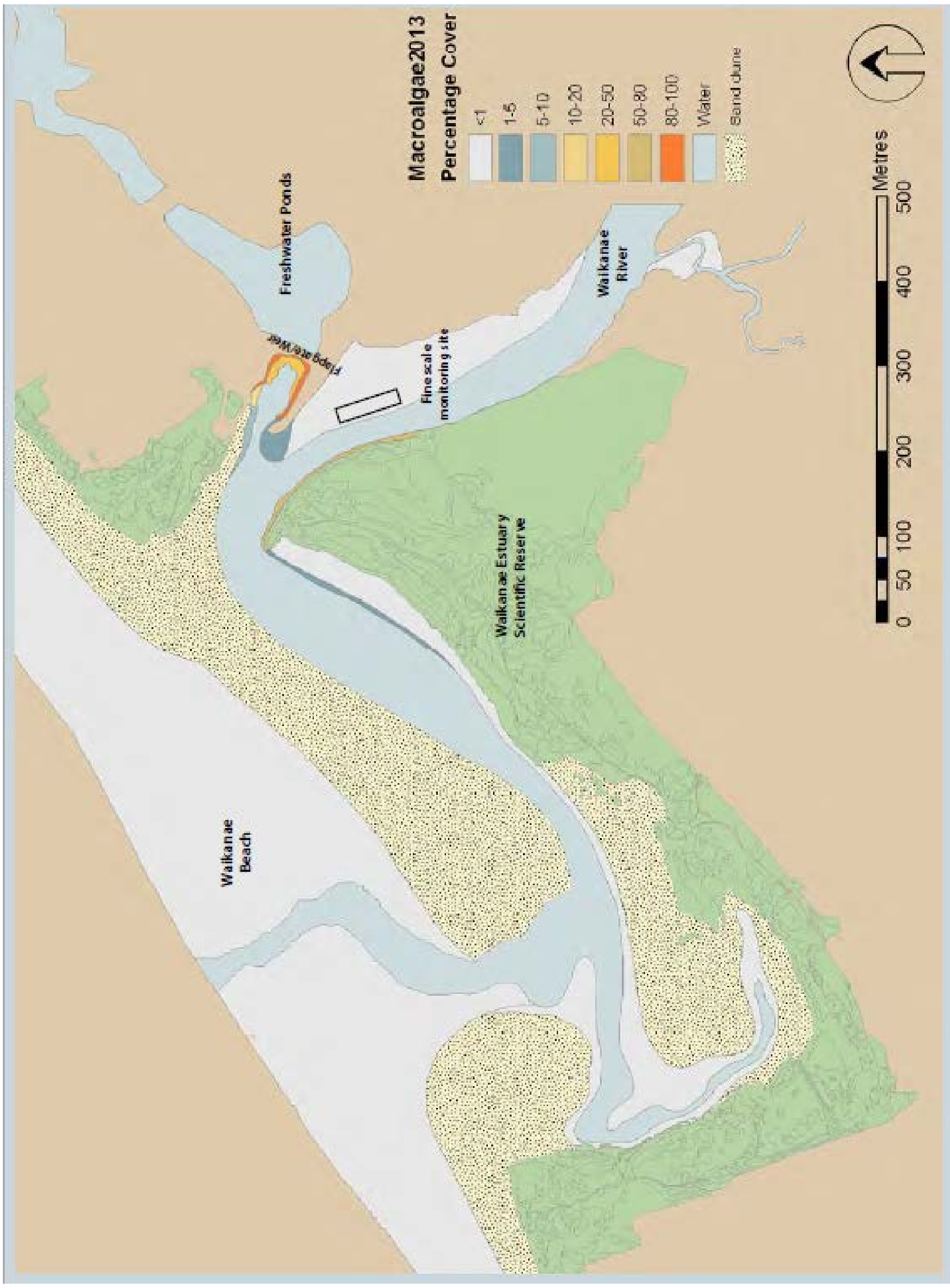

Figure 3-17: Map of intertidal macroalgae cover – Waikanae Estuary, Jan 2013 (from Stevens & Robertson, 2013)

3.2.7 Macroinvertebrates

Fine scale monitoring results reported by Robertson & Stevens (2012) includes a survey of infauna (animals within sediments) from 10 sediment core samples collected from the Waikanae Estuary Site A (see Figure 3-17) in 2010, 2011 and 2012 . In all three years the macroinvertebrate community had a low to moderate number of species and a moderate to high mean abundance compared to other New Zealand estuaries. The mud tolerance of the Waikanae Estuary macroinvertebrate community was in the “moderate” category in all three monitoring years. The results show that the community was dominated by taxa that prefer mud rather than those that prefer sand.

Robertson & Stevens (2012) found that overall, the three years of monitoring indicates predominantly muddy conditions that favour a macroinvertebrate community dominated by mud tolerant species. Combined with the elevated sedimentation rate, such conditions indicate excessive catchment loads of fine sediment are detrimentally affecting the upper/middle estuary.

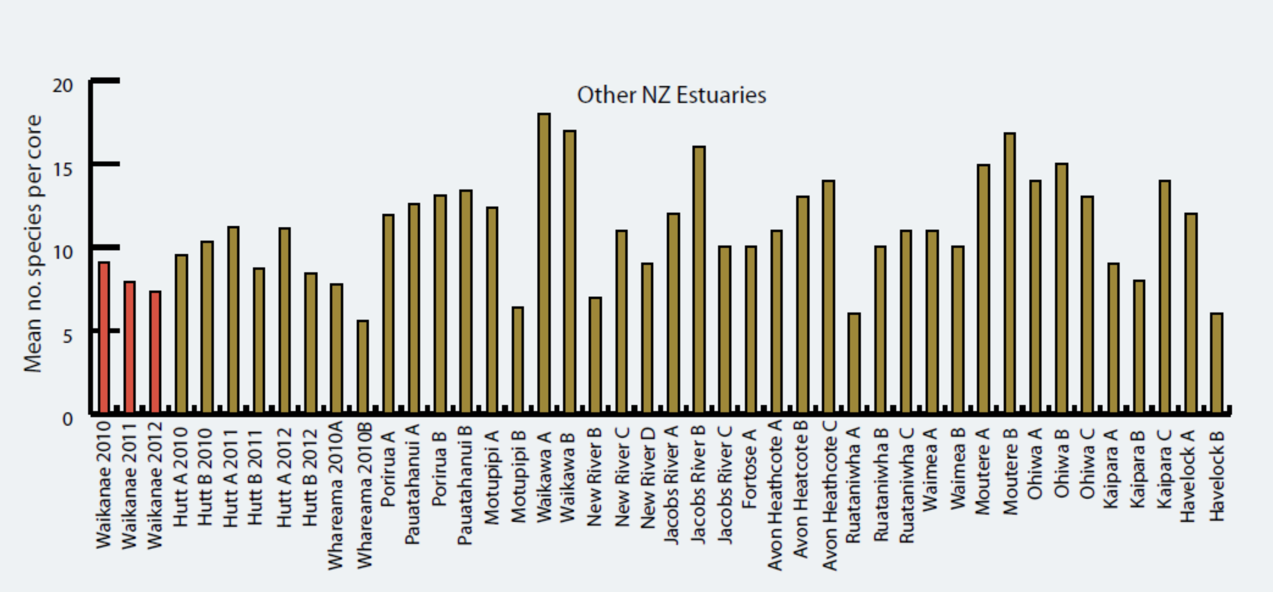

Figure 3-18: Mean number of infauna species, Waikanae Estuary compared with other NZ estuaries (from Robertson & Stevens, 2012)

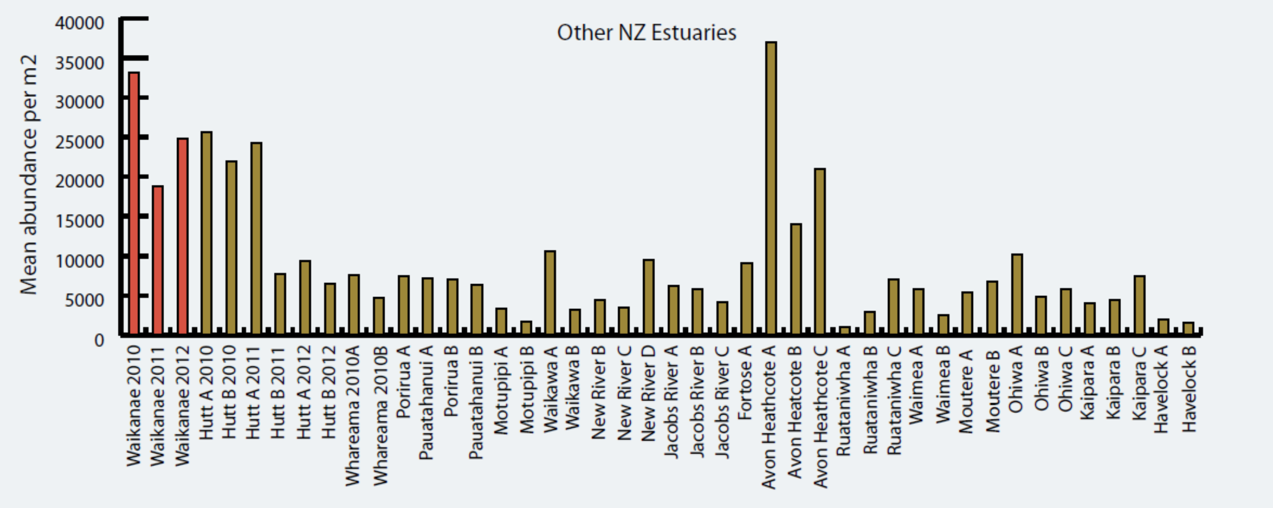

Figure 3-19: Mean total abundance of macrofauna, Waikanae Estuary compared with other NZ estuaries (from Robertson & Stevens, 2012)

3.2.8 Fish

The fish community of the Waikanae River has been described in Section 3.1.7.1. Of the 35 NZFFD records available for the catchment only two were located within the estuarine reach (<2km from the sea). These are dated July 2006 and December 2010, and both surveys were conducted by electric fishing machine (EFM), indicating that the survey reach was in freshwater. Six fish species were recorded; these are longfin eel, shortfin eel, inanga, common bully, redfin bully and black flounder. The most abundant fish were shortfin eel and common bully.

Taylor & Kelly (2001) identified potential areas of inanga spawning habitat downstream of Otaihanga Domain, predominantly on the true right bank (refer Appendix B). Recommendations for the protection of inanga spawning habitat are provided in Section 7.6. and have been incorporated into the Code.

3.2.9 Birds

The birds of Waikanae River have been described in Section 3.1.9. The Waikanae Estuary, and its associated wetlands and ponds, are identified by McArthur, Robertson, Adams, & Small (2015) as a site of significance for indigenous birds. It supports one of only two known populations of North Island fernbird in the Wellington Region, and one of the largest nesting colonies of pied shags in the region. At least twelve threatened or at risk species are known to be resident or regular visitors to this site. These are the banded dotterel, North Island fernbird, NZ dabchick, South island pied oyster catcher, variable oyster catcher, bar tailed godwit, pied stilt, blag shag, pied shag, red-billed gull, white fronted tern and Caspian tern. Species such as the variable oyster catcher occupy the sand-spit where the river affords some protection from cats, ferrets, dogs and trail bikes on the other side of the reserve.

The critical period for this site in terms of the potential for negative effects extends all year round: (important summer site for Arctic-breeding shorebird; important winter site for NZ breeding shorebirds; all-year habitat for North Island fernbird).

3.3 Waimeha Estuary

The Ngarara (Waimeha) Estuary is a small tidal estuary located on a sandy beach just north of the Waikanae Estuary. The estuary is narrow (5-10m) and shallow, situated between high marram grass and lupin dunes near the beach. Further inland the estuary is highly modified, channelised and bordered by houses and parkland (see Figure 3-20). Human use of the estuary is moderate; it is a picnic spot and is used for bathing and white-baiting. Ecologically, habitat diversity is low, given the highly modified upstream channels and the absence of tidal flats and salt/marsh vegetation, the regularly modified beach channel and lagoon and the high incidence of weeds (Robertson & Stevens, 2007).

Nevertheless, Taylor & Kelly (2001) identified potential areas of inanga spawning habitat on the Waimeha Stream downstream of the Ngarara Stream confluence and mostly on the true left bank (south), as shown in Figure 3-20.

The bird fauna of Waimeha Stream has been described in Section 3.1.10. Sixteen species of birds have been recorded at the stream mouth, including 12 native species and four introduced species. Of the native species, six are ranked as ‘At Risk’ or Threatened under the New Zealand Threat Classification System (refer to Appendix H for a full species list). McArthur (2015a) observed that the area of habitat at the Waimeha Stream mouth is very small and that the bird populations using this small area are transitory. The Waimeha Estuary has not been listed by McArthur, Robertson, Adams, & Small (2015) as a habitat of significance for indigneous birds.

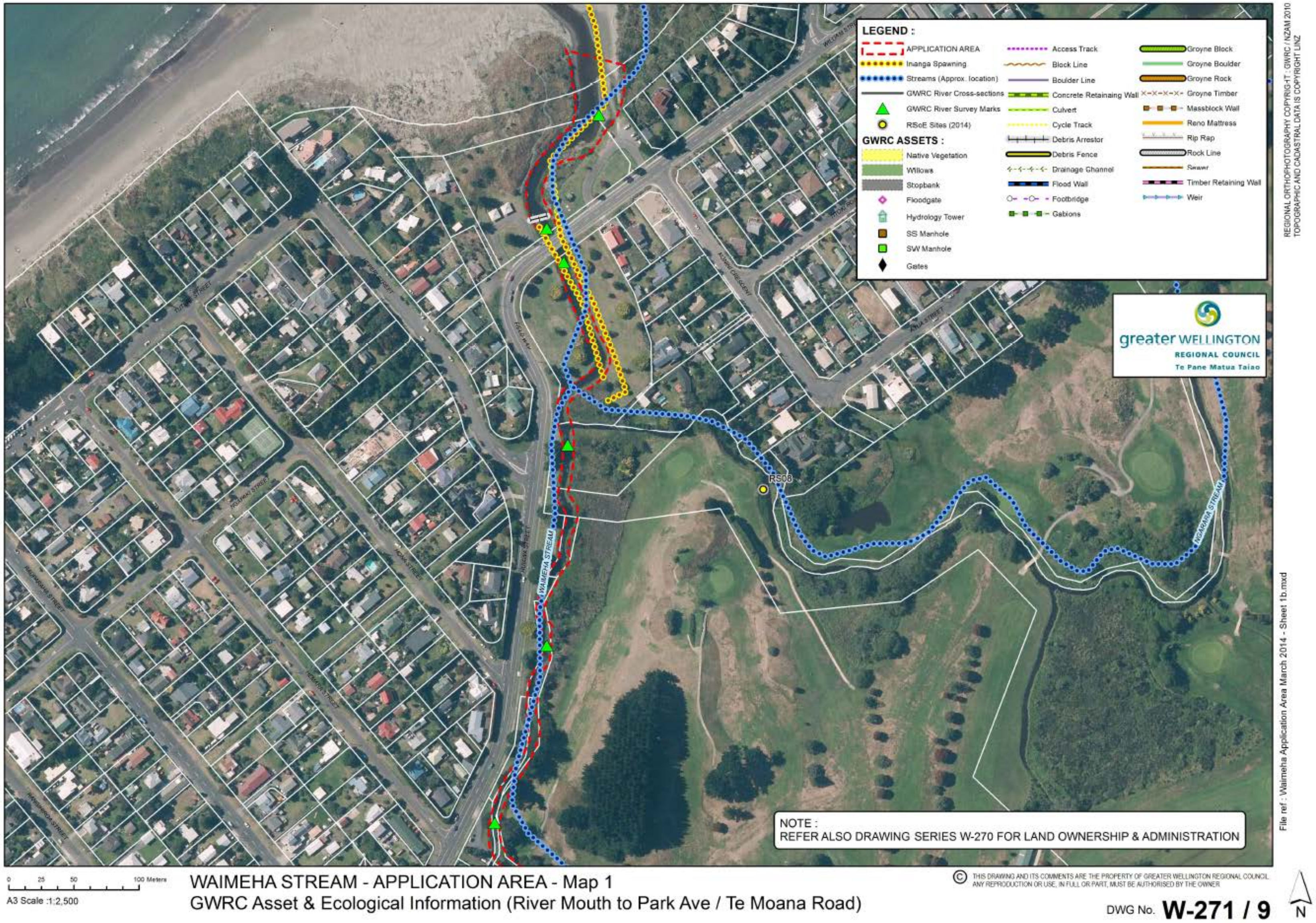

Figure 3-20: Map of the lower Waimeha Stream, estuary and mouth showing location of potential inanga spawning habitat (yellow dotted line) and the application area (red dashed line)

4 Flood Protection Activities

4.1 Purpose

As described in the Resource Consent Applications for Operations and Maintenance Activities in the Waikanae River (Tonkin and Taylor 2014), the main aims of the river operation and maintenance work programme are to:

- maintain a design channel alignment (as defined in the defined in the Waikanae River Floodplain Management Plan);
- maintain the flood capacity of the existing channel by removal of obstructions and gravel build-ups as necessary;
- maintain the integrity and security of existing flood defences, (including stop banks and bank protection works).

In addition, the works programme aims to maintain, or where possible improve, the in-river and adjacent riparian environment.

These aims are applicable to flood protection operations and maintenance activities throughout the Wellington Region.

4.2 Description of Activities

To achieve the purposes listed above, GWRC currently undertakes a range of flood protection activities in the Waikanae River and Waimeha Stream, as listed below in Table 4-1. The consent application seeks to have the continued ability to use these tools as appropriate; it should be noted that many of these activities are not used frequently (or at all in some areas) and the pattern and frequency of use is not expected to change significantly in future.

4.2.1 Maintenance of channel alignment

Channel alignment is maintained using a combination of:

- Hard edge protection works such as rock rip-rap linings or groynes
- Soft edge protection works such as planted, or layered and tethered, willows
- Mechanical shaping of the beaches and channel (beach and bed re-contouring)
- River mouth realignment

4.2.2 Maintenance of channel capacity

Tools currently used to maintain channel capacity are:

- Gravel Extraction
- Clearance of vegetation from gravel beaches (scalping)
- Removal of unwanted vegetation
- Clearance of flood debris
- Excavation of berms

4.2.3 Maintenance of existing flood defences

This includes all of the works necessary to maintain the existing in-river structures, and repairs to flood defences outside the river bed – principally the stop banks.

Table 4-1: Summary of operations and maintenance activities in the Waikanae River and Waimeha Stream (current and proposed).

Type of Activity	Individual Activities
Construction of "Impermeable" Erosion Protection Structures on & in the river bed	Groynes constructed of rock and/or concrete block Rock linings (rip-rap and toe rock) Gabion baskets Driven rail and mesh gabion walls Reno mattresses Rock or concrete grade control structures
Construction of "Permeable" Erosion Protection Structures on & in the river bed	Debris fences Debris arrester Permeable groynes
Construction of other works outside the river bed (on berms and stopbanks within the river corridor)	New stormwater drainage channels associated with cycleway/walkway construction New stormwater culverts associated with cycleway/walkway construction Footbridges associated with cycleways/walkways Fences Access roads Floodwalls
Demolition and removal of existing structures on & in the river bed	Formation of access-way (where required) – removal of vegetation, reshaping of bank, temporary placement of gravel. River crossing by machinery Demolition by mechanical and/or hand methods. Removal of material from river bed.
Maintenance of existing structures on & in the river bed	Formation of access-way (where required) – removal of vegetation, reshaping of bank, temporary placement of gravel. Structural repairs and maintenance to: • Existing erosion protection structures in the river bed • Existing culverts and outlet structures that discharge directly to the river
Structural maintenance work outside the river bed	Structural repairs and maintenance to: • Stopbanks & training banks • Flood walls • Stormwater culverts • Stormwater drainage channels • Footbridges located on the river berms • Fences located on the river berms • Berms
Development of vegetative bank protection	Tree Planting Willow layering, cabling & tethering
Maintenance of vegetative works	Trimming of trees Removal of old trees Removal of damaged structures Additional planting New layering of trees Re-cabling of tethered willows
Channel shaping or realignment	Mechanical beach re-contouring Mechanical bed re-contouring Mechanical ripping in the wetted channel
Channel maintenance	Removal of vegetation and silt Beach ripping Clearance of flood debris Gravel extraction
Non-structural maintenance works outside the river bed	Mowing stopbanks & berms (not involving machinery in river bed) Planting & landscaping

Type of Activity	Individual Activities
Activities in the CMA	Waikanae River mouth - excavation of diversion cut through foreshore Waimeha Stream mouth – excavation of diversion cut through foreshore Maintenance of existing groyne at Waikanae River mouth Placement of rip-rap/toe rock at Waikanae River mouth Maintenance training bank at Waimeha river mouth

5 Effects of Flood Protection Activities on River Ecology

5.1 Overview

The physical character of a river determines the quality and quantity of habitat available to biological organisms and the river's aesthetic and amenity values. Physical habitat is the living space for all in-stream flora and fauna, it is spatially and temporally dynamic and its condition and characteristics set the background for any assessment of the health of a waterway. The quantity and quality of physical habitat has a major bearing on the successful colonisation and maintenance of instream populations (Harding *et al* 2009) and it is well recognised that morphological change in river channels can impact the ecology of riverine environments.

River management schemes in New Zealand have in many instances influenced channel morphology, particularly in terms of reducing channel width and area, reduced morphological complexity, and reduced connectivity to the floodplain. Such changes can have significant implications for the composition and distribution of riparian and aquatic communities (i.e. Richardson and Fuller 2010; GJ Williams, 2013).

In the Waikanae catchment, although some straightening and confinement has occurred, the river has retained a relatively high degree of natural character and habitat quality compared with other rivers in the western Wellington Region. Nevertheless, the challenge facing GWRC is to continue to meet its statutory responsibility for the minimisation and prevention of flood and erosion damage, while ensuring that there is no further loss of biodiversity and, where possible, the quality of the environment is enhanced

The following sections provide an assessment of the potential effects of the individual operations and/or maintenance activities listed in Table 4-1 on the water quality and ecology of the Waikanae River and Waimeha Stream. While all of the listed activities are potentially available for use in the Waimeha Stream, in practice, and based on past experience, they are most likely to involve only the following:

- Removal of vegetation and silts (by mechanical excavation and/or manual removal)
- Clearance of flood debris
- Clearance and maintenance of a debris arrester
- Mowing of stop-banks and berms
- Planting and landscaping
- Maintenance of a training bank at stream mouth
- Excavation of a diversion cut through foreshore at the stream mouth

5.2 Water Quality

The primary effects on water qualityassociated with mechanical disturbance of the river bed are those relating to the release of fine sediment into the water column, resulting in increased levels of suspended sediment and turbidity, reduced water clarity, and increased sediment deposition downstream. Other potential water quality effects include the release of nutrients or bacteria into the water column.

The results of turbidity and suspended solids measurements undertaken in the Hutt River during a gravel extraction operation are summarised in Table 5-1. The gravel extraction activity entailed extensive mechanical disturbance of the river bed, including pushing river bed material from the flowing river up onto a beach. This type of activity is at the high end of the scale for flood protection routine activities discussed in this report. Maximum turbidity and suspended solids values of 306 NTU and 207 mg/L, respectively, were recorded in the River during bulldozer operation. Turbidity levels ranging from 70 to 163 NTU were recorded in the River 1400m downstream of the works over the same period (Perrie, 2013a).

Table 5-2 summarises the results of turbidity and suspended solids monitoring undertaken during repeated truck crossings of the Hutt River at the same location. Truck crossing activity had a relatively minor effect on river water quality, causing turbidity and suspended solids increases of up to 16 NTU and 2 mg/L, respectively; which is at the low end of the scale for activities discussed in this report. River crossings by larger tracked vehicles can generate suspended solids levels of around 130 mg/L (refer Table 5-3). Bulldozer channel shaping in the Waikanae River has generated suspended solids concentrations as high as 690 mg/L.

The results in Table 5-1 and 5-2 confirm earlier observations that while very high suspended solids concentrations may occur during a large disturbance, water clarity returns to near ambient levels rapidly, often within one hour of the activity ceasing.

In the Hutt River, and probably also in the Waikanae River, suspended solids concentrations as high as 780 mg/L occur during larger flood events (a one-year flood). For smaller more frequent events, i.e., those occurring three to four times each year, suspended solids concentrations typically fall in the range 100 to 400 mg/L (data from HCC and GWRC). Hicks & Griffiths (1992) note that, in rivers around New Zealand, peak suspended solid concentrations during floods range from a few hundred to a few thousand mg/L for relatively small undisturbed catchments in low hill country. The channel shaping results listed above are therefore not outside of the normal range for a mobile gravel bedded river.

Recent monitoring of water quality variables during channel realignment in the Hutt River at Belmont showed that, in addition to elevated levels of suspended solids, the discharge plume contained elevated levels of total nitrogen and total phosphorus. There was, however, no corresponding increase in dissolved nutrients in the water column indicating that the nutrients were bound to particulate matter (Table 5-4). The river bed disturbance is therefore unlikely to have stimulated periphyton growth because the nutrients were not present in a form that could be readily taken up by aquatic plants. The particulate material in the discharge plume may also harbour microbiological contaminants, but the results of the Hutt River study indicate that any increase in indicator bacteria in the water column is likely to be intermittent and localised (Cameron, 2015).

Mechanical disturbance during low flows is likely to result in some settlement of fine sediment on the riverbed downstream of the works area, however this effect is relatively short lived in run and riffle habitat as water velocities during subsequent minor flood flows are sufficient to remove most of the fine sediment from the affected reach ((Death & Death, 2013; Cameron, 2015).

In summary, the available data indicate that:

- River crossings by off-road truck generate relatively low suspended solids concentrations, from 2 to 10 mg/L above background;
- River crossings by bulldozer can increase river suspended solids concentrations by 130 mg/L;
- Channel shaping by bulldozer can increase suspended solids concentrations by nearly 700 mg/L;
- Suspended solids and turbidity levels return close to ambient levels rapidly, typically within 1 hour of the river works activity ceasing.

- Typically a major gravel extraction operation has been undertaken for a number of weeks, for up to eight hours a day, five days a week. The presence of elevated suspended solids concentrations have therefore occurred over the same timeframes;
- The discharge plume may also contain elevated levels of total nitrogen and total phosphorus, but monitoring undertaken in the Hutt River indicates that these nutrients are bound to particulate material and that there is no associated increase in water column concentrations of dissolved nutrients (and therefore little risk of stimulating excessive algae growth).
- Channel shaping may result in a temporary increase in fine sediment deposition on the riverbed downstream of the works.
- A larger flood event (annual and above) in the river can increase river suspended solids by over 700 mg/L, but more common smaller events typically increase river concentrations in the range 100 to 400 mg/L.

Table 5-1: Turbidity and suspended solids (SS) monitoring results for the Hutt River during gravel excavation by bulldozer in flowing water 500m Upstream of Kennedy Good Bridge on 28 November 2012 (data from Geotechnics Ltd)

Time*	Bulldozer activity	Upstream		100m Downstream		500m Downstream	
		Turbidity (NTU)	SS (mg/L)	Turbidity (NTU)	SS (mg/L)	Turbidity (NTU)	SS (mg/L)
16:10	Excavating gravel from river	6	1	175	90	47	29
16:35	Excavating gravel from river	5	2	306	207	102	51
17:00	No activity (work ceased at 17:00)	6	1	52	180	84	100
17:35	No activity	4	1	13	72	64	17
18:00	No activity	5	1	7	1	8	1

*Sampling commenced at the upstream site followed by 100m and 500m downstream over a 15 minute period.

Table 5-2: Turbidity and suspended solids monitoring results for the Hutt River during truck crossings of the river 500m Upstream of Kennedy Good Bridge on 28 November 2012 (data from Geotechnics Ltd)

Time	Truck activity	Upstream		100m Downstream	
		Turbidity (NTU)	Suspended solids (mg/L)	Turbidity (NTU)	Suspended solids (mg/L)
15:40	Prior to crossing river	1	1	6	2
15:48	Truck crossing river (1)	-	-	17	4
15:52	Truck crossing river (2)	-	-	5	2
15:54	Truck crossing river (3)	-	-	8	3
15:56	Truck crossing river (4)	-	-	12	2
15:58	Truck crossing river (5)	-	-	4	2
16:00	Truck crossing river (6)	-	-	7	2
16:02	Post crossing river	1	1	7	3

Table 5-3: Suspended solids concentrations in Waikanae River at river works (GWRC data 1998).

River	Activity	Suspended solids concentration in river (mg/L)		
		Background	Downstream (100m)	Downstream (300m)
Hutt	Channel shaping	2	480	-
	Bulldozer crossing river	2	130	-
	High river flow event (410m^3/s @ Birchville on 19/11/96)	780	-	-
	High river flow event (160m^3/s @ Birchville on 8/10/2007)	397	-	-
	High river flow event (80m^3/s @ Birchville on 5/2/2013)	65	-	
Waikanae	Placement of rip-rap	<2	98	68

River	Activity	Suspended solids concentration in river (mg/L)		
		Background	Downstream (100m)	Downstream (300m)
Hutt	Channel shaping	2	480	-
	Bulldozer crossing river	2	130	-
	High river flow event (410m^3/s @ Birchville on 19/11/96)	780	-	-
	High river flow event (160m^3/s @ Birchville on 8/10/2007)	397	-	-
	High river flow event (80m^3/s @ Birchville on 5/2/2013)	65	-	
	Truck crossing	<2	<2	11
	Thalweg cutting by bulldozer	<2	690	160

Table 5-4: Water quality results at three sites on the Hutt River on two occasions prior to realignment works and two occasions during the works (from Cameron, 2015)

	Upstream				Works Area				Downstream			
	Pre-works#1	Pre-works#2	Works#1	Works#2	Pre-works#1	Pre-works#2	Works#1	Works#2	Pre-works#1	Pre-works#2	Works#1	Works#2
Date sampled	4/05/2015	11/05/2015	26/05/2015	29/05/2015	4/05/2015	11/05/2015	26/05/2015	29/05/2015	4/05/2015	11/05/2015	26/05/2015	29/05/2015
Time sampled	15:00	10:40	10:39	11:37	14:20	10:30	10:55	12:00	13:30	10:15	11:24	12:20
Easting	2672993	2672993	2672993	2672993	2672293	2672293	2672993	2672993	2671686	2671686	2672993	2672993
Northing	6000694	6000694	6000694	6000694	6000046	6000046	6000694	6000694	5999634	5999634	6000694	6000694
Water Quality												
turbidity (NTU)	0.64	1.54	1.04	0.96	0.79	2.2	1010	59	0.96	1.8	29	20
TSS (g/m^3)	<0.5	1.6	1	<0.6	<0.5	3.3	770	82	<0.5	1.7	30	14.8
TN (g/m^3)	0.35	0.33	0.45	0.42	0.33	0.34	1.05	0.5	0.47	0.48	0.49	0.48
Total ammoniacal-N (g/m^3)	<0.010	0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.010	<0.010	<0.01	<0.01
Nitrate+nitrite-N (g/m^3)	0.28	0.26	0.34	0.36	0.28	0.26	0.35	0.36	0.38	0.36	0.38	0.4
TKN (g/m^3)	<0.1	<0.1	0.11	<0.10	<0.1	<0.1	0.7	0.14	<0.1	0.12	0.11	<0.1
DRP (g/m^3)	0.006	0.007	0.008	0.006	0.006	0.007	0.006	0.006	0.01	0.009	0.006	0.006
TP (g/m^3)	0.006	0.008	0.014	0.008	0.006	0.01	0.62	0.077	0.012	0.018	0.032	0.018
E. coli (cfu/100ml)	65	250	140	110	130	200	2100	150	150	300	230	220

5.3 Construction of impermeable erosion protection structures

5.3.1 Rock groynes

Description of activity

Rock groynes are structures that extend from the bank into the river bed and which deflect the direction of flow. They are designed to slow flow velocities and gravel bed movement in the immediate vicinity of the river bank and hence prevent bank erosion.

Groynes are constructed by using an hydraulic excavator to excavate a trench typically 1.0 – 3.0m deep. Rock is placed in the trench and keyed into the adjacent bank to form the base of the groyne. Additional rock is then placed to shape the groyne. In most cases groynes are constructed from solid rock but for larger groynes a river gravel core may be used.

Size is dependent on the situation, but would typically be 10 to 15m long by 6 to 8m wide at the bank, tapered to 4m wide at the toe. The structure would not normally project more than 10m beyond the bank edge into the channel. A series of four or five groynes may be constructed on a long sweeping bend. In the Waikanae River, sets of groynes are located at Sunny Glen (approximately 200 m downstream of SH 1), at Maple Lane (see Figure 5-1) and at Jim Cooke Park (Appendix A, Map 5a).

Potential effects

Construction of a trench and placement of rock would include some disturbance of bed materials and would also include a localised increase in suspended solids concentrations, possibly by as much as 100 mg/L immediately downstream of the works area. A suspended solids concentration of this order would cause a noticeable reduction in water clarity and would be clearly visible from the bank. It would, however, be less than that generated by a moderate fresh in the river.

Monitoring in gravel bedded rivers has confirmed that suspended solids concentrations return rapidly to ambient levels once the in-stream activity ceases. Therefore, the maximum continuous duration of a discharge plume generated by in-stream channel works would be little more that the length of a working day; the aquatic biota would have the benefit of normal water quality for at least half of each 24 hour period.

An investigation conducted before and after installation of rock groynes and bed recontouring on the Waiohine River in the Wairarapa (Death & Death, 2013) identified some changes in macroinvertebrate and fish communities at the works site and at a downstream site (due to deposited sediment) however these communities recovered within a few weeks, returning to their pre-works state after the first fresh. A similar response could be expected in the Hutt River provided key habitat types such as swift riffles are retained.

Rock groynes are typically placed on the outside of bends where there are relatively high current velocities and deeper water. The introduction of rock groynes at such locations may increase the morphological complexity of the river particularly if they are constructed against what was previously an eroding bank. This often results in deep pools associated with the toe of the structure, and sheltered water sheltered in the lee of the structure (Cameron, 2015). This combination of fast water, sheltered water, deep pools and large crevices amongst the boulders can potentially provide a variety of habitat for both native fish and trout. In the Hutt River, Perrie (2013) recorded shortfin eel, longfin eel, koaro, inanga, crans bully, common bully, giant bully, brown trout and shrimp in deep water habitat associated with groynes near Kennedy Good Bridge. The longfin eels were up to 800mm and trout up to 500mm in length. Mitchell (1997) considered that rock groynes could provide feeding lies for trout in areas where this type of habitat is naturally uncommon. A recent Fish & Game survey in the Hutt River near Kennedy Good Bridge showed that trout numbers are relatively high, and that many were located in deep holes associated with the rock groynes (Cameron, 2015).

It can be concluded that rock groynes have the potential to enhance some forms of fish habitat and that the overall effect of this structure on native fish and trout populations in the Waikanae River is likely to range from neutral to positive.

McArthur (2015) reported that no shorebirds were observed breeding on the exposed gravel beaches of Waikanae River during the 2012-15 surveys and that no sites of value for indigenous birds were identified, with the exception of Waikanae Estuary. Although there is one existing groyne in the river channel within the Waikanae Estuary, works in this area are likely to be limited to maintenance of this structure. In light of that information the risk of adverse effects on river birds from groyne construction in the river upstream of the estuary or maintenance of existing groynes is assessed as negligible.

Figure 5-1: Rock groyne on the Waikanae River at Maple Lane

5.3.2 Rock rip-rap lining

Description of activity

Rock rip-rap consists of rock boulders placed against a section of river bank to form a longitudinal rock wall (Figures 5-2 and 5-3). Hydraulic excavators are used to contour a section of river bank to a specified slope and to excavate a trench in the river bed to the design scour depth. Rock is then placed in the trench and against the shaped bank. A full rock wall extends up to a height equivalent to a 2 year return period flood.

In areas requiring lesser amounts of protection, rock lining may be placed at the toe of a bank; this is constructed in a similar way except that the structure generally does not extend higher than approximately 1m above the low flow water level and is not deeply founded into the riverbed.

Rip-rap rock linings have been constructed on approximately 1.6km or 11% of the total bank length within the area of the Waikanae River managed by GWRC, which is less than in the Hutt and Otaki River but more than in the Wainuiomata River (Table 5-5).

Table 5-5: Summary of rock rip-rap lineal lengths with flood protection management areas

River	Total bank length (left + right bank)	Total rock rip-rap lineal length	Percentage of bank length lined with rock rip rap
Hutt	56km	13.8km	25%
Waikanae	14km	1.6km	11%
Wainuiomata	9.6km	0.015km	0.2%
Otaki	22.2km	4.3km	19%

Figure 5-2: Rock rip-rap lining against deep water on the Hutt River

Figure 5-3: Rock rip rap construction on the Waikanae River at Otaihanga

Potential effects

Construction of a trench and placement of rock would include disturbance of bed materials and a localised increase in suspended solids concentrations. Short term effects on water quality and habitat quality are likely to be similar to those described for the construction of rock groynes in the previous section.

Mechanical disturbance of the bed will disrupt invertebrate habitat and may cause some mortality of smaller fish which seek shelter within the substrate. The extent of this disturbance would depend on the quantum of rip-rap to be constructed and the type of habitat which is being replaced.

Longer term effects of rock rip-rap lining are likely to be site specific. Bank contouring could destroy valuable fish habitat beneath undercut banks or overhanging vegetation, and placement of boulders against the bank may reduce the availability of deep water habitat for larger fish. Within the tidal reach at Otaihanga and in the lower Waimeha Stream construction of rock rip-rap could potentially destroy inanga spawning habitat. A suggested monitoring plan outlined in Section 8 and in the EMP includes the re-survey and mapping of potential inanga spawning habitat so that adverse effects on areas of remaining habitat can be avoided.

In other instances, where deep water is maintained against the toe of the rock rip-rap lining, protruding boulders and those which have worked free might potentially provide feeding lies for trout and shelter for other fish species. Crevices between boulders may provide shelter for small and in some cases larger fish. The establishment of vegetation amongst the rock lining has the potential to provide overhanging cover, which may improve fish habitat.

Overall this activity would appear to have a neutral to negative ecological impact, depending on the extent of undercut banks and/or the net loss of overhanging vegetation. There is, however, opportunity to include specific design elements which may potentially result in a net positive effect in some instances. These might include:

- Planting at the rear of the rip-rap where this is likely to provide bankside shade, cover and woody inputs;
- Provision of fish refuges, for instance by placement of boulders to form crevices within the structure; and
- Inclusion of additional boulders protruding out from the wall to break up the uniform flow.

McArthur (2015) reported that no shorebirds were observed breeding on the exposed gravel beaches of Waikanae River during the 2012-15 surveys and that no sites of value for indigenous birds were identified, with the exception of Waikanae Estuary, where works are likely to be limited to maintenance of the existing rock line. In light of that information the risk of adverse effects on river birds is assessed as negligible.

5.3.3 Other impermeable erosion protection structures

Construction of other impermeable erosion protection structures including driven rail and mesh gabion walls, gabion baskets, reno mattresses include the same basic components as outlined above for rock rip-rap linings. Some excavation or disturbance of riverbed material is required in preparation for construction, and the finished structure will generally result in some loss of channel complexity. This may include some loss of fish habitat, particularly if the structure is replacing an undercut bank or dense overhanging vegetation. However, in other instances erosion protection structures may enhance channel complexity and create new habitat for fish, particularly where they incorporate large gaps, crevices and occasional blocks to break up the uniform flow of water.

Rock or concrete grade control structures would also include minor, localised riverbed disturbance during construction, and care would need to be taken that such structures did not impede fish passage subsequently.

5.4 Construction of permeable erosion protection structures

5.4.1 Debris fence, debris arrester, timber groyne

Description of activity

Debris fences are iron and cable fences that extend from the bank into the river channel. They are used to help create or re-establish a willow buffer zone along the edge of the river channel, and so maintain channel alignment. The structures afford protection to willow plantings by trapping flood debris and slowing flows and gravel movement.

Fences are constructed by driving railway iron posts 3 - 5 metres apart into the river bed in a series of discrete lines generally at an angle of 45 degrees from the channel alignment. The posts stand approximately 1.2m above the bed. Three or four steel cables are strung through the posts to form the fence. It is usually necessary to shape the site with a bulldozer to create a smooth construction platform and also to divert the flowing channel away from the site. Irons are driven with a hydraulic hammer mounted on a large excavator (Figure 5-4).

Debris arresters are generally constructed from railway irons driven into the bed and tied together with horizontal irons and in general would entail some mechanical disturbance of river bed material as described for debris fences. These structures are used at relatively few locations in the Waikanae catchment, but remain a useful tool in the right situation.

Timber groynes are constructed in a similar way to debris fences, but typically consist of round hardwood timber piles with two horizontal hardwood cross members.

Figure 5-4: Completed debris fence (Otaki River)

Potential effects

Diversion of the river and shaping of the site by bulldozer involves some disturbance of river bed materials. The initial diversion of the river flow away from the works area will likely result in the discharge of suspended sediment into the flowing river, causing elevated turbidity and suspended solids levels, probably in the upper end of the range outlined in Tables 5-1 and 5-3. However the diversion (and subsequent removal of the bund) would typically be completed quickly, usually within a matter of hours, after which the works are undertaken mostly in the dry, with minimal effects on river water quality.

Mechanical disturbance of riverbed materials will disrupt invertebrate habitat and may cause some mortality of smaller fish which seek shelter within the substrate. The extent of this disturbance would depend on the quantum of debris fence to be constructed and the type of habitat which is being replaced.

The maintenance of debris arresters may cause a temporary release of sediment and other material into the stream, but any discharge is likely to be of short duration and is unlikely to have any lasting adverse effect on downstream aquatic biota.

These structures work as sediment and debris traps so that flood borne debris snags on the rails or cables and rapidly accumulates. At high flows turbulence causes scour on the lee of the structure, often creating a gutter which leads downstream to intersect with the main channel. When this gutter remains full of water at normal flows it can provide sheltered rearing habitat for juvenile fish. Larger eels, trout and a range of native fish may also find cover beneath the debris trapped on the cables, provided the hole is both stable and large enough (Mitchell, 1997).

Mitchell (1997) also noted that as a debris fence or groyne ages, willows and other plants can begin to grow from the trapped debris, until the structure eventually becomes largely obscured and supplanted by the establishment of vegetation. This may result in the accumulation of gravels and silts around the structure causing the river channel to shift away from the structure, with the area around the groyne gradually becoming dewatered. The structure will then have become largely irrelevant for instream values except as shelter for fishes during flood conditions. These structures can create sheltered habitat in areas where it previously may not have been available and, on balance, would appear to have a positive to neutral effect on fish habitat.

5.5 Construction of other works outside of the river bed

Activities such as the construction of cycle ways, walkways, fences and drainage channels outside of the river bed (on berms and stop banks within the river corridor) are unlikely to have any direct effect on the aquatic ecology of these rivers, except possibly by way of sediment runoff from areas of disturbed soils. Sedimentation effects can be adequately managed by the preparation of and adherence to an erosion and sediment control plan, in accordance with the Erosion and Sediment Control Guidelines for the Wellington Region (GWRC, 2002).

5.6 Demolition and removal of existing structures

The effects of demolition and removal of an existing structure will be site specific, depending on the type of structure and its location. The magnitude of these effects could be expected to fall within a range up to and including those described above for the construction of those structures. It is noted that in the past structures have been removed where they presented a health and safety risk to river users. This is not a major activity and is undertaken on an as required basis, typically for no more than one or two days per year in the Waikanae River. It is unlikely to have a significant impact on invertebrate or fish habitat.

5.7 Maintenance of existing structures on and in the river bed

The repair, replacement, extension or alteration of existing structures on or in the river bed may have a wide range of effects depending on the type of structure and its location. The magnitude of these effects could be expected to fall within a range up to and including those described above for the construction of those structures.

5.8 Maintenance of works outside of the river bed

This activity includes regular maintenance work on berms or stopbanks such as mowing and riparian planting as well as intermittent repairs to damaged structural works (stopbanks, flood walls, culverts, drainage channels, and berms) caused by flood events, stormwater runoff or vandalism. It may also include repairs, enhancements or extensions to walking tracks and cycle ways, and upgrade or repair to any drainage channels that cross the berm, including mechanical or hand removal of weeds from stormwater drains. Some of these drains may potentially provide habitat for eels or other fish. Strategies for mitigating the adverse effects of drain clearance on the aquatic ecology are outlined in Section 7.5. Subject to the provisions in Section 7.5, and provided appropriate measures are taken to control sediment runoff and erosion, these activities are not expected to have significant adverse effects on river ecology or water quality.

In those cases where banks are mowed right down to the waters' edge, as occurs on parts of Waimeha Stream, it is recommended that the Code includes a requirement for consideration to be given to alternative strategies, as outlined in 7.3.

5.9 Development of vegetative bank protection

5.9.1 Willow planting

Description of activity

Willows were introduced to New Zealand and Australia in the 1880's for the purpose of stream-bank stabilisation in degraded pastoral systems and as shelter and supplementary fodder for livestock. Extensive willow plantings for erosion control, however, took place in New Zealand in the 1970s to early 1980s (Wagenhoff & Young, 2013).

Willow planting forms an essential part of current river protection work nationwide. Willows are easy to establish, grow rapidly and form an intricate root system that is ideal for binding and strengthening river banks and structural measures such as permeable groynes and debris fences. Generally, the same results cannot be achieved using native species. GWRC established a trial at three sites on the Hutt River in 2001 to investigate the use of native planting for river edge protection. The results of this work are reported in Phillips *et al (*2009). In summary, the report concluded that while native plants could be used to stabilise smaller order streams, there were limitations to the use of native planting for edge protection in larger rivers. In particular, natives are:

- slower to establish
- have shallower root systems
- have higher maintenance costs

The native species with the most potential for river edge protection are toetoe (*Cortaderia fulvida*), flax (*Phormium tenax*) and some grasses (*Carex sp*.). However it was also noted that in flood events there is potential for erosion of these clump-type plants to cause channel blockages.

In light of the trial outcomes, native planting cannot be regarded as a comprehensive or comparable alternative to willows; the most realistic alternative at this stage is likely to be structural work (e.g. rock lining), which involves higher costs and arguably increased environmental impact.

As indicated in Table 5-6 over half of the total river bank length within the Waikanae flood protection area has vegetative bank protection, however GWRC has advised that it does not plan to significantly extend the total area of willow plantings in the Waikanae River corridor in the future, and that GWRC undertakes significant planting of native trees in the river corridor (behind the 'frontline' willow defence plantings.

Table 5-6: Summary of vegetative bank protection lineal lengths within GWRC managed flood protection areas

River	Total bank length (left + right bank)	Total vegetative planting lineal length	Percentage of bank length with vegetative bank protection
Waikanae	14km	7.4km	53%
Hutt	56km	32km	57%
Wainuiomata	9.6km	5.6km	59%
Otaki	22.2km	18.8km	85%

The development of vegetative bank protection involves planting vegetation along the edges of river banks generally within the design buffer zone, in order to bind and support the bank edge and so maintain a stable river alignment. Branch growth also reduces water velocities at the bank edge which assists in erosion protection. Trees may be used to further reinforce structural works.

Planting is generally carried out between June and August. Four planting methods are used:

- By hand, using a crow bar. Willow stakes are cuttings 1 – 1.5 m long and approximately 2.5 cm in diameter.
- Planting using an excavator or planting tine. The tine is dragged through the soil at up to 1 m depth and the stakes or rooted stock planted behind the moving tine. The movable arm of the excavator allows planting to be undertaken on quite steep banks and amongst established trees. This is most commonly used where large areas of planting are required.
- Planting using a digger. Willow poles (large cuttings of 3 m long or more) are planted in a trench dug and backfilled by the excavator. This method is used where willows are planted in very dry areas or immediately adjacent to fast flowing water.
- Planting using a mechanical auger to prepare holes for stakes or poles (Figure 5-5).

Figure 5-5: Willow pole planting (note native plantings at rear)

Potential effects

Short term construction effects are expected to be negligible because the works involve minor disturbance and occur outside of the active river channel.

A recent review of effects of willows on stream ecosystems in Australia and New Zealand concluded that riparian willows at moderate density are more beneficial to trout and benthic macroinvertebrates when compared with riparian pasture reaches (Wagenhoff & Young, 2013). Most of those benefits are related to functions such as the provision of shade and shelter, control of water temperature, and control of sediment and nutrient levels. Mitchell (1997) observed that a chaotic tangle of fallen willow trunks, undercut banks and root mats, with the river eddying and cutting scour holes, provides deep water and many opportunities for cover for eels in particular but also for a range of other fish species.

On the other hand the widespread use of willows along river margins in New Zealand has, in many cases, reduced the natural biodiversity of the riparian edge ecosystem. Wagenhoff and Young (2013) found that, when compared with native vegetation, willow reaches supported fewer terrestrial invertebrate and bird species and lower bird numbers.

It is recognised also that use of willow plantings and other bank protection methods to train and hold the river channel in a design alignment could result in restriction or reduction of habitat diversity unless the design alignment also provides for preservation of habitat diversity through a number of deliberate measures.

It is evident that willow management is complex and context dependent, and that factors such as stream size, geomorphology, hydrology and catchment land-use may influence the outcome. We note that the use of willows forms the keystone of much of GW’s (and other regional council’s) flood protection work and if it were to be discontinued it would need to be associated with quite significant shifts in both river management policy and practice and in the community’s use of the land beside the rivers. Consideration of this matter is beyond the scope of the current application.

On balance, the approach adopted by GW, including the continued use of willows as front line river bank protection, in conjunction with an active programme of planting native trees in the river corridor, may provide a reasonable compromise. Such an approach is likely to enhance some forms of fish habitat without undue adverse effects within the riparian margin, and the overall effect on native fish and trout populations is likely to be positive.

5.9.2 Maintenance of willow plantings and removal or layering of old trees

Description of activity

Maintenance of willow plantings on the river edge would generally involve removal of unstable trees, replanting with new poles, or layering and tethering of mature trees.

Layering is achieved by partially cutting through the trunk of large willow or poplar trees and obliquely felling the trees towards the river in a downstream direction. The intent is to allow the willows to sucker from the branches lying on the ground once they become covered in silt and gravel. The tree is wired to the stump to prevent it breaking off during a flood event. In a stand of willows, it is common for only the front two or three rows to be layered in any one year.

In some instances large unstable trees would be completely removed, but this would normally be followed by replanting for bank stabilisation and to re-instate bird roosting and aquatic ecology values.

Potential effects

Short term effects of layering trees are expected to be negligible. However the removal of old trees may result in the immediate loss of fish habitat (see below), and possibility a temporary and localised increased sediment inputs to the stream via stormwater runoff.

Willow layering for edge protection can benefit the aquatic ecology due to the creation of shade, cover and the supply of woody debris to the river as discussed in the previous section. Willow trunks layered over the bank into the channel may provide many opportunities for cover for eels and other fish species.

On the other hand the removal of trees may result in the loss of good quality fish habitat. While re-planting would normally be undertaken following tree removal, a delay of 10 – 15 years may occur before the full benefits of riparian planting are realised.

Wagenhoff and Young (2013) noted in their review that the potential risks of reach-scale willow removal are related to the influence willows have on geomorphic processes and the consequences of their removal. These include changes to the stream channel, pool-riffle sequences or channel migration associated with stream bank and floodplain erosion with further consequences for stream biota.

The review also showed that risks of willow removal are associated with the loss of the important functions riparian vegetation fulfils. These include increase in water temperature, sediment and nutrient levels, decrease in dissolved oxygen levels, organic matter input, shade and shelter, changes in periphyton community structure and stream metabolism, and eutrophication with direct negative effects on sensitive macorinvertebrate and fish species or indirect food-wed mediated effects associated with reduced detrital food sources (Wagenhoff & Young, 2013).

In some smaller water courses where there is little in-stream cover in the form of logs or undercut banks, willows may constitute a crucial habitat element (Dr Mike Joy, *pers. com*.). Given the paucity of focused information about the effects of willow removal on fish habitat it may be appropriate for a targeted study to be undertaken in a selected watercourse where this activity is likely to be required on a large scale, as part of the EMP.

In summary, the removal of one or two rows of a stand of willows, or of isolated unstable trees, is unlikely to have any long term effects on river ecology, whereas willow removal at the reach-scale may have significant adverse effects, particularly in smaller watercourses.

5.10 Channel maintenance

5.10.1 Removal of woody vegetation

Description of activity

Willows or other tree species may be removed from the channel or adjacent banks, so as to minimise potential for blockages during floods, or to prevent dislodged willows re-growing in the channel. Trimming of willows on the bank edges is also required to clear survey sight lines and to maintain recreational access to the river. Clearance may be done by excavator and/or by hand.

Potential effects

The effects of willow removal are as described in the preceding section. They may include reduced habitat heterogeneity, and the addition of wood and carbon sources to the river.

5.10.2 Removal of aquatic vegetation and silt

Description of activity

This activity includes the clearance of aquatic macrophytes (aquatic plants) and silt from low gradient watercourses so as to maintain channel capacity. High densities of these plants can increase sediment deposition, reduce flows and potentially flood surrounding land. Clearance may be done by mechanical or manual extraction of plant material. This activity is regularly undertaken in the Waimeha Stream but is unlikely to be required elsewhere within the application area.

In the Waimeha Stream the “residential” upper reaches are usually hand cleared three times a year while the lower reaches are cleared by hydraulic excavator around once each year. Excavated vegetation is either placed on the bank to drain or held in the bucket to drain before being dumped into a truck for transport to a disposal area (see Figure 5-6).

Potential effects

Clearance of aquatic macrophytes and silt from the Waimeha Stream is likely to result in significant short term disturbance. Hand clearance is the least disruptive method but may not be viable in the wider lower reaches of stream. Mechanical excavation can result in the immediate loss of a high proportion of the available plant cover.

A study undertaken by Ohau Plants Ltd (2009) for the GWRC Flood Protection department, during mechanical weed clearance of a 600m reach of the Waimeha Stream, recorded six species of native fish, including three at risk species (the longfin eel, inanga, and giant kokopu). A total of 179 fish were recorded over the reach, included 116 elvers (juvenile eels). Many of these fish were removed from the stream by the digger during the excavation process and dumped on the stream bank together with excavated weeds and mud. Two people monitoring the operation were able to successfully return most of the larger fish to the stream (although some mortality was reported, particularly of elvers).

Potential adverse effects of vegetation removal listed by Greer (2014) include the following:

- *Loss of fish spawning habitat.* Inanga spawn along banks of tidal reaches of creek and drains. Eggs are deposited in vegetation on a spring tide and develop out of the water. Removal of vegetation immediately prior to spawning limits availability of suitable habitat. If excavation is conducted while eggs are developing they may be crushed or removed.
- *Stranding of fish and removal of invertebrates during digger operation.* Many native fish species are nocturnal and utilise macrophyte stands as cover during the day. During weed harvesting and mechanical excavation, fish within macrophyte stands can be removed from the waterway alongside the vegetation. Although eels can sometimes make their own way back to the channel most stranded fish either die from desiccation or bird predation. Macro-invertebrates are also removed in large numbers during weed harvesting and mechanical excavation.
- *Suspended sediment causing fish mortality.* If sediment suspended by mechanical excavation has a large organic component, dissolved oxygen in the water column can be reduced. Sustained oxygen depletion can be lethal to fish.
- *Non-lethal effects of suspended sediment impacting fauna.* Suspended sediment concentrations are increased by the physical process of mechanical excavation and the resulting reduction in bed and bank stability. Suspended sediment concentrations can remain elevated for over two months following large drain clearing operations. A persistent increase in suspended sediment concentrations reduces macro-invertebrate prey availability, impairs the feeding ability of some fish species, and impairs respiration. Most native fish and trout avoid high sediment environments; long term increases in suspended sediment reduces abundance. High suspended sediment concentrations and turbidity can affect upstream migrations of native fish and trout. High levels of fine sediment released during excavation can smother benthic fish and invertebrates when deposited in downstream receiving environments, causing death. Sediment released during drain clearing may reduce benthic fish habitat suitability in receiving environments by clogging interstitial spaces. Population densities can be reduced as a result.
- *Fish and invertebrate populations affected by changes in habitat structure.* Invertebrate community structure is strongly influenced by benthic habitat and is likely to be negatively affected by riffle disturbance and coarse substrate removal during excavation. Macrophytes and woody debris provide important habitat for invertebrates in soft-bottomed low-land streams. Therefore, the removal of these structures during excavation may have a significant impact on invertebrate populations. Nocturnal fish species such as the giant kokopu and the longfin eel spend daylight hours in cover provided by macrophytes, woody debris and undercut banks. Disturbance of these structures during drain cleaning may reduce their suitability as habitat. Disturbance of riffles and the removal of course substrates during excavation decreases population densities of some fish species and reduces spawning habitat availability for bullies and trout.
- *Changes in channel morphology and hydrology*. Channel morphology and hydrology can be altered by excavation of macrophytes which can have an impact on habitat availability for aquatic organisms. The removal of macrophytes and deposited sediment decreases water depth, increases current velocity and increases channel depth. However, repeated cleaning can over widen and deepen channels, slowing water movement. Removal of riparian vegetation and alterations to bank shape during excavation can decrease bank stability. This increases the risk of bank collapse which can affect the shape, path and hydrology of the waterway.

Greer (2014) proposed a series of strategies aimed at mitigating the adverse effects of watercourse clearing, noting that not all of these strategies will be successful or necessary all of the time. Those strategies that are applicable to clearing in the Waimeha Stream are listed in Section 7.5.

Figure 5-6: Vegetation clearing in Waimeha Stream by digger fitted with a 'weed bucket'

Beach ripping and scalping

Description of activity

Beach scalping involves mechanical clearance of woody and herbaceous weeds and grasses from gravel beaches. Mechanical clearance is typically performed using a bulldozer, large excavator or front end loader to strip the vegetation and thus remove vegetative obstacles in the channel that might lead to gravel deposition in floods and consequent shifts in the desired channel alignment. The vegetation is crushed and left to break down or become light flood debris.

Ripping involves loosening of thegravel armouring layer by dragging a tine through it. This lfacilitates the mobilisation of the gravel during floods (Figure 5-9).

Both activities involve excavation or disturbance of bed material but do not typically result in a discharge of sediment to the flowing channel.

Figure 5-7: Beach ripping (Hutt River)

Potential effects

This activity is unlikely to have any immediate downstream effects on water quality or aquatic habitat. It will, however, loosen the beach gravels so that in the next flood, gravels and interstitial sand will be more readily mobilised, possibly causing additional siltation and gravel accumulation in the reach downstream. These processes already occur during floods and consequently river biota are well adapted to a dynamic, mobile bed environment. In this context the additional silt and gravel from lengths of loosened beaches is unlikely to be important.

Clearing areas that are in the process of becoming more stable and covered by pioneer weeds creates more open gravels. There is evidence that removing weeds has considerable value for those birds which roost and breed on open riverbeds (i.e., Rebergen 2011 & 2012). However, McArthur *et al* (2015) found no evidence of breeding populations of banded dotterel, pied stilt or black-fronted dotterel on the Waikanae River.

5.10.3 Clearance of flood debris

Description of activity

Flood debris is material deposited on the river bed as a result of wreckage or destruction resulting from flooding. It can include trees, slip debris, collapsed banks, the remains of structures, and other foreign material including abandoned vehicles, but does not include the normal fluvial build-up of gravel.

Removal of flood debris is necessary because blockages reduce channel cross-sectional area which result in higher flood levels. In addition, if allowed to occur, build-up of obstacles may deflect flood flows into banks, causing lateral erosion.

Removal of flood debris covers only the minimal amount of work needed to clear the bed or structures within the bed of flood debris; GWRC has advised that any beach or bed contouring completed at a location where debris removal occurs is accounted for as beach or bed recontouring in work records.

This activity may also include the occasional dredging of accumulated debris in the tidal reach of Waimeha Stream.

Potential effects

Mitchell (1997) notes that debris clearance has implications for fish living in large open rivers. Trees and debris stranded in the river channel by a flood event will have formed local disruptions to flow. Turbulence results in scour around the debris and there can be a subsequent range of habitats formed. During flood events, debris clusters can provide shelter for fish where they could otherwise be swept downstream. In normal flows these same areas can provide feeding lies for trout if they remain at least partially submerged and are beside the main flow. Small fish are attracted to the cover provided beneath debris in shallow, slow-flowing water (biologists will head for these areas during electric fishing surveys because of the high probability of finding fish in this type of habitat).

Overall, there is little doubt that flood debris can increase the range of water depth and velocities which in turn provide for a variety of habitat preferences for fish, although Jowett (1995) suggests that flood debris are not sufficiently abundant to influence fish distribution to any great extent. It seems therefore that where there is opportunity to leave flood debris that presents no apparent risk to structures or public safety, it would be beneficial to enhancement of available habitat for fish.

As the tidal reaches of both the Waikanae River and Waimeha Stream are known to provide inanga spawning habitat, the timing of any works in these areas will be important. Disturbance of these areas should be avoided and particular care is needed during spawning, from March to May, inclusive (refer Section 7.6).

5.10.4 Gravel Extraction

Description of activity

In the Waikanae River GWRC proposes a programme of gravel extraction to achieve, and then maintain, mean bed levels (set at or about 1991 levels) within an envelope of minimum and maximum allowable bed levels. The aim is to maintain a balance between flood capacity (reduced by high bed levels) and the threat of undermining bank protection works (increased by lower bed levels). The reasons for gravel extraction from the Waikanae River are further detailed in a GWRC memo prepared by Hooker (2013).

The work would entail an initial lowering of the riverbed from cross section XS 50 at the boundary of the CMA (refer Appendix A) up to cross section XS 300 at Jim Cooke Park. It is anticipated that works would commence at the upstream end of the extraction reach as this will interrupt the sediment supply to the tidal reach (where extraction is more difficult to undertake). The initial bed lowering works would be followed by a 'maintenance' gravel extraction programme from the deposition reach in the vicinity of Greenaway Road, the amount of which which would be determined by the sediment supply delivered to this reach by river transport processes.

A combination of both 'wet' and 'dry' extraction methods are proposed. Within the tidal reach, from cross section XS 50 to XS 80, the entire channel is submerged much of the time and 'wet extraction' will be untaken from within the active channel, but would probably be limited to two hours either side of low tide. It is proposed that material would be pushed to the bank edge by a D8 or D9 bulldozer. The windrowed material will then be placed by excavator in a temporary stockpile adjacent to the river or it may be loaded onto an off-road dumper for transport to a temporary stockpile area adjacent to the Otaihanga boat ramp. Material would be left for a minimum of one day (to allow it to drain) prior to transport offsite via the access road of Makora Road. Extraction of approximately 11,500m^3 of material is required to achieve the design bed level in this reach. Based on an estimated capability of the machinery to push 400m^3 per day (over a four hour period), the initial bed lowering work in this reach would involve 30 days or six weeks work in the active channel. The duration of works could increase if weather or tide conditions are unfavourable.

Above the tidal reach from cross sections XS 80 to XS 300, the proposed method includes wet extraction from the low flow channel, with a lower channel being formed beach by beach to a meander pattern with a pool and riffle form. Generally a combination of excavators and off-road dumper trucks will be used over the entire reach.

In the lower part of this reach, between cross section XS 80 and XS 130, due to the narrow channel and difficult access the entire operation will be undertaken within the active channel, and off-road dumpers will track within the riverbed. Entry and exit to the riverbed will be on the left bank at XS 110 via Otaihanga Domain. Extracted material would be transported to a stockpile area in Otaihanga Domain.

Approximately 14,000m^3 is required to be extracted in the reach from XS 80 to XS 130 to achieve the design bed levels. Based on the machinery being able to move 600m^3 per day over an eight hour period, this would involve 23 days or five weeks work in the active channel. The duration of works could increase if weather conditions were unfavourable.

Between XS 130 and XS 300, the low flow channel will be deepened by an excavator and material temporarily stockpiled on the adjacent beach for a minimum of one day. An excavator or front end loader will then be used to load gravel either onto road trucks or dumper trucks for transport offsite. It is intended that access by existing entry points to the riverbed at XS 130 and XS 175 will be used, however in places where direct access to the working area is not available there may be a requirement for new access points to be formed from the bank edge. If no access is possible from the bank edge, there may be a requirement for river crossing points to be formed and for off-road dumpers to track within the riverbed.

Approximately 18,200m^3 is required to be extracted in the reach from XS 130 to XS 300 to achieve the design bed levels. Based on the machinery being able to move 600m^3 per day over an eight hour period, this would involve 30 days or six weeks work in the active channel.

In summary, the initial bed lowering works would entail the extraction of 11,500m^3 of material from the tidal reach, 14,000m^3 from the middle reach and 18,200m^3 from the upper reach, giving a total extraction volume of 43,700m^3 over a total lineal river length of 2.8km. Overall this is expected to require a total of seventeen weeks work in the active channel, or four to five months. Potentially the works programme couldbe spread over two or three years.

Once the target bed levels have been achieved, GWRC would need to maintain this profile by extraction from the Greenaway Road reach (between XS200 and XS300, approx.) to balance the annual gravel inflow rate from further upstream, estimated at 6000m^3 on average. As this material typically arrives as a pulse during a large flood event, extraction will likely be undertaken in response to a major flood event and not necessarily as part of a regular annual programme. Based on machinery being able to move 600m^3 per day (over an eight hour period) this would, on average, involve 10 working days or two weeks work in the active channel each year (or four weeks work after two years accumulation, etc). Both wet and dry extraction methods are expected to be used.

Potential effects in Waikanae River

(i) Disturbance of birds

Gravel extraction from beaches above the active channel (in the dry) may have implications for river bird roosting and breeding habitat. However, McArthur *et al* (2015) found no evidence of breeding populations of banded dotterel, pied stilt or black-fronted dotterel on the Waikanae River. McArthur *et el* (2015) noted also that, in contrast to the locally-breeding shorebird species, the majority of the remaining bird species recorded in the river corridor are terrestrial species that are common and widespread in the surrounding landscape, and are considered unlikely to be adversely impacted by the localised effects of flood protection activities occurring in the bed of the river itself. In light of that information it is concluded that, outside of the Waikanae Estuary, there are no birds within the river corridor likely to be at risk from gravel extraction activities. (Potential effects in the estuary are discussed below).

(ii) Disturbance of Herpetofauna

Only one lizard species, the northern grass skink, has been recorded within the vicinity of the Waikanae River, and the likelihood of this lizard being present in those areas frequently flooded by the river is considered to be low. Accordingly, the risk of negative effects on herpetofauna is assessed to be negligible and no specific mitigation measures are considered to be necessary in respect of herpetofauna.

(iii) Fine sediment mobilisation and deposition

Gravel extraction from the dry is likely to have minimal effects on water quality of the Waikanae River, although in those cases where trucks are required to cross the river there is potential for minor temporary discharge of suspended sediment (refer Section 5.2) and disturbance of bed material. This can be managed by requiring vehicles to use designated crossing points.

There is evidence from a study of the Pohangina River that gravel extraction in the dry can lead to the accumulation of fine sediment on the river bank at locations where it can be carried into the river during a small fresh (Death *et al,* 2011). That is likely to be a consequence of the mudstone geology and high fine sediment content of gravels in the Pohangina River, which is not the case for the Waikanae catchment which has hard-sedimentary geology, and where the fine sediment content of gravels is low. It is noted however that Perrie (2013) reported a reduction in substrate size on dry beaches of the Hutt River, where gravel had been previously stockpiled and then removed.

Gravel extraction which involves working in the active channel, as is proposed in the Waikanae River, entails extensive disturbance of bed material and significant release of suspended sediment into the water column. Monitoring of river water quality indicates that this activity generates suspended solids concentrations in the river immediately downstream of the works of up to 800 mg/L, or about the same order as an annual flood (Section 5.2). Monitoring results also indicate that suspended solids concentrations decrease fairly rapidly with distance downstream, and return to near ambient levels within an hour of the completion of works. Consequently, if works in the actively flowing channel are limited to no more than 12 hours each day the aquatic biota downstream of the works would have the benefit of normal water quality for half of each 24 hour period, including night time when much of the native fish feeding activity occurs.

Death *et al* (2013) found that bed recontouring on Waingawa River, using a similar method to that applied during gravel extraction, resulted in a marked increase in levels of deposited sediment downstream of the works but that effect was temporary, with a return to ambient levels after the first fresh. Extensive bed recontouring works on the Hutt River at Belmont caused a conspicuous sediment plume while machines were operating in the river (up to 770 mg/L) but there was no increase in fine sediment cover in riffle habitat 750m downstream of the works Cameron (2015a).

In summary, gravel extraction works caused a major increase in water column suspended solids, but this effect is temporary and does not continue much beyond the cessation of works. The works also caused increased rates of sediment deposition in downstream river habitats but this effect was is short-lived, seldom extending much beyond the first fresh.

(iv) Disturbance of benthic habitats

Habitat mapping studies undertaken in the Waingawa River during channel re-alignment (Perrie, 2009), the Hutt River during gravel extraction (Cameron, 2015d) and the Hutt River during channel re-alignment (Cameron, 2015a) show that these works can cause a major change in the relative areas of in-stream habitat types, often resulting in a reduction of pool and swift riffle habitat and an increase in run habitat; and nearly always with an associated loss in hydraulic complexity. In some instances the river quickly reverted to a more natural form after the first fresh in the river, but this is not always the case. In some instances the re-establishment of specific habitat types may require a series of high flow events over several months. The time required for recovery can be reduced by incorporation of an engineered channel design, with a well-defined low flow channel with a 'natural' slope to the beach, and creation of well-formed pools and riffles (refer Section 7.4) as part of the works.

(v) Disturbance of macroinvertebrate communities

The Waikanae is a relatively small river with moderately high water clarity, and with high ecological values within the affected gravel extraction reaches. The proposed gravel extraction will cause a physical disturbance over a sustained period. Difficult access, especially in the reach upstream of Otaihanga Domain, is likely to result in heavy machinery tracking for some distance within the riverbed.

Fenwick *et al* (2003) found that despite the major disturbance created by in-stream gravel extraction operations, in large braided rivers like the Waimakariri River, which are characterised by frequent floods and discoloured waters, gravel extraction from the active channel does not appear to have a major effect on the benthic fauna downstream of the works area, although some changes in invertebrate faunal composition occurred (and it is noted that smaller rivers with clear water conditions for a greater proportion of time, like the Waikanae River, may be less resilient).

There is strong evidence that macroinvertebrate re-colonisation of shallow riffle areas disturbed by in-stream works is rapid and that any impacts are likely to be short lived, i.e., Perrie (2009); Sagar (1983); Perrie (2013b) and Death *et al* (2013). The majority of these studies identified clear impacts on macroinvertebrate communities immediately after the works but found that recovery to the pre-works condition had occurred rapidly, within seven or eight weeks, typically after the first significant fresh has passed through and re-worked the river gravels. This is likely to be the case in the Waikanae River where a healthy and diverse benthic community in the river upstream of the works area would be available to assist in the re-colonisation of disturbed reaches (as already occurs after major floods). It is noted however, that where the area of mechanical disturbance involves multiple riffles over a longer river length, the overall productivity of that reach is likely to be reduced, potential reducing food supplies for fish.

(vi) Disturbance of fish communities

Perrie (2013a) undertook a 'before and after' survey of fish abundance by EFM in three shallow riffle habitat sites on the Hutt River where gravel extraction occurred. One site was located in the immediate area of the gravel extraction activity, a second site was located 1.2 km downstream and a third 1.2 km upstream. The results show that juvenile koaro were abundant at all three sites in the first survey in November but numbers decreased at all three sites in second survey in December and no koaro were caught in the final survey in February. The author concluded that this reflected the annual upstream migration (whitebait run) of this species to upstream habitat. Redfin bullies were also juveniles likely to be migrating upstream. Bluegill bullies were the most abundant species and were sufficiently abundant to be compared between sites and across sampling occasions (and are expected to be resident in this part of the river system). Perrie (2013a) observed that:

> *"Overall, given that a reduction in bluegill bully densities occurred at the upstream site, it is not conclusive that the gravel extraction caused the decline observed in the impact site. However given that the gravel extraction changed the habitat at the impact site from that considered ideal for bluegill bullies (riffles) to that considered less favourable (run), it seems highly plausible that the gravel extraction contributed at least in some way to the decline in density at this site. Further work is clearly required to better understand how gravel extraction from the wetted channel may be affecting bluegill bully populations in the Hutt River."*

More recently an investigation was conducted in the Hutt River at Belmont before and after channel re-alignment works over a 220m river length (Cameron, 2015a). That study showed that the engineering works caused a major change in habitat characteristics at the works site. The channel was straightened and simplified by removal of a meander and gravel bar. Several areas of swift riffle habitat were lost and had not been re-established seven weeks after completion of works. The loss of swift riffle habitat had implications for the local bluegill bully population which were the most abundant fish species in this reach. The abundance of bluegill bullies declined at the works site as a result of river engineering activities, and had not recovered seven weeks after completion of the works. It was evident that the bullies had not returned to the engineered reach because there was no longer good quality habitat for them there.

Death *et al* (2013) found that bed re-contouring on Waingawa River temporarily affected fish numbers, but that the fish fauna recovered rapidly, usually after the first fresh, provided suitable habitat is available (Death & Death, 2013). The authors concluded in relation to the Wairarapa Rivers that:

> "…*the weight of evidence provides no indication that any fish (except for trout in the Waingawa) were adversely affected by the engineering activities, in fact eels and/or bullies in some of the rivers increased in abundance*".

Fenwick *et al* (2003) found that juvenile torrentfish and bullies in the Waimakariri were more abundant and had more food in their guts downstream of gravel extraction than at the control site. One explanation for this is that the in-channel disturbance caused by gravel extraction dislodged benthic invertebrates and increased drift downstream. As a result, the fish may have preferred the riffle downstream of the digger because of the increased food availability. The mayfly *Deleatidium* spp. comprised a major proportion of the foods found in the guts of juvenile torrentfish (a species that is typically a nocturnal feeder) and is probably susceptible to dislodgement and drifting downstream from in-channel gravel extraction activities. The possibility of greater availability of food for fish with in-channel disturbance is evident in the fact that some anglers prefer to fish for trout downstream of active extraction sites because of greater catch rates, believed to be due to increased feeding by fish at such sites (Fenwick *et al,* 2003). The Hutt River study also showed an increased bluegill bully population downstream of the works, which may also be caused by increased food supply, but Perrie (2013a) considers that other factors may explain the increase, including a 'displacement' effect whereby bullies were inhibited from upstream migration, and/or moved downstream due to changes in habitat at the works site.

It is concluded that where there is a potential for loss of important habitat due to river engineering works, the Code should require that consideration should be given to options for avoiding or mitigating any such loss, for instance by incorporating a design meander pattern into the works, with a focus on creation of alternative or replacement riffle and pool habitat. For large scale works affecting a long length of river and multiple riffles, consideration should also be given to leaving some riffles (perhaps every second riffle) untouched so as to maintain sufficient reserves in the local fish population to enable the efficient recolonization of the engineered reaches (refer Section 7.4).

(vii) Disruption of fish spawning and/or migration

As described in Section 3.1.7 the Waikanae River application area provides spawning habitat for a variety of fish, including:

- Inanga spawning habit is located in tidal estuary edge vegetation, and is discussed below in relation to the Waikanae Estuary.
- Other galaxiid species including koaro, banded kokopu and giant kokopu, spawn in vegetation or cobbles at the riparian margin between April and August. Spawning habitat is generally thought to occur near typical adult habitats, which for most of these species will be in minor watercourses outside (upstream) of the application area.
- Bullies spawn in riverbed substrate, often under large rocks, between August and February. Some spawning habitat is expected to occur within the application area.
- Torrentfish spawn in riverbed substrate, probably in the lower river near the coast (within the application area), mostly between January and April.
- Trout move into headwater tributaries, or suitable areas on the main-stem, to spawn during May and June. Trout spawning occurs throughout much of the Waikanae catchment, including parts of the main-stem of the river, potentially including some reaches within the application area. Recommendations for the protection of trout spawning habitat are given in Section 7.6.

(viii) General comments

It is clear that the proposed gravel extraction programme has the potential to cause significant adverse effects on the river ecology, at least in the short term. Potentially disturbance of the bed could be expected to occur over a period of many weeks over a 2.8km reach of river. Consequently the bed disturbance and discharge plume would have the potential to interfere with juvenile fish migration and to disrupt spawning of inanga, bullies, torrentfish and brown trout. Potential adverse effects on juvenile native fish migration and spawning could, however, be addressed by limiting the amount of bed disturbance that can occur during period of peak upstream migration & spawning, as specified in Section 7.6 (and summarised in Table 5-7).

Table 5-7: Recommended constraints of works in the wetted river channel – Waikanae River

<table>
<tr><th></th><th>Jan</th><th>Feb</th><th>Mar</th><th>Apr</th><th>May</th><th>Jun</th><th>Jul</th><th>Aug</th><th>Sep</th><th>Oct</th><th>Nov</th><th>Dec</th></tr>
<tr><td>Waikanae River main-stem</td><td></td><td></td><td></td><td></td><td colspan="3">No works in trout spawning reaches</td><td></td><td colspan="4" rowspan="2">No more than 3 day's work per site or 15 days in the application area</td></tr>
<tr><td>Waikanae River Estuary</td><td></td><td></td><td colspan="3">No works at inanga spawning habitat</td><td></td><td></td><td></td></tr>
</table>

Given these constraints, and to minimise adverse effects on river ecology, it would be desirable to spread the bed lowering gravel extraction over two of three years. For instance gravel extraction could be undertaken in the upper reach (XS 300 to XS 130) in year one, the middle reach (XS130 to XS80) in year two, and the tidal reach (XS 80 to XS 50) in year three. Subsequent maintenance extraction from the Greenaway Road reach (XS300 to XS200), to maintain the bed levels, should also observe these exclusion periods.

Potential Effects in Waikanae Estuary

(i) Birds

The Waikanae Estuary and its associated wetlands and ponds are identified as a site of value for indigenous birds. The proposed gravel extraction reach extends from XS 80 downstream to XS50, well within the estuarine reach, raising the possibility of adverse effects on valuable bird habitat, including the nesting habits of the North Island fernbird and the pied shag. These risks can be avoided or mitigated by ensuring that gravel extraction and associated activities do not affect any area within the Waikanae Estuary Scenic Reserve (refer Figure 3-17) and are limited to the following areas:

- the main river channel up to the line of high tide, and
- existing access tracks shown in Waikanae River application area map 2a (Appendix A), and
- a grassed area near the boat ramp, proposed to be used to stockpile excavated material.

It is recommended that the residual risk of adverse effects to bird feeding and roosting habitat in the upper estuary should be addressed by the development of a management plan in consultation with DoC and GWRC biodiversity staff.

(ii) Sediment deposition

Estuaries are a sink for sediments; their natural cycle is to slowly infill with fine muds and clays. However, prior to European settlement they were dominated by sandy sediments and had low sedimentation rates, typically <1mm/year (Stevens & Robertson, 2014). Monitoring over the period 2010 to 2014 in the Waikanae Estuary gives a mean sedimentation rate of 26.4mm/year, indicating rapid sediment deposition. This material is mostly settling out in the upper estuary, while the lower estuary near the coast remains dominated by clean sands (Stevens & Robertson, 2014). Activities within the Waikanae catchment that are thought to have driven this increase include vegetation clearance, wetland drainage and land development for agriculture and settlements. Plantation forest harvesting in the upper Waikanae catchment is thought to have been a particularly important driver of increased fine sediment loads in the river.

The proposed gravel extraction activity would not add to the total fine sediment load in the river (in fact it would reduce it slightly), but may accelerate the rate of sediment transport to the estuary and deposition within the estuary in the short term. The main settlement zone for fine sediment is currently the upper estuary flats, at the downstream end of the application area, where soft mud overlays firm muddy sands. In the short term, while the gravel extraction programme is underway it is likely that deposition rates would increase further in the upper estuary, potentially worsening the risk of sediment related impacts such as poor water clarity and muddy intertidal substrates, which favour mud tolerant invertebrate taxa and may have implications for resident and migrating fish.

However, it is anticipated that a proportion of fine sediment in upper estuary flats will be removed during the last phase of the gravel extraction programme. It is expected also that the lowering of the river bed level will halt the current tendency or aggrading bed levels, and facilitate the transport sediment out through the mouth during flood events, which may have the effect of reducing sedimentation rates in the estuary in the medium term (Hooker, 2013).

Hooker (2013) noted that sediment accumulation within the estuary is likely to be a cyclical process characterised by long periods of sediment accumulation punctuated by occasional major flood events, such as the January 2005 flood, which reportedly scoured out much of the sediment from within the estuary.

(iii) Disruption of Inanga Spawning

Inanga spawning habit is located in tidal estuary edge vegetation and occurs during March, April and May. Suitable areas of inanga spawning habitat have been observed on the Waikanae River within and downstream of Otaihanga Reserve, predominantly on the true left (south) bank. Recommendations for the protection of inanga spawning habitat are provided in Section 7.6.

Potential adverse effects on juvenile native fish migration and spawning could be addressed by limiting the amount of bed disturbance that can occur during period of peak upstream migration & spawning, as specified in Section 7.6 and summarised in Table 5-7.

5.11 Channel shaping and realignment

5.11.1 Beach recontouring

Description of activity

Beach recontouring can be undertaken on its own, and also in conjunction with the removal of vegetation from beaches, establishment of structures or in association with bed recontouring. It is undertaken in the dry bed, away from the flowing channel. The purpose is to streamline the beaches to avoid any future obstructions to flow that may lead to unexpected and unwanted shifts in channel alignment.

Potential effects

A survey of river birds conducted during 2012 indicates that river bird nesting is rare or absent on the Waikanae River (McArthur *et al* 2012). In light of that information the risk of adverse effects on river nesting species resulting from beach re-contouring is assessed as low.

McArthur *et al* (2012) also made a number of recommendations about further monitoring to be carried out to provide quantitative data to describe on-going trends in the distribution and abundance of riverbed nesting birds, which have been included in the baseline monitoring plan of the EMP (refer Section 8).

As this work is undertaken in the dry bed, away from the active channel, there is little risk of short term construction impacts on water quality or aquatic ecology. There is no evidence of negative impacts in the long term.

5.11.2 Bed recontouring

Description of activity

Bed recontouring is mechanical shaping of the active channel to realign the low flow channel so as to reduce erosion (typically at the outside of a bend) or to prepare the bed for construction or planting works. Straightening of the channel and removing sharp bends increases the hydraulic efficiency of a reach and thereby reduces flood levels.

Bed recontouring to realign a bend in the channel involves cutting a newchannel through a dry beach on the inside of a bend, leaving a bund at both ends to minimise silt discharges. Excavated material is placed at the outside edge of the new channel. When the new channel is completed, the end bunds are removed, and the excavated material pushed across the old channel alignment to the required finished bed profile.

In the Waikanae River bed recontouring will also be done in conjunction with gravel extraction in order to establish the design meander pattern, and in that case will not necessarily shorten the channel (see previous section).

An analysis of the length of river bed affected by recontouring over the duration of the current consents is summarised in Table 5-6. (The figures for the Hutt River do not include bed re-contouring associated with gravel extraction works).

Table 5-8: Lineal lengths of river bed affected by re-contouring over the 13 years to Jan 2012

	Waikanae	Hutt	Otaki
Total lineal length (m)	2580	7050	9620
Average per year (m)	184	542	740
Permitted by existing consent: Total (m) per year	600	800	1200

Potential effects

Bed recontouring involves mechanical working in the active channel and entails extensive disturbance of bed material and significant temporary release of suspended sediment into the water column. The short term construction effects on water quality, macroinvertebrate and fish populations are likely to be similar to those described above for wet gravel extraction because the two processes are very similar in terms of bed disturbance (refer Section 5.10), although the extent and duration of works in the active channel may be less than required for wet gravel extraction (days rather than weeks) because much of the work can be completed in the dry and generally bend realignment affects a lesser extent of the riverbed than extraction works.

Where it is used to straighten the channel, bed recontouring is likely to result in loss of channel complexity and a reduction in aquatic habitat diversity. Mitchell (1997) observed that major channel re-alignment involves the direct loss of habitat and offers few direct ecological benefits apart from greater channel stability. Mitchell concluded that channel realignment was the flood protection practice most likely to have significant impacts on the environment (but noted that, overall, the river management approaches used on Wairarapa Rivers should result in an enhancement of biological activity).

More recently, Perrie (2009) observed that channel realignment on the Waingawa River resulted in significant straightening of the river channel in the study reach and had a clear impact on the diversity of habitat types. In particular deep runs were reduced in overall extent and pools were completely removed, while the proportion of shallow run and riffle habitats increased. Perrie considered this to be a net reduction in the overall diversity of habitat in this reach because of the relative scarcity of deep water habitat and because of the higher complexity of that habitat type relative to shallow water habitats.

In summary, the medium to long term effects on the aquatic ecology of bed recontouring, where it is used to merely straighten the channel, are mostly negative, and the significance of those effects for the river ecology at the reach scale will depend on the quantum of bed recontouring undertaken over time and any new suitable ecological habitat that is created to replace or offset the negative effects on the existing habitat. It may be possible that this activity could be undertaken at a rate that balances the destabilising effects of floods, without on-going loss of habitat complexity, provided measures are in place to ensure the number of pools and riffles within a specified reach are maintained.

There is also an opportunity to mitigate many of these adverse effects by applying the principles developed for the Hutt River gravel extraction programme, whereby the works are designed to form a well-defined low flow channel with a ‘natural’ slope to the beach and well-formed pools and riffles, which provide good quality habitat for invertebrates and fish. The maintenance or creation of backwaters as part of these works should also be considered. These additional design elements would minimise the loss of habitat diversity.

5.11.3 Wet ripping

Description of activity

Mechanical ripping of the bed in the wet channel is a technique used in some rivers to improve the low flow channel form and alignment through the riffle zones in particular.

The activity involves dragging a tine that is mounted on a bulldozer or excavator through riffle sections of the active channel, in order to encourage the mobility of bed material. Mobilisation of bed material occurs naturally in flood events. The wet ripping activity is intended to facilitate that process by loosening bed material in target areas, leaving the river move the bed material. The intention is to mitigate any sharp directional changes in the channel at such points and thus maintain a more regular channel meander pattern.

Potential effects

Wet ripping involves mechanical disturbance of the riverbed, with associated aquatic habitat disturbance and release of sediment to the water column, however the activity is generally less extensive and can be completed more quickly than bed recontouring and thus the scale of effects is relatively less than with bed recontouring.

These works cause some disruption to periphyton, invertebrate and fish communities. Nevertheless, as described above for bed-recontouring, re-colonisation is rapid and the impact is generally short lived.

5.12 Flood Protection Activities in the CMA

5.12.1 Waikanae River mouth realignment

Description of activity

A diversion cut is excavated at the Waikanae River mouth when the channel outlet migrates more than 500m south or 200m north of the groyne on the south bank of the river, or when the water level increases 300mm or more above normal river levels at the Otaihanga footbridge. The cut is alignedto lead directly on from the main river channel to the sea. A trench is excavated through the foreshore and beach to form a pilot channel for the new river mouth. Sand from the excavation is used to block off the active river channel and prevent flow to the sea. This work begins at low tide when the sand is firmer and the machinery does not have to work in water. The block is left until sufficient water has ponded in the Otaihanga reach of the river. At the following low tide the top of the pilot channel is opened to release the ponded water into the new channel and out to sea. The sudden release of water scours the new channel deeper and wider than the original excavation.

This work is usually undertaken at spring tides when the tidal variation is greatest. The operation usually takes a maximum of 24 hours to complete and involves the use of up to six earth moving machines. This would typically include two hydraulic excavators, one large dump truck for the long hauling of sand and three rubber tyre loaders for short hauls.

This activity was been known to be undertaken eleven times since 1930, once every 7.5 years on average, however the last cut was undertaken on 10 December 2001.

Potential effects

The excavation cut will disturb the foreshore and beach immediately in front of the river channel. The foreshore can develop into a sand-spit extending up to 700m to the southwest. This area is naturally unstable, being periodically affected by flood flows and frequently eroded or submerged by wave action during high tides and storm surges. As the pilot channel is opened, ponded water scours a channel through to the sea, mobilised large quantities of sand. This creates a visible discharge plume in near-shore coastal waters similar to that generated by a large flood event. Much of the scoured material is deposited within the surf zone and then gradually dispersed by wave action and tidal currents, predominantly in a southerly direction. Finer material is likely to remain in suspension causing a temporary reduction in visual clarity in coastal water in the vicinity of the cut, especially during the first few hours of the breach, but is likely to have little effect on the biota of the surf zone.

Bird species such as the variable oystercatcher occupy the sand-spit where the river affords some protection from predators such and cats, dogs and ferrets. The excavation cut initially converts the sand-spit into an island as the river typically maintains the old channel to the south as well as the new channel opposite the main river channel. The quality of safe roosting habitat is therefore maintained and even enhanced at such times, although the total area may be reduced. However, aerial photographs taken between 2005 and 2013 (currently available on Google Earth), indicate that this is a dynamic situation and that at times the island disappears or is submerged at high tide, possibly following major storm events.

Robertson and Stevens (2012) consider that the artificial opening of the channel to the sea effectively causes the loss of the lower part of the estuary and reduces the ecological values of the area because there is limited potential for long term estuarine communities to develop. We note that the instability of this area is a natural feature of a dynamic river system and that the breaching of the sand-spit would naturally occur from time to time, without mechanical intervention, albeit at a lower frequently than under the present management regime. In this context the additional adverse effects resulting from mechanical opening are probably minimal.

5.12.2 Waimeha Stream mouth realignment

Description of activity

A diversion cut is excavated at Waimeha Stream mouth when the channel outlet migrates more than 250m south or 150m north of the centre line determined by the training wall adjacent to Field Way, or the channel outlet creates a vertical scarp in the sand dunes which exceeds 2m in height, or when the water level increases by 300mm or more above the normal river level as measured at the Field Way road bridge. GWRC records indicate that this typically occurs two of three times each year (on 24 occasions over the last 12 years). The operation usually takes a maximum of 24 hours to complete.

The activity and methodology is essentially the same as described for the Waikanae River but on a smaller scale. That is, a pilot trench is excavated through the beach and the excavated material is used to block the existing channel, eventually causing the stream to scour out a new channel along the preferred alignment.

Potential effects

The excavation cut will disturb the beach immediately in front of the stream channel. This area, being part of the stream mouth, is naturally unstable and is frequently affected by flood flows, wave action during high tides and storm surges. As described above the Waikanae River, the realignment works cause the stream to scour a channel through to the sea, mobilising large quantities of sand and creating a visible discharge plume in near shore coastal waters. Much of the scoured material is deposited within the surf zone, and gradually dispersed by wave action and tidal currents. Finer material is likely to remain in suspension causing a temporary reduction in visual clarity in coastal water in the vicinity of the cut, especially during the first few hours of the breach. These effects are localised and temporary and are not expected to continue for more than 24 hours after completion of works. Effects on aquatic and benthic ecology are expected to be negligible.

5.12.3 Maintenance of rock groyne and rip-rap lining at Waikanae River mouth

Maintenance of the rock groyne and rock rip-rap lining at the mouth of the Waikanae River on the true left bank is undertaken relatively infrequently; most recently in May 2005 to repair flood damage. Rock is hauled by truck along an existing road through Waikanae Estuary Scientific Reserve and placed by hydraulic excavator. No adverse effects are anticipated or likely.

5.12.4 Maintenance of training wall at Waimeha Stream mouth

Maintenance of the rubble mound training wall on the right bank of the Waimeha Stream mouth is undertaken as required, typically by topping up rock that has been eroded by sea action or flooding. No adverse effects are anticipated or likely.

5.12.5 Clearance of debris arrester on Waimeha Stream

A debris arrester consisting of a row of 8 timber poles across the width of the stream prevents logs and other large debris from being washed upstream by the incoming tide and wind. Accumulated material is periodically removed by hydraulic excavator and/or hand clearance, typically once each year. Debris from the arrestor is buried on the beach above the high tide mark near the stream mouth. No adverse effects are anticipated or likely.

6 Cumulative Effects

The potential for the effects of GWRC operations and maintenance activities to be increased by other similar activities undertaken in the catchment by other parties include those associated with the proposed new bridge crossing of Waikanae River for the Western Link Road, which will entail in-river and bank protection works. The Kapiti Coast District Council's water supply project, which would include groundwater recharge of the river, may also have effects on the river, although the types of activities involved are very different and their relevance to flood protection activities (if any)are uncertain.

There may be a cumulative effect resulting from the extension of permanent works (i.e. rip-rap linings) in the long term, however the extent of such structures is relatively low in the Waikanae River. Furthermore, there is evidence that fish abundance and diversity can be relatively high in river reaches that are intensively managed (for instance the Hutt River at Belmont), suggesting that the cumulative effect of flood protection activities on the riverine ecology may be relatively minor. Indeed, trout abundance is consistently higher in the Melling – Belmont reach compared with unmanaged reaches upstream of the application area.

It is acknowledged, however, that the cumulative effects of multiple flood protection activities have not been systematically monitored in the past and, in the absence of suitable information, there remains some uncertainty around the long term cumulative effects of these activities.

The monitoring programme outlined in Section 8 and detailed in the EMP is intended to establish a long term monitoring framework covering both geomorphological and biological measures of river health. It includes the development of a natural character index (NCI) which, it is expected, will provide a measure of the cumulative effects of river-channel activities on river morphology, and by inference on habitat quality. Further investigations will need to be undertaken to better establish the link between NCI scores and ecological condition, and is noted that the applicability of this approach has yet to be tested.

7 Mitigation

7.1 Overview

Many of the flood protection activities assessed here are identified as having potential adverse effects on the river ecology due to changes that they cause to water quality, riverine or riparian habitat, or due to direct impacts on river bird, benthic macroinvertebrate or fish communities. In many cases the adverse effects of individual works will be temporary, or can be avoided or mitigated by the application of good practice methods, and by scheduling the works so as to avoid periods of peak sensitivity at specific locations, such as river-bird nesting, fish spawning and peak fish migrations.

GWRC has prepared an Environmental Code of Practice (Code) and Monitoring Plan (EMP) in support of the flood protection consent applications which are intended to guide and monitor how all flood protection and erosion control activities are done across the Region. It is intended that flood protection activities will be conducted in accordance with the Code, using methods selected from the Code, that monitoring of the effects of those activities will be conducted in accordance with the EMP, and that the results of monitoring will feed into a regular review process. Over time this process will facilitate the adaptive management of flood protection activities, with the objective of avoiding unacceptable adverse effects and mitigating other negative effects while still enabling the conduct of flood protection activities for the public good.

Specific measures which have been identified in this report as being important considerations for the avoidance or mitigation of adverse effects in the Waikanae River and Waimeha Stream are outlined in the following sections.

7.2 River Bird Habitat

McArthur*et al* (2015) made a number of recommendations to minimise the risk to nesting bird populations of the Hutt, Waikanae and Otaki Rivers from flood protection activities on gravel beaches. However, unlike the Hutt and Otaki Rivers, the Waikanae River does not support a breeding population of riverbed nesting shorebirds, and accordingly no specific recommendations have been made in respect of dry gravel beaches on the Waikanae River or Waimeha Stream.

7.3 River Edge Biodiversity

For vegetative bank protection where willows are used as front line river bank protection, give consideration to:

- provision of an active programme for the planting and maintenance of native trees in the river corridor,
- seek to integrate native and willow planting where appropriate,
- as far as is practicable avoid disturbance of existing areas of native vegetation,
- give consideration to the protection of high-value areas of riparian native vegetation where such areas are threatened by erosion, and
- for the Waimeha Stream where current practice is to mow right down to the waters' edge, give consideration to restoring native vegetation to at least one bank of the stream so as to improve in-stream conditions, or allow a strip of grass at the stream edge to grow long on both banks.

7.4 Habitat of Benthic Biota and Fish - Rivers

Various flood protection activities have been identified as having the potential to adversely affect the habitat of macroinvertebrates and fish. In particular, bed recontouring, channel realignment and wet gravel extraction can involve extensive mechanical disturbance of the wetted riverbed, causing considerable short term impacts on invertebrate and fish communities.

For the maintenance or enhancement of in-stream habitat during in-channel works it is recommended that works should be undertaken in accordance with a 'design channel alignment' which aims to achieve:

- optimum flood carrying capacity,
- a stable channel alignment,
- a well-defined low flow channel with a 'natural' slope to the beach, and
- well-formed pools and riffles providing good quality habitat for macroinvertebrates and fish to recolonise. (In those instances where the works will extend over a long river length affecting multiple riffles, also give consideration undertaking works only on every second riffle, so as to maintain sufficient reserves in the local fish population to allow efficient recolonization of the engineered reach).

For construction of new rock rip-rap bank protection or significant extension of existing rip-rap, consider the following:

- planting downstream of rip-rap where this is likely to provide bankside cover and overhanging vegetation,
- provision of fish refuges, for instance in spaces between large rocks within the structure, and
- inclusion of additional boulders protruding out from the wall to break up the uniform flow.

For the clearance of flood debris:

- Adopt a balanced approach whereby flood debris (trees, logs, etc) is left in the river unless it presents an apparent risk.

7.5 Habitat of Benthic Biota and Fish – Streams and Drains

In small soft bedded watercourses such as the Waimeha Stream where macrophyte or silt removal is required, develop a mitigation strategy that should include most, but not necessarily all, of the following:

1. Return stranded mega fauna (fish, crayfish, shellfish etc.) to the waterway;
2. Encourage the digger operator to ensure the bucket is submerged at the end of each cut (to give fish an opportunity to escape);
3. Distribute spoil in such a way that it cannot slump or be washed back into the waterway;
4. Distribute spoil so that stranded eels can make their own way back to the waterway;
5. Use a weed rake rather than a conventional bucket in gravel bottom waterways;
6. Use a conventional bucket rather than a weed rake where large amounts of fine sediment are present;
7. In heavily silted waterways prevent suspended sediment moving downstream by using artificial or natural filters;
8. Recover distressed fish from the disturbed waterway and relocate them upstream;
9. Do not return recovered fish to highly turbid water.
10. Maintain beneficial plant refuges by only partially clearing plants from the waterway (leaving the margins or entire sections of waterway un-cleared);
11. Maintain ecological refuges by not cleaning all waterways in a catchment or property at once;
12. Replace lost habitat complexity with reinstated artificial structures (such as artificial refuse structures made of PVC piping, cinderblocks or bogwood);
13. Between 1 March and 30 May avoid clearing waterways identified as potential inanga spawning and between 1 May and 30 September avoid clearing waterways identified as trout spawning habitat.
14. Preserve specific important habitats such as riffles, if they exist;
15. Avoid removing course gravel and cobble substrates, if it is present;
16. Where practicable maintain variability in stream bed depth and contours.

7.6 Protection of Fish Life

For the protection of indigenous fish it is recommended that:

- Disturbance of the wetted channel (by bed re-contouring, channel realignment or wet gravel extraction) should not be undertaken between 1 September and 31 December, inclusive, for more than three days at any works site or for more than 15 days within the 7km long application area.
- Disturbance of the wetted channel should not be undertaken when the river flow has receded below the minimum flow specified in GWRC's Regional Plan (for water allocation purposes), unless it can be demonstrated that the work is urgent and necessary, and appropriate approval is obtained.
- Works should not block the channel in such a way that fish passage is prevented at any time.
- Any fish that are stranded during dewatering of any channel shall be immediately placed back into the flowing channel.

For the protection of inanga spawning activity:

- Avoid works in the bed or river banks in the immediate vicinity of inanga spawning areas during spawning from 1 March to 30 May.

For the protection of trout spawning activity it is recommended that:

- No work shall be undertaken in the wetted channel of the Waikanae River during the trout spawning period between 1 May and 31 July.

8 Monitoring

8.1 Overview

Monitoring the effects of flood protection activities on geomorphology, river nesting birds and aquatic ecology is proposed by GWRC to be undertaken in accordance with the EMP, which is included in Section 2 of the Code. The EMP proposes a programme of baseline monitoring and specific event monitoring. Baseline monitoring will consist of regular (three yearly) measurement of geomorphological and biological variables in each of the six Waikanae River reaches defined for the NCI, which would be used to assess the cumulative effects of flood protection activities over time.

The Code specifies trigger levels for each monitoring component which, if exceeded, will be used as inputs to the regular review process prescribed by the Code. That review could, where appropriate, result in a modification of a specific activity, and require some other measures (such as offset of habitat loss by creation of new habitat elsewhere) to be implemented.

Event monitoring for moderate scale works would consist of before/after habitat assessments and for large scale works would include comprehensive before/after/control/impact investigations of water quality habitat quality, biological monitoring and calculation of NCI (definitions for 'moderate' and 'large' scale works are given in Section 8.3).

8.2 Baseline Monitoring

8.2.1 Riparian Vegetation

Vegetation types within the riparian margins of rivers in the application area will be broadly mapped using aerial photography (or LiDAR survey) supported by selected site visits to confirm interpretation. It is intended that these surveys would be completed within three years of the consents being granted and at 9-year intervals thereafter and that this will enable any changes in the extent and composition of riparian vegetation to be tracked over time.

8.2.2 River Birds

Baseline river bird monitoring was undertaken during 2012, 2013 and 2014 on the Waikanae River. It is proposed that three year sets of annual surveys are repeated on a regular basis, with a gap of 5 years between surveys (i.e., in years 2012, 2013, 2014, 2020, 2021, 2022, etc.).

8.2.3 Fish Communities

The New Zealand Freshwater Fish Database (NZFFD) contains a significant amount of information about freshwater fish communities in the Wellington Region. However, some habitats in which flood protection activities can occur, including deeper water habitats, which are difficult to survey by electric fishing methods, are not well represented in the database.

It is recommended that surveys of fish communities be undertaken at three yearly intervals in selected reaches of the Waikanae River for the duration of the consent (or until modified by review of the EMP). It is further recommended that these reaches should be coordinated with those defined for NCI assessment and to include reference and impact sites (to the extent that is possible within the application area), so as to provide information on the relationship between fish populations and natural character of the river.

8.2.4 Trout Abundance

Annual monitoring of trout abundance will be continued using drift dive methodology, at five reaches on the Waikanae River as described in Pilkington (2014). If possible it would be desirable to align drift dive reaches with NCI survey reaches (Table 3-18)

8.2.5 River Bed Level Surveys

Monitoring of riverbed levels is important due to their impact on flood capacity and channel stability. GWRC currently undertakes riverbed surveys at five yearly intervals on the Hutt River. Survey data are used to analyse trends in gravel movement and to determine river management policies and gravel extraction volumes for the succeeding five year period.

8.2.6 Aerial Photography

Aerial photographs provide a useful tool for river management planning and allow quantification of river morphology and depiction of changes in this over time. Aerial photography mosaics will be produced at least once every three years over the reaches of the Hutt River managed by GWRC to ensure that up to date data for management planning and a regular record of river morphology for potential use in assessment of effects of river works is available over the life of the new consents.

8.2.7 Pool and Riffle Counts

The numbers of pools and riffles in a river is a measure of the diversity of aquatic habitat and morphological complexity of a river, which in turn can be used as an indicator of the overall ecological health of the river (particularly when considered in conjunction with other aquatic survey data). Pool and riffle counts will be conducted at least once every three years in each of the reaches identified for calculation of NCI. It is intended that counts will be undertaken by representatives of Wellington Fish and Game and GWRC according to an agreed methodology using aerial photography mosaics flown no more than 12 months prior to the count.

8.2.8 Deposited Sediment

The amount of deposited sediment on the river bed can be used as an indicator of aquatic habitat quality, and changes in the amounts of deposited sediment can also be used to indicate changes in habitat quality over time. Deposited sediment measurements will be undertaken once every three years in each of the reaches identified for calculation of NCI to allow comparison of the resultant data. These measurements will also be co-ordinated, as far as is practicable, with the 3-yearly aerial photography outlined above, for the same reason. The measurements will include visual estimates of fine sediment cover and assessment of substrate grain size by Wolman pebble count, in accordance with the protocols provided in Clapcott *et al* (2011).

8.2.9 Riverbank undercutting and overhanging vegetation

River bank undercutting and overhanging vegetation provide opportunities for aquatic habitat diversity, which in turn may contribute to overall aquatic ecological health. Length of riverbank undercutting and overhanging vegetation will be measured once every three years in each of the reaches identified for calculation of NCI to allow for this parameter to be included in the overall NCI calculation.

8.2.10 Natural Character Index

WRC is proposing to further investigate the use of a natural character index (NCI), currently under development by Massey University researchers, to monitor the degree of departure from a reference condition of geomorphological characteristics in the selected rivers on a regular basis.

Wave amplitude (from aerial photography), pool and riffle counts, deposited sediment levels, substrate grain size, length of undercutting, and length of overhanging vegetation would be assessed and selected variable used as input to the NCI (details to be confirmed). It is intended that the NCI be used as part of the baseline monitoring programme to assess departure from an historic reference condition at each of the NCI reaches defined for these rivers (refer Williams 2013). It is anticipated that this will provide a measure of the cumulative effects on river morphology for specific river reaches.

It is also intended that NCI would form part of any site specific monitoring programme to be developed for larger flood protection works (see Event Monitoring below). The geomorphological variables would be assessed at the works reach and a similar length of river upstream before and after the works. The ratio of these variables (expressed as a combined index of before to after) would be calculated for the works and upstream reaches (i.e. to produce a ‘works reach’ NCI and an ‘upstream reach’ NCI).

It should be noted that this science is relatively new and that further work is required to develop and refine the NCI for use in the rivers of the Wellington Region. Further investigations will need to be undertaken to better establish the link between NCI scores and ecological condition before the NCI could be confidently used as an indicator of ecological condition, or as a trigger for mitigation action.

8.3 Event Monitoring

In the first instance, event monitoring will focus on those activities deemed to have the most potential for adverse effects, namely wet gravel extraction and bed recontouring. The need for inclusion of other activities would be identified through the Code review process. For the purpose of determining an appropriate level of monitoring for these riverbed disturbance events, activities have been categorised as minor, moderate and large scale, as described in the following sections.

8.3.1 Minor Scale Works in the Wetted Riverbed

Minor scale works are defined as those affecting less than 175m lineal length of wetted riverbed and/or no more than 3 days of in-river works. [5]

Baseline monitoring at each NCI reach will be undertaken as described in 8.2 above. Over time the baseline monitoring results would be used detect cumulative change, either by aggregation of a range of habitat measures via the NCI or as individual components of habitat quality.

No site specific monitoring is proposed for work sites in this category.

8.3.2 Moderate Scale Works in the Wetted Riverbed

Moderate scale works are defined as those affecting between 175m and 800m lineal length of wetted riverbed and/or between 3 days and 8 days of in-river works.

In addition to the baseline monitoring as described in Section 8.2, site specific before/after habitat assessments will be undertaken at each work site by the operations supervisor using the habitat assessment template[6] included in Appendix 2 of the Code.

8.3.3 Large Scale Works in the Wetted Riverbed

Large scale works are defined as those affecting more than 800m of wetted riverbed length and/or more than 8 days of in-river works. This will include large scale wet gravel extraction or bed re-contouring works which occur relatively infrequently but which result in extensive riverbed disturbance.

At these works, in addition to the baseline monitoring as described in Section 8.2, a site specific EMP will be developed prior to the commencement of work by a suitably experienced aquatic ecologist. The site specific EMP is likely to include some or all of the following, and where possible would be based on a before/after/control/impact design:

- Water quality monitoring (suspended solids, turbidity, Total-Nitrogen, Total-Phosphorus)
- Deposited sediment monitoring (sediment cover and substrate size)
- Habitat mapping at impact and reference sites
- Macroinvertebrate re-colonisation
- Survey of fish populations
- NCI calculated for the works and upstream reaches (i.e. to produce a 'works reach' NCI and an 'upstream reach' NCI)

8.3.4 Mechanical Weed Removal from low gradient watercourses

During the first three year period under the new consents, fish surveys will be undertaken on all perennial streams affected by mechanical clearance of aquatic weeds, before and after the clearance operation. Fish surveys will be undertaken by backpack electric fishing (and where appropriate by trapping and/or spotlighting) in general accordance with the New Zealand Freshwater Fish Sampling

[5] From Northern Wairarapa River works records (1 July 2011 to 31 Dec 2014) approximately 20% of works sites included bed disturbance lengths greater than 175m. On that basis 175m is taken as the upper limit for 'minor scale' bed distance.
[6] The applicability of habitat assessment form as a monitoring tool is under development.

Protocols (Joy, David, & Lake, 2013). The need for further monitoring of fish populations in these watercourses will be determined at the first five yearly review of the EMP.

8.3.5 Disturbance of Terrestrial Vegetation at the River Margins

Any flood protection activities likely to involve disturbance of large areas of indigenous forest or scrublands should be preceded by a lizard survey within the affected area. Such surveys will be designed to determine the presence or absence of lizard species within the works area and indicate the severity of potential impacts on any populations. If lizards are found and a severe impact is predicted, a lizard management plan should be prepared for the area.

9 Summary and Conclusions

GWRC Flood Protection department undertakes a range of river management activities within the Waikanae River and Waimeha Stream application area in order to maintain the river channels within their design alignment, maintain the flood capacity of the river channels, and maintain the integrity and security of existing flood defences. Many of the flood protection activities assessed here are identified as having potential adverse effects on the river ecology due to changes in water quality, riverine or riparian habitat, or due to direct impacts on river bird, benthic macroinvertebrate or fish communities. In many cases the adverse effects of individual works will be temporary, or can be avoided or mitigated by the application of good practice methods as specified in the Code, and by scheduling the works so as to avoid periods of peak sensitivity at specific locations, such as river-bird nesting, fish spawning and peak fish migrations.

Some practices such as the establishment of vegetative buffer zones, willow planting and layering, and construction of rock groynes, will have mostly positive effects on river ecology, while other activities involving a greater level of disruption to benthic habitats will tend to have more negative effects. Bed recontouring, channel realignment and gravel extraction are identified as having the greatest potential for adverse effects on river ecology in the short term. These activities involve major mechanical disturbance of benthic habitats, and create a visible discharge plume as well as increased rates of fine sediment deposition downstream. Research conducted on rivers in the northern Wairarapa Valley shows that individual works on short reaches (100m to 150m lineal length) do not have a lasting effect on benthic ecology or fish communities, and that adverse effects are not likely to last much beyond the first fresh. However a more recent study conducted in the Hutt River at Belmont shows that bed disturbance over a 200m to 250m lineal length resulting in a loss of swift riffle habitat can have a more lasting effect, probably requiring a series of high river flow events to re-establish good riffle habitat.

The potential effects of larger scale in-channel works, for instance where mechanical disturbance of the river bed extends over river lengths of greater than 800m, are less well characterised, mainly because works on this scale occur infrequently and the opportunity to assess the effects of such activities has not arisen in recent years. The gravel extraction program proposed for the Waikanae River to achieve the design profile will involve a larger scale of works than has occurred over the last 15 years, and will affect a total river length of 2.8km. It is assumed that the scale of effects could increase roughly in proportion with the scale of works but that hypothesis is yet to be tested. For this reason the EMP proposes a tiered ‘event’ monitoring approach, with increasing monitoring effort required for larger scale works sites.

It is recognised that information on the cumulative effects of multiple small works undertaken at different locations and at different times is currently limited. Effects of this type are more difficult to identify and will not necessarily be detected by monitoring focused on individual works sites. For this reason, in addition to the proposed event monitoring, an ongoing baseline programme is proposed to detect changes in geomorphological characteristics at specified river reaches over time, utilising a natural characteric index to combine these various monitoring results. Baseline monitoring will also include biological variables and it is anticipated that, in the longer term, the monitoring programme will provide an improved understanding of the relationship between natural character and ecological health.
It is proposed also that the results of monitoring under the EMP will feed into a regular review of the activities and processes specified in the Code with the aim of improving environmental and other outcomes over time.

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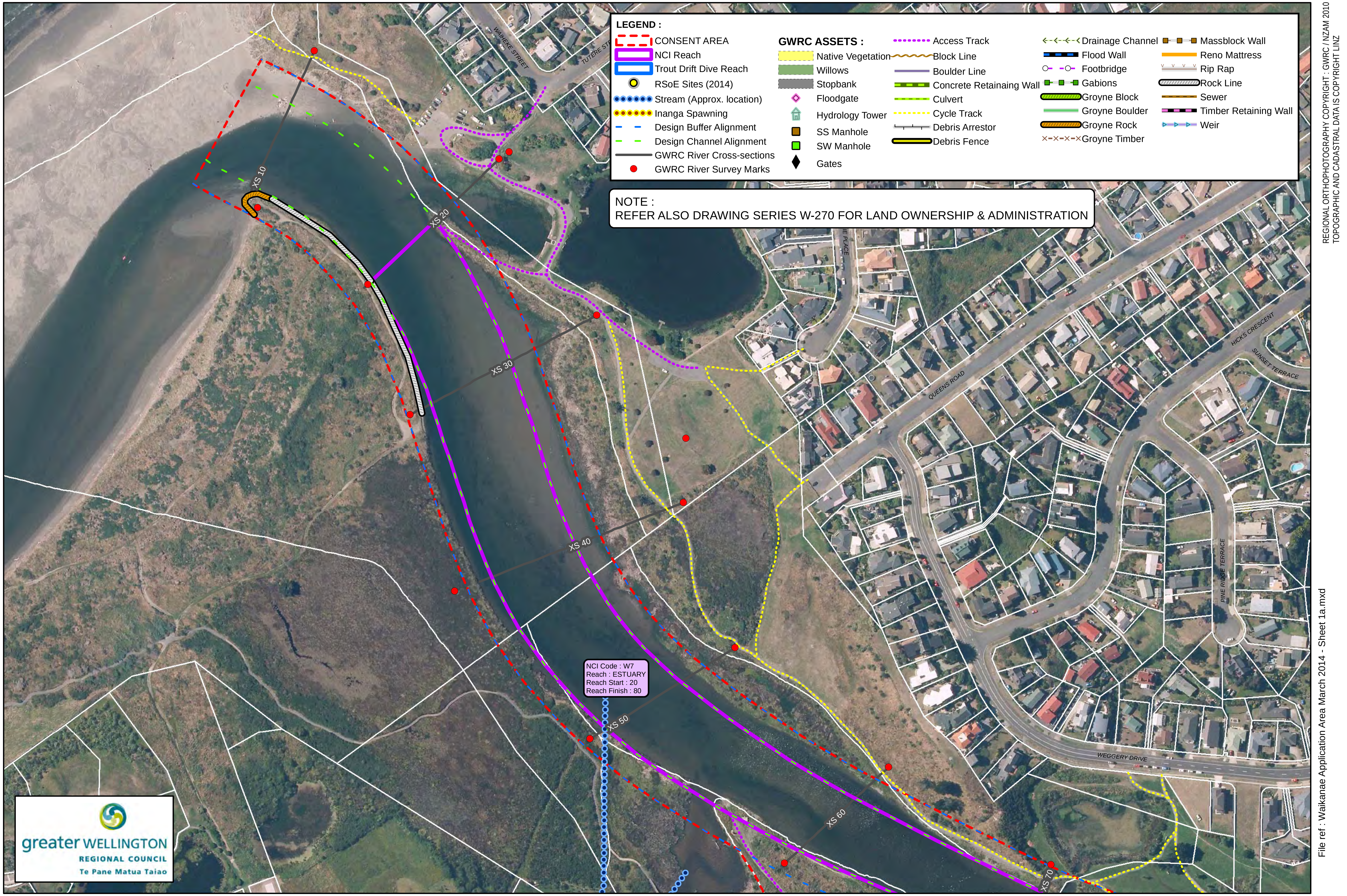
Appendix A Waikanae River Maps Series W-271/1-8



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WAIKANAE RIVER - CONSENT AREA - Map 1a

GWRC Asset, Fish & Ecological Information (River Mouth to Water Treatment Plant Weir)

Drawn : P.Cook, Date Plotted : 7 July 2015
Aerial Photo : GWRC 2013

DWG No. **W-271 / 1**

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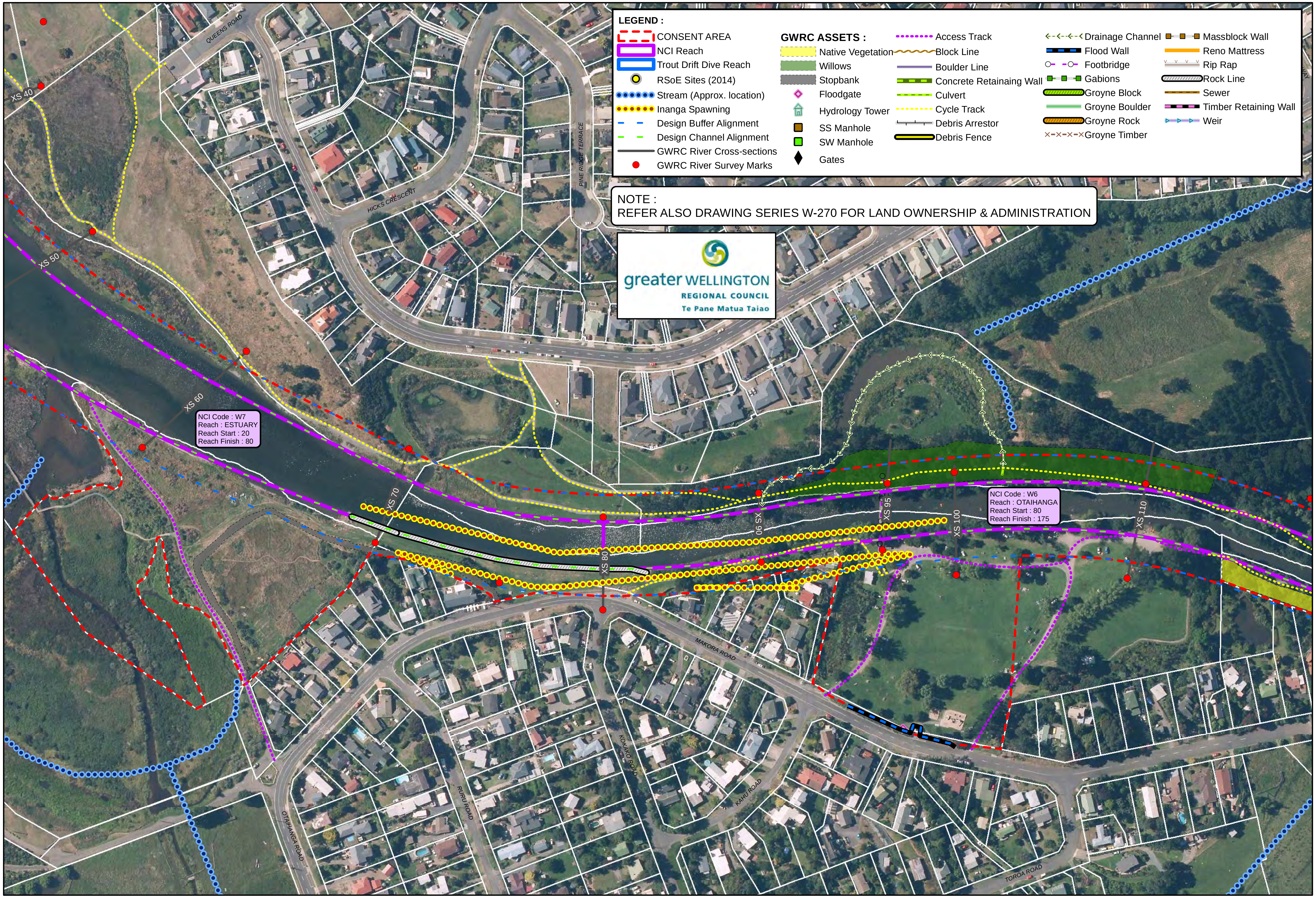

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File ref : Waikanae Application Area March 2014 - Sheet 2a.mxd

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1:2,500

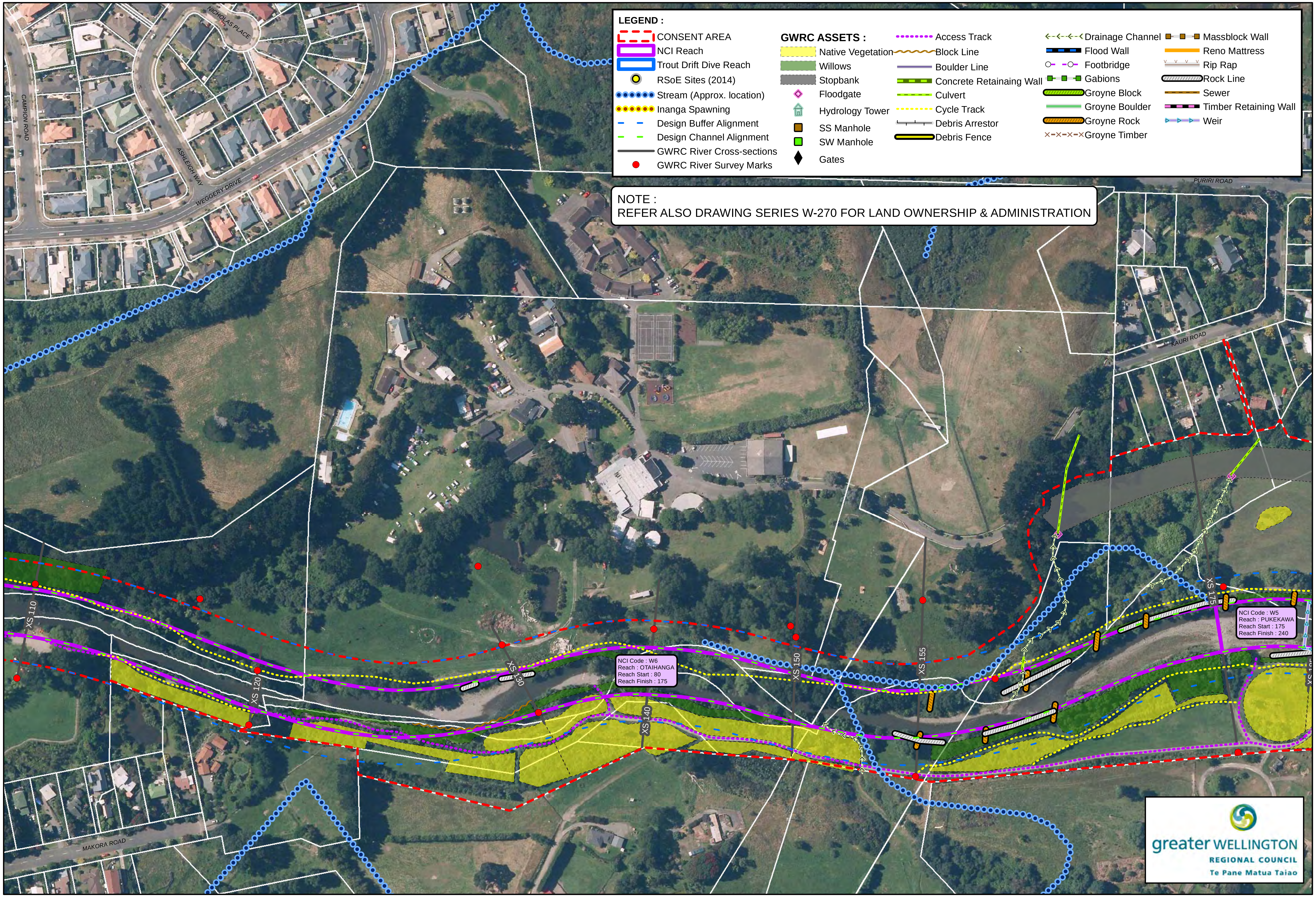
WAIKANAE RIVER - CONSENT AREA - Map 2a

GWRC Asset, Fish & Ecological Information (River Mouth to Water Treatment Plant Weir)

Drawn : P.Cook, Date Plotted : 7 July 2015
Aerial Photo : GWRC 2013

DWG No. **W-271 / 2**

N



0 25 50 100 Meters

A3 Scale :1:2,500

WAIKANAE RIVER - CONSENT AREA - Map 3a

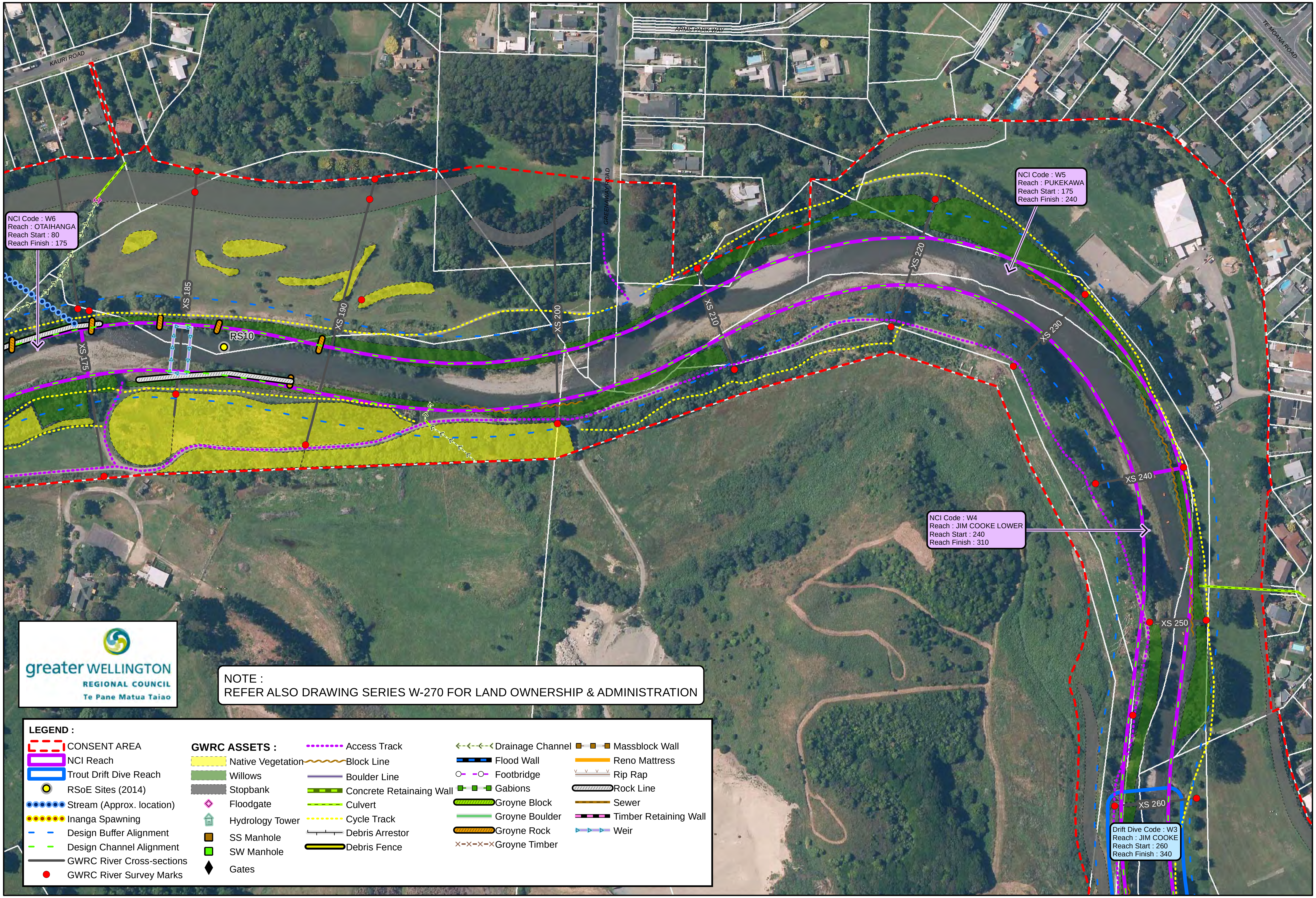
GWRC Asset, Fish & Ecological Information (River Mouth to Water Treatment Plant Weir)

Drawn : P.Cook, Date Plotted : 7 July 2015
Aerial Photo : GWRC 2013

DWG No. **W-271 / 3**

N

File ref : Waikanae Application Area March 2014 - Sheet 3a.mxd



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File ref : Waikanae Application Area March 2014 - Sheet 4a.mxd

0 25 50 100 Meters

A3 Scale :1:2,500

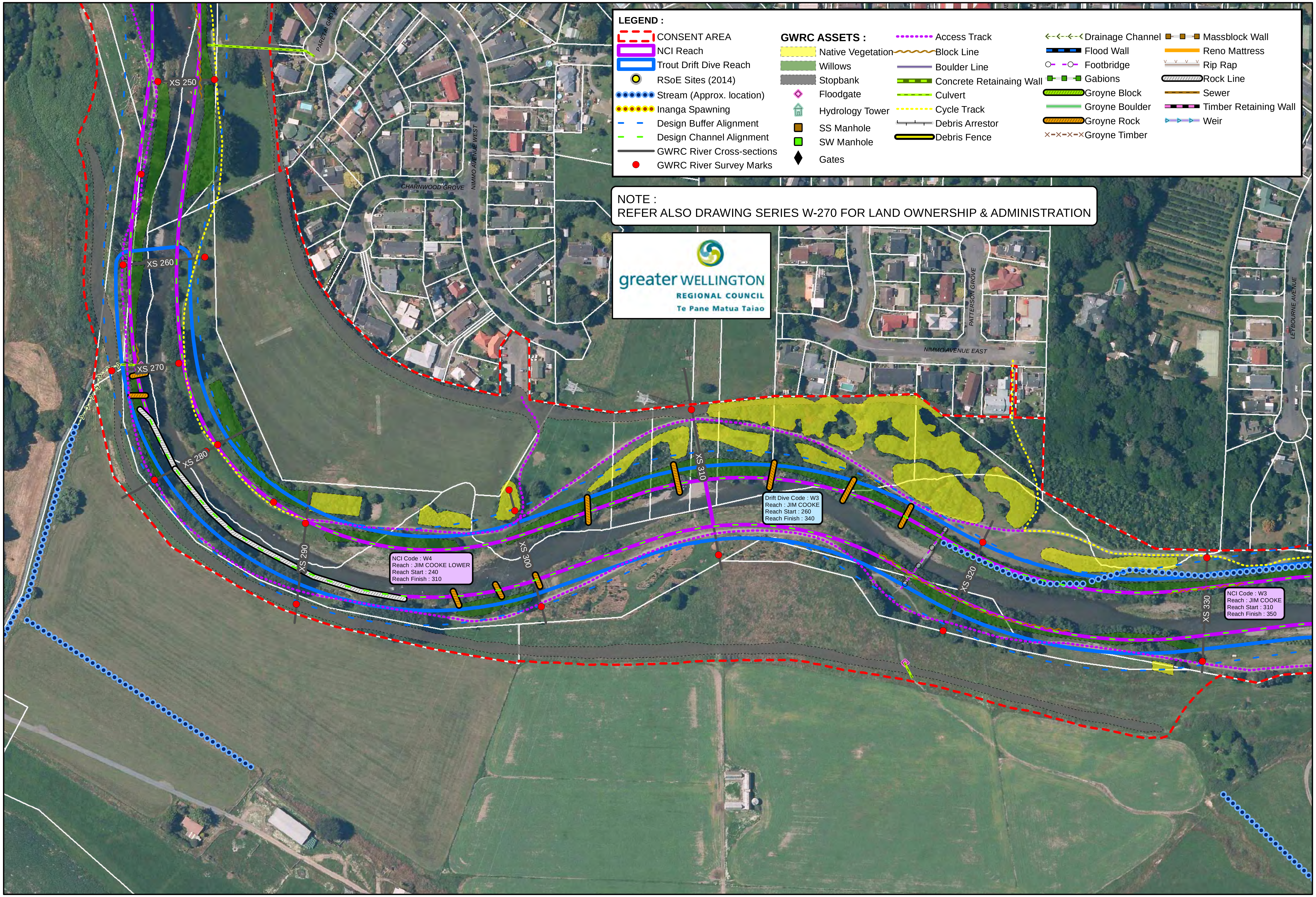
WAIKANAE RIVER - CONSENT AREA - Map 4a

GWRC Asset, Fish & Ecological Information (River Mouth to Water Treatment Plant Weir)

Drawn : P.Cook, Date Plotted : 7 July 2015
Aerial Photo : GWRC 2013

DWG No. **W-271 / 4**

N



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File ref : Waikanae Application Area March 2014 - Sheet 5a.mxd

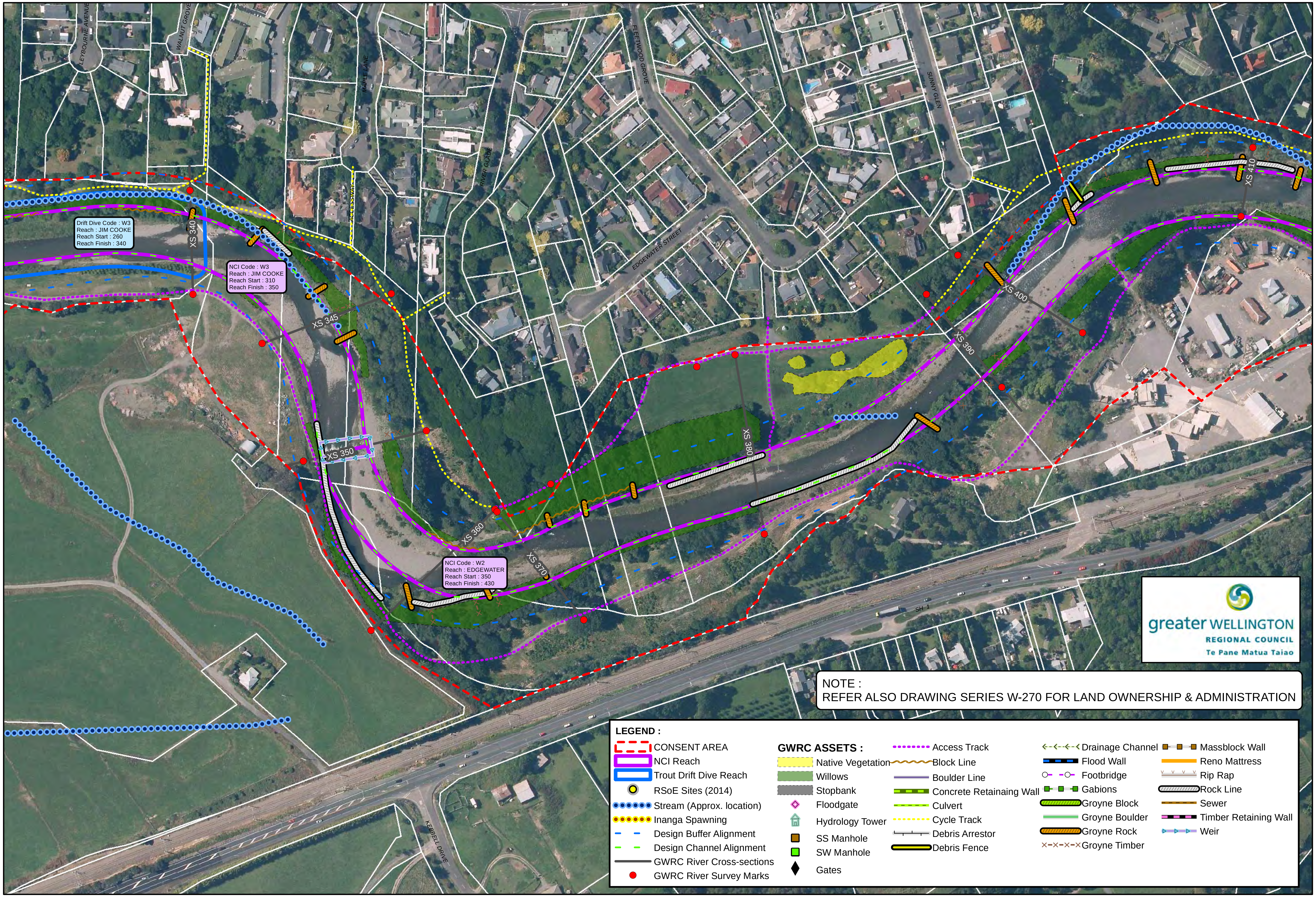
A3 Scale :1:2,500

WAIKANAE RIVER - CONSENT AREA - Map 5a

GWRC Asset, Fish & Ecological Information (River Mouth to Water Treatment Plant Weir)

Drawn : P.Cook, Date Plotted : 7 July 2015
Aerial Photo : GWRC 2013

DWG No. **W-271 / 5**



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File ref : Waikanae Application Area March 2014 - Sheet 6a.mxd

0 25 50 100 Meters

A3 Scale :1:2,500

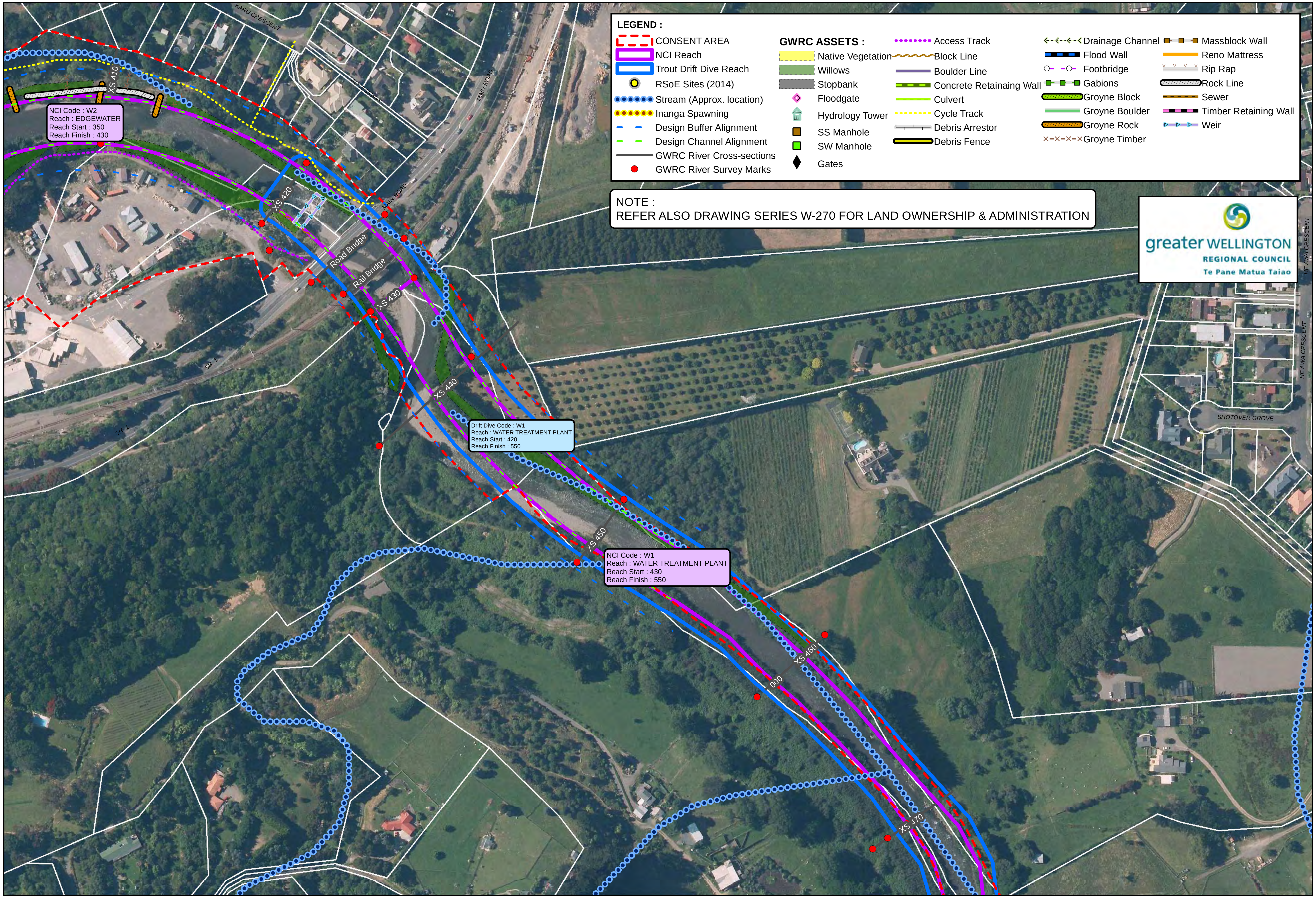
WAIKANAE RIVER - CONSENT AREA - Map 6a

GWRC Asset, Fish & Ecological Information (River Mouth to Water Treatment Plant Weir)

Drawn : P.Cook, Date Plotted : 7 July 2015
Aerial Photo : GWRC 2013

DWG No. **W-271 / 6**

N



File ref : Waikanae Application Area March 2014 - Sheet 7a.mxd

0 25 50 100 Meters

1:2,500

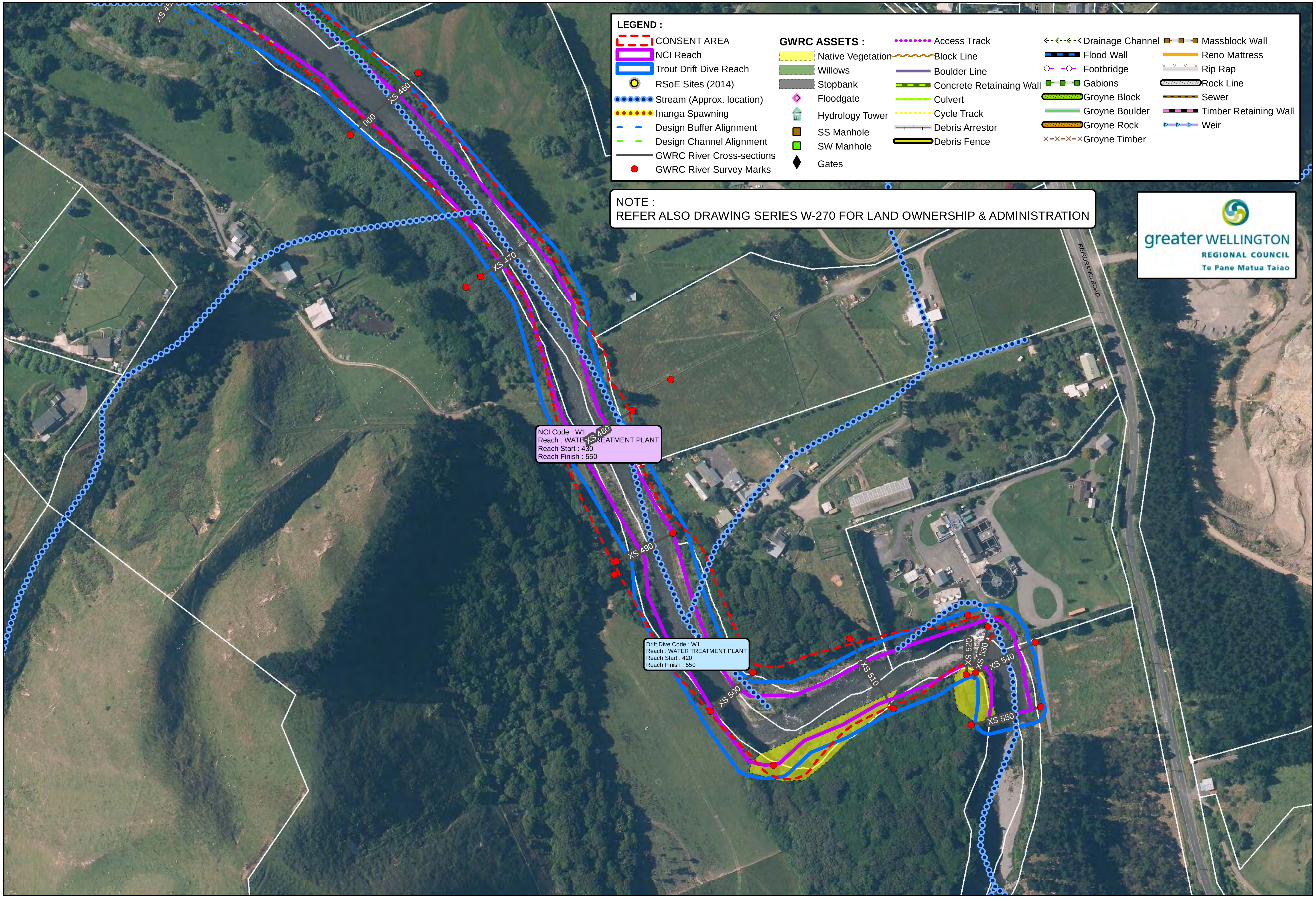
WAIKANAE RIVER - CONSENT AREA - Map 7a

GWRC Asset, Fish & Ecological Information (River Mouth to Water Treatment Plant Weir)

Drawn : P.Cook, Date Plotted : 7 July 2015
Aerial Photo : GWRC 2013

DWG No. **W-271 / 7**

N



0 25 50 100 Meters

1:2,500

WAIKANAE RIVER - CONSENT AREA - Map 8a

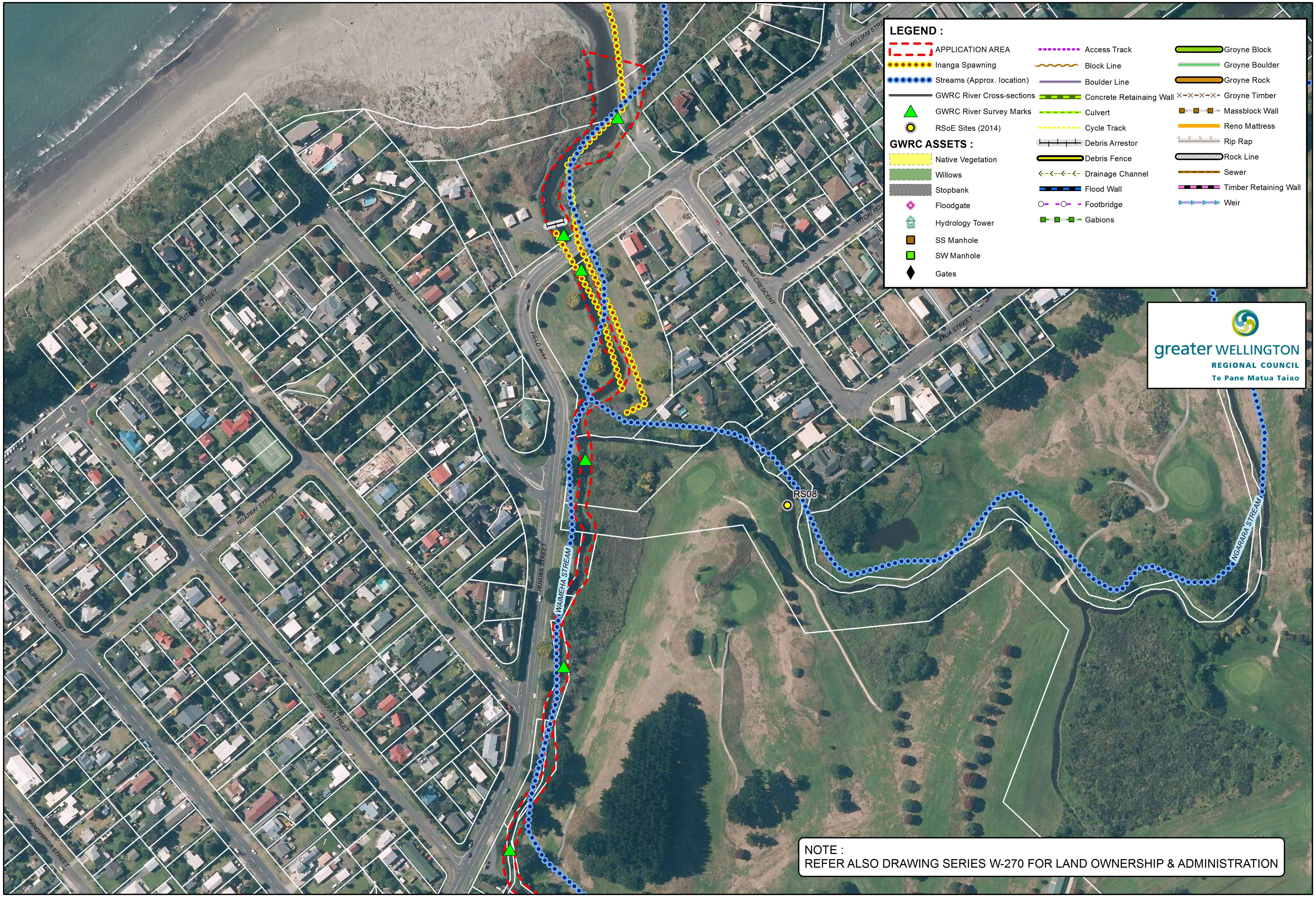
GWRC Asset, Fish & Ecological Information (River Mouth to Water Treatment Plant Weir)

Drawn : P.Cook, Date Plotted : 7 July 2015
Aerial Photo : GWRC 2013

DWG No. **W-271 / 8**

N

Appendix B Waimeha Stream Map Series W-271/9-11



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File ref : Waimeha Application Area March 2014 - Sheet 1b.mxd

0 25 50 100 Meters

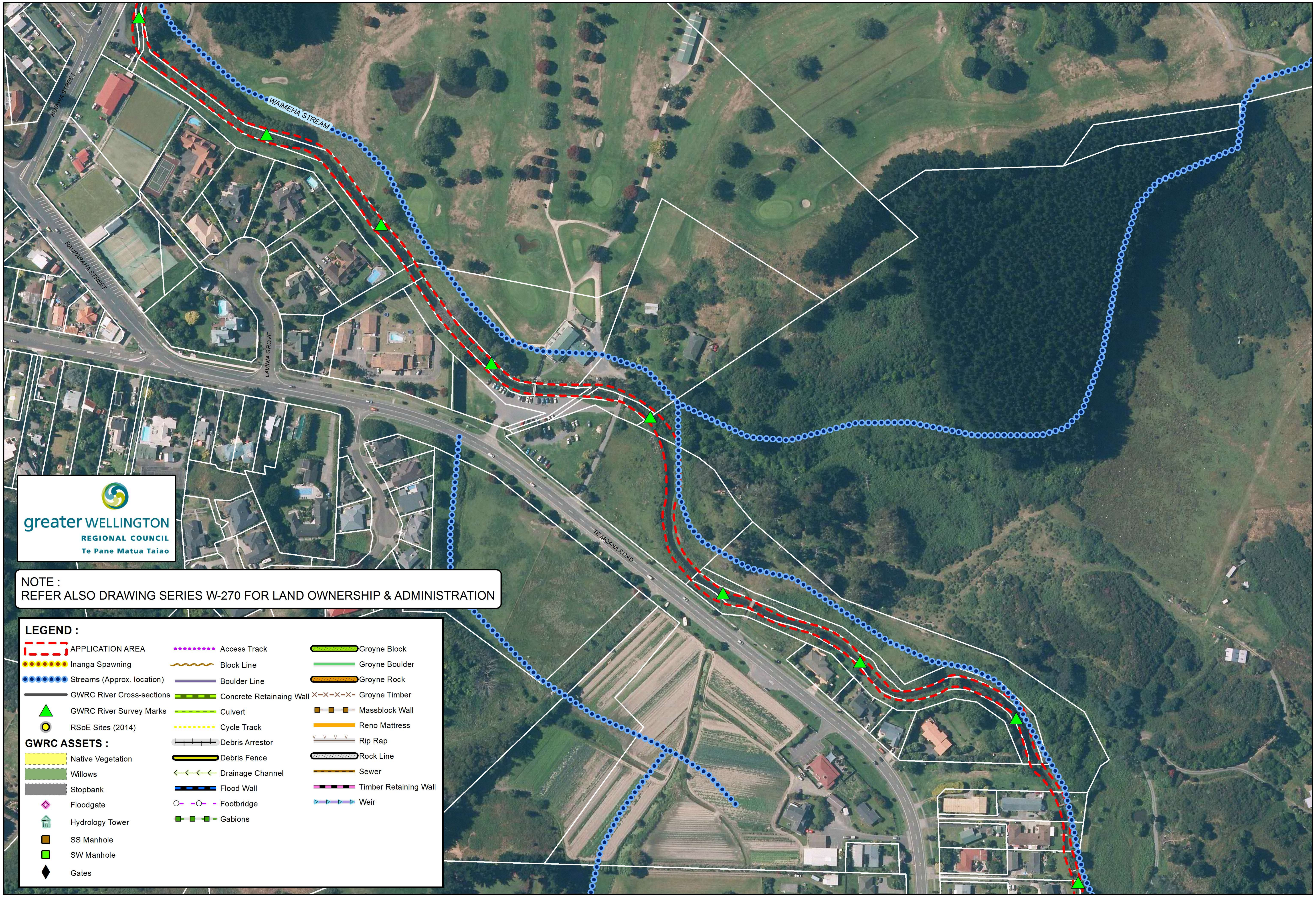
A3 Scale :1:2,500

WAIMEHA STREAM - APPLICATION AREA - Map 1

GWRC Asset & Ecological Information (River Mouth to Park Ave / Te Moana Road)

DWG No. **W-271 / 9**

N



0 25 50 100 Meters
A3 Scale :1:2,500

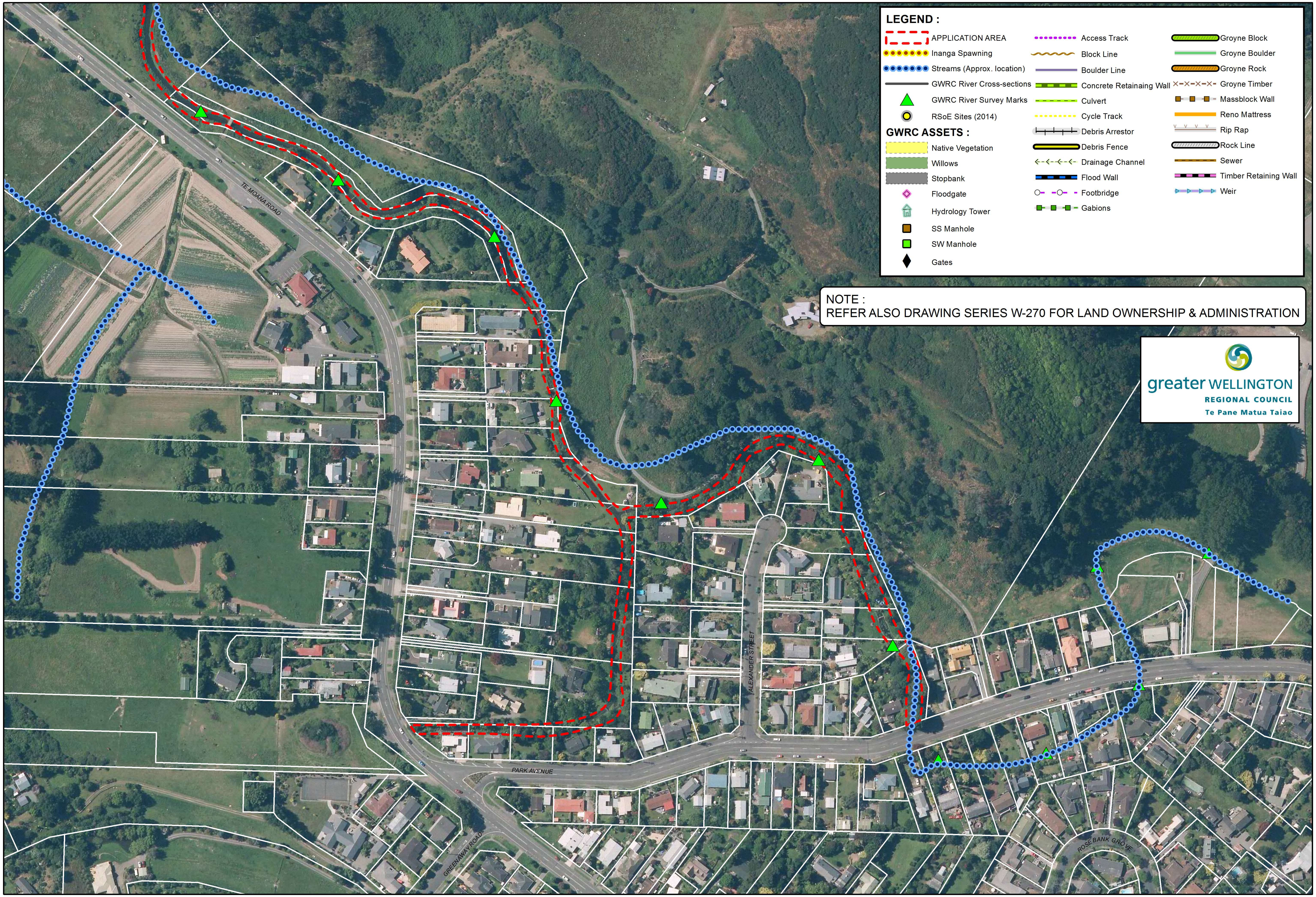
WAIMEHA STREAM - APPLICATION AREA - Map 2a

GWRC Asset & Ecological Information (River Mouth to Park Ave / Te Moana Road)

Drawn : P.Cook, Date Plotted : 7 July 2015
Aerial Photo : GWRC 2013

DWG No. **W-271 / 10**

N



File ref : Waimeha Application Area March 2014 - Sheet 3a.mxd

0 25 50 100 Meters
A3 Scale :1:2,500

WAIMEHA STREAM - APPLICATION AREA - Map 3a
GWRC Asset & Ecological Information (River Mouth to Park Ave / Te Moana Road)

Drawn : P.Cook, Date Plotted : 7 July 2015
Aerial Photo : GWRC 2013

DWG No. **W-271 / 11**

N

Appendix C Boxplots of water quality results by year, 2004 to 2015 (GWRC monthly data)

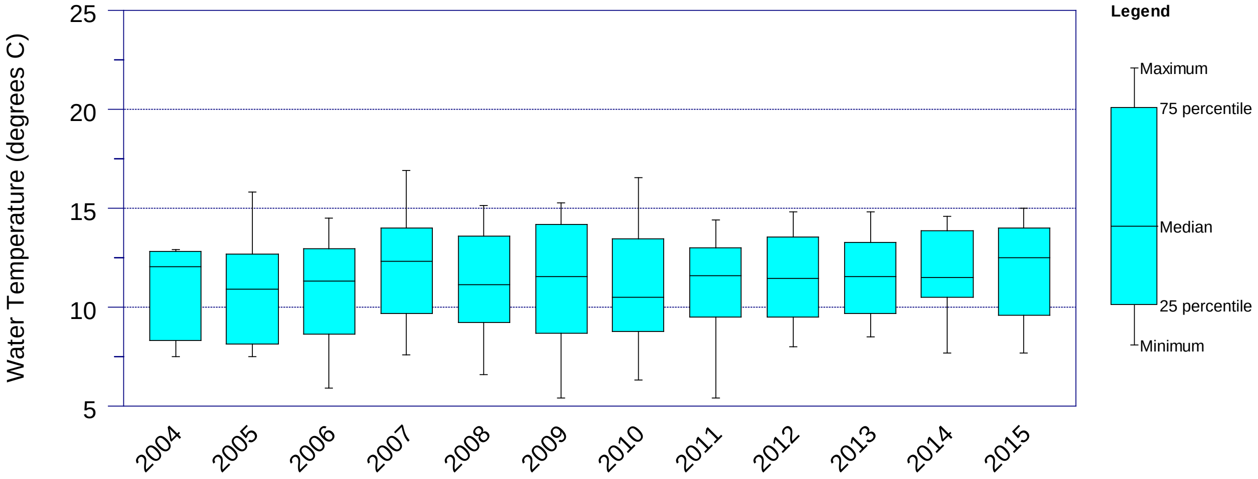


Figure C1: Water temperature (ºC) by year in the Waikanae River at Mangaone Walkway (RSoE Site RS09).

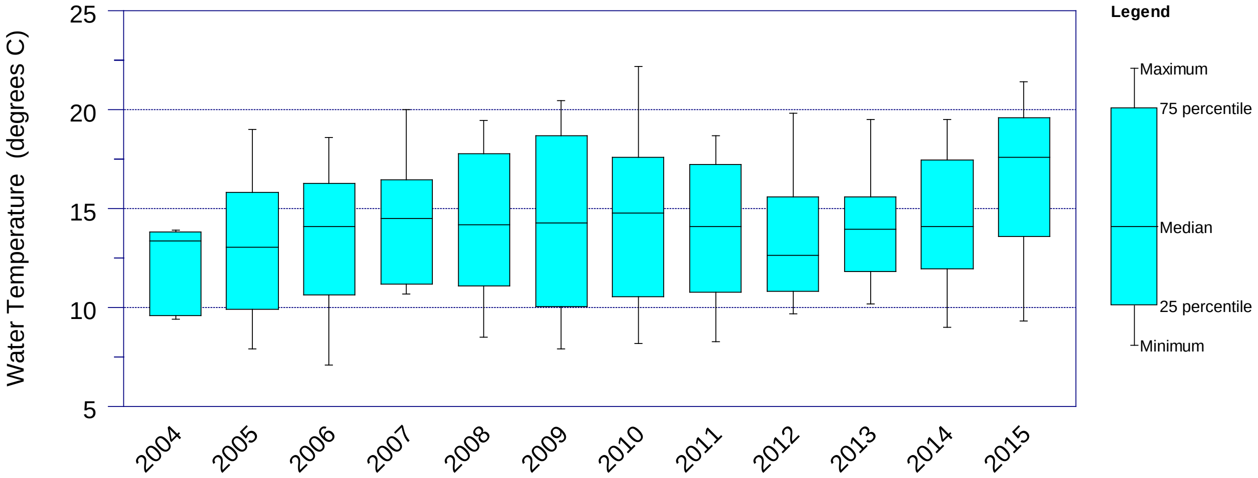


Figure C2: Water temperature (ºC) by year in the Waikanae River at Greenaway Road (RSoE Site RS10).

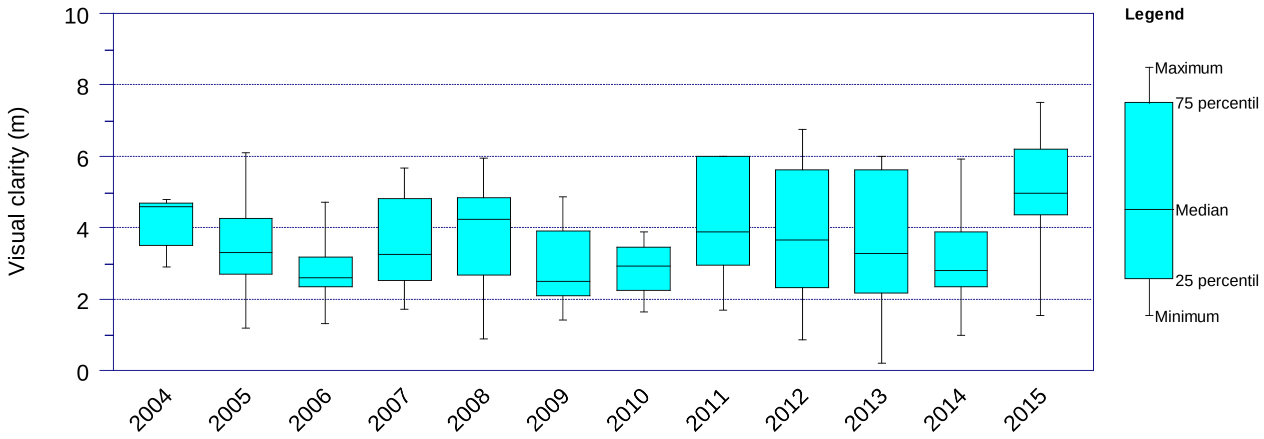


Figure C3: Water clarity (m) by year in the Waikanae River at Mangaone Walkway (RS09).

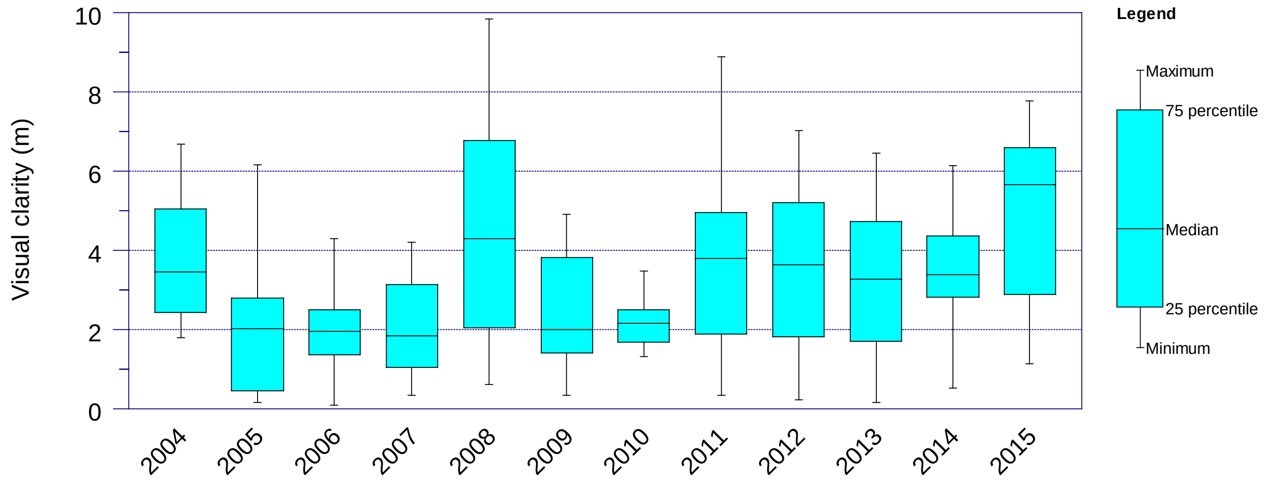


Figure C4: Water clarity (m) by year in the Waikanae River at Greenaway Road (RS10).

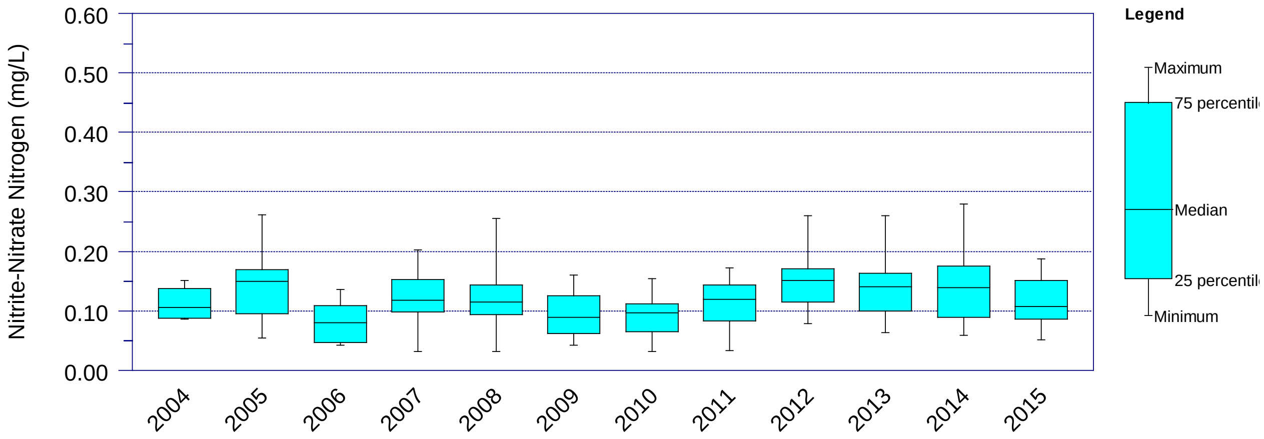


Figure C5: Nitrate + nitrite nitrogen (mg/L) by year in the Waikanae River at Mangaone Walkway (RS09).

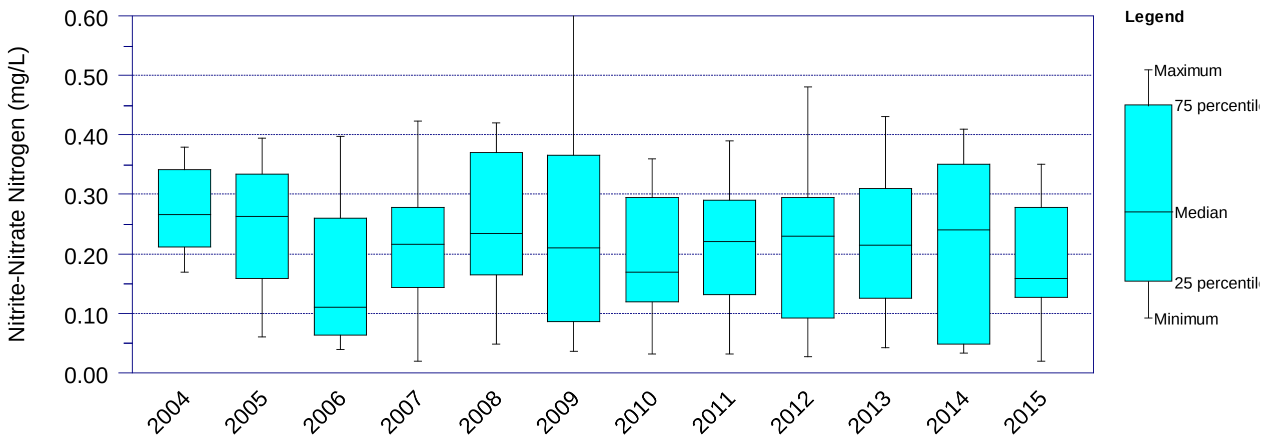


Figure C6: Nitrate + nitrite nitrogen (mg/L) by year in the Waikanae River at Greenaway Road (RS10).

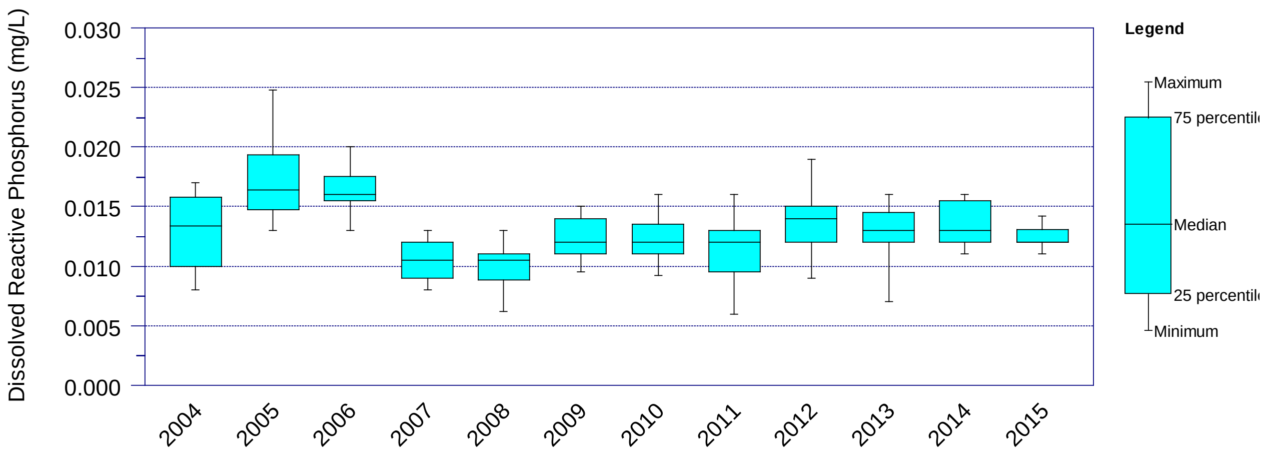


Figure C7: Dissolved reactive phosphorus (mg/L) by year in Waikanae River at Mangaone Walkway (RS09).

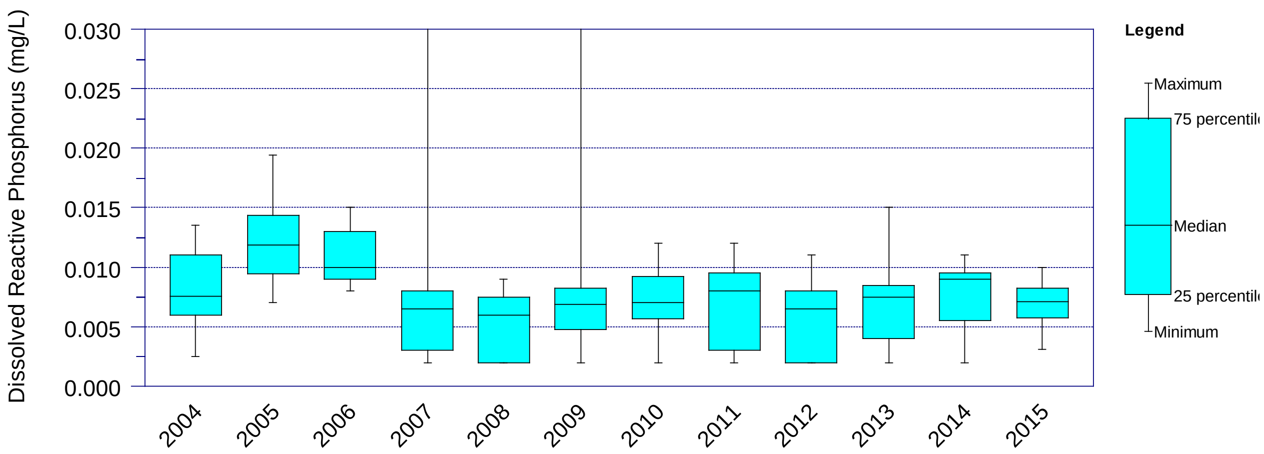


Figure C8: Dissolved reactive phosphorus (mg/L) by year in the Waikanae River at Greenaway Road (RS10).

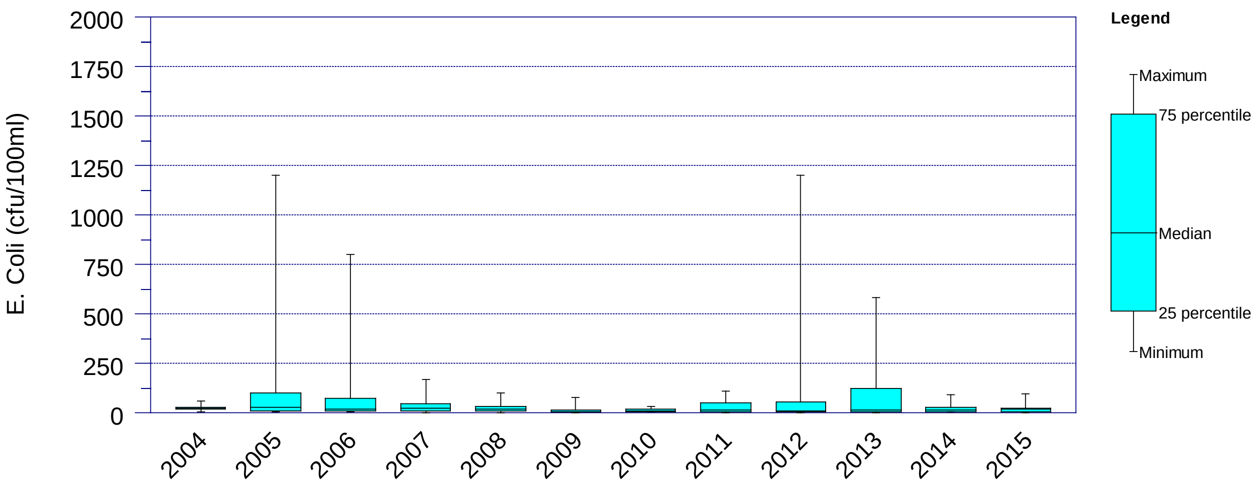


Figure C9: *E. coli* (cfu/100ml) by year in the Waikanae River at Mangaone Walkway (RS09).

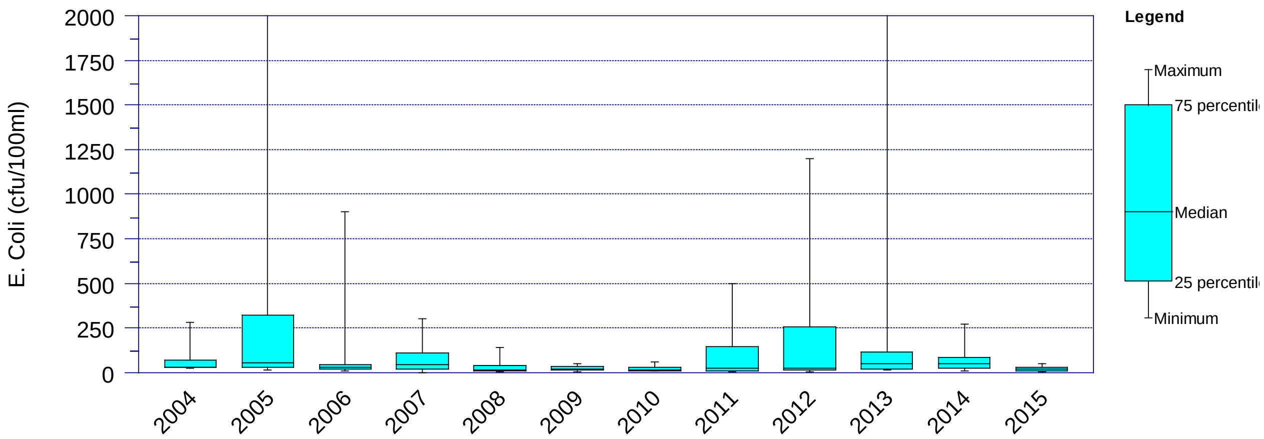
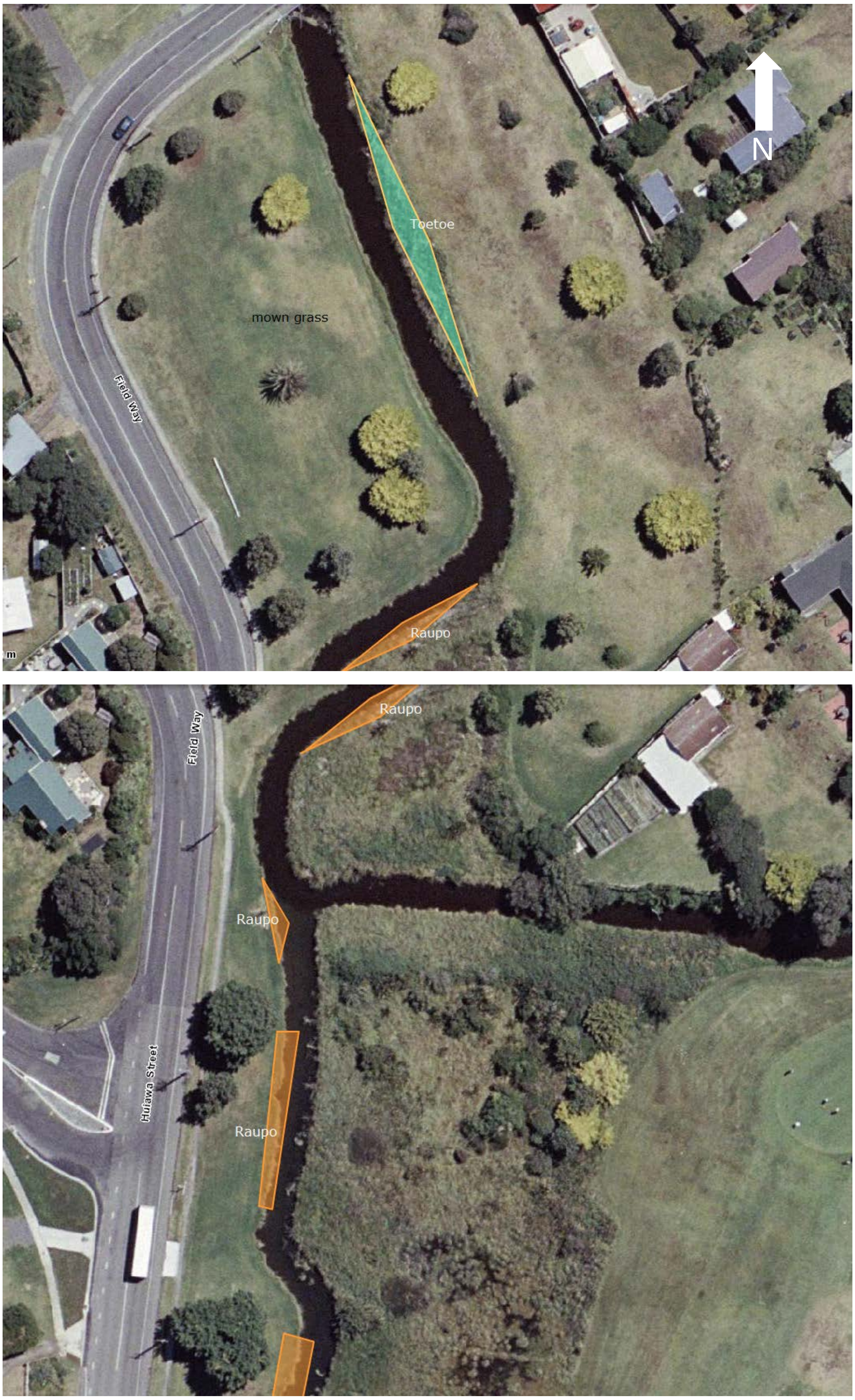
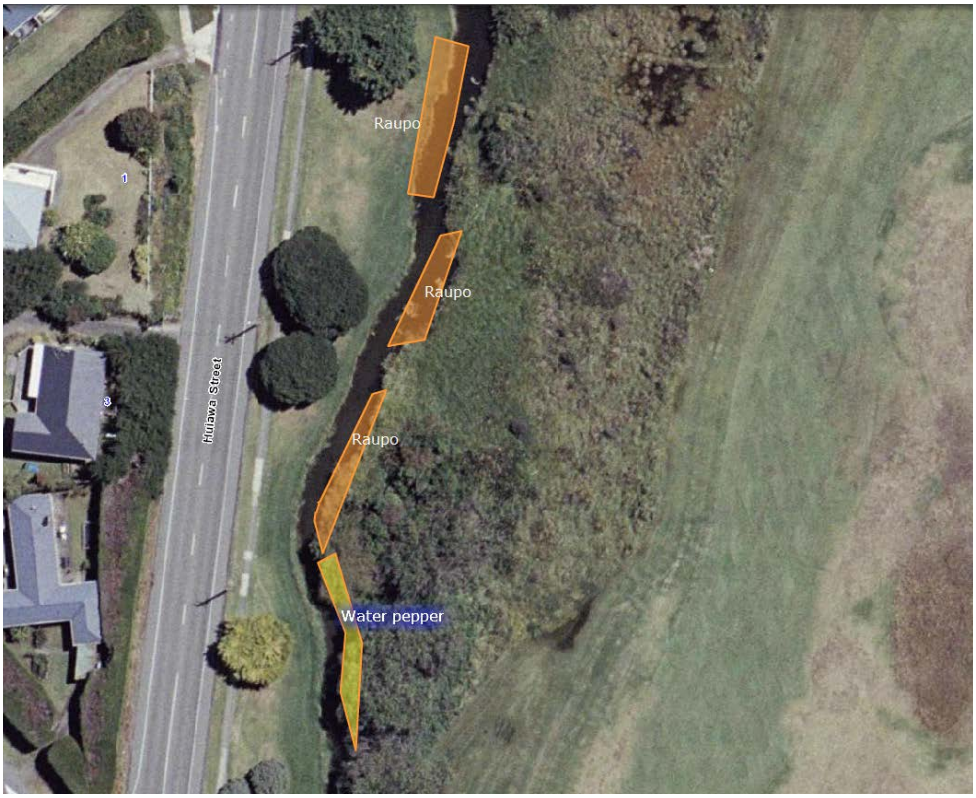


Figure C10: *E. coli* (cfu/100ml) by year in the Waikanae River at Greenaway Road (RS10).

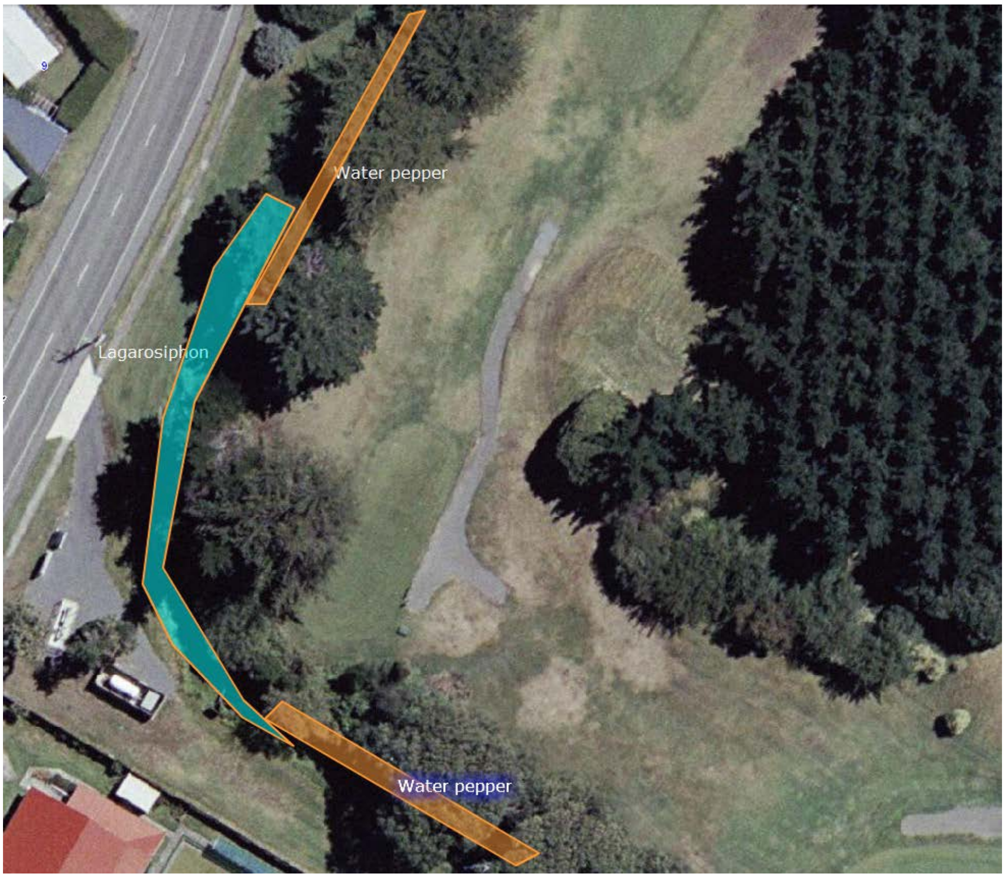
Appendix D Aquatic Vegetation of Waimeha Stream

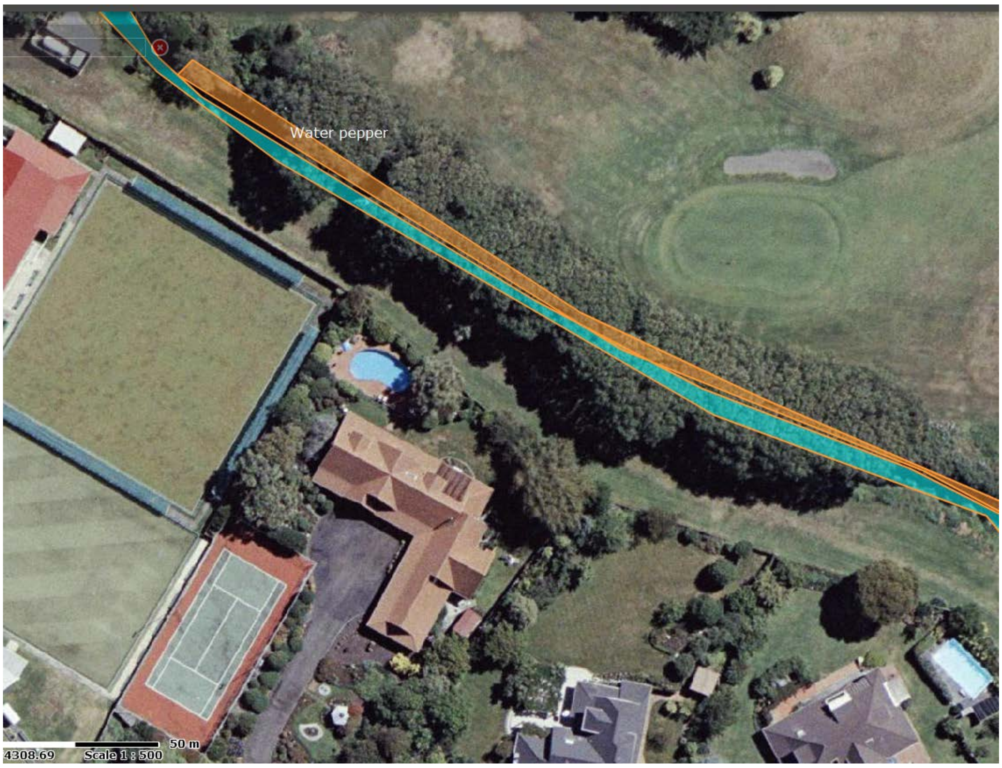
Survey conducted by D. Cameron, MWH (27/7/2015)




Raupo
Raupo
Raupo
Water pepper
Hulawa Street


Water pepper
Parrots feather
Water pepper
Cape pondweed
Parrots feather
Water pepper
Hulawa Street


Water pepper
Lagarosiphon
Water pepper


Water pepper
50 m
4308.69
Scale 1 : 500


Parrots feather
Water pepper
Lagarosiphon


Water pepper
Lagarosiphon

Appendix E Macroinvertebrate results for 2014/15

2014 SOE and Additional Data	Site No	RS08	W1	RS09	RS10
	Site Name	Ngarara Stream at Field Way	Waimeha Stream at Hona Street	Waikanae River at Mangaone Walkway	Waikanae River at Greenaway Rd
	Date sampled	28/01/2014	27/07/2015	28/01/2014	28/01/2014
Generic Grouping	MCI-level taxa				
Acari	Acari	4			1
Coelenterata	Hydra				
Coleoptera	Antiporus				
	Berosus				
	Elmidae			27	50
	Enochrus				
	Hydraenidae			3	
	Hydrophilidae				
	Liodessus				
	Ptilodactylidae				
	Scirtidae				
Collembola	Collembola				
Crustacea	Amphipoda	3	286		
	Amphipoda		1		
	Cladocera	31			
	Copepoda	23			
	Isopoda				
	Ostracoda	6	167		
	Paracalliope	400	2404	4	
	Paraleptamphopus				
	Paranephrops				
	Paratya	1			
Diptera	Aphrophila			P	2
	Austrosimulium			1	1
	Ceratopogonidae				
	Chironomidae	1		P	
	Chironomus	3	1		
	Corynoneura	1			
	Empididae				1
	Ephydridae				
	Eriopterini			P	
	Harrisius				
	Hexatomini				
	Maoridiamesa				
	Mischoderus				
	Muscidae				

	Neocurupira			P	
	Orthocladiinae		1	1	22
	Paradixa				
	Psychodidae				
	Sciomyzidae				
	Stictocladius				
	Stratiomyidae				
	Tabanidae				
	Tanypodinae	5	24		
	Tanytarsini	1			6
	Zelandotipula				
Ephemeroptera	Acanthophlebia			P	
	Ameletopsis			P	
	Austroclima			P	
	Coloburiscus			40	2
	Deleatidium		1	81	61
	Ichthybotus				
	Neozephlebia				
	Nesameletus				
	Oniscigaster				
	Rallidens				
	Zephlebia			1	
Hemiptera	Anisops	1			
	Microvelia	1			
	Sigara				
Hirudinea	Hirudinea		1		
Lepidoptera	Hygraula				
Megaloptera	Archichauliodes			1	P
Mollusca	Ferrissia				
	Gyraulus				
	Physa		48		
	Potamopyrgus	147	5069	1	5
	Sphaeriidae		1		
Nematoda	Nematoda				
Nemertea	Nemertea		1		
Neuroptera	Kempynus				
Odonata	Anisoptera				
	Antipodochlora				
	Austrolestes	1			
	Xanthocnemis	3	48		
Oligochaeta	Oligochaeta		1	1	14
Platyhelminthes	Platyhelminthes		1	2	2
Plecoptera	Acroperla				
	Austroperla			2	

	Megaleptoperla				
	Spaniocerca				
	Stenoperla			3	
	Zelandobius				
	Zelandoperla			9	1
Polychaeta	Polychaeta				1
Trichoptera	Aoteapsyche			2	23
	Beraeoptera				P
	Costachorema				1
	Helicopsyche				
	Hudsonema				
	Hydrobiosella			8	
	Hydrobiosis			1	2
	Hydrochorema				
	Neurochorema				
	Oecetis				
	Oeconesidae				
	Olinga			84	4
	Orthopsyche				
	Oxyethira				
	Paroxyethira				
	Plectrocnemia				
	Polyplectropus	7			
	Psilochorema			1	1
	Pycnocentria				
	Pycnocentrodes				2
	Triplectides	5			
	Fixed Count	644		273	202
	Squares counted	1		2	3
Metrics	TOTAL	20544	6125	4368	2155
	TAXA Richness	19	16	27	22
	MCI-hb	88.42		130.37	104.55
	MCI-sb	72.95	76.1	124.81	113.45
	EPT Richness	2	2	14	10
	Hydroptilid EPT	0	0	0	0
	EPT (- Hydropts)	2	2	14	10
	QMCI-hb	4.75		8.17	5.46
	QMCI-sb	4.33	4.8	7.03	5.58
	% EPT abundance	1.87	13	84.91	48.02
	% Hydropts	0.00	0.00	0.00	0.00
	% EPT (- Hydropts)	1.87	0.0	84.91	48.02

Appendix F Peak periods for upstream fish migration and spawning

F1: Periods of peak sensitivity for upstream fish migration (dark grey) and range (light grey) in the Waikanae River system (compiled from McDowell, 1990; McDowall, 1995; and Hamer, 2007, and references therein)

Species	Life stage	Summer		Autumn			Winter			Spring			Summer
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Shortfin eel	juvenile												
Longfin eel	juvenile												
Inanga	juvenile												
Kōaro	juvenile												
Giant kōkopu	juvenile												
Shortjaw kopopu	juvenile												
Banded kōkopu	juvenile												
Common bully	juvenile												
Redfin bully	juvenile												
Bluegill bully	juvenile												
Lamprey	adult												
Common smelt	juvenile												
Torrentfish	juvenile												
Black flounder	juvenile												
brown trout	adult												

F2: Periods of peak sensitivity for fish spawning (dark grey) and range (light grey) in the Hutt River system (compiled from McDowell, 1990; McDowall, 1995; and Hamer, 2007, and references therein)

Species	Critical habitat	Summer		Autumn			Winter			Spring			Summer
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Inanga	margin, estuary												
Kōaro	margin												
Giant kōkopu	margin												
Shortjaw kopopu													
Banded kōkopu	margins												
Common bully	bed												
Redfin bully	bed												
Bluegill bully	bed												
Lamprey	upper reaches												
Common smelt	Lower reaches												
Torrentfish	bed												
Dwarf galaxias	?												
Upland bully	bed												
Cran's bully	bed												
brown trout	bed												

Appendix G List of bird species recorded on the Waikanae River, 2012-15, (McArthur, et al, 2015)

Threat rankings are as per Robertson *et al* (2013). Species names and taxonomic order are as per Gill *et al* (2010). Habitat use columns describe which habitats each species was observed using, or is likely to be using for feeding (F), roosting (R) and breeding (B) within the Waikanae River corridor. Date ranges provided delimit the breeding season for each bird species observed or likely to be breeding in the river corridor, breeding season information was sourced from the New Zealand Birds Online website, accessed 30th July, 2015.

Scientific name	Common name	Threat ranking	Habitat use	
			Dry sand and gravels	Riparian vegetation
Phasianus colchicus	common pheasant	Introduced and Naturalised	F, R,	F, R, B (Jul – Mar)
Cygnus atratus	black swan	Not Threatened	R	Species unlikely to be using this habitat
Branta canadensis	Canada goose	Introduced and Naturalised	R	Species unlikely to be using this habitat
Tadorna variegata	paradise shelduck	Not Threatened	R	Species unlikely to be using this habitat
A. platyrhynchos	mallard	Introduced and Naturalised	R	B (Jul – Dec)
A. rhynchotis	Australasian shoveler	Not Threatened	R	Species unlikely to be using this habitat
Cairina moschata	Muscovy duck	N/A[3]	R	Species unlikely to be using this habitat
Phalacrocorax melanoleucos	little shag	Not Threatened	R	Species unlikely to be using this habitat
P. carbo	black shag	At Risk, Naturally Uncommon	R	Species unlikely to be using this habitat
P. varius	pied shag	Nationally Vulnerable	R	R, B (all year around)
Egretta novaehollandiae	white-faced heron	Not Threatened	F, R	R
Circus approximans	Australasian harrier	Not Threatened	F, R	F, R
Platalea regia	royal spoonbill	At Risk, Naturally Uncommon	R	Species unlikely to be using this habitat
Porphyrio melanotus	pukeko	Not Threatened	F, R	F, R, B (all year around)

Scientific name	Common name	Threat ranking	Habitat use	
			Dry sand and gravels	Riparian vegetation
Haematopus unicolor	variable oystercatcher	At Risk, Recovering	R, B (Sep – Mar)	Species unlikely to be using this habitat
Himantopus himantopus	pied stilt	At Risk, Declining	F, R	Species unlikely to be using this habitat
Charadrius bicinctus	banded dotterel	Nationally Vulnerable	F, R	Species unlikely to be using this habitat
Vanellus miles	spur-winged plover	Not Threatened	F, R	Species unlikely to be using this habitat
Larus dominicanus	black-backed gull	Not Threatened	F, R	Species unlikely to be using this habitat
L. novaehollandiae	red-billed gull	Nationally Vulnerable	F, R	Species unlikely to be using this habitat
Hydroprogne caspia	Caspian tern	Nationally Vulnerable	R	Species unlikely to be using this habitat
Sterna striata	white-fronted tern	At Risk, Declining	R	Species unlikely to be using this habitat
Columba livia	rock pigeon	Introduced and Naturalised	F, R	Species unlikely to be using this habitat
Hemiphaga novaeseelandiae	New Zealand pigeon (kereru)	Not Threatened	Species unlikely to be using this habitat	F, R
Platycercus eximius	eastern rosella	Introduced and Naturalised	F, R	F, R, B (Sep – Mar)
Chrysococcyx lucidus	shining cuckoo	Not Threatened	Species unlikely to be using this habitat	F, R, B (Oct – Mar)
Todiramphus sanctus	kingfisher	Not Threatened	F, R	F, R, B (Oct – Jan)
Gerygone igata	grey warbler	Not Threatened	Species unlikely to be using this habitat	F, R, B (Aug – Feb)
Anthornis melanura	Bellbird	Not Threatened	Species unlikely to be using this habitat	F, R
Prosthemadera novaeseelandiae	tui	Not Threatened	Species unlikely to be using this habitat	F, R
Gymnorhina tibicen	Australian magpie	Introduced and Naturalised	F, R	F, R, B (Jul – Jan)
Rhipidura fuliginosa	New Zealand fantail	Not Threatened	F, R	F, R, B (Aug - Mar)
Alauda arvensis	Eurasian skylark	Introduced and Naturalised	F, R	Species unlikely to be using this habitat
Zosterops lateralis	silvereye	Not Threatened	F, R	F, R, B (Aug – Feb)

Scientific name	Common name	Threat ranking	Habitat use	
			Dry sand and gravels	Riparian vegetation
Hirundo neoxena	welcome swallow	Not Threatened	R	Species unlikely to be using this habitat
Turdus merula	blackbird	Introduced and Naturalised	F, R	F, R, B (Aug – Feb)
T. philomelos	song thrush	Introduced and Naturalised	F, R	F, R, B (Aug – Feb)
Sturnus vulgaris	starling	Introduced and Naturalised	F, R	F, R, B (Sep – Dec)
Passer domesticus	house sparrow	Introduced and Naturalised	F, R	F, R, B (Sep – Mar)
Prunella modularis	dunnock	Introduced and Naturalised	F, R	F, R, B (Sep – Feb)
Fringilla coelebs	chaffinch	Introduced and Naturalised	F, R	F, R, B (Sep – Feb)
Carduelis chloris	greenfinch	Introduced and Naturalised	F, R	F, R, B (Oct – Mar)
C. carduelis	goldfinch	Introduced and Naturalised	F, R	F, R, B (Oct – Mar)
C. flammea	redpoll	Introduced and Naturalised	F, R	F, R, B (Oct – Mar)
Emberiza citrinella	Yellowhammer	Introduced and Naturalised	F, R	R, B (Oct – Mar)

Appendix H List of bird species recorded at the mouth of the Waimeha Stream (from McArthur, 2015a)

Scientific name	Common name	Threat ranking	Date last recorded	Source
Haematopus unicolor	variable oystercatcher	At Risk, Recovering	11th June 2009	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Haematopus haematopus	South Island pied oystercatcher	At Risk, Declining	11th June 2009	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Himantopus himantopus	pied stilt	At Risk, Declining	16th February 2014	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Vanellus miles	spur-winged plover	Not Threatened	16th February 2014	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Larus novaehollandiae	red-billed gull	Nationally Vulnerable	11th June 2009	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
L. dominicanus	black-backed gull	Not Threatened	16th February 2014	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Chlidonias albostriata	black-fronted tern	Nationally Endangered	3rd May 2009	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Sterna striata	white-fronted tern	At Risk, Declining	3rd May 2009	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Gerygone igata	grey warbler	Not Threatened	16th February 2014	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Rhipidura fuliginosa	New Zealand fantail	Not Threatened	16th February 2014	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Hirundo neoxena	welcome swallow	Not Threatened	16th February 2014	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Zosterops lateralis	silvereye	Not Threatened	16th February 2014	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Turdus merula	blackbird	Introduced and Naturalised	16th February 2014	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Sturnus vulgaris	starling	Introduced and Naturalised	16th February 2014	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Carduelis carduelis	goldfinch	Introduced and Naturalised	16th February 2014	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Passer domesticus	house sparrow	Introduced and Naturalised	16th February 2014	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015

Appendix I Important trout spawning waters

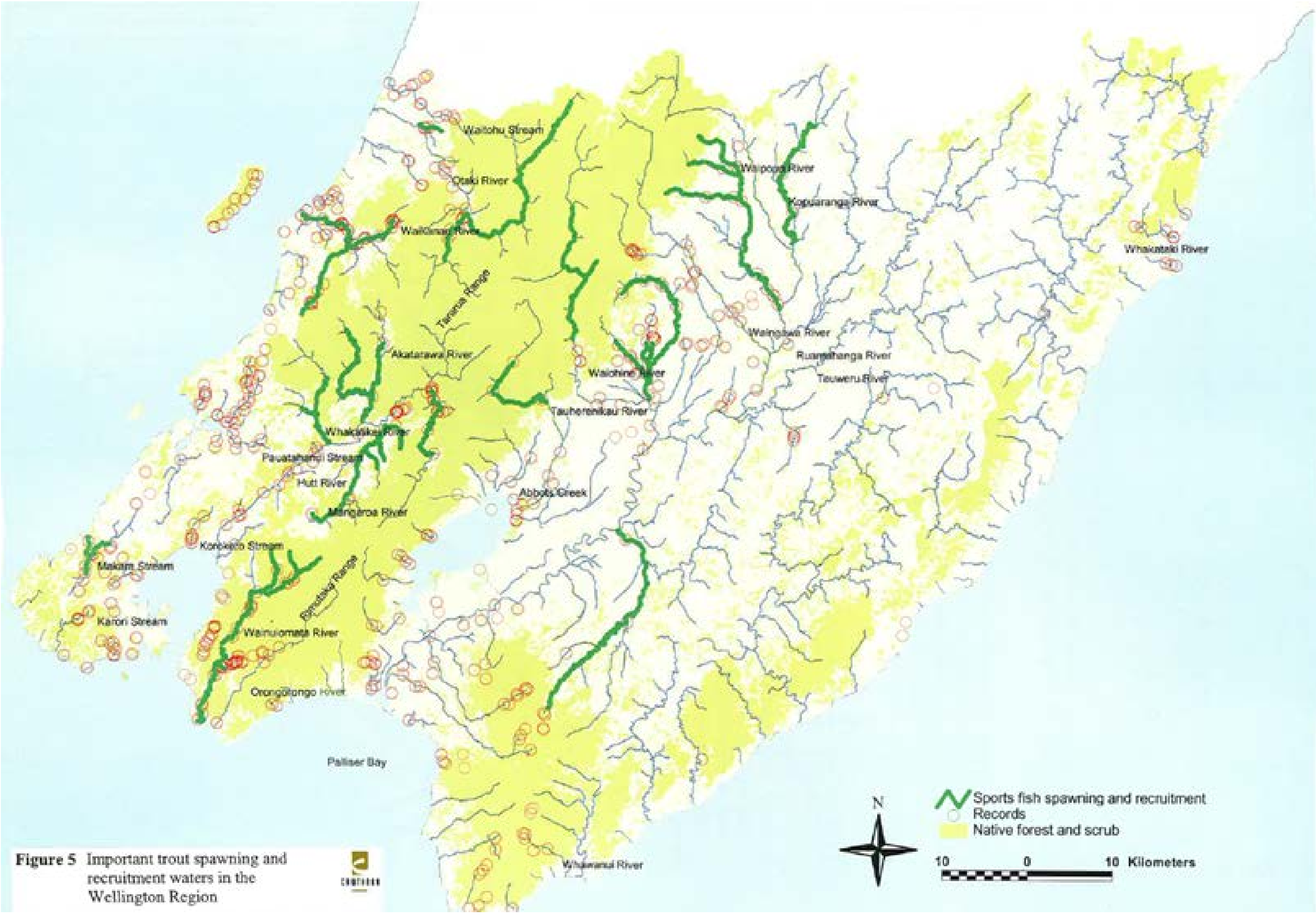
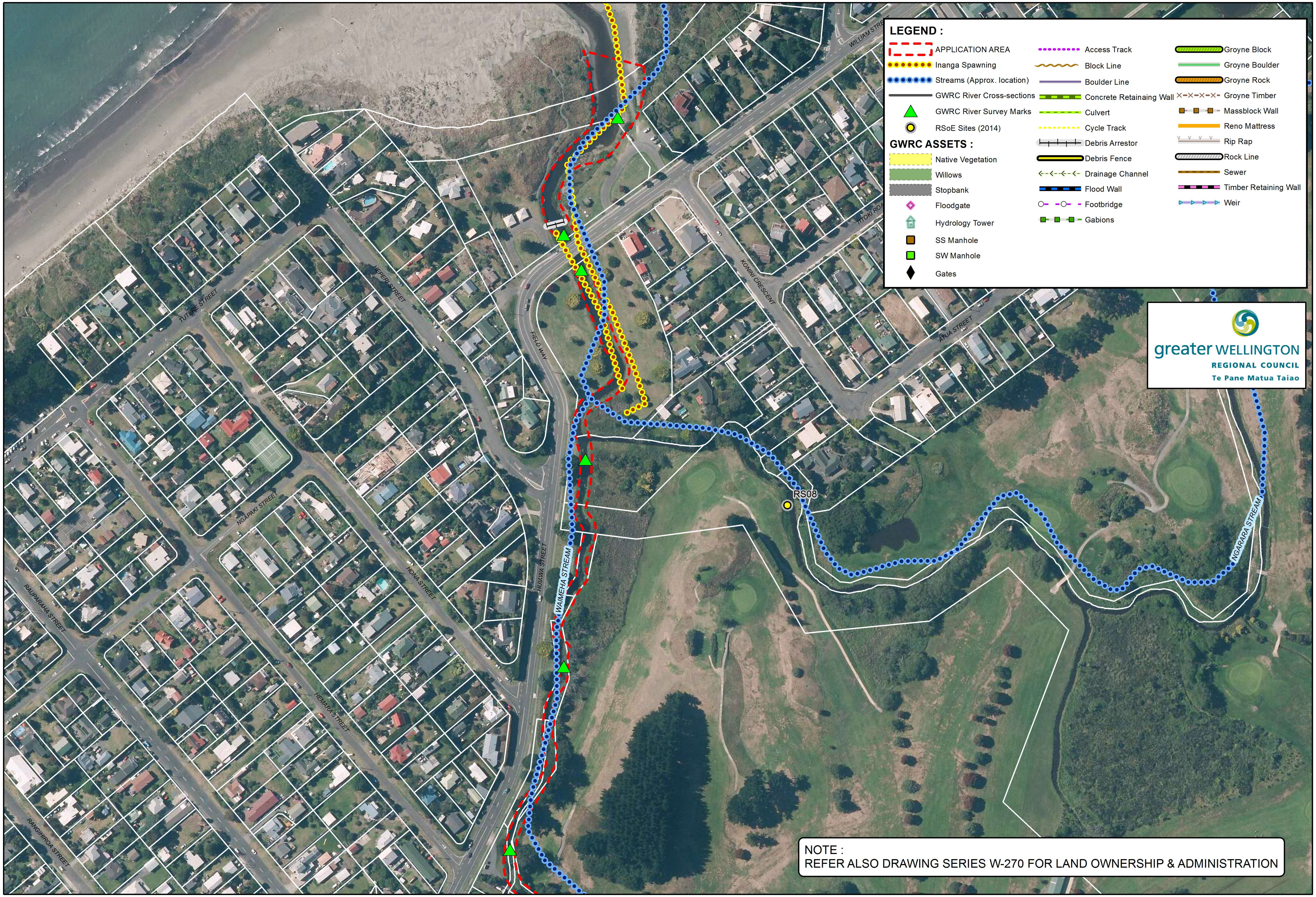


Figure 5 Important trout spawning and recruitment waters in the Wellington Region



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TOPOGRAPHIC AND CADASTRAL DATA IS COPYRIGHT LINZ

File ref : Waimeha Application Area March 2014 - Sheet 1b.mxd

0 25 50 100 Meters

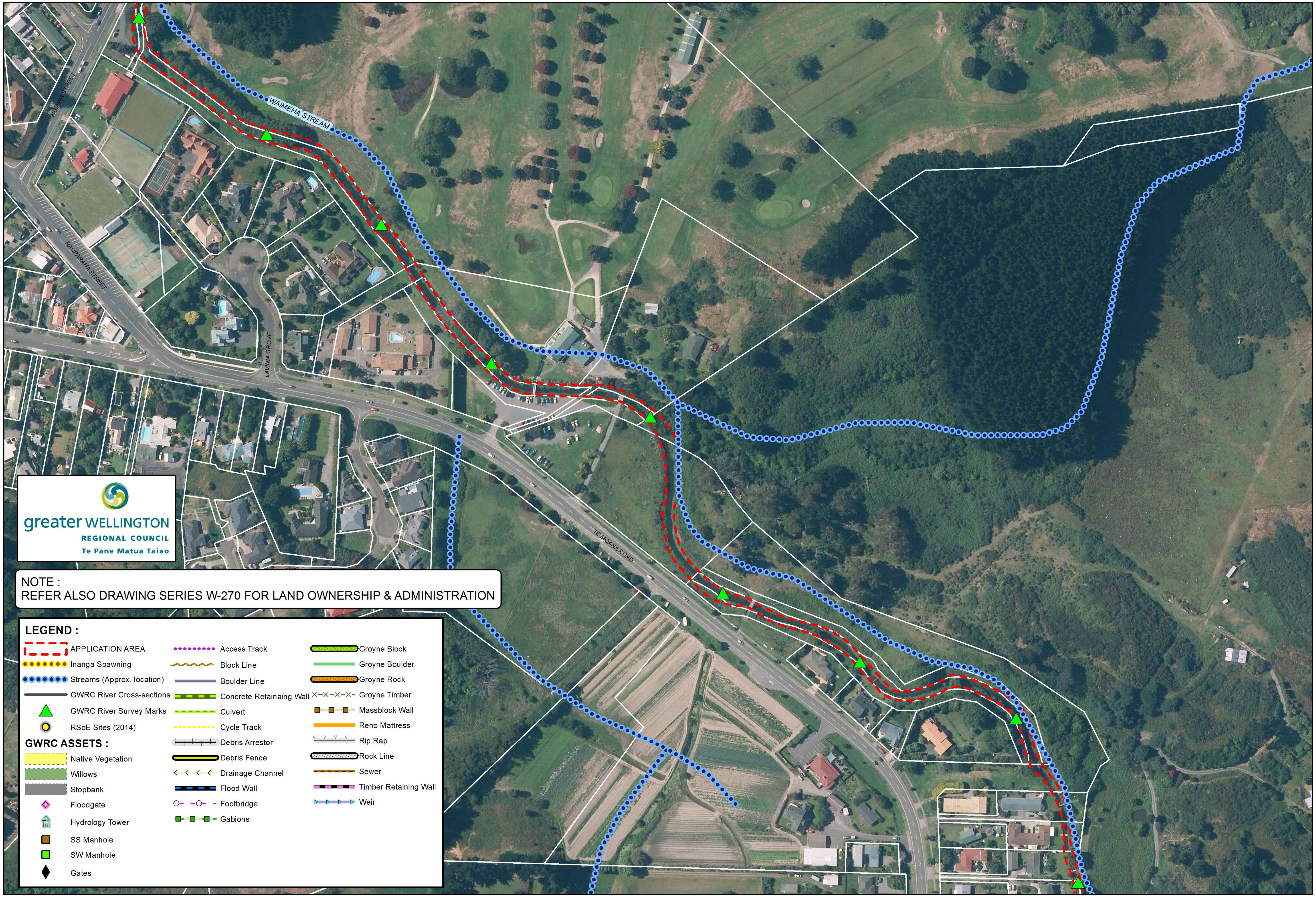
A3 Scale :1:2,500

WAIMEHA STREAM - APPLICATION AREA - Map 1

GWRC Asset & Ecological Information (River Mouth to Park Ave / Te Moana Road)

DWG No. W-271 / 9

N



File ref : Waimeha Application Area March 2014 - Sheet 2a.mxd

0 25 50 100 Meters

A3 Scale :1:2,500

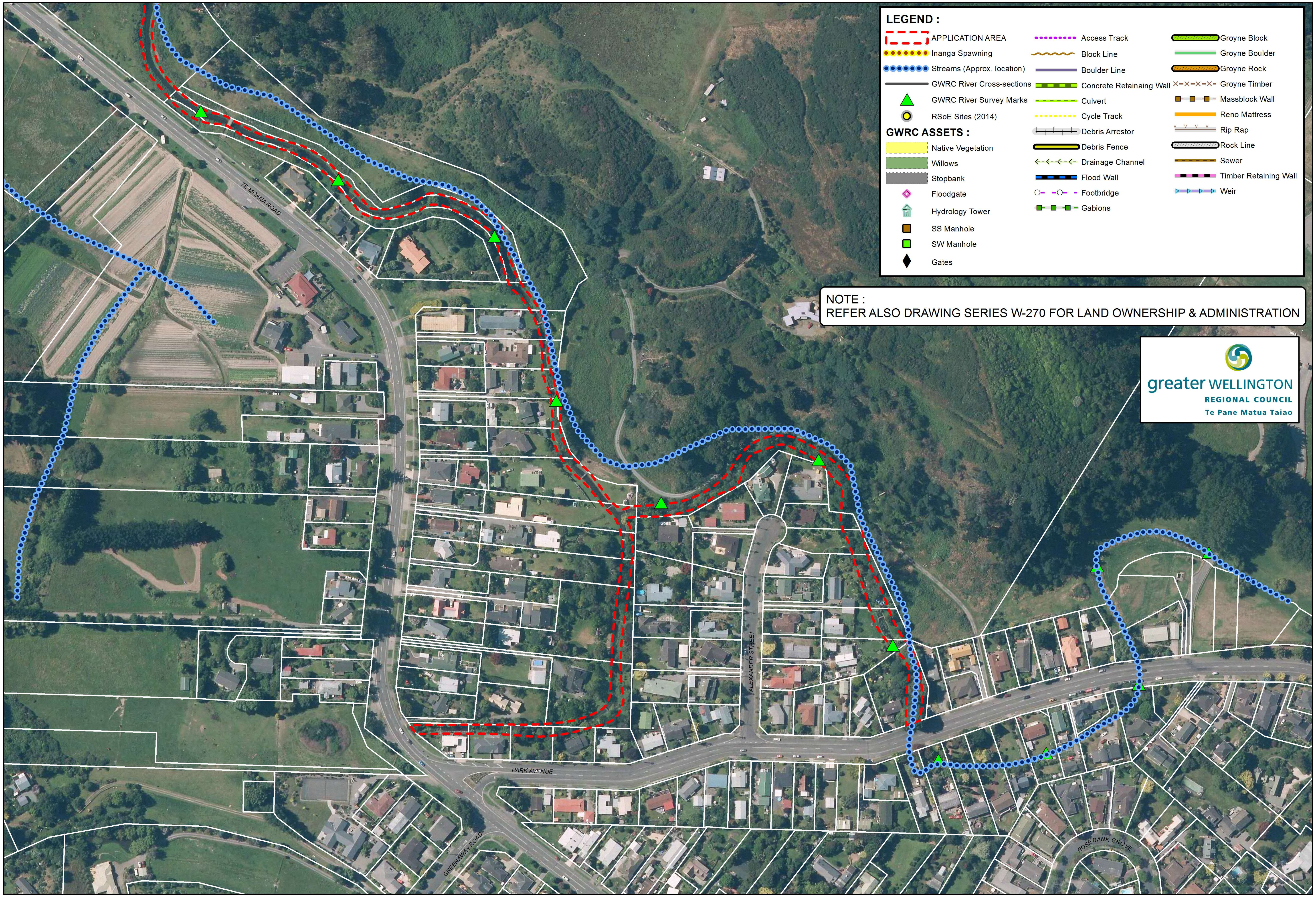
WAIMEHA STREAM - APPLICATION AREA - Map 2a

GWRC Asset & Ecological Information (River Mouth to Park Ave / Te Moana Road)

Drawn : P.Cook, Date Plotted : 7 July 2015
Aerial Photo : GWRC 2013

DWG No. **W-271 / 10**

N



File ref : Waimeha Application Area March 2014 - Sheet 3a.mxd

0 25 50 100 Meters

A3 Scale :1:2,500

WAIMEHA STREAM - APPLICATION AREA - Map 3a

GWRC Asset & Ecological Information (River Mouth to Park Ave / Te Moana Road)

Drawn : P.Cook, Date Plotted : 7 July 2015
Aerial Photo : GWRC 2013

DWG No. **W-271 / 11**

N